TECHNICAL MANUAL
No. 1-424

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# AIRCRAFT HARDWARE AND MATERIALS



462576°—42——1

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## SECTION I

## GENERAL



**1. Purpose.**—*a.* The purpose of this manual is to provide aircraft maintenance personnel with general information about the principal materials and hardware used in aircraft construction and repair. The subject matter is not to be construed as supplementing or replacing information contained in specifications or the Air Corps Standards Book. Requirements for various aircraft materials and specific items of hardware must conform to existing specifications when used in the maintenance and repair of aircraft.

*b.* Materials used in aircraft construction are carefully selected for specific properties. Constant research and experimentation have resulted in the successful production and application of lightweight metals which have strength and other qualities necessary to withstand the rigorous treatment to which modern military aircraft are subjected. Likewise, new and improved nonmetallic materials have been produced for use in aircraft. Despite the high degree of development of both material and design, failures occur under certain conditions. Therefore, a knowledge of the correct application and treatment of materials is of value in the inspection and maintenance of aircraft to insure efficient and safe operation.

**2. Definitions.**—An understanding of the following terms is necessary in the study of materials and their use in aircraft construction:

*a. Terms relating to physical characteristics.*—(1) *Hardness.*—Hardness refers to the ability of a material to resist abrasion, penetration, indentation, or cutting action. The wearing qualities of a material are dependent upon its hardness. Hardness and strength are properties which are closely related. Parts such as bearings and stressed shafts must possess hardness to resist wear and strength to sustain loads. Methods of testing materials for hardness are explained in TM 1-423.

(2) *Brittleness.*—Brittleness is the property of a material which permits little bending or deformation without fracture. Brittleness and hardness are closely associated.

(3) *Malleability.*—A metal which can be hammered, rolled, or pressed into various shapes without fracturing or other detrimental effects is said to be malleable. This condition is necessary in sheet metal which is worked into curved shapes such as cowling, fairing, wing tips, etc. Malleability and brittleness are opposite characteristics.

(4) *Ductility.*—Ductility is the property of a material which permits it to be permanently drawn, bent, or twisted into various shapes without fracture. Wire used in control cables and electrical conductors is drawn from ductile material. Ductility is similar to malleability.

(5) *Elasticity.*—Elasticity is that property which enables a material to return to its original shape when the force which causes the change of shape is removed. This property is especially desirable in springs.

(6) *Toughness.*—A material which possesses toughness will withstand tearing or shearing, and may be stretched or otherwise deformed without fracturing. Toughness is a desirable property in aircraft materials, and is the opposite of brittleness.

(7) *Heat conductivity.*—Heat conductivity is the property of a material which determines the rate of transfer of heat within the material. Metals vary in their ability to conduct heat. Aluminum alloy has a relatively high rate of heat conductivity, and therefore is used in cylinder heads of air-cooled engines to dissipate the heat of combustion.

(8) *Tensile strength.*—The tensile strength of a material is its resistance to a force which tends to pull it apart. Tensile strength is measured in pounds per square inch and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

(9) *Compressive strength.*—The compressive strength of a material is its resistance to a crushing force. Compressive strength of a material is measured in pounds per square inch. Landing gear shock absorbers are subjected to compressive forces.

(10) *Shearing strength.*—The resistance offered by a material to a force tending to cause one layer of the material to slide over an adjacent layer is known as its shearing strength. Two riveted plates in tension subject the rivets to a shearing force. Usually the shearing strength of a material is either equal to or less than its tensile or compressive strength.

(11) *Bending strength.*—Bending may be described as the deflection or curving of a member due to forces acting upon it. The bending strength of material is the resistance it offers to deflecting forces.

(12) *Torsional strength.*—Torsion is a twisting force such as would occur in a member fixed at one end and twisted at the other. The torsional strength of material is its resistance to torsion.

(13) *Fatigue resistance.*—(*a*) Fatigue occurs in materials which are subjected to frequent reversals of loading or repeatedly applied loads, if the fatigue limit is reached or exceeded. Repeated vibration or bending will ultimately cause a minute crack to occur at the weakest point of a material. As vibration or bending continues the crack progresses until complete failure of the part results. This is known as fatigue failure and resistance to this condition is known as fatigue resistance.

(*b*) Fatigue failures in aircraft parts may originate from a number of causes dependent upon design or processing. Many instances of failure may be traced to nicks, scratches, corrosion, or other damage to the surface of metals. It is highly important that care be exercised to avoid tool marks or other damage to metals to prevent fatigue failures.

(*c*) Cracks in magnetic material which are not revealed by visual inspection may be detected by the magnaflux inspection method. In this process the material to be inspected is magnetized and covered with iron filings or black oxide of iron suspended in a light petroleum oil. Any crack or break in the surface is made readily visible by the accumulation of filings about it. This method of inspection is explained in TM 1-423.

(14) *Strength-weight ratio.*—The relationship between the strength of a material and its weight per cubic inch expressed as a ratio is known as the strength-weight ratio. This ratio forms the basis of comparing the desirability of various materials for use in aircraft construction. Neither strength nor weight alone can be used as a means of true comparison.

(15) *Work-hardening.*—The hardening of metals by cold working or forming is termed work-hardening. Stainless steel is hardened by cold working and heat treating. Bending or hammering copper tubing produces undesirable work-hardening characteristics. Vibra-

tion also produces undesirable work-hardening effects. These effects may be removed by annealing to lessen the possibility of fracturing.

*b. Terms relating to heat treatment.*—Heat treatment is a process which involves the heating and cooling of a metal (in its solid state) to obtain certain desirable properties. By heat treatment, a hard metal may be made soft, a ductile metal made elastic, or a soft metal made tough and strong. Heat treatment includes the processes of hardening, annealing, tempering, normalizing, and case-hardening. (Details of these processes are given in TM 1-423.)

(1) *Hardening.*—The process of hardening consists of heating a metal slightly above a predetermined temperature called the critical point of the metal, and rapidly cooling by quenching in one of various media depending on the properties desired and the chemical composition of the metal.

(2) *Annealing.*—Annealing is done to induce softness, reduce stresses, alter ductility, or refine the grain structure of metal. It is accomplished by heating a metal above its critical temperature and allowing it to cool slowly.

(3) *Tempering.*—Tempering may be considered a form of annealing done to remove internal strains in metal which develop during the hardening process. It is accomplished by heating the metal to a point below its critical temperature, and cooling in one of various media.

(4) *Normalizing.*—Normalizing relieves internal strains in steel which develop during machining, welding, or forging processes. It consists of heating a metal to a point above its critical temperature and cooling in still air.

(5) *Case-hardening.*—Case-hardening is a combined process of carburizing (heating an iron-base alloy to an elevated temperature in contact with carbonaceous material) and heat treatment, to produce a hard, wear-resisting surface and a soft tough core. Such parts as gears, piston pins, roller bearings, etc., are case-hardened.

## Section II

## FERROUS METALS



**3. General.**—*a.* The term "ferrous" applies to the group of metals having iron as the principal constituent.

*b.* Iron obtained directly from the smelting process contains an excess of carbon and various impurities which render it undesirable for commercial use. After refining, only small amounts of carbon and impurities remain in the iron. This process greatly improves the physical properties of the metal, making it adaptable for industrial use.

*c.* The presence of limited quantities of carbon greatly affects the useful properties of iron. If carbon in percentages ranging up to approximately 1.00 percent is added to iron, the product will be vastly superior to iron in toughness, strength, hardness, etc., and is classified as carbon steel. Numerous types of carbon steels, ranging from mild to very hard, can be produced by heat treating the various metals having carbon contents within this range. Manganese, silicon, sulfur, and phosphorus are also present in steel in small percentages.

*d.* Carbon steel forms the base of the alloy steels which are produced by combining carbon steel with sufficient quantities of certain other elements known to improve the properties of steel. Silicon, manganese, nickel, vanadium, tungsten, molybdenum, and chromium are the common elements used and are known as alloying elements. Each element imparts special properties to the alloy in which it is used. These elements alter the rate and temperature at which internal structural changes take place during the heat treatment, resulting in a finer quality of alloy. Except in rare instances, the superiority of steel alloys over carbon steels is demonstrated only after proper heat treatment. The composition of the principal steels used in aircraft construction is given in table I.

**4. Forms and shapes of steel.**—Steel stock is manufactured in forms of sheets, bars, rods, tubing, extrusions, formings, forgings, and castings.

*a.* Sheet metal is made in a number of sizes and thicknesses. Specifications designate thicknesses in thousandths of an inch. A comparison of sheet metal and wire gages is given in table II.

*b.* Bars and rods are supplied in a variety of cross-sectional shapes, such as round, square, rectangular, hexagonal, and octagonal.

*c.* Tubing can be obtained in round, oval, rectangular, and streamlined cross-sectional shapes. The size of tubing is generally specified by outside diameter and wall thickness.

*d.* Extrusions are produced by forcing metal, under pressure, through dies having the desired cross-sectional shape.

*e.* Formings are manufactured from sheet metal. The sheet metal is usually formed cold in such machines as presses, bending brakes, draw benches, and rolls. Small angles, U-channels, and large curved sections are produced in this manner.

