Online Continuing Education for Professional Engineers
Since 2009

Hydraulic Fittings and Fluid Lines

PDH Credits:

2 PDH

Course No.:

HFF101

Publication Source:

US Naval Education and Training

1265 San Juan Dr. - Merritt Island, FL 32952
Phone: 321-501-5601

CHAPTER 5

FLUID LINES AND FITTINGS

The control and application of fluid power would be impossible without suitable means of transferring the fluid between the reservoir, the power source, and the points of application. Fluid lines are used to transfer the fluid, and fittings are used to connect the lines to the power source and the points of application.

This chapter is devoted to fluid lines and fittings. After studying this chapter, you should have the knowledge to identify the most commonly used lines and fittings, and be able to explain the procedure for fabricating, testing, and labeling the lines.

TYPES OF LINES

The three types of lines used in fluid power systems are pipe (rigid), tubing (semirigid), and hose (flexible). A number of factors are considered when the type of line is selected for a particular fluid system. These factors include the type of fluid, the required system pressure, and the location of the system. For example, heavy pipe might be used for a large stationary fluid power system, but comparatively lightweight tubing must be used in aircraft and missile systems because weight and space are critical factors. Flexible hose is required in installations where units must be free to move relative to each other.

PIPES AND TUBING

There are three important dimensions of any tubular product—outside diameter (OD), inside diameter (ID), and wall thickness. Sizes of pipe are listed by the nominal (or approximate) ID and the wall thickness. Sizes of tubing are listed by the actual OD and the wall thickness.

SELECTION OF PIPES AND TUBING

The material, ID, and wall thickness are the three primary considerations in the selection of lines for a particular fluid power system.

The ID of a line is important, since it determines how much fluid can pass through the line in a given time period (rate of flow) without loss of power due to excessive friction and heat. The velocity of a given flow is less through a large opening than through a small opening. If the ID of the line is too small for the amount of flow, excessive turbulence and friction heat cause unnecessary power loss and overheated fluid.

Sizing of Pipes and Tubing

Pipes are available in three different weights: standard (STD), or Schedule 40; extra strong (XS), or Schedule 80; and double extra strong (XXS). The schedule numbers range from 10 to 160 and cover 10 distinct sets of wall thickness. (See table 5-1.) Schedule 160 wall thickness is slightly thinner than the double extra strong.

As mentioned earlier, the size of pipes is determined by the nominal (approximate) ID. For example, the ID for a 1/4-inch Schedule 40 pipe is 0.364 inch, and the ID for a 1/2-inch Schedule 40 pipe is 0.622 inch.

It is important to note that the IDs of all pipes of the same nominal size are not equal. This is because the OD remains constant and the wall thickness increases as the schedule number increases. For example, a nominal size 1-inch Schedule 40 pipe has a 1.049 ID. The same size Schedule 80 pipe has a 0.957 ID, while Schedule

Table 5-1.—Wall Thickness Schedule Designations for Pipe

Nominal size	Pipe OD	Inside diameter									
		Sched. 10	Sched. 20	Sched. 30	Sched. 40	Sched. 60	Sched. 80	Sched. 100	Sched. 120	Sched. 140	Sched. 160
1/8	0.405				0.269		0.215				
1/4	.540				.364		.302				
3/8	.675				.493		.423				
1/2	.840				.622		.546				0.466
3/4	1.050				.824		.742				.614
1	1.315				1.049		.957				.815
1 1/4	1.660				1.380		1.278				1.160
1 1/2	1.900				1.610		1.500				1.338
2	2.375				2.067		1.939				1.689

160 pipe has a 0.815 ID. In each case the OD is 1.315 (table 5-1) and the wall thicknesses are 0.133 $(\frac{1.315 - 1.049}{2})$, 0.179 $(\frac{1.315 - 9.957}{2})$, and 0.250 $(\frac{1.315 - 0.815}{2})$ respectively. Note that the difference between the OD and ID includes two wall thicknesses and must be divided by 2 to obtain the wall thickness.

Tubing differs from pipe in its size classification. Tubing is designated by its actual OD. (See table 5-2.) Thus, 5/8-inch tubing has an OD of 5/8 inch. As indicated in the table, tubing is available in a variety of wall thicknesses. The diameter of tubing is often measured and indicated in 16ths. Thus, No. 6 tubing is 6/16 or 3/8 inch, No. 8 tubing is 8/16 or 1/2 inch, and so forth.

The wall thickness, material used, and ID determine the bursting pressure of a line or fitting. The greater the wall thickness in relation to the ID and the stronger the metal, the higher the bursting pressure. However, the greater the ID for a given wall thickness, the lower the bursting pressure, because force is the product of area and pressure.

Materials

The pipe and tubing used in fluid power systems are commonly made from steel, copper, brass, aluminum, and stainless steel. Each of these metals has its own distinct advantages or disadvantages in certain applications.

Steel pipe and tubing are relatively inexpensive and are used in many hydraulic and pneumatic systems. Steel is used because of its strength, suitability for bending and flanging, and adaptability to high pressures and temperatures. Its chief disadvantage is its comparatively low resistance to corrosion.

Copper pipe and tubing are sometimes used for fluid power lines. Copper has high resistance to corrosion and is easily drawn or bent. However, it is unsatisfactory for high temperatures and has a tendency to harden and break due to stress and vibration.

Aluminum has many of the characteristics and qualities required for fluid power lines. It has high resistance to corrosion and is easily drawn or bent. In addition, it has the outstanding characteristic of light weight. Since weight elimination is a vital factor in the design of aircraft, aluminum alloy tubing is used in the majority of aircraft fluid power systems.

Stainless-steel tubing is used in certain areas of many aircraft fluid power systems. As a general rule, exposed lines and lines subject to abrasion or intense heat are made of stainless steel.

An improperly piped system can lead to serious power loss and possible harmful fluid

Table 5-2.—Tubing Size Designation

Tube OD	Wall thickness	Tube ID
1/8	0.028	0.069
	.032	.061
	.035	.055
3/16	0.032	0.1235
	.035	.1175
1/4	0.035	0.180
	.042	.166
	.049	.152
	.058	.134
	.065	.120
5/16	0.035	0.2425
	.042	.2285
	.049	.2145
	.058	.1965
	.065	.1825
3/8	0.035	0.305
	.042	.291
	.049	.277
	.058	.259
	.065	.245
1/2	0.035	0.430
	.042	.416
	.049	.402
	.058	.384
	.065	.370
	.072	.356
	.083	.334
	.095	.310

Tube OD	Wall thickness	Tube ID
5/8	0.035	0.555
	.042	.541
	.049	.527
	.058	.509
	.065	.495
	.072	.481
	.083	.459
	.095	.435
3/4	0.049	0.652
	.058	.634
	.065	.620
	.072	.606
	.083	.584
	.095	.560
	.109	.532
7/8	0.049	0.777
	.058	.759
	.065	.745
	.072	.731
	.083	.709
	.095	.685
	.109	.657
1	0.049	0.902
	.058	.884
	.065	.870
	.072	.856
	.083	.834
	.095	.810
	.109	.782
	.120	.760

Tube OD	Wall thickness	Tube ID
1 1/4	0.049	1.152
	.058	1.134
	.065	1.120
	.072	1.106
	.083	1.084
	.095	1.060
	.109	1.032
	.120	1.010
1 1/2	0.065	1.370
	.072	1.356
	.083	1.334
	.095	1.310
	.109	1.282
	.120	1.260
	.134	1.232
1 3/4	0.065	1.620
	.072	1.606
	.083	1.584
	.095	1.560
	.109	1.532
	.120	1.510
	.134	1.482
2	0.065	1.870
	.072	1.856
	.083	1.834
	.095	1.810
	.109	1.782
	.120	1.760
	.134	1.732

contamination. Therefore in maintenance and repair of fluid power system lines, the basic design requirements must be kept in mind. Two primary requirements are as follows:

1. The lines must have the correct ID to provide the required volume and velocity of flow with the least amount of turbulence during all demands on the system.

2. The lines must be made of the proper material and have the wall thickness to provide sufficient strength to both contain the fluid at the required pressure and withstand the surges of pressure that may develop in the system.

PREPARATION OF PIPES AND TUBING

Fluid power systems are designed as compactly as possible, to keep the connecting lines short. Every section of line should be anchored securely in one or more places so that neither the weight of the line nor the effects of vibration are carried on the joints. The aim is to minimize stress throughout the system.

Lines should normally be kept as short and free of bends as possible. However, tubing should not be assembled in a straight line, because a bend tends to eliminate strain by absorbing vibration and also compensates for thermal expansion and contraction. Bends are preferred to elbows, because bends cause less of a power loss. A few of the correct and incorrect methods of installing tubing are illustrated in figure 5-1.

Bends are described by their radius measurements. The ideal bend radius is 2 1/2 to 3 times the ID, as shown in figure 5-2. For example, if the ID of a line is 2 inches, the radius of the bend should be between 5 and 6 inches.

While friction increases markedly for sharper curves than this, it also tends to increase up to a certain point for gentler curves. The increases in friction in a bend with a radius of more than 3 pipe diameters result from increased turbulence near the outside edges of the flow. Particles of fluid must travel a longer distance in making the change in direction. When the radius of the bend is less than 2 1/2 pipe diameters, the increased pressure loss is due to the abrupt change in the direction of flow, especially for particles near the inside edge of the flow.

During your career in the Navy, you may be required to fabricate new tubing to replace damaged or failed lines. Fabrication of tubing consists of four basic operations: cutting, deburring, bending, and joint preparation.

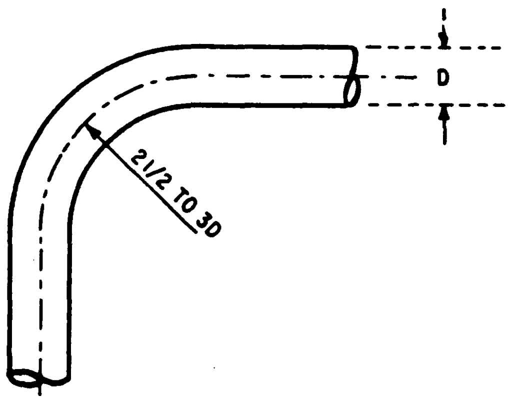


Figure 5-2.—Ideal bend radius.

