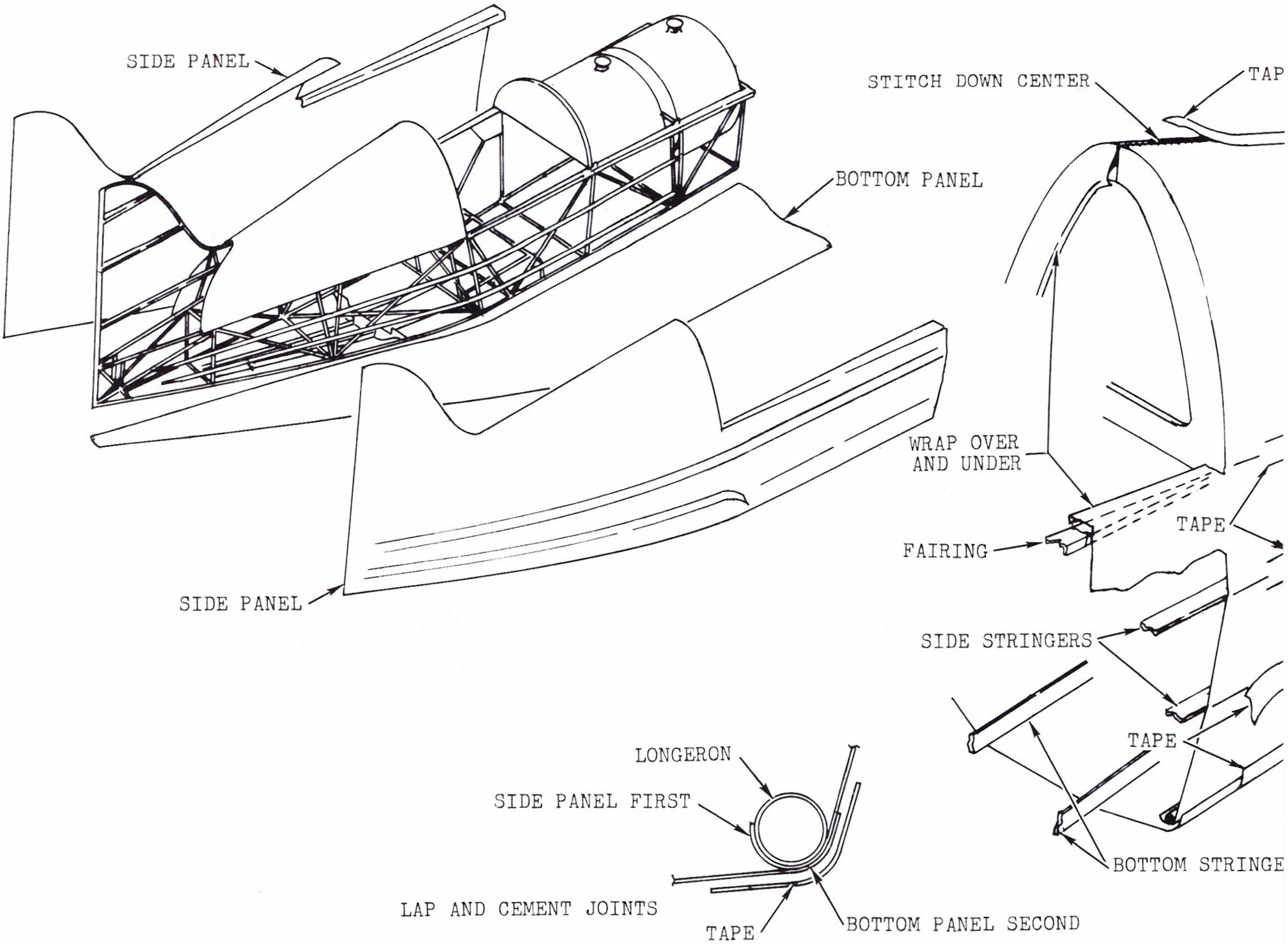
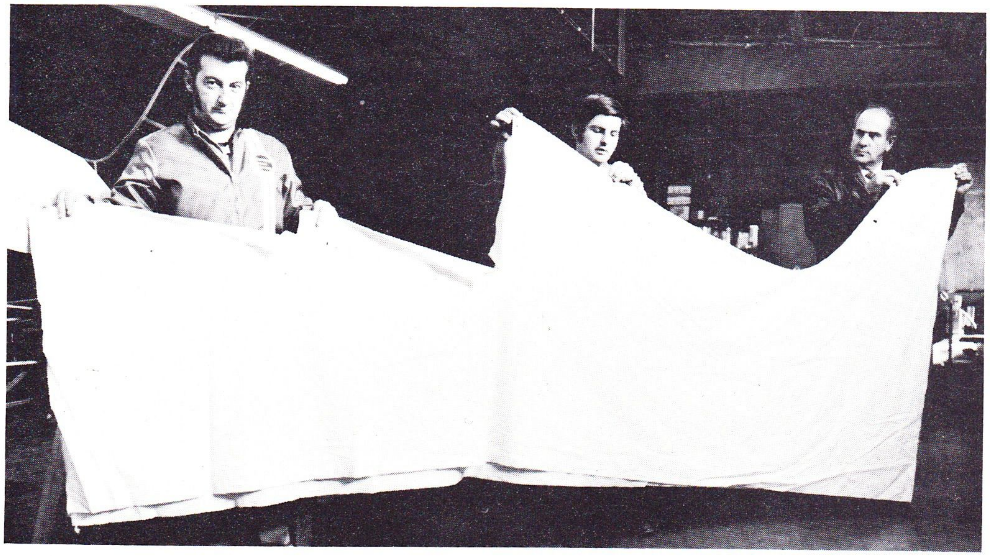
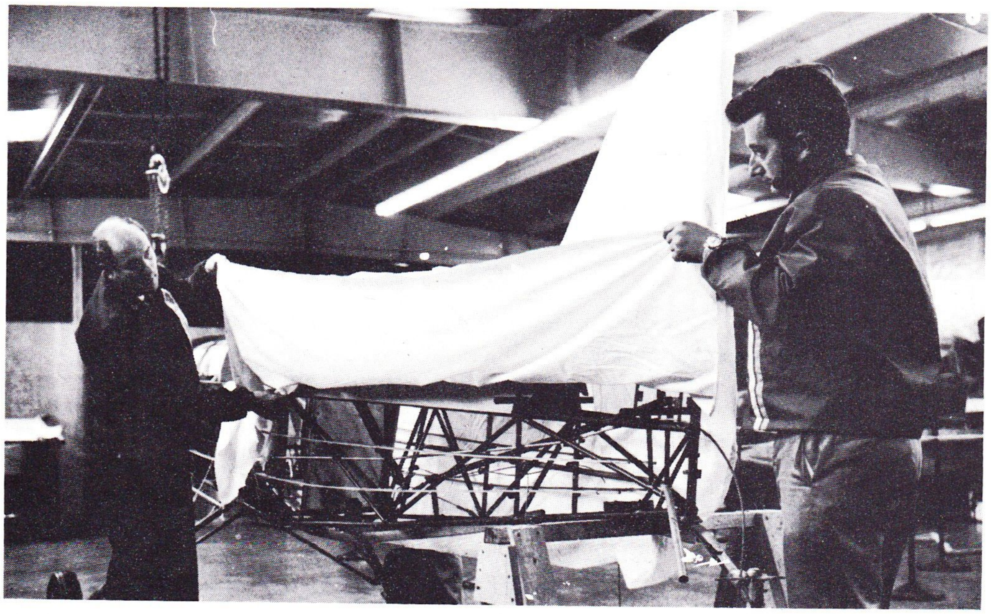


must sew together to make a large envelope. Procedures are called out in Civil Aeronautics Manual 18, available from EAA, on the methods of sewing fabric together. A pillow slip arrangement for the wings is made after the pieces are sewn together. The pillow slip, with the seams being placed on the outside, is pinned at the edge — not too tightly, allowing sufficient sag so that when water is rubbed on the fabric after being put into position and all wrinkles are out, the dope coats will not shrink the fabric to a degree that it will cause wing warpage. You will note that there are several photographs in this manual showing the covering of the fuselage. Two sixty inch wide grade A pieces of fabric were cut to proper lengths, pinned together at the top of the vertical fin, held into a square position and pinned down the leading edge of the vertical fin and up the turtle deck. Excess material was cut off, following the curvature of the vertical fin and turtle deck. Excess fabric in the area of the turtle deck headrest and top longerons is cut away as well as the excess material from the bottom longerons. With the excess material gone, it becomes much easier to sew the seams in accordance with CAM 18, down the vertical fin and turtle deck. Upon completion of the sewing, the excess material is cut away, allowing approximately a quarter inch material from the seam. The envelope is then turned inside out and fitted over the fin, turtle deck and around the upper longerons. Again, excess material is cut away from the longeron. Always keep in mind that the fabric must remain squared off to the basic fuselage, so that when it is doped to the fuselage, permanent wrinkles are not built in. It is best to attach the fabric to the top longerons in cockpit forward area, then to the bottom longerons, wrapping the fabric almost completely around the tubing. Any wrinkles then can be pulled out by pulling fore and aft when one dopes the fabric to the vertical fin post. Then make the fairing and cowling attach ring at the forward section of the fuselage. The fabric doesn't have to be drawn tight, just snug enough so that it sits on the frame without sagging. Small wrinkles are of little concern, but creases of any kind will show up and once dope is applied, creases will not come out. If the cloth is wrinkled and creased, iron it smooth with a warm flat iron. If properly shipped and stored it should be smooth, anyway. When all edges around the frame, the longerons, tailpost and forward cowling are dry, use a sponge with clean pure water and brush lightly over the complete fuselage.

You will note it will tighten up and all wrinkles will be gone. If water in your area is full of minerals, use distilled water because impurities left on the air-



The EAA Acro fuselage fabric cover with some of the excess fabric removed to make it easy to work.

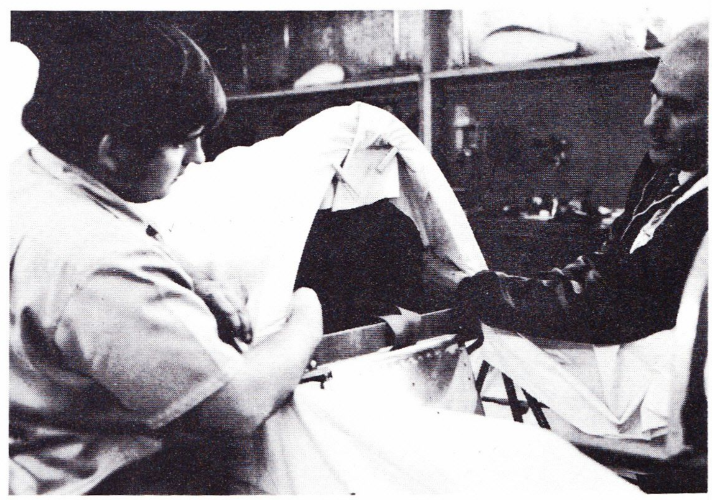


Aligning fabric for fuselage cover, a dope proof primer should be sprayed on all metal surfaces before covering.