TABLE I.—*Composition of steels used in aircraft construction* [1]

| SAE No. | Composition (approximate percentage) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Carbon | Silicon | Manganese | Phosphorus (maximum) | Sulfur (maximum) | Chromium | Nickel | Molybdenum | Vanadium | Other (maximum) |
| 1025 | 0.20 to 0.30 | | 0.50 to 0.80 | 0.045 | 0.050 | | | | | |
| 1035 | .30 to .40 | 0.15 to 0.35 | .50 to .80 | .045 | .050 | | | | | |
| 1045 | .40 to .50 | .15 to .35 | .50 to .80 | .045 | .050 | | | | | |
| 1095 | .90 to 1.05 | .15 to .35 | .25 to .60 | .040 | .050 | | | | | |
| 2330 | .25 to .35 | .15 to .30 | .50 to .80 | .040 | .050 | | 3.25 to 3.75 | | | |
| X-4130 | .25 to .35 | 15 to .30 | .50 to .80 | .040 | .050 | 0.80 to 1.10 | | 0.15 to 0.25 | | |
| X-4135 | .32 to .39 | | .40 to .60 | .040 | .045 | .80 to 1.10 | | .15 to .25 | | |
| 4140 | .35 to .45 | .15 to .30 | .60 to .90 | .040 | .050 | .80 to 1.10 | | .15 to .25 | | |
| 3140 | .35 to .45 | .15 to .30 | .60 to .90 | .040 | .050 | .45 to .75 | 1.00 to 1.50 | | | |
| 3250 | .45 to .55 | .15 to .30 | .30 to .60 | .040 | .050 | .90 to 1.25 | 1.50 to 2.00 | | | |
| X-4340 | .35 to .42 | | .60 to .90 | .025 | .025 | .60 to .90 | 1.65 to 2.00 | .20 to .30 | | |
| 4615 | .10 to .20 | | .40 to .70 | .040 | .050 | | 1.65 to 2.00 | .20 to .30 | | |
| 6135 | .30 to .40 | .15 to .30 | .50 to .80 | .040 | .045 | .80 to 1.10 | | | 0.15 to 0.20 | |
| 6150 | .45 to .55 | .15 to .30 | .60 to .90 | .040 | .045 | .80 to 1.10 | | | .15 to .20 | |
| 6195 | .90 to 1.05 | .15 to .30 | .20 to .45 | .030 | .035 | .80 to 1.10 | | | .15 to .20 | |
| 51235 | .30 to .40 | .50 (max.) | .50 (max.) | .035 | .035 | 11.5 to 14.0 | | | | Al. 0.95 to 1.35 |

[1] Compiled from War Department specification.

*f*. Forgings are shaped or formed by pressing or hammering heated metal in dies. The forging process compresses the metal and increases the hardness.

*g*. Castings are produced by pouring molten metal into molds. The casting is finished by machining.

**5. Methods of identifying steel stock.**—*a*. A numerical index system devised by the Society of Automotive Engineers (SAE) identifies the composition of SAE steels. Each SAE number consists of a group of digits, the first of which represents the type of steel; the second, the percentage of the principal alloying element; and usually the last two or three digits, the percentage (in hundredths of one percent) of carbon in the alloy.

(1) The common SAE symbols used in the identification of steels are as follows:

| Type of steel: | *Classification* |
|---|---|
| Carbon | 1xxx |
| Nickel | 2xxx |
| Nickel-chromium | 3xxx |
| Molybdenum | 4xxx |
| Chromium | 5xxx |
| Chromium-vanadium | 6xxx |
| Tungsten | 7xxx |
| Silicon-manganese | 9xxx |

(2) Examples of the application of SAE numbers are as follows:

(*a*) The SAE number 4150 indicates a molybdenum steel containing 1 percent molybdenum and 0.50 percent carbon.

(*b*) The SAE number 1010 denotes a carbon steel containing 0.10 percent carbon. The first 0 indicates the lack of a principal alloying element, and hence a plain carbon steel.

(*c*) The percentages indicated in the SAE number are average; for example, the carbon content of SAE 1050 steel may vary from 0.45 to 0.55 percent and is indicated as 0.50 percent.

*b*. In order to provide a visual means of identification for steel tubes, bars, and sheets stocked by the Army Air Forces, such material is marked with an identifying color code. The identification marking consists of colored stripes as follows:

Three sets of stripes, one in the middle and one near each end, are painted around each bar and tube and across one face of each sheet. Each set of stripes consists of two parallel stripes, the one a broad stripe approximately 5 inches wide, and the other a narrow stripe approximately 2 inches wide. When the broad or narrow stripe consists of two colors, one-half the width of the stripe is used for each color. The 2-inch stripe represents the last two digits of the steel number. The 5-inch stripe represents the preceding digits of the steel number. Table III lists the combinations of colors used to identify the various steels.

**6. Aircraft steels and their uses.**—*a. Carbon steels.*—(1) Steel containing carbon in percentages ranging from 0.10 to 0.30 percent is classed as low carbon steel. The equivalent SAE numbers range from 1010 to 1030. Steels of this grade are used for the manufacture of articles such as safety wire, certain nuts, cable bushings, and threaded rod ends. This steel in sheet form is used for secondary structural parts and clamps and in tubular form for moderately stressed structural parts.

(2) Steel containing carbon in percentages ranging from 0.30 to 0.50 percent is classed as medium carbon steel. This steel is especially adaptable for machining, forging, and where surface hardness is important. Certain rod ends, light forgings, and parts such as Woodruff keys are made from SAE 1035 steel.

(3) Steel containing carbon in percentages ranging from 0.50 to 1.05 percent is classed as high carbon steel. The addition of other elements in varying quantities adds to the hardness of this steel. In the fully heat-treated condition it is very hard and will withstand high shear and wear but little deformation. It has limited use in aircraft construction. SAE 1095 in sheet form is used for making flat springs and in wire form for making coil springs.

*b. Nickel steels.*—The various nickel steels are produced by combining nickel with carbon steel. Steels containing from 3 to 3.75 percent nickel are commonly used. Nickel increases the hardness, tensile strength, and elastic limit of steel without appreciably decreasing the ductility. It also intensifies the hardening effect of heat treatment. SAE 2330 steel is used extensively for aircraft parts such as bolts, terminals, keys, clevises, and pins.

*c. Chromium steels.*—Chromium steel is high in hardness, strength, and corrosion-resistant properties. SAE 51235 steel is particularly adaptable for heat-treated forgings which require greater toughness and strength than may be obtained in plain carbon steel. It may be used for such articles as the balls and rollers of antifriction bearings.

*d. Chrome-nickel steels.*—(1) Chromium and nickel in various proportions mixed with steel form the chrome-nickel steels. The general proportion is about two and one-half times as much nickel as chromium. For all ordinary steels in this group the chromium content ranges from 0.45 to 1.25 percent, while the nickel content ranges from 1 to 2 percent. Both nickel and chromium influence the properties of steel; nickel toughens it, while chromium hardens it. Chrome-nickel steel is used for machined and forged parts requiring strength, ductility, toughness, and shock resistance. Parts such as crankshafts, connecting rods, etc., are made of SAE 3140 steel.

(2) Chrome-nickel steel containing approximately 18 percent chromium and 8 percent nickel is known as corrosion-resistant steel. In plate and sheet form it is used extensively in the fabrication of engine exhaust stacks, collector rings, and manifolds.

*e. Chrome-vanadium steels.*—The vanadium content of this steel is approximately 0.18 percent and the chromium content approximately 1.00 percent. Chrome-vanadium steels when heat-treated have excellent properties such as strength, toughness, and resistance to wear and fatigue. A special grade of this steel in sheet form can be cold-formed into intricate shapes. It can be folded and flattened without signs of breaking or failure. Chrome-vanadium steel with medium high carbon content (SAE 6150) is used to make springs. Chrome-vanadium steel with high carbon content (SAE 6195) is used for ball and roller bearings.

*f. Chrome-molybdenum steels.*—Molybdenum in small percentages is used in combination with chromium to form chrome-molybdenum steel; this steel has important applications in aircraft. Molybdenum is a strong alloying element, only 0.15 to 0.25 percent being used in the chrome-molybdenum steels; the chromium content varies from 0.80 to 1.10 percent. Molybdenum raises the ultimate strength of steel without affecting ductility or workability. Molybdenum steels are tough, wear resistant, and harden throughout from heat treatment. They are especially adaptable for welding and for this reason are used principally for welded structural parts and assemblies. Tubing made from X-4130 steel is used for structural parts such as welded fuselages, engine mounts, and landing gear structures.

TABLE II.—*Comparison of sheet metal and wire gages* [1]

| Gage No. | Decimal equivalents of gage numbers | | | | |
|---|---|---|---|---|---|
| | AWG [2] | NW [3] | MW [4] | US [5] | BW [6] |
| 000000 (6-0) | 0.5800 | 0.4615 | 0.004 | 0.4688 | |
| 00000 (5-0) | .5165 | .4305 | .005 | .4375 | 0.500 |
| 0000 (4-0) | .4600 | .3938 | .006 | .4063 | .454 |
| 000 (3-0) | .4096 | .3625 | .007 | .3750 | .425 |
| 00 (2-0) | .3648 | .3310 | .008 | .3438 | .380 |
| 0 (1-0) | .3249 | .3065 | .009 | .3125 | .340 |

[1] Compiled from A. C. Technical Order 23-1-3.

[2] Brown & Sharp and American Standard Wire. Applied to: Nonferrous wire and sheet aluminum, aluminum alloy, copper and brass rod.

[3] National Wire, Roebling, Washburn & Moen, American Steel & Wire, and U. S. Steel Wire. Applied to: All bare, galvanized, and annealed steel wire, all tinned steel wire, and corrosion-resisting steel.

[4] Music Wire. Applied to: Spring wire (piano wire).

[5] United States Standard. Applied to: All commercial planished, galvanized, tinned, and terne plate of iron and steel, sheet steel.

[6] Birmingham Wire, Stubs Iron Wire. Applied to: All tubing, sheet spring steel.

TABLE II.—*Comparison of sheet metal and wire gages*—Continued

| Gage No. | Decimal equivalents of gage numbers | | | | |
|---|---|---|---|---|---|
| | AWG | NW | MW | US | BW |
| 1 | .2893 | .2830 | .010 | .2813 | .300 |
| 2 | .2576 | .2625 | .011 | .2656 | .284 |
| 3 | .2294 | .2437 | .012 | .2500 | .259 |
| 4 | .2043 | .2253 | .013 | .2344 | .238 |
| 5 | .1819 | .2070 | .014 | .2188 | .220 |
| 6 | .1620 | .1920 | .016 | .2031 | .203 |
| 7 | .1443 | .1770 | .018 | .1875 | .180 |
| 8 | .1285 | .1620 | .020 | .1719 | .165 |
| 9 | .1144 | .1483 | .022 | .1563 | .148 |
| 10 | .1019 | .1350 | .024 | .1406 | .134 |
| 11 | .0907 | .1205 | .026 | .1250 | .120 |
| 12 | .0808 | .1055 | .029 | .1094 | .109 |
| 13 | .0720 | .0915 | .031 | .0938 | .095 |
| 14 | .0641 | .0800 | .033 | .0781 | .083 |
| 15 | .0571 | .0720 | .035 | .0703 | .072 |
| 16 | .0508 | .0625 | .037 | .0625 | .065 |
| 17 | .0453 | .0540 | .039 | .0563 | .058 |
| 18 | .0403 | .0475 | .041 | .0500 | .049 |
| 19 | .0359 | .0410 | .043 | .0438 | .042 |
| 20 | .0320 | .0348 | .045 | .0375 | .035 |
| 21 | .0285 | .0317 | .047 | .0344 | .032 |
| 22 | .0253 | .0286 | .049 | .0313 | .028 |
| 23 | .0226 | .0258 | .051 | .0281 | .025 |
| 24 | .0201 | .0230 | .055 | .0250 | .022 |
| 25 | .0179 | .0204 | .059 | .0219 | .020 |
| 26 | .0159 | .0181 | .063 | .0188 | .018 |
| 27 | .0142 | .0173 | .067 | .0172 | .016 |
| 28 | .0126 | .0162 | .071 | .0156 | .014 |
| 29 | .0113 | .0150 | .075 | .0141 | .013 |
| 30 | .0100 | .0140 | .080 | .0125 | .012 |
| 31 | .0089 | .0132 | .085 | .0109 | .010 |
| 32 | .0080 | .0128 | .090 | .0102 | .009 |
| 33 | .0071 | .0118 | .095 | .0094 | .008 |
| 34 | .0063 | .0104 | .100 | .0086 | .007 |
| 35 | .0056 | .0095 | .106 | .0078 | .005 |
| 36 | .0050 | .0090 | .112 | .0070 | .004 |
| 37 | .0045 | .0085 | .118 | .0066 | |
| 38 | .0040 | .0080 | .124 | .0063 | |
| 39 | .0035 | .0075 | .130 | | |
| 40 | .0031 | .0070 | .138 | | |