Tube Cutting and Deburring

The objective of cutting tubing is to produce a square end that is free from burrs. Tubing may be cut using a standard tube cutter (fig. 5-3), a chipless cutter (fig. 5-4), or a fine-toothed hacksaw if a tube cutter is not available.

When you use the standard tube cutter, place the tube in the cutter with the cutting wheel at the point where the cut is to be made. Apply light pressure on the tube by tightening the adjusting knob. Too much pressure applied to the cutting wheel at onetime may deform the tubing or cause excessive burrs. Rotate the cutter toward its open side (fig. 5-3). As you rotate the cutter, adjust the tightening knob after each complete turn to maintain light pressure on the cutting wheel.

When you use the chipless cutter, take the following steps:

1. Select the chipless cutter according to tubing size.
2. Rotate the cutter head to accept the tubing in the cutting position. Check that the cutter ratchet is operating freely and that the cutter wheel is clear of the cutter head opening (fig. 5-4).
3. Center the tubing on two rollers and the cutting blade.
4. Use the hex key provided with the kit to turn the drive screw in until the cutter wheel touches the tube.

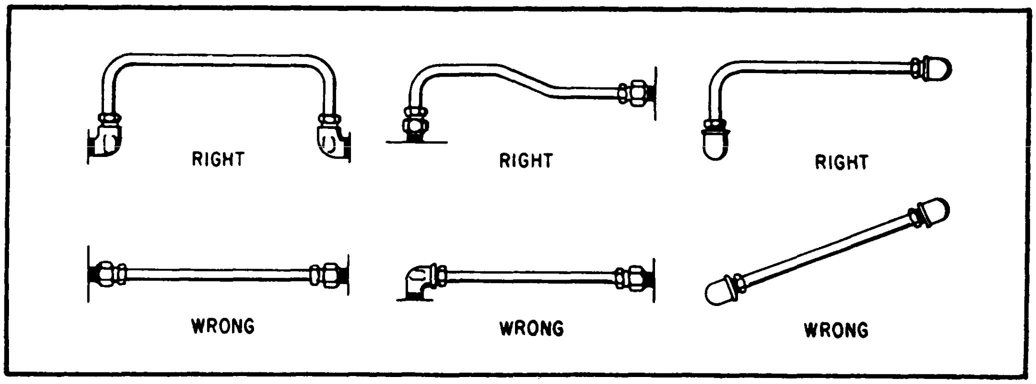


Figure 5-1.—Correct and incorrect methods of installing tubing.

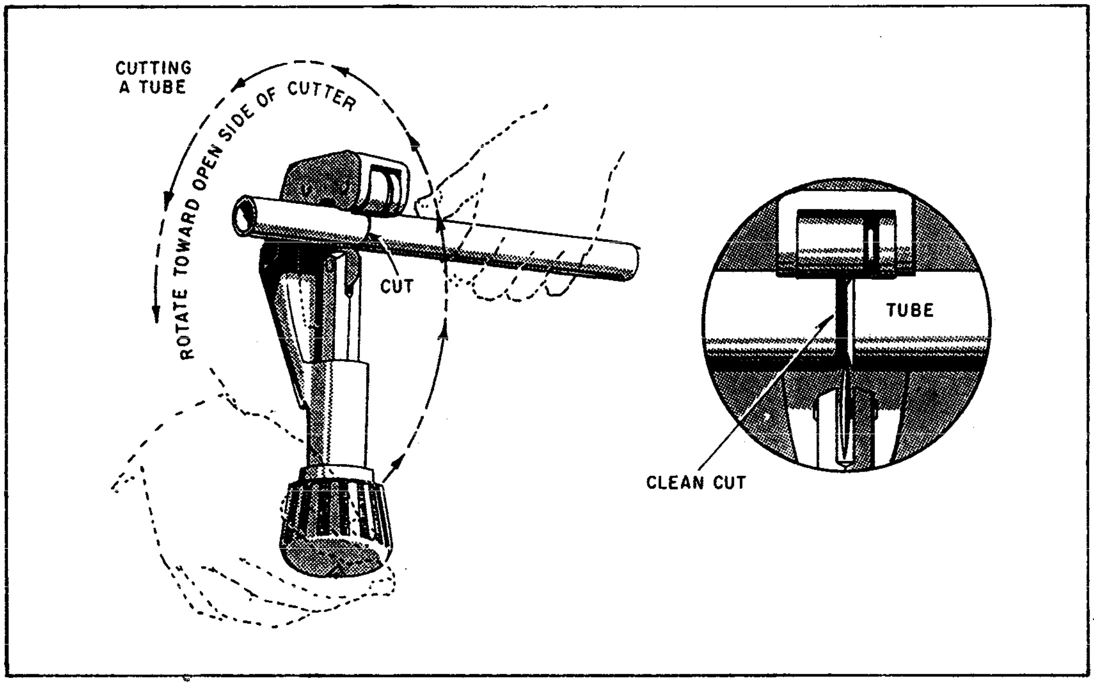


Figure 5-3.—Tube cutting.

5. Tighten the drive screw 1/8 to 1/4 turn. Do not overtighten the drive screw. Overtightening can damage soft tubing or cause excessive wear or breakage of the cutter wheel in hard tubing.

6. Swing the ratchet handle back and forth through the available clearance until there is a noticeable ease of rotation. Avoid putting side force on the cutter handle. Side force will cause the cutter wheel to break.

7. Tighten the drive screw an additional 1/8 to 1/4 turn and swing the ratchet handle back and forth, retightening the drive screw as needed until the cut is completed. The completed cut should be 1/2 degree square to the tube centerline.

After the tubing is cut, remove all burrs and sharp edges from inside and outside of the tube (fig. 5-5) with deburring tools. Clean out the tubing. Make sure no foreign particles remain.

A convenient method for cutting tubing with a hacksaw is to place the tube in a flaring block and clamp the block in a vice. After cutting the tubing with a hacksaw, remove all saw marks by filing.

Tube Bending

The objective in tube bending is to obtain a smooth bend without flattening the tube. Tube bending is usually done with either a hand tube bender or a mechanically operated bender.

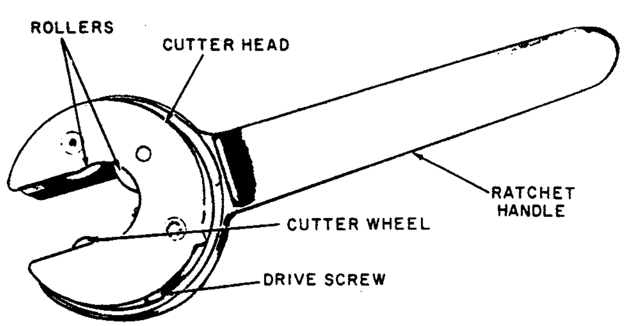


Figure 5-4.—Chipless cutter.

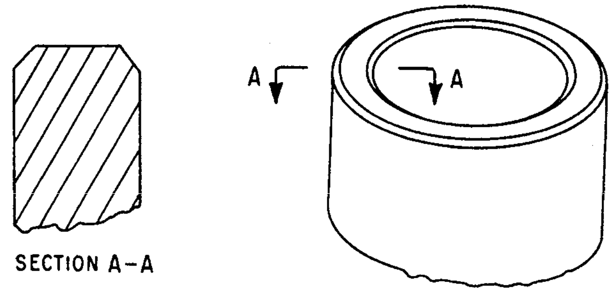


Figure 5-5.—Properly burred tubing.

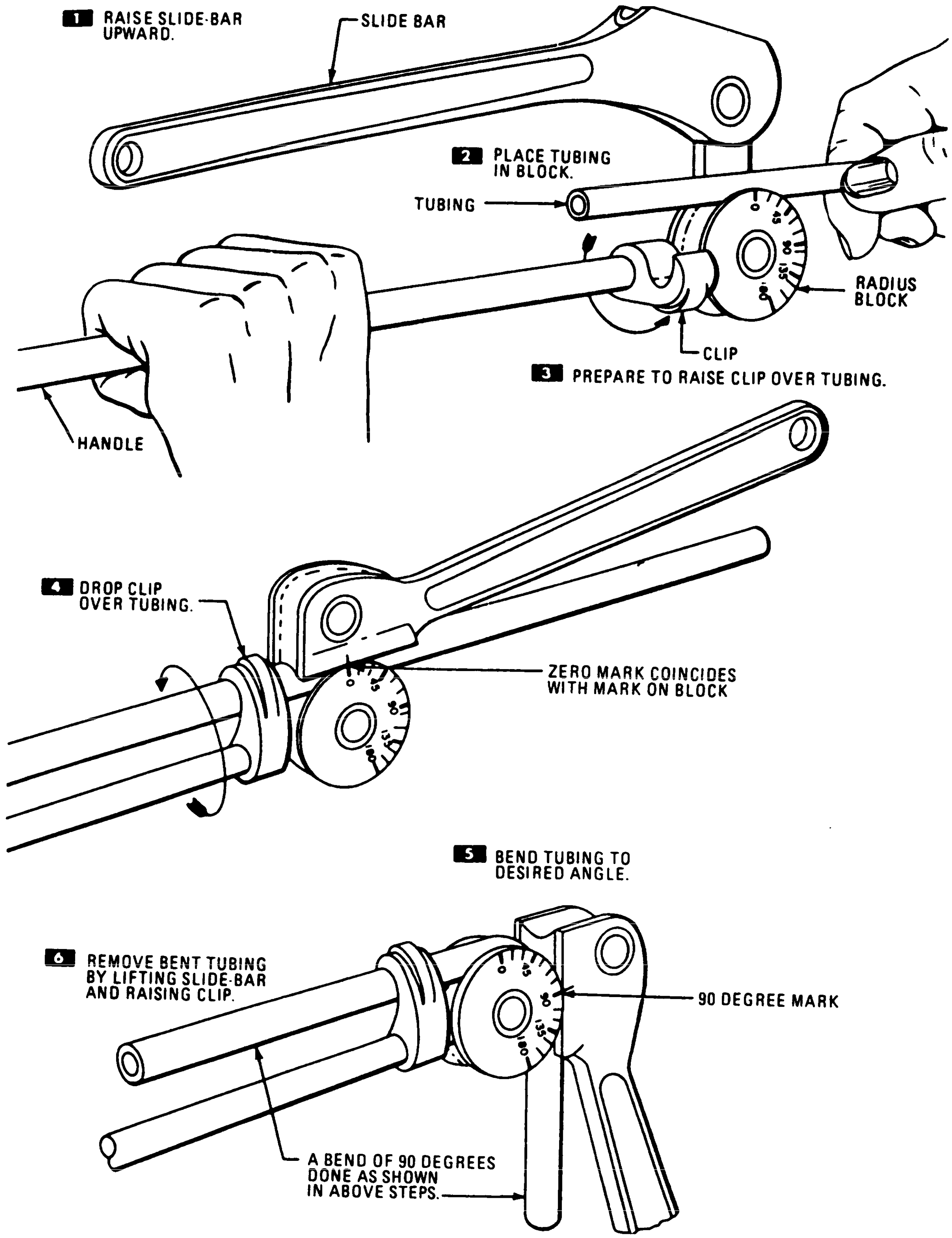


Figure 5-6.—Bending tubing with hand-operated tube bender.

