How to Design Your Own Airplane

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Light Airplane Designer

This little ship, weighing only 400 lbs., flies with a 20 hp motorcycle engine—and it doesn't use all the horsepower at that! For description of such a plane read accompanying article, the first ever written in non-technical language for the novice.

"How can I get into aviation?" That question is on the lips and in the minds of the ever ready, progressive young Americans of today. Thousands upon thousands of young Americans realize that within 25 years the airplane industry will out-rival even the stupendous proportions of the automobile industry of today. These young men know in their very souls that aviation is the game for them. But the greater portion of this newly air-minded population is bound to be disappointed. There are only so many positions open in the aircraft factories — and these are not only filled — but each position has hundreds of applicants ready to step into a vacant place.

One of the oldest and best known airplane concerns in the country recently found itself beset with a total of 25,000 applications from ambitious young men willing to work for little or nothing in order to get a start in the aviation industry.

There's a much easier and less competitive way for the young American to learn aviation from the ground up, and this is — build your own airplane.

The question naturally arises in the reader's mind — "Is it hard to build a plane — is it hard to design a plane — and if I do design it and build it, will it really fly?"

There is but one answer: You *can* design a plane, you *can* build it yourself at small cost — and there is one way in which you may be absolutely sure it will fly. All it takes to be sure your plane will get into the air is a little plain arithmetic and the formula given here.

To fly, and fly successfully, a plane must meet the following requirements:

1. The lift exerted by the wings must be greater than the weight of the plane loaded for flight.

2. The power delivered from the motor must be enough so that the thrust by the propeller will overcome the *resistance* which the machine presents to the air. Resistance is measured in pounds, and so is thrust.

3. The plane as a whole must be *balanced* about a common carrier, known as the center of gravity

— with control surfaces which, when moved, will revolve the ship about this common center. This means that the ship will be controllable in flight.

A light plane such as described above may be easily designed to fly with a motorcycle engine. By this we do not mean to infer that an engine might be taken directly from a motorcycle frame and fitted into the engine bed of a light plane ready for service. The Indian motorcycle engine of 72 cu. in. piston displacement will develop approximately 18 hp at 4,500 rpm in a motorcycle frame. Taken from the motorcycle, and tuned especially for airplane service, this same motor may be made to develop in the vicinity of 25 hp with a degree of reliability which is astonishing. Just how the horsepower of the motorcycle engine may be increased is described in an article on page 18 of this manual.

Design of Light Sport Monoplane

Let us take the case of a light sport monoplane which will fly with less than 20 hp, carrying one person with ease. In designing this plane, we will strive for stability and low landing speed rather than high speed. Low landing speed is more desirable from a safety standpoint.

A monoplane is selected because its simplicity makes it more easily built than a biplane, there being only one wing to construct. The monoplane type is today enjoying great popularity and the trend toward this design in commercial planes has been marked, especially since Lindbergh's flight.

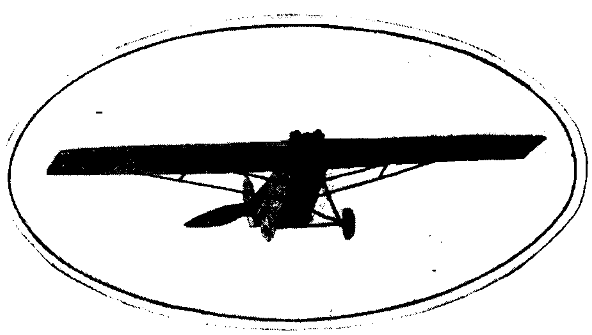
The very first essential for us to know before we can use any airplane design formula is the *weight* of the plane loaded for flight. The weight of the body of this machine will be about 150 lbs., including gas tank, seating and control arrangements, as well as the landing gear. The monoplane wing, including struts and wiring, will weigh about 65 lbs. The rudder and tail works will weigh about 20 lbs., which gives us a total of 235 lbs.

Let us add 20 lbs. for fabric covering, fittings, etc. The motor, complete with propeller, will weigh about 125 lbs., which gives us a total *empty* weight of 380 lbs. These weights can be checked up by the reader as we go further into the construction of the plane, as wood weighs a certain number of pounds per cubic foot, according to the species. Spruce weighs 25 lbs. per cubic foot, pine weighs 25, fir weighs 28, and ash weighs 39 lbs. per cubic foot.

