strength. The splice is rarely used except on some antique aircraft where the effort is made to keep all parts in their original configuration.

- Nicopress® process—a patented process using copper sleeves and may be used up to the full rated strength of the cable when the cable is looped around a thimble. *[Figure 2-66]* This process may also be used in place of the 5-tuck splice on cables up to and including $^3/_8$-inch diameter. Whenever this process is used for cable splicing, it is imperative that the tools, instructions, and data supplied by Nicopress® be followed exactly to ensure the desired cable function and strength is attained. The use of sleeves that are fabricated of material other than copper requires engineering approval for the specific application by the FAA.
- Swage-type terminals—manufactured in accordance with Army-Navy (AN) and Military Standards (MS), are suitable for use in civil aircraft up to, and including, maximum cable loads. *[Figure 2-67]*

When swaging tools are used, it is imperative that all the manufacturer's instructions, including 'go' and 'no-go' dimensions, be followed exactly to avoid defective and inferior swaging. Compliance with all of the instructions should result in the terminal developing the full-rated strength of the cable. The following basic procedures are used when swaging terminals onto cable ends:

- Cut the cable to length, allowing for growth during swaging. Apply a preservative compound to the cable end before insertion into the terminal barrel. Measure the internal length of the terminal end/barrel of the fitting to determine the proper length of the cable to be inserted. Transfer that measurement to the end of the cable and mark it with a piece of masking tape wrapped around the cable. This provides a positive mark to ensure the cable did not slip during the swaging process.

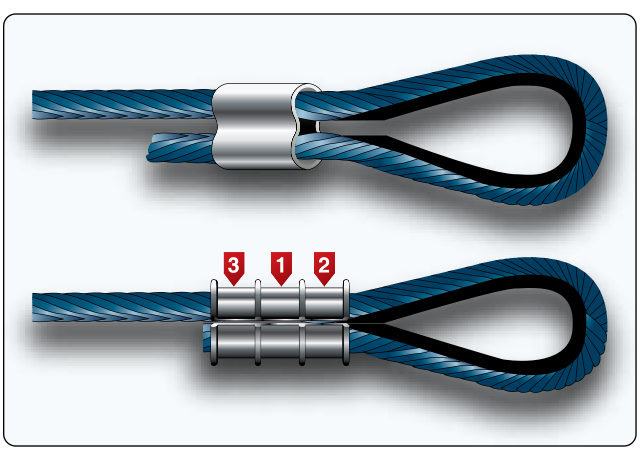



**Figure 2-66.** *Typical Nicopress® thimble-eye splice.*

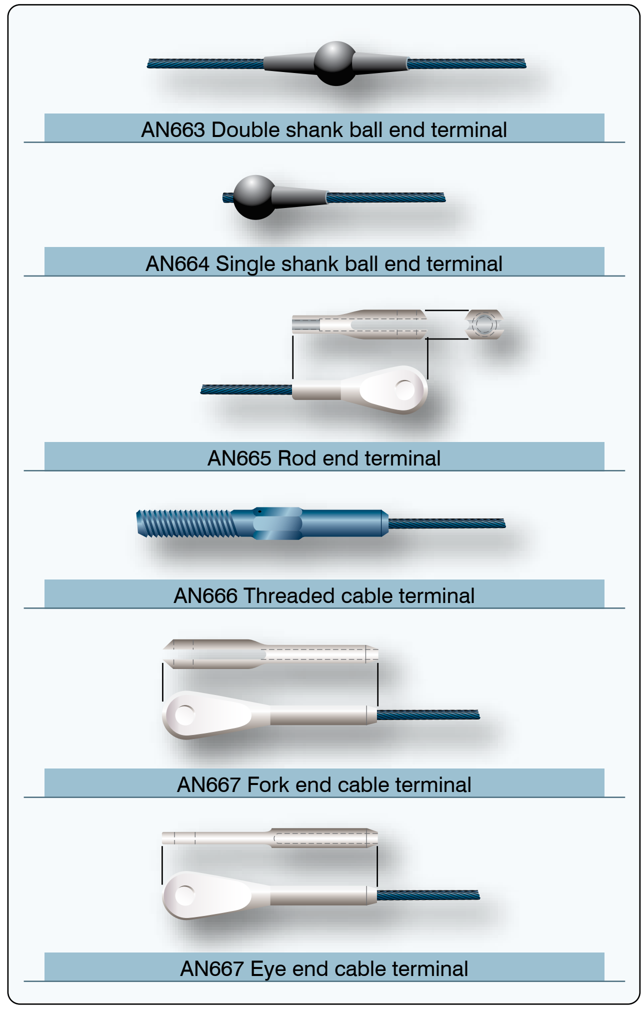



**Figure 2-67.** *Swage-type terminal fittings.*

***Note:*** Never solder the cable ends to prevent fraying since the solder greatly increases the tendency of the cable to pull out of the terminal.

- Insert the cable into the terminal approximately one inch and bend it toward the terminal. Then, push the cable end all the way into the terminal. The bending action puts a slight kink in the cable end and provides enough friction to hold the terminal in place until the swaging operation is performed. *[Figure 2-68]*
- Accomplish the swaging operation in accordance with the instructions furnished by the manufacturer of the swaging equipment.
- Inspect the terminal after swaging to determine that it is free of die marks and splits and is not out of round. Check the cable for slippage at the masking tape and for cut and broken wire strands.
- Using a go/no-go gauge supplied by the swaging tool manufacturer or a micrometer and swaging chart, check the terminal shank diameter for proper dimension. *[Figures 2-69* and *2-70]*

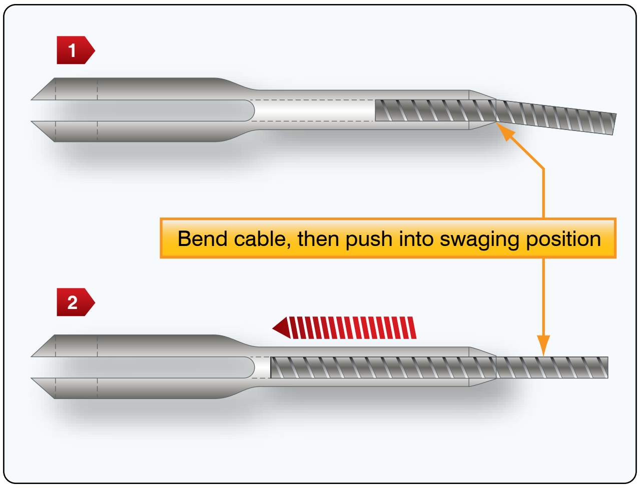



**Figure 2-68.** *Insertion of cable into terminal.*

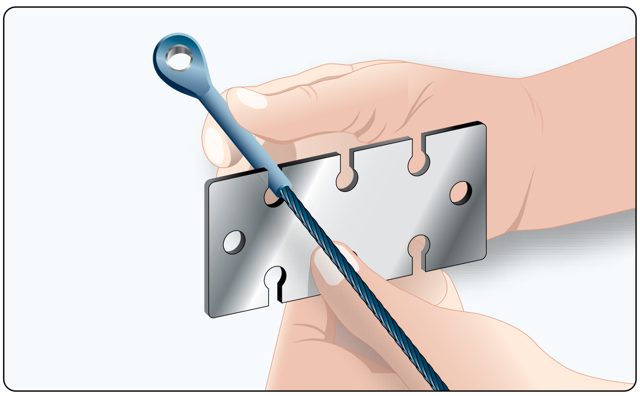


**Figure 2-69.** *Gauging terminal shank dimension after swaging.*

- Test the cable by proof-loading locally fabricated splices and newly installed swage terminal cable fittings for proper strength before installation. This is conducted by slowly applying a test load equal to 60 percent of the rated breaking strength of the cable listed in *Figure 2-71*.

This load should be held for at least 3 minutes. Any testing of this type can be dangerous. Suitable guards should be placed over the cable during the test to prevent injury to personnel in the event of cable failure. If a proper test fixture is not available, the load test should be contracted out and performed by a properly equipped facility.

### Cable Inspection

Aircraft cable systems are subject to a variety of environmental conditions and deterioration. Wire or strand breakage is easy to recognize visually. Other kinds of deterioration, such as wear, corrosion, and distortion, are not easily seen. Special attention should be given to areas where cables pass through battery compartments, lavatories, and wheel wells. These are prime areas for corrosion. Special attention should be given to critical fatigue areas. Those areas are defined as anywhere the cable runs over, under, or around a pulley, sleeve, or through a fairlead; or any section where the cable is flexed, rubbed, or within 1 foot of a swaged-on fitting. Close inspection in these critical fatigue areas can be performed by rubbing a rag along the cable. If there are any broken strands, the rag snags on the cable. A more detailed inspection can be performed in areas that may be corroded or indicate a fatigue failure by loosing or removing the cable and bending it. This technique reveals internal broken strands not readily apparent from the outside. *[Figure 2-72]*

### Cable System Installation

*Cable Guides*

Pulleys are used to guide cables and also to change the direction of cable movement. Pulley bearings are sealed and need no lubrication other than the lubrication done at the factory. Brackets fastened to the structure of the aircraft support the pulleys. Cables passing over pulleys are kept in place by guards. The guards are close fitting to prevent jamming or

| | | Before Swaging | | | | After Swaging | |
|---|---|---|---|---|---|---|---|
| Cable size (inches) | Wire strands | Outside diameter | Bore diameter | Bore length | Swaging length | Minimum breaking strength (pounds) | Shank diameter * |
| 1/16 | 7 x 7 | 0.160 | 0.078 | 1.042 | 0.969 | 480 | 0.138 |
| 3/32 | 7 x 7 | 0.218 | 0.109 | 1.261 | 1.188 | 920 | 0.190 |
| 1/8 | 7 x 19 | 0.250 | 0.141 | 1.511 | 1.438 | 2,000 | 0.219 |
| 5/32 | 7 x 19 | 0.297 | 0.172 | 1.761 | 1.688 | 2,800 | 0.250 |
| 3/16 | 7 x 19 | 0.359 | 0.203 | 2.011 | 1.938 | 4,200 | 0.313 |
| 7/32 | 7 x 19 | 0.427 | 0.234 | 2.261 | 2.188 | 5,600 | 0.375 |
| 1/4 | 7 x 19 | 0.494 | 0.265 | 2.511 | 2.438 | 7,000 | 0.438 |
| 9/32 | 7 x 19 | 0.563 | 0.297 | 2.761 | 2.688 | 8,000 | 0.500 |
| 5/16 | 7 x 19 | 0.635 | 0.328 | 3.011 | 2.938 | 9,800 | 0.563 |
| 3/8 | 7 x 19 | 0.703 | 0.390 | 3.510 | 3.438 | 14,400 | 0.625 |

*Use gauges in kit for checking diameters.

**Figure 2-70.** *Straight shank terminal dimensions.*

| | | | | Minimum Breaking Strength (Pounds) | | |
|---|---|---|---|---|---|---|
| Nominal diameter of wire rope cable | Construction | Tolerance on diameter (plus only) | Allowable increase of diameter at cut end | MIL-W-83420 COMP A | MIL-W-83420 COMP B (CRES) | MIL-C-18375 (CRES) |
| INCHES | | INCHES | INCHES | POUNDS | POUNDS | POUNDS |
| 1/32 | 3 x 7 | 0.006 | 0.006 | 110 | 110 | |
| 3/64 | 7 x 7 | 0.008 | 0.008 | 270 | 270 | |
| 1/16 | 7 x 7 | 0.010 | 0.009 | 480 | 480 | 360 |
| 1/16 | 7 x 19 | 0.010 | 0.009 | 480 | 480 | |
| 3/32 | 7 x 7 | 0.012 | 0.010 | 920 | 920 | 700 |
| 3/32 | 7 x 19 | 0.012 | 0.010 | 1,000 | 920 | |
| 1/8 | 7 x 19 | 0.014 | 0.011 | 2,000 | 1,760 | 1,300 |
| 5/32 | 7 x 19 | 0.016 | 0.017 | 2,800 | 2,400 | 2,000 |
| 3/16 | 7 x 19 | 0.018 | 0.019 | 4,200 | 3,700 | 2,900 |
| 7/32 | 7 x 19 | 0.018 | 0.020 | 5,000 | 5,000 | 3,800 |
| 1/4 | 7 x 19 | 0.018 | 0.021 | 6,400 | 6,400 | 4,900 |
| 9/32 | 7 x 19 | 0.020 | 0.023 | 7,800 | 7,800 | 6,100 |
| 5/16 | 7 x 19 | 0.022 | 0.024 | 9,800 | 9,000 | 7,600 |
| 11/32 | 7 x 19 | 0.024 | 0.025 | 12,500 | | |
| 3/8 | 7 x 19 | 0.026 | 0.027 | 14,400 | 12,000 | 11,000 |
| 7/16 | 6 x 19 IWRC | 0.030 | 0.030 | 17,600 | 16,300 | 14,900 |
| 1/2 | 6 x 19 IWRC | 0.033 | 0.033 | 22,800 | 22,800 | 19,300 |
| 9/16 | 6 x 19 IWRC | 0.036 | 0.036 | 28,500 | 28,500 | 24,300 |
| 5/8 | 6 x 19 IWRC | 0.039 | 0.039 | 35,000 | 35,000 | 30,100 |
| 3/4 | 6 x 19 IWRC | 0.045 | 0.045 | 49,600 | 49,600 | 42,900 |
| 7/8 | 6 x 19 IWRC | 0.048 | 0.048 | 66,500 | 66,500 | 58,000 |
| 1 | 6 x 19 IWRC | 0.050 | 0.050 | 85,400 | 85,400 | 75,200 |
| 1 - 1/8 | 6 x 19 IWRC | 0.054 | 0.054 | 106,400 | 106,400 | |
| 1 - 1/4 | 6 x 19 IWRC | 0.057 | 0.057 | 129,400 | 129,400 | |
| 1 - 3/8 | 6 x 19 IWRC | 0.060 | 0.060 | 153,600 | 153,600 | |
| 1 - 1/2 | 6 x 19 IWRC | 0.062 | 0.062 | 180,500 | 180,500 | |

**Figure 2-71.** *Flexible cable construction.*

to prevent the cables from slipping off when they slacken due to temperature variations. Pulleys should be examined to ensure proper lubrication; smooth rotation and freedom from abnormal cable wear patterns which can provide an indication of other problems in the cable system. *[Figure 2-73]*

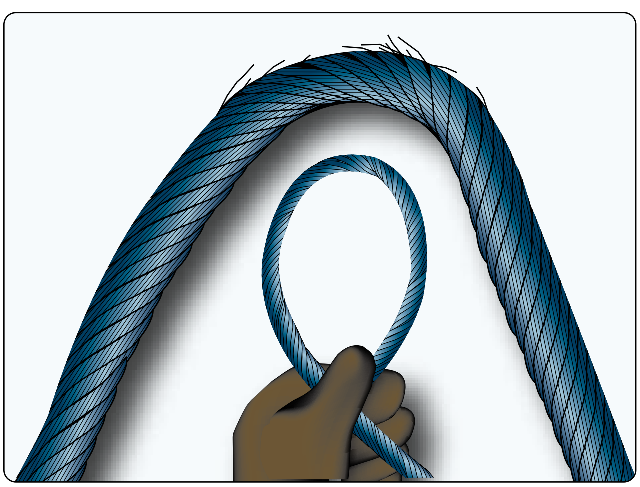


**Figure 2-72.** *Cable inspection technique.*

Fairleads may be made from a nonmetallic material, such as phenolic, or a metallic material, such as soft aluminum. The fairlead completely encircles the cable where it passes through holes in bulkheads or other metal parts. Fairleads are used to guide cables in a straight line through or between structural members of the aircraft. Fairleads should never deflect the alignment of a cable more than 3° from a straight line.

Pressure seals are installed where cables (or rods) move through pressure bulkheads. The seal grips tightly enough to prevent excess air pressure loss but not enough to hinder movement of the cable. Pressure seals should be inspected at regular intervals to determine that the retaining rings are in place. If a retaining ring comes off, it may slide along the cable and cause jamming of a pulley. *[Figure 2-74]*

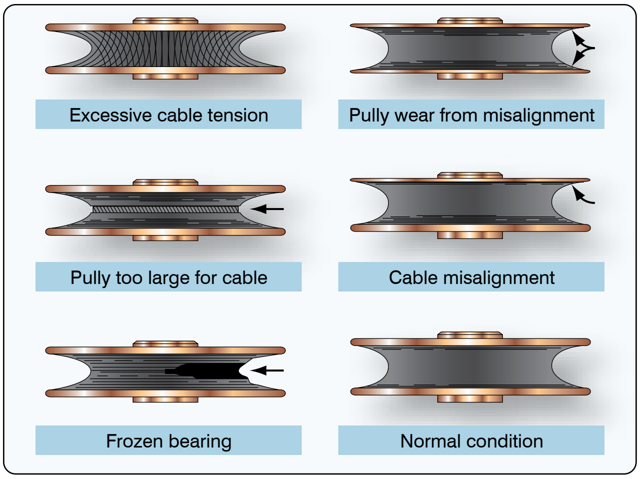



**Figure 2-73.** *Pulley wear patterns.*

*Travel Adjustment*

Control surfaces should move a certain distance in either direction from the neutral position. These movements must be synchronized with the movement of the flight deck controls. The flight control system must be adjusted (rigged) to obtain these requirements. The tools for measuring surface travel primarily include protractors, rigging fixtures, contour templates, and rulers. These tools are used when rigging flight control systems to assure that the desired travel has been obtained. Generally speaking, the rigging consists of the following:

1. Positioning the flight control system in neutral and temporarily locking it there with rig pins or blocks;
2. Adjusting system cable tension and maintaining rudder, elevator, and ailerons in the neutral position; and
3. Adjusting the control stops to the aircraft manufacturer's specifications.

*Cable Tension*

For the aircraft to operate as it was designed, the cable tension for the flight controls must be correct. To determine the amount of tension on a cable, a tensiometer is used. When properly maintained, a tensiometer is 98 percent accurate. Cable tension is determined by measuring the amount of force needed to make an offset in the cable between two hardened steel blocks called anvils. A riser or plunger is pressed against the cable to form the offset. Several manufacturers make a variety of tensiometers, each type designed for different kinds of cable, cable sizes, and cable tensions. *[Figure 2-75]*

*Rigging Fixtures*

Rigging fixtures and templates are special tools (gauges) designed by the manufacturer to measure control surface travel. Markings on the fixture or template indicate desired control surface travel.

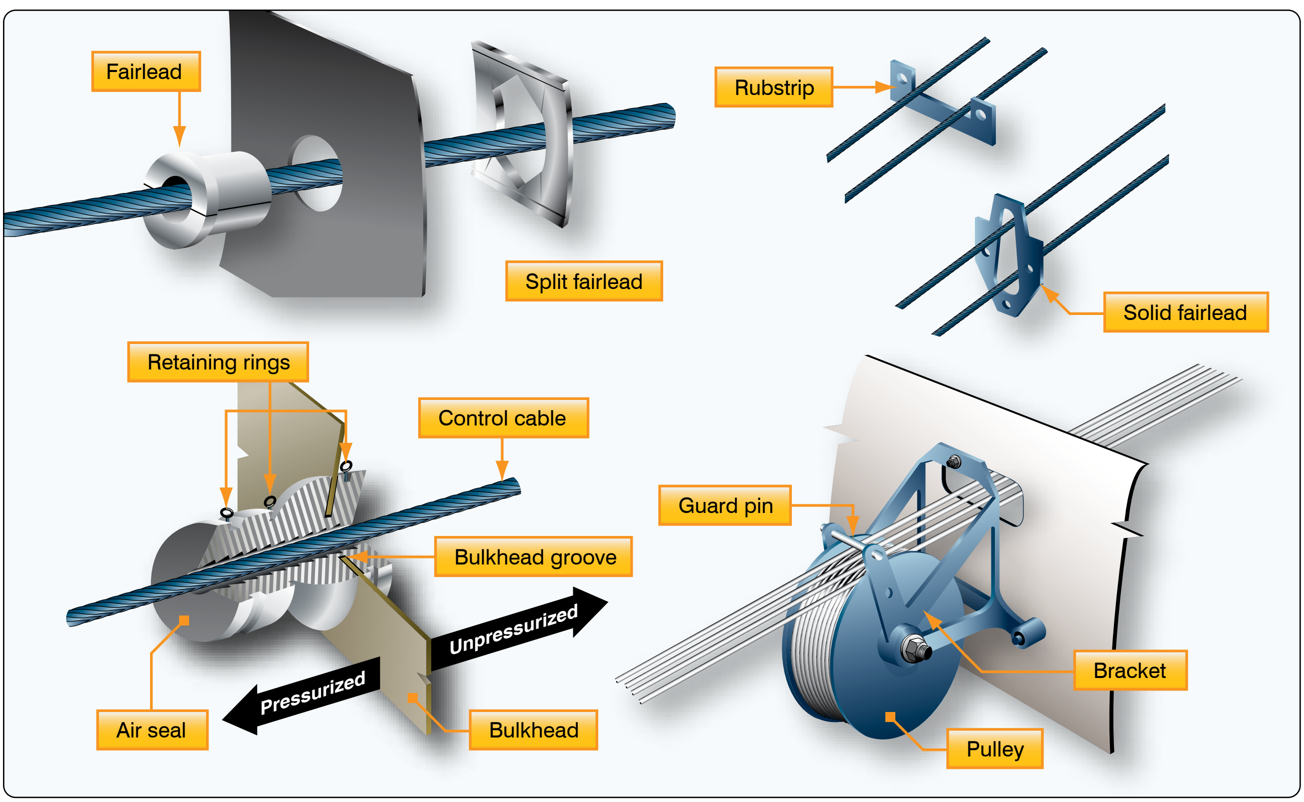



**Figure 2-74.** *Cable guides.*

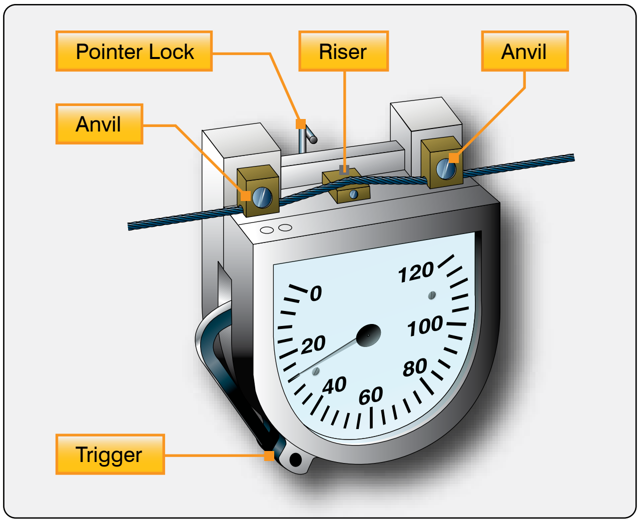



**Figure 2-75.** *Tensiometer.*

*Tension Regulators*

Cable tension regulators are used in some flight control systems because there is considerable difference in temperature expansion of the aluminum aircraft structure and the steel control cables. Some large aircraft incorporate tension regulators in the control cable systems to maintain a given cable tension automatically. The unit consists of a compression spring and a locking mechanism that allows the spring to make correction in the system only when the cable system is in neutral.

*Turnbuckles*

A turnbuckle assembly is a mechanical screw device consisting of two threaded terminals and a threaded barrel. *[Figure 2-76]* Turnbuckles are fitted in the cable assembly for the purpose of making minor adjustments in cable length and for adjusting cable tension. One of the terminals has right-hand threads, and the other has left-hand threads. The barrel has matching right- and left-hand internal threads. The end of the barrel with the left-hand threads can usually be identified by a groove or knurl around that end of the barrel.

When installing a turnbuckle in a control system, it is necessary to screw both of the terminals an equal number of turns into the barrel. It is also essential that all turnbuckle terminals be screwed into the barrel until not more than three threads are exposed on either side of the turnbuckle barrel. After a turnbuckle is properly adjusted, it must be safetied. There are a number of methods to safety a turnbuckle and/or other types of swaged cable ends that are satisfactory. A double-wrap safety wire method is preferred.

Some turnbuckles are manufactured and designed to accommodate special locking devices. A typical unit is shown in *Figure 2-77*.

*Cable Connectors*

In addition to turnbuckles, cable connectors are used in some systems. These connectors enable a cable length to be quickly connected or disconnected from a system. *Figure 2-78* illustrates one type of cable connector in use.

*Spring-Back*

With a control cable properly rigged, the flight control should hit its stops at both extremes prior to the flight deck control. The spring-back is the small extra push that is needed for the flight deck control to hit its mechanical stop.

### Push Rods (Control Rods)

Push rods are used as links in the flight control system to give push-pull motion. They may be adjusted at one or both ends. *Figure 2-79* shows the parts of a push rod. Notice that it consists of a tube with threaded rod ends. An adjustable antifriction rod end, or rod end clevis, attaches at each end of the tube. The rod end, or clevis, permits attachment of the tube to flight control system parts. The checknut, when tightened, prevents the rod end or clevis from loosening. They may have adjustments at one or both ends.

The rods should be perfectly straight, unless designed to be otherwise. When installed as part of a control system, the assembly should be checked for correct alignment and free movement.

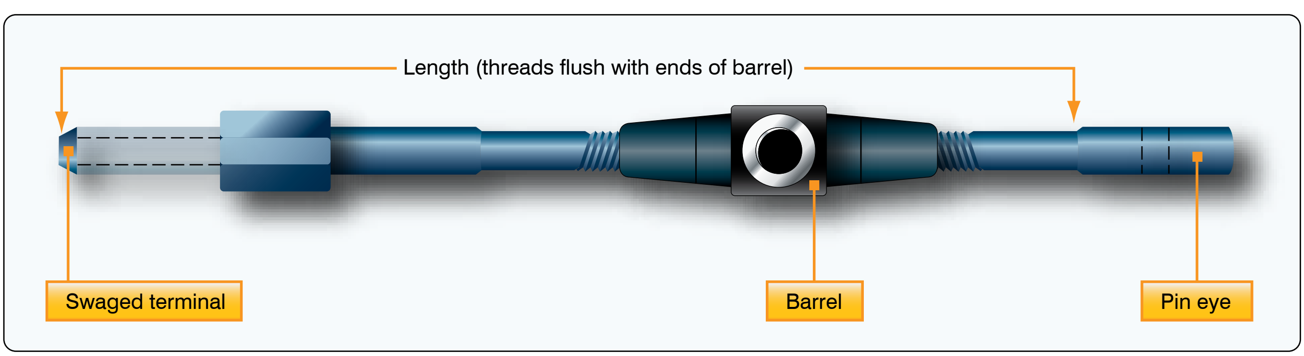



**Figure 2-76.** *Typical turnbuckle assembly.*

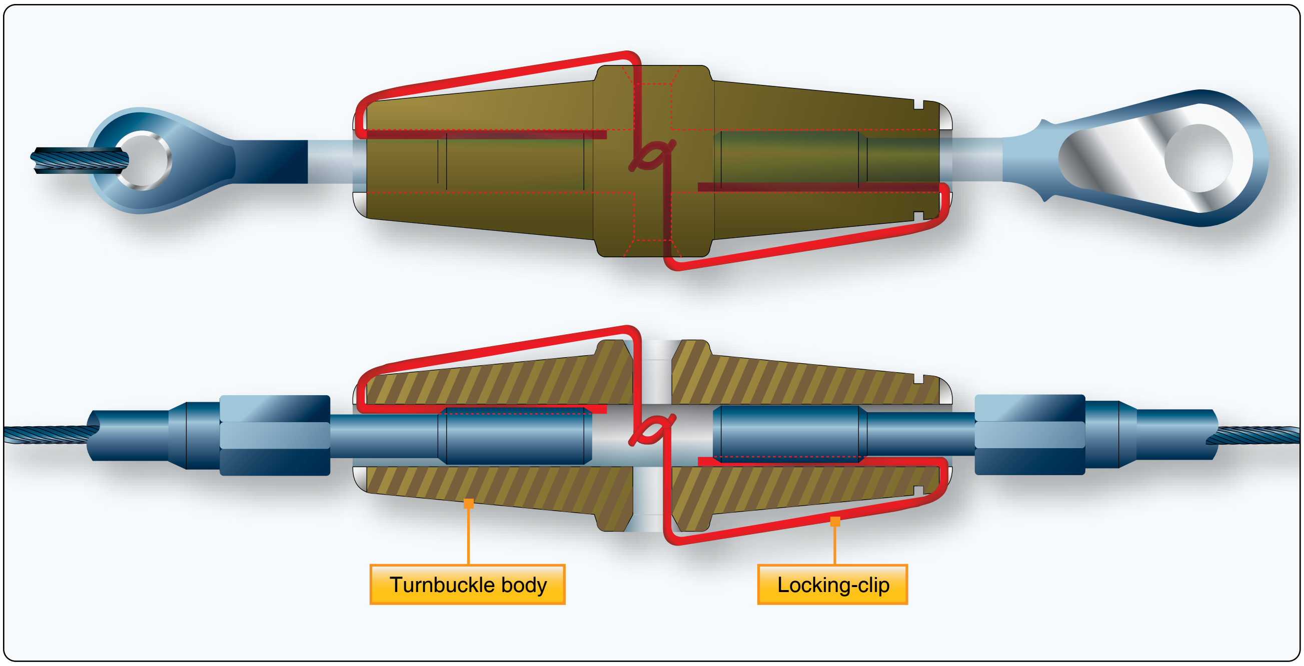



**Figure 2-77.** *Clip-type locking device and assembling in turnbuckle.*

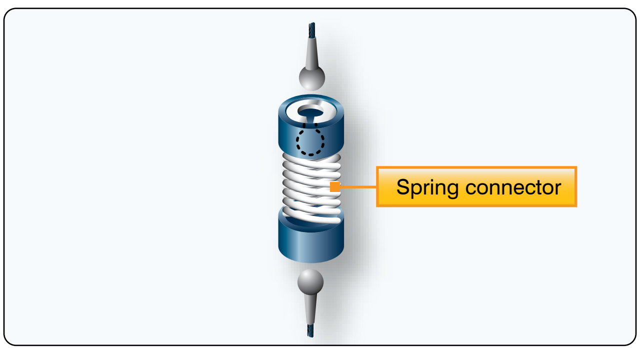



**Figure 2-78.** *Spring-type connector.*

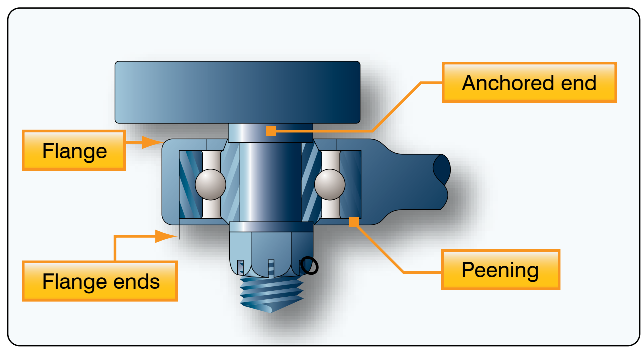



**Figure 2-80.** *Attached rod end.*

It is possible for control rods fitted with bearings to become disconnected because of failure of the peening that retains the ball races in the rod end. This can be avoided by installing the control rods so that the flange of the rod end is interposed between the ball race and the anchored end of the attaching pin or bolt as shown in *Figure 2-80*.