HAND TUBE BENDER.— The hand tube bender shown in figure 5-6 consists of a handle, a radius block, a clip, and a slide bar. The handle and slide bar are used as levers to provide the mechanical advantage necessary to bend the tubing. The radius block is marked in degrees of bend ranging from 0 to 180 degrees. The slide bar has a mark which is lined up with the zero mark on the radius block. The tube is inserted in the tube bender, and after the marks are lined up, the

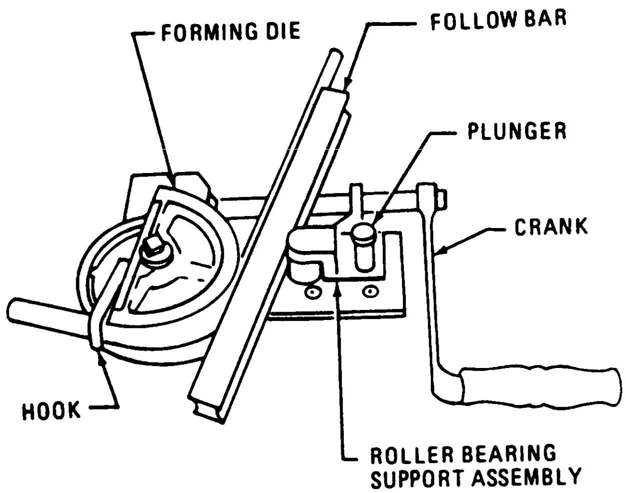


Figure 5-7.—Mechanically operated tube bender.

slide bar is moved around until the mark on the slide bar reaches the desired degree of bend on the radius block. See figure 5-6 for the six procedural steps in tube bending with the hand-operated tube bender.

MECHANICAL TUBE BENDER.— The tube bender shown in figure 5-7 is issued as a kit. The kit contains the equipment necessary for bending tubing from 1/4 inch to 3/4 inch in diameter.

This tube bender is designed for use with aircraft grade, high-strengths stainless-steel tubing, as well as all other metal tubing. It is designed to be fastened to a bench or tripod. The base is formed to provide a secure grip in a vise.

This type of tube bender uses a hand crank and gears. The forming die is keyed to the drive gear and is secured by a screw.

The forming die on the mechanical tube bender is calibrated in degrees, similarly to the radius block of the hand bender. A length of replacement tubing may be bent to a specified number of degrees or it may be bent to duplicate a bend either in a damaged tube or in a pattern. Duplicating a bend of a damaged tube or of a pattern is done by laying the sample or pattern on top of the tube being bent and slowly bending the new tube to the required bend.

Tube Flaring

Tube flaring is a method of forming the end of a tube into a funnel shape so it can be held by a threaded fitting. When a flared tube is prepared, a flare nut is slipped onto the tube and the end of the tube is flared. During tube installation, the flare is seated to a fitting with the inside of the flare against the cone-shaped end of the fitting, and the flare nut is screwed onto the fitting, pulling the inside of the flare against the seating surface of the fitting.

Either of two flaring tools (fig. 5-8) may be used. One gives a single flare and the other gives a double flare. The flaring tool consists of a split die block that has holes for various sizes of tubing,

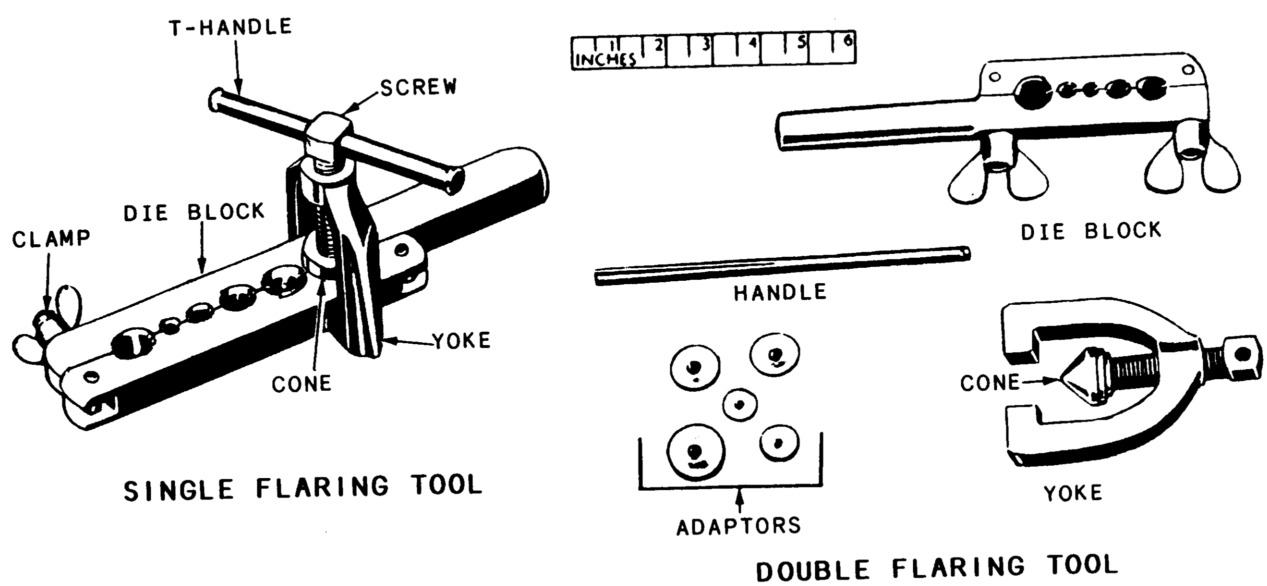


Figure 5-8.—Flaring tools.

a clamp to lock the end of the tubing inside the die block, and a yoke with a compressor screw and cone that slips over the die block and forms the 45-degree flare on the end of the tube. The screw has a T-handle. A double flaring tube has adaptors that turn in the edge of the tube before a regular 45-degree double flare is made.

To use the single flaring tool, first check to see that the end of the tubing has been cut off squarely and has had the burrs removed from both inside and outside. Slip the flare nut onto the tube before you make the flare. Then, open the die block. Insert the end of the tubing into the hole corresponding to the OD of the tubing so that the end protrudes slightly above the top face of the die blocks. The amount by which the tubing extends above the blocks determines the finished diameter of the flare. The flare must be large enough to seat properly against the fitting, but small enough that the threads of the flare nut will slide over it. Close the die block and secure the tool with the wing nut. Use the handle of the yoke to tighten the wing nut. Then place the yoke over the end of the tubing and tighten the handle to force the cone into the end of the tubing. The completed flare should be slightly visible above the face of the die blocks.

FLEXIBLE HOSE

Shock-resistant, flexible hose assemblies are required to absorb the movements of mounted equipment under both normal operating conditions and extreme conditions. They are also used for their noise-attenuating properties and to connect moving parts of certain equipment. The two basic hose types are synthetic rubber and polytetrafluoroethylene (PTFE), such as Du Pont's Teflon® fluorocarbon resin.

Rubber hoses are designed for specific fluid, temperature, and pressure ranges and are provided in various specifications. Rubber hoses (fig. 5-9) consist of a minimum three layers; a seamless synthetic rubber tube reinforced with one or more layers of braided or spiraled cotton, wire, or synthetic fiber; and an outer cover. The inner tube is designed to withstand the attack of the fluid that passes through it. The braided or spiraled layers determine the strength of the hose. The greater the number of these layers, the greater is the pressure rating. Hoses are provided in three

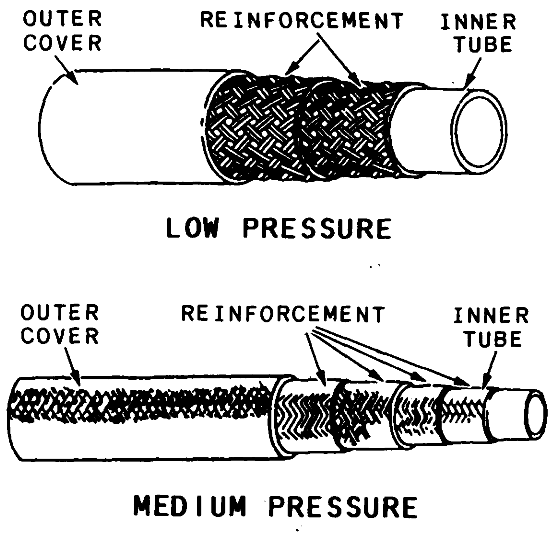


Figure 5-9.—Synthetic rubber hoses.

pressure ranges: low, medium, and high. The outer cover is designed to withstand external abuse and contains identification markings.

