THE MODEL AEROPLANE MANUAL by L.H. SPAREY C.A. RIPPON

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THE COMPLETE GUIDE TO BUILDING AND FLYING.

By L.H. SPAREY & C.A. RIPPON

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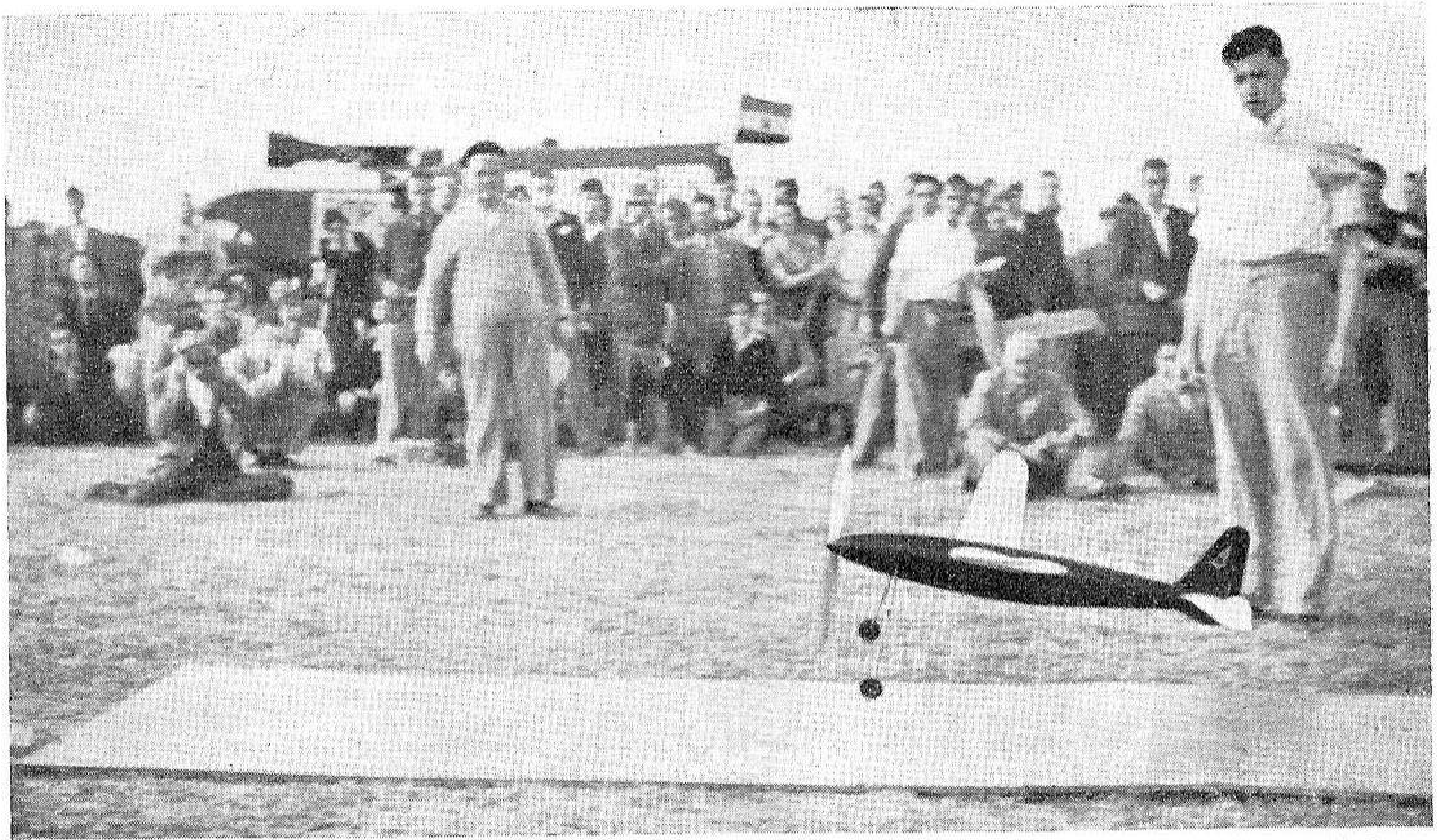

Photo by courtesy] [*I. Lucas*

" AIRBORNE "

The " G.B. 3," holder of the British and World's model aeroplane duration record, leaving the take-off board

THE MODEL AEROPLANE MANUAL

A Practical Handbook on the Building and Flying of Model Aeroplanes

Third Edition

By LAWRENCE H. SPAREY
and CHARLES A. RIPPON

with a Preface by
A. P. THURSTON, D.Sc., M.I.Mech.E., F.R.Ae.S., M.I.A.E.

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PREFACE

By A. P. THURSTON,
D.Sc., M.I.Mech.E., F.R.Ae.S., M.I.A.E.

WHEN Benjamin Franklin made his world-famous experiments on atmospheric electricity by flying a kite in a thunder storm, he found it necessary to shield himself from public ridicule by taking a small boy to help him fly the kite, because public opinion at that time considered kite-flying beneath a man's dignity. In our own time, enthusiastic aeromodellists have for similar reasons occasionally been glad of the company of somebody more youthful than themselves. No doubt critics of the sport are misled by its cheapness, and do not realise that the closeness of approach obtainable in all respects to the "real thing" is out of all proportion to the modest outlay involved.

The pleasure of building and experimenting with flying models is keenest when supplemented by sound technical information, and the practical knowledge of aeronautics so acquired will not only enable the ordinary man to keep abreast of the times, but will give the requisite stimulus to those few who may be especially talented in this direction. In fact, many of our leading aeroplane designers and manufacturers have graduated from the ranks of aeromodellists, and still retain a keen interest in the welfare of the sport. Aeromodellists may truly be said to form the connecting link between the select band of trained aeronautical specialists of to-day and the mass of everyday people who will shortly be using aviation as they now use motor transport.

The best book on Aeromodels which I have ever read is the "Model Aeroplane Manual," written by Mr. Lawrence H. Sparey and Mr. Charles A. Rippon, which appears to be one of the most comprehensive and serious surveys of the subject yet published in this country.

This book will undoubtedly prove of real help and service to aeromodellists—the ideas and constructions shown or described appear to be sound in theory and to have been tested and proved in practice.

I confidently recommend this publication to all interested in model aeronautics.

A. P. THURSTON.

AUTHORS' NOTE TO THIRD EDITION

"THE Model Aeroplane Manual" was originally written to be a guide to the beginner and mid-stage builder, and the excellent reception which the previous editions of this book has received has persuaded us that it has, at least, attained its object.

In this third edition the book remains of a similar nature, yet, in order that it may still remain a guide to the very latest advances and methods of model aeroplane building, certain portions of the book have been rewritten. Nevertheless, it has not been fundamentally altered, for, however much methods may change, the principles of model aeronautics remain the same.

Some advanced matter, which was considered to be out of place in such a volume, has been removed; much new information has been added, and designs for new, up-to-date machines have been incorporated. These include the World's Official Duration Record Holder, "G.B.3," and the British Glider Record Holder, "The Twenty-minute Glider." These machines, in themselves, are lessons in the newest technique.

Technique, however, is only the outcome of skill and experience, and it is hoped that this latest edition of this book may continue to provide the basic knowledge upon which your own technique may be founded.

LAWRENCE H. SPAREY,
CHARLES A. RIPPON.

THE
Model Aeroplane Manual

CHAPTER I

THE PROBLEM

It is essential to the success of any undertaking that it must first be understood just what it is one wishes to do. The artist who would paint a masterpiece must have clearly in mind the precise effect he would convey, and however skilled he may be in the use of his materials, the result will fall short of perfection if his aim has not been clearly defined.

In the making of model aeroplanes, this principle in no way varies, and the successful aeromodellist is the one that understands just how his arrangements of wood and paper and wire will function when in action. Let us see, therefore, if we can define, in as simple and non-technical a manner as possible, the principles of this most fascinating hobby.

So long ago as 1809, Sir George Caley, who has been described as "the Father of British Aeronautics," correctly defined the problem of mechanical flight as being :—"To make a surface support a given weight by the application of power to the resistance of air," and the whole of the technique of aeronautics centres around this proposition.

Everyone knows that an aeroplane has wings. It also has many other things, but it is the wings which enable an aeroplane to rise into the air, and differentiate it from less fortunate, earth-bound means of transport. It is also a commonplace that an aeroplane must have forward speed —or a forward speed relative to the air—before it will rise. How is it then, that this motion, when applied to a wing, can counteract the force of gravity ?

Any flat plate, when held at an acute angle to the airflow, is a wing, and its action is not difficult to understand. In Fig. 1 is shown such a plate, which, we will imagine, is being moved through the air. Now, air has weight (14 cubic feet weigh one pound), and consequently inertia, which means that it will resist change of movement. Our moving plate will tend to push the air below the leading edge, in a downward direction, or alternatively, the plate in an upward direction. It is easy to see that the faster our plate is moved

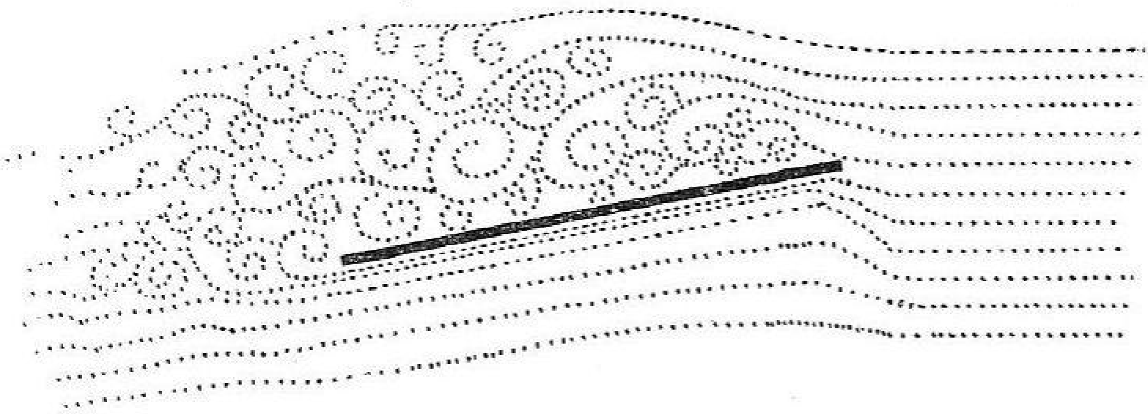

Fig. 1

the greater will be the resistance of the displaced air—which cannot get out of the way quickly enough—and the greater will be the tendency of the plate to move upwards.

Now this would be an ideal condition, and the theory of the wing settled, were it not for the behaviour of the air above and behind the moving plate. The air in these regions is a mass of swirling eddies, which have a very bad effect on the plate as a wing—in certain conditions destroying the lift altogether.

It now remains, therefore, to alter the section of the plate in such a manner that the air will be disturbed as little as possible, and will tend to resume its natural, steady flow without undue commotion. We now arrive, in Fig. 2, at a section typical of a modern aerofoil, where the air streams naturally over and under the surfaces, and eddy currents are reduced to a minimum. We can thus take full advantage of the upward push given to our wing from below, but this is only half the story, for we now find, on examination, that by curving the top surface in this manner, a new and highly important factor arises. It is now possible to obtain lift from the *top* of the wing !

On first glancing at the aerofoil section in Fig. 2, it would seem that the curved portion at " A " would be acted upon in a *downward* manner by the airflow, and therefore, a retrograde step had been taken in our search for maximum lift. Let us consider this more closely. The airflow striking the aerofoil is divided into two streams, one flowing above and the other below, and reuniting beyond the trailing edge. A little thought will show us that the air over the curved top surface must travel a longer distance than the air along the lower surface, and must therefore move more quickly if it is to unite at the trailing edge at the same moment. This increase of speed, means that the faster moving air will press more lightly on the wing top than the slower moving air will press beneath, and will thus impart a lift to the top surface.

This action is well known, and is utilized in such articles as scent-sprays and cellulose spraying guns, where a fast moving stream of air passing over the top of a tube exerts sufficient lift to raise liquids.

The reader may conduct a simple experiment to demon-

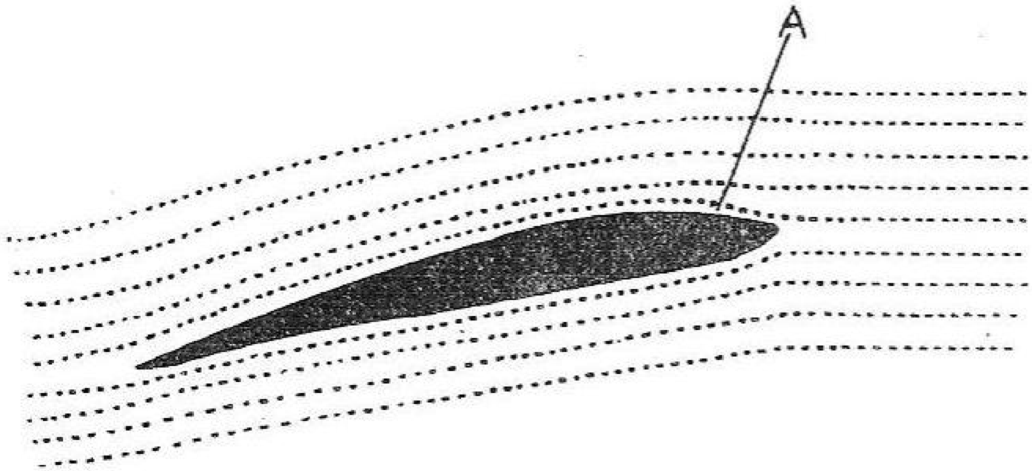

Fig. 2

strate this principle. Fig. 3 represents a sheet of writing paper, one end of which is bent at right angles to form a hinge ; the free end being roughly curved to represent an aerofoil. On holding the hinged portion in the hand, and blowing across the paper in the direction indicated by the arrow, it will be found, that instead of being blown downwards as would be expected, the free end of the paper will rise.

Except for small eddy currents caused by skin friction, our wing is now in an ideal condition to supply the lift, but, things being what they are, we must look for the inevitable snag. This lies in the fact that our wing is only ideal when meeting the airflow at a certain angle of incidence; any change in this making it increasingly difficult for the air to follow smoothly the contour of the surfaces, until, at the exaggerated angle of incidence shown in Fig. 4, we are back again to the same problem which we encountered with our flat plate in Fig. 1. This condition is known as "stalling," and presents one of the greatest problems of aviation.

The importance of skin friction on the behaviour of a wing is very great. The term "skin friction" is used to describe the behaviour of the air at the surfaces of an aerofoil or other moving body. A thin "layer" of air will "stick" to the aerofoil surfaces, just as a thin "layer" of water will "stick" to the hand if it is immersed and withdrawn. The air in contact with this first layer will also tend to adhere, and small eddy currents are set up which break and roll over each other in the manner of waves upon a sea shore. When the wing is moving through the air in a normal manner, and the airflow is streaming naturally past, these small eddies are blown away, and no harm is done beyond the drag or resistance which they cause. If, however, the wing's angle of attack becomes so great that the airflow "breaks away," the restraining influence upon the small skin friction eddies is removed, and they begin to build-up in the manner shown in Fig. 4.

Various methods and contrivances have been evolved to overcome or minimise these difficulties, but for the model

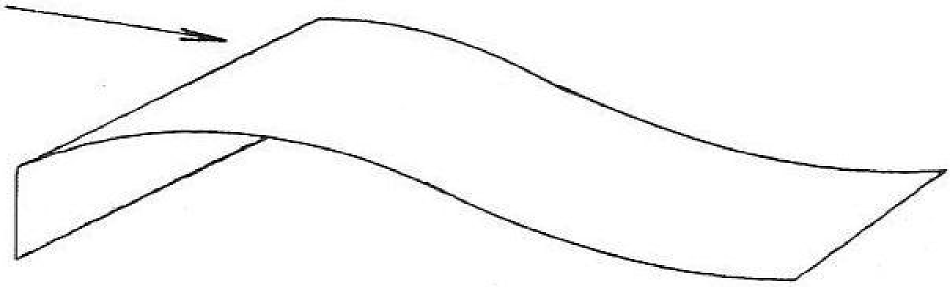

Fig. 3

builder the only solution is to use an aerofoil which allows a certain latitude of incidence without the airstream becoming "unstuck," and to design his machines to be automatically stable in a longitudinal direction. In other words, some form of stabiliser must be used which will prevent the machine from assuming too great an angle of attack. Wing surfaces must be kept as smooth as possible to lessen the effects of skin friction drag and turbulence.

These questions will be dealt with as they arise; meanwhile we can deduce that the whole problem of model

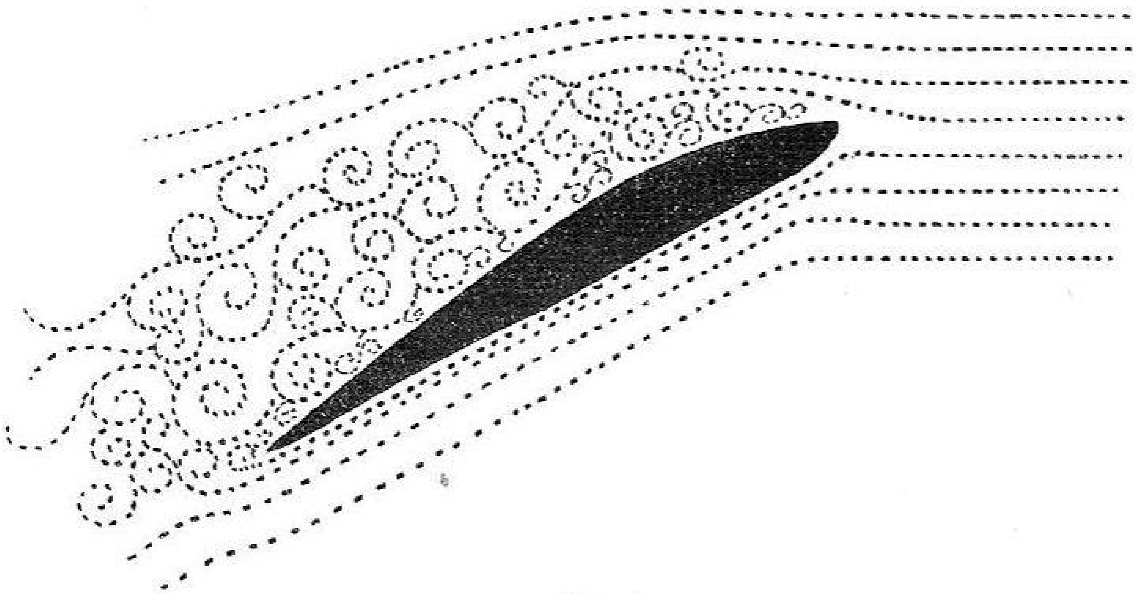

Fig. 4

aeronautics is as follows :—

1. To build a wing that will lift.
2. To provide that wing with forward motion through the air.
3. To provide methods of stabilising that wing in all directions.

With these aims clearly in mind, let us devote ourselves to their achievement.

CHAPTER II

MATERIALS

Before proceeding to the design and construction of model aircraft, it seems reasonable to examine the substances from which our models will be made. Strictly speaking, there is no limit to the materials which may be utilised, in so far as it is highly desirable to be on the look out for substances, hitherto overlooked, which may be suitable for certain purposes. It is one of the chief joys of the aeromodellist that his hobby offers more scope for experiment than most others, and the use of materials in no wise departs from this tenet. However, like all experiments, these must be of a reasonable nature, and the beginner is advised to stick to the orthodox at first.

Balsa

Probably the most useful material at the disposal of the model builder is *Balsa Wood*, and it is no exaggeration to say that its introduction into model aeronautics has revolutionised the pastime. Balsa wood was first used in America, and was forcibly brought to the notice of English model builders when an American all-balsa machine won the Wakefield International Cup in 1930. English model makers quickly discerned the possibilities of this substance, and since that time the use of balsa has become increasingly popular in this country, while in America, it can be safely said, it has ousted all competitors—even heavy, petrol-driven models being entirely constructed of balsa wood. The American climatic conditions seem to be extremely favourable to model flyers, but in the British Isles, unfortunately, our particular brand of weather subjects the use of balsa to some limitations. The English builder will be well advised to bear in mind that balsa is a very short-grained wood, and it is inadvisable to use it in any highly stressed part of a model of six ounces weight or over, without recourse to strengthening agents such as silver spruce or birch. Balsa is also very prone to absorb moisture and rubber lubricant, but may be protected by a coat of cellulose lacquer or cement.

Nevertheless, this remarkable substance is of the utmost importance in model aeroplane building by reason of its light weight, as it is six times lighter than spruce. Besides this most valuable asset, it is easily worked and lends itself readily to almost every purpose where wood can be used in a model. Balsa wood is used commercially for sound-proofing, insulating, and in boat and aeroplane construction, and comes from South America, where it grows wild in the dense tropical forests. It has recently been cultivated also, and as a balsa tree will attain a girth of nine feet in five years it must form a very curious branch of forestry.

There are several kinds of balsa wood obtainable for model work, ranging from the soft variety which is of a very spongy nature, to the hard type which is of good toughness and strength. Unfortunately, the weight of balsa varies with the toughness, which, in turn, determines the strength. The ultra-soft variety is so fragile as to be almost useless for model purposes, but, on the other hand, the very hard kind, though possessing ample strength, is almost as heavy as ordinary "hard" woods. The best variety for our purpose is the *medium hard* balsa, which possesses considerable strength at the same time retaining its desirable lightness.

Balsa wood is now available in many sections specially prepared for model aeroplane use. In Fig. 5 some of these sections are represented, with a note as to some suitable purposes to which they may be put. It is also obtainable in sheets, in thicknesses from 1/64th inch upwards, and in blocks up to quite large sizes, from which such things as wheels, spats, noseblocks and a variety of similar components may be carved. It is here that the advantages of balsa are readily discernible, as quite a large amount may be used without great increase in weight. For flying scale models it is invaluable for use in the many trimmings which a scale model must possess.

Spruce

Leaving this most valuable substance—balsa wood, we will now turn our attention to other woods which are of great use to the aeromodellist. Next to balsa, *Silver Spruce* is probably of the greatest value, being light and extremely tough and strong. It is used extensively in the manufacture of full-sized aeroplanes, and is of great utility to the aeromodellist for the heavier types of model. One of its greatest virtues is that it may be easily steamed to mild curves, a process to which balsa does not readily submit. Spruce may be used for fuselage longerons, bracing struts and for wing spars, and is usually sold in lengths of square or rectangular section, although similar sections to those shown for balsa may be obtained from some dealers.

Birch

This is another wood much favoured by the devotees of the heavier type of machine. It is stronger than silver spruce but also heavier, and its uses are similar to those of spruce. It may be readily steamed to acute curves, and may be employed in cases where extreme strength is required, as in the construction of power models and heavy rubber-driven machines. As an example of what can be done by a judicious use of materials, the writer has in his possession a wing of 36 inches span and 5 inches chord, built with twenty-four balsa ribs and five 1/16th inch by 1/16th inch square section birch spars, covered with silk with three coats of dope, the total weight of which is one and one quarter ounces. This wing has seen plenty of service and is extremely strong and true.

Basswood

This wood has been extensively employed as a balsa substitute. Although harder and heavier than balsa, its working properties are similar, while, at the same time, it is stronger. A model using thinner spars of basswood than would commonly be employed in balsa construction, may be produced at about the same weight and strength. Its general characteristics are similar to those of the hard type of balsa, and, for this reason, should be extremely useful in model petrol-driven 'plane construction. Basswood, in blocks, is a most suitable substance for propeller manufacture, and for carving bodies and wings for solid, scale models.

The foregoing remarks also apply to other woods, such as "obeechi wood," which are sometimes used as balsa substitutes.

Bamboo and Cane

Among the lesser used woods which are of great service for many purposes are *Bamboo* and *Reed Cane*. In the early days of the model aeroplane, these substances were used

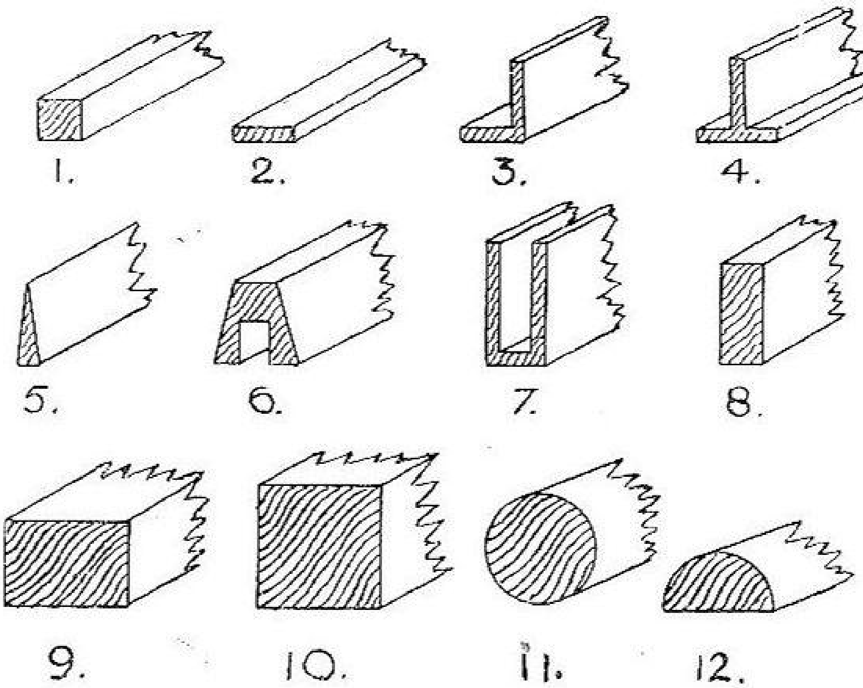

Fig. 5

(1) Longerons and spars
(2) Longerons and wing spars
(3) Longerons and wing spars
(4) Wing spars
(5) Trailing edges
(6) Leading edges
(7) Wing spars and motor sticks (with the addition of No. 2 can be converted to box spar)
(8) Longerons and motor sticks
(9) and (10) Block balsa for carving
(11) Leading edges and tail spars
(12) Beading

to the exclusion of almost all others, and it is a matter for wonder why these woods are now so seldom employed. It is not generally appreciated that bamboo can be planed and shaped quite easily, and lends itself to innumerable purposes. For tail and rudder frames it is invaluable, being light, flexible and strong. Bamboo is ideal for undercarriage legs, and there is nothing to equal its efficiency in any position where great strength is required for little material, as its standard of strength remains constant however small the section. This renders it particularly applicable to scale models, where it may be used for such items as scale-size streamlined wires, horn balances and pitot tubes.