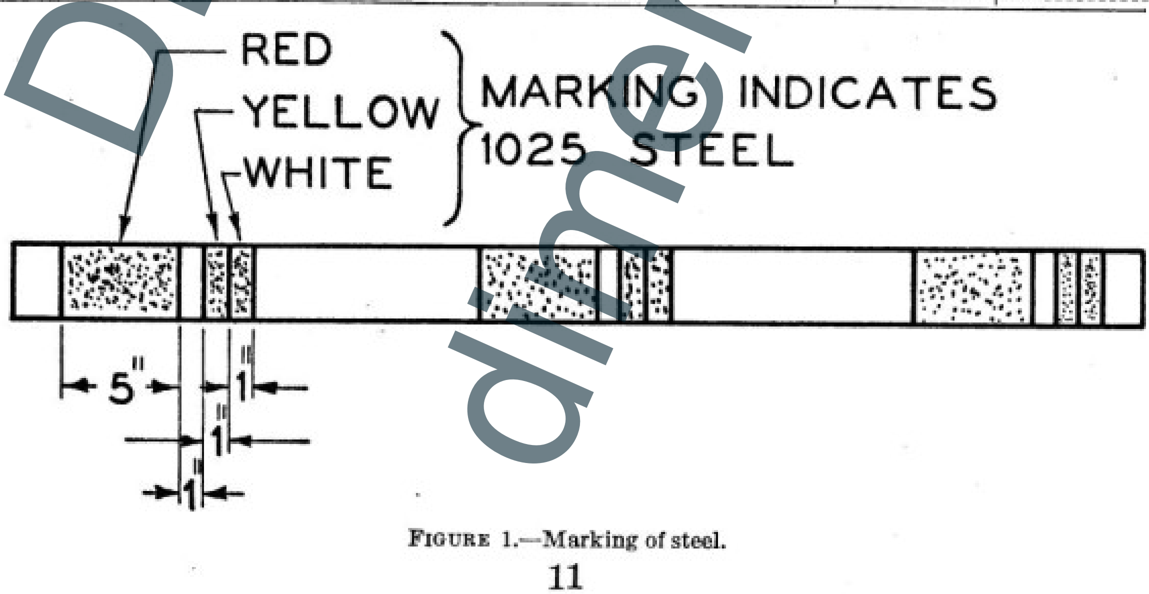


FIGURE 1.—Marking of steel.

the line assembled to the fitting. The fitting is finally secured in place by tightening the lock nut against the boss. The union (fig. 13 ①) requires no positioning and is assembled by placing the gasket in the groove and tightening the fitting against the boss. Universal fittings

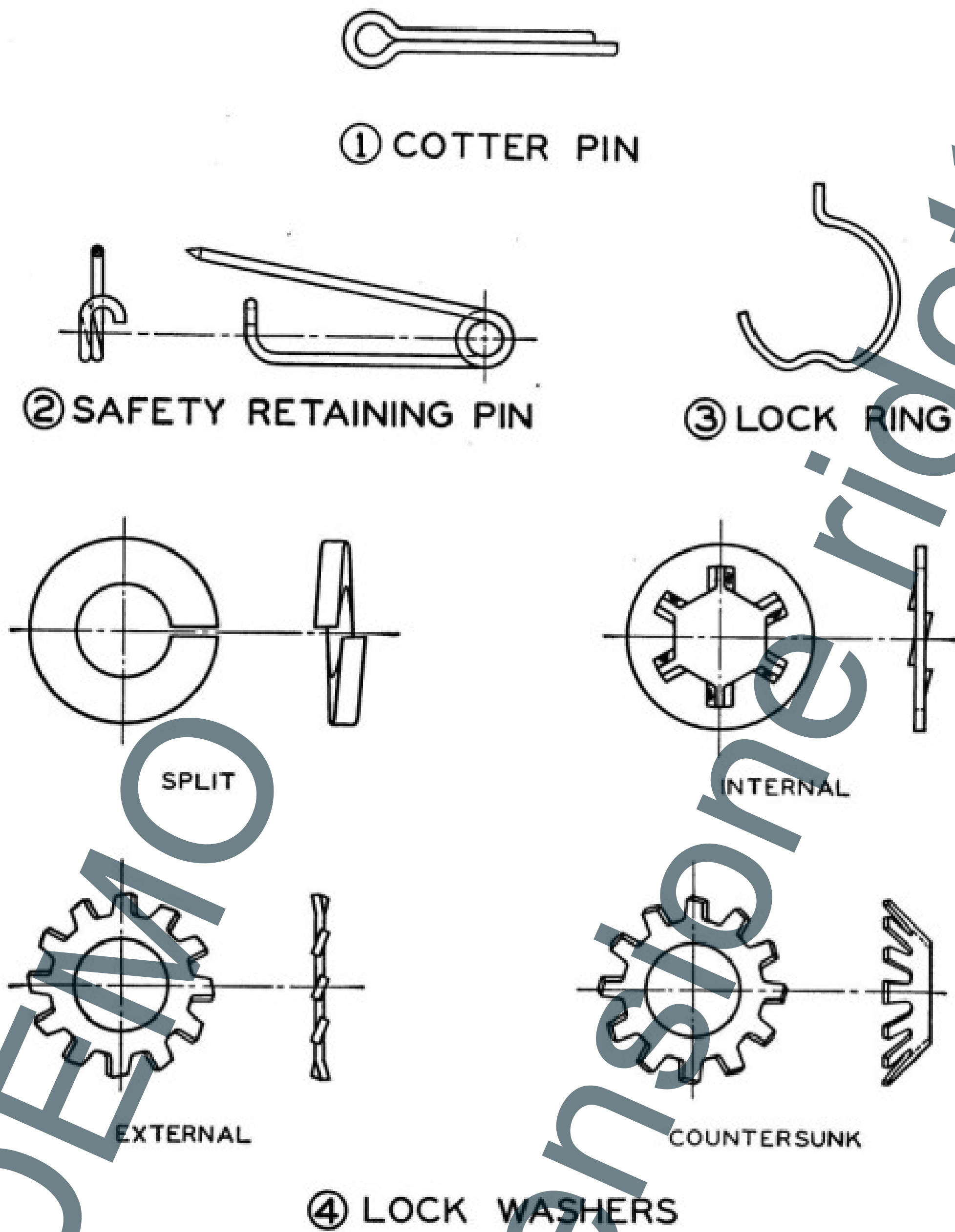


FIGURE 11.—Safety devices.

are made of aluminum alloy or steel. The nut is made of steel or aluminum alloy and the gasket is of oil-resistant synthetic compound.

(3) The swivel type fitting, figure 14, can also be positioned. Swivel type and universal type complete assembles may be used interchangeably. Swivel type fittings are made of aluminum alloy or steel. The gasket is of copper or aluminum.

fewer than three threads remain exposed, the clamp should be removed and the bolt inserted in another hole which will permit proper tightening. Figure 18 ③ illustrates a hose connection with thumbscrew type clamp.