Synthetic rubber hoses with rubber covers are identified with the military specification number, the size by dash number, the quarter and year of cure or manufacture, and the manufacturer's code identification number or federal supply code number printed along their layline (fig. 5-10, view A). The layline is a legible marking parallel to the longitudinal axis of a hose used in determining the straightness or lay of the hose.

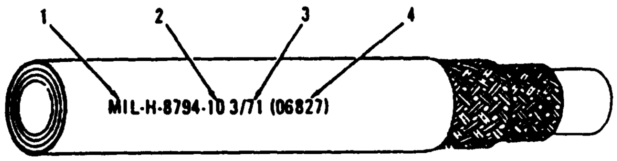
Synthetic rubber hoses with wire braid cover are identified by bands (fig. 5-10, view B) wrapped around the hose ends and at intervals along the length of the hose.

Sizing

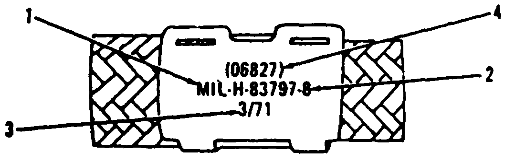
The size of a flexible hose is identified by the dash (-) number, which is the ID of the hose expressed in 16ths of an inch. For example, the ID of a -64 hose is 4 inches. For a few hose styles this is the nominal and not the true ID.

Cure Date

Synthetic rubber hoses will deteriorate from aging. A cure date is used to ensure that they do not deteriorate beyond material and performance specifications. The cure date is the quarter and year the hose was manufactured. For example,



A. SYNTHETIC RUBBER HOSE



B. WIRE BRAID COVERED SYNTHETIC RUBBER HOSE

1. MILITARY SPECIFICATION OF HOSE
2. SIZE INDICATED BY A DASH (–) NO. OR FRACTION OF AN INCH FOR MIL-H-6000 AND MIL-H-7938 HOSES
3. CURE DATE FOR AGE CONTROL
4. MANUFACTURER'S FEDERAL SUPPLY CODE NO.

MANUFACTURER	AEROQUIP
MANUFACTURER'S CODE	00624
PART NO. WITH DASH (SIZE) NO.	AE206-10
LOT NO.	305496
OPERATING PRESSURE	3000 PSI
MILITARY SPECIFICATION	MIL-H-83298

C. WIRE BRAID COVERED PTFE HOSE LABEL

Figure 5-10.—Hose identification.

1Q89 or 1/89 means the hose was made during the first quarter (1 Jan to 31 Mar) of 1989.

The cure date limits the length of time a rubber hose can be stored, in bulk or as an assembly, prior to being placed into service. The storage or shelf life for rubber hose is 4 years. For the hose manufactured in 1Q89, the storage or shelf life will end on the 31st of March 1993. At this point, the hose is no longer considered usable and should be discarded or downgraded. The *Aviation Hose and Tube Manual,* NAVAIR 01-1A-20, and the *Technical Directive for Piping Devices and Flexible Hose Assemblies,* NAVSEA S6430-AE-TED-010. volume 1. provide detailed instructions on discarding and downgrading of rubber hoses exceeding their shelf life.

PFTE

PFTE hose is a flexible hose designed to meet the requirements of higher operating pressures and temperatures in present fluid power systems. This type of hose is made from a chemical resin, which is processed and extruded into a tube shaped to a desired size. It is reinforced with one or more layers of braided stainless-steel wire or with an even number of spiral wrap layers with an outer wire braid layer.

PTFE hose is unaffected by all fluids presently used in fluid power systems. It is inert to acids, both concentrated and diluted. Certain PFTE hose may be used in systems where operating temperatures range from –100°F to +500°F. PTFE is nonflammable; however, where the possibility of open flame exists, a special asbestos fire sleeve should be used.

PFTE hose will not absorb moisture. This, together with its chemical inertness and anti-adhesive characteristics, makes it ideal for missile fluid power systems where noncontamination and cleanliness are essential.

In lieu of layline marking, PTFE hoses are identified by metal or pliable plastic bands at their ends and at intervals along their length. Figure 5-10, view C, shows a hose label for a PTFE hose. Usually the only condition that will shorten the life of PTFE hose is excessive temperature. For this reason there is no manufacture date listed on the identification tag.

APPLICATION

As mentioned earlier, flexible hose is available in three pressure ranges: low, medium, and high. When replacing hoses, it is important to ensure that the replacement hose is a duplicate of the one removed in length, OD, material, type and contour, and associated markings. In selecting hose, several precautions must be observed. The selected hose must

1. be compatible with the system fluid,
2. have a rated pressure greater than the design pressure of the system,

3. be designed to give adequate performance and service for infrequent transient pressure peaks up to 150 percent of the working pressure of the hose, and
4. have a safety factor with a burst pressure at a minimum of 4 times the rated working pressure.

There are temperature restrictions applied to the use of hoses. Rubber hose must not be used where the operating temperature exceeds 200°F. PTFE hoses in high-pressure air systems must not be used where the temperature exceeds 350°F. PTFE hoses in water and steam drain applications must not be used where the operating temperature exceeds 380°F.

FABRICATION AND TESTING

The fabrication of flexible hose assemblies is covered in applicable training manuals, technical publications, and NAVAIR 01-1A-20. After a hose assembly has been completely fabricated it must be cleaned, visually inspected for foreign materials, and proof tested.

A hose assembly is proof tested by the application of a nondestructive pressure for a minimum of 1 minute but not longer than 5 minutes to ensure that it will withstand normal working pressures. The test pressure, known as normal proof pressure, is twice the rated working pressure. While the test pressure is being applied, the hose must not burst, leak, or show signs of fitting separation. NAVAIR 01-1A-20 and NAVSEA S6430-AE-TED-010, volume 1, provide detailed instructions on cleaning of hoses, cleaning and test media, proof pressure and proof testing.

After proof testing is completed, the hose must be flushed and dried and the ends capped or plugged to keep dirt and other contaminants out of the hose.

IDENTIFICATION

The final step after fabrication and satisfactory testing of a hose assembly is the attachment of identification tags as shown in figure 5-11 (for ships) and in figure 5-12 (for aircraft). The tag shown in figure 5-12, view B, is used in areas where a tag maybe drawn into an engine intake. Hose assemblies to be installed in aircraft fuel and oil tanks are marked with an approved electric engraver on the socket-wrench flats with the required information.

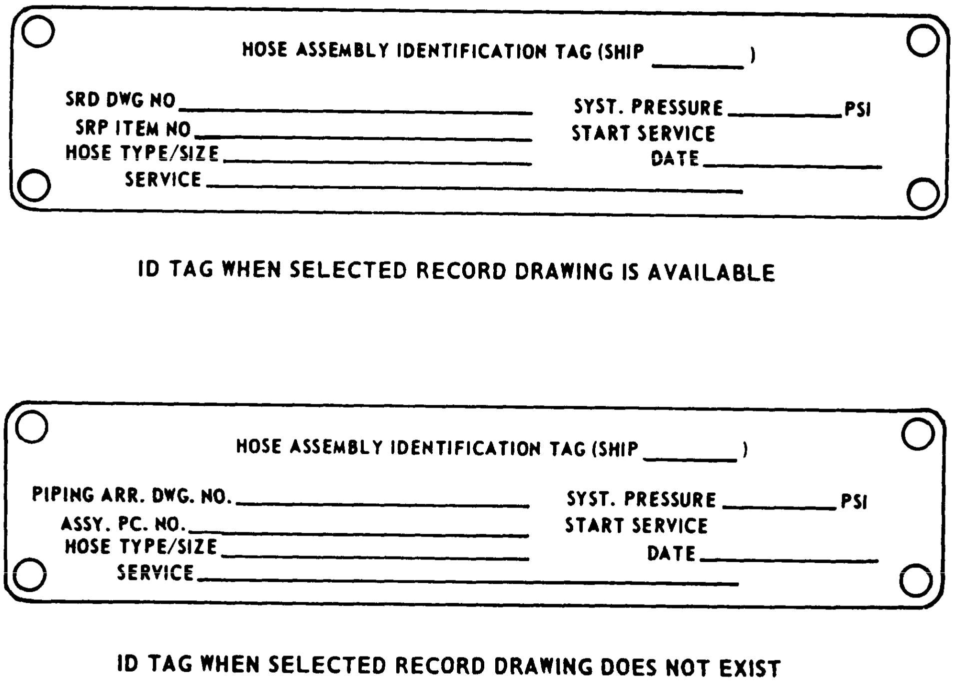


Figure 5-11.—Hose assembly identification tags (ships).

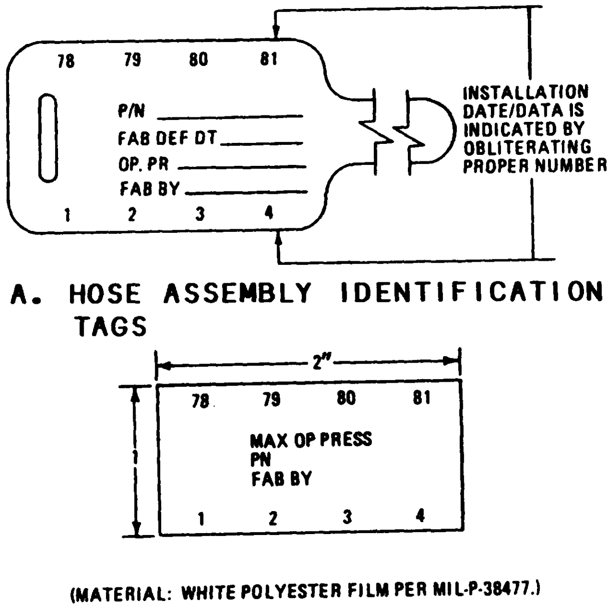


Figure 5-12.—Hose assembly identification tags (aircraft).

