SUBCOURSE
AL 0907

EDITION
A

BASIC HYDRAULICS AND HYDRAULIC PLUMBING

READINESS/
PROFESSIONALISM
THRU
GROWTH

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

BASIC HYDRAULICS AND HYDRAULIC PLUMBING

Subcourse Number AL0907

EDITION A

US Army Aviation Logistics School
Fort Eustis, Virginia 23604-5439

4 Credit Hours

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SUBCOURSE OVERVIEW

We designed this subcourse to provide instruction on the science of hydraulics, an explanation of hydraulic principles, and a study of the fluids used in aircraft hydraulic systems. You will also be introduced to the fundamentals of hydraulic plumbing, techniques of fabricating tubes and hoses, principles of installing these lines, and use of seals and gaskets to control leakage in plumbing systems.

The time was early in the 1920s. From a grassy field on one of the aerodromes of that era, a young pilot of the Army Air Corps was preparing to take up a recently developed aircraft. He had been anxious to test-fly this model because it had the first retractable landing gear. He recalled the biplanes of World War I from which the landing gear jutted like the legs of a chicken. Now, if the gear could be retracted out of the airstream, power could be saved and greater speeds attained.

After becoming airborne, the pilot reached down for the retraction handle and started cranking. It was a fatiguing and sluggish process, but sure enough the gear came up.

Today, huge jets are scarcely airborne before landing gear weighing thousands of pounds is retracted by the mere push of a button and the hydraulic system is activated, effortlessly tucking these assemblies into the fuselage.

This text deals with the aircraft hydraulic system. Hydraulics have done more than replace the hand crank for landing gear retraction of the post-World War I aircraft. It has, in essence, made modern day aviation possible.

This subcourse is to be completed on a self-study basis. You will grade your lessons as you complete them using the lesson answer keys which are enclosed. If you have answered any question incorrectly, study the question reference shown on the answer key and evaluate all possible solutions.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

TERMINAL LEARNING OBJECTIVE

ACTION: You will demonstrate a knowledge of the basic concepts, applications, and characteristics of the hydraulic system including the lines, hoses, fluids, and other components which make the system work.

CONDITIONS: You will use the material in this subcourse.

STANDARD: You must correctly answer a minimum of 70 percent of the questions on the subcourse examination to pass this subcourse.

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LESSON 1

BASIC HYDRAULICS

STP TASK: 551-758-1071

OVERVIEW

LESSON DESCRIPTION: In this lesson you will learn the definition of hydraulics, its basic applications and characteristics, and the types of hydraulic fluid used.

LEARNING OBJECTIVE:

ACTION: After this lesson you will demonstrate a knowledge of the principles of hydraulics, its characteristics and applications, and the fluids used in the system.

CONDITIONS: You will study the material in this lesson in a classroom environment or at home.

STANDARD: You will correctly answer all the questions in the practice exercise before you proceed to the next lesson.

REFERENCES: The material contained in this lesson was derived from the following publications, FM 1-509, FM 10-69, and TM 1-1500-204-23 Series

INTRODUCTION

Hydraulics has proven to be the most efficient and economical system adaptable to aviation. First used by the ancient Greeks as a means of elevating the stages of their amphitheaters, the principles of hydraulics were explained scientifically by the seventeenth century scholars Pascal and Boyle. The laws discovered by these two men regarding the effects of pressure and temperature on fluids and gases in confined areas form the basis of the principle of mechanical advantage; in other words, the "why and how" of hydraulics.

This chapter explains to you the basic applications of hydraulics in Army aviation and the characteristics of these systems. The explanations include detailed definitions of the terminology peculiar to hydraulics with which you must be familiar to fully understand this subject.

In aviation, hydraulics is the use of fluids under pressure to transmit force developed in one location on an aircraft or other related equipment to some other point on the same aircraft or equipment. Hydraulics also includes the principles underlying hydraulic action and the methods, fluids, and equipment used in implementing those principles.

HYDRAULIC AND HYDRAULICS

The word "hydraulic" is derived from two Greek words: "hydro" meaning liquid or water and "aulos" meaning pipe or tubing. "Hydraulic," therefore, is an adjective implying that the word it modifies is in some major way concerned with liquids. Examples can be found in the everyday usage of "hydraulic" in connection with familiar items such as automobile jacks and brakes. As a further example, the phrase "hydraulic freight elevator" refers to an elevator ascending and descending on a column of liquid instead of using cables and a drum.

On the other hand, the word "hydraulics" is the generic name of a subject. According to the dictionary "hydraulics" is defined as a branch of science that deals with practical applications (such as the transmission of energy or the effects of flow) of a liquid in motion.

USES OF HYDRAULICS ON ARMY AIRCRAFT

On fixed-wing aircraft, hydraulics is used to operate retractable landing gear and wheel brakes and to control wing flaps and propeller pitch. In conjunction with gases, hydraulics is used in the operation of--

- Rotor and wheel brakes.
- Shock struts.
- Shimmy dampers.
- Flight control systems.

- Loading ramps.
- Folding pylons.
- Winch hoists.

CHARACTERISTICS OF HYDRAULIC SYSTEMS

Hydraulic systems have many desirable features. However, one disadvantage is the original high cost of the various components. This is more than offset by the many advantages that make hydraulic systems the most economical means of power transmission. The following paragraphs discuss some of the advantages of hydraulic systems.

Efficiency. Discounting any losses that can occur in its mechanical linkage, practically all the energy transmitted through a hydraulic system is received at the output end -- where the work is performed. The electrical system, its closest competitor, is 15 percent to 30 percent lower in efficiency. The best straight mechanical systems are generally 30 percent to 70 percent less efficient than comparable hydraulic systems because of high inertia factors and frictional losses. Inertia is the resistance to motion, action, or change.

Dependability. The hydraulic system is consistently reliable. Unlike the other systems mentioned, it is not subject to changes in performance or to sudden unexpected failure.

Control Sensitivity. The confined liquid of a hydraulic system operates like a bar of steel in transmitting force. However, the moving parts are lightweight and can be almost instantaneously put into motion or stopped. The valves within the system can start or stop the flow of pressurized fluids almost instantly and require very little effort to manipulate. The entire system is very responsive to operator control.

Flexibility of Installation. Hydraulic lines can be run almost anywhere. Unlike mechanical systems that must follow straight paths, the lines of a hydraulic system can be led around obstructions. The major components of hydraulic systems, with the exception of power-driven pumps located near the power source, can be installed in a variety of places. The advantages of this feature are readily recognized when you study the many locations of hydraulic components on various types of aircraft.

Low Space Requirements. The functional parts of a hydraulic system are small in comparison to those of other systems; therefore, the total space requirement is comparatively low.

These components can be readily connected by lines of any length or contour. They can be separated and installed in small, unused, and out-of-the-way spaces. Large, unoccupied areas for the hydraulic system are unnecessary; in short, special space requirements are reduced to a minimum.

Low Weight. The hydraulic system weighs remarkably little in comparison to the amount of work it does. A mechanical or electrical system capable of doing the same job weighs considerably more. Since nonpayload weight is an important factor on aircraft, the hydraulic system is ideal for aviation use.

Self-Lubricating. The majority of the parts of a hydraulic system operate in a bath of oil. Thus, hydraulic systems are practically self-lubricating. The few components that do require periodic lubrication are the mechanical linkages of the system.

Low Maintenance Requirements. Maintenance records consistently show that adjustments and emergency repairs to the parts of hydraulic systems are seldom necessary. The aircraft time-change schedules specify the replacement of components on the basis of hours flown or days elapsed and require relatively infrequent change of hydraulic components.

FORCE

The word "force," used in a mechanical sense, means a push or pull. Force, because it is a push or pull, tends to cause the object on which it is exerted to move. In certain instances, when the force acting on an object is not sufficient to overcome its resistance or drag, no movement will take place. In such cases force is still considered to be present.

Direction of Force. Force can be exerted in any direction. It may act downward: as when gravity acts on a body, pulling it towards the earth. A force may act across: as when the wind pushes a boat across the water. A force can be applied upwards: as when an athlete throws (pushes) a ball into the air. Or a force can act in all directions at once: as when a firecracker explodes.

Magnitude of Force. The extent (magnitude) of a given force is expressed by means of a single measurement. In the United States, the "pound" is the unit of measurement of force. For example, it took 7.5 million pounds of thrust (force) to lift the Apollo moonship off its launch pad. Hydraulic force is measured in the amount of pounds required to displace an object within a specified area such as in a square inch.

PRESSURE

The word "pressure," when used in conjunction with mechanical and hydromechanical systems, has two different uses. One is technical; the other, nontechnical. These two uses can be easily distinguished from each other by the presence or absence of a number. In technical use, a number always accompanies the word "pressure." In nontechnical use no number is present. These definitions are further explained in the following paragraphs.

Technical. The number accompanying pressure conveys specific information about the significant strength of the force being applied. The strength of this applied force is expressed as a rate at which the force is distributed over the area on which it is acting. Thus, pounds per square inch (psi) expresses a rate of pressure just as miles per hour (mph) does of speed. An example of this is: "The hydraulic system in UH-1 aircraft functions at 1500 psi."

Nontechnical. The word "pressure," when used in the nontechnical sense simply indicates that an unspecified amount of force is being applied to an object. Frequently adjectives such as light, medium, or heavy are used to remove some of the vagueness concerning the strength of the applied force.

PRESSURE MEASUREMENT

When used in the technical sense, pressure is defined as the amount of force per unit area. To have universal, consistent, and definite meaning, standard units of measurement are used to express pressure. In the United States, the pound is the unit of measurement used for force, and the square inch is the unit for area. This is comparable with the unit of measurement used for speed: the mile is the unit of measurement for distance, and the hour is the measurement for time.

A pressure measurement is always expressed in terms of both units of measurement just explained: amount of force and unit area. However, only one of these units, the amount of force, is variable. The square inch is used only in the singular -- never more or less than one square inch.

A given pressure measurement can be stated in three different ways and still mean the same thing. Therefore, 50 psi pressure, 50 pounds pressure, and 50 psi all have identical meanings.

Examples of Pressure Measurement. A table with a 10-inch by 10-inch flat top contains 100 square inches of surface. If a 100-pound slab of exactly the same dimensions is placed on the table top, one pound per square inch pressure is exerted over the entire table surface.

Now, think of the same table (100 square inches) with a 100-pound block instead of the slab resting on its top. Assume this block has a face of only 50 square inches contacting the table. Because the area of contact has been cut in half and the weight of the block remains the same, the pressure exerted on the table doubles to 2 psi.

As a final example, suppose a long rod weighing 100 pounds with a face of 1 square inch is balanced upright on the table top. The pressure now being exerted on the table is increased to 100 psi, since the entire load is being supported on a single square inch of the table surface. These examples are illustrated in Figure 1-1.

Force-Area-Pressure Formulas. From the preceding discussion, you can see that the formula to find the pressure acting on a surface is "pressure equals force divided by area." If "P" is the symbol for pressure, "A" the symbol for area, and “F" the symbol for force, the formula can be expressed as follows:

$$P = \frac{F}{A}$$

By transposing the symbols in this formula, two other important formulas are derived: one for area; one for force. Respectively, they are--

$$A = \frac{F}{P} \qquad F = A \times P$$

However, when using any of these formulas, two of the factors must be known to be able to determine the third unknown factor.

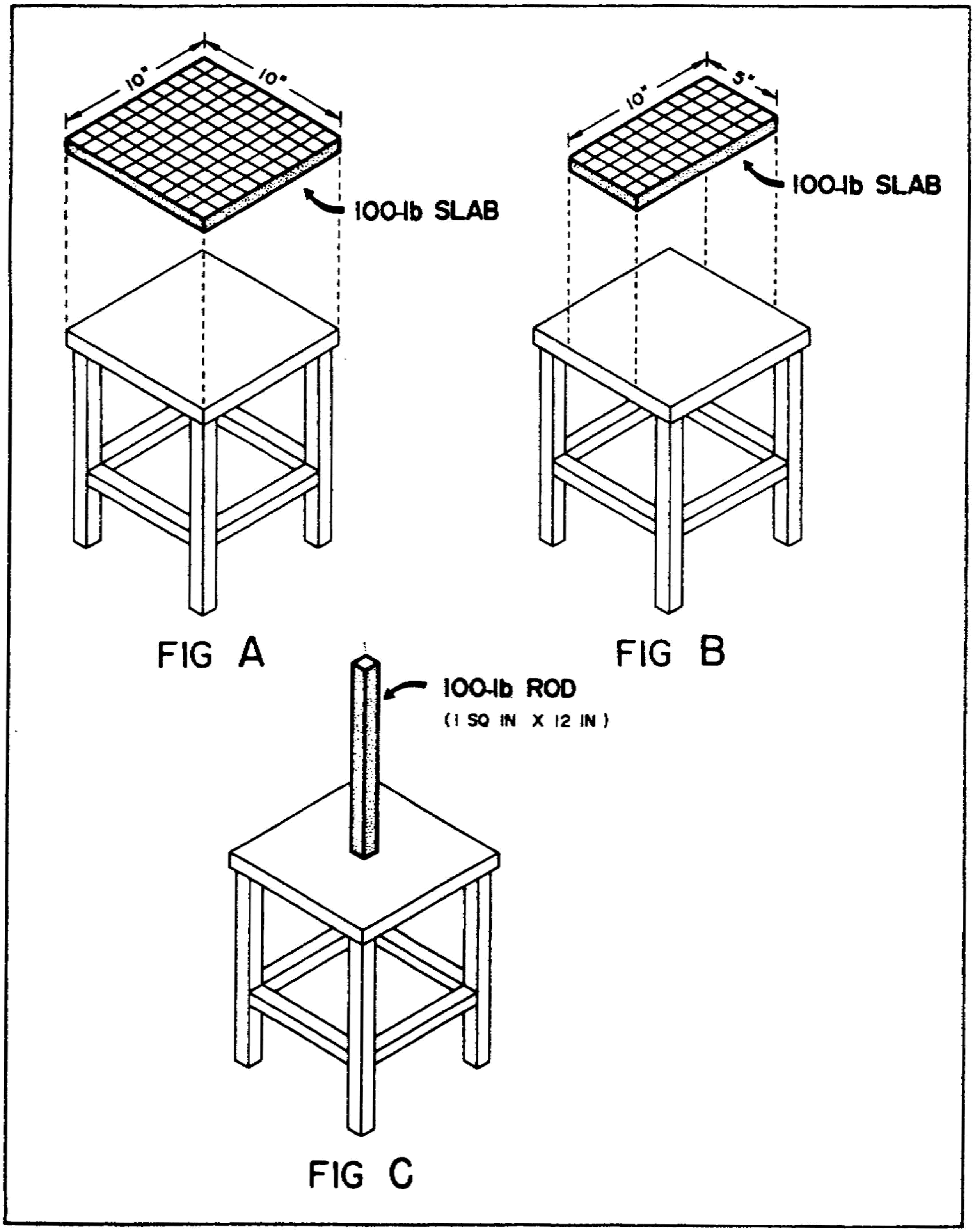

Figure 1-1. Measuring Pressure.

The triangle shown in Figure 1-2 is a convenient memory device for the force-area-pressure formulas. It helps you recall the three factors involved: F, A, and P. Because the F is above the line in the triangle, it also reminds you that in both formulas indicating division, F is always divided by one of the other two factors.

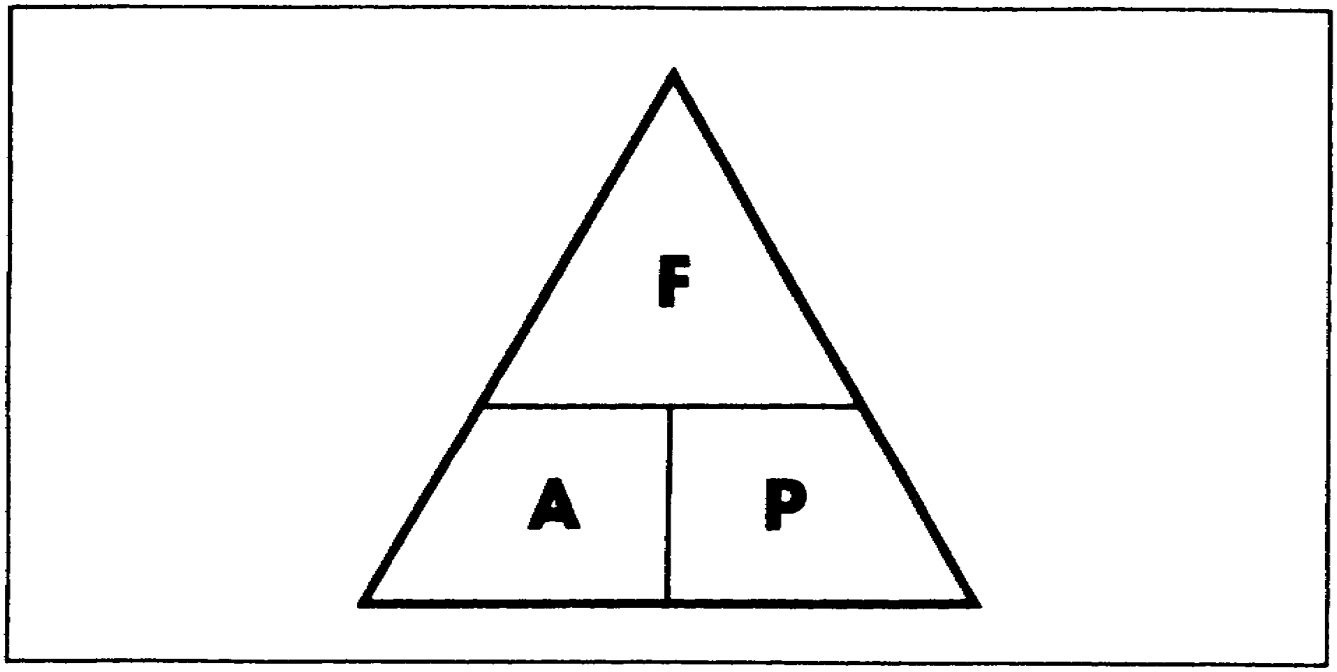

Figure 1-2. Relationship of Force, Area, and Pressure.

TRANSMISSION OF FORCE

Two means of transmitting force are through solids and through liquids. Since this text is on hydraulics, the emphasis is on fluids. Force transmission through solids is presented only as a means of comparison.

Transmission of Force Through Solids. Force applied at one point on a solid body follows a straight line undiminished to an opposite point on the body. This is illustrated in Figure 1-3.

Transmission of Force Through Confined Liquids. Applied forces are transmitted through bodies of confined liquids in the manner described by Pascal's Law. This law of physics, formulated in the seventeenth century by the French mathematician Blaise Pascal, states: pressure applied to any part of a confined liquid is transmitted without change in intensity to all parts of the liquid. This means that wherever it is applied on the body of liquid, pressure pushes equal force against every square inch of the interior surfaces of the liquid's container. When pressure is applied to a liquid's container in a downward direction, it will not only act on the bottom surface; but on the sides and top as well.

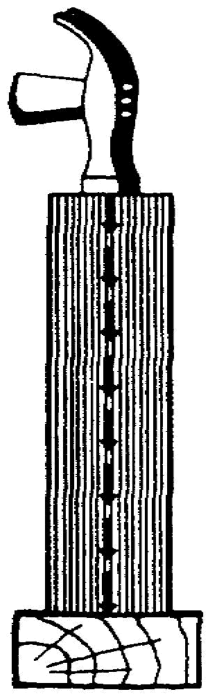

Figure 1-3. Transmission of Force Through Solids.

The illustration in Figure 1-4 helps to better understand this explanation. The piston on the top of the tube is driven downward with a force of 100 psi. This applied force produces an identical pressure of 100 psi on every square inch of the interior surface. Notice the pressure on the interior surface is always applied at right angles to the walls of the container, regardless of its shape. From this it can be seen that the forces acting within a body of confined liquid are explosive in pattern. If all sides are equal in strength, they will burst simultaneously if sufficient force is applied.

