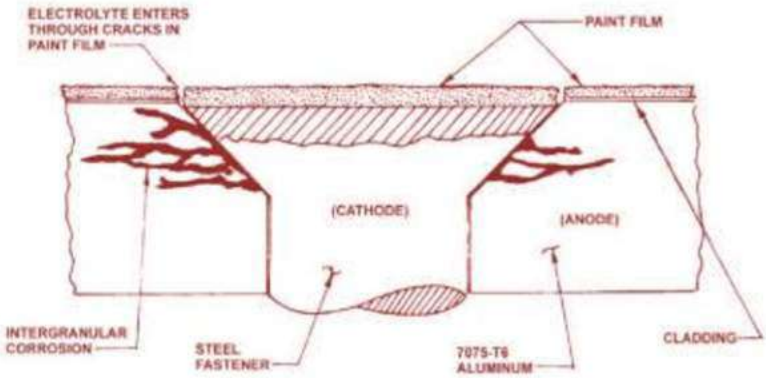
Intergranular Corrosion:

This type of corrosion is an attack along the grain boundaries of an alloy and commonly results from a lack of uniformity in the alloy structure. Aluminum alloys and some stainless steels are particularly susceptible to this form of electrochemical attack. The lack of uniformity is caused by changes that occur in the alloy during heating and cooling during the material's manufacturing process. After the heat treatment if quenching is delayed for even a few seconds, the particles of the allying agents precipitate out of the metal matrix and can become very large. It quenching is delayed too long, these metal grains can reach a size that produces areas of dissimilar metals large enough to form effective Cathode and Anode so that intergranular corrosion can occur. Intergranular corrosion may exist without visible surface evidence. Very severe intergranular corrosion may sometimes cause the surface of a metal to "exfoliate." This is a lifting or flaking of the metal at the surface due to delamination of the grain boundaries. This type of corrosion is also known as "Exfoliation Corrosion" This type of corrosion is difficult to detect in its initial stage. Extruded components such as spars can be subject to this type of corrosion. Ultrasonic and eddy current inspection methods are being used with a great deal of success.



the compressive stress must be overcome by the tensile force before the stress corrosion can form.

Exfoliation

Stress Corrosion:

Stress corrosion occurs as the result of the combined effect of sustained tensile stresses and a corrosive environment. Stress corrosion cracking is found in most metal systems; however, it is particularly characteristic of aluminum, copper, certain stainless steels, and high strength alloy steels (over 240,000

psi). It usually occurs along lines of cold working and may be trans granular or intergranular in nature. Aluminum alloy bell cranks with pressed in bushings, landing gear shock struts with pipe thread type grease fittings, clevis pin joints, shrink fits, and overstressed tubing B-nuts are examples of parts which are susceptible to stress corrosion cracking.
Since stress corrosion can occur only in the presence of tensile stress, one method of preventing this type of corrosion in some heat treated aluminum alloy parts is to short peen the surface to provide a uniform compressive stress on the surface.

Fretting Corrosion:

Fretting corrosion is a particularly damaging form of corrosive attack that occurs when two mating surfaces, normally at rest with respect to one another, are subject to slight relative motion. It is characterized by pitting of the surfaces. This type of corrosion is the result of the abrasive wear caused by two surfaces rubbing against each other. This rubbing known as fretting, prevents the formation of protective oxide film, exposing active metal to the atmosphere. Presence of water vapour greatly increases this type of deterioration. If the contact areas are small and sharp, deep grooves resembling brinell markings or pressure indentations may be worn in the rubbing surface. As a result, this type of corrosion (on bearing surfaces) has also been called false brinelling.

Fretting corrosion occur around rivets in a skin and is indicated by dark deposits around the rivet heads streaming out behind giving the appearance of rivet smoking. Rivets showing this sign of fretting corrosion must be drilled out and replaced.

CORROSIVE AGENTS:

Corrosive agents are substances that are capable of causing a corrosive reaction. Most corrosive agents fall into one of the two categories, acids and alkalis. However care must be taken not to overlook other less obvious corrosive agents such as the atmosphere which contains moisture, salt or corrosive industrial agents.

Acid and Alkalis:

Almost all acids and alkalis form effective electrolyte as they react with the metals to form metallic salts, but some electrolytes are more active than others. For example sulphuric acid found in aircraft batteries is active in corroding aluminum. However a weak solution of chromic or phosphoric acid is often used as a surface treatment to prepare metal for painting. Ferrous metals are subject to damage from both acids and alkalis, but aluminum is more vulnerable to strong alkaline solutions than it is to acids.

Salts:

It is very important to remember that many compounds other than sodium chloride fall into the category of salt. In general salts are the result of the metallic element combining with non- metal. The resulting compound is always a good electrolyte and can promote corrosive attack. Magnesium is particularly susceptible to corrosive attack from electrolyte formed by salt solution.

Mercury:

Although it is not commonly found in any quantity around aircraft, there is definite possibility that mercury could be spilled in an aircraft. Hazardous cargos are often carried in aircraft and damage from a shifting loads can result in damaged container and hazardous spills. Mercury attacks aluminum by a chemical reaction known as amalgamation. In this process the mercury attacks along the grain boundaries within the alloy, and in very short time completely destroys it.

Extreme care must be taken when removing spilled mercury as it is very slippery and flows through tiny cracks to get to the lowest part of the aircraft structure where it causes extreme damage. In addition mercury and its vapours are poisonous to humans. If mercury is spilled then remove every particle with vacuum cleaner having mercury trap in the suction line. Never try to remove mercury by blowing with compressed air. This only scatters it and spreads the damage.

Water:

Pure water reacts with metals to form corrosion or oxidation, but water holding a concentration of salts or other contaminants causes much more rapid corrosion. Seaplanes operating in salt water are especially vulnerable to attack and when it is being taken out of salt water it should be wash down with large volumes of fresh water to get every trace of salt off the structure. Float bottoms are subject to the abrasive effect of high velocity water during take-off and landings. Since this abrasion tends to damage the natural protective oxide film, seaplane must be carefully inspected to detect any damage which could allow water to get to the base metal of the structure.

Air:

It is impossible to isolate an aircraft structure from the air in which it exist. The presence of air is very important factor in the deterioration of metal. Marine atmosphere and air above industrial areas hold large concentration of salts. The chemicals precipitate out of the air and collect on the surface of an aircraft where they attract moisture from the air to form the corrosion.

Organic Growths:

Jet aircrafts uses high viscosity fuel which holds more water in suspension than other aviation fuel. Jet aircraft also fly higher than reciprocating engine aircrafts and the low temperature flight conditions associated with these altitudes causes water that is suspended in the fuel to condense out and collect in the bottom of the tanks. This water contains microscopic animal and plant life called microbes. These organic bodies live in the water and feed on the hydrocarbon fuel. Further the dark conditions inside the fuel tanks promote their growth and in very short period of time these tiny creatures multiply and forms scum inside the tank structure. This provides the place for concentration cell corrosion to form. If the scum forms along the edge of the sealant in an integral fuel tank, the sealant can pull away from the structure, causing a leak and expensive resealing operation.

It is practically impossible to prevent the formation of this scum as long as microbes are allowed to live in the fuel. The most successful solution to the problem has been to use additives in the fuel which kills these organic growths and prevents the formation of the corrosion forming scum. In addition this same fuel additive serves as antifreeze to prevent suspended water from freezing. If the suspended water freezes the resulting slush could plug the fuel screens and cause fuel starvation.

Corrosion Detection:

Corrosion can often be detected by careful visual inspection of the aircraft structure. Corrosion of aluminum or magnesium appears as a white or gray powder along the edges of skin and around rivet head. Also since corrosion salt have more volume than sound aluminum they tend to push out against the skin. Therefore small blisters appearing under the finished or painted surfaces or at the lap joints are the indications of the corrosion.
To aid in the detection of corrosion other than visual inspection we should also make use of other detection methods. We can make use of magnifying glasses, inspection mirror, fiber optics, borescope and other optical inspection tools. We can also make use of dye penetrant inspection for the detection of stress corrosion cracks.

Another means of corrosion detection is through the use of ultrasonic equipment. There are two types of ultrasonic equipment used for corrosion detection, one is pulse echo and the other is resonance method. Like ultrasonic radiography such as X-rays is also used to determine if there is any corrosion inside the structure.

CORROSION PRONE AREAS

Modern aircrafts are made of thin reactive metals which can tolerate very little loss of strength. Hence one of the most important function you perform as AME is to check the entire aircraft for indication of corrosion which could degrade the strength of the structure. Almost all parts of an airplane are subject to this type of damage, but certain areas are more prone to corrosion than others.

Engine Exhaust Area

Reciprocating and turbine engines generate power by converting chemical energy from hydrocarbon fuel into heat energy. Much of this heat energy along with energy rich gases passes out of the engine through the exhaust. The exhaust gases contain all of the constituents for a strong electrolyte and because of the elevated temperature corrosion forms rapidly. Exhaust deposits may be trapped and not reached by normal cleaning methods. Pay special attention to areas around rivet heads and in skin lap joints and other crevices like fairing on the nacelles, hinges and inspection door fasteners. Remove and inspect fairings and access plates in the exhaust areas. Do not overlook exhaust deposit buildup in remote areas, such as the empennage surfaces. Build up in these areas will be slower and may not be noticed until corrosive damage has begun.

Battery Compartment and Vents:

Battery store electrical energy by converting it into chemical energy and are therefore active chemical plants complete with environment polluting exhaust. Aircraft having lead acid batteries must have their boxes protected by a material that resists corrosion from sulfuric acid fumes and aircraft with nickel cadmium batteries must have their battery area protected with an alkaline resistance finish. This finish can have rubber base or can be polyurethane finish. During the inspection the areas around the battery must be carefully checked, especially under the battery, and all traces of corrosion must be removed and area refinished. Also ensure that the battery has a sump vent jar containing an absorbent pad moist with neutralizing agent. If the battery electrolyte is spilled during servicing it must be cleaned up immediately and the area neutralized. It can be checked by using litmus paper. If the area is acidic the paper turns pink and if the area is alkaline it turns blue. The entire area should be neutralized and the litmus paper should not change its colour.

Lavatories and Food Service Areas:

Organic materials such as food and human waste are highly corrosive to aluminum surfaces. Therefore areas in proximity to these materials such as lavatories and food service areas must be inspected with extreme care. Food services area can be troublesome if there is a possibility of food debris getting into cracks under or behind the galley where it cannot be removed. While this material in itself may not be corrosive but it can hold water which can cause the structure to corrode.

The lavatory area is very important area to check for corrosion. Human waste are usually acidic and rapidly promote corrosion if allowed to remain on the skin of the aircraft or to get into the cracks and seams in the structure. Also some disinfectant used in the lavatory areas can cause further damage to the aircraft. Because of this you must ensure that the disinfectant carried on board is of the type which is not harmful to aluminum.

Wheel Wells & Landing Gear:

More than any other area on the aircraft, this area probably receives more punishment due to mud, water, salt, gravel, and other flying debris which are being thrown up from runway surface during take-off and landings. This can be more troublesome during winter when chemicals are used on runways for ice control. Also abrasion can remove the protective finish given in this area and can cause corrosion. Because of the many complicated shapes, assemblies, and fittings, complete area paint film coverage is difficult to attain and maintain. A partially applied preservative tends to mask corrosion rather than prevent it. Due to heat generated by braking action, preservatives cannot be used on some main landing gear wheels. During inspection of this area, pay particular attention to the following trouble spots:

1. Magnesium wheels, especially around bolt heads, lugs, and wheel web areas, particularly for the presence of entrapped water or its effects
2. Exposed rigid tubing, especially at B-nuts and ferrules, under clamps and tubing identification tapes
3. Exposed position indicator switches and other electrical equipment
4. Crevices between stiffeners, ribs, and lower skin surfaces, which are typical water and debris Traps.

External Skin Areas:

One of the first places corrosion appears on the surface of an aircraft is along seams and lap joints. It is here that concentration cell corrosion frequently appears. In clad skins the sheared edges of Alclad material are exposed without the protection of the pure aluminum. There is also a danger of water or cleaning solvents becoming entrapped in the lap joints and providing a effective electrolyte.

Relatively little corrosion trouble is experienced with magnesium skins if the original surface finish and insulation are adequately maintained. Trimming, drilling, and riveting destroy some of the original surface treatment, which is never completely restored by touchup procedures. Any inspection for corrosion should include all magnesium skin surfaces with special attention to edges, areas around fasteners, and cracked, chipped, or missing paint.

Corrosion may start in a spot welded seam if the spot welding process has left an enlarge grain structure in the metal. The area is then susceptible to corrosion when moisture seeps between the skins.

To check the bulging along the spot weld hold the straightedge along the row of spots and if there is a corrosion in the seam, the surface bulges between the spots and shows up wavy skin. Corrosion in the skin can progress to such a degree that the spot actually pull apart.

Engine Inlet Areas:

One of the most vital parts of an aircraft is the area directly in front of the engine where air is taken in. This area is usually quite large on jet aircraft and air rushes into the engine at a very high velocity. Abrasion by his high velocity air and by contaminants carried in the air tends to remove any protective coating. Therefore abrasion strips along the leading edge of intake ducts help protect these areas. However careful inspection and maintenance of the finish in these inlet areas is mandatory.

Fuel Tanks:

There is probably no single pace in an aircraft that is less accessible for inspection and repair than the inside of the fuel tank. Fuel tanks are highly susceptible to corrosion because of formation of organic growth. If ignored this organic growth can grow into the water holding scum which attaches to the aluminum alloy skin. In addition to the organic growth, sealant used to convert the internal structure of the wing into a fuel tank are resistant to fuel, hence it is possible for water to seep through the sealant and cause oxygen concentration cell corrosion. Corrosion under the sealant is extremely difficult to detect and must usually be found with X-ray or ultrasonic inspection from outside of the wing.

Piano Hinges:

Piano-type hinges are prime spots for corrosion due to the dissimilar metal contact between the steel pin and aluminum hinge. They are also natural traps for dirt, salt, and moisture. Inspection of hinges should include lubrication and actuation through several cycles to ensure complete lubricant penetration. Use water- displacing lubricants when servicing piano hinges.

Control Surface Recesses:

Aircrafts have areas in the wing or empennage where the movable surfaces recess back in to the fix structure. Dirt and water may collect in flap and spoiler recesses and go unnoticed because they are normally retracted. For this reason, these recesses are potential corrosion problem areas. Inspect these areas with the spoilers and/or flaps in the fully deployed position. A thin film of water dispensing lubricants can be used to protect the skin lap joints in these areas.

Bilge Area:

The bottom of the fuselage below the floor is an area where water and all forms of liquid and solid debris can accumulate and cause corrosion. These areas are ideal for the formation of corrosion because of the almost constant exposure to an electrolyte. Also due to their inaccessibility corrosion often goes undetected until it has caused major damage. These areas are provided with drain holes to prevent accumulation of water. But due to other solid debris and dirt these drain holes often get clogged. Hence in every inspection you should carefully inspect any area where water might accumulate and make sure all drain holes are clear. A water dispensing liquid spray that forms a thin film on the surface of the metal can be used to prevent further contact with moisture.

Control Cables:

The cables used in aircraft control system are made of either carbon steel or corrosion resistance steel. If carbon steel cables are left unprotected and water is allowed to get between the cable strands, the cable will corrode. The corrosion that forms on the inside of the cable is difficult to detect. If the corrosion is suspected release the tension from the cable and open the strands by twisting them against the lay, allowing you to see between the strands. Cable showing any indication of corrosion should be replaced. To prevent this type of corrosion you should spray the cable with water dispensing type lubricant. For control cables used in seaplane or those expose to agricultural chemicals coat them with waxy grease such asPar-Al-Ketone

Welded Areas:

Welding requires the use of flux to exclude oxygen from weld. This flux may contain lithium chloride, potassium chloride, potassium bisulphite or potassium fluoride. All of these compounds are extremely corrosive to aluminium and therefore all traces of flux must be removed after welding. Also it absorbs moisture from the air to further corrode the metal. Welding flux is soluble in water and can be removed with hot water and non-metallic brush.

Electronic Equipment:

The use of copper, lead, tin and other metals in the electronic wiring and printed circuit boards makes them a target for corrosion. Therefore circuit boards are protected by sealing the wiring and circuit boards with a transparent film which excludes all oxygen and moisture from the surface.

Corrosion of Ferrous Metals:

One of the most familiar types of corrosion is ferrous oxide (rust), generally resulting from atmospheric oxidation of steel surfaces. Some metal oxides protect the underlying base metal, but rust is not a protective coating in any sense of the word. Its presence actually promotes additional attack by attracting moisture from the air and acting as a catalyst for additional corrosion. If complete control of the corrosive attack is to be realized, all rust must be removed from steel surfaces.

Rust first appears on bolt heads, hold-down nuts or other unprotected aircraft hardware. Its presence in these areas is generally not dangerous and has no immediate effect on the structural strength of any major components. The residue from the rust may also contaminate other ferrous components, promoting corrosion of those parts. The rust is indicative of a need for maintenance and of possible corrosive attack in more critical areas. It is also a factor in the general appearance of the equipment. When paint failures occur or mechanical damage exposes highly stressed steel surfaces to the atmosphere, even the smallest amount of rusting is potentially dangerous in these areas and must be removed and controlled.

Corrosion of Aluminum and Aluminum Alloys:

Corrosion on aluminum surfaces is usually quite obvious, since the products of corrosion are white and generally more voluminous than the original base metal. Even in its early stages, aluminum corrosion is evident as general etching, pitting, or roughness of the Aluminum surfaces.

NOTE: Aluminum alloys commonly form a smooth surface oxidation that is from 0.001 to 0.0025 inch thick. This is not considered detrimental; the coating provides a hard shell barrier to the introduction of corrosive elements. Such oxidation is not to be confused with the severe corrosion discussed in this paragraph.

General surface attack of aluminum penetrates relatively slowly, but is speeded up in the presence of dissolved salts. Considerable attack can usually take place before serious loss of structural strength develops. At least three forms of attack on aluminum alloys are particularly serious: (1) the penetrating pit-type corrosion through the walls of aluminum tubing, (2) stress corrosion cracking of materials under sustained stress, and (3) intergranular corrosion which is characteristic of certain improperly heat-treated aluminum alloys. In general, corrosion of aluminum can be more effectively treated in place compared to corrosion occurring on other structural materials used in aircraft. Treatment includes the mechanical removal of as much of the corrosion products as practicable, and the inhibition of residual materials by chemical means, followed by the restoration of permanent surface coatings.

Corrosion of Magnesium Alloys:

Magnesium is the most chemically active of the metals used in aircraft construction and is the most difficult to protect. When a failure in the protective coating does occur, the prompt and complete correction of the coating failure is imperative if serious structural damage is to be avoided. Magnesium attack is probably the easiest type of corrosion to detect in its early stages, since magnesium corrosion products occupy several times the volume of the original magnesium metal destroyed. The beginning of attack shows as a lifting of the paint films and white spots on the magnesium surface. These rapidly develop into snow-like mounds or even "white whiskers." Re protection involves the removal of corrosion products, the partial restoration of surface coatings by chemical treatment, and a reapplication of protective coatings.

CORROSION PROTECTION:

Regardless of the type of corrosion or the metal involved corrosion treatment requires three basic steps,

1. Removal of as much of the corrosion as possible.
2. Neutralize any residual material.
3. Restore the protective surface film.

CORROSION REMOVAL:

Corrosion under the paint finish cannot be inspected and removed without first removing the all the paint. This can be done with the application of paint remover. However before using an unfamiliar paint remover first test it on the piece of metal similar to that of the structure to be worked on. Never use caustic paint remover.

Prior to applying a paint remover all areas not to be striped should be masked with heavy aluminum foil to keep paint remover from accidently coming in contact with these areas. Water rinsable paint remover having syrupy consistency is best for aircraft structure. Apply a heavy coat of paint remover on the surface with brush and wait until the paint swells and wrinkles up. This breaks the bond between the paint and the metal. Sometimes it is necessary to reapply the paint remover if all the paint is not removed in first application. Many solvents used in paint remover attack rubber and synthetic rubber products, hence tires, hoses and seals must be protected from contact with paint remover.

Treatment of Aluminum alloys:

Corrosion on aluminum surfaces is usually quite obvious, since the products of corrosion are white and generally more voluminous than the original base metal. Even in its early stages, aluminum corrosion is evident as general etching, pitting, or roughness of the aluminum surfaces.

Mechanical Corrosion Removal:

After the paint is removed from a corroded area all traces of corrosion must be removed from the surface. Mild corrosion can be removed by using nylon scrubbers. More severe corrosion can be removed by brushing with an aluminum wire brush. Never used steel wire brush. Blasting the surface with the glass beads smaller than 500 mesh can be used to remove the corrosion from the pits. For the most severely corroded aluminum alloy use rotary files of power grinder using rubber wheels impregnated with aluminum oxide to grind out corrosion damage. After the corrosion is removed inspect the surface with five or ten power magnifying glass for any trace of corrosion. Remove about two thousandth of an inch more material to be sure that ends of intergranular cracks have been reached.

Chemical Neutralization:

After removing all the corrosion treat the surface with ten percent chromic acid solution to neutralize any remaining corrosion salts. After the acid has been on the surface for at least five minutes it should be washed off with water and allowed to dry. Alodine treatment confirming to MIL C-5541 will also neutralize the corrosion.

PROTECTIVE COATING:

Cladding:

Pure aluminum readily combines with oxygen to form an oxide film. This film is so dense that it excludes air from the metal's surface thereby preventing additional corrosion forming. The disadvantage of using pure aluminum for aircraft construction is that it is not strong enough for the aircraft structural components and hence must be alloyed with other metals. These alloys can be Prevented from corrosion by coating them with the layer of pure aluminum, this is known as cladding. Pure aluminum is rolled onto the surface of an aluminum alloy and accounts for five to ten percent of total sheet thickness. The cladding material is anodic as compared to the core material.

Surface Oxide Film:

In areas where cladding is not practicable metallurgists have found other way of forming films on metal surfaces that are hard, decorative, waterproof, and airtight. The process of applying an oxide film is performed in the factories by an electrolyte process known as anodizing.

Anodizing is the most common surface treatment of non clad aluminum alloy surfaces. It is typically done in specialized facilities. The aluminum alloy sheet or casting is the positive pole in an electrolytic bath in which solution of chromic acid and water or other oxidizing agent produces an aluminum oxide film on the metal surface. Aluminum oxide is naturally protective, and anodizing merely increases the thickness and density of the natural oxide film. When this coating is damaged in service, it can only be partially restored by chemical surface treatments. Therefore, when an anodized surface is cleaned including corrosion removal, the technician should avoid unnecessary destruction of the oxide film.

The anodized coating provides excellent resistance to corrosion. The coating is soft and easily scratched, making it necessary to use extreme caution when handling it prior to coating it with primer. Aluminum wool, nylon webbing impregnated with aluminum oxide abrasive, fine grade nonwoven abrasive pads or fiber bristle brushes are the approved tools for cleaning anodized surfaces. The use of steel wool, steel wire brushes, or harsh abrasive materials on any aluminum surfaces is prohibited. In addition to its corrosion resistant qualities, the anodic coating is also an excellent bond for paint. In most cases, parts are painted as soon as possible after anodizing. The anodic coating is a poor conductor of electricity; therefore, if parts require bonding, the coating is removed where the bonding wire is to be attached. Alclad surfaces that are to be left unpainted require no anodic treatment; however, if the Alclad surface is to be painted, it is usually anodized to provide a bond for the paint.

When the protective anodized film has been damaged or removed in the field, the part can have a protective film applied through a chemical rather than an electrolytic process. This process is known as ALODIZING and uses a chemical that meets specification MIL-C-5541 and is available under several proprietary names such as ALODINE 1201. Prior to alodizing a component all traces of corrosion should be removed, the surface should then be cleaned with a metal cleaner until it supports an unbroken water film. In this water break test any break in the film of water indicates the presence of wax, grease or oil on the surface and further cleaning must be done. While the surface is still wet, apply the chemical with brush or spray and allow it to stand for 2-5 minutes then rinse it off. If the surface is not kept wet while the chemical is working, Streaks may appear and the film will not adequately protect the metal. The surface is ready to paint after the ALODINE solution dries.

Organic film

One of the most universally used corrosion control device for metal surfaces is a good coat of paint. Paint adhesion is not a problem on porous surfaces, but on smooth ones such as those found on aluminum, the surface must be prepared order for the paint to have rough surface to which it can adhere. An aluminum surface is roughened with a mild chromic acid itch or by formation of an oxide film through anodizing or alodizing. The surface can also be mechanically roughened by carefully sanding it with 400 grit sand paper, then clean the surface with aliphatic naphtha, thus the surface is ready for primer.

Zinc chromate

This primer has been used for years in enamel. It is a corrosion inhibiting primer. It confirms to the specification of MIL-P-8585A and can have either yellow-green or dark-green color. It is thinned with toluol. Prior to applying zinc chromate, the surface to be painted is cleaned of all finger prints and traces of oil, then a thin wet coat of zinc chromate s applied with a spray gun. Use appropriate personal protective equipment. The zinc chromate primer provides a good bond between the finish and the metal. It also has the property of being dope proof which means aircraft dope does not cause it to lift. When the repair is made or the part is fabricated zinc chromate is often applied to stop corrosion before it ever gets a chance to start.

Wash primer

A wash primer is used in aircraft factories for priming a new aircraft before it is being painted. This is two part primer consisting of resin and an alcohol-phosphoric acid catalyst. The material is mixed and allowed to stand for a short time, it is then sprayed on to the surface with a very light coat followed by a full bodied wet coat.

Epoxy primer

Epoxy primer is one of the most popular primers for use under polyurethane finish because they provide maximum corrosion protection. A typical epoxy primer consist of two component materials that produces a tough dope proof coat between the finish and the surface. Epoxy primers can be used on magnesium, aluminum or steel. For maximum corrosion protection they can be applied over a wash primer.

TREATMENT OF FERROUS METALS:

As with other materials ferrous metals structures and components also requires some form of protection from corrosive agents to maintain their strength. However due to their different chemical composition ferrous materials must be treated differently to achieve the same result.

Mechanical corrosion removal:

Unlike aluminum the oxide film that forms on ferrous metals is pours and attracts moisture to further corrode the metal. The most effective method of removing rust is by mechanical means. Abrasive paper and wire brushes can be used, but the most thorough means of removing all corrosion from unprotected steel parts is by abrasive blasting. It is done using sand or glass beads. Highly stressed steel parts such as those used in landing gear and engine, must be cleaned with extreme care. If corrosion found on these parts it should be eliminated immediately by removing the absolute minimum amount of material. A fine stone, fine abrasive paper works well. Wire brushes should not be used as they caused minute scratches which can produced stress concentration that potentially weaken the part. If abrasive blasting is used it must be done with caution using very fine grit abrasive. After all corrosion has been removed the surface should be primed as soon as possible. A dry clean surface is an ideal setting for corrosion and if not protected immediately new damage rapidly sets in. Zinc Chromate primer is used to protect most freshly cleaned steel surfaces.

Surface Treatment:

A number of options exist for treating ferrous metal surfaces. These options include plating, galvanizing, painting and metal spraying.

Chrome Plating:

One way to protect ferrous metal from corrosion is through chrome plating. This process produced an airtight coating over the surface that excludes moisture from the base metal. There are two types of chrome plating used in aircraft construction, decorative and hard chrome.

Decorative chrome is used primarily for its appearance and surface protection, while hard chrome is used to form a wear resistance surface on the piston rods, cylinder walls and other parts which are subject to abrasion. Parts to be plated with hard chrome are normally ground undersize and plated back to their proper dimensions. Engine cylinder walls are often plated with porous chrome whose surface has thousands of tiny cracks which hold oil to aid in lubrication.

Cadmium Plating:

Almost all steel aircraft hardware is cadmium plated. This soft, silvery-gray metal is electroplated onto the steel to a minimum thickness of 0.005 inch. It provides an attractive finish as well as protection against corrosion. When the cadmium plating on the part is scratched through to the steel, galvanic action takes place and the cadmium corrodes. The oxide which forms on the surface of the Cadmium are similar to those which forms on aluminum in that they are dense, airtight and watertight. This means that no further corrosion can take place once the initial film has formed. This type of protection is also called as Sacrificial Corrosion.

Galvanizing:

Steel parts such as firewall are typically treated with coating of Zinc in a process called galvanizing. The protection offered by this process is similar to that provided by cadmium plating, in that when penetrated the zinc corrodes and forms an airtight oxides film. Steel is galvanized by passing through containers of molten zinc and then rolling it smooth through a series of rollers.

Metal spraying:

Aircraft engine cylinders are sometimes protected from corrosion by spraying molten aluminum on their surface. To accomplish this process a steel cylinder barrel is sand blasted absolutely clean, then aluminum wire is fed into an acetylene flame where the wire is melted and blown onto the surface by high pressure compressed air. Corrosion protection offered by this treatment is sacrificial corrosion, similar to that provided by cadmium and zinc coating.

Organic Coatings:

The most common organic coating used to protect ferrous metals is paint. However like aluminum the surface must be properly prepared to ensure a good bond. Dry abrasive blasting typically removes all of the surface oxides and roughens the surface enough to provide a good bond for the paint. However the parts which have been cadmium plated must normally have their surface etched with five percent solution of chromic acid before the primer adheres. After surface preparation a thin wet coat of zinc chromate primer is sprayed on and allowed to dry. The final finish can usually be applied after about an hour.

TREATMENT OF TITANIUM AND TITANIUM ALLOYS

Attack on titanium surfaces is generally difficult to detect. Titanium is, by nature, highly corrosion resistant, but it may show deterioration from the presence of salt deposits and metal impurities, particularly at high temperatures. Therefore, the use of steel wool, iron scrapers, or steel brushes for cleaning or for the removal of corrosion from titanium parts is prohibited. If titanium surfaces require cleaning, hand polishing with aluminum polish or a mild abrasive is permissible, if fiber brushes only are used and if the surface is treated following cleaning with a suitable solution of sodium dichromate. Wipe the treated surface with dry cloths to remove excess solution, but do not use a water rinse.

CORROSION LIMITS:

Corrosion, however slight, is damage. Therefore, corrosion damage is classified under the four standard types, as is any other damage. These types are: (1) negligible damage, (2) damage repairable by patching, (3) damage repairable by insertion, and (4) damage Necessitating replacement of parts. The term “negligible,” as used here, does not imply that little or nothing should be done. The corroded surface should be cleaned, treated, and painted as appropriate. Negligible damage, generally, is corrosion that has scarred or eaten away the surface protective coats and begun to etch the metal. Corrosion damage extending to classifications of “repairable by patching” and “repairable by insertion” should be repaired in accordance with the applicable structural repair manual.
When corrosion damage exceeds the Damage limits to the extent that repair is not possible, the component or structure should be replaced.

MODULE 6.5: FASTENERS

SCREW THREADS

Various type of fastening devices allow quick dismantling or replacement of aircraft parts that must be taken apart and put back together at frequent intervals. Riveting or welding these parts each time they are serviced would soon weaken or ruin the joint. Furthermore, some joints require greater tensile strength and stiffness than rivets can provide. Bolts and screws are two types of fastening devices which give the required security of attachment and rigidity. Generally, bolts are used where great strength is required, and screws are used where strength is not the deciding factor. Bolt and screws are similar in many ways. They are both used for fastening or holding, and each has a head on one end and screw threads on the other. Regardless of these similarities, there are several distinct differences between the two types of fasteners. The threaded end of a bolt is always blunt while that of a screw may be either blunt or pointed. The threaded end of a bolt usually has a nut screwed onto it to complete the assembly. The threaded end of a screw may fit into a female receptacle, or it may fit directly into the material being secured. A bolt has a fairly short threaded section and a comparatively long grip length or unthreaded portion; whereas a screw has a longer threaded section and may have no clearly defied grip length. A bolt assembly is generally tightened by turning the nut on the bolt; the head of the bolt may or may not be designed for turning. A screw is always tightened by turning its head.

Screw Thread Terminology

Definitions

The screw thread is a complex geometrical figure involving several elements.

Pitch

The pitch of a screw thread is the distance in inches or millimeters from any point on a thread to the corresponding point on the next thread measured parallel to the axis.
The pitch is equal to 1 Threads per inch

Effective Diameter

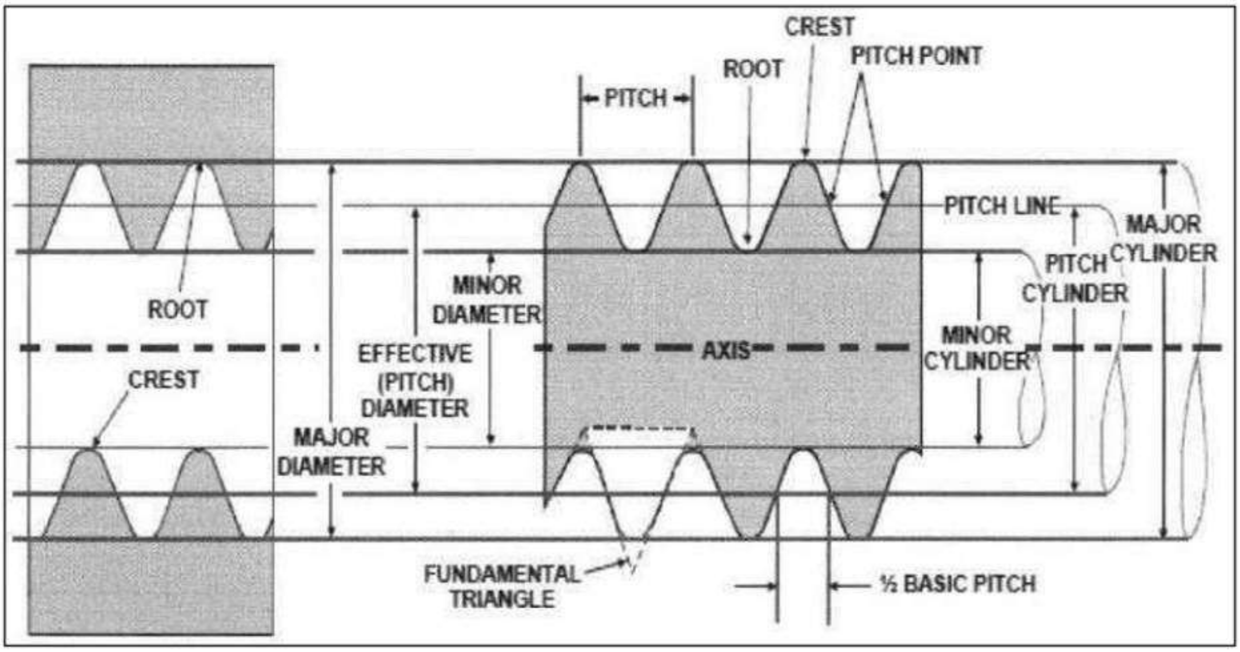
This may also be called the pitch diameter, and is the diameter of an imaginary cylinder (Pitch Cylinder) which splits the fundamental triangles exactly in half.

Minor Diameter

The minor diameter is the distance measured between the roots of the thread, in the case of a male thread and between the crests of the head in the case of a female thread.

Major Diameter

Is the measured diameter over the crests of the thread (roots in the female)



Crest
The top surface joining the flanks of the thread.

Root
The root is the bottom of the groove joining adjacent sides or flanks of the thread, whether of the male screw or of the female screw.

Flank or Side
The surface of the thread form which connects the crest with the root.

Thread Angle
The included angle between the flanks measured in the axial plane.

Lead
The distance a screw thread advances axially in one complete turn (i.e. same as pitch for single start thread).

Length of Engagement
The axial distance over which two mating threads are designed to make contact.

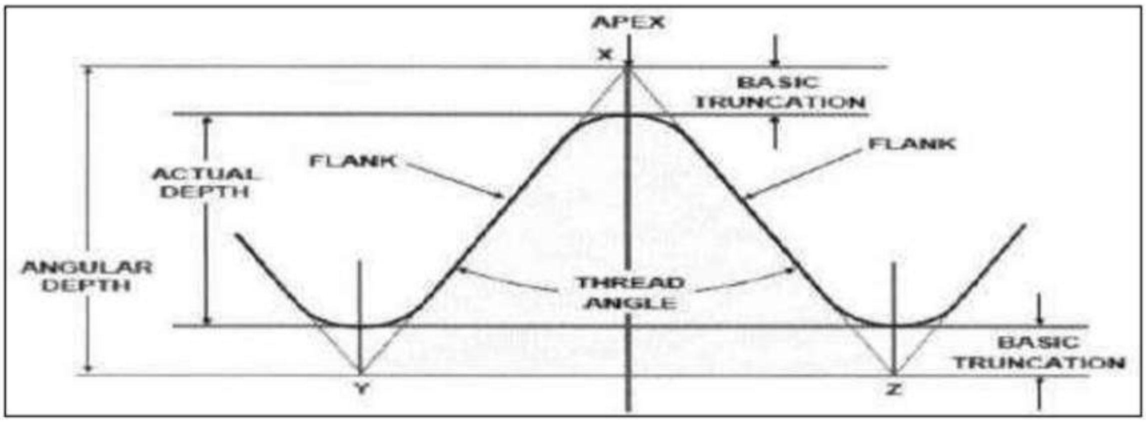
Angular Depth
The triangle formed by the intersection of the extended flanks. The vertical height of this triangle is the angular depth.

Actual Depth
The distance between the crest and the root of the thread measured perpendicular to the axis.

Fundamental Triangle
The triangle formed by the intersection of the extended flanks.

Truncation
The distance measured radially from the crest or root of the thread to the adjacent apex of the

fundamental triangle.



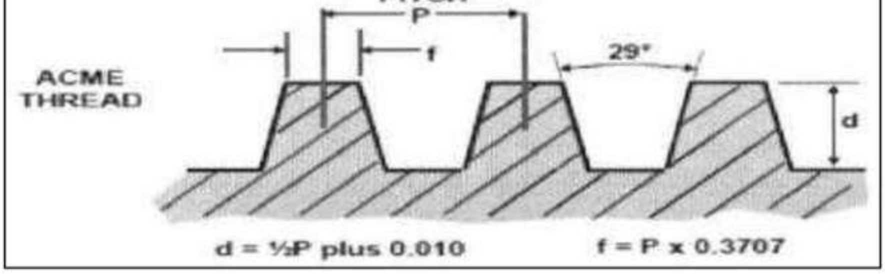
Threads are also designated by Class of fit. The Class of a thread indicates the tolerance allowed in manufacturing.

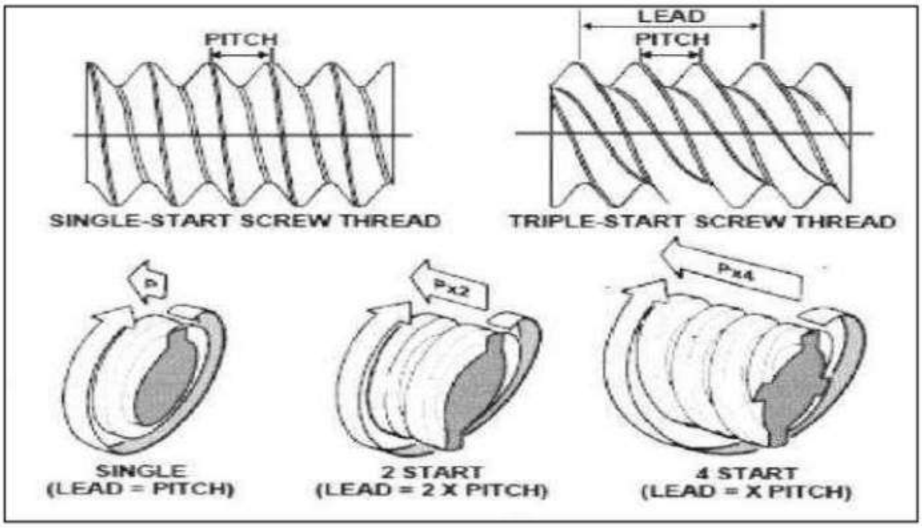
Class 1 is a loose fit, Class 2 is a free fit, Class 3 is a medium fit, and Class 4 is a close fit. Aircraft bolts are almost always manufactured in the Class 3, medium fit. A Class 4 fit requires a wrench to turn the nut onto a bolt, whereas a Class 1 fit can easily be turned with the fingers. Generally, aircraft screws are manufactured with a Class 2 thread fit for ease of assembly.

Bolts and nuts are also produced with right-hand and left-hand threads. A right-hand thread tightens when turned clockwise; a left- hand thread tightens when turned counter clockwise.

Single and Multiple Threads

When a thread formed by one continuous groove is said to be single or single start. The majority of threads used for adjustment and fastening are single thread. In such threads the lead, that is, the distance travelled axially by an engaged threaded part in a complete turn, is always equal to the pitch of the thread.
Multiple start threads consist of two or more ridges left by grooves cut side by side. In this way the axial travel or lead of the thread is increased without changing the pitch. For example, a nut engaged with a double start thread will travel twice as far in one complete turn as one engaged with a single thread of similar pitch. In multiple threads the lead is equal to the Pitch of the thread (P) multiplied by the number of starts. Press fit requires some sort of driving force.



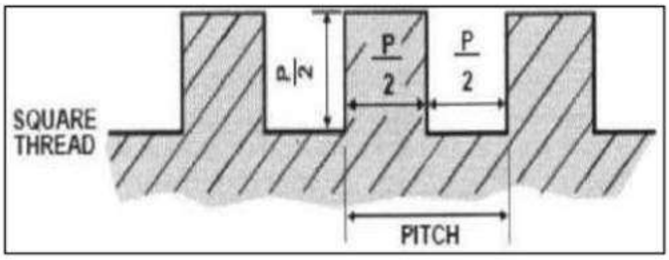


Right and Left Hand Threads

A right hand thread is one on which the thread is cut so that turning of the nut in a clockwise direction will tighten it on a bolt. A left hand thread requires the nut to be turned anti-clockwise to tighten it. Left hand threads are only used for special purposes.

Power Transmission Threads Square Thread

The thread form is a square. It is used on lead screws and feed shafts in machine tools. The rams of aircraft lifting jacks have a square thread for the locking collars.

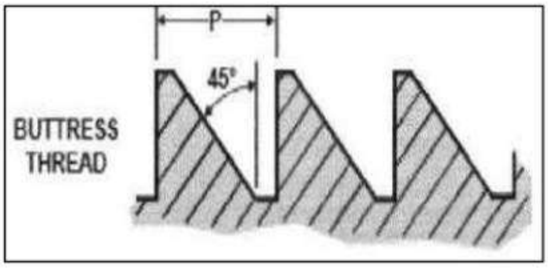


Acme Thread

A modified form of square thread with sloping faces and flat roots and crests. Largely employed in making lead screws and feed shafts for machine tools. May be multi-start to provide fast traversing motion when this is necessary.

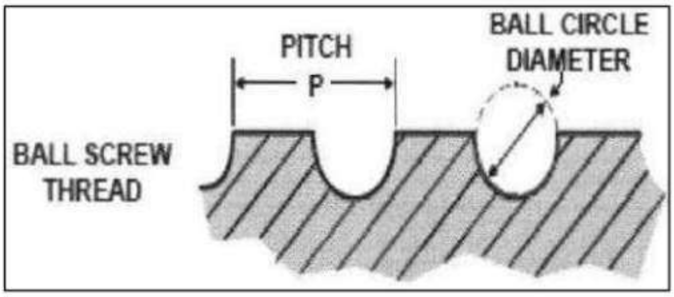
Buttress Thread

The form is triangular with one face 90oor nearly so to the screw axis and a second face inclined at 45o. It combines low friction with resistance to shear. The thread takes axial loads in one direction only. It is used in bench vices having quick release jaws.



Ball Screw Thread

A modified square thread for use with recalculating ball nuts in which the female thread element is comprised of hardened steel balls. This type of high strength, low friction thread is commonly used on aircraft for flap drive and stabilizer drive units.



CLASSIFICATION OF THREADS

Aircraft bolts, screws, and nuts are threaded in the NC (American National Coarse) thread series, the NF (American National Fine) thread series, the UNC (American Standard Unified Coarse) thread series, or the UNF (American Standard Unified Fine) thread series. There is one difference between the American National series and the American Standard Unified series that should be pointed out. In the 1-inch diameter size, the NF thread specifies14 threads per inch (1-14 NF), while the UNF thread specifies 12 threads per inch (1-12 UNF). Both types of threads are designated by the number of times the incline (threads) rotates around a 1-inch length of a given diameter bolt or screw. For example, a 4-28 thread indicates that a 1⁄4-inch (4⁄16 inch) diameter bolt has 28 threads in 1 inch of its threaded length.

UNJC and UNJF threads

"J" threads are made in both external and internal forms. The external thread has a much larger root radius than the corresponding UNC or UNF threads. This radius is mandatory and its inspection is required, whereas no root radius is required on UNC, UNF, or UNEF threads. Since the larger root radius increases the minor diameter, a UNJF or UNJC fastener has a larger net tensile area than a corresponding UNF or UNC fastener. This root radius also gives a smaller stress concentration factor in the threaded section. Therefore, high-strength bolts usually have "J" threads. These threads are manufactured to Class 3 fit only. Because of the enlarged root radius a UNJ bolt cannot be used with a UN nut, but a UN bolt is compatible with either a UN or UNJ nut. Thread types are not interchangeable i.e. a UNF screw must be used with a UNF nut of the same size.

Self-Tapping Threads

Self-Tapping threads are tapered male screw threads which are designed to cut their own mating thread in softer materials such as wood, plastic and aluminum. They are not used structurally on modern aircraft but are often found securing internal trim items and fittings.

The thread form and dimensioning varies depending on the intended use of the fastener and various numbering systems are employed. They should always be installed into pre-drilled holes at or below the core diameter.

CUTTING SCREW THREADS AT THE BENCH GENERAL

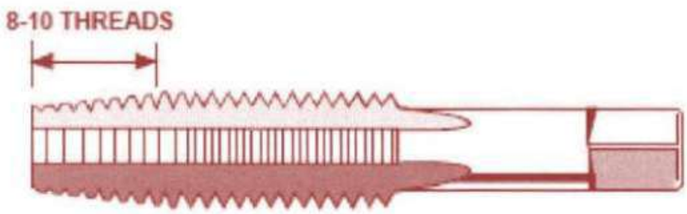
Screw threads of up to about 1 1/4" can be successfully produced by hand methods using taps for internal threads and dies for external threads. Before tapping, a hole must be drilled which should be equivalent to, or slightly larger than the minor diameter of the thread. Reference tables giving recommended drill tapping sizes are a part of every engineer's tool kit.

Taps

These are used for cutting internal screw-threads. Made of hardened and tempered high carbon steel or high speed steel, they are Fluted shafts with multiple cutting edges and driving flats on one end. The flutes are provided to clear the swarf during the cutting process. Usually manufactured in sets of 3, comprising taper, intermediate and bottoming.

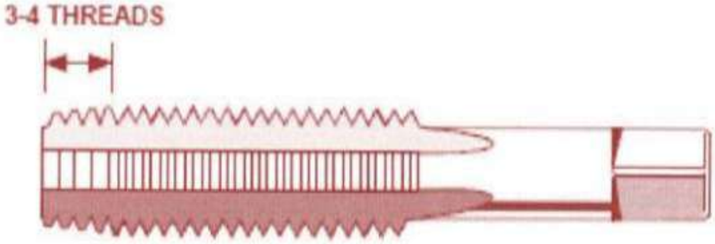
Taper Tap (or First)

Used for starting thread, diameter at point is less than the minor diameter of the thread.



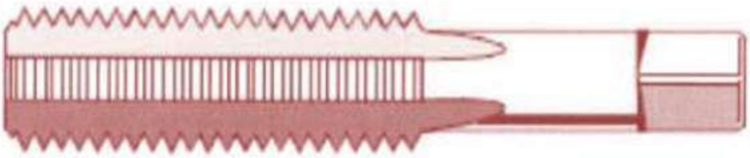
Intermediate (or Second)

Used to deepen thread cut by taper tap



Bottoming (or Plug)

This is not tapered and its purpose is to finish the thread to the bottom of blind or deep through holes.



Care and Use of Taps

Care must be taken not to damage the cutting edges and a chipped tap must never be used. When not in use, taps should be kept clean, and stored in a rack.
Taps are normally used in a tap wrench. At the start of the tapping process great care must be taken to ensure that the tap is perpendicular to the hole in both planes. It must be kept square to the hole throughout the cutting process. The tap must turned 180° forward to cut and then 90° backward to release the swarf. Use of a cutting compound will lubricate the tap, help clear swarf and produce a better finish.

Dies

Dies are used for cutting external screw threads.

Circular Split Dies

Made of hardened and tempered high carbon steel or high speed steel, these are split rings with multiple cutting edges and cut-outs to clear the swarf. These usually cut a full thread in one operation, but a split in the die allows adjustment of the depth of cut. The threads in the die are tapered on one side to aid starting so it is important to use the die the right way up.

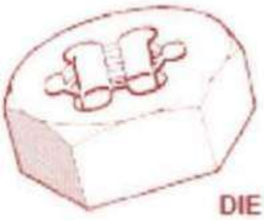
Dies are used in a Die Stock, which has three grub screws for retention and adjustment. The center screw must be aligned with the split in the die and is used to 'spread' it and reduce the cutting depth. The outer two screws align with dimples in the die and are used to retain it in the stock and prevent rotation. When the center screw is released, the outer two can be used to 'close' the split and deepen the cut. Care must be taken not to over-adjust the die as they are brittle and fracture easily.

Use of Dies

The rod to be threaded should have a 45° chamfer to aid starting the cut and provide a lead-in on the finished thread. The die must be presented the correct way up and perpendicular in both planes. Again the cut is made 90° forward and 90° back to clear the swarf and cutting compound will improve the quality of the thread.

Die Nuts

Used to run down an existing thread which has become damaged. They are not adjustable and should only be used where permitted



6.5.2 Bolts, studs and screws

AIRCRAFT BOLTS

Aircraft bolts are fabricated from cadmium- or zinc plated corrosion resistant steel, un-plated corrosion resistant steel or anodized aluminum alloys. Most bolts used in aircraft structures are general purpose, AN bolts, or NAS internal wrenching or close tolerance bolts, or MS bolts. In certain cases, aircraft manufacturers make bolts of different dimensions or greater strength than the standard types. Such bolts are made for a particular application, and it is of extreme importance to use like bolts in replacement. Special bolts are usually identified by the letter “S” stamped on the head. AN bolts come in three head styles—hex head, clevis, and eyebolt. NAS bolts are available in hex head, internal wrenching, and countersunk head styles. MS bolts come in hex head and internal wrenching styles.