It is astonishingly simple to calculate the weights of the wing panel, fuselage, and other parts, merely by finding the volume of each strut, longeron and wing rib, just as a school boy finds the volume of the water contained in a vessel of certain dimensions.

Now then — the weight of the plane empty is 380 lbs., and we must add the weight of the pilot,

Up aloft, free to go where you will! This little ship is being flown with a twin cylinder motorcycle engine and can make 65 miles an hour.



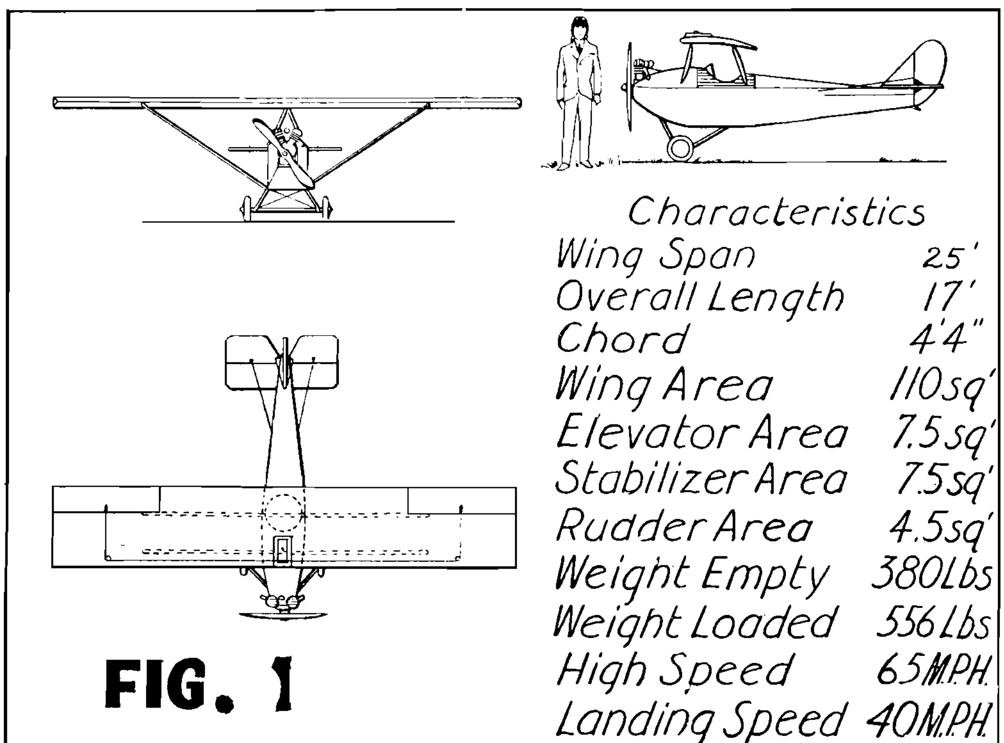
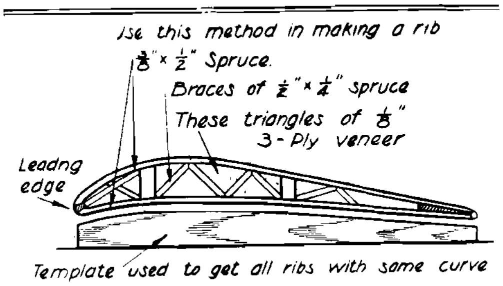


FIG. 1



Hints on building wing

160 lbs., the weight of the gas and oil, 16 lbs. This gives a total weight, *loaded for flight* of just 556 lbs.

How Is the Lift Obtained?

In building or designing a plane of any sort we must first select a definite wing curve to use. We will select the U.S.A. 27 wing curve, using the data which is listed in Figure 2 of the drawings. This is scientific data, and without it we would not be able to calculate the possibilities of the plane's actual flying. The lift coefficient for the U.S.A. 27 wing curve at 8 deg. angle of incidence is .002521, as will be seen from the list in Figure 2 of the drawings. Lift coefficient is a name given to a number which, when it is multiplied by the other factors entering into the design will give the desired answer.