Plywood

Thin plywood in either birch or elder, of 1/32nd inch or 1/16th inch thickness, is often employed for fuselage formers, wing tips and panelling. Plywood is very strong and highly suitable for certain purposes, but should be used sparingly on account of its heavy weight. Thicker plywood of five or seven laminations is sometimes employed for noseblocks and nose formers, especially in heavy models where accidental landing impacts must be guarded against. Nose-blocks, however, are usually carved from satin walnut, mahogany or pine for the heavier machines, and, of course, balsa for the light-weights.

Balsa plywood is manufactured commercially, but is rather difficult to obtain, and the aeromodellist is advised to make his own by sticking two or three sheets of balsa together, the grains, of course, running in different directions. Balsa plywood is useful for any parts where a strength greater than that of ordinary sheet balsa is required, as is the case in such components as wheel discs.

Propeller Woods

Satin Walnut, *Mahogany*, *Pine*, *Basswood*, *White Wood* and *Balsa* are all used for the manufacture of propellers; the weight of the model usually being the deciding factor. It may be pointed out here that it is advisable to keep the propeller as light as possible. It is a common fallacy that a benefit is obtained by the "flywheel" effect of a heavy propeller. This is not true, as the energy stored as momentum is exactly offset by the energy absorbed by inertia.

Paper Tissue and Silk

Among the chief substances with which the aeromodellist is concerned is *paper tissue* for covering the lighter types of wings and fuselages. This is invariably Japanese tissue, which is sold in sheets measuring 21 inches by 30 inches. It may be had in various weights and qualities, in white, colours and silver, the coloured variety being usually more fragile than the white, and sold in smaller sheets. A more robust covering is *bamboo paper*, which when doped, is almost as strong as silk. It is heavier than the Japanese tissue, being about half the weight of doped silk. As compared with silk it has the advantage of being easier to apply; it also dopes somewhat tighter, and may be used with advantage for the covering of fuselages or any part of a model subject to much handling.

For power-driven models and other heavy machines the only suitable covering is *Bamboo Paper, Japanese* or *Chinese silk*. This material is extremely strong, and is usually sold by the yard, and is 36 inches wide. The weight should not exceed ½ oz. per square yard, and it is always advisable to use the plain white variety, as coloured silk never dopes clearly, thus presenting a patchy appearance. If colours are desired, these should be obtained by using a coloured dope, but further information on this point will be found in Chapter VIII, which is devoted to covering and doping.

The reader is warned not to use synthetic silk such as "Celanese," as these fabrics are a cellulose product, and dissolve under the action of dope. Any structure covered in artificial silk and then doped will, in the space of an hour, reduce itself to the bare structure again, and much time and money will be wasted. Undoped synthetic silk is very heavy, and should not be used ; in fact, it is a substance to be avoided by the aeromodellist.

Dope

On the subject of dopes a whole book could be written, and considerable space is devoted to the matter in Chapter VIII. No useful purpose will be served by anticipation at this juncture beyond a mention of dope as an important accessory to model aircraft construction.

Wire

An important material greatly used in our hobby is *Spring Steel Wire*, popularly known as "piano wire." This is used for undercarriage construction, propeller shafts, wing tips, tail and rudder frames and the various small fittings such as wing fixing hooks usually associated with model aeroplanes. Piano wire, although indispensable for certain purposes, should not be used too freely as its great weight is highly undesirable. This will need no emphasis when it is pointed out that steel wire weighs approximately *thirteen* times heavier than hard woods, and *seventy-eight* times heavier than balsa ! On the other hand, it is many hundreds of times stronger, but its lack of rigidity makes it unsuitable for use in long lengths.

For binding purposes *florists' wire* or *thin copper wire* is useful, especially for binding metal parts. However, thread or silk should, for preference, be used for binding wooden parts together, as wire is liable to cut into the wood. All wire binds should be anchored with a touch of solder, and all thread binding cemented with glue.

Adhesives

No aeromodellist will proceed very far with his hobby without encountering the question of glues and cements. Fortunately, to-day, this problem has been settled as the result of experience, and only one or two adhesives are in common use. These are all non-brittle glues, and are usually of the " fish glue " type such as " Seccotine," or the cellulose types such as " Durofix " or " Aeroglue." " Seccotine " is useful for the joining of woods such as spruce and birch, while for balsa " Durofix " or " Aeroglue " are admirable. These two latter cements dry either white or transparent. and give a very clean appearance to the finished model. " Aeroglue," being an ether cement, drys more quickly than " Durofix," and although not so strong when set, is admirable for the lighter models. Please remember that cellulose cements will dissolve celluloid, and should, therefore, be employed sparingly for sticking such things as celluloid windows or for affixing bushes in celluloid wheels.

" Le Pages Glue " is a cellulose cement which can be purchased from most model shops. This adhesive is highly suitable for model aeroplane construction.

Although *Scotch Glue* has been used quite successfully on heavy machines, it is very brittle and apt to be messy. Probably its most useful application is in the covering of models with silk, the glue holding sufficiently tight, when unset, to enable the silk to be pulled tightly across the framework. On the other hand, extra pressure will remove any wrinkles or slack places.

Paper tissues may be affixed quite satisfactorily with a flour and water paste, or, better still, any dextrine paste as sold commercially. Do not use gum, as this is too " wet," and is liable to make the tissue pulpy and extremely fragile.

Rubber

Every model aeroplane must be provided with motive power of some sort, and in fully 99 per cent. of models to-day, strip rubber performs this essential function. There are two kinds in general use for this purpose : the black and the brown. Both are sold by the yard, but a cheaper way of buying is by the pound, if one intends to do a fair amount of model flying. Various thicknesses are available, this being governed by the type of machine it is intended to fly.

Rubber was first employed to drive model aeroplanes in 1871, by Penaud, a Frenchman, who constructed and sold quaint little flying machines made of bird feathers. Since that time it has held unrivalled supremacy, and, indeed, with good reason, for it is simple, inexpensive and easily handled. The power-weight ratio is higher than that of any other form of motive power, almost all the energy which we can store in it being given out with very little loss. Unfortunately, this giving out of power is not equal over the period of the motor's run, being very great at first and gradually falling off to nothing as the rubber unwinds. This factor has a marked effect on model aeroplane design, as the first burst of power, and consequent great lift obtained, tends to put the aeroplane into a stall. However, more of this anon ; for the present the model aviator can take comfort in the fact that he has at his command a very efficient and light motor.

Some model makers claim that more turns can be applied to the black rubber than the brown sort will accommodate. On the other hand, some model flyers of good experience say that the black rubber breaks more easily. From the above, and in the absence of true experimental data, it may be assumed that there is not a great deal of difference, although some model flyers are obtaining first-class results from a new brown rubber recently marketed by Dunlop. This is of a light brown colour and is very similar to the American brown rubber.

Rubber should be stored in French chalk in an airtight tin, leaving plenty of room for expansion. Do not use a glass jar, as sunlight has a deteriorating effect.

Before using rubber it should be well lubricated with rubber lubricant, which is sold by all aero model dealers, or it can be prepared from the following ingredients :—

Pure soft soap	70 per cent.
Salicylic acid	½ per cent.
Glycerine	20 per cent.
Water	9½ per cent.

However, as a great quantity is not required, it seems hardly worth the trouble of making it oneself.

Rubber lubricant should not be used excessively, as the surplus does no good, and is only flung off, as the motor rotates, on to the fuselage, where it has a very harmful effect on the covering and structure. Just sufficient quantity should be employed to ensure that the rubber has an even coating. It is advantageous to lubricate a motor at least one day before using.

Other Materials

Among the multitude of minor things used in model aeroplane construction, a few of the most important are detailed below with their general applications :—

Materials:	Uses:
Brass Tubing	Propeller-shaft bushes, undercarriage fixings, tail fixings, etc.
Aluminium Tubing ..	As above (remember that aluminimum cannot be soldered easily).
Brass and Aluminium Strip and rod	Small fittings.
Gummed paper tape and Cartridge paper	For strengthening purposes : may also be rolled into tubes.
Celluloid	Cabin windows and windscreens (use sparingly, as celluloid is heavy).
Cellophane	Cabin windows.
Small Nails	Obvious purposes, but always avoid nails if possible as they greatly weaken a structure.
Rubber bands	For wing fixing, undercarriage springing, etc.
Bicycle Valve Tubing ..	For covering rubber-motor hooks.
Microfilm	For covering light-weight models.

Any model aeroplane can be constructed with the materials mentioned in this chapter. All of them are inexpensive, the cost of materials for any average machine being only a few shillings. Our hobby possesses, as not the least of its merits, the virtue of cheapness.

CHAPTER III

FUNDAMENTALS

In the first place it is necessary to understand the principles which underlie the problem of the flight of heavier-than-air machines. We have seen, in Chapter I, why it is that a suitable wing, when relatively in motion to the air, will exert a lift in opposition to the force of gravity, and it will be necessary to go over some well-known ground to determine how this lift can be utilised satisfactorily.

The flight of a model aeroplane may be divided into five stages. First, the *take off*, when the model leaves the ground or the hand ; then comes the *climb*, when the aeroplane gains altitude at a comparatively steep angle ; then a period of *normal horizontal flight*, during which the model proceeds at a more or less constant speed and height from the ground ; then a *glide* back to earth, after the power is expended ; and lastly, the *landing*.

Now, each of these evolutions is governed by a different set of conditions : in other words, the alteration in the speed and the flying angle of the model will cause the forces acting upon it to operate in a different manner, and we must decide which set of circumstances we will take as our standard when designing our machines. The obvious condition is that of normal horizontal flight ; the design being modified to meet the requirements of the other conditions. We must, therefore, first determine the forces which combine to keep our machine in a state of normal horizontal flight.

There are four main forces acting upon our aeroplane. Firstly, the lift, created by the wing, and tending to raise the machine vertically ; secondly, the force of gravity, or weight of the machine, tending to pull the model downwards ; thirdly, the thrust given by the propeller, acting through the propeller shaft, and tending to move the aeroplane forward ; lastly, the drag or resistance of the machine to forward motion through the air, and operating in opposition to the thrust. Fig. 6 shows, diagrammatically, these forces acting upon an aeroplane. In practice, of course, other factors such as upward air currents, act upon an aeroplane, but these are irrelevant to the subject of normal horizontal flight.

When all these forces are equal—the lift being equal to the weight, and the thrust equal to the drag—an aeroplane is said to be in " equilibrium," and is in a condition for free flight. It is not necessary, as some think, for certain forces to be greater than others, say, for instance, the lift greater that the weight ; for equilibrium means that conditions

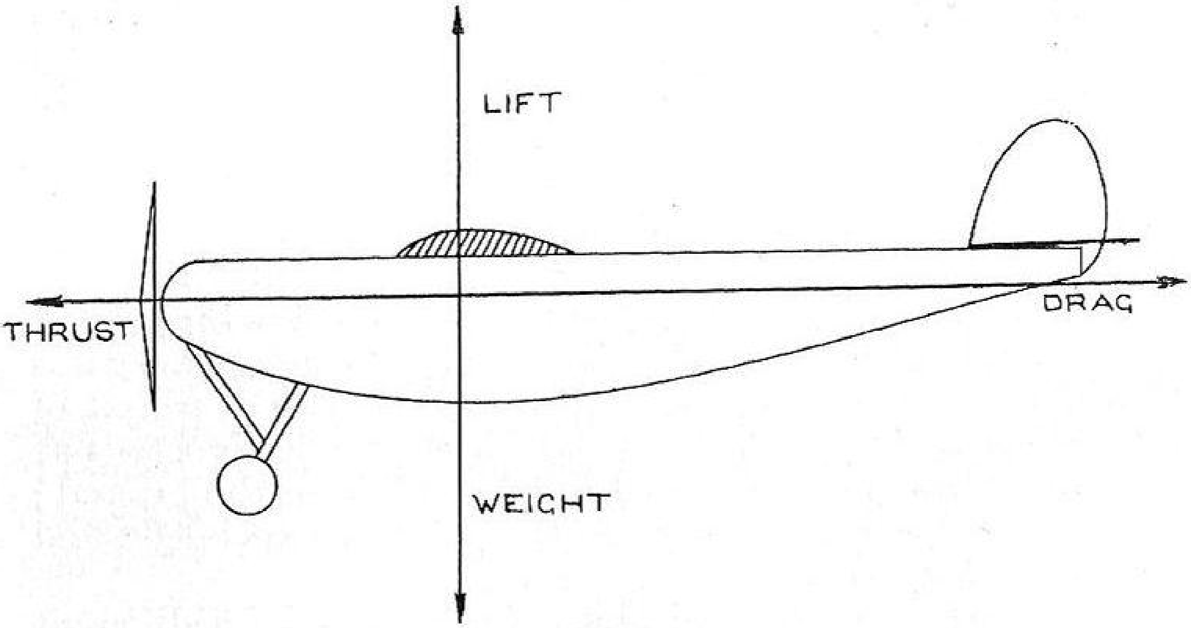

Fig. 6

remain unchanged, and, therefore, a model aeroplane in equilibrium would continue to fly indefinitely, or, as is actually the case, until one of the conditions altered.

It is often rather difficult for the beginner to understand this simple law, and it may be helpful to point out that, to maintain level flight, it is no more necessary for the lift to be greater than the force of gravity, than for gravity to be greater than the lift. If the lift is greater, then the machine will rise ; if gravity is greater, then the machine will drop, and in neither case will *level* flight be maintained. In like manner, to obtain constant speed, it is only required that the thrust and drag be equal ; if the thrust is increased, the speed of the machine will increase, until the drag again becomes equal to the thrust, at which point, the speed will become constant. Should the thrust decrease, the machine will slow down, and thus decrease the drag, until a point is reached where the thrust and drag are again equal.

Returning to the illustration in Fig. 6, it will be seen that the various forces are shown acting at the same point. In actual fact, of course, this is not the case; the drag, for instance, being distributed over the whole machine. It is for convenience that we assume a centre of resistance; in like manner, we assume that all the weight is concentrated at the centre of gravity. In the matter of thrust we are in a better case, as this is actually along the propeller shaft, and forms the line of thrust. The lift will operate through the centre of pressure of the wing, and will depend upon the position in which the wing is placed upon the fuselage.

The illustration in Fig. 6 shows all the forces ideally balanced, but, unfortunately, in practice it is impossible to arrange matters in such a happy manner. Even were it possible, things would not remain in this ideal state for long, as the slightest alteration in the flying angle of the model would disturb the equilibrium. For instance, the centre of pressure would move across the wing, and the centre of resistance would alter owing to the aeroplane presenting a different surface to the airstream.

It may be imagined that we are up against a rather hopeless proposition, but, happily, a tolerable solution may be found in compromise. This is accomplished by making the thrust and drag operate, as nearly as possible, along the same line, and by purposely moving the centre of gravity, and placing it in front of the centre of pressure, in the manner shown in Fig. 7. This illustration shows the normal placing of the various forces acting upon a high-wing monoplane when in flight. The centre of resistance comes too high to be exactly balanced by the line of thrust, which is necessarily low to allow the rubber motor to be accommodated. On the other hand, although it is quite possible to exactly balance the centre of pressure and the centre of gravity, it is advantageous to place the weight just a little ahead, so that the nose of the machine will drop, and the model assume the correct gliding angle when the power from the rubber motor is expended.

The reader who has understood our remarks to this point, will at once ask a very pertinent question. What prevents our aeroplane from assuming a nose-down position when the propeller is running? This brings us to that most important accessory, the tail plane, which takes the form of a small plane placed at a considerable distance from the main wing, and exerting a force in an upward or downward direction in opposition to the riotous conduct of the forces of lift and weight. Only a small plane is necessary, as the distance of the tail plane, or "stabiliser," as it is sometimes called, from the centre of gravity, causes the correcting forces to act through a considerable lever. It will at once be evident that the angle of incidence given to the tail plane will have a marked effect upon its action, as will also the design of the tail itself.

Tail planes may be roughly divided into two types:— "lifting" and "non-lifting." The term "non-lifting tail"

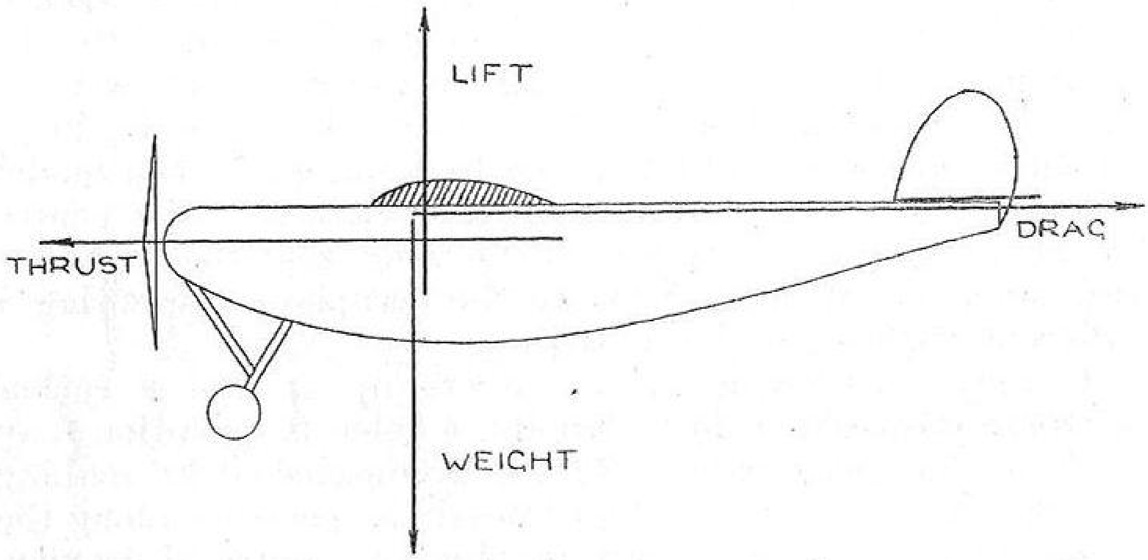

Fig. 7

is really a misnomer; what is actually meant is that the tail exerts no lift at an angle of attack of zero degrees. These two types are illustrated in Fig. 8, and it will be seen that the lifting-tail is cambered in the same way as the wing, while the non-lifting tail may be of flat section or have an equal camber on both top and bottom surfaces. Although a chapter is devoted later on to tail units, this will be mostly concerned with constructional methods, so that a description of the functioning of the two types may be given here.

The non-lifting or "negative" tail will be dealt with first, as this is the most popular type for model aeroplanes, and presents fewer difficulties in operation than the lifting-tail. When an aeroplane is in flight, there is a considerable backward rush of the air displaced by the propeller. This is known as the "slipstream." By placing the non-lifting tail at a small negative angle of incidence to the main plane, the slipstream will exert pressure upon the top surface of the tail plane and thus hold it down. Fig. 9 illustrates this method in operation, and shows how the natural nose-heaviness of the aeroplane is counteracted when the propeller is turning.* When the slipstream ceases, this holding-down force on the tail is absent, and the machine assumes a

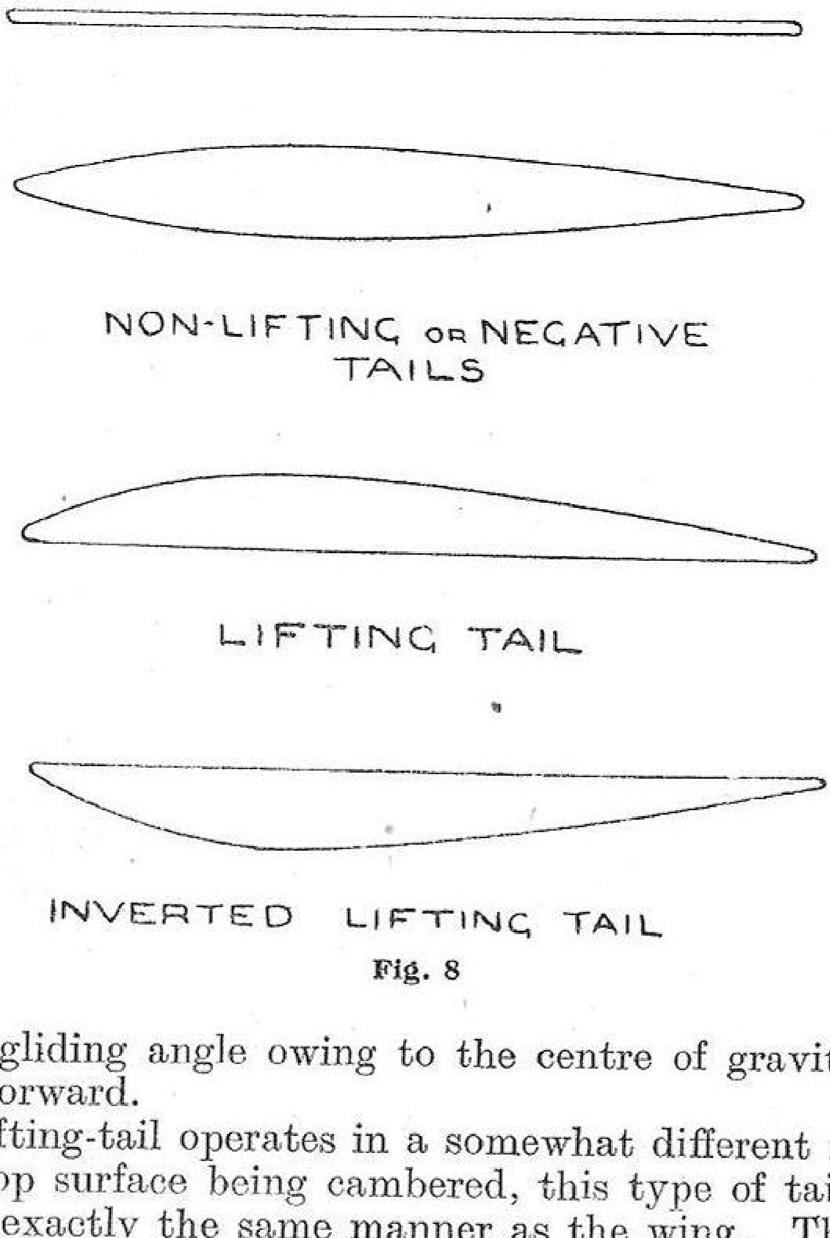

Fig. 8

natural gliding angle owing to the centre of gravity being placed forward.

The lifting-tail operates in a somewhat different manner, as the top surface being cambered, this type of tail exerts a lift in exactly the same manner as the wing. This force may be used in either an upward or downward direction, according to whether the tail is cambered on the top or bottom surfaces. In either case, the tail exerts a more or less

*In actual practice, of course, the slipstream is nowhere near so smooth and even as shown in the illustration: it has a whirling movement and a great deal of turbulence due to encounter with the wing and other parts of the aeroplane.

permanent force in either an upward or downward direction, and is of use when it is impossible to balance the main forces in themselves. In the case of the top surface being cambered, an upward lift will be exerted, varying, within limits, with the angle of attack of the tail plane, or the speed of the model through the air. When the flying speed of the

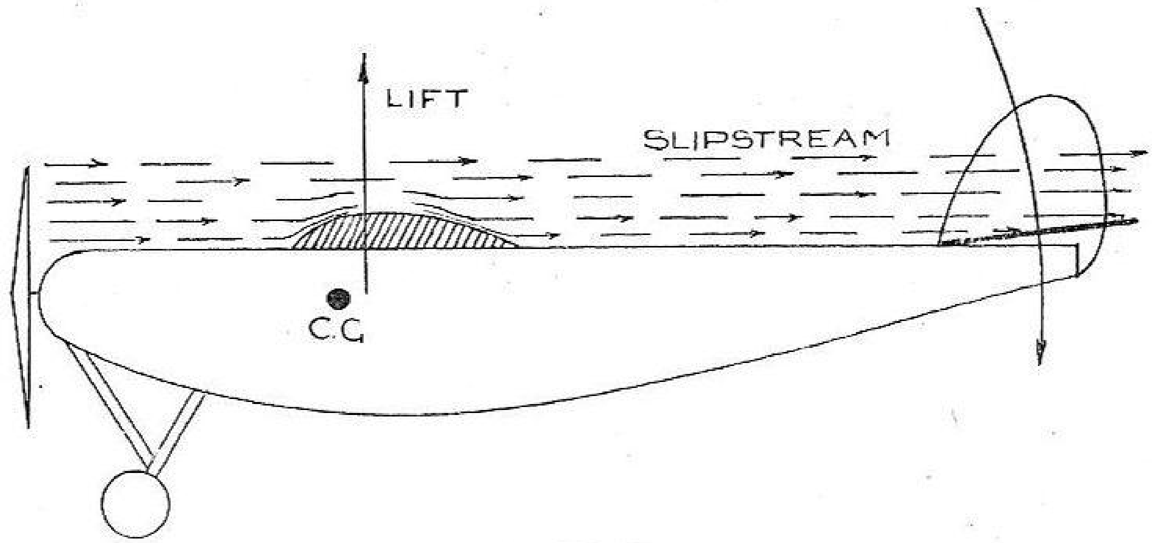

Fig. 9

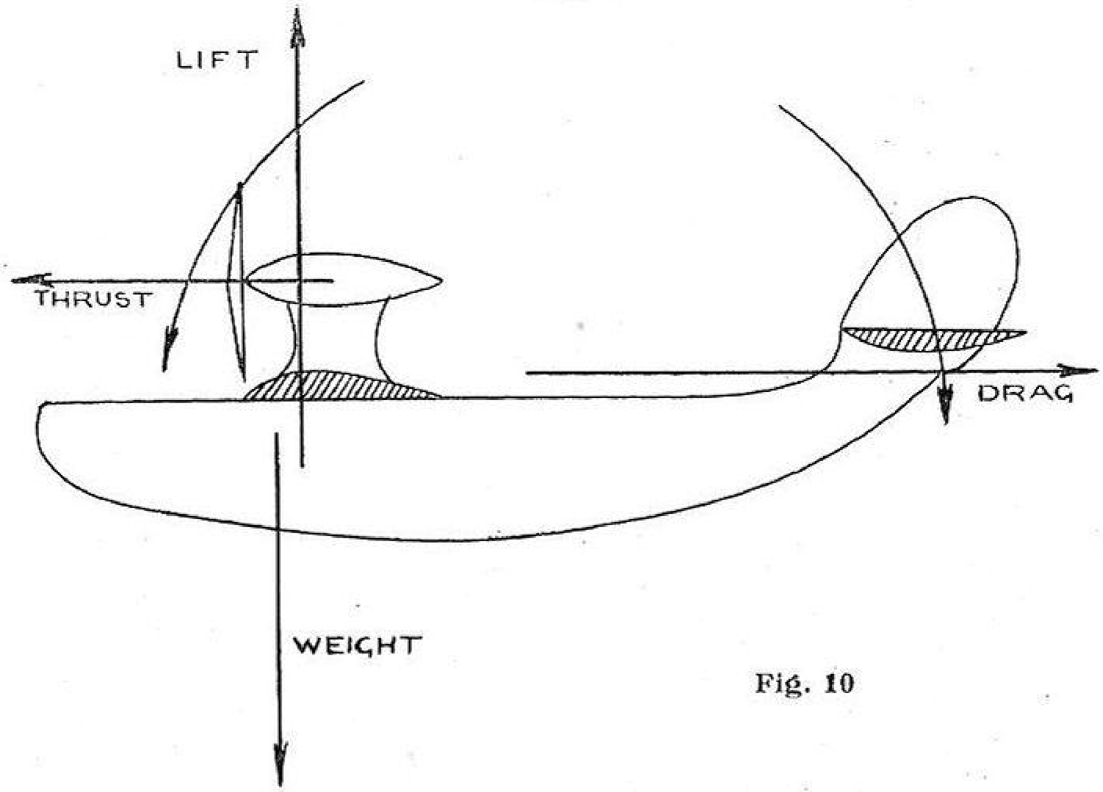

Fig. 10

machine is great, the increased airflow and slipstream cause the tail to exert a considerable lift in an upward direction ; thus very fast and steep climbs may be attained without the model stalling, as any tendency for the nose of the machine to " rear up," immediately results in an increased angle of attack of the lifting-tail. This increased angle causes the tail to exert a greater upward lift, which, as it were, pulls the machine out of the stall. On the other hand, when the power ceases and the speed and slipstream drop, the lifting-tail loses its relative effectiveness, the natural nose-heaviness of the machine exerts itself, and the model glides to earth.