General Purpose Bolts

The hex head aircraft bolt (AN-3 through AN-20) is an all-purpose structural bolt used for general applications involving tension or shear loads where a light drive fit is permissible (0.006-inch clearance for a 5⁄8-inch hole, and other sizes in proportion).
Alloy steel bolts smaller than No. 10-32 and aluminum alloy bolts smaller than 1⁄4 inch in diameter are not used in primary structures. Aluminum alloy bolts and nuts are not used where they will be repeatedly removed for purposes of maintenance and inspection. Aluminum alloy nuts may be used with cadmium-plated steel bolts loaded in shear on land airplanes, but are not used on seaplanes due to the increased possibility of dissimilar metal corrosion.
The AN-73 drilled head bolt is similar to the standard hex bolt, but has a deeper head which is drilled to receive wire for safe tying. The AN-3 and the AN-73 series bolts are interchangeable, for all practical purposes, from the standpoint of tension and shear strengths.

Close Tolerance Bolts

This type of bolt is machined more accurately than the general purpose bolt. Close tolerance bolts may be hex headed (AN-173 through AN-186) or have a 100° countersunk head (NAS-80 through NAS-86). They are used in applications where a tight drive fit is required. (The bolt will move into position only when struck with a 12- to 14-ounce hammer.)

Internal Wrenching Bolts

These bolts, (MS-20004 through MS-20024 or NAS-495) are fabricated from high-strength steel and are suitable for use in both tension and shear applications. When they are used in steel parts, the bolt hole must be slightly countersunk to seat the large corner radius of the shank at the head. In Dural material, a special heat- treated washer must be used to provide an adequate bearing surface for the head. The head of the internal wrenching bolt is recessed to allow the insertion of an internal wrench when installing or removing the bolt. Special high-strength nuts are used on these bolts. Replace an internal wrenching bolt with another internal wrenching bolt. Standard AN hex head bolts and washers cannot be substituted for them as they do not have the required strength.

Identification And Coding

Bolts are manufactured in many shapes and varieties. A clear-cut method of classification is difficult. Bolts can be identified by the shape of the head, method of securing, material used in fabrication, or the expected usage. AN-type aircraft bolts can be identified by the code markings on the bolt heads. The markings generally denote the bolt manufacturer, the material of which the bolt is made, and whether the bolt is a standard AN-type or a special purpose bolt. AN standard steel bolts are marked with either a raised dash or asterisk; corrosion resistant steel is indicated by a single raised dash; and AN aluminum alloy bolts are marked with two raised dashes.

Additional information, such as bolt diameter, bolt length, and grip length may be obtained from the bolt part number. For example, in the bolt part number AN3DD5A, the "AN" designates that it is an Air Force-Navy Standard bolt, the "3" indicates the diameter in sixteenths of an inch (3⁄16), the "DD" indicates the material is 2024 aluminum alloy. The letter "C" in place of the "DD" would indicate corrosion resistant steel, and the absence of the letters would indicate cadmium plated steel. The "5" indicates the length in eighths of an inch (5⁄8), and the "A" indicates that the shank is undrilled. If the letter "H" preceded the "5" in addition to the "A" following it, the head would be drilled for safetying. Close tolerance NAS bolts are marked with either a raised or recessed triangle. The material markings for NAS bolts are the same as for AN bolts, except that they may be either raised or recessed. Bolts inspected magnetically (Magna flux) or by florescent means (Zyglo) are identified by means of colored lacquer, or a head marking of a distinctive type.

SPECIAL-PURPOSE BOLTS

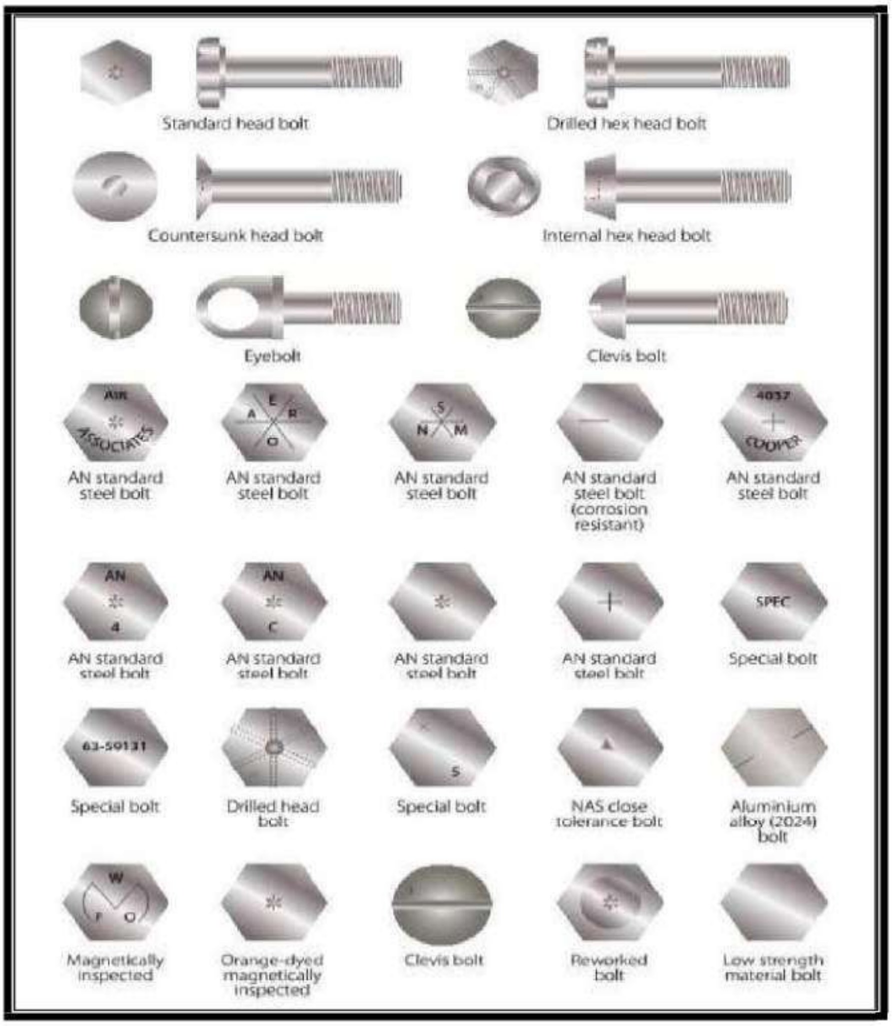
Bolts designed for a particular application or uses are classified as special-purpose bolts. Clevis bolts, eyebolts, Jo-bolts, and lock bolts are special-purpose bolts.

Clevis Bolts

The head of a clevis bolt is round and is either slotted to receive a common screwdriver or recessed to receive a cross point screwdriver. This type of bolt is used only where shear loads occur and never in tension. It is often inserted as a mechanical pin in a control system.

Eyebolt

This type of special purpose bolt is used where external tension loads are to be applied. The eyebolt is designed for the attachment of such devices as the fork of a turnbuckle, a clevis, or a cable shackle. The threaded end may or may not be drilled for safe tying.



Jo-Bolt

Jo-bolt is a trade name for an internally threaded three piece rivet. The Jo-bolt consists of three parts — a threaded steel alloy bolt, a threaded steel nut, and an expandable stainless steel sleeve. The parts are factory preassembled. As the Jo-bolt is installed, the bolt is turned while the nut is held. This causes the sleeve to expand over the end of the nut, forming the blind head and clamping against the work. When driving is complete, a portion of the bolt breaks off. The high shear and tensile strength of the Jo-bolt makes it suitable for use in cases of high stresses where some of the other blind fasteners would not be practical. Jo-bolts are often a part of the permanent structure of late model aircraft. They are used in areas which are not often subjected to replacement or servicing. (Because it is a three-part fastener, it should not be used where any part, in becoming loose, could be drawn into the engine air intake.) Other advantages of using Jo-bolts are their excellent resistance to vibration, weight saving, and fast installation by one person. Presently, Jo-bolts are available in four diameters: The 200 series, approximately 3⁄16 inch in diameter; the 260 series, approximately 1⁄4 inch in diameter; the 312 series, approximately 5⁄16 inch in diameter; and the 375 series, approximately 3⁄8 inch in diameter. Jo-bolts are available in three head styles which are: F (flash), P (hex head), and FA (flush millable).

Lock bolts

Lock bolts are used to attach two materials permanently. They are lightweight and are equal in strength to standard bolts. Lock bolts are manufactured by several companies and conform to Military

Standards. Military Standards specify the size of a lock bolt's head in relation to the shank diameter, plus the alloy used in its construction. The only drawback to lock bolt installations is that they are not easily removable compared to nuts and bolts. The lock bolt combines the features of a high-strength bolt and rivet, but it has advantages over both. The lock bolt is generally used in wing splice fittings, landing gear fittings, fuel cell fittings, longerons, beams, skin splice plates, and other major structural attachments. It is more easily and quickly installed than the conventional rivet or bolt and eliminates the use of lock washers, cotter pins, and special nuts. Like the rivet, the lock bolt requires a pneumatic hammer or "pull gun" for installation; when installed, it is rigidly and permanently locked in place.

Three types of lock bolts are commonly used: the pull type, the stump type, and the blind type.

Pull type: Pull-type lock bolts are used mainly in aircraft primary and secondary structures. They are installed very rapidly and have approximately one-half the weight of equivalent AN steel bolts and nuts. A special pneumatic "pull gun" is required to install this type of lock bolt. Installation can be accomplished by one person since bucking is not required.

Stump type: Stump-type lock bolts, although they do not have the extended stem with pull grooves, are companion fasteners to pull- type lock bolts. They are used primarily where clearance will not permit installation of the pull-type lock bolt. A standard pneumatic riveting hammer (with a hammer set attached for swaging the collar into the pin locking grooves) and a bucking bar are tools necessary for the installation of stump-type lock bolts.

Blind type: Blind-type lock bolts come as complete units or assemblies. They have exceptional strength and sheet pull-together characteristics. Blind lock bolts are used where only one side of the work is accessible and, generally, where it is difficult to drive a conventional rivet. This type of lock bolt is installed in the same manner as the pull-type lock bolt. Common features: Common features of the three types of lock bolts are the annular locking grooves on the pin and the locking collar which is swaged into the pin's lock grooves to lock the pin in tension. The pins of the pull- and blind-type lock bolts are extended for pull installation. The extension is provided with pulling grooves and a tension break off groove.

Composition: The pins of pull- and stump-type lock bolts are made of heat-treated alloy steel or high strength aluminum alloy. Companion collars are made of aluminum alloy or mild steel. The blind lock bolt consists of a heat-treated alloy steel pin, blind sleeve and filer sleeve, mild steel collar, and carbon steel washer.

Substitution: Alloy steel lock bolts may be used to replace steel high-shear rivets, solid steel rivets, or AN bolts of the same diameter and head type. Aluminum alloy lock bolts may be used to replace solid aluminum alloy rivets of the same diameter and head type. Steel and aluminum alloy lock bolts may also be used to replace steel and 2024T aluminum alloy bolts, respectively, of the same diameter. Blind lock bolts may be used to replace solid aluminum alloy rivets, stainless steel rivets, or all blind rivets of the same diameter.

Numbering system:

The numbering systems for the various types of lock bolts are explained by the break outs in Figure below.
Grip Range: To determine the bolt grip range required for any application, measure the thickness of the materials with a hook scale inserted through the hole. Once this measurement is determined, select the correct grip range by referring to the charts provided by the rivet manufacturer. Examples of grip range charts are shown in Figures below.

Pull-and stump-type lock bolt grip ranges

¼-inch Diameter			5/16-inch Diameter		
Grip No.	Grip Range		Grip No.	Grip Range	
	Min.	Max.		Min.	Max.
1	.031	.094	2	.094	.156
2	.094	.156	3	.156	.219
3	.156	.219	4	.219	.281
4	.219	.281	5	.281	.344
5	.281	.344	6	.344	.406
6	.344	.406	7	.406	.469
7	.406	.469	8	.469	.531
8	.469	.531	9	.531	.594
9	.531	.594	10	.594	.656
10	.594	.656	11	.656	.718
11	.656	.718	12	.718	.781
12	.718	.781	13	.781	.843
13	.781	.843	14	.843	.906
14	.843	.906	15	.906	.968
15	.906	.968	16	.968	1.031
16	.968	1.031	17	1.031	1.094
17	1.031	1.094	18	1.094	1.156
18	1.094	1.156	19	1.156	1.219
19	1.156	1.219	20	1.219	1.281
20	1.219	1.281	21	1.281	1.343
21	1.281	1.343	22	1.343	1.406
22	1.344	1.406	23	1.406	1.469
23	1.406	1.469	24	1.460	1.531
24	1.469	1.531			
25	1.531	1.594			

Blind-type lockbolt grip ranges.

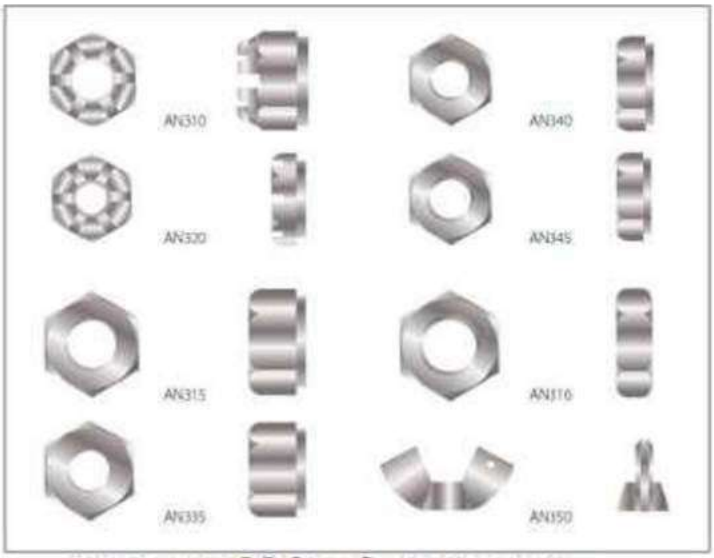
NUTS

Aircraft nuts are made in a variety of shapes and sizes. They are made of cadmium plated carbon steel, stainless steel, or anodized 2024T aluminum alloy, and may be obtained with either right- or left-hand threads. No identifying marking or lettering appears on nuts. They can be identified only by the characteristic metallic luster or color of the aluminum, brass, or the insert when the nut is of the self-locking type. They can be further identified by their construction. Aircraft nuts can be divided into two general groups: Non-self-locking and self-locking nuts. Non-self-locking nuts are those that must be safe-tied by external locking devices, such as cotter pins, safety wire, or locknuts. Self-locking nuts contain the locking feature as an integral part.

Non-Self-Locking Nuts:

Most of the familiar types of nuts, including the plain nut, the castle nut, the castellated shear nut, the plain hex nut, the light hex nut, and the plain check nut are the non-self-locking type. The castle nut, AN310, is used with drilled shank AN hex head bolts, clevis bolts, eyebolts, drilled head bolts, or studs. It is fairly rugged and can withstand large tensional loads. Slots (called castellations) in the nut are designed to accommodate a cotter pin or locking wire for safety. The castellated shear nut, AN320, is designed for use with devices (such as drilled clevis bolts and threaded taper pins) which are normally subjected to shearing stress only. Like the castle nut, it is castellated for safe tying. Note, however, that the nut is not as deep or as strong as the castle nut; also that the castellations are not as deep as those in the castle nut.
The plain hex nut, AN315 and AN335 (fie and coarse thread), is of rugged construction. This makes it suitable for carrying large tensional loads. However, since it requires an auxiliary locking device, such as a check nut or lock washer, its use on aircraft structures is somewhat limited. The light hex nut,

AN340 and AN345 (fie and coarse thread), is a much lighter nut than the plain hex nut and must be locked by an auxiliary device. It is used for miscellaneous light tension requirements.
The plain check nut, AN316, is employed as a locking device for plain nuts, set screws, threaded rod ends, and other devices. The wing nut, AN350, is intended for use where the desired tightness can be obtained with the fingers and where the assembly is frequently removed.



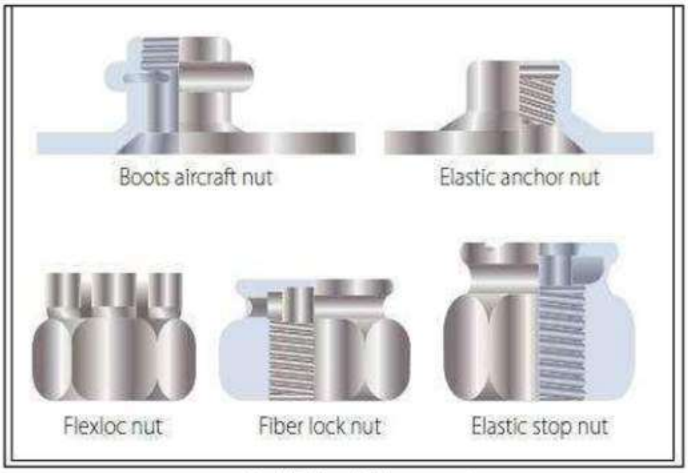
Non-self-locking nuts.

Self Locking Nuts

As their name implies, self-locking nuts need no auxiliary means of safe tying but have a safe tying feature included as an integral part of their construction. Many types of self-locking nuts have been designed and their use has become quite widespread. Common applications are:
(1) attachment of antifriction bearings and control pulleys;
(2) attachment of accessories, anchor nuts around inspection holes and small tank installation openings; and
(3) attachment of rocker box covers and exhaust stacks.

Self-locking nuts are acceptable for use on certificated aircraft subject to the restrictions of the manufacturer. Self-locking nuts are used on aircraft to provide tight connections which will not shake loose under severe vibration. Do not use self-locking nuts at joints which subject either the nut or bolt to rotation. They may be used with antifriction bearings and control pulleys, provided the inner race of the bearing is clamped to the supporting structure by the nut and bolt. Plates must be attached to the structure in a positive manner to eliminate rotation or misalignment when tightening the bolts or screws.

The two general types of self-locking nuts currently in use are the all-metal type and the fiber lock type. For the sake of simplicity, only three typical kinds of self-locking nuts are considered in this handbook: the Boots self-locking and the stainless steel self-locking nuts, representing the all-metal types; and the elastic stop nut, representing the fiber insert type.



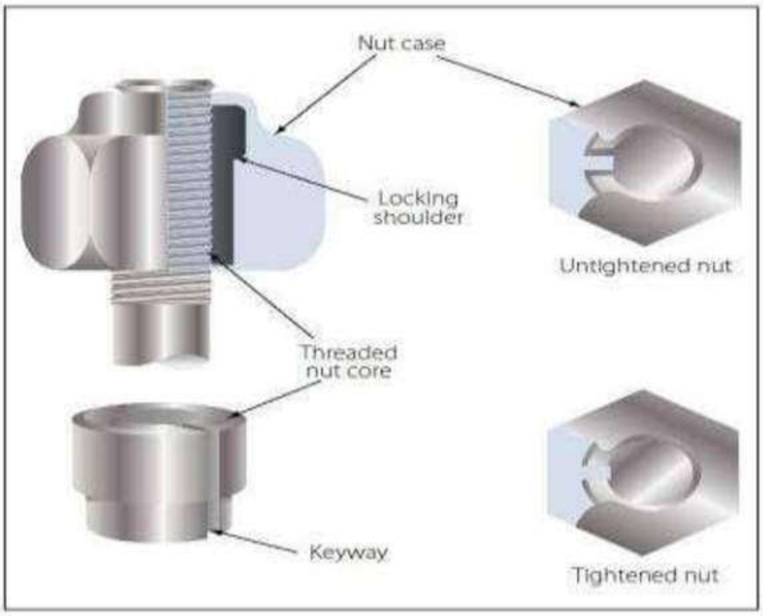
Self-locking nuts

Boots Self-Locking Nut

The Boots self-locking nut is of one piece, all-metal construction, designed to hold tight in spite of severe vibration. Note in Figure that it has two sections and is essentially two nuts in one, a locking nut and a load-carrying nut. The two sections are connected with a spring which is an integral part of the nut. The spring keeps the locking and load-carrying sections such a distance apart that the two sets of threads are out of phase; that is, so spaced that a bolt which has been screwed through the load carrying section must push the locking section outward against the force of the spring to engage the threads of the locking section properly. Thus, the spring, through the medium of the locking section, exerts a constant locking force on the bolt in the same direction as a force that would tighten the nut. In this nut, the load-carrying section has the thread strength of a standard nut of comparable size, while the locking section presses against the threads of the bolt and locks the nut firmly in position. Only a wrench applied to the nut will loosen it. The nut can be removed and reused without impairing its efficiency. Boots self-locking nuts are made with three different spring styles and in various shapes and sizes. The wing type, which is the most common, ranges in size from No. 6 up to 1⁄4 inch, the Rol-top ranges from 1⁄4 inch to 1⁄6 inch, and the bellows type ranges in size from No. 8 up to 3⁄8 inch. Wing-type nuts are made of anodized aluminum alloy, cadmium-plated carbon steel, or stainless steel. The Rol-top nut is cadmium-plated steel, and the bellows type is made of aluminum alloy only.

Stainless Steel Self-Locking Nut

The stainless steel self-locking nut may be spun on and off with the fingers, as its locking action takes place only when the nut is seated against a solid surface and tightened. The nut consists of two parts: a case with a beveled locking shoulder and key, and a threaded insert with a locking shoulder and slotted keyway. Until the nut is tightened, it spins on the bolt easily because the threaded insert is the proper size for the bolt. However, when the nut is seated against a solid surface and tightened, the locking shoulder of the insert is pulled downward and wedged against the locking shoulder of the case. This action compresses the threaded insert and causes it to clench the bolt tightly. The cross-sectional view in Figure 5-27 shows how the key of the case fits into the slotted keyway of the insert so that when the case is turned, the threaded insert is turned with it. Note that the slot is wider than the key. This permits the slot to be narrowed and the insert to be compressed when the nut is tightened.



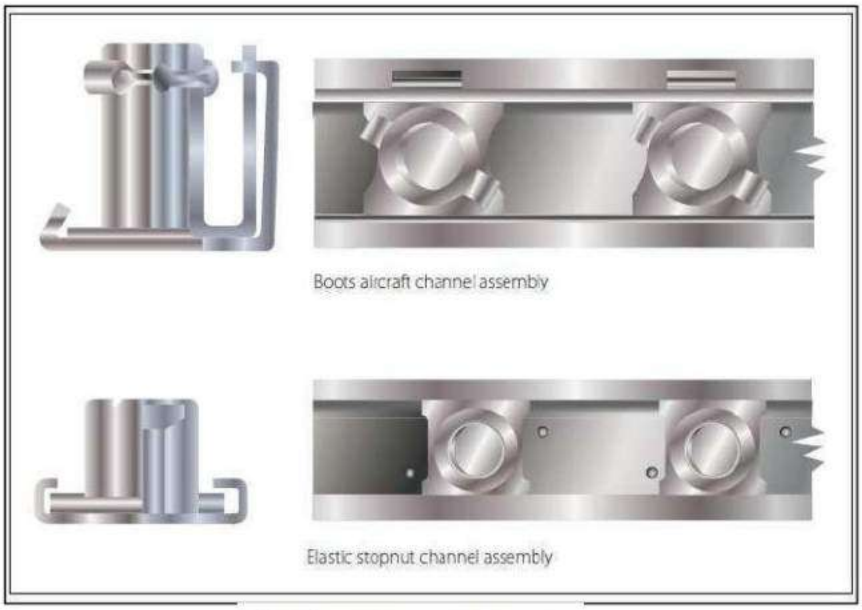
Stainless steel self-locking nut.

Elastic Stop Nut

The elastic stop nut is a standard nut with the height increased to accommodate a fiber locking collar. This fiber collar is very tough and durable and is unaffected by immersion in hot or cold water or ordinary solvents, such as ether, carbon tetrachloride, oils, and gasoline. It will not damage bolt threads or plating. As shown in Figure, the fiber locking collar is not threaded and its inside diameter is smaller than the largest diameter of the threaded portion or the outside diameter of a corresponding bolt. When the nut is screwed onto a bolt, it acts as an ordinary nut until the bolt reaches the fiber collar. When the bolt is screwed into the fiber collar, however, friction (or drag) causes the fiber to be pushed upward. This creates a heavy downward pressure on the load carrying part and automatically throws the load carrying sides of the nut and bolt threads into positive contact. After the bolt has been forced all the way through the fiber collar, the downward pressure remains constant. This pressure locks and holds the nut securely in place even under severe vibration. Nearly all elastic stop nuts are steel or aluminum alloy. However, such nuts are available in practically any kind of metal. Aluminum alloy elastic stop nuts are supplied with an anodized finish. Steel nuts are cadmium plated. Normally, elastic stop nuts can be used many times with complete safety and without detriment to their locking efficiency. When reusing elastic stop nuts, be sure the fiber has not lost its locking friction or become brittle. If a nut can be turned with the fingers, replace it. After the nut has been tightened, make sure the rounded or chamfered end of the bolts, studs, or screws extends at least the full round or chamfer through the nut. Flat end bolts, studs, or screws should extend at least 1⁄32 inch through the nut. Bolts of 5⁄16-inch diameter and over with cotter pin holes may be used with self-locking nuts, but only if free from burrs around the holes. Bolts with damaged threads and rough ends are not acceptable. Do not tap the fiber locking insert. The self-locking action of the elastic stop nut is, the result of having the bolt threads impress themselves into the untapped fiber. Do not install elastic stop nuts in places where the temperature is higher than 250 °F, because the effectiveness of the self-locking action is reduced beyond this point. Self-locking nuts may be used on aircraft engines and accessories when their use is specified by the engine manufacturer.

Elastic Stop Nut

Self-locking nut bases are made in a number of forms and materials for riveting and welding to aircraft structure or parts. Certain applications require the installation of self-locking nuts in channels, an arrangement which permits the attachment of many nuts with only a few rivets. These channels are track-like bases with regularly spaced nuts which are removable or non- removable. The removable type carries a floating nut, which can be snapped in or out of the channel, thus making possible the easy removal of damaged nuts. Nuts, such as the clinch-type and spline type, which depend on friction for their anchorage, are not acceptable for use in aircraft structures.



Self-locking nut bases.

Sheet Spring Nuts

Sheet spring nuts, such as speed nuts, are used with standard and sheet metal self-tapping screws in nonstructural locations. They find various uses in supporting line clamps, conduit clamps, electrical equipment, access doors, and the like, and are available in several types. Speed nuts are made from spring steel and are arched prior to tightening. This arched spring lock prevents the screw from working loose. These nuts should be used only where originally used in the fabrication of the aircraft.

Internal and External Wrenching Nuts

Two commercial types of high strength internal or external wrenching nuts are available; they are the internal and external wrenching elastic stop nut and the Unbrako internal and external wrenching nut. Both are of the self-locking type, are heat treated, and are capable of carrying high strength bolt tension loads.

Identification and Coding

Part numbers designate the type of nut. The common types and their respective part numbers are: Plain, AN315 and AN335; castle AN310; plain check, AN316; light hex, AN340 and AN345; and castellated shear, AN320. The patented self-locking types are assigned part numbers ranging from MS20363 through MS20367. The Boots, the Flex loc, the fiber locknut, the elastic stop nut, and the self-locking nut belong to this group. Part number AN350 is assigned to the wing nut.

Letters and digits following the part number indicate such items as material, size, threads per inch, and whether the thread is right or left hand. The letter "B" following the part number indicates the nut material to be brass, a "D" indicates 2017-T aluminum alloy, a "DD" indicates 2024-T aluminum alloy, a "C" indicates stainless steel, and a dash in place of a letter indicates cadmium-plated carbon steel.

The digit (or two digits) following the dash or the material code letter is the dash number of the nut, and it indicates the size of the shank and threads per inch of the bolt on which the nut will fit. The dash number corresponds to the first figure appearing in the part number coding of general purpose bolts. A dash and the number 3, for example, indicates that the nut will fit an AN3 bolt (10-32); a dash and the number 4 means it will fit an AN4 bolt (1/4-28); a dash and the number 5, an AN5 bolt (5/16-24); and so on. The code numbers for self-locking nuts end in three or four digit numbers.

The last two digits refer to threads per inch, and the one or two preceding digits stand for the nut size in 16ths of an inch.

Some other common nuts and their code numbers are:

Code Number AN310D5R:
AN310 = aircraft castle nut
D = 2024-T aluminum alloy "D" indicates 2017-T aluminum alloy,
5 = 5⁄16 inch diameter
R = right-hand thread (usually 24 threads per inch)

Code Number AN320-10:
AN320 = aircraft castellated shear nut, cadmium- plated carbon steel
10 = 5⁄8 inch diameter, 18 threads per inch
(this nut is usually right-hand thread)

Code Number AN350B1032:
AN350 = aircraft wing nut B = brass
10 = number 10 bolt 32 = threads per inch

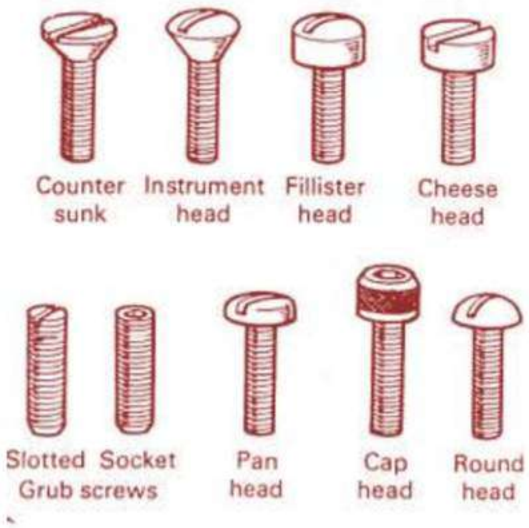
SCREWS

Screws are, probably, the most commonly used threaded fastener in aircraft construction. They differ from bolts in that they are generally made from lower strength materials. They can be fastened by a variety of tools, including screwdrivers, spanners and

Allen keys. Most screws are threaded along their complete length, whilst some have a plain portion for part of their length. There are a number of different types of screw, which, can be used for a wide range of tasks. It is common sense that great care must be taken to replace screws with the correct items, by using the markings on the screw, the IPC and any other systems in current use within the supply department, to protect against incorrect screws being installed. Another point, requiring care, is the difference in terminology between the British and American names for screw heads. What the British refer to as a 'countersunk headed' screw, the Americans call a 'flat-head' or 'flush' screw. Similarly, 'mushroom-headed' screws are known as 'truss-heads' in the USA.

Machine Screws

Machine screws are used extensively for attaching fairings, inspection plates, fluid line clamps and other light structural parts. The main difference between aircraft bolts and machine screws, is that the threads of a machine screw usually run the length of the shank, whereas bolts usually have an unthreaded grip length. The most common machine screw used in aviation is the fillister-head screw, which can be wire-locked using the drilled hole in the head. The flat-head (countersunk-head) screw is available with single or cross-point slotted heads. The round-head screw and the truss-head (mushroom-head) screw, provide good holding properties on thin metal sheets.



A Selection of Machine Screws

The commonly used machine screws are the flush-head, round- head, fillister-head, socket- head, pan-head and truss-head types.

- Flush-Head - Flush-head machine screws are used in countersunk holes where a flush finish is desired. These screws are available in 82 and 100 degrees of head angle, and have various types of recesses and slots for driving.
- Round-Head - Round-head machine screws are frequently used in assembling highly stressed

aircraft components.

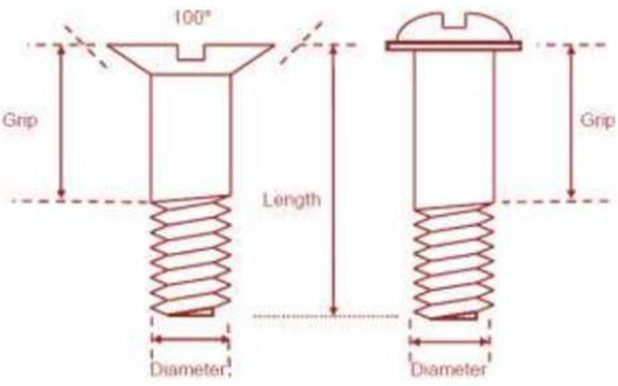
• Fillister-Head - Fillister-head machine screws are used as general-purpose screws. They may also be used as cap screws in light applications such as the attachment of cast aluminum gearbox cover plates.

• Socket-Head - Socket-head machine screws are designed to be screwed into tapped holes by internal wrenching. They are used in applications that require high-strength precision products, compactness of the assembled parts, or sinking of the head into holes.

• Pan- and Truss-Head (AN526) - Pan-head and truss- head screws are general-purpose screws used where head height is unimportant. These screws are available with cross-recessed heads only.

STRUCTURAL SCREWS

Structural screws are made of alloy steel, are heat-treated and can be used in many structural situations. They have a definite grip and the same shear strength as a bolt of the same size. They are available with fillister, flat or washer heads. The washer head screw has a washer formed into its head to increase its holding ability with thin materials, much like the truss or mushroom head.

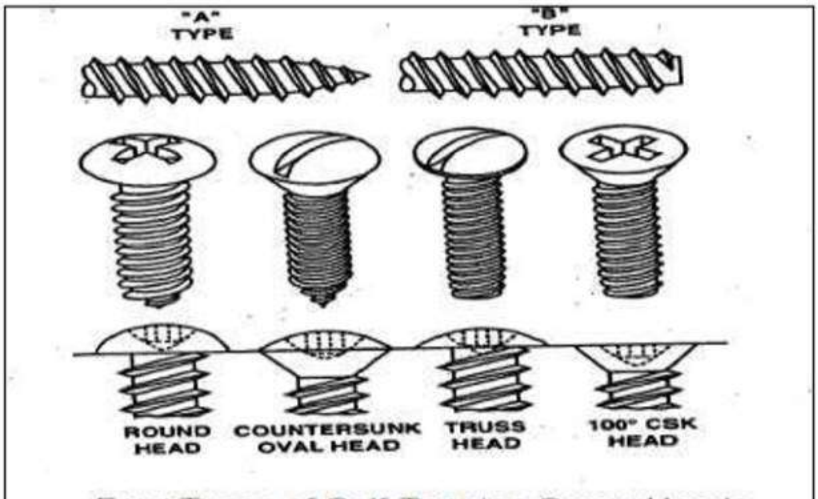


Structural Screw Terminology

SELF-TAPPING SCREWS

Self-tapping screws (refer to Fig. 51) have coarse threads and are used to hold thin sheets of metal, plastic and plywood together. The type A screw has a gimlet (sharp) point, and the type B has a blunt point with threads that are slightly finer than the type A. There are four types of head in normal use:

- round head
- countersunk oval-head
- truss or mushroom-head
- flat countersunk-head.

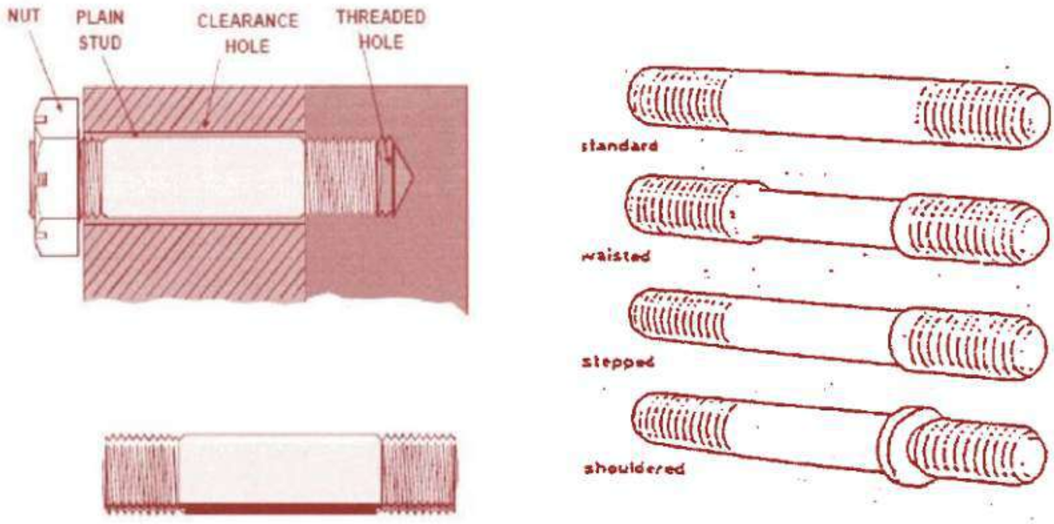


Four Types of Self-Tapping Screw Heads

STUDS

General

Studs are metal rods which are threaded at each end. They are used, where it is not desirable or possible to drill through both components for the fitting of bolts. One end of the stud is screwed, to the full extent of the thread, into a tapped hole in one component- the 'fast' end; a second component is placed onto the exposed plain portion of the stud and clamped by a nut. They also provide a means of alignment control, particularly when they are irregularly spaced.



Typical Studs

Standard Studs

By far the most widely used stud is the standard (plain, or parallel) type, in which the diameter of the whole stud, along its length, is constant. Standard studs are classified by the thread type, diameter and overall length. The 'metal' thread is, usually, finished very slightly oversize to give a tight fit into the tapped hole. Other variants of the standard stud are available for use in circumstances that require special consideration. To meet special requirements, the various types of standard studs may also be supplied with non standard lengths of plain portion and 'metal' end. A simple method of fitting and removing a stud is by running two plain nuts down the 'nut' end of the stud and cinching (locking) them together using two spanners. The stud can then be screwed into or removed from the material. Breaking the cinch then separating and removing the nuts completes the operation.

These are supplied in the following sizes: 3/16, 1/4, 5/16 and 3/8 UNF. The plain portion is the same diameter as the major diameter of the thread and the length is indicated by the part number. The lengths of the threaded portions are dictated by the specification.

Waisted Studs

Waisted studs are used where reduction of weight, without the loss of strength, is of paramount importance. The diameter of the plain portion of the stud is reduced to the minor diameter of the end threads, thus lightening the stud without impairing its effective strength.

Stepped Studs

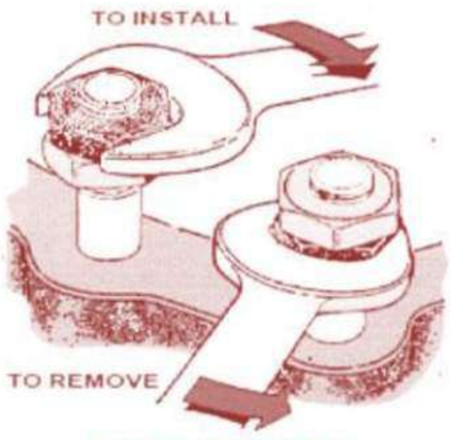
This type affords a stronger anchorage than the standard type, if the 'metal' end of the stud has to be housed in soft metal. The thread of the 'metal' end is one size larger than that of the 'nut' end. For example, a ¼ inch BSF stepped stud has a plain portion of ¼ inch thread on the 'nut' end and a 3/16-inch thread on the 'metal' end. Stepped studs are also used as replacements for standard studs when the tapped stud-hole has to be re-drilled and tapped with a larger thread, due to damage.

Shouldered Studs

This type is used where maximum rigidity of assembly is of prime importance. The stud is machined from oversize bar and a projecting shoulder is left between the 'metal' end of the thread and the normal diameter plain portion. This shoulder seats firmly on the surface of the 'metal' and gives additional resistance to sideways stresses. The clearance hole in the second component, through which the 'nut' end and plain portion of the stud passes, must be machined at the inner end to give clearance to the stud shoulder Insertion and Removal of Studs Stud Replacement. A stud must be a good fit and should remain in position when the nut is removed. Studs that are damaged or loose are to be removed and new ones fitted. There are a number of accepted methods of stud replacement; some of the more common ones are detailed in the following.
Note: If an anti-seize or locking compound is specified this must be applied prior to replacement and in accordance with the manufacturer's instructions.

Locknuts

Two plain nuts are screwed onto the top thread and locked against each other, the lower nut being held by a spanner whilst the upper nut is tightened down onto it. The complete assembly is screwed in using the top nut. When the stud is finally screwed down into position both locknuts are removed and discarded. For removal, the two nuts are locked in the same way and the lower one turned to loosen the stud.



LOCKNUTS METHOD

Thread Inserts

Thread inserts are a means of providing a stronger anchorage, for bolts, screws or studs, in the comparatively softer metal alloys (aluminium, magnesium, bronze), wood, plastics or composite materials. They may also be used when it is necessary to do a repair to a threaded hole that has suffered damage. There are two basic types of thread insert (Wire and Thin Wall), but the designs of each type will vary according to the many manufacturers or to the environment in which the fastener must operate.

Wire Thread Inserts

Wire thread inserts consist of a very accurately formed helical coil of wire, which has a diamond (rather than a round) cross- section and is usually made from corrosion-resistant steel or heat-resistant nickel alloy. Specifically sized drills, taps and thread gauges (provided by the insert manufacturer) are required to form the tapped holes for the inserts and another special tool is necessary to insert the wire coils correctly into their prepared holes.

Thin Wall Inserts

Thin wall inserts appear in a variety of designs, materials and surface finishes and consist of a thin tube, which is threaded internally and may, or may not, be threaded externally. Similarly, special tools are required from the manufacturer to prepare the holes for the inserts and various methods are adopted to secure each particular type of thin wall insert into its hole. Thin Wall inserts include:

• Key-Locked Inserts: Key-Locked inserts are threaded both internally and externally and, after being screwed into the prepared hole, are (as their name implies), locked into their holes by tiny wedges or keys. The keys are then pressed (or hammered) into place between the insert and the wall of the hole.

• Swaged Inserts: Swaged inserts are also threaded internally and externally and are, again, screwed into the hole before a tool is used to deform (swage) the insert so that it is locked into the hole.

• Ring-Locked Inserts: Ring-Locked inserts, with internal and external threads, are screwed into holes which are counter bored, to allow a special lock-ring to be installed, (after the insert) and yet another special tool is used to complete the locking action of the lock-ring.

• Bonded Inserts: Bonded inserts are, usually, only internally threaded (to hold the bolt, screw, stud etc) and are secured in the prepared hole by the use of adhesives.

Obviously, from this information, it can be seen that great care must be taken to ensure that only the approved types of inserts are used in aerospace components and that the procedures for their installation and removal (laid out in the relevant Manuals) are carefully followed.

DOWELS

While not usually used as fasteners, dowels are rods or pins of the appropriate material which are fixed (often permanently) in one of the components of a joint such that the protruding shank of the dowel locates with a corresponding hole in the item being attached, thus ensuring accurate assembly. Two examples of the use of dowels may be found where a Propeller Control Unit is attached to an engine casing and there is a requirement for absolute accuracy in the alignment of the oil tubes and, again, where the segments of an engine compressor need to be joined with precision so that the rotating members do not foul the stationary parts.

Locking Devices

The problems associated with threaded devices, and the effects of vibration on their security, were discussed previously, when the use of stiff nuts and anchor nuts was considered. In addition to using methods which increase the friction between threads, there are several other ways in which the integrity of a threaded joint can be assured.

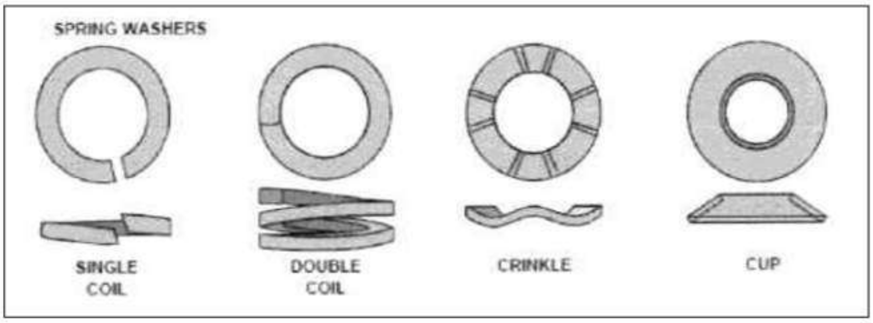
SPRING WASHERS

These washers are available in a variety of forms. In some instances (particularly with light alloy assemblies), spring washers are assembled with plain facing washers between the spring washer and the component. This is done to prevent damage to the surface finish when the spring washer is compressed although, with steel assemblies, the plain washer is usually omitted. It is good practice to renew spring washers during overhaul or repair. This procedure is most essential in engines and engine components as well as where units have reciprocating parts; such as in compressors or pumps. In normal circumstances, however, spring washers can be re-used if they have retained their 'springiness' and 'sharpness'. Types of spring washers include: •

Single and Double Coil Washers: Manufactured from rectangular-sectioned steel sheet and formed into a portion of a helix, the single and double coil are the most common types of spring washer to be found on aircraft components.

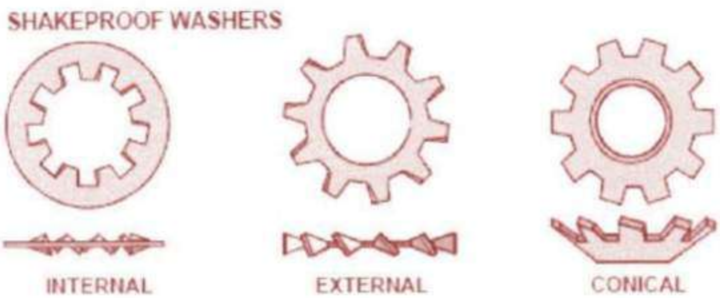
Crinkle Washers: Crinkle washers are usually manufactured from either copper alloy or corrosion-resistant steel. They are often used in lightly loaded applications such as instruments and electrical installations.

Cup Washers: Cup (or Belleville) washers are manufactured from spring steel and are 'dished' to form a spring of high rating. The flattening of the washer, during tightening, exerts an axial load to the nut, which will resist any tendency of the nut to lose torque. Assembly should always be in accordance with the manufacturer's instructions.



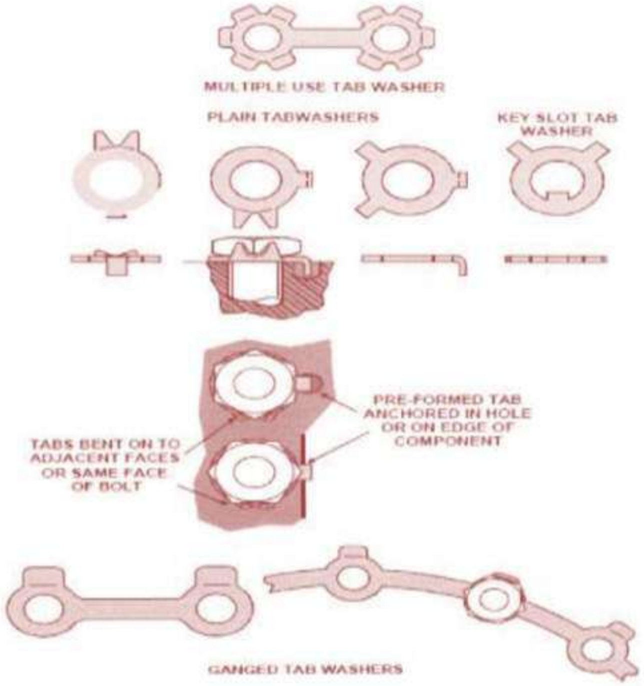
Shake proof Washers : Flat washers of this type, made of steel or phosphor bronze, are sometimes used instead of spring washers and in certain circumstances, conical shake proof washers are used for locking countersunk screws. Either the internal diameter or external diameter is serrated, the serrations being set to bite into the component and nut to prevent rotation. Shake proof washers should only be used once.

Note: These washers will not normally be specified in assemblies where anti-corrosion treatment of components has been carried out.



Tab Washers

Tab washers, are normally used on plain nuts. The washers are manufactured from thin metallic sheet material and have two or more tabs projecting from the external diameter. They can also be designed for locking two or more nuts. When the washer is installed, one tab is bent against the component or inserted into a hole provided, whilst a second tab is bent against the flat (or flats), of the nut, after it has been torqued down correctly. Note: Multi-tab washers can be re-used until all tabs have been used once.



Tab washers are manufactured from thin metallic sheet materials, to standard or proprietary specifications, and have one or more tabs projecting from the external diameter; they may also be ganged for locking two or more nuts. When the washer is fitted, one tab (usually pre-formed) is anchored against the component or fitted into a hole provided for that purpose, whilst another tab (or tabs) is bent against a flat or flats of the nut, after the nut has been correctly torqued.

The component tab should not be bent against a curved surface or across the junction of two faces, since this would permit movement of the nut or bolt. Before bending the second tab, an examination should be made of the tab already fixed to ensure that it is not disturbed, sheared or distorted as a result of the washer turning with the nut. When the second tab has been bent, this too should be examined for cracks.

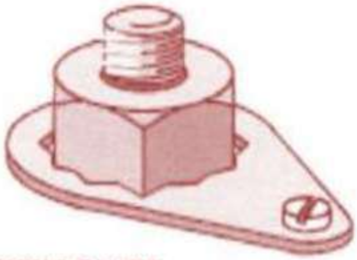
In some assemblies, washers having a tab projecting from the inside diameter is used. The tab fits into a key slot machined in the male thread, whilst an external tab is bent up against the nut flat to lock it. Tabs must not be bent more than once. Multiple tab washers may be reused after removing the used tab, dressing sharp edges, and carefully inspecting the remaining tabs for cracks or scoring

Lock Plates

In certain circumstances, the torque applied, the thread, or the type of nut, being used may not guarantee that the nut would not un wind in use (such as during vibration). Lock plates(refer to Fig. 59) are used where positive retention of a nut is required.

The nut is torque loaded and then (only if necessary) turned a small amount, (< 1/12 revolution) until its flats align with the hole in the lock plate. The plate usually has 12 facets to allow for this adjustment. The plate is then placed over the nut and the small setscrew fastened into the tapped hole adjacent to the nut. Removal of the nut simply involves removing the setscrew, lifting off the plate and unwinding the nut.

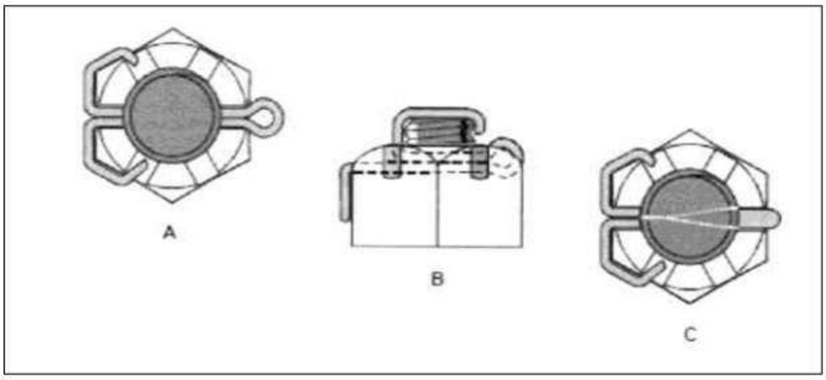
Note: A Tab washer could be used to do the same task. The lock plate is used where the nut is frequently removed – the plate can be used indefinitely providing it retains a good fit with the nut.