We select the 8 deg. position because we want to get the most lift possible in leaving the ground at slow speed. What we want to know first is — the number of square feet wing area needed to take the plane off the ground at 45 mph, so we use the formula:

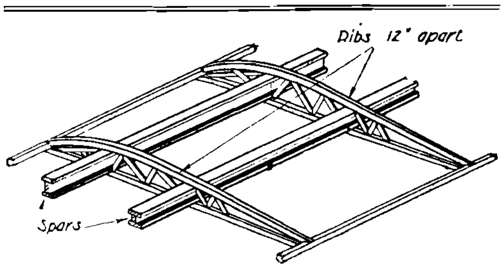
$$\text{WING AREA} = \frac{\text{WEIGHT OF PLANE}}{\text{Coefficient} \times \text{Speed} \times \text{Speed}}$$

It is really quite simple to substitute weights in this formula. We know the coefficient of the wing, and we know the weight of the plane, and the speed is 45 mph, so substituting and dividing, we get 556 lbs., divided by the coefficient .002521 x 45 x 45, and the answer comes out as 109.01 sq. ft. of the wing area needed to fly the ship at 45 mph. Let us figure high, and call it 110 sq. ft. of wing needed.

Next, let us determine the size of our plane. Good dimensions are as follows:

Wing span . . . . **25 ft.**
Chord of wing (width) . . . . **4 ft. 4 in.**
Overall length . . . . **15 ft.**

Now that we have the sizes determined, let us look at the assembly drawings in Figure 1. As you will see — this is a parasol type monoplane, with the wing above the body. This design is noted for its strength with light weight, economy of construction, and most of all, for its stability in flight. Let us now figure the power needed to fly this monoplane. Note that we are basing all calculations on a take-off speed of 45 mph with the wings set at an angle of 8 deg. to the air. Actually, the wing is at 3 deg. with the fuselage.



The formula for power required is:

$$\text{Horsepower Needed} = \frac{\text{Resistance} \times \text{Speed}}{375}$$

Now before we can use this formula we must determine the resistance which the plane presents to the air at 45 mph. This is done by using the following formula with the data we have in the lists in Figure 2.

K is a shape coefficient determined from wind tunnel tests, listed in Figure 2 of the drawings. Area as referred to above is the cross section area as shown in the frontal drawings in Figure 2.

First let us use the above formula in determining the wing resistance. Consulting the list of coefficients, we find that the *K* for the U.S.A. 27 wing curve at 8 deg. is .00011534, and we know that we have 110 sq. ft. of wing area. Hence, substituting in the formula we get: .0001534 x 45 x 45, which equals 34.16 lbs. We must find the resistance of the various other pieces of the structure and add them all up to get the total resistance.

$$\text{RESISTANCE} = \text{K (Coefficient)} \times \text{SPEED} \times \text{SPEED} \times \text{AREA}$$