Lifting-tails are tricky in use, and present difficulties in design and operation, unless the above principles are thoroughly understood. The beginner is advised not to design machines embodying the lifting-tail until considerable experience of model aeroplanes has been gained, nor to alter the angle of tail incidence in existing designs, as this has usually been carefully worked out by the designer.

The "inverted lifting-tail" as shown in Figs. 8 and 10, is very little used in model work, but is sometimes employed

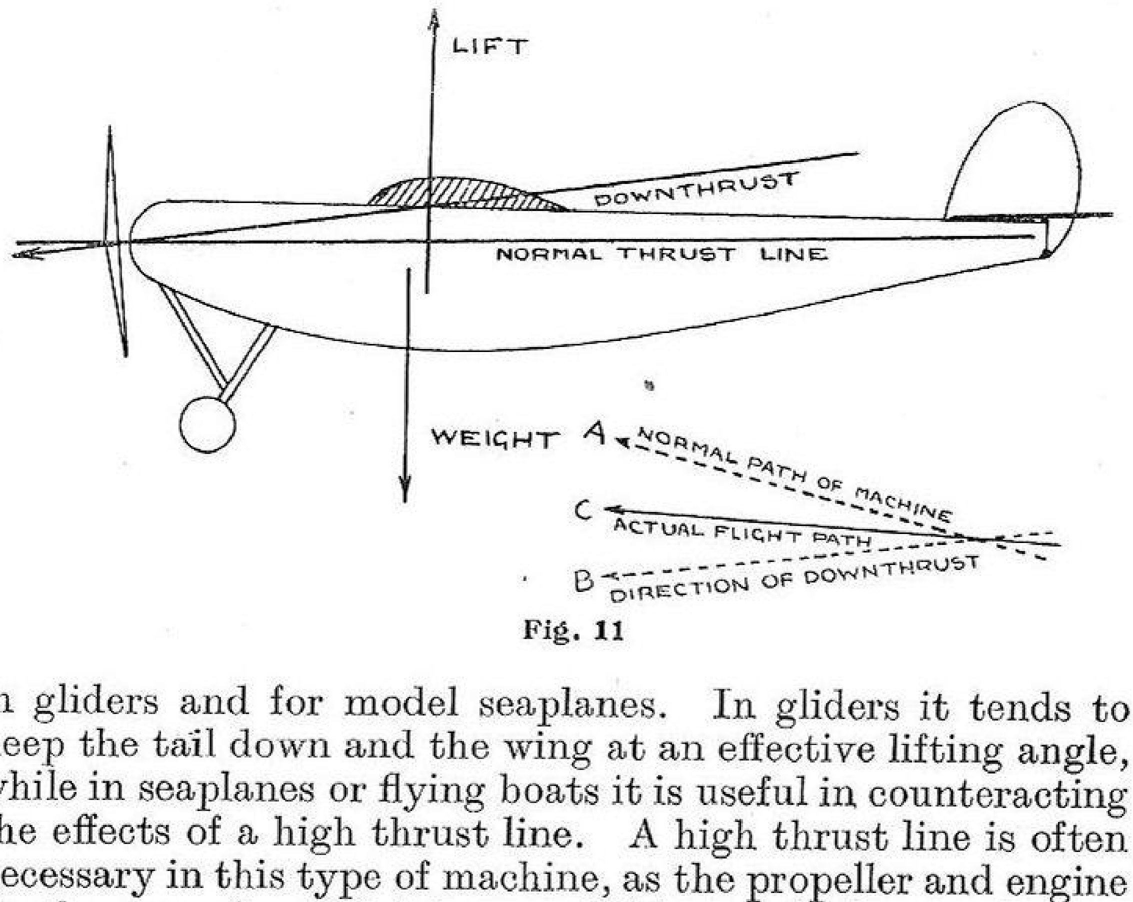

Fig. 11

in gliders and for model seaplanes. In gliders it tends to keep the tail down and the wing at an effective lifting angle, while in seaplanes or flying boats it is useful in counteracting the effects of a high thrust line. A high thrust line is often necessary in this type of machine, as the propeller and engine (in the case of petrol-driven models) must be kept well clear of the water. As a high thrust line in relationship to the centre of resistance tends to make a model "nose-over," the inverted lifting-tail is utilised to counteract this tendency, the tail being held well down. However, this system is rather inefficient, as the downward pull of the tail plane constitutes a more or less permanent load on the machine.

A popular method for the prevention of stalling, and of obtaining longitudinal stability during the first burst of speed due to the great initial outburst of power from the rubber motor, is by the use of "downthrust." This is obtained by inclining the shaft of the propeller in a downward direction. Fig. 11 shows, in an exaggerated manner, how this system is applied, and it will be seen that, while retaining the position at which the thrust will act, the axis of the thrust line is altered.

The smaller drawing indicates how downthrust actually operates. The line marked "A" shows the normal path of the aeroplane, which is at so steep an angle that the machine would undoubtedly stall. Line "B" shows the direction in which the propeller is tending to drag the machine. In accordance with a well-known law of forces, the actual path of the aeroplane will lie along line "C," which lies at a point determined by the relative strengths of forces "A" and "B." The use of downthrust has its limitations, however, and very little should be incorporated in the design of any normal model.

So far, we have only dealt with the problem of longitudinal stability, and there yet remain the questions of lateral and directional stability in the designing of our models. Luckily,

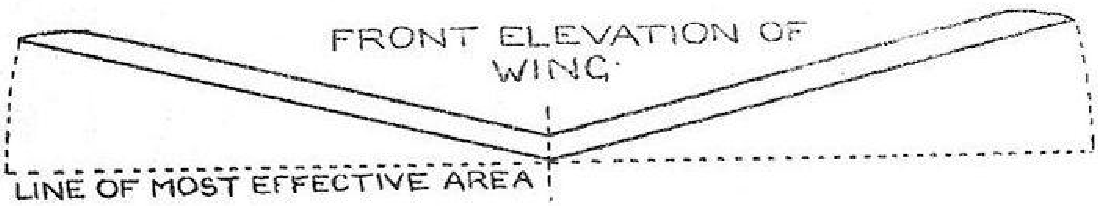

Fig. 12

these problems do not present the difficulties which we encountered in stabilising our machines in a longitudinal direction. In the case of lateral stability, this is obtained by the simple expedient of incorporating dihedral angle in the wing. This is shown in Fig. 12. The lift which may be obtained from any aerofoil is largely dependent upon its effective area (Fig. 12). We will, therefore, imagine a wing, embodying a fair amount of dihedral, in actual flight. While the wing remains in a steady horizontal position, each half-wing will exert an equal amount of lift, and its lateral stability will be maintained. If, however, owing to disturbing influences, one wing-tip should dip, the effective area, and consequently the lift, will be increased. At the same time, the effective area and lift of the opposite half-wing will be lessened, and the aerofoil will automatically resume a balanced position. Lateral stability may also be assisted by keeping the centre of gravity low, and this point will be considered a little later on.

Directional stability may be attained in two ways, one of which is to provide a vertical fin or rudder at a considerable distance behind the machine's vertical turning axis, which passes through the centre of gravity. It must be remembered that any side area of the machine which lies behind this

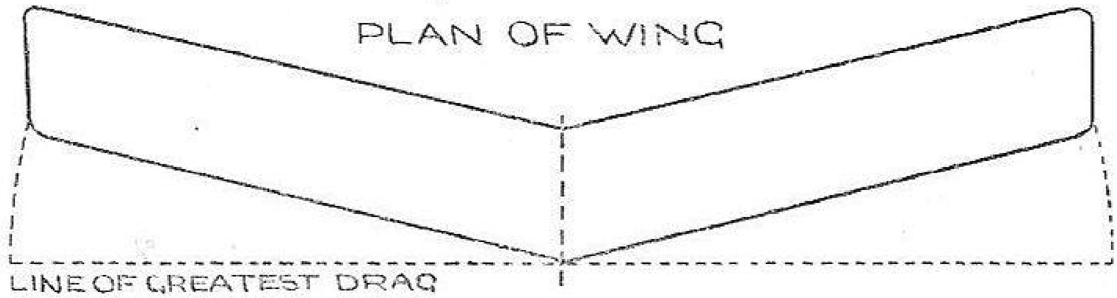

Fig. 13

turning axis will tend to keep the machine directionally stable. Of course, any area in front of the centre of gravity will act in opposition, so that we must ensure that more side area lies to the rear, and it is for this reason that a tail fin is used.

Directional stability may also be attained or assisted by the use of a swept-back wing, as illustrated in Fig. 13. This is really a wing which has a dihedral angle in the horizontal plane, and its action is exactly similar to that of the dihedral angle used to maintain lateral stability, except that the varying factor is the drag or resistance of each half-wing, instead of the effective area. Only in very unusual machines, such as the "Pteradactyl," is sweep-back solely relied upon for directional stability, yet, as an adjunct to the tail fin it is very valuable, and ensures a remarkable degree of stability in any model in which it is incorporated.

The manner in which these various methods are employed to stabilise a model aeroplane is known as the "line-up," and having covered this in a general manner, we will proceed to its application in the various types of model aeroplanes which the constructor may build.

It is often a problem for the novice to decide which type of aeroplane is most likely to give him the best results, and the choice is so wide that the beginner may easily be pardoned for any hesitation in his selection. We shall, therefore, put forward a suggestion which will not be readily received by some people, but one which is, nevertheless, of the utmost necessity. *Do not attempt too ambitious a model at first.* This advice is so often given and so often disregarded, that particular emphasis must be put upon it here. We presume you are reading this book because you are anxious to know something of model aeronautics. We, on our part, are just as anxious to tell you all we know, and we must ask you to believe that our only desire is to give you help and good guidance. Therefore, *do not attempt too ambitious a model at first.*

The desire to make a beautiful and complicated machine is a laudable one, as it denotes a keen interest, and confidence in one's abilities. Yet, in model aeronautics, there is no precept so true as the one which says we must walk before we can run. The successful building and flying of model aeroplanes is a skilful business ; easily learned, it is true, but one which demands knowledge, and which does not respond favourably to haphazard or hasty methods.

It was the fashion at one time to recommend that the novice should build a spar model as his first attempt. This was little more than a stick, to which was affixed a simple wing, a tail unit, a propeller and a few strands of rubber. Fortunately, the introduction of balsa wood, and the consequent ease of construction, makes such stark simplicity unnecessary, and, to-day, an interesting, graceful and highly efficient fuselage model is well within the scope of the beginner.

Ignoring triplanes and other unusual types, aeroplanes may be divided into two classes, namely : monoplanes and biplanes. For several reasons, mainly structural, monoplanes are by far and away the most popular type for model work, and may be subdivided into four types : low-wing, high-wing, mid-wing and parasol. Illustrations of all these types are given.

High-Wing Monoplanes

Fig. 14 shows the high-wing monoplane, which is, undoubtedly, the most popular type of model aeroplane. It is easy to build, has good flying qualities and is a design which lends itself very well to a successful compromise with our old acquaintances, the four main forces. As will be seen in the theoretical drawing in Fig. 7, the chief difficulty lies in balancing the thrust and drag. As all the components, except the undercarriage, are placed high, the centre of resistance is high also, and it is impossible to place the thrust in exact opposition, as the rubber motor must have ample clearance within the fuselage.

The reader will, by now, have gathered that the drag or resistance of a model aeroplane is the real villain of the piece. In the cases of the lift, thrust and weight, these may be placed, more or less, in any desired position ; but the drag is such an intangible quality that it is almost impossible to

Fig. 14.—High-wing monoplane with box-fuselage

compute it accurately, without recourse to complicated wind-tunnel experiments which are entirely outside the scope of the amateur.

To resume. This low thrust line and high centre of resistance tends to raise the nose of the machine when the propeller is running ; the tail may thus be set at a slightly less angle of incidence than is necessary in the low-wing or mid-wing types.* This is an advantage, because very little load is imposed on the machine by an excessive downward pull on the tail plane.

* The question of the actual angle of incidence is discussed in Chapter V.

In addition, the centre of gravity can easily be kept low, which means that less dihedral is needed in the main plane to obtain lateral stability, and, therefore, a good proportion of the effective area may be utilised. This, coupled with the advantage of easy construction, makes the high-wing monoplane so extremely popular with the majority of model aircraft constructors.

The Mid-Wing

On paper this appears to be the ideal type, as the thrust and drag can be placed in exact opposition, and very little dihedral is needed, thus retaining much of the wing's efficiency. It also lends itself to clean design; the wing being easily faired into the fuselage. On the other hand, a larger angle of incidence is necessary in the setting of the tail plane than is required on the high-wing type. This, as we have already pointed out, virtually increases the load which the aeroplane must carry. However, this theoretical objection seems to have very little existence in actual practice.

The disadvantages of the mid-wing type are chiefly structural, it being difficult to obtain rigidity of the wings. This is caused by the inability to carry the wing spars through the fuselage, owing to the presence of the rubber motor. Bracing wires or struts may be used, but these are apt to be a nuisance in use, and can, in very few cases, be placed at an effective bracing angle. Another drawback is that there exists a mechanical difficulty in providing movement of the wings in a fore and aft direction along the fuselage as an aid in trimming the model for flight.

In petrol-driven model aircraft the inability to stiffen the wings by a continuation of the wing spars through the fuselage does not exist, and the mid-wing should, for this reason, be excellent for this type of machine. Doubtless more will be done in this direction as the popularity of the miniature petrol engine increases.

Fig. 15 and Fig. 16 illustrate the mid-wing type of model aeroplane.

The Low-Wing

Many successful models of this type have been designed yet the writer has always felt that too little has been done with this type of machine.

The low-wing aeroplane has two great advantages. In

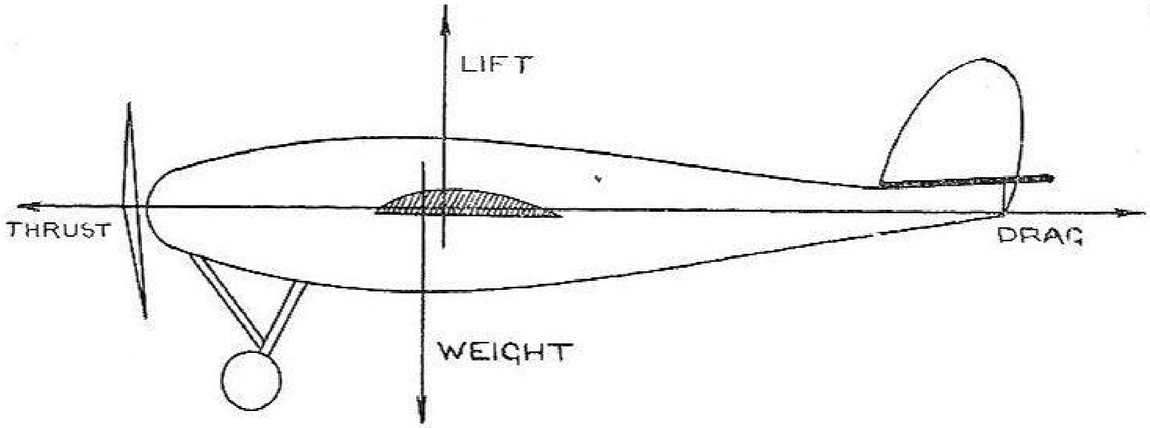

Fig. 15

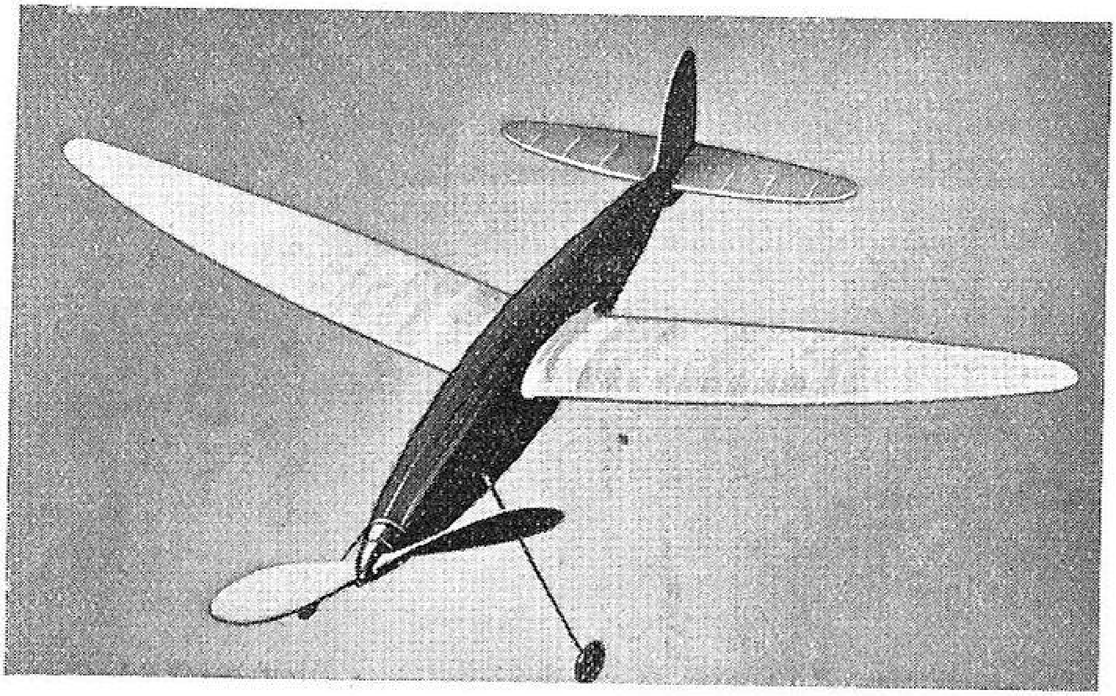

Fig. 16.—Mid-wing monoplane

the first place, the thrust line can coincide exactly with the line of drag; secondly, the wing spars can be continued from one half-wing to the other thus ensuring good rigidity. Against these qualities may be set the necessity for rather a large dihedral in the wing, and a fairly big incidence in the setting of the tail plane. Care is also needed not to get the machine top-heavy.

The disposition of the forces acting upon a low-wing monoplane is shown in Fig. 17 and an illustration in Fig. 18.

Low-wing models are capable of very good performance, have exceptional stability, and form one of the most interesting and promising types.

Parasol and Gull-Wing Machines

The great success which has attended this type of model in America has, recently, made it very popular in this country. The great advantage gained by this arrangement is that the centre of gravity falls very low, and little or no dihedral angle is required in the wing.

Opposed to this advantage is the fact that it is almost

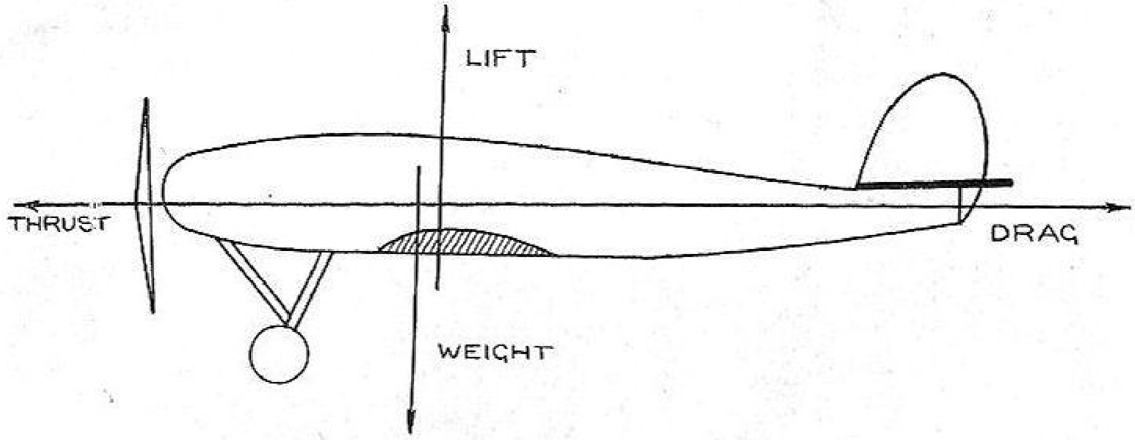

Fig. 17

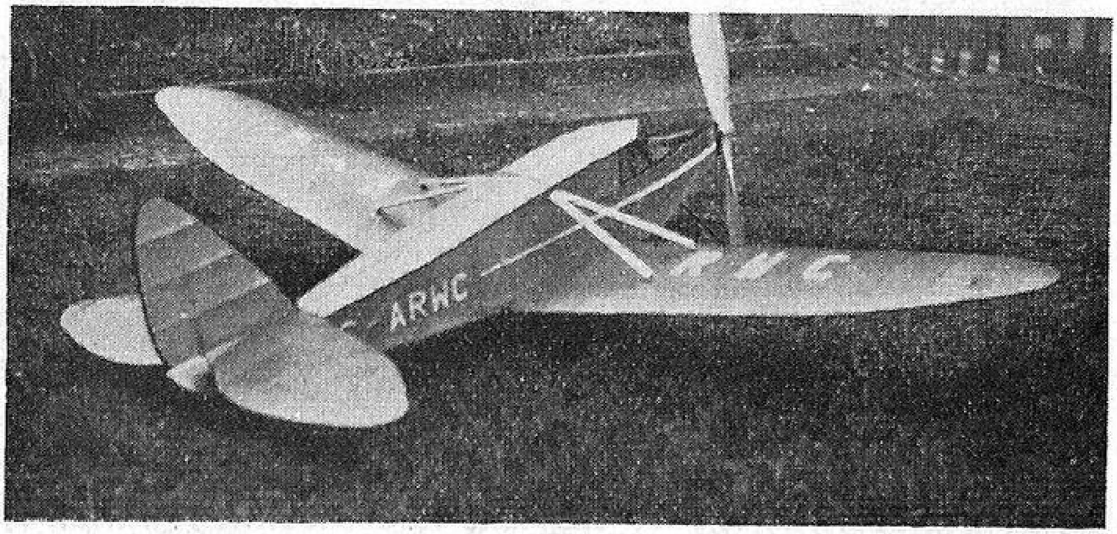

Fig. 18.—Low-wing monoplane

impossible to get the lines of thrust and drag to coincide; the centre of resistance being very high. This state of affairs is shown in Fig. 19, and calls for a somewhat complicated "line-up." In some cases the difficulty has been met by setting a "negative" tail at a positive angle to the main plane, a plan which calls for considerable skill in design and adjustment. This arrangement really means that a lifting tail is used, as we have seen in Chapter I that a flat plate, when moved at a suitable angle through the air, will exert a

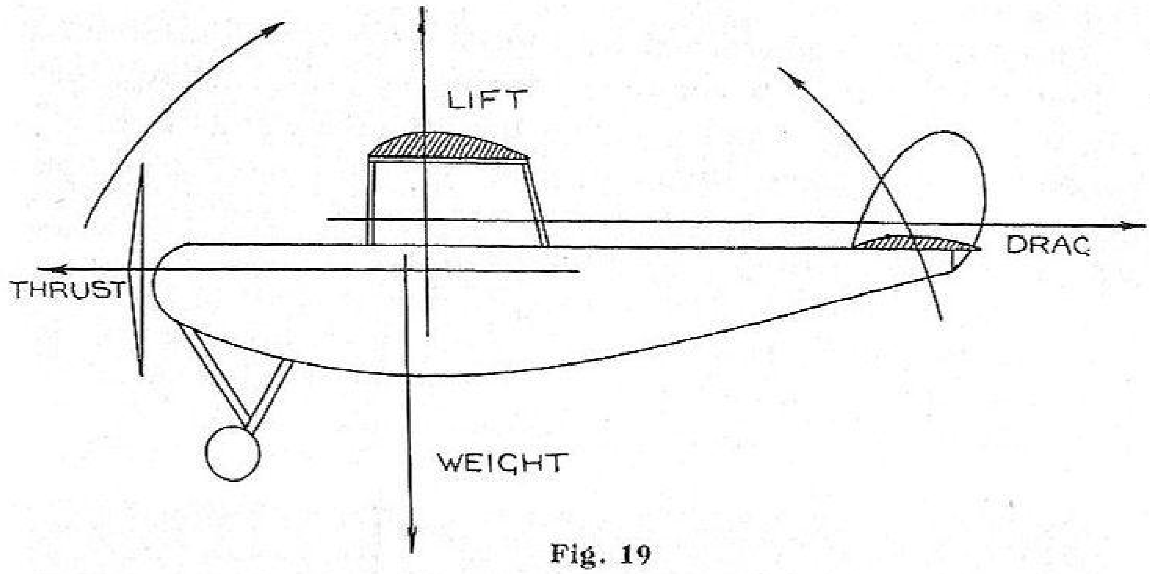

Fig. 19

lift. The most reasonable course is to use an orthodox lifting tail, as already described, and most of the outstandingly successful machines use this type.