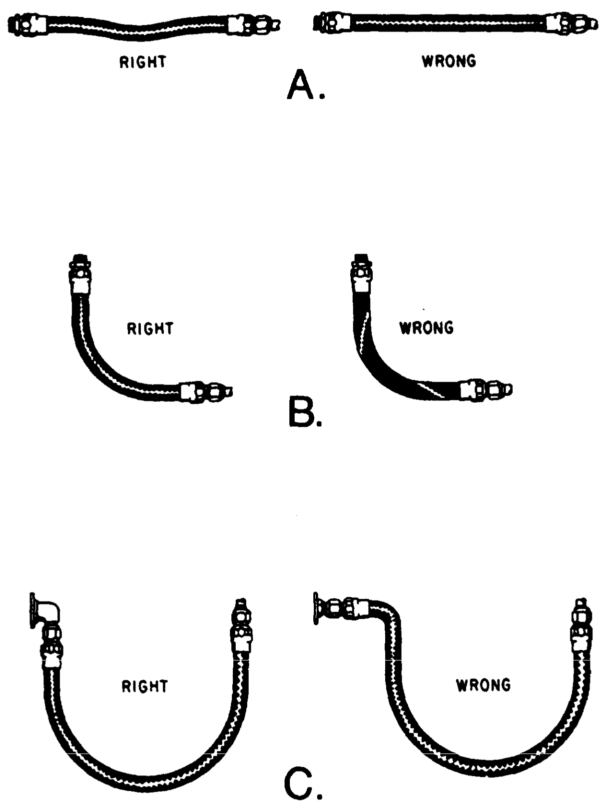


Figure 5-13.—Correct and incorrect installation of flexible hose.

INSTALLATION

Flexible hose must not be twisted during installation, since this reduces the life of the hose considerably and may cause the fittings to loosen as well. You can determine whether or not a hose is twisted by looking at the layline that runs along the length of the hose. If the layline does not spiral around the hose, the hose is not twisted. If the layline does spiral around the hose, the hose is twisted (fig. 5-13, view B) and must be untwisted.

Flexible hose should be protected from chafing by using a chafe-resistant covering wherever necessary.

The minimum bend radius for flexible hose varies according to the size and construction of the hose and the pressure under which the system operates. Current applicable technical publications contain tables and graphs showing minimum bend radii for the different types of installations. Bends that are too sharp will reduce the bursting pressure of flexible hose considerably below its rated value.

Flexible hose should be installed so that it will be subjected to a minimum of flexing during operation. Support clamps are not necessary with short installations; but for hose of considerable length (48 inches for example), clamps should be placed not more than 24 inches apart. Closer supports are desirable and in some cases may be required.

A flexible hose must never be stretched tightly between two fittings. About 5 to 8 percent of the total length must be allowed as slack to provide freedom of movement under pressure. When under pressure, flexible hose contracts in length and expands in diameter. Examples of correct and incorrect installations of flexible hose are illustrated in figure 5-13.

PFTE hose should be handled carefully during removal and installation. Some PFTE hose is preformed during fabrication. This type of hose tends to form itself to the installed position in the system. To ensure its satisfactory function and reduce the likelihood of failure, anyone who works with PFTE hose should observe the following rules:

1. Do not exceed recommended bend limits.
2. Do not exceed twisting limits.
3. Do not straighten a bent hose that has taken a permanent set.
4. Do not hang, lift, or support objects from PFTE hose.

Once flexible hose assemblies are installed, there are no servicing or maintenance requirements other than periodic inspections. These inspections are conducted according to maintenance instruction manuals (MIMs), maintenance requirement cards (MRCs), and depot-level specifications.

TYPES OF FITTINGS AND CONNECTORS

Some type of connector or fitting must be provided to attach the lines to the components of the system and to connect sections of line to each other. There are many different types of connectors and fittings provided for this purpose. The type of connector or fitting required for a specific system depends on several factors. One determining factor, of course, is the type of fluid line (pipe, tubing, or flexible hose) used in the system. Other determining factors are the type of fluid medium and the maximum operating pressure of the system. Some of the most common types of fittings and connectors are described in the following paragraphs.

THREADED CONNECTORS

There are several different types of threaded connectors. In the type discussed in this section, both the connector and the end of the fluid line (pipe) are threaded. These connectors are used in some low-pressure fluid power systems and are usually made of steel, copper, or brass, and are available in a variety of designs.

Threaded connectors are made with standard pipe threads cut on the inside surface. The end of the pipe is threaded with outside threads. Standard pipe threads are tapered slightly to ensure tight connections. The amount of taper is approximately 3/4 inch in diameter per foot of thread.

Metal is removed when a pipe is threaded, thinning the pipe and exposing new and rough surfaces. Corrosion agents work more quickly at such points than elsewhere. If pipes are assembled with no protective compound on the threads, corrosion sets in at once and the two sections stick together so that the threads seize when disassembly is attempted. The result is damaged threads and pipes.

To prevent seizing, a suitable pipe thread compound is sometimes applied to the threads. The two end threads must be kept free of compound so that it will not contaminate the fluid. Pipe compound, when improperly applied, may get inside the lines and components and damage pumps and control equipment.

Another material used on pipe threads is sealant tape. This tape, which is made of PTFE, provides an effective means of sealing pipe connections and eliminates the necessity of torquing connections to excessively high values in order to prevent pressure leaks. It also provides for ease of maintenance whenever it is necessary to disconnect pipe joints. The tape is applied over the male threads, leaving the first thread exposed. After the tape is pressed firmly against the threads, the joint is connected.

FLANGE CONNECTORS

Bolted flange connectors (fig. 5-14) are suitable for most pressures now in use. The flanges are attached to the piping by welding, brazing, tapered threads (for some low-pressure systems), or rolling and bending into recesses. Those illustrated are the most common types of flange joints used. The same types of standard fitting shapes (tee, cross, elbow, and so forth) are manufactured for flange joints. Suitable gasket material must be used between the flanges.

WELDED CONNECTORS

The subassemblies of some fluid power systems are connected by welded joints, especially in high-pressure systems which use pipe for fluid lines. The welding is done according to standard

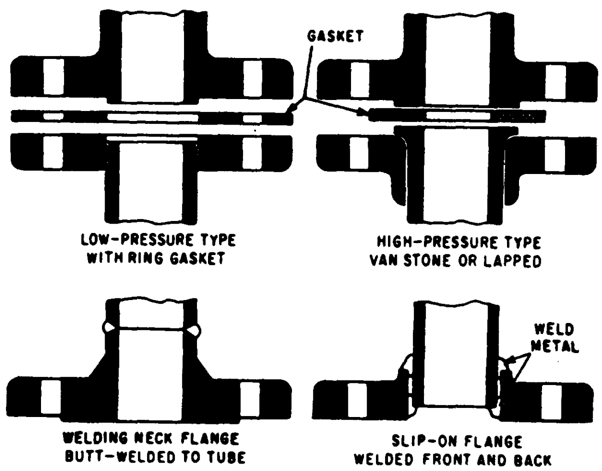


Figure 5-14.—Four types of bolted flange connectors.

specifications which define the materials and techniques.

BRAZED CONNECTORS

Silver-brazed connectors are commonly used for joining nonferrous (copper, brass, and soon) piping in the pressure and temperature range where their use is practical. Use of this type of connector is limited to installations in which the piping temperature will not exceed 425°F and the pressure in cold lines will not-exceed 3,000 psi. The alloy is melted by heating the joint with an oxyacetylene torch. This causes the alloy insert to melt and fill the few thousandths of an inch annular space between the pipe and the fitting.

A fitting of this type which has been removed from a piping system can be rebrazed into a system, as in most cases sufficient alloy remains in the insert groove for a second joint. New alloy inserts may be obtained for fittings which do not have sufficient alloy remaining in the insert for making a new joint.

FLARED CONNECTORS

Flared connectors are commonly used in fluid power systems containing lines made of tubing. These connectors provide safe, strong, dependable connections without the need for threading, welding, or soldering the tubing. The connector consists of a fitting, a sleeve, and a nut (fig. 5-15).

The fittings are made of steel, aluminum alloy, or bronze. The fitting used in a connection should be made of the same material as that of the sleeve, the nut, and the tubing. For example, use steel connectors with steel tubing and aluminum alloy connectors with aluminum alloy tubing. Fittings are made in union, 45-degree and 90-degree elbow, tee, and various other shapes (fig. 5-16).

Tees, crosses, and elbows are self-explanatory. Universal and bulkhead fittings can be mounted solidly with one outlet of the fitting extending through a bulkhead and the other outlet(s) positioned at any angle. Universal means the fitting can assume the angle required for the specific installation. Bulkhead means the fitting is long enough to pass through a bulkhead and is designed so it can be secured solidly to the bulkhead.

For connecting to tubing, the ends of the fittings are threaded with straight machine threads to correspond with the female threads of the nut. In some cases, however, one end of the fitting may be threaded with tapered pipe threads to fit

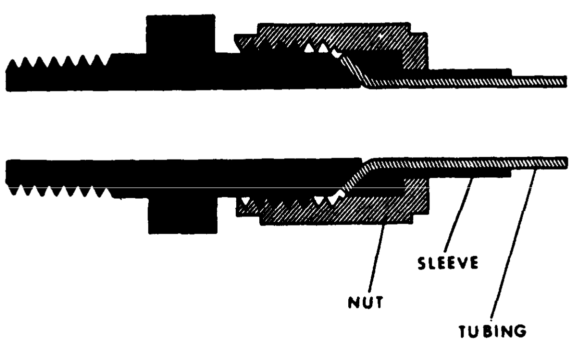


Figure 5-15.—Flared-tube fitting.