To Figure the Fuselage Resistance

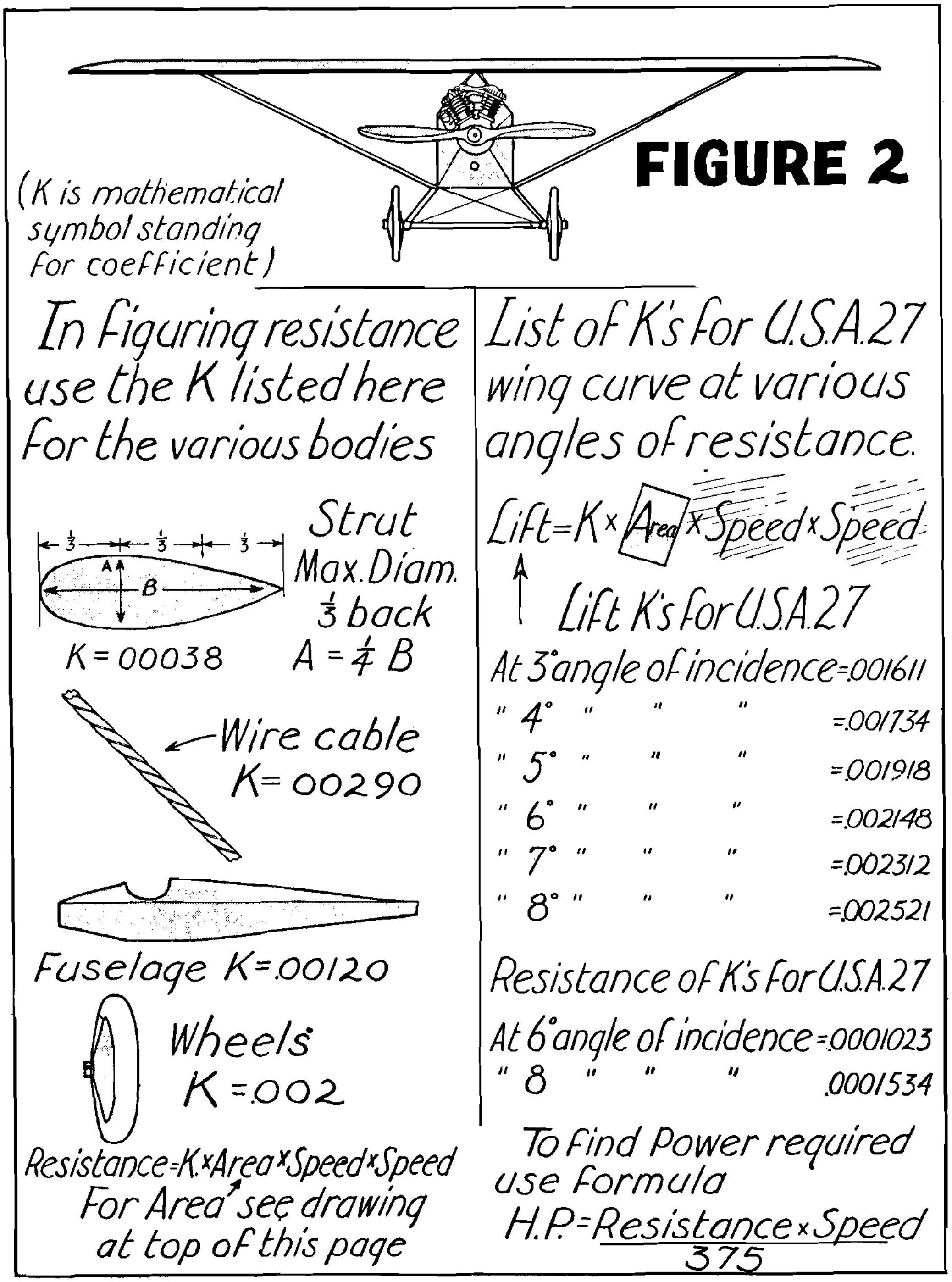
Now let us determine the resistance of the fuselage, landing gear, struts and tail surfaces. Looking at the list again we find that the *K* for fuselage shapes is .00120 and by looking at the frontal area drawings, we see that the area is about 6 sq. ft. Hence, the resistance figures up at .00120 x 6 x 45 x 45 or 14.5 lbs.

It is easily possible to find the resistance of all the other items exactly as we found this one, so we will not go into further calculations here. For more information on the methods to use in determining the resistance of the various parts of an airplane, see the textbook of military airplanes, "Military Airplanes" by Grover C. Loening. This textbook is a masterpiece on elementary aircraft design, and constitutes much food for thoughtful study on the part of any aviation enthusiast who really desires to acquire some first hand information which is not too deep.

The resistance of the machine shown in the drawings will be as follows:

Wing resistance	**35 lbs.**
Fuselage resistance	**14.5 lbs.**
Wheels and landing gear . . .	**2.18 lbs.**
Tail surfaces and struts	**10 lbs.**
TOTAL RESISTANCE . . .	**61.68 lbs.**

It is advisable now to add at least 10 percent to these figures, because it will be remembered that the



ship is inclined at an angle of 8 deg. for the take-off, hence the resistance will be somewhat greater. Adding 10 percent to 61.68 lbs., we get 67.84 lbs. as the total resistance.