LOCKING PLATE

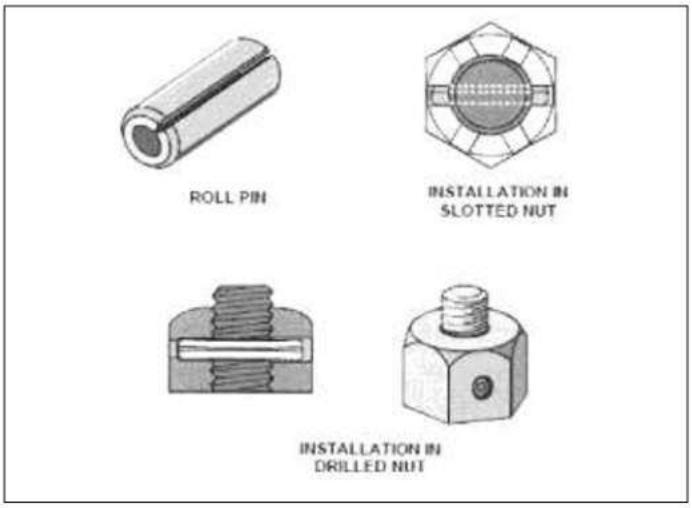
Split (Cotter) Pins

These pins are usually manufactured from either cadmium plated carbon steel or from corrosion-resistant steel. Their primary purpose is to lock slotted and castellated nuts as well as for securing clevis pins. The nuts are locked onto their bolts by passing the pin through the hole in the bolt and the nut castellations. The legs of the pin are spread in one of two methods. Whilst either of these methods will secure the nut to the bolt, different airworthiness authorities prefer one method to the other. The pins are measured by diameter and length. It must be noted that the nuts must never be over-torqued to get the holes into line. The nut must either be backed-off, if this is permitted, or washers added under the nut. Often a stated torque value will be over a small range rather than a set figure. This allows very small movement of the nut to facilitate alignment of the locking pins. Details of the correct method for each task will be in the AMM.



Roll pins

The Roll pin (or spring pin) is a pressed-fit parallel pin with chamfered ends. It is tubular in shape and is slotted the full length of the tube. The pin is inserted with hand tools and is compressed as it is driven into place. Pressure exerted by the roll pin against the hole walls keeps it in place, until deliberately removed with a Pin Punch. It may be used with a drilled bolt and slotted or castellated nut or with a nut drilled for the purpose. Roll pins must be used only once.



WIRE LOCKING GENERAL

Wire Locking (also known as Lock Wiring and Safety Wiring) is one of the most commonly used methods of preventing threaded

- The locking wire should be taut and there should be no untwisted lengths in excess of 3/8 in. and lengths of unsupported wire should not exceed 3inches.
- The lay of the wire should always be such as to resist any tendency of the locked parts to come loose.
- The angle of approach of the wire should not be less than 45° to the rotational axis of the component to be locked. The line of approach should be tangential to the parts being locked.
- Finish each run of locking wire with approximately five complete twists of wire, cut and double back to avoid fouling and injury to personnel.
- When locking tabs are used, they should be fitted in such a way that the tabs and the wire are in complete alignment.
- Locking wire is used only once.
- Sometimes controls or switches are wire locked into their normal operating position using thin copper wire. Selection of an emergency position necessitates physically breaking the wire.
- The wire must be adequately tensioned; over-tensioning may

Elements from loosening. Corrosion resisting steel and heat resisting nickel alloy are the materials normally recommended for locking wire. Care should be taken to ensure that the wire used is to the correct specification. Attention should be paid to the following when using locking wire:

- Use wire of the correct specification and gauge.
- The wires must be twisted together so that each wire is twisted around the other.

Lead to fracture of the wire, or of the metal around the locking hole.

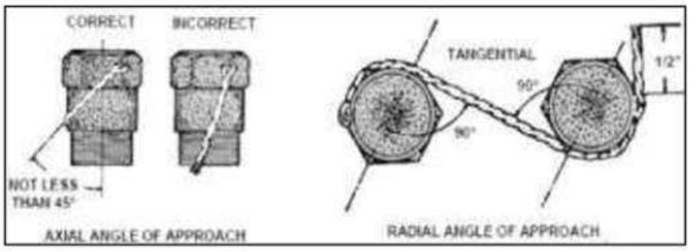
- Sharp edges of locking holes must be removed and there must be no obstruction by the locking wire of any moving parts, controls, etc.
- All off-cuts and used locking wire must be removed from the aircraft or component and disposed of safely.

In the normal twisting method of wire locking, a suitable length of wire should be cut from the coil and passed through the hole provided for the purpose in the component. The wire should be twisted over the length required to reach the locking point, through which one end of the wire should be passed, and then twisted for not less than a further ½ inch (13 mm) whilst being pulled taut.
It is necessary to pull the wire taut to ensure that the final twists are close to the locking hole, but

neither this nor the twisting should be too severe. After surplus wire has been removed, the twisted ends should be bent in such a manner as to prevent their catching in clothing, cleaning cloths, etc. There should be no untwisted lengths in excess of 0.374 inch (9.5 mm) and lengths of unsupported wire should not normally exceed 3 inches (76mm).

The angle of approach of the wire should not be less than 45° to the rotational axis of the component to be locked whilst the radial line of approach should be tangential (90°) to the parts being locked.
The lay of the wire must always be such as to resist any tendency of the locked part or parts to become loose, and for this reason it is essential to ascertain whether the parts have left or right hand threads before fitting the wire.

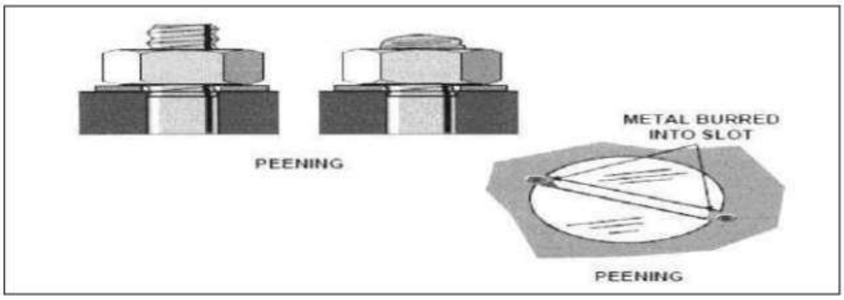
Note: When using pliers to pull or twist the locking wire great care must be taken to avoid damage to the wire. Any wire damaged during installation will be weakened and must be replaced.



Peening and Grub Screws

Peening

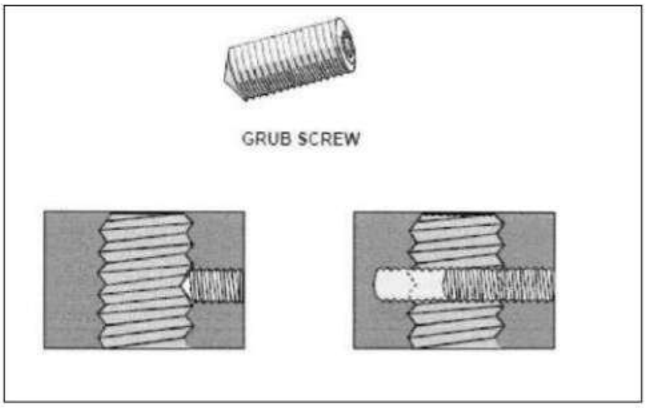
The peening of bolts for locking purposes should only be carried out when specified in the drawing, or the relevant manual, as the operation prevents re-use of the nut and bolt and may cause difficulty in dismantling. About VA threads of the bolt should be projecting and the peening carried down to the nut to prevent it slackening. Adequate support should be given to the bolt during the peening operation and care taken to prevent damage to the part by misdirected blows with the hammer. Countersunk screws may be locked by the method illustrated below when the thread is inaccessible. Protective treatment damaged by the peening operation must be restored.



Grub Screws

These are used as a method of locking two threaded components together. In one method the outer component only is drilled and threaded and the grub screw may be machined at the inner end to a

tapered point or a parallel plain shank to fit either a conical recess or parallel hole in the inner component. Other grub screws may be fitted into a single hole drilled and threaded in both inner and outer components. Grub screws may be locked by peening, by a wire type locking ring or by means of a nylon insert or adhesive patch in either the male or female thread.
Grub screws are also used, with the variations already mentioned, in non-threaded assemblies to retain the parts and ensure correct alignment. They may be fitted as additional or precautionary locking devices in assemblies with interference fits or bonded joints, or, in some cases, they may be the only means of retention. In these cases, however, several grub screws may be fitted around the component and these may be locked by lock nuts or clamping type lock rings.



PINS

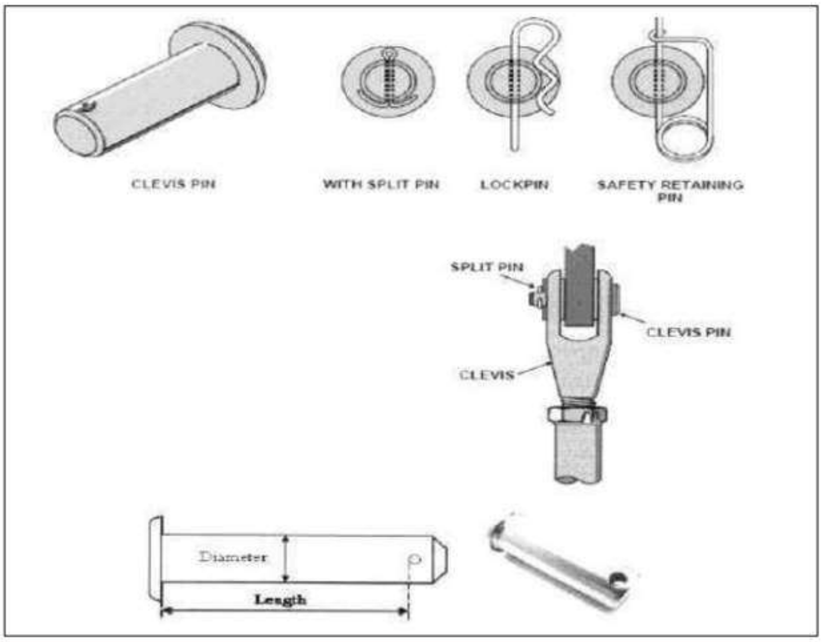
General

Taper pins with taper of 1 in 48 and parallel pins, are used on both tubular and solid sections, to secure control levers to torque shafts and forked ends to control rods, etc. Most taper pins, and parallel pins, are locked by peening into a countersunk recess or by forming reaction rivet heads. To avoid slackness, the pins are usually assembled in reamed holes, the head being supported during the locking process. Careful inspection is required after fitment of pins through hollow tubes, to ensure that undue force during the peening operation has not bent the pins, and thus impaired the security of the fittings. Taper pins are subjected to shear load.
To fit a taper pin, a hole less than the small diameter is drilled in the tube. It is then enlarged by the correct size taper pin reamer so that the small end of the taper pin, when pushed through the hole, is flush with the surface. The taper pin is then driven into position, ensuring that the component is adequately supported. To avoid excessive work with the taper reamer when fitting pins to solid circular sections a stepped hole may be drilled. Care being taken not to extend the second hole to a depth greater than the diameter of the taper pin.
Some taper pins are bifurcated so that the legs are spread for locking, the pin protrudes through the hole and the legs are spread forming an included angle of 60 degrees. Other pins are solid and may be peened for locking, care being taken to support large end of pin during this operation to prevent slackening.

Clevis Pins

Clevis Pins are flat headed parallel pins which are drilled at the end of the shank to accommodate a retention device. Made of high tensile or stainless steel, they are usually used in conjunction with split pins, lock pins or safety retaining pins as illustrated.

As their name suggests, they are often used in a 'clevis', a forked fitting which allows a degree of rotation. They may be used in cable end fittings, as hinges for nonstructural items such as stay rods, and as temporary restraints.



Special fasteners

Special fasteners have been designed to hold fairings, cowlings and inspection panels in position and to allow their rapid removal and replacement during servicing.
of the shank to accommodate a retention device. Made of high tensile or stainless steel, they are usually used in conjunction with split pins, lock pins or safety retaining pins as illustrated.

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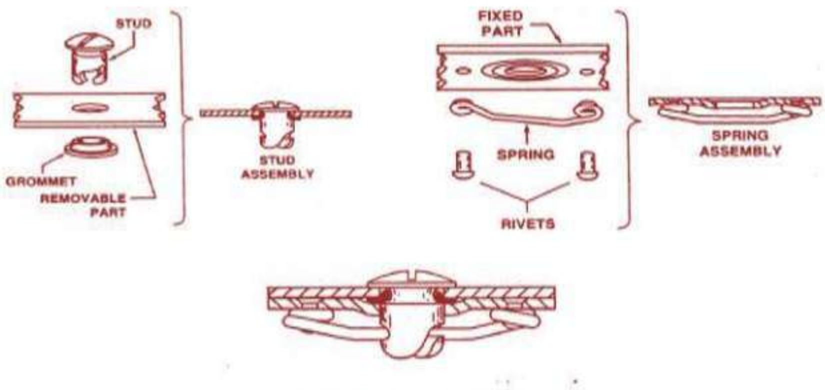
Turnlock Fasteners

Turnlock fasteners are used to secure inspection plates, doors, and other removable panels on aircraft. Turnloc fasteners are also referred to by such terms as quick opening, quick action, and stressed panel fasteners The most desirable feature of these fasteners is that they permit quick and easy removal of access panels for inspection and servicing purposes. Turnlock fasteners are manufactured and supplied by a number of manufacturers under various trade names. Some of the most commonly used are the Dzus, Camloc, and Airloc.

Dzus Fasteners

The Dzus turn lock fastener consists of a stud, grommet, and receptacle. Figure below illustrates an installed Dzus fastener and the various parts. The grommet is made of aluminum or aluminum alloy material. It acts as a holding device for the stud. Grommets can be fabricated from 1100 aluminum tubing, if none are available from normal sources. The spring is made of steel, cadmium plated to prevent corrosion. The spring supplies the force that locks or secures the stud in place when two assemblies are joined. The studs are fabricated from steel and are cadmium plated. They are available in three head styles: wing, flush, and oval. Body diameter, length, and head type may be identified or determined by the markings found on the head of the stud. [Figure 5-59] The diameter is always measured in sixteenths of an inch. Stud length is measured in hundredths of an inch and is the distance from the head of the stud to the bottom of the spring hole A quarter of a turn of the stud (clockwise) locks the fastener. The fastener may be unlocked only by turning the stud counterclockwise. A Dzus key or a specially ground screwdriver locks or unlocks the fastener.



Dzus Fastener Construction

Camloc Fasteners

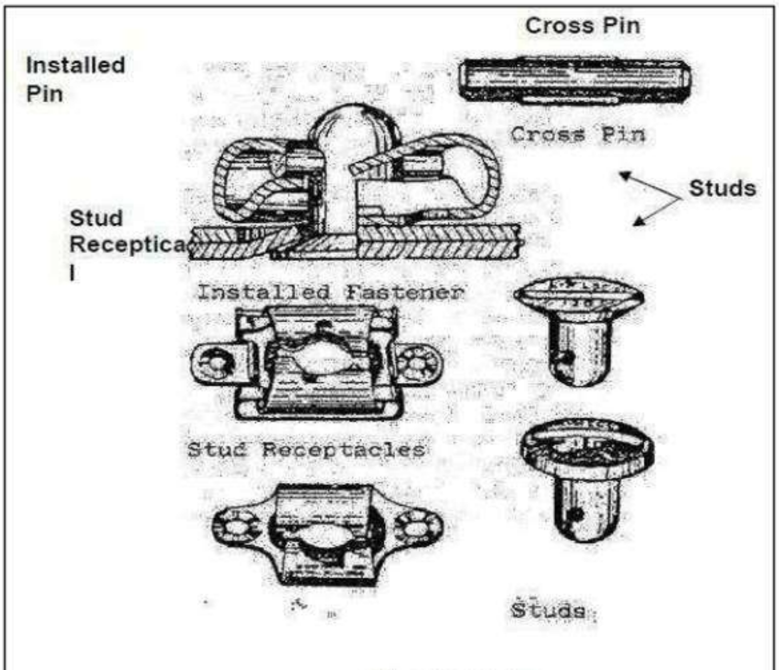
Camloc fasteners are made in a variety of styles and designs. Included among the most commonly used are the 2600, 2700, 40S51, and 4002 series in the regular line, and the stressed panel fastener in the heavy duty line. The latter is used in stressed panels which carry structural loads. The Camloc fastener is used to secure aircraft cowlings and fairings. It consists of three parts: a stud assembly, a grommet, and a receptacle. Two types of receptacles are available: rigid and floating. The stud and grommet are installed in the removable portion; the receptacle is riveted to the structure of the aircraft. The stud and grommet are installed in either a plain, dimpled, countersunk, or counterbored hole, depending upon the location and thickness of the material involved. A quarter turn (clockwise) of the stud locks the fastener. The fastener can be unlocked only by turning the stud counterclockwise.

Camloc Fastener

Airloc Fasteners

The Airloc fastener consists of three parts: a stud, a cross pin, and a stud receptacle. The studs are manufactured from steel and casehardened to prevent excessive wear. The stud hole is reamed for a press fit of the cross pin. The total amount of material thickness to be secured with the Airloc fastener must be known before the correct length of stud can be selected for installation. The total thickness of material that each stud will satisfactorily lock together is stamped on the head of the stud in thousandths of an inch (0.040, 0.070, 0.190, and so forth). Studs are manufactured in three head styles: flush, oval, and wing.

The cross pin is manufactured from chrome-vanadium steel and heat treated to provide maximum strength, wear, and holding power. It should never be used the second time; once removed from the stud, replace it with a new pin. Receptacles for Airloc fasteners are manufactured in two types: rigid and floating. Sizes areclassifiedbynumber—No.2,No.5,andNo.7.Theyarealsoclassified by the center-to-center distance between the rivet holes of the receptacle: No. 2 is 3⁄4 inch; No. 5 is 1 inch; and No. 7 is13⁄8 inch. Receptacles are fabricated from high-carbon, heat-treated steel. An upper wing assures

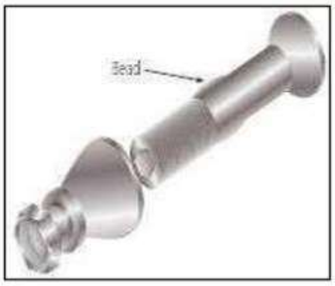


Airloc Fastener

ejection of the stud when unlocked and enables the cross pin to be held in a locked position between the upper wing, cam, stop, and wing detent, regardless of the tension to which the receptacle is subjected.

Taper-Lok

Taper-Loks are the strongest special fasteners used in aircraft construction. The Taper-Lok exerts a force on the walls of the hole because of its tapered shape. The Taper-Lok is designed to completely fill the hole, but unlike the rivet, it fills the hole without deforming the shank. Instead, the washer head nut squeezes the metal with tremendous force against the tapered wall of the hole. This creates radial compression around the shank and vertical compression lines as the metals are squeezed together. The combination of these forces generates strength unequaled by any other fastener.
aluminum, titanium, and stainless steel alloys. The collars are composed of compatible metal alloys and come in two types: sealing and non-sealing. Just like the Hi-Loks, they can be installed using an Allen wrench and a box-end wrench.



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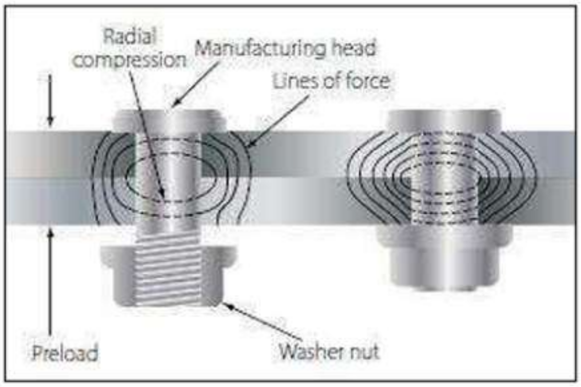
Taper-Loks

Hi-Tigue



Hi-Tigue special fastener

Circlips and Locking Rings

Many of these locking devices are standard parts manufactured from spring steel wire, sheet or plate, but they may also be specially designed for a particular application. All are hardened and tempered to give inward or outward spring for locking screwed

The Hi-Tigue special fastener has a bead that encircles the bottom of its shank. The bead preloads the hole it fills, resulting in increased joint strength. At installation, the bead presses against the sidewall of the hole, exerting radial force that strengthens the surrounding area. Because it is preloaded, the joint is not subjected to the constant cyclic action that normally causes a joint to become cold worked and eventually fail. Hi-Tigue fasteners are made of parts together, for locking grub screws, or for locating components within bores or housings.

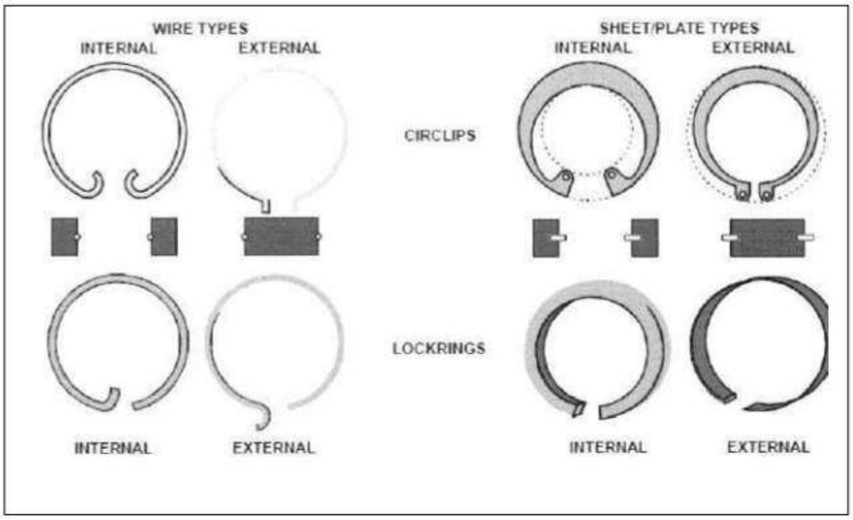
Wire circlips have both ends bent whilst other types have drilled ends which facilitate expansion or contraction for fitting into position. Generally, wire locking rings have one bent end which is inserted into a radial hole drilled through the outer or inner component, depending on whether it is an external or internal type.

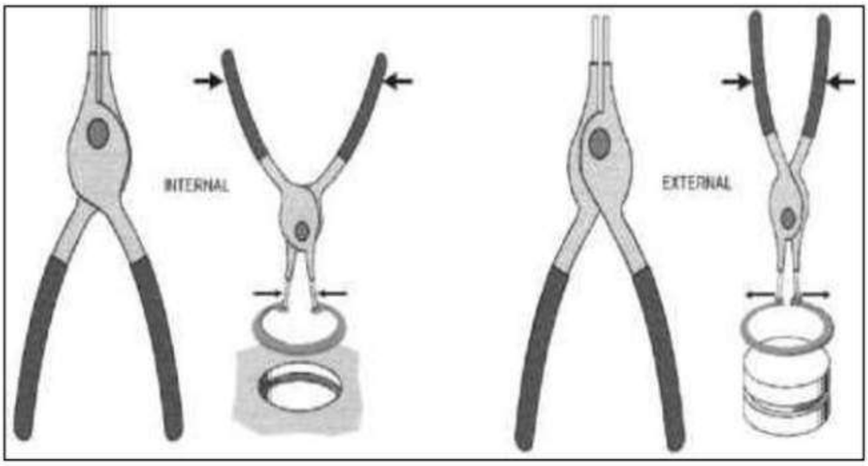
Locking rings of sheet or plate are seldom provided with a bent end, and the fitting of these entails the use of special expanding/contracting tools and protecting sleeves. The advantages of circlips are locking component in housing. Internal circlips can be used to restore a ball bearing in housing.
Grooves for circlips and locking rings are semi-circular for wire types and of rectangular section for others. Before fitting, precautions should be taken to ensure that these are free from deformation, burring or dirt.

The installation of circlips is usually accomplished with circlip pliers as shown below. These are produced as both internal and external models and also reversible dual purpose tools. They are available in different sizes and some have interchangeable nibs. It is important to select the correct size of tool and nib for your own safety and to prevent damage to the circlip. Inspection should ensure that all of these devices are bedding correctly and that the locking end of locking rings is correctly engaged.

Identification of these devices is difficult and every care should be taken to ensure that the correct items are fitted. Items should be obtained by part numbers and not identified by comparing the old and new, since the diameters of the old are likely to differ considerably from those of new items. Part numbers of the correct part to be fitted should be verified from the appropriate drawings, Overhaul or Repair Manuals or Parts Catalogue.

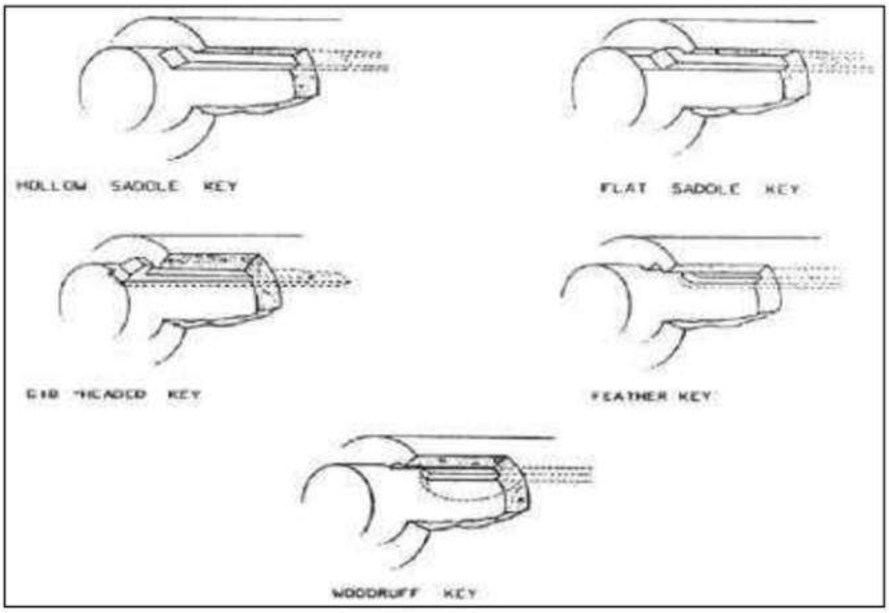
Some manufacturers stipulate that circlips and locking rings must not be used more than once. However, in some instances, it is specified that the gap between the ends of a circlip or locking ringshould,afterfitting,bewithinprescribedlimitsandassuchindividual selection may be necessary, the radial position of the gap may also be specified





Keys and Keyways

These items can be found where chain-wheels or pulleys are located on shafts. A key, with its associated keyways (the name given to the channel, which is cut into the respective components, to receive the key), is used to transmit the driving force from one part to the other.



Keys and Keyways

AIRCRAFT RIVETS

An aircraft, even though made of the best materials and strongest parts, would be of doubtful value unless those parts were firmly held together. Several methods are used to hold parts together; welding or soldering, threaded fasteners and riveting being three of the main methods. The use of threaded fasteners, and soldering, has been mentioned previously. Rivets are an alternative method of fastening structure, a rivet being a metal pin on which a head is formed, during manufacture. The rivet is inserted into a predrilled hole and the plain end of its shank is deformed ('set' or 'closed') by the use of a hand- or power-tool. Rivets create a joint at least as strong as the material that is being joined.

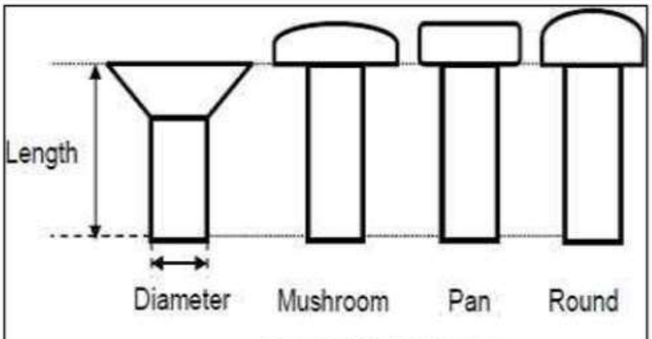
Rivets are normally strong in shear, but they should not be subjected to excessive tensile loads. There are two main categories of rivet:

• **Solid rivets:** which are 'set' using a riveting gun on the manufactured head and a reaction (bucking) bar on the remote side

• **Blind rivets:** which may be installed where access is restricted to the shank end of the rivet.

SOLID RIVETS

There are a number of different types of rivet head, the most common being the mushroom and round heads. Both of these rivets project above the surface of the metal that is being riveted. The countersunk head, however, provides a flush and smooth surface, when closed and the flat (or pan) head can be used internally, when a flat head will make closing the rivet easier.



Types of Solid Rivets

The majority of aircraft rivets are manufactured from aluminium alloys. Rivets can also be made from other materials such as steel, Monel metal, titanium or copper. Material specifications for British and American rivets are not identical. The manufacturer's publications (AMM or CMM) will give details on which rivets can be used if the specified ones are unavailable. The dimensions that identify the size of a rivet are simply its length and diameter. Other identifying features are the shape of the head, (including the countersink angle, if applicable) and the material from which the rivet is made. This latter requirement involves many different identifying marks and letters.

Aircraft rivets are not hardware store rivets. Rivets purchased at a hardware store should never be used as a substitute for aircraft quality rivets. The rivets may be made from very different materials, the strength of the rivets differs greatly, and their shear strength qualities are very different. The countersunk heads on hardware store rivets are 78°, whereas countersunk aircraft rivets have 100°angle heads for more surface contact to hold it in place.

Standards and Specifications

The FAA requires that the structural strength and integrity of type- certificated aircraft conform to all airworthiness requirements. These requirements apply to performance, structural strength, and integrity as well flight characteristics. To meet these requirements, each aircraft must meet the same standards. To accomplish standardization, all materials and hardware must be manufactured to a standard of quality. Specifications and standards for aircraft hardware are usually identified by the organization that originated them. Some of the common standardizing organizations include:

AMS Aeronautical Material Specifications AN Air Force-Navy
AND Air Force-Navy Design AS Aeronautical Standard
ASA American Standards Association
ASTM American Society for Testing Materials MS Military Standard
NAF Naval Aircraft Factory
NAS National Aerospace Standard SAE Society of Automotive Engineers

When a MS20426-AD4-6 rivet is required, the specifications have already been written for it in the Military Standard (MS) specifications. That information is available to the aircraft manufacturers and to the rivet manufacturers as well as to the mechanic. The specifications designate the material to be used as well as the head type, diameter, and length of the rivet. The use of standardized materials in the production of aircraft makes each aircraft exactly the same as the previous one and makes them less expensive to build. Aircraft rivets are manufactured to much higher standards and specifications than rivets manufactured for general use. When aircraft manufacturers started building all-metal aircraft in the 1930s, different manufacturers had different rivet head designs. Brazier heads, modified brazier heads, button heads, mushroom heads, flatheads, and 78 ° countersunk heads were used. As aircraft standardized, four rivet head designs almost completely replaced all of the others. Rivets exposed to the airflow over the top of the structure are usually either universal head MS20470 or 100° countersunk head MS20426 rivets. For rivets used in internal structures, the roundhead MS20430 and the flathead MS20442 are generally used.

Solid Shank Rivets

Solid shank rivets are generally used in repair work. They are identified by the kind of material of which they are made, their head type, size of shank, and their temper condition. The designation of the solid shank rivet head type, such as universal head, roundhead, flathead, countersunk head, and brazier head, depends on the cross- sectional shape of the head. The temper designation and strength are indicated by special markings on the head of the rivet. The material used for the majority of aircraft solid shank rivets is aluminum alloy. The strength and temper conditions of aluminum alloy rivets are identified by digits and letters similar to those adopted for the identification of strength and temper conditions of aluminum and aluminum alloy stock. The 1100, 2017-T, 2024-T, 2117-T, and 5056 rivets are the five grades usually available. The 1100 rivet, which is composed of 99.45 percent pure aluminum, is very soft. It is for riveting the softer aluminum alloys, such as 1100, 3003, and 5052, which are used for nonstructural parts (all parts where strength is not a factor). The riveting of map cases is a good example of where a rivet of 1100 aluminum alloy may be used.

The 2117-T rivet, known as the field rivet, is used more than any other for riveting aluminum alloy structures. The field rivet is in wide demand because it is ready for use as received and needs no further heat treating or annealing. It also has a high resistance to corrosion. The 2017-T and 2024-T rivets are used in aluminum alloy structures where more strength is needed than is obtainable with the same size 2217-T rivet. These rivets are known as “ice box rivets,” are annealed, and must be kept refrigerated until they are to be driven. The 2017-T rivet should be driven within approximately 1 hour and the 2024-T rivet within 10 to 20 minutes after removal from refrigeration. The 5056 rivet is used for riveting magnesium alloy structures because of its corrosion-resistant qualities in combination with magnesium. Mild steel rivets are used for riveting steel parts.

The corrosion-resistant steel rivets are for riveting corrosion- resistant steels in firewalls, exhaust stack brackets, and similar structures. Monel rivets are used for riveting nickel-steel alloys. They can be substituted for those made of corrosion resistant steel in some cases.

The use of copper rivets in aircraft repair is limited. Copper rivets can be used only on copper alloys or nonmetallic materials such as leather. Metal temper is an important factor in the riveting process, especially with aluminum alloy rivets. Aluminum alloy rivets have the same heat-treating characteristics as aluminum alloy stock. They can be hardened and annealed in the same manner as aluminum.

Rivet Identification Chart

The rivet must be soft, or comparatively soft, before a good head can be formed. The 2017-T and 2024-T rivets are annealed before being driven. They harden with age. The process of heat treating (annealing) rivets is much the same as that for stock. Either an electric air furnace, a salt bath, or a hot oil bath is needed. The heat-treating range, depending on the alloy, is 625 °F to 950 °F.

For convenient handling, rivets are heated in a tray or a wire basket. They are quenched in cold water (70 °F) immediately after heat treating. The 2017-T and 2024-T rivets, which are heat- treatable rivets, begin to age harden within a few minutes after being exposed to room temperature. Therefore, they must be used immediately after quenching or else be placed in cold storage. The most commonly used means for holding heat-treatable rivets at low temperature (below 32 °F) is to keep them in a refrigerator. They are referred to as "icebox" rivets. Under this storage condition, they will remain soft enough for driving for periods up to 2 weeks. Any rivets not used within that time should be removed for reheat treating. Icebox rivets attain about one-half their maximum strength in approximately 1 hour after driving and full strength in about 4 days. When 2017-T rivets are exposed to room temperature for 1 hour or longer, they must be subject to reheat treatment. This also applies to 2024-T rivets exposed to room temperature for a period exceeding 10 minutes. Once an icebox rivet has been taken from the refrigerator, it should not be mixed with the rivets still in cold storage. If more rivets are removed from the refrigerator than can be used in 15 minutes, they should be placed in a separate container and stored for reheat treatment. Heat treatment of rivets may be repeated a number of times if done properly. Proper heating times and temperatures are shown in Figure.

Heating Time — Air Furnace		
Rivet Alloy	Time at Temperature	Heat Treating Temperature
2024	1 hour	910 °F – 930 °F
2017	1 hour	925 °F – 950 °F
Heating Time — Salt Bath		
Rivet Alloy	Time at Temperature	Heat Treating Temperature
2024	30 minutes	910 °F – 930 °F
2017	30 minutes	925 °F – 950 °F

Most metals, and therefore aircraft rivet stock, are subject to corrosion. Corrosion may be the result of local climatic conditions or the fabrication process used. It is reduced to a minimum by using metals which are highly resistant to corrosion and possess the correct strength-to-weight ratio.
Ferrous metals placed in contact with moist salt air will rust if not properly protected. Nonferrous

metals, those without an iron base, do not rust, but a similar process known as corrosion takes place. The salt in moist air (found in the coastal areas) attacks the aluminum alloys. It is a common experience to inspect the rivets of an aircraft which has been operated near salt water and find them badly corroded. If a copper rivet is inserted into an aluminum alloy structure, two dissimilar metals are brought in contact with each other. Remember, all metals possess a small electrical potential. Dissimilar metals in contact with each other in the presence of moisture cause an electrical current to flow between them and chemical by products to be formed. Principally, this results in the deterioration of one of the metals. Certain aluminum alloys react to each other and, therefore, must be thought of as dissimilar metals.

The commonly used aluminum alloys may be divided into the two groups shown in Figure

Group A	Group B
1100	2117
3003	2017
5052	2124
6053	7075

Members within either group A or group B can be considered as similar to each other and will not react to others within the same group. A corroding action will take place, however, if any metal of group A comes in contact with a metal in group B in the presence of moisture. Avoid the use of dissimilar metals whenever possible. Their incompatibility is a factor which was considered when the AN Standards were adopted. To comply with AN Standards, the manufacturers must put a protective surface coating on the rivets. This may be zinc chromate, metal spray, or an anodized finish. The protective coating on a rivet is identified by its color. A rivet coated with zinc chromate is yellow, an anodized surface is pearl gray, and the metal sprayed rivet is identified by a silvery gray color. If a situation arises in which a protective coating must be applied on the job, paint the rivet with zinc chromate before it is used and again after it is driven.

Identification

Markings on the heads of rivets are used to classify their characteristics. These markings may be either a raised teat, two raised teats, a dimple, a pair of raised dashes, a raised cross, a single triangle, or a raised dash; some other heads have no markings. The different markings indicate the composition of the rivet stock. As explained previously, the rivets have different colors to identify the manufacturers' protective surface coating.

Roundhead rivets are used in the interior of the aircraft, except where clearance is required for adjacent members. The roundhead rivet has a deep, rounded top surface. The head is large enough to strengthen the sheet around the hole and, at the same time, offer resistance to tension. The flathead rivet, like the roundhead rivet, is used on interior structures. It is used where maximum strengthis needed and where there isn' t sufficient clearance to use a roundhead rivet. It is seldom, if ever, used on external surfaces. The brazier head rivet has a head of large diameter, which makes it particularly adaptable for riveting thin sheet stock (skin). The brazier head rivet offers only slight resistance to the airflow, and because of this factor, it is frequently used for riveting skin on exterior surfaces, especially on aft sections of the fuselage and empennage. It is used for riveting thin sheets exposed to the slipstream. A modified brazier head rivet is also manufactured; it is simply a brazier head of reduced diameter.

The universal head rivet is a combination of the roundhead, flathead, and brazier head. It is used in aircraft construction and repair in both interior and exterior locations. When replacement is necessary for protruding head rivets — roundhead, flathead, or brazier head—they can be replaced by universal head rivets. The countersunk head rivet is flat topped and beveled toward the shank so that it fits into a countersunk or dimpled hole and is flush with the material's surface. The angle at which the head slopes may vary from 78°to 120°. The 100° rivet is the most commonly used type. These rivets are used to fasten sheets over which other sheets must fit. They are also used on exterior surfaces of the aircraft because they offer only slight resistance to the slipstream and help to minimize turbulent airflow. The markings on the heads of rivets indicate the material of which they are made and, therefore, their strength.

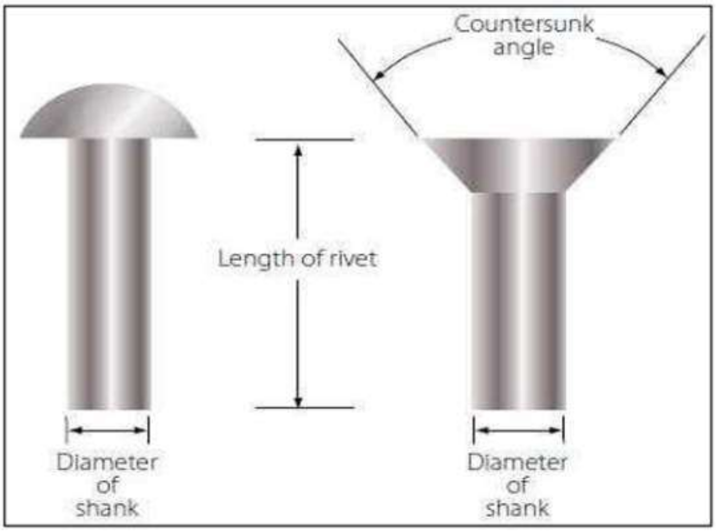
Although there are three materials indicated by a plain head, it is possible to distinguish their difference by color. The 1100 is aluminum color; the mild steel is a typical steel color; and the copper rivet is a copper color. Any head marking can appear on any head style of the same material. Each type of rivet is identified by a part number so that the user can select the correct rivet for the job. The type of rivet head is identified by AN or MS standard numbers. The numbers selected are in series and each series represents a particular type of head. The most common numbers and the types of heads they represent are:

AN426 or MS20426—countersunk head rivets (100°) AN430 or MS20430—roundhead rivets
AN441—flathead rivets
AN456—brazier head rivets
AN470 or MS20470—universal head rivets

There are also letters and numbers added to a part number. The letters designate alloy content; the numbers designate rivet diameter and length. The letters in common use for alloy designation are: A—aluminum alloy, 1100 or 3003 composition AD—aluminum alloy, 2117-T composition D— aluminum alloy, 2017-T composition DD—aluminum alloy, 2024-T composition B—aluminum alloy, 5056 composition C—copper, M—monel

The absence of a letter following the AN standard number indicates a rivet manufactured from mild steel. The first number following the material composition letters expresses the diameter of the rivet shank in 32nds of an inch (Examples: 3 indicates 3⁄32, 5indicates 5⁄32, and so forth). The last number(s), separated by a dash from the preceding number, expresses the length of the rivet shank in 16ths of an inch (Examples: 3 indicates 3⁄16 , 7 indicates 7⁄16 , 11 indicates 11 ⁄ 16 , and so forth). An example of identification marking of a rivet is:

AN470AD3-5—complete part number, AN—Air Force-Navy standard number, 470—universal head rivet, AD—2117-T aluminum alloy 3—3⁄32 in diameter 5—5⁄16 in length



BLIND RIVETS

There are many places on an aircraft where access to both sides of a riveted structure or structural part is impossible, or where limited space will not permit the use of a bucking bar. Also, in the attachment of many nonstructural parts, such as aircraft interior furnishings, flooring, deicing boots, and the like, the full strength of solid shank rivets is not necessary. For use in such places, special rivets have been designed which can be bucked from the front. They are sometimes lighter than solid shank rivets, yet amply strong for their intended use. These rivets are produced by several manufacturers and have unique characteristics that require special installation tools, special installation procedures and special removal procedures. That is why they are called special rivets. Because these rivets are often inserted in locations where one head (usually the shop head) cannot be seen, they are also called blind rivets.

Mechanically Expanded Rivets

Two classes of mechanically expanded rivets are discussed here:

(1) Non structural.

(a) Self-plugging (friction lock) rivets.

(b) Pull-thru rivets.

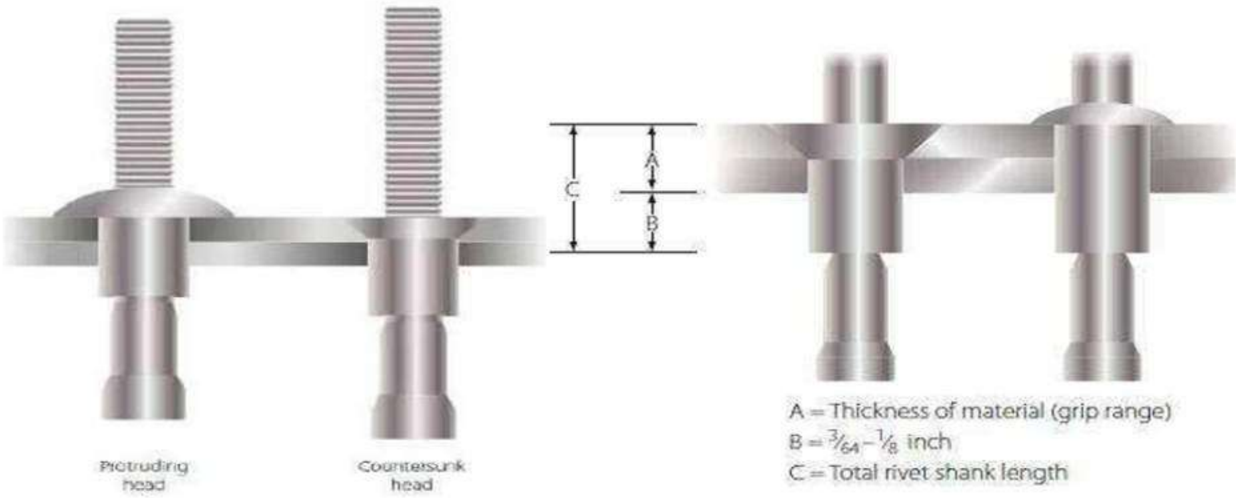
(2) Mechanical lock, flush fracturing, self plugging rivets.

Self-Plugging Rivets (friction lock)

The self-plugging (friction lock) blind rivets are manufactured by several companies; the same general basic information about their fabrication, composition, uses, selection, installation, inspection, and removal procedures apply to all of them. Self-plugging (friction lock) rivets are fabricated in two parts: a rivet head with a hollow shank or sleeve, and a stem that extends through the hollow shank. Figure below illustrates a protruding head and a countersunk head self-plugging rivet produced by one manufacturer. Several events, in their proper sequence, occur when a pulling force is applied to the stem of the rivet: (1) the stem is pulled into the rivet shank; (2) the mandrel portion of the stem forces the rivet shank to expand; and (3) when friction (or pulling action pressure) becomes great enough, it will cause the stem to snap at a break off groove on the stem. The plug portion (bottom end of the stem) is retained in the shank of the rivet giving the rivet much greater shear strength than could be obtained from a hollow rivet. Self-plugging (friction lock) rivets are fabricated in two common head styles: (1) a protruding head similar to the MS20470 or universal head, and (2) a 100 countersunk head. Other head styles are available from some manufacturers. The stem of the self- plugging (friction lock) rivet may have a knot or knob on the upper portion or it may have a serrated portion. Self-plugging (friction lock) rivets are fabricated from several materials. Rivets are available in the following material combinations: stem 2017 aluminum alloy and sleeve 2117 aluminum alloy; stem 2017 aluminum alloy and sleeve 5056 aluminum alloy; and stem steel and sleeve steel.

Self-plugging (friction lock) rivets are designed so that installation requires only one person; it is not necessary to have the work accessible from both sides. The pulling strength of the rivet stem is such that a uniform job can always be assured. Because it is not necessary to have access to the opposite side of the work, self plugging (friction lock) rivets can be used to attach assemblies to hollow tubes, corrugated sheet, hollow boxes, and so forth. Because a hammering force is not necessary to install the rivet, it can be used to attach assemblies to plywood or plastics. Factors to consider in the selection of the correct rivet for installation are: (1) installation location,(2)composition of the material being riveted, (3) thickness of the material being riveted, and (4) strength desired. If the rivet is to be installed on an aerodynamically smooth surface, or if clearance for an assembly is needed, countersunk head rivets should be selected. In other areas where clearance or smoothness is not a factor, the protruding head type rivet may be utilized.

Material composition of the rivet shank depends upon the type of material being riveted. Aluminum alloy 2117 shank rivets can be used on most aluminum alloys. Aluminum alloy 5056 shank rivets should be used when the material being riveted is magnesium. Steel rivets should always be selected for riveting assemblies fabricated from steel. The thickness of the material being riveted determines the overall length of the shank of the rivet. As a general rule, the shank of the rivet should extend beyond the material thickness approximately 3⁄64 inch to 1⁄8 inch before the stem is pulled



Self-plugging (friction lock) Determining length of friction rivet slack rivet

Pull-Thru Rivets

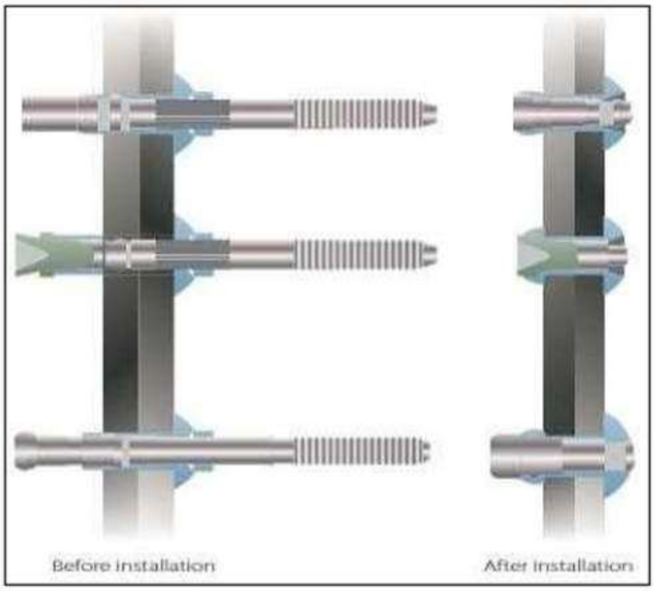
The pull-thru blind rivets are manufactured by several companies; the same general basic information about their fabrication, composition, uses, selection, installation, inspection, and removal procedures apply to all of them. Pull-thru rivets are fabricated in two parts: a rivet head with a hollow shank or sleeve and a stem that extends through the hollow shank. Figure below illustrates a protruding head and a countersunk head pull-thru rivet. Several events, in their proper sequence, occur when a pulling force is applied to the stem of the rivet: (1) The stem is pulled through the rivet shank; (2) the mandrel portion of the stem forces the shank to expand forming the blind head and filling the hole.

Pull-thru rivets are fabricated in two common head styles: (1) protruding head similar to the MS20470 or universal head, and (2) a 100° countersunk head. Other head styles are available from some manufacturers. Pull-thru rivets are fabricated from several materials. Following are the most commonly used: 2117-T4 aluminum alloy, 5056 aluminum alloy, Monel. Pull-thru rivets are designed so that installation requires only one person; it is not necessary to have the work accessible from both sides. Factors to consider in the selection of the correct rivet for installation are:
(1) Installation location, (2) composition of the material being riveted, (3) thickness of the material being riveted, and (4) strength desired. The thickness of the material being riveted determines the overall length of the shank of the rivet. As a general rule, the shank of the rivet should extend beyond the before the stem is pulled. Each company that manufactures pull-thru rivets has a code number to help users obtain correct rivet for the grip range of a particular installation. In addition, MS numbers are used for identification purposes. Numbers are similar to those shown on the preceding pages.