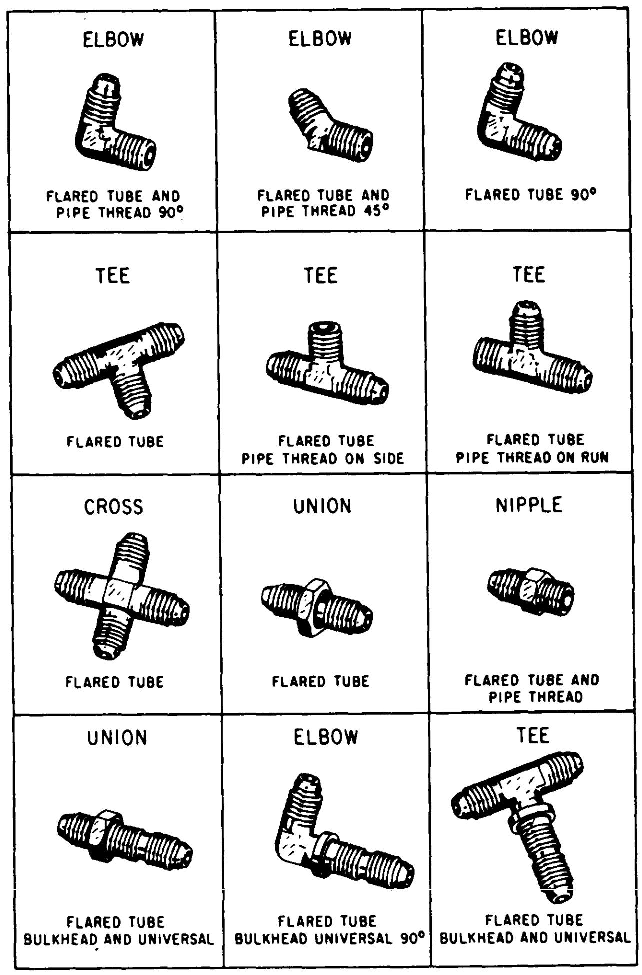


Figure 5-16.—Flared-tube fittings.

threaded ports in pumps, valves, and other components. Several of these thread combinations are shown in figure 5-16.

Tubing used with flare connectors must be flared prior to assembly. The nut fits over the sleeve and when tightened, it draws the sleeve and tubing flare tightly against the male fitting to form a seal.

The male fitting has a cone-shaped surface with the same angle as the inside of the flare. The sleeve supports the tube so vibration does not concentrate at the edge of the flare, and distributes the shearing action over a wider area for added strength. Tube flaring is covered in *Tools and Their Uses,* NAVEDTRA 10085 (series), and other applicable training manuals.

Correct and incorrect methods of installing flared-tube connectors are illustrated in figure 5-17. Tubing nuts should be tightened with a torque wrench to the value specified in applicable technical publications.

If an aluminum alloy flared connector leaks after being tightened to the required torque, it must not be tightened further. Overtightening may severely damage or completely cut off the tubing flare or may result in damage to the sleeve or nut. The leaking connection must be disassembled and the fault corrected.

If a steel tube connection leaks, it may be tightened 1/6 turn beyond the specified torque in an attempt to stop the leakage; then if it still leaks, it must be disassembled and repaired.

Undertightening of connections may be serious, as this can allow the tubing to leak at the connector bemuse of insufficient grip on the flare by the sleeve. The use of a torque wrench will prevent undertightening.

CAUTION

A nut should never be tightened when there is pressure in the line, as this will tend to damage the connection without adding any appreciable torque to the connection.

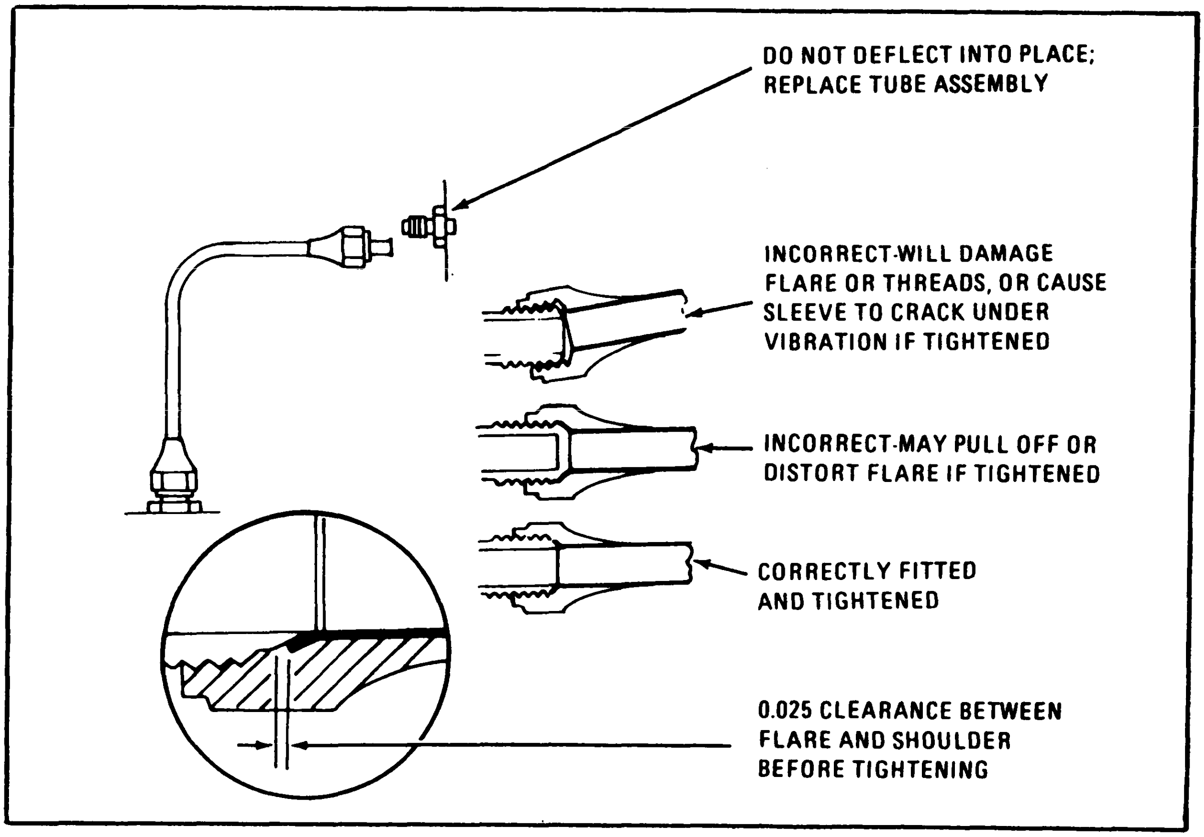


Figure 5-17.—Correct and incorrect methods of installing flared fittings.

FLARELESS-TUBE CONNECTORS

This type of connector eliminates all tube flaring, yet provides a safe, strong, and dependable tube connection. This connector consists of a fitting, a sleeve or ferrule, and a nut. (See fig. 5-18.)

NOTE

Although the use of flareless tube connectors is widespread, NAVSEA policy is to reduce or eliminate use of flareless fittings in newly designed ships; the extent to which flareless fittings are approved for use in a particular ship is reflected in applicable ship drawings.

Flareless-tube fittings are available in many of the same shapes and thread combinations as flared-tube fittings. (See fig. 5-16.) The fitting has a counterbore shoulder for the end of the tubing to rest against. The angle of the counterbore causes the cutting edge of the sleeve or ferrule to cut into the outside surface of the tube when the two are assembled.

The nut presses on the bevel of the sleeve and causes it to clamp tightly to the tube. Resistance to vibration is concentrated at this point rather than at the sleeve cut. When fully tightened, the sleeve or ferrule is bowed slightly at the midsection and acts as a spring. This spring action of the sleeve or ferrule maintains a constant tension between the body and the nut and thus prevents the nut from loosening.

Prior to the installation of a new flareless-tube connector, the end of the tubing must be square, concentric, and free of burrs. For the connection to be effective, the cutting edge of the sleeve or ferrule must bite into the periphery of the tube (fig. 5-19). This is ensured by presetting the sleeve or ferrule on the tube.

Presetting

Presetting consists of deforming the ferrule to bite into the tube OD and deforming the end of the tube to form a shallow conical ring seating surface. The tube and ferrule assembly should be preset in a presetting tool that has an end section identical to a fitting body but which is made of specially hardened steel. This tool hardness is needed to ensure that all deformation at the tube end seat goes into the tube.

Presetting is done with a hydraulic presetting tool or a manual presetting tool, either in the shop or aboard ship. The tool vendor's instructions must be followed for the hydraulic presetting tool. If a presetting tool is not available, the fitting body intended for installation is used in the same manner as the manual presetting tool. (If an aluminum fitting is used, it should not be reused in the system.) The manual tool is used as follows:

WARNING

Failure to follow these instructions may result in improperly preset ferrules with insufficient bite into the tube. Improperly preset ferrules have resulted in joints that passed hydrostatic testing and operated for weeks or years, then failed catastrophically under shock, vibration, or normal operating loads. Flareless fitting failures have

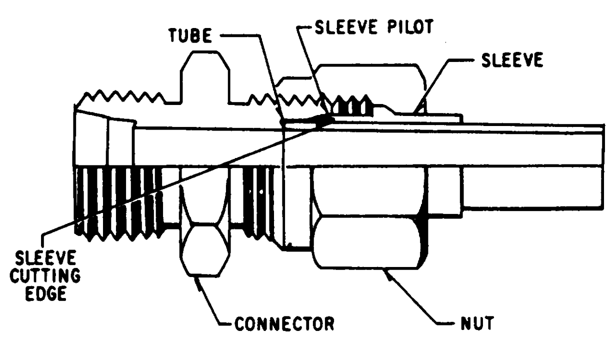


Figure 5-18.—Flareless-tube connector.

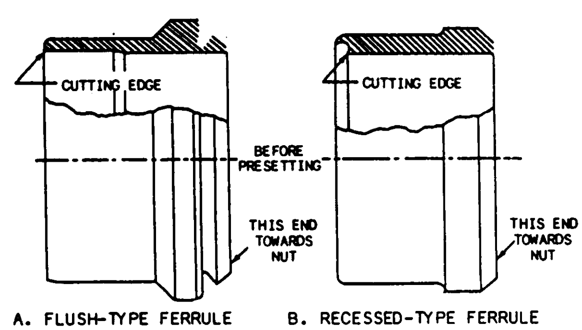


Figure 5-19.—Unused ferrules.

caused personnel injury, damage to equipment, and unnecessary interruption of propulsion power.