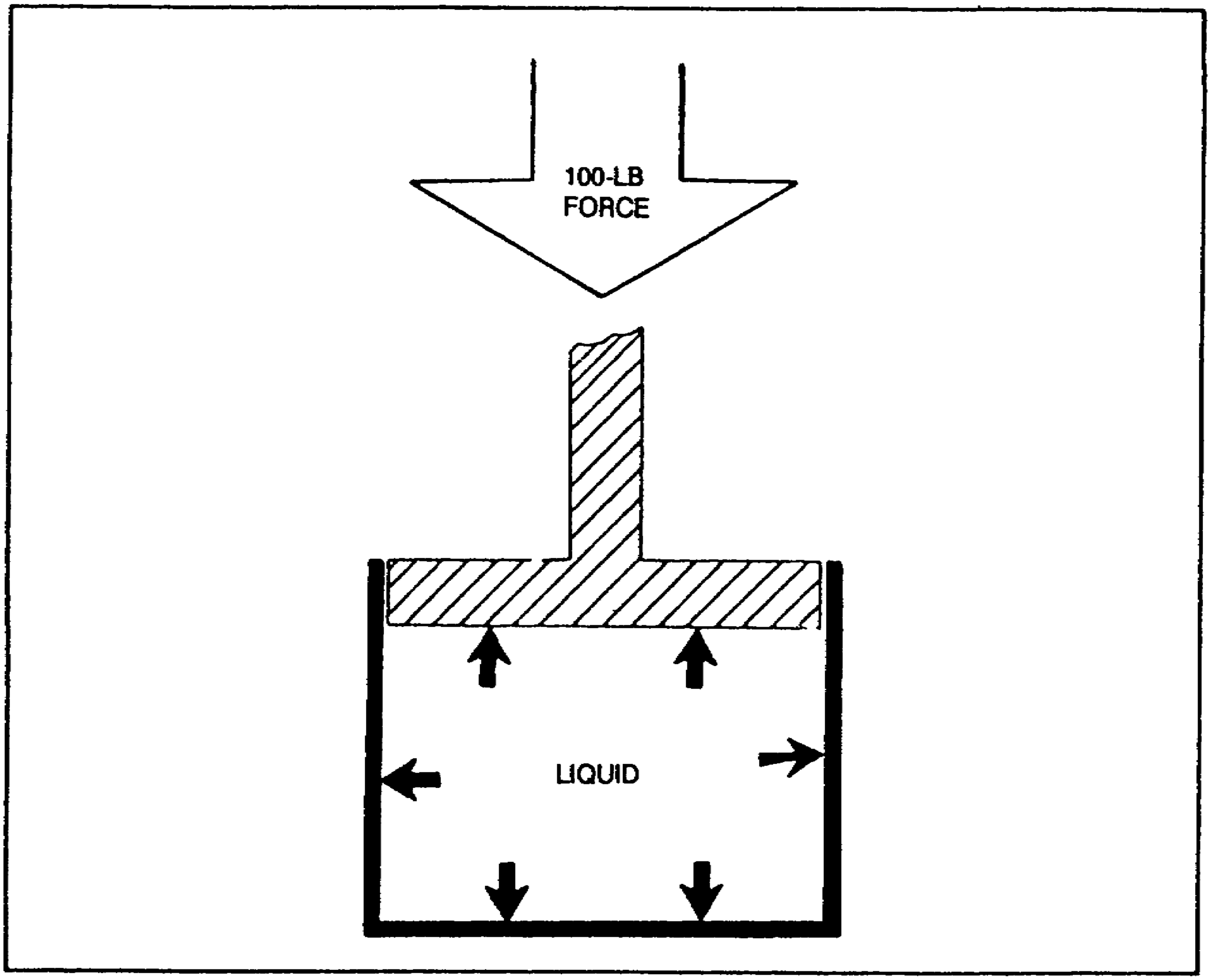

Figure 1-4. Transmission of Force Through Confined Liquids.

CHARACTERISTICS OF FLUIDS

The vast difference in the manner in which force is transmitted through confined liquids, as compared with solid bodies, is due to the physical characteristics of fluids -- namely, shape and compressibility. Liquids have no definite shape; they readily and instantly conform to the form of the container. Because of this characteristic the entire body of confined fluid tends to move away from the point of the initial force in all directions until stopped by something solid such as the walls of the container. Liquids are relatively incompressible. That is, they can only be compressed by approximately 1 percent of their volume. Because liquids lack their own shape and are incompressible, an applied force transmitted through a body of liquid confined in a rigid container results in no more compression than if it were transmitted through solid metal.

Movement of Fluid Under Pressure. Force applied to a confined liquid can cause the liquid to move only when that force exceeds any other force acting on the liquid in an opposing direction. Fluid flow is always in the direction of the lowest pressure. If the opposing forces are equal, no movement of fluid takes place.

Fluid under pressure can flow into already filled containers only if an equal or greater quantity simultaneously flows out of them. This is an obvious and simple principle, but one that is easily overlooked.

Effects of Temperature on Liquids. As in metals, temperature changes produce changes in the size of a body of liquid. With the exception of water, whenever the temperature of a body of liquid falls, a decrease (contraction) in size of the body of fluid takes place. The amount of contraction is slight and takes place in direct proportion to the change in temperature.

When the temperature rises, the body of liquid expands. This is referred to as "thermal expansion." The amount of expansion is in direct proportion to the rise in temperature. Although the rate of expansion is relatively small, it is important; some provision is usually necessary in a hydraulic system to accommodate the increase in size of the body of liquid when a temperature rise occurs.

MECHANICAL ADVANTAGE

By simple definition, mechanical advantage is equal to the ratio of a force or resistance overcome by the application of a lesser force or effort through a simple machine. This represents a method of multiplying forces. In mechanical advantage, the gain in force is obtained at the expense of a loss in distance. Discounting frictional losses, the percentage gain in force equals the percentage loss in distance. Two familiar applications of the principles of mechanical advantage are the lever and the hydraulic jack. In the case of the jack, a force of just a pound or two applied to the jack handle can raise many hundreds of pounds of load. Note, though, that each time the handle is moved several inches, the load is raised only a fraction of an inch.

Application in Hydraulics. The principle used in hydraulics to develop mechanical advantage is simple. Essentially it is obtained by fitting two movable surfaces of different sizes to a confining vessel, such as pistons within cylinders. The vessel is filled with fluid, and force (input) is applied to the smaller surface. This pressure is then transferred, by means of the fluid, to the larger surface where a proportional force (output) is produced.

Rate. The rate mechanical advantage is produced by hydraulic means is in direct proportion to the ratio of the size of the smaller (input) area to the size of the larger (output) area. Thus, 10 pounds of force applied to one square inch of surface of a confined liquid produces 100 pounds of force on a movable surface of 10 square inches. This is illustrated in Figure 1-5. The increase in force is not free, but is obtained at the expense of distance. In this case, the tenfold increase in output force is gained at the expense of a tenfold increase in distance over which the initial force is applied.

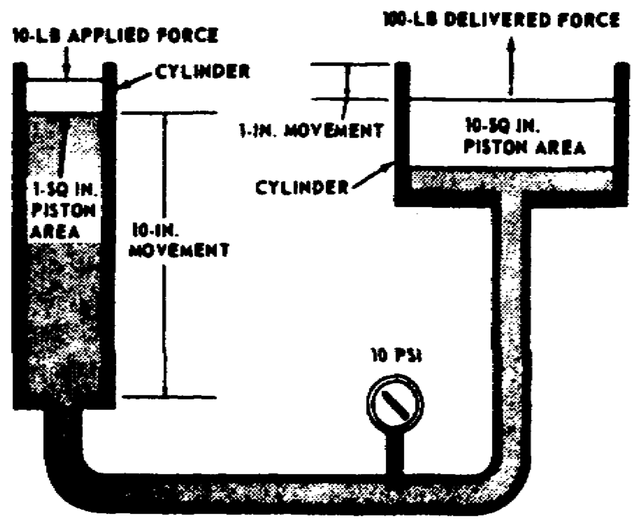

Figure 1-5. Hydraulics and Mechanical Advantage.

THE ROLE OF AIR IN HYDRAULICS

Some hydraulic components require air as well as hydraulic oil for their operation. Other hydraulic components do not, and instead their performance is seriously impaired if air accidentally leaks into the system.

Familiarization with the basic principles of pneumatics aids in understanding the operation of both the hydraulic components requiring air as well as those that do not. It aids, also, in understanding how air can upset the normal operation of a hydraulic system if it is present in the system where it must not be.

Air. When used in reference to hydraulics, air is understood to mean atmospheric air. Briefly, air is defined as a complex, indefinite mixture of many gases. Of the individual gases that make up atmospheric air, 90 percent or more is oxygen and nitrogen.

Some knowledge of the physical characteristics of air is quite important to this instruction. Because the physical properties of all gases, including air, are the same, a study of these properties is made with reference to gases in general. It is important to realize, however, though similar in physical characteristics, gases differ greatly in their individual chemical composition. This difference makes some gases extremely dangerous when under pressure or when they come in contact with certain substances.

Air and Nitrogen. Air and pure nitrogen are inert gases and are safe and suitable for use in hydraulic systems.

CAUTION: Only air and pure nitrogen are authorized for use in Army aircraft hydraulic systems or related hydraulic equipment (Ref: TO 1-1-312 "Use of High Pressure Air and Nitrogen, all Aircraft."). Under no circumstances can any other gases be used, since disastrous explosions are almost certain to result. Beware especially of oxygen and of acetylene.

Most frequently the air used in hydraulic systems is drawn out of the atmosphere and forced into the hydraulic system by means of an air compressor. Pure nitrogen, however, is available only as a compressed bottle gas.

Application in Hydraulics. The ability of a gas to act in the manner of a spring is important in hydraulics. This characteristic is used in some hydraulic systems to enable these systems to absorb, store, and release fluid energy as required. These abilities within a system are often provided by means of a single component designed to produce a springlike action. In most cases, such components use air, even though a spring might be equally suitable from a performance standpoint. Air is superior to a spring because of its low weight and because it is not subject to failure from metal fatigue as is a spring. The most common use of air in hydraulic systems is found in accumulators and shock struts.

Malfunctions Caused by Air. In general, all components and systems that do not require gases in their operation are to some extent impaired by the presence of air. Examples are excessive feedback of loud noises from flight controls during operation, and the failure of wheel and rotor brakes to hold. These malfunctions can be readily corrected by "bleeding the system": a controlled way of allowing the air to escape. The process is explained in detail in the -20 TMs of the particular aircraft involved.

FLUIDS USED IN HYDRAULICS

Two general types of fluids can be used in the operation and maintenance of hydraulic systems and equipment: vegetable-base and mineral-base. Although both types of fluids possess characteristics suitable for hydraulic use, they are not interchangeable, nor are they compatible as mixtures. At present, only mineral base fluids are used for the maintenance and operation of hydraulic systems and self-contained hydraulic components of Army aircraft. Despite this, vegetable-base hydraulic fluids cannot be left entirely out of this discussion.

In the past, some Army aircraft have used vegetable-base fluids for hydraulic system maintenance and operation. Also, all known brake systems in automotive vehicles are currently being operated on vegetable-base fluid. It is quite possible that a supply of this type of fluid may erroneously fall into the aviation supply system. Therefore, maintenance personnel must be familiar with both types of fluids so they can recognize the error and avoid use of the improper fluid. Moreover, knowledge of the effects of using the improper fluid and the corrective action to take if this occurs is as important as knowledge of the system itself.

Rubber parts of hydraulic systems are particularly sensitive to incorrect fluids. The rubber parts used in systems operating on vegetable-base fluids are made of natural rubber; those operating on mineral-base fluids are made of synthetic rubber. Both types of rubber are seriously damaged by contact with the wrong type of fluid.

Vegetable-Base Hydraulic Fluids. Vegetable-base hydraulic fluids are composed essentially of castor oil and alcohol. These fluids have an easily recognized pungent odor, suggestive of their alcohol content.

There are two types of vegetable-base hydraulic fluids that aviation personnel can be issued in error; aircraft and automotive types. Their descriptions follow:

- The aircraft vegetable-base fluid is colored with a blue dye for identification and is designated MIL-H-7644.

- The vegetable-base hydraulic fluid currently used for automotive hydraulic systems is amber in color. The military designation of this fluid is MIL-F-2111.

Remember: Neither of these fluids are acceptable for use in aircraft hydraulic systems, and are NOT to be used in hydraulic jacks or other aircraft ground-handling equipment.

Mineral-Base Hydraulic Fluids. Three categories of mineral base hydraulic fluids are used in Army aviation today: operational, preservative, and cleaning.

Operational Fluid. During extreme cold weather the operational fluid now used in aircraft hydraulic systems and components is MIL-H-5606. This fluid is colored with a red dye for identification and has a very distinctive odor. MIL-H-83282 is to be used in components and systems as prescribed in TB 55-1500-334-25.

Preservative Fluid. Preservative fluid contains a special corrosion-inhibiting additive. Its primary purpose is to fill hydraulic components as a protection against corrosion during shipment or storage. Designated as MIL-H-6083A, preservatite fluid is very similar to operational fluid in viscosity, odor, and color. Operational fluid, MIL-H-5606, and preservative fluid, MIL-H-6083A, are compatible but not interchangeable. Therefore, when preparing to install components preserved with 6083A, the preservative fluid must be drained to the drip point before installation, and the components refilled with operational fluid. The preservative fluid, 6083A, need not be flushed out with 5606. When using MIL-H-83282, the preservative must be flushed as prescribed in TB 55-1500-334-25.

Cleaning Fluid. TM 55-1500-204-23-2 contains a list of authorized cleaning agents and details their use in hydraulic systems and components. Because of constant improvement of cleaning agents, changes to the basic technical manual are printed and distributed as necessary. For that reason, always refer to the current technical manual and its latest changes, for the authorized cleaning agent to be used on types of hydraulic systems and components.

Table of Fluid Uses. The following table is a brief summary of the permissible uses of mineral-base hydraulic fluids.

Table 1-1. Uses of Mineral-Base Hydraulic Fluids.

USE	FLUID
Operation of system or self-contained units.	MIL-H-83282 or MIL-H-5606
Flushing of assembled system.	MIL-H-83282 or MIL-H-5606
Flushing of assembled individual component.	MIL-H-83282 or MIL-H-5606
Preserving of individual components.	MIL-H-6083A
Washing seals.	MIL-H-83282 or MIL-H-5606 or MIL-H-6083A
Washing parts (except rubber parts) of disassembled components.	Refer to TM 1-1500-204-23-2

Corrective Action Following Improper Servicing. If a hydraulic system or component is erroneously serviced with vegetable-base fluid, the system must be drained immediately and then flushed with lacquer thinner: military specification MIL-T-6094A. Following this, the components of the system must be removed and disassembled to the extent necessary to remove all seals. The components are washed, seals are replaced with new ones, and the system is reassembled for return to operation.

HANDLING OF FLUIDS

Trouble-free operation of hydraulic systems depends largely on the efforts made to ensure the use of pure hydraulic fluid in a clean system. Bulk containers of fluids must be carefully opened and completely closed immediately after dispensing any fluid. After dispensing, unused fluid remaining in gallon and quart containers must be disposed of according to TM 10-1101. Dispensing equipment must be absolutely clean during use. Filler plugs and caps and the bosses in which they are installed must be carefully cleaned before removal and dispensing any fluid.

Besides taking precautions while dispensing hydraulic fluids, you must also ensure safe storage of fluids and observation of safety regulations by the fluid handlers.

Fire Hazards. Hydraulic fluids are quite flammable and must be kept away from open flames, sparks, and objects heated to high temperatures. Fluid leaks in aircraft are a definite fire hazard and must be constantly looked for and promptly corrected. The flash point for MIL-H-5606 is 275° Fahrenheit. Because MIL-H-83282 has a flash point of 400° Fahrenheit, it is much safer to use and is replacing MIL-H-5606. Although the two fluids are compatible, care must be taken so that a mixture of the two types has a volume of no more than 3 percent MIL-H-5606. A mixture with a volume of more than 3 percent MIL-H-5606, degrades the flash point of MIL-H-83282.

The regulations for storing hydraulic fluids are the same as those for other POL products, and their enforcement is equally as important.

Toxicity. Hydraulic fluids are not violently poisonous but are toxic to an extent. Unnecessary breathing of the fumes and prolonged contact of quantities of fluid with bare skin must be avoided.

SUMMARY

Hydraulics is the use of fluid under pressure to transmit force. In Army aviation, hydraulics is used to operate retractable landing gear, brakes, flight controls, propeller pitch, and loading ramps.

The characteristics of hydraulic systems are efficiency, dependability, control sensitivity, flexibility of installation, low space requirements, light weight, self-lubrication, and low maintenance requirements.

Hydraulics operates on the principles of force and pressure. The unit of measurement of force is the pound, and the area of pressure measurement is the square inch. Thus, force-pressure measurement is expressed in pounds per square inch (psi). Force is transmitted through confined liquids without change in intensity to all parts of the liquid.

Mechanical advantage is equal to the ratio of a force or resistance overcome by the application of a lesser force or effort through a simple machine. Gain in force is obtained at the expense of loss in distance. The rate at which mechanical advantage is produced by hydraulic means is in direct proportion to the ratio of the size of the smaller (input) area to the size of the larger (output) area.

Some hydraulic components, like shock struts and accumulators, require air with the hydraulic fluid for their operation. Atmospheric air and pure nitrogen are the only gases authorized for use in Army aircraft.

Only mineral-base hydraulic fluids are authorized for use in aircraft hydraulic systems. Operational fluid MIL-H-83282 is replacing MIL-H-5606; the preservative fluid is MIL-H-6083A.

Care must be taken to ensure no contamination is allowed to enter the hydraulic system. Hydraulic fluids are quite flammable and must be handled and stored with the same precautions as other POL products.

LESSON 1

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each question. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. What is the unit of area for pressure measurement in the United States?

___ A. Inch-pounds.
___ B. Square inch.
___ C. Foot-pounds.
___ D. Square foot.

2. What happens to a body of liquid when a rise in its temperature takes place?

___ A. It decreases in size.
___ B. It increases in size.
___ C. It stays the same.
___ D. It builds up static pressure.

3. How much of the energy transmitted through a hydraulic system is received at the output end?

___ A. 88 percent.
___ B. 99 percent.
___ C. Practically none.
___ D. Practically all.

4. What formula is used to find the amount of pressure exerted?

___ A. $P = \frac{F}{A}$
___ B. $P = F x A$
___ C. $F = \frac{P}{A}$
___ D. $A = \frac{F}{P}$

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5. Fluid under pressure always flows in the direction of--

   A. Equal pressure.
   B. Medium pressure.
   C. Highest pressure.
   D. Lowest pressure.

6. What gases can be used when servicing a hydraulic system or related equipment?

   A. Oxygen and pure nitrogen.
   B. Air and pure nitrogen.
   C. Acetylene and pure oxygen.
   D. Nitrogen and acetylene.

7. How many general types of hydraulic fluids are there?

   A. One.
   B. Two.
   C. Three.
   D. Six.

8. What is the military designation number for preservative fluid?

   A. MIL-H-8063A.
   B. MIL-H-6380A.
   C. MIL-H-6083A.
   D. MIL-H-5083A.

9. What technical manual covers the disposal of used fluid left in gallon or quart containers?

   A. TM 10-1001.
   B. TM 10-1011.
   C. TM 10-1101.
   D. TM 10-1110.

10. In what technical manual can you find a list of authorized cleaning agents and details of their use in hydraulics and components?