Another alternative is to place a washer, having a larger diameter than the hole in the flange, under the retaining nut on the end of the attaching pin or bolt. This retains the rod on the bolt in the event of a bearing failure.

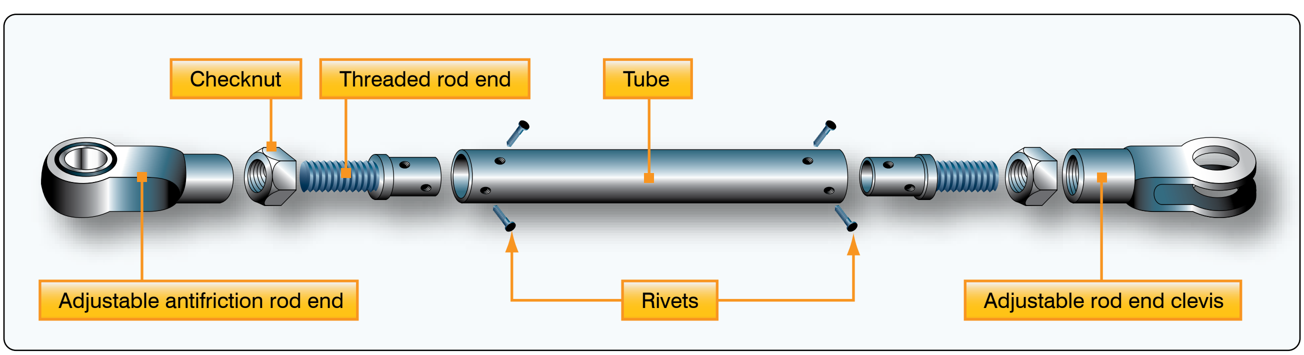



**Figure 2-79.** *Push rod.*

### *Torque Tubes*

Where an angular or twisting motion is needed in a control system, a torque tube is installed. *Figure 2-81* shows how a torque tube is used to transmit motion in opposite directions.

### *Cable Drums*

Cable drums are used primarily in trim tab systems. As the trim tab control wheel is moved clockwise or counterclockwise, the cable drum winds or unwinds to actuate the trim tab cables. *[Figure 2-82]*

## Rigging Checks

All aircraft assembly and rigging must be performed in accordance with the requirements prescribed by the specific aircraft and/or aircraft component manufacturer. Correctly following the procedures provides for proper operation of the components in regard to their mechanical and aerodynamic function and ensures the structural integrity of the aircraft. Rigging procedures are detailed in the applicable manufacturer's maintenance or service manuals and applicable structural repair manuals. Additionally, aircraft specification or TCDS also provide information regarding control surface movement and weight and balance limits.

The purpose of this section is to explain the methods of checking the relative alignment and adjustment of an aircraft's main structural components. It is not intended to imply that the procedures are exactly as they may be in a particular aircraft. When rigging an aircraft, always follow the procedures and methods specified by the aircraft manufacturer.

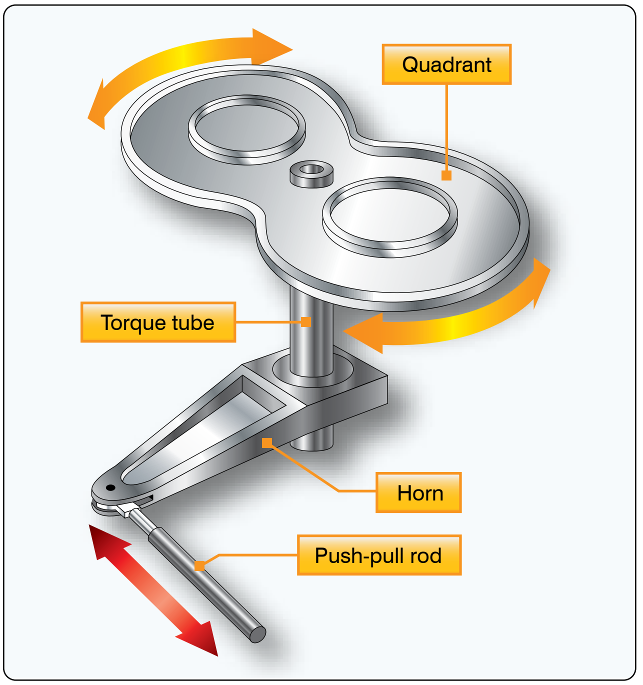



**Figure 2-81.** *Torque tube.*

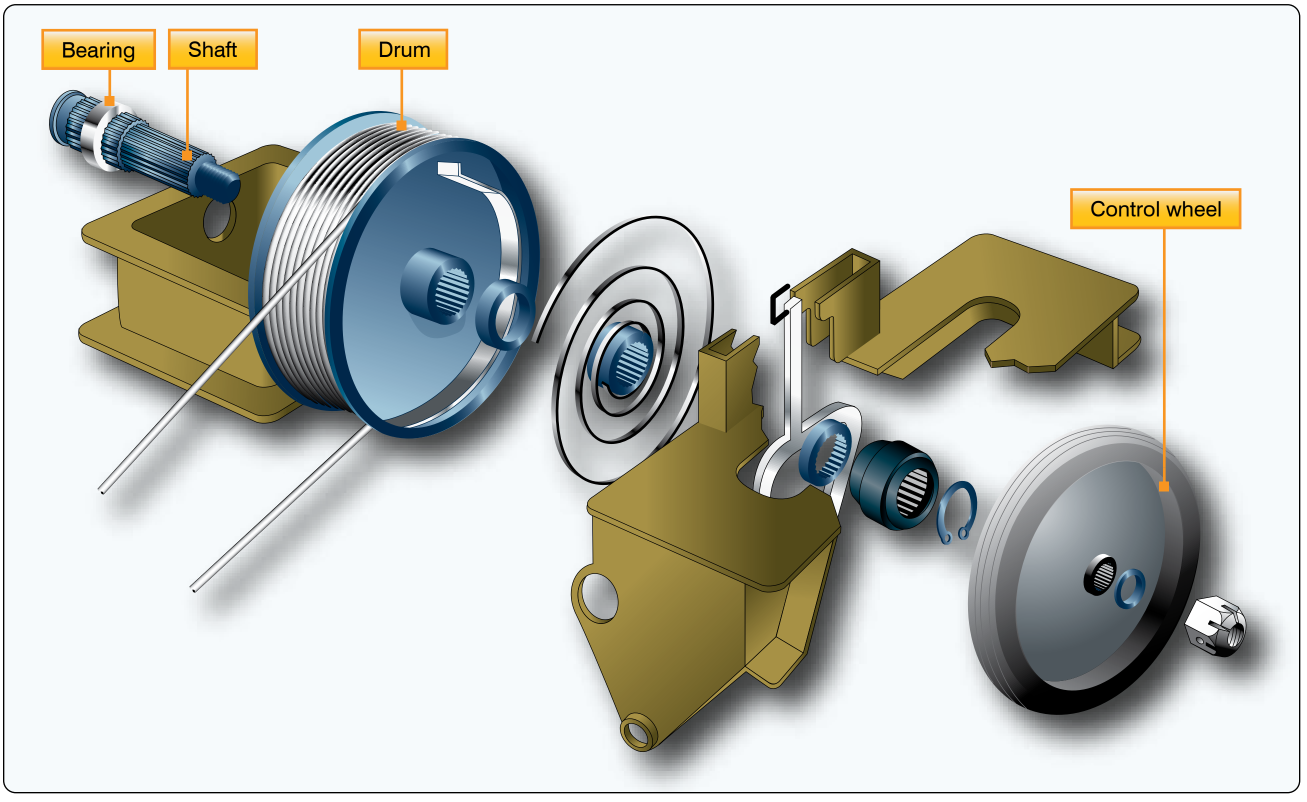



**Figure 2-82.** *Trim tab cable drum.*

### *Structural Alignment*

The position or angle of the main structural components is related to a longitudinal datum line parallel to the aircraft center line and a lateral datum line parallel to a line joining the wing tips. Before checking the position or angle of the main components, the aircraft must be jacked and leveled.

Small aircraft usually have fixed pegs or blocks attached to the fuselage parallel to or coincident with the datum lines. A spirit level and a straight edge are rested across the pegs or blocks to check the level of the aircraft. This method of checking aircraft level also applies to many of the larger types of aircraft. However, the grid method is sometimes used on large aircraft. The grid plate is a permanent fixture installed on the aircraft floor or supporting structure. *[Figure 2-83]*

When the aircraft is to be leveled, a plumb bob is suspended from a predetermined position in the ceiling of the aircraft over the grid plate. The adjustments to the jacks necessary to level the aircraft are indicated on the grid scale. The aircraft is level when the plumb bob is suspended over the center point of the grid.

Certain precautions must be observed in all instances when jacking an aircraft. Normally, rigging and alignment checks should be performed in an enclosed hangar. If this cannot be accomplished, the aircraft should be positioned with the nose into the wind.

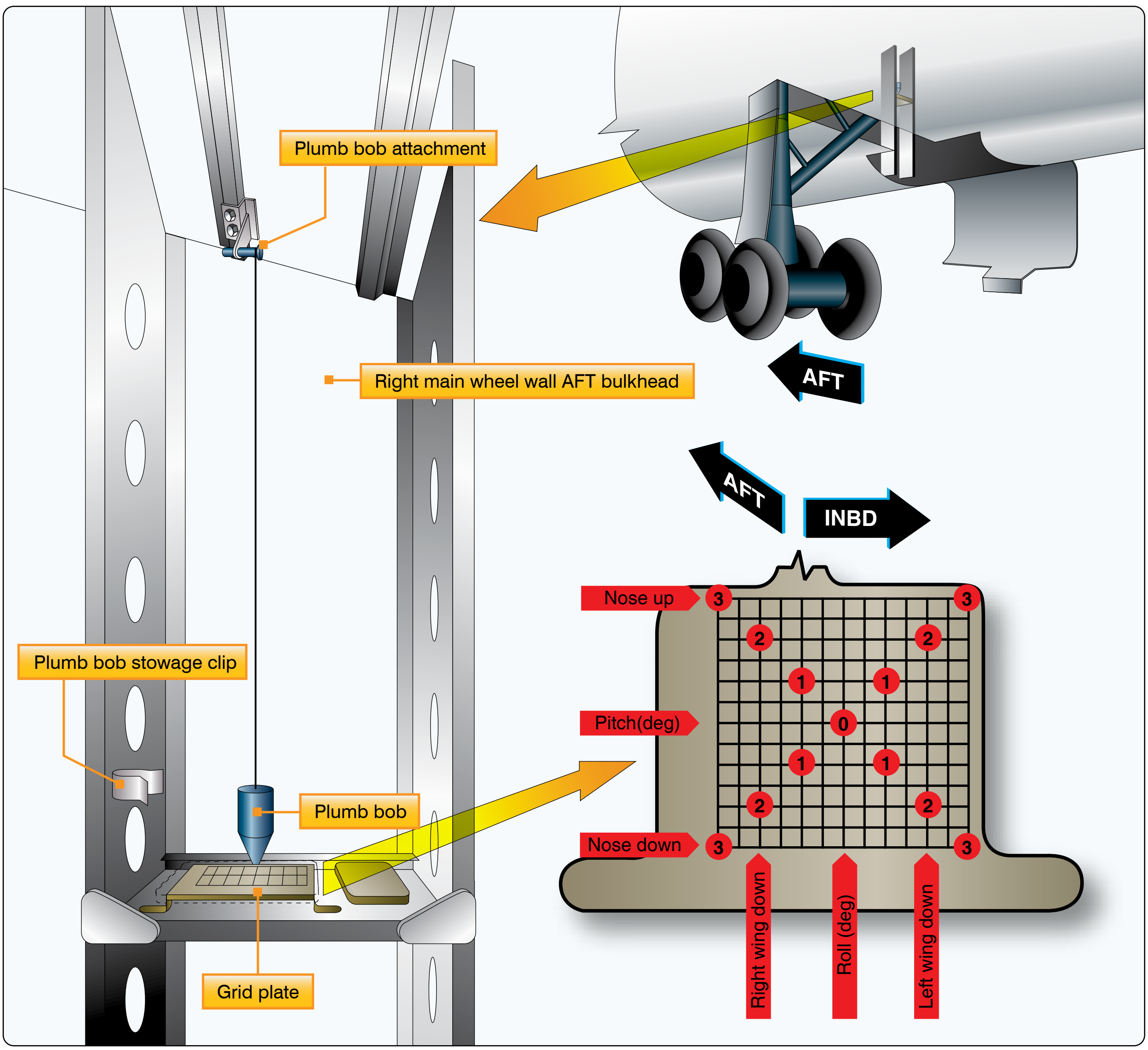



**Figure 2-83.** *Grid plate installed.*

The weight and loading of the aircraft should be exactly as described in the manufacturer's manual. In all cases, the aircraft should not be jacked until it is determined that the maximum jacking weight (if applicable) specified by the manufacturer is not exceeded.

With a few exceptions, the dihedral and incidence angles of conventional modern aircraft cannot be adjusted. Some manufacturers permit adjusting the wing angle of incidence to correct for a wing-heavy condition. The dihedral and incidence angles should be checked after hard landings or after experiencing abnormal flight loads to ensure that the components are not distorted and that the angles are within the specified limits.

There are several methods for checking structural alignment and rigging angles. Special rigging boards that incorporate, or on which can be placed, a special instrument (spirit level or inclinometer) for determining the angle are used on some aircraft. On a number of aircraft, the alignment is checked using a transit and plumb bobs or a theodolite and sighting rods. The particular equipment to use is usually specified in the manufacturer's maintenance manual.

When checking alignment, a suitable sequence should be developed and followed to be certain that the checks are made at all the positions specified. The alignment checks specified usually include:

- Wing dihedral angle
- Wing incidence angle
- Verticality of the fin
- Engine alignment
- A symmetry check
- Horizontal stabilizer incidence
- Horizontal stabilizer dihedral

### *Checking Dihedral*

The dihedral angle should be checked in the specified positions using the special boards provided by the aircraft manufacturer. If no such boards are available, a straight edge and a inclinometer can be used. Dihedral is normally checked using the front spar. The methods for checking dihedral are shown in *Figure 2-84*.

It is important that the dihedral be checked at the positions specified by the manufacturer. Certain portions of the wings or horizontal stabilizer may sometimes be horizontal or, on rare occasions, anhedral angles may be present.

### *Checking Incidence*

Incidence is usually checked in at least two specified positions on the surface of the wing to ensure that the wing is free from twist. A variety of incidence boards are used to check the incidence angle. Some have stops at the forward edge, which must be placed in contact with the leading edge of the wing. Others are equipped with location pegs which fit into some specified part of the structure. The purpose in either case is to ensure that the board is fitted in exactly the position intended. In most instances, the boards are kept clear of the wing contour by short extensions attached to the board. A typical incidence board is shown in *Figure 2-85*.

When used, the board is placed at the specified locations on the surface being checked. If the incidence angle is correct, a inclinometer on top of the board reads zero, or within a specified tolerance of zero. Modifications to the areas where incidence boards are located can affect the reading. For example, if leading edge deicer boots have been installed, the position of a board having a leading edge stop is affected.

### *Checking Fin Verticality*

After the rigging of the horizontal stabilizer has been checked, the verticality of the vertical stabilizer relative to the lateral datum can be checked. The measurements are taken from a given point on either side of the top of the fin to a given point on the left and right horizontal stabilizers. *[Figure 2-86]* The measurements should be similar within prescribed limits. When it is necessary to check the alignment of the rudder

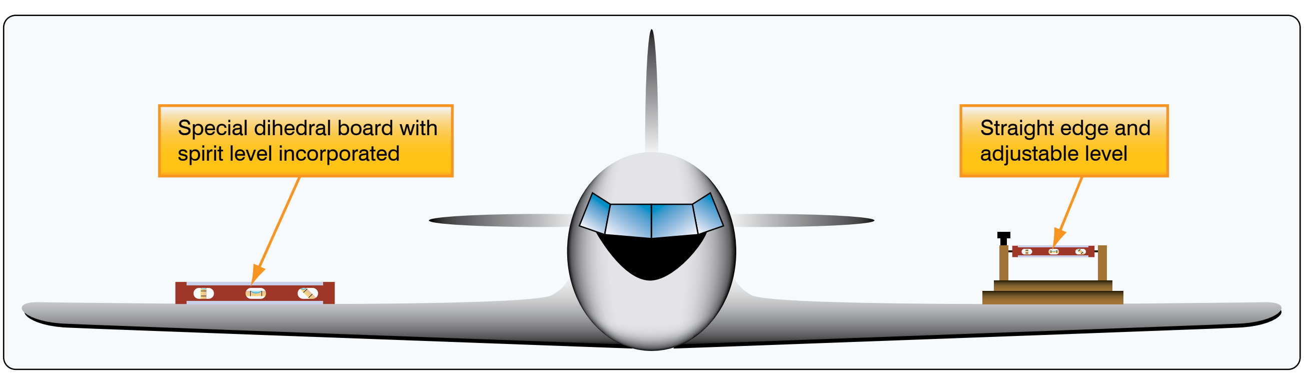



**Figure 2-84.** *Checking dihedral.*

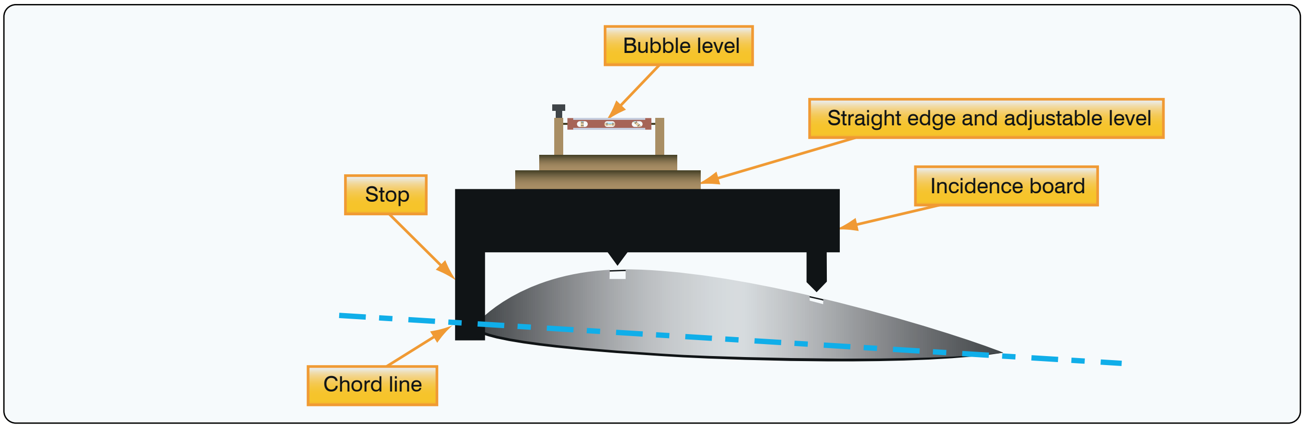



**Figure 2-85.** *A typical incidence board.*

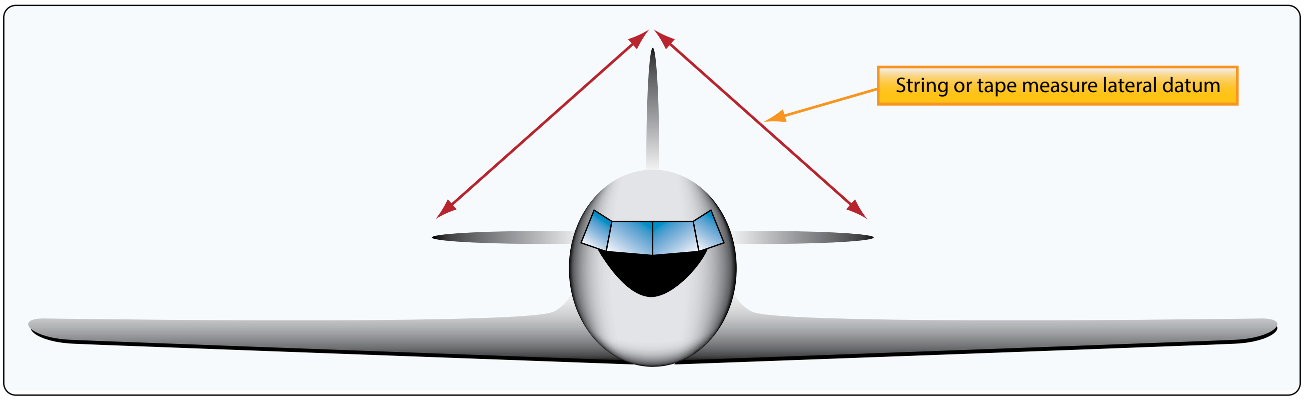



**Figure 2-86.** *Checking fin verticality.*

hinges, remove the rudder and pass a plumb bob line through the rudder hinge attachment holes. The line should pass centrally through all the holes. It should be noted that some aircraft have the leading edge of the vertical fin offset to the longitudinal center line to counteract engine torque.

*Checking Engine Alignment*

Engines are usually mounted with the thrust line parallel to the horizontal longitudinal plane of symmetry. However, this is not always true when the engines are mounted on the wings. Checking to ensure that the position of the engines, including any degree of offset is correct, depends largely on the type of mounting. Generally, the check entails a measurement from the center line of the mounting to the longitudinal center line of the fuselage at the point specified in the applicable manual. *[Figure 2-87]*

*Symmetry Check*

The principle of a typical symmetry check is illustrated in *Figure 2-87*. The precise figures, tolerances, and checkpoints for a particular aircraft are found in the applicable service or maintenance manual.

On small aircraft, the measurements between points are usually taken using a steel tape. When measuring long distances, it is suggested that a spring scale be used with the tape to obtain equal tension. A five-pound pull is usually sufficient.

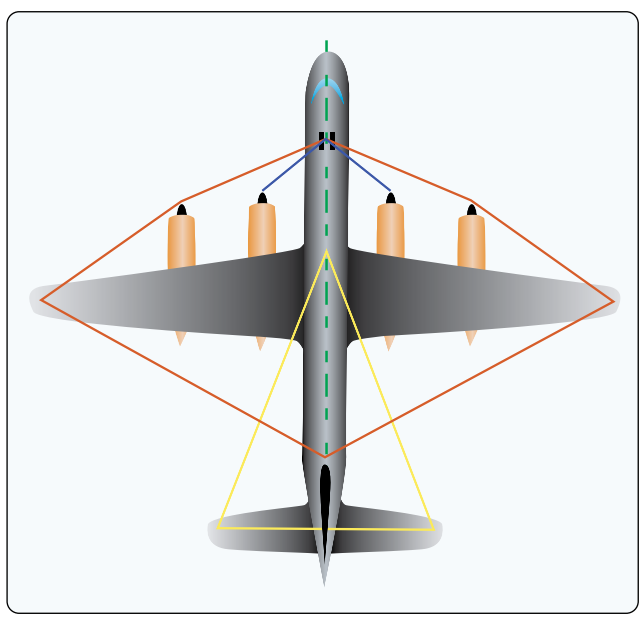


**Figure 2-87.** *Typical measurements used to check aircraft symmetry.*

On large aircraft, the positions at which the dimensions are to be taken are usually chalked on the floor. This is done by suspending a plumb bob from the checkpoints and marking the floor immediately under the point of each plumb bob. The measurements are then taken between the centers of each marking.

### *Cable Tension*

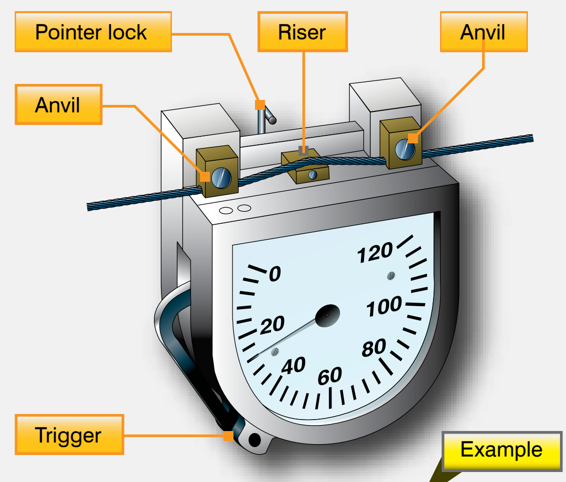
When it has been determined that the aircraft is symmetrical and structural alignment is within specifications, the cable tension and control surface travel can be checked. To determine the amount of tension on a cable, a tensiometer is used. When properly maintained, a tensiometer is 98 percent accurate. Tensiometers are calibrated to maintain accuracy. Cable tension is determined by measuring the amount of force needed to make an offset in the cable between two hardened steel blocks called anvils. A riser or plunger is pressed against the cable to form the offset. Several manufacturers make a variety of tensiometers, each type designed for different kinds of cable, cable sizes, and cable tensions. One type of tensiometer is illustrated in *Figure 2-88*.

Following the manufacturer's instructions, lower the trigger. Then, place the cable to be tested under the two anvils and close the trigger (move it up). Movement of the trigger pushes up the riser, which pushes the cable at right angles to the two clamping points under the anvils. The force that is required to do this is indicated by the dial pointer. As the sample chart beneath the illustration shows, different numbered risers are used with different size cables. Each riser has an identifying number and is easily inserted into the tensiometer.

Included with each tensiometer is a conversion chart, which is used to convert the dial reading to pounds. The dial reading is converted to pounds of tension as follows. Using a No. 2 riser to measure the tension of a 5/32" diameter cable, a reading of 30 is obtained. The actual tension (see chart) of the cable is 70 lbs. Referring to the chart, also notice that a No. 1 riser is used with 1/16", 3/32", and 1/8" cable. Since the tensiometer is not designed for use in measuring 7/32" or 1/4" cable, no values are shown in the No. 3 riser column of the chart.

When actually taking a reading of cable tension in an aircraft, it may be difficult to see the dial. Therefore, a pointer lock is built in on the tensiometer. Push it in to lock the pointer, then remove the tensiometer from the cable and observe the reading. After observing the reading, pull the lock out and the pointer returns to zero.

Another variable that must be taken into account when adjusting cable tension is the ambient temperature of cable and the aircraft. To compensate for temperature variations, cable rigging charts are used when establishing cable tensions




| No. 1 | | | Riser | No. 2 | | No. 3 | |
|---|---|---|---|---|---|---|---|
| Diameter | | | Tension (lb) | 5/32 | 3/16 | 7/32 | 1/4 |
| 1/16 | 3/32 | 1/8 | | | | | |
| 12 | 16 | 21 | 30 | 12 | 20 | | |
| 19 | 23 | 29 | 40 | 17 | 26 | | |
| 25 | 30 | 36 | 50 | 22 | 32 | | |
| 31 | 36 | 43 | 60 | 26 | 37 | | |
| 36 | 42 | 50 | 70 | 30 | 42 | | |
| 41 | 48 | 57 | 80 | 34 | 47 | | |
| 46 | 54 | 63 | 90 | 38 | 52 | | |
| 51 | 60 | 69 | 100 | 42 | 56 | | |
| | | | 110 | 46 | 60 | | |
| | | | 120 | 50 | 64 | | |

**Figure 2-88.** *Cable tensiometer and sample conversion chart.*

in flight control, landing gear, and other cable-operated systems. *[Figure 2-89]*

To use the chart, determine the size of the cable that is to be adjusted and the ambient air temperature. For example, assume that the cable size is 1/8" diameter, which is a 7-19 cable and the ambient air temperature is 85 °F. Follow the 85 °F line upward to where it intersects the curve for 1/8" cable. Extend a horizontal line from the point of intersection to the right edge of the chart. The value at this point indicates the tension (rigging load in pounds) to establish on the cable. The tension for this example is 70 pounds.

### *Control Surface Travel*

In order for a control system to function properly, it must be correctly adjusted. Correctly rigged control surfaces move through a prescribed arc (surface-throw) and are synchronized with the movement of the flight deck controls. Rigging any control system requires that the aircraft manufacturer's instructions be followed as outlined in their maintenance manual.