Due to the fact that many duration competitions have fallen to parasol model aeroplanes they have come in for a great deal of concentration from model flyers. It is open to question, however, whether an equal attention, *on modern lines*, to the more orthodox types of model aeroplanes would not yield equal results.

Gull-wings, which partake of the nature of parasols, are subject to these remarks, a typical machine of this class being illustrated in Fig. 20.

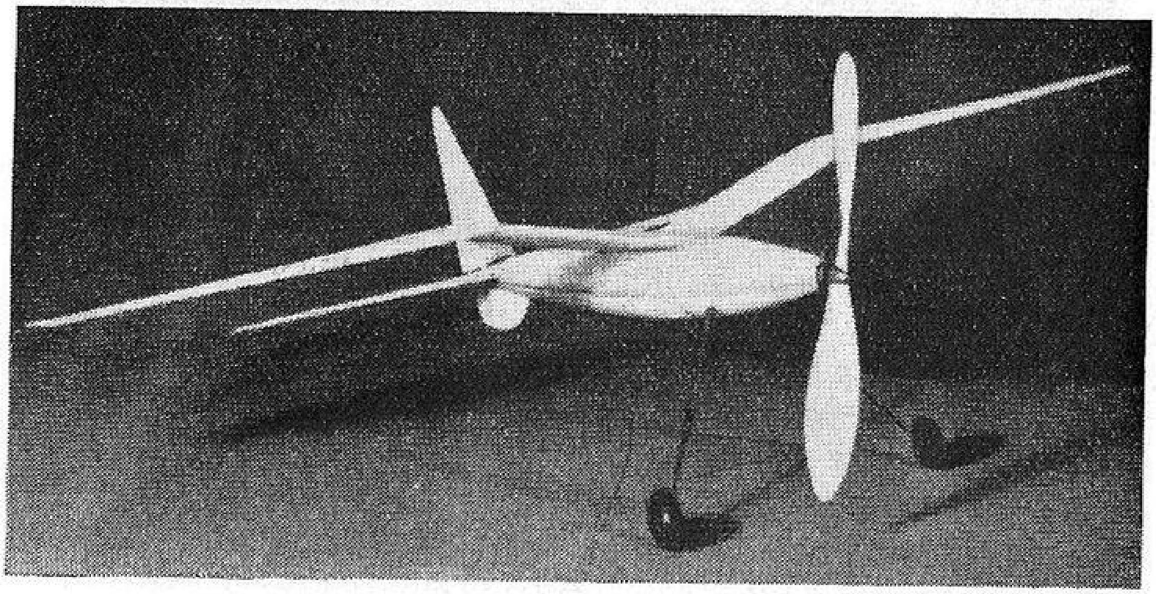

Fig. 20.—Gull-wing monoplane

Biplanes

Though much neglected by model aeroplane builders, the biplane is not only a very fascinating type but is capable of giving very good results. The use of two wings enables a large lifting surface to be utilised without excessive span, and without any proportionate increase in weight. In this way the wing loading may be kept low.*

The biplane illustrated in Fig. 21, has a span of 36 inches, is of exceptionally robust construction, and although weighing seven and one-half ounces, has a wing loading of only two and one-half ounces per square foot.

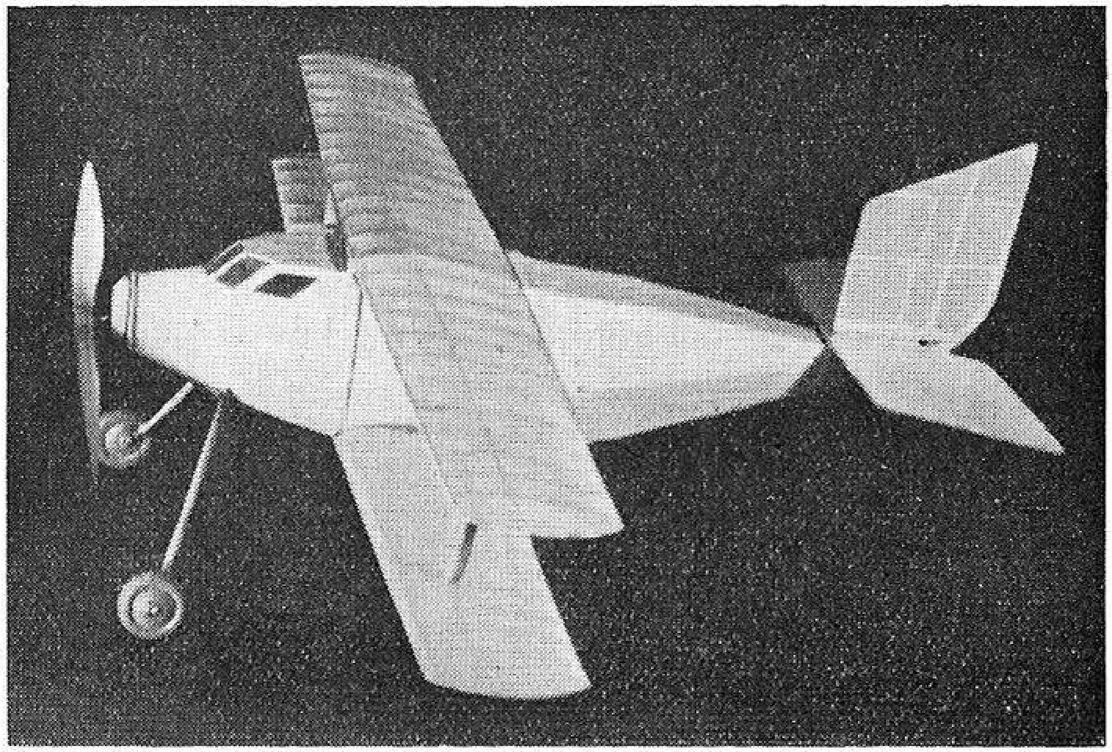

Fig. 21.—Cabin biplane

The constructional difficulties are somewhat great in biplanes, and call for a certain amount of skill and ingenuity, the great trouble being that of obtaining a rigid wing fixing without excessive complication and weight. In the model illustrated, this was overcome by the use of a very stiff top wing, the lower half-wings being hinged at the roots to the fuselage, and depending from the top wing by hollow paper struts. Rubber bands, affixed to hooks on the main spars of both top and bottom wings, pass through the hollow

* In model work, the term "wing-loading" always expresses the number of ounces carried per square foot of main wing area.

struts and clamp the assembly together. These points are given in illustration of the manner in which biplane design may be approached.

In the matter of line-up, the biplane presents no great difficulties, it being possible exactly to oppose the thrust and drag. No excessive incidence is required in the tail plane setting. Tails may be placed above or on the half-way point between the two main planes ; but should not be situated lower than this. They may be of rather larger area than those of monoplanes, as the erratic behaviour of two main wings has to be corrected. Better stability may sometimes be obtained by setting the lower wing at a negative angle of incidence to the top wing.

The usual line-up of biplanes is shown in Fig. 22.

Biplanes often hold a great attraction for the novice on account of their somewhat "real" appearance, but the

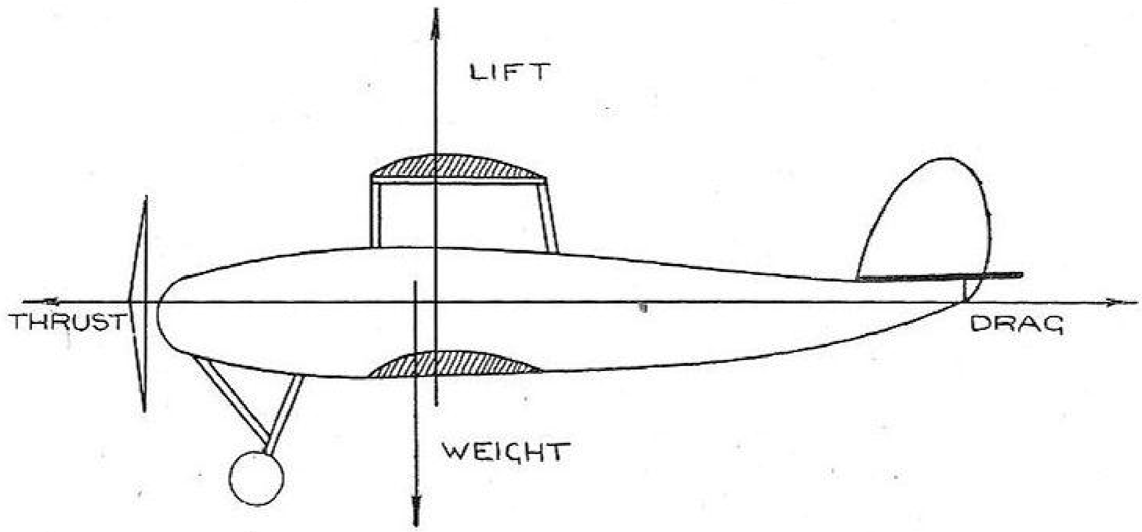

Fig. 22

beginner is warned not to attempt this type of aeroplane except it be to some well-known design, until experience has been gained in flying and trimming the more simple types.

Pusher Type Aeroplanes

This term describes all models where the propeller is situated behind the main wing. This type was very popular before the Great War of 1914-18, but later years have seen very few upon our flying fields. Their growing popularity in full-sized practice will, no doubt, tend to revive this type of model, which has, indisputably, some interesting features.

They are certainly worthy of experiment in the light of modern knowledge, with special regard to the fact that the wing moves forward through *undisturbed* air ; the slipstream, of course, lying behind.

A great advantage is that the propeller is protected in the event of a bad landing, a particularly useful feature in the case of power models driven by an expensive petrol engine.

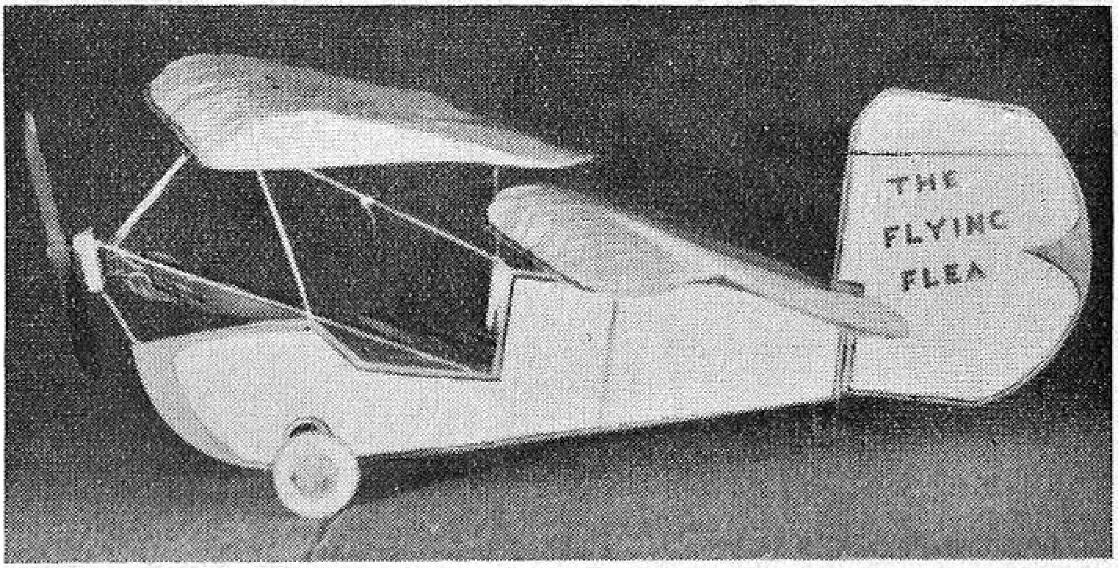

Fig. 23.—Model "Flying Flea"

It is interesting to note that Stringfellow's módel aeroplane of 1848, which was the first aeroplane to fly, was a twin-screw " pusher."

Unusual Types

Aeroplanes such as the " Autogiro," " Pteradactyl," and " Flying Flea," form unusual types which cannot be adequately dealt with here. In any case they are unsuitable for inclusion in such a book as this, as they are usually the product of experienced builders who have made a study of the various peculiar factors in design. The " Flying-Flea " and the " Autogiro " illustrated here (Fig. 23 and Fig. 24), are both successful models, but were only evolved after a considerable amount of experiment had been undertaken. Please do not attempt to design either of these as your first model.

Classification

Having dealt with the various features of the several types of model aeroplane, there yet remains a further classification.

It is obvious that any one of the types mentioned in the foregoing pages may be constructed from various materials, and may be elaborated or simplified to almost unlimited degrees. Thus, for instance, a 36 inch span high-wing monoplane may weigh twelve ounces or only three ounces, according to the materials and methods employed, and these two machines will have vastly different flying qualities and performances. This makes some other classification, other than that of mere lay-out, necessary, and the obvious and most useful is a classification for weight. Thus it comes about that model aeroplanes are divided into classes, by a system which ignores lay-out, wing-loading and appearance, and is based solely on the total weight of the machine, as follows :—

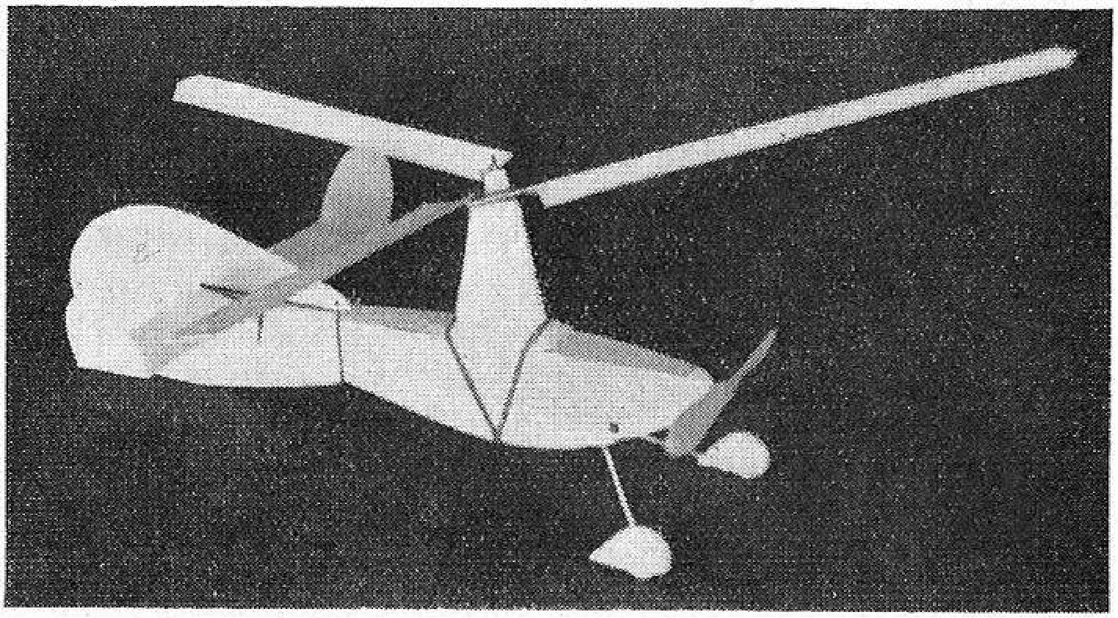

Fig. 24.—Model Autogiro

No. 1 Ultra-light-weight duration models and indoor flyers, up to three ounces.
No. 2 Light-weight duration and general purpose models, from three to five ounces.
No. 3 Medium-weight general purpose and duration models, from five to nine ounces.
No. 4 Heavy-weight general purpose models, over nine ounces (rubber driven).
No. 5 Power-driven models.

The above is the generally accepted classification, but models are sometimes constructed which do not conform to these particulars. For instance, a heavy-weight duration model may be required, but these are usually built to comply with rules laid down by some special competition in which the builder may wish to participate.

It will be noticed that only the lighter machines are classed as duration models, and this is due entirely to the present use of balsa wood in model aeroplane construction. He would be a very daring or optimistic man who would enter a model over these weights in any ordinary duration contest, in view of the wonderful performances which are now the order of the day.

Ultra-Light-weight Class

Machines in this category are usually built with only one purpose in view—duration. To that end they are always of the simplest design and construction, all "trimmings" being rigorously avoided. It goes without saying that this type is always of all-balsa construction—and not much of that—while the covering is of the lightest Japanese tissue paper. In some instances, to save weight, the paper is not even doped, but is sprayed with water and left to shrink. It is almost unbelievable to what extent a model of this class may be lightened, and the author has seen fuselage machines of 40 inches span weighing about one and one-half ounces!

In spite of their simplicity, this class of machine is not easy to construct successfully, owing to the excessive care and accuracy involved. The design calls for considerable skill, inasmuch as the smallest amount of material must be utilised in the most efficient way. There is no margin for error either in design or manufacture.

Although highly efficient in their way, their successful functioning depends so much upon weather conditions that it is rarely one meets a day upon which the ultra-light-weights can do themselves justice. However, there are few sights so fascinating to the model flyer as that of an ultra-light-weight machine in flight, its huge propeller turning lazily round in the calm of a summer evening.

Indoor flyers include a vast variety, ranging from tiny tissue paper machines to quite large, microfilm covered aeroplanes. They are not vastly popular in this country, owing, chiefly, to the difficulty of obtaining the use of large rooms or halls suitable for the purpose. In America, where aeromodellists seem to be well favoured, indoor flying forms a distinct and not unimportant branch of the pastime. The flying of these small machines by means of a thread attached to a central pole is, however, gaining popularity with British flyers. In this system, the machine is secured to one end of a thread—usually by one wing tip—and the other end of the thread is swivelled to the top of a pole which stands in the middle of the room. The aeroplane is then flown in the usual manner under its own power. Quite interesting flights may thus be obtained, even in the space of an ordinary living room.

Some of the American microfilm covered machines are real works of art, and the author knows of at least one which is a miracle of fragility. It has a span of 36 inches, and weighs, complete with rubber and propeller, one quarter of an ounce! It is built of 1/64th inch balsa, strutted with writing paper, and its two strands of 1/32nd inch square section rubber will accommodate thousands of turns. This motor will only just turn the propeller, which revolves with a hesitating "flop," and imparts a jerky motion to the machine which is very weird and amusing to watch. It will fly for twenty minutes, and its owner steers it up and down the hall by means of a dexterous touch upon the tail.

Light-weight Class

Aeroplanes under this head, by reason of their straightforward design and good performance, are probably the most popular of all types. It is to this class of machine that victory often falls in competitions for duration, and the resultant concentration upon these models has lifted them to a very high pitch of performance. As in the case of the ultra-light-weights, only the bare necessities of flight are incorporated, and the light-weight model is thus usually reduced to a plain rectangular section fuselage carrying a simple wing and tail unit. This pursuit of simplicity also confines these machines almost solely to the high-wing variety, which is undoubtedly the most straightforward design.

These models are not so prone to the influence of the weather as their lighter brothers, and a well-designed light-weight will perform satisfactorily on most average English days.

All-balsa construction is again a feature of the light-weight aeroplane, and a minimum amount of such necessities as wire is used. A very light wing loading—two to three ounces

—ensures a good climb, at the same time facilitating the glide, and rendering the machine less likely to mishap in landing.

Altogether, the light-weight aeroplane forms an almost ideal model, being simple, inexpensive and capable of extraordinary performance. At the same time it is not so fragile as to preclude the exercise of a little experiment in its design and making.

Medium-weight Class

Although the light-weight model is undoubtedly the most popular type to-day, no serious aeromodellist will neglect the machines of medium weight. Their great feature is that, not being hampered by the restrictions of weight and fragility to the extent of the light-weight classes, the builder is able to give full play to the exercise of his ingenuity and fancy. With the eight ounces or so of material available, some very beautiful machines may be evolved. The fuselage may assume a round, oval or composite section ; cabins may be incorporated, and there is scope for experiment and clever device in a thousand directions.

Good design and workmanhip are essential, and particular care must be taken to stabilise the machine perfectly. These qualities are rendered necessary by the fact that models of this weight fly comparatively fast, and any inaccuracy, such as a warped wing or tail, has a very detrimental effect on the model's behaviour. Also, the landing speed is comparatively great, and, therefore, a good, clean landing is necessary if damage is to be avoided.

Medium-weight models may incorporate in their make-up a certain amount of spruce or birch, but very successful and interesting machines are built with an all-balsa construction. This practice is to be commended. as balsa has considerable strength when used in large section. Good strength and rigidity may be obtained for small weight, and this seems to constitute an intelligent use of material. This method is standard practice in America, where, as stated before, even heavy petrol-driven machines follow this principle.

A well-designed medium-weight model is well worth the trouble expended upon it, as the quality of flight is good ; in other words, it flies steadily and in a very determined manner.

As the well-known "Wakefield" class of machine falls into this category, it has received more attention from model makers than has any other type of model aeroplane. In consequence, the duration of flight which these machines are capable of is remarkable, being measured in parts of an hour rather than in minutes! The "G.B.3" which is described elsewhere in this book, is a typical example of the trend of these machines, and its design should be carefully studied by all aeromodellers.

Heavy-weights

It is now very seldom that one sees the real heavy-weight rubber-driven model aeroplane, because, to-day, there are so many small power plants available. These are so much more suitable than rubber for this class of work, that a heavy-weight model is seldom contemplated without a mechanical power plant in view. However, some interesting machines make their appearance from time to time, and they may still be considered a live branch of the pastime.

Spruce and birch are, or course, the main materials used in construction, and these models are invariably covered with silk or bamboo paper. The quality of flight is good, but naturally, the duration is not much longer than that of the motor run, as, omitting exceptional cases, not much can be expected in the way of soaring flights. Usually two or more skeins of rubber are geared together, as a fair amount of power is required to fly these machines.

As may be imagined, the heavy-weights fly relatively fast, and the greatest problem is to ensure a good landing. This landing question is apt to lead one into a vicious circle. An attempt to strengthen a machine to withstand fast landings usually results in added weight, which, in turn, causes the machine to land yet more speedily. Thus, an almost unending competition between speed and safety often ensues, the speed, alas! usually winning in the end.

Power Models

This term, to-day, usually means a model powered by a small petrol engine, and for this reason power models constitute quite a distinct branch of model aeronautics, with separate problems of design and construction of its own.

While it is as well to leave the power class of model aeroplane until a great deal of proficiency has been obtained in the making of the other types, no aeromodellist has tasted the full joys of his pursuit until he has experienced the thrill of beholding his own power-driven model aeroplane in full flight. The flying and behaviour is so much like that of the real thing, that the constructor of a successful power-driven heavy-weight may truly be considered to have "won his wings."

CHAPTER IV

WINGS

Every part of a model aeroplane is important, in so far as no model will function without all its essential components. If any part, however, can be considered of more import than another, surely it is the wing. In view of this, it is surprising how little attention some aeromodellists pay to the design of this most fundamental accessory, especially in the matter of wing section. It is true that aerofoil section does not seem to be of such critical importance on models as it is on the full-sized aeroplane, probably because so many other factors contribute to a model's performance that the relative efficiency of one wing section compared with that of another is, as it were, swamped in the general behaviour.

In spite of this, wind-tunnel experiments conducted with models in connection with full-sized aeroplanes, show that a model aerofoil is governed by the same laws, and reacts to the same conditions, as its full-sized counterpart. This being so, it would seem beneficial to select a wing section which has the best characteristics for our purpose. Now, the most desirable feature which a wing can possess, from our point of view, is its non-stalling property, and we shall do wisely to turn to the result of full-sized practice in selecting an aerofoil for our models. In a study of the characteristics of the hundreds of sections available, two stand out as possessing great non-stalling qualities, in other words, they will accommodate themselves to a considerable change in flying incidence without stalling. These are the " Clark YH " and " R.A.F. 28 " sections. Almost all constructional articles on model aeroplanes state that the wing section is "roughly Clark Y," and as fully fifty per cent. of aeromodellists have never troubled to find out just what a " Clark Y " section really is, the various interpretations may be better imagined than described.