The fuselage cover is fitted over the vertical fin.

plane fabric affect dope adhesion and absorb moisture. If all the fabric on the fuselage is properly water tightened when the fabric has dried, brush on the first coat of dope. You cannot simply brush dope out thin and smooth like paint . . . it begins to dry almost at once and any attempt at brushing it out will cause it to drag irregularly on the brush. Take a generous brush full of dope, spread it out with a few good firm quick strokes and fill the brush again, keeping wet dope going right on to drying dope so everything mixes and adheres. Don't let puddles of dope form for they will leak through. The droplets on the inner side then harden and the fabric weave is so ridigly locked that one day a brittle spot will develop. Don't let dope drop on the inside of fabric, such as through fitting holes or at cockpit edges. When drops dry inside they shrink and make a visible bump on the outside surface. When the first coat is dry the fabric will have a limp puckered look. After the first coat has thoroughly dried, apply the second. You will note that the fabric will begin to shrink, however, the fabric will take on a rough finish. This is created by the drying dope. Letting the fabric dry, you can then apply the pinked tape to all edges and seams. Apply dope for a few feet along the edge desired and then lay the tape down, push it down into the dope with a brush and apply more dope over it. When dry, go over the rough edges of the tape very lightly with fine abrasive sand paper, to smooth the projections. Then apply another coat of dope. An important tip is don't let long periods of time, such as several weeks, elapse between coats of clear dope. If you do, the last coat will then be quite dry and hard, and the next one won't bond so well. This leads to poor tightening and eventual peeling. Overnight waits, or a wait of a couple of days are all right, but try to schedule the fabric work so that when the doping begins it can be carried right through to completion. After the second coat of dope and each succeeding one, lightly sand paper the surface to cut the fuzz and tiny bubbles. When sanding your fuselage stringers or wing ribs and other hard spots in the covering, be **extremely** careful not to let the sandpaper **cut** the fabric. After the third or fourth coat of clear dope, affix any plastic inspection rings to the fabric in areas called out for in need of entrance to controls, etc.

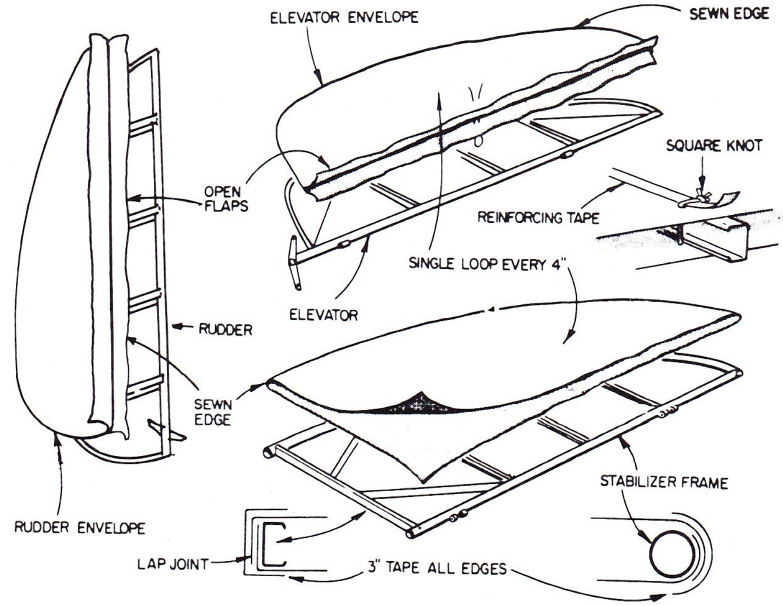
Usually four or five coats of clear dope will tighten fabric. The cloth should feel quite smooth to the touch, but not really completely glossy in appearance. After sanding with very fine abrasive papers, spray on a coat of clear dope into which has been mixed very fine powdered aluminum. Add enough of it to get a fluid that obviously has good bonding power, yet not so much as to make a stiff dry mix that will spray poorly. Let it dry overnight and then sand all over the fuselage or wings or tailgroup with No. 280 wet sandpaper such as the wet or dry used by auto body shops. Water acts as a lubricant without scratching thus keeping the abrasive paper from clogging. Wipe off the resulting mud with a small window cleaner, rubber blade or with a wet, lint free cloth. It is recommended that at least



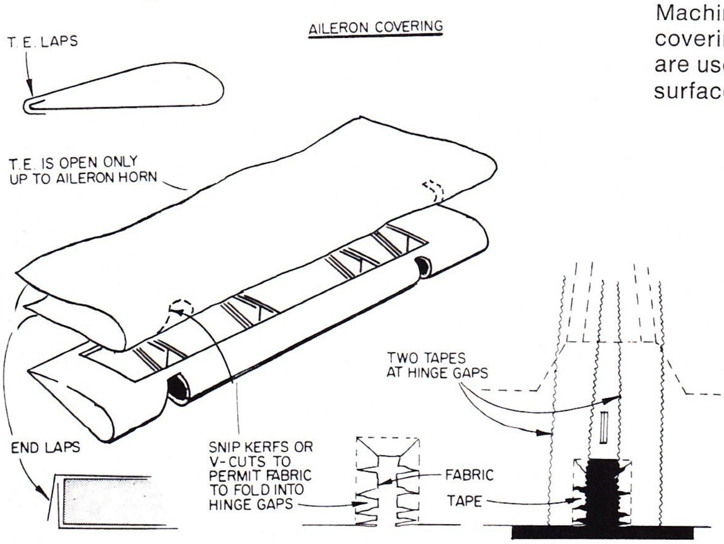
Fuselage slip cover sewed and being fitted around baggage door, excess material is cut away for ease of working.

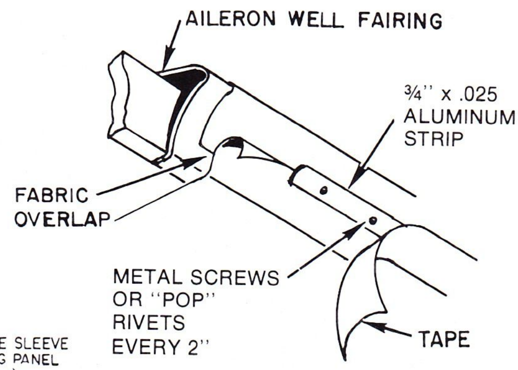
The fuselage slip cover is fitted to the fuselage. Cover is made from two 60'' pieces. The bottom of the fuselage is covered separately.

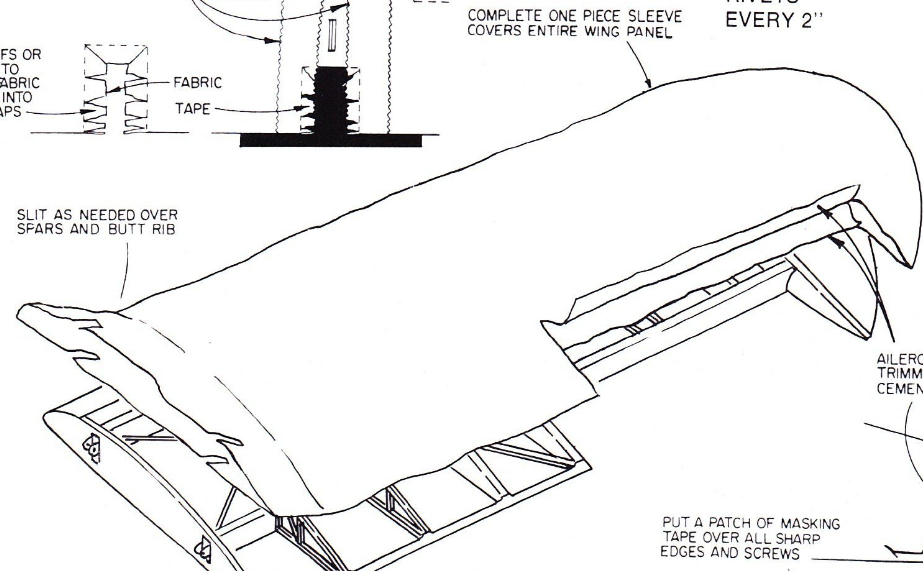
Fuselage fabric is doped to upper longerons, fabric cement is also used. Fabric is wrapped well under the longeron.



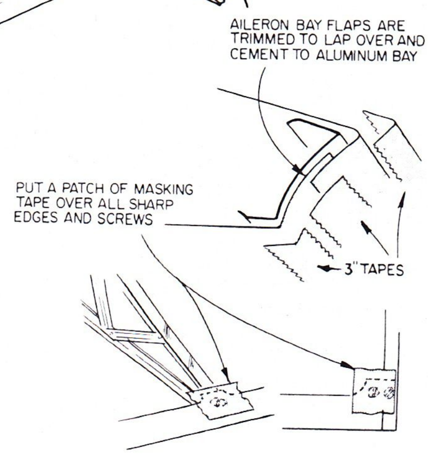
Machine sewed covering envelopes are used for control surfaces.



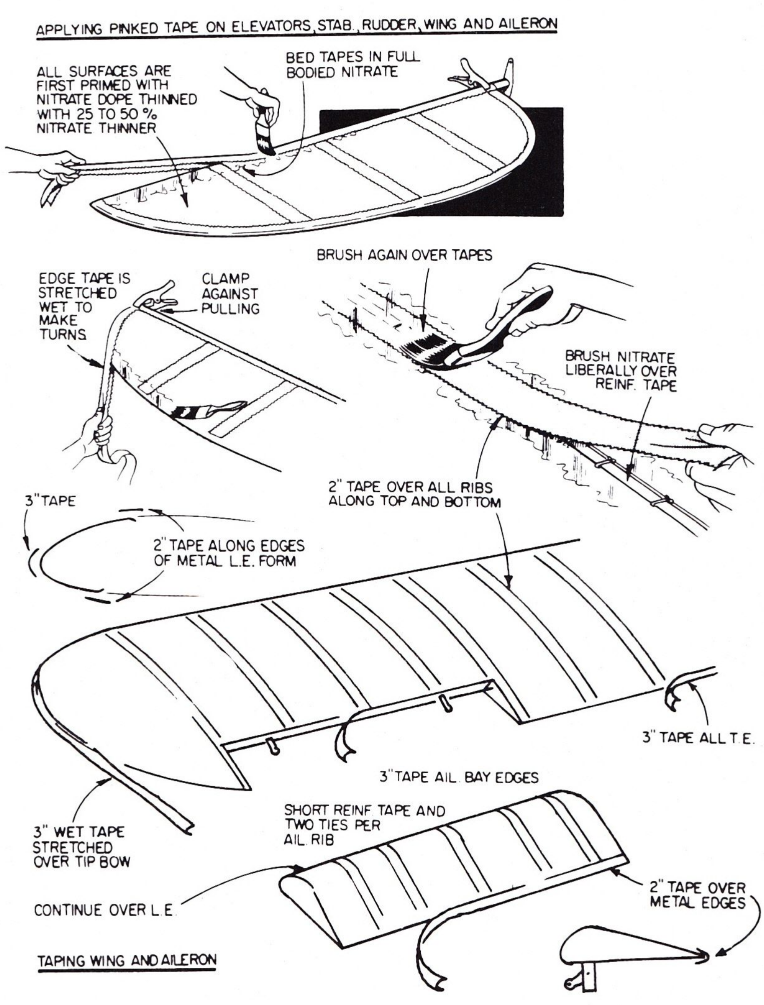


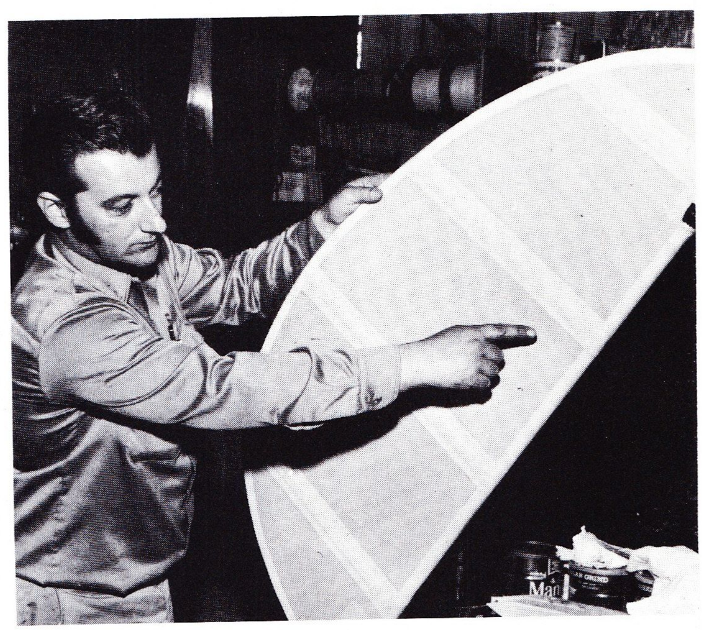


Wing slip covers are sewed according to FAA Procedures, turned inside out and slipped over wing panel and doped into position.