Pull-thru rivets

Self-Plugging Rivets (Mechanical Lock)

Self-plugging (mechanical lock) rivets are similar to self-plugging (friction lock) rivets, except for the manner in which the stem is retained in the rivet sleeve. This type of rivet has a positive mechanical locking collar to resist vibrations that cause the friction lock rivets to loosen and possibly fall out. Also, the mechanical locking type rivet stem breaks off flush with the head and usually does not require further stem trimming when properly installed. Self-plugging (mechanical lock) rivets display all the strength characteristics of solid shank rivets and in most cases can be substituted rivet for rivet.



Bulbed Cherrylock Rivets

The large blind head of this fastener introduced the word "bulb" to blind rivet terminology. In conjunction with the unique residual preload developed by the high stem break load, its proven fatigue strength makes it the only blind rivet interchangeable structurally with solid rivets.

Bulbed cherry lock rivet

Wiredraw Cherry lock Rivets

There is a wide range of sizes, materials, and strength levels from which to select. This fastener is especially suited for sealing applications and joints requiring an excessive amount of sheet take up.

Wiredraw cherry lock rivet.

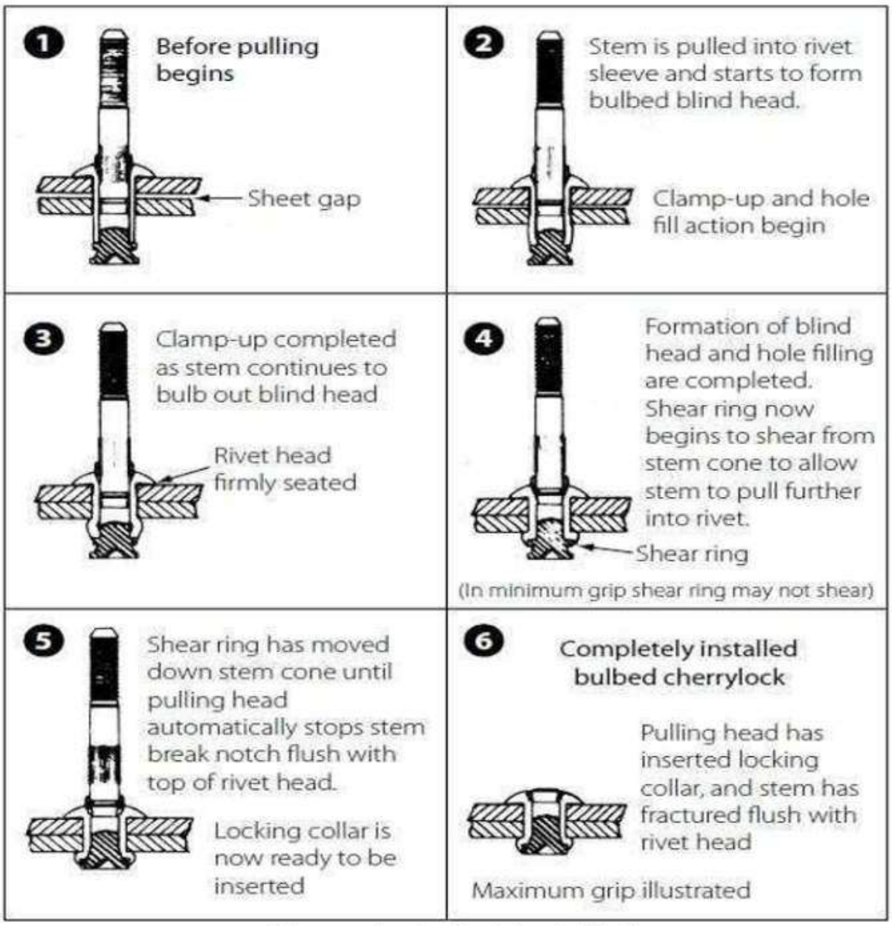
Huck Mechanical Locked Rivets

Self-plugging (mechanical lock) rivets are fabricated in two sections: a head and shank (including a conical recess and locking collar in the head), and a serrated stem that extends through the shank. Unlike the friction lock rivet, the mechanical lock rivet has a locking collar that forms a positive lock for retention of the stem in the shank of the rivet. This collar is seated in position during the installation of the rivet.

Material

Self-plugging (mechanical lock) rivets are fabricated with sleeves (rivet shanks) of 2017 and 5056 aluminum alloys, Monel, or stainless steel. The mechanical lock type of self-plugging rivet can be used in the same applications as the friction lock type of rivet.

In addition, because of its greater stem retention characteristic, installation in areas subject to considerable vibration is recommended. The same general requirements must be met in the selection of the mechanical lock rivet as for the friction lock rivet. Composition of the material being joined together determines the composition of the rivet sleeve; for example, 2017 aluminum alloy rivets for most aluminum alloys and 5056 aluminum rivets for magnesium. Figure below depicts the sequences of a typical mechanically locked blind rivet. The form and function may vary slightly between blind rivet styles and specifics should be obtained from manufacturers.



Cherry lock rivet installation

<u>Head Styles</u>

Self-plugging mechanical locked blind rivets are available in several head styles depending on the installation requirements.

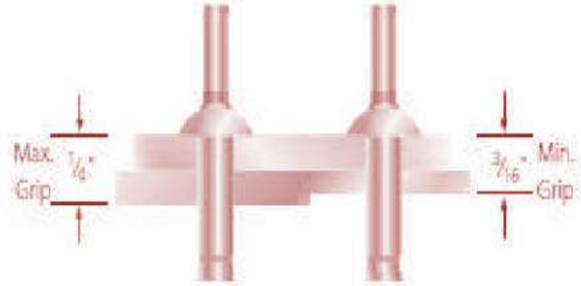
Grip Length

Grip length refers to the maximum total sheet thickness to be riveted and is measured in 1 / 6 of an inch. This is generally identified by the second dash number. Unless otherwise noted, most blind rivets have their grip lengths (maximum grip) marked on the rivet head and have a total grip range of 1⁄16 inch. [Figure 5-48] To determine the proper grip rivet to use, measure the material thickness with a grip selection gauge (available from blind rivet manufacturers). The proper use of a grip selector gauge is shown in Figure below. The thickness of the material being riveted determines the overall length of the shank of the rivet. As a general rule, the shank of the rivet should extend beyond the material thickness approximately 3⁄64 inch to 1⁄8 inch before the stem is pulled.

Cherry lock rivet heads.

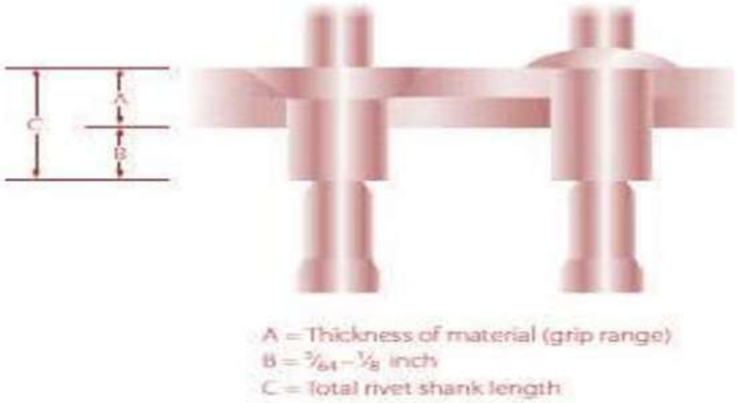
Diameters

Shank diameters are measured in 1/32-inch increments and are generally identified by the first dash number: -3 indicates 3⁄32 inch diameter, -4 indicates 1⁄8 inc diameter, and so forth. Both nominal and 1⁄64-inch oversize diameters are available.



Typical grip length

Grip gauge use



Determining rivet length

Rivet Identification

Each company that manufactures self-plugging (friction lock) rivets has a code number to help users obtain the correct rivet for the grip range or material thickness of a particular installation. In addition, MS numbers are used for identification purposes. Figures below contain examples of part numbers for self-plugging (friction lock) rivets that are representative of each.

Military Standard Number

MS 20600 B 4 K 2

MS	**Military Standard**
0600	**Type of rivet and head style:** 20600 = self-plugging (friction lock) protruding head 20600 = self-plugging (friction lock) 100° countersunk head
B	**Material composition of sleeve:** AD = 2117 aluminium alloy B = 5056 aluminium alloy
4	**Shank diameter in 32nds of an inch:** 4 = 1/8 inch 6 = 3/16 inch 5 = 5/32 inch 8 = 1/4 inch
K	**Type of stem:** K = knot head stem W = serrated stem
2	**Grip range (material thickness) in 16ths of an inch**

Huck Manufacturing Comany

9SP-B A 6 3

9SP-B **Head Style**
9SP-B = brazier or universal head
9SP-100 = 100° countersunk head

A **Material composition of shank**
A = 2017 aluminium alloy
B = 5056 aluminium alloy
R = mild steel

6 **Shank diameter in 32nds of an inch:**
4 = 1/8 inch 6 = 3/16 inch
5 = 5/32 inch 8 = 1/4 inch

3 Grip range (material thickness) in 16ths of an inch

Townsend Company, Cherry Rivet Division

CR 163 6 6

CR **Cherry rivet**

163 **Series number**
Designates rivet material, type of rivet, and head style (163 = 2117 aluminium alloy, self-plugging (friction lock) rivet, protruding head)

6 **Shank diameter in 32nds of an inch:**
4 = 1/8 inch 6 = 3/16 inch
5 = 5/32 inch 8 = 1/4 inch

6 **Grip range (material thickness):**
knob stem in 32nds of an inch; serrated stem in 16ths of an inch

Olympic Screw and Rivet Corporation

RV 2 0 0 4 2

RV **Manufacturer**
Olympic Screw and Rivet Corporation

2 **Rivet type**
2 = self plugging (friction lock)
5 = holow pull thru

0 **Material composition of shank**
0 = 2017 aluminium alloy
5 = 5056 aluminium alloy
7 = mild steel

0 **Head style**
0 = universal head
1 = 100° countersunk

4 **Shank diameter in 32nds of an inch:**
4 = 1/8 inch 6 = 3/16 inch
5 = 5/32 inch 8 = 1/4 inch

2 Grip range in 16ths of an inch

Pin Rivets

Pin (Hi-Shear) rivets are classified as special rivets but are not of the blind type. Access to both sides of the material is required to install this type of rivet. Pin rivets have the same shear strength as bolts of equal diameters, are about 40 percent of the weight of a bolt, and require only about one-fifth as much time for installation as a bolt, nut, and washer combination. They are approximately three times as strong as solid shank rivets. Pin rivets are essentially thread less bolts. The pin is headed at one end and is grooved about the circumference at the other. A metal collar is swaged onto the grooved end effecting a firm, tight fit. Pin rivets are fabricated in a variety of materials but should be used only in shear applications. They should never be used where the grip length is less than the shank diameter. Part numbers for pin rivets can be interpreted to give the diameter and grip length of the individual rivets.

A typical part number breakdown would be:

NAS177-14-17

NAS = National Aircraft Standard,177 = 100° countersunk head rivet OR 178 = flathead rivet, 14 = Nominal diameter in 32nds of an inch, 17 = Maximum grip length in 16ths of an inch.

Pin (Hi-Shear) rivet.

6.6: PIPES AND UNIONS

Identification of, and types of rigid and flexible pipes and their connectors used in aircraft;
Aircraft fluid lines are usually made of metal tubing or flexible hose. Metal tubing (also called rigid fluid lines) is used in stationary applications and where long, relatively straight runs are possible. They are widely used in aircraft for fuel, oil, coolant, oxygen, instrument, and hydraulic lines. Flexible hose is generally used with moving parts or where the hose is subject to considerable vibration. Occasionally, it may be necessary to repair or replace damaged aircraft fluid lines. Very often the repair can be made simply by replacing the tubing. However, if replacements are not available, the needed parts may have to be fabricated. Replacement tubing should be of the same size and material as the original tubing. All tubing is pressure tested prior to initial installation, and is designed to withstand several times the normal operating pressure to which it will be subjected. If a tube bursts or cracks, it is generally the result of excessive vibration, improper installation, or damage caused by collision with an object. All tubing failures should be carefully studied and the cause of the failure determined.

RIGID FLUID LINES TUBING MATERIALS

Copper

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

Aluminum Alloy Tubing

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

Corrosion resistant steel tubing

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

Titanium 3AL-2.5V

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

Material Identification

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

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

Fig 6.1

Sizes

Code, not more than 4" in width, painted at the two ends and approximately midway between the ends of some tubing. When the band consists of two colors, one-half the width is used for each color. [Figure 6.1] If the code markings are hard or impossible to read, it may be necessary to test samples of the material for hardness by hardness testing.

Metal tubing is sized by outside diameter (o.d.), which is measured fractionally in sixteenths of an inch. Thus, number 6 tubing is 6/16" (or 3⁄8") and number 8 tubing is 8/16" (or 1⁄2"), and so forth. The tube diameter is typically printed on all rigid tubing. In addition to other classifications or means of identification, tubing is manufactured in various wall thicknesses. Thus, it is important when installing tubing to know not only the material and outside diameter, but also the thickness of the wall. The wall thickness is typically printed on the tubing in thousands of an inch. To determine the inside diameter (i.d.) of the tube, subtract twice the wall thickness from the outside diameter. For example, a number 10 piece of tubing with a wall thickness of 0.063" has an inside diameter of 0.625" – 2(0.063") =0.499".

Fabrication of Metal Tube Lines

Damaged tubing and fluid lines should be repaired with new parts whenever possible. Unfortunately, sometimes replacement is impractical and repair is necessary. Scratches, abrasions, or minor corrosion on the outside of fluid lines may be considered negligible and can be smoothed out with a burnishing tool or aluminum wool. If a fluid line assembly is to be replaced, the fittings can often be salvaged; then the repair will involve only tube forming and replacement. Tube forming consists of four processes: Cutting, bending, flaring, and beading. If the tubing is small and made of soft material, the assembly can be formed by hand bending during installation. If the tube is 1⁄4" diameter or larger, hand bending without the aid of tools is impractical.

Tube Cutting

When cutting tubing, it is important to produce a square end, free of burrs. Tubing may be cut with a tube cutter or a hacksaw. The cutter can be used with any soft metal tubing, such as copper, aluminum, or aluminum alloy. Correct use of the tube cutter is shown in Figure 6.2 Special chip less cutters are available for cutting aluminum 6061-T6, corrosion resistant steel and titanium tubing. A new piece of tubing should be cut approximately 10 percent longer than the tube to be replaced to provide for minor variations in bending. Place the tubing in the cutting tool, with the cutting wheel at the point where the cut is to be made. Rotate the cutter around the tubing, applying a light pressure to the cutting wheel by intermittently twisting the thumbscrew. Too much pressure on the cutting wheel at one time could deform the tubing or cause excessive burring. After cutting the tubing, carefully remove any burrs from inside and outside the tube. Use a knife or the burring edge attached to the tube cutter. The deburring operation can be accomplished by the use of a de burring tool as shown in Figure 6.3. This tool is capable of removing both the inside and outside burrs by just turning the tool end for end.

When performing the de burring operation, use extreme care that the wall thickness of the end of the tubing is not reduced or fractured. Very slight damage of this type can lead to fractured flares or defective flares which will not seal properly. Use a fine- tooth file to file the end square and smooth. If a tube cutter is not available, or if tubing of hard material is to be cut, use a fine-tooth hacksaw, preferably one having 32 teeth per inch. The use of a saw will decrease the amount of work hardening of the tubing during the cutting operation. After sawing, file the end of the tube square and smooth, removing all burrs. An easy way to hold small diameter tubing, when cutting it, is to place the tube in a combination flaring tool and clamp the tool in a vise. Make the cut about one half inch from the flaring tool. This procedure keeps sawing vibrations to a minimum and prevents damage to the tubing if it is accidentally hit with the hacksaw frame or file handle while cutting. Be sure all filings and cuttings are removed from the tube.

Fig 6.2

Fig 6.3

Tube Bending

The objective in tube bending is to obtain a smooth bend without flattening the tube. Tubing under 1⁄4"in diameter usually can be bent without the use of a bending tool. For larger sizes, either portable hand benders or production benders are usually used Using a hand bender, insert the tubing into the groove of the bender, so that the measured end is left of the form block. Align the two zeros and align the mark on the tubing with the L on the form handle. If the measured end is on the right side, then align the mark on the tubing with the R on the form handle. With a steady motion, pull the form handle till the zero mark on the form handle lines up with the desired angle of bend, as indicated on the radius block. [Figure 6.4] Bend the tubing carefully to avoid excessive flattening, kinking, or wrinkling. A small amount of flattening in bends is acceptable, but the small diameter of the flattened portion must not be less than 75 percent of the original outside diameter. Tubing with flattened, wrinkled, or irregular bends should not be installed. Wrinkled bends usually result from trying to bend thin wall tubing without using a tube bender. Excessive flattening will cause fatigue failure of the tube. Examples of correct and incorrect tubing bends are shown in Figure 6.5.

Fig 6.4

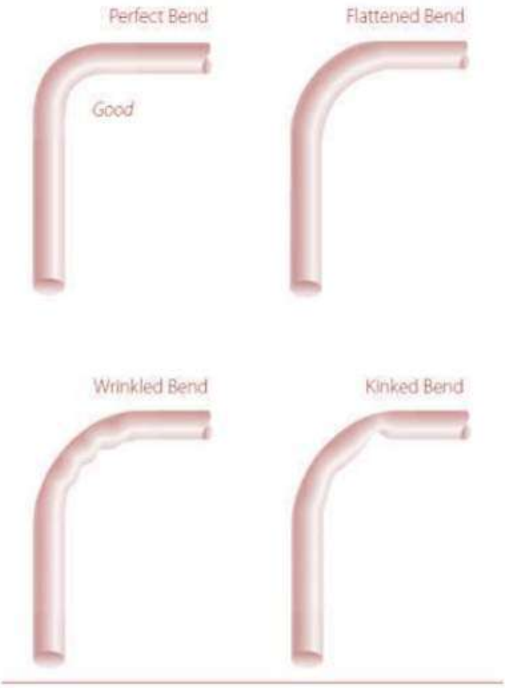


Fig 6.5

Tube Flaring

Two kinds of flares are generally used in aircraft tubing: the single flare and the double flare. [Figure 6.6 (A and B)] Flares are frequently subjected to extremely high pressures; therefore, the flare on the tubing must be properly shaped or the connection will leak or fail. A flare made too small produces a weak joint, which may leak or pull apart; if made too large, it interferes with the proper engagement of the screw thread on the fitting and will cause leakage. A crooked flare is the result of the tubing not being cut squarely. If a flare is not made properly, flaws cannot be corrected by applying additional torque when tightening the fitting. The flare and tubing must be free from cracks, dents, nicks, scratches, or any other defects. The flaring tool used for aircraft tubing has male and female dies ground to produce a flare of 35° to 37°. Under no circumstance is it permissible to use an automotive-type flaring tool which produces a flare of45°.

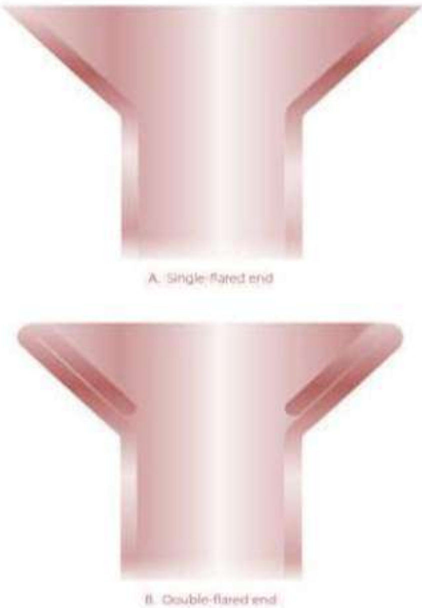


Fig 6.6

The single-flare hand flaring tool, similar to that shown in Figure6.7 , is used for flaring tubing. The tool consists of a flaring block or grip die, a yoke, and a flaring pin. The flaring block is a hinged double bar with holes corresponding to various sizes of tubing. These holes are countersunk on one end to form the outside support against which the flare is formed. The yoke is used to center the flaring pin over the end of the tube to be flared. Two types of flaring tools are used to make flares on tubing: the impact type and the rolling type.

Fig 6.7 Instructions for Rolling-Type Flaring Tools

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

<u>Double Flaring</u>

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

<u>Double Flaring Instructions</u>

Deburr both the inside and outside of the tubing to be flared. Cut off the end of the tubing, if it appears damaged. Anneal brass, copper, and aluminum by heating to a dull red and cool rapidly in cold water. Open the flaring tool by unscrewing both clamping screws. Select the hole in the flaring bar that matches the tubing diameter and place the tubing with the end you have just prepared, extending above the top of the bar by a distance equal to the thickness of the shoulder of the adapter insert. Tighten clamping screws to hold tubing securely. Insert pilot of correctly sized adapter into tubing. Slip yoke over the flaring bars and center over adapter. Advance the cone downward until the shoulder of the adapter rests on the flaring bar. This bells out the end of the tubing. Next, back off the cone just enough to remove the adapter. After removing the adapter, advance the cone directly into the belled end of the tubing. This folds the tubing on itself and forms an accurate double flare without cracking or splitting the tubing. To prevent thinning out of the flare wall, do not over tighten.

Fluid Line Identification

Fluid lines in aircraft are often identified by markers made up of color codes, words, and geometric symbols. These markers identify each line's function, content, and primary hazard. Figure 6.8 illustrates the various color codes and symbols used to designate the type of system and its contents. Fluid lines are marked, in most instances with 1" tape or decals, as shown in Figure 6.9 (A). On lines 4" in diameter (or larger), lines in oily environment, hot lines, and on some cold lines, steel tags may be used in place of tape or decals, as shown in Figure 6.9 (B). Paint is used on lines in engine compartments, where there is the possibility of tapes, decals, or tags being drawn into the engine induction system. In addition to the above-mentioned markings, certain lines may be further identified regarding specific function within a system; for example, drain, vent, pressure, or return. Lines conveying fuel may be marked FLAM; lines containing toxic materials are marked TOXIC in place of FLAM. Lines containing physically dangerous materials, such as oxygen, nitrogen, or Freon™, may be marked PHDAN. [Figure 6.9]

Aircraft and engine manufacturers are responsible for the original installation of identification markers, but the aviation mechanic is responsible for their replacement when it becomes necessary. Tapes and decals are generally placed on both ends of a line and at least once in each compartment through which the line runs. In addition, identification markers are placed immediately adjacent to each valve, regulator, filter, or other accessory within a line. Where paint or tags are used, location requirements are the same as for tapes and decals

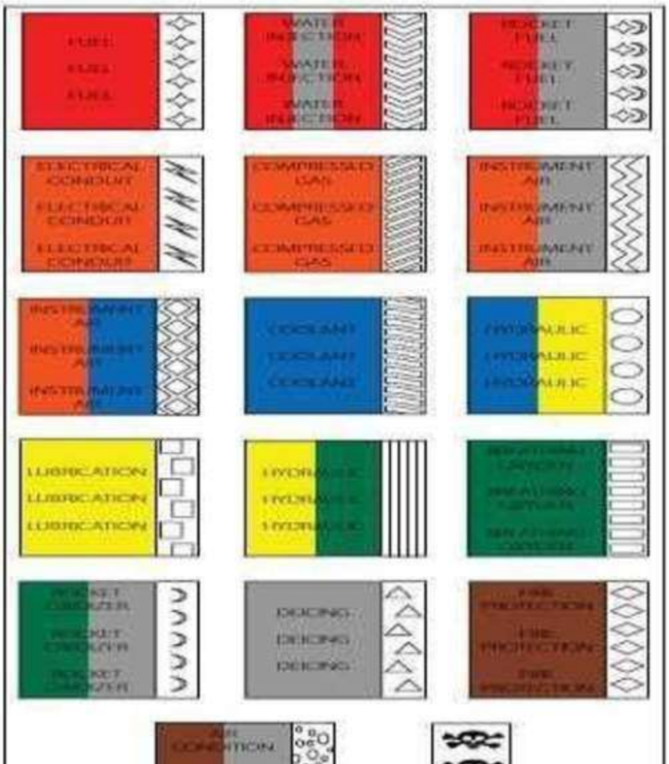


Fig 6.8

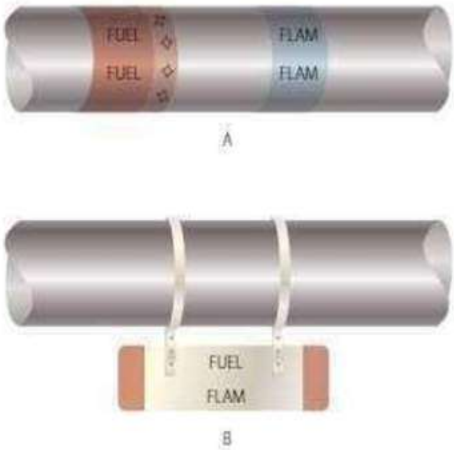


Fig 6.9

Rigid Tubing Installation and Inspection

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

Connection and Torque

Never apply compound to the faces of the fitting or the flare, for it will destroy the metal-to-metal contact between the fitting and flare, a contact which is necessary to produce the seal. Be sure that the line assembly is properly aligned before tightening the fittings. Do not pull the installation into place with torque on the nut. Always tighten fittings to the correct torque value when installing a tube assembly. Over tightening a fitting may badly damage or completely cut off the tube flare, or it may ruin the sleeve or fitting nut. Failure to tighten sufficiently also may be serious, as this condition may allow the line to blow out of the assembly or to leak under system pressure. The use of torque wrenches and the prescribed torque values prevents over tightening or Under tightening. If a tube fitting assembly is tightened properly, it may be removed and retightened many times before re flaring is necessary.

Flare less Tube Installation

Tighten the nut by hand until an increase in resistance to turning is encountered. Should it be impossible to run the nut down with the fingers, use a wrench, but be alert for the first signs of bottoming. It is important that the final tightening commence at the point where the nut just begins to bottom. Use a wrench and turn the nut one-sixth turn (one flat on a hex nut). Use a wrench on the connector to prevent it from turning while tightening the nut. After the tube assembly is installed, the system should be pressure tested. It is permissible to tighten the nut an additional one-sixth turn (making a total of one-third turn), should a connection leak. If leakage still occurs after tightening the nut a total of one-third turn, remove the assembly and inspect the components for scores, cracks, presence of foreign material, or damage from over tightening. Several aircraft manufacturers include torque values in their maintenance manuals to tighten the flare less fittings. The following notes, cautions, and faults apply to the installation of rigid tubing.

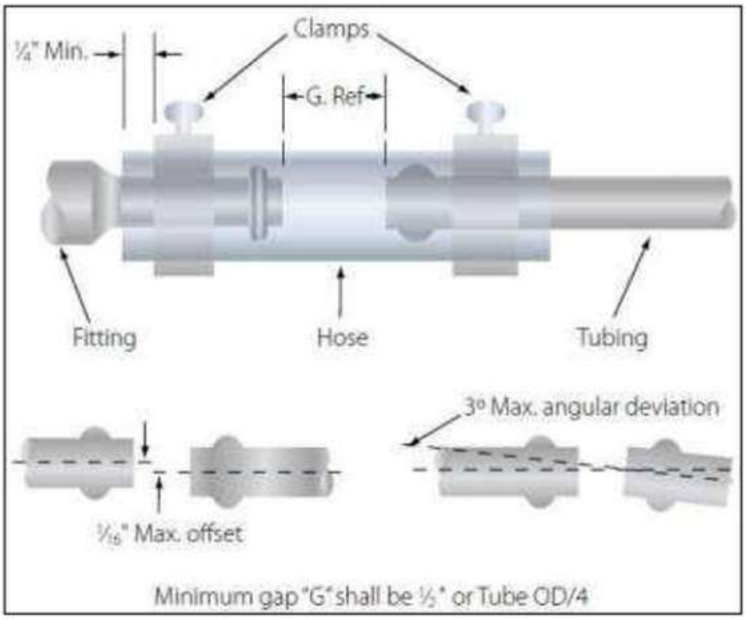
Note: Over tightening a flare less tube nut drives the cutting edge of the sleeve deeply into the tube, causing the tube to be weakened to the point where normal in-flight vibration could cause the tube to shear. After inspection (if no discrepancies are found), reassemble the connections and repeat the

pressure test procedures.
Caution: Never tighten the nut beyond one-third turn (two flats on the hex nut); this is the maximum the fitting may be tightened without the possibility of permanently damaging the sleeve and nut.

Common faults: Flare distorted into nut threads; sleeve cracked; flare cracked or split; flare out of round; inside of flare rough or scratched; and threads of nut or union dirty, damaged, or broken.

Rigid Tubing Inspection and Repair

Minor dents and scratches in tubing may be repaired. Scratches or nicks not deeper than 10 percent of the wall thickness in aluminum alloy tubing, which are not in the heel of a bend, may be repaired by burnishing with hand tools. The damage limits for hard, thin walled corrosion-resistant steel and titanium tubing are considerably less than for aluminum tubing, and might depend on the aircraft manufacturer. Consult the aircraft maintenance manual for damage limits. Replace lines with severe die marks, seams, or splits in the tube. Any crack or deformity in a flare is unacceptable and is cause for rejection. A dent of less than 20 percent of the tube diameter is not objectionable, unless it is in the heel of a bend. To remove dents, draw a bullet of proper size through the tube by means of a length of cable, or push the bullet through a short straight tube by means of a dowel rod. In this case, a bullet is a ball bearing or slug normally made of steel or some other hard metal. In the case of soft aluminum tubing, a hard wood slug or dowel may even be used as a bullet. A severely damaged line should be replaced. However, the line may be repaired by cutting out the damaged section and inserting a tube section of the same size and material. Flare both ends of the undamaged and replacement tube sections and make the connection by using standard unions, sleeves, and tube nuts. Aluminum 6061-T6, corrosion resistant steel 304-1/8h and Titanium 3AL-2.5V tubing can be repaired by swaged fittings. If the damaged portion is short enough, omit the insert tube and repair by using one repair union. When repairing a damaged line, be very careful to remove all chips and burrs. Any open line that is to be left unattended for some time should be sealed, using metal, wood, rubber, or plastic plugs or caps. When repairing a low-pressure line using a flexible fluid connection assembly, position the hose clamps carefully to prevent overhang of the clamp bands or chafing of the tightening screws on adjacent parts. If chafing can occur, the hose clamps should be repositioned on the hose. Figure below illustrates the design of a flexible fluid connection assembly and gives the maximum allowable angular and dimensional offset.



When replacing rigid tubing, ensure that the layout of the new line is the same as that of the line being replaced. Remove the damaged or worn assembly, taking care not to further damage or distort it, and use it as a forming template for the new part. If the old length of tubing cannot be used as a pattern, make a wire template, bending the pattern by hand as required for the new assembly. Then bend the tubing to match the wire pattern. Never select a path that does not require bends in the tubing. A tube cannot be cut or flared accurately enough so that it can be installed without bending and still be free from mechanical strain. Bends are also necessary to permit the tubing to expand or contract under temperature changes and to absorb vibration. If the tube is small (under 1⁄4") and can be hand formed, casual bends may be made to allow for this. It the tube must be machine formed, definite bends must be made to avoid a straight assembly. Start all bends a reasonable distance from the fittings because the sleeves and nuts must be slipped back during the fabrication of flares and during inspections. In all cases, the new tube assembly should be so formed prior to installation that it will not be necessary to pull or deflect the assembly into alignment by means of the coupling nuts.

FLEXIBLE HOSE FLUID LINES

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

Hose Materials and Construction

Pure rubber is never used in the construction of flexible fluid lines. To meet the requirements of strength, durability, and workability, among other factors, synthetics are used in place of pure rubber. Synthetic materials most commonly used in the manufacture of flexible hose are Buna-N, neoprene, butyl, ethylene propylene diene rubber (EPDM) and Teflon™. While Teflon™ is in a category of its own, the others are synthetic rubber. Buna-N is a synthetic rubber compound which has excellent resistance to petroleum products. Do not confuse with Buna-S. Do not use for phosphate ester base hydraulic fluid (Skydrol). Neoprene is a synthetic rubber compound which has an acetylene base. Its resistance to petroleum products is not as good as Buna-N, but it has better abrasive resistance. Do not use for phosphate ester base hydraulic fluid (Skydrol).

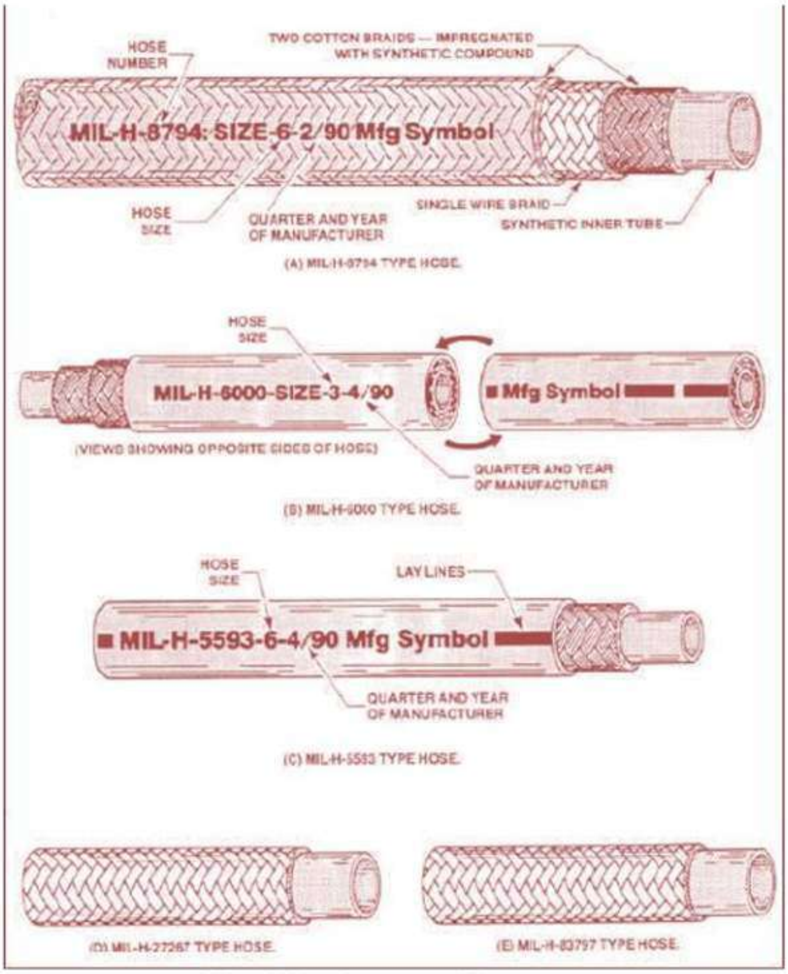
Butyl is a synthetic rubber compound made from petroleum raw materials. It is an excellent material to use with phosphate ester base hydraulic fluid (Skydrol). Do not use with petroleum products. Flexible rubber hose consists of a seamless synthetic rubber inner tube covered with layers of cotton braid and wire braid and an outer layer of rubber-impregnated cotton braid. This type of hose is suitable for use in fuel, oil, coolant, and hydraulic systems.
The types of hose are normally classified by the amount of pressure they are designed to withstand under normal operating conditions. Low, Medium, and High Pressure Hoses Operating pressures.

• Low pressure — below 250 psi. Fabric braids reinforcement.
• Medium pressure — up to 3,000 psi. One wire braid reinforcement. Smaller sizes carry up to 3,000 psi. Larger sizes carry pressure up to 1,500 psi.
• High pressure — all sizes up to 3,000psi

Hose Identification

Lay lines and identification markings consisting of lines, letters, and numbers are printed on the hose. Most hydraulic hose is marked to identify its type, the quarter and year of manufacture, and a 5-digit code identifying the manufacturer. These markings are in contrasting colored letters and numerals which indicate the natural lay (no twist) of the hose and are repeated at intervals of not more than 9 inches along the length of the hose. Code markings assist in replacing a hose with one of the same specifications or a recommended substitute. Hose suitable for use with phosphate ester base hydraulic fluid will be marked Skydrol use. In some instances, several types of hose may be suitable for the same use. Therefore, to make the correct hose selection, always refer to the applicable aircraft maintenance or parts manual.

Teflon™ is the DuPont trade name for tetra fluoroethylene resin. It has a broad operating temperature range (−65 °F to +450 °F). It is compatible with nearly every substance or agent used. It offers little resistance to flow; sticky, viscous materials will not adhere to it. It has less volumetric expansion than rubber, and the shelf and service life is practically limitless. Teflon™ hose is flexible and designed to meet the requirements of higher operating temperatures and pressures in present aircraft systems. Generally, it may be used in the same manner as rubber hose. Teflon™ hose is processed and extruded into tube shape to a desired size. It is covered with stainless steel wire, which is braided over the tube for strength and protection. Teflon™ hose is unaffected by any known fuel, petroleum, or synthetic base oils, alcohol, coolants, or solvents commonly used in aircraft. Teflon™ hose has the distinct advantages of a practically unlimited storage time, greater operating temperature range, and broad usage (hydraulic, fuel, oil, coolant, water, alcohol, and pneumatic systems). Medium- pressure Teflon™ hose assemblies are sometimes preformed to clear obstructions and to make connections using the shortest possible hose length. Since pre forming permits tighter bends that eliminate the need for special elbows, preformed hose assemblies save space and weight. Never straighten a preformed hose assembly. Use a support wire if the hose is to be removed for maintenance.



Hose identification marking

Flexible Hose Inspection

Check the hose and hose assemblies for deterioration at each inspection period. Leakage, separation of the cover or braid from the inner tube, cracks, hardening, lack of flexibility, or excessive—cold flows are apparent signs of deterioration and reason for replacement. The term—cold flow describes the deep, permanent impressions in the hose produced by the pressure of hose clamps or supports. When failure occurs in a flexible hose equipped with swaged end fittings, the entire assembly must be replaced. Obtain a new hose assembly of the correct size and length, complete with factory installed end fittings. When failure occurs in hose equipped with reusable end fittings, a replacement line can be fabricated with the use of such tooling as may be necessary to comply with the assembly instructions of the manufacturer.

Flexible Hose Testing

All flexible hose must be proof-tested after assembly and applying pressure to the inside of the hose assembly. The proof-test medium may be a liquid or gas. For example, hydraulic, fuel, and oil lines are generally tested using hydraulic oil or water, whereas air or instrument lines are tested with dry, oil-free air or nitrogen. When testing with a liquid, all trapped air is bled from the assembly prior to tightening the cap or plug. Hose tests, using a gas, are conducted underwater. In all cases, follow the hose manufacturer's instructions for proof-test pressure and fluid to be used when testing a specific hose assembly. When a flexible hose has been repaired or overhauled using existing hardware and new hose material, and before the hose is installed on the aircraft, it is recommended that the hose be tested to at least 1.5 system pressure. A hydraulic hose burst test stand is used for testing flexible hose. A new hose can be operationally checked after it is installed in the aircraft using system pressure.

Size Designations

Hose is also designated by a dash number, according to its size. The dash number is stenciled on the side of the hose and indicates the size tubing with which the hose is compatible. It does not denote inside or outside diameter. When the dash number of the hose corresponds with the dash number of the tubing, the proper size hose is being used.

Hose Fittings

Flexible hose may be equipped with either swaged fittings or detachable fittings, or they may be used with beads and hose clamps. Hoses equipped with swaged fittings are ordered by correct length from the manufacturer and ordinarily cannot be assembled by the mechanic. They are swaged and tested at the factory and are equipped with standard fittings. The detachable fittings used on flexible hoses may be detached and reused if they are not damaged; otherwise, new fittings must be used.

Installation of Flexible Hose Assemblies

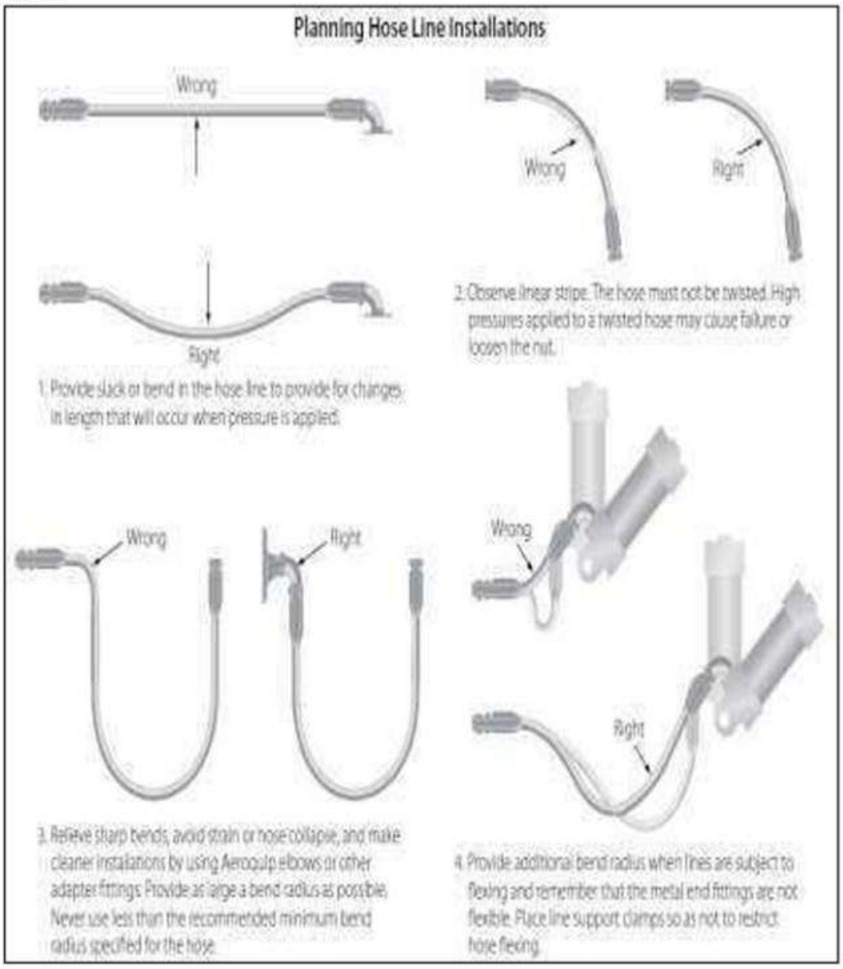
Slack—Hose assemblies must not be installed in a manner that will cause a mechanical load on the hose. When installing flexible hose, provide slack or bend in the hose line from 5 to 8 percent of its total length to provide for changes in length that will occur when pressure is applied. Flexible hose contracts in length and expands in diameter when pressurized. Protect all flexible hoses from excessive temperatures, either by locating the lines so they will not be affected or by installing shrouds around them.

Flex— When hose assemblies are subject to considerable vibration or flexing, sufficient slack must be left between rigid fittings. Install the hose so that flexure does not occur at the end fittings. The hose must remain straight for at least two hose diameters from the end fittings. Avoid clamp locations that will restrict or prevent hose flexure.

Twisting— Hoses must be installed without twisting to avoid possible rupture of the hose or loosening of the attaching nuts.
Use of swivel connections at one or both ends will relieve twist stresses. Twisting of the hose can be determined from the identification stripe running along its length. This stripe should not spiral around the hose.

Bending— To avoid sharp bends in the hose assembly, use elbow fittings, hose with elbow-type end fittings, or the appropriate bend radii. Bends that are too sharp will reduce the bursting pressure of flexible hose considerably below its rated value.

Clearance— The hose assembly must clear all other lines, equipment, and adjacent structure under every operating condition.



1. Provide slack or bend in the hose line to provide for changes in length that will occur when pressure is applied.

2. Observe linear stripe. The hose must not be twisted. High pressures applied to a twisted hose may cause failure or loosen the nut.

3. Relieve sharp bends, avoid strain or hose collapse, and make cleaner installations by using Aeroquip elbows or other adapter fittings. Provide as large a bend radius as possible. Never use less than the recommended minimum bend radius specified for the hose.

4. Provide additional bend radius when lines are subject to flexing and remember that the metal end fittings are not flexible. Place line support clamps so as not to restrict hose flexing.

Flexible hose should be installed so that it will be subject to a minimum of flexing during operation. Although hose must be supported at least every 24 inches, closer supports are desirable. Flexible hose must never be stretched tightly between two fittings. If clamps do not seal at specified tightening, examine hose connections and replace parts as necessary. The above is for initial installation and should not be used for loose clamps. For retightening loose hose clamps in service, proceed as follows: Non-self-sealing hose—if the clamp screw cannot be tightened with the fingers, do not disturb unless leakage is evident. If leakage is present, tighten one-fourth turn. Self-sealing hose—if looser than finger-tight, tighten to finger-tight and add one-fourth turn.

Hose Clamps

To ensure proper sealing of hose connections and to prevent breaking hose clamps or damaging the hose, follow the hose clamp tightening instructions carefully. When available, use the hose clamp torque-limiting wrench. These wrenches are available in calibrations of 15 and 25 in-lb limits. In the absence of torque limiting wrenches, follow the finger-tight-plus-turns method. Since hose connections are subject to —cold flow or a setting process, a follow-up tightening check should be made for several days after installation. Support clamps are used to secure the various lines to the airframe or power plant assemblies. Several types of support clamps are used for this purpose. The most commonly used clamps are the rubber-cushioned and plain. The rubber-cushioned clamp is used to secure lines subject to vibration; the cushioning prevents chafing of the tubing. The plain clamp is used to secure lines in areas not subject to vibration. A Teflon™-cushioned clamp is used in areas where the deteriorating effect of Skydrol, hydraulic fluid, or fuel is expected. However, because it is less resilient, it does not provide as good a vibration- damping effect. as other cushion materials.
Use bonded clamps to secure metal hydraulic, fuel, or oil lines in place. Unbounded clamps should be used only for securing wiring. Remove any paint or anodizing from the portion of the tube at the bonding clamp location. Make certain that clamps are of the correct size. Clamps or supporting clips smaller than the outside diameter of the hose may restrict the flow of fluid through the hose. All fluid lines must be secured at specified intervals

(b)Standard unions for aircraft hydraulic, fuel, oil, pneumatic and air system pipes.

Fittings

Rigid tubing may be joined to either an end item (such as a brake cylinder), another section of either rigid tubing, or to a flexible hose (such as a drain line). In the case of connection to an end item or another tube, fittings are required, which may or may not necessitate flaring of the tube. In the case of attachment to a hose, it may be necessary to bead the rigid tube so that a clamp can be used to hold the hose onto the tube.

Depending on the type and use, fittings will have either pipe threads or machine threads. Pipe threads are similar to those used in ordinary plumbing and are tapered, both internal and external. External threads are referred to as male threads and internal threads are female threads. When two fittings are joined, a male into a female, the thread taper forms a seal.
Machine threads have no sealing capability and are similar to those used on common nuts and bolts. This or for attachment through bulkheads. A flared tube connection, a crush washer, or a synthetic seal is used to make the connection fluid tight.

Universal Bulkhead Fittings

When a fluid line passes through a bulkhead, and it is desired to secure the line to the bulkhead, a bulkhead fitting should be used. The end of the fitting that passes through the bulkhead is longer than the other end(s), which allows a locknut to be installed, securing the fitting to the bulkhead. Fittings attach one piece of tubing to another, or to system units. There are four types:
(1) bead and clamp, (2) flared fittings, (3) flareless fittings, and (4) permanent fittings (Permaswage™, Permalite™, andCyrofit™).
The beaded type of fitting, which requires a bead and a section of hose and hose clamps, is used only in low- or medium-pressure systems, such as vacuum and coolant systems. The flared, flare less, or permanent type fittings may be used as connectors in all systems, regardless of the pressure.

AN Flared Fittings

A flared tube fitting consists of a sleeve and a nut, as shown in Figure 6.10. The nut fits over the sleeve and, when tightened, draws the sleeve and tubing flare tightly against a male fitting to form a seal. Tubing used with this type of fitting must be flared before installation. The male fitting has a cone-shaped surface with the same angle as the inside of the flare. The sleeve supports the tube so that vibration does not concentrate at the edge of the flare, and distributes the shearing action over a wider area for added strength.

Standard AN fittings are identified by their black or blue color. All AN steel fittings are colored black, all AN aluminum fittings are colored blue, and aluminum bronze fittings are cadmium plated and natural in appearance. A sampling of AN fittings is shown in Figure6.11.

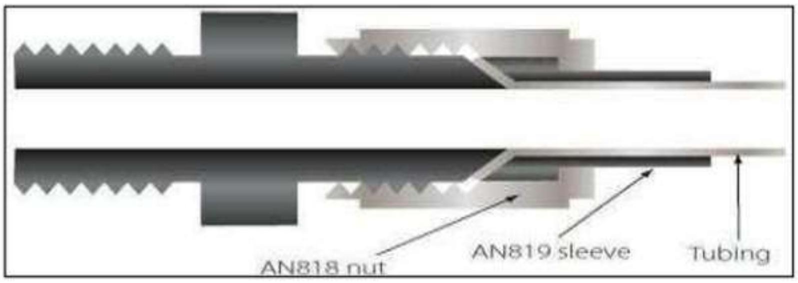


Fig 6.10

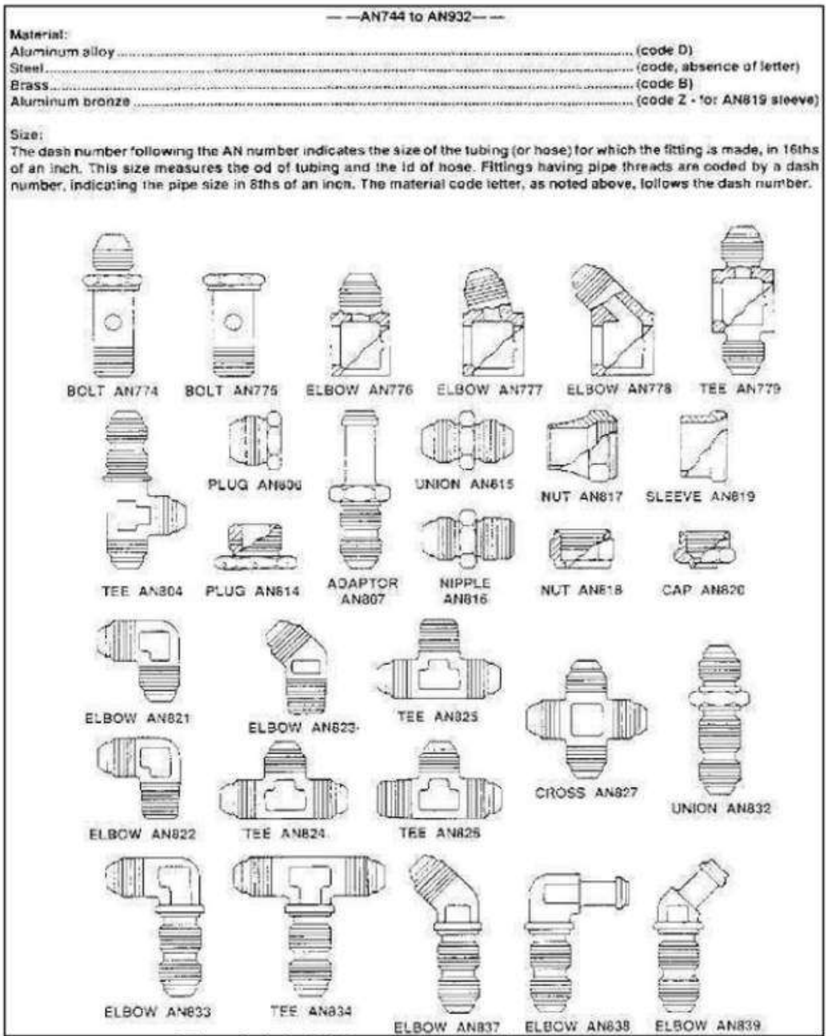


Fig 6.11 AN standard fittings.