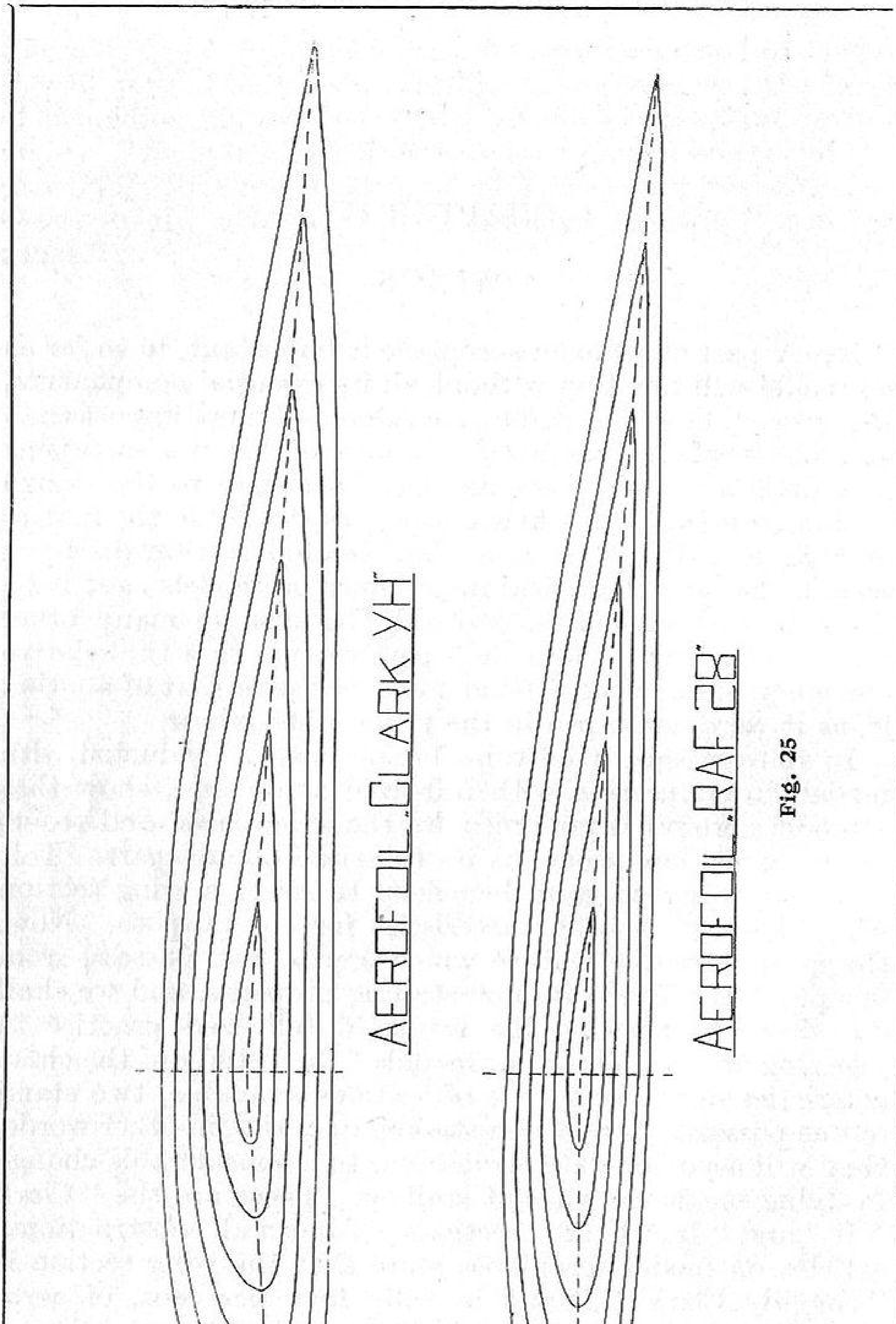

Fig. 25

That the reader of this book may become acquainted with these most useful wing sections if he is not familiar with them already—we give, in Fig. 25, full-size templates of both, in sizes from six inches to one inch. We are aware that other useful sections exist, but, as it is impossible to give them here, it will be left for the experimentally minded to discover them for themselves.

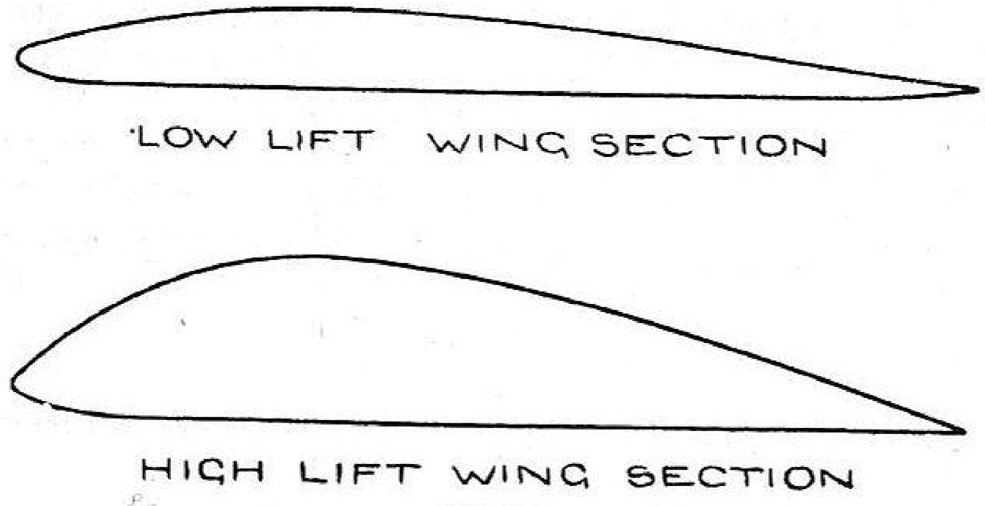

Fig. 26

The two illustrations in Fig. 26 show respectively, the thick, "high-lift" wing section and the thin, "low-lift," high-speed section. As its name implies, the thick section is capable of exerting more lift, at a given speed, than the thin aerofoil, and the reader will easily see the reason for this in the light of our remarks in Chapter I. Strangely enough, the very high-lift aerofoil is of little use in rubber-driven model work, as not only is the drag or resistance very high,

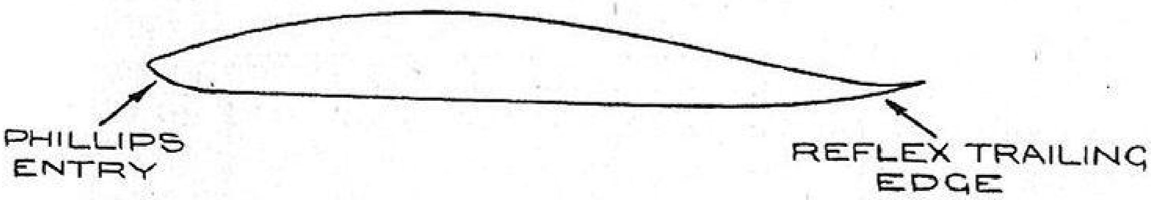

Fig. 27

but the position of the centre of pressure varies greatly with the angle of incidence, thereby increasing the liability to stall. On heavily loaded power-driven models the high-lift has its uses, when it is desired to keep the flying speed low. With rubber-driven machines the initial burst of power and subsequent great speed of the model, makes the high-lift aerofoil unsuitable. On the other hand, the constant poweroutput of the petrol engine offers no complications in this respect.

Fig. 27 shows a wing section illustrating the meanings of two terms often used when speaking of aerofoils : " Phillips Entry " describes the particular type of leading edge shown in the drawing, while the turned-up trailing edge is known as a " Reflex Edge," the advantage of which is that it limits

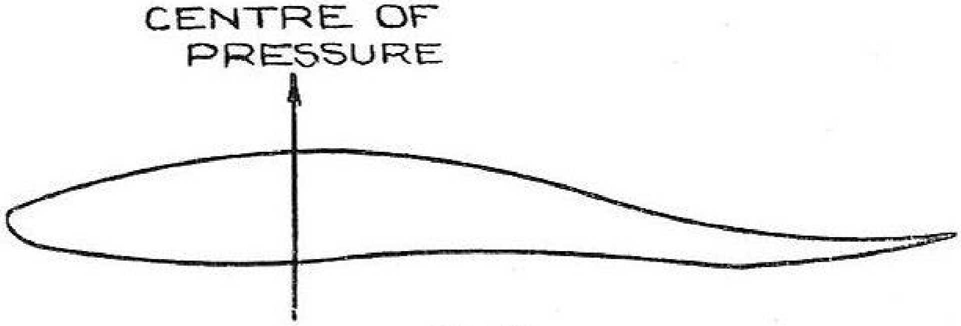

Fig. 28

the travel of the centre of pressure caused by an alteration in the flying angle. It is, therefore, helpful in preventing the wing from stalling.

In rubber-driven model work it may generally be considered that a thin, low-lift section is preferable to the high-lift type, and that a Phillips entry and reflex trailing edge may often be usefully incorporated. A concave undersurface improves the glide, but do not overdo this as there

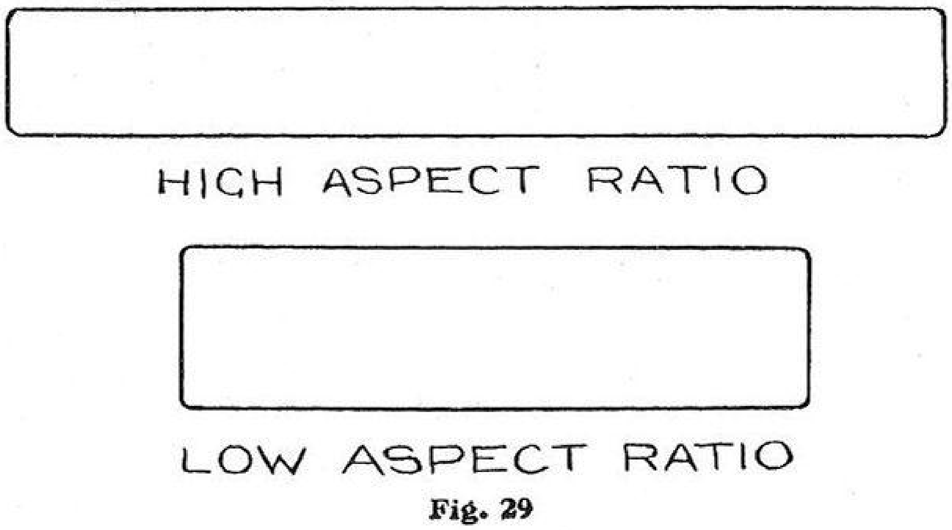

Fig. 29

are other factors to be considered. The concave portion should commence behind a point vertically below the centre of pressure, as shown in Fig. 28.

The distance from wing-tip to wing-tip is known as the " span," while the width of the wing is called the " chord."

The ratio of chord to span constitutes the "aspect ratio"; thus a wing with a 42-inch span and a 7-inch chord would be said to have an aspect ratio of six (see Fig. 29).

Following theoretical considerations, it has been found in practice that wings of comparatively large aspect ratio perform better than those of small ratio, especially on model gliders, where aspect ratios of as large as 20 to 1 are being employed. Such large ratios, however, create complications when applied to powered model aeroplanes, and they should be in the region of from 6 to 10 to 1—say about 8 to 1.

The superior performance of high ratio wings lies, briefly, in the fact that the leading edge of a wing, or rather that portion of the wing which lies nearest to the leading edge, is more efficient in producing lift than the portion nearer to the trailing edge. Lift is only produced by the reaction

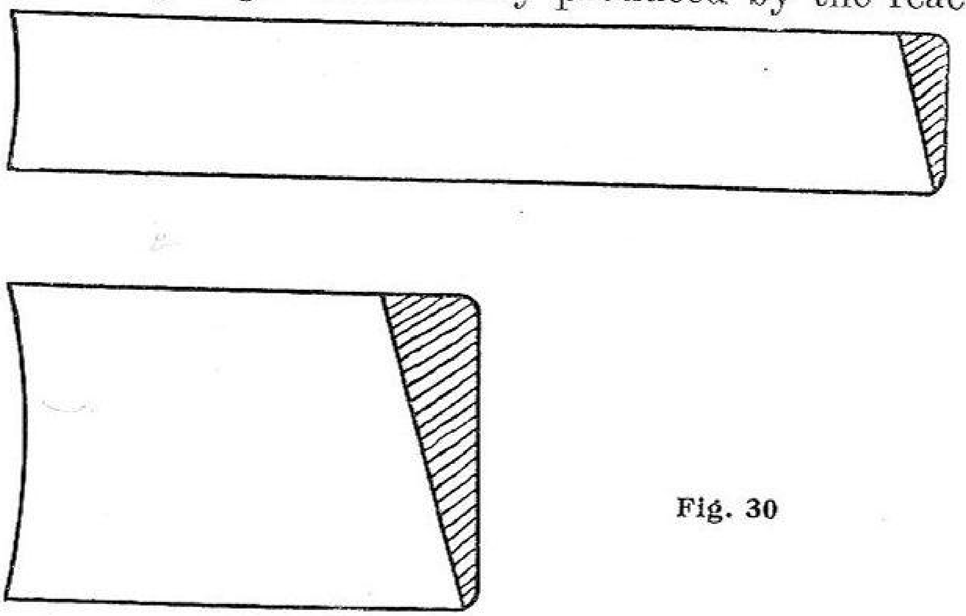

Fig. 30

of the wing upon the air, and the air is more affected by the leading edge of the wing than by other parts.

Among other considerations which also prevail, one of the most important is shown, diagrammatically, in Fig. 30. Here we see two wings, one of high aspect ratio and one of low, the area being, in each case, the same. On all wings there is an inefficient area at the tips, due to the air spilling over at this point. The diagram shows this inefficient area as a shaded portion, and it is obvious that a larger proportionate area is ineffective in the broad, short wing than in the one of high aspect ratio. A secondary beneficial effect is that the stabilising influence of dihedral is greater owing to the levelling tendency of the outer wing portions acting through a considerable lever. This effect may, however, be somewhat discounted by the fact that the disturbing influences also have the advantage of this leverage.

In spite of the above, many good model 'planes have been built with lower aspect ratios than those stated, even ratios as low as four or five to one performing satisfactorily. Probably other factors react in the favour of the lower ratio model wings. These may be connected with the drag, or with the comparatively low flying speed of the model aeroplane. Also, with very high aspect ratio wings, too much air may be disturbed for such small wing loadings.

Some plan forms of wings are given in Fig. 31, marked "A" to "E," while "F" and "G" show two front elevations. These, of course, only outline the general characteristics of the various types in use, as there are dozens of possible combinations and varieties. The simplest type is the plain rectangular wing marked "A," with a constant section as in "F." The chief merit of this type is ease of construction; all the ribs being of the same width and section. These wings perform quite well; their main disadvantage is that, owing to the parallel arrangement of the main spars, no triangulation of these can be utilised. This makes them rather weak, especially in large spans. A further disadvantage is that directional stability is lacking.

A much better arrangement is presented by "B" in combination with "G." This class of aerofoil tapers in both plan and thickness which results in great strength; the spars tapering in accordance with the load which they must carry. At the wing root the triangulation is deepest, and, as it is here that the load is greatest, this forms an ideal arrangement. Furthermore, the centre of the area of a tapered wing is nearer the wing-root than in other types, thus the bending effect of the air load is considerably lessened. This means that wings of large span and high aspect ratio may be constructed quite satisfactorily, with the minimum danger of wing flutter when in flight.

In the diagram marked "C" the wing is tapered only on the front edge, and this method is quite satisfactory. Diagram "D," on the contrary, indicates a wing tapered on the trailing edge only.

This arrangement has become increasingly popular, although directional stability is lacking.

Tapered wings have a distinct tendency to directional stability, the operation being exactly similar to that of the swept-back wing described in Chapter III. They are slightly more difficult to construct than the parallel type, owing to the wing ribs being of different sizes; but as an easy method of cutting these will be described later, there is little to bother about on this score.

Swept-back wings, though presenting certain constructional difficulties, are remarkable for their stability. Not

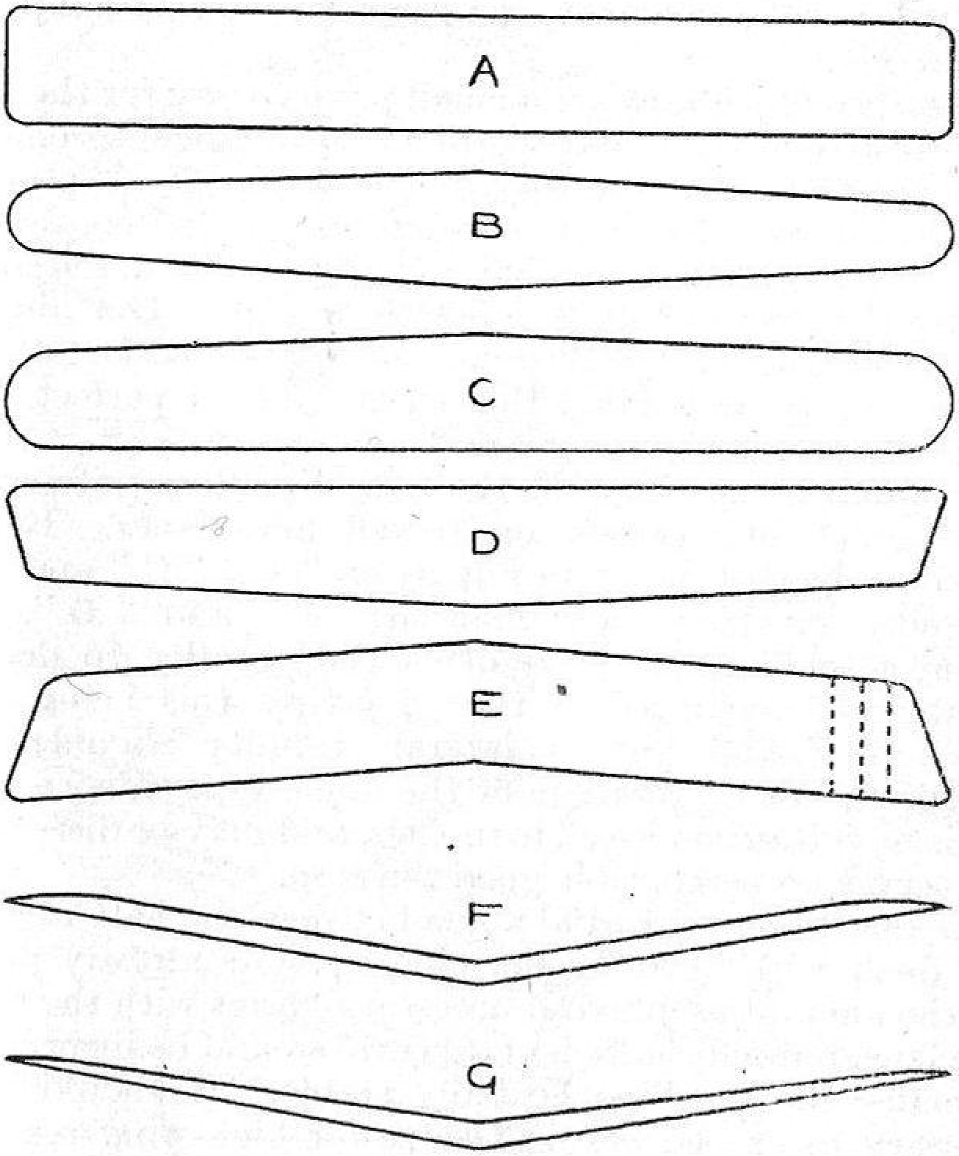

Fig. 31

only are the directional properties great, but they have a marked effect on the longitudinal stability of the model. Tail units may thus be made smaller and consequently lighter, and owing to the centre of pressure being situated well back, the wing may be placed farther forward on the fuselage. This is a great help in obtaining the correct balance of the aeroplane.

Against these manifest advantages may be set the fact that swept-back wings offer more difficulties in construction, as two angles—those of dihedral and sweep-back—must be incorporated. This tends to complicate the centre wing section, and forms the main reason why they are so seldom seen on our model flying fields. Also the effective area of lift is lessened, as two dihedral angles are incorporated, and the reader will remember our remarks on this subject in Chapter III.

These two objections are a small price to pay for the benefits bestowed, as the greatest difficulties in model aeronautics are connected with stability. The secret of a successful pursuit of our hobby lies in compromise, and it is useless to build a model incorporating all the finest aerodynamic features if it will not fly in a stable manner. Our object is not to construct a model as an example of perfect theory, but to modify and blend this theory into a perfect flying machine.

In practice, the shape of the wing-tips does not seem to be of great importance on model aeroplanes. Broadly speaking, the tips shown in Fig. 31 on " B," " C " and " E " are quite suitable; those marked " A " and " D " being the most inefficient. It is often the practice to decrease the angle of incidence of the wing-tips, this being called " wash-out," and greater lateral stability should result. " Wash-in," or an increase of the angle of incidence at the tips, is not often employed in models, and may be disregarded as it serves no perceptible good purpose.

The question of dihedral angle between the half-wings has been dealt with in an earlier chapter. As already pointed out, the amount of dihedral necessary varies with the type of aeroplane, but only sufficient dihedral should be incorporated to render the machine laterally stable. It should not be necessary to exceed one in twelve for high-wing machines, or one in eight for the low-wing types.

In the illustration marked " E." in Fig. 31, the wing ribs are indicated by dotted lines. It will be seen that these are set parallel to the direction of flight.

Construction

The actual methods of wing construction employed vary greatly, according to the type of wing or machine it is desired to build. A description of every arrangement of ribs and spars is obviously impossible, so one or two of the more usual and satisfactory will be described.

Plywood ribs are seldom used in any but the heaviest of power-driven models, except, perhaps, for centre sections. As a goodly number of ribs is usually employed in any wing construction, each individual rib has to withstand very little strain, and quite frail materials may be successfully used.

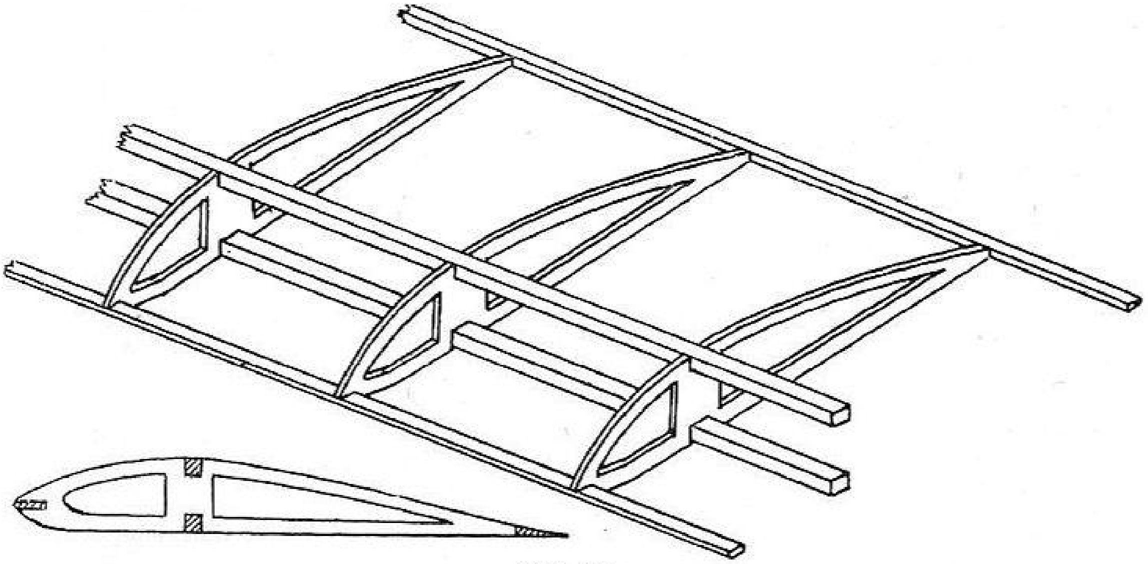

Fig. 32

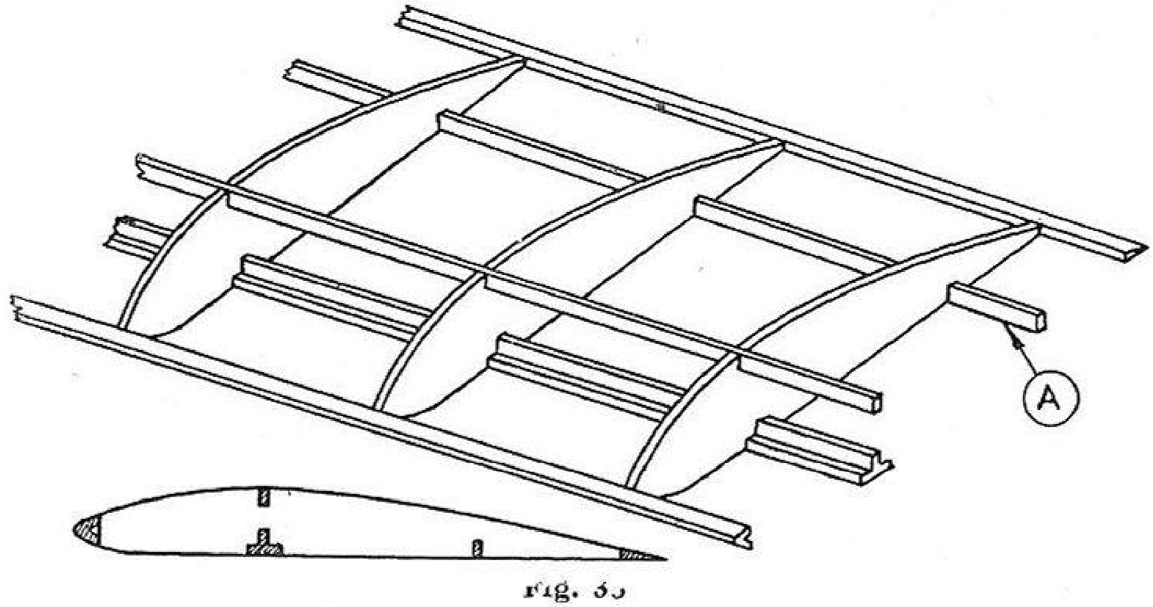

Fig. 33

A wing embodying plywood construction is shown in Fig. 32, together with a possible arrangement of spruce or birch spars. This type of square spar construction is not to be recommended unless the wing tapers considerably in section, as constant section wings of this type are extremely liable to break at the root of the top spar. However the model-maker who has progressed far enough to tackle a machine calling for plywood-rib construction, should have a sufficient knowledge of the problems involved to be able to solve them for himself.

The universally used balsa rib construction is well illustrated in Fig. 33, which also shows a very good spar arrangement. In this method the square section main spars are replaced by a " T " spar in the lower position and a top spar of rectangular section. The leading edge may be of " V " or even of round section, while the trailing edge is of triangular strip. The reader is advised to refer to the illustrations of wood sections in Fig. 5 in Chapter II as we shall be touching upon the practical applications of these. The small spar marked " A " in the illustration in Fig. 33, is particularly useful in silk covered wings, where the contraction of the doped silk often tends to bend the ribs at this point.