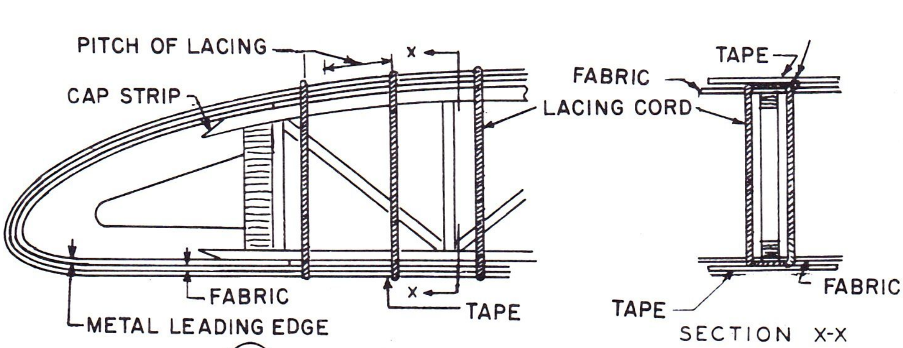
four, possibly five coats of silver dope be applied to all fabric, wet sanding between each coat to provide fill and smoothness. The cloth should feel quite smooth to the touch, the aluminum powder in the dope filling all the pores and giving a metallic appearance. Sanding invariably shows up thin places in the silver coat. Spray on another coat and repeat the sanding if needed. The purpose of silver dope is to block out sunrays from reaching the clear dope and the fabric, thus greatly prolonging the life of the covering job. Out in the sun look inside the fuselage — sunlight will be seen through the cloth to some degree, but at least it should be nearly uniform in intensity, indicating uniform silver dope coverage. It is best that no light penetrate the silver at all. The design of one's paint scheme is very important with as much work and effort as goes into an aircraft, its final appearance is very important to the builder. Final coat of pigmented dopes are applied and we would suggest using a manufacturer's manual on doping as a guide in this particular case. If not enough thinner is used in dope, it will spray on dry and produce a rough or orange peel effect. Remember, dope begins to dry immediately upon contact with air, and the mist from a spray gun is no exception. You will find that thinning of twenty five to fifty percent is commonly needed to get good spraying. The speed of a spray gun movement, distance of the nozzle from the surface, and dope consistency all affect the matter of avoiding runs. Temperature is very important. A temperature of seventy five or eighty degrees Fahrenheit being desirable. Humidity should be as low as possible. Spraying dope is easy enough, yet the chances of pulling a boner on one's first trial is very high. If possible, have an experienced friend help you out. One might even consider preparing several panels out of wood, stretching fabric across them, and applying your clear, your silver and pigment for practice. A total of four or five coats of pigmented dope will produce an attractive durable finish. If there is any roughness in the first pigmented coat, wet sand it lightly with 320 wet sandpaper. If dope is properly mixed, the gun working right and the air dust-free, the next coat should need no sanding. The final coat is thinned as much as possible without making it run, so that it will flow on smooth and dry with a nice gloss. Invariably some spray dust is in the air and will settle on the work and make it look dull and dusty. However, with a good suction fan, proper ventilation, this can be brought to a minimum. It is advisable to wait at least a month or six weeks before going over dope surfaces with an auto body cleaner or followed by waxing. If the aircraft is constructed in your home, your family will probably object to the strong smell of dope and make you do some of your doping out in the garage in warm weather. If the air is humid you may encounter





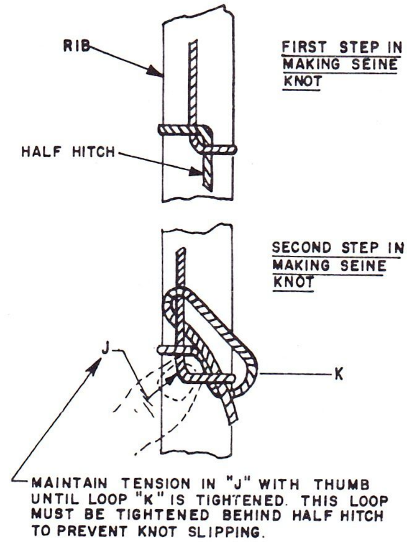
Pinked tape is used to cover ribs
and leading and trailing edges.

Applying re-inforcing tape
and pinked tape to wings and controls.

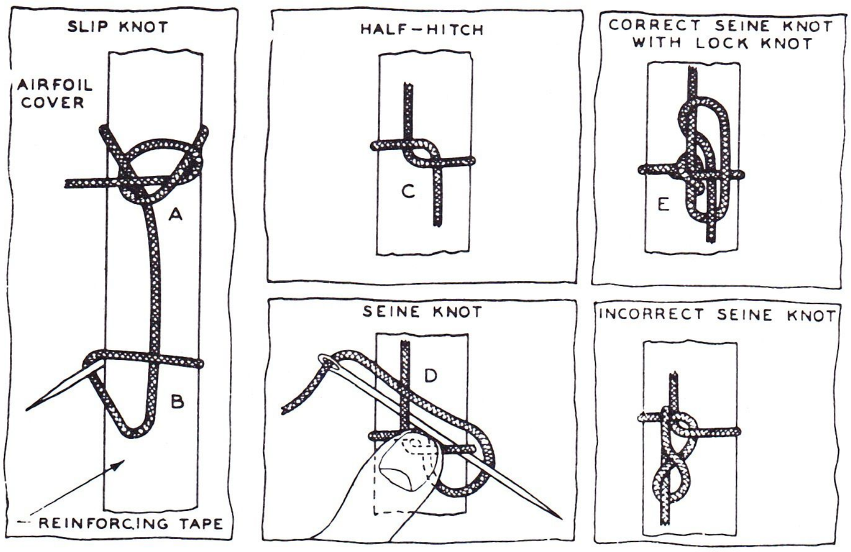


① WING RIB LACING

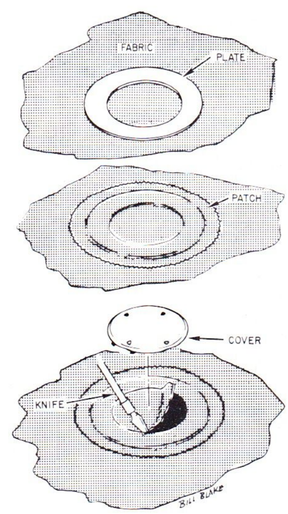
After placing the appropriate size re-inforcing tape over wing or control surface ribs, the fabric is laced to the structure.



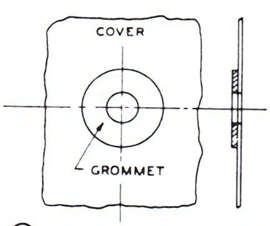
HOW TO TIE THE SEINE KNOT



② RIB LACING KNOTS

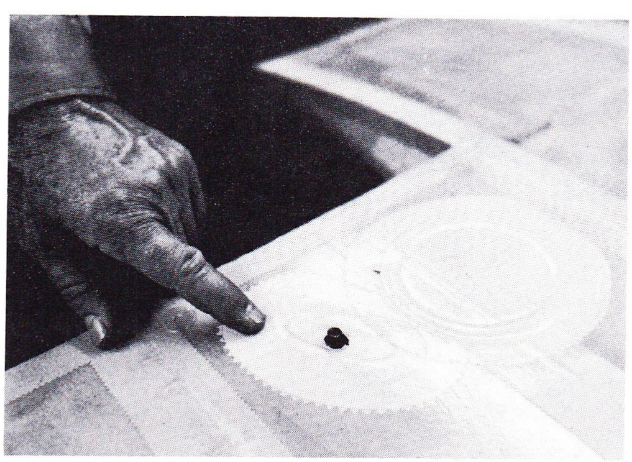


Round fabric patch is placed over plastic inspection grommets to prevent coming loose in flight.

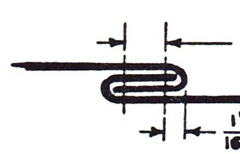


① PLASTIC GROMMET

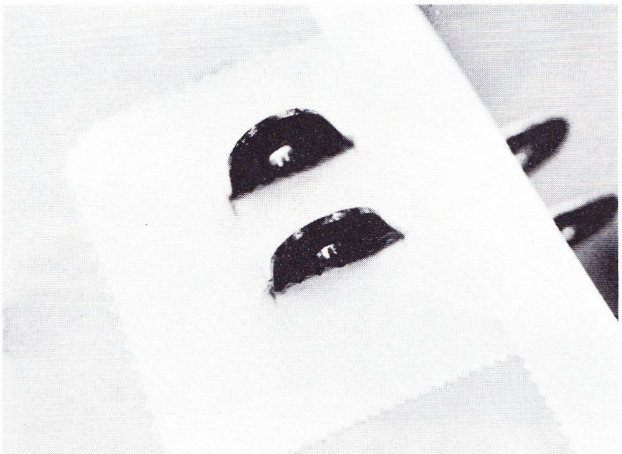
Plastic grommets are used to drain water See page 68 for placement.



Plastic inspection rings are doped into position and covered with fabric to prevent peeling off. Finger points to aileron control bell crank fitting prior to cutting the fabric from the slot in which it moves.