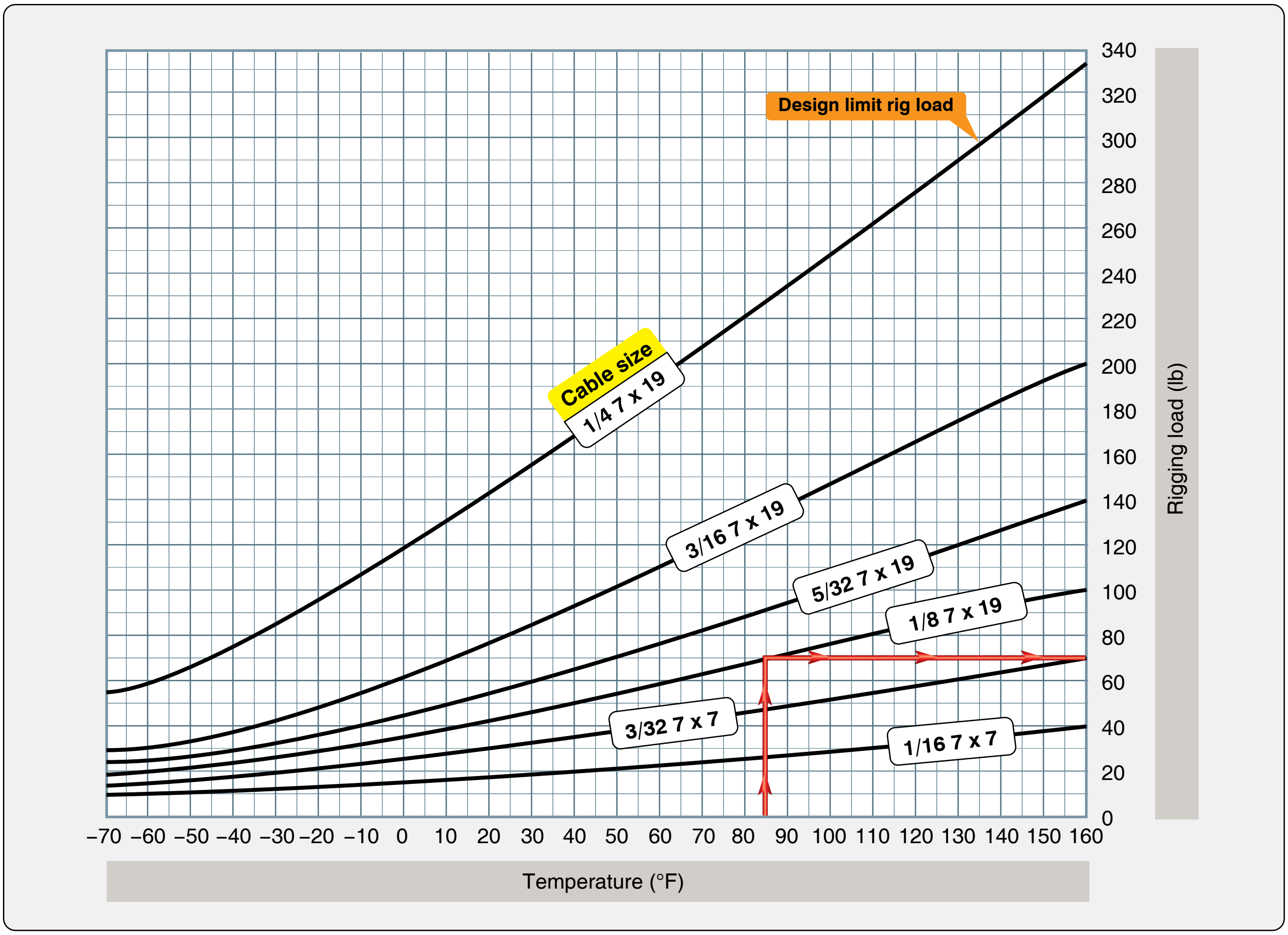



**Figure 2-89.** *Typical cable rigging chart.*

Therefore, the explanations in this chapter are limited to the three general steps listed below:

1. Lock the flight deck control, bellcranks, and the control surfaces in the neutral position.
2. Adjust the cable tension, maintaining the rudder, elevators, or ailerons in the neutral position.
3. Adjust the control stops to limit the control surface travel to the dimensions given for the aircraft being rigged.

The range of movement of the controls and control surfaces should be checked in both directions from neutral. There are various tools used for measuring surface travel, including protractors, rigging fixtures, contour templates, and rulers. These tools are used when rigging flight control systems to ensure that the aircraft is properly rigged and the manufacturer's specifications have been complied with.

Rigging fixtures and contour templates are special tools (gauges) designed by the manufacturer to measure control surface travel. Markings on the fixture or template indicate desired control surface travel. In many instances, the aircraft manufacturer gives the travel of a particular control surface in degrees and inches. If the travel in inches is provided, a ruler can be used to measure surface travel in inches.

Protractors are tools for measuring angles in degrees. Various types of protractors are used to determine the travel of flight control surfaces. One protractor that can be used to measure aileron, elevator, or wing flap travel is the universal propeller protractor shown in *Figure 2-90*.

This protractor is made up of a frame, disc, ring, and two spirit levels. The disc and ring turn independently of each other and of the frame. (The center spirit level is used to position the frame vertically when measuring propeller blade angle.) The center spirit level is used to position the disc when measuring control surface travel. A disc-to-ring lock is provided to secure the disc and ring together when the zero on the ring vernier scale and the zero on the disc degree scale align. The ring-to-frame lock prevents the ring from moving when the disc is moved. Note that they start at

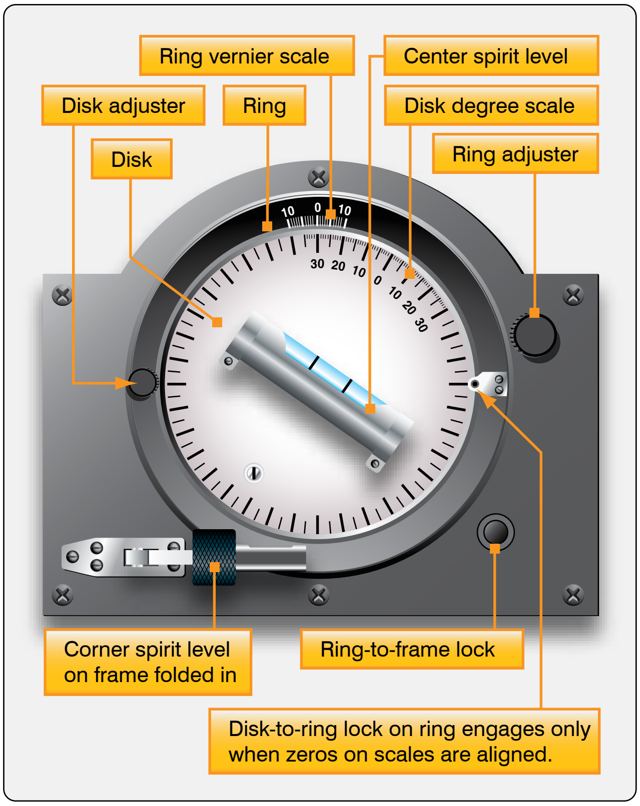



**Figure 2-90.** *Universal propeller protractor.*

the same point and advance in opposite directions. A double 10-part vernier is marked on the ring.

The rigging of the trim tab systems is performed in a similar manner. The trim tab control is set to the neutral (no trim) position, and the surface tab is usually adjusted to streamline with the control surface. However, on some aircraft, the specifications may require that the trim tabs be offset a degree or two from streamline when in the neutral position. After the tab and tab control are in the neutral position, adjust the control cable tension.

Pins, usually called rig pins, are sometimes used to simplify the setting of pulleys, levers, bellcranks, etc., in their neutral positions. A rig pin is a small metallic pin or clip. When rig pins are not provided, the neutral positions can be established by means of alignment marks, by special templates, or by taking linear measurements.

If the final alignment and adjustment of a system are correct, it should be possible to withdraw the rigging pins easily. Any undue tightness of the pins in the rigging holes indicates incorrect tensioning or misalignment of the system.

After a system has been adjusted, the full and synchronized movement of the controls should be checked. When checking the range of movement of the control surface, the controls must be operated from the flight deck and not by moving the control surfaces. During the checking of control surface travel, ensure that chains, cables, etc., have not reached the limit of their travel when the controls are against their respective stops.

Adjustable and nonadjustable stops (whichever the case requires) are used to limit the throw-range or travel movement of the ailerons, elevator, and rudder. Usually there are two sets of stops for each of the three main control surfaces. One set is located at the control surface, either in the snubber cylinders or as structural stops; the other, at the flight deck control. Either of these may serve as the actual limit stop. However, those situated at the control surface usually perform this function. The other stops do not normally contact each other, but are adjusted to a definite clearance when the control surface is at the full extent of its travel. These work as override stops to prevent stretching of cables and damage to the control system during violent maneuvers. When rigging control systems, refer to the applicable maintenance manual for the sequence of steps for adjusting these stops to limit the control surface travel.

Where dual controls are installed, they must be synchronized and function satisfactorily when operated from both positions.

Trim tabs and other tabs should be checked in a manner similar to the main control surfaces. The tab position indicator must be checked to see that it functions correctly. If jackscrews are used to actuate the trim tab, check to see that they are not extended beyond the specified limits when the tab is in its extreme positions.

After determining that the control system functions properly and is correctly rigged, it should be thoroughly inspected to determine that the system is correctly assembled and operates freely over the specified range of movement.

### *Checking & Safetying the System*

Whenever rigging is performed on any aircraft, it is good practice to have a second set of eyes inspect the control system to make certain that all turnbuckles, rod ends, and attaching nuts and bolts are correctly safetied.

As a general rule, all fasteners on an aircraft are safetied in some manner. Safetying is defined as securing by various means any nut, bolt, turnbuckle, etc., on the aircraft so that vibration does not cause it to loosen during operation.

Most aircraft manufacturers have a Standard Practices section in their maintenance manuals. These are the methods that should be used when working on a particular system of a

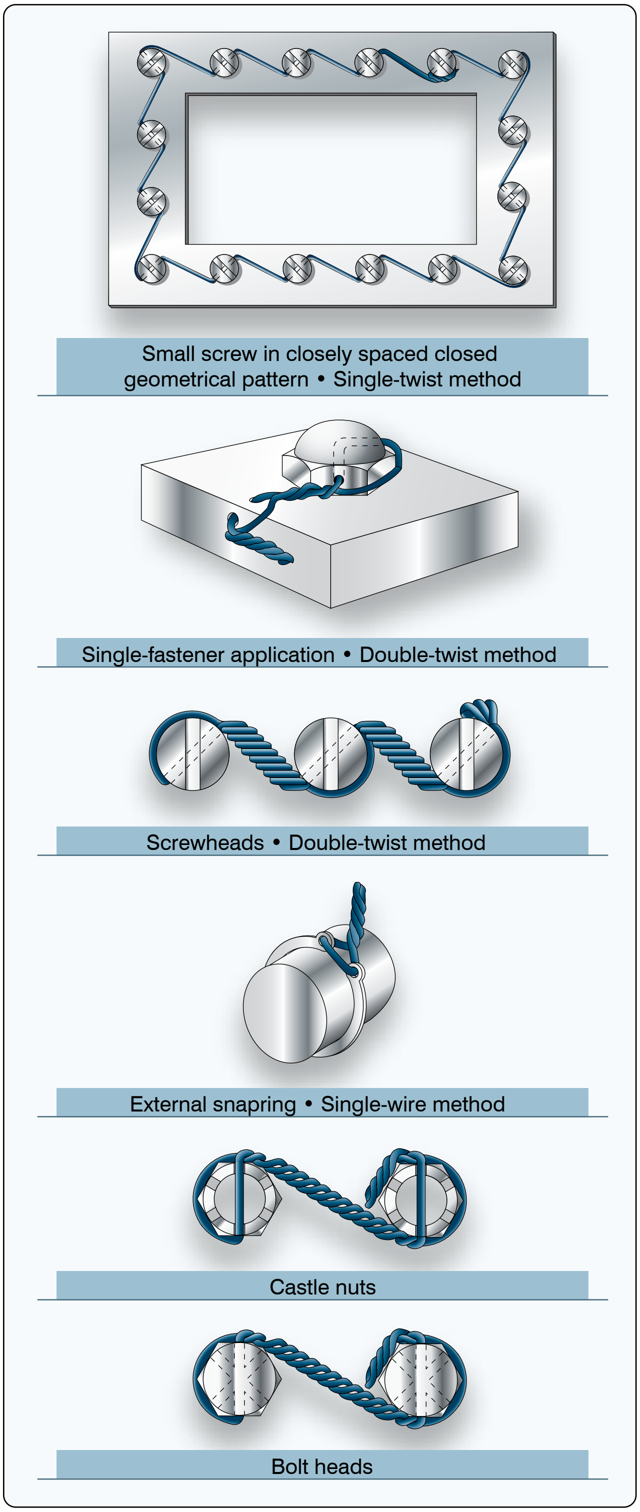



**Figure 2-91.** *Double-wrap and single safety wire methods for nuts, bolts, and snap rings.*

specific aircraft. However, most standard aircraft hardware has a standard method of being safetied. The following information provides some of the most common methods used in aircraft safetying.

The most commonly used safety wire method is the double-twist, utilizing stainless steel or Monel wire in the .032 to .040-inch diameter range. This method is used on studs, cable turnbuckles, flight controls, and engine accessory attaching bolts. A single-wire method is used on smaller screws, bolts, and/or nuts when they are located in a closely spaced or closed geometrical pattern. The single-wire method is also used on electrical components and in places that are difficult to reach. *[Figure 2-91]*

Safety-of-flight emergency equipment, such as portable fire extinguishers, oxygen regulators, emergency valves, firewall shut-offs, and seals on first-aid kits, are safetied using a single copper wire (.020-inch diameter) or aluminum wire (.031-inch diameter). The wire on this emergency equipment is installed only to indicate the component is sealed or has not been actuated. It must be possible to break the wire seal by hand, without the use of any tools.

The use of safety wire pliers, or wire twisters, makes the job of safetying much easier on the mechanic's hands and produces a better finished product. *[Figure 2-92]*

The wire should have six to eight twists per inch of wire and be pulled taut while being installed. Where practicable, install the safety wire around the head of the fastener and twist it in such a manner that the loop of the wire is pulled close to the contour of the unit being safety wired, and in the direction that would have the tendency to tighten the fastener. *[Figure 2-93]*

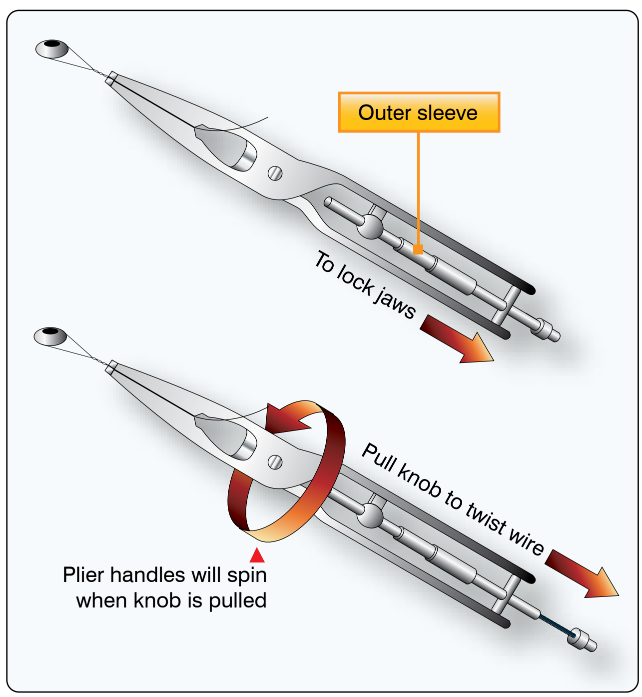



**Figure 2-92.** *Use of safety-wire pliers or wire twisters.*

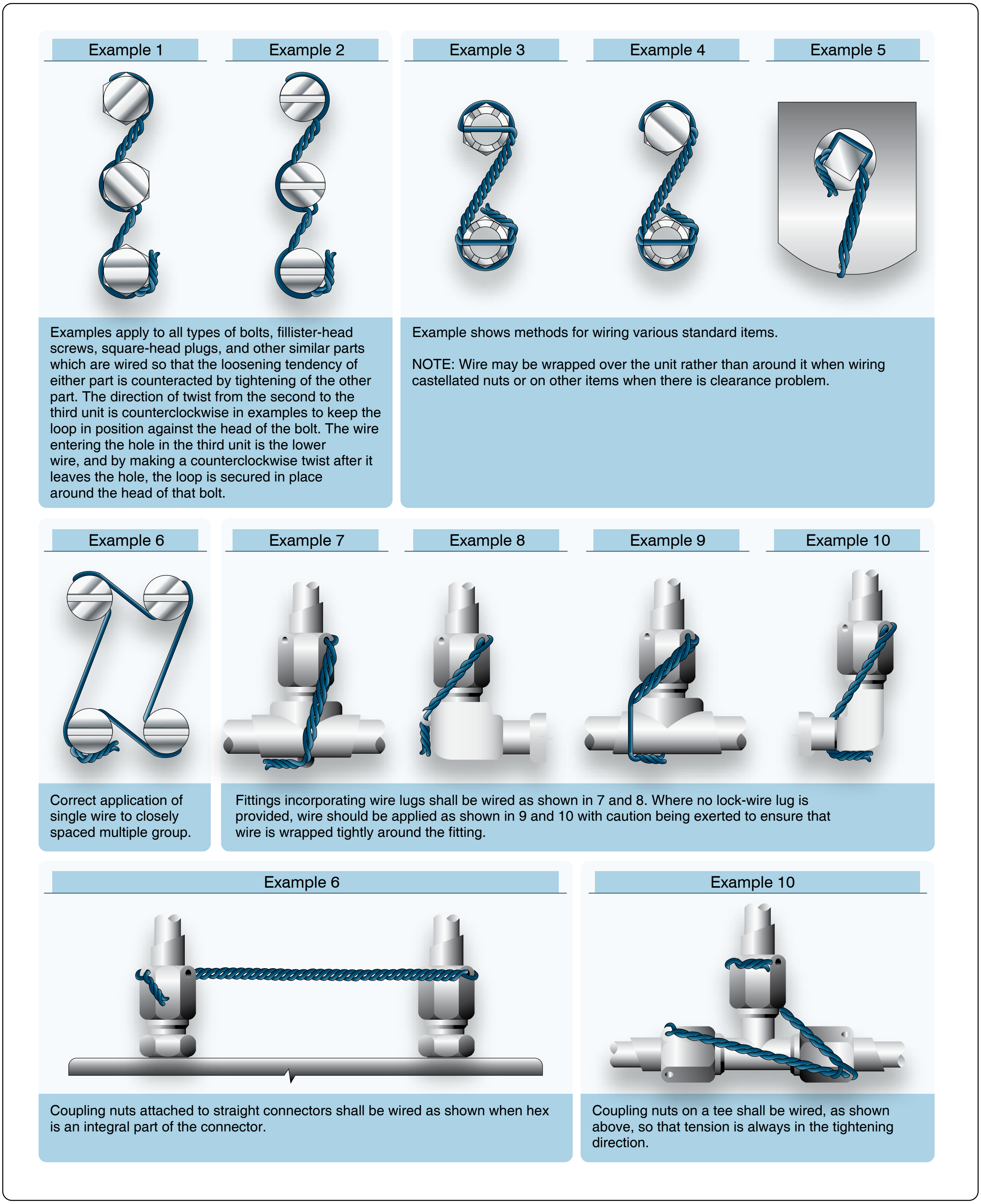



**Figure 2-93.** *Examples of various fasteners and methods of safetying.*

Cotter pins are used to secure such items as bolts, screws, pins, and shafts. They are used at any location where a turning or actuating movement takes place. The diameter of the cotter pin selected for any application should be the largest size that will fit consistent with the diameter of the cotter pin hole and/or the slots in the castellated nut. Cotter pins, like safety wire, should never be re-used on aircraft. *[Figure 2-94]*

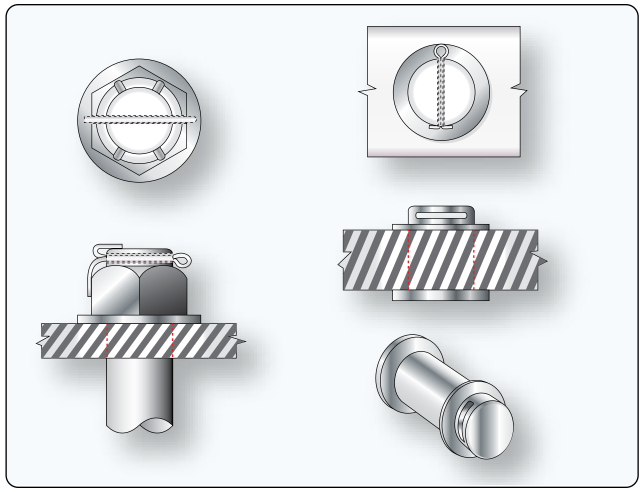


**Figure 2-94.** *Securing hardware with cotter pins.*

Self-locking nuts are used in applications where they are not removed often. There are two types of self-locking nuts currently in use. One is all metal and the other has an insert, usually of fiber or nylon.

It is extremely important that the manufacturer's Illustrated Parts Book (IPB) be consulted for the correct type and grade of lock nut for various locations on the aircraft. The finish or plating color of the nut identifies the type of application and environment in which it can be used. For example, a cadmium-plated nut is gold in color and provides exceptionally good protection against corrosion, but should not be used in applications where the temperature may exceed 450 °F.

Repeated removal and installation causes the self-locking nut to lose its locking feature. They should be replaced when they are no longer capable of maintaining the minimum prevailing torque. *[Figure 2-95]*

| Fine Thread Series | |
|---|---|
| Thread Size | Minimum Prevailing Torque |
| 7/16 - 20 | 8 inch-pounds |
| 1/2 - 20 | 10 inch-pounds |
| 9/16 - 18 | 13 inch-pounds |
| 5/8 - 18 | 18 inch-pounds |
| 3/4 - 16 | 27 inch-pounds |
| 7/8 - 14 | 40 inch-pounds |
| 1 - 14 | 55 inch-pounds |
| 1-1/8 - 12 | 73 inch-pounds |
| 1-1/4 - 12 | 94 inch-pounds |

| Coarse Thread Series | |
|---|---|
| Thread Size | Minimum Prevailing Torque |
| 7/16 - 14 | 8 inch-pounds |
| 1/2 - 13 | 10 inch-pounds |
| 9/16 - 12 | 14 inch-pounds |
| 5/8 - 11 | 20 inch-pounds |
| 3/4 - 10 | 27 inch-pounds |
| 7/8 - 9 | 40 inch-pounds |
| 1 - 8 | 51 inch-pounds |
| 1-1/8 - 8 | 68 inch-pounds |
| 1-1/4 - 8 | 68 inch-pounds |

**Figure 2-95.** *Minimum prevailing torque values for reused self-locking nuts.*

Lock washers may be used with bolts and machine screws whenever a self-locking nut or castellated nut is not applicable. They may be of the split washer spring type, or a multi-serrated internal or external star washer.

Pal nuts may be a second nut tightened against the first and used to force the primary nut thread against the bolt or screw thread. They may also be of the type that are made of stamped spring steel and are to be used only once and replaced with new ones when removed.

## Biplane Assembly & Rigging

Biplanes were some of the very first aircraft designs. The first powered heavier-than-air aircraft, the Wright Brothers' Wright Flyer, successfully flown on December 17, 1903, was a biplane.

The first biplanes were designed with very thin wing sections and, consequently, the wing structure needed to be strengthened by external bracing wires. The biplane configuration allowed the two wings to be braced against one another, increasing the structural strength. When the assembly and rigging of a biplane is accomplished in accordance with the approved instructions, a stable airworthy aircraft is the result.

Whether assembling an early model vintage aircraft that may have been disassembled for repair and restoration, or constructing and assembling a new aircraft, the following are some basic alignment procedures to follow.

To start, the fuselage must be level, fore and aft and laterally. The aircraft usually has specific leveling points designated

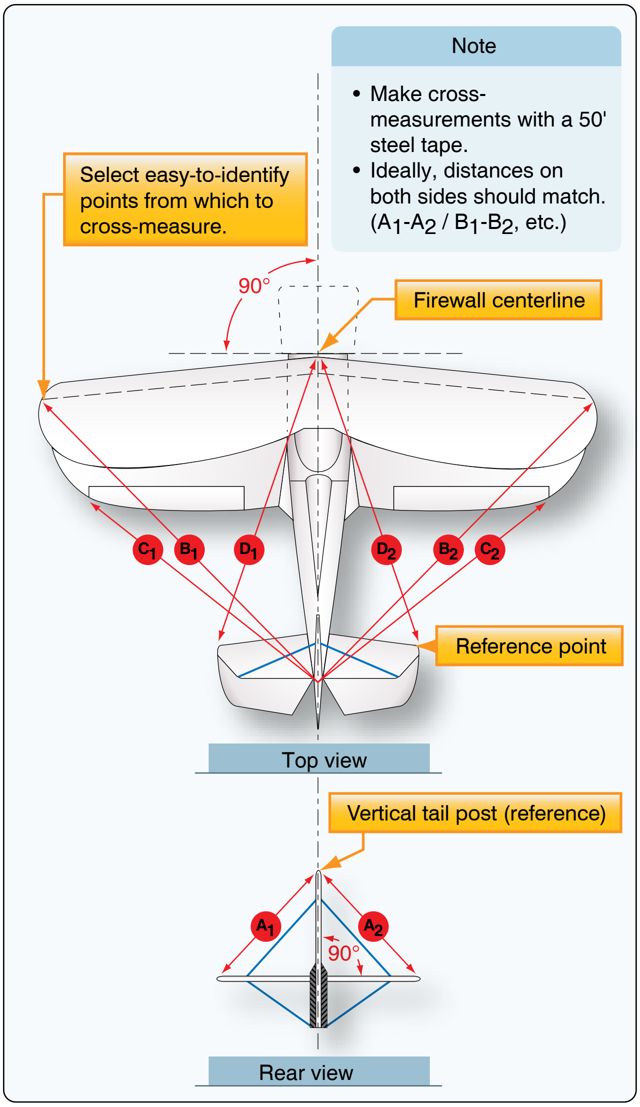



**Figure 2-96.** *Checking aircraft symmetry.*

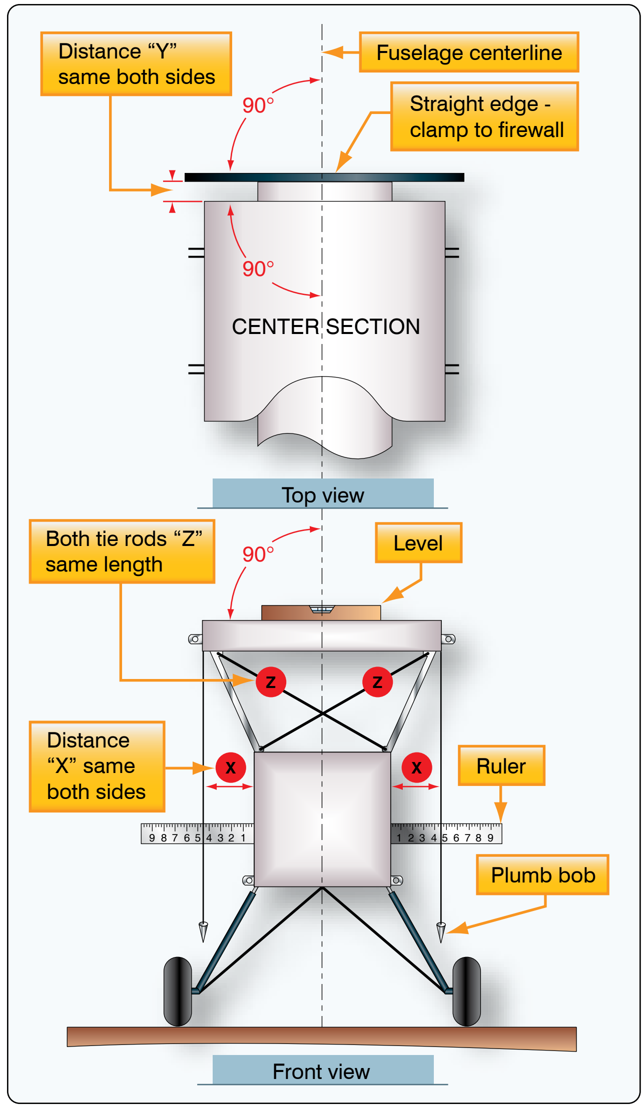



**Figure 2-97.** *Center section alignment.*

by the manufacturer or indicated on the plans. The fuselage should be blocked up off the landing gear so it is stable. A center line should be drawn on the floor the length of the fuselage and another line perpendicular to it at the firewall, for use as an additional alignment reference.

With the horizontal and vertical tail surfaces installed, the incident angle for the horizontal stabilizer should be set. The tail brace wires should be connected and tightened until the slack is removed. Alignment measurements should be checked as shown in *Figure 2-96*.

Install the elevator and rudder and clamp them in a neutral position. Verify the neutral position of the control stick and rudder pedals in the flight deck and secure them in order to simplify the connecting and final tensioning of the control cables.

If the biplane has a center section for the upper wing, it must be aligned as accurately as possible, because even the smallest error is compounded at the wing tip. Applicable cables and turnbuckles should be connected and the tension set as specified. *[Figure 2-97]* The stagger measurement can be checked as shown in *Figure 2-98*.

The lower wing sections should be individually attached to the fuselage and blocked up for support while the landing wires are connected and adjusted to obtain the dihedral called for in the specifications or plans. *[Figure 2-99]*

Next, connect the outer “N” struts to the left and right sections of the lower wing. Now, the upper wing can be attached and the flying wires installed. The slave struts can be installed and the ailerons connected using the same alignment and adjustment procedures used for the elevator and rudder. The incidence angle can be checked, as shown in *Figure 2-100*.