MS Flareless Fittings

MS flareless fittings are designed primarily for high pressure (3,000 psi) hydraulic systems that may be subjected to severe vibration or fluctuating pressure. Using this type of fitting eliminates all tube flaring, yet provides a safe and strong, dependable tube connection. [Figure 6.12] The fitting consists of three parts: a body, a sleeve, and a nut. [Figure 6.13]

Swaged Fittings

A popular repair system for connecting and repairing hydraulic lines on transport category aircraft is the use of Permaswage™ fittings. Swaged fittings create a permanent connection that is virtually maintenance free. Swaged fittings are used to join hydraulic lines in areas where routine disconnections are not required and are often used with titanium and corrosion resistant steel tubing. The fittings are installed with portable hydraulically powered tooling, which is compact enough to be used in tight spaces. [Figure 6.14] The movement of the ring along the fitting body results in deformation of the tube with a leak-tight joint. [Figure 6.15]

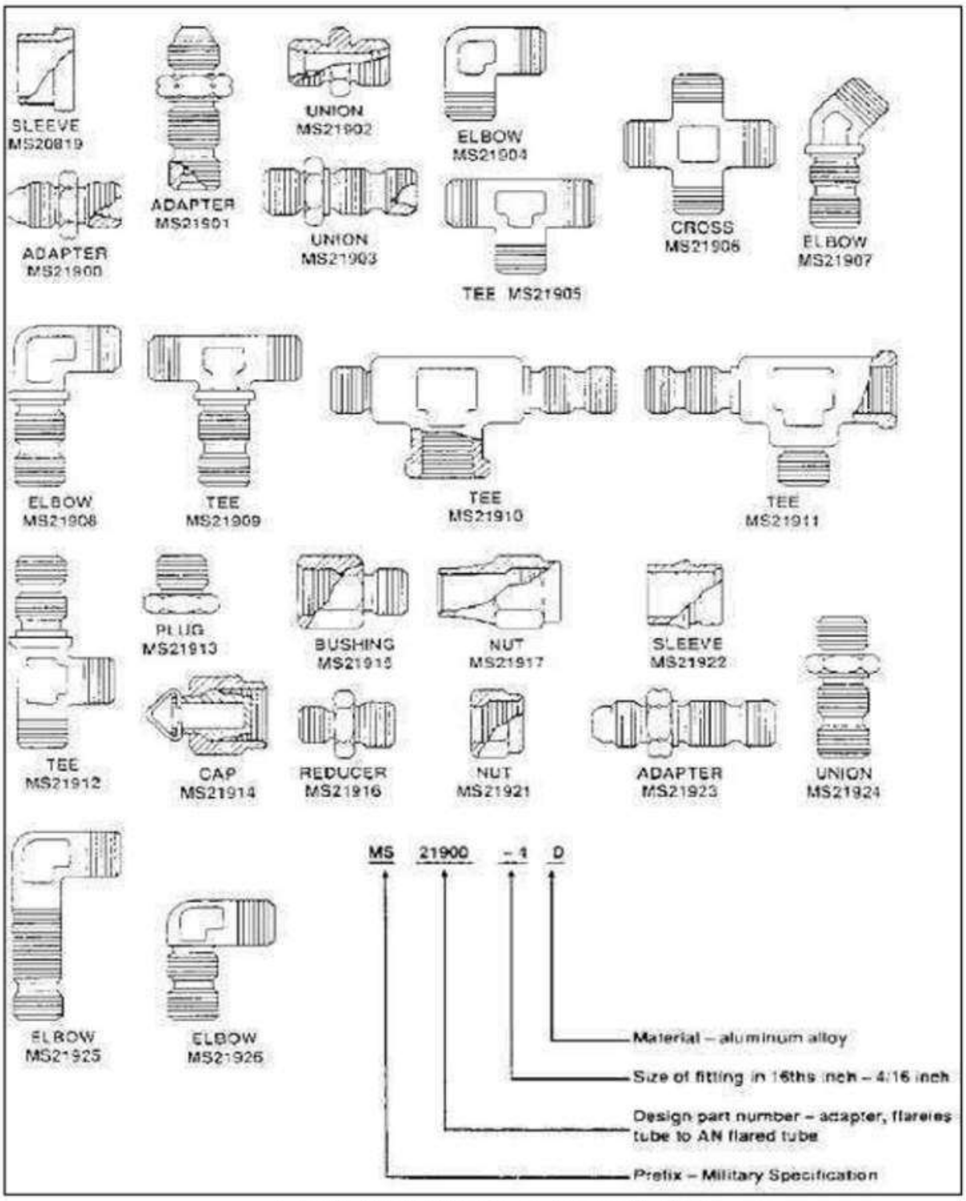


Fig 6.12 MS Flare less Fittings

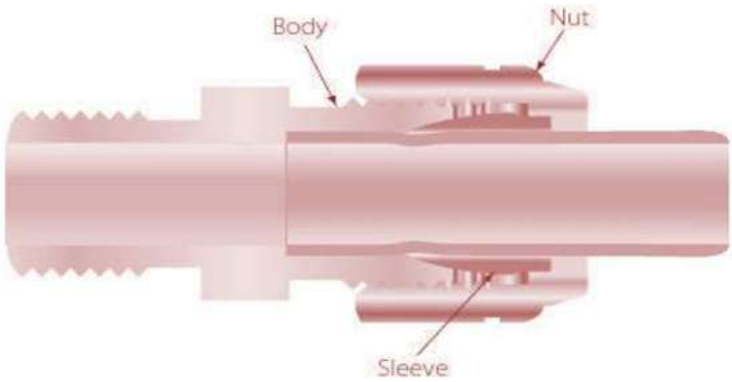


Fig 6.13 Flare less Fittings

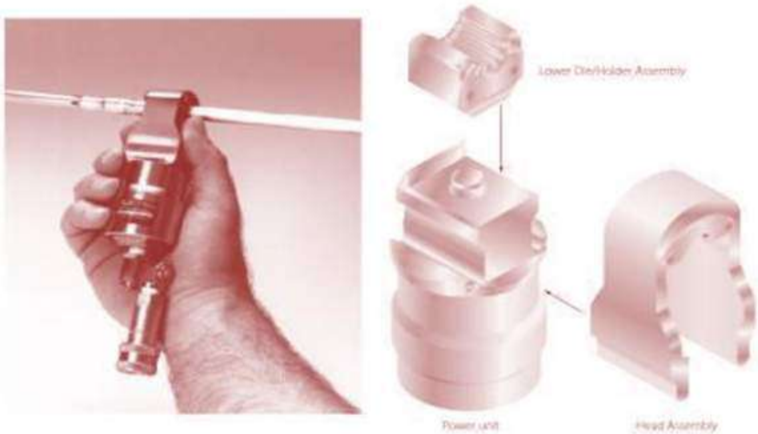


Fig 6.14 Swaged fitting tooling

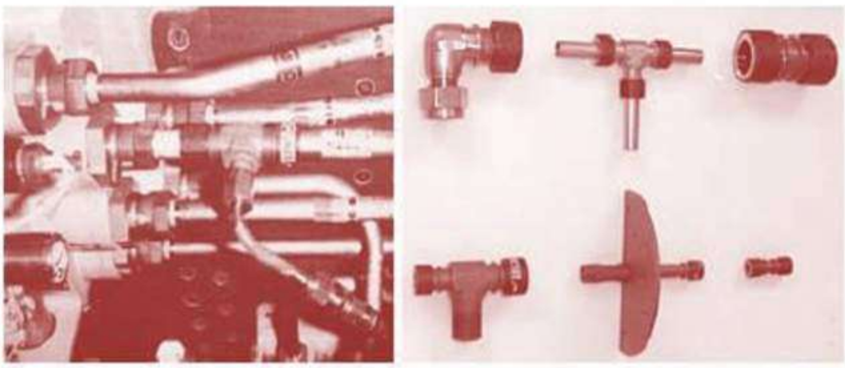


Fig 6.15 Permal*ite*™ *fittings*

Cryofit Fittings

Many transport category aircraft use Cryofit fittings to join hydraulic lines in areas where routine disconnections are not required. Cryofit fittings are standard fittings with a cryogenic sleeve. The sleeve is made of a shape memory alloy, Tinel™. The sleeve is manufactured 3 percent smaller, frozen in liquid nitrogen, and expanded to 5 percent larger than the line. During installation, the fitting is removed from the liquid nitrogen and inserted onto the tube. During a 10 to 15 second warming up period, the fitting contracts to its original size (3 percent smaller), biting down on the tube, forming a permanent seal. Cryofit fittings can only be removed by cutting the tube at the sleeve.

Fig 6.16 Cryofit fittings

Beading

Tubing may be beaded with a hand beading tool, with machine beading rolls, or with grip dies. The method to be used depends on the diameter and wall thickness of the tube and the material from which it was made The hand beading tool is used with tubing having 1⁄4" to 1" outside diameter. The bead is formed by using the beader frame with the proper rollers attached. The inside and outside of the tube is lubricated with light oil to reduce the friction between the rollers during beading. The sizes, marked in sixteenths of an inch on the rollers, are for the outside diameter of the tubing that can be beaded with the rollers. [Figure6.17]
As a rule, beading machines are limited to use with large diameter tubing, over 115⁄16", unless special rollers are supplied. The grip- die method of beading is confined to small tubing.

Fig 6.17 Hand beading tool

Module 6.7: SPRINGS

SPRINGS

GENERAL

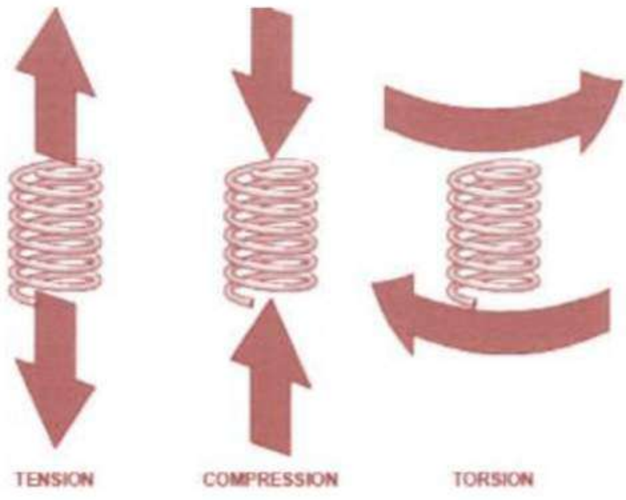
While springs are simple devices, they are an essential working part of most machines in one form or another.
They use the property of elasticity, inherent in many materials, which allows them to absorb energy by distorting or deflecting when under load, store it in their loaded state, and then release it in a controlled manner as they return to their original shape after the load has moderated (or has been removed). Early springs consisted of flat and curved sections of wood (and later metal), used in the suspension of carts and carriages
The subject of spring technology is vast and well beyond the scope of these notes, so it is sufficient for the student to know the basic uses of springs in the aerospace environment and the functions that they fulfil.

TYPES OF SPRING

The three basic forces, which may be exerted on, and applied by springs are:

- Compression
- Tension
- Torsion

These forces may act singly, in combinations of any two or all three.



Springs have evolved into various shapes and sizes (and degrees of stiffness), which have been dictated by the uses to which they have been put, and the loads they absorb, store and release. The more common forms are described here.

Flat Springs

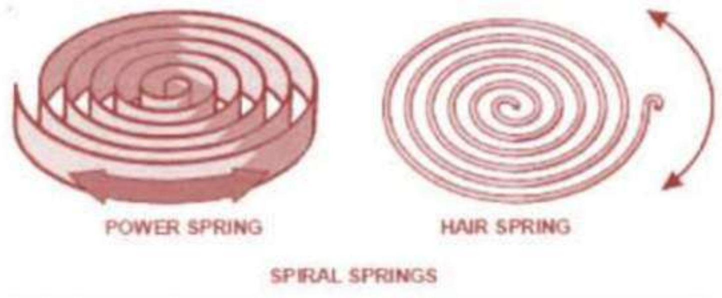
while they were a development of flat, rectangular-sectioned strips of metal, they can actually be found in forms other than simply flat as, for instance, in the shape of the springs which control the contact breaker points in the magneto of an aircraft piston-type engine.

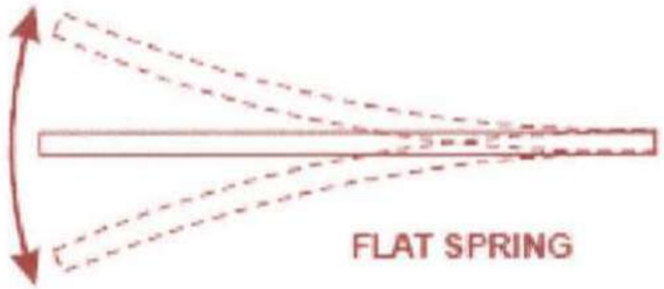
Leaf Springs

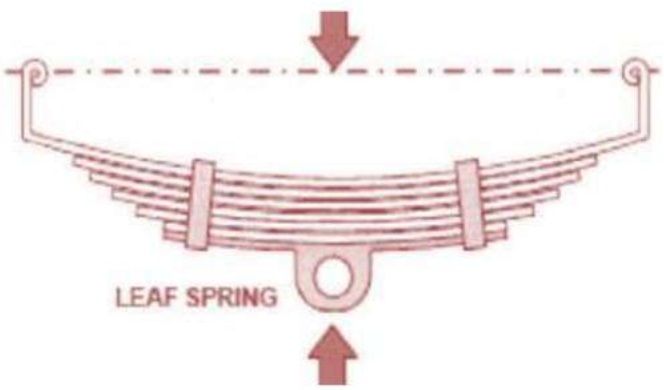
Leaf springs are formed by layers of flat springs and while very early aircraft embodied leaf springs in their landing gear, this type of spring is more familiar in the automobile and railway industries.

Spiral Springs

Spiral springs may be found in the form of spirally wound flat springs (known as motor or power springs) or as spirally wound wire, such as the hair springs of many types of instruments. They are used to store or absorb torsional forces.

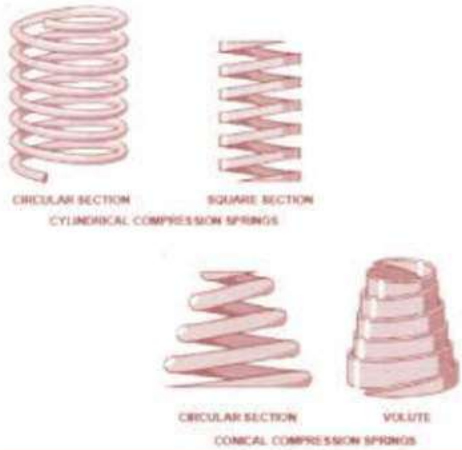






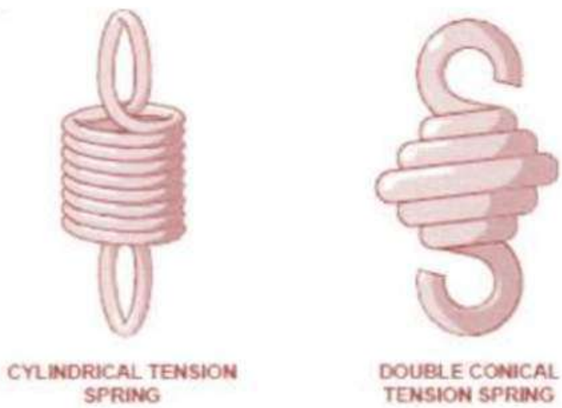
Helical Compression And Tension Springs

Helical compression and tension springs are the most commonly found springs. They are made in a wide variety of materials and sizes and may be found in a seemingly endless number of applications. Compression springs are open wound to accommodate the axial movement.



Tension Springs

Tension springs may be open or close wound but usually have hooks or loops formed at their ends as attachment points. Both Compression and Tension springs may be made of circular, square or rectangular cross section wire.

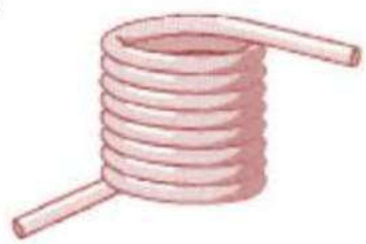


Helical Springs

Helical springs are usually cylindrical in basic form, however Conical Compression springs may replace cylindrical compression springs when the space in the axial direction is limited. The spring coils fold into each other when the spring is completely compressed. A Conical Compression spring of rectangular cross section is referred to as a Volute spring.

Helical Torsion Springs

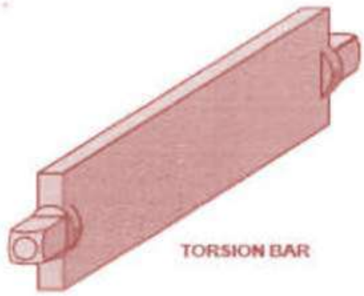
Helical torsion springs while being similarly wound to the cylindrical Compression and Tension springs, have specially shaped ends to permit a torque force to be applied, and transmitted, in a plane normal to the helix axis.



HELICAL TORSION SPRING

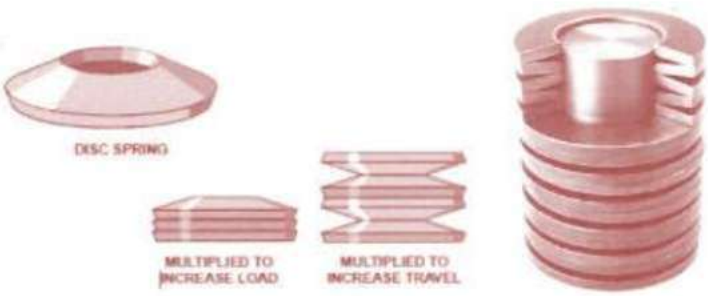
Torsion-Bar Springs

Torsion-bar springs are, basically, straight bars of metal, with splined, square or flanged ends, that can accept and transmit torsional forces.



Disc (Or Cone, Cupped Or Belleville Washer) Springs

Disc springs are shaped like the cup washers used as locking devices. Often referred to as Belleville Springs or Washers, they are capable of exerting frictional or linear forces and can be multiplied in the same direction to increase the spring load or back to back to increase travel.



SPRING MATERIALS

GENERAL

The materials, used for the manufacture of springs, cover a very wide range of metallic and non-metallic (plastic and elastomeric) substances. These notes will, however, be confined mainly to the discussion of metallic types, with a small consideration being given to some composite materials.

There are numerous factors that can affect a choice of material for use in a spring. Perhaps the most important of these is the strength of the material: carbon spring steel is the strongest of the common spring materials, closely followed by Inconel and then stainless steel. But, of course, carbon steel will very quickly corrode, even in normal operation. Put it in salt water and it will be useless within a few weeks. Stainless steel may be used in these sort of conditions but it is slightly more expensive and not so strong. Inconel is a strong material and very corrosion resistant but it is also very expensive, it is usually only used in extremely corrosive environments or where reliability is crucial.

The operating temperature will also play a part in the choice of material. The maximum reliable operating temperature of a spring can be as low as 150°C for carbon spring steel, 300°C for stainless, but up to about 550°C for InconelX750.

The final choice of material may also depend on other factors such as appearance. Stainless steel or Inconel will not corrode but after heat treatment they are not shiny as would be expected. Stainless steel goes a yellowish colour and Inconel goes dark brown. If a shiny finish is required then the material could be plated after manufacture in which case standard carbon spring steel may be more appropriate.

Steels Used For Cold-Wound Springs

A cross-sectional diameter of approximately 9.5 to 18.5 mm (0.375 in to 0.725 in) certain steels are drawn into wires and cold-wound to form the required shape. The wires are then usually, given some form of heat-treatment, to relieve the stresses imposed by the winding processes. Typical types of carbon- and alloy-steel are used for the manufacture of cold wound springs and include:

• HARD-DRAWN SPRING WIRE which is of a low-quality (and cheap) carbon steel. This wire has fine seams in its surface, and as such, would only be used in applications of low stress and low fatigue.

• OIL-TEMPERED SPRING WIRE which is of a better quality, high-carbon steel, though it may also contain surface discontinuities and would be found where long fatigue life is not required.

• MUSIC WIRE which is a carbon-steel of high quality and is suitable for small-sized, helical springs in applications involving high fatigue stresses.

• CHROME-VANADIUM STEEL WIRE which is a material that has been used for piston-type aero-engine valve springs and is, suitable for high temperature and high-stress conditions

• CHROME-SILICON STEEL WIRE which when used in valve springs, has a higher fatigue life in the lower cycle ranges (10-100 kHz) than other wires

• STAINLESS-STEEL SPRING WIRE which as is obvious from its name, is used in conditions where high corrosion- resistance is the requirement. This grade of wire would also be utilised in applications where resistance to creep at elevated temperatures is desired. Some grades of Stainless-Steel wires can be made to accept magnetism, where this characteristic is needed alongside the other qualities.

Steels Used For Hot-Wound Springs

Above the cross-sectional diameters, previously mentioned, it is considered impractical to cold-wind and so, the larger diameter metals (bars or rods) are hot-wound and then also subjected to various stress relieving processes.
Similar carbon- and alloy-steels to those already discussed are employed in the manufacture of hot-wound springs, with the necessary variations in their contents of carbon, chromium, manganese, molybdenum, nickel, silicon, and vanadium.

Steels Used For Cold-Rolled, Flat Springs

These steels vary in composition, depending on their location, but are commonly based on carbon and manganese as the main constituent elements. They may be formed from oil-tempered steels (thin sections - clock-type springs) or from annealed steels which are subsequently heat treated.

Non-Ferrous Metals Used For Springs

Based mainly on copper alloys, where corrosion resistance and good electrical conductivity is required, and on nickel alloys where the ability to work at elevated temperatures and resist corrosion is desirable, these alloys include:

Spring Brass which is comparatively inexpensive, has good electrical conductivity, but is unsuitable for high-stress applications.

Nickel Silver (also called German silver) which has better characteristics than brass and is made from different percentages of copper, zinc and nickel.

Phosphor Bronze which has a minimum percentage of 90% copper content and has excellent electrical conductivity. It is suitable for applications of higher stress levels than those of brass.

Silicon Bronze which has similar characteristics to those of phosphor bronze but is less expensive to produce.

Beryllium Copper which has similar conductivity (and corrosion resistance) qualities to those of copper with the addition of beryllium (2.0-2.5%) imparting greater hardness and other superior mechanical properties.

HIGH-NICKEL ALLOYS which are the types more commonly found in aero engine applications and which fall under various, familiar, trade names such as:

- Monel
- 'K' Monel (3%aluminium)
- Perm nickel
- Inconel
- Inconel 'X' (2.5%Titanium)

Another high-nickel alloy goes under the name of Ni-Span-C and contains almost 50%iron.

All of these non-ferrous alloys can be found in the cold-rolled or drawn conditions for the manufacture of many types of springs.

Corrosion Protection

Depending on application, metallic springs may require corrosion protection. Protective coatings may be of plastic, zinc, nickel, chromium ortin.

COMPOSITE MATERIALS USED FOR SPRINGS

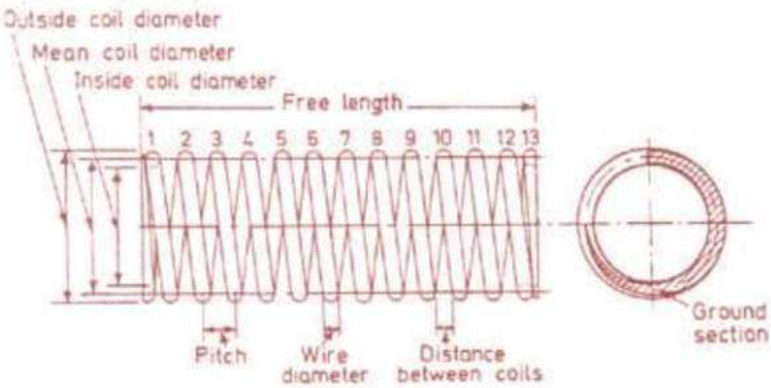
Some composite springs involve the joining of certain metals with elastomers to form the anti-vibration mountings such as those found in aero-engine and auxiliary power unit (APU) installations.

Others combine synthetic rubber strands, encased within a sheath of braided cotton, nylon or similar materials. They are usually referred to as 'Shock Absorbers' or 'Shock Cords' rather than 'Springs' and are more familiarly known by the generic name of 'Bungee Cords'. Bungee Cords may be encountered on many light- and medium-sized aircraft while their use on heavier aircraft is not unknown.

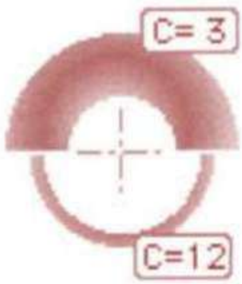
Springs of resin impregnated Aramid and Carbon fiber construction can be made but cost of production usually outweighs any weight saving achieved.

SPRING DIMENSIONS

The helical spring is the type of spring most frequently encountered, and it alone is shown below. It is made from wire of diameter'd'wound into a helix of mean diameter 'D', pitch'p', and total number of turns 'nt'. This last is the number of wire coils prior to end treatment.



The ratio of mean coil diameter to wire diameter is known as the spring index, C = D/d. Portions of two springs which have the same mean coil diameter but different wire diameters and hence different indices are compared here. It is clear that low indices result in difficulty with spring manufacture and in stress concentrations induced by curvature. Springs in the range 5 < C < 10 are preferred, while indices less than 3 are generally impracticable.



Loads are transferred into a spring by means of platens, which are usually just flat surfaces bearing on the spring ends.

PLAIN ENDS when the wire is just cropped off to length - are suitable only for large index, light duty applications unless shaped platens or coil guides are employed, because each spring end contacts its platen at a point offset from the spring axis and this leads to bending of the spring and uncertain performance.

GROUND ENDS distribute the load into the spring more uniformly than do plain ends. One or more turns at the end of a spring may be wound with zero pitch, this is called a squared or closed end Subsequent grinding produces a seating best suited for uniform load transfer, and so squared and ground ends are invariably specified when the duty is appreciable. Grinding the ends becomes difficult when the spring index exceeds 10, and is obviously inappropriate for small wire sizes - say under 0.5mm.

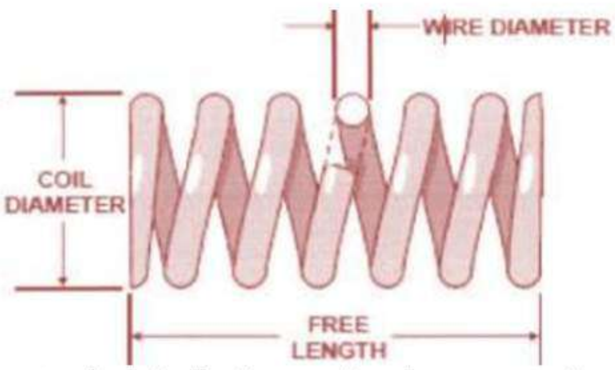
The active turns are the coils which actually deform when the spring is loaded, as opposed to inactive turns at each end which are in contact with the platen and therefore do not deform though they may move bodily with the platen. The free length L0 of a compression spring is the spring's maximum length when lying freely prior to assembly into its operating position and hence prior to loading. The solid length Ls of a compression spring is its minimum length when the load is sufficiently large to close all the gaps between the coils.

SPRING CHARACTERISTICS

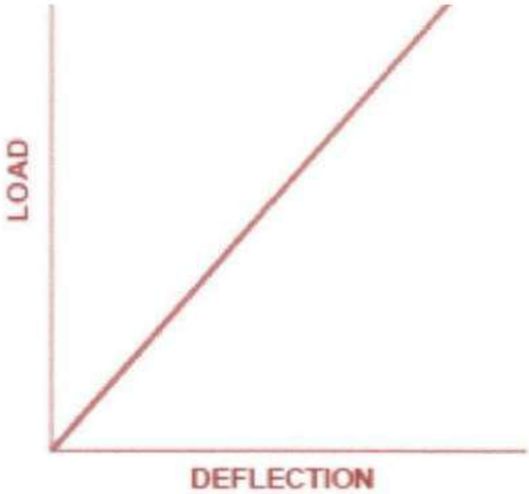
Spring are normally specified by:

- Material
- Wire diameter or cross sectional area
- External diameter
- Internal diameter
- Free length
- Solid length
- Pitch
- End style - open, closed, ground, looped etc.
- Spring Rate

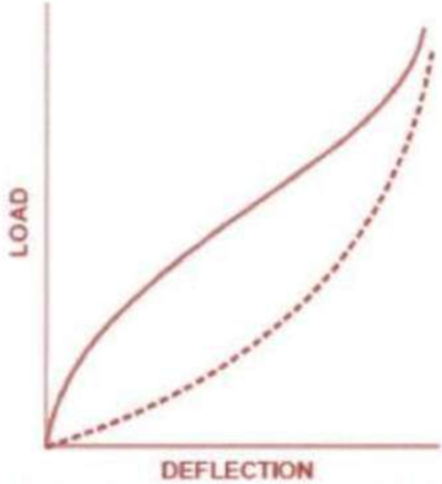
The Spring Rate or stiffness of a spring is the load required to produce a unit of deflection.



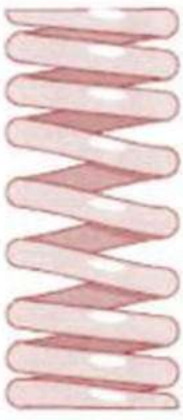
If a Load/Deflection graph for a typical, helical-wound spring were to be plotted, a straight-line (or linear) load/deflection graph would be the result (see below). (Provided the spring was not loaded beyond its elastic limit and the effects of temperature and repeated loading were ignored.) This indicates that the deflection is directly proportional to the load, so if the load is doubled, then the deflection also doubles.

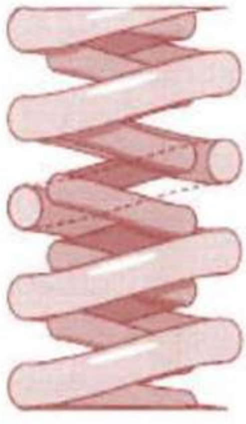


LINEAR LOAD/DEFLECTION GRAPH



NON-LINEAR LOAD/DEFLECTION GRAPH


PROGRESSIVE RATE SPRING


CONTRA-WOUND VALVE SPRINGS

Non-linear load/deflection graphs can be produced by springs with unevenly spaced coils (see below, broken line). These Progressive or Variable Rate springs are of particular use in valves. Belleville springs share these particular characteristics and prove extremely useful in certain control and indicating functions. Another non-linear plot (refer to solid line) can be found when a thin, flat, circular disk is loaded to a large deflection. The individual characteristics of these different spring types are used to good effect in many aeronautical applications.

Piston engine valve springs are made of heat treated spring steel and are usually duplicated and of different strengths to reduce valve bounce. When duplicated they are wound in opposite directions to prevent coil interlocking.

APPLICATION OF SPRINGS IN AIRCRAFT ENGINEERING

There are many applications involving the use of springs in aircraft engineering and some examples are:

- Pressure Regulating/Limiting Devices: in Fuel, Hydraulic, Lubrication, and Pneumatic systems
- 'Fail Safe' or 'Return to Neutral Condition' Devices: in Electrical Relays and Solenoids, and also in Electric, Hydraulic, Mechanical, or Pneumatic Actuators
- Acceleration and Speed Control Devices: in Engine and Propeller control systems and in Power-Assisted Flight Controls and Wheel Braking systems
- Shock Absorbing Devices: in Landing Gear systems and as Anti-Vibration Mountings for delicate instruments and

Components which are subject to movement

- Devices which are capable of applying a constant force (linear or rotary) in a desired direction, as in the holding of an aero engine valve in closed position.
- Devices with the ability to accurately indicate (and control) the value of an applied force, as used in many instruments such as Ammeters, Voltmeters, Fuel Flow Meters and Tachometers provide typical examples.

SPRING MAINTENANCE GENERAL

Most springs are contained inside units and assemblies and are not accessible during aircraft maintenance; these will be inspected, tested and if necessary replaced during component overhaul.

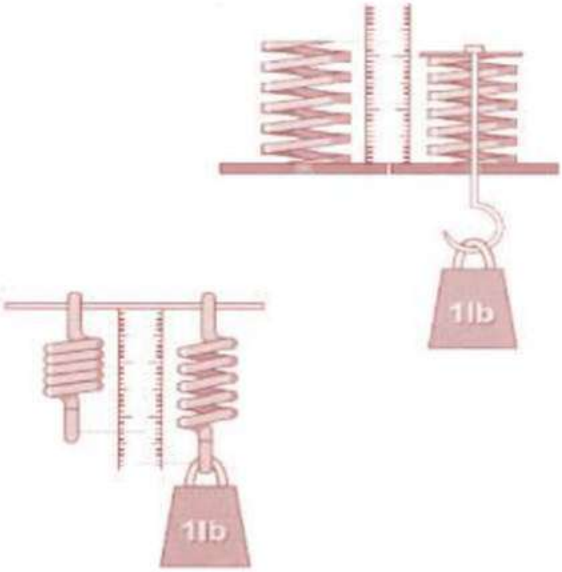
Springs which are accessible generally require very little maintenance. When visible, inspection must be carried out at the specified intervals for damage such as;

- Fretting against adjacent components,
- Distortion - crushing, bending and stretching,
- Overheating as evidenced by discoloration,
- Cracking and
- Corrosion.

Spring Rate may be tested in-situ by measuring the load applied by, or need to overcome a spring loaded mechanism. For instance, a spring balance may be used on a door handle to measure the force required to operate the spring mechanism of a door latch system.

For disassembled springs Spring Rate may be assessed by measuring the length of the relaxed item then applying a specified load and measuring the compressed or extended length.

Any defect found is cause for replacement. It is essential that only the correct spring is used as these parts are often vital to the operation of the system in which they are installed. For this reason replacement springs must be selected by part number with reference to the Illustrated Parts Catalogue.



INSPECTION AND TESTING OF SPRINGS

Springs will generally require little in the way of maintenance. Those that are in exposed areas can become corroded over time and those in areas of high temperature can, if they become over heated, lose their temper and cease to have the necessary mechanical compliance to satisfy the task for which they were designed.

Corrosion, that occurs on static springs, can reduce the loads that the spring can carry, whilst if a spring that carries cyclic loads becomes corroded, then the combination of fatigue and corrosion can result in a serious loss of fatigue strength.

Overheating, usually shown as blistering of the surface protection can, in extreme circumstances, show a change of colour of the metal due to the loss of temper. It must be assumed in this event that the spring is not suitable for the designed task.

It is important that any exposed springs are carefully inspected for signs of either of the problems of corrosion and overheating.

In some instances, springs have to be checked against figures or graphs to prove whether they are in a suitable condition to continue in service. Some checks have to be done out at prescribed intervals whilst others are done on an 'opportunity basis', such as when a brake unit of a hydraulic actuator is dismantled for overhaul.

The most common check done on coil springs is on its static measurement.

The manufacturer will publish the exact dimension of the unloaded spring with some small tolerance, whilst the servicing technician will accurately measure the spring's length and compare the two dimensions.

Providing that the spring is within the published figures, then the spring is considered to be serviceable.

The other check, usually completed in a workshop environment, is the load/deflection check.
This check is done on the springs which are used in more critical services, such as piston engine valve

springs.

A special test rig is used, to load the spring with either a compressive, tensile or a torsional loading and a meter on the rig will display the load versus deflection figures. A series of loads are subsequently applied to the spring and the relevant deflections noted.

On completion, the figures are compared to a graph, published by the spring manufacturer, to establish the serviceability of the spring.

If a spring fails any of these checks it is simply replaced with a serviceable item.

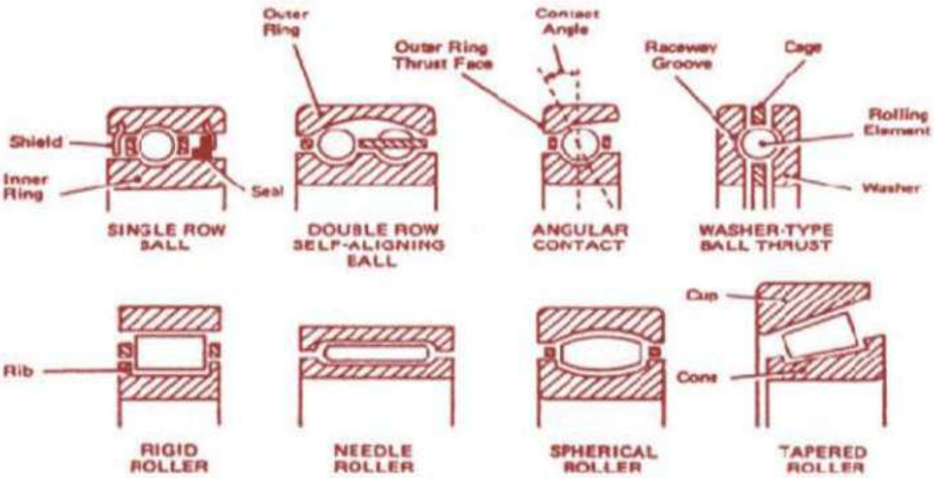
MODULE 6.8: BEARINGS GENERAL

Bearings are broadly classified by the type of rolling element used in their construction. Ball bearings employ steel balls which rotate in grooved raceways, whilst roller bearings utilize cylindrical, tapered or spherical rollers, running in suitably shaped raceways. Both types of bearings are designed for operation under continuous rotary or oscillatory conditions, but, whilst ball bearings and tapered roller bearings accept both radial and axial loads, other types of roller bearings accept mainly radial loads. The following paragraphs amplify the uses of the various types of bearings, and examples are shown.

Caged bearings are in general use for engine applications and in equipment with rotational speeds in excess of approximately 100 rev/mm. Most other bearings on an aircraft are intended for oscillating or slow rotation conditions and do not have a cage; they are generally shielded and pre-packed with grease, but some have republication facilities.

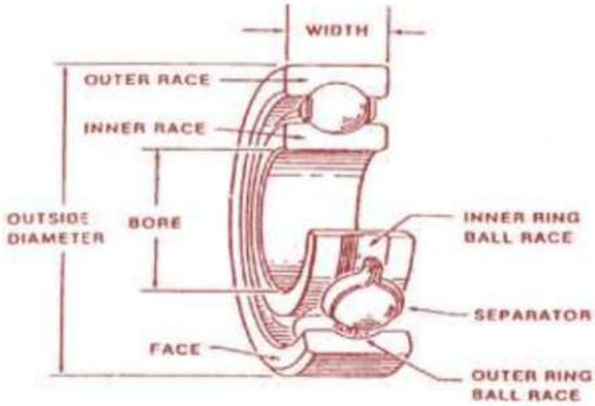
TYPES OF BEARINGS

Although these notes give information on the uses of the various types of ball and roller bearings, - together with general information on installation, maintenance and inspection, - the Aircraft Maintenance Manual (AMM) should be the final arbiter for specific installations.



BALL BEARINGS

These consist of an inner and outer race separated by hardened steel balls. This class of bearing relies on the motion of the balls to reduce friction between the inner race carried on the shaft of the machine and the outer race which is normally fitted inside a housing on the stationary part of the machine. The bearing may be constructed using single or double rows of balls, each row controlled by bronze or brass cage, but bearings which do not have a cage are often used. Ball bearings are designed for RADIAL or THRUST loads or a combination of both and are able to operate in either direction of rotation. Ball bearings can be of rigid or self-aligning type depending on the requirement, this being determined at the time of manufacture.



Ball bearings may be divided into four main types that define the way in which the bearings are used. The main types of Ball bearings are:

- Radial Bearings
- Angular-Contact Bearings
- Thrust Bearings
- Instrument Precision Bearings

RADIAL BEARINGS

Radial bearings are the most common type of bearing and can be found in all types of transmission assemblies such as shafts, gears, control rods and end fittings. They are manufactured with either a single or double row of balls, rigid for normal applications and self-aligning for positions where accurate alignment cannot be maintained, such as in control rod ends.

ANGULAR-CONTACT BEARINGS

Angular-Contact bearings are capable of accepting radial loads and axial loads in one direction only. The outer ring is recessed on one side to allow the ball and cage assembly to be installed, thus enabling more balls to be used and the cage to be in one piece. The axial load capacity depends on the contact angle.

In applications where axial loads will always be in one direction, a single angular-contact bearing may be used but, where they vary in direction, an opposed pair of bearings may be used.

THRUST BEARINGS

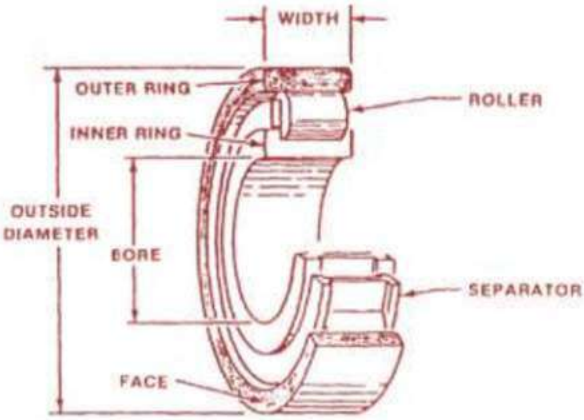
Thrust bearings are designed for axial loading only. They will usually be found in use together with roller or radial ball bearings. The balls are retained in a cage and run on flat or grooved washers. These bearings are adversely affected by centrifugal force and so work best under high-load, low-speed situations.

INSTRUMENT PRECISION BEARINGS

Instrument Precision Bearings are manufactured to high accuracy and finish. They are generally of the radial bearing type and can be found in both instruments and communication equipment.

ROLLER BEARINGS

These consist of an inner and outer race separated by hardened steel rollers instead of balls. Roller bearings are normally only used to support radial loads but can be designed to compensate for linear expansion of the shaft or housing, by ensuring that the inner and outer races are truly parallel. Location and control of the rollers is achieved by a groove cut in the inner or outer races which act as recesses for the rollers. This arrangement allows the rollers to take up lateral expansion of the shaft by allowing the rollers to slide across the surface during rotation.



Roller bearings may be divided into three main types that define their use. They are:

- Cylindrical Roller Bearings
- Spherical Roller Bearings
- Tapered Roller Bearings

CYLINDRICAL ROLLER BEARINGS

Cylindrical Roller bearings will accept greater radial loads than ball bearings of the same size. This is due to the greater contact area of the rolling elements and, if they have ribs on both rings, cylindrical roller bearings will also accept light, intermittent, axial loads. Normally the rollers have a length equal to their diameter, although some rollers have a length greater than their diameter to cater for special applications.

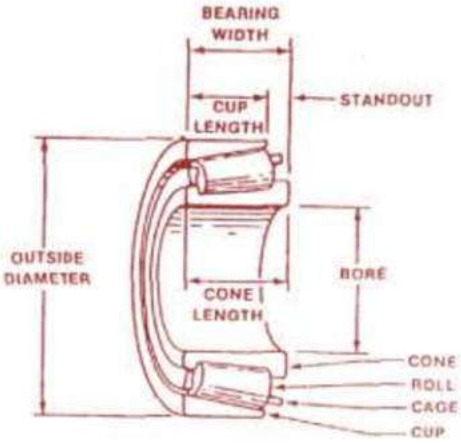
Roller bearings, which have a length much greater than their diameter, are normally called needle roller bearings. These are designed for radial loads only and are best used in situations where the movement is oscillatory rather than rotary, such as in universal joints and control rod ends.

SPHERICAL ROLLER BEARINGS

Spherical Roller bearings can be found with single or double rows of rollers, which run in a spherical raceway in the outer ring, thus enabling the bearing to accept a small degree of misalignment. These bearings will accept high radial loads and moderate axial loads.

TAPER ROLLER BEARINGS

These bearings obtain their description from the shape of the inner race, this being in the shape of a cone. The tapered bearing consists of the coned shaped inner and a cup shaped outer race. The rollers are tapered and made from hardened steel. This class of bearing can support radial loads in one direction only. Because of this, this class of bearing will often be found to contain two individual rows of bearings, each row using the same inner and outer races, but with the rollers arranged with the tapers on the rollers in opposite directions, thus allowing the bearings to withstand radial loads in either direction.

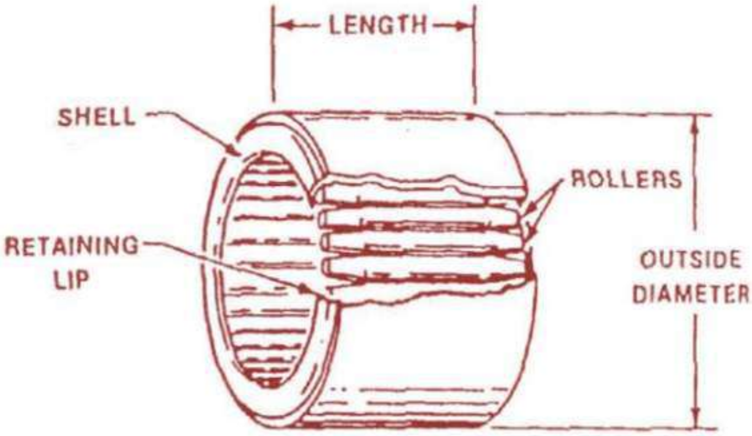


Tapered Roller bearings are designed so that the axes of the rollers form an angle to the shaft axis. They are capable of accepting radial and axial loads simultaneously, in one direction only. It is common to find tapered roller bearings mounted in pairs - Back to back - so that loads can be accepted in both directions.

NEEDLE ROLLER BEARINGS

These bearings consist of an inner and outer race separated by narrow trunnion ended rollers. This class of bearing normally used where space saving is an important factor as they are physically smaller in diameter than other classes of bearing but are longer and will support the same loading as an equivalent sized ball or roller bearing. This class of bearing are able to support only radial loads.

OTHER BEARING TYPES AND FEATURES



SELF-ALIGNING BEARINGS

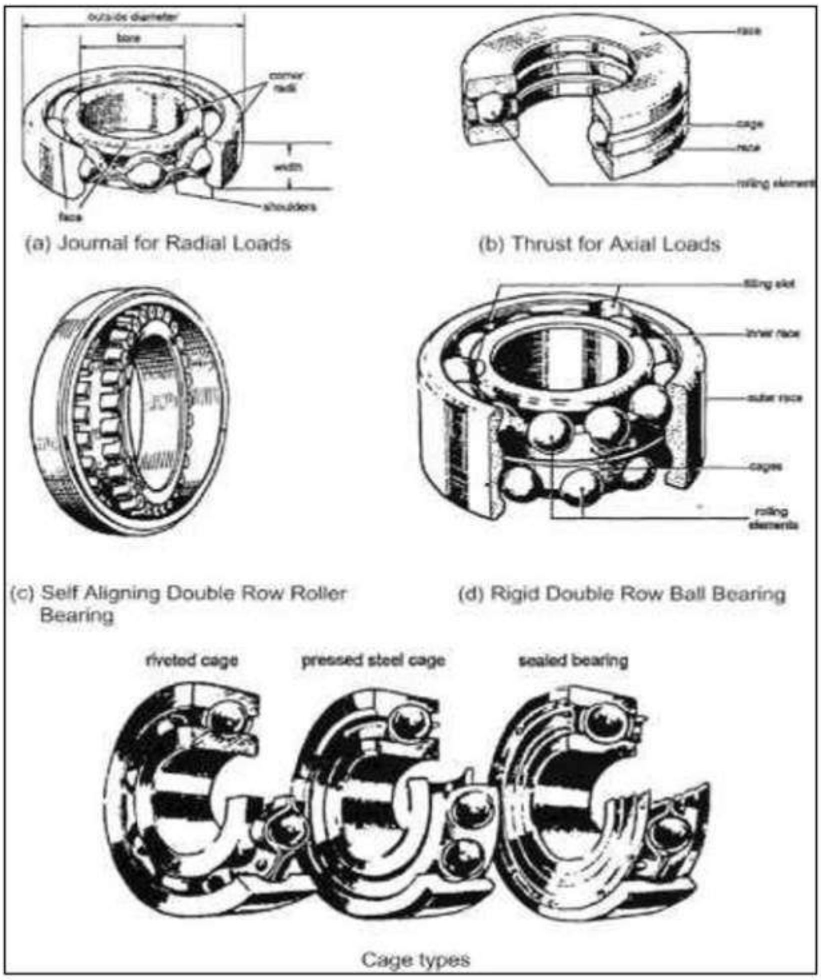
Bearings which allow a limited movement of the shaft. So that the inner and outer races are not always exactly aligned with each other. The action is, of course, achieved without impairing the operation of the bearing and is a type common to ball and roller class of bearing.

SINGLE AND DOUBLE ROW BEARINGS

These bearings employ either a single or double row of either ball or roller bearings. Balls and rollers are never mixed within the same bearing races.

SEALED BEARINGS

Some bearings will have a seal in the form of a circular plate fitted at one end of the bearing, this prevents the lubrication used in the bearing from escaping into other parts of the machinery and causing contamination, this type is called SEMI-SEALED. If the basic idea of a seal is applied to both ends of the bearing and the bearing is primed with the correct amount and tradeoff lubricant during manufacture, then sealed, it is called a FULLY SEALED bearing. Foreign matter cannot enter this type of bearing, but the bearing cannot be lubricated or maintained other than to wipe the bearing clean and check it for roughness or wear by carrying out a hand rotation test.