We may now proceed to find out how many horsepower are actually required to fly the plane at 45 mph. The formula with values in it will look as follows:

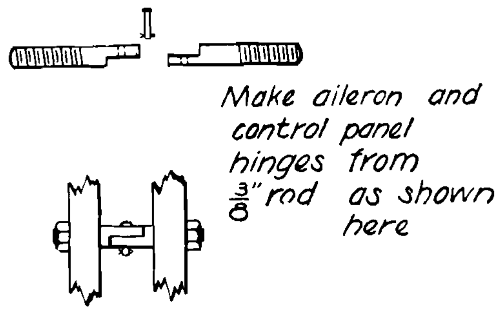
$$\text{HORSEPOWER} = \frac{\text{Resistance } (67.7) \times \text{Speed } (45)}{375}$$

Multiplying and dividing this out we get: 8.11 hp actually required. Considerably less than 9 hp will fly this plane then at 45 mph.

Now that we have taken up the elementary principles of airplane design, it should be possible for anyone, with a little study, to get designs together, and make drawings or have them made from their own preliminary sketches. Of course, the designs which we have followed through in the first part of this article are such that the plane will fly, and it may be that the builder will prefer to utilize them as they are.

In constructing the plane, it is most essential to get the structure as light as possible, with the greatest of strength. After you have designs for your plane complete, and have had drawings made, the complete drawings should be submitted to a reliable engineer for stress analysis, in order that you may be sure the structure will be strong enough.

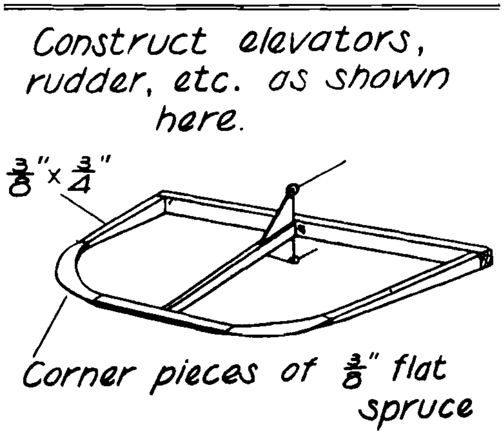
An engineer can make stress calculations and tell you if the sizes of the various members are strong enough to stand the strains imposed on them. Each type of airplane demands different strength in different parts, hence it is very important that you proceed to get your plane drawings inspected.



How to Construct a Fuselage

In the drawings in Figure 3 we show a good type of modern, inexpensive, easily built fuselage construction. This type, known as the stick and wire type of building, is familiar to almost all light plane builders, and while it is being rapidly supplanted by steel tubing, the welding of the steel tubing and its uncertain strength when built by amateurs has led us to defer the building of such a fuselage until a later date. The fuselage shown in the drawings has plywood formers, ash longerons, and the small turnbuckles are made from motorcycle spokes and 19 gauge sheet steel, cold-rolled.

In the fuselage shown, which will do for any light plane of the type under consideration for motorcycle power, the longerons should be 7/8 by 7/8 in. at the bow of the ship tapering to 5/8 x 3/4 in. at the stern post. The struts and engine bearers should be of spruce. No particular paring of dimensions should be done on such a fuselage, as there are so few structural members that the weight saved would be inconsequential. The plywood formers are of the brand of plywood known as Haskelite, and may be secured from the Johnson Airplane Supply Co., which does a large airplane parts business at Dayton, Ohio. The wire for the turnbuckles and the nickel steel bolts may also be secured from the same source.



Another type of fuselage construction consists of framing with a Warren truss of light spruce members. These are secured to the longerons with a set of plywood gusset plates. Such a method of building up a fuselage is very cheap, but is not so rugged as the somewhat heavier type shown in Figure 3. The fuselage in Figure 3 should not cost over $10.00 to build.

A light, strong landing gear assembly is shown in the drawings. Upright members of steel tubing, with a plate welded or bolted across the bottoms to hold the rigid axle, with diagonal wire bracing as well as bracing to front and rear. Use wheels which can be purchased from any Aero supply house, but do not use wheels with less than 3 in. tires, as these wheels will catch in ruts and will prevent easy handling on the ground.

Tail Surface, Size, Construction

In constructing the tail surfaces, construct them to dimensions which may be a trifle oversize, rather than undersize. Construct framework as shown in the drawings, with dimensions given. These tail surfaces should be ample for a plane of the size shown in Figure 1.