FRENCH FELL SEAM

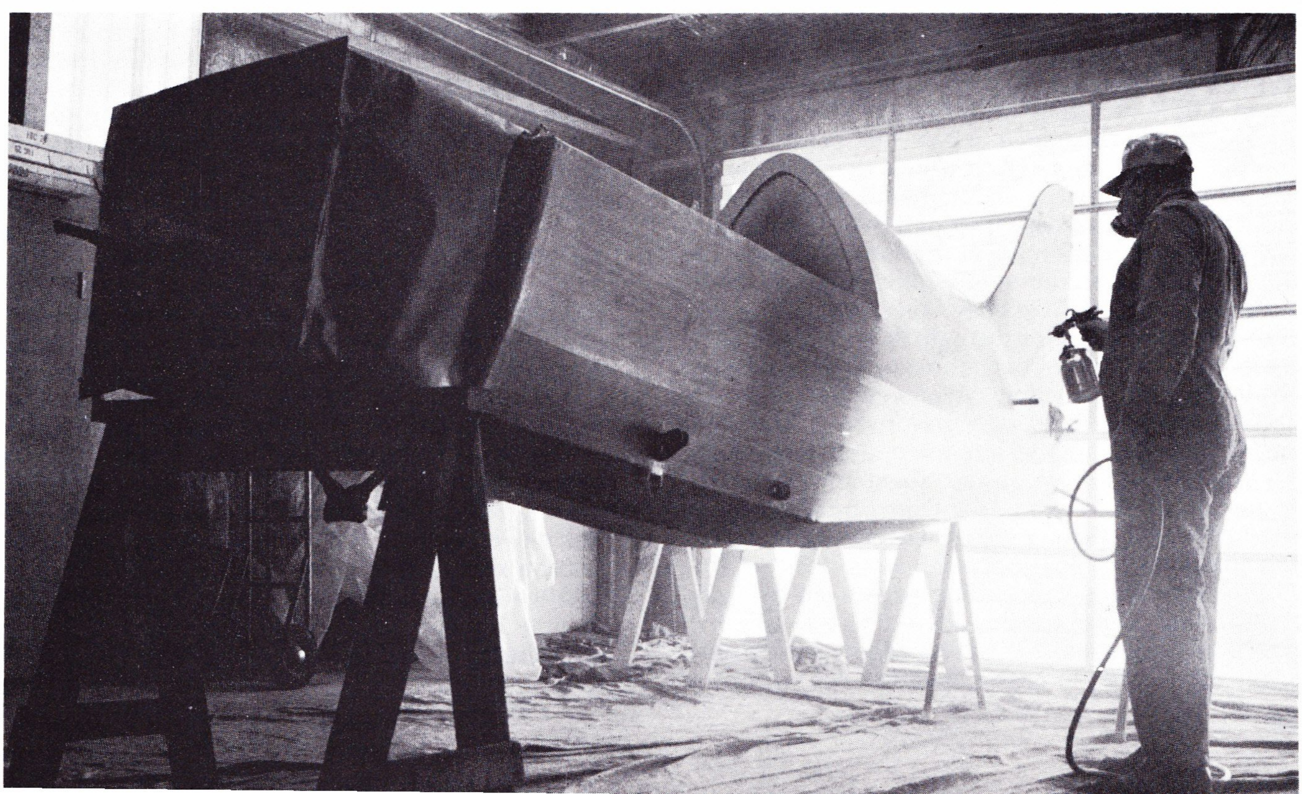


Fabric patch cut with pinking shears reinforces wing fitting fabric. Note pinked tape along edge.

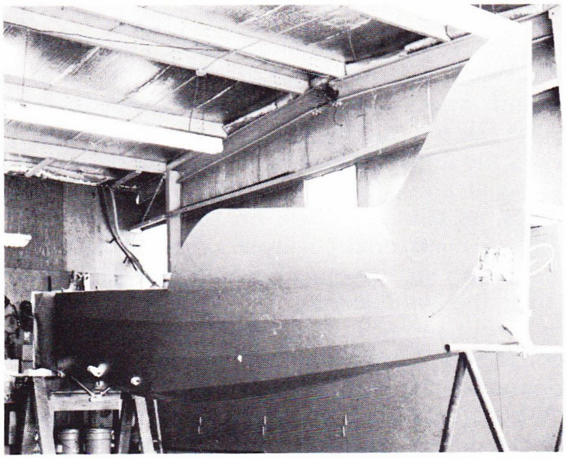
"blushing". This is rapid drying of the dope giving a whitish appearance. If you experience blushing use a retarder which is especially designed to reduce rapid drying in dope. This liquid slows down the rate of drying considerably and is of great help.

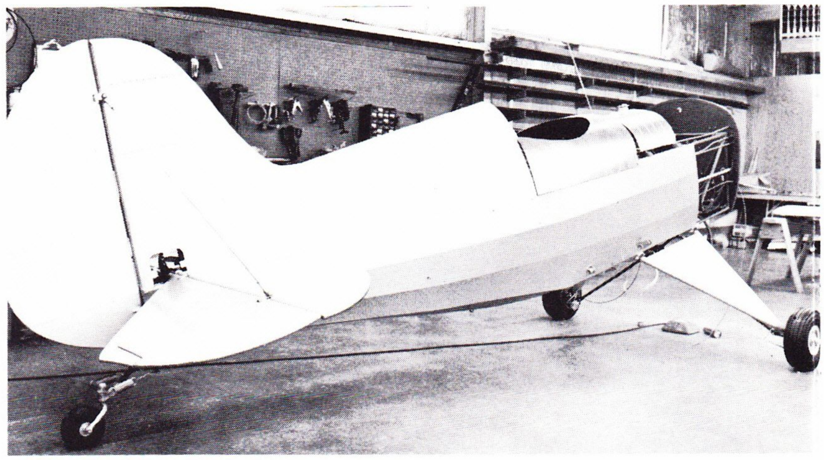
Regarding covering wings, we mentioned sewing the fabric strips together to form a blanket for each wing panel. The "French fell" seam is used to sew the strips together. Two methods of attaching fabric can be used. One is doping the fabric to the trailing edge of the wing, being sure that the fabric at the top of the wing is securely fastened to the top and bottom of the trailing edge. Excess material is cut off. We would recommend using the pillow slip method, and that is sewing all pieces of fabric together and when the pillow slip is inside out, bringing the fabric into place around the fiber glass wing tip and the metal trailing edge. It is good to use a pencil line at all center points to aid in sewing. Again, a double stitch is made on the sewing machine, all excess material cut away, the pillow slip turned inside out so all seams are in the inside and slipped over the wing panel. The area where the aileron fits is not sewed but glued with dope or fabric cement to the aluminum in the aileron section. It is recommended that three quarter inch strips of aluminum be sheet metal screwed to the inside curvature of the aileron fairing, to prevent the fabric from pulling away. After the slip is pulled into position, it can be pulled at the root or butt end of the wing rib to take out wrinkles and doped to the butt end of the rib. When all panels and center sections are covered, water again is used to take out any wrinkles prior to putting on the first coats of dope as spelled out and used in covering the fuselage. After the second coat of dope, rib stitching must be done. This is a manner of lacing the fabric to the ribs from the upper surface to the lower and back again. It keeps air suction from lifting fabric away from the ribs. If that happens, the airfoil would be changed considerably. It is recommended that the rib stitching be spaced one inch apart in the slipstream directly behind the propeller. This holds true for the elevators and stabilizer, as well as the rudder and fin, and two inches apart outside the propeller tips. The Civil Aeronautics Manual 18 on aircraft maintenance describes how the rib stitching is ac-

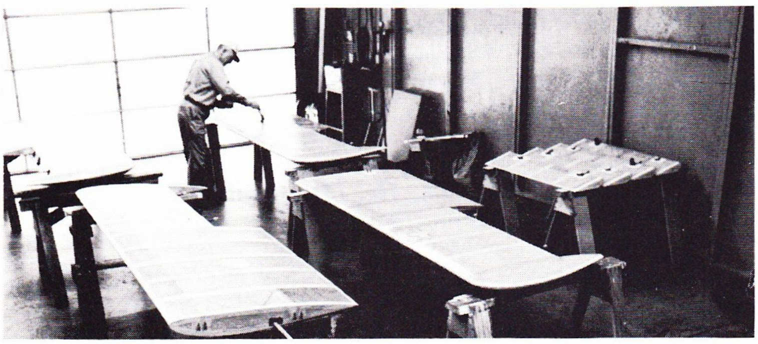
Charlie sprays second coat of silver on Acro fuselage. First coat was wet sanded to add smoothness to fabric. Forward section of fuselage masked to keep out silver dust.



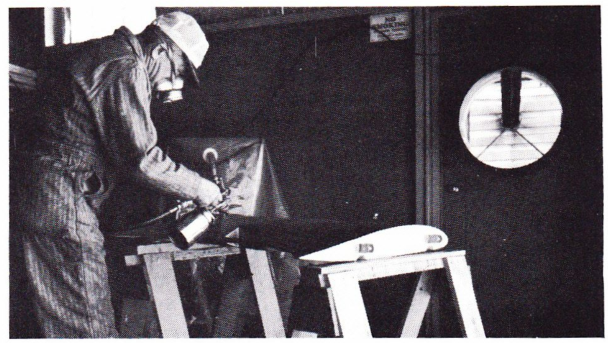
EAA Acro Sport fuselage after final coat of silver.







The wing panels and ailerons receive their final coat of clear dope prior to being sprayed silver. Note that all wing ribs and edges are covered with pinked tape.



Spraying silver to the center section.

complished. The rib cord that is used is a special, very strong aircraft grade which is treated with bee's wax for smooth working and water resistance. The knots that hold the fabric into place are usually run along one side of the wing rib cap strip instead of on top of it, and each knot is pushed down with the thumb so it does not show above the surface of the fabric. It is recommended that a ruler be used to mark the one and two inch spacings along the top and bottom side of the wing rib. This makes for a very neat appearance when the paint tape is applied. A long rib stitch needle is used to sew the fabric to the wing rib. Prior to rib stitching a quarter inch reinforcement tape is doped over the wing rib cap strips, the reinforcing tape is attached over the wood, behind the aluminum leading edge and ahead of the aluminum trailing edge. This helps in keeping the rib cord from cutting through the fabric and gives greater strength in holding fabric in place. When the rib stitching is done, apply the pinked tape over each rib. Start at the trailing edge, go forward and around the leading edge and back to the trailing edge, making sure that you have perfect alignment, for if you do not, it will show up underneath your final finish and give less than a craftmanship appearance. After all tapes are applied to the wing ribs, run one strip of tape along the leading edge from the wing root around to the trailing edge of the wing tip. It is recommended that the leading edge tape be doped firmly into place along the leading edge up to the fiber glass wing tip. The pinked tape when wetted with water and pulled tightly around the wing tip is held in place with a clothespin until it is dry. Upon drying you will find that the fabric has a curved set to it and can easily be doped into a nice curved and well fitted position. All edges, such as trailing edge of the aileron area, top and bottom, and trailing edge of the wing ribs should have pinked tape as well as the butt rib on the end board wing rib that attaches to the fuselage. Also between both the center section and the upper wing panels. All pinked tape is two inches wide and it should be mentioned that where the "French fell" seams are used to sew the fabric together in sheets on the wings, tape should be placed over these areas, at the same time the pinked tape is put over the wing ribs. This will protect the sewing and provide a smooth finish. Doping and finishing of the wings will continue the same as with the fuselage. Put inspection rings on the lower surfaces where drag and anti-drag wires attach to the spars, as well as where bell cranks or any moving fittings that are bolted into place are located, so that future inspections can be easily made. Drain grommets, little plastic circles with a hole in them, should be placed on each side of the trailing edge of each wing rib, just ahead of the aluminum. Upon final coats of dope, the little holes cut out. This allows moisture or any water that may accumulate in the wing to drain properly.