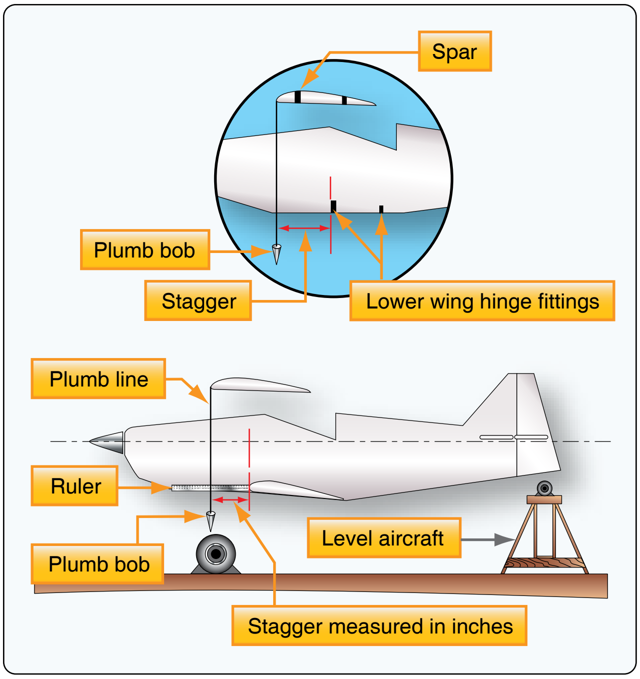



**Figure 2-98.** *Measuring stagger.*

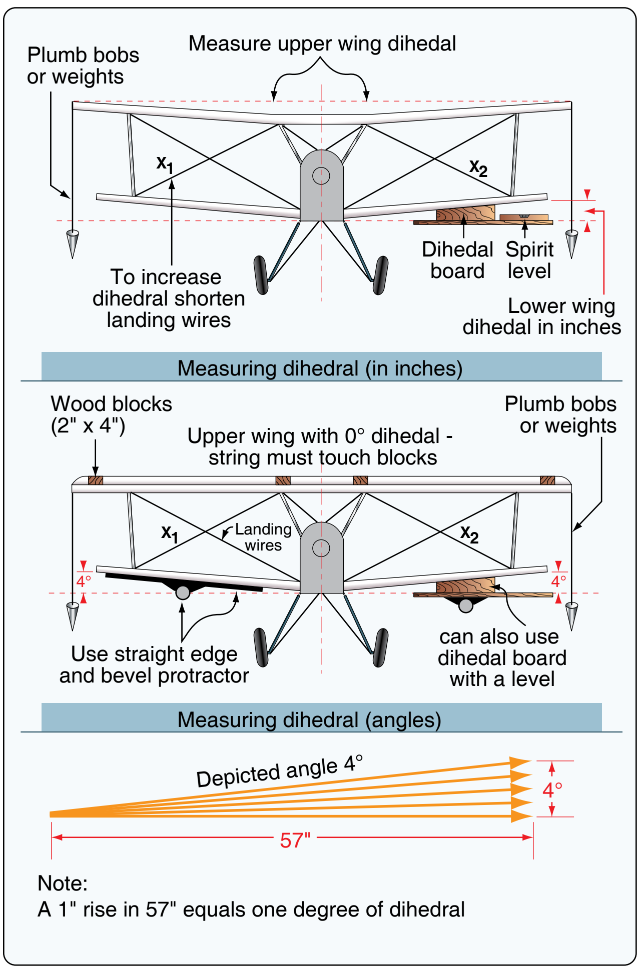



**Figure 2-99.** *Measuring dihedral.*

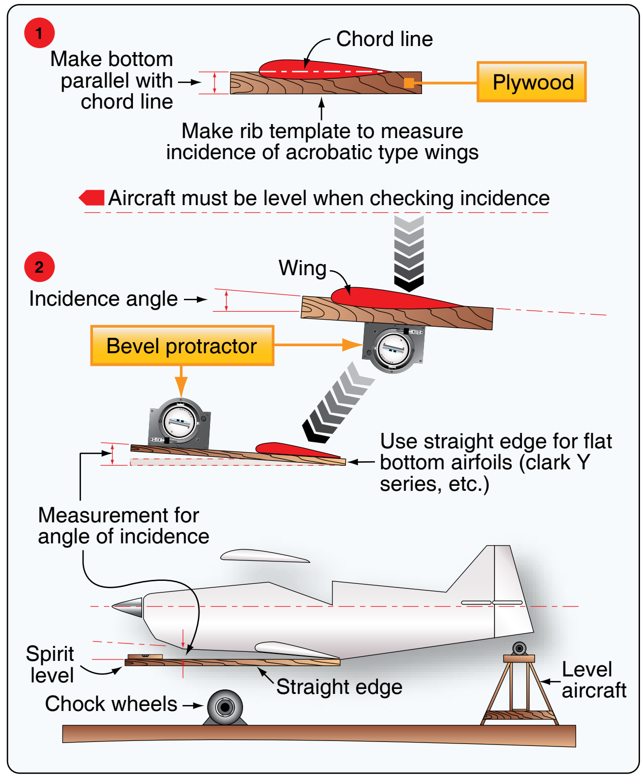



**Figure 2-100.** *Checking incidence.*

Once this point is reached, it is a matter of measuring, checking angles, and adjusting the various components to obtain the overall aircraft symmetry and desired alignment, as shown in *Figure 2-96.*

Also, remember that care should be used when tightening the wing wires because extra stress can be inadvertently induced into the wings. Always loosen one wire before tightening the opposite wire. Flying and landing wires are typically set at about 600 pounds and tail brace wires at about 300 pounds of tension.

When convinced the aircraft is properly rigged, move away from it and take a good look at the finished product. Are the wings symmetrical? Does the dihedral look even? Is the tail section square with the fuselage? Are the wing attaching hardware, flying wires, and control cables safetied? And the final task, before the first flight, is to complete the maintenance record entries.

As with any aircraft maintenance or repair, the instructions and specifications from the manufacturer, or the procedures and recommendations found in the construction plans, should be the primary method to perform the assembly and rigging of the aircraft.

## Aircraft Inspection

### Purpose of Inspection Programs

The purpose of an aircraft inspection program is to ensure that the aircraft is airworthy. Per 14 CFR part 3, section 3.5, "airworthy" means the aircraft conforms to its type design and is in a condition for safe operation. By this definition and according to subsequent case law relating to the term and regulations for the issuance of a standard airworthiness certificate, there are two conditions that must be met for the aircraft to be considered airworthy:

1. *The aircraft must conform to its type design or properly altered condition.* Conformity to type design is considered attained when the aircraft configuration and the components installed are consistent with the drawings, specifications, and other data that are part of the type certificate (TC), which includes any supplemental type certificate (STC) and field approved alterations incorporated into the aircraft.
2. *The aircraft must be in a condition for safe operation.* This refers to the condition of the aircraft relative to wear and deterioration (e.g., skin corrosion, window delamination/crazing, fluid leaks, and tire wear beyond specified limits).

When flight hours and calendar time are accumulated into the life of an aircraft, some components wear out and others deteriorate. Inspections are developed to find these items, and repair or replace them before they affect the airworthiness of the aircraft.

### Performing an Airframe Conformity & Airworthiness Inspection

To establish conformity of an aircraft product, start with a TCDS. This document is a formal description of the aircraft, the engine, or the propeller. It is issued by the Federal Aviation Administration (FAA) when they find that the product meets the applicable requirements for certification under 14 CFR.

The TCDS lists the limitations and information required for type certification of aircraft. It includes the certification basis and eligible serial numbers for the product. It lists airspeed limits, weight limits, control surface movements, engine make and models, minimum crew, fuel type, etc.; the horsepower and rpm limits, thrust limitations, size and weight for engines; and blade diameter, pitch, etc., for propellers. Additionally, it provides all the various components by make and model, eligible for installation on the applicable product.

A manufacturer's maintenance information may be in the form of service instructions, service bulletins, or service letters that the manufacturer publishes to provide instructions for product improvement or to revise and update maintenance manuals. Service bulletins are not regulatory unless:

1. All or a portion of a service bulletin is incorporated as part of an airworthiness directive.
2. The service bulletins are part of the FAA-approved airworthiness limitations section of the manufacturer's manual or part of the type certificate.
3. The service bulletins are incorporated directly or by reference into an FAA-approved inspection program, such as an approved aircraft inspection program (AAIP) or continuous aircraft maintenance program (CAMP).
4. The service bulletins are listed as an additional maintenance requirement in a certificate holder's operations specifications (OpSpecs).

Airworthiness directives (ADs) are published by the FAA as amendments to 14 CFR part 39, section 39.13. They apply to the following products: aircraft, aircraft engines, propellers, and appliances. The FAA issues airworthiness directives when an unsafe condition exists in a product, and the condition is likely to exist or develop in other products of the same type design.

To perform the airframe conformity and verify the airworthiness of the aircraft, records must be checked and the aircraft inspected. The data plate on the airframe is inspected to verify its make, model, serial number, type certificate, or production certificate. Check the registration and airworthiness certificate to verify they are correct and reflect the "N" number on the aircraft.

Inspect aircraft records. Check current inspection status of aircraft, by verifying:

- The date of the last inspection and aircraft total time in service.
- The type of inspection and if it includes manufacturer's bulletins.
- The signature, certificate number, and the type of certificate of the person who returned the aircraft to service.

Identify if any major alterations or major repairs have been performed and recorded on an FAA Form 337, Major Repair and Alteration. Review any flight manual supplements (FMS) included in the Pilot's Operating Handbook (POH) and determine if there are any airworthiness limitations or required placards associated with the installation(s) that must be inspected.

Check for a current weight and balance report, and the current equipment list, current status of airworthiness directives for airframe, engine, propeller, and appliances. Also, check the limitations section of the manufacturer's manual to verify the status of any life-limited components.

Obtain the latest revision of the airframe TCDS and use it as a verification document to inspect and ensure the correct engines, propellers, and components are installed on the airframe.

## Required Inspections

### *Preflight*

Preflight for the aircraft is described in the POH for that specific aircraft and should be followed with the same attention given to the checklists for takeoff, inflight, and landing checklists.

### *Periodic Maintenance Inspections*

*Annual Inspection*

With few exceptions, no person may operate an aircraft unless, within the preceding 12 calendar months, it has had an annual inspection in accordance with 14 CFR part 43 and was approved for return to service by a person authorized under section 43.7. (A certificated mechanic with an Airframe and Powerplant (A&P) rating must hold an inspection authorization (IA) to perform an annual inspection.) A checklist must be used and include as a minimum, the scope and detail of items (as applicable to the particular aircraft) in 14 CFR part 43, Appendix D.

*100-hour Inspection*

This inspection is required when an aircraft is operated under 14 CFR part 91 and used for hire, such as flight training. It is required to be performed every 100 hours of service in addition to the annual inspection. (The inspection may be performed by a certificated mechanic with an A&P rating.) A checklist must be used and as a minimum, the inspection must include the scope and detail of items (as applicable to the particular aircraft) in 14 CFR part 43, Appendix D.

*Progressive Inspection*

This inspection program can be performed under 14 CFR part 91, section 91.409(d), as an alternative to an annual inspection. However, the program requires that a written request be submitted by the registered owner or operator of an aircraft desiring to use a progressive inspection to the local FAA Flight Standards District Office (FSDO). It shall provide:

1. The name of a certificated mechanic holding an inspection authorization, a certificated airframe repair station, or the manufacturer of the aircraft to supervise or conduct the inspection.
2. A current inspection procedures manual available and readily understandable to the pilot and maintenance personnel containing in detail:
   - An explanation of the progressive inspection, including the continuity of inspection responsibility, the making of reports, and the keeping of records and technical reference material.
   - An inspection schedule, specifying the intervals in hours or days when routine and detailed inspections will be performed, and including instructions for exceeding an inspection interval by not more than 10 hours while en route, and for changing an inspection interval because of service experience.
   - Sample routine and detailed inspection forms and instructions for their use.
   - Sample reports and records and instructions for their use.
3. Enough housing and equipment for necessary disassembly and proper inspection of the aircraft.
4. Appropriate current technical information for the aircraft.

The frequency and detail of the progressive inspection program shall provide for the complete inspection of the aircraft within each 12 calendar months and be consistent with the manufacturer's recommendations and kind of operation in which the aircraft is engaged. The progressive inspection schedule must ensure that the aircraft will be airworthy at all times. A certificated A&P mechanic may perform a progressive inspection, as long as they are being supervised by a mechanic holding an Inspection Authorization.

If the progressive inspection is discontinued, the owner or operator must immediately notify the local FAA FSDO in writing. After discontinuance, the first annual inspection will be due within 12 calendar months of the last complete inspection of the aircraft under the progressive inspection.

*Large Airplanes (over 12,500 lb)*

Inspection requirements of 14 CFR part 91, section 91.409, to include paragraphs (e) and (f).

Paragraph (e) applies to large airplanes (to which 14 CFR part 125 is not applicable), turbojet multiengine airplanes, turbo propeller powered multiengine airplanes, and turbine-powered rotorcraft. Paragraph (f) lists the inspection programs that can be selected under paragraph (e).

The additional inspection requirements for these aircraft are placed on the operator because the larger aircraft typically are more complex and require a more detailed inspection program than is provided for in 14 CFR part 43, Appendix D.

An inspection program must be selected from one of the following four options by the owner or operator of the aircraft:

1. A continuous airworthiness inspection program that is part of a continuous airworthiness maintenance program currently in use by a person holding an air carrier operating certificate or an operating certificate issued under 14 CFR part 121 or 135.
2. An approved aircraft inspection program approved under 14 CFR part 135, section 135.419, and currently in use by a person holding an operating certificate issued under 14 CFR part 135.
3. A current inspection program recommended by the manufacturer.
4. Any other inspection program established by the registered owner or operator of the airplane or turbine-powered rotorcraft and approved by the FAA. This program must be submitted to the local FAA FSDO having jurisdiction of the area in which the aircraft is based. The program must be in writing and include at least the following information:
   (a) Instructions and procedures for the conduct of inspections for the particular make and model airplane or turbine-powered rotorcraft, including the necessary tests and checks. The instructions and procedures must set forth in detail the parts and areas of the airframe, engines, propellers, rotors, and appliances, including survival and emergency equipment, required to be inspected.
   (b) A schedule for performing the inspections that must be performed under the program expressed in terms of the time in service, calendar time, number of system operations (cycles), or any combination of these.

   This FAA approved owner/operator program can be revised at a future date by the FAA, if they find that revisions are necessary for the continued adequacy of the program. The owner/operator can petition the FAA within 30 days of notification to reconsider the notice to make changes.

*Manufacturer's Inspection Program*

This is a program developed by the manufacturer for their product. It is contained in the "Instructions for Continued Airworthiness" required under 14 CFR part 23, section 23.1529 and part 25, section 25.1529. It is in the form of a manual, or manuals as appropriate, for the quantity of data to be provided and including, but not limited to, the following content:

- A description of the airplane and its systems and installations, including its engines, propellers, and appliances.
- Basic information describing how the airplane components and systems are controlled and operated, including any special procedures and limitations that apply.
- Servicing information that covers servicing points, capacities of tanks, reservoirs, types of fluids to be used, pressures applicable to the various systems, lubrication points, lubricants to be used, equipment required for servicing, tow instructions, mooring, jacking, and leveling information.
- Maintenance instructions with scheduling information for the airplane and each component that provides the recommended periods at which they should be cleaned, inspected, adjusted, tested, and lubricated, and the degree of inspection and work recommended at these periods.
- The recommended overhaul periods and necessary cross references to the airworthiness limitations section of the manual.
- The inspection program that details the frequency and extent of the inspections necessary to provide for the continued airworthiness of the airplane.
- Diagrams of structural access plates and information needed to gain access for inspections when access plates are not provided.
- Details for the application of special inspection techniques, including radiographic and ultrasonic testing where such processes are specified.
- A list of special tools needed.
- An Airworthiness Limitations section that is segregated and clearly distinguishable from the rest of the document. This section must set forth:
  1. Each mandatory replacement time, structural inspection interval, and related structural inspection procedures required for type certification or approved under 14 CFR part 23 or part 25.
  2. Each mandatory replacement time, inspection interval, related inspection procedure, and all critical design configuration control limitations approved under 14 CFR part 23 or part 25, for the fuel tank system.

The Airworthiness Limitations section must contain a legible statement in a prominent location that reads: "The Airworthiness Limitations section is FAA-approved and specifies maintenance required under 14 CFR part 43, sections 43.16 and part 91, section 91.403, unless an alternative program has been FAA-approved."

Any operator who wishes to adopt a manufacturers' inspection program should first contact their local FAA Flight Standards District Office, for further guidance.

### *Altimeter & Static System Inspections in Accordance with 14 CFR Part 91, Section 91.411*

Any person operating an airplane or helicopter in controlled airspace under instrument flight rules (IFR) must have had, within the preceding 24 calendar months, each static pressure system, each altimeter instrument, and each automatic pressure altitude reporting system tested and inspected and found to comply with 14 CFR part 43, Appendix E. Those tests and inspections must be conducted by appropriately rated persons under 14 CFR.

### *Air Traffic Control (ATC) Transponder Inspections*

Any person using an air traffic control (ATC) transponder must have had, within the preceding 24 calendar months, that transponder tested and inspected and found to comply with 14 CFR part 43, Appendix F, and part 91, section 91.411. Additionally, following any installation or maintenance on an ATC transponder where data correspondence error could be introduced, the integrated system must be tested and inspected and found to comply with 14 CFR part 43, Appendix E, and part 91, section 91.411 by an appropriately rated person under 14 CFR.

### *Emergency Locator Transmitter (ELT) Operational & Maintenance Practices in Accordance with Advisory Circular (AC) 91-44*

This AC combined and updated several ACs on the subject of ELTs and receivers for airborne service.

Under the operating rules of 14 CFR part 91, most small U.S. registered civil airplanes equipped to carry more than one person must have an ELT attached to the airplane. 14 CFR part 91, section 91.207 defines the requirements of what type aircraft and when the ELT must be installed. It also states that an ELT that meets the requirements of Technical Standard Order (TSO)-C91 may not be used for new installations.

The pilot-in-command of an aircraft equipped with an ELT is responsible for its operation and, prior to engine shutdown at the end of each flight, should tune the VHF receiver to 121.5 MHz and listen for ELT activations. Maintenance personnel are responsible for accidental activation during the actual period of their work.

Maintenance of ELTs is subject to 14 CFR part 43 and part 91, section 91.413 and should be included in the required inspections. It is essential that the impact switch operation and the transmitter output be checked using the manufacturer's instructions. Testing of an ELT prior to installation or for maintenance reasons, should be conducted in a metal enclosure in order to avoid outside radiation by the transmitter. If this is not possible, the test should be conducted only within the first 5 minutes after any hour.

Manufacturers of ELTs are required to mark the expiration date of the battery, based on 50 percent of the useful life, on the outside of the transmitter. The batteries are required to be replaced on that date or when the transmitter has been in use for more than 1 cumulative hour. Water activated batteries, have virtually unlimited shelf life. They are not usually marked with an expiration date. They must be replaced after activation regardless of how long they were in service.

The battery replacement can be accomplished by a pilot on a portable type ELT that is readily accessible and can be removed and reinstalled in the aircraft by a simple operation. That would be considered preventive maintenance under 14 CFR part 43, section 43.3(g). Replacement batteries should be approved for the specific model of ELT and the installation performed in accordance with section 43.13.

AC 91-44 also contains additional information on:

- Airborne homing and alerting equipment for use with ELTs.
- Search and rescue responsibility.
- Alert and search procedures including various flight procedures for locating an ELT.
- The FAA Frequency Management Offices, for contacting by manufacturers when they are demonstrating and testing ELTs.

Although there is no regulatory requirement to install a 406 ELT, the benefits are numerous, regardless of regulatory minimums. All new installations must be a 406 MHz digital ELT. It must meet the standards of TSO C126. When installed, the new 406 MHz ELT should be registered so that if the aircraft were to go down, search and rescue could take full advantage of the benefits the system offers. The digital circuitry of the 406 MHz ELT can be coded with information about the aircraft type, base location, ownership, etc. This coding allows the search and rescue (SAR) coordinating centers to contact the registered owner or operator if a signal is detected to determine if the aircraft is flying or parked. This type of identification permits a rapid SAR response in the event of an accident, and will save valuable resources from a false alarm search.

## Annual & 100-Hour Inspections

### *Preparation*

An owner/operator bringing an aircraft into a maintenance facility for an annual or 100-hour inspection may not know what is involved in the process. This is the point at which the person who performs the inspection sits down with the customer to review the records and discuss any maintenance issues, repairs needed, or additional work the customer may want done. Moreover, the time spent on these items before starting the inspection usually saves time and money before the work is completed.

The work order describes the work that will be performed and the fee that the owner pays for the service. It is a contract that includes the parts, materials, and labor to complete the inspection. It may also include additional maintenance and repairs requested by the owner or found during the inspection.

Additional materials such as ADs, manufacturer's service bulletins and letters, and vendor service information must be researched to include the avionics and emergency equipment on the aircraft. The TCDS provides all the components eligible for installation on the aircraft.

The review of the aircraft records is one of the most important parts of any inspection. Those records provide the history of the aircraft. The records to be kept and how they are to be maintained are listed in 14 CFR part 91, section 91.417. Among those records that must be tracked are records of maintenance, preventive maintenance, and alteration, records of the last 100-hour, annual, or other required or approved inspections for the airframe, engine propeller, rotor, and appliances of an aircraft. The records must include:

- A description (or reference to data acceptable to the FAA) of the work performed.
- The date of completion of the work performed and the signature and certificate number of the person approving the aircraft for return to service.
- The total time in service and the current status of life-limited parts of the airframe, each engine, each propeller, and each rotor.
- The time since the last overhaul of all items installed on the aircraft which are required to be overhauled on a specified time basis.
- The current inspection status of the aircraft, including the time since the last inspection required by the program under which the aircraft and its appliances are maintained.
- The current status of applicable ADs including for each, the method of compliance, the AD number, and revision date. If the AD involves recurring action, the time and date when the next action is required.
- Copies of the forms prescribed by 14 CFR part 43, section 43.9, for each major alteration to the airframe and currently installed components.

The owner/operator is required to retain the records of inspection until the work is repeated, or for 1 year after the work is performed. Most of the other records that include total times and current status of life-limited parts, overhaul times, and AD status must be retained and transferred with the aircraft when it is sold.

14 CFR part 43, section 43.15 requires that each person performing a 100-hour or annual inspection shall use a checklist while performing the inspection. The checklist may be one developed by the person, one provided by the manufacturer of the equipment being inspected, or one obtained from another source. The checklist must include the scope and detail of the items contained in part 43, Appendix D.

The inspection checklist provided by the manufacturer is the preferred one to use. The manufacturer separates the areas to inspect such as engine, cabin, wing, empennage and landing gear. They typically list Service Bulletins and Service Letters for specific areas of the aircraft and the appliances that are installed.

Initial run-up provides an assessment to the condition of the engine prior to performing the inspection. The run-up should include full power and idle rpm, magneto operation, including positive switch grounding, fuel mixture check, oil and fuel pressure, and cylinder head and oil temperatures. After the engine run, check it for fuel, oil, and hydraulic leaks.

Following the checklist, the entire aircraft shall be opened by removing all necessary inspection plates, access doors, fairings, and cowling. The entire aircraft must then be cleaned to uncover hidden cracks or defects that may have been missed because of the dirt.

Following in order and using the checklist, visually inspect each item, or perform the checks or tests necessary to verify the condition of the component or system. Record discrepancies when they are found. The entire aircraft should be inspected and a list of discrepancies be presented to the owner.

A typical inspection following a checklist, on a small single-engine airplane may include in part, as applicable:

- The fuselage for damage, corrosion, and attachment of fittings, antennas, and lights; for "smoking rivets" especially in the landing gear area indicating the possibility of structural movement or hidden failure.

- The flight deck and cabin area for loose equipment that could foul the controls; seats and seat belts for defects and TSO tags; windows and windshields for deterioration; instruments for condition, markings, and operation; flight and engine controls for proper operation.
- The engine and attached components for visual evidence of leaks; studs and nuts for improper torque and obvious defects; engine mount and vibration dampeners for cracks, deterioration, and looseness; engine controls for defects, operation, and safetying; the internal engine for cylinder compression; spark plugs for operation; oil screens and filters for metal particles or foreign matter; exhaust stacks and mufflers for leaks, cracks, and missing hardware; cooling baffles for deterioration, damage, and missing seals; and engine cowling for cracks and defects.
- The landing gear group for condition and attachment; shock absorbing devices for leaks and fluid levels; retracting and locking mechanism for defects, damage, and operation; hydraulic lines for leakage; electrical system for chafing and switches for operation; wheels and bearings for condition; tires for wear and cuts; and brakes for condition and adjustment.
- The wing and center section assembly for condition, skin deterioration, distortion, structural failure, and attachment.
- The empennage assembly for condition, distortion, skin deterioration, evidence of failure (smoking rivets), secure attachment, and component operation and installation.
- The propeller group and system components for torque and proper safetying; the propeller for nicks, cracks, and oil leaks; the anti-icing devices for defects and operation; and the control mechanism for operation, mounting, and restricted movement.
- The radios and electronic equipment for improper installation and mounting; wiring and conduits for improper routing, insecure mounting, and obvious defects; bonding and shielding for installation and condition; and all antennas for condition, mounting, and operation. Additionally, if not already inspected and serviced, the main battery inspected for condition, mounting, corrosion, and electrical charge.
- Any and all installed miscellaneous items and components that are not otherwise covered by this listing for condition and operation.

With the aircraft inspection checklist completed, the list of discrepancies should be transferred to the work order. As part of the annual and 100-hour inspections, the engine oil is drained and replaced because new filters and/or clean screens have been installed in the engine. The repairs are then completed and all fluid systems serviced.

Before approving the aircraft for return to service after the annual or 100-hour inspection, 14 CFR states that the engine must be run to determine satisfactory performance in accordance with the manufacturers recommendations. The run must include:

- Power output (static and idle rpm)
- Magnetos (for drop and switch ground)
- Fuel and oil pressure
- Cylinder and oil temperature

After the run, the engine is inspected for fluid leaks and the oil level is checked a final time before close up of the cowling.

With the aircraft inspection completed, all inspections plates, access doors, fairing and cowling that were removed, must be reinstalled. It is a good practice to visually check inside the inspection areas for tools, shop rags, etc., prior to close up. Using the checklist and discrepancy list to review areas that were repaired will help ensure the aircraft is properly returned to service.

Upon completion of the inspection, the records for each airframe, engine, propeller, and appliance must be signed off. The record entry in accordance with 14 CFR part 43, section 43.11, must include the following information:

- The type inspection and a brief description of the extent of the inspection.
- The date of the inspection and aircraft total time in service.
- The signature, the certificate number, and kind of certificate held by the person approving or disapproving for return to service the aircraft, airframe, aircraft engine, propeller, appliance, component part, or portions thereof.
- For the annual and 100-hour inspection, if the aircraft is found to be airworthy and approved for return to service, enter the following statement: "I certify that this aircraft has been inspected in accordance with a (insert type) inspection and was determined to be in airworthy condition."
- If the aircraft is not approved for return to service because of necessary maintenance, noncompliance with applicable specifications, airworthiness directives, or other approved data, enter the following statement: "I certify that this aircraft has been inspected in accordance with a (insert type) inspection

and a list of discrepancies and unairworthy items has been provided to the aircraft owner or operator."

If the owner or operator did not want the discrepancies and/or unairworthy items repaired at the location where the inspection was accomplished, they may have the option of flying the aircraft to another location with a Special Flight Permit (Ferry Permit). An application for a Special Flight Permit can be made at the local FAA FSDO.

### Other Aircraft Inspection & Maintenance Programs

Aircraft operating under 14 CFR part 135, Commuter and On Demand, have additional rules for maintenance that must be followed beyond those in 14 CFR parts 43 and 91.

14 CFR part 135, section 135.411 describes the applicable sections for maintaining aircraft that are type certificated for a passenger seating configuration, excluding any pilot seat, of nine seats or less, and which sections are applicable to maintaining aircraft with 10 or more passenger seats. The following sections apply to aircraft with nine seats or less:

- Section 135.415—requires each certificate holder to submit a Service Difficulty Report, whenever they have an occurrence, failure, malfunction, or defect in an aircraft concerning the list detailed in this section of the regulation.
- Section 135.417—requires each certificate holder to mail or deliver a Mechanical Interruption Report, for occurrences in multi-engine aircraft, concerning unscheduled flight interruptions, and the number of propeller featherings in flight, as detailed in this section of the regulation.
- Section 135.421—requires each certificate holder to comply with the manufacturer's recommended maintenance programs, or a program approved by the FAA for each aircraft, engine, propeller, rotor, and each item of emergency required by 14 CFR part 135. This section also details requirements for single-engine IFR passenger-carrying operations.
- Section 135.422—this section applies to multi-engine airplanes and details requirements for Aging Airplane Inspections and Records review. It excludes airplanes in schedule operations between any point within the State of Alaska.

Any certificated operator using aircraft with ten or more passenger seats must have the required organization and maintenance programs, along with competent and knowledgeable people to ensure a safe operation. Title 14 of the CFR, sections 135.423 through 135.443 are numerous and complex, and compliance is required; however, they are not summarized in this handbook. It is the responsibility of the certificated operator to know and comply with these and all other applicable equirements of 14 CFR, and they should contact their local FAA FSDO for further guidance.

The approved aircraft inspection program (AAIP) is an FAA-approved inspection program for aircraft of nine or less passenger seats operated under 14 CFR part 135. The AAIP is an operator developed program tailored to their particular needs to satisfy aircraft inspection requirements. This program allows operators to develop procedures and time intervals for the accomplishment of inspection tasks in accordance with the needs of the aircraft, rather than repeat all the tasks at each 100-hour interval.

The operator is responsible for the AAIP. The program must encompass the total aircraft; including all avionics equipment, emergency equipment, cargo provisions, etc. FAA Advisory Circular 135-10 (as revised) provides detailed guidance to develop an approved aircraft inspection program. The following is a summary, in part, of elements that the program should include:

- A schedule of individual tasks (inspections) or groups of tasks, as well as the frequency for performing those tasks.
- Work forms designating those tasks with a signoff provision for each. The forms may be developed by the operator or obtained from another source.
- Instructions for accomplishing each task. These tasks must satisfy 14 CFR part 43, section 43.13(a), regarding methods, techniques, practices, tools, and equipment. The instructions should include adequate information in a form suitable for use by the person performing the work.
- Provisions for operator-developed revisions to referenced instructions should be incorporated in the operator's manual.
- A system for recording discrepancies and their correction.
- A means for accounting for work forms upon completion of the inspection. These forms are used to satisfy the requirements of 14 CFR part 91, section 91.417, so they must be complete, legible, and identifiable as to the aircraft and specific inspection to which they relate.
- Accommodation for variations in equipment and configurations between aircraft in the fleet.
- Provisions for transferring an aircraft from another program to the AAIP.