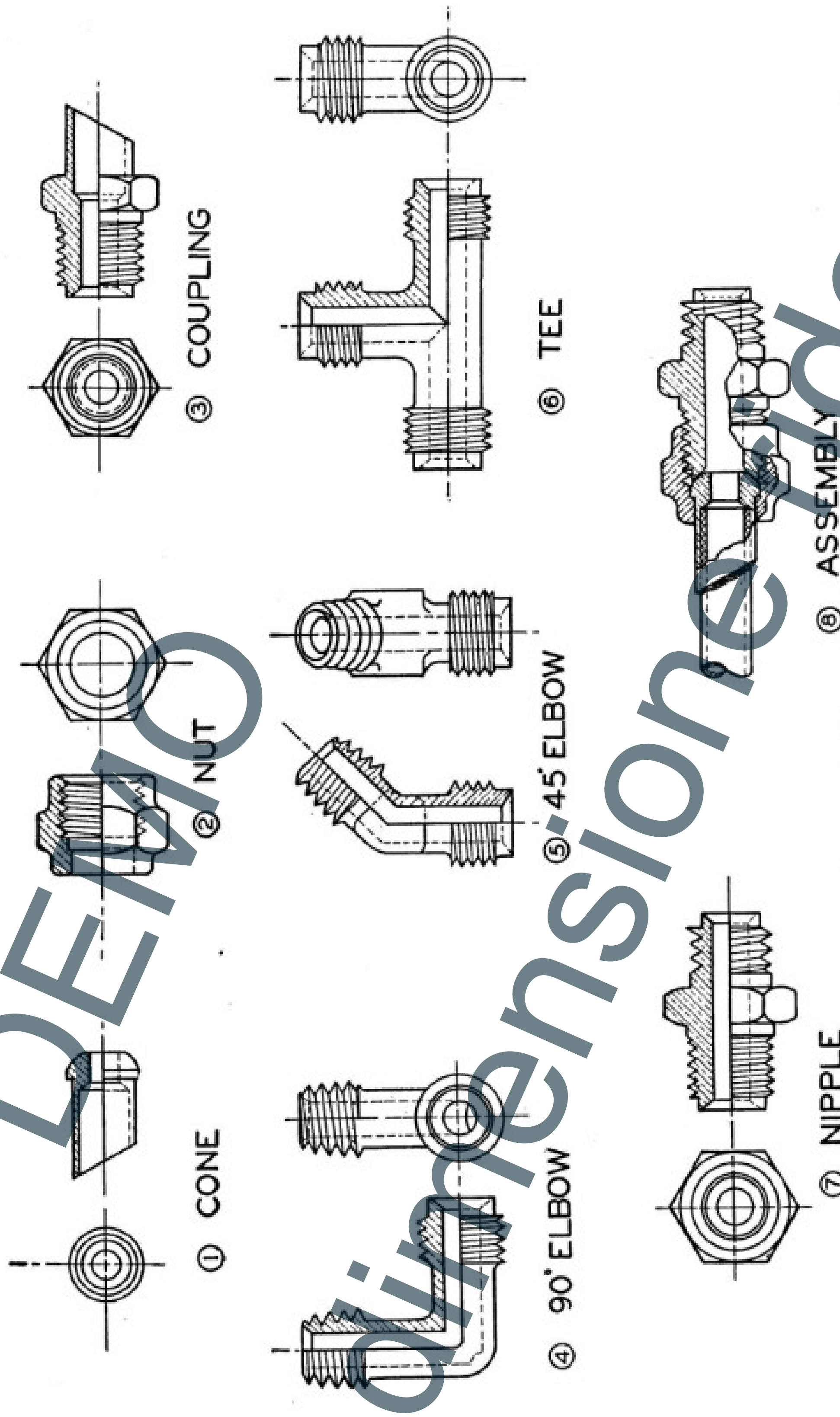


FIGURE 15.—Cone union fittings.

*e.* The pipe flange (fig. 16 ③) is supplied with pipe or straight threads and affords a means of connecting tubing or a pipe fitting to a tank. The flange is riveted or welded to the tank.

*f.* Tube clips (fig. 17 ① and ②) made of aluminum alloy are used to support tubing or conduit and prevent excessive vibration of these

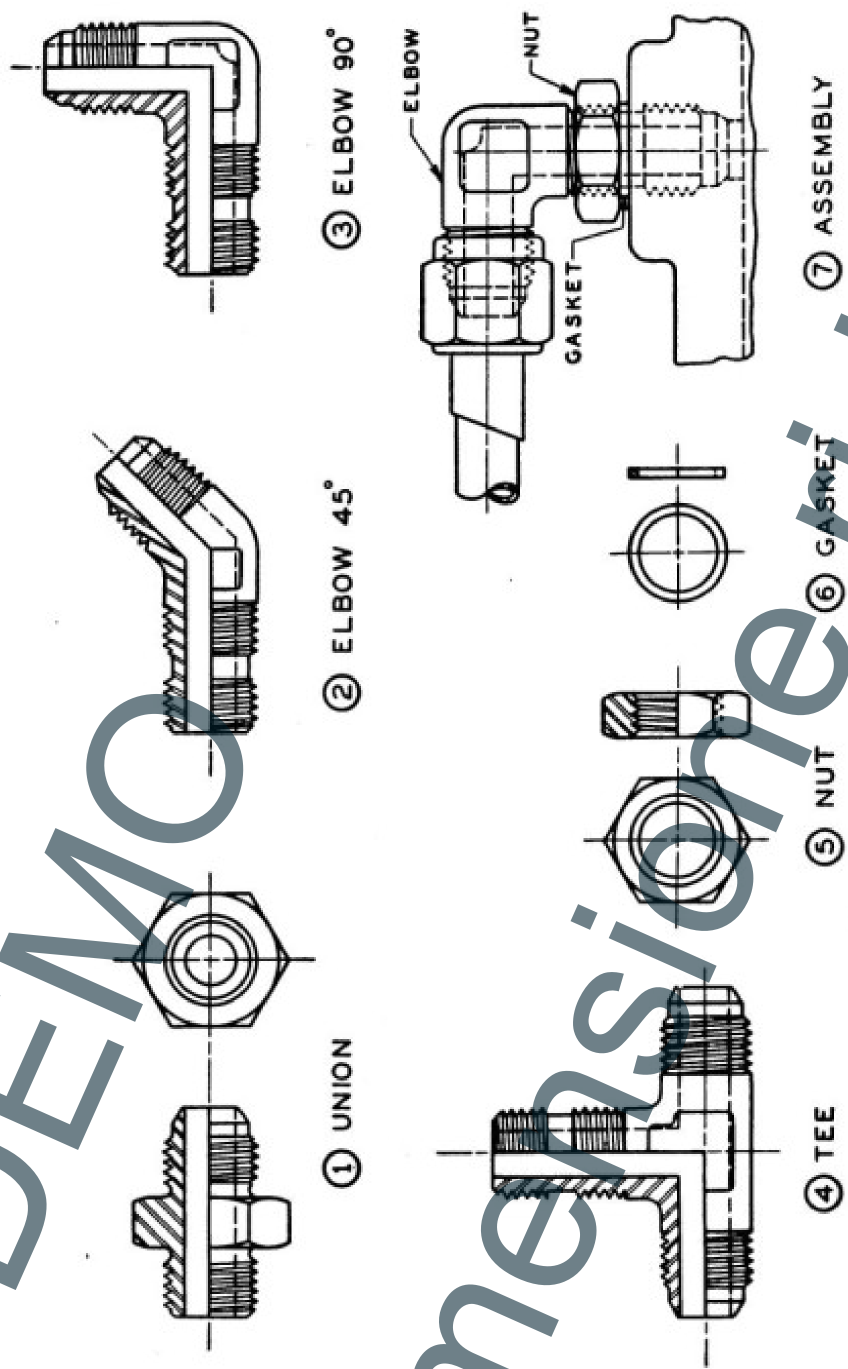


FIGURE 13.—Universal type fittings.

lines during flight. A rubber bushing is installed between the pipe and the clip to protect the pipe. Typical applications of the clips are shown in fig. 17 ③.

*g.* (1) Wherever there is relative motion between two points connected by piping, a flexible hose connection is used at each point.

Flexible synthetic hose connections have application in fuel, oil, and cooling systems. Tube ends on which flexible connections are to be placed are beaded to prevent the hose from slipping.

(2) Hose connections should have a minimum length of one-quarter inch exposed to liquid flow in order to provide flexibility, and a maximum exposed length of one hose diameter if the system is under suction.

*h.* Hose nipples are available with pipe thread or straight thread as shown in figure 18 ①. The straight thread nipple is used for connec-

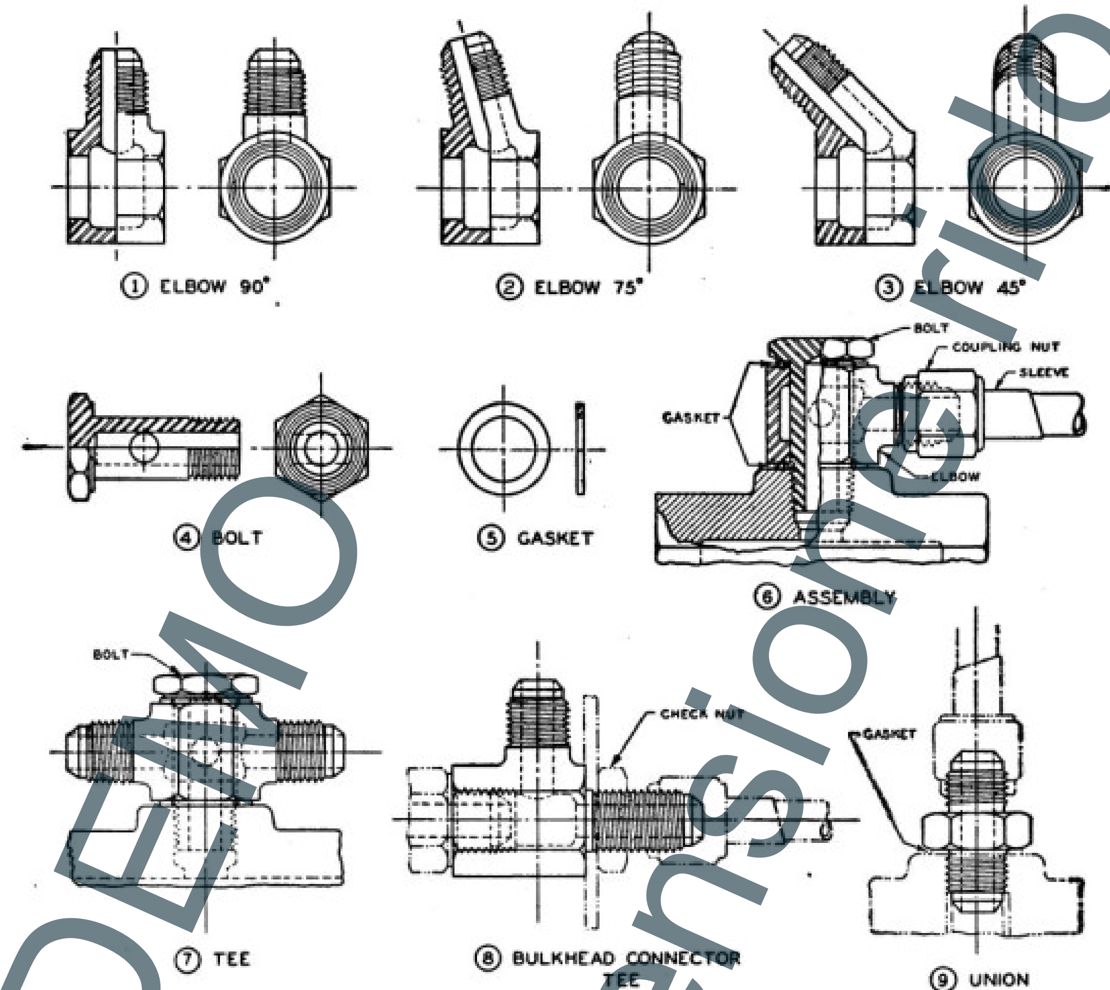


FIGURE 14.—Swivel type fittings.

tion to a flared tube fitting. A shoulder is provided on the nipple end to prevent the hose from working off. The round-shouldered nipple is intended for use with either one or two hose clamps, depending upon the length of end. The high bead nipple is replacing the round-shouldered type and one clamp is being used instead of two.