Hinges for rudder, elevators, and ailerons may be simply and easily constructed from pieces of cold-rolled rod, as shown. Horns or levers to attach control wires to are made integral with the different surfaces as shown in the sketches.

Construction of the Wing Panels

The wing panel must be constructed with the curve of each rib exactly the same, and to facilitate matters, a template must be made, as shown in the drawings. To make one of these templates, it is necessary to secure a full size blueprint of the wing curve. we selected to use—the U.S.A. 27. Any airplane supply house will supply a blueprint of this curve, or it may be obtained from the National Advisory Committee for Aeronautics, Washington, D.C. If the wing curve is not followed in each and every rib, the wing will not lift as it should, and you are likely to have a plane which will not fly at all. It is very necessary to have a wing which is correct.

Build the two wing spars up to fit the two spaces in the wing curve, as shown in the drawings. You will have to determine the actual cross section of the spars from the blueprint of the wing curve you use. It is possible to build a light, strong, spar up out of three pieces of spruce, making them up into an "I" section, gluing and nailing them together. The front spar should be heavier and stronger than the rear one, as it has to take about 60 percent of the load on the wing. The spars form the backbone of the wing structure, as shown in the top view of the wing panel in Figure 4 of the drawings. The ribs, built

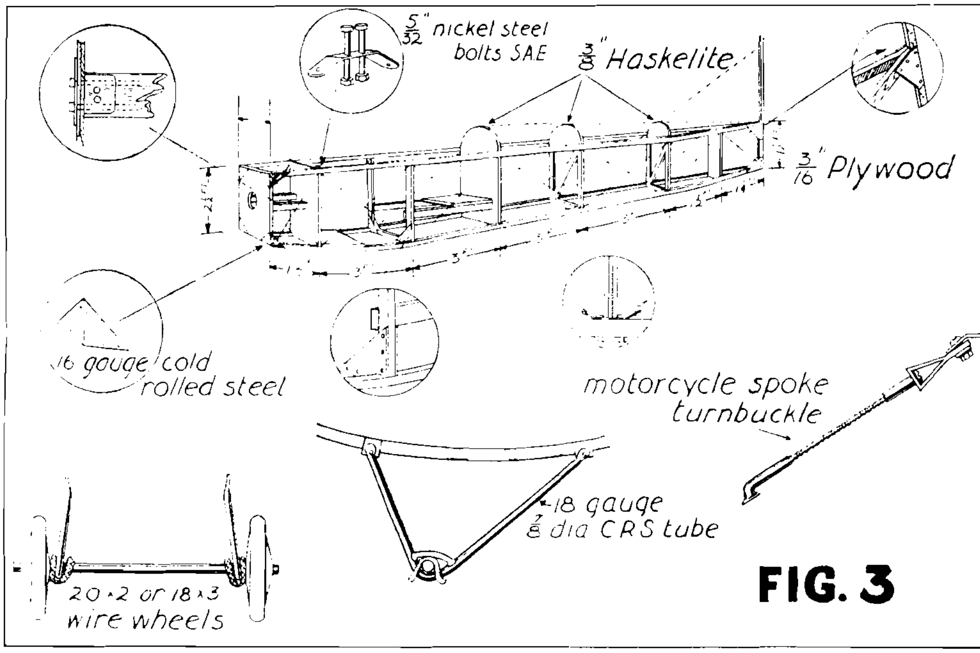
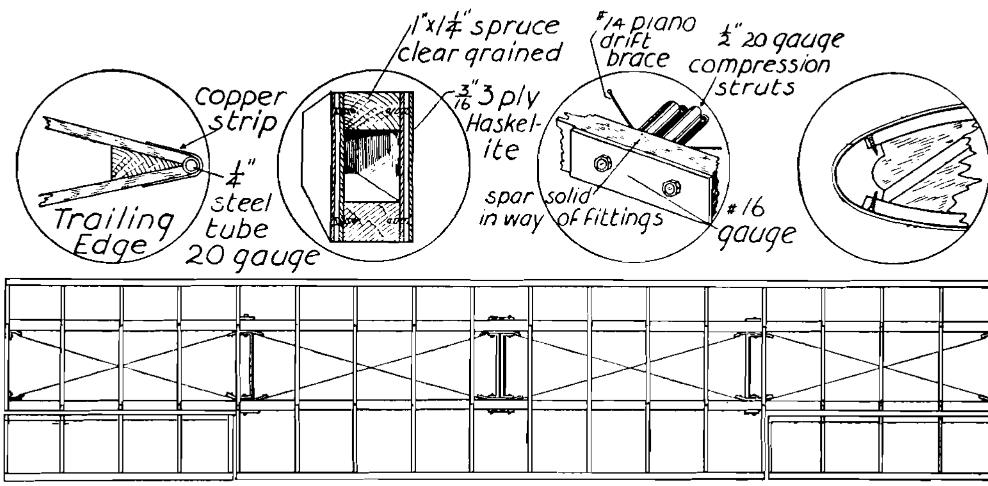
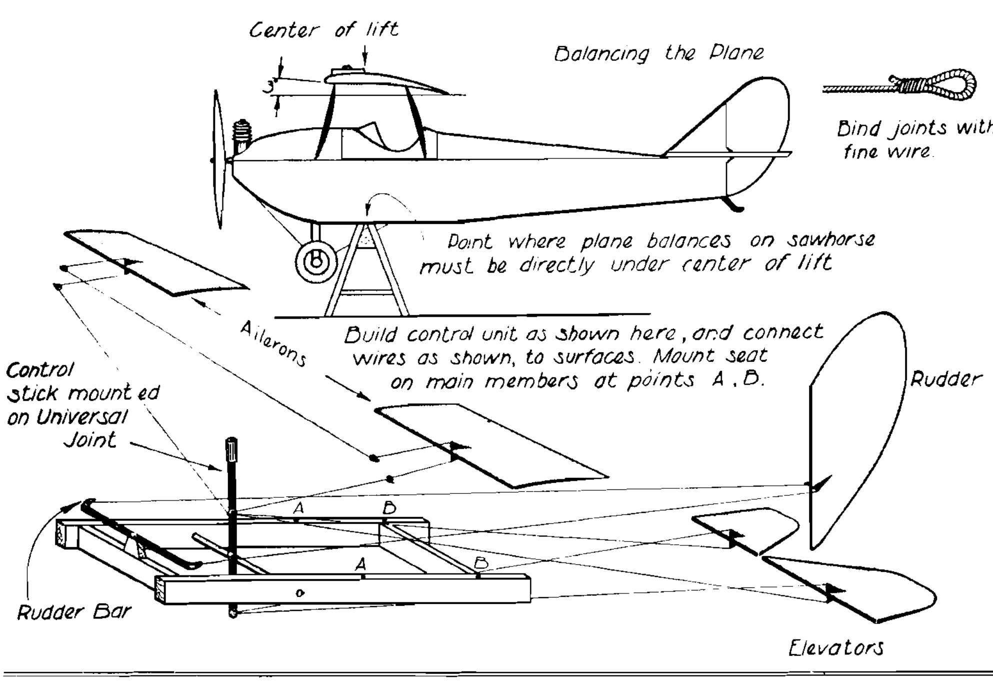