1. Cut the tubing square and lightly deburr the inside and outside corners. For corrosion resisting steel (CRES) tubing, use a hacksaw rather than a tubing cutter to avoid work hardening the tube end. For CRES, and if necessary for other materials, dress the tube end smooth and square with a file. Tube ends with irregular cutting marks will not produce satisfactory seating surface impressions.

2. Test the hardness of the ferrule by making a light scratch on the tubing at least 1/2 inch back from the tube end, using a sharp corner on the ferrule. If the ferrule will not scratch the tube, no bite will be obtained. This test maybe omitted for flush-type ferrules where the bite will be visible. Moderate hand pressure is sufficient for producing the scratch.

3. Lubricate the nut threads, the ferrule leading and trailing edges, and the preset tool threads with a thread lubricant compatible with the system. Slide the nut onto the tubing so the threads face the tube end. Note whether the ferrule is a flush type or recessed type (fig. 5-19), and slide the ferrule onto the tube so the cutting edge is toward the tube end (large end toward the nut).

4. Bottom the end of the tubing in the presetting tool. Slide the ferrule up into the presetting tool, and confirm that the nut can be moved down the tube sufficiently to expose at least 1/8 inch of tubing past the ferrule after the presetting operation (fig. 5-20) to allow for inspection of the ferrule.

5. While keeping the tube bottomed in the presetting tool, tighten the nut onto the fitting body until the ferrule just grips the tube by friction. This ring grip point may be identified by lightly turning the tube or the presetting tool and slowly tightening the nut until the tube cannot be turned in the presetting tool by hand. Mark the nut and the presetting tool at this position.

6. Tighten the nut according to the number of turns given in table 5-3, depending on tube size.

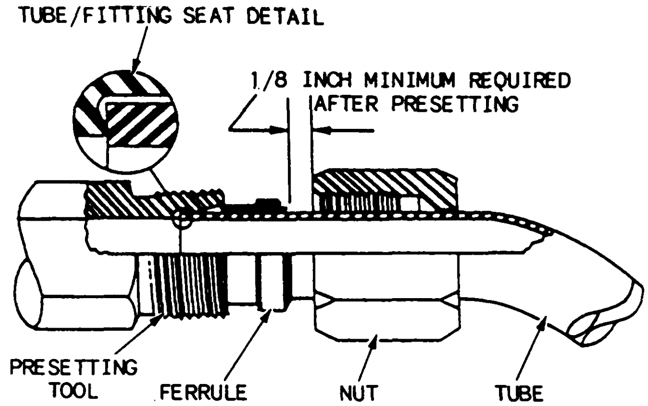


Figure 5-20.—Tube and ferrule assembled for presetting, showing nut position required for inspecting ferrule.

Inspection

Disassemble and inspect the fitting as follows (mandatory):

1. Ensure that the end of the tubing has an impression of the presetting tool seat surface (circular appearing ring) for 360 degrees. A partial circle, a visibly off-center circle, or a circle broken by the roughness of the tube end is unsatisfactory.

2. Check for proper bite:

a. For flush-type ferrules, a raised ridge (fig. 5-21) of tube metal must be visible completely around the tube at the leading edge of the ferrule. The best practice is to obtain a ridge about 50 percent of the ferrule edge thickness.

Table 5-3.—Number of Turns

Tube OD Inches	Number of Turns
1/8 to 1/2	1-1/6 (seven flats of the nut)
5/8 to 7/8	1 (six flats)
1	5/6 (five flats)
1-1/4 to 2	1 (six flats)

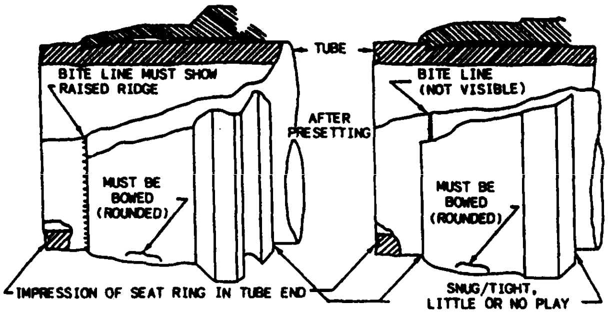


Figure 5-21.—Ferrules installed on tube, preset and removed for inspection.

b. For recessed-type ferrules, the leading edge must be snug against the tube OD. Determine this visually and by attempting to rock the ferrule on the tube.

3. Ensure that the nut end of the ferrule (both types) is collapsed around the tube to provide support against bending loads and vibration.

4. The ferrule (both types) must have little or no play along the direction of the tube run. Check this by trying to move the ferrule back and forth by hand. The ferrule will often be free to rotate on the tubing; this does not affect its function.

5. For flush-type ferrules, check that the gap between the raised metal ridge and the cutting end of the ferrule stays the same while the ferrule is rotated. (Omit this check for recessed-type ferrules or if the flush-type ferrule will not rotate on the tube).

6. Check that the middle portion of the ferrule (both types) is bowed or sprung into an arc. The leading edge of the ferrule may appear flattened into a cone shape; this is acceptable as long as there is a bowed section near the middle of the ferrule. If the whole leading section of the ferrule is flattened into a cone with no bowed section, the ferrule (and possibly the fitting body, if used) has been damaged by overtightening and will not seal reliably.

Final Assembly

When you make a final assembly in the system, use the following installation procedure:

1. Lubricate all threads with a liquid that is compatible with the fluid to be used in the system.

2. Place the tube assembly in position and check for alignment.

3. Tighten the nut by hand until you feel an increase in resistance to turning. This indicates that the sleeve or ferrule pilot has contacted the fitting.

4. If possible, use a torque wrench to tighten flareless tubing nuts. Torque values for specific installations are usually listed in the applicable technical publications. If it is not possible to use a torque wrench, use the following procedures for tightening the nuts:

After the nut is handtight, turn the nut 1/6 turn (one flat on a hex nut) with a wrench. Use a wrench on the connector to prevent it from turning while tightening the nut. After you install the tube assembly, have the system pressure tested. Should a connection leak, you may 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, remove the assembly and inspect the components of the assembly for scores, cracks, presence of foreign material, or damage from overtightening.

NOTE: Overtightening a flareless-tube nut drives the cutting edge of the sleeve or ferrule deeply into the tube, causing the tube to be weakened to the point where normal vibration could cause the tube to shear. After you complete the inspection (if you do not find any discrepancies), reassemble the connection 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 or the tube.

CONNECTORS FOR FLEXIBLE HOSE

As stated previously, the fabrication of flexible hose assemblies is covered in applicable training manuals, technical publications, and NAVAIR 01-1A-20. There are various types of end fittings for both the piping connection side and the hose connection side of hose fittings. Figure 5-22 shows commonly used fittings.

Piping Connection Side of Hose Fitting

The piping side of an end fitting comes with several connecting variations: flange, JIC 37° flare, O-ring union, and split clamp, to name a few. Not all varieties are available for each hose. Therefore, installers must consult the military specification and manufacturer's data to determine the specific end fittings available.

Hose Connection Side of Hose Fitting

Hose fittings are attached to the hose by several methods. Each method is determined by the fitting manufacturer and takes into consideration such things as size, construction, wall thickness, and pressure rating. Hoses used for flexible connections use one of the following methods for attachment of the fitting to the hose.

ONE-PIECE REUSABLE SOCKET.— The socket component of the fitting is fabricated as a single piece. One-piece reusable sockets are screwed or rocked onto the hose OD, followed by insertion of the nipple component.

SEGMENTED, BOLTED SOCKET.— The segmented, bolted socket consists of two or more segments which are bolted together on the hose after insertion of the nipple component.

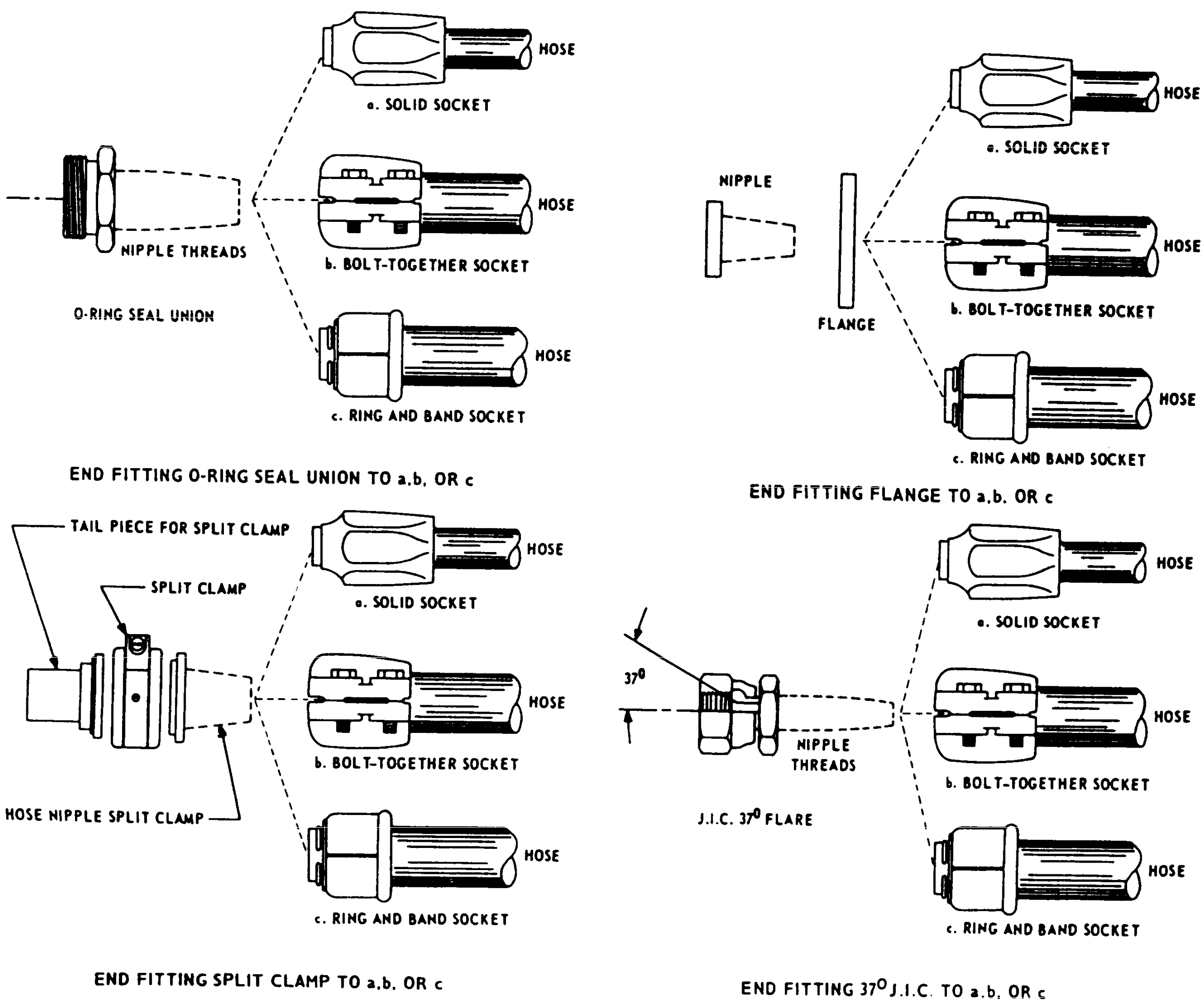


Figure 5-22.—End fittings and hose fittings.