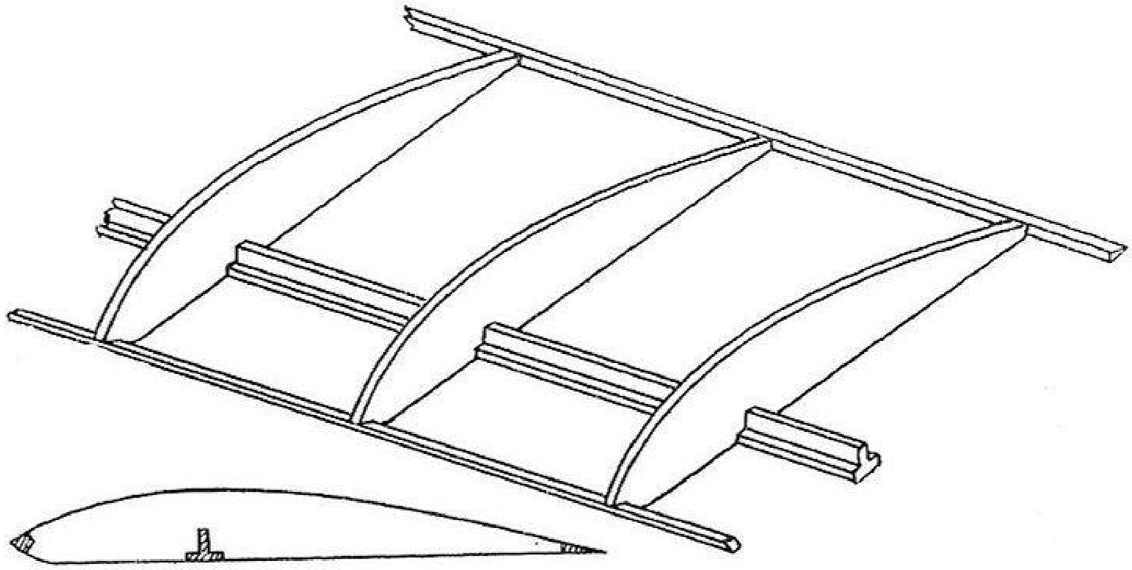

Fig. 34

The construction shown is extremely strong and is suitable for quite large spans in an all-balsa construction. A sectional drawing is also given of a method of assembly, and it will be noticed that the leading and trailing edges are simply butt-glued to the ribs, this being quite strong enough for all ordinary purposes.

Spruce or birch spars may be substiuted as the requirements of strength may dictate, or certain spars may be lightened or omitted altogether for the very light types. A wing thus simplified is shown in Fig. 34, where the top spar and the spar marked " A " in Fig. 33 are removed and square section balsa *on edge* is substituted for the heavier

"V" section front spar. This construction is suitable for wings up to 36 inches span.

Very light wings for balsa models may be made on the lines suggested in Fig. 36, where the main spar is of simple flat strip section placed on edge ; the front spar is of similar type, and the usual triangular section is used for the trailing edge. This is quite sufficient for light duration 'planes, as the strength of all wing structures is considerably increased

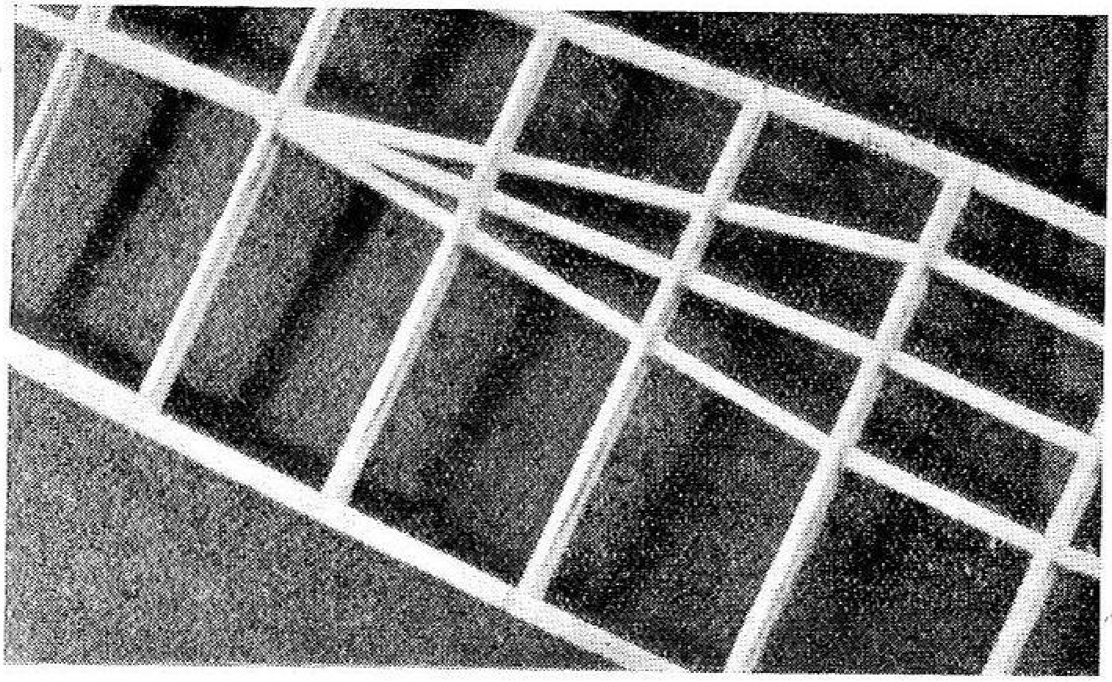

Fig. 35.—Wing construction, showing rectangular spars inset into ribs. Note triangular bracing at root

by the doped covering. The added strength given by covering should always be allowed for in the design of main planes, as this amounts, in some cases, to as much as 50 per cent, No great advantage is to be gained by excessive strength. which usually denotes that the model could have been made lighter with a resultant increase in performance.

If added strength is required at the wing roots it is a good plan to build up the main spar to the depth of the ribs for a distance or two or three inches. This is indicated by the shaded portion in Fig. 36, which also illustrates the use of corner blocks as a method of reinforcing. Two or three such blocks, cut from balsa sheet, and placed at intervals along the wing, give a great deal of strength without much added weight. These blocks should be a good fit, and may have the inside corner removed, as shown in Fig. 36, as a help to this end.

Use as many wing ribs as are compatible with the design and weight of the model under construction. A large number of 1/32nd inch balsa ribs are better than a few ribs of $\frac{1}{8}$-inch balsa, both from the point of view of strength and as an aid to the correct maintenance of the wing section. On wings of few ribs the covering is apt to sag in the spaces between, thus destroying the aerofoil section. If lightness is aimed at, half ribs, as shown in Fig. 38, may be incorporated to support the covering at these points. This diagram also

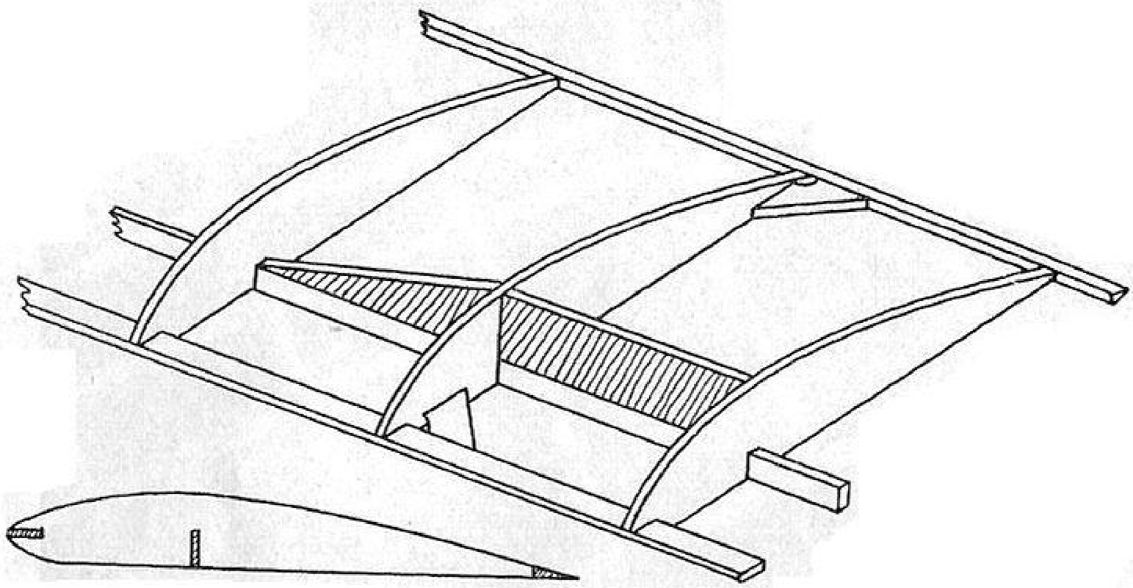

Fig. 36

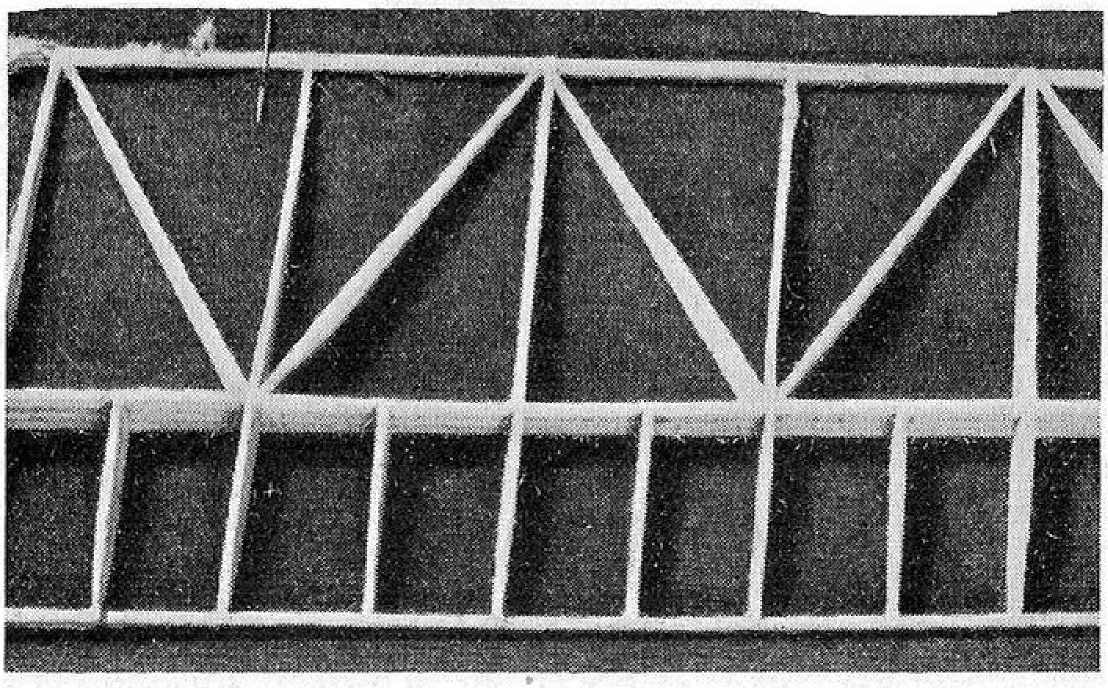

Fig. 37.—Showing main "T" spar built up to depth of ribs; also shows half-ribs and cross-bracing to trailing edge

indicates a useful method of bracing the wing structure with triangular pieces of balsa placed between the main spars and the trailing edge. It is not always necessary to brace between each rib ; every three or four often being sufficient.

Gull-wings (Fig. 40), are really a variation of the parasol type, and any aeroplane which incorporates this design is subject to the same conditions as the parasol. The object is to place the centre of gravity low and thus ensure lateral stability. Gull-wings are apt to be fragile owing to the

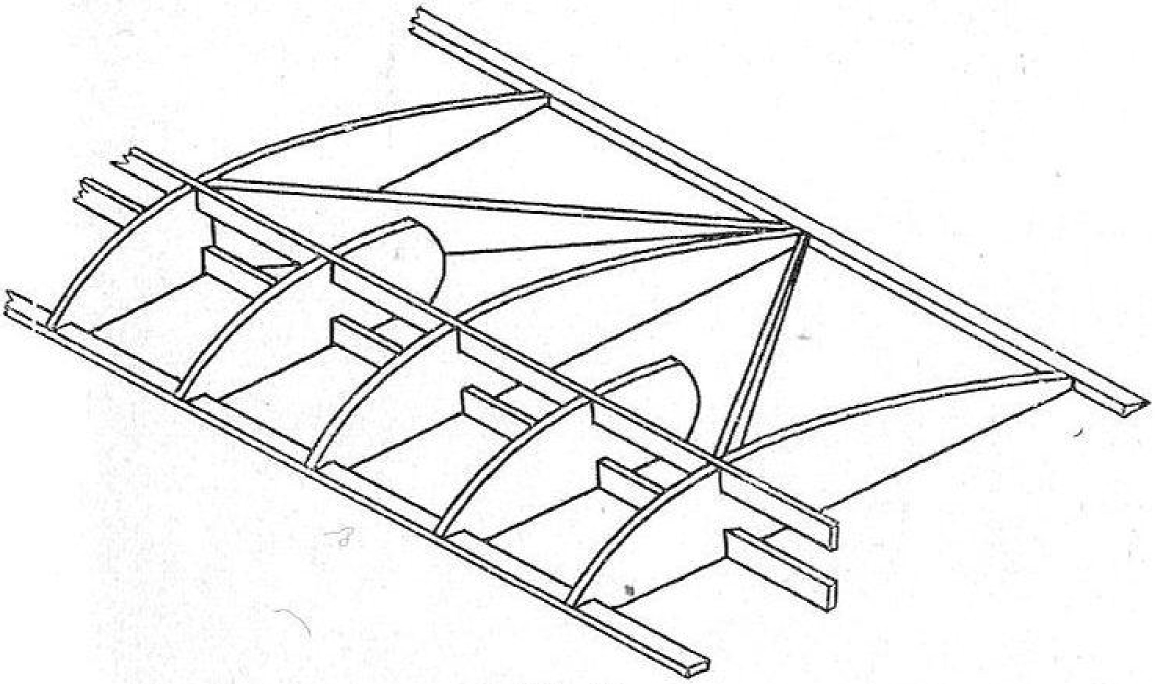

Fig. 38

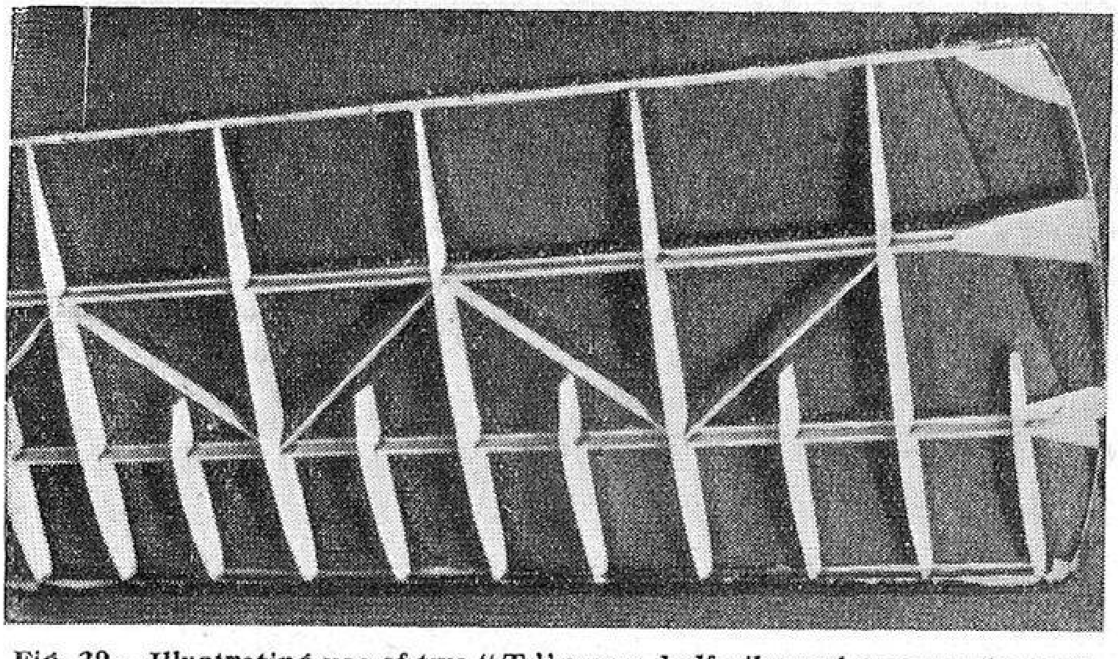

Fig. 39.—Illustrating use of two "T" spars, half-ribs and an arrangement of cross-bracing

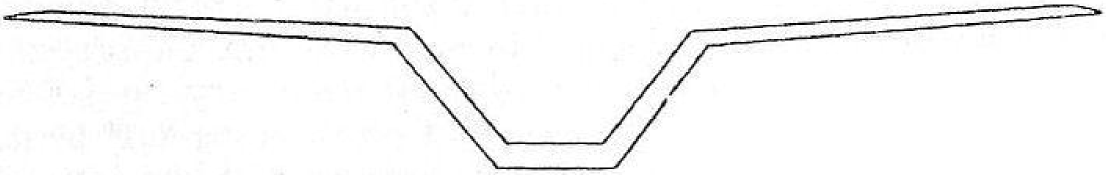

Fig. 40

difficulty of obtaining sufficient strength at the angle in the wing. For the benefits offered, they appear to demand too much in the way of constructional difficulty.

A design which has found some favour in America and has been, to a small extent, followed in this country, is that illustrated in Fig. 42. In this arrangement, lateral stability has been attained by incorporating most of the dihedral at

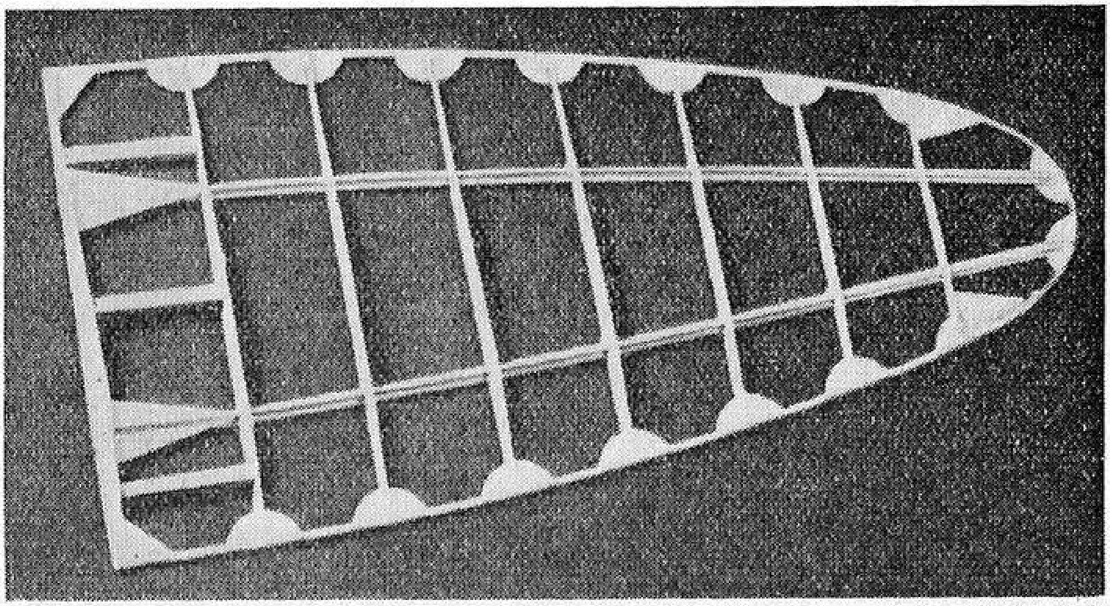

Fig. 41.—Low aspect ratio wing, with two "T" spars. Note wing-root reinforcement, and use of gummed paper discs to strengthen joints of ribs, and leading and trailing edges.

the wing tips. In spite of the almost flat centre portion, the effective lift is little different from the more usual types, as what is gained by the flat section is lost by the exaggerated dihedral of the tips. On the whole, this arrangement may be a little more efficient from the view point of lateral stability, owing to the levelling tendency exerting its

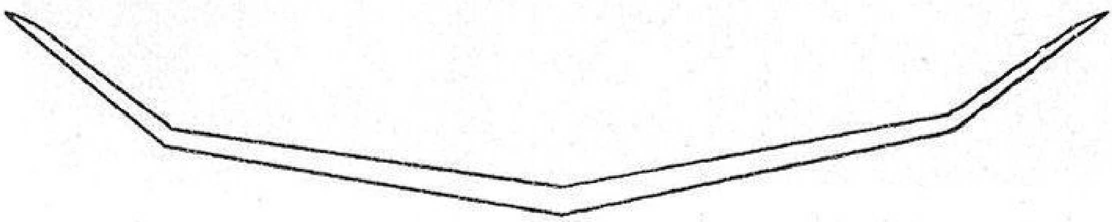

Fig. 42

influence through a long lever. Here again, constructional difficulties seem to discount the small advantage, although they seem particularly suitable for gliders.

Wings tapering in plan only are seldom used ; a tapering of both plan and thickness being preferable. This means that the ribs required must decrease in size at a uniform

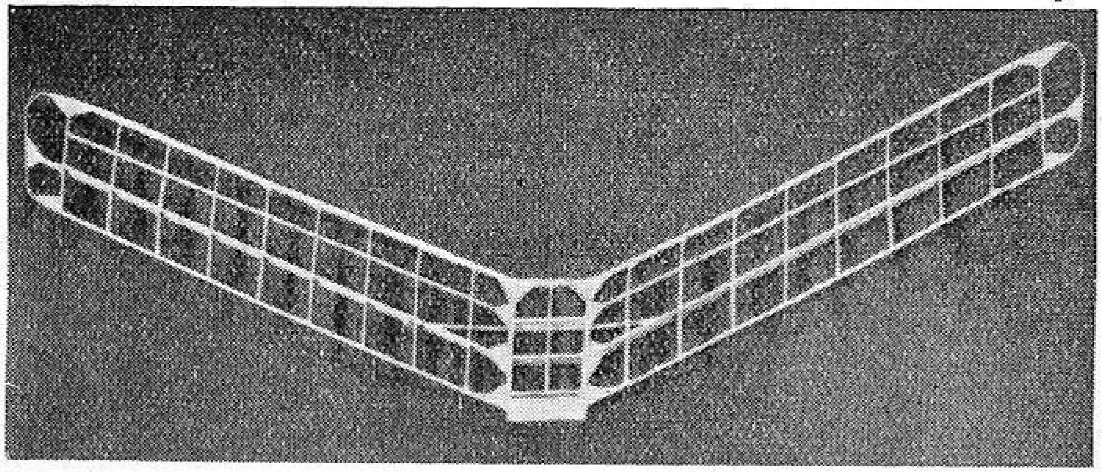

Fig. 43.—Swept-back wing, showing balsa corner blocks, and dihedral keeper across centre section

rate from the wing root to the tip. It is, of course, possible to set out each rib to its respective size on a sheet of balsa, and cut out separately, but this is a very tedious method, which leaves much scope for error. There are two other ways of doing the job which are superior from all points of view. A popular method is to shape a suitable block of balsa as shown in Fig. 44. The larger end is cut to the size and shape of the largest rib, and the other end conforms to the smallest rib required. The ribs are sliced off after-

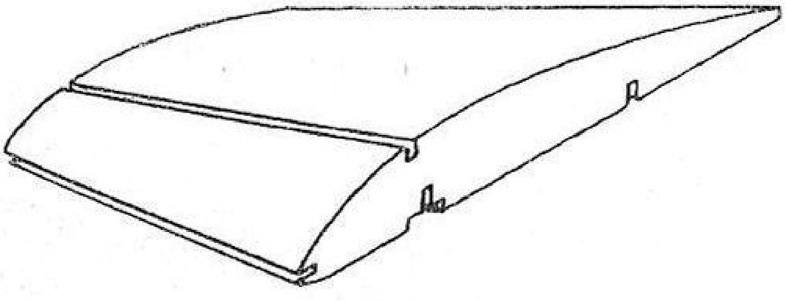

Fig. 44

wards, the thickness of each rib and the number required determining the width of the block.

An alternative method is to make two plywood templates ; one to the size of the largest rib, and the other to the dimensions of the smallest. Between these two templates pieces of balsa are clamped (the number being determined by the number of ribs required) and are held together by lengths of screwed brass rod and nuts, which are passed through holes suitably drilled in the templates and balsa strips. The pieces of balsa are then pared down to conform to the templates, the slots for the spars cut, and the whole finished off with sandpaper used on a wide rubbing block. This

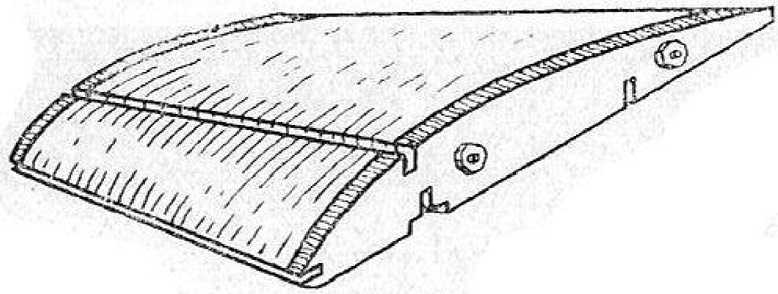

Fig. 45

second method (Fig. 45) is very accurate, and although entailing a little more preparation than the first, is well worth the trouble, especially as the templates may be kept for use at some other time.

Suitable thicknesses of balsa ribs for wings of various spans are as under :—

Wings up to 20 inches span	1/32nd inch.
Wings from 20 inches to 40 inches span	1/16th inch.
Wings from 40 inches to 60 inches span	3/32nd inch.
Wings above 60 inches span	$\frac{1}{8}$ inch.

Balsa ribs of $\frac{1}{8}$ inch thickness are strong enough for the largest model with which the reader of this book is likely to be concerned.