   A. TM 10-1101.
   B. TM 1-1500-204-23-2.
   C. TM 55-1500-334-25.
   D. TM 750-125.

LESSON 1

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	B. Square inch.
	In the United States the square inch is the measurement used when expressing applied force to an area. (Page 5)
2.	B. It increases in size.
	Temperatures have an effect on liquids. Applied heat causes liquids to expand slightly, while cold has the opposite effect. (Page 11)
3.	D. Practically all.
	A hydraulic system is very efficient. There is virtually no loss except that which may be in the mechanical linkage. (Page 3)
4.	A. $P = \frac{F}{A}$
	Pressure exerted can be determined by dividing force by area. (Page 6)
5.	D. Lowest pressure.
	Fluid flows toward the area of least resistance. (Page 11)
6.	B. Air and pure nitrogen.
	Using the wrong combination of gases could cause an explosion. You should use only air and pure nitrogen. (Page 13)
7.	B. Two.
	You may use either vegetable-base or mineral-base hydraulic fluids; however, you must not mix them or switch from one to the other. (Page 14)

8. C. MIL-H-6083A.

MIL-H-6083A is a preservative fluid. Care must be taken not to confuse it with an operational fluid. (Page 15)

9. C. TM 10-1101.

TM 10-1101 tells you how to get rid of unused fluid remaining in gallon and quart containers. (Page 16)

10. B. TM 1-1500-204-23-2.

If you want to know what cleaning agent to use, check TM 1-1500-204-23-2. Be sure the technical manual is current with all changes. (Page 15)

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LESSON 2

HYDRAULIC PLUMBING

STP TASKS: 551-758-1007, 551-758-1008,
551-758-1012, and 551-758-1071

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the identification, fabrication, installation, and storage requirements for tubes and hoses. You will also learn the types of seals and gaskets.

TERMINAL LEARNING OBJECTIVE:

ACTION: After this lesson you will demonstrate a knowledge of the identification, fabrication, installation and storage requirements for tubes and hoses, along with the types of seals and gaskets.

CONDITIONS: You will study the material in this lesson in a classroom environment or at home.

STANDARD: You will correctly answer all the questions in the practice exercise before you proceed to the examination.

REFERENCES: The material contained in this lesson was derived from the following publications:

AR 310-25 (Dictionary of United States Army Terms).
AR 310-50 (Authorized Abbreviations and Brevity Codes).
FM 1-563 (Fundamentals of Airframe Maintenance).
FM 1-509 (Fundamentals of Aircraft Pneudraulics).
TM 1-1500-204-23 Series (General Aircraft Maintenance Manual).

INTRODUCTION

Aircraft plumbing is that phase of aircraft maintenance dealing with the metal tubing, flexible hoses, and necessary fittings and seals providing a pathway for the fluids and gases to move between the components on aircraft.

Although this text deals mainly with the hydraulic system, the plumbing principles explained herein apply to the plumbing requirements for the fuel, ventilation, pneumatic, and Pitot-static systems as well. Because of this similarity, the maintenance personnel responsible for hydraulic plumbing are usually required to perform the repair and maintenance of all aircraft plumbing systems.

For the mechanic to repair aircraft plumbing, or for the NCO or maintenance officer to supervise this work effectively, he must be familiar with the material, equipment, and fabrication techniques necessary to repair and install these lines.

Part A of this lesson deals with the identification and methods of fabricating the tubes that connect the components of hydraulic systems. In Part B, the uses and advantages of hose or flexible tubing are explained, including the markings, fabrication and installation methods, and storage requirements of these materials. Part C describes the different types of seals and gaskets used to prevent leaks in the interconnecting tubes, hoses, and fittings of plumbing systems.

VARIETY OF LINES

Throughout this lesson you will see terms such as plumbing lines, tubing, flexible tubing, and hose used extensively. By definition, plumbing lines refer to any duct work used to transfer fluids or gases from one location to another. These lines may fall into one of two general categories: tubes (rigid lines), and hose (flexible lines). Many materials are used to fabricate these lines; each one offers a different advantage. When replacing a damaged or defective line, make every effort to duplicate the original line as closely as possible. Under some circumstances, however, field expediency requires replacement of the damaged line with a similar, but not identical, line. In choosing what size and type of line to use, evaluate the following important elements:

- Type of fluid or gas the line is to conduct.
- Pressure it must operate under.
- Temperatures it must operate under.

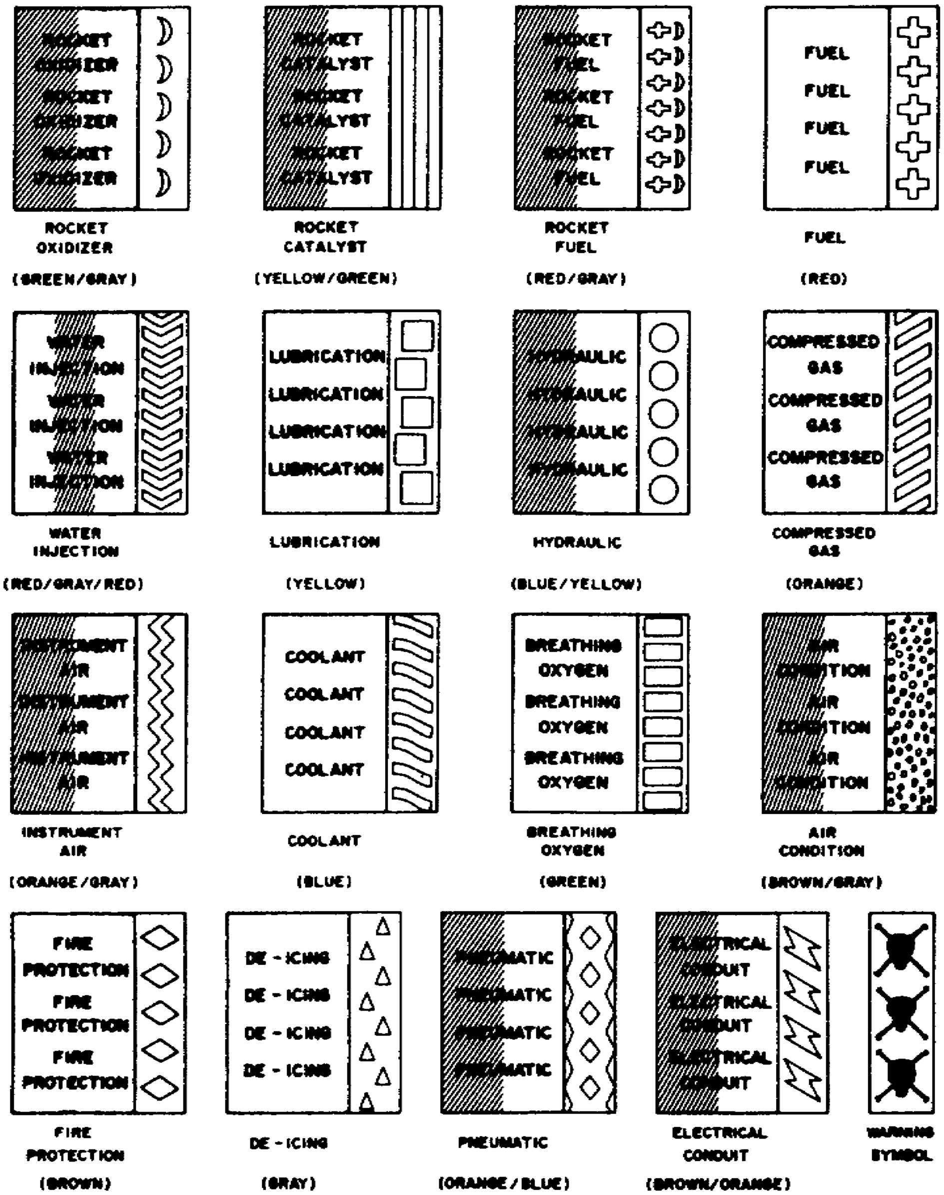
- Temperatures it must withstand.
- Vibrations it is subject to.

IDENTIFICATION OF LINES

Except for the inlet and exhaust sections of the engine compartment, plumbing lines are identified with adhesive bands of different colors coded to the particular system to which each line belongs. In the Army, two types of identification code systems are used: the print-symbolized tape system (the preferred method), and the solid-color tape system (the alternate method). The preferred system uses tape bands of two or more colors printed with identifying geometrical symbols and the name of the system. Examples of these bands are shown in Figure 2-1. The alternate method uses one, two, or three bands of 1/2-inch solid-color tape wrapped on the various lines for identification. The color code used with this system is shown in Figure 2-2.

In areas near the inlet section of the engine compartment where the tape might be ingested (sucked in) or near the exhaust section where high temperatures might burn the tape, suitable paints conforming to the color codes in Figure 2-2 mark plumbing lines.

Additional white tapes labeled "pressure," "drain," or "return" can be used next to the color bands of either code system to identify the lines. These tapes are also printed with arrows indicating the direction of fluid flow.



THE ABOVE COLOR CODES REPRESENT DESIGNATION FOR SYSTEMS ONLY FOR CODING LINES WHICH DO NOT FALL INTO ONE OF THESE SYSTEMS, THE CONTENTS SHALL BE DESIGNATED BY BLACK LETTERING ON A WHITE TAPE

SUBSIDIARY FUNCTIONS OR IDENTIFICATION OF LINE CONTENT MAY BE INDICATED BY THE USE OF ADDITIONAL WORDS OR ABBREVIATIONS WHICH SHALL BE CARRIED ON A SECOND TAPE ADJACENT TO THE FIRST OR, ALTERNATIVELY, INTERPOSED BETWEEN THE WORDS DESCRIPTIVE OF THE MAIN FUNCTION

WARNING SYMBOL TAPES, 3 8 INCH WIDE, SHALL BE APPLIED TO THOSE LINES WITH CONTENTS CONSIDERED TO BE DANGEROUS TO MAINTENANCE PERSONNEL. WARNING TAPES ARE TO BE PLACED ADJACENT TO SYSTEM IDENTIFICATION TAPES.

ONE BAND SHALL BE LOCATED ON EACH TUBE SEGMENT, 24 INCHES OR SHORTER ONE BAND SHALL BE LOCATED AT EACH END OF EACH TUBE SEGMENT LONGER THAN 24 INCHES ADDITIONAL BANDS SHALL BE APPLIED WHEN THE TUBE SEGMENT PASSES THROUGH MORE THAN ONE COMPARTMENT OR BULKHEAD AT LEAST ONE BAND SHALL BE VISIBLE IN EACH COMPARTMENT OR ON EACH SIDE OF THE BULKHEAD.

PRESSURE TRANSMITTER LINES SHALL BE IDENTIFIED BY THE SAME COLORS AS THE LINES FROM WHICH THE PRESSURE IS BEING TRANSMITTED.

FILLER LINES, VENT LINES, AND DRAIN LINES OF A SYSTEM SHALL BE IDENTIFIED BY THE SAME COLORS AS THE RELATED SYSTEM.

TAPES SHALL NOT BE USED ON FLUID LINES IN THE ENGINE COMPARTMENT WHERE THERE IS A POSSIBILITY OF THE TAPE BEING DRAWN INTO THE ENGINE INTAKE FOR SUCH LOCATIONS, SUITABLE PAINTS, CONFORMING TO THIS COLOR CODE AND WHICH HAVE NO DELETERIOUS EFFECT ON THE MATERIAL USED FOR THE LINES, SHALL BE USED FOR IDENTIFICATION PURPOSES IN THESE CASES, THE GEOMETRICAL SYMBOLS MAY BE OMITTED

Figure 2-1. Color-Coded Tape.

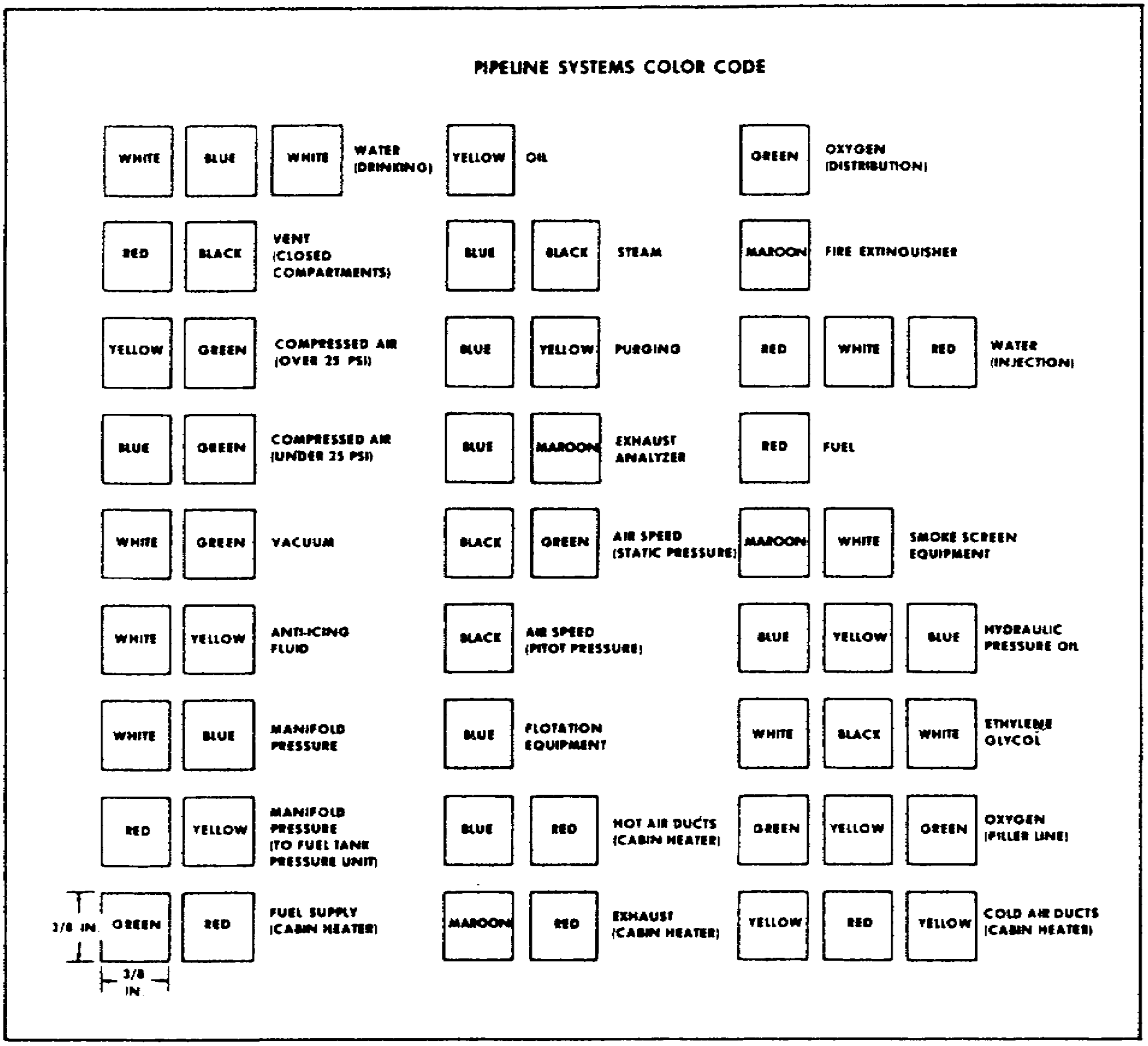


Figure 2-2. Solid-Color Band System.

PART A - TUBING

The procedures, fabrication techniques, and use of proper tools are as important as the selection of the tubing material in repairing and replacing damaged plumbing lines. Unless you take extreme care during all phases of line repair, the finished product is likely to be as defective as the original. This part discusses--

- Criteria for selecting the proper type of tubing.
- Correct procedure for routing lines and for cutting and bending tubing.

- Types of tube fittings.
- Methods of tube flaring and installation.
- Techniques of tube repair if tubes are not extensively damaged.

TUBING

In Army aviation three types of metal tubing are used: aluminum alloy, stainless steel, and copper. Generally, determine the type of metal visually. If this is not possible, mark the tubing at three-foot intervals with the manufacturer's name or trademark, the tubing material, and its specification number. Tubing that is too small to be marked in this manner, identify by attaching a tag with this information to it.

Aluminum. In aircraft plumbing, the most widely used metal tubing is made of aluminum alloy. This general-purpose tubing has the advantages of workability, resistance to corrosion, and light weight. A list of the aluminum tubing authorized for use in Army aircraft is found in TM 1-1500-204-23-2.

The aluminum tubing generally used in Army aircraft hydraulic systems operating at pressures of 1,500 psi and below is type 5052, Military Specification WW-T-700/4. Because of the workability of this tubing, assemblies can be readily fabricated in the field. For those hydraulic systems operating at pressures above 1,500 psi, aluminum alloy tubing types 6061 and 6062, both Military Specification T-7081, are used. To process this tubing into tubing assemblies requires special procedures and equipment not generally available in the field. Therefore, assemblies made from this aluminum must be obtained through supply channels as factory prefabricated parts or through depot maintenance shops.

Stainless Steel. Tubing of stainless steel can also be used where pressures exceed 1,500 psi. Stainless steel must be used for outside lines, such as brake lines attached to landing gear struts or other exposed lines that can be damaged by flying objects or ground-handling mishaps. Stainless steel tubing, like the high-pressure aluminum alloy tubing, is difficult to form without special tools and is obtained through supply channels or depot repair facilities.

Copper. Copper tubing is primarily used in high-pressure oxygen systems. The fittings on copper tubing are soldered on with silver. Copper tubing used for high-pressure oxygen systems is 3/16-inch diameter, 0.032-inch wall thickness, Federal Specification WW-T-799, Type N. Low-pressure oxygen systems use a larger diameter aluminum tubing with flared aluminum fittings. Only in case of an emergency can copper tubing with the same diameter and wall thickness of the aluminum tubing be used to replace it. It must then conform to Federal Specification WW-T-799, Type N. Steel tubing must not be used to replace high-pressure oxygen system copper tubing because it loses ductility and becomes brittle at low temperatures.

ROUTING OF LINES

If a damaged line is discovered, the first step for repair is to determine the cause of the damage. If it was caused by chafing structural members of the aircraft or poor layout planning, the condition must be corrected. If the line was defective and the same layout is acceptable, carefully remove the damaged tube and use it as a pattern for fabrication of the replacement tube.

Generally, replacement lines follow the path of the original line; however, when the line must be rerouted use the standards that are discussed in the paragraphs that follow.

Number of Bends. When fluid flows around a bend, it creates friction which generates heat and causes an overall loss in system efficiency. With this in mind, tubing layout must always follow a path that results in gradual bends. On the other hand, a path with no bends is likely to result in even more problems. First, to cut a replacement line to an exact length is virtually impossible. This can result in a mechanical strain being exerted on the tube when the attaching nut is drawn up on the fitting. Because the greatest amount of strain is already concentrated on the flared portion of the tube as a result of the flaring operation, this additional strain is likely to weaken the tube beyond tolerances. Second, if the tube has no bends it cannot flex when subjected to vibrations. This lack of flexibility promotes fatigue of the tubing metal and makes it more susceptible to failure. Third, a straight line installation allows no provision for the normal contraction and expansion of the tubing caused by temperature change. Examples of correct and incorrect tube layout are shown in Figure 2-3.