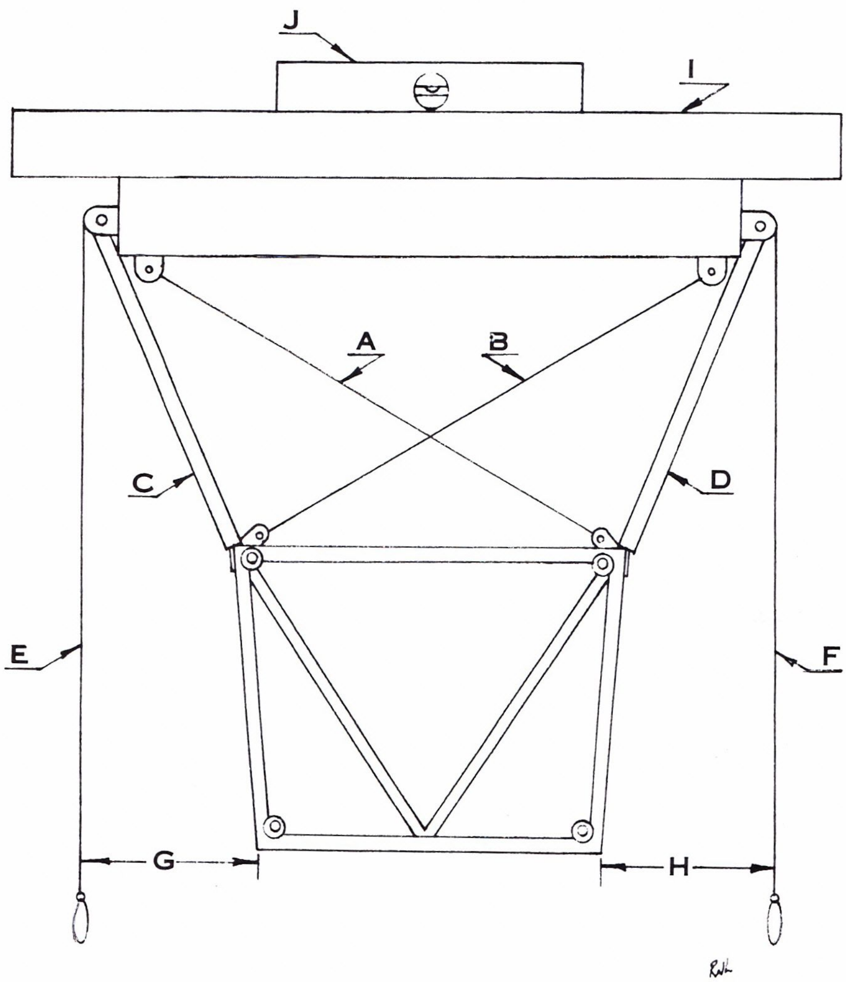


FIG. 1

For the best flight characteristics of any airplane, it is extremely important that all planes, — wings, center section, vertical fin and horizontal stabilizer — be in perfect alignment to the path of flight.

An improperly rigged aircraft can be a hazard, especially so on its first flight. It could cause excessive use of control at the time when a pilot needs his attention on completing a safe and successful first flight.

For example; if the trailing edge of the lower right wing extend downward an inch more than the left, the increased angle of attack would cause the wing to come up and turn the airplane to the left. This then would cause the pilot to apply the control stick to the right, dropping the left aileron to counteract this unwanted lift, and also applying right rudder to maintain direction. The pressures on the controls can be excessive depending both on forward speed and the degree of misalignment.

The Acro Sport has been designed with a center section, four wing panels, two uppers, and two lowers, a left and right horizontal stabilizer, and a fixed vertical fin.

The center section "N" struts, as they are known, are constructed of steel tubing and hold the center section into position. It is important that extremely accurate dimensions — as called out in the assembly drawings — be maintained and that both center section struts are perfectly matched, as well as the fuselage attach fittings and bolt hole dimensions.

All wing-to-fuselage and center section spar fittings must also maintain accuracy to insure perfect and equal alignment. For example; the center section and the two upper outer wing panels should be placed on a jig board, and center section spar wing bolts slipped into position to insure mating and alignment of the four bolts thru all attach fittings. The Acro Sport has been designed in such a manner that the upper ends

rigging

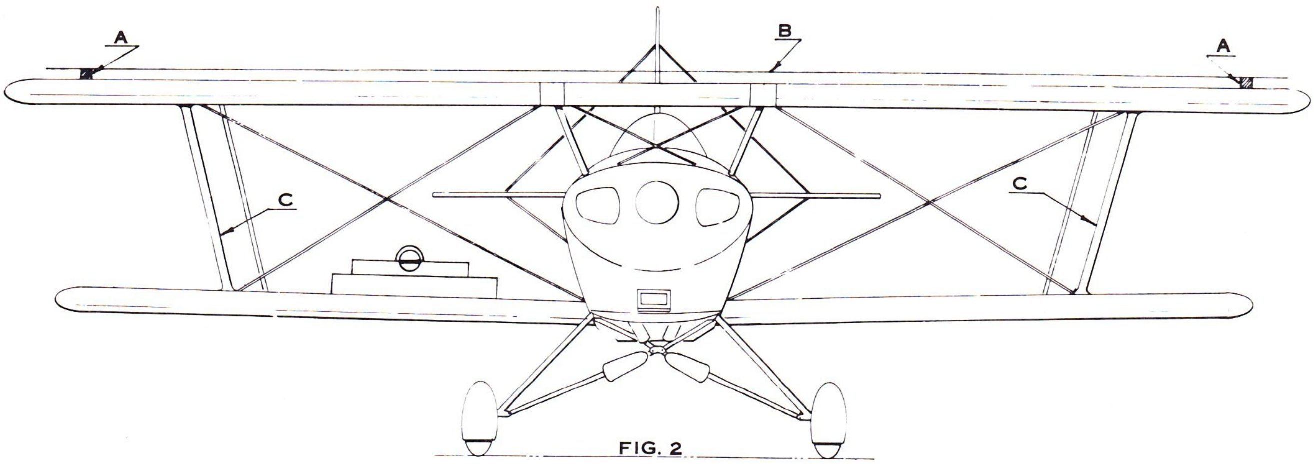


FIG. 2

of the cabanes fit into the spar butt ends of both the center section and the wing panels. This buried fitting has the advantage of reducing the wind drag load by fairing into the wing, rather than an extra external fitting. It does make for an extra problem as the two upper wing panels must be put into position prior to rigging of the center section.

During construction it is wise to fit the lower wings into position prior to gluing butt rib and covering. This will insure that all spar butt fittings and bolts will easily slip into position and that the inboard trailing edges at the wing walks are of equal distance. It will also insure that all aileron push-pull tubes have adequate clearance while passing through the compression and standard wing ribs in full travel each direction. The aileron bell cranks inside of the lower wings must maintain adequate clearance so that the bolts and nuts adequately clear the drag and anti-drag wires.

RIGGING THE CENTER SECTION

The tools needed to rig the Acro center section consists of plumb bobs and lines, steel tape, a spirit level, straight-edge and a various assortment of wrenches.

The first step in rigging is to position the center section so that the longitudinal center line of the section is directly above the center of the fuselage. To accomplish this, the attached center section roll wires (A) and (B) in Fig. 1 must be adjusted until they measure (trammel) the same distance from clevis pin to pin.

If the length of wire (A) is greater than that of wire (B), loosen wire (B) and tighten wire (A). If your fuselage and strut attach fittings are in alignment, when wires (A) and (B) are adjusted to equal length, the center section will then be in proper position to check the accuracy of the work drop plumb lines (E) and (F) from the upper center section front spar fittings. Measure the horizontal distance of these lines from some structure of the fuselage. If the airplane is level laterally and the center section is centered over the fuselage center line, the distance (G) and (H) will measure the same.

Next, place a straight-edge (I) directly over the center section front spar and place a level (J) on it. If the center section is not level the struts are not of equal length and then must be altered to maintain accuracy.

The Acro Sport uses an "I" strut to hold the upper and lower wing panels into position. The wings are braced with four flying wires on each side as well as dual landing wires.

To insure accuracy in rigging, be sure that both "I" struts are identical in dimension as wash-in or wash-out of wing trailing edges is accomplished by adding or subtracting washers between the strut, fittings, and the wing spars. This will cope with any wing heaviness problems.

The lower wings can be put into position, as well as the outer wing "I" strut. The flying and landing wires can also be put into position while rigging the center section. Upper wings must be on for center section alignment.

After all center section wing strut bolts and roll wire lock nuts have been tightened and checked, the rigging of the center section can be considered complete.

RIGGING WINGS

When rigging the Acro Sport, all flying wires should be loose and the lower wings rigged first for dihedral. The front spar of the wing can be used as the wing reference line, therefore, the angle of dihedral 2 degrees for the Acro Sport can be measured by placing a straight-edge along the top of the front spar, holding a level protractor on the top of this and adjusting and reading the instrument as illustrated in Fig. 2.

Tightening the landing wires increases the dihedral and loosening the landing wires decreases dihedral. After the dihedral of 2 degrees has been established in the lower wings, the upper wings should be rigged for 0 degrees dihedral. If your "I" struts have been made accurately and both are matched, small adjustments for wash-in or wash-out and 0 degree dihedral can be accomplished by placing washers between the "I" strut and all four spar points. Another method to insure that the upper wing is straight or level transversely is to place two blocks, Fig. 2, of equal dimension over the last full size rib at the front wing spar, and stretch a string (B) as shown, the distance from the string to any corresponding portions of the wing or center section should be the same. As an additional check, sight along the leading edge of the wing to see if it is straight.

Remember that the basic adjustments to be made is the dihedral angle of the front spar of each lower wing. After this has been accomplished, raising and lowering of both rear spars to obtain equal and uniform measurements must be accomplished. This is done by adding or decreasing washers between either the rear upper or lower rear wing spars.

After adjustments have been made, the flying wires can be tightened and safetied with the lock nuts. A wood dowel of ¾" notched out appropriately, depending on the angle of the wires, can be installed to hold the wires against excessive vibration.

RIGGING THE TAIL GROUP

The most important alignment in the tail group is that of the horizontal stabilizer, in relationship to the wings. Before attempting to rig this surface, the lateral position of the Acro Sport should again be checked to make sure it is still level. The rear spar of the stabilizer can be used for a leveling position. This can be measured by placing a straight-edge and spirit level directly on the stabilizer spar.

The vertical fin is designed to be at 90° to the plane of the stabilizer. Therefore, the alignment of the vertical fin and the horizontal stabilizer have to proceed at the same time. This tail group is braced by adjustable streamline wires as shown in Fig. 3. A common method of procedure is to adjust wires (A) and (B) so that they trammel (measure) the same length from pin to pin.