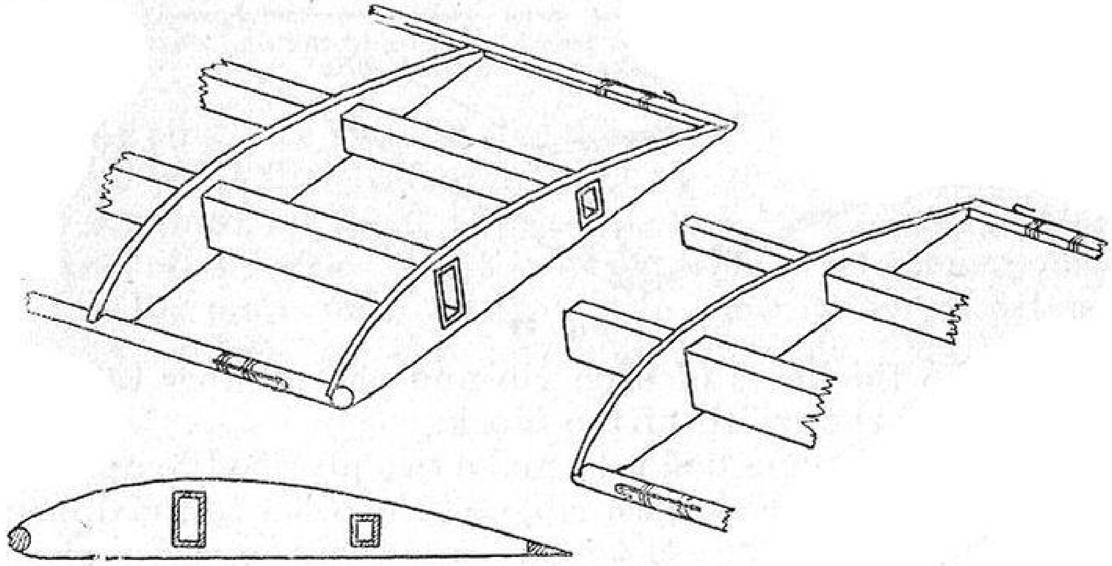

Fig. 46

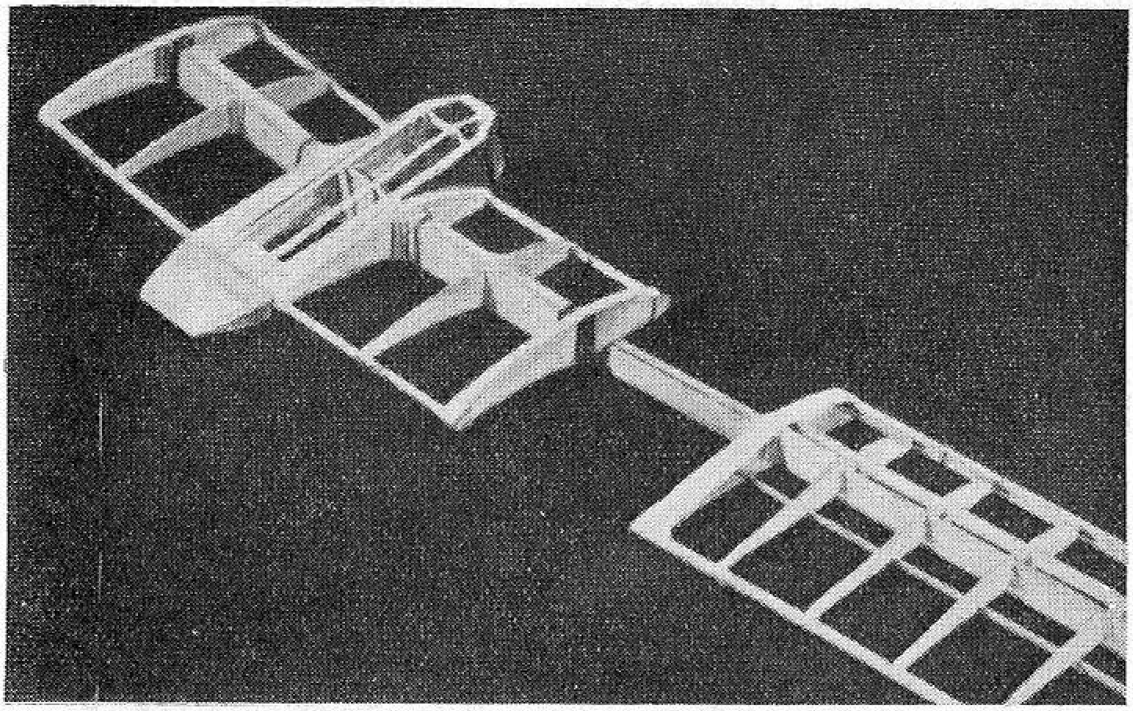

Fig. 47.—Plug-and-socket wing fixing. The centre box spar is built into a cabin structure, which may be moved along the fuselage top to obtain flying trim

The ribs for wings of constant chord and thickness are easier to make than those for taper wings, and are usually cut out from balsa sheet by the aid of a zinc or aluuminim template. This template is held firmly down upon the wood which is then cut with a safety razor blade around the edge of the template. Swept-back wings are often of uniform

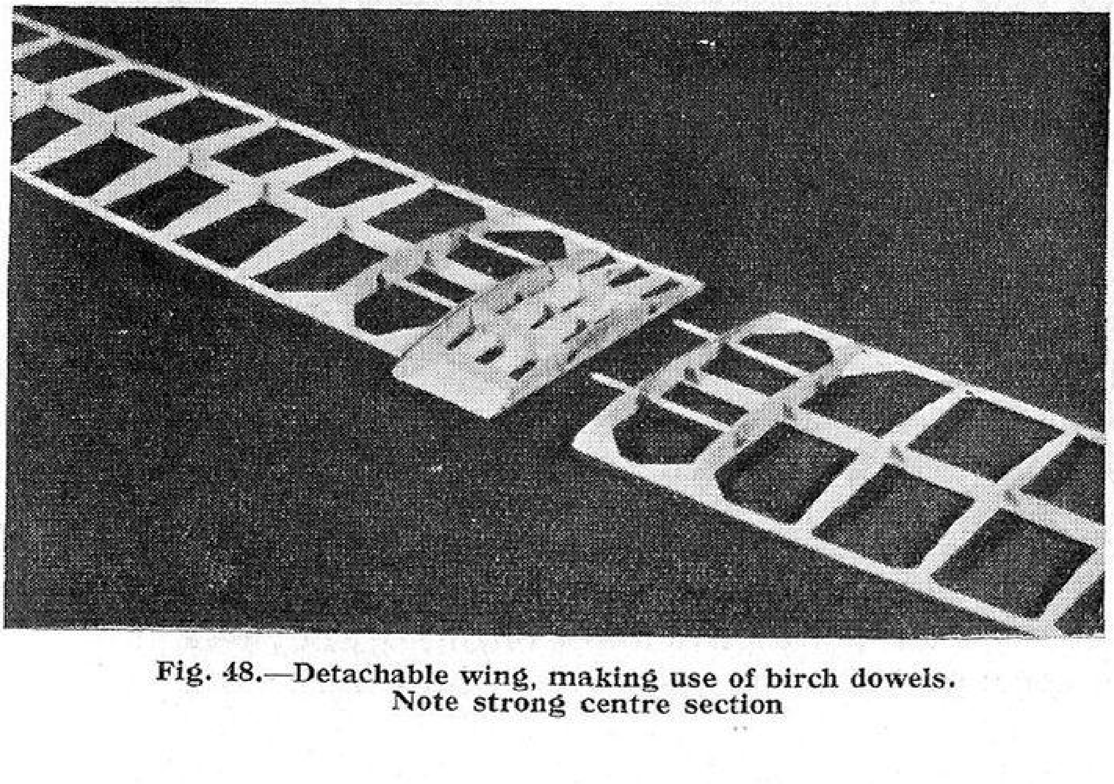

Fig. 48.—Detachable wing, making use of birch dowels. Note strong centre section

section, although it is better from the point of view of strength, to taper them in thickness.

The use of box spars in model wings is mostly confined to the larger types, as the depth of the ribs will seldom allow room for a box spar of reasonable depth to be accommodated. Where this is possible, however, they are to be greatly recommended, as they are of exceptionally strong section. Their suitability is further enhanced by the fact that large wings, for the sake of portability, must usually be made in sections, and the box spar lends itself admirably to a simple form of assembly. Fig. 46 shows a suggested method,

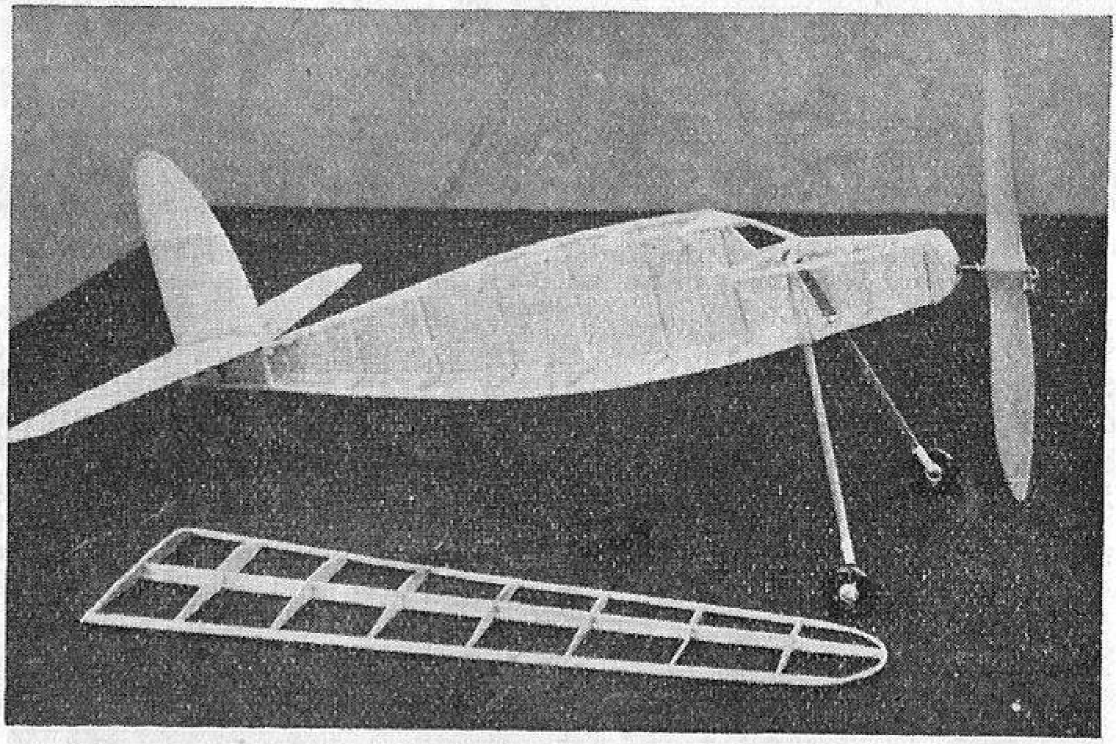

Fig. 49.—Low-wing monoplane of extremely simple construction. Note particularly the simple wing framework

utilising the plug and socket principle ; the box spar forming the socket as well as doing duty as the main spar. If balsa plugs are used in this arrangement, it is advisable to make them detachable, rather than to fix them rigidly into one side of the construction. This renders them easily replaceable in the event of breakage. The small wire hooks shown affixed to the leading and trailing edges, in the illustration, form anchorages for rubber bands which are used to hold the assembly together.

To be useful, box spars must be of a reasonable depth, and few main planes will allow of this. They can, however, be accommodated in quite thin wings if the wing ribs are divided and glued to each side of the spar, but this type of construction is awkward and increases the difficulty of building the wing true.

Wing tips may be constructed of wire, thin birch strip, plywood or balsa sheet. For the heavier models, embodying a mixed construction, the wire, birch and plywood types are very suitable, but in these " all balsa days " wing tips

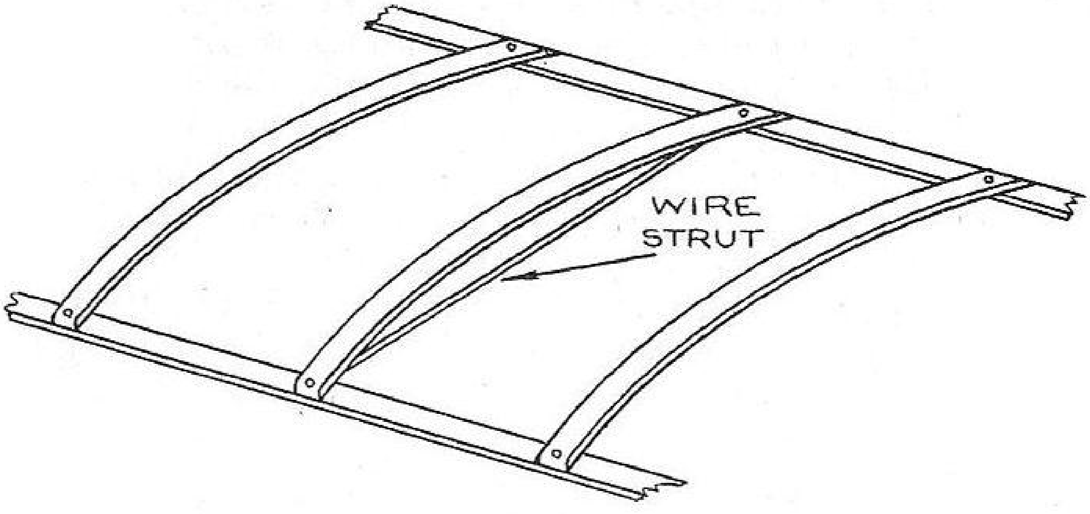

Fig. 50

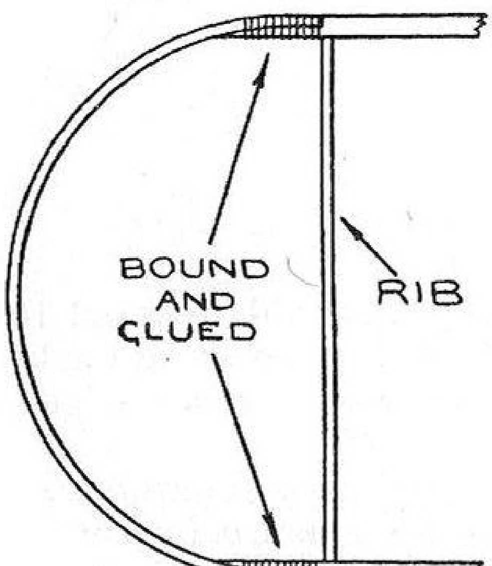

Fig. 51

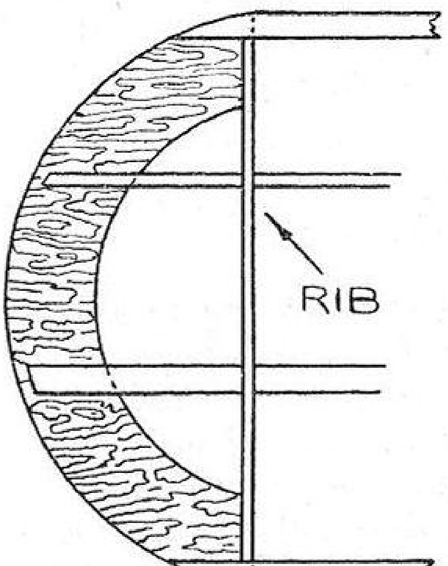

Fig. 52

of balsa are often employed. A typical wire or birch tip is illustrated in Fig. 51, and a suggested use of thin plywood or balsa in indicated in Fig. 52. In this connection, thin bamboo splits or reed cane must not be overlooked, as they form wing tips which are light, flexible and strong. They may be utilised in the manner shown for birch.

The single surfaced wing is, of course, the most simple of all, and, while not of the most efficient type, is useful for extremely light, indoor flyers. These simple wings have extremely good gliding properties, and their flexibility not only renders them extremely serviceable, but enables outdoor models to perform in quite high winds. A typical construction is shown in Fig. 50. The frame work of such wings is usually built as a flat structure, the cross-members being steamed to a camber afterwards, and stiffened, here and there, with wire or wooden struts. On the light, indoor flyers, however, these struts cannot be added by reason of the weight. The ribs are, therefore, cut to a curved shape from thin sheet balsa, and are cemented, *on edge*, between the leading and trailing edges of the wing.

Model aeroplane wings should always be built upon a flat board or jig, upon which the design of the wing and the position of each rib should be marked out. The main spars

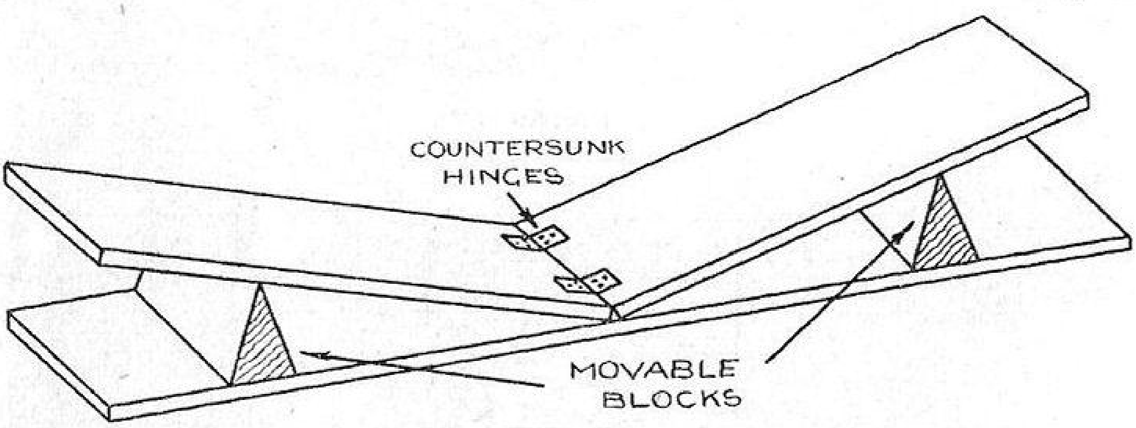

Fig. 53

and the leading and trailing edges should be fixed to the board with drawing pins, the leading edge being packed to the required height, and, in the case of reflex edges, the trailing edge also.

A suitable jig for use in building wings is shown in Fig. 53 ; the dihedral being steamed into the spars before assembly. This jig is also useful for keeping wings true between the periods of flying.

Some builders construct the wings on a flat board, the spars running straight from tip to tip, without any dihedral angle. This is put in afterwards by cutting small " V " nicks in the spars at suitable points, steaming to the required angle, and reinforcing the points of dihedral in some suitable manner. Others again, build each half-wing separately, and incorporate the dihedral in a centre section.

Between the various methods employed there seems little to choose ; the first seeming to be the simplest, however. In any case, the important point is that the wing be built on a flat surface, and not removed until the glue or cement is thoroughly set. Never attempt to assemble a wing without this precaution as it is highly improbable that the finished article will be true.

Of the various ways which may be employed for securing the wing to the fuselage one stands out as being by far the most suitable for the majority of machines. This is the

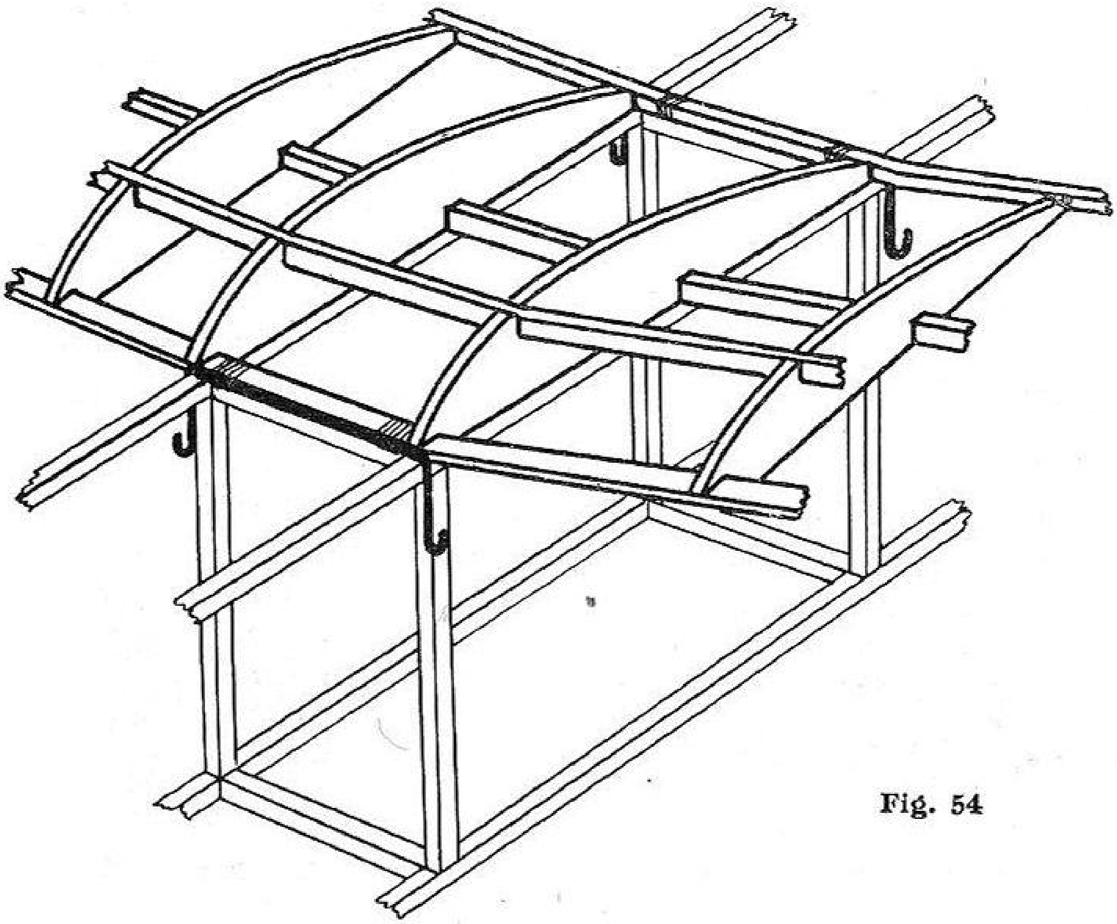

Fig. 54

simple method of fixing by rubber bands, a system used in 99 out of every 100 model aeroplanes to-day. In this arrangement (Fig. 54) rubber bands attached to small wire hooks on the main plane, pass under the fuselage, the tension of the rubber band holding the wing in position. Besides the merits of lightness and simplicity, this method enables the wing to be moved easily along the fuselage, thus facilitating the attainment of correct flying trim. In the event of a wing-tip landing or encounter with trees or other obstacles during flight, this method of wing-fixing, being only semi-rigid, allows the wing to be knocked out of place instead of being broken, as would probably be the result were the wings fixed rigidly to the fuselage.

In place of the small wire hooks shown in the illustration, small bamboo pegs may be cemented to the centre wing section. The rubber fixing bands are then passed under the fuselage in the usual manner, the ends being looped over the bamboo pegs. In some ways, this method is preferable to the wire hook system, as there is then no danger of the hooks tearing the paper covering of the fuselage.

Rubber bands may be used for wing attachment in either high or low-wing monoplanes, and for biplanes, but the mid-wing type does not lend itself to this arrangement. Mid-wing model aeroplanes are, therefore, usually of the " fixed-

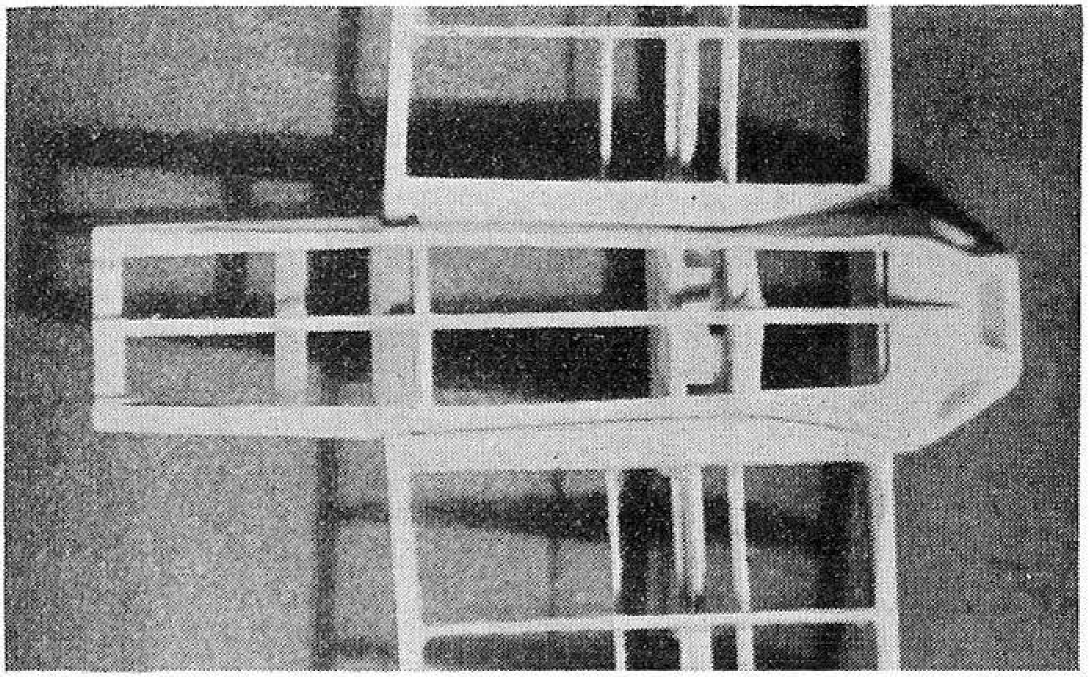

Fig. 55.—An arrangement for non-detachable wings. A movable cabin structure comprises the centre section

wing " type, which means that the wings are attached rigidly at a predetermined point along the fuselage, the trim being obtained by the addition of weight to the nose or the tail as the case may require. To avoid the addition of excessive weight, mid-wing machines require very careful design, so that the centre of gravity may be " built in " at the correct position relative to the centre of pressure. Plugging the wings, by means of dowels, into celluloid or rolled-paper tubes, constitutes a very sound method of wing fixing for mid-wing machines. This principle is illustrated in Fig. 89. Alternatively, the wing may be mounted on a wire cradle, attached to the fuselage with rubber bands, and capable of longitudinal movement.

The question of incorporating ailerons in the design of model aeroplane wings is one which often troubles the novice, as ailerons play such an important part in the functioning of full-sized aircraft, that it would appear that benefit might accrue from their use in models. A consideration of the actual functioning of ailerons in full-size practice will serve to show that they have little or no utility in model work.

Ailerons usually take the form of hinged flaps situated at a point along the trailing edge, and their function is to provide the pilot with control of the lateral stability of the aeroplane. It is not feasible to control the ailerons of a model aeroplane as the needs of stability may arise in flight, therefore their use is restricted to a preliminary adjustment of flying trim before the model takes to the air. For this reason ailerons on model aircraft seem to constitute an unnecessary complication, as flying trim may be obtained in much simpler ways. However, they have been employed by some model flyers.

Model wings call for careful construction, as in no other part of a model aeroplane is there need for more accuracy and truth. A badly-finished model may perform very well; an inaccurate one will never do so.

CHAPTER V

FUSELAGES

Of all the component parts of a model aeroplane, none is called upon to perform so many functions as the fuselage. Not only must it form a rigid structure upon which the wing and tail may be placed in their relative positions, but it must house the rubber motor, and be able to withstand the various stresses which this imposes. In addition, it must carry the loads from the wing and tail, and also meet the strains from the undercarriage in take-off and landing. Altogether, it is a very highly stressed part, wherein all the forces acting upon a model aeroplane must converge.

The chief function of a fuselage is, of course, to provide a basis upon which the several component parts may be mounted, and in designing a fuselage for any model this must be the first consideration, as the "line-up" of the machine depends upon it. The other functions are all connected with strength, and as the "line-up" constitutes a distinct problem, it seems the best course to separate the two questions. We shall, therefore, treat firstly of the designs which certain types of models render necessary, leaving the question of strength to be dealt with in the constructional portion of this chapter.

The design of any fuselage will depend primarily upon the placing of the four main forces in the type of machine we may wish to construct. As these forces will be mentioned time and again in this volume, it will be as well to emphasise that they have a real existence, and are not just theoretical notions evolved to make the blackboard look interesting in lectures on aeronautics. To many people it comes almost as a surprise to discover that these forces have any existence outside the pages of a textbook, which fact may account, in some measure, for the curious machines one often sees.

Before proceeding to discuss individual design, it will be as well to consider a few general principles.

More machines give disappointing results through a failure to place the wing, tail and centre of resistance in the correct relationship to the line of thrust than from any other cause. The placing of the tail-plane is most important. The *negative* tail should be placed at an angle of incidence to the main wing corresponding to that of the line of thrust. For normal horizontal flight, which is the condition upon which we have agreed to base our design, it is advantageous to place the tail plane (which, we must remember, is only required to exert a correcting force) in the direct line of flight, without it influencing the machine in either an upward or downward direction while the machine is flying steadily on an even keel. It is true, that to balance the nose heaviness, the airflow, and slipstream from the propeller, is "holding the tail down," but it is obvious that once the tail has assumed an angle of zero incidence, the slipstream can exert no further pressure on it.

Lifting tails are another matter, and will be considered later.

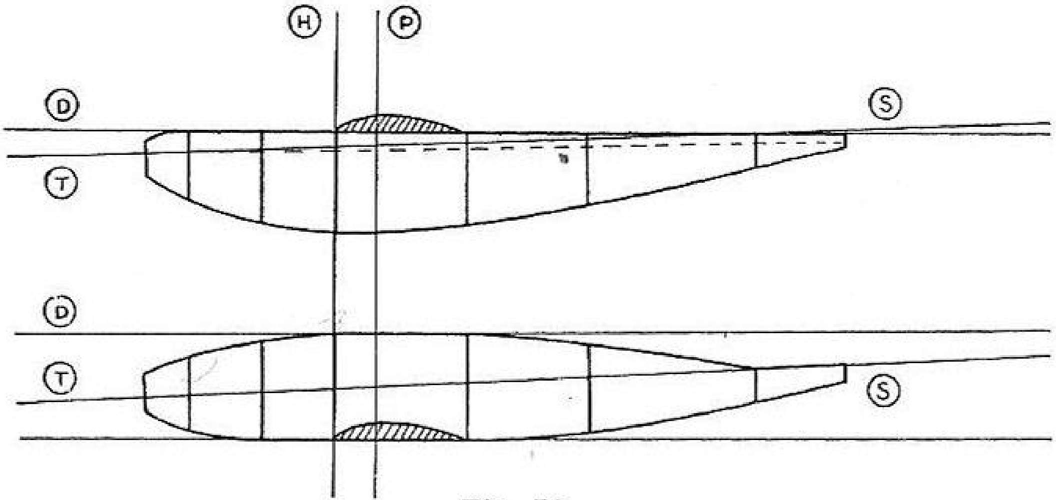

Fig. 56

As we are already aware, the line of thrust should coincide, as nearly as possible, with the line of resistance, and it is here that the greatest difficulty arises. It is impossible for the amateur, with the limited means at his disposal, to do anything other than make a shrewd guess at the position of the line of resistance. A drawing should be prepared of the front elevation of the proposed model, and a point assumed, taking into consideration the amount of projected area presented either above or below the centre of the machine. Neither we nor anyone else can give you more exact information than this. To descend to that engineer's horror, "rule of thumb," it may be helpful to suggest that in a high-wing machine the centre of resistance may lie somewhere in the region of the top longerons, while in the low-wing type a point situated about one-third of the fuselage height above the bottom longerons is the probable area. In biplanes and mid-wings it lies approximately half-way between these two points.

The several types of model aeroplanes, i.e., high-wing, low-wing, etc., have already been introduced to the reader, who is, by now, familiar with their various characteristics. In view of this there seems no reason why we should not proceed to a consideration of the fuselage lay-out necessary for these types.

We will presume that a high-wing monoplane is under consideration, and that we are standing before a clean sheet of paper, our pencil sharpened, and our "T" square or ruler at hand. Our first procedure is to draw a horizontal line across the paper. This is called the "datum line," and we will denote this by marking it "D."

We have, of course, decided upon our wing span, and it may be helpful to suggest that the fuselage length be two-thirds the wing span of a high aspect ratio wing, or, in the case of a wing of low aspect ratio, the fuselage length may be equal to the span. Having decided the fuselage length, and marked this upon the datum line, we will now fix a point one-third the distance along, and mark this "P" (See Fig. 56). It is here that we will place the wing, the centre of pressure of which should lie over the point "P."

It is now necessary to decide the depth of the fuselage, and for this we will consult the fuselage formula laid down by the Society of Model Aeronautical Engineers, which states that the greatest cross sectional area of any fuselage must at least equal $\frac{\text{overall length of model}^2}{100}$ * This formula has been evolved to form a basis of distinction between fuselage models and those approaching the spar type.

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* Example :—

Length of machine : 20 inches.

$\frac{20}{10} \times \frac{20}{10} = 4$ square inches.

Therefore :—fuselage may be :—
4″ × 1″, or 2″ × 2,″
or any factors the product of which is 4.

It is desirable to make our fuselage deeper than it is wide at the point of greatest area, as on a high-wing model this enables the centre of gravity to be kept low. It is advisable not to make the fuselage height too great in relationship to the width, a ratio of about 2 : 1 being an average figure. High and narrow fuselages offer a considerable rudder effect.

The length of the model having determined the minimum amount of cross sectional area, we can now decide upon a suitable depth and width. The greatest depth having been ascertained, we will set this measurement along a line drawn vertically downwards from the leading edge of the wing, as " H " in Fig. 56. We now have two dimensions, length

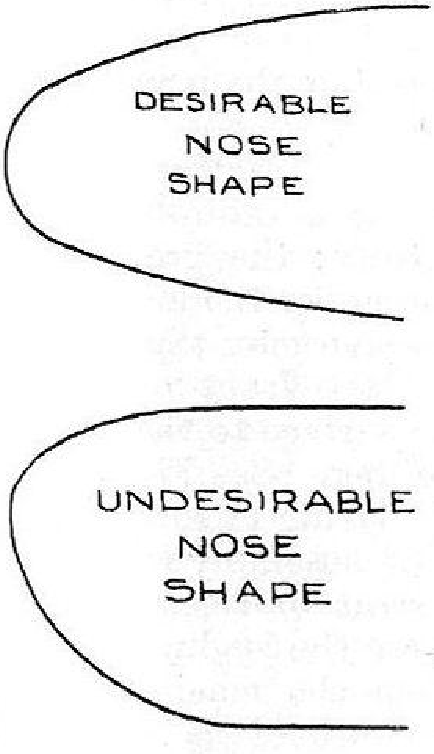

Fig. 57

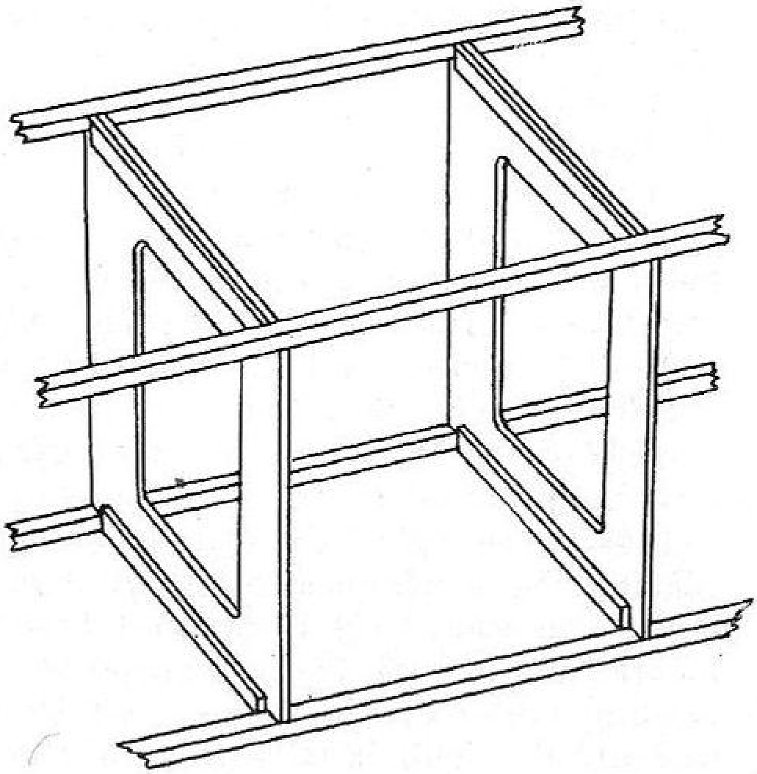

Fig. 58

and breadth, or rather, three dimensions, as we also know the width of the fuselage. However, we shall not require this until later.

Our next step is to determine the angle at which the tail plane will be set upon the fuselage. As we are concerned with a high-wing monoplane, the incidence need not be very great, two degrees usually being ample. We shall, therefore, draw a line at this angle at the appropriate position on the datum line. This represents the tail plane, and is marked " S " in the illustration. It will be seen that this tail line commences on the datum line. It is the practice of some designers to bend the top longerons at this point to conform to the angle of incidence of the tail. This is quite good, but seems an unnecessary complication in a simple high-wing monoplane. The easier and more straightforward method is to keep the top longerons straight, and pack the tail, with a small piece of balsa, to the small amount of incidence necessary. This also avoids a prolific source of inaccuracy and goes far to ensure that the tail and main plane sit squarely to each other upon the fuselage.

We know that it is desirable to keep the line of thrust parallel with or in line with the tail, so we will now indicate this by a continuation of the tail line, and mark this "T." This actually forms the line of the propeller shaft, but it is obvious that the rubber motor cannot function in this position, so the rubber line must be dropped at the rear end as shown by the dotted line in the illustration.

It now remains to draw in the outline of the fuselage, and this may assume any reasonable shape. It is desirable to keep the nose of a blunt, rounded outline; the greatest depth of the fuselage should preferably lie under the leading edge of the wing, and the rear of the fuselage may taper to a knife edge or to a point. Do not let the front under-surface of the fuselage present a wall-like surface to the air-stream as this tends to aid a model in stalling. See Fig. 57.

Finally we may fix the positions of the struts or formers, placing these where strength and ease of assembly render them necessary. It is as well that a strut or former be located under each of the two points where the leading and trailing edges of the wings will lie when the machine is assembled. This is to withstand the pressure of the wing-fixing rubber bands.

No matter what shape may be desired for a fuselage, whether it be of round, oval or composite section, the above method of setting out may be used satisfactorily.

As the centre of resistance will be situated lower down in a low-wing aeroplane, a slightly different "line-up" is called for to enable the line of thrust to exactly oppose the line of resistance. It is still desirable that the tail shall form a continuation of the line of thrust or lie parallel with it, and for this reason a lowering of the tail position is expedient, as shown in the lower drawing in Fig. 57.

We shall proceed to work from the datum line as in the high-wing case, but our first step is to draw a line parallel with this at a distance corresponding to the depth of the fuselage. On this line we will locate the wing. We know that, in this instance, it is advisable to give the tail plane a greater angle of incidence, say, three degrees. We will, therefore, draw the line of the tail plane at this angle in such a position that this line will coincide with the desired line of thrust. In a simple, rectangular, four longeron fuselage it is necessary to steam the top longerons to the desired tail position, but if a round, oval, or composite section is desired, straight through longerons may again be utilised. In this case they will lie parallel with the line of thrust, and be located at the sides of the nose former, the top decking and other additional features being added afterwards by means of stringers.

The formers or struts may now be indicated, bearing in mind the requirements of strength. It is, of course, necessary that the bottom longerons be steamed to a shape which will allow the wing to locate parallel with the datum line. This usually means that a flat portion must be allowed in the bottom longerons at this point.

Enough has been said to indicate suitable methods of laying-out simple types of fuselages. Although only actually dealing with the high and low-wing types, both the mid-wing and the biplane may be approached in this manner. In all types the nose former may be set at an angle of ninety degrees to the line of thrust. When using the lifting type of tail, the above procedure may again be adopted ; that is, the tail plane may again be situated parallel with the thrust line. In trimming the machine, however, it is usual to place the centre of gravity directly below the centre of pressure of the wing, or even behind it, instead of forward, as is the case with the negative tail.

Parasols and gull-wings may call for different treatment, as a lifting tail must usually be utilised. This may be placed on the top longerons or in a position just below these, the angle at which the tail is set being chiefly governed by the distance of the centre of resistance above the line of thrust. Other things being equal, it may be considered that the greater this distance, the more lift is required from the tail, which may even be set at a positive angle to ensure this. The line of thrust may be parallel with the datum line, and both the tail plane and the main plane may be set at a positive angle to this. Slight downthrust may be used. The amount of lift actually required from the tail is a difficult matter to calculate, and the reader will begin to perceive the force of our remarks on lifting tails in Chapter III.

Construction

It must be remembered that the constructional methods detailed in this book form only a tithe of the possible systems. They are a few of the most popular, and all have stood the test of time.

Generally speaking, two methods hold the field to-day. In one of these, the fuselage is built upon formers cut from sheet balsa or thin plywood, and is known as the "ply-former system." This is shown in Fig. 58, and it will be noted that the formers are reinforced across the grain with small strips of wood. This method is useful when round, oval or multi-sided fuselages are being constructed, the formers being cut to the shape of the particular section of the fuselage at which

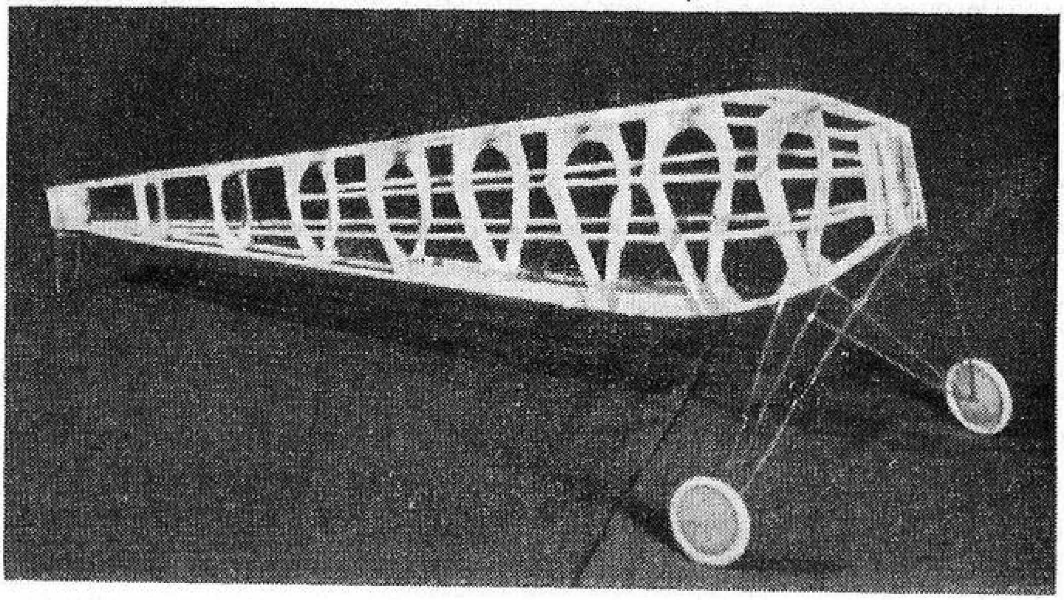

Fig. 59.—An all-balsa multi-sided fuselage, built on sheet balsa formers

they will be situated. In this way quite complicated fuselages may be formed, as, for instance those which taper from round at the front to oval or rectangular at the tail end. The formers are held together by longerons or stringers placed at the positions which the design will dictate.

The usual method of assembly is as follows : The plan of the fuselage is marked out upon a sheet of paper which is fixed firmly to a flat board by means of drawing pins, and the nose and tail formers are secured in their correct positions upon this. The position of all the formers is also indicated.

The longerons, which have been steamed to the appropriate curves, are then glued or cemented to the nose and tail formers, and when set, the *largest* former is inserted. The fuselage will now assume the approximate shape desired, the insertion of the remaining formers completing this. Before allowing the job to set it should be checked for alignment. Particular care should be taken to ensure that the fuselage sides are truly vertical, and this should be checked from the

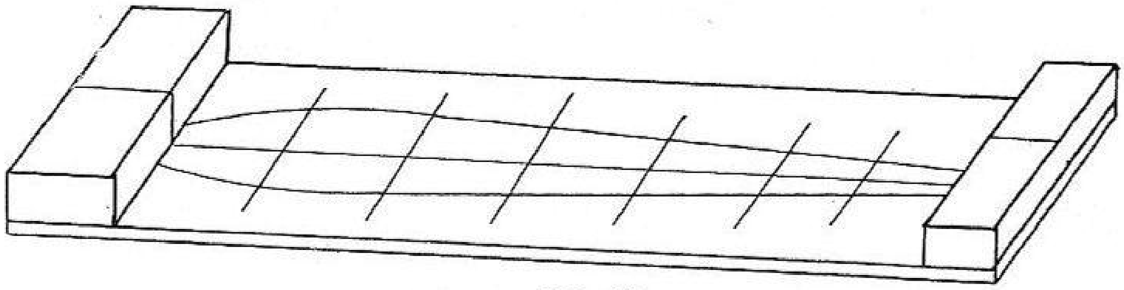

Fig. 60

board with a small set square. A suitable set square may be cut from a piece of 1/16th inch three-ply or cut from a plain postcard.

When the glue or cement is dry, the structure may be removed from the board, and any struts or other reinforcements put in. Take care not to distort the fuselage in doing this. Bracing struts should be a good fit, but do not cut them too long and force them into position, as this will push

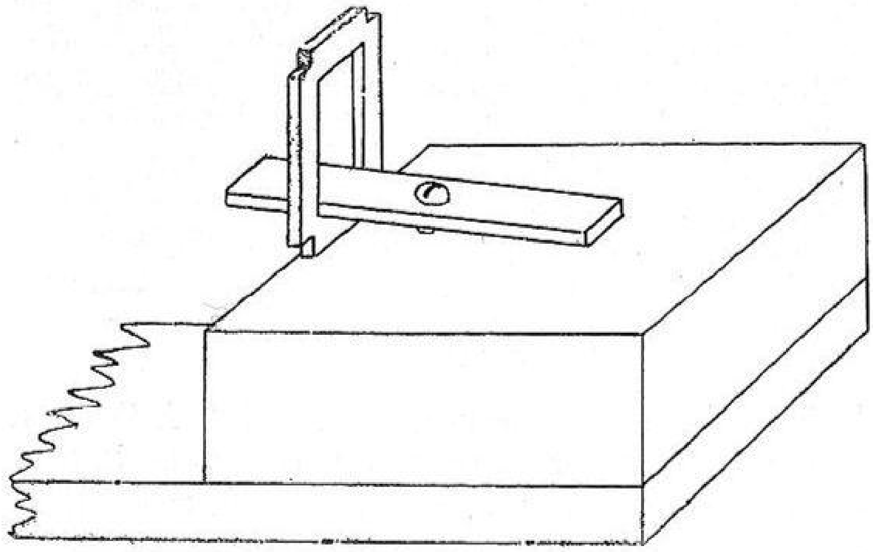

Fig. 61

the structure out of square. The building of fuselages by this method is much facilitated by the use of straight-through longerons as already described. When these are employed it is possible to fix the longerons to the plan and build the fuselage "upside down." In this manner only the nose former need be packed to the required height.

Fig. 60 shows a suitable jig for building ply-former fuselages. The blocks for raising the nose and tail formers to the correct height are shown, also the plan of the fuselage set-out. A practical way of rigidly securing the nose and tail formers is indicated in Fig. 61.

A system much employed in America is illustrated in Fig. 62. In this method the formers are cut into halves, and each half fuselage is assembled separately. It will be

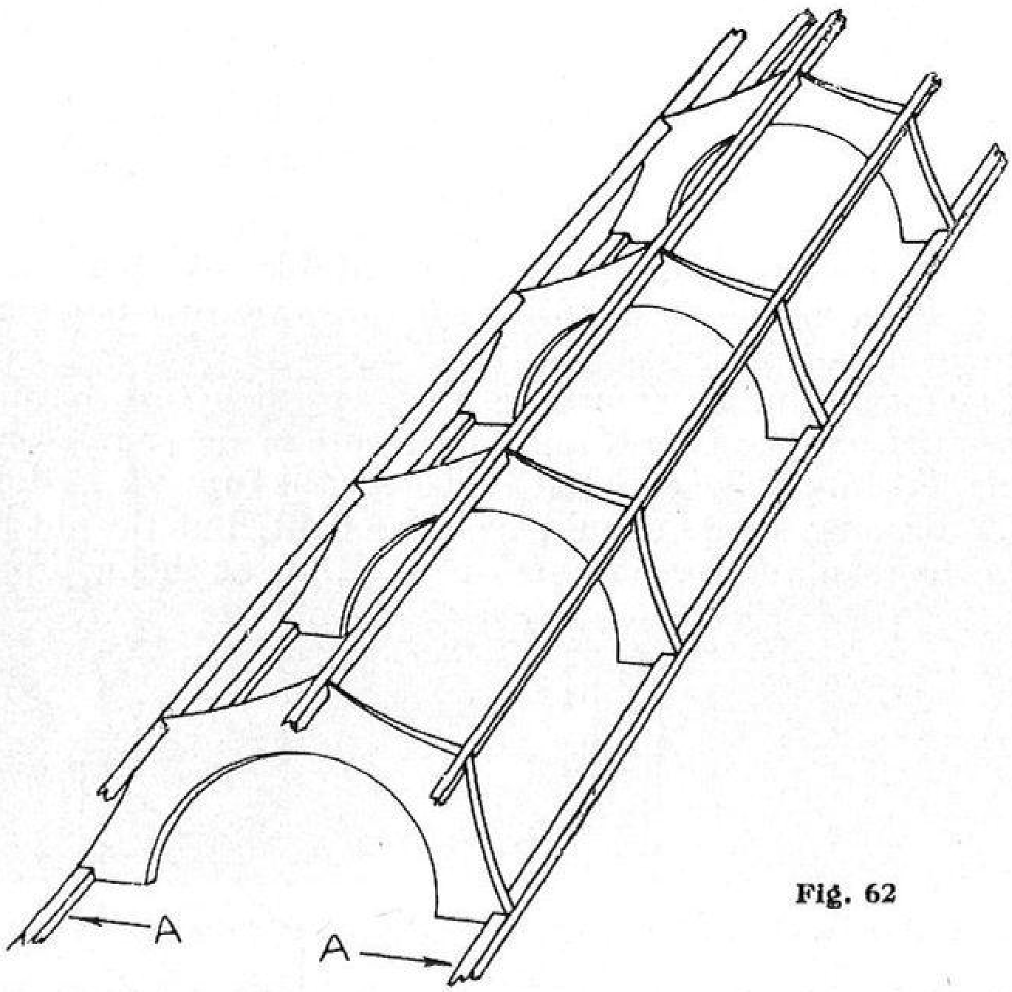

Fig. 62

noticed that the two stringers marked "A" lie upon the board. These stringers are used in each half, and are cemented together along their whole lengths when the two half fuselages are assembled together. This method is fairly simple, and ensures a good degree of accuracy. It is particularly applicable to round or oval fuselages which are usually difficult to build truly by other means.

Although the drawing in Fig. 62 represents a construction for a "round" fuselage, it will be seen that the outer edges of the formers are cut slightly concave between the longerons. This is done to enable the doped covering to follow closely the shape of the fuselage. If perfectly round formers are used the covering will "pocket" between each former, and a bad appearance will result. Furthermore, this series of pockets, when presented to the airstream in flight, sets up eddy currents which are very detrimental to performance. Strictly speaking, the fuselage represented in Fig. 62 is of an octagonal section, but the round can be approached very closely by the use of many longerons or stringers. Perfectly round fuselages may be obtained only by encasing the framework in thin sheet balsa.