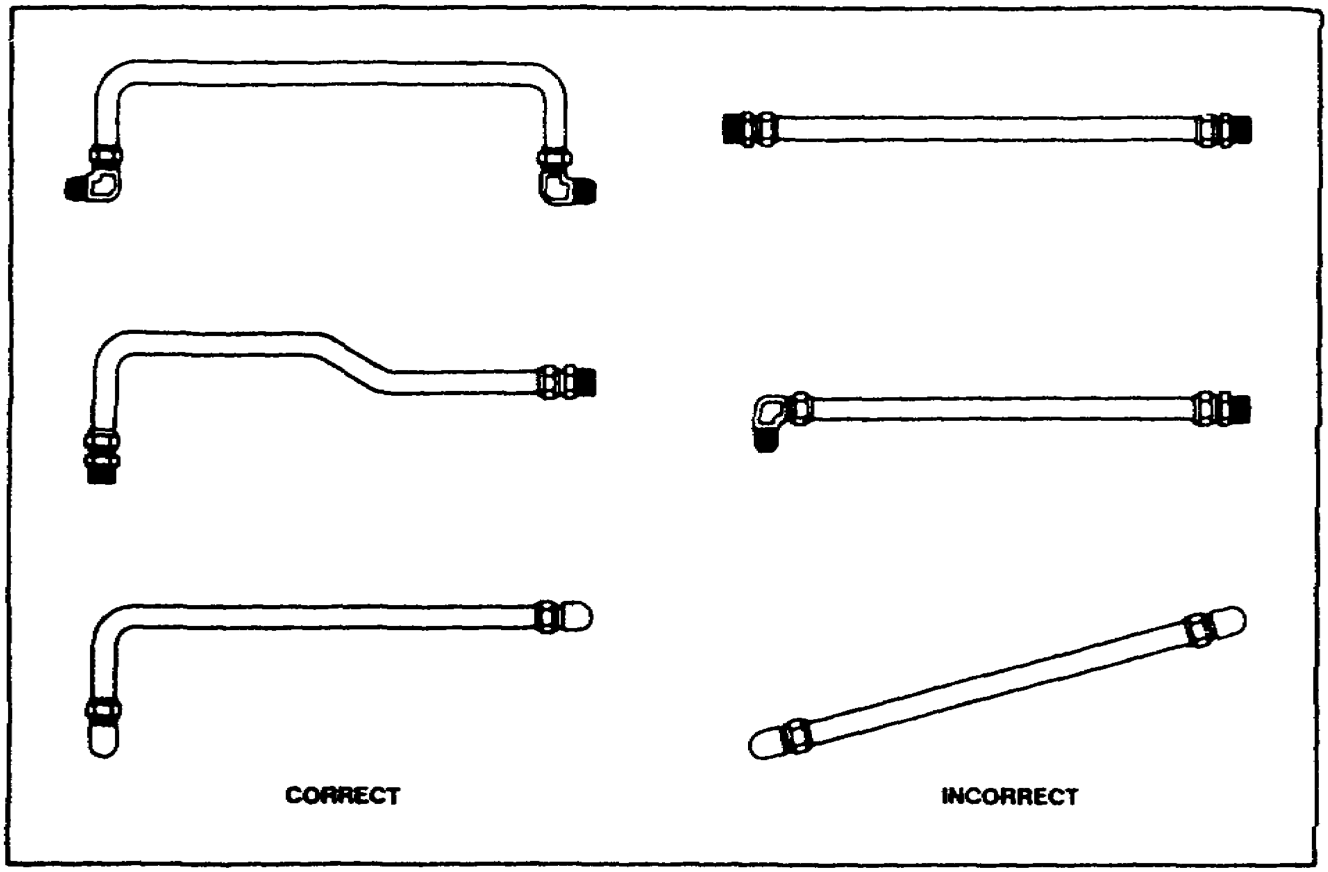


Figure 2-3. Correct and Incorrect Tube Layout.

Minimum Bend Radius. The metal at the heel of a bend in tubing is always stretched to some extent. This stretching weakens the tubing and must be kept within limits. The radius of the sharpest bend permissible in a given size tubing is designated the "minimum bend radius." If this limit is exceeded, the metal at the bend is subject to rupture under operating pressure. Bends of a greater radii than the minimum allowed are always preferred. The methods of tube bending and the tools used in bending operations are discussed later in this section.

The table of minimum bend radii for various types and sizes of tubing is contained in TM 1-1500-204-23-2. A copy of this table is shown in Table 2-1 on the following page.

Table 2-1. Table of Bend Radii.

	MINIMUM BEND RADII[1][2]		STEEL TUBING	
NOMINAL TUBE OD (INCHES)	1100-½ H, 5052-O (INCHES)	CORROSION RESISTANT (INCHES)	DESIRABLE RADIUS (INCHES)	MINIMUM RADIUS[4] (INCHES)
⅛ ---	⅜	---	---	---
3/16 ---	7/16	21/32	¾	⅜
¼ ---	9/16	⅞	1	⅜
5/16 ---	11/16	---	1-¼	⅜
⅜ ---	15/16	1-5/16	1-½	⅜
½ ---	1-¼	1-¾	2	½
⅝ ---	1-½	2-3/16	2-½	⅝
¾ ---	1-¾	2-⅝	3	¾
⅞ ---	2	---	3-½	⅞
1 ---	3	3-½	4	1
1-⅛ ---	3-½	---	4-½	1-⅛
1-¼ ---	3-¾	4-⅜	5	1-½
1-⅜ ---	4-¼	---	5-½	1-¾
1-½ ---	5	5-¼	6	2-⅛
1-⅝ ---	6	---	6-½	2-½
1-¾ ---	7	6-⅛	7	2-⅞
1-⅞ ---	7-½	---	7-½	3-¼
2 ---	8	7	8	3-⅝

[1] Bend radii measured to inside of bend.
[2] Increase bend radii when wall thickness is below standard.
[3] Equal to 3-½ times tube diameter.
[4] The minimum radius will be used only when the desirable radius cannot be used.

Supports. Supports are used in tube layout to limit the sideward movement of the tube due to pressure surges or vibrations. The maximum distance between supports is determined by the tube material and its outside diameter (OD). Rules governing the specifications of these supports are found in Chapter 4 of TM 1-1500-204-23-2.

TEMPLATES

If the damaged tube cannot be used as a pattern for the replacement line, use wire to make a template. Do this by running a wire between the fittings where the line must be installed and bending the wire to conform with the tube layout standards previously described.

TUBING CUTTING

When making replacement tubing from stock material, the stock must be measured and cut approximately 10 percent longer than the damaged tube. This ensures sufficient length for forming the flares and for small deviations in bending the tube to the pattern. Any extra length must be cut off before forming the last flare.

There are two accepted methods of tube cutting: one using the standard tube cutting tool shown in Figure 2-4, the other using a hacksaw. After completion of the tube cutting in either of these processes, remove all residue produced. To do this, ream the end of the tube slightly and flush the entire piece of tubing thoroughly. These methods are discussed in detail further in this text.

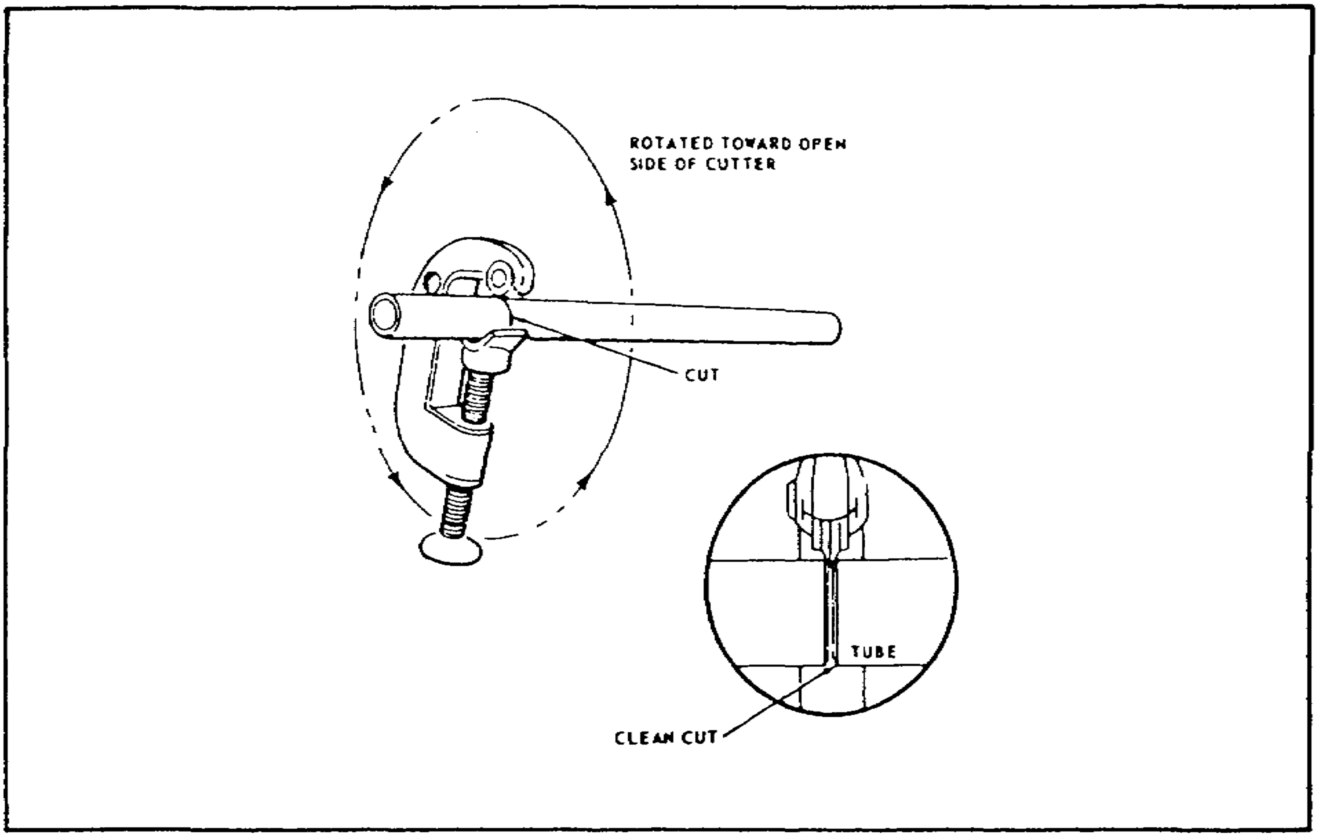


Figure 2-4. Standard Tube-Cutting Tool.

Standard Tube-Cutting Tool. The ideal method of cutting tubing is with a standard cutting tool. The tube is slipped through the cutting tool at a right angle, and the cutting wheel is adjusted against the tube. Take care not to force the wheel against the tube too tightly, as this forces the tube out-of-round. While the tool is being rotated, the cutting-wheel feed must be tightened a little with each turn until the wheel has cut through the tube. The tube cutter must be rotated in only one direction, with its handle being swung in the same direction that the opening faces. When properly used, this tool leaves a smooth end on the tube square with its axis.

Hacksaw. If a cutting tool is not available, use a fine-tooth hacksaw, preferably one with 32 teeth per inch. Since it is difficult to get a good, square, flush cut on the tube with this method, the tube end must be filed after the cut is made. During hacksaw cutting and filing, the tube must be clamped in tube blocks or other suitable holders to prevent scratching or bending and to aid in producing a 900 cut on the tube end.

METHODS OF TUBE BENDING

Tube bending can be done with any one of a variety of hand or power bending tools. Regardless of method used, the object is to obtain a smooth, even bend without flattening or buckling. Examples of these results are shown in Figure 2-5.

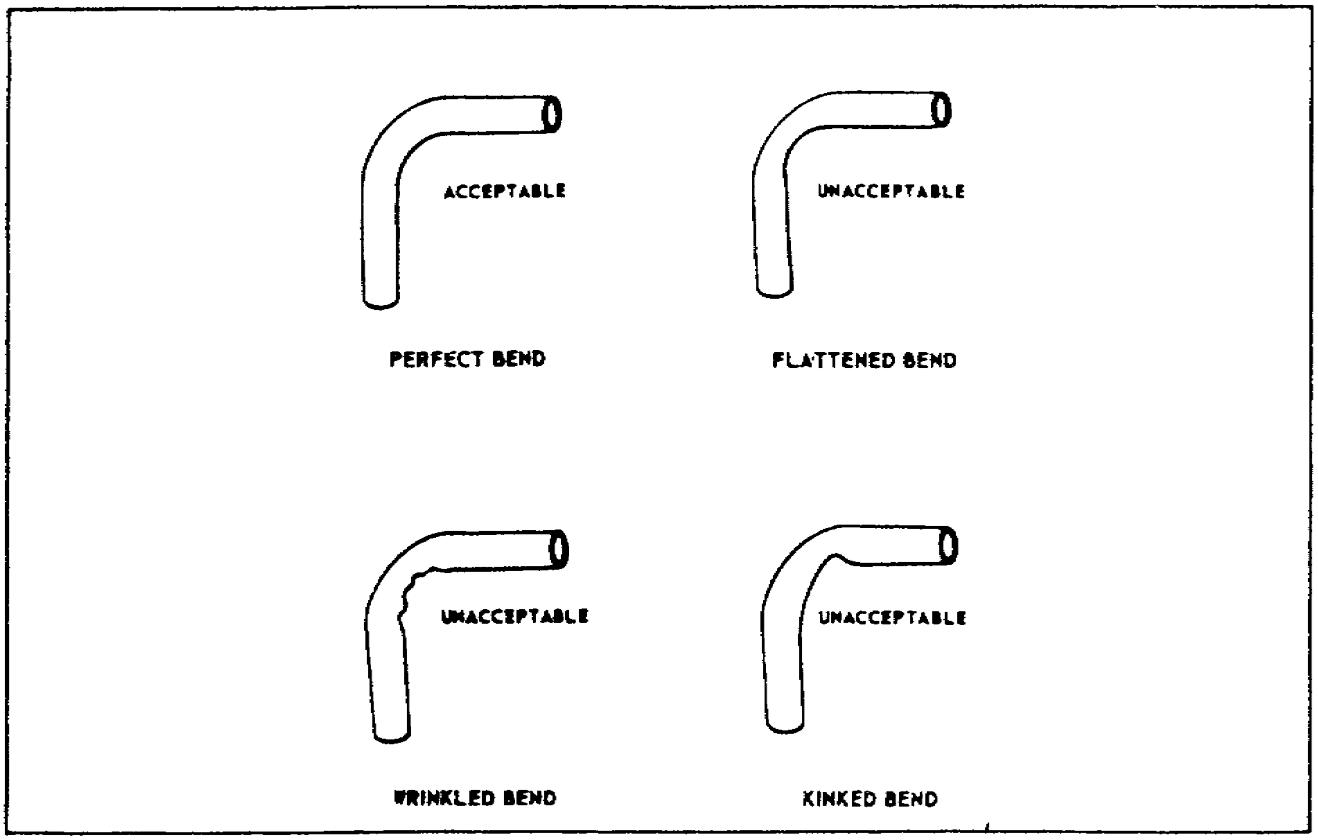


Figure 2-5. Acceptable and Unacceptable Tube Bends.

Hand Bending Methods. Tubes less than 1/4-inch in diameter can be bent with hands, but take care to work the bend gradually. For sizes larger than 1/4-inch in diameter, use a bending tool; however, this tool is only effective on thin-walled tubing of soft material. Two common bending tools are--

- Bending springs. They are used by matching the inside diameter (ID) of the spring with the outside diameter (OD) of the tube to be bent. The tubing is then inserted and centered on the heel of the bend. The bend must be started larger than desired and gradually worked down to the correct size. The coiled spring adds structural strength to the tubing wall during bending and prevents the tube from crushing or kinking.

- Roller Bending Tool. This tool bends a tube to a desired radius very efficiently. It consists of a grooved roller with a degree scale marked on the outside and a slide bar on the handle to point to the degree mark where the tube is bent. To use the tool, the straight tubing must be secured in the tool, and the incidence mark set to indicate zero degree of bend on the scale. Then, pressure is applied to the slide bar, bending the tube as shown in Figure 2-6 to the desired degree.

Power Bending Tool. Tube bending machines are generally used in depot maintenance shops. With such equipment, proper bends can be made in tubing of large diameters and hard materials. The production tube bender is an example of this type of machine.

Alternate Methods. Tubing that has a 1/2-inch or large OD is difficult to bend with hand tools. For this type tubing, power tools must be used whenever possible, since they have an internal support to prevent flattening and wrinkling. However, when power tools are not available, a filler method using sand, shot, or fusible alloy can be used. The steps involved are quite similar regardless of the filler material used. Because the process using the fusible alloy is the most complex, and the most accurate, it is presented in detail in the following paragraphs.

Fusible alloy is a metal alloy with a melting point of approximately 160°F. The material must be melted under hot water at or near the boiling point to ensure that the molten metal flows freely. NEVER APPLY A FLAME TO THE TUBING OR TO THE FUSIBLE ALLOY. EXCESS HEAT DESTROYS THE STRENGTH OF HEAT-TREATED TUBING AND THE MELTING CHARACTERISTICS OF THE FUSIBLE ALLOY. Boiling water will not melt fusible alloy after the flame has been applied. Furthermore, if the tubing is held over a direct flame to remove the alloy, particles of this metal can stick to the inside of the tube and cause corrosion.

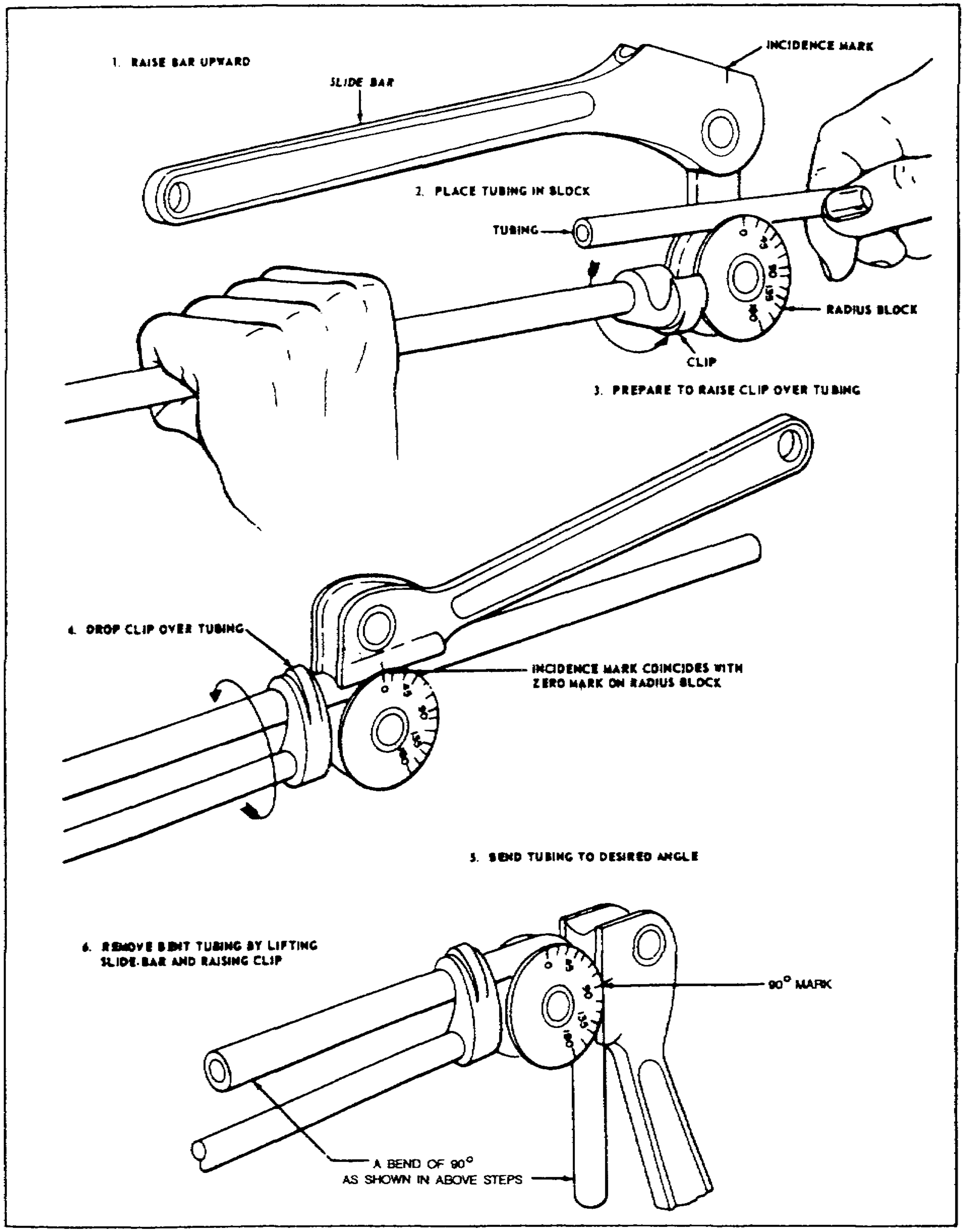


Figure 2-6. Roller Bending Tool.

The six steps taken in the fusible alloy process are as follows:

- Coat the inner surface of the tube to be bent with a light engine oil, specifications MIL-L-6082A.

- Close one end of the tube.

- Place fusible alloy in a clean steel ladle and submerge both tube and ladle in a hot water tank. The fusible alloy stays in the ladle, not combining with the hot water.

- When the alloy has melted, pour it into the tube to be bent, keeping both the tube and ladle under water. As it fills the tube, the alloy displaces the water from the tube. After the tube is full of alloy, remove it from the water and quench it in cold water or air cool until the alloy is completely solidified.

- The tube is now solid and can be bent with any suitable bending tool. As this alloy bends readily when cold but breaks when warm or under suddenly applied loads, care must be taken that the alloy in the tube is bent slowly.