(a) Journal for Radial Loads

(b) Thrust for Axial Loads

(c) Self Aligning Double Row Roller Bearing

(d) Rigid Double Row Ball Bearing

Cage types

LIMIT SYSTEM

GENERAL

For ease of manufacture and replacement it is essential that the components of similar mechanisms should be inter-changeable. For this reason limits are imposed on the manufacturing errors to ensure that any two mating parts are manufactured to the limits stated on the drawing. The limits are based on the tolerance and allowance applied to the dimensions of a manufactured part. The correct functioning of a component of any mechanism depends upon their size. A rotating part must have clearance in its bearing, too large a shaft or too small a hole can lead to damage and mechanical failure. Due to imperfections in workmanship, it is not possible to manufacture component parts to theoretically correct dimensions, but interchangeability of parts can be achieved if their dimensions are within certain limits, thus the need for a limits system which defines how much bigger or smaller than the basic size a part can be made and still be considered acceptable. The actual numerical values of tolerances are listed in the form of engineering tables contained in the revised version of British Standard 1961, limits for Engineering. The limits system used in the manufacture of a particular component should always be shown in the title block of the engineering drawing for the component.

Fits

Defined as being the difference before assembly, between the sizes of two parts which are to be assembled. By using various methods of assembly, some gentle–some extremely forceful, it is possible in engineering to obtain a fit whether or not the shaft is smaller than the hole. When the shaft is smaller, a clearance exists between the parts, therefore the assembly is relatively easy. When the reverse is true, an interference is said to occur and force of some kind is needed to compete the assembly. From these two basic situations, three types of fits emerge, Clearance, Transition and Interference:

- Clearance Fit
  A fit which always has a positive clearance or, technically, where the tolerance zone of the hole is always above that of the shaft.
- Transition Fit
  A fit which can be either a clearance or interference fit or where the tolerance zones of the hole and shaft over lap.
- Interference Fit
  A fit which always has interference, or where tolerance zones of the shaft, is always above that of the hole.

Handling

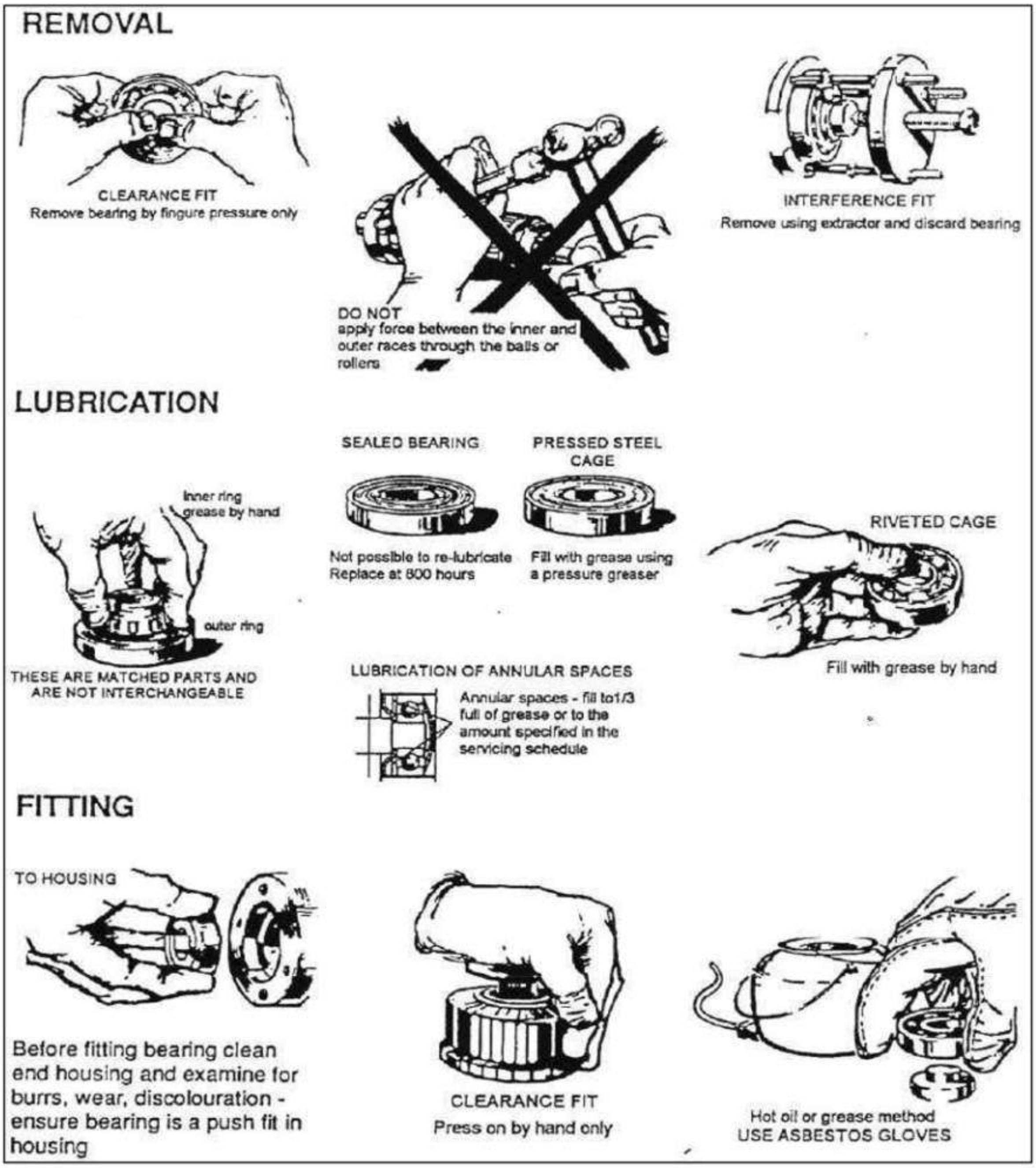
Most bearings used for aircraft and aircraft components are costly because of high precision in their manufacture. Bearings must never be spun in an un-lubricated condition since dust, moisture or other foreign matter may contaminate the bearing and lead to slight damage to the races, balls or rollers, which will lead to increased wear rates and encourage corrosion. Bearings should also be handled using lint free gloves as the natural oils and dirt may cause contamination of the lubricant.

Cleaning

Cleanliness is vital. Key points to cleanliness:

- Do not unpack bearing until required for use.
- Clean using Tri chloro ethane or white spirit only.
- When cleaning use a brush not rag.
- Do not handle bearing unnecessarily.
- Do not rotate bearing at high speed unless lubricated.

Removal, Lubrication And Fitting



EFFECTS OF BAD MAINTENANCE PRACTICE OR ADVERSE WORKING CONDITIONS

In order that the maintenance carried out on aircraft or aircraft components is of the highest possible standard, the following points must be remembered:

• Misalignment

Bearings which are misaligned will have a reduced life. The balls or rollers will be unable to cope with this condition and will overheat and fail. A broken or distorted cage or signs of non-concentric wear on the race surfaces are signs that the bearing is incorrectly aligned.

• Ingress Of Foreign matter

This will cause rapid wear of the bearings, because even small particles will prevent the correct rolling action of the balls or rollers and will causes coring.

•Inadequate Or Contaminated lubricants

This will cause rapid wear, overheating and stiffness in the bearing. These defects are usually detected by the lubricant being discolored and the bearings being stiff when operated by hand, or the balls, rollers or cages and races will show signs of excessive heat by discoloration.

•Vibration

This will cause indentations in the surface of the races and ball or roller, which will cause a roughness in running and result in rapid wear.

•Excessive Interference fit

Will place unbearable strain on the races which when combined with the heating effects and vibration can cause cracking and eventual disintegration of the bearing.

•Excessive pre-Loading

This will cause overheating of the ball or rollers and will lead to breakdown of the lubricant resulting in the tightening of the bearing, rapid wear and eventual disintegration of the bearing.

BEARING LUBRICATION

GENERAL

One of the major contributing factors to achieving reliability of bearings is proper lubrication. Bearings operate on very thin films of lubricant, which have to be maintained to ensure that design life is achieved. The ways of ensuring this, and to maximizing bearing life, are to a)select the correct lubricant, b) apply it properly, and c) maintain it in a clean condition. Neglect or failure in any of these areas will seriously increase the risk of premature bearing failures and interfere with the trouble free running that is now of such crucial importance in ultra- competitive global markets.

The increased speeds and higher temperatures at which modern bearings routinely operate combined with the demands placed upon them for improved accuracy and reliability, mean that the process of selecting a suitable bearing lubrication, today, is more critical than it has ever been. Properly selected a lubricant will:

- Reduce friction and wear by providing a hydrodynamic film of sufficient strength and thickness to support the load and separate the balls from the raceways, preventing metal-to- metal contact.
- Minimize cage wear by reducing sliding friction in cage pockets and land surfaces.
- Prevent oxidation/corrosion of the bearing rolling elements.
- Act as a barrier to contaminants.
- Serve as a heat transfer agent in some cases, conducting heat away from the bearing.

Bearing lubricants fall into three main categories; Oils, Greases and Solid Dry Film Lubricants, which are usually limited to moderate speed and very light loading conditions.

Greases, because of their convenience, are by far the most widely used of the three, and have been the focus of much development over the last decade.

Lubricant Selection

The selection of a particular type of bearing lubricant is generally governed by the operating conditions and limitations of a bearing system. Three of the most significant factors in selecting a lubricant are:

- The viscosity of the lubricant at operating temperature.
- The maximum and minimum allowable operating temperatures.
- The speed at which the bearing will operate.

Grease Considerations

The primary advantage of grease over oil is that bearings can be pre-lubricated, eliminating the need for - and the cost of – an external lubrication system. Besides simplicity, grease lubrication also requires less maintenance and has less stringent sealing requirements than oil systems. Grease tends to remain in proximity to bearing components, metering its oil content to operating surfaces as needed.

The negatives with grease are that it does not conduct heat away from a bearing as efficiently as oil. In addition, grease can increase the initial torque within a bearing and cause running torque to be slightly higher.

Finally, the speed limits for greases (expressed as a dN value, with dN being the bearing bore in mm multiplied by rpm) are generally lower than for oils due to the plastic nature of grease that tends to cause overheating at high speed.

Oil Considerations

While grease lubrication is inherently simpler than lubrication with oil, there are still applications where oil is the better choice. In high-speed spindle and turbine applications, for example oil is supplied continuously and provides cooling as well as lubrication. A further example is instrument bearings with extremely low values of starting and running torque. These require only a minimal, one-time lubrication, each bearing receiving just a few milligrams of oil- a single drop or less.

The limiting speeds for oil-lubricated bearings are imposed by the bearing size and cage design, rather than by the lubricant. To illustrate this point, petroleum or di-ester-based oils can accommodate bearing speeds up to 1,500,000 dN or higher. In addition, to ensure long life at high speeds, the lubrication system should provide for retention, circulation, filtration and possibly cooling of the oil.

Solid Soft Film Lubricants

Solid Soft films are primarily used to provide solid lubrication for bearings in extreme applications where traditional fluid lubricants would be rendered ineffective. They offer the advantages that their friction is independent of temperature (from cryogenic to extreme high temperature applications), and they do not evaporate or creep in vacuum or space environments.

INSPECTION OF BEARINGS SAFETY PRECAUTIONS

The cleaning of bearings for inspection normally involves the use of solvents, so the appropriate PPE should be worn. This will include respiratory, eye and skin protection by using breathing masks, goggles and inspection gloves. The moisture from the human hand may contaminate a bearing surface, as easily as the lubricant can cause damage to the skin.

Points For Inspection

1. A darkening color of the grease will indicate the presents of metallic particles in suspension in the grease.
2. Rotate bearing by hand and check for roughness, after thoroughly cleaning and lubricate with oil.
3. Examine the cage for hairline cracks
4. Examine both edges of each ball pocket for wear
5. Serviceable balls have a shiny polished appearance, whereas a dull leaden appearance indicates

excessive wear.

6. Examine both races for signs of serious scratching and fretting corrosion which has the red appearance of rust.

FEEL TEST

A bearing is tested for roughness by turning the bearing slowly and hand feeling and listening for any defect. Remember - the bearing must NOT be spun in an un lubricated state.

RUN TEST

Running smoothness may be checked by mounting it on a shaft and rotating at 500 - 1,000 rpm and applying alternate axial and radial loads in either direction.

BEARING DEFECTS

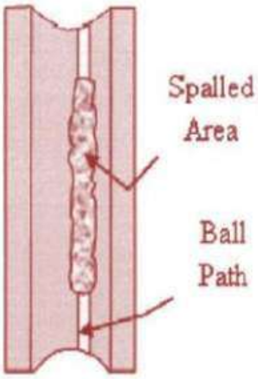
Fault	What to look for
Worn races	Excessive clearance radially /axially, flaking of raceway groove.
Worn balls/rollers	Excessive axial/radial clearances, miss happen rolling elements.
Creep	Shiny marks on outside of outer race caused by incorrect interference fit in housing Shiny marks on inside of inner race caused by incorrect interference fit on shaft.
Worn cage	Soft metal dust in and around the bearing.
	Inspect for loose rivets.
Overheating	Look for bluing of elements and raceways.
Brinelling	Indentation of raceways may be seen or felt in a dismantled bearing. Roughness will be present on a spin test of an assembled bearing. Caused by 'skidding' of the rolling elements due to sudden increases in speed under high load (wheel bearings on landing for example).
False Brinelling	Indentation of raceways may be seen or felt in a dismantled bearing. Caused by vibration transmitted through the bearing when the machine is stationary (in transit for example).
Corrosion	Pitting of elements and raceways
Chipping	Roughness and clicking on spin test.
Spalling	The separation/flaking of the surface layer of the raceway caused by thermal or mechanical Stresses.

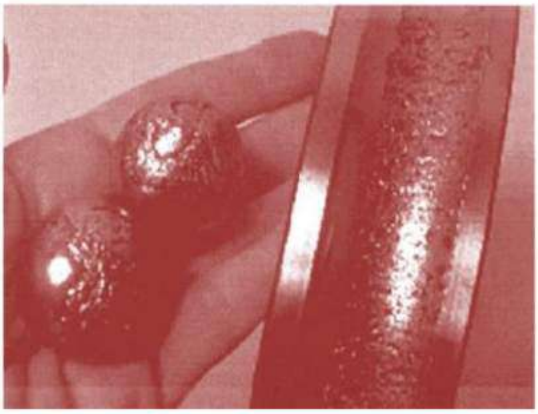
Normal Fatigue

Normal fatigue failure is often shown as a fracture of the running surface, with subsequent removal of small particles of metal and is commonly called palling.
It occurs on both rolling elements and raceways, and is always accompanied by an increase in vibration. Moderately spalled areas show the bearing has reached the end of its normal service life.

Excessive Loads

Excessive loading of a bearing is usually the same as normal fatigue, but the rolling elements wear path is usually heavier. There is also increased evidence of overheating with a widespread and deeper fatigue or spalled area. This often causes premature bearing failure.





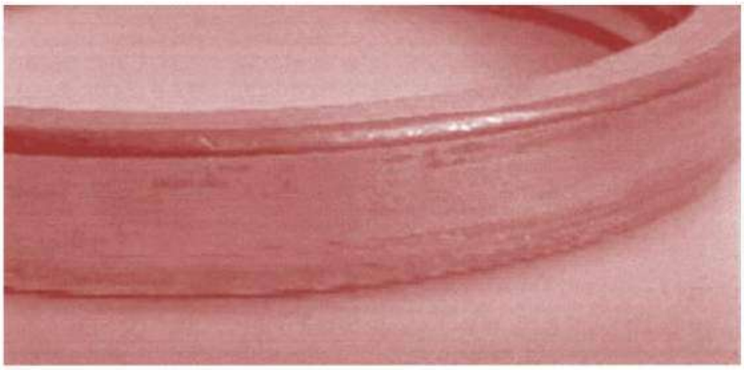
Damage due to excessive loads

Installation And Misalignment

Installation damage is usually the result of an impact that occurs when a bearing is fitted incorrectly. This may be due to a sharp strike from a drift or pressing the wrong raceway when mounting the bearing.
Misalignment damage can be seen on the raceway of the non- rotating ring because the rolling element wear path is not parallel to the raceway edge. Excessive misalignment can cause high temperatures as well as heavy wear of the cage.

Loose Fit

A bearing should always be mounted onto a shaft or housing with an interference fit. If the raceway becomes loose then it will rotate on these surfaces and cause fretting. This fretting will remove metal particles, which oxidise and leave a distinctive brown colour. It usually occurs when the bearing outer raceway rotates inside a worn housing. The external surface of the raceway will be scored and discolored as a result of a loose fitting bearing.



Loose fit damage

Brinelling - True And False

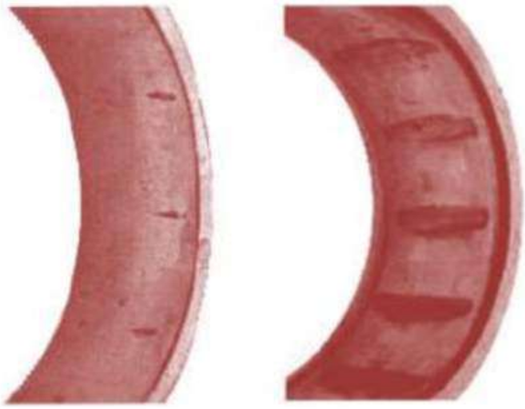
Brinelling marks on a bearing raceway resemble the indentations that result from a Brinell Hardness Test. They are described as being either True Brinell or False Brinell marks.

Brinelling is caused when a load is applied to a ball bearing that exceeds the elastic limits of the steel and the raceways are permanently deformed. Brinelling creates measurable dents at eachball location similar to the deformation caused by a Brinell Hardness Tester. This type ofdamage can occur quite easily if proper care is not taken. High energy impacts (from hammers), improper bearing handling and incorrect spindle assembly can all damage bearings. Remember that we are talking about bearings with raceways with roundness measured in millionths of an inch. You might not even realize the damage has occurred except for increases in vibration.

False brinelling is not related to excessive loads. False brinellingis caused by ambient vibration. Even a brand new bearing, sealed in a box on a shelf, is subject to false brinelling if it is exposed to environmental vibrations for an extended period. When a bearing is not operating it is subject to false brinelling in the box or in the machine. When a bearing is operating, there is an oil film between the rolling elements and the raceways. This is called elasto-hydro-dynamic(EHD) film. Most people can relate to hydroplaning. When you reach a certain speed on a wet road your tyres actually lift off the road (not good). But when a bearing operates with the proper lubrication and at the right speed the balls or rollers lift off the raceway slightly (this is good).

This extremely thin film protects and lubricates the bearing while it is running. When the bearingis stopped there is no EHD film and there is metal to metal contact. That is when false brinelling can quietly attack your bearings. The combination of metal to metal contact and vibration create a wear and corrosion pattern that mimics brinelling.

The prevention is to rotate spindles routinely if they are not in use to reposition the rolling elements and lubrication. Take steps to reduce vibration or isolate machines from each other through properly designed mounting pads. Store bearings and spindles in a clean dry area free from vibration.



False Brinelling (left) and True Brinelling (right)

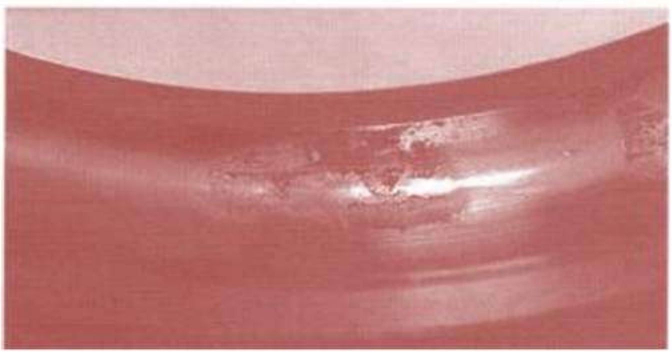
Overheating And Lubrication Failure

Excessive heating of a bearing manifests itself as discoloration of the rings, rolling elements and cages from gold to blue. Excessive temperatures will usually be in excess of 400°C. In extreme cases the rolling elements and raceways will deform. A blue/black colour indicates an area close to the heat source and changes to a silver/gold discoloration the further you move away.
Failure or lack of lubrication often has similar signs as overheating because good lubrication should cool the material and transfer away any heat produced during rotation. Restricted flow and excessive temperatures can also degrade the chemical composition of the oil, making it ineffective and increase wear rates.
The outcome of either overheating or lubrication failure will always result in the eventual failure of the bearing.

Contamination And Corrosion

Contamination is one of the leading causes of premature bearing failure. The symptoms are dents or scratches embedded in the bearing raceway and rolling elements, resulting in bearing vibration and wear.
The contaminant would be an abrasive substance that gets into the bearing, such as sand, gritor dust. The principal sources are dirty tools, contaminated work areas, dirty hands and foreign matter in the lubricant or cleaning solutions. Corrosion is usually the result of a chemical attack on the bearing material by an in compatible fluid such as moisture. It manifests itself as either black pitting marks or red/brown rust coloured areas on the rolling elements, raceways, or cages. It usually results in increased vibration followed by wear.

Contamination damage



Corrosion damage

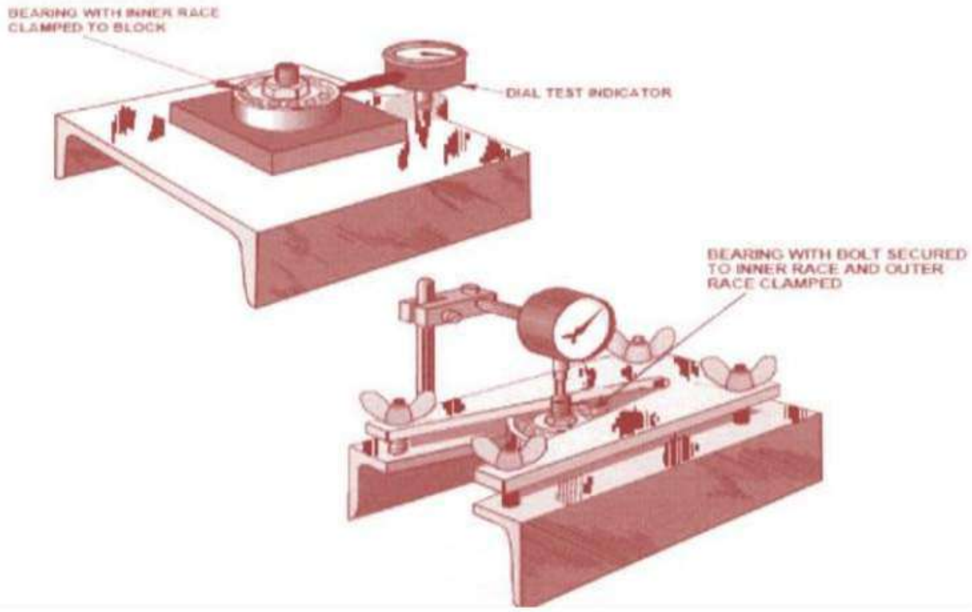
Electric Current Damage

When an electric current passes through a bearing, i.e. proceeds from one ring to the other via the rolling elements, damage will occur. At the contact surfaces the process is similar to electric arc welding.

Such electric currents can be of a low level but last for considerable lengths of time (such as voltage leakage from a motor or generator) or be very high level for a short duration (such as that caused by a lightning strike of the aircraft). Equal amounts of damage can occur from both situations.

The appearance of the damage is dark brown or greyish black fluting (corrugation) or craters in raceways and rollers. Balls have dark dis coloration only. Sometimes zigzag burns in ball bearings raceways. Also, localised burns in raceways and on rolling elements.

The material is heated to temperatures ranging from tempering to melting levels. This leads to the appearance of discoloured areas, varying in size, where the material has been tempered,re- hardened or melted. Small craters also form where the metal has melted.



Checking Radial And Axial Movement

STORAGE

If a bearing is to be used immediately after inspection, it should be lubricated with correct lubricant and installed. If there is liable to be a delay before installation, then the bearing should be coated in rust-preventing inhibiting oil, wrapped in greaseproof paper, boxed and labelled. The bearing should always be stored horizontally, in a clean dry atmosphere.

Module 6.9: TRANSMISSIONS

TRANSMISSIONS GEARS

GENERAL

Gears are toothed wheels used to transmit power between components of a machine where the centre distances between the shafts is limited. They give a positive drive of a fixed velocity ratio and do not slip.
Gears are used in conjunction with the various bearings and shafts in various components to transmit power, change direction of rotation and to increase or decrease speed.
Gears may be cast, molded or cut from solid steel, brass, bronze and plastics.

When two gears are running together the large one is called the gear and the smaller is called a pinion. If the pinion drives the gear, the unit is a speed reducer; if the gear drives the pinion, it is a speed increaser. Gears are more often used as speed reducers.

The second major function of gears is to provide a usable range of gear ratios in a machine. Four or five forward gears in a motor car for example or a wide range of cutting speeds in a lathe. The gear ratio is the ratio of the number of teeth on one gear to the number of teeth on the other and determines the amount of speed reduction or increase which takes place. For example, if a pinion has twenty teeth and the gear has sixty, the ratio is 1:3 and the gear will make one revolution for every three of the pinion.

When one gear drives another, they turn in opposite directions (unless one of them is an internally toothed gear). If it is required that they turn in the same direction, a third gear called an idler gear is interposed between them.

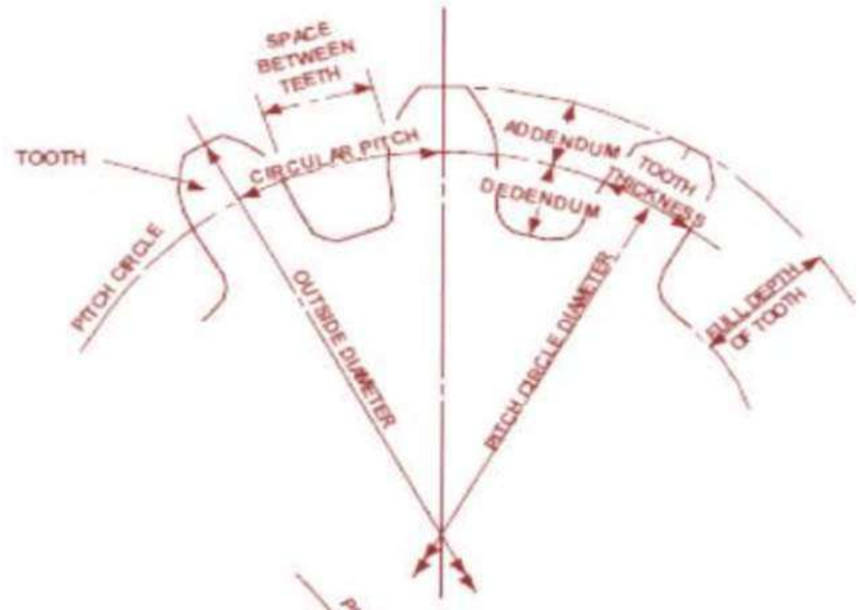
GEAR NOMENCLATURE

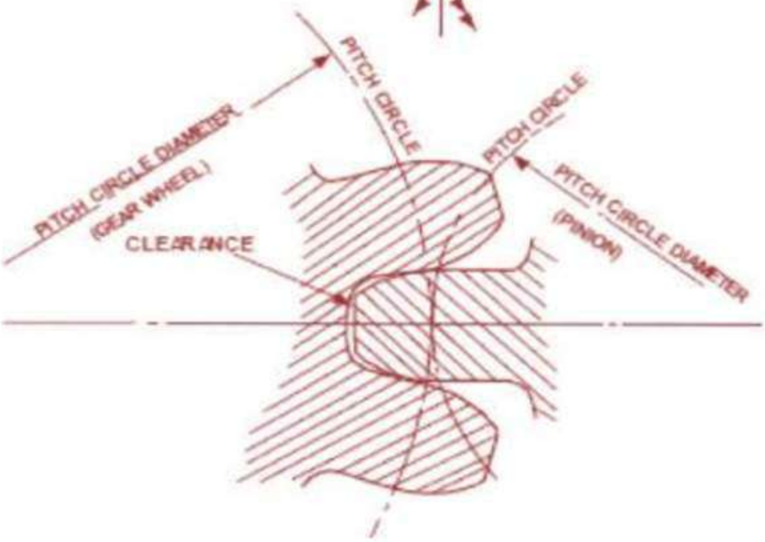
If two gears running together are imagined to be two smooth wheels whose surfaces are touching, the diameter of each wheel is the PITCH DIAMETER or the PITCH CIRCLE of the gear.

The part of the gear tooth that extends beyond the pitch circle is called the ADDENDUM; the DEDENDUM is the part of the tooth inside the circle.

The ROOT CIRCLE is the diameter of the gear measured at the base of the tooth.

The PITCH is the distance between a point on a tooth and the corresponding point on the next tooth, measured on the pitch circle. This is known as the CIRCULAR PITCH. To facilitate calculations, the DIAMETRICAL PITCH is more commonly used, this being the number of teeth per unit of diameter, measured on the pitch circle



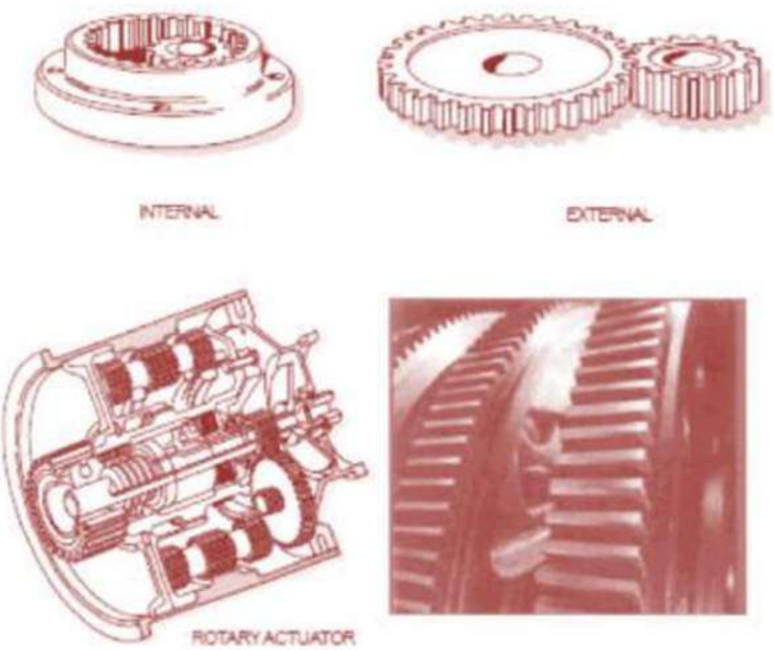


SPUR GEARS

Spur gears are the most common and cheapest type. The have straight teeth and are used to transmit power between two parallel shafts or shafts in the same axis.

The sides of the teeth, in profile, describe an in volute curve. (If a piece of string is wrapped around a cylinder, a point on the piece of string will describe the in volute curve as the string is held tautly and unwound.) The sides of the teeth must be curved, otherwise the operation of the gears would be noisy, wear would be excessive and a great deal of vibration would be generated.

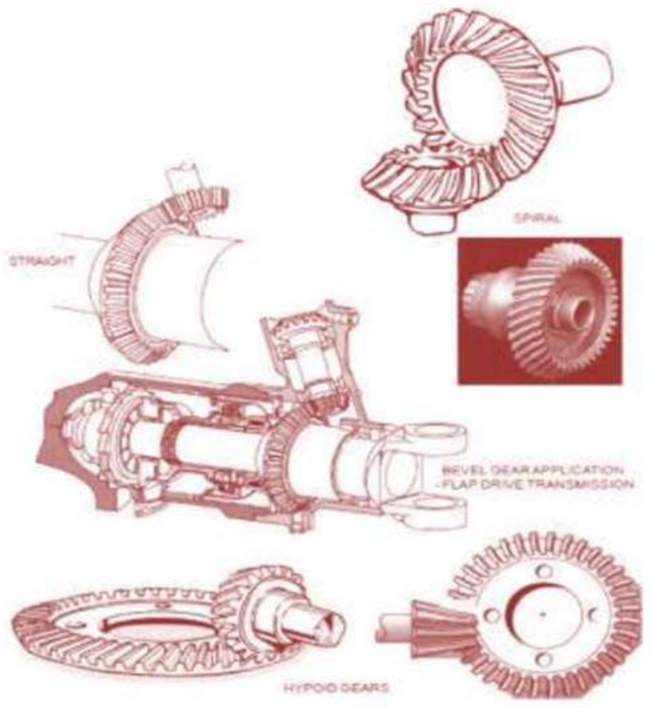
The in volute curve has been found to be best because when an in volute curved tooth surface transmits power to an in volute curved mating tooth, as much of the power is transmitted as possible even if the centre distance between the shafts varies slightly. The point on the side of the tooth which is also a point on the pitch diameter of the gear is the point at which the power is transmitted most efficiently.



Spur Gear applications

BEVEL GEARS

Bevel gears are shaped liked sections of cones. They are used to transmit power between nonparallel shafts whose axes intersect. The teeth on an ordinary bevel gear are straight but tapered in length and depth; if extended in length, they would meet at a point ahead of the gear on the axis of the shaft called the pitch cone apex. The most common types are straight cut and usually mounted on shafts 90° to each other and are used for fairly low speed application where smoothness and noise are not a problem. Spiral bevel gears have curved teeth and can be used for higher loads and speeds and are quieter in operation. When the axes of the two shafts do not intersect, the gear is known as 'hypoid'. Hypoid gears required to be lubricated with an oil containing an EP (Extreme Pressure) additive.



HELICAL GEARS

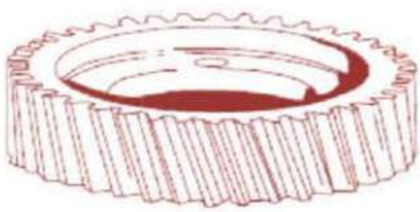
Bevel gears or spur gears can have spiral teeth on them, enabling them to be designed to transmit power between shafts at any angle to each other, according to the spiral of the teeth. They are called helical gears.

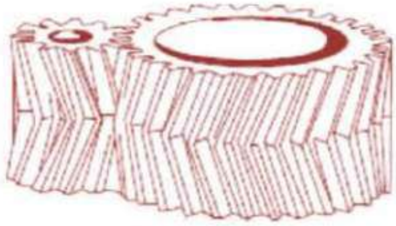
The curved teeth enter the mating teeth while the previously meshing teeth are still in contact. This means that some sliding of the teeth against each other takes place and that power is transmitted with relative smoothness and silence.

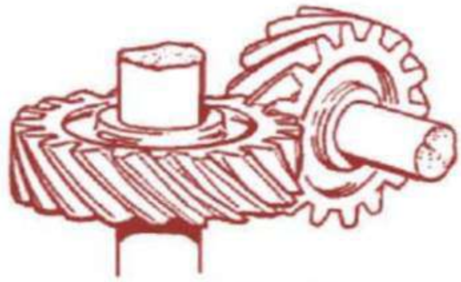
Helical gears are more expensive than spur gears and are normally used for high speed, that is pinion RPM greater than 3600 and high load applications. Lubrication demands are high and thrust bearings are required to withstand the trust arising from helical meshing.

To overcome this, two sets of helical gears can be used, with the thrust in opposite directions, cancelling each other out. For this application, the gears are sometimes machined out of one piece of metal with helical teeth meeting in the centre of the face and spiraling outward from each other. These are called herringbone or double helical gears.

Helical gears are most common in parallel shaft drives. Single helical gears can be used for non intersecting, non-parallel shaft applications provided they have the same pitch and pressure angle. These are known as crossed helical gears or skew gears and can only carry comparatively low loads.

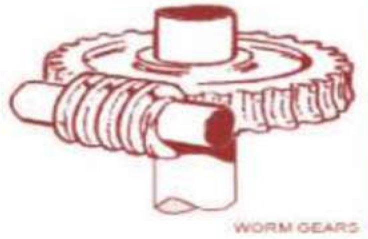

SINGLE HELICAL

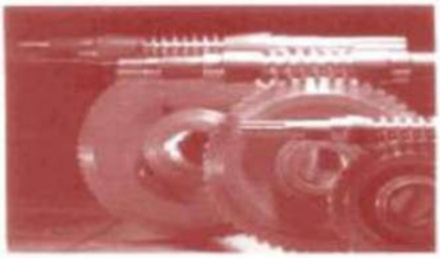

DOUBLE HELICAL

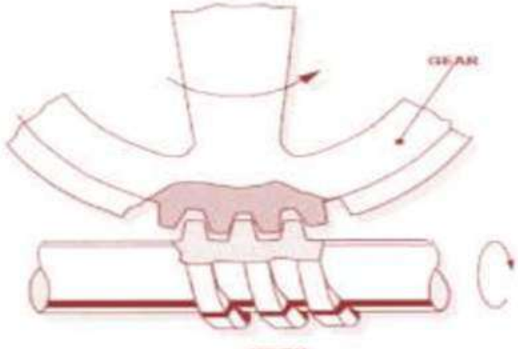

SKEW GEARS

WORM GEARS

Worm gears are capable of large speed reduction and high load applications where non parallel, non-intersecting shafts are used and have an advantage over crossed helical gears. The 90°shaft configuration is the commonest with the worm as the driver. The worm is a screw thread with one continuous gear tooth which engages with the helical gear. The set is irreversible and self locking and is often used in aircraft flap drive mechanisms.

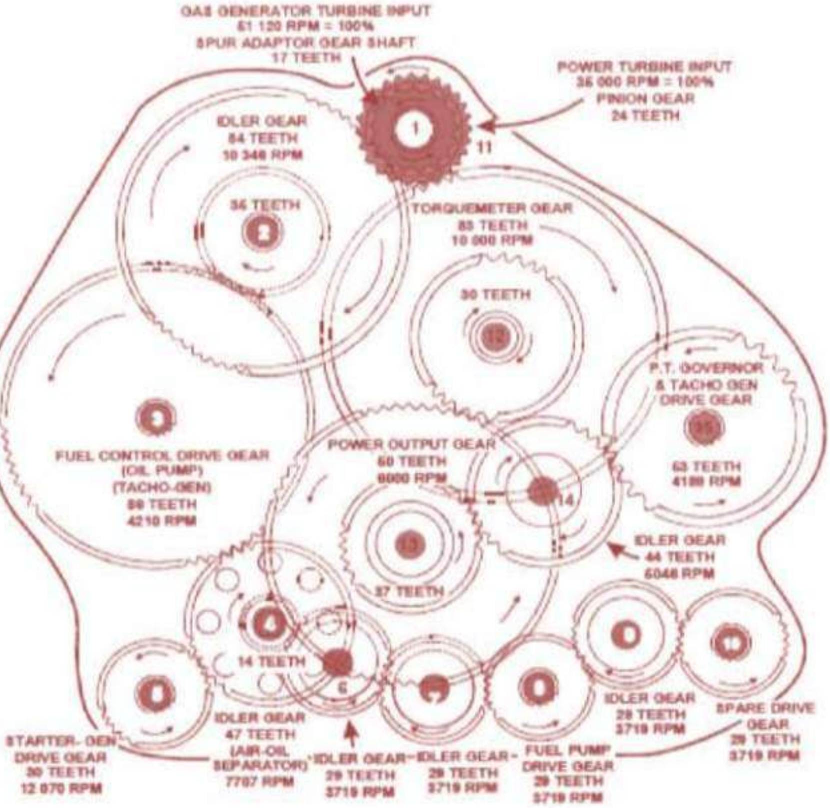






ACCESSORY DRIVES

Aircraft engines also employ multiple gear trains, in their internal and external gearboxes. These provide the drives for accessories such as fuel, hydraulic and oil pumps, electrical generators, engine speed indicators and many other devices. Here it can be seen that 'idler' gears are added to reverse the rotation and possibly to alter the final ratio of several drives and, while the majority of the gears are of spur and helical configuration, the drive from the engine shaft, to the gearbox, has bevel gears.



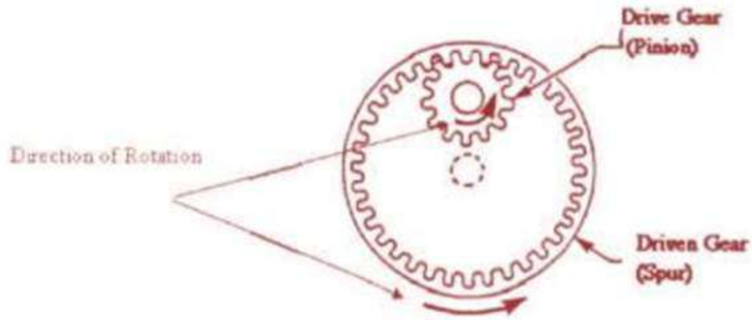
Accessory Drives Section of Helicopter Gas Turbine Engine

SPUR AND PINION REDUCTION GEAR TRAIN

The smaller, of a high-ratio pair of spur gears, is referred to as the 'Pinion', while the larger remains the 'Spur' and spur and pinion gear arrangements also vary, depending on the desired results.

Where the drive pinion is located inside the spur-cut ring gear it has the advantage of not only stepping down the ratio of input to output but also (as can be seen), both gears rotate in the same direction.

Considerable space is also saved, compared to a system using two, externally-cut gears, for a similar reduction in output speed.

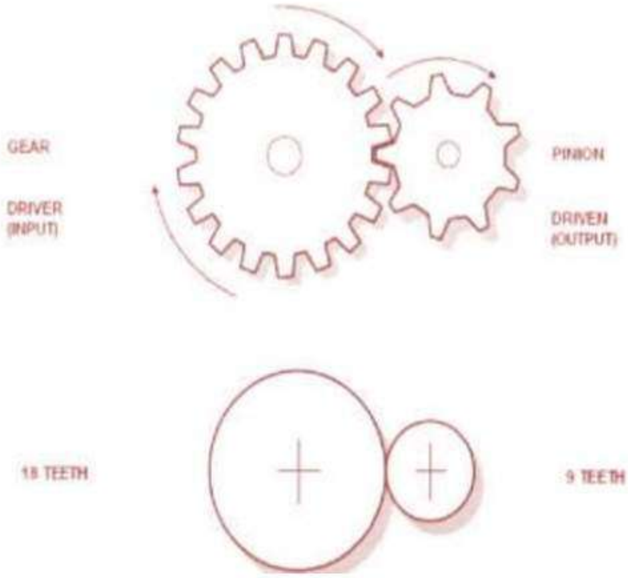


GEAR RATIO

Simple Gear train

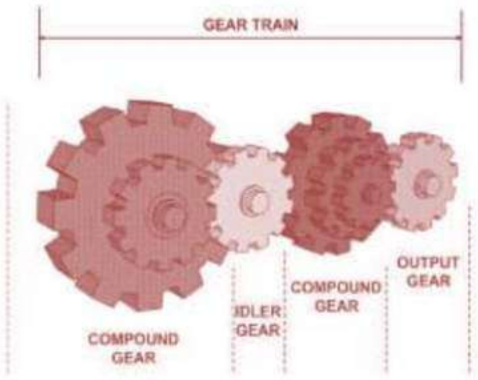
When a gear train consists of two or more gears, mounted on separate shafts called simple gear train.

The illustration shows two meshed spur gears of different sizes. This is a simple gear train, with one wheel on each shaft. The smaller 9 toothed pinion will have to turn two revolutions for each revolution of the larger 18 toothed wheel and so when the wheel is used as the driver (input) gear output motion will be faster than the input.
Sometimes the gear ratio is defined as the ratio of the driven gear speed to that of the driver. To avoid confusion the gear ratio should be clearly specified.



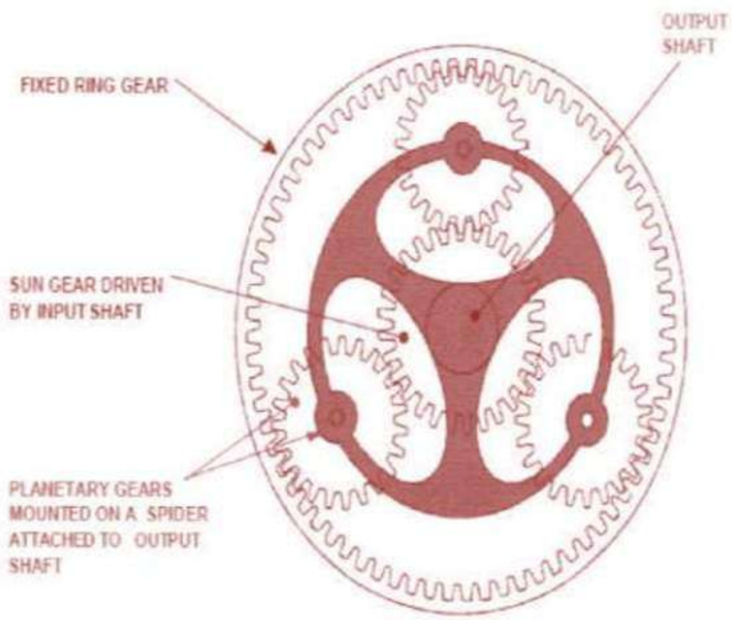
Compound Gear Train

In a compound train at least one shaft carries a compound gear or two wheels which rotate at the same speed. The advantage of a compound gear train is that it can produce a high gear ratio without the disproportionate gear sizes that would be necessary in a simple gear train.

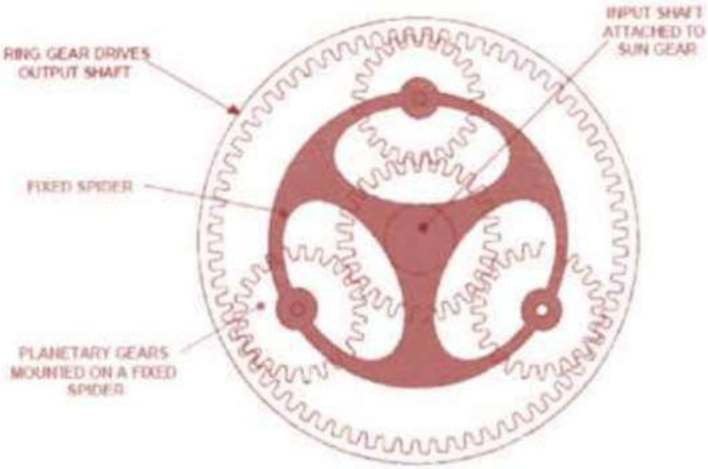


Epicyclic Reduction Gear

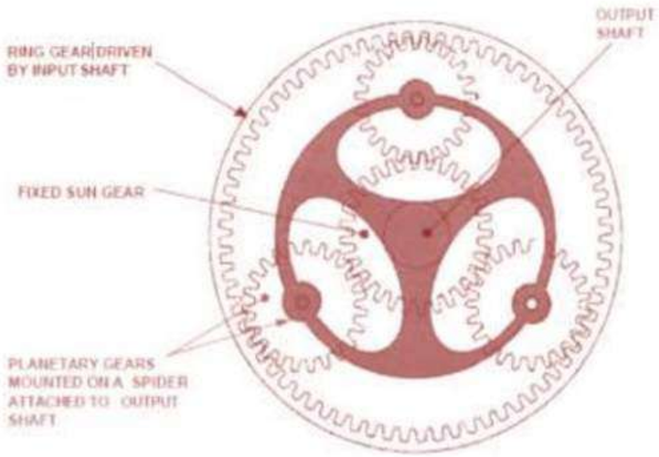
There are several basic types of planetary gear arrangements. In one type the ring gear is fixed and the sun gear is the driven gear. The sun gear meshes with and drives three equi-spaced gears known as planet gears. These gears are mounted on a carrier or spider and rotate independently on their axles. Surrounding this gear train is an internally toothed wheel known as the annulus or ring gear whose teeth are in mesh with the planet gears. If the ring gear is fixed, rotation of the sun gear will cause the planet gears to rotate about their axes and at the same time to move around the ring gear. This causes the planet gear spider to rotate at a lower speed than the sun gear. When high torque is to be transmitted, the gear tooth is helical.



Another type of planetary gear system has the ring gear as the driven gear and the sun gear is fixed. The output shaft is mounted on the spider that holds the planetary gears. Again the output turns more slowly that the input.



In a third type the spider is fixed, input being provided by a shaft attached to the sun gear, and output by a shaft connected to the rotating ring gear. This arrangement is commonly used in gas turbine air driven starter motors.
Epicyclic reduction gears are also used in the reduction gear assemblies of turbo prop engines.



Reduction Gears

Reduction gears are driven by gas turbine engines, and normally drive a propeller or helicopter rotor. Power turbines run at speeds, which suit the design characteristics of the rest of the engine. This does not have anything in common with the speed of the propeller, which is set by its own characteristics, chiefly blade diameter.

As power turbines can be spinning at up to 38,500 RPM and anything much over 2,000 RPM is considered quite fast for a propeller, it is obvious that a means of reducing this speed difference must be found. A suitable gear train will carry out this function.

Types Of Reduction Gear

There are two main types available to the designer.

- The parallel spur gear type
- The epicyclic type

BACKLASH OR LASH

General

BACKLASH or LASH is the play between two meshing gears and is defined as the difference between the two teeth and the width of the engaging tooth. Backlash between two gears can be altered by changing the centre distance between them. The correct amount of backlash is designed into a gear system, which means that the distance between the centres must be with intolerance.

If the teeth of one gear are set too tightly into the teeth of another, there will be no backlash and the gears will not be properly lubricated because a film of oil must be present between the teeth of the gears as they mesh. This will also cause overheating of the gears.

If the gears are meshed too high in relation to the teeth the load will be transmitted to the smallest portion of the tooth, causing the teeth to break. The ideal placement of the teeth is in the middle area. At this position the teeth will receive proper lubrication and loading. A typical gear may have0.003 to 0.004 in (0.08 to 0.1mm) backlash .and will distribute wear evenly amongst all the teeth on the pair. Wear can be further equalised by making the pinion harder than the gear wheel since the pinion does more work per tooth than the gear.

Condition monitoring by continuous checking of temperature and vibration is common practice for large gearbox installations.

Gear Terms Backlash (Or Lash)

The terms used to describe the clearance which must exist between gear teeth at point of mesh, essential with all forms of gearing to allow for expansion and lubrication.

Idler Gear

A gear which is interposed between the driving and driven gear, its function is to connect the drive between two shafts. A spur idler gear is used between two parallel shafts to maintain the direction of rotation and does not affect the ratio of the gears. A bevel idler may be used where two shafts intersect and/or are co-axial.

Intermediate Gear

A gear which is positioned between the driving gear and one or more driven gears in a gear train. It may function as an idler gear or transmit drive through its own shaft.

Compound Gear

This is a gear wheel which has more than one driving face. These faces may be formed integrally on one casting or forging, or it may comprise two or more gears bolted or splined together to transmit drive to a number of shafts.

Pinion

This term is usually applied to the smaller of two mating gears.

Lay-Shaft

A shaft which supports an idler gear or intermediate gear, it may be integral with the gear and be supported by bearings, or may be fixed and provide a bearing surface for the rotating gear.