*i.* (1) Two types of hose clamps commonly used on aircraft are illustrated in figure 18 ②. After adjustment, not less than three threads should remain exposed on the bolt of the wing nut type clamp. If fewer than three threads remain exposed, the clamp should be removed and the bolt inserted in another hole which will permit proper tightening. Figure 18 ③ illustrates a hose connection with thumbscrew type clamp.

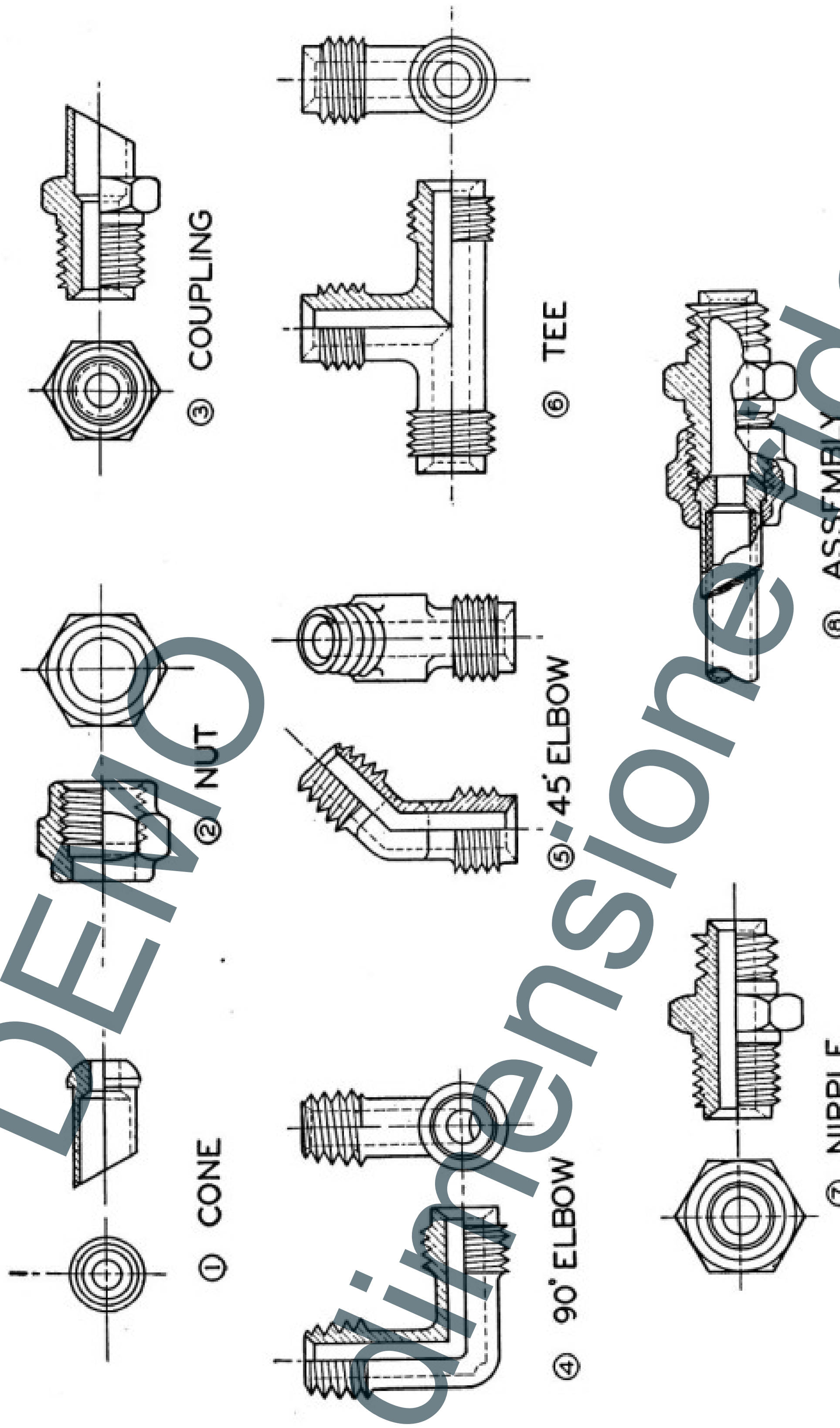


FIGURE 15.—Cone union fittings.

(2) Hose clamps should provide effective bearing on the complete circumference of the hose under the clamp. The adjusting screw should be of the thumbscrew type and should require no special tools

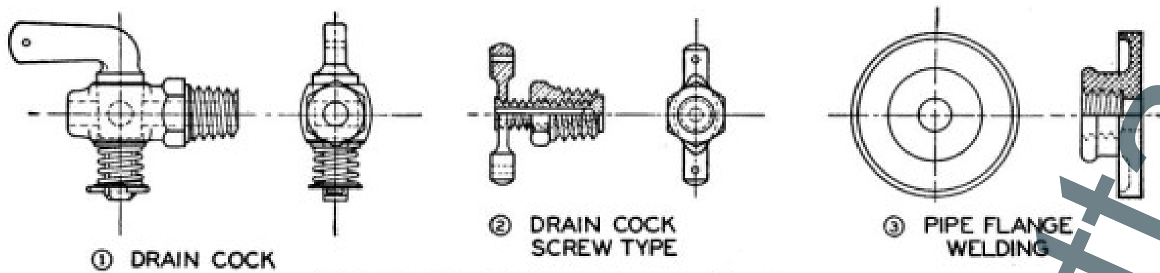


FIGURE 16.—Drain cocks and pipe flange.

for tightening the clamp. The thumb grip should be provided with a hole for safetying with wire.

*j.* The hose assembly (fig. 18 ④) is a complete unit with the connectors attached. It is used for connections to units requiring free

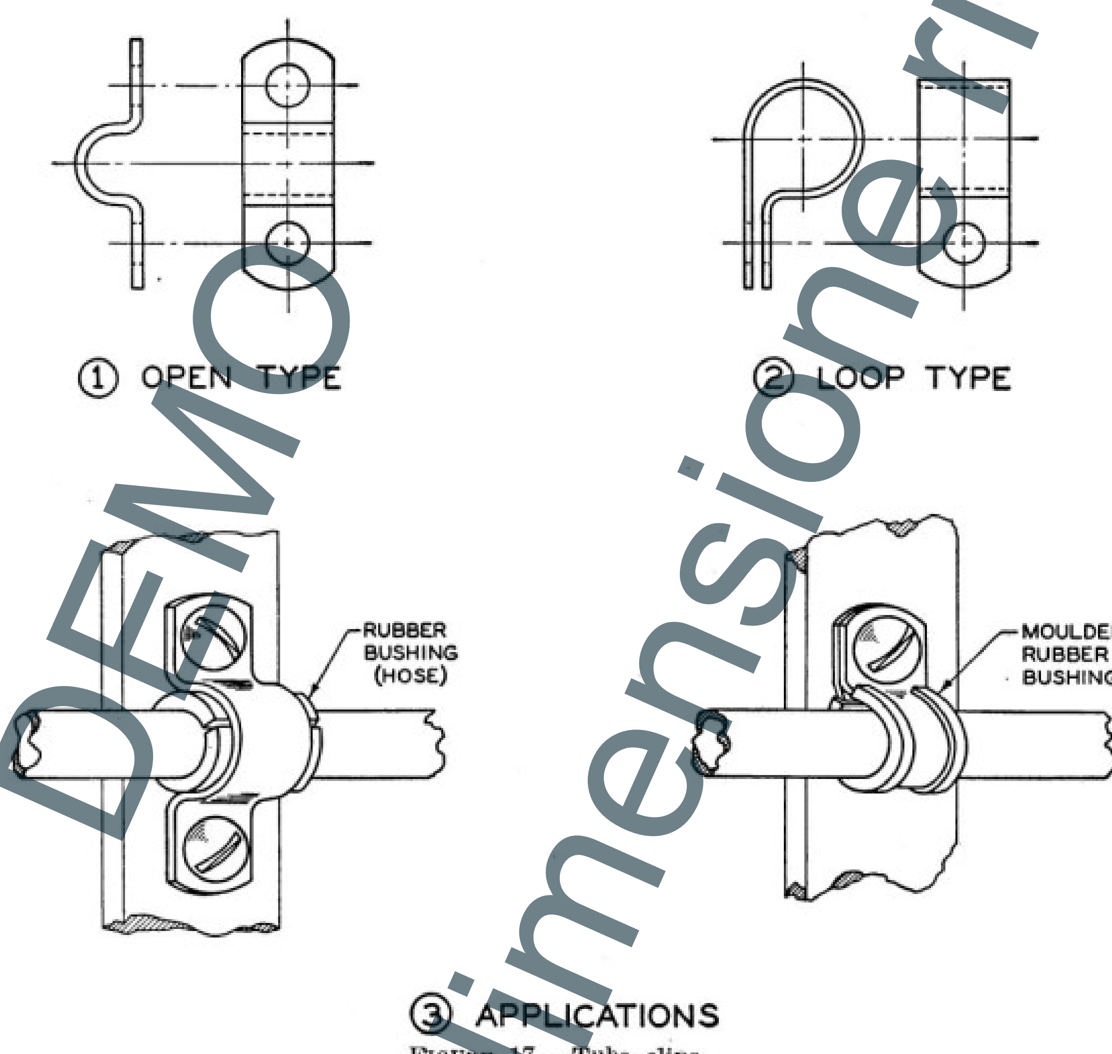


FIGURE 17.—Tube clips.

movement, such as actuating cylinders in hydraulic systems. The maximum operating pressure of hose should be one-fifth the design burst pressure.