5/32" nickel steel bolts SAE
3/8" Haskelite
3/16" Plywood
16 gauge cold rolled steel
motorcycle spoke turnbuckle
18 gauge 7/8 dia CRS tube
20 x 2 or 18 x 3 wire wheels

FIG. 3


1"x1/4" spruce clear grained
#14 piano drift brace
1/2" 20 gauge compression struts
copper strip
3/16" 3 ply Haskel-ite
1/4" steel tube 20 gauge
Trailing Edge
spar solid in way of fittings
#16 gauge


Center of lift
3"
Balancing the Plane
Bind joints with fine wire
Point where plane balances on sawhorse must be directly under center of lift
Ailerons
Build control unit as shown here, and connect wires as shown, to surfaces. Mount seat on main members at points A, B.
Control stick mounted on Universal Joint
Rudder
A
B
A
B
Rudder Bar
Elevators

and braced as shown, may all be built at once and then slipped on over the spars and nailed in place.

When nails are mentioned we refer to small brads about 3/4 in. long — never use nails any larger.

Build ailerons as shown in wing panel drawing.

After the ribs are in place on the spars, put the leading edge and the trailing edge in place and nail them to the ribs as shown. The entire wing panel should now be well braced diagonally with wire and turn buckles. See top view of wing panel. Use a good grade of piano wire for this diagonal bracing.