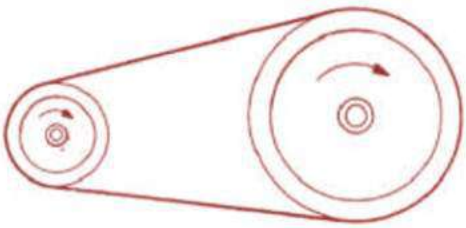
Rack And Pinion

A device in which a toothed rod (rack) meshes with a mating pinion to translate the rotary movement of the pinion into linear movement.

Step-Up Drive

A drive through a gear train in which the speed of rotation of the output (driven) shaft is increased.

Step-Down Drive



A reduction gear in which the rev/mm of the output shaft is reduced whiles the torque is increased.

BELTS AND PULLEYS

It is rare to find belt drives being used on modern aircraft. Due to the risk of slippage once the belt has taken on a slight stretch, there has to be some method, often automatic, to retain the set tension over a long period.

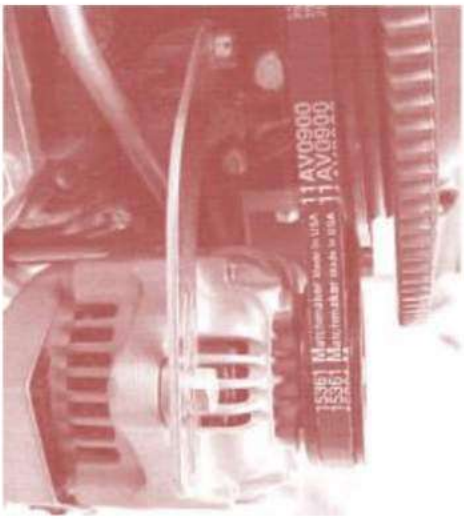
Nominally flat belts and pulleys use only friction to transmit the power from input to output shafts. These are, unfortunately, prone to slippage so, to reduce the problem, vee-section belts were devised and yet a further improvement has seen the development of serrated or 'toothed' belts and pulleys, which use the principle of 'engagement', rather than 'friction', to provide drive.

Some of the uses to which belt drives are put can include a change of ratio, usually in a step-down situation, as well as a simple connection between input and output shafts which are displaced by some distance.

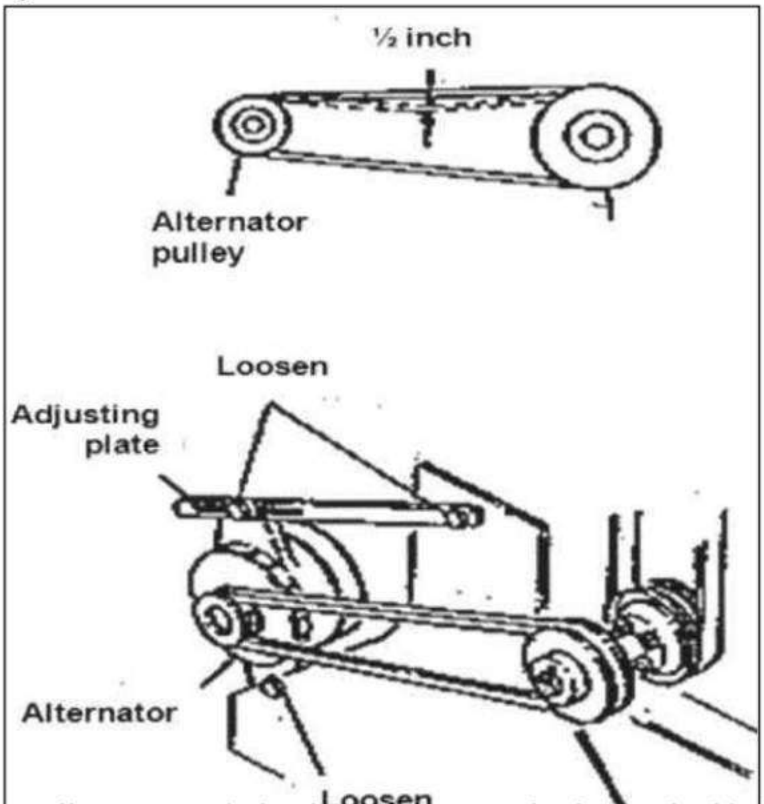
The simple belt and pulley system, has a step-up or step-down facility, depending on which pulley is driven. It will give a mechanical advantage of 2:1 if the smaller pulley is driven, due to it being half the diameter of the larger pulley. The larger pulley will rotate at half the speed of the smaller one, and can be driven using half the torque.

There are a number of places inside piston engines where toothed belts, are used to drive camshafts and other accessories from the crankshaft.

In some installations, the drive from the high-speed engine to the low-speed propeller is accomplished by the use of a 'toothed' belt drive. The teeth on the inside of the belt engage with grooves machined onto the drive (and driven) pulleys. This reduces the chance of slippage. Most piston engines on smaller aircraft have a belt drive to the AC generator or the vacuum pump, similar to that found on many motor cars.



Maintenance of belts usually involves the measurement of their tension, by measuring the amount of flexure at the middle of the longest unsupported length, excessive slack is taken up by adjusting the position of one of the pulleys by slackening its retaining bolt, sliding to a new position then retightening the retaining bolt.



The same maintenance applies to most belts, in that the security is checked before each flight. The belts must also be checked, at regular intervals, for signs of wear, fraying and splitting, in addition to a tension check. The majority of belts (whatever their usage), have a finite life and are also subject to 'on- condition' monitoring.

CONTROL CHAINS, CHAIN WHEELS AND PULLEYS

GENERAL

Chains are used to change direction of control runs in systems where considerable force is required, such as aileron and elevator controls.

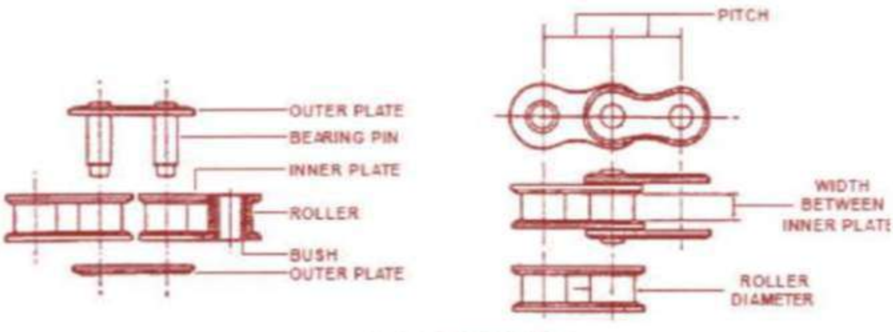
The change of direction is achieved by the use of chain wheels or pulleys. Chains may be found in control column installations, aileron and elevator controls and in trim control systems.
Chains may be used in conjunction with cable assemblies. Incorrect assembly of the chains is prevented by the use of non- reversible chains in conjunction with the appropriate types of wheels, guards and connectors.

CHAIN ASSEMBLIES

Chain consists of a series of inner plates, rollers and bushes, connected together by outer plates and bearing pins. The pitch of the chain is the distance between the centres of the rollers.

Chain assemblies should be obtained as complete, proof loaded units. No attempt should be made to break and reassemble rivets links or riveted attachments.

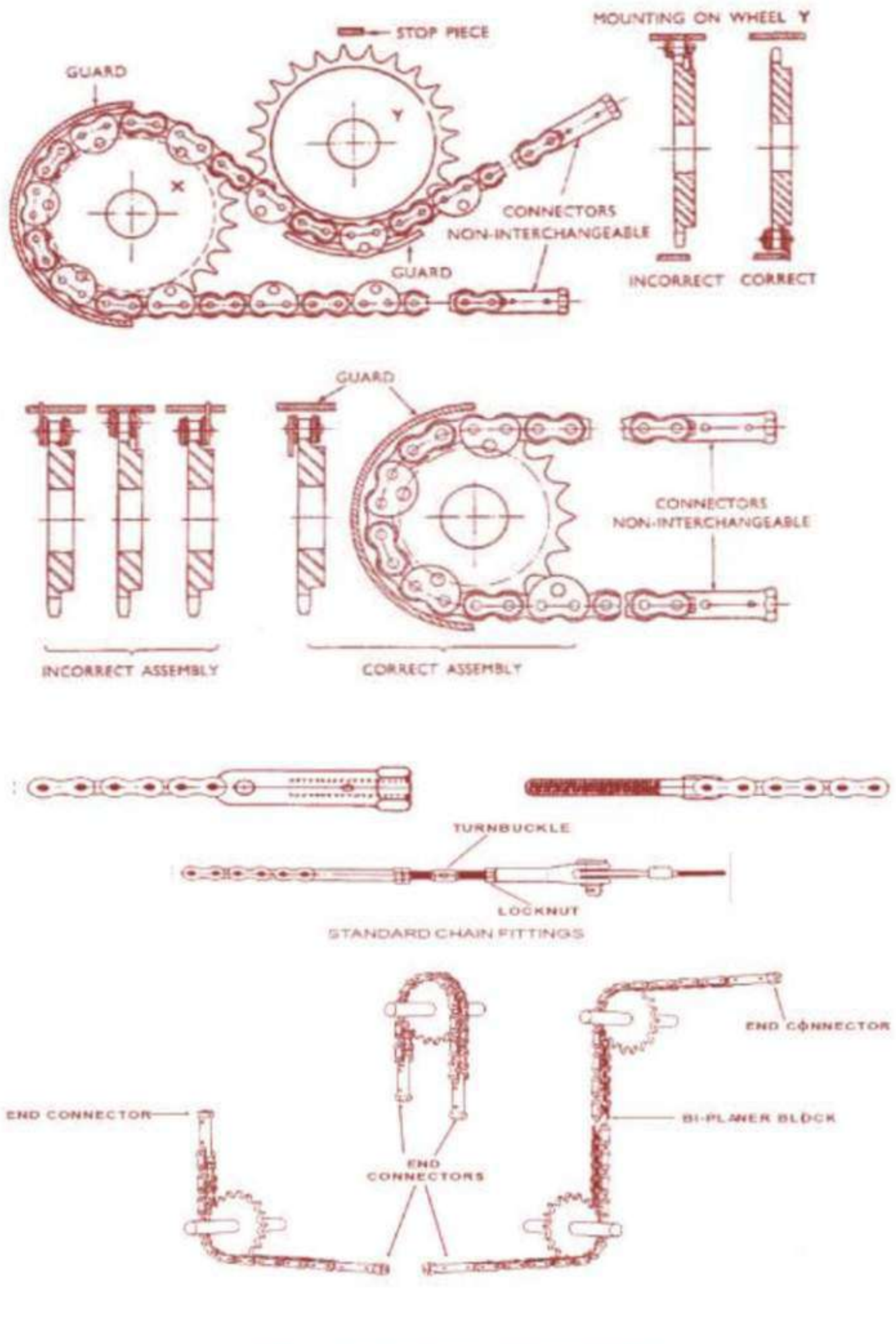
Joining the chain to an end connector is achieved by a bolt, which passes through the outer plate and into a threaded hole in the opposite outer plate. A nut is fitted to the protruding thread, and split pinned.



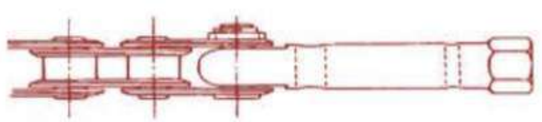
CHAIN ASSEMBLIES

Installation Of Chain Assemblies

The illustration shows typical arrangements of chain assemblies. Change of direction of straight line motion in two planes is achieved by using a 'bi-planer' block. The transfer of straight line to rotary motion is achieved by using a chain wheel (sprocket). A chain wheel is also used to change the direction of the straight line motion.



TYPICAL CHAIN ASSEMBLY ARRANGEMENTS



Typical chain end assembly

Non-reversible chains are similar to standard chains except that every second outer plate is extended in one direction in order to break up the symmetry of the chain.

Inspection After Assembly

After installation in the aircraft, the chain should be examined for:

- Freedom from twist, particularly in instances where the attachment is made to threaded rods by means of screwed end connectors, or where a twist may inadvertently be applied to the chain during the locking of the assembly.
- Care should also be taken to ensure that the chain is not pulled out of line by the chain wheel; the chain should engage smoothly and evenly with the wheel teeth and there should be no tendency for the chain to ride up the teeth.
- The pre-tensioning of chains should not be excessive, as this will cause friction, but should be just sufficient to prevent any back-lash in the system.
- The guarding should be checked to ensure that jamming could not occur and that the chain would not come off the wheel should it become slack.
- The security of end connections should be checked, care being taken to ensure that the split pins in the chain connecting bolts are correctly locked.
- The initial lubricant on new chains should not be removed and the chains should be further lubricated after assembly by brushing all over, particularly on link edges, with lubricant complying with specification DTD 417A, unless otherwise specified.
- The wheel or pulley mountings should be examined to ensure that the wheels or pulleys are firmly secured to the shafts or spindles, that they are correctly located and are running freely.

MAINTENANCE

Chain assemblies should be inspected for serviceability at the periods specified in the relevant Maintenance Schedule.

Generally the inspection would be as follows:

- The continued smoothness of operation between the chain and the chain wheel or pulley should be checked. If the chain does not pass freely round the wheel or pulley, it should be removed and checked as described.
- The chain should be checked for wear; if it is worn so that the links are loose and can be lifted away from the wheel teeth, it should be removed and checked for excessive elongation.
- The chain should be checked for damage, cleanliness, adequacy of lubrication and freedom from corrosion. If the inspection shows the chain to be corroded or otherwise defective, it should be removed.
- If it becomes necessary to adjust the tension of the chain, care should be taken to ensure that the chain itself is not twisted during the adjustment.

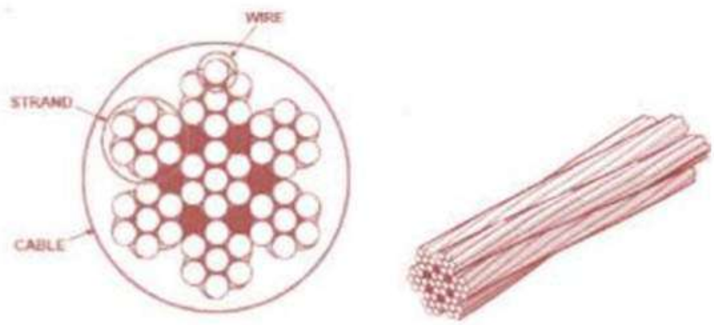
Chain assemblies should be removed from the aircraft for complete inspection at the periods specified in the Maintenance Schedule.

Module 06.10: CONTROL CABLES

GENERAL

Metal cables (or wire ropes as some manufacturers refer to them) are used as a method of transferring movement from one place to another, for instance from the control column to the control surface. A cable is constructed from a number of wires twisted together to form a strand. Depending on configuration a number of strands may then be twisted in the opposite direction to form the cable.

Being flexible they can transfer this motion round corners and into different planes via pulleys. However, being flexible, they can only transfer a tension or pulling movement, so usually they are used in pairs as a circuit to enable travel in both directions. Occasionally a single cable maybe used with a spring loaded return device to maintain tension (like the brakes on a bicycle).



Cables are usually 'preformed' during manufacture. Performing is a process in which each strand is formed into the shape that it will take up in the completed cable. This makes the cable more flexible, less prone to kinking and more fatigue resistant.

Another advantage of preformed cables is that, in the event of a wire breaking, it will lie flat within its strand, so that the cable is less likely to jam in its pulleys and fair leads.

Preformed cables are manufactured from galvanised (zinc coated), or tin over zinc coated Carbon Steel, or uncoated Corrosion- Resistant Steel (CRS or Stainless Steel), and are impregnated with friction reducing lubricant during manufacture. CRS cables are slightly weaker than the carbon steel equivalents but are less prone to corrosion and may be used in harsh environments. Non- preformed single strand cable may be found on some minor aircraft systems.

Safety Factors

The safety factor is the ratio of the strength of the cable to the working load. A cable with a strength of 10,000 pounds and a total working load of 2,000 pounds would be operating with a safety factor of five.

Bending And Fatigue

All cables, except stationary ones used as bracing, are subjected to bending around pulleys.

The detrimental effects of bending may be classified as:

- Loss of strength due to bending.
- Fatigue effect of bending.

A cable may be considered a machine in which the individual elements (wires and strands) slide upon each other when the cable is bent. Loss of strength due to bending is caused by the inability of the individual strands and wires to adjust themselves to their changed position when the cable is bent. Therefore, for the satisfactory operation of a cable over pulleys, the cable must be internally lubricated. This lubricant is applied during manufacture and care must be taken that it is not removed during maintenance.

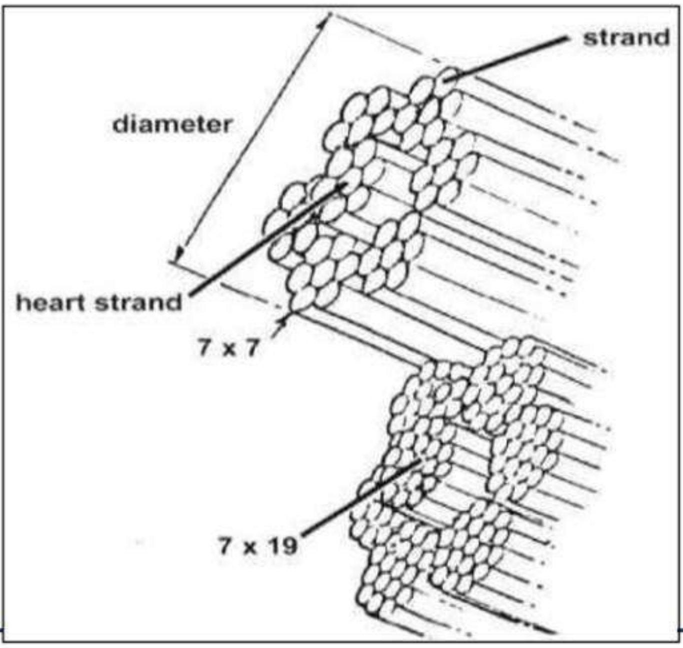
Repetitive flexing of the wires as the cable passes over a pulley, and their straightening, as the cable leaves the pulley develops bending loads which, even though well within the elastic limit of the wires, set up points of stress concentration. Fatigue failure of the wires in a cable is the result of the propagation of small cracks from these stress points.

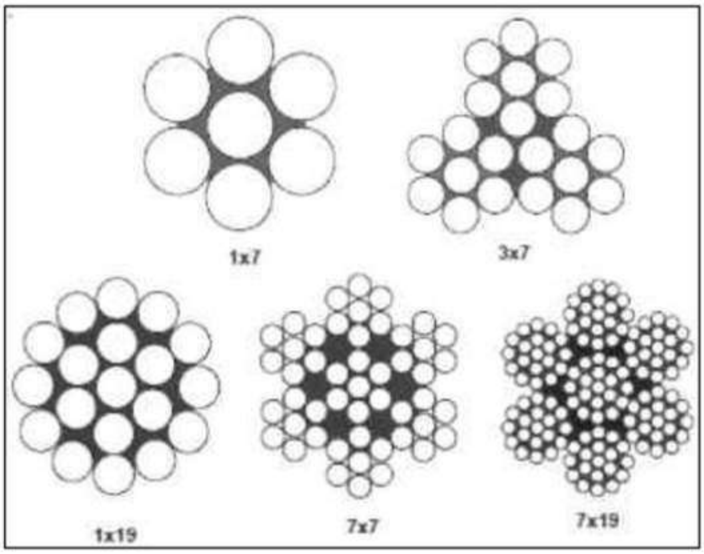
<u>Abrasive Wear</u>

The ability of a cable to withstand abrasion is determined by the size and composition of the outer wires and the construction of the cable. The larger outer wires of the less flexible constructions are better able to withstand abrasion than the finer outer wires of the more flexible cables.

CABLE CONSTRUCTION

As we have seen, the thickness of the individual wires determines the flexibility of the cable, so a cable composed of 19 wires will be more flexible than a similar sized cable constructed from 7 thicker wires. Thicker wires may offer slightly greater strength in larger diameter cables.
The designation of the cable is determined by the number of strands it contains, and the number of wires in each strand. For example a cable designated as 7x19, consists of 7 strands, each containing 19 wires. A specific diameter of cable may be available in two or more configurations e.g. 1/8 inch cable as 1x19 or 7x19.Themost common configurations for commercial aircraft cables are 7x7 and 7x19.
The aircraft manufacturer will specify both diameter and construction.





There is also a overspecialized form of aircraft control cable known as Lock clad. Lock clad control cable consists of standard aircraft cable over which is swaged an Aluminium tube of proper thickness and length.
This combination provides several advantages:

- It lowers the creep stretch
- The smooth cylindrical surface provides for closer sealing through pressure walls.
- It dampens the vibration of the cable.

The swaged tubing compacts the cable which minimizes undesirable stretch characteristics caused by load application. This combination also provides a coefficient of expansion of the cable closer to that of the airframe and this may produce an improvement in sensitivity of control.

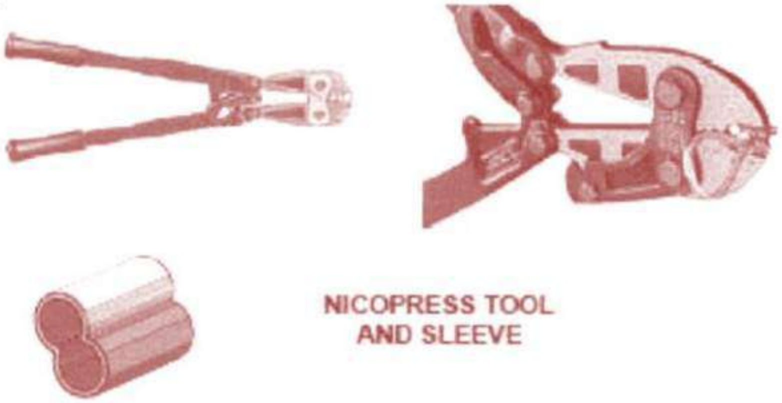
The Aluminium tubing is swaged only to straight runs of cable assemblies, those sections passing around pulleys must be left bare. For this reason, no increase in strength over the bare cable is obtained by the use of Lock clad. The rigidity of the cladding also makes the routing of long cable runs impossible so it is rarely used on large commercial aircraft.

END-FITTINGS

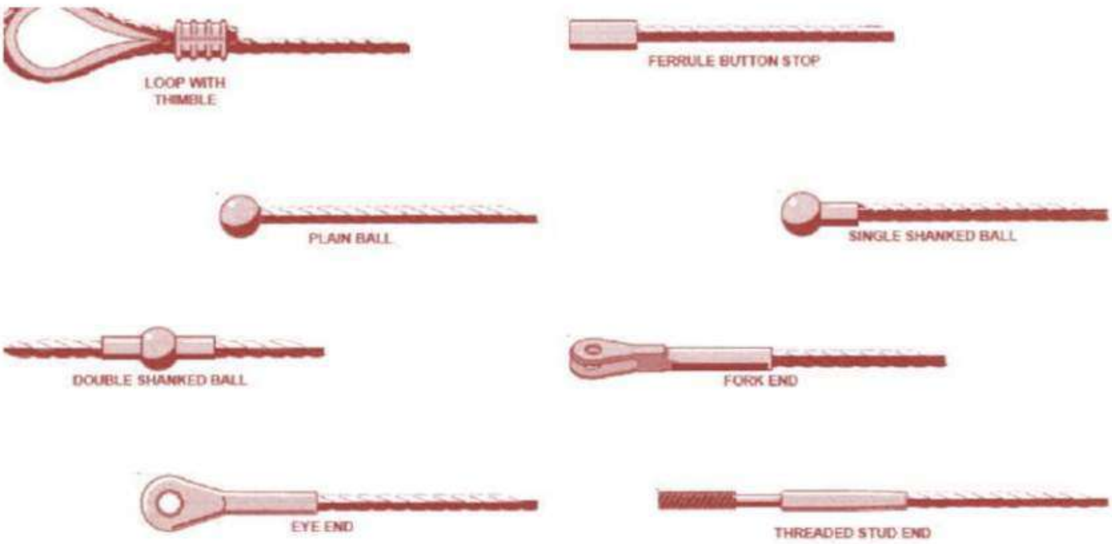
GENERAL

The majority of modern cables have a 'swaged' type end-fitting where a hollow shank or sleeve on the fitting is physically distorted to grip the cable. Lightly loaded Aluminium and copper end fittings may be installed with simple hand crimping pliers while the stronger steel fittings used on most commercial aircraft cables are swaged on using specialised manual or hydraulic powered tooling.

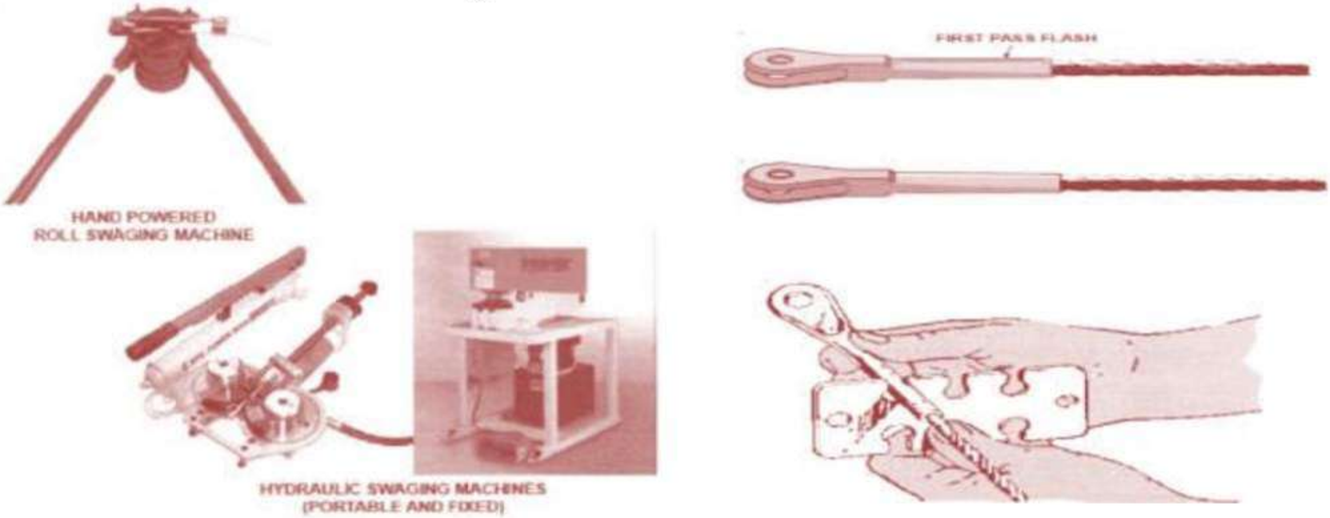
Relatively low strength cables with the loop and thimble type end fitting are formed using a Nico press tool. The cable is passed through a Nico press sleeve, around the thimble and back through the sleeve. When satisfied that there is sufficient protrusion, the sleeve is placed inside the tool and deformed by compressing the handles. The finished sleeve is then inspected for cracks and distortion and tested with a go/no-go gauge for adequate formation.

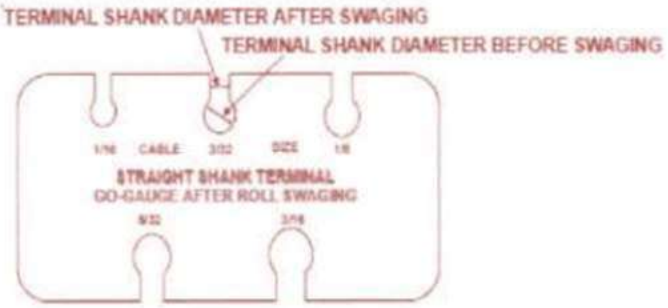


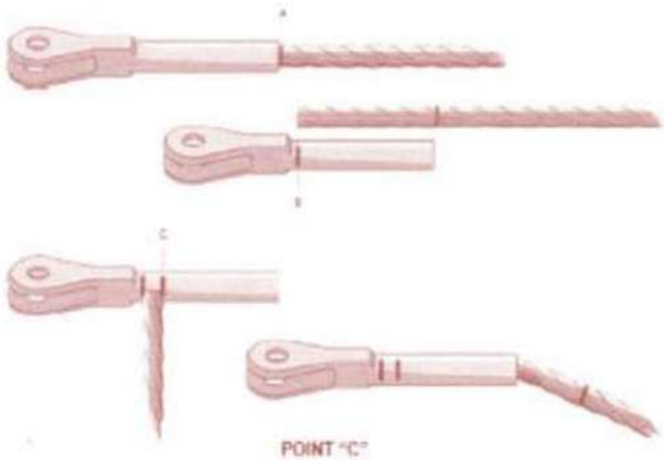
Most high strength end-fittings on control cables are special type and those such as fork, threaded (internal and external), and ball fittings can be found in various locations. The grip of a correctly fitted terminal will be greater than the breaking strength of the cable.

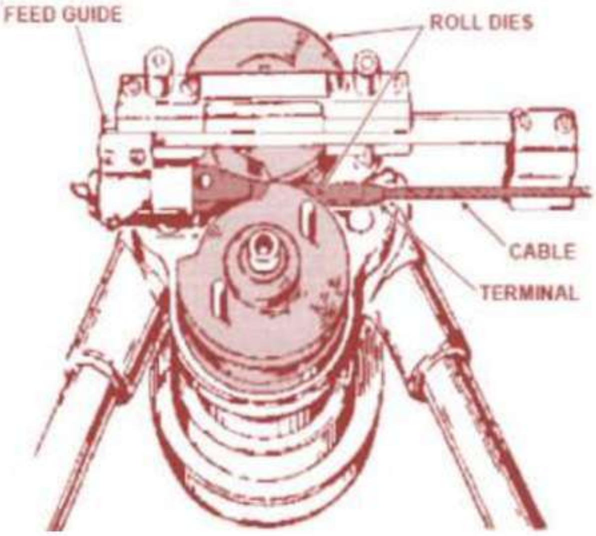


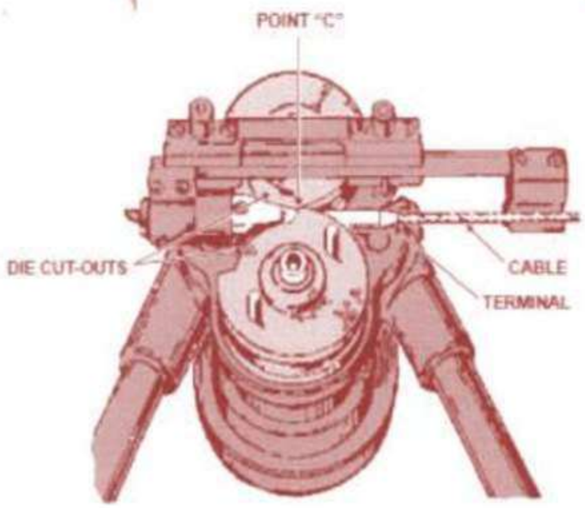
Swaging machines may be hand portable or bench mounted manually or hydraulically powered units. Most small machines work on the same principle in that rotating dies turn and progressively compress the sleeve or shank of the end fitting causing it to grip the cable. Large hydraulic machines may apply pressure to dies which form the swage in one action.









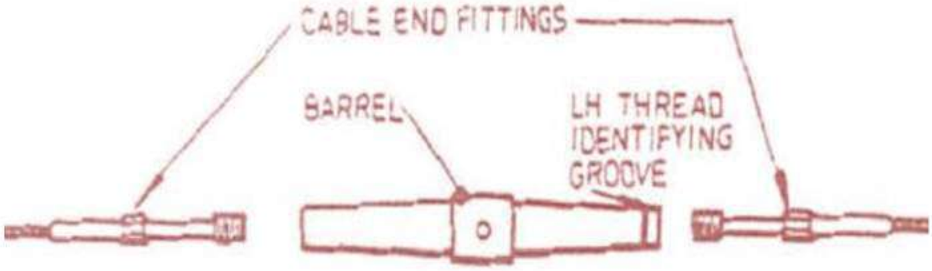


Caution

Over-swaging will only cause work hardening, or may lead to embrittlement which may induce terminal cracking. For this reason you must never use more than four passes. If after the fourth pass the diameter on the sleeve has not been reduced to the proper size, examine the equipment and recheck instructions in order to determine what is causing the problem. Irrespective of which method was used for installing the end fitting, the cable assembly must be inspected and proof tested. A visual inspection for cracks and distortion is performed and then the cable is proof loaded to 50% of the minimum breaking load for British spec cables and 60%for American spec. This proof load is about 10 times the static tension applied to the cable in normal operation and tests the integrity of the cable assembly whilst also pre-stretching it.

TURNBUCKLES

Turnbuckles are the usual device for tensioning a cable system. A turnbuckle assembly consists of a left hand threaded fitting swaged on to one cable end, and a right hand threaded fitting swaged to the other cable end, and a barrel, tapped left and right hand between them.



Turnbuckles are in safety when:

British Types

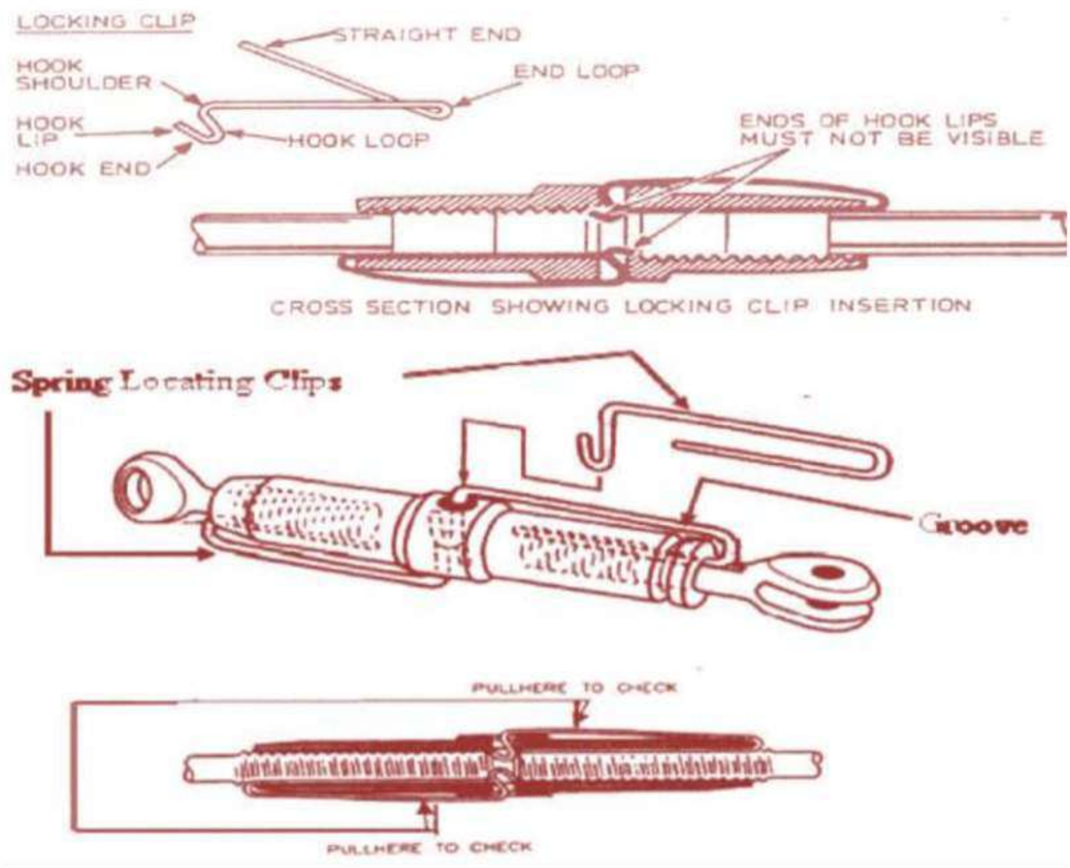
A hardened steel pin will not pass through the safety inspection hole.

American Types

All of the fitting thread is engaged in the barrel.

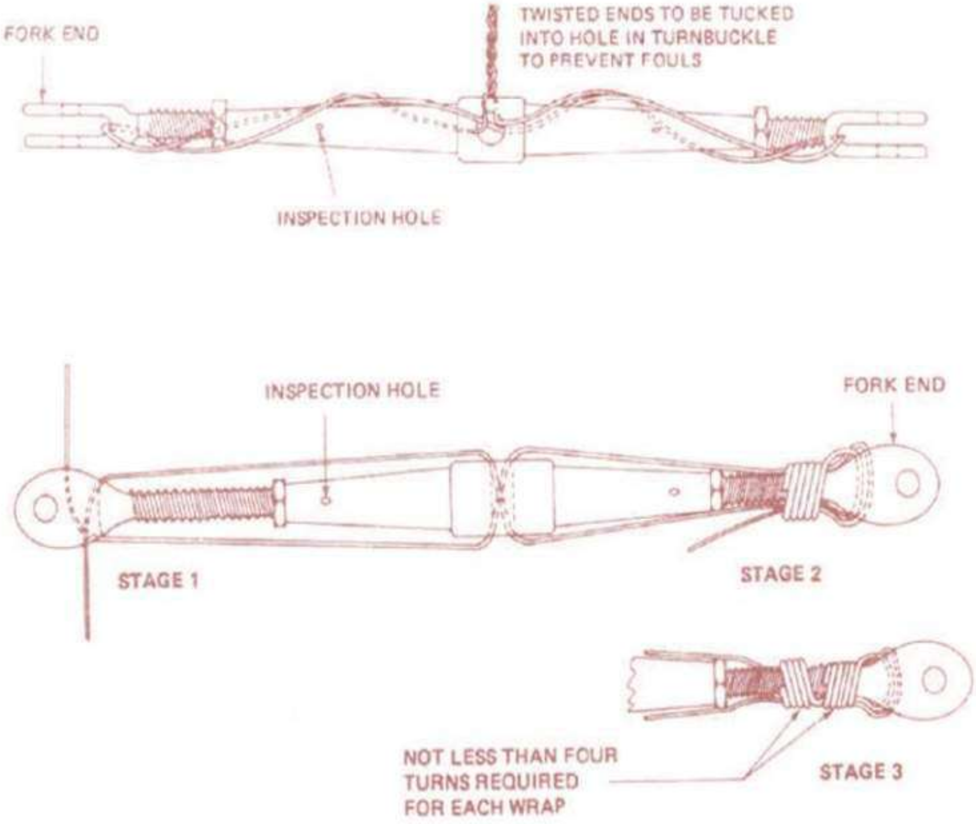
Turnbuckle Locking

Most turnbuckles currently are locked using spring clips which are passed down grooves cut inthe



A turnbuckle locked with a clip

Threads of the fittings and the barrel. The clip is positively located when the locking tongue is located under the lip of the barrel centre hole.



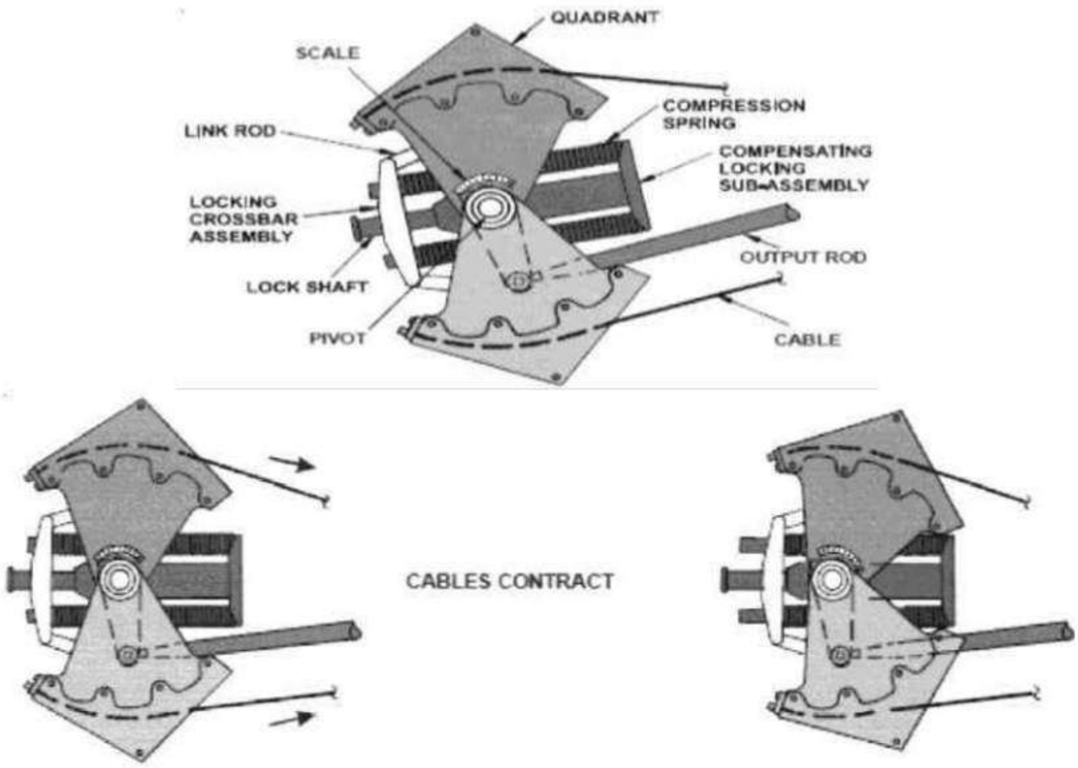
Turnbuckle wire locking procedure

When use of a clip is not possible, or wire locking is specified, this should be done in accordance with the aircraft manufacturer's requirements, usually to the FAA or CAA standards as appropriate.

CABLE TENSIONING DEVICES

GENERAL

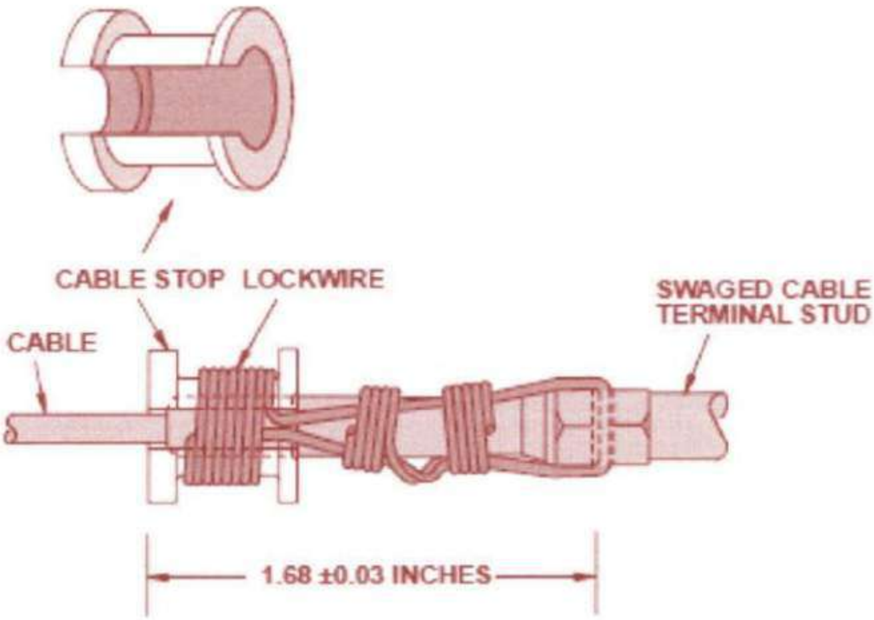
Although the cable tension can be correctly adjusted on the ground, this tension may alter once the aircraft is in flight. This can be due to the large temperature differentials involved and the consequent expansion and contraction. Flexing of the airframe in flight will also affect the tension. To overcome these problems a tension regulator is installed in some control runs. The tension regulator shown here is typical. As the tension in the cables varies, due to expansion, contraction or flexing, the Quadrants will rotate independently about the central Pivot. The Link Rods transfer this motion to the Locking Crossbar Assembly. The Compensating Locking Sub-assembly Compression Springs which push against the Locking Crossbar Assembly, expand or contract to maintain uniform tension.



TENSION REGULATOR

Cable Stops

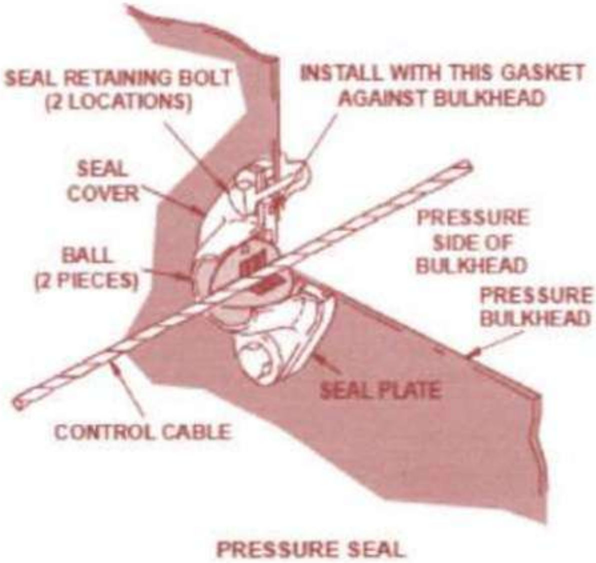
Some control systems have Cable Stops attached to turn buckles or end fittings. These are designed to contact stop brackets on the aircraft structure in the event of cable failure or over-travel, to limit the movement of a control. They are typically used on throttle cables. The stop is usually wire locked into position at a specific distance from a datum.



Cable Fairleads

The cables of a control run must be supported to reduce the possibility of fouling, vibration and fluctuations. They are supported by fairleads which are usually made from plastic or fiber materials. These fairleads should not be lubricated as this will collect dirt and dust, which will cause extra wear on the cable and fairlead.

To prevent chafing of the cables, fairleads are fitted to the aircraft structure where the cables pass through, e.g. bulkheads and frames. They are made of Teflon or Nylon, and are normally of two halves bolted together. The cable runs through a hole in the fairlead. Fairleads must not be lubricated as they will collect dust and dirt.



A sealed fairlead assembly

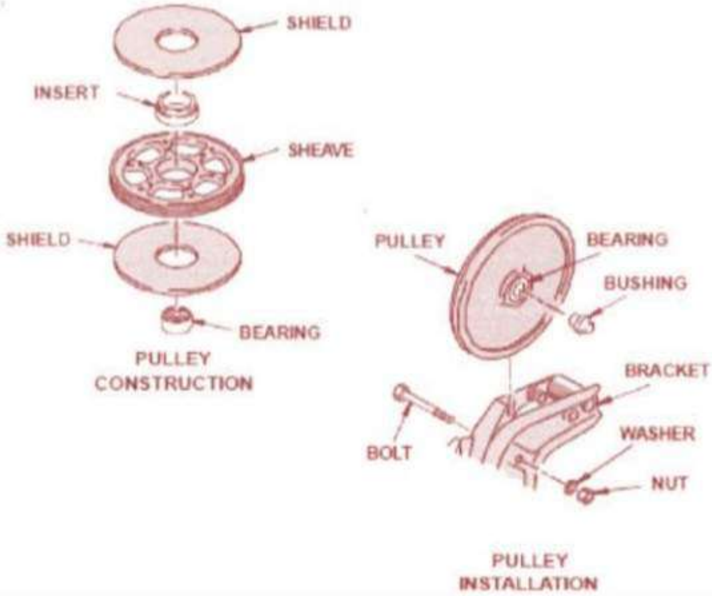
CABLE PULLEYS

Cables that run for long distances inside an aircraft will need to change direction to allow for the complicated structure. The usual method is by means of a pulley, as this allows the change of direction with little increase in friction.

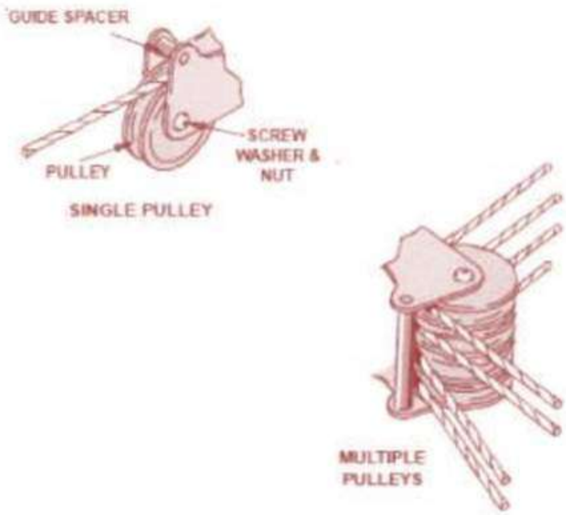
Aircraft pulley's are usually made from resin impregnated fiber materials like Teflon with a sealed bearing fitted in the centre.

A typical example would be a flying control system opposite, which has pulleys that change the direction of the cable through various of angles. Where a change in direction of the cable is required, a pulley is normally used, due to its low friction in comparison with fairleads. Guards are fitted to pulleys when the risk of the cable riding off the pulley is high.

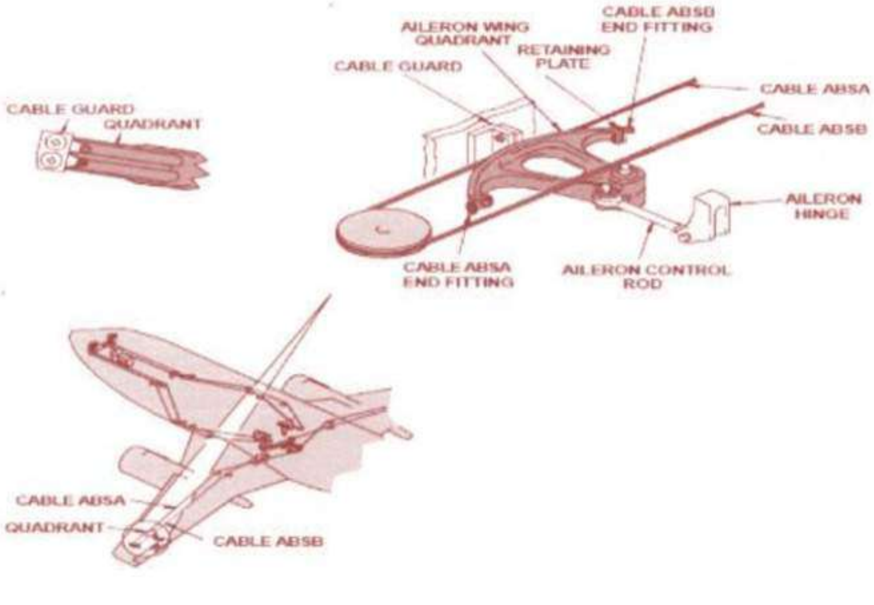
As previously mentioned pulley diameter is selected by the airframe manufacturer to minimize stress and wear on the cable.