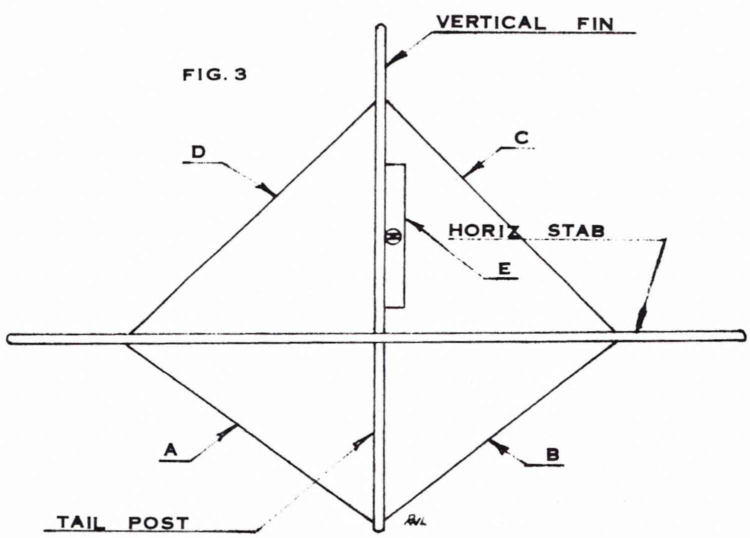
Next, the wires (C) and (D) are adjusted so that they are at the proper tension and that they trammel the same length from pin to pin.

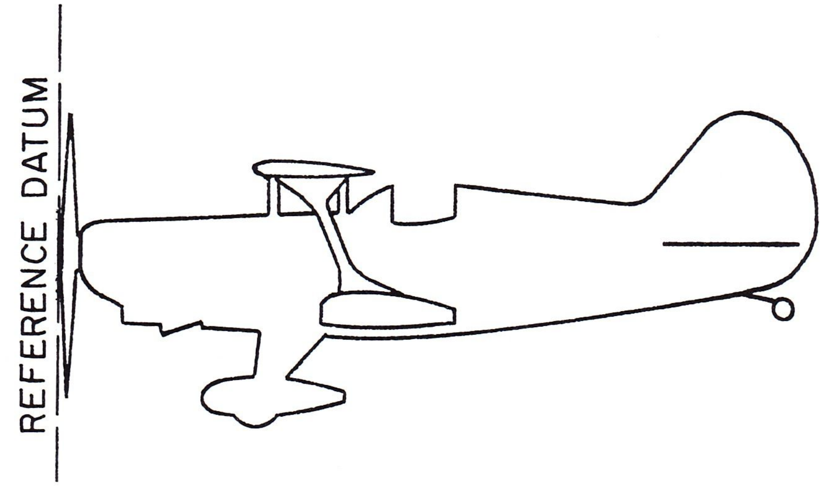
If the vertical fin rudder post has been installed accurately, if all wires are equal and the horizontal stabilizer rear spar is in level plane, the tail group, the brace wires, and lock nuts can be given their final tightening.

A plumb level can be held against the tail post to insure accuracy, or a plumb bob can be suspended from the top of the vertical fin post to visually inspect its position with reference to the center line of the tubing. The rudder must be removed to accomplish this.

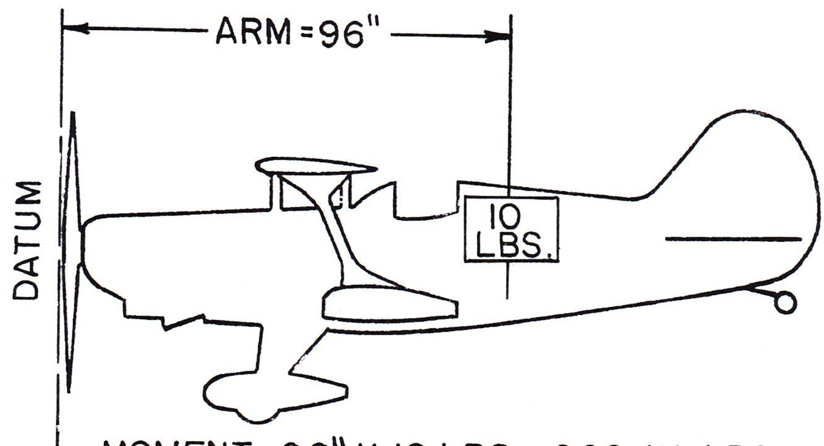
This view clearly shows the tail group of the Acro Sport. A servo tab has been added to left elevator, not shown here, to adjust elevator control pressures.

FIG. 3





weight & balance

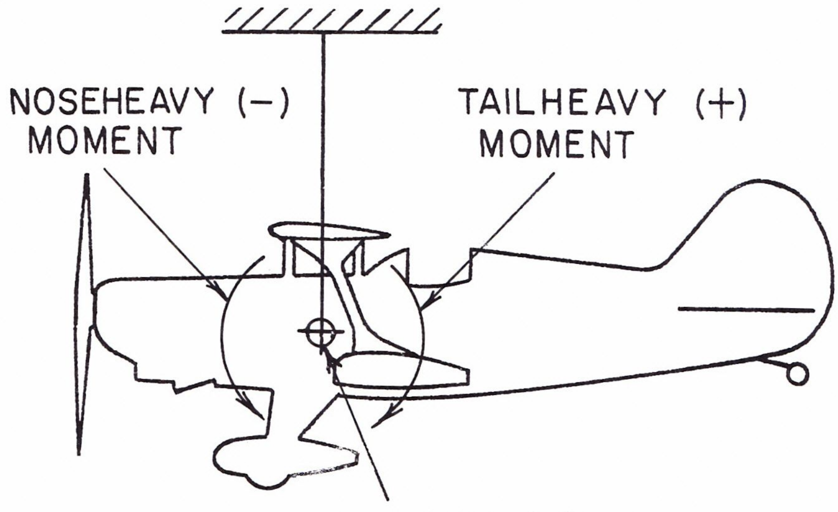


The center of gravity of an airplane may be defined, for the purpose of balance computations, as an imaginary point about which the nose heavy (−) moments and tail heavy (+) moments are exactly equal in magnitude. If the aircraft were suspended therefrom, it would have no tendency to rotate in either direction (nose up or nose down). The weight of the aircraft can be assumed to be concentrated at its CG.

The allowable variation of the CG location is called the CG range. Since CG limits constitute the range of movement that the airplane CG can have without making the airplane unstable or unsafe to fly, the CG of the loaded airplane must be within these limits at takeoff, in the air, and on landing.

The datum line, or simply datum, is a plane or line in a plane used as a reference in order to show relative locations of objects. In computations for weight and balance the reference datum is vertical and is located at the nose of the airplane as in our case for convenience. As stated previously, all clockwise moments are positive and counterclockwise moments are negative. When the datum is located at the nose of the airplane, all moments must be positive and a nose-heavy moment is negative. If the airplane were suspended at its nose, it is obvious that the tail would be downward; hence all moments are tail heavy or positive.

It is very important to determine the exact location of the datum line before starting to solve



the weight and balance problem.

The moment arm, or merely the arm, is the horizontal distance in inches to the CG of an item measured aft of the datum. With the datum at the nose of the airplane, all measurements are aft and therefore positive.

The moment is the product of the weight and the arm. Thus, the moment of an item about the datum is obtained by multiplying the weight of the item by its horizontal distance from the datum. Moment is manifest as a tendency to cause rotation of the aircraft about its CG.

Before proceeding with the method of computing weight and balance, a thorough understanding of these terms is necessary:

EMPTY WEIGHT: The empty weight of an aircraft includes the weight of the airplane, powerplant, equipment which has a fixed location and is normally carried in the airplane, fixed ballast, and any other parts or equipment which are required during flight and are installed in the airplane. Fuel and oil are drained and only residual fuel and oil is included in the empty weight.

MAXIMUM WEIGHT: Maximum weight is the maximum authorized takeoff weight of the aircraft and its contents.

USEFUL LOAD: Useful load is the empty weight subtracted from the maximum authorized takeoff weight for the aircraft. This load includes pilot, maximum oil, maximum fuel and baggage.

WEIGHT CHECK: A weight check consists of checking the sum of the weights of all items of useful load against the allowable useful load of the aircraft.

EMPTY-WEIGHT CG: The empty-weight CG is the center of gravity of an aircraft in its empty condition.

OPERATING CG: The operating CG is the center of gravity of an aircraft in its loaded or operating condition.

WEIGHING POINT: The weighing points of an airplane are the points by which the airplane is supported at the time it is weighed. In this case, the landing gear and tail wheel are the weighing points.

TARE: Tare is the weight of the equipment necessary for weighing the airplane (such as chocks, blocks, etc.) which is included in the scale readings but is not a part of the actual weight of the airplane. Tare must be subtracted from the scale readings in order to obtain the actual weight of the airplane.

LEVELING MEANS: Leveling means are the reference points used for leveling the aircraft. In this case it is the top of the top fuselage longerons in the cockpit.

DETERMINATION OF EMPTY WEIGHT CENTER OF GRAVITY LOCATION

In order to obtain an accurate reading of the aircraft weight, the following procedures should be followed:

1. The aircraft should be weighed inside a closed building to avoid errors which may be caused by wind.
2. The airplane must be leveled longitudinally and laterally.
3. The accuracy of the scales must be established.
4. All items of equipment to be installed in the aircraft and included in the empty weight should be in place for weighing.
5. The oil system should be drained. It is permissible to weigh the airplane with full oil, but the weight of the oil must be subtracted from the total weight to obtain the empty weight of the aircraft. The moment of the oil must be taken into consideration when the CG location is computed.
6. The fuel tank should be empty, or the fuel in the tank will have to be condisered during CG location computation.
7. The weight of thc tare should be recorded, either before or after weighing the airplane, and the

tare weight should then be subtracted from the total weight as obtained from the scales.

8. When the airplane is in the level position, the exact horizontal distance between the supporting points must be recorded.

9. The weights of the right wheel, left wheel, and tail wheel must be recorded to provide information needed for the CG determination.

The fundamental rule for determining the location of the CG for an airplane is: DIVIDE THE TOTAL MOMENT OF AN AIRPLANE (TAKEN FROM A SPECIFIC REFERENCE POINT) BY THE TOTAL WEIGHT OF THE AIRPLANE. THE RESULT WILL BE THE DISTANCE OF THE CG FROM THE REFERENCE POINT.

In the figure, the Acro Sport is weighed and it is found that the right wheel weight is 381.5 lb., the left wheel weight is 381.0 lb., and the tail wheel weight is 24.5 lb.

These weights, with the location of the weighing points, give us the information we need to find the location of the CG. The weight of the blocks that are used on the scales must be removed as tare.