**38. Rods and fittings.**—*a.* Rods used in aircraft may be classified generally either as tie rods or control rods.

(1) Tie rods (fig. 19 ①) are made of high strength steel and are used for bracing purposes. The streamlined tie rod is used for external

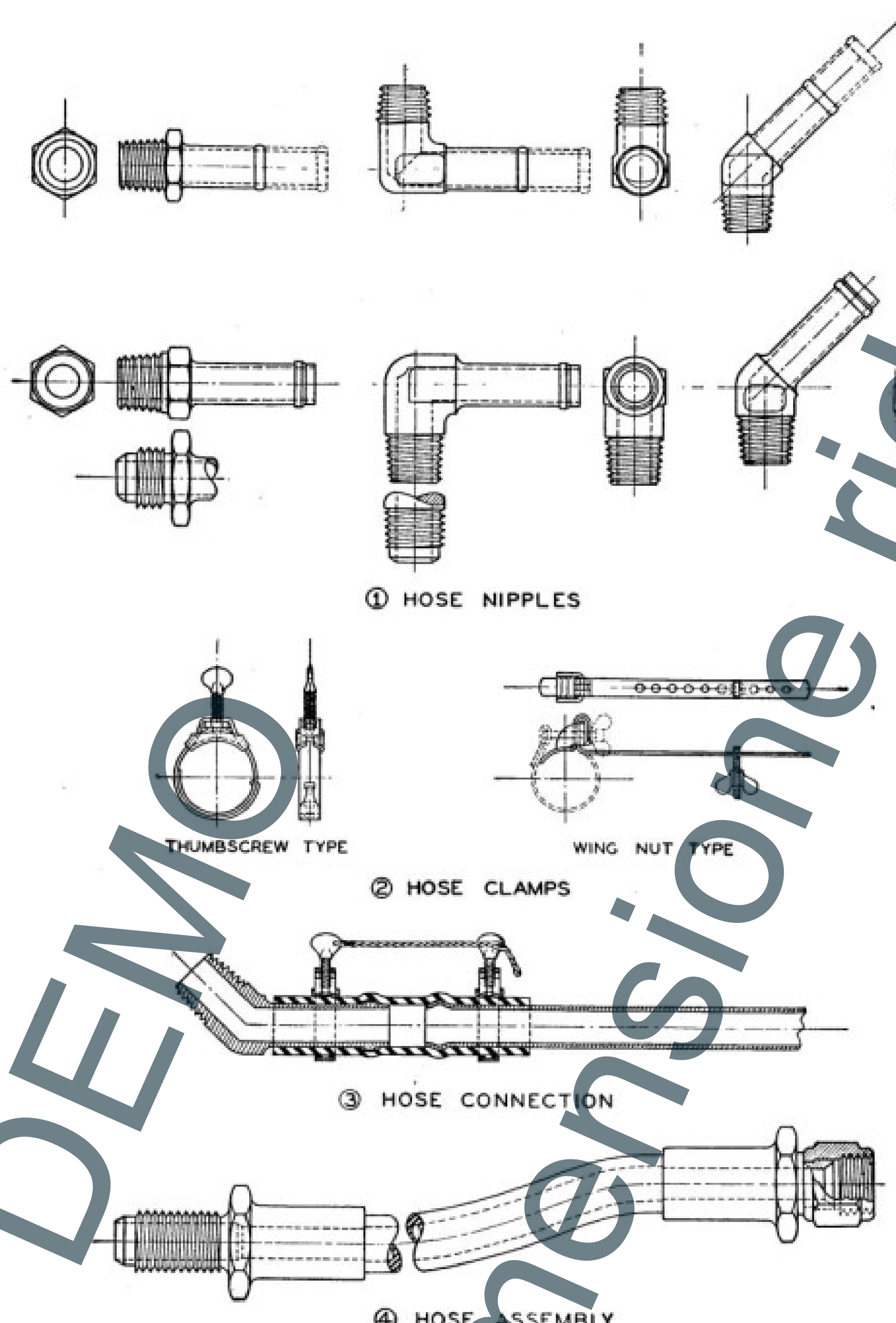


FIGURE 18.—Hose connections and fittings.

applications, whereas the round and square types are used internally. The ends of a tie rod are oppositely threaded, and adjustment of tension is accomplished by turning the rod. The circular tie rod is provided with "flats" near each end to accommodate a wrench.

(2) Control rods are used extensively in the various engine control arrangements (throttle, mixture, carburetor air heat, cowling, shutter, etc.). Such rods are usually tubular steel.

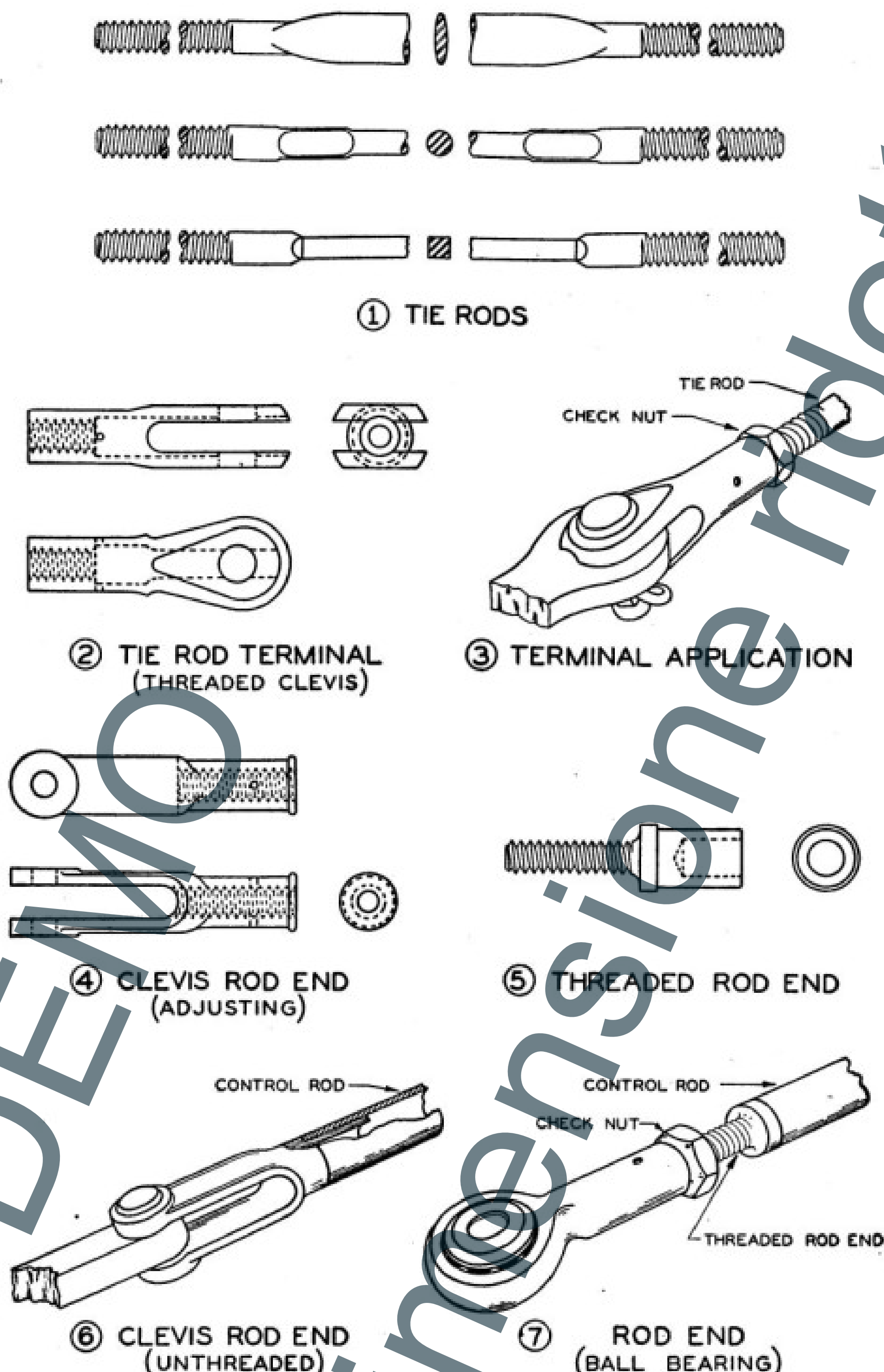


FIGURE 19.—Rods and rod ends.

*b.* (1) The terminal or end used in conjunction with a tie rod is a threaded clevis shown in figure 19 ②. Such terminals are available with right- or left-hand threads to correspond with the threads on the tie rod. A small inspection hole in the terminal, just beyond the thread limit, is used to determine whether the rod is threaded into the terminal for a safe distance; if the rod end does not extend beyond this hole, a longer rod should be used. The application of the terminal is shown in figure 19 ③.

(2) Various rod ends are used in conjunction with control rods for attachment to a crank arm, lever, etc.

(*a*) The threaded clevis end (fig. 19 ④) is adjustable and is also provided with an inspection hole. The type of end is adapted to a tubular control rod by use of a threaded rod end (fig. 19 ⑤).

(*b*) The unthreaded clevis end (fig. 19 ⑥) is used with tubular control rods and is attached directly to the rod.

(*c*) The ball bearing rod end (fig. 19 ⑦) has extensive application, and is particularly adaptable where the control rod tends to twist during its movement. This type of rod end is also adapted to the control rod by use of a threaded rod end, and is provided with an inspection hole.

(*d*) The universal joint (fig. 20) is used to transmit rotational movement between control rods or between a control rod and a mechanism, where the axes of the rotating members are at an angle to each other. The universal joint may be used in fuel cock, engine, armament and flap controls, and landing gear retracting mechanisms, etc. The joint is available in light and heavy duty types. The working parts of the heavy duty type are enclosed within a flexible cover to exclude dust and dirt and retain lubricant.

**39. Pins.**—*a*. The flat head pin (fig. 21 ①), commonly called clevis pin, is made of steel and is used in conjunction with a tie rod terminal (fig. 19 ③). It may also be used in secondary controls which are not subjected to continuous operation and where the chances of becoming loose are negligible. The pin should be safetied with a cotter pin. The pin should be installed with the head up so that in the event the cotter pin should fail, or work out, the pin will tend to remain in place.

*b*. Taper pins are made of steel and are used in connections which are seldom broken and where the absence of play is essential.

(1) The plain taper pin and its applications with a universal joint is shown in figure 21 ② and ③. The plain taper pin is drilled, and safetied with wire.

(2) The threaded taper pin and its application with sprocket on a trim tab control is shown in figure 21 ④ and ⑤. The threaded taper pin is used with a taper pin washer and shear nut (safetied with cotter pin) or self-lock nut.

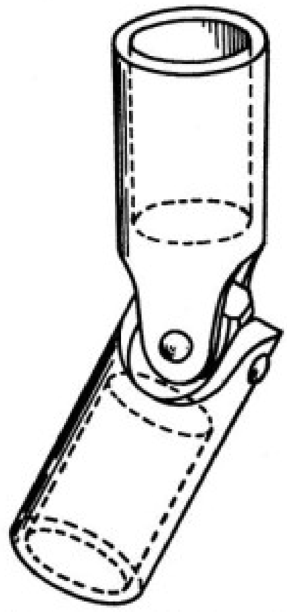

FIGURE 20.—Universal joint.