The development of the AAIP may come from one of the following sources:

- An adoption of an aircraft manufacturer's inspection in its entirety. However, many aircraft manufacturers' programs do not encompass avionics, emergency equipment, appliances, and related installations that must be incorporated into the AAIP. The inspection of these items and systems will require additions to the program to ensure they comply with the air carrier's operation specifications and as applicable to 14 CFR.
- A modified manufacturer's program. The operator may modify a manufacturer's inspection program to suit its needs. Modifications should be clearly identified and provide an equivalent level of safety to those in the manufacturer's approved program.
- An operator-developed program. This type of program is developed in its entirety by the operator. It should include methods, techniques, practices, and standards necessary for proper accomplishment of the program.
- An existing progressive inspection program (14 CFR part 91.409(d)) may be used as a basis for the development of an AAIP.

As part of this inspection program, the FAA strongly recommends that a Corrosion Protection Control Program and a supplemental structural inspection type program be included.

A program revision procedure should be included so that an evaluation of any revision can be made by the operator prior to submitting them to the FAA for approval.

Procedures for administering the program should be established. These should include: defining the duties and responsibilities for all personnel involved in the program, scheduling inspections, recording their accomplishment, and maintaining a file of completed work forms.

The operator's manual should include a section that clearly describes the complete program, including procedures for program scheduling, recording, and accountability for continuing accomplishment of the program. This section serves to facilitate administration of the program by the certificate holder and to direct its accomplishment by mechanics or repair stations. The operator's manual should include instructions to accomplish the maintenance/inspections tasks. It should also contain a list of the necessary tools and equipment needed to perform the maintenance and inspections.

The FAA FSDO will provide each operator with computer-generated Operations Specifications when they approve the program.

### *Continuous Airworthiness Maintenance Program (CAMP)*

The definition of maintenance in 14 CFR part 1 includes inspection. The inspection program required for 14 CFR part 121 and part 135 air carriers is part of the Continuous Airworthiness Maintenance Program (CAMP). CAMP is not required of every part 135 carrier; it depends on aircraft being operated. It is a complex program that requires an organization of experienced and knowledgeable aviation personnel to implement it.

The FAA has developed an Advisory Circular, AC 120-16 (as revised) Air Carrier Maintenance Programs, which explains the background as well as the FAA regulatory requirements for these programs. The AC applies to air carriers subject to 14 CFR parts 119, 121, and 135. For part 135, it applies only to aircraft type certificated with ten or more passenger seats.

Any person wanting to place their aircraft on this type of program should contact their local FAA FSDO for guidance.

### *Title 14 CFR part 125, section 125.247, Inspection Programs & Maintenance*

This regulation applies to airplanes having a seating capacity of 20 or more passengers or a maximum payload capacity of 6,000 pounds or more when the aircraft is not required to be operated under 14 CFR parts 121, 129, 135, and 137. Inspection programs which may be approved for use under this 14 CFR part include, but are not limited to:

1. A continuous inspection program which is part of a current continuous airworthiness program approved for use by a certificate holder under 14 CFR part 121 or part 135;
2. Inspection programs currently recommended by the manufacturer of the airplane, airplane engines, propellers, appliances, or survival and emergency equipment; or
3. An inspection program developed by a certificate holder under 14 CFR part 125.

   The airplane subject to this part may not be operated unless:

   - The replacement times for life-limited parts specified in the aircraft type certificate data sheets, or other documents approved by the FAA are complied with;
   - Defects disclosed between inspections, or as a result of inspection, have been corrected in accordance with 14 CFR part 43; and
   - The airplane, including airframe, aircraft

engines, propellers, appliances, and survival and emergency equipment, and their component parts, is inspected in accordance with an inspection program approved by the FAA. These inspections must include at least the following:

- Instructions, procedures and standards for the particular make and model of airplane, including tests and checks. The instructions and procedures must set forth in detail the parts and areas of the airframe, aircraft engines, propellers, appliances, and survival and emergency equipment required to be inspected.
- A schedule for the performance of the inspections that must be performed under the program, expressed in terms of the time in service, calendar time, number of system operations, or any combination of these.
- The person used to perform the inspections required by 14 CFR part 125, must be authorized to perform maintenance under 14 CFR part 43. The airplane subject to part 125 may not be operated unless the installed engines have been maintained in accordance with the overhaul periods recommended by the manufacturer or a program approved by the FAA; the engine overhaul periods are specified in the inspection programs required by 14 CFR part 125, section 125.247.

### *Piston-Engine & Turbine-Powered Helicopter Inspections*

A piston-engine helicopter must be inspected in accordance with the scope and detail of 14 CFR part 43, Appendix D for an Annual Inspection. However, there are additional performance rules for inspections under 14 CFR part 43, section 43.15, requiring that each person performing an inspection under 14 CFR part 91 on a rotorcraft shall inspect these additional components in accordance with the maintenance manual or Instructions for Continued Airworthiness of the manufacturer concerned:

1. The drive shaft or similar systems.
2. The main rotor transmission gear box for obvious defects.
3. The main rotor and center section (or the equivalent area).
4. The auxiliary rotor.

The operator of a turbine-powered helicopter can elect to have it inspected under 14 CFR part 91, section 91.409:

1. Annual inspection.
2. 100-hour inspection, when being used for compensation or hire.
3. A progressive inspection, when authorized by the FAA.
4. An inspection program listed under 14 CFR part 91, section 91.409 (f), when selected by the owner/operator and the selection is recorded in the aircraft maintenance records (14 CFR part 91, section 91.409(e)).

When performing any of the above inspections, the additional performance rules under 14 CFR part 43, section 43.15, for rotorcraft must be complied with.

### *Light Sport Aircraft & Aircraft Certificated as Experimental*

Light sport aircraft and aircraft that are certificated in the experimental category are issued a Special Airworthiness Certificate by the FAA. Operating limitations are issued to these aircraft as a part of the Special Airworthiness Certificate that specify the required inspections and inspection intervals for the aircraft.

Typically, the operating limitations issued to these aircraft require that a condition inspection be performed once every 12 months. If the aircraft is used for compensation or hire (e.g., towing a glider, flight training), then it must also be inspected each 100 hours. A condition inspection is equivalent to the scope and detail of an annual inspection, the requirements of which are outlined in 14 CFR part 43, Appendix D.

An A&P or an appropriately rated repair station can perform the condition inspection on any of these aircraft. The FAA issues repairman certificates to individuals who are the builder of an amateur-built aircraft, which authorizes performance of the condition inspection. Additionally, repairman certificates can be issued to individuals for conducting inspections on light sport aircraft. There are two ratings available for light sport repairman certificate, each with different privileges as described in 14 CFR part 65, section 65.107, but both ratings authorize the repairman to conduct the annual condition inspection.

The operating limitations issued to the aircraft also require that the condition inspection be recorded in the aircraft maintenance records. The following or similarly worded statement is used:

“I certify that this aircraft has been inspected on [insert date] per the [insert either: scope and detail of 14 CFR part 43, Appendix D; or manufacturer’s inspection procedures] and was found to be in a condition for safe operation.” The entry will include the aircraft’s total time-in-service (cycles if appropriate), and the name, signature, certificate number, and type of certificate held by the person performing the inspection.

# Chapter 3
# Aircraft Fabric Covering

## General History

Fabric-covered aircraft play an important role in the history of aviation. The famous Wright Flyer utilized a fabric-covered wood frame in its design, and fabric covering continued to be used by many aircraft designers and builders during the early decades of production aircraft. The use of fabric covering on an aircraft offers one primary advantage: light weight. In contrast, fabric coverings have two disadvantages: flammability and lack of durability.

Finely woven organic fabrics, such as Irish linen and cotton, were the original fabrics used for covering airframes, but their tendency to sag left the aircraft structure exposed to the elements. To counter this problem, builders began coating the fabrics with oils and varnishes. In 1916, a mixture of cellulose dissolved in nitric acid, called nitrate dope, came into use as an aircraft fabric coating. Nitrate dope protected the fabric, adhered to it well, and tautened it over the airframe. It also gave the fabric a smooth, durable finish when dried. The major drawback to nitrate dope was its extreme flammability.

To address the flammability issue, aircraft designers tried a preparation of cellulose dissolved in butyric acid called butyrate dope. This mixture protected the fabric from dirt and moisture, but it did not adhere as well to the fabric as nitrate dope. Eventually, a system combining the two dope coatings was developed. First, the fabric was coated with nitrate dope for its adhesion and protective qualities. Then, subsequent coats of butyrate dope were added. Since the butyrate dope coatings reduced the overall flammability of the fabric covering, this system became the standard fabric treatment system.

The second problem, lack of durability, stems from the eventual deterioration of fabric from exposure to the elements that results in a limited service life. Although the mixture of nitrate dope and butyrate dope kept out dirt and water, solving some of the degradation issue, it did not address deterioration caused by ultraviolet (UV) radiation from the sun. Ultraviolet radiation passed through the dope and degraded not only the fabric, but also the aircraft structure underneath. Attempts to paint the coated fabric proved unsuccessful, because paint does not adhere well to nitrate dope. Eventually, aluminum solids were added to the butyrate coatings. This mixture reflected the sun's rays, prevented harmful UV rays from penetrating the dope, and protected the fabric, as well as the aircraft structure.

Regardless of treatments, organic fabrics have a limited lifespan; cotton or linen covering on an actively flown aircraft lasts only about 5–10 years. Furthermore, aircraft cotton has not been available for over 25 years. As the aviation industry developed more powerful engines and more aerodynamic aircraft structures, aluminum became the material of choice. Its use in engines, aircraft frames, and coverings revolutionized aviation. As a covering, aluminum protected the aircraft structure from the elements, was durable, and was not flammable.

Although aluminum and composite aircraft dominate modern aviation, advances in fabric coverings continue to be made because gliders, home-built, and light sport aircraft, as well as some standard and utility certificated aircraft, are still produced with fabric coverings. *[Figure 3-1]* The nitrate/butyrate dope process works well, but does not mitigate the short lifespan of organic fabrics. It was not until the introduction of polyester fabric as an aircraft covering in the 1950s that the problem of the limited lifespan of fabric covering was solved. The transition to polyester fabric had some problems because the nitrate and butyrate dope coating


**Figure 3-1.** *Examples of aircraft produced using fabric skin.*

process is not as suitable for polyester as it is for organic fabrics. Upon initial application of the dopes to polyester, good adhesion and protection occurred; as the dopes dried, they would eventually separate from the fabric. In other words, the fabric outlasted the coating.

Eventually, dope additives were developed that minimized the separation problem. For example, plasticizers keep the dried dope flexible and nontautening dope formulas eliminate separation of the coatings from the fabric. Properly protected and coated, polyester lasts indefinitely and is stronger than cotton or linen. Today, polyester fabric coverings are the standard and use of cotton and linen on United States certificated aircraft has ceased. In fact, the long staple cotton from which grade-A cotton aircraft fabric is made is no longer produced in this country.

Re-covering existing fabric aircraft is an accepted maintenance procedure. Not all aircraft covering systems include the use of dope coating processes. Modern aircraft covering systems that include the use of nondope fabric treatments show no signs of deterioration even after decades of service. In this chapter, various fabrics and treatment systems are discussed, as well as basic covering techniques.

## Fabric Terms

To facilitate the discussion of fabric coverings for aircraft, the following definitions are presented. *Figure 3-2* illustrates some of these items.

- Warp—the direction along the length of fabric.
- Fill or weave—the direction across the width of the fabric.
- Count—the number of threads per inch in warp or filling.
- Ply—the number of yarns making up a thread.
- Bias—a cut, fold, or seam made diagonally to the warp or fill threads.
- Pinked edge—an edge which has been cut by machine or special pinking shears in a continuous series of Vs to prevent raveling.
- Selvage edge—the edge of cloth, tape, or webbing woven to prevent raveling.
- Greige—condition of polyester fabric upon completion of the production process before being heat shrunk.
- Cross-coat—brushing or spraying where the second coat is applied 90° to the direction the first coat was applied. The two coats together make a single cross coat. *[Figure 3-3]*

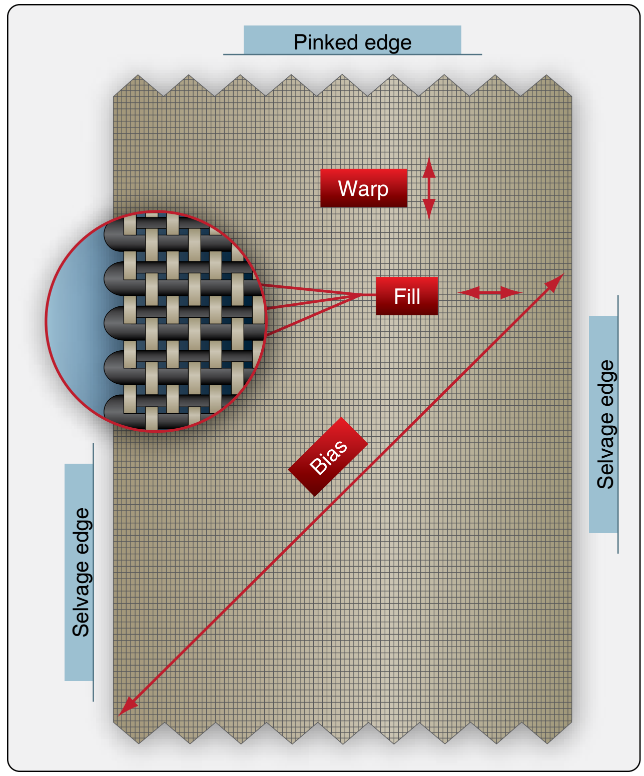



**Figure 3-2.** *Aircraft fabric nomenclature.*

## Legal Aspects of Fabric Covering

When a fabric-covered aircraft is certificated, the aircraft manufacturer uses materials and techniques to cover the aircraft that are approved under the type certificate issued for that aircraft. The same materials and techniques must be used by maintenance personnel when replacing the aircraft fabric. Descriptions of these materials and techniques are in the manufacturer's service manual. For example, aircraft originally manufactured with cotton fabric can only be re-covered with cotton fabric unless the Federal Aviation Administration (FAA) approves an exception. Approved exceptions for alternate fabric-covering materials and procedures are common. Since polyester fabric coverings deliver performance advantages, such as lighter weight, longer life, additional strength, and lower cost, many older aircraft originally manufactured with cotton fabric have received approved alteration authority and have been re-covered with polyester fabric.

There are three ways to gain FAA approval to re-cover an aircraft with materials and processes other than those with which it was originally certificated. One is to do the work in accordance with an approved supplemental type certificate (STC). The STC must specify that it is for the particular aircraft model in question. It states in detail exactly what alternate materials must be used and what procedure(s) must be followed. Deviation from the STC data in any way renders

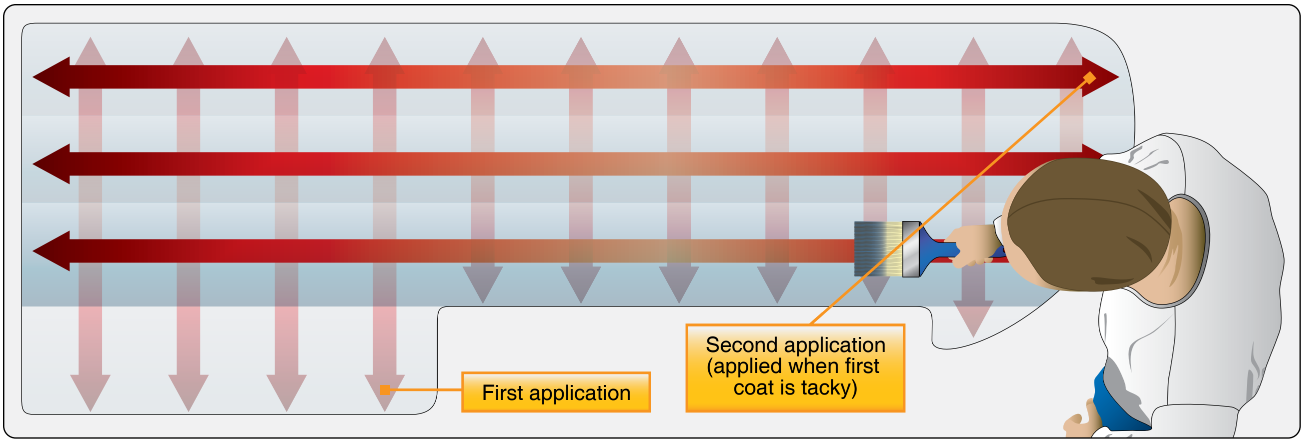



**Figure 3-3.** *A single cross coat is made up of two coats of paint applied 90° to each other.*

the aircraft unairworthy. The holder of the STC typically sells the materials and the use of the STC to the person wishing to re-cover the aircraft.

The second way to gain approval to re-cover an aircraft with different materials and processes is with a field approval. A field approval is a one-time approval issued by the FAA Flight Standards District Office (FSDO) permitting the materials and procedures requested to replace those of the original manufacturer. A field approval request is made on FAA Form 337. A thorough description of the materials and processes must be submitted with proof that, when the alteration is completed, the aircraft meets or exceeds the performance parameters set forth by the original type certificate.

The third way is for a manufacturer to secure approval through the Type Certificate Data Sheet (TCDS) for a new process. For example, Piper Aircraft Co. originally covered their PA-18s in cotton. Later, they secured approval to recover their aircraft with Dacron fabric. Recovering an older PA-18 with Dacron in accordance with the TCDS would be a major repair, but not an alteration as the TCDS holder has current approval for the fabric.

Advisory Circular (AC) 43.13-1, Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair, contains acceptable practices for covering aircraft with fabric. It is a valuable source of general and specific information on fabric and fabric repair that can be used on Form 337 to justify procedures requested for a field approval. Submitting an FAA Form 337 does not guarantee a requested field approval. The FSDO inspector considers all aspects of the procedures and their effect(s) on the aircraft for which the request is being filed. Additional data may be required for approval.

Title 14 of the Code of Federal Regulations (14 CFR) part 43, Appendix A, states which maintenance actions are considered major repairs and which actions are considered major alterations. Fabric re-covering is considered a major repair and FAA Form 337 is executed whenever an aircraft is re-covered with fabric. Appendix A also states that changing parts of an aircraft wing, tail surface, or fuselage when not listed in the aircraft specifications issued by the FAA is a major alteration. This means that replacing cotton fabric with polyester fabric is a major alteration. A properly executed FAA Form 337 also needs to be approved in order for this alteration to be legal.

FAA Form 337, which satisfies the documentation requirements for major fabric repairs and alterations, requires participation of an FAA-certificated Airframe and Powerplant (A&P) mechanic with an Inspection Authorization (IA) in the re-covering process. Often the work involved in re-covering a fabric aircraft is performed by someone else, but under the supervision of the IA (IA certification requires A&P certification). This typically means the IA inspects the aircraft structure and the re-cover job at various stages to be sure STC or field approval specifications are being followed. The signatures of the IA and the FSDO inspector are required on the approved FAA Form 337. The aircraft logbook also must be signed by the FAA-certificated A&P mechanic. It is important to contact the local FSDO before making any major repair or alteration.

## Approved Materials

There are a variety of approved materials used in aircraft fabric covering and repair processes. In order for the items to legally be used, the FAA must approve the fabric, tapes, threads, cords, glues, dopes, sealants, coatings, thinners, additives, fungicides, rejuvenators, and paints for the manufacturer, the holder of an STC, or a field approval.

### Fabric

A Technical Standard Order (TSO) is a minimum performance standard issued by the FAA for specified materials, parts, processes, and appliances used on civil aircraft. For example, TSO-C15d, Aircraft Fabric, Grade A, prescribes the minimum performance standards that approved aircraft fabric must meet. Fabric that meets or exceeds the TSO can be used as a covering. Fabric approved to replace Grade-A cotton, such as polyester, must meet the same criteria. TSO-C15d also refers to another document, Society of Automotive Engineers (SAE) Aerospace Material Specification (AMS) 3806D, which details properties a fabric must contain to be an approved fabric for airplane cloth. Lighter weight fabrics typically adhere to the specifications in TSO-C14b, which refers to SAE AMS 3804C.

When a company is approved to manufacture or sell an approved aviation fabric, it applies for and receives a Parts Manufacturer Approval (PMA). Currently, only a few approved fabrics are used for aircraft coverings, such as the polyester fabrics Ceconite™, Stits/Polyfiber™, and Superflite™. These fabrics and some of their characteristics are shown in *Figure 3-4*. The holders of the PMA for these fabrics have also developed and gained approval for the various tapes, chords, threads, and liquids that are used in the covering process. These approved materials, along with the procedures for using them, constitute the STCs for each particular fabric covering process. Only the approved materials can be used. Substitution of other materials is forbidden and results in the aircraft being unairworthy.

## Other Fabric Covering Materials

The following is an introduction to the supplemental materials used to complete a fabric covering job per manufacturer's instruction or a STC.

### *Anti-Chafe Tape*

Anti-chafe tape is used on sharp protrusions, rib caps, metal seams, and other areas to provide a smoother surface to keep the fabric from being torn. It is usually self-adhesive cloth tape and is applied after the aircraft is cleaned, inspected, and primed, but before the fabric is installed.

### *Reinforcing Tape*

Reinforcing tape is most commonly used on rib caps after the fabric covering is installed to protect and strengthen the area for attaching the fabric to the ribs.

### *Rib Bracing*

Rib bracing tape is used on wing ribs before the fabric is installed. It is applied spanwise and alternately wrapped around a top rib cap and then a bottom rib cap progressing from rib to rib until all are braced. *[Figure 3-5]* Lacing the ribs in this manner holds them in the proper place and alignment during the covering process.

### *Surface Tape*

Surface tape, made of polyester material and often pre-shrunk, is obtained from the STC holder. This tape, also known as finishing tape, is applied after the fabric is installed. It is used over seams, ribs, patches, and edges. Surface tape can have straight or pinked edges and comes in various widths. For curved surfaces, bias cut tape is available, which allows the tape to be shaped around a radius.

| Approved Aircraft Fabrics | | | | | |
|---|---|---|---|---|---|
| **Fabric Name or Type** | **Weight (oz/sq yd)** | **Count (warp x fill)** | **New Breaking Strength (lb) (warp, fill)** | **Minimum Deteriorated Breaking Strength** | **TSO** |
| Ceconite™ 101 | 3.5 | 69 x 63 | 125,116 | 70% of original specified fabric | C-15d |
| Ceconite™ 102 | 3.16 | 60 x 60 | 106,113 | 70% of original specified fabric | C-15d |
| | | | | | |
| Polyfiber™ Heavy Duty-3 | 3.5 | 69 x 63 | 125,116 | 70% of original specified fabric | C-15d |
| Polyfiber™ Medium-3 | 3.16 | 60 x 60 | 106,113 | 70% of original specified fabric | C-15d |
| Polyfiber™ Uncertified Light | 1.87 | 90 x 76 | 66,72 | uncertified | |
| | | | | | |
| Superflight™ SF 101 | 3.7 | 70 x 51 | 80,130 | 70% of original specified fabric | C-15d |
| Superflight™ SF 102 | 2.7 | 72 x 64 | 90,90 | 70% of original specified fabric | C-15d |
| Superflight™ SF 104 | 1.8 | 94 x 91 | 75,55 | uncertified | |
| Grade A Cotton | 4.5 | 80 x 84 | 80,80 | 56 lb/in (70% of New) | C-15d |

**Figure 3-4.** *Approved fabrics for covering aircraft.*

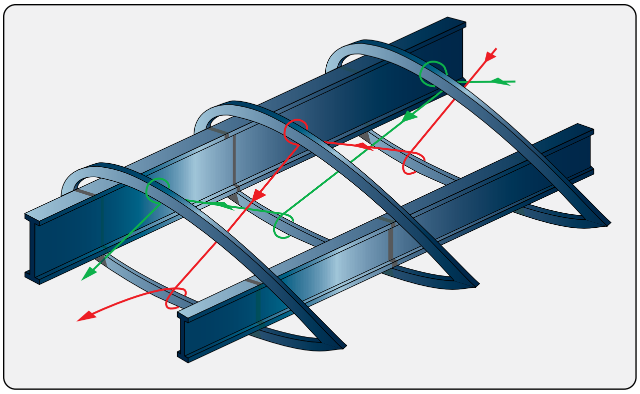


**Figure 3-5.** *Inter-rib bracing holds the ribs in place during the covering process.*

### *Rib Lacing Cord*

Rib lacing cord is used to lace the fabric to the wing ribs. It must be strong and applied as directed to safely transfer in-flight loads from the fabric to the ribs. Rib lacing cord is available in a round or flat cross-section. The round cord is easier to use than the flat lacing, but if installed properly, the flat lacing results in a smoother finish over the ribs.

### *Sewing Thread*

Sewing of polyester fabric is rare and mostly limited to the creation of prefitted envelopes used in the envelope method covering process. When a fabric seam must be made with no structure underneath it, a sewn seam could be used. Polyester threads of various specifications are used on polyester fabric. Different thread is specified for hand sewing versus machine sewing. For hand sewing, the thread is typically a three-ply, uncoated polyester thread with a 15-pound tensile strength. Machine thread is typically four-ply polyester with a 10-pound tensile strength.

### *Special Fabric Fasteners*

Each fabric covering job involves a method of attaching the fabric to wing and empennage ribs. The original manufacturer's method of fastening should be used. In addition to lacing the fabric to the ribs with approved rib lacing cord, special clips, screws, and rivets are employed on some aircraft. *[Figure 3-6]* The first step in using any of these fasteners is to inspect the holes into which they fit. Worn holes may have to be enlarged or re-drilled according to the manufacturer's instructions. Use of approved fasteners is mandatory. Use of unapproved fasteners can render the covering job unairworthy if substituted. Screws and rivets often incorporate the use of a plastic or aluminum washer. All fasteners and rib lacing are covered with finishing tape once installed to provide a smooth finish and airflow.

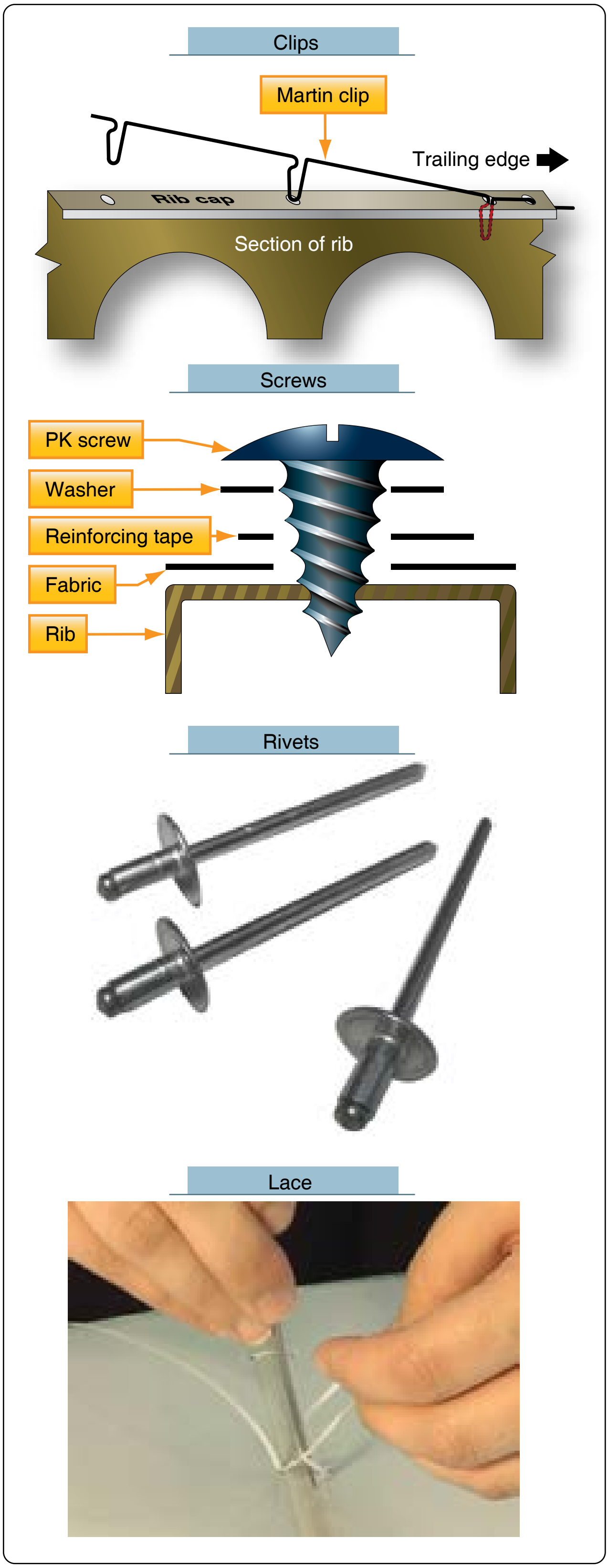



**Figure 3-6.** *Clips, screws, rivets, or lace are used to attach the fabric to wing and empennage ribs.*

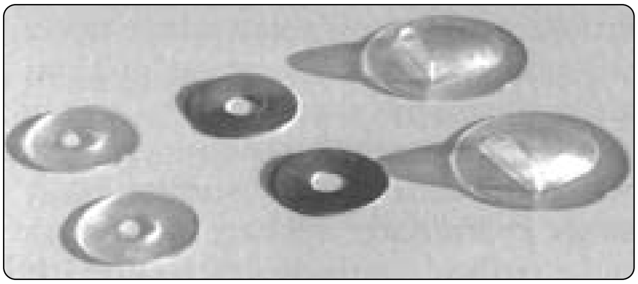


**Figure 3-7.** *Plastic, aluminum, and seaplane grommets are used to reinforce drain holes in the fabric covering.*

### *Grommets*

Grommets are used to create reinforced drain holes in the aircraft fabric. Usually made of aluminum or plastic, they are glued or doped into place on the fabric surface. Once secured, a hole is created in the fabric through the center of the grommet. Often, this is done with a hot soldering pencil that also heat seals the fabric edge to prevent raveling. Seaplane grommets have a shield over the drain hole to prevent splashed water from entering the interior of the covered structure and to assist in siphoning out any water from within. *[Figure 3-7]* Drain holes using these grommets must be made before the grommets are put in place. Note that some drain holes do not require grommets if they are made through two layers of fabric.