SEGMENTED SOCKET, RING AND BAND ATTACHED.— The segmented, ring and band attached socket consists of three or more segments. As with the bolt-together segments, the segments, ring and band are put on the hose after insertion of the nipple. A special tool is required to compress the segments.

SEGMENTED SOCKET, RING AND BOLT ATTACHED.— The segmented, ring and bolt attached socket consists of three or more segments. As with other segmented socket-type fittings, the segments, ring, and nuts and bolts are put on the hose after insertion of the nipple.

SOLID SOCKET, PERMANENTLY ATTACHED.— This type of socket is permanently attached to the hose by crimping or swaging. It is not reusable and is only found on hose assemblies where operating conditions preclude the use of other fitting types. Hose assemblies with this type of fitting attachment are purchased as complete hose assemblies from the manufacturer.

QUICK-DISCONNECT COUPLINGS

Self-sealing, quick-disconnect couplings are used at various points in many fluid power systems. These couplings are installed at locations where frequent uncoupling of the lines is required for inspection, test, and maintenance. Quick-disconnect couplings are also commonly used in pneumatic systems to connect sections of air hose and to connect tools to the air pressure lines. This provides a convenient method of attaching and detaching tools and sections of lines without losing pressure.

Quick-disconnect couplings provide a means for quickly disconnecting a line without the loss of fluid from the system or the entrance of foreign matter into the system. Several types of quick-disconnect couplings have been designed for use in fluid power systems. Figure 5-23 illustrates a coupling that is used with portable pneumatic tools. The male section is connected to the tool or to the line leading from the tool. The female section, which contains the shutoff valve, is installed in the pneumatic line leading from the pressure source. These connectors can be separated or connected by very little effort on the part of the operator.

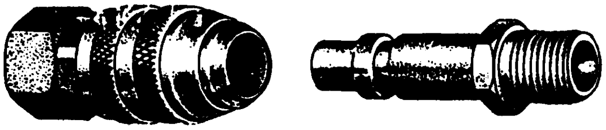


Figure 5-23.—Quick-disconnect coupling for air lines.

The most common quick-disconnect coupling for hydraulic systems consists of two parts, held together by a union nut. Each part contains a valve which is held open when the coupling is connected, allowing fluid to flow in either direction through the coupling. When the coupling is disconnected, a spring in each part closes the valve, preventing the loss of fluid and entrance of foreign matter.

MANIFOLDS

Some fluid power systems are equipped with manifolds in the pressure supply and/or return lines. A manifold is a fluid conductor that provides multiple connection ports. Manifolds eliminate piping, reduce joints, which are often a source of leakage, and conserve space. For example, manifolds may be used in systems that contain several subsystems. One common line connects the pump to the manifold. There are outlet ports in the manifold to provide connections to each subsystem. A similar manifold may be used in the return system. Lines from the control valves of the subsystem connect to the inlet ports of the manifold, where the fluid combines into one outlet line to the reservoir. Some manifolds are equipped with the check valves, relief valves, filters, and so on, required for the system. In some cases, the control valves are mounted on the manifold in such a manner that the ports of the valves are connected directly to the manifold.

Manifolds are usually one of three types—sandwich, cast, or drilled. The sandwich type is constructed of three or more flat plates. The center plate (or plates) is machined for passages, and the required inlet and outlet ports are drilled into the outer plates. The plates are then bonded together to provide a leakproof assembly. The cast type of manifold is designed with cast passages and drilled ports. The casting may be iron, steel, bronze, or aluminum, depending upon the type of system and fluid medium. In the drilled type of manifold, all ports and passages are drilled in a block of metal.

A simple manifold is illustrated in figure 5-24. This manifold contains one pressure inlet port and several pressure outlet ports that can be blocked off with threaded plugs. This type of manifold can be adapted to systems containing various numbers of subsystems. A thermal relief valve may be incorporated in this manifold. In this case, the port labeled T is connected to the return line to provide a passage for the relieved fluid to flow to the reservoir.

Figure 5-25 shows a flow diagram in a manifold which provides both pressure and return passages. One common line provides pressurized fluid to the manifold, which distributes the fluid to any one of five outlet ports. The return side of the manifold is similar in design. This manifold is provided with a relief valve, which is connected to the pressure and return passages. In the event of excessive pressure, the relief valve opens and allows the fluid to flow from the pressure side of the manifold to the return side.

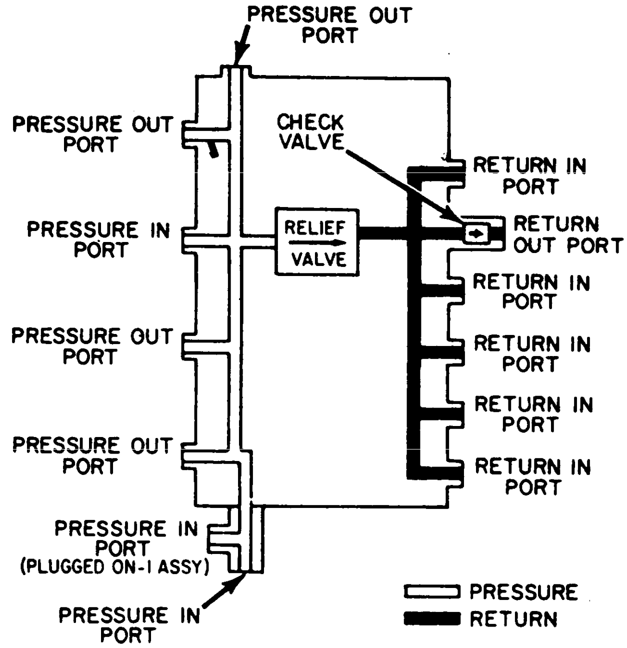


Figure 5-25.—Fluid manifold—flow diagram.

PRECAUTIONARY MEASURES

The fabrication, installation, and maintenance of all fluid lines and connectors are beyond the scope of this training manual. However, there are some general precautionary measures that apply to the maintenance of all fluid lines.

Regardless of the type of lines or connectors used to make up a fluid power system, make certain they are the correct size and strength and perfectly clean on the inside. All lines must be absolutely clean and free from scale and other foreign matter. Iron or steel pipes, tubing, and fittings can be cleaned with a boiler tube wire brush or with commercial pipe cleaning apparatus. Rust and scale can be removed from short, straight pieces by sandblasting, provided there is no danger that sand particles will remain lodged in blind holes or pockets after the piece

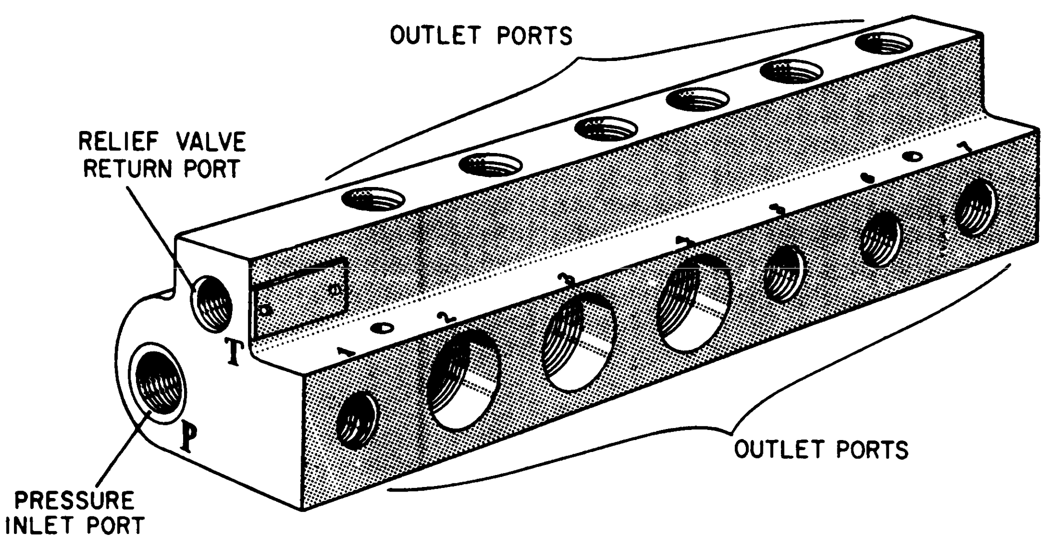


Figure 5-24.—Fluid manifold.

is flushed. In the case of long pieces or pieces bent to complex shapes, rust and scale can be removed by pickling (cleaning metal in a chemical bath). Parts must be degreased prior to pickling. The manufacturer of the parts should provide complete pickling instructions.

Open ends of pipes, tubing, hose, and fittings should be capped or plugged when they are to be stored for any considerable period. Rags or waste must not be used for this purpose, because they deposit harmful lint which can cause severe damage to the fluid power system.