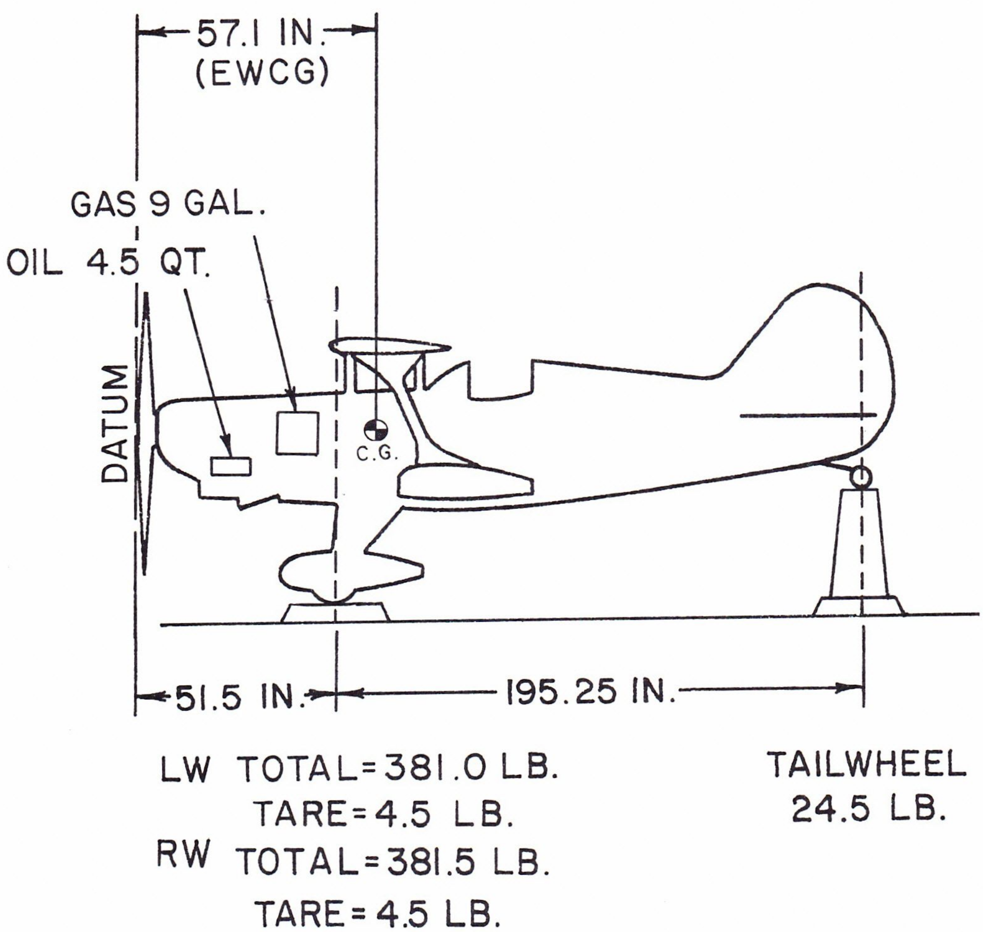
We establish the datum line on the front face of the propeller hub. All moments will be determined from here. The moments and CG location are found as follows:

Item	Scale	Tare	Lbs. Net	Inches Arm	In. Lbs. Moment
Left Wheel	381.0	4.5	376.5	51.5	19,389.75
Right Wheel	381.5	4.5	377.0	51.5	19,415.50
Tail Wheel	24.5		377.0	195.25	4,783.63
Less Oil	4.5 Qt.		-8.5	23.0	-195.50
Less Gas	9 Gal.		-54.0	47.0	-2,538.00

Empty Weight Total Moment 40,855.38 in. lbs.

$$\text{Empty Weight CG} = \frac{\text{Total Moment}}{\text{Empty Weight}} = \frac{40{,}855.38}{715.5} = 57.1 \text{ inches}$$

Care must be taken to insure that the proper sign is applied to each quantity expressed in a weight and balance computation. All moments are positive (+) in this instance, since the datum is at the nose. The weight of an airplane is always positive. Also, the weight of any item installed in the airplane is positive. The weight of any item removed from the airplane is negative (-). According to the rules of algebra, the product of numbers with like signs is positive, the product of numbers with unlike signs is negative.



LOADING THE AIRPLANE

The Acro Sport has a CG range within which the CG must lie if the aircraft is to be operated safely. In order to determine whether the loaded CG falls within the approved limits, it is necessary that two computations be made, one for most forward loading and one for most rearward loading.

To determine the conditions for most forward loading, we must consider the fuel quantity and arm, oil quantity and arm, and pilot and arm. Except for the pilot, these are all quantities which tend to move the CG forward. Our computations must include maximum quantities of these items. We do not include baggage, as this would tend to move the CG aft.

Assuming that the empty weight of the airplane is 715.5 lb. and the empty weight CG is +57.1, we can load the airplane to determine whether the forward CG is within limits with maximum forward loading.

Unit weights have been established for weight and balance purposes. Gasoline is taken as 6 lb. per U. S. gallon, lubricating oil is 7.5 lb. per U. S. gallon, and 170 lb. is usually allowed for the pilot. Of course, exceptional pilot weights should be taken into consideration.

ITEM	WEIGHT	ARM	MOMENT
Aircraft EW	715.5	57.1	40,855.38
Oil (8 Qt.)	15.2	23.0	349.60
Pilot	170.0	93.5	15,895.00
Smoke Oil (5 Gal.)	32.5	65.0	2,112.50
Fuel (20 Gal.)	120.0	47.0	5,640.00
Baggage	———	———	———
TOTALS	1,053.2	———	64,852.48

$$\text{Most Forward CG} = \frac{\text{Total Moment}}{\text{Total Weight}} = \frac{64{,}852.48}{1{,}053.2} = 61.57 \text{ inches}$$

This falls within the allowable CG range, as it falls aft of the most forward CG limit of 60.0 inches.

To check the airplane for rearward CG limit, we must use a maximum of all weights to the rear of the CG limit and a minimum of all weights forward of the rearward CG limit. Now the problem is arranged as follows:

ITEM	WEIGHT	ARM	MOMENT
Aircraft EW	715.5	57.1	40,855.38
Oil (8 Qt.)	15.2	23.0	349.60
Pilot	170.0	93.5	15,895.00
Smoke Oil (5 Gal.)	———	———	———
Fuel (20 Gal.)	———	———	———
Baggage	25.0	119.0	2,975.00
TOTALS	925.7	———	60,074.98

$$\text{Most Rearward CG} = \frac{\text{Total Moment}}{\text{Total Weight}} = \frac{60{,}074.98}{925.7} = 64.98 \text{ inches}$$

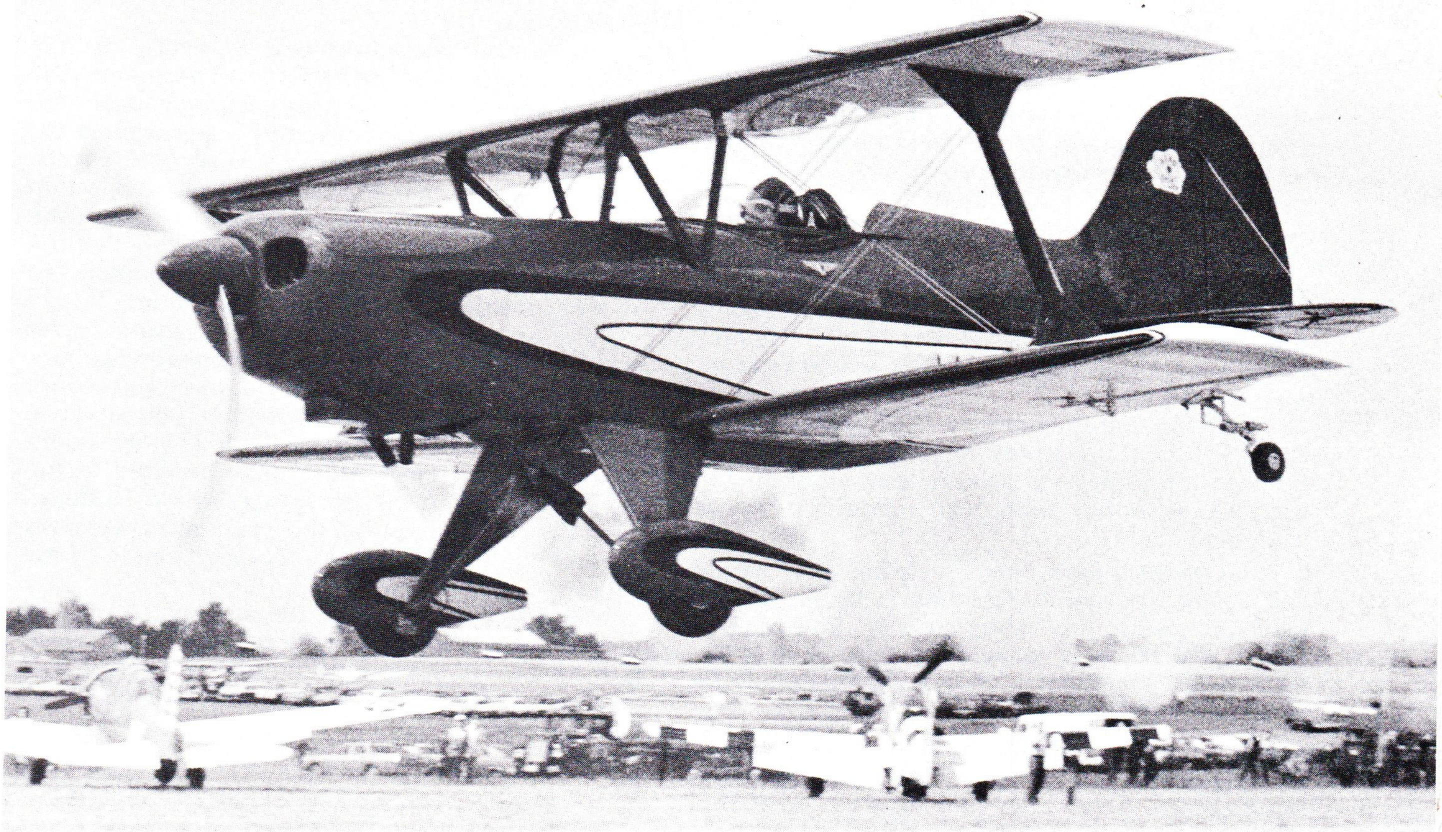
This falls within the allowable CG range, since it falls forward of the most rearward CG limit of 66.75 inches.

It must be pointed out that the figures used in these examples are for the Acro Sport prototype. The weights and arms will vary for each individual Acro Sport, but the forwardmost and rearwardmost CG **limits** given here are applicable to **all** Acro Sports.

In the event that the CG does not fall within the approved range, it is necessary to correct the condition with ballast. It is highly unlikely that the builder will encounter a tail-heavy condition, so we will consider the nose-heavy condition.

The first step necessary in the computation for the correction of the CG is to determine what moment is necessary to provide the required correction. The moment necessary for correction is the distance of the CG outside the limit multiplied by the weight of the airplane. Lead ballast may be fixed in the tail just forward of the tail spring mount. To determine the weight required the moment necessary is divided by the arm of the intended location of the ballast.

During the lifetime of the airplane, it may be desirable to change the type of equipment which is installed. In every case of such a change it is necessary to figure the effect on weight and balance.



regulations

Following is a partial text of the latest FAA Advisory Circular pertaining to Homebuilt Aircraft . . .

SUBJECT: CERTIFICATION AND OPERATION OF AMATEUR-BUILT AIRCRAFT

1. **PURPOSE.** This advisory circular provides information and guidance concerning certification and operation of amateur-built aircraft, including gliders, free balloons, helicopters, and gyroplanes, and sets forth an acceptable means, not the sole means, of compliance with Federal Aviation Regulations (FAR) Part 21, Sections 21.191 and 21.193, and FAR Part 91, Section 91.42.

2. **CANCELLATION.** Advisory Circular No. 20-27A, "Certification and Operation of Amateur-built Aircraft" dates 8/12/68 is cancelled.