- When the bending is completed submerge the tube in hot water and allow the alloy to run out of the tube into the ladle or other suitable container. All of the alloy must be removed from the bent tubing, as the alloy will cause corrosion. Also, any alloy left in the tube will obstruct the tube and alter the flow characteristics of the fluid.

TUBE CONNECTIONS

Three basic types of connections are used with aircraft tubing. The two most common, the military standard (MS) flareless connection and the flared connection, are depicted in Figure 2-7. The third, less frequently used is the beaded connection.

> **NOTE:** Army-Navy standards (AN) designated for government standards were changed over to military standard (MS) designations.

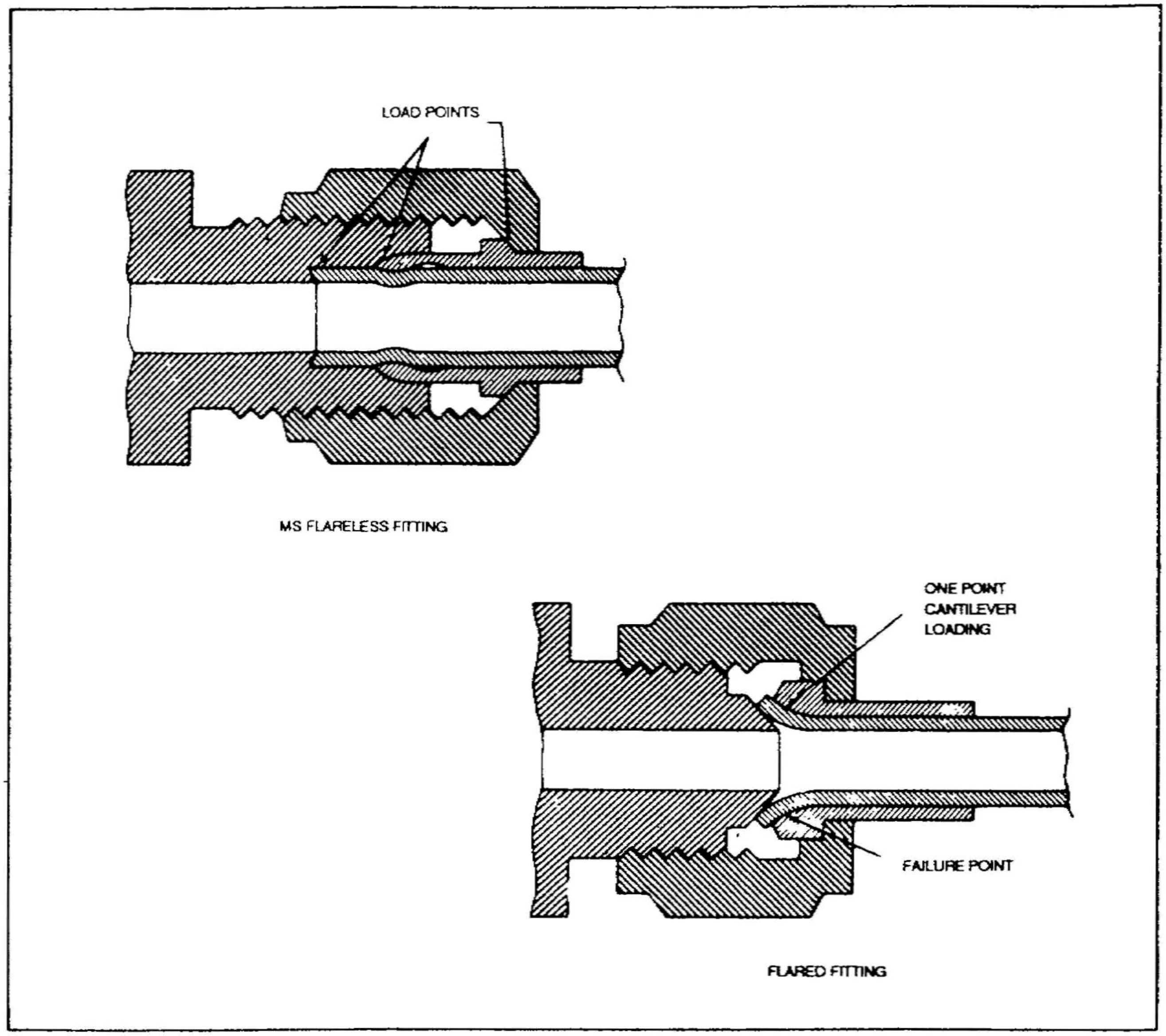


Figure 2-7. Flareless and Flared Fittings.

The MS Flareless Connection. This connection is being used extensively on newer model aircraft. This fitting is designated primarily for high-pressure gas or liquid systems and for service where it is subjected to severe vibrations or fluctuating pressures. This connection retains a seal under these conditions better than any of the other types. The MS flareless connection consists of a connector, sleeve, and nut, as shown in Figure 2-8. The tail on the sleeve dampens out tube vibrations, preventing fatigue and breakage, while the spring washer action of the sleeve prevents the nut from loosening, keeping a better seal.

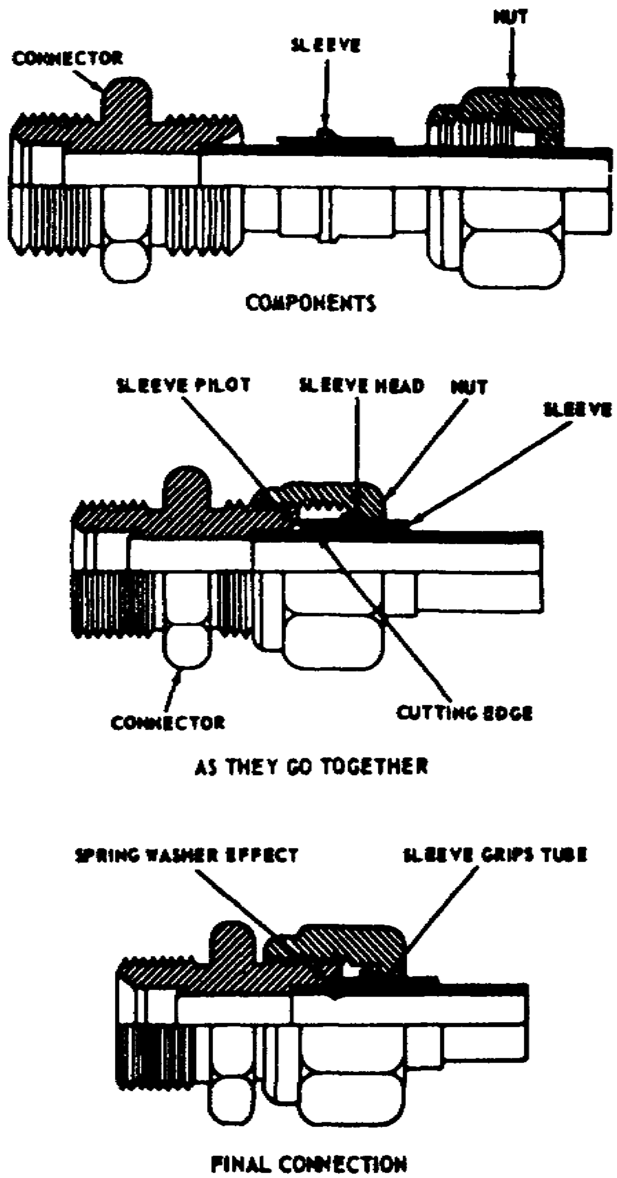


Figure 2-8. Flareless Fitting.

The Flared Connection. This connection withstands high pressure and is used extensively in hydraulic systems. The component pieces necessary to form a flared connection are a nut, sleeve, and properly formed (flared) tube end. These pieces are assembled with the nut screwed on a threaded fitting. These nuts and sleeves are available in both steel and aluminum alloy; the use varies with the material of the tube. Two types of flares can be made on tubing:

- The single flare. Single flares are used for all sizes of stainless steel tubing, for 6061 aluminum alloy tubing, and for 5052 aluminum alloy tubing larger than 1/2-inch OD.

- The double flare. Double flares are specified for 5052 tubing 1/2-inch OD and smaller.

The Beaded Connection. This connection is used only to tubing or to fittings. This type of connection is not capable of withstanding high pressures and is used only in low-pressure systems. No picture of beading is included here, but Figure 2-12, which illustrates a low-pressure tube splice, shows an example of a beaded connection.

PREPARING TUBING FOR FLARING

Two steps are used to prepare tubing for flaring: reaming and cleaning. They must be followed carefully so the tube is not damaged or weakened, and to prevent foreign object damage when the tube is installed.

Reaming. After a square cut has been made bylations, marks, seams, and excessive graphite. Check the fittings for mutilations to the threaded areas, nicks,

Cleaning. Three prescribed methods of cleaning tubing are given in TM 1-1500-204-23 series manuals. Refer to the TM for materials and how they are to be used because cleaning chemicals are constantly improved. These improvements are incorporated in the TM through printed changes. An example is the use of solvent PS-661 which has been changed to the use of naptha TT-N-95. The list can go on and on. Therefore, when using a cleaning agent on or in hydraulic system, always refer to the latest applicable publications for the correct material and usage. The tube must be free of all dirt and grease before clamping it in the flaring tool. The flaring tool die block must be properly cleaned to prevent slips and deformation of the tubing.

FLARING TOOLS

Two basic types of hand flaring tools provide a single flare: the screw and the combination. These tools are described in the following paragraphs.

The Screw Flaring Tool. There are two kinds of screw flaring tools: one threaded and the other with a plain die. The stem of the plunger on the screw flaring tool is threaded so that its pointed end is forced into the tube by turning instead of by tapping with a hammer. The screw flaring tool also has the advantage of the tube being visible, so it is easy to determine when the flare is completed.

CAUTION: DO NOT USE FLARING TOOLS THAT HAVE SERRATIONS IN THE CLAMP BLOCK.

The Combination Flaring Tool. The combination flaring tool is designed to single-flare all grades of aircraft tubing including stainless steel. This tool can also form double-lap flare in aluminum and copper tubing. The component parts of the combination flaring tool are: clamp blocks, a rotor that incorporates a punch for forming double-lap flares, and a cone-shaped punch for forming single flares. With each tool, there are two sets of die blocks; each set has four accurately machined grooves to accommodate four different sizes of tubing. The two sets of die blocks make it possible to flare eight different sizes of tubing. A clamp screw is used to hold the tube between the die blocks, and a compression screw is located in front of the dial containing the flaring punches. A slide stop is used for setting the tube for the proper depth of flare.

DOUBLE FLARES

Double flaring is required on all 5052 aluminum alloy tubing with less than 1/2-inch OD. The double flare provides a double thickness of metal at the flare itself. This double thickness reduces the danger of cutting the flare by overtorquing during assembly and also minimizes the danger of flare failure. Examples of correct and incorrect double flares are shown in Figure 2-9.

Figure 2-9. Correct and Incorrect Double Flares.

Double flares can be formed by double-lap flaring tools of the shock or rotary type or by the combination flaring tool previously described.

The steps in the formation of a double-lap flare are described in the following paragraphs and illustrated in Figure 2-10.

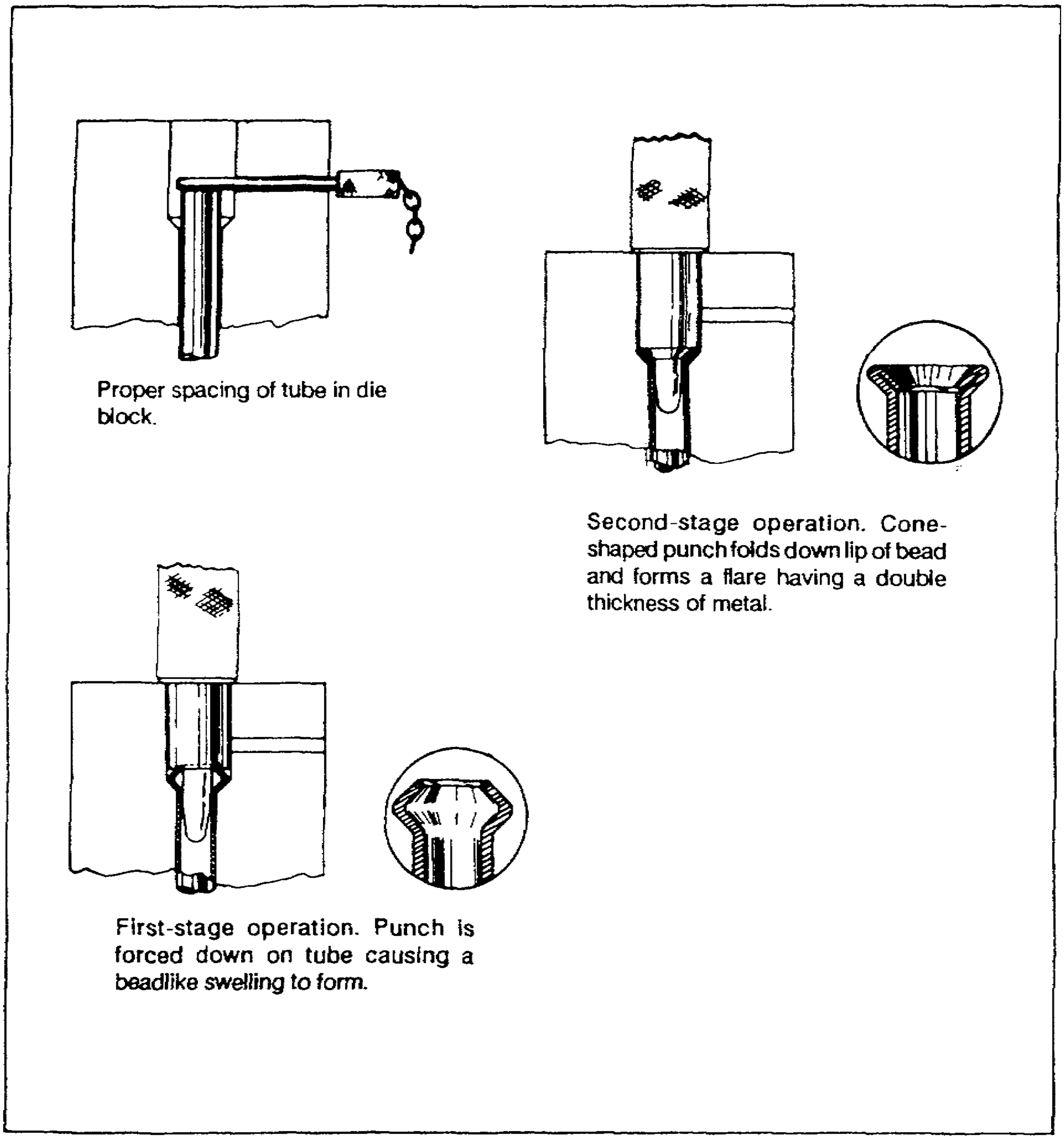


Figure 2-10. Double Flaring.

First Step. The tube is gripped between the halves of the die block with the end of the tube projecting slightly above the bevel of the die block hole. Then, the first-step die plunger is placed against the tube with the end of the tubing resting in the plunger recess. The plunger is then forced toward the die block, causing a bead-like swelling at the end of the tubing. The first-step plunger is then removed, leaving the tube in the die block.

Second Step. The cone is placed at the beaded end of the tubing. This plunger is then forced against the bead, causing the metal at the upper half of the bead to fold into the lower half. This forms a flare with a double thickness of metal at the lip.

FAULTY FLARES

Lack of care and attention to detail in forming flares is likely to result in producing a faulty flare. If the tubing is not cut squarely, a lopsided flare results. A faulty flare is also produced if the tube is not inserted far enough into the die block resulting in an underflared condition. An underflared tube has a small gripping area and will pull apart under pressure. If the tube is inserted until it protrudes too far past the edge of the die block, an overflared condition results. This can cause the flare to crack or break. Use of the stop will prevent this type of overflare. Too much force used on the forming tool when making a flare results in a cracked or flushed flare.

CLEANING TUBING

After the tubing has been formed and flared, all oil, grease, and other foreign material must be removed before installation. Removal of every trace of oil and grease from oxygen tubing is a matter of critical importance because contact between bottled oxygen (used for breathing) and oil or grease results in spontaneous combustion and explosion.

PLUMBING FITTINGS

Fittings are used to assemble and interconnect tubes and hoses to plumbing components and for connecting lines through bulkheads. Examples of these fittings are shown in Figure 2-11.

Prior to installation, all fittings must be carefully examined to ensure that their surfaces are smooth. Smoothness consists of freedom from burrs, nicks, scratches, and tool marks.

Following inspection of the fittings, a thin coat of antiseize compound, Federal Specification TT-A-580, must be applied to the threads of the fittings, except for hydraulic and oxygen fittings. Hydraulic fluid must be used to lubricate fittings of hydraulic plumbing lines. Antiseize compound MIL-T-5542 is used to lubricate the fittings of oxygen systems.

FITTING NUTS

Aircraft plain checknuts are used to secure the tubing and fitting assembly together and to connect the entire tube assembly to components of the plumbing system. Only special-fitting nut wrenches of the torque-indicating type should be used for installing tube assemblies. If not available, open-end wrenches can be used.

Tightening the fitting nuts to the proper torque during installation is very important. Overtorquing these nuts can severely damage the tube flare, the sleeve, and the nut. Undertorquing is equally serious; it can allow the line to blow out of the fitting or to leak under pressure. When fittings are properly torqued, a tube assembly can be removed and installed many times before reflareing becomes necessary.

When installing a fitting, through a bulkhead. Take care to ensure that the nuts are tight enough to prevent any movement between the bulkhead and the fitting. If any movement takes place, vibrations can cause the fittings to enlarge the hole through the bulkhead beyond tolerance and damage the fitting.

> **CAUTION:** A FITTING NUT MUST NEVER BE TIGHTENED WHEN THERE IS PRESSURE IN THE SYSTEM, AS THIS RESULTS IN AN UNDERTORQUES CONDITION AND TENDS TO CUT THE FLARE.

INSTALLATION OF TUBING ASSEMBLIES

Before the tubing assembly is installed in the aircraft, it must be carefully inspected, and all dents and nicks must be removed. Sleeves must be snug-fitting with 1/16 to 1/8 inch of the tube protruding above the top sleeve. The line assembly must be clean and free from all foreign matter as described in an earlier paragraph. During installation, the fitting nuts must be screwed down by hand until they are seated and then properly torqued. The tubing assemblies must not have to be pulled into place with the nut, but must be aligned before tightening.