### *Inspection Rings*

The structure underneath an aircraft covering must be inspected periodically. To facilitate this in fabric-covered aircraft, inspection rings are glued or doped to the fabric. They provide a stable rim around an area of fabric that can be cut to allow viewing of the structure underneath. The fabric remains uncut until an inspection is desired. The rings are typically plastic or aluminum with an approximately three-inch inside diameter. Spring clip metal panel covers can be fitted to close the area once the fabric inside the inspection ring has been cut for access. *[Figure 3-8]* The location of the inspection rings are specified by the manufacturer. Additional rings are sometimes added to permit access to important areas that may not have been fitted originally with inspection access.

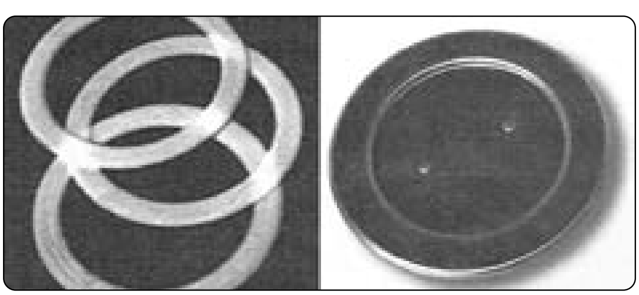


**Figure 3-8.** *Inspection rings and an inspection cover.*

### *Primer*

The airframe structure of a fabric covered aircraft must be cleaned, inspected, and prepared before the fabric covering process begins. The final preparation procedure involves priming the structure with a treatment that works with the adhesive and first coats of fabric sealant that are to be utilized. Each STC specifies which primers, or if a wood structure, which varnishes are suitable. Most often, two-part epoxy primers are used on metal structure and two-part epoxy varnishes are used on wood structure. Utilize the primer specified by the manufacturer's or STC's instructions.

### *Fabric Cement*

Modern fabric covering systems utilize special fabric cement to attach the fabric to the airframe. There are various types of cement. *[Figure 3-9]* In addition to good adhesion qualities, flexibility, and long life, fabric cements must be compatible with the primer and the fabric sealer that are applied before and after the cement.

### *Fabric Sealer*

Fabric sealer surrounds the fibers in the fabric with a protective coating to provide adhesion and keep out dirt and moisture. The sealer is the first coat applied to the polyester fabric after it is attached to the airframe and heat shrunk to fit snugly. Dope-based fabric coating systems utilize non-tautening nitrate dope as the primary fabric sealant. The application of tautening dope may cause the fabric to become too taut resulting in excess stress on the airframe that could damage it. Nondope coating systems use proprietary sealers that are also nontautening. *[Figure 3-9]*

### *Fillers*

After the fabric sealer is applied, a filler is used. It is sprayed on in a number of cross coats as required by the manufacturer or the fabric covering process STC. The filler contains solids or chemicals that are included to block UV light from reaching the fabric. Proper fill coating is critical because UV light is the single most destructive element that causes polyester fabric to deteriorate. Dope-based processes use butyrate dope fillers while other processes have their own proprietary formulas. When fillers and sealers are combined, they are known as fabric primers. Aluminum pastes and powders, formerly added to butyrate dope to provide the UV protection, have been replaced by premixed formulas.

### *Topcoats*

Once the aircraft fabric has been installed, sealed, and fill-coat protected, finishing or topcoats are applied to give the aircraft its final appearance. Colored butyrate dope is common in dope-based processes, but various polyurethane topcoats are also available. It is important to use the topcoat

| Aircraft Covering Systems | | | | | | | |
|---|---|---|---|---|---|---|---|
| APPROVED PROPRIETARY PRODUCT NAME | | | | | | | |
| Covering System | STC # | Allowable Fabrics | Base | Cement | Filler | UV Block | Topcoats |
| Air-Tech | SA7965SW | Ceconite™<br>Poly-Fiber™<br>Superflite™ | Urethane | UA-55 | PFU 1020<br>PFU 1030 | PFU 1020<br>PFU 1030 | CHSM Color Coat |
| | | | Water | | PFUW 1050 | PFUW 1050 | |
| Ceconite™/ Randolph System | SA4503NM | Ceconite™ | Dope | New Super Seam | Nitrate Dope | Rand-O-Fill | Colored Butyrate Dope<br>Ranthane Polyurethane |
| Stits/Poly-Fiber™ | SA1008WE | Poly-Fiber™ | Vinyl | Poly-tak | Poly-brush | Poly-spray | Vinyl Poly-tone, Aero-Thane, or Ranthane Polyurethane |
| Stewart System | SA01734SE | Ceconite™<br>Poly-Fiber™ | Water-borne | EkoBond | EkoFill | EkoFIll | EkoPoly |
| Superflite™<br>• System1<br>• System VI | SA00478CH and others | Superflite™ 101,102 | Dope | U-500 | Dacproofer | SrayFil | Tinted Butyrate Dope |
| | | Superflite™ 101,102 | Urethane | U-500 | SF6500 | SF6500 | Superflite™ CAB |

**Figure 3-9.** *Examples of FAA-approved fabric covering processes.*

products and procedures specified in the applicable STC to complete an airworthy fabric re-covering job.

The use of various additives is common at different stages when utilizing the above products. The following is a short list of additional products that facilitate the proper application of the fabric coatings. Note again that only products approved under a particular STC can be used. Substitution of similar products, even though they perform the same basic function, is not allowed.

- A catalyst accelerates a chemical reaction. Catalysts are specifically designed for each product with which they are mixed. They are commonly used with epoxies and polyurethanes.
- A thinner is a solvent or mixture of solvents added to a product to give it the proper consistency for application, such as when spraying or brushing.
- A retarder is added to a product to slow drying time. Used mostly in dope processes and topcoats, a retarder allow more time for a sprayed coating to flow and level, resulting in a deeper, glossier finish. It is used when the working temperature is elevated slightly above the ideal temperature for a product. It also can be used to prevent blushing of a dope finish when high humidity conditions exist.
- An accelerators contains solvents that speed up the drying time of the product with which it is mixed. It is typically used when the application working temperature is below that of the ideal working temperature. It can also be used for faster drying when airborne contaminants threaten a coating finish.
- Rejuvenator, used on dope finishes only, contains solvents that soften coatings and allow them to flow slightly. Rejuvenator also contains fresh plasticizers that mix into the original coatings. This increases the overall flexibility and life of the coatings.
- Fungicide and mildewicide additives are important for organic fabric covered aircraft because fabrics, such as cotton and linen, are hosts for fungus and mildew. Since fungus and mildew are not concerns when using polyester fabric, these additives are not required. Modern coating formulas contain premixed anti-fungal agents, providing sufficient insurance against the problem of fungus or mildew.

## Available Covering Processes

The covering processes that utilize polyester fabric are the primary focus of this chapter. Examples of FAA-approved aircraft covering processes are listed in *Figure 3-9*. The processes can be distinguished by the chemical nature of the glue and coatings that are used. A dope-based covering process has been refined out of the cotton fabric era, with excellent results on polyester fabric. In particular, plasticizers added to the nitrate and butyrate dopes minimize the shrinking and tautening effects of the dope, establish flexibility, and allow esthetically pleasing tinted butyrate dope finishes that last indefinitely. Durable polyurethane-based processes integrate well with durable polyurethane topcoat finishes. Vinyl is the key ingredient in the popular Poly-Fiber covering system. Air Tech uses an acetone thinned polyurethane compatible system.

The most recent entry into the covering systems market is the Stewart Finishing System that uses waterborne technology to apply polyurethane coatings to the fabric. The glue used in the system is water-based and nonvolatile. The Stewart Finishing System is Environmental Protection Agency (EPA) compliant and STC approved. Both the Stewart and Air Tech systems operate with any of the approved polyester fabrics as stated in their covering system STCs.

All the modern fabric covering systems listed in *Figure 3-9* result in a polyester fabric covered aircraft with an indefinite service life. Individual preferences exist for working with the different approved processes. A description of basic covering procedures and techniques common to most of these systems follows later in this chapter.

Ceconite™, Polyfiber™, and Superflight™ are STC-approved fabrics with processes used to install polyester fabric coverings. Two companies that do not manufacturer their own fabric have gained STC approval for covering accessories and procedures to be used with these approved fabrics. The STCs specify the fabrics and the proprietary materials that are required to legally complete the re-covering job.

The aircraft fabric covering process is a three-step process. First, select an approved fabric. Second, follow the applicable STC steps to attach the fabric to the airframe and to protect it from the elements. Third, apply the approved topcoat to give the aircraft its color scheme and final appearance.

Although Grade-A cotton can be used on all aircraft originally certificated to be covered with this material, approved aircraft cotton fabric is no longer available. Additionally, due to the shortcomings of cotton fabric coverings, most of these aircraft have been re-covered with polyester fabric. In the rare instance the technician encounters a cotton fabric covered aircraft that is still airworthy, inspection and repair procedures specified in AC 43.13-1, Chapter 2, Fabric Covering, should be followed.

## Determining Fabric Condition—Repair or Recover?

Re-covering an aircraft with fabric is a major repair and should only be undertaken when necessary. Often a repair to the present fabric is sufficient to keep the aircraft airworthy. The original manufacturer's recommendations or the covering process STC should be consulted for the type of repair required for the damage incurred by the fabric covering. AC 43.13-1 also gives guidelines and acceptable practices for repairing cotton fabric, specifically when stitching is concerned.

Often a large area that needs repair is judged in reference to the overall remaining lifespan of the fabric on the aircraft. For example, if the fabric has reached the limit of its durability, it is better to re-cover the entire aircraft than to replace a large damaged area when the remainder of the aircraft would soon need to be re-covered.

On aircraft with dope-based covering systems, continued shrinkage of the dope can cause the fabric to become too tight. Overly tight fabric may require the aircraft to be re-covered rather than repaired because excess tension on fabric can cause airframe structural damage. Loose fabric flaps in the wind during flight, affecting weight distribution and unduly stressing the airframe. It may also need to be replaced because of damage to the airframe.

Another reason to re-cover rather than repair occurs when dope coatings on fabric develop cracks. These cracks could expose the fabric beneath to the elements that can weaken it. Close observation and field testing must be used to determine if the fabrics are airworthy. If not, the aircraft must be re-covered. If the fabric is airworthy and no other problems exist, a rejuvenator can be used per manufacturer's instructions. This product is usually sprayed on and softens the coatings with very powerful solvents. Plasticizers in the rejuvenator become part of the film that fills in the cracks. After the rejuvenator dries, additional coats of aluminum-pigmented dope must be added and then final topcoats applied to finish the job. While laborious, rejuvenating a dope finish over strong fabric can save a great deal of time and money. Polyurethane-based finishes cannot be rejuvenated.

## Fabric Strength

Deterioration of the strength of the present fabric covering is the most common reason to re-cover an aircraft. The strength of fabric coverings must be determined at every 100-hour and annual inspection. Minimum fabric breaking strength is used to determine if an aircraft requires re-covering.

Fabric strength is a major factor in the airworthiness of an aircraft. Fabric is considered to be airworthy until it deteriorates to a breaking strength less than 70 percent of the strength of the new fabric required for the aircraft. For example, if an aircraft was certificated with Grade-A cotton fabric that has a new breaking strength of 80 pounds, it becomes unairworthy when the fabric strength falls to 56 pounds, which is 70 percent of 80 pounds. If polyester fabric, which has a higher new breaking strength, is used to re-cover this same aircraft, it would also need to exceed 56 pounds breaking strength to remain airworthy.

In general, an aircraft is certified with a certain fabric based on its wing loading and its never exceed speed ($V_{NE}$). The higher the wing loading and $V_{NE}$, the stronger the fabric must be. On aircraft with wing loading of 9 pounds per square foot and over, or a $V_{NE}$ of 160 miles per hour (mph) or higher, fabric equaling or exceeding the strength of Grade A cotton is required. This means the new fabric breaking strength must be at least 80 pounds and the minimum fabric breaking strength at which the aircraft becomes unairworthy is 56 pounds.

On aircraft with wing loading of 9 pounds per square foot or less, or a $V_{NE}$ of 160 mph or less, fabric equaling or exceeding the strength of intermediate grade cotton is required. This means the new fabric breaking strength must be at least 65 pounds and the minimum fabric breaking strength at which the aircraft becomes unairworthy is 46 pounds.

Lighter weight fabric may be found to have been certified on gliders or sailplanes and may be used on many uncertificated aircraft or aircraft in the Light Sport Aircraft (LSA) category. For aircraft with wing loading less than 8 pounds per square foot or less, or $V_{NE}$ of 135 mph or less, the fabric is considered unairworthy when the breaking strength has deteriorated to below 35 pounds (new minimum strength of 50 pounds). *Figure 3-10* summarizes these parameters.

### How Fabric Breaking Strength is Determined

Manufacturer's instructions should always be consulted first for fabric strength inspection methodology. These instructions are approved data and may not require removal of a test strip to determine airworthiness of the fabric. In some cases, the manufacturer's information does not include any fabric inspection methods. It may refer the IA to AC 43.13-1, Chapter 2, Fabric Covering, which contains the approved FAA test strip method for breaking strength.

The test strip method for the breaking strength of aircraft covering fabrics uses standards published by the American Society for Testing and Materials (ASTM) for the testing of various materials. Breaking strength is determined by cutting a 1¼ inch by 4–6 inch strip of fabric from the aircraft covering. This sample should be taken from an area that is exposed to the elements—usually an upper surface. It is also wise to take the sample from an area that has a dark colored finish since this has absorbed more of the sun's UV rays and degraded faster. All coatings are then removed and the edges raveled to leave a 1-inch width. One end of the strip is clamped into a secured clamp and the other end is clamped such that a suitable container may be suspended from it. Weight is added to the container until the fabric breaks. The breaking strength of the fabric is equal to the weight of the lower clamp, the container, and the weight added to it. If the breaking strength is still in question, a sample should be sent to a qualified testing laboratory and breaking strength tests made in accordance with ASTM publication D5035.

Note that the fabric test strip must have all coatings removed from it for the test. Soaking and cleaning the test strip in methyl ethyl ketone (MEK) usually removes all the coatings.

Properly installed and maintained polyester fabric should give years of service before appreciable fabric strength degradation occurs. Aircraft owners often prefer not to have test strips cut out of the fabric, especially when the aircraft or the fabric covering is relatively new, because removal of a test strip damages the integrity of an airworthy

| Fabric Performance Criteria | | | | |
|---|---|---|---|---|
| IF YOUR PERFORMANCE IS. . . | | FABRIC STRENGTH MUST BE. . . | | |
| Loading | $V_{NE}$ Speed | Type | New Breaking Strength | Minimum Breaking Strength |
| > 9 lb/sq ft | > 160 mph | ≥ Grade A | > 80 lb | > 56 |
| < 9 lb/sq ft | < 160 mph | ≥ Intermediate | > 65 lb | > 46 |
| < 8 lb/sq ft | < 135 mph | ≥Lightweight | > 50 lb | > 35 |

**Figure 3-10.** *Aircraft performance affects fabric selection.*

component if the fabric passes. The test strip area then must be repaired, costing time and money. To avoid cutting a strip out of airworthy fabric, the IA makes a decision based on knowledge, experience, and available nondestructive techniques as to whether removal of a test strip is warranted to ensure that the aircraft can be returned to service.

An aircraft made airworthy under an STC is subject to the instructions for continued airworthiness in that STC. Most STCs refer to AC 43.13-1 for inspection methodology. Poly-Fiber™ and Ceconite™ re-covering process STCs contain their own instructions and techniques for determining fabric strength and airworthiness. Therefore, an aircraft covered under those STCs may be inspected in accordance with this information. In most cases, the aircraft can be approved for return to service without cutting a strip from the fabric covering.

The procedures in the Poly-Fiber™ and Ceconite™ STCs outlined in the following paragraphs are useful when inspecting any fabric covered aircraft as they add to the information gathered by the IA to determine the condition of the fabric. However, following these procedures alone on aircraft not re-covered under these STCs does not make the aircraft airworthy. The IA must add their own knowledge, experience, and judgment to make a final determination of the strength of the fabric and whether it is airworthy.

Exposure to UV radiation appreciably reduces the strength of polyester fabric and forms the basis of the Poly-Fiber™ and Ceconite™ fabric evaluation process. All approved covering systems utilize fill coats applied to the fabric to protect it from UV. If installed according to the STC, these coatings should be sufficient to protect the fabric from the sun and should last indefinitely. Therefore, most of the evaluation of the strength of the fabric is actually an evaluation of the condition of its protective coating(s).

Upon a close visual inspection, the fabric coating(s) should be consistent, contain no cracks, and be flexible, not brittle. Pushing hard against the fabric with a knuckle should not damage the coating(s). It is recommended the inspector check in several areas, especially those most exposed to the sun. Coatings that pass this test can move to a simple test that determines whether or not UV light is passing through the coatings.

This test is based on the assumption that if visible light passes through the fabric coatings, then UV light can also. To verify whether or not visible light passes through the fabric coating, remove an inspection panel from the wing, fuselage, or empennage. Have someone hold an illuminated 60-watt lamp one foot away from the exterior of the fabric. No light should be visible through the fabric. If no light is visible, the fabric has not been weakened by UV rays and can be assumed to be airworthy. There is no need to perform the fabric strip strength test. If light is visible through the coatings, further investigation is required.

### Fabric Testing Devices

Mechanical devices used to test fabric by pressing against or piercing the finished fabric are not FAA approved and are used at the discretion of the FAA-certificated mechanic to form an opinion on the general fabric condition. Punch test accuracy depends on the individual device calibration, total coating thickness, brittleness, and types of coatings and fabric. If the fabric tests in the lower breaking strength range with the mechanical punch tester or if the overall fabric cover conditions are poor, then more accurate field tests may be made.

The test should be performed on exposed fabric where there is a crack or chip in the coatings. If there is no crack or chip, coatings should be removed to expose the fabric wherever the test is to be done.

The Maule punch tester, a spring-loaded device with its scale calibrated in breaking strength, tests fabric strength by pressing against it while the fabric is still on the aircraft. It roughly equates strength in pounds per square inch (psi) of resistance to breaking strength. The tester is pushed squarely against the fabric until the scale reads the amount of maximum allowable degradation. If the tester does not puncture the fabric, it may be considered airworthy. Punctures near the breaking strength should be followed with further testing, specifically the strip breaking strength test described above. Usually, a puncture indicates the fabric is in need of replacement.

A second type of punch tester, the Seyboth, is not as popular as the Maule because it punctures a small hole in the fabric when the mechanic pushes the shoulder of the testing unit against the fabric. A pin with a color-coded calibrated scale protrudes from the top of the tester and the mechanic reads this scale to determine fabric strength. Since this device requires a repair regardless of the strength of the fabric indicated, it is not widely used.

Seyboth and Maule fabric strength testers designed for cotton- and linen-covered aircraft, not to be used on modern Dacron fabrics. Mechanical devices, combined with other information and experience, help the FAA-certificated mechanic judge the strength of the fabric. *[Figure 3-11]*

## General Fabric Covering Process

It is required to have an IA involved in the process of re-covering a fabric aircraft because re-covering is a major repair

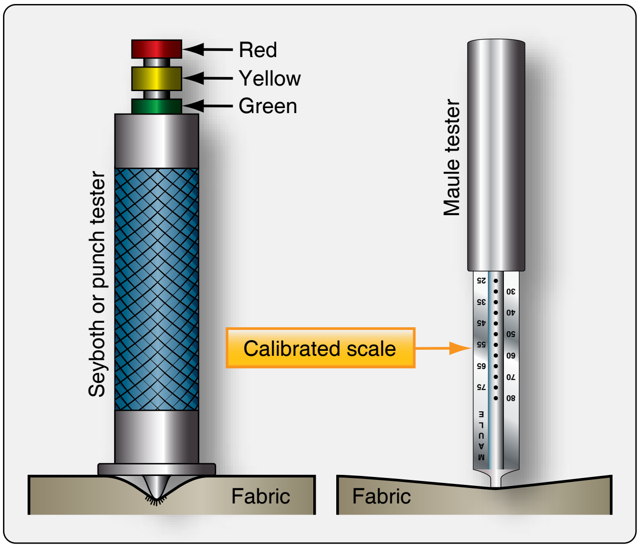



**Figure 3-11.** *Seyboth and Maule fabric strength testers.*

or major alteration. Signatures are required on FAA Form 337 and in the aircraft logbook. To ensure work progresses as required, the IA should be involved from the beginning, as well as at various stages throughout the process.

This section describes steps common to various STC and manufacturer covering processes, as well as the differences of some processes. To aid in proper performance of fabric covering and repair procedures, STC holders produce illustrated, step-by-step instructional manuals and videos that demonstrate the correct covering procedures. These training aids are invaluable to the inexperienced technician.

Since modern fabric coverings last indefinitely, a rare opportunity to inspect the aircraft exists during the re-covering process. Inspectors and owner-operators should use this opportunity to perform a thorough inspection of the aircraft before new fabric is installed.

The method of fabric attachment should be identical, as far as strength and reliability are concerned, to the method used by the manufacturer of the aircraft being recovered or repaired. Carefully remove the old fabric from the airframe, noting the location of inspection covers, drain grommets, and method of attachment. Either the envelope method or blanket method of fabric covering is acceptable, but a choice must be made prior to beginning the re-covering process.

### Blanket Method vs. Envelope Method

In the blanket method of re-covering, multiple flat sections of fabric are trimmed and attached to the airframe. Certified greige polyester fabric for covering an aircraft can be up to 70 inches in width and used as it comes off the bolt. Each aircraft must be considered individually to determine the

**Figure 3-12.** *Laying out fabric during a blanket method re-covering job.*

size and layout of blankets needed to cover it. A single blanket cut for each small surface (i.e., stabilizers and control surfaces) is common. Wings may require two blankets that overlap. Fuselages are covered with multiple blankets that span between major structural members, often with a single blanket for the bottom. Very large wings may require more than two blankets of fabric to cover the entire top and bottom surfaces. In all cases, the fabric is adhered to the airframe using the approved adhesives, following specific rules for the covering process being employed. *[Figure 3-12]*

An alternative method of re-covering, the envelope method, saves time by using precut and pre-sewn envelopes of fabric to cover the aircraft. The envelopes must be sewn with approved machine sewing thread, edge distance, fabric fold, etc., such as those specified in AC 43.13-1 or an STC. Patterns are made and fabric is cut and stitched so that each major surface, including the fuselage and wings, can be covered with a single, close-fitting envelope. Since envelopes are cut to fit, they are slid into position, oriented with the seams in the proper place, and attached with adhesive to the airframe. Envelope seams are usually located over airframe structure in inconspicuous places, such as the trailing edge structures and the very top and bottom of the fuselage, depending on airframe construction. Follow the manufacturer's or STC's instructions for proper location of the sewn seams of the envelope when using this method. *[Figure 3-13]*

### Preparation for Fabric Covering Work

Proper preparation for re-covering a fabric aircraft is essential. First, assemble the materials and tools required to complete the job. The holder of the STC usually supplies a materials and tools list either separately or in the STC manual. Control of temperature, humidity, and ventilation is needed in the work environment. If ideal environmental conditions cannot be met, additives are available that compensate for this for most re-covering products.

Rotating work stands for the fuselage and wings provide

**Figure 3-13.** *A custom-fit presewn fabric envelope is slid into position over a fuselage for the envelope method of fabric covering. Other than fitting, most steps in the covering process are the same as with the blanket covering method.*

easy, alternating access to the upper and lower surfaces while the job is in progress. *[Figure 3-14]* They can be used with sawhorses or sawhorses can be used alone to support the aircraft structure while working. A workbench or table, as well as a rolling cart and storage cabinet, are also recommended. *Figure 3-15* shows a well conceived fabric covering workshop. A paint spray booth for sprayed-on coatings and space to store components awaiting work is also recommended.

Many of the substances used in most re-covering processes are highly toxic. Proper protection must be used to avoid serious short- and long-term adverse health effects. Eye protection, a proper respirator, and skin protection are vital. As mentioned in the beginning of this chapter, nitrate dope is very flammable. Proper ventilation and a rated fire extinguisher should be on hand when working with this and other covering process materials. Grounding of work to prevent static electricity build-up may be required. All fabric re-covering processes also involve multiple coats of various products that are sprayed onto the fabric surface. Use of a high-volume, low-pressure (HVLP) sprayer is recommended. Good ventilation is needed for all of the processes.

### Removal of Old Fabric Coverings

Removal of the old covering is the first step in replacing an aircraft fabric covering. Cut away the old fabric from the airframe with razor blades or utility knife. Care should be taken to ensure that no damage is done to the airframe. *[Figure 3-16]* To use the old covering for templates in transferring the location of inspection panels, cable guides, and other features to the new covering, the old covering should be removed in large sections. NOTE: any rib stitching fasteners, if used to attach the fabric to the structure, should be removed before the fabric is pulled free of the airframe. If fasteners are left in place, damage to the structure may occur during fabric removal.

### Preparation of the Airframe Before Covering

Once the old fabric has been removed, the exposed airframe structure must be thoroughly cleaned and inspected. The IA collaborating on the job should be involved in this step of the process. Details of the inspection should follow the manufacturer's guidelines, the STC, or AC 43.13-1. All of the old adhesive must be completely removed from the airframe with solvent, such as MEK. A thorough inspection must be done and various components may be selected to be removed for cleaning, inspection, and testing. Any repairs that are required, including the removal and treatment of all corrosion, must be done at this time. If the airframe is steel tubing, many technicians take the opportunity to grit blast the entire airframe at this stage.

The leading edge of a wing is a critical area where airflow

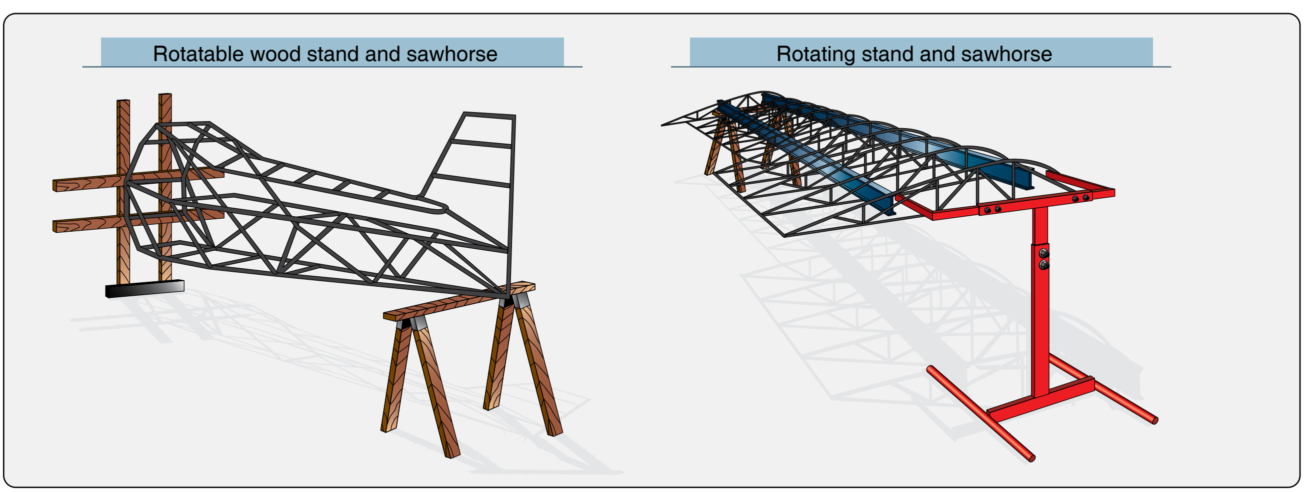



**Figure 3-14.** *Rotating stands and sawhorses facilitate easy access to top and bottom surfaces during the fabric covering process.*

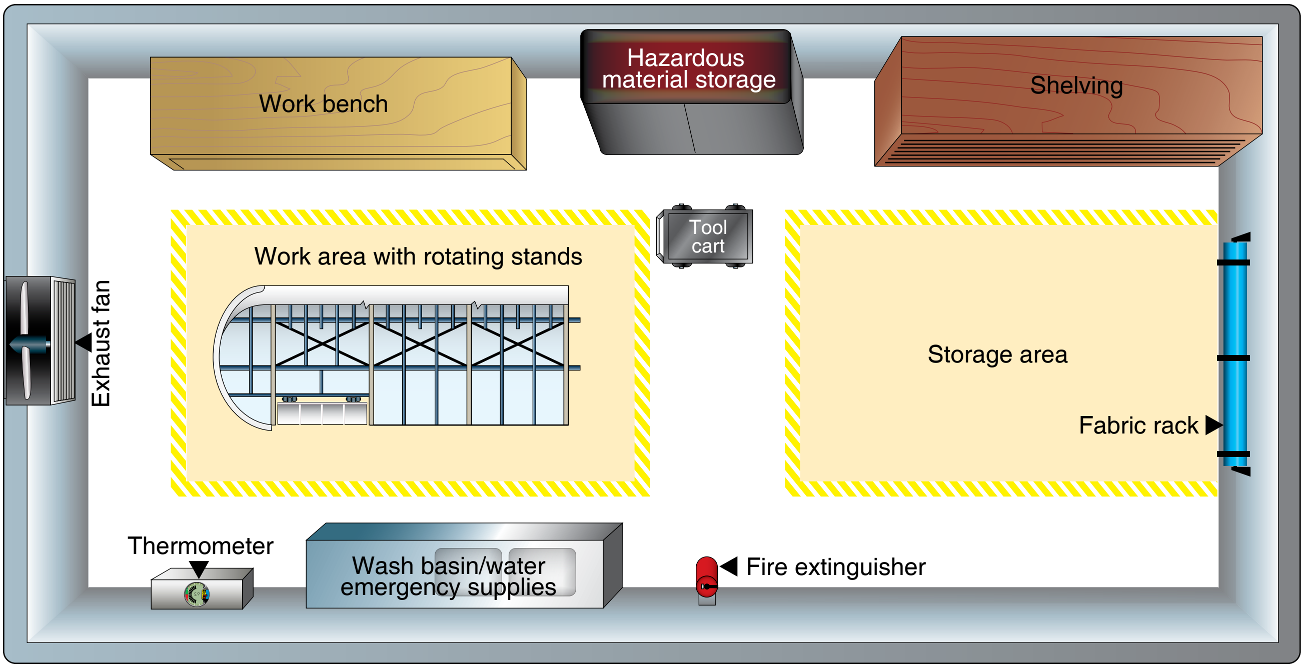



**Figure 3-15.** *Some components of a work area for covering an aircraft with fabric.*

diverges and begins its laminar flow over the wing's surfaces, which results in the generation of lift. It is beneficial to have a smooth, regular surface in this area. Plywood leading edges must be sanded until smooth, bare wood is exposed. If oil or grease spots exist, they must be cleaned with naphtha or other specified cleaners. If there are any chips, indentations, or irregularities, approved filler may be spread into these areas and sanded smooth. The entire leading edge should be cleaned before beginning the fabric covering process.