3. **BACKGROUND.** The Federal Aviation Administration has received many requests from amateur-builders for information concerning building, certification, operation, and pilot requirements for amateur-built aircraft of all types. Advisory Circular No. 20-27 was originally prepared to provide information and guidance based on Civil Air Regulations (CAR) Part 1, Section 1.74, which has since been recodified into FAR Part 21, Section 21.191. This advisory circular has been prepared to update the information formerly in AC No. 20-27, incorporate information formerly in CAM Part 1, Section 1.74-3, and to set forth an acceptable means of compliance with FAR Part 21, Sections 21.191 and 21.193, and FAR Part 91, Section 91.42.

4. **ELIGIBILITY.** Under FAR Part 21, Section 21.191, an experimental certificate for an amateur-built aircraft may be issued if the major portion of the aircraft has been fabricated and assembled by persons who undertook the construction project solely for their own education or recreation. In meeting the requirements of this section:

   a. Many components, parts, and materials need not be fabricated by the applicant but may be procured through normal trade channels. (For example: engines, propellers, rotor blades and hubs, wheel and brake assemblies, "standard" aircraft hardware such as pulleys and fasteners, and materials such as tubing, fabric, and extrusions). In addition, raw material construction kits and structural components of other aircraft may be used provided the builder has fabricated and assembled the major portion of the aircraft for education or recreation.

   b. Aircraft which are merely assembled from kits composed completely of prefabricated components and parts, and pre-cut, pre-drilled materials, are not considered to be eligible for certification as amateur-built aircraft, since the major portion of the aircraft would not have been fabricated and assembled by the builder.

5. **DESIGN AND CONSTRUCTION.** The following is intended to provide guidance and information in the interest of safety for the design and construction of amateur-built aircraft.

   a. The design should avoid, or provide for padding on, sharp corners or edges, protrusions, knobs, and similar objects which may cause injury to the pilot or passengers in the event of a minor accident.

   b. Any kind of engines, propellers, wheels, and similar components, and any kind of materials may be used in the construction of an amateur-built aircraft; however, it is suggested that FAA approved components and established aircraft quality material be used wherever possible, and especially in fabricating parts such as wing spars, critical attachment fittings, and fuselage structural members.

   c. It is suggested that the instruments and equipment specified in the applicable paragraphs of FAR Part 91, Section 91.33 be installed in amateur-built aircraft.

   d. Prior to first flight of the aircraft, the powerplant installation should undergo at least one hour of ground operation at various speeds from idle to full power, to determine and ensure that all systems are operating properly. The grade of fuel recommended by the engine manufacturer should be used for all operations, and a fuel flow check should be accomplished to ensure that adequate fuel is supplied to the engine in all anticipated flight attitudes.

   e. Suitable means, consistent with the size and complexity of the aircraft, should be provided to reduce fire hazard wherever possible, including a fire wall between the engine compartment and the fuselage. A system for providing carburetor heat should also be provided to minimize the possibility of carburetor icing.

f. Additional information and guidance of value to an amateur-builder is provided in FAA Advisory Circulars No. 43.13-1 and 43.13-2.

6. **APPLICATION FOR EXPERIMENTAL CERTIFICATE.** The following regulations are applicable to an applicant for an experimental certificate.

a. The appropriate sections of FAR Part 47, Aircraft Registration, which prescribe the requirements for:

(1) Obtaining an identification number (nationality and registration marks) and,

(2) Registering the aircraft. (NOTE: In addition to general provisions, FAR Part 47, Section 47.33(c) applies specifically to applicants for registration of amateur-built aircraft.)

b. FAR Part 21, Section 21.182, which prescribes aircraft identification requirements.

c. FAR Part 45, which establishes requirements for:

(1) Data and location for identification plates;

(2) Display of airworthiness classification marks; and,

(3) Display of the identification number.

d. FAR Part 21, Sections 21.173 and 21.193, which prescribe the requirements for submittal of an application for airworthiness certificate. An application form may be obtained from the nearest office of the FAA Flight Standards Service.

7. **INSPECTION.**

a. The airworthiness certification procedure includes inspection of the aircraft by an authorized FAA representative to determine that the aircraft is in condition for safe operation.

b. In order that the inspection can be conducted with the least burden to all concerned, it is recommended that the amateur-builder contact the nearest office of the FAA Flight Standards Service prior to starting his project, to discuss his intentions and to generally outline his proposed program for fabrication and assembly of his aircraft. The FAA representative will establish a tentative plan for inspection of the aircraft at stages in its construction which will permit inspection of structures, such as wings or fuselage, before external covering is applied or before an area is permanently closed.

c. To preclude any problems or questions concerning source or specifications of materials, parts, appliances, etc. used in fabricating the aircraft, it would be helpful if the builder kept copies of all invoices or other shipping documents.

d. The final inspection of the aircraft will include a determination by the FAA representative that:

(1) The aircraft is properly registered;

(2) The aircraft identification requirements of FAR Part 45 have been complied with; and,

(3) FAR 91.31 has been complied with, as applicable.

8. **OPERATING LIMITATIONS.**

a. With the issuance of an experimental certificate, conditions and limitations are prescribed by the FAA. The operating limitations are generally considered in two phases; (1) those prescribed with the original issuance of the certificate, and, (2) those prescribed following satisfactory operation in an assigned flight test area. FAR Part 91, Section 91.42 prescribes general operating limitations for all experimental aircraft; however, the FAA inspector will also normally issue additional limitations specifically applicable to amateur-built aircraft.

b. After completion of the appropriate period of operation in an assigned flight test area, application may be made to the FAA for amendment of the operating limitations to permit flight outside of the area. An application for airworthiness certificate is the form used to apply for amendment of operating limitations and may be obtained from the nearest FAA Flight Standards Service Office.

9. **OPERATION OF AMATEUR-BUILT AIRCRAFT.** An amateur-built aircraft is governed by the operating rules contained in FAR Part 91, "General Operating and Flight Rules", except that, a "gyroglider" flown while attached to a ground or water towing vehicle is considered a kite and subject to FAR Part 101, "Moored Balloons, Kites, Unmanned Rockets, and Unmanned Free Balloons". The pilot in command of an amateur-built aircraft being operated under FAR Part 91 is subject to FAR Part 61, "Certification: Pilots and Flight Instructors".

10. **SAFETY PRECAUTIONS.**

a. Before first flight of an amateur-built aircraft, the operator should take precautions to ensure that adequate emergency equipment and service is readily available in the event of an accident during initial takeoffs and landings. If the aircraft is a seaplane operated from a body of water, it is recommended that a boat with appropriate rescue equipment and personnel be stationed near the takeoff and landing area.

b. The operator should thoroughly familiarize himself with the ground handling characteristics of his aircraft by conducting taxi tests, before attempting flight operations.

c. Acrobatics or violent maneuvers should not be attempted on the first flight of an amateur-built aircraft, nor until sufficient flight experience in gentle maneuvers has been gained to establish that the aircraft is satisfactorily controllable.

d. If the aircraft is built from purchased plans or raw material kits, with which the seller provides a flight manual, the flight manual instructions should be followed.

e. The following precautions are specifically applicable to amateur-built helicopters or gyroplanes.

(1) The pilot should be prepared to cope with a nonconventional aircraft which has flight characteristics unlike that of an airplane.

(2) The effect of collective pitch and cyclic pitch control movements should be thoroughly understood by the operator.

(3) Operators of rotorcraft having three-bladed, fully articulated rotor systems should be particularly cautious of "ground resonance". This condition of rotor unbalance, if allowed to progress, can be extremely dangerous and usually results in structural failure.

(4) Tests showing that stability, vibration, and balance are satisfactory should be completed with the rotorcraft tied down, before beginning hover or horizontal flight operations.

WILLIAM G. SHREVE, JR.
Acting Director
Flight Standards Service

Maintenance crew shakedown after an aerobatic flight.

cg limits & longitudinal

By L. D. Sunderland, EAA 5477

An important part of the design of a new aircraft is the establishment of center of gravity limits. This is a critical design problem which should be solved through a stability and control analysis. A second and less dependable method is to copy the limits of an existing airplane and hope that flight tests will prove the selection correct. In any case, CG limits must be determined before the designer can firmly establish such important design parameters as elevator area, and the location of engine, seats, and landing gear.

Many early airplane designers, as well as some contemporary homebuilders, got into trouble because they did not understand the importance of CG location. The purpose of this article is to give the person with little or no experience in aircraft design some insight into the problem. A stability and control analysis is a complex undertaking and generally can be accomplished only by someone who has become thoroughly acquainted with the subject. Although most homebuilders will never perform such an analysis, they should understand what is involved and how modifications to an existing design will affect performance.

It is desirable for the designer to arrange the loads in an aircraft in a manner which will maintain center of gravity variations to as small a value as possible. This can be realized if variable loads are located near or on the CG. Since some variation is unavoidable, it is necessary to plan for this variation, and determine the limits on the CG range which will maintain flying qualities of the aircraft above acceptable standards.

AFT CG LIMIT

The aft center of gravity limit is determined primarily by stability considerations. It is based on the location of the stick-fixed neutral point. It is necessary to keep the aft limit a short distance forward of this neutral point for all flight conditions.

NEUTRAL POINT

The stick-fixed neutral point is usually defined as the CG location at which the derivative dC_m/dC_L equals zero. It is also defined as the condition when the pitching moment is independent of angle of attack, and the static stability is neutral. This means that regardless of the angle-of-attack of the aircraft, it will experience no pitching moment with the stick fixed. When the CG is in front of this neutral point, the pitching moment is in a direction which will cause the aircraft to return to trim position after being disturbed and is thus stable. When the CG is aft of the neutral point, it will cause the aircraft to depart from some trim position and go unstable.

The common assumption that the CG must be forward of the center of pressure of the wing is far from true. It is common for the neutral point to be as far aft as 37 percent of the chord of the wing, while the center of pressure of the wing is approximately at the 25 percent point. Then what allows the CG to move so far aft of the center of lift of the wing? There can be only one answer. The horizontal tail must supply upward lift in order to establish balanced conditions. The fuselage and other parts of the airplane also affect the center of pressure, but the combined center of pressure for the wing and fuselage is usually forward of the center of lift of the wing alone.

Here is another way of looking at the neutral point. When the CG is located at the forward limit, the airplane is very stable. It takes considerable force on the control stick to maneuver the aircraft in pitch. As the CG is moved aft, the force on the control stick becomes less. At one point, the force required to maneuver the airplane becomes zero. This is called the stick-free maneuver neutral point. Move the CG aft of this point and the aircraft will begin to pitch up or down, and continue in a maneuver without application of any force on the stick.

A simplified explanation of what causes static longitudinal stability can be given using the example of an airplane with two tandem wings of equal area and dimension, (see Fig. 1). If the angle-of-attack on both wings is equal, the CG must be located halfway between the aerodynamic centers since the lift on each is identical. Changes in alge-of-attack of this airplane result in no change in pitching moments, so the combination is therefore neutrally stable. If it is caused to pitch-up by a wind gust it will continue pitching-up and will not return to its original angle-of-attack. This combination can be made stable, however, by moving the CG forward and setting the rear wing at a smaller angle-of-attack.

For simplicity, assume the angle-of-attack is two degrees on the front wing and one degree on the rear wing. When the angle-of-attack increases an