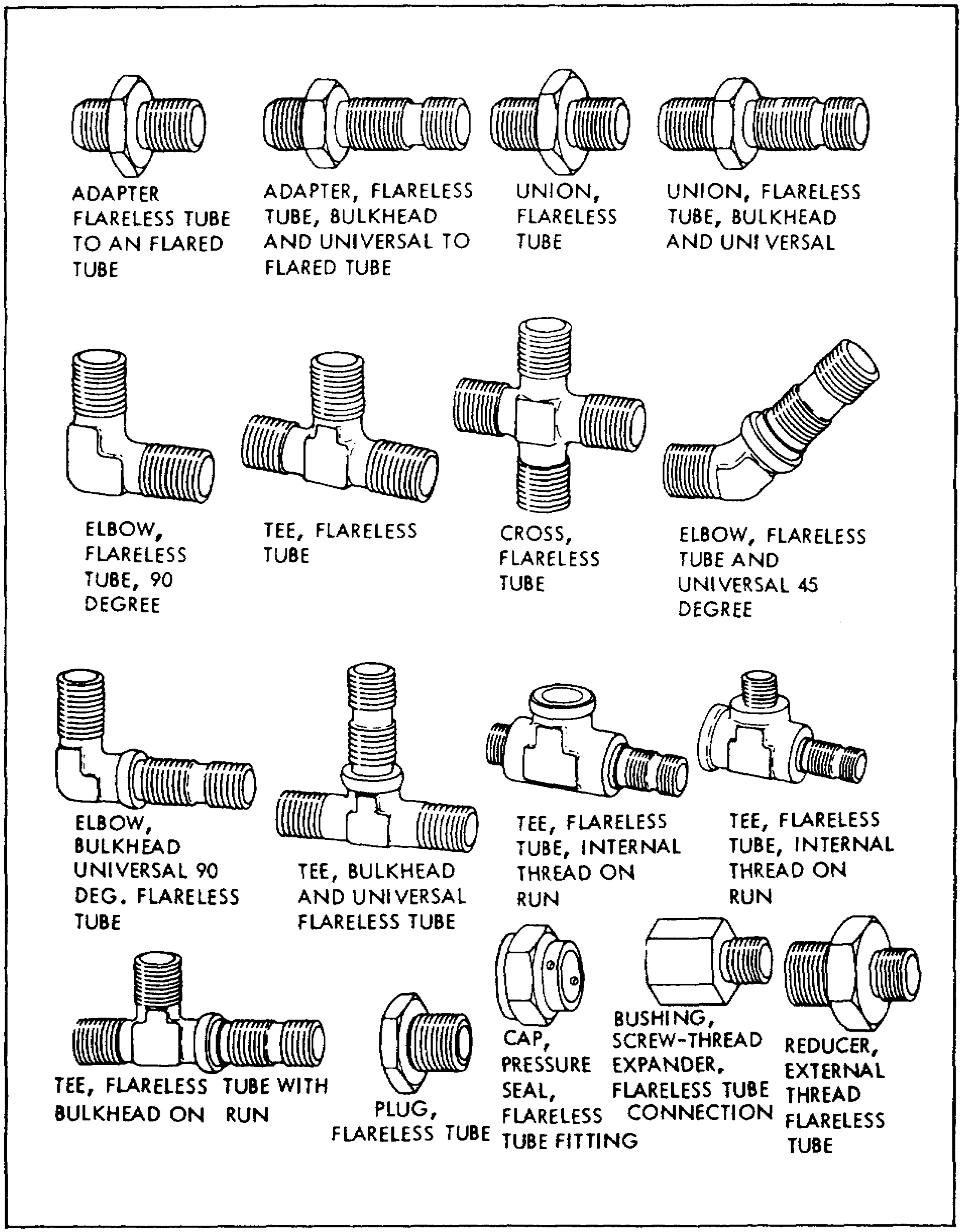


Figure 2-11 Typical Fittings.

If the tubing is to be run through a bulkhead, instead of being connected through the bulkhead by a fitting, take extra care so that the tubing is not scratched. For added protection in this operation, the edges of the cutout must be taped before the line is installed.

TUBE REPAIR

A large percent of minor damage to aircraft plumbing is a result of careless maintenance practices. A misplaced foot or tool can scratch, nick, or dent the tubing beyond tolerances. Therefore, caution on the part of maintenance personnel can prevent a great deal of work.

When a damaged tube is discovered, the ideal solution is to replace the complete section of tubing. In some instances, however, this may not be possible. In these cases minor damages can usually be repaired, providing the damages are within specified limits. Minor repair techniques are described in the paragraphs that follow.

Dents. Any dent less than 20 percent of tubing diameter is not objectionable unless it is on the heel of a short bend radius in which case the tubing is discarded. Dents exceeding 20 percent of tube diameter must be replaced. Burnishing is not allowed in the heel of bends where material has already been stretched thin during forming.

Nicks. A nick in a piece of tubing subjects the tubing to failure because of stress concentration caused by vibrations at the point of the nick. Nicks weaken tubing against internal pressure, and such nicks must be burnished out to reduce a notch effect. A nick no deeper than 15 percent of wall thickness of aluminum, aluminum alloy, copper, or steel tubing may be reworked by burnishing with hand tools. Any aluminum alloy, copper, or steel tubing with nicks in excess of 15 percent of its wall thickness should be rejected. Tubing which is nicked in a bend should be replaced if it is carrying over 100 psi pressure. For tubing carrying pressure of 100 psi or less, a nick no deeper than 20 percent of wall thickness of aluminum, aluminum alloy, copper, or steel may be reworked by burnishing with hand tools.

Splicing. When tube damages exceed the tolerances for repair described in the preceding paragraphs and when it is not possible to replace the entire section of tubing, a splice can be installed. There are two different methods of splicing damaged tubing: one for repairing low-pressure tubing, the other for repairing high-pressure tubing. The steps involved in each of these methods are shown along with graphic illustrations of the process in Figure 2-12 for low-pressure tubing, and in Figure 2-13 for high-pressure tubing. Whenever this type of tube repair is used, particular attention must be paid to ensure compliance with tube tolerances and torque limitations of the clamp connections.

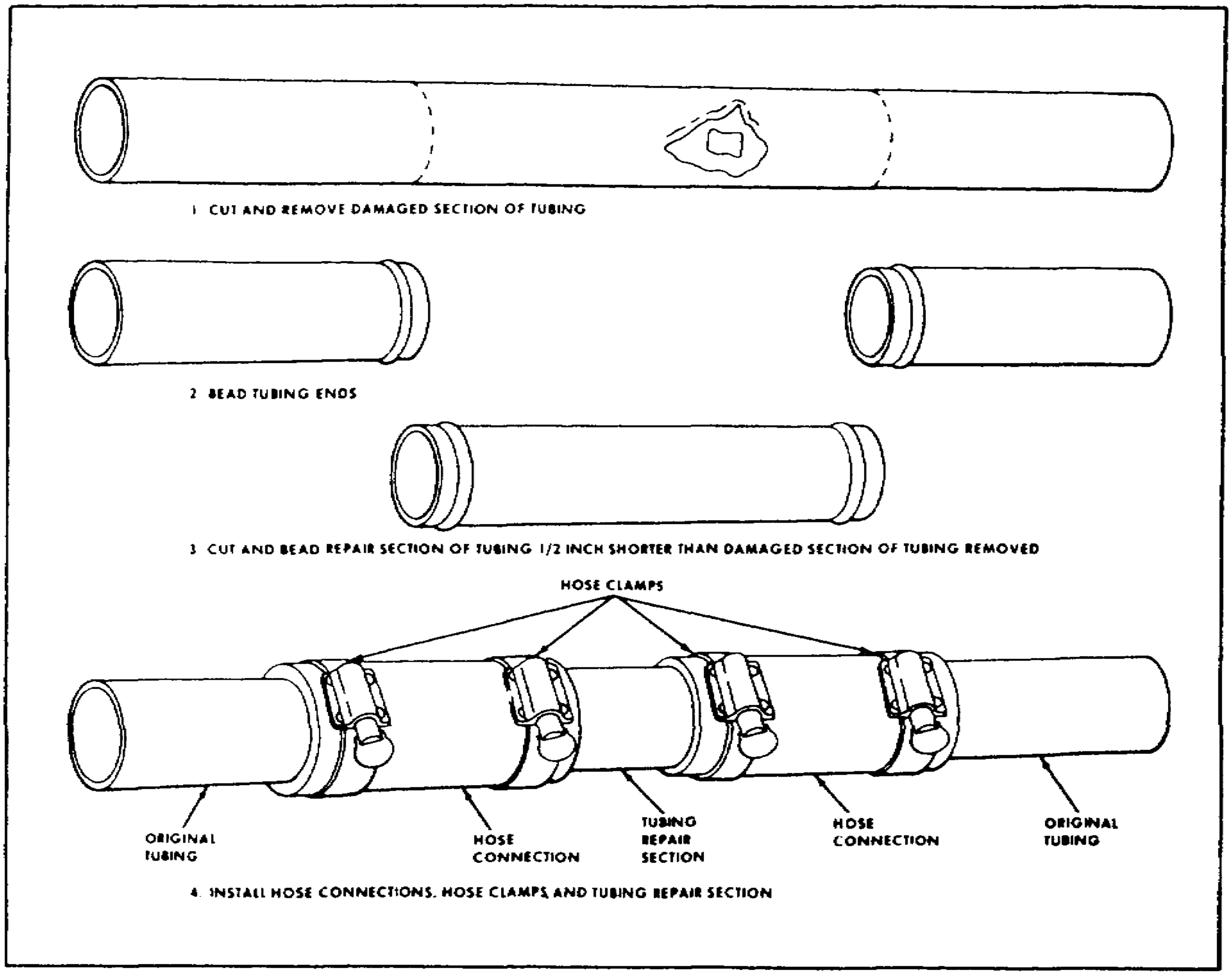


Figure 2-12. Low-Pressure Tube Splice.

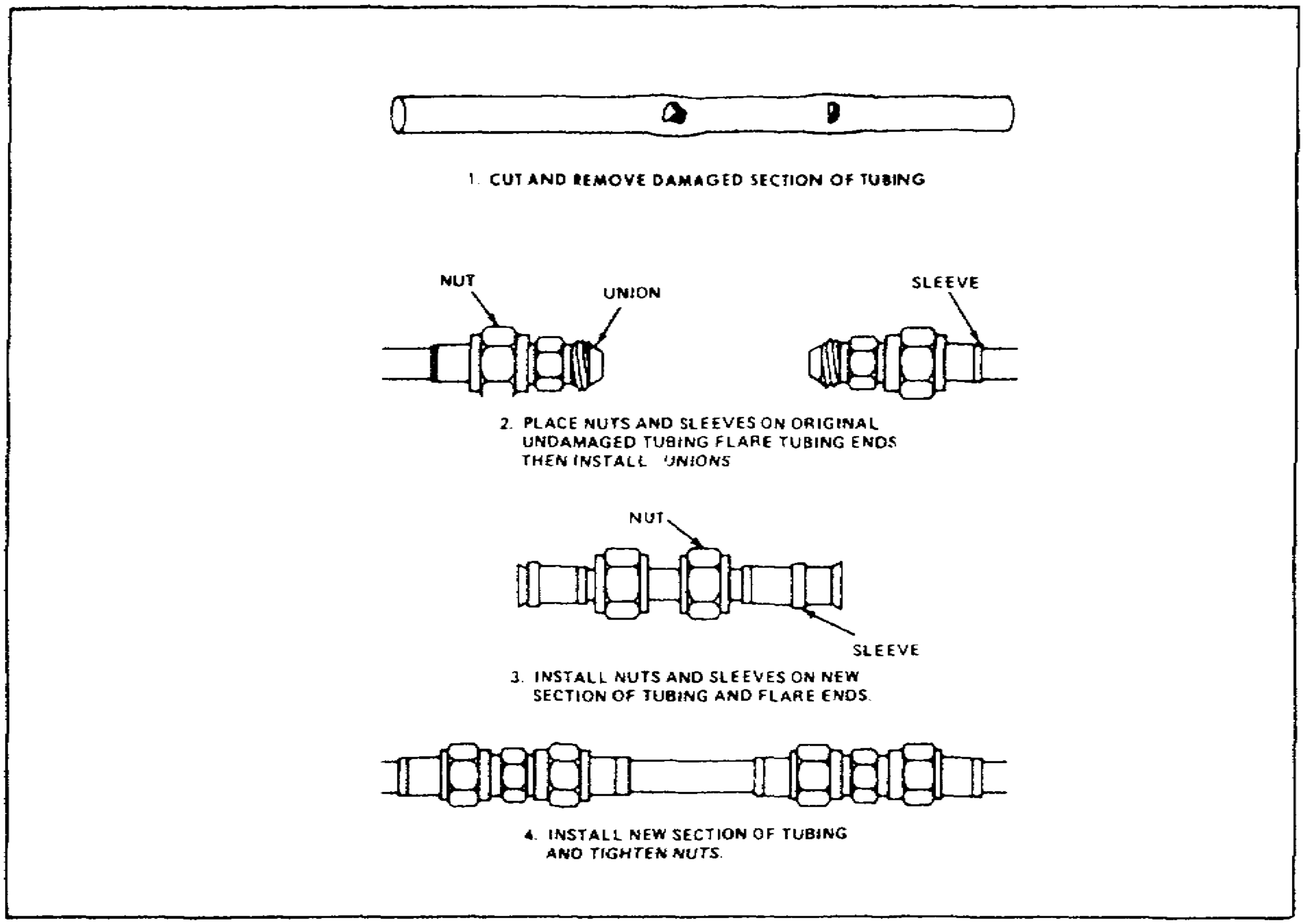


Figure 2-13. High-Pressure Tube Splice.

SUMMARY

Three types of metal tubing are used in aircraft plumbing systems: aluminum alloy, stainless steel, and copper. Aluminum alloy tubing is the most widely used because of its workability, resistance to corrosion, and light weight. Stainless steel tubing is used in high-pressure systems and in places where the tubing is exposed to possible flying-object damage or ground-handling mishaps. Copper tubing is normally used only in high-pressure oxygen systems.

In routing replacement lines, the path of the original line is usually followed. However, when a different route must be used, care must be taken in planning the layout to ensure the bends in the tubing do not exceed the minimum bend radius specified for the particular type of tubing. Care must also be taken not to route the tubing without bends as this allows for no flexibility in response to vibrations or pressure fluctuations.

The Army has two acceptable methods of tube cutting. The most accurate and commonly used method is with the standard tube cutting tool. When properly used, this tool leaves a smooth end on the tube square with its axis. The second method of tube cutting is by using a fine tooth hacksaw. This method does not provide the square cut produced with the standard cutting tool and necessitates filing the tube end after cutting a square off the ends.

A variety of tools and methods are available for tube bending, each having capabilities and advantages applicable to a particular type or size of tubing. Regardless of the method used, the object is to obtain a smooth, even bend without flattening or buckling.

The two most common types of connection used with aircraft tubing are the MS flareless and the flared connection. The MS flareless connection has distinct advantages over the flared connection: it is easier to construct, has three load points to prevent leaks (as opposed to one for flared connections), and can be used many times without danger of cracking. Flared connections are formed by means of a flaring tool. When properly formed, they are capable of withstanding high pressures and are used extensively in hydraulic systems. One of two kinds of flares can be used depending on the type of tubing being used. Single flares are used for all sizes of 5052 aluminum alloy tubing with outside diameters greater than 1/2 inch. Double flares are used on all sizes of tubing with an outside diameter of 1/2 inch or less. The third type of connection used in aircraft plumbing systems is the beaded connection. This type of connection is not capable of withstanding high pressures and is used only in low-pressure systems.

Fittings are used in aircraft plumbing systems to connect the various lines with each other and with the components they operate. Prior to installation all fittings must be inspected to ensure their surfaces are smooth and then coated with the appropriate lubricant.

Fitting nuts must always be tightened with torque-indicating wrenches to ensure the proper seal. Overtorquing of these nuts can severely damage the tubing assembly. Likewise, under-torquing can allow the line to blow out of the fitting or to leak under pressure.

When a damaged tube is discovered, the ideal solution is to replace the complete section of tubing. When this is not possible, minor dents, nicks, and scratches can usually be repaired, providing the damages are within specified limits. If tube damages are extensive or exceed repair limitations, a tube splice can be installed as a temporary repair measure.

PART B - HOSE

Hose, flexible line, is used in aircraft plumbing whenever the connected components must be free to move, or wherever extreme vibrations are a problem. This part deals with the different types of hose used on Army aircraft, the materials from which they are manufactured, and the methods of fabricating hose assemblies. Also explained are the proper methods of hose installation and the requirements for storing the different types of hose. Hose assemblies are used to conduct air, fuel, engine oil, hydraulic fluid, water, and antifreeze. Hose pressure capabilities range from vacuums found in some instrument lines to several thousand psi found in some hydraulic systems. Hose assemblies, however, are never used in aircraft oxygen systems.

TYPES OF HOSE

Aircraft hose is composed of two or more layers of differing materials. The inner layer, or liner, is a leak-tight nonmetallic tube made from either synthetic rubber or teflon. The liner is reinforced against swelling or bursting by one or more outer layers of braid that encircle it. The kind and number of layers of braid depend on the intended operating pressure range of the hose assembly. The two materials used as inner liner for flexible hoses are synthetic rubber and teflon. The two materials and their uses are discussed in the paragraphs that follow.

Rubber Hose. The inner liner of rubber hose used in aircraft plumbing systems is made of synthetic rubber. Various compounds of rubber are used for these inner liners. Each compound provides the hose with some special capability, such as usability with certain fluids or operability within certain ranges of temperature. The outer covering of rubber hose is made of either fabric or rubber.

Rubber hose is used in aircraft plumbing systems only in the form of assemblies. An assembly is formed by attaching metal end connections to each end of a section of bulk hose.

Teflon Hose. Teflon is the registered name for tetrafluoroethylene, which is a synthetic resin. Teflon hose has a flexible leak-proof inner tube, reinforced on the outside with one or more layers of stainless steel braid. The teflon linear is chemical inert to all fuel, oil, alcohol, water, acid, and gas. The linear can withstand fluid temperatures ranging from -100 F to + 500 F (-73 C to +260 C). Like rubber hose, teflon hose is used in aircraft plumbing systems only as assemblies.

PRESSURE CAPABILITIES

The type of material and the number of layers used as reinforcement braid determine the pressure range of the hose. The two pressure-range classifications of aircraft hose are medium pressure and high pressure.

Medium Pressure. The medium-pressure range includes operating pressures of 1,500 psi and below.

High Pressure. High-pressure hose is designated for operating pressure systems up to but not exceeding 3,000 psi.

HOSE MARKINGS

Aircraft hose and hose assemblies can be readily identified by markings found either stenciled along the length of the hose or imprinted on an affixed metal band. These markings include the date of manufacture or fabrication, size, military specification number, and date of pressure test, as illustrated in Figure 2-14.

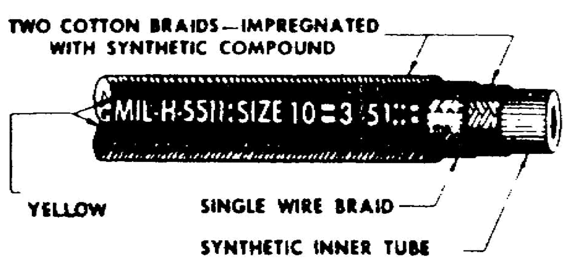


Figure 2-14. Hose Markings.

Marking on Rubber Hose. Bulk rubber hose has ink or paint markings on its outer cover for identification. The information provided by these markings include the identity of the manufacturer, date made, size, and military specification number. The military specification (MS) number provides additional information when referenced with a specification table in chapter 7 of TM 1-1500-204-23-2. This information includes the hose-pressure capability, temperature limitations, and the fluids that can be used. On some hose, a lay strip provides an easy method to determine if an installed hose is twisted.

To identify field-fabricated rubber hose assemblies, a metal band is placed around the hose to identify the federal or national stock number of the assembly and to give the operating pressure and pressure test date.

Marking on Teflon Hose. Bulk teflon hose is identified by brass bands spaced at 3-foot intervals marked with the specification number and manufacturers code number.

Factory-fabricated teflon hose assemblies are identified by permanently attached metal bands marked with the military specification, operating pressure in PSI, assembly part number, date of proof test, and the hose manufacturers code number.

Locally manufactured teflon hose assemblies are identified by an aluminum band. The markings on the band can be impression-stamped, etched, or engraved to include the federal or national stock number of the hose assembly, part number, manufacturers part number or depot code, operating pressure, and date of pressure test.

HOSE SIZE

The size of a hose is expressed as a dash number. This refers to the inside diameter (ID) of the hose and is expressed in sixteenths of an inch; for example, -2 is 2/16, -3 is 3/16, -4 is 4/16.

Whenever hose is used in conjunction with tubing, both the hose and the tube must be equal in size. For example, if the tube size is 1/4 inch OD, a -4 (4/16) hose must be used with it.

CAUSES FOR HOSE REPLACEMENT

Replacement of rubber hose assemblies must be accomplished at inspection intervals prescribed in the applicable aircraft maintenance manual. Teflon hose does not deteriorate as a result of age; therefore, periodic replacement is not required. However, both rubber and teflon hose assemblies are subject to damage during operation that can be cause for replacement of the line.

In any case, the replacement of the hose assembly must duplicate the original hose in length, OD, ID, and contour, unless the line must be rerouted for reasons specified in the paragraph which discusses routing of lines near the beginning of this lessons.

Rubber Hose. Evidence of deterioration of rubber hose assemblies is urgent cause for hose replacement. Examples of such deterioration are separation of rubber covers or braid from the liner, cracks, hardening, and lack of flexibility.