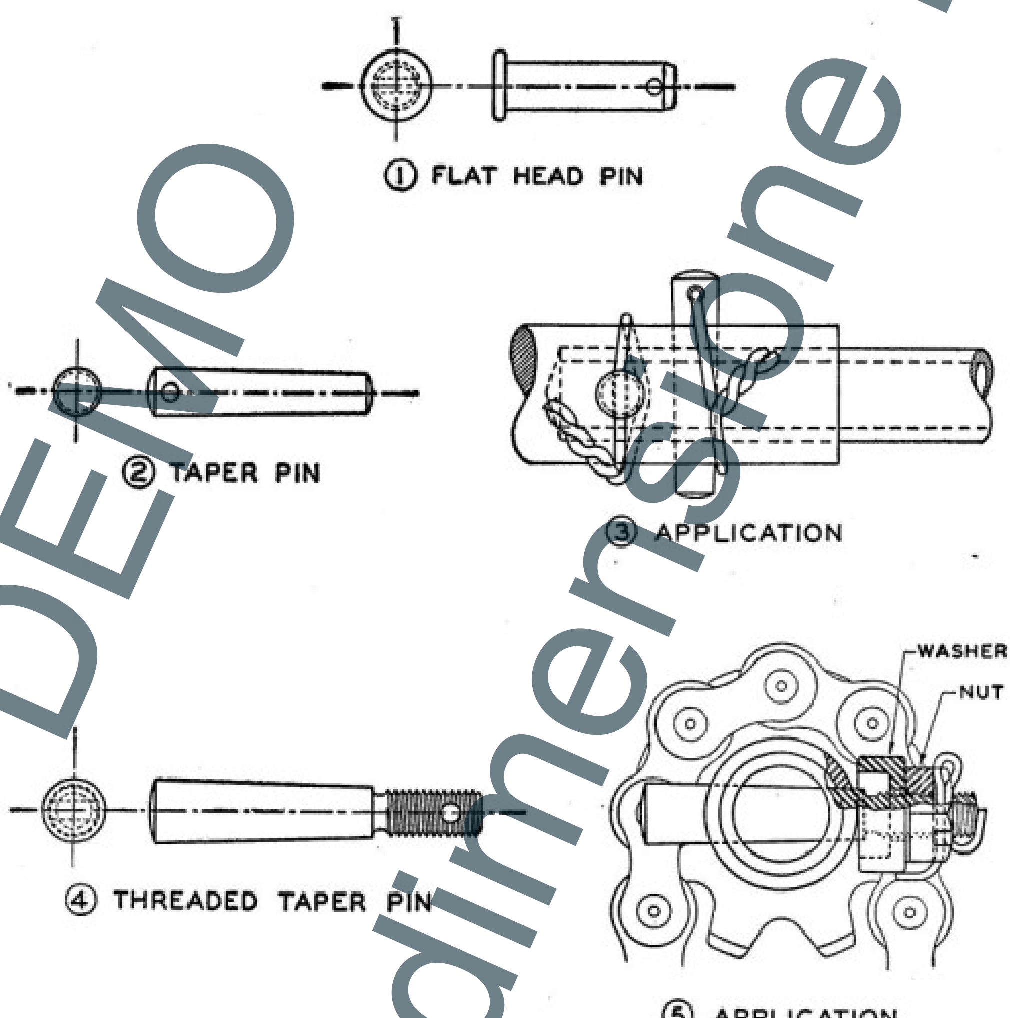


FIGURE 21.—Pins.

**40. Wiring equipment.**—*a.* (1) In aircraft, conduit serves to protect electrical conductors and to prevent radio interference by acting as an electrostatic shield.

(*a*) Rigid conduit (fig. 22 ①) is made of aluminum alloy and is used for installations of a relatively permanent nature. Rigid conduit is securely attached to aircraft structural members and is used extensively to encase wiring in the fuselage and wing sections.

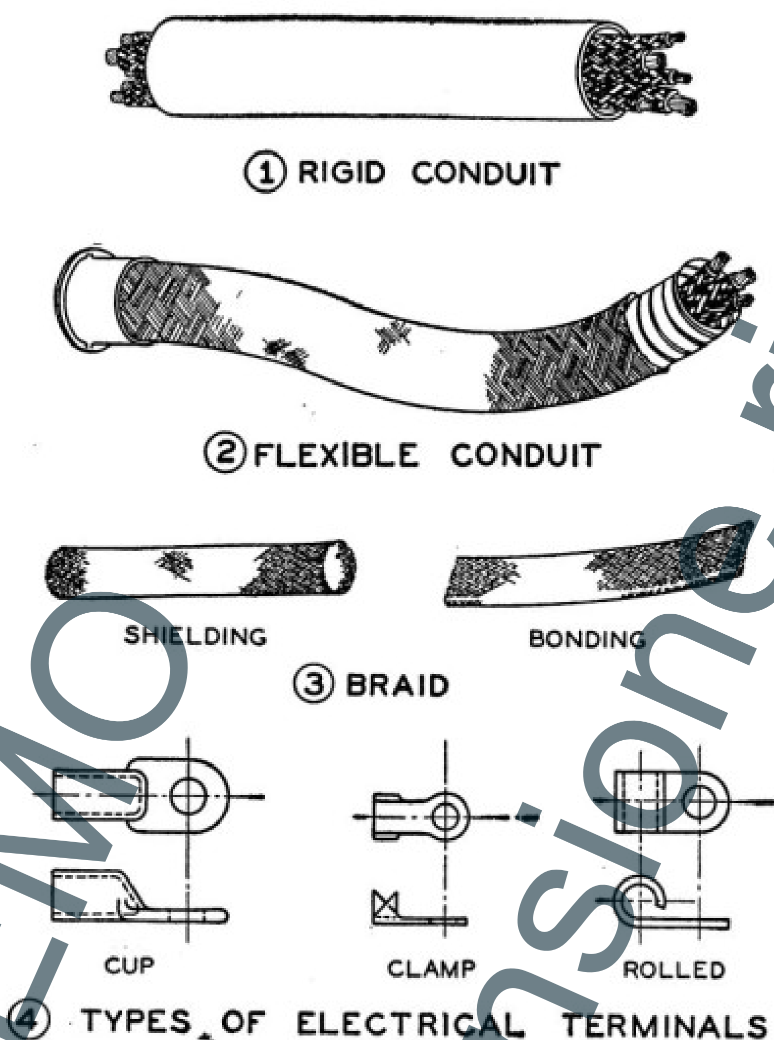


FIGURE 22.—Wiring equipment.

(*b*) Flexible conduit (fig. 22 ②) consists usually of a flexible aluminum tube of interlocking construction, covered with wire braid (shielding braid) to improve its shielding properties. Flexible conduit is little affected by vibration, and consequently is used where vibration is a factor. Flexible conduit is also easily removed and installed and is therefore used where periodic disconnection is required.

(2) Installation of conduit involves the use of conduit fittings. Types of conduit fittings and manner of assembly are shown in figures 23 and 24.

*b.* Tinned copper braid (fig. 22③) is used for both shielding and bonding purposes, except where flexible aluminum conduit is used; in this case, aluminum braid is used. Braid which is used to interconnect electrically isolated metallic parts of the aircraft is known as bonding braid.

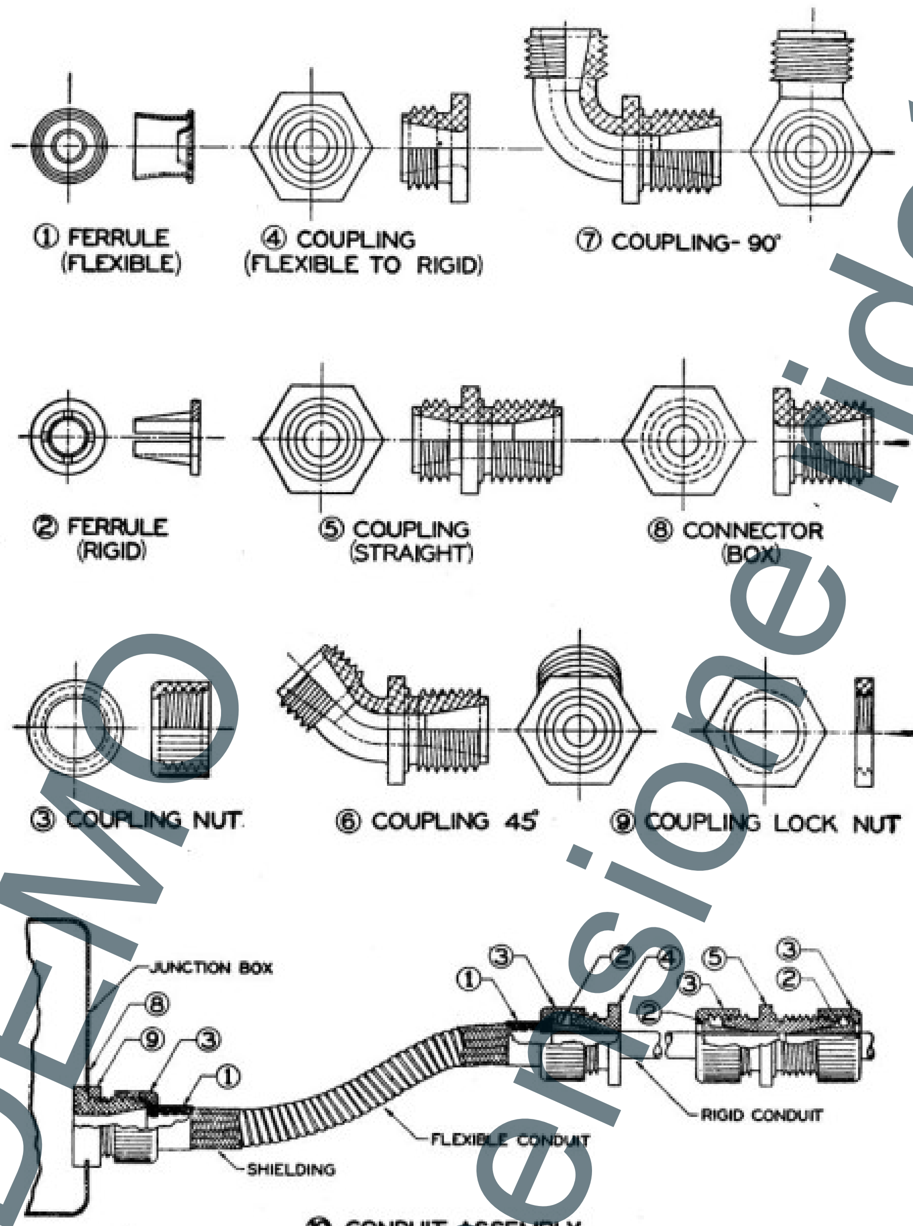


FIGURE 23.—Conduit fittings.