Steel Tube Wing Struts

The center cabane struts which hold the wing panel at its center above the fuselage, should be made of 3/4 in. steel tubing, flattened at the ends to take bolts. These struts attach to the four heavy fuselage uprights. See fuselage drawing. Likewise, the outrigger struts which brace the wing panel at a point several feet from their tips should be of 3/4 in. steel tubing. These steel tubing struts should be streamlined by fairing as shown, and wrapped with cotton or linen airplane tape.

The wing panel should now be covered with cotton or unbleached muslin. Tack it along the leading edge, using copper tacks, and draw it back toward the trailing edge as tightly as possible, then tack it in place and cover the bottom of the wing panel likewise. See that it is tacked to each rib, both top and bottom, at least a foot apart. Follow same procedure in covering rudder, elevators, fuselage, etc.

Now obtain some airplane *dope* from any airplane supply house, and apply this liquid with a good paint brush about 2 in. wide. Spread the dope evenly and not too thickly onto the entire wings, elevators, rudder, fuselage, etc. After one coat of dope, it is time for the tape. Get some scalloped airplane tape about 1 1/2 in. wide, and fasten it along the places where there are rows of tacks. Then dope it and it will stick down in place tightly, making a neat streamline job of all joints. This applies to the leading and trailing edges of the wing, the tops and bottoms of the ribs, and the corners of the fuselage also. The cloth will be drum tight after doping, and a thin coat of paint or varnish can now be applied. The wheels also may be covered to advantage.

Control Mechanism and Seat

The seat, rudder bar and control stick should be built in one unit on a pair of chassis members of spruce about 2 in. by 2 in., as shown in the drawings. The stick is made of steel tubing, arranged so that it will pivot in any direction. About 6 in. above the pivot, attach a clip for the control wires, as well as to the bottom end of the stick, which should be about 6 in. below the pivot. The rudder bar may be made of steel tubing or of spruce, according to the builder's ingenuity. In all this work, bear in mind that extreme lightness with greatest of strength is necessary. Connect controls as shown in the diagram—*but do not connect the controls until you have balanced the airplane as a whole as described in the next section.*

In balancing an airplane, the center of gravity — the point about which the machine will balance — must be directly under the center of lift. Looking at the diagram showing center of lift you see the airplane mounted upon a sawhorse. It may be actually balanced by this simple method.

This balancing operation must be conducted after the engine has been fitted in place, complete with propeller. Get the tank filled with gasoline, the oil tank filled, and get into place in the pilot's seat yourself — with the machine on a sawhorse, as shown. Now have a helper move the plane forward and backward until the plane balances on the sawhorse. The point at which it balances must be *directly underneath the point on the wing which is the center of lift.* The center lift for the U.S.A. wing will come at a line drawn from wing tip to tip about 35 percent or 40 percent back from the leading edge. In the case of the U.S.A. 27 wing curve, with a chord of 4 ft. 4 in., such as we figured on here, the center of lift will be about 20 in. back from the front of the wing.

If you find the wing is not in the correct place, balance the plane by moving the whole pilot's seat and control assembly backward or forward — or alter the position of the wing itself by shortening or lengthening the center struts which hold the panel above the fuselage.

This wing panel should be set at exactly 3 deg. angle of incidence, when the plane is absolutely horizontal in flying position, as it is shown in the side view. Use a protractor and a straight edge for lining this work up. ••••

MAN-MADE GALES HELP AIRPLANES LAND

Huge fans which can whip up a 65-mile gale that will act as a brake on landing airplanes will be the next piece of equipment installed in the modern airport, according to experimenters.

Aviators have long known that it is easier to land in a stiff breeze than in still air, and it is proposed to take advantage of this fact by arranging 12 to 20 fans on the landing field to supply an artificial gale.

The fans would be arranged at the end of the field to cover a section 200 ft. wide and 90 ft. high. The air would be driven through a screen of steel bars one inch wide and two feet apart. This screen would serve to break up the eddies of the air.

Flying into this man-made breeze, the aviator would be able to land in the small space of a city block, or even on top of a moderate sized office building.

The fans would be equally helpful in aiding the plane to take off.