Other types of damage that are cause for replacement of rubber hose are--

- Cold flow -- a deep permanent impression or crack produced by pressure of the hose clamp.
- Weather check -- weather damage that is deep or wide enough to expose the fabric.
- Broken wires -- two or more broken wires per plait, six or more broken wires per linear foot, or any broken wire in a position where kinking is suspected. (For pressures of 500 psi and over)

Teflon Hose. Installed teflon hose assemblies must be inspected for evidence of deterioration due to wire fatigue or chafing at the periods prescribed in the applicable aircraft inspection or maintenance manuals. Replacement of these lines must be made when any of the following conditions are found:

- Leaking -- static leaks exceeding one drop per hour.
- Excessive wire damage -- two or more broken wires in a single plait, more than six wires pre linear foot, or any broken wire in a position where kinking is suspected.
- Distortion -- any evidence of abrasion, kinking, bulging, or sharp bending.

FABRICATION OF HOSE ASSEMBLIES

Hose assemblies, for the most part, are available through supply channels as factory prefabricated parts. For field expediency or when the required assemblies are not available they can be field fabricated in accordance with the following specifications and procedures.

Fabricating Medium-Pressure Rubber Hose Assemblies. Medium-pressure rubber hose assemblies are fabricated from bulk hose conforming to military specification MIL-H-8794 and fittings conforming to military standard MS 28740. Prior to the assembly process and before cutting, visually check the bulk hose for any mutilations, marks, seams, and excessive graphite. Check the fittings for mutilations to the threaded areas, nicks, distortions, scratches, or any other damage to the cone seat sealing surface, or to the finish that can affect the corrosion resistance of the fitting.

CAUTION: DO NOT INTERMIX THE SOCKET AND NIPPLE FROM ONE MANUFACTURER WITH THOSE OF ANOTHER. ALL FITTINGS ARE MARKED WITH THE MANUFACTURER'S SYMBOL.

After the hose and fittings have been inspected, determine the correct length of hose required as shown in Figure 2-15. Cut the hose squarely, using a fine tooth hacksaw; then, using compressed air, clean the hose to remove all cutting residue.

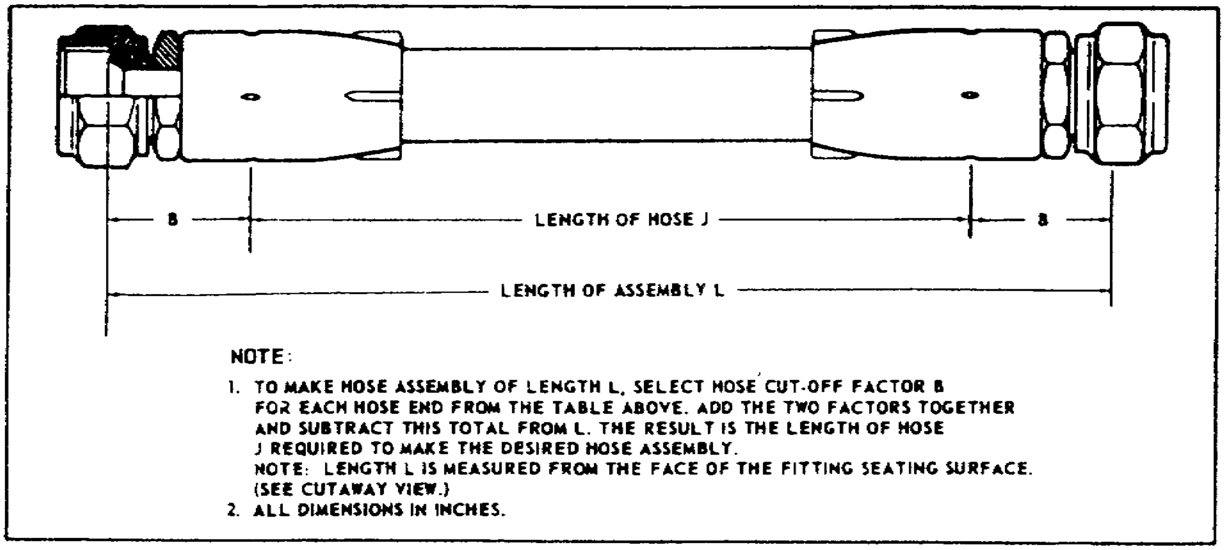


Figure 2-15. Determination of Correct Hose Length.

Assembly of the hose and fittings is illustrated in Figure 2-16, and outlined in the following steps:

- Place the socket in a vise and screw the hose into the socket counterclockwise until it bottoms out; then back off the hose 1/4 of a turn. CAUTION: DO NOT OVERTIGHTEN THE VISE ON THIN-WALLED SOCKETS OF LIGHTWEIGHT FITTINGS.

- Tighten the nipple and the nut on the appropriate assembly tool from Aeroquip Kit, Part No. S-1051.

- Lubricate the nipple threads and the inside of the hose liberally, using a lightweight motor oil or hydraulic fluid, MIL-H-5605 or MIL-H-83282.

• Screw the nipple into the socket and hose using a wrench on the nipple hex nut. The nut must swivel freely when the assembly tool is removed.

After the fabrication process is completed, inspect the hose assembly externally for cuts or bulges of the inner liner. The final step of any hose fabrication process is to proof-test the hose assembly to insure its pressure capabilities. This step is discussed in the paragraph on testing hose assemblies.

<u>Fabricating High-Pressure Rubber Hose Assemblies</u>. High-pressure rubber hose assemblies MS 28759 an MS 28762, are fabricated from high-pressure bulk hose conforming to military specifications MIL-H-8788 or MIL-H-8790, and fittings conforming to military standard MS 28760 or MS 28761.

The fabrication techniques and tools for assembling high-pressure hose are the same as those outlined for medium-pressure hose fabrication.

CAUTION: DO NOT REUSE HIGH-PRESSURE HOSE OR HIGH-PRESSURE HOSE FITTINGS. ALSO, NEVER REINSTALL A FITTING ON THE SAME AREA OF HOSE WHERE IT WAS FIRST INSTALLED. IF AN ERROR IS MADE DURING ASSEMBLY, CUT AWAY THE OLD AREA OR USE A NEW LENGTH OF HOSE AND REINSTALL THE FITTING.

<u>Fabricating Medium-Pressure Teflon Hose Assemblies</u>. Medium-pressure teflon hose assemblies are manufactured to the requirements of military specification MIL-H-25579 from bulk hose conforming to military specification MIL-H-27267 and end-fittings conforming to military specification MIL-F-27272.

All field-fabricated teflon hose assemblies must be identified by aluminum-alloy tags, NSN 9535-00-232-7600.

The composition and dimensions of these tags are found on chapter 4 of TM 1-1520-204-23-2. The tags are marked to show the federal or national stock number or part number, depot or unit code, operating pressure, and date of pressure test.

The steps to be followed when fabricating these hose assemblies are described in TM 1-1500-204-23-2.

<u>Fabricating High-Pressure Teflon Hose Assemblies</u>. High-pressure teflon hose assemblies are manufactured from bulk hose conforming to MIL-H-83298 and end fittings conforming to MIL-H-83296.

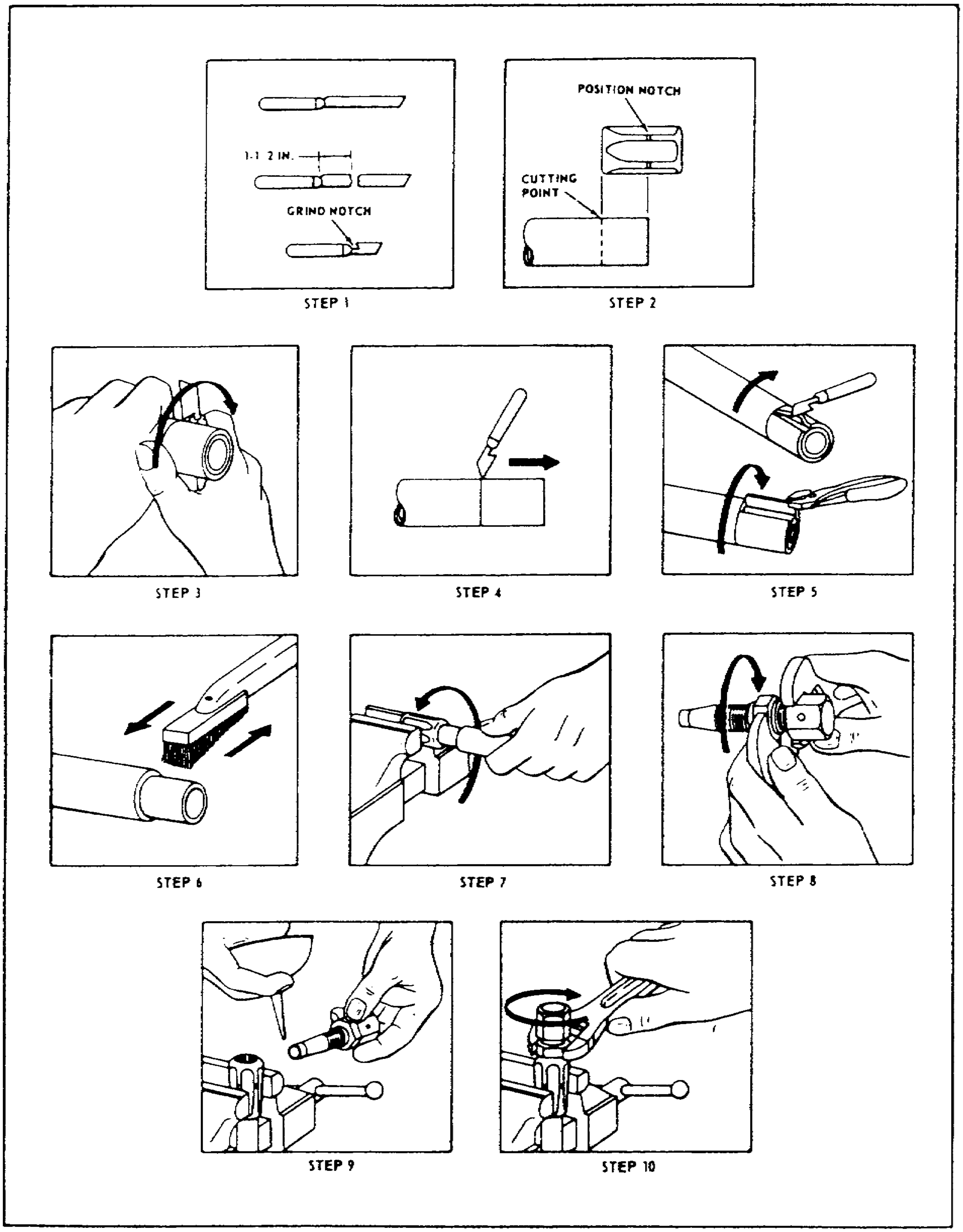


Figure 2-16. Assembly of Hose and End Fitting.

TESTING HOSE ASSEMBLIES

Prior to installation, all field fabricated hose assemblies must be pressure-tested. This applies regardless of whether they were just fabricated or were previously fabricated, tested, and placed in storage. All factory or depot fabricated assemblies must be pressure-tested prior to installation.

Hose assemblies to be used in hydraulic, pneumatic, fuel, oil, or coolant systems are tested on a hydrostatic test unit filled with hydraulic fluid conforming to military specification MIL-H-5606, MIL-H-83282, or MIL-H-6083; lubricating oil conforming to military specification MIL-H-6082; or water. Hose assemblies to be used in instrument systems are tested using dry, oil-free air, or nitrogen, federal specification 1313-N-411, grade A, type 1.

The steps involved in the testing process are explained in detail in TM 1-1500-204-23-2.

INSTALLING HOSE ASSEMBLIES

During operation, the hose assemblies changes in length from +2 percent to -4 percent because of pressurization. To compensate for this, slack equal to at least five percent of the hose length must be allowed for expansion and shrinkage. The five percent allowance must be provided during cutting and fabricating. In addition to hose length, care must be taken not to twist the hose or to exceed the allowed bend radius. Supports and grommets must be used, fittings lubricated, and protection against temperature provided. Each of these is discussed in the paragraphs that follow and illustrated in Figure 2-17.

Twisting. Most hose is marked with a lengthwise solid line (lay strip) for ease in detecting any twists of the line during installation. A twisted hose tends to untwist when pressurized causing the end fitting to become loosened or sheared. To avoid twisting hose assemblies when connecting the second end, use two wrenches: one to hold the stationary fitting and one to turn the swivel nut.

Bend Radius. Hose, like rigid tubing, has a limit to its bend allowance. Bends exceeding the permissible limit lead to early failure of the hose assembly. The radius of the sharpest bend permissible for a hose is referred to as the minimum bend radius for that hose. This bend radius is measured in the same manner as the minimum bend radius of rigid tubing as described in the paragraph of this lesson entitled "routing of lines".

Supports and Grommets. Teflon hose requires a different kind of support than that used for rubber hose. However, the following principles in using supports apply to both rubber and teflon hose. Hose must be supported along its length at intervals of 24 inches or less, depending on the size of the hose. These supports, shown in Figure 2-18, must be installed in such a manner that they do not cause deflection of any rigid lines where they are connected.

When a hose is connected to an engine by a hose clamp, a support must be placed approximately three inches from the connection, and at least 1-1/2 inches of hose slack provided between the connection and the engine, to keep vibration and torsion from damaging the connections.

When a hose passes through a bulkhead, a grommet must be installed in the bulkhead hole to provide support for the hose and to prevent it from chafing. As an alternative, a cushioned clamp can be used at the hole if the hole is large enough to provide adequate clearance around the hose.

A hose assembly connecting two rigidly mounted fittings must be supported firmly but not rigidly.

Lubrication. The swiveling parts and mating surfaces-of hose assemblies must be lubricated before installation. This ensures effective seating and tightening of the component parts. Oil or water can be used on all, types of fuel, oil, and coolant hose when installation is made except for self-sealing hose which must never be lubricated during installation. However, only oil or the operational fluid of the system must be used on hydraulic and pneumatic hose.

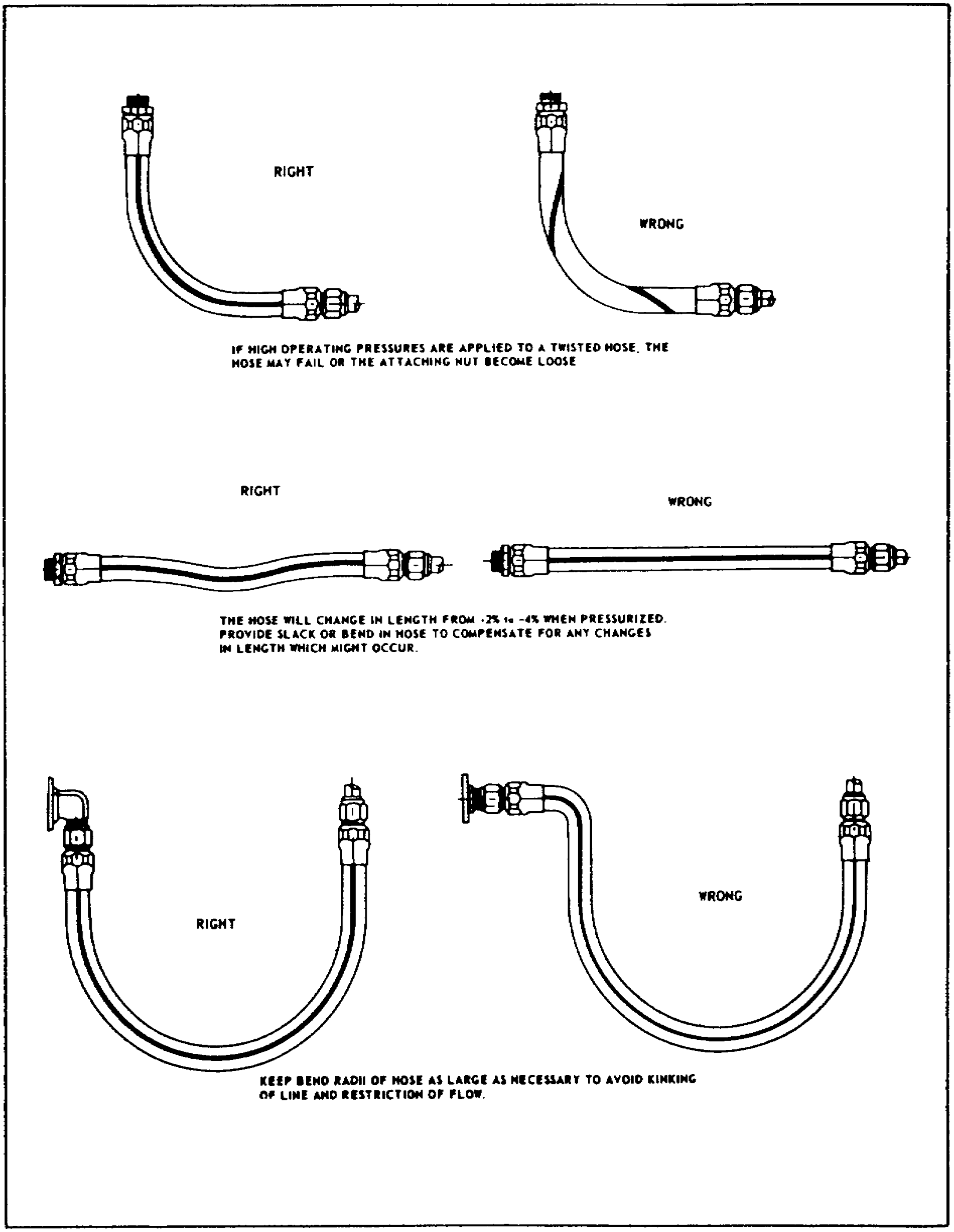


Figure 2-17. Connecting Hose Assemblies.

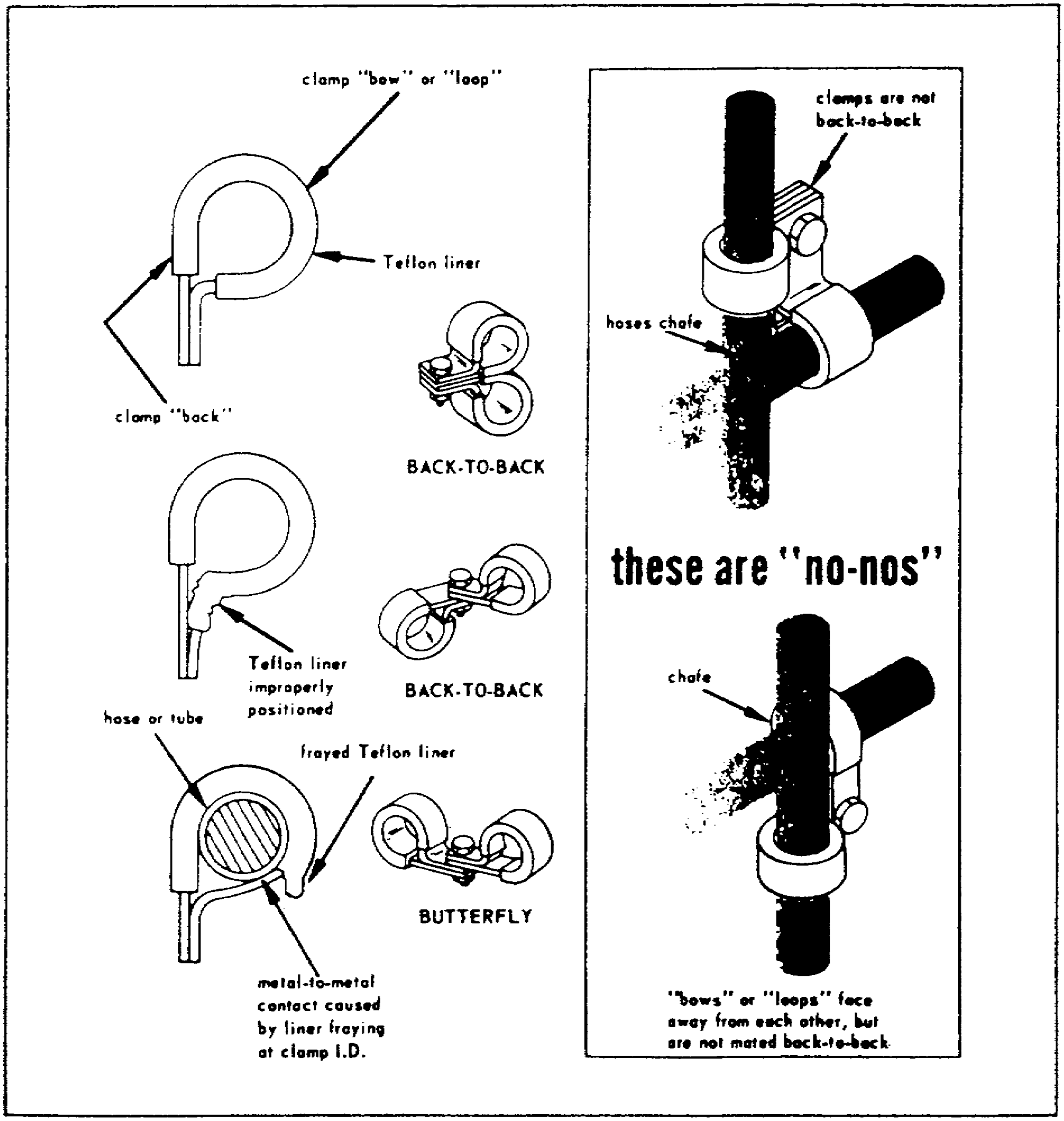


Figure 2-18. Hose Support.