*c.* In figure 22 ④ are shown three types of terminals (copper soldering lugs) used on aircraft as a convenient means of connecting wiring to electrical equipment. The cup type is used on cables larger than No. 16 American wire gage, and is available in capacities ranging from 25 to 325 amperes. The clamp type is used for cables No. 16 and smaller. The rolled type is generally used on cables larger than No. 16, and is available in capacities ranging from 15 to 125 amperes.

**41. Miscellaneous equipment.**—*a. Grommets.*—Celluloid grommets (fig. 25 ①) are employed to drain fabric-covered airfoils, such as wings, ailerons, and elevators. Grommets are located on the un-

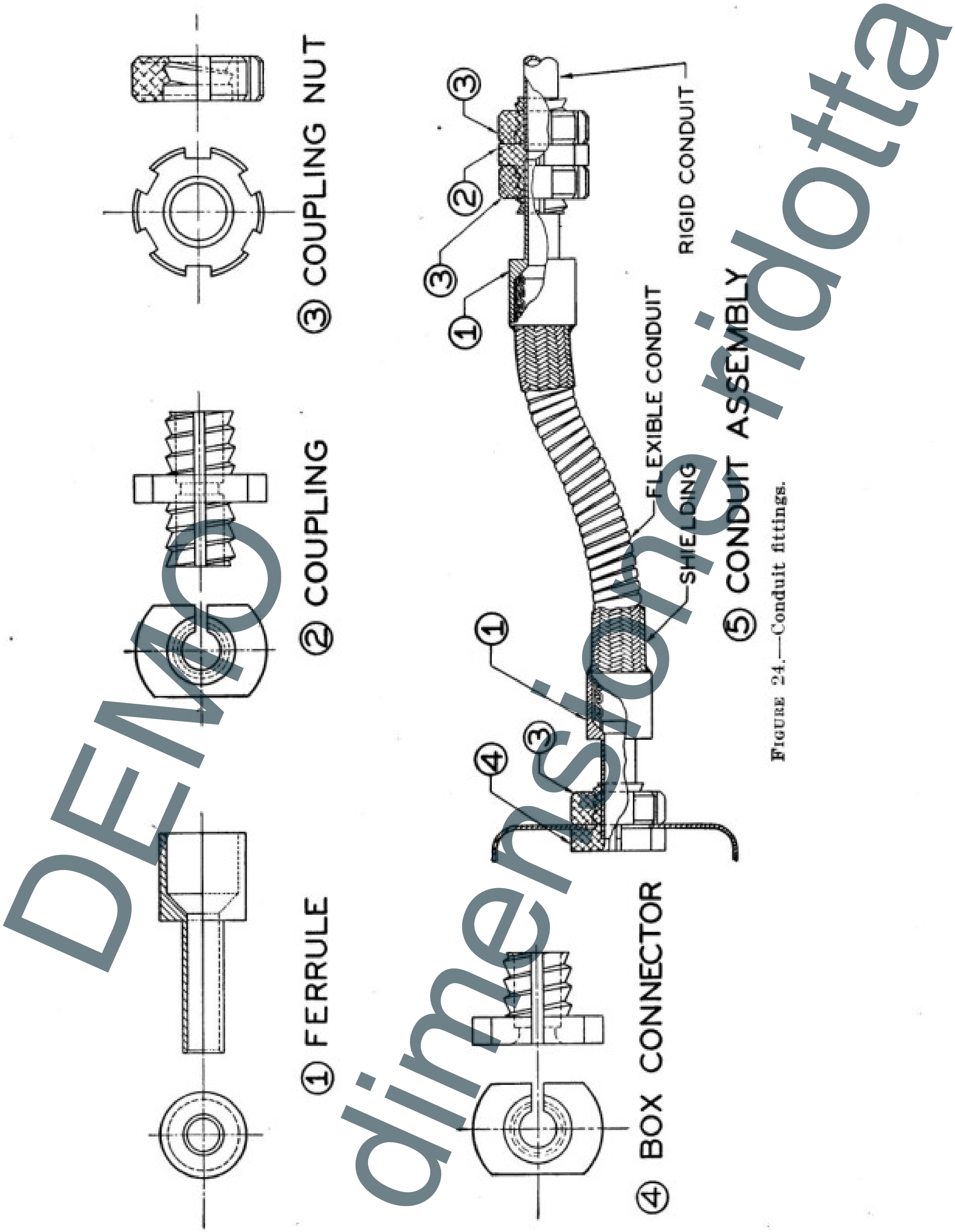


Figure 24.—Conduit fittings.

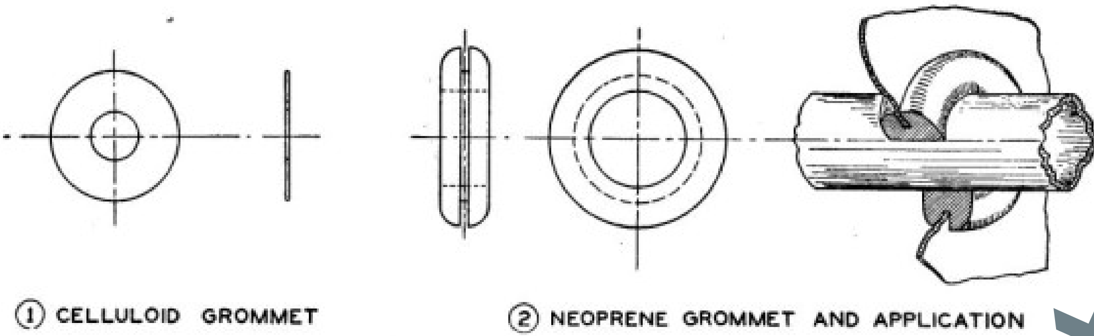


FIGURE 25.—Grommets.

derside of the trailing edge, close to the rib, and are doped directly to the main covering. Care should be exercised to insure that the hole in the grommet is unobstructed. If a brass grommet is used it is mounted on a fabric patch. The Neoprene grommet (fig. 25 ②) is used to line and protect the edges of holes in sheet metal through which tubing or conduit passes. The grommet prevents vibration and chafing.

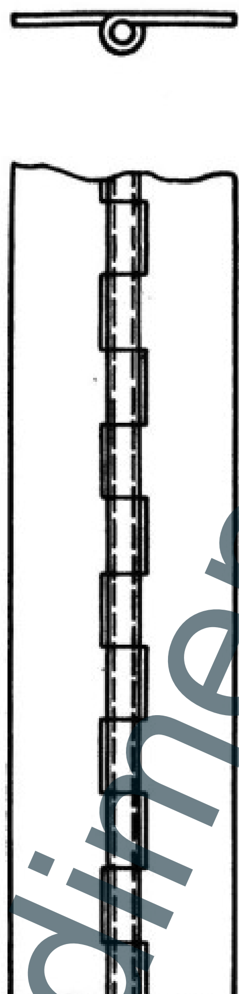

FIGURE 26.—Continuous hinge.

*b. Continuous hinge.*—The continuous hinge (fig. 26) is used in aircraft in such installations as inspection cover plates, compartment doors, wing flaps, trim tabs, bomb doors, etc. Continuous hinges are made of stainless steel or aluminum alloy, depending upon the installation. When a continuous hinge is used on a control surface, it is fabricated of stainless steel.

*c. Pressure-grip lubricator fitting.*—The lubricator fitting shown in figure 27 is used on various aircraft mechanisms where grease is required for lubrication, to provide a means of attachment for a grease gun. The fitting is available in the shapes illustrated, to permit access to various installations. The fitting operates on the principle of a check valve, permitting the grease to enter but preventing it from backing out.

*d. Fasteners.*—The flush type fastener (Dzus) shown in figure 28 is used to secure cowling, and inspection plates, panels, etc., situated

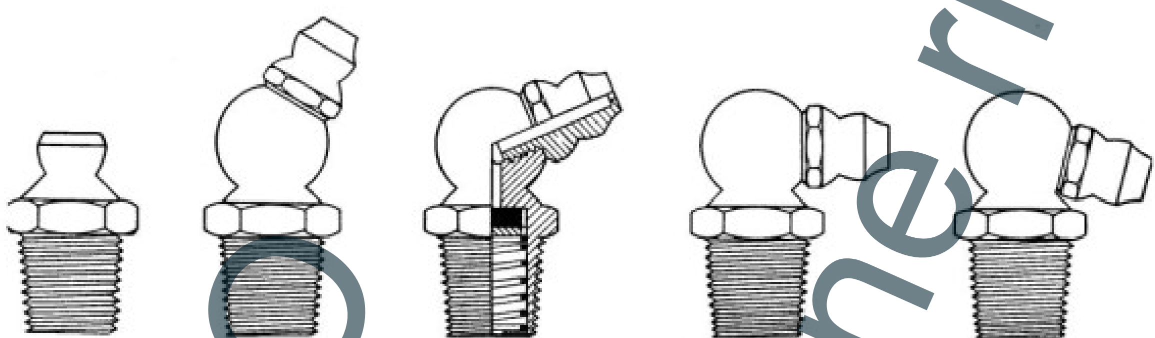


FIGURE 27.—Pressure lubricator fittings.

on the external surface of the aircraft where streamlining is desirable and frequent removal is required. The wing type is used in the interior of aircraft on such parts as junction box and control panel covers. The complete unit consists of a stud, grommet, and spring as shown in the assembly. A quarter turn of the stud serves to lock or loosen the fastener.

## SECTION VII

## PROCESSES RELATED TO HARDWARE

Paragraph



**42. Application of safety devices.**—Vibration in aircraft tends to loosen or alter the adjustment of various parts, such as nuts, turnbuckles, etc.; consequently, parts which are intended for disassembly