To obtain a smooth finish on fabric-covered leading edges of aluminum wings, a sheet of felt or polyester padding may be applied before the fabric is installed. This should only be done with the material specified in the STC under which

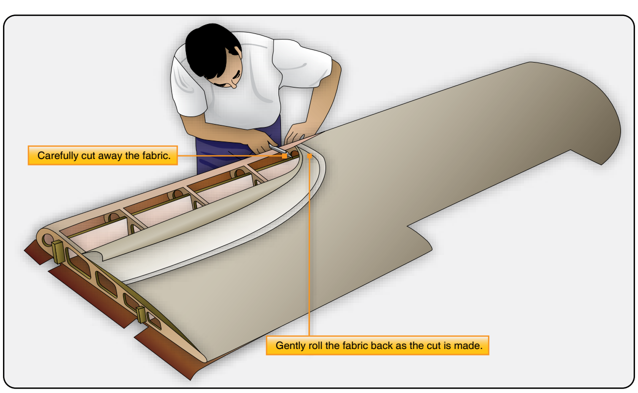



**Figure 3-16.** *Old fabric coverings are cut off in large pieces to preserve them as templates for locating various airframe features. Sharp blades and care must be used to avoid damaging the structure.*

the technician is working. The approved padding ensures compatibility with the adhesives and first coatings of the covering process. When a leading edge pad is used, check the STC process instructions for permission to make a cemented fabric seam over the padding. *[Figure 3-17]*

When completely cleaned, inspected, and repaired, an approved primer, or varnish if it is a wood structure, should be applied to the airframe. This step is sometimes referred to as dope proofing. Exposed aluminum must first be acid etched. Use the product(s) specified by the manufacturer or in the STC to prepare the metal before priming. Two part epoxy primers and varnishes, which are not affected by the fabric adhesive and subsequent coatings, are usually specified. One part primers, such as zinc chromate and spar varnish, are typically not acceptable. The chemicals in the adhesives dissolve the primers, and adhesion of the fabric to the airframe is lost.

Sharp edges, metal seams, the heads of rivets, and any other feature on the aircraft structure that might cut or wear through the fabric should be covered with anti-chafe tape. As described above, this cloth sticky-back tape is approved and should not be substituted with masking or any other kind of tape. Sometimes, rib cap strips need to have anti-chafe tape applied when the edges are not rounded over. *[Figure 3-18]*

Inter-rib bracing must also be accomplished before the fabric is installed. It normally does not have an adhesive attached to it and is wrapped only once around each rib. The single wrap

**Figure 3-17.** *The use of specified felt or padding over the wing leading edges before the fabric is installed results in a smooth regular surface.*

**Figure 3-18.** *Anti-chafe tape is applied to all features that might cut or wear through the fabric.*

around each rib is enough to hold the ribs in place during the covering process but allows small movements during the fabric shrinking process. *[Figure 3-19]*

**Figure 3-19.** *Inter-rib bracing holds the ribs in place during the re-covering process.*

### Attaching Polyester Fabric to the Airframe

Inexperienced technicians are encouraged to construct a test panel upon which they can practice with the fabric and various substances and techniques to be used on the aircraft. It is often suggested to cover smaller surfaces first, such as the empennage and control surfaces. Mistakes on these can be corrected and are less costly if they occur. The techniques employed for all surfaces, including the wings and fuselage, are basically the same. Once dexterity has been established, the order in which one proceeds is often a personal choice.

When the airframe is primed and ready for fabric installation, it must receive a final inspection by an A&P with IA. When approved, attachment of the fabric may begin. The manufacturer's or STC's instructions must be followed without deviation for the job to be airworthy. The following are the general steps taken. Each approved process has its own nuances.

#### *Seams*

During installation, the fabric is overlapped and seamed

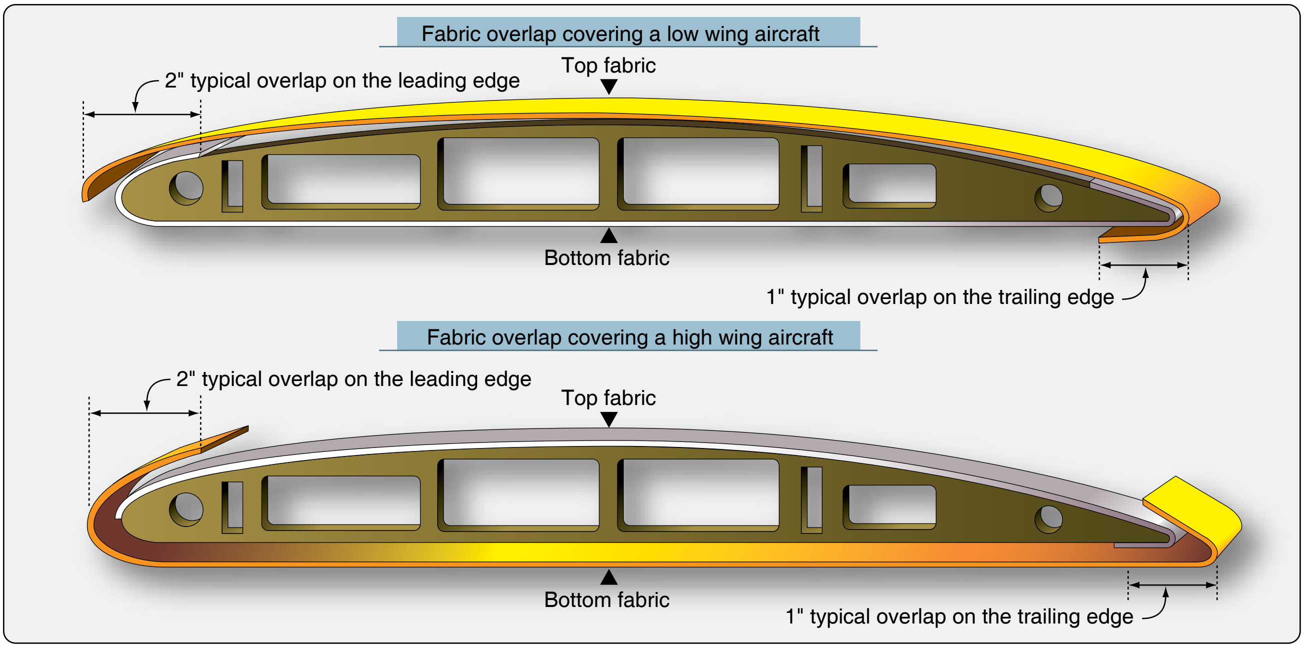



**Figure 3-20.** *For appearance, fabric can be overlapped differently on high wing and low wing aircraft.*

together. Primary concerns for fabric seams are strength, elasticity, durability, and good appearance. Whether using the blanket method or envelope method, position all fabric seams over airframe structure to which the fabric is to be adhered during the covering process, whenever possible. Unlike the blanket method, fabric seam overlap is predetermined in the envelope method. Seams sewn to the specifications in AC 43.13-1, the STC under which the work is being performed, or the manufacturer's instructions should perform adequately.

Most covering procedures for polyester fabric rely on doped or glued seams as opposed to sewn seams. They are simple and easy to make and provide excellent strength, elasticity, durability, and appearance. When using the blanket method, seam overlap is specified in the covering instructions and the FAA-certificated A&P mechanic must adhere to these specifications. Typically, a minimum of two to four inches of fabric overlap seam is required where ends of fabric are joined in areas of critical airflow, such as the leading edge of a wing. One to two inches of overlap is often the minimum in other areas.

When using the blanket method, options exist for deciding where to overlap the fabric for coverage. Function and the final appearance of the covering job should be considered. For example, fabric seams made on the wing's top surface of a high wing aircraft are not visible when approaching the aircraft. Seams on low wing aircraft and many horizontal stabilizers are usually made on the bottom of the wing for the same reason. *[Figure 3-20]*

#### *Fabric Seams*

Seams parallel to the line of flight are preferable; however, spanwise seams are acceptable.

#### *Sewn Seams*

Machine-sewn seams should be double stitched using any of the styles illustrated in *Figure 3-21* A, B, C, or D. A machine-sewn seam used to close an envelope at a wingtip, wing trailing edge, empennage and control surface trailing edge, and a fuselage longeron may be made with a single stitch when the seam will be positioned over a structure. *[Figure 3-21E]* The envelope size should accommodate fittings or other small protrusions with minimum excess for installation. Thick or protruding leading edge sewn seams should be avoided on thin airfoils with a sharp leading edge radius because they may act as a stall strip.

Hand sew, with plain overthrow or baseball stitches at a minimum of four stitches per inch, or permanent tacking, to the point where uncut fabric or a machine-sewn seam is reached. Lock hand sewing at a maximum of 10 stitch intervals with a double half hitch, and tie off the end stitch with a double half hitch. At the point where the hand-sewing or permanent tacking is necessary, cut the fabric so that it can be doubled under a minimum of 3/8 inch before sewing or permanent tacking is performed.

After hand sewing is complete, any temporary tacks used to secure the fabric over wood structures may be removed.

Cover a sewn spanwise seam on a wing's leading edge with

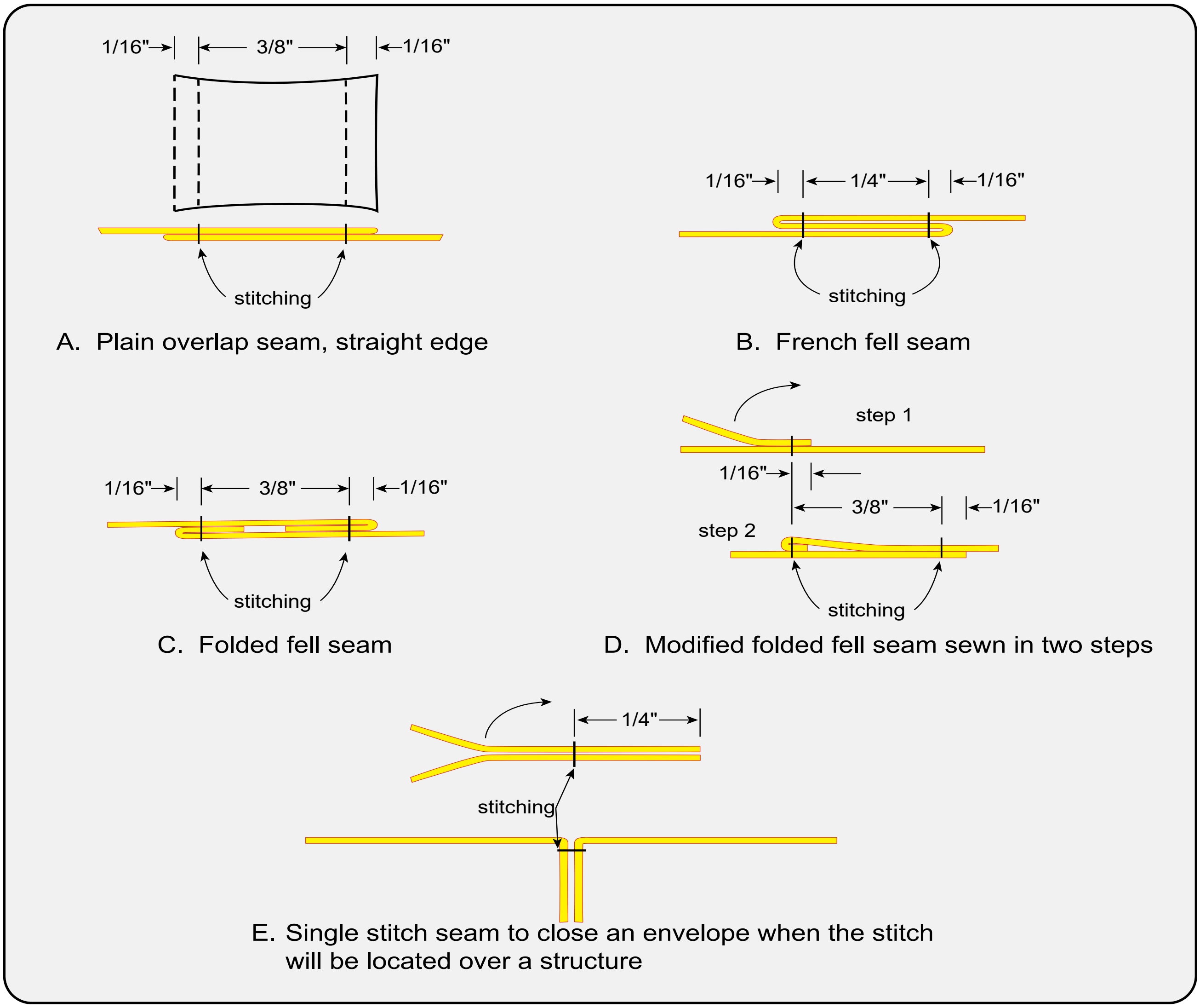



**Figure 3-21.** *Fabric Seams.*

a minimum 4-inch wide pinked-edged surface tape with the tape centered on the seam.

Cover a spanwise-sewn seam at the wing trailing edge with pinked-edge surface tape that is at least 3 inches wide. For aircraft with never-exceed speeds in excess of 200 mph, cut V notches at least 1 inch in depth and 1/4 inch in width in both edges of the surface tape when used to cover spanwise seams on trailing edges of control surfaces. Space notches at intervals not exceeding 6 inches. On tape less than 3 inches wide, the notches should be 1/3 the tape width. In the event the surface tape begins to separate because of poor adhesion or other causes, the tape will tear at a notched section, thus preventing progressive loosening of the entire length of the tape which could seriously affect the controllability of the aircraft. A loose tape acts as a trim tab only on a movable surface. It becomes a spoiler on a fixed surface and has no effect at the trailing edge other than drag.

Make spanwise-sewn seams on the wing's upper or lower surfaces in a manner that will minimize any protrusions. Cover the seams with finishing tape at least 3 inches wide, centering the tape on the seam.

Sewn seams parallel to the line of flight (chordwise) may be located over ribs. However, careful attention must be given to avoid damage to the seam threads by rib lace needles, screws, rivets, or wire clips that are used to attach the fabric to the rib. Cover chordwise seams with a finishing tape at least 3 inches wide with the tape centered on the seam.

### *Doped Seams*

For an overlapped and doped span-wise seam on a wing's leading edge, overlap the fabric at least 4 inches and cover with finishing tape at least 4 inches wide, with the tape centered at the outside edge of the overlap seam.

For an overlapped and doped span-wise seam at the trailing edge, lap the fabric at least 3 inches and cover with pinked-edge surface tape at least 4 inches wide, with the tape centered on the outside edge of the overlap seam.

For an overlapped and doped seam on wingtips, wing butts, perimeters of wing control surfaces, perimeters of empennage surfaces, and all fuselage areas, overlap the fabric 2 inches and cover with a finishing tape that is at least 3 inches wide, centered on the outside edge of the overlap seam.

For an overlapped and doped seam on a wing's leading edge, on aircraft with a velocity never exceed speed ($V_{NE}$) up to and including 150 mph, overlap the fabric 2 inches and cover with a finishing tape that is at least 3 inches wide, with the tape centered on the outside edge of the overlap seam.

For an overlapped and doped seam on the perimeter of a wing (except a leading edge), perimeters of wing control surfaces, perimeters of empennage surfaces, and all areas of a fuselage, on aircraft with a $V_{NE}$ speed up to and including 150 mph, overlap the fabric 1 inch and cover with a finishing tape that is at least 3 inches wide, centered on the outside edge of the overlap seam.

**Figure 3-22.** *Irons used during the fabric covering process.*

### *Fabric Cement*

A polyester fabric covering is cemented or glued to the airframe structure at all points where it makes contact. Special formula adhesives have replaced nitrate dope for adhesion in most covering processes. The adhesive (as well as all subsequent coating materials) should be mixed for optimum characteristics at the temperature at which the work is being performed. Follow the manufacturer's or STC's guidance when mixing.

To attach the fabric to the airframe, first pre-apply two coats of adhesive to the structure at all points that will come in contact with the fabric. (It is important to follow the manufacturer's or STC's guidance as all systems are different.) Allow these to dry. The fabric is then spread over the surface and clamped into position. It should not be pulled tighter than the relaxed but not wrinkled condition it assumes when lying on the structure. Clamps or clothespins are used to attach the fabric completely around the perimeter. The Stewart System STC does not need clamps because the glue assumes a tacky condition when precoated and dried. There is sufficient adhesion in the precoat to position the fabric.

The fabric should be positioned in all areas before undertaking final adhesion. Final adhesion often involves lifting the fabric, applying a wet bed of cement, and pressing the fabric into the bed. An additional coat of cement over the top of the fabric is common. Depending on the process, wrinkles and excess cement are smoothed out with a squeegee or are ironed out. The Stewart System calls for heat activation of the cement precoats through the fabric with an iron while the fabric is in place. Follow the approved instructions for the covering method being used.

### *Fabric Heat Shrinking*

Once the fabric has been glued to the structure, it can be made taut by heat shrinking. This process is done with an ordinary household iron that the technician calibrates before use. A smaller iron is also used to iron in small or tight places. *[Figure 3-22]* The iron is run over the entire surface of the fabric. Follow the instructions for the work being performed. Some processes avoid ironing seams while other processes begin ironing over structure and move to spanned fabric or vice-versa. It is important to shrink the fabric evenly. Starting on one end of a structure and progressing sequentially to the other end is not recommended. Skipping from one end to the other, and then to the middle, is more likely to evenly draw the fabric tight. *[Figure 3-23]*

The amount polyester fabric shrinks is directly related to the temperature applied. Polyester fabric can shrink nearly 5 percent at 250 °F and 10 percent at 350 °F. It is customary to shrink the fabric in stages, using a lower temperature first, before finishing with the final temperature setting. The first shrinking is used to remove wrinkles and excess fabric. The final shrinking gives the finished tautness desired. Each process has its own temperature regime for the stages of

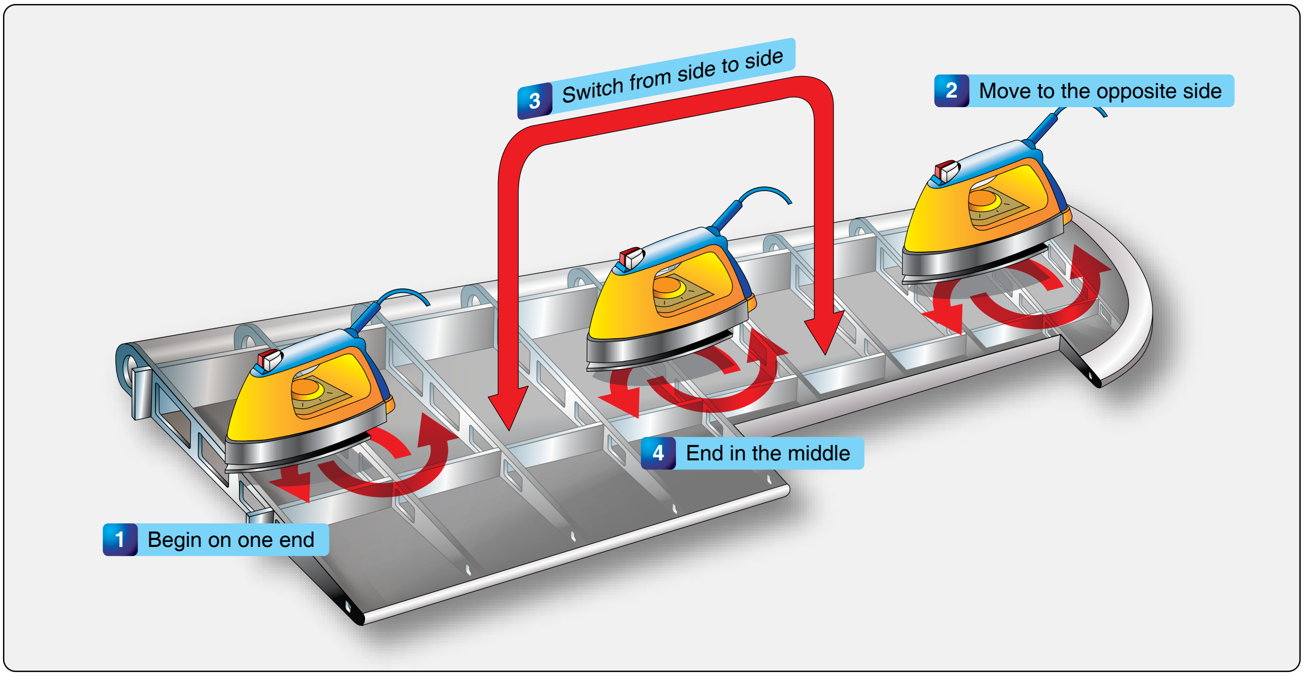



**Figure 3-23.** *An example of a wing fabric ironing procedure designed to evenly tauten the fabric.*

tautening. Typically ranging from 225 °F to 350 °F, it is imperative to follow the process instructions. Not all fabric covering processes use the same temperature range and maximum temperature. Ensure irons are calibrated to prevent damage at high temperature settings.

### Attaching Fabric to the Wing Ribs

Once the fabric has been tautened, covering processes vary. Some require a sealing coat be applied to the fabric at this point. It is usually put on by brush to ensure the fibers are saturated. Other processes seal the fabric later. Whatever the process, the fabric on wings must be secured to the wing ribs with more than just cement. The forces caused by the airflow over the wings are too great for cement alone to hold the fabric in place. As described in the materials section, screws, rivets, clips and lacing hold the fabric in place on manufactured aircraft. Use the same attach method as used by the original aircraft manufacturer. Deviation requires a field approval. Note that fuselage and empennage attachments may be used on some aircraft. Follow the methodology for wing rib lacing described below and the manufacturer's instructions for attach point locations and any possible variations to what is presented here.

Care must always be taken to identify and eliminate any sharp edges that might wear through the fabric. Reinforcing tape of the exact same width as the rib cap is installed before any of the fasteners. This approved sticky-back tape helps prevent the fabric from tearing. *[Figure 3-24]* Then, screws, rivets, and clips simply attach into the predrilled holes in the rib caps to hold the fabric to the caps. Rib lacing is a more involved process whereby the fabric is attached to the ribs with cord.

#### *Rib Lacing*

There are two kinds of rib lacing cord. One has a round cross-section and the other flat. Which to use is a matter of preference based on ease of use and final appearance. Only approved rib lacing cord can be used. Unless a rib is unusually deep from top to bottom, rib lacing uses a single length of cord that passes completely through the wing from the upper surface to the lower surface thereby attaching the top and bottom skin to the rib simultaneously.

Holes are laid out and pre-punched through the skin as close to the rib caps as possible to accept the lacing cord. *[Figure 3-25]* This minimizes leverage the fabric could develop while trying to pull away from the structure and prevents tearing. The location of the holes is not arbitrary. The spacing between lacing holes and knots must adhere to manufacturer's instructions, if available. STC lacing guidance refers to manufacturer's instructions or to that shown on the chart in *Figure 3-26* which is taken from AC 43.13-1. Notice that because of greater turbulence in the area of the propeller wash, closer spacing between the lacing is required there. This slipstream is considered to be the width of the propeller plus one additional rib. Ribs are normally laced from the leading edge to the trailing edge of the wing.

Rib lacing is done with a long curved needle to guide the cord in and out of holes and through the depth of the rib.

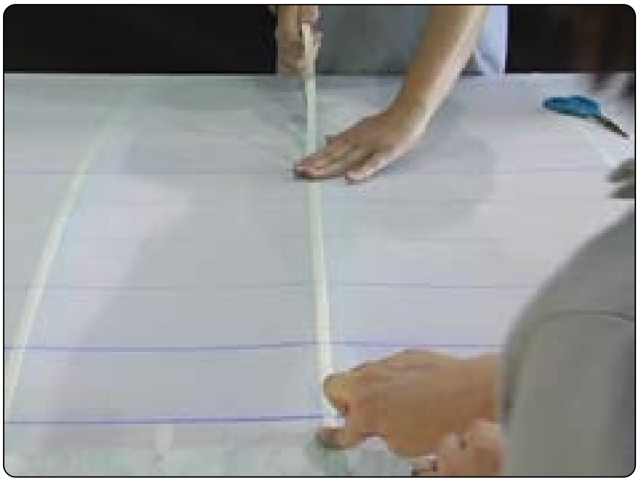


**Figure 3-24.** *Reinforcing tape the same width as the wing ribs is applied over all wing ribs.*

**Figure 3-25.** *A premarked location for a lacing hole, which is punched through the fabric with a pencil.*

The knots are designed not to slip under the forces applied and can be made in a series out of a single strand of lacing. Stitching can begin at the leading edge or trailing edge. A square knot with a half hitch on each side is typically used for the first knot when lacing a rib. *[Figure 3-27]* This is followed by a series of modified seine knots until the final knot is made and secured with a half hitch. *[Figure 3-28]* Hidden modified seine knots are also used. These knots are placed below the fabric surface so only a single strand of lacing is visible across the rib cap. *[Figure 3-29]*

Structure and accessories within the wing may prevent a continuous lacing. Ending the lacing and beginning again can avoid these obstacles. Lacing that is not long enough to complete the rib may be ended and a new starting knot can be initiated at the next set of holes. The lacing can also be extended by joining it with another piece of lacing using the splice knot shown in *Figure 3-30*.

Occasionally, lacing to just the rib cap is employed without lacing entirely through the wing and incorporating the cap on the opposite side. This is done where ribs are exceptionally deep or where through lacing is not possible, such as in an area where a fuel tank is installed. Changing to a needle with a tighter radius facilitates threading the lacing cord in these areas. Knotting procedures remain unchanged.

Technicians inexperienced at rib lacing should seek assistance to ensure the correct knots are being tied. STC holder videos are invaluable in this area. They present repeated close-up visual instruction and guidance to ensure airworthy lacing. AC 43.13-1, Chapter 2, Fabric Covering, also has in-depth instructions and diagrams as do some manufacturer's manuals and STC's instructions.

### *Rings, Grommets, & Gussets*

When the ribs are laced and the fabric covering completely attached, the various inspection rings, drain grommets, reinforcing patches, and finishing tapes are applied. Inspection rings aid access to critical areas of the structure (pulleys, bell cranks, drag/anti-drag wires, etc.) once the fabric skin is in place. They are plastic or aluminum and normally cemented to the fabric using the approved cement and procedures. The area inside the ring is left intact. It is removed only when inspection or maintenance requires access through that ring. Once removed, preformed inspection panels are used to close the opening. The rings should be positioned as specified by the manufacturer. Lacking that information, they should be positioned as they were on the previous covering fabric. Additional rings should be installed by the technician if it is determined a certain area would benefit from access in the future. *[Figure 3-31]*

Water from rain and condensation can collect under the fabric covering and needs a way to escape. Drain grommets serve this purpose. There are a few different types as described in the materials section above. All are cemented into position in accordance with the approved process under which the work is being performed. Locations for the drain grommets should be ascertained from manufacturer's data. If not specified, AC 43.13-1 has acceptable location information. Each fabric covering STC may also give recommendations. Typically, drain grommets are located at the lowest part of each area of the structure (e.g., bottom of the fuselage, wings, empennage). *[Figure 3-32]* Each rib bay of the wings is usually drained with one or two grommets on the bottom of the trailing edge. Note that drain holes without grommets are sometimes approved in reinforced fabric.

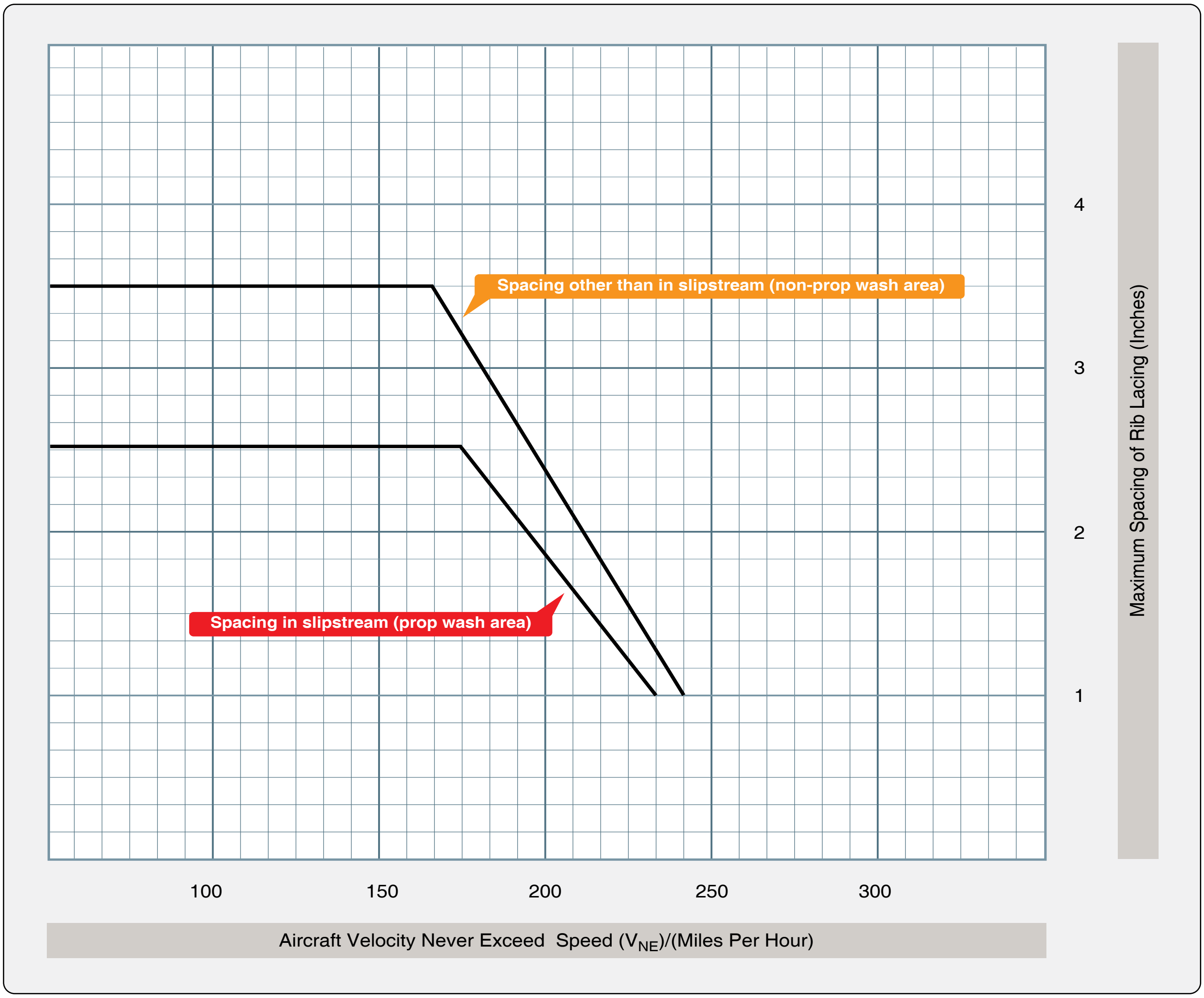



**Figure 3-26.** *A rib lacing spacing chart. Unless manufacturer data specifies otherwise, use the spacing indicated.*

It is possible that additional inspection rings and drain grommets have been specified after the manufacture of the aircraft. Check the Airworthiness Directives (ADs) and Service Bulletins for the aircraft being re-covered to ensure required rings and grommets have been installed.