Temperature Protection. Hose must be protected from high temperatures such as exhaust blast and hot engine parts. In these areas the hose must either be shielded or relocated. A shield for temperature protection is shown in Figure 2-19.

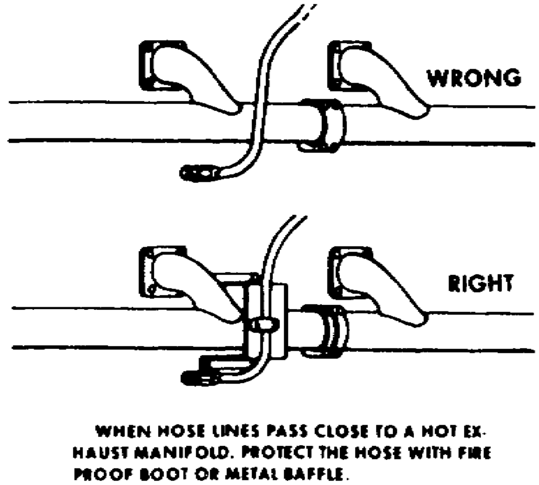


Figure 2-19. Temperature Protection.

STORAGE

Proper storage and handling of aircraft hose and hose assemblies are the responsibility of all activities engaged in aircraft maintenance. Aircraft hose and associated rubber components must be stored in a dark, cool, dry place protected from exposure to strong air currents and dirt. Stored rubber hose and seals must also be protected from electric motors or other equipment emitting heat or ozone. Hose and hose components must be stored in the original packing and issued so that the oldest items are issued first.

Neither teflon nor rubber hose has limited shelf life. However, prior to installation all hose assemblies must be inspected to ensure serviceability and tested according to the procedures listed in the paragraph on testing hose assemblies.

Bulk Hose. Prior to being placed in storage, the ends of the hose must be capped to prevent flareout and dirt contamination. Storage in a straight position is the preferred manner; however, if coiling is necessary, large loose coils must be made.

CAUTION: UNDER NO CIRCUMSTANCES MUST HOSE BE PILED TO A HEIGHT THAT CAN RESULT IN DAMAGE TO THE UNDER SECTIONS. THIS CAUTION APPLIES TO HOSE IN CARTONS AS WELL AS TO UNPACKAGED HOSE.

Hose Assemblies. The ends of all hose assemblies must be capped during storage with polyethylene protective plugs conforming to National Aerospace Standard (NAS) 815 or equivalent to prevent contamination.

SUMMARY

Hose is used in aircraft plumbing whenever the connected components must be free to move or whenever extreme vibrations are a problem. Aircraft hose is composed of two or more layers of differing materials. The inner layer, or liner, is a leak-tight nonmetallic tube made from either synthetic rubber or teflon. The liner is reinforced against swelling or bursting by one or more outer layers of braid. The kind and number of braid layers depend on the intended operating pressure range of the hose assembly.

The pressure capabilities of hose assemblies are divided into two general categories: medium pressure and high pressure. The medium-pressure range includes operating pressures of 1,500 psi and below. High-pressure hose is designated for operating pressure systems up to but not exceeding 3,000 psi.

Aircraft hose and hose assemblies can be readily identified by markings found either stenciled along the length of the hose or imprinted on an affixed, metal band. These markings include the date of manufacture or fabrication, size, military specification number, and date of pressure test.

Hose size is expressed in sixteenths of an inch by a dash number referring to the inside diameter (ID) of the hose.

Replacement of rubber hose assemblies must be accomplished at inspection intervals prescribed in the applicable aircraft maintenance manual. Teflon hose does not deteriorate as a result of age; therefore, periodic replacement is not required. Both rubber and teflon hose assemblies are subject to damage during operation that can be cause for replacement. Examples of these damages are: cold flow, weather checking, leaks, or broken wires exceeding limitations.

For the most part, hose assemblies are available through supply channels as factory prefabricated parts. For expediency, however, they can be field fabricated in accordance with the outlined specifications. High-pressure teflon hose is available in prefabricated assemblies only. Field fabrication is not authorized.

Prior to installation, all field-fabricated hose assemblies must be pressure tested; factory or depot lubricated assemblies must be pressure tested regardless of whether they were tested at the time of manufacture.

During installation, care must be taken to ensure the line is not twisted or bent to exceed limitations. Hose must be supported along its length at intervals of 24 inches or less, depending on the size of the hose.

The swiveling parts and mating surfaces of hose assemblies must be lubricated before installation to ensure effective seating of the component parts. Self-sealing hose must never be lubricated.

Aircraft hose and rubber components must be stored in a dark, cool, dry place protected from exposure to strong air currents and dirt. Neither Teflon nor rubber hose is limited in its shelf life; however, prior to installation all hose assemblies and seals must be inspected to ensure serviceability.

PART C - SEALS AND GASKETS

Seals and gaskets are used throughout aircraft plumbing systems to prevent leaks when two components are joined together. The material from which the seals are manufactured varies depending upon the fluid or gas being conducted and the operating pressure range of the system. Using the proper type of seal and exercising care during installation are two of the most important phases of plumbing maintenance. Lack of care during this phase of maintenance is one of the most frequent causes of system failure or leaks. In this part, the types of seals and gaskets used in aircraft plumbing systems are discussed; and their capabilities, advantages, limitations, and installation procedures are presented.

CAUTION: UNDER NO CIRCUMSTANCES MUST SEALS OR GASKETS BE REUSED AFTER THEY HAVE BEEN REMOVED FROM SERVICE, EVEN IF THEIR REMOVAL WAS ONLY INCIDENTAL TO THE DISASSEMBLY OF A COMPONENT.

SEALS

The seals or packings used in hydraulic systems are manufactured from rubber, leather, teflon, metal, or a combination of any of these. Two types of rubber, natural and synthetic, are used for making hydraulic seals; however, only synthetic rubber seals can be used with mineral-base hydraulic fluid. Examples of some of the different kinds of seals used in plumbing systems are shown in Figure 2-20 and discussed in the following paragraphs.

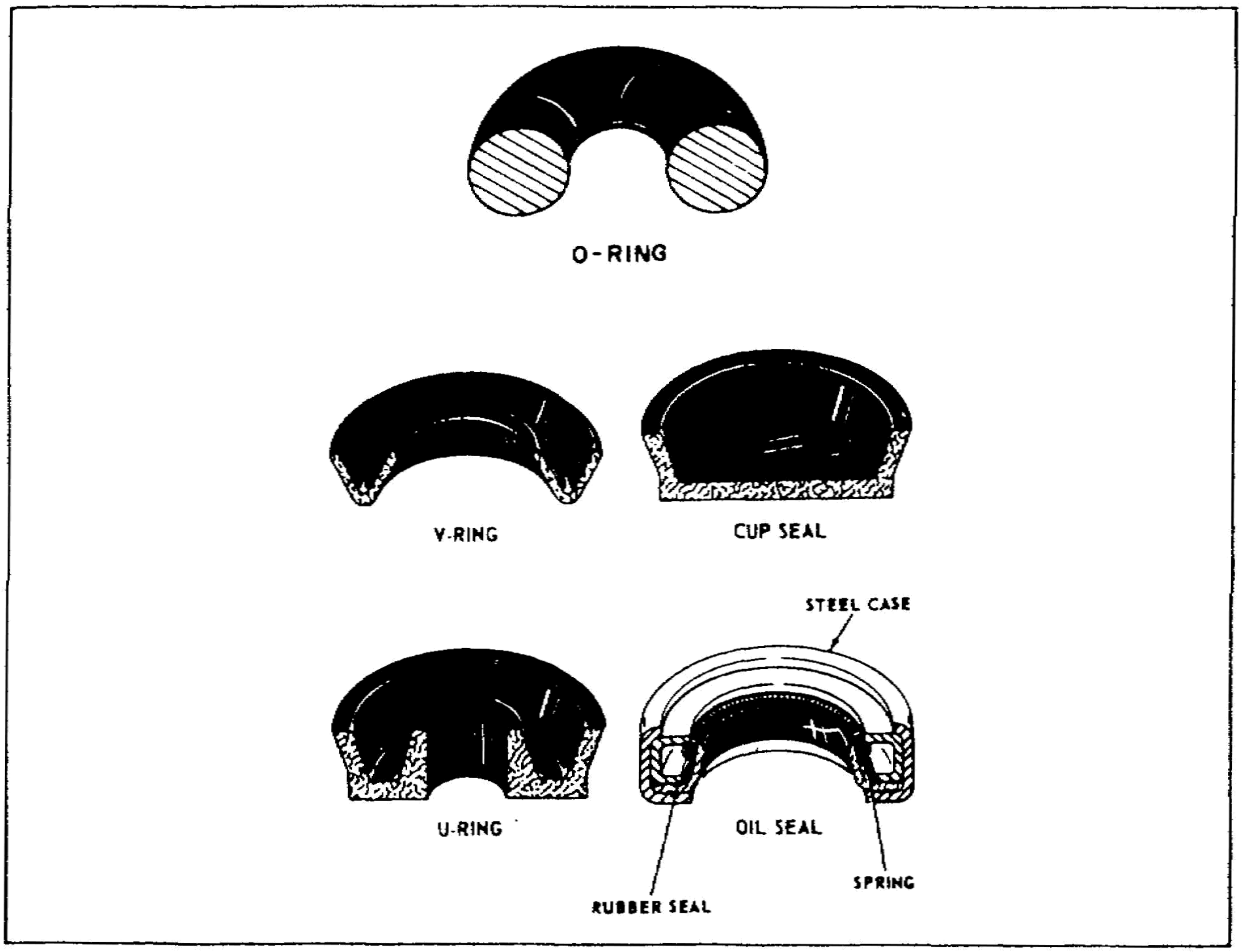


Figure 2-20. Seals Used in Plumbing Systems.

O-Rings. In Army aircraft, the O-ring is the most commonly used type of hydraulic seal. It is designed to control leaks against pressures coming from any direction and can be used where there is either rotative- or linear-relative movement between parts. An O-ring can also be used between nonmoving parts to eliminate leaks such as in the joint between two parts of a housing. When used in this manner the O-ring is called an O-ring gasket.

Backup Rings. When the pressure to be retained by an O-ring exceeds 1,500 psi, a backup ring is used in the groove along with the O-ring. Backup rings prevent O-ring material from extruding into the clearance gap between the sealed surfaces.

Extrusions tend to cause the moving parts to bind, the O-ring seal to fail, and particles of the O-ring seal to contaminate the fluid. Backup rings can also be used with lower pressure systems to extend O-ring life.

When installed, a backup ring is placed on the side of the O-ring not subjected to pressure. In cases where the O-ring is subject to pressure from both sides, two backup rings are used, one on each side of the O-ring.

<u>V-Rings</u>. The use of V-rings is rather limited in hydraulic systems; however, they are used in some shock struts. A V-ring can seal in only one direction and can be used to seal surfaces regardless of whether there is movement between the parts.

<u>U-Rings</u>. Similar to V-rings in design and function, U-rings are used to seal pistons and shafts on some master brake cylinders.

<u>Cup Seals</u>. Another type of seal used frequently on master brake cylinders is cup seals. They are effective in controlling leaks in only one direction, and when installed the lip of the cup must be facing the fluid to be contained.

<u>Oil Seals</u>. Composite seals made from both rubber and metal are called oil seals, and they are used to seal hydraulic pump and motor drive shafts. Their outer body, or case, is made from pressed steel and is force-fitted into the component housing. Inside the metal case is a lipped rubber seal and a spring. The rubber seal is securely anchored against movement to the metal case, and the spring encircles the lip, holding it firmly to the surface it seals and is commonly referred to as a Garloc Seal. During installation, the housing must be free from foreign matter or burrs, and the seals must be seated squarely with proper special tools.

<u>Wiper Seals</u>. Scrapers or wiper seals are made of metal, leather, or felt and used to clean and lubricate the exposed portion of piston shafts. When installed and operating properly, wiper seals prevent dirt from entering the system and aid in preventing piston shafts from binding.

INSTALLING SEALS

Prior to use, all seals must be examined to ensure they are made from the correct material, in the proper shape and size, and free from nicks, cracks, rough spots, or other defects. Immediately prior to assembly, clean and lubricate the seals and contact surfaces with the operational fluid of the system.

When installing seals, care must be taken so they are not stretched or distorted. Any twists or strains to the seal can lead to its early failure and must be prevented by gently working the seal into place.

GASKETS

A gasket is a piece of material placed between two parts where there is no movement. The gasket is used as a filler to compensate for irregularities on the surfaces of the two mating parts permitting possible leaks. Many different materials are used for making gaskets. For use in hydraulic systems the gaskets may be made from treated paper, synthetic rubber, copper, or aluminum.

O-Ring Gaskets. The most common type of gasket used in aircraft hydraulic systems is the O-ring. When used as a gasket the O-ring has the same advantage as when used as a seal, as explained in a previous paragraph.

Crush Washers. The second most commonly used gasket is the crush washer, used in hydraulic systems and made from aluminum or copper. Fittings using these washers have concentric grooves and ridges that bear against or crush the washer. These grooves and ridges seal the washer and fitting as the connecting parts are tightened together.

FABRICATING GASKETS

Some types of gaskets can be field-fabricated as long as the bulk material conforms to the required military specifications. When you cut replacement gaskets from bulk material, the most important consideration is the exact duplication of the thickness of the original gasket.

INSTALLING GASKETS

Like seals, gaskets must be examined before installation to ensure their serviceability. The component surfaces to be connected must be thoroughly cleaned. During assembly, care must be taken not to crimp or twist the gaskets. When tightening the components, the gaskets must not be compressed into the threads where they can be cut, damaged, or block mating surfaces from being flush.

STORING SEALS AND GASKETS

Seals and gaskets must be stored in accordance with the same specifications outlined for hose and hose assemblies in a previous paragraph. By way of review, those specifications require that seals and gaskets be stored in a cool, dark, dry place; they must be protected from dirt, heat, strong air currents, dampness, petroleum products, and electric motors or equipment giving off ozone.

SUMMARY

Seals and gaskets are used in aircraft plumbing systems to prevent leaks when two components are joined together. The fluid being conducted and the operating pressure of the system determine the type of seal or gasket to be used and the material to be used in its manufacture. Once a seal or gasket has been removed from service it must never be reused, even if removal was only incidental to the disassembly of a component.

In hydraulic systems, seals manufactured from rubber, leather, felt, cork, paper, teflon, or metal are used. The O-ring is the most widely used type of hydraulic seal. It is effective in controlling pressures coming from any direction or for use where there is either linear or rotative motion. Backup rings are used with O-rings as a means of preventing O-ring extrusions, prolonging O-ring life, or when system pressure exceeds 1,500 psi. Other types of seals used in hydraulic systems are: V-rings, U-rings, cup seals, oil seals, and wiper seals. These are special seals, used to contain fluid or prevent leaks in the various components of the aircraft plumbing systems.

All seals must be inspected for serviceability prior to installation, and care must be taken not to damage them during assembly.

A seal placed between two components where there is no relative movement is termed a gasket. Its function is to compensate for any irregularities on the surfaces of two mating parts and thus to prevent leaks.

Crush washers and O-ring gaskets are the most common types of gaskets used in aircraft hydraulic systems. If a gasket is to be field fabricated, ensure that the exact thickness of the original gasket is duplicated.

Gaskets, like seals, must be examined prior to installation to ensure their serviceability. During assembly, do not exceed the recommended torque value of the components. Overtightening is likely to crimp the gasket or compress it into the threads of the component, and hence, break the seal.

When stored, seals and gaskets must be protected from excessive heat, dampness, air currents, dirt, petroleum products, and equipment emitting ozone.

LESSON 2

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. How many types of identification code systems are used to identify tube assemblies?

___ A. One.
___ B. Two.
___ C. Three.
___ D. Four.

2. What pressure application is the beaded connection used for?

___ A. Low pressure.
___ B. Medium pressure.
___ C. High pressure.
___ D. Extreme high pressure.

3. How many prescribed methods of cleaning tubing are there?

___ A. One.
___ B. Two.
___ C. Three.
___ D. Four.

4. Compared to the diameter of a tube, which of the following percentages represents unacceptable dent depth?

___ A. 5.
___ B. 10.
___ C. 15.
___ D. 25.

5. Which is an unacceptable percentage of depth for a nick on a tube assembly carrying less than 100 psi?

___ A. 5.
___ B. 10.
___ C. 15.
___ D. 25.

6. What type of material is used in high pressure oxygen systems?

   A. Aluminum tubing.
   B. Copper tubing.
   C. Stainless steel tubing.
   D. High-pressure teflon hose.

7. When installing a tube assembly on an aircraft, you should tighten the fitting nut when the system is at--

   A. 0 psi.
   B. 500 psi.
   C. 750 psi.
   D. 1,000 psi

8. How many types of seals or packing are used in hydraulic systems?

   A. Two.
   B. Three.
   C. Four.
   D. Seven

9. When can seals be reused after they have been removed from service?

   A. After inspection when no defects are found.
   B. When you are told to by higher authority.
   C. In emergencies.
   D. Never.

10. When cutting gaskets from bulk material, how much leeway are you allowed to use between the thickness of the bulk material and the original gasket?

   A. None.
   B. ±2 percent.
   C. ±3 percent.
   D. ±5 percent.

LESSON 2

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	B. Two. The two types of identification code systems are the solid color band system and the tape system. (Page 27)
2.	A. Low pressure. The beaded connection is not constructed to be reliable in high-pressure systems. It should be used only in a system that is designated low pressure. (Page 41)
3.	C. Three. There are three methods of cleaning tubing according to TM 1-1500-204-23-Series: vapor degreasing method, naptha method, and hot inhibited alkaline cleaner method. Always check the technical manual for proper usage. (Page 41)
4.	D. 25. Any dent that exceeds 20 percent of the tube diameter will cause a construction in the tube resulting in a reduction in the fluid traveling through the line. (Page 47)
5.	D. 25. The criteria for tubing carrying less than 100 psi is not as critical. These tubes are usually only return or drain lines. (Page 25)
6.	B. Copper tubing. Copper tubing is used in oxygen systems because it is a nonferrous metal and will not cause any sparks when a wrench is applied to any fittings. (Page 30)
7.	A. 0 psi. You should never tighten a fitting under pressure because the pressure causes resistance which results in an undertorqued condition. (pg 45)
8.	D. Seven. The types of seals or packing are o-rings, backup rings, V-rings, U-rings, cup seals, oil seals, and wiper seals. Each serves a special purpose. (pg 65-66)
9.	D. Never. Seals or gaskets must never be reused after being removed due to the possibility of their being damaged during removal. Once damaged, they cannot serve the original purpose. (pg 64)
10.	A. None. When you cut replacement gaskets from bulk material, the most important consideration is the exact duplication of the thickness of the original gasket due to the close-tolerance machining of the parts. (pg 67)