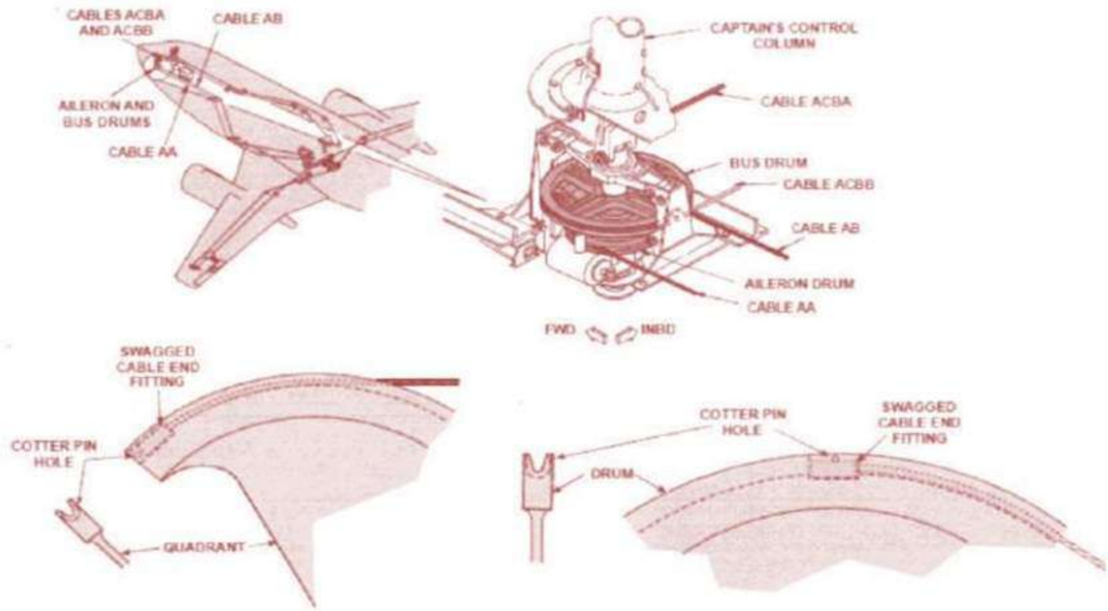


QUADRANTS AND DRUMS



Quadrants and Drums are used where an input to, or output from the cable system is made. The cables always terminate at these components, the swaged ferrule or ball type end fitting being anchored to a cut-out in the track. Quadrants and drums often have rig pin holes or other rigging facilities.





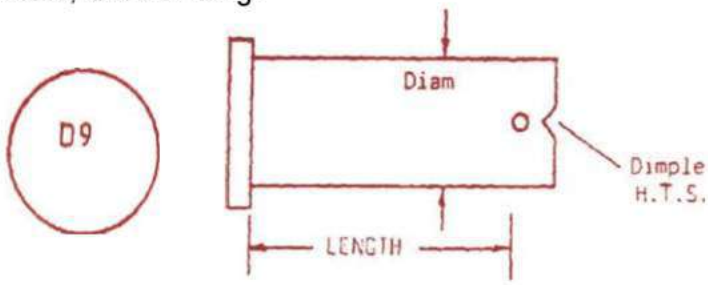
Shackle Pins

These are used with fork joints, fork ends and other applications where they take shear loads. They are secured in place with split pins.

Shackle pins are made from High Tensile Steel and High Tensile Stainless Steel. H.T.S.S. shackle pins have a dimple at the shank end and/or the letter 'Z' marked on the head.

The diameter is denoted by a letter starting from A which is 5/32 in and rising by 1/32 in from each letter up to T. Length is indicated by a number starting with 1 which is 0.25 in and rising 0.050 in per number, and is measured from the underside of the head to the nearer side of the split pin hole.

Example: D9 is 1/4 in diameter, 0.65 in long.



Control Cable System Inspection

GENERAL

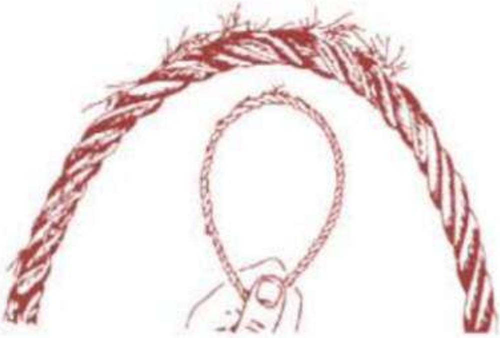
This section gives the typical inspections for control cable systems. Always check the AMM for specific information.

Tests show that flexible cables can have broken wires without an important decrease in strength. A 7x7 cable, for example, can have two broken wires in a one-foot length and continue to hold its specified load. However, it is good practice to replace a cable whenever broken or corroded wires are found.

Control Cables Inspection

Clean the airplane control cable with a dry, clean cloth. Do not use solvents or abrasive materials clean the control cable; solvents will remove the cables internal lubricant, which will cause corrosion and rapid wear. If necessary, apply applicable grease to carbon steel cable. Do not put grease or corrosion preventive agents on corrosion resistant steel cables, because attraction of grit increases wear rate on CRES cables.

Check for broken wires. Rub a cloth along the length of the cable in both directions, do not use bare hands. Broken wires are indicated where the cloth gets caught on the cable. Broken wires which lay flat can be difficult to detect.



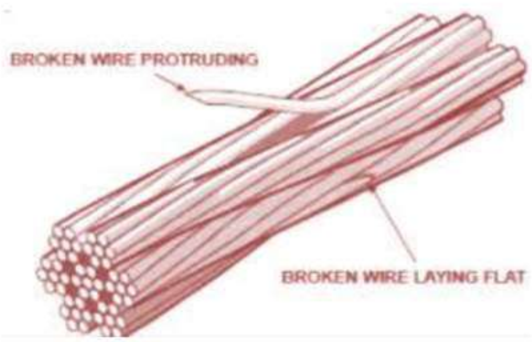
Move the control cable to full travel in each direction to inspect where it passes through seals, pulleys, drums, quadrants and fairleads, wires usually break where cables pass over or through these components. Examine these areas carefully paying special attention to cable runs outside the pressurized areas. Use a torch and mirror to aid inspection in hard to see places.

Replace a 7 x 7 control cable when one of the following conditions is found.

- Two wires are broken in a 12-inch length of cable.
- More than three wires are broken in the total cable length between the two terminals.
- One wire is broken caused by rust or corrosion.

Replace a 7 x 19 control cable when one of these conditions are found.

- Four wires are broken in a 12-inch length of cable.
- More than six wires are broken in a total cable length between the two cable terminals.
- One wire is broken caused by rust or corrosion.

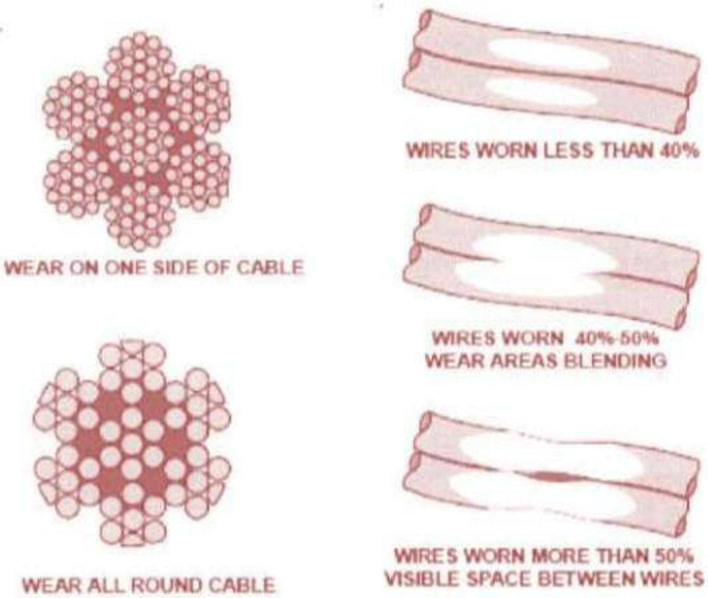


Broken wire is only permitted in a cable assembly if it is in a straight part of the cable assembly and does not go over a pulley, through a pressure seal, or through a fairlead.

Check for wear on cables. For cables in the pressurized area (fuselage cables), replace a cable if one strand has worn wires where one wire cross section is decreased by 40 percent or more. Flex the cable at the shiny portion to see if any wires break.

For cables in the unpressurised areas, replace a worn cable where you cannot identify the wire strands on the worn side.

Replace all cable assemblies which have damage caused by rust or corrosion. A whitish deposition High Tensile Steel galvanised cables indicates corrosion of the zinc coating. Red rust indicates that the steel wires are corroding.



Examine for 'bird-caging'. This is caused when the cable is subjected to a sudden tensile load which, although insufficient to break the cable causes the pre-formed strands to straighten out at the point of maximum stress. When the load is removed from the cable these strands standout causing 'bird-caging'. Affected cables must be rejected.

Check for kinking. If the cable has a permanent bend when not under tension it must be rejected. If the heart strand protrudes from between the pre-formed strands it must be rejected.

Check swaged end fittings for cracks, corrosion and signs of pulling off the cable, indicated by a shiny portion adjacent to the end fitting. Check the hole in the end fitting for elongation using a new bolt.

Check for a broken heart strand, indicated by thinning of the cable, or loss of tension in an installed cable.

Control Cable Pulley Inspection

Visually examine the pulleys for roughness, sharp edges, and unwanted material in the grooves.

Visually examine the pulley wear pattern for the conditions shown below.
Examine the pulley bearings to make sure they are lubricated correctly, can turn smoothly, and have no flat spots. Examine the pulley bolts for worn areas. Remove and replace a pulley when you find:

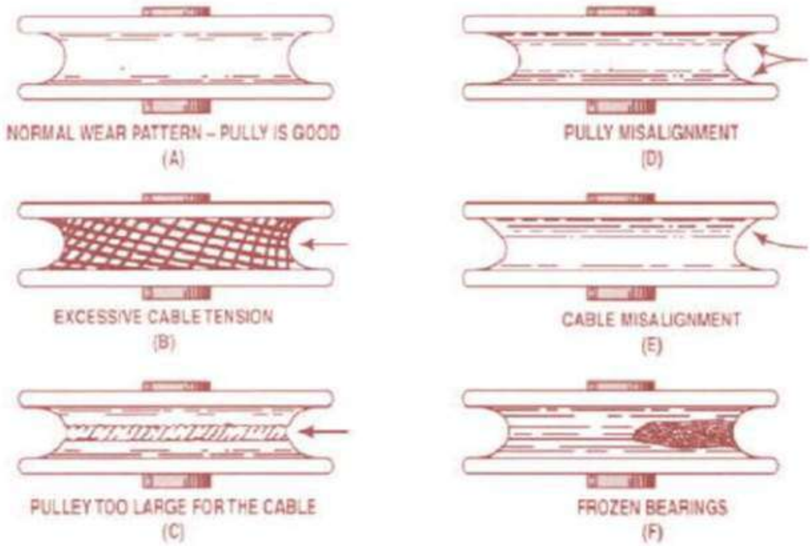
- There is an unusual pulley wear pattern.
- There is too much pulley wobble.
- The pulley does not turn freely and smoothly.

Examine the pulley brackets for cracks, and for other damage to the structure.

Repair or replace damaged brackets, if necessary. Pulleys are fitted to change the direction of a cable run. They are made from Teflon or Micarta. An integral sealed ball bearing is provided. Cable guards are provided to prevent the cable coming off the pulley.

When inspecting cables for the previously mentioned wear and breakages, the complete cable runs must be examined for incorrect routing, fraying, twisting or wear at fairleads, pulleys and guards.

Pulleys must be inspected for wear, to detect indications of seizure, flat spots, embedded foreign material and excessive tension. Any signs of contact with adjacent structure, pipe-work, wiring and other controls must also be thoroughly investigated.



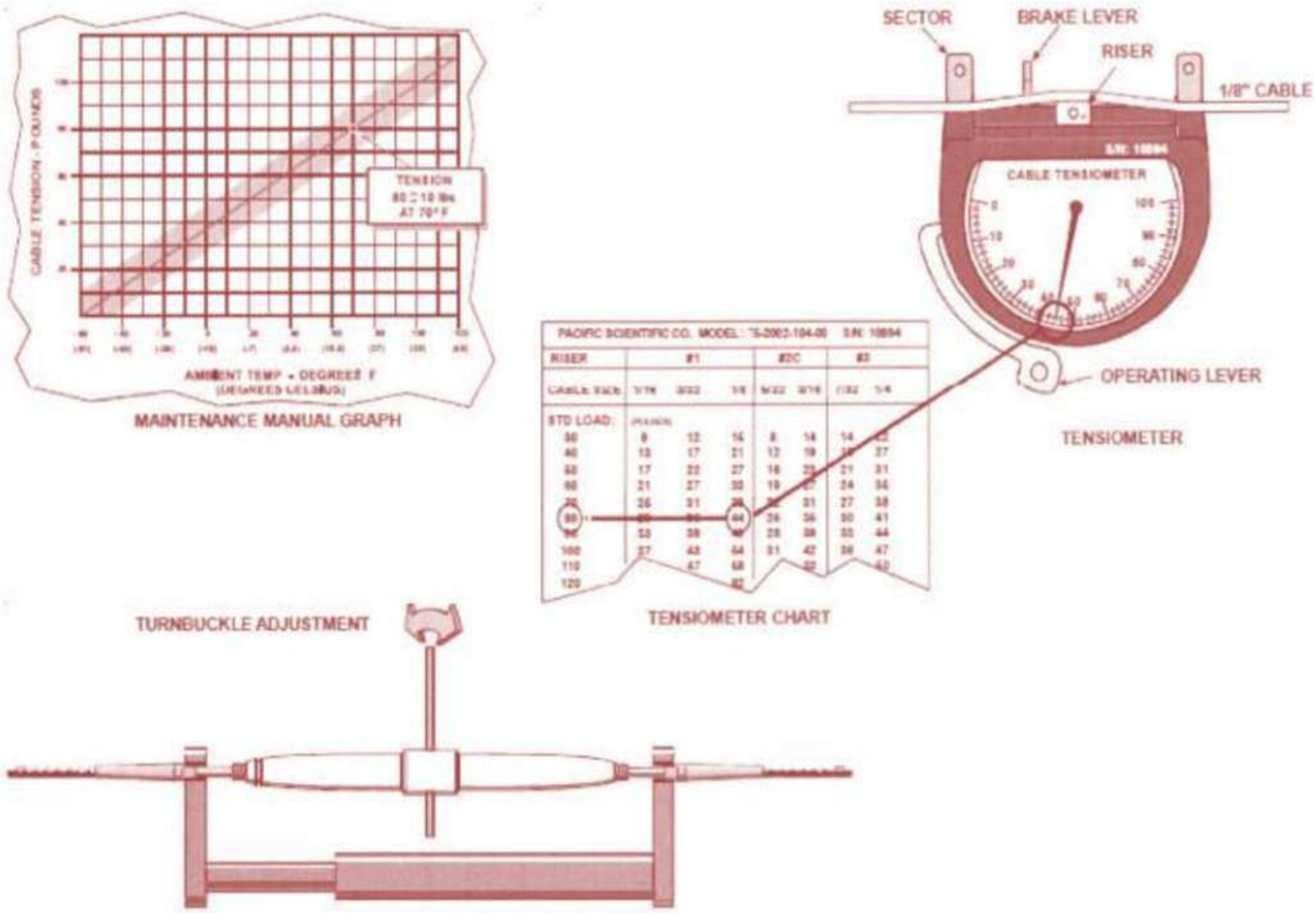
Pulley wear patterns

Control Cable Run And Travel Inspection

Examine the cable guides and fairleads for worn areas, broken parts, correct alignment, clean parts, and correctly attached parts.
Make sure the cable deflection angle at the fairleads is not more than three degrees.
Examine the cables to the make sure they go along the correct routing, and do not have twists. Check the minimum clearance from the adjacent structure.
Make sure the cable is free to move through its full travel.

Cable Tension

As mentioned, the correct cable tension is important to ensure safe and proper system operation and continued serviceability of the components. The correct tension for a control cable is specified in the AMM. It is checked by the use of a Tensiometer and adjusted on the turn buckles.

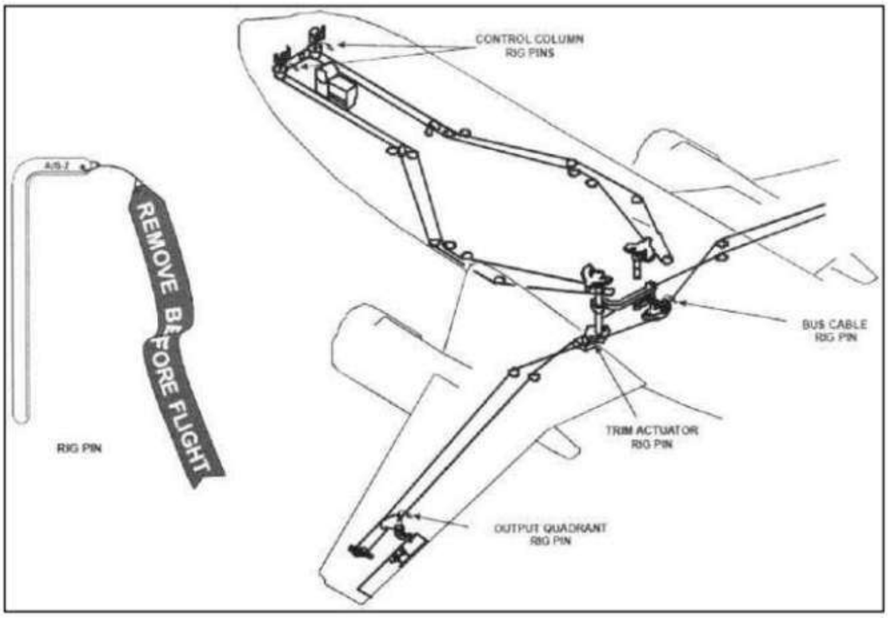


Cable Rigging

A control system will require rigging after a cable change, system maintenance or when a control problem is found or suspected. Rigging is the means to ensure that all the parts of the system are in the correct position to allow full travel in the correct sense.

Rig pins are part numbered tools of specific length which have a red flag attached to show when they are installed. (Dispatch of an aircraft with rig pins still installed could have catastrophic consequences!). They are inserted into holes in quadrants, drums and other components at certain points in the system which align with holes in brackets or the adjacent structure when in the correct position. If they do not align the cable must be adjusted by loosening and tightening the turnbuckles until correct alignment is achieved.

NOTE: When working on flying controls and particularly hydraulic powered systems, surfaces can move with great speed and force. Ensure all staff are briefed and all safety precautions taken.
Specific details of the rigging procedure vary with aircraft type so it is vital to refer to the AMM.

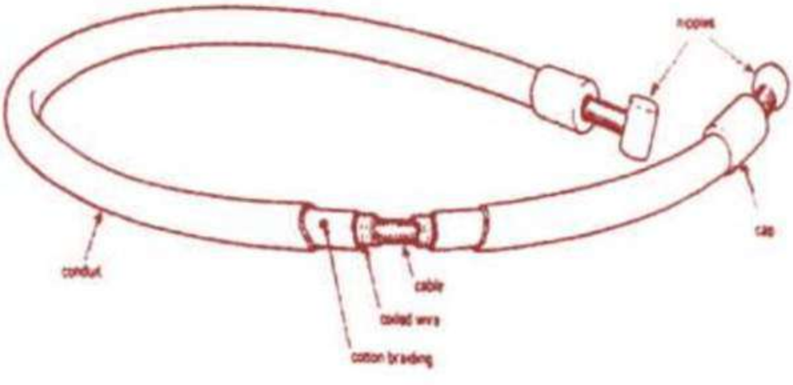


FLEXIBLE CONTROL SYSTEMS

Normal aircraft cables are only capable of performing a pulling action, due to their lack of rigidity and so are used in a circuit. Where a two directional movement of push and pull is required in areas of limited space it would be necessary either to use control rods, with the increased weight penalty, or to use flexible control systems. The two most common types of flexible control system are Bowden Cables and Teleflex Control Systems.

BOWDEN CABLE SYSTEMS

A typical Bowden cable control might be a brake lever on the control column operating a remote brake control valve.



Maintenance of Bowden cable systems is usually restricted to cleaning and lubrication of the inner cable at regular intervals and adjustment of the outer conduit (e.g. if the brakes needed adjustment). The lubrication would keep moisture out of the cable to prevent it freezing at low temperatures.

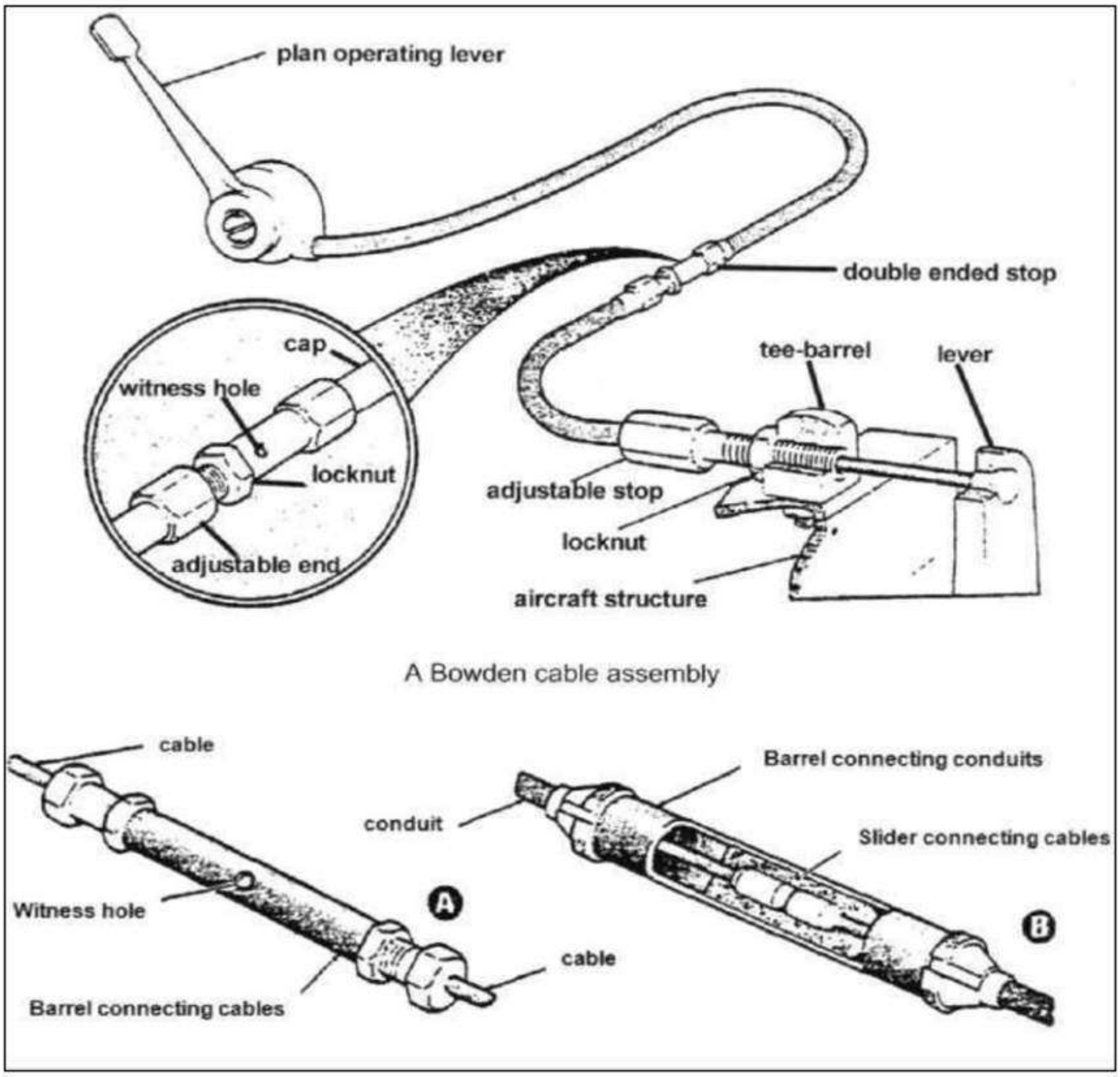
SERVICING

- Inspect the cable ends for fraying and corrosion
- Inspect the conduit for kinks and signs of wear
- Adjust the cable for slackness by adjuster (screw out, i.e. increase the length of conduit to take

up the slackness in cable) Check for adequate locking.

- Lubricate, on assembly, with recommended grease.

Bowden cable connections



A Bowden cable assembly

TELEFLEX CABLE SYSTEMS

The Teleflex cable system is more complex than the Bowden cable system in that the operating cable, within the conduit, is actually a number of spirally wound cables which surround a core tension cable, giving it support. This allows the cable to transmit a push force as easily as a pull force, doing away with the need for any form of return spring.

A typical use of a Teleflex system might be a throttle lever to engine fuel control system connection.

The Teleflex cable system is a snug fit within the conduit and, because there might be the chance of it becoming seized, due to foreign objects, dirt or freezing, it is vital that the inner cables are regularly removed, cleaned and lubricated with low temperature grease. It is also important that the conduits are thoroughly cleaned using a form of 'pull-through', prior to the inner cable being installed.

At longer intervals, it might become necessary to inspect the outer conduit for signs of damage or kinking; which can cause the control to become tight or 'notchy'.

BOWDENFLEX CABLES

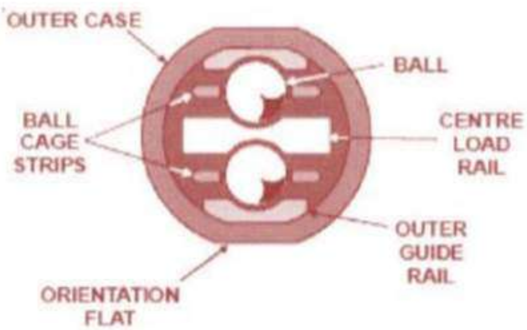
Bowden flex cables are another form of push-pull cable which may be encountered. However, due to their method of construction, they are flexible in only one plane.

The tension and compression loads are transmitted by a flexible Centre Load Rail. This is supported by a set of Balls either side, which are kept at regular intervals by two flexible Ball Cage Strips. Each set of balls runs in an Outer Guide Rail and the whole assembly is retained in a flexible casing. Orientation flats are formed on the outer casing parallel to the flat face of the Centre Load Rail to ensure that the correct plane of flex is evident on installation.

End fittings are attached to the Centre Load Rail to allow input and output loads to be applied.

The cable requires no lubrication in service and will operate at temperatures of between -40°and +250°C. Minimum bend radius is around 3 inches while stroke range is normally 1-4 inches. Bending in the wrong plane will result in high friction and excessive wear.

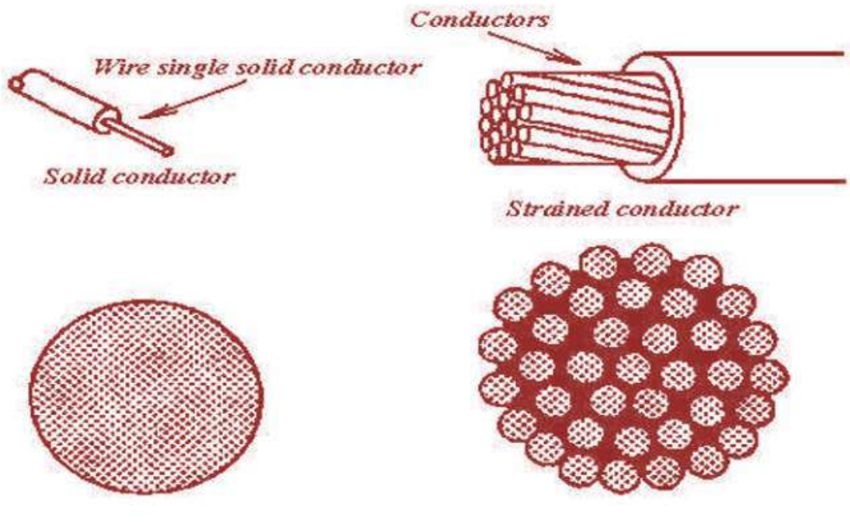
Applications are similar to those of the Teleflex cable although they are far less common.



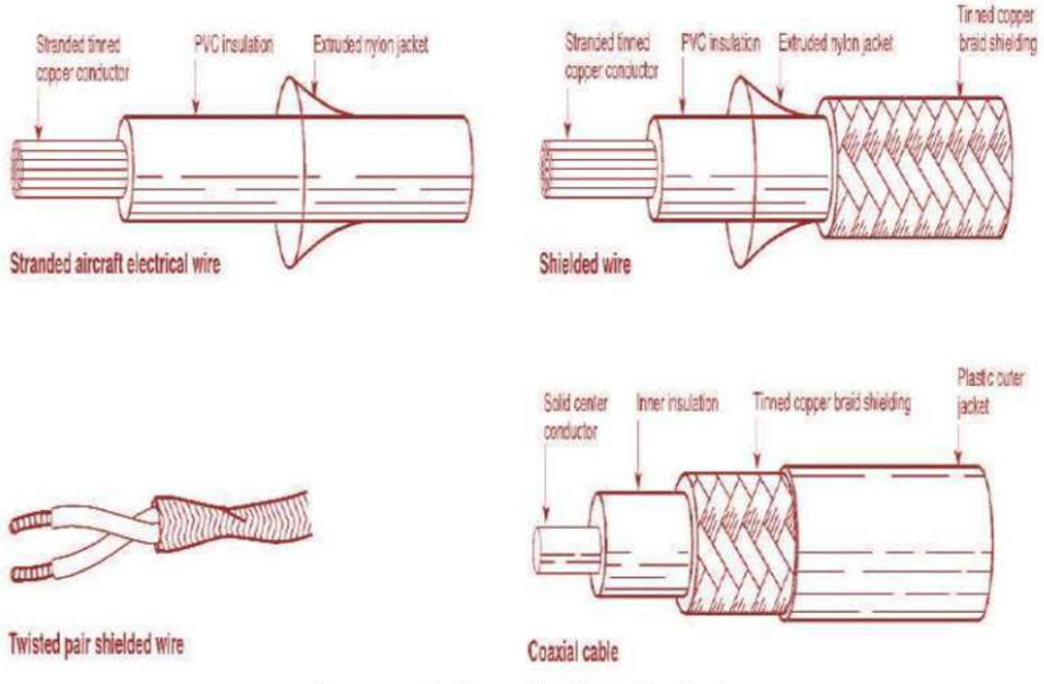
MODULE 6.11: ELECTRICAL CABLES AND CONNECTORS

The satisfactory performance of any modern aircraft depends to a very great degree on the continuing reliability of electrical systems and subsystems. Improperly or carelessly installed or maintained wiring can be a source of both immediate and potential danger. The continued proper performance of electrical systems depends upon the knowledge and technique of the mechanic who installs, inspects, and maintains the electrical wire and cable of the electrical systems.

Commonly a wire is described as a single solid conductor, or a stranded conductor covered with an insulating material



Two types of aircraft wire



Types of aircraft electrical wire

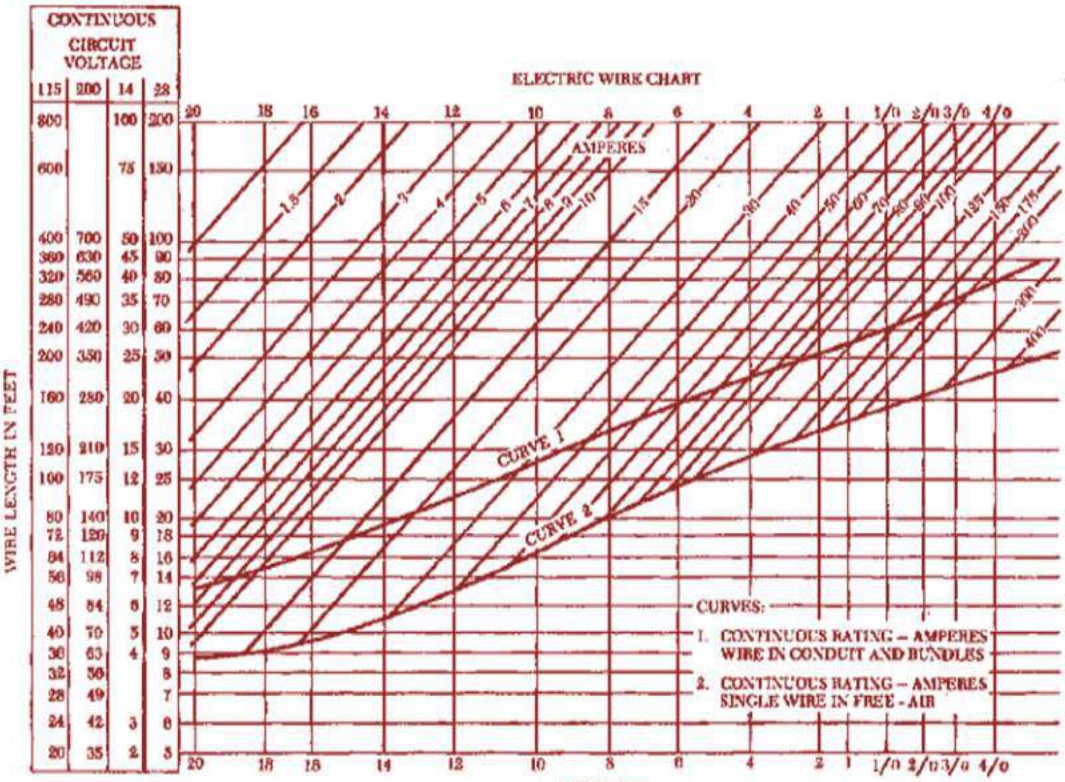
Term “cable” or “wire” as used in aircraft electrical installations (Fig. includes:

A - Two or more separately insulated conductors in the same jacket (multi-conductor cable);
B - Two or more separately insulated conductors twisted together (twisted pair);
C - One or more insulated conductors, covered with a metallic braided shield (shielded cable);
D - A single insulated centre conductor with a metallic braided outer conductor (radio frequency cable).

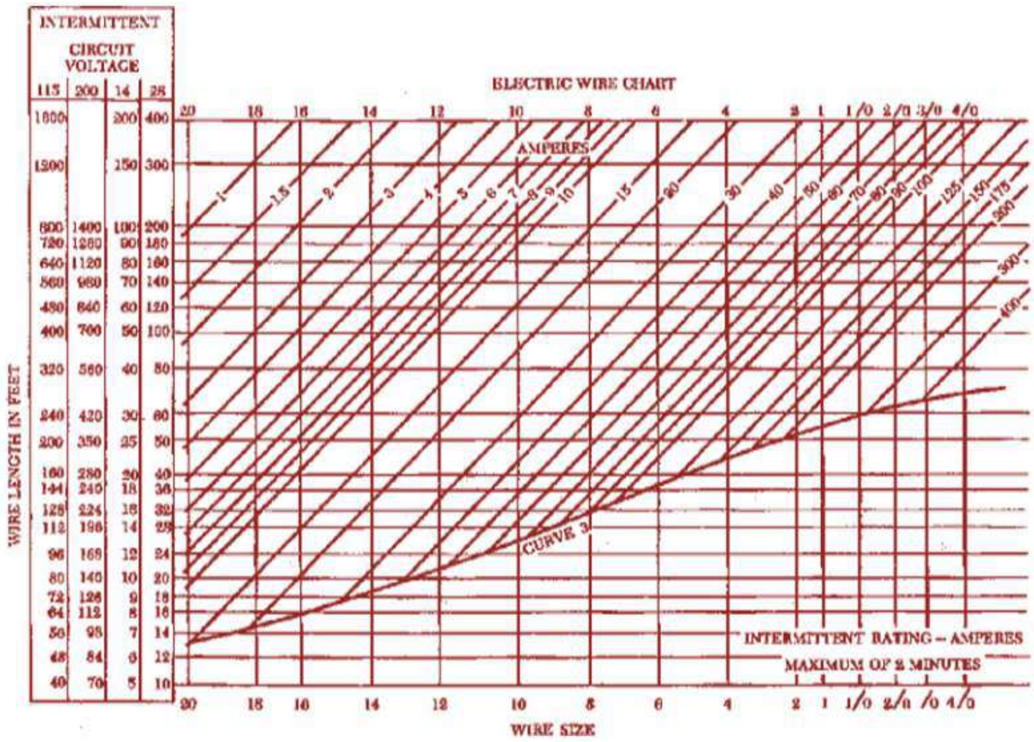
There are several conditions to be considered when choosing an aircraft electrical wire. The design temperature, flexibility requirements, abrasion resistance, strength, insulation, electrical resistance, weight, applied voltage and current flow. These factors will determine the type of conductor and insulation necessary for a given installation. Most aircraft wire is made with a stranded copper conductor, either 7 or 19 strands for small wire and 19 or more for larger wire. The use of stranded or twisted wire increases the flexibility of the conductor thus decreasing the chance of fatigue failure.

Characteristics of some typical aircraft wires are as follows:

MIL-W-22759/1: Silver-coated copper conductor. TFE floro corbon and glass insulator, 600V, 2600C.
MIL-W-22759/41: Nickel-coated copper conductor. ETFE dual insulator, 600V, 1050C.
MIL-W-22759/16: Tin-coated copper conductor. ETFE insulator, 600V, 1500C.
MIL-W-22759/19: Silver plated high-strength copper alloy conductor, ETFEinsulator,600V, 1500C.
MIL-W-81044/9: Tin-coated copper conductor, Ployalkene-reinforced PVFinsulation,600V,1500C.
WIRE SIZE: The wire used for electrical installations is sized according to the American Wire Gauge (AWG).The size of the wire is according to its diameter and is indicated by a unit called the circular mil. One circular mil is equal to the cross sectional area of 0.001in.The square mil is the unit of measure for rectangular conductor. One square mil is the measure of a rectangular conductor having sides that are 0.001in in length.



Conductor chart, continuous rating (Applicable to copper conductors)



Conductor chart, intermittent rating (Applicable to copper conductors)

Segments of high-voltage cables

The cable system must prevent contact of the high-voltage conductor with other objects or persons, and must contain and control leakage current. Cable joints and terminals must be designed to control the high-voltage stress to prevent breakdown of the insulation. Often a high-voltage cable will have a metallic shield layer over the insulation, connected to earth ground and designed to equalize the dielectric stress on the insulation layer, and to prevent shock.

High voltage cables may be any length, with relatively short cables used in apparatus, longer cables run within buildings or as buried cables in an industrial plant or for power distribution, and the longest cables are often run as submarine cables under the ocean for power transmission Construction

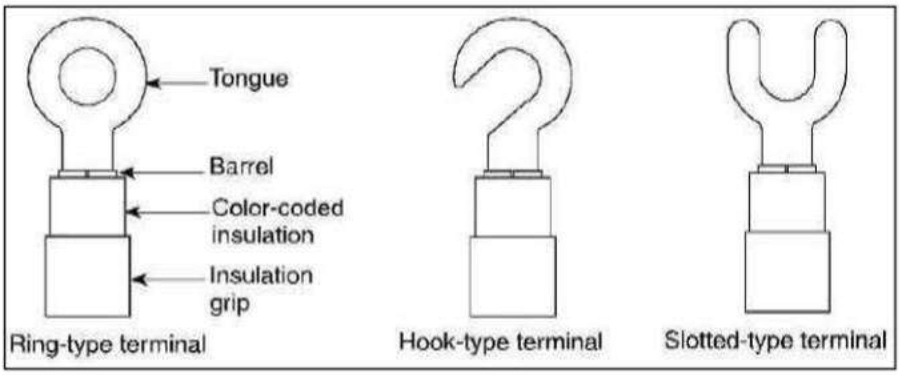
Like in other, the structural elements of HV-cables have one or more conductors, insulation, and a protective jacket. HV cables differ from lower-voltage cables in that they have additional internal layers in the insulation jacket to control the electric field around the conductor shows the stranded segmented copper conductor in the center, semiconducting and insulating layers, copper shield conductors, aluminum sheath and plastic outer jacket. For circuits operating at or above 2,000 volts between conductors, a conductive shield may surround each Connectors are often plated with high-conductivity metals such as silver or gold. Due to the skin effect, the RF signal is only carried by the plating and does not penetrate to the connector body. Although silver oxidizes quickly, the silver oxide that is produced is still conductive. While this may pose a cosmetic issue, it does not degrade performance.

A shielded wire containing a solid copper conductor is called coaxial cable. Commonly used for connecting an antenna to a radio receiver or transmitter

Solderless Terminals And Splices

Splicing of electrical cable should be kept to a minimum and avoided entirely in locations subject to extreme vibrations. Individual wires in a group or bundle can usually be spliced, provided the completed splice is located so that it can be inspected periodically. The splices should be staggered so that the bundle does not become excessively enlarged. Many types of aircraft splice connectors are available for splicing individual wires. Self-insulated splice connectors are usually preferred; however, a non-insulated splice connector can be used if the splice is covered with plastic sleeving secured at both ends. Solder splices may be used, but they are particularly brittle and not recommended

Electric wires are terminated with solderless terminal lugs to permit easy and efficient connection to and disconnection from terminal blocks, bus bars, or other electrical equipment. Solderless splices join electric wires to form permanent continuous runs. Solderless terminal lugs and splices are made of copper or aluminium and are pre-insulated or un insulated, depending on the desired application.
Terminal lugs are generally available in three types for use in different space conditions

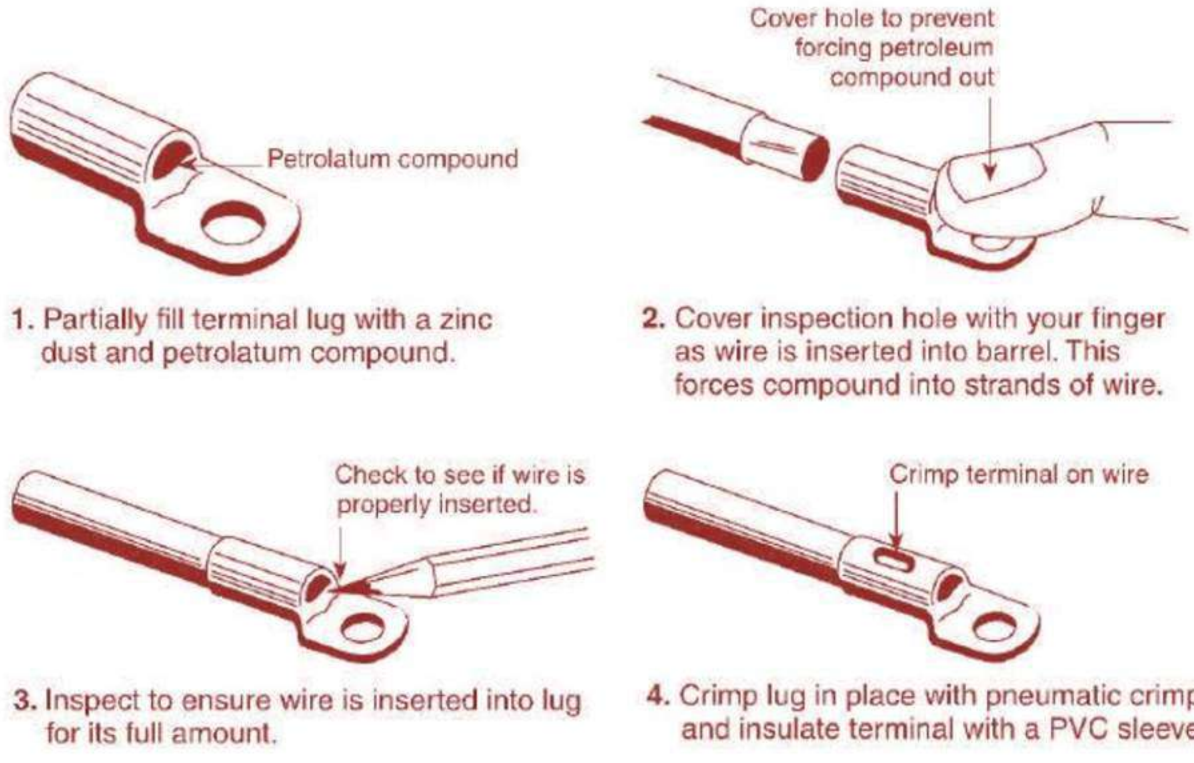


Terminal lug types

Terminal lugs are "crimped" (sometimes called "staked" or "swaged") to the wires by means of hand or power crimping tools.
The terminals used in aircraft applications are of ring type to prevent effect of vibrations on contacts properties.

Copper Wire Terminals

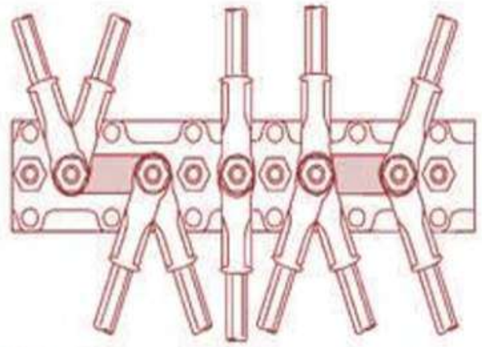
Copper wires are terminated with solderless, pre-insulated straight copper terminal lugs. The insulation is part of the terminal lug and extends beyond its barrel so that it will cover a portion of the wire insulation, making the use of an insulation sleeve unnecessary (Fig. In addition, pre-insulated terminal lugs contain an insulation grip (a metal reinforcing sleeve) beneath connection by excluding moisture and air. The compound is retained inside the terminal lug barrel by a plastic or foil seal at the end of the barrel.



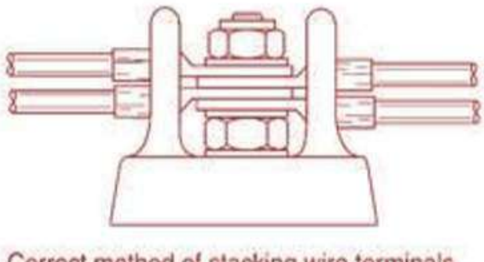
Installation of an aluminium terminal lug on a large aluminium wire

Connecting Terminal Lugs to Terminal Blocks

Terminal lugs should be installed on terminal blocks in such a manner that they are locked against movement in the direction of loosening



When it is necessary to connect more than 4 wires to a single point, 2 or more studs are connected with a bus strap.



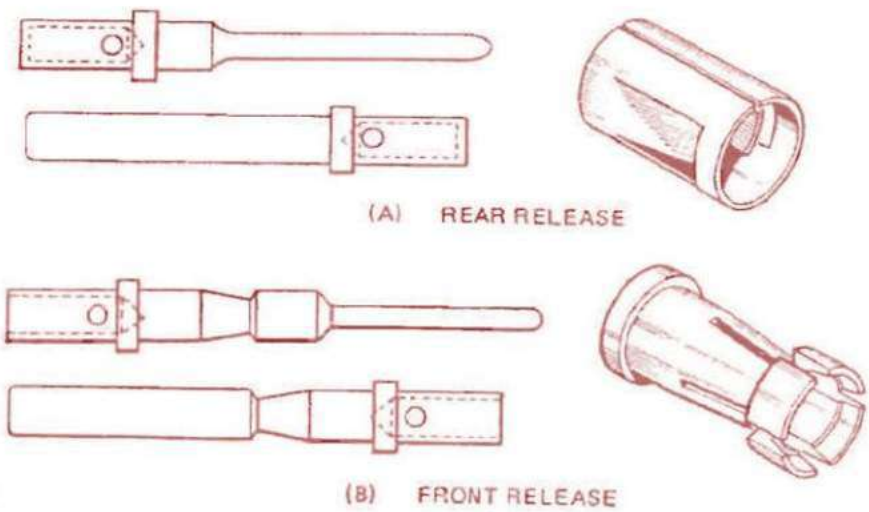
Correct method of stacking wire terminals on a stud

Connecting terminals to terminal block

Terminal blocks are normally supplied with studs secured in place by a plain washer, an external tooth lock washer, and a nut. In connecting terminals, a recommended practice is to place copper terminal lugs directly on top of the nut, followed with a plain washer and elastic stop nut, or with a plain washer, split steel lock washer and plain nut.
Aluminium terminal lugs should be placed over a plated brass plain washer, followed with another plated brass plain washer, split steel lock washer, and plain nut or elastic stop nut. The plated brass washer should have a diameter equal to the tongue width of the aluminium terminal lug. Consult the

Contact Insertion and Extraction

Modern connectors are manufactured with locking mechanism built into the insert which accept a whole range of contact sizes. There are two types of locking mechanism, FRONT and REAR release (Fig.; both systems use a similar mechanism but the tools used are not interchangeable between the two types.

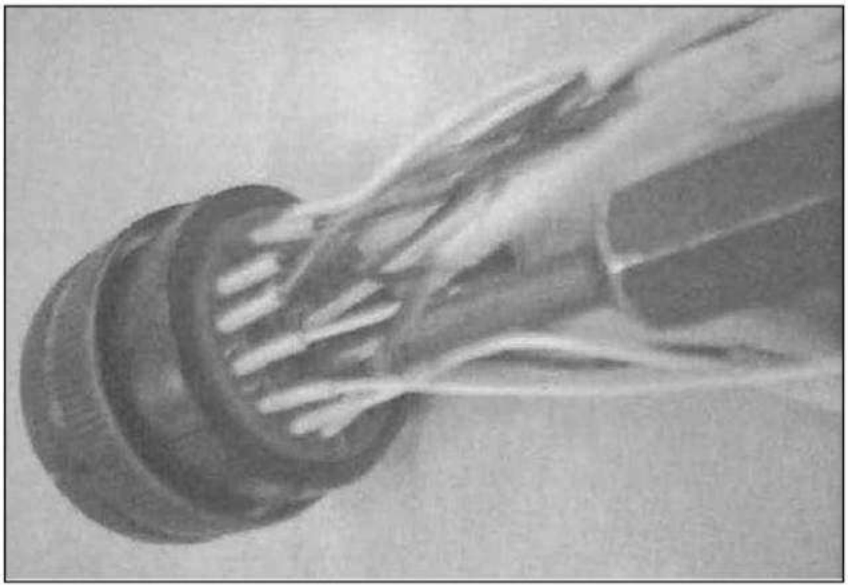


Rear and front contact release arrangement

Tool selection is critical and tooling information for both insertion and extraction tools can be found in Maintenance Manual.

Pin Removal

There are two basic types of contact retention used in plug and socket connectors, one with the contacts being released for removal from the rear of the contact insert and the other from the front. Each system requires the use of different types of insertion/extraction tools, therefore. It is essential that the correct procedures and tools are used for a particular type of plug or socket.
Rear Release The appropriate extraction tool should be positioned over the cable connected to the contact to be removed 3.



Rear-release pin removal