Cable guide openings, strut-attach fitting areas, and similar features, as well as any protrusions in the fabric covering, are reinforced with fabric gussets. These are installed as patches in the desired location. They should be cut to fit exactly around the feature they reinforce to support the original opening made in the covering fabric. *[Figure 3-33]* Gussets made to keep protrusions from coming through the fabric should overlap the area they protect. Most processes call for the gusset material to be preshrunk and cemented into place using the approved covering process cementing procedures.

### *Finishing Tapes*

Finishing tapes are applied to all seams, edges, and over the ribs once all of the procedures above have been completed. They are used to protect these areas by providing smooth aerodynamic resistance to abrasion. The tapes are made from the same polyester material as the covering fabric. Use of lighter weight tapes is approved in some STCs. Preshrunk tapes are preferred because they react to exposure to the environment in the same way the as the fabric covering. This minimizes stress on the adhesive joint between the two. Straight edged and pinked tapes are available. The pinking provides greater surface area for adhesion of the edges and a smoother transition into the fabric covering. Only tapes approved in the STC under which work is being accomplished may be used to be considered airworthy.

Finishing tapes from one to six inches in width are used. Typically, two inch tapes cover the rib lacing and fuselage seams. Wing leading edges usually receive the widest tape with four inches being common. *[Figure 3-34]* Bias cut tapes are often used to wrap around the curved surfaces of the

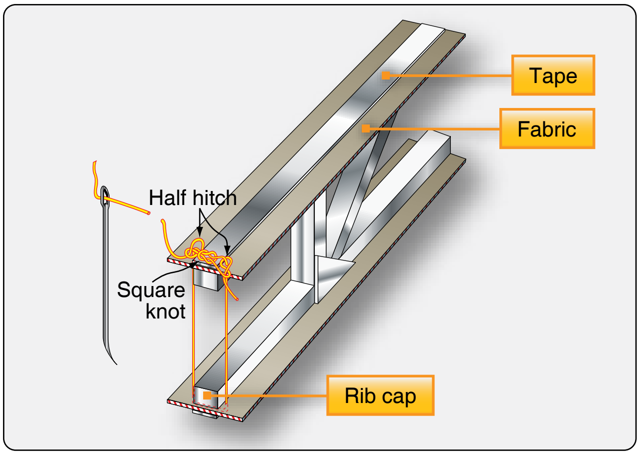



**Figure 3-27.** *A starter knot for rib lacing can be a square knot with a half hitch on each side.*

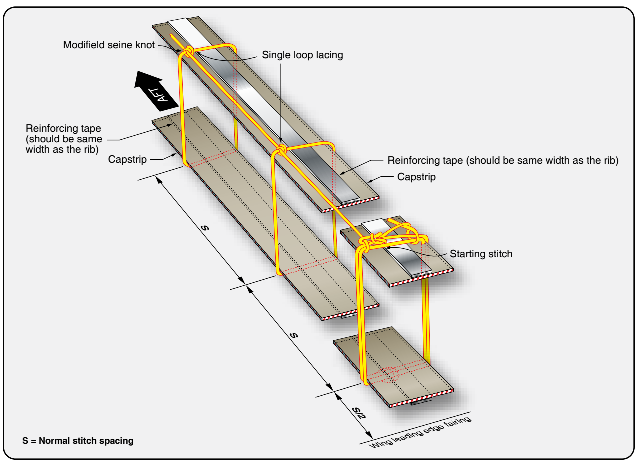



**Figure 3-28.** *In this example of rib lacing, modified seine knots are used and shown above the fabric surface. Hidden modified seine knots are common. They are made so that the knots are pushed or pulled below the fabric surface.*

airframe, such as the wing tips and empennage surface edges. They lay flat around the curves and do not require notching. Finishing tapes are attached with the process adhesive or the nitrate dope sealer when using a dope-based process. Generally, all chordwise tapes are applied first followed by the span-wise tapes at the leading and trailing edges. Follow the manufacturer's STC or AC 43.13-1 instructions.

### *Coating the Fabric*

The sealer coat in most fabric covering processes is applied after all finishing tapes have been installed unless it was applied prior to rib lacing as in a dope-based finishing process. This coat saturates and completely surrounds the fibers in the polyester fabric, forming a barrier that keeps water and contaminants from reaching the fabric during its life. It is also used to provide adhesion of subsequent

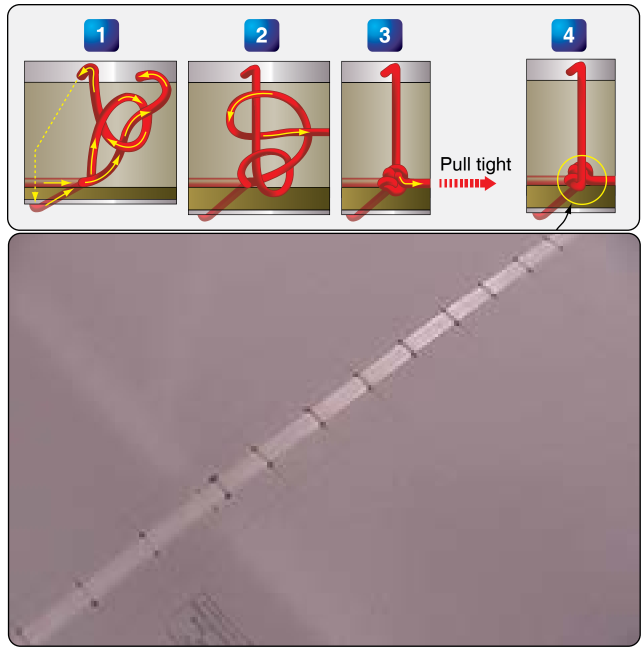



**Figure 3-29.** *Hiding rib lacing knots below the fabric surface results in a smooth surface.*

coatings. Usually brushed on in a cross coat application for thorough penetration, two coats of sealer are commonly used but processes vary on how many coats and whether spray coating is permitted.

With the sealer coats installed and dried, the next step provides protection from UV light, the only significant cause of deterioration of polyester fabric. Designed to prevent UV light from reaching the fabric and extend the life of the fabric indefinitely, these coating products, or fill coats, contain aluminum solids premixed into them that block the UV rays. They are sprayed on in the number of cross coats as specified in the manufacturer's STC or AC 43.13-1 instructions under which work is done. Two to four cross coats is common. Note that some processes may require coats of clear butyrate before the blocking formula is applied.

Fabric primer is a coating used in some approved covering processes that combines the sealer and fill coatings into one. Applied to fabric after the finishing tapes are installed, these fabric primers surround and seal the fabric fibers, provide good adhesion for all of the following coatings, and contain UV blocking agents. One modern primer contains carbon solids and others use chemicals that work similarly to sun block for human skin. Typically, two to four coats of fabric primer are sufficient before the top coatings of the final finish are applied. *[Figure 3-35]*

The FAA-certificated mechanic must strictly adhere to all instructions for thinning, drying times, sanding, and cleaning.

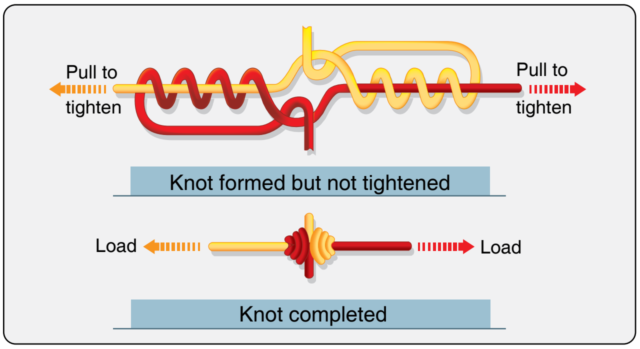



**Figure 3-30.** *The splice knot can be used to join two pieces of rib lacing cord.*

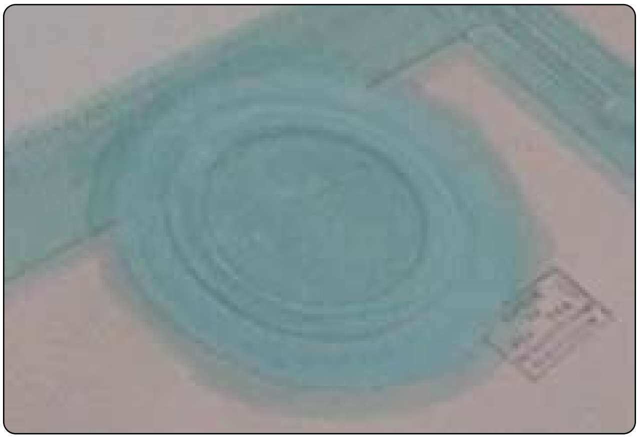


**Figure 3-31.** *This inspection ring was cemented into place on the fabric covering. The approved technique specifies the use of a fabric overlay that is cemented over the ring and to the fabric.*

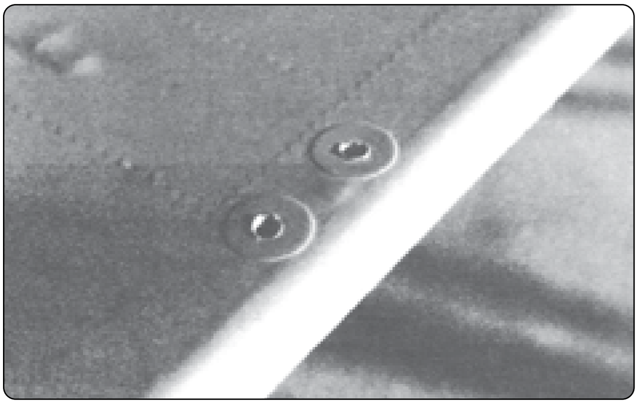


**Figure 3-32.** *Drain grommets cemented into place on the bottom side of a control surface.*

**Figure 3-33.** *A strut fitting and cable guide with reinforcing fabric gussets cemented in place.*

**Figure 3-34.** *Cement is brushed through a four-inch tape during installation over the fabric seam on a wing leading edge. Two-inch tapes cover the wing ribs and rib lacing.*

**Figure 3-35.** *Applying a primer with UV blocking by spraying cross coats.*

Small differences in the various processes exist and what works in one process may not be acceptable and could ruin the finish of another process. STCs are issued on the basis of the holder having successfully proven the effectiveness of both the materials and the techniques involved.

When the fill coats have been applied, the final appearance of the fabric covering job is crafted with the application of various topcoats. Due to the chemical nature of the fill coating upon which topcoats are sprayed, only specified materials can be used for top coating to ensure compatibility. Colored butyrate dope and polyurethane paint finishes are most common. They are sprayed on according to instructions.

Once the topcoats are dry, the trim (N numbers, stripes, etc.) can be added. Strict observation of drying times and instructions for buffing and waxing are critical to the quality of the final finish. Also, note that STC instructions may include insight on finishing the nonfabric portions of the airframe to best match the fabric covering finish.

## Polyester Fabric Repairs

### Applicable Instructions

Repairs to aircraft fabric coverings are inevitable. Always inspect a damaged area to ensure the damage is confined to the fabric and does not involve the structure below. A technician who needs to make a fabric repair must first identify which approved data was used to install the covering that needs to be repaired. Consult the logbook where an entry and reference to manufacturer data, an STC, or a field approval possibly utilizing practices from AC 43.13-1 should be recorded. The source of approved data for the covering job is the same source of approved data used for a repair.

This section discusses general information concerning repairs to polyester fabric. Thorough instructions for repairs made to cotton covered aircraft can be found in AC 43.13-1. It is the responsibility of the holder of an STC to provide maintenance instructions for the STC alteration in addition to materials specifications required to do the job.

### Repair Considerations

The type of repair performed depends on the extent of the damage and the process under which the fabric was installed. The size of the damaged area is often a reference for whether a patch is sufficient to do the repair or whether a new panel should be installed. Repair size may also dictate the amount of fabric-to-fabric overlap required when patching and whether finishing tapes are required over the patch. Many STC repair procedures do not require finishing tapes. Some repairs in AC 43.13-1 require the use of tape up to six inches wide.

While many cotton fabric repairs involve sewing, nearly all repairs of polyester fabric are made without sewing. It is possible to apply the sewing repair techniques outlined in AC 43.13-1 to polyester fabric, but they were developed primarily for cotton and linen fabrics. STC instructions for repairs to polyester fabric are for cemented repairs which most technicians prefer as they are generally considered easier than sewn repairs. There is no compromise to the strength of the fabric with either method.

Patching or replacing a section of the covering requires prepping the fabric area around the damage where new fabric is to be attached. Procedures vary widely. Dope-based covering systems tend toward stripping off all coatings to cement raw fabric to raw fabric when patching or seaming in a new panel. From this point, the coatings are reapplied and finished as in the original covering process. Some polyurethane-based coating processes require only a scuffing of the topcoat with sandpaper before adhering small patches that are then refinished. *[Figure 3-36]* Still, other processes may remove the topcoats and cement a patch into the sealer or UV blocking coating. In some repair processes, preshrunk fabric is used and in others, the fabric is shrunk after it is in place. Varying techniques and temperatures for shrinking and gluing the fabric into a repair also exist.

These deviations in procedures underscore the critical nature of identifying and strictly adhering to the correct instructions from the approved data for the fabric covering in need of repair. A patch or panel replacement technique for one covering system could easily create an unairworthy repair if used on fabric installed with a different covering process.

Large section panel repairs use the same proprietary adhesives

**Figure 3-36.** *A patch over this small hole on a polyurethane top coat is repaired in accordance with the repair instructions in the STC under which the aircraft was re-covered. It requires only a two-inch fabric overlap and scuffing into the top coat before cementing and refinishing. Other STC repair instructions may not allow this repair.*

and techniques and are only found in the instructions for the process used to install the fabric covering. A common technique for replacing any large damaged area is to replace all of the fabric between two adjacent structural members (e.g., two ribs, two longerons, between the forward and rear spars). Note that this is a major repair and carries with it the requirement to file an FAA Form 337.

## Cotton-Covered Aircraft

You may encounter a cotton fabric-covered aircraft. In addition to other airworthiness criterion, the condition of the fabric under the finished surface is paramount as the cotton can deteriorate even while the aircraft is stored in a hangar. Inspection, in accordance with the manufacturer maintenance manual or AC 43.13-1, should be diligent. If the cotton covering is found to be airworthy, repairs to the fabric can be made under those specifications. This includes sewn-in and doped-in patches, as well as sewn-in and doped-in panel repairs. Due to the very limited number of airworthy aircraft that may still be covered with cotton, this handbook does not cover specific information on re-covering with cotton or cotton fabric maintenance and repair procedures. Refer to AC 43.13-1, Chapter 2, Fabric Covering, which thoroughly addresses these issues.

## Fiberglass Coverings

References to fiberglass surfaces in aircraft covering STCs, AC 43.13-1, and other maintenance literature address techniques for finishing and maintaining this kind of surface. However, this is typically limited to fiberglass radomes and fiberglass reinforced plywood surfaces and parts that are still in service. Use of dope-based processes on fiberglass is well established. Repair and apply coatings and finishes on fiberglass in accordance with manufacturer data, STC instructions, or AC 43.13-1 acceptable practices. Mildew, moisture, chemicals, or acids have no effect on glass fabric when used as a structure material. For more information on glass fabric, refer to AC 43.13-1(as revised).

Chapter 4

# Aircraft Metal Structural Repair

## Aircraft Metal Structural Repair

The satisfactory performance of an aircraft requires continuous maintenance of aircraft structural integrity. It is important that metal structural repairs be made according to the best available techniques because improper repair techniques can pose an immediate or potential danger. The reliability of an aircraft depends on the quality of the design, as well as the workmanship used in making the repairs. The design of an aircraft metal structural repair is complicated by the requirement that an aircraft be as light as possible. If weight were not a critical factor, repairs could be made with a large margin of safety. In actual practice, repairs must be strong enough to carry all of the loads with the required factor of safety, but they must not have too much extra strength. For example, a joint that is too weak cannot be tolerated, but a joint that is too strong can create stress risers that may cause cracks in other locations.

As discussed in Chapter 3, Aircraft Fabric Covering, sheet metal aircraft construction dominates modern aviation. Generally, sheet metal made of aluminum alloys is used in airframe sections that serve as both the structure and outer aircraft covering, with the metal parts joined with rivets or other types of fasteners. Sheet metal is used extensively in many types of aircraft from airliners to single engine airplanes, but it may also appear as part of a composite airplane, such as in an instrument panel. Sheet metal is obtained by rolling metal into flat sheets of various thicknesses ranging from thin (leaf) to plate (pieces thicker than 6 mm or 0.25 inch). The thickness of sheet metal, called gauge, ranges from 8 to 30 with the higher gauge denoting thinner metal. Sheet metal can be cut and bent into a variety of shapes.

Damage to metal aircraft structures is often caused by corrosion, erosion, normal stress, and accidents and mishaps. Sometimes aircraft structure modifications require extensive structural rework. For example, the installation of winglets on aircraft not only replaces a wing tip with a winglet, but also requires extensive reinforcing of the wing structure to carry additional stresses.

Numerous and varied methods of repairing metal structural portions of an aircraft exist, but no set of specific repair patterns applies in all cases. The problem of repairing a damaged section is usually solved by duplicating the original part in strength, kind of material, and dimensions. To make a structural repair, the aircraft technician needs a good working knowledge of sheet metal forming methods and techniques. In general, forming means changing the shape by bending and forming solid metal. In the case of aluminum, this is usually done at room temperature. All repair parts are shaped to fit in place before they are attached to the aircraft or component.

Forming may be a very simple operation, such as making a single bend or a single curve, or it may be a complex operation, requiring a compound curvature. Before forming a part, the aircraft technician must give some thought to the complexity of the bends, the material type, the material thickness, the material temper, and the size of the part being fabricated. In most cases, these factors determine which forming method to use. Types of forming discussed in this chapter include bending, brake forming, stretch forming, roll forming, and spinning. The aircraft technician also needs a working knowledge of the proper use of the tools and equipment used in forming metal.

In addition to forming techniques, this chapter introduces the airframe technician to the tools used in sheet metal construction and repair, structural fasteners and their installation, how to inspect, classify, and assess metal structural damage, common repair practices, and types of repairs.

The repairs discussed in this chapter are typical of those used in aircraft maintenance and are included to introduce some of the operations involved. For exact information about specific repairs, consult the manufacturer's maintenance or structural repair manuals (SRM). General repair instructions are also discussed in Advisory Circular (AC) 43.13.1, Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair.

### Stresses in Structural Members

An aircraft structure must be designed so that it accepts all of the stresses imposed upon it by the flight and ground loads without any permanent deformation. Any repair made must accept the stresses, carry them across the repair, and then transfer them back into the original structure. These stresses are considered as flowing through the structure, so there must be a continuous path for them, with no abrupt changes in cross-sectional areas along the way. Abrupt changes in cross-sectional areas of aircraft structure that are subject to cycle loading or stresses result in a stress concentration that may induce fatigue cracking and eventual failure. A scratch or gouge in the surface of a highly stressed piece of metal causes a stress concentration at the point of damage and could lead to failure of the part. Forces acting on an aircraft, whether it is on the ground or in flight, introduce pulling, pushing, or twisting forces within the various members of the aircraft structure. While the aircraft is on the ground, the weight of the wings, fuselage, engines, and empennage causes forces to act downward on the wing and stabilizer tips, along the spars and stringers, and on the bulkheads and formers. These forces are passed from member to member causing bending, twisting, pulling, compression, and shearing forces.

As the aircraft takes off, most of the forces in the fuselage continue to act in the same direction; because of the motion of the aircraft, they increase in intensity. The forces on the wingtips and the wing surfaces, however, reverse direction; instead of being downward forces of weight, they become upward forces of lift. The forces of lift are exerted first against the skin and stringers, then are passed on to the ribs, and finally are transmitted through the spars to be distributed through the fuselage. The wings bend upward at their ends and may flutter slightly during flight. This wing bending cannot be ignored by the manufacturer in the original design and construction and cannot be ignored during maintenance. It is surprising how an aircraft structure composed of structural members and skin rigidly riveted or bolted together, such as a wing, can bend or act so much like a leaf spring.

The six types of stress in an aircraft are described as tension, compression, shear, bearing, bending, and torsion (or twisting). The first four are commonly called basic stresses; the last two, combination stresses. Stresses usually act in combinations rather than singly. *[Figure 4-1]*

### *Tension*

Tension is the stress that resists a force that tends to pull apart. The engine pulls the aircraft forward, but air resistance tries to hold it back. The result is tension, which tends to stretch the aircraft. The tensile strength of a material is measured in pounds per square inch (psi) and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

The strength of a member in tension is determined on the basis of its gross area (or total area), but calculations involving tension must take into consideration the net area of the member. Net area is defined as the gross area minus that removed by drilling holes or by making other changes in the section. Placing rivets or bolts in holes makes no appreciable difference in added strength, as the rivets or bolts will not transfer tensional loads across holes in which they are inserted.

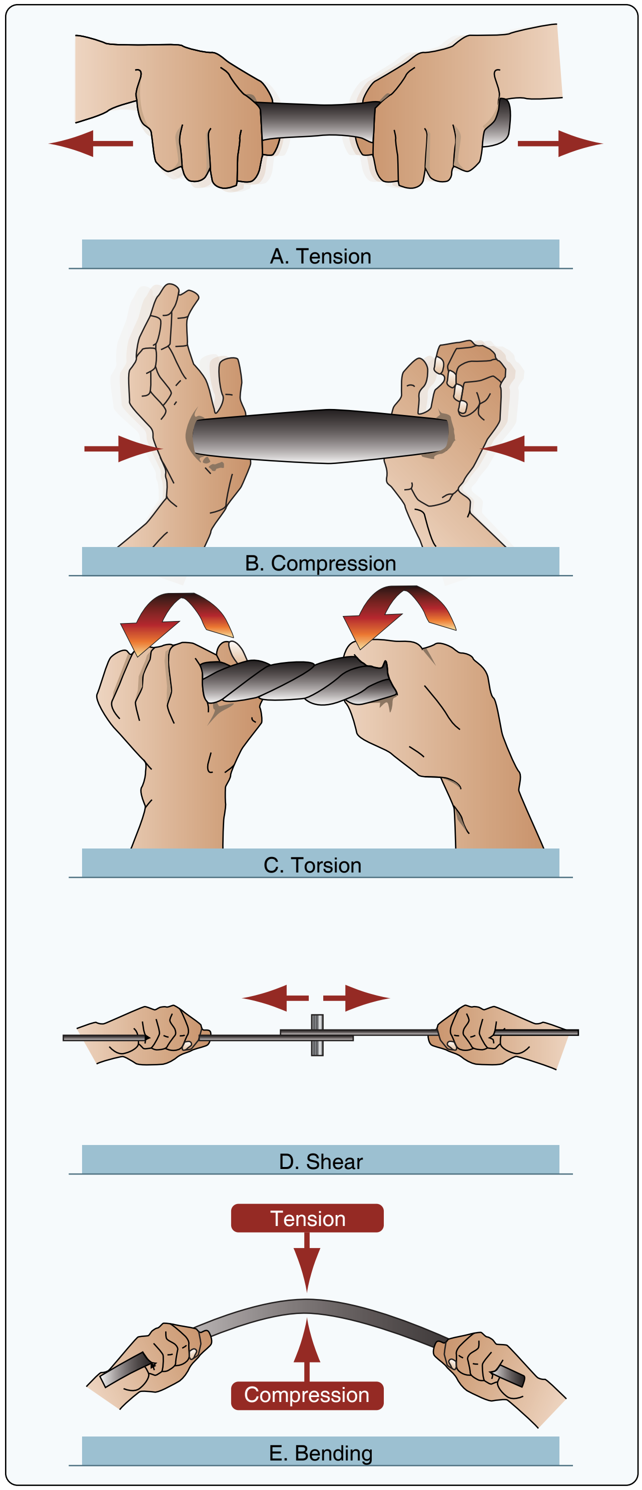



**Figure 4-1.** *Stresses in aircraft structures.*

### *Compression*

Compression, the stress that resists a crushing force, tends to shorten or squeeze aircraft parts. The compressive strength of a material is also measured in psi. Under a compressive load, an undrilled member is stronger than an identical member with holes drilled through it. However, if a plug of equivalent or stronger material is fitted tightly in a drilled member, it transfers compressive loads across the hole, and the member carries approximately as large a load as if the hole were not there. Thus, for compressive loads, the gross or total area may be used in determining the stress in a member if all holes are tightly plugged with equivalent or stronger material.

### *Shear*

Shear is the stress that resists the force tending to cause one layer of a material to slide over an adjacent layer. Two riveted plates in tension subject the rivets to a shearing force. Usually, the shear strength of a material is either equal to or less than its tensile or compressive strength. Shear stress concerns the aviation technician chiefly from the standpoint of the rivet and bolt applications, particularly when attaching sheet metal, because if a rivet used in a shear application gives way, the riveted or bolted parts are pushed sideways.

### *Bearing*

Bearing stress resists the force that the rivet or bolt places on the hole. As a rule, the strength of the fastener should be such that its total shear strength is approximately equal to the total bearing strength of the sheet material. *[Figure 4-2]*

### *Torsion*

Torsion is the stress that produces twisting. While moving the aircraft forward, the engine also tends to twist it to one side, but other aircraft components hold it on course. Thus, torsion is created. The torsional strength of a material is its resistance to twisting or torque (twisting stress). The stresses arising from this action are shear stresses caused by the rotation of adjacent planes past each other around a common reference axis at right angles to these planes. This action may be illustrated by a rod fixed solidly at one end and twisted by a weight placed on a lever arm at the other, producing the equivalent of two equal and opposite forces acting on the rod at some distance from each other. A shearing action is set up all along the rod, with the center line of the rod representing the neutral axis.

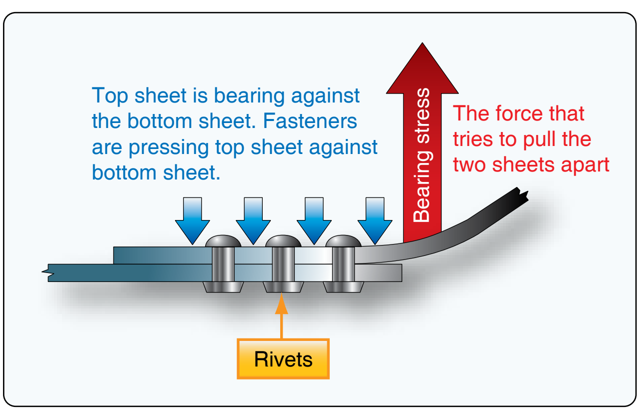



**Figure 4-2.** *Bearing stress.*

### *Bending*

Bending (or beam stress) is a combination of compression and tension. The rod in *Figure 4-1E* has been shortened (compressed) on the inside of the bend and stretched on the outside of the bend. Note that the bending stress causes a tensile stress to act on the upper half of the beam and a compressive stress on the lower half. These stresses act in opposition on the two sides of the center line of the member, which is called the neutral axis. Since these forces acting in opposite directions are next to each other at the neutral axis, the greatest shear stress occurs along this line, and none exists at the extreme upper or lower surfaces of the beam.

## Tools for Sheet Metal Construction & Repair

Without modern metalworking tools and machines, the job of the airframe technician would be more difficult and tiresome, and the time required to finish a task would be much greater. These specialized tools and machines help the airframe technician construct or repair sheet metal in a faster, simpler, and better manner than possible in the past. Powered by human muscle, electricity, or compressed air, these tools are used to lay out, mark, cut, sand, or drill sheet metal.

### Layout Tools

Before fitting repair parts into an aircraft structure, the new sections must be measured and marked, or laid out to the dimensions needed to make the repair part. Tools utilized for this process are discussed in this section.

### *Scales*

Scales are available in various lengths, with the 6-inch and 12-inch scales being the most common and affordable. A scale with fractions on one side and decimals on the other side is very useful. To obtain an accurate measurement, measure with the scale held on edge from the 1-inch mark instead of the end. Use the graduation marks on the side to set a divider or compass. *[Figure 4-3]*

### *Combination Square*

A combination square consists of a steel scale with three heads that can be moved to any position on the scale and locked in place. The three heads are a stock head that measures 90° and 45° angles, a protractor head that can measure any angle between the head and the blade, and a center head that uses one side of the blade as the bisector of a 90° angle. The center of a shaft can be found by using the center head. Place the end of the shaft in the V of the head and scribe a line along the edge of the scale. Rotate the head about 90° and scribe another line along the edge of the scale. The two lines will cross at the center of the shaft. *[Figure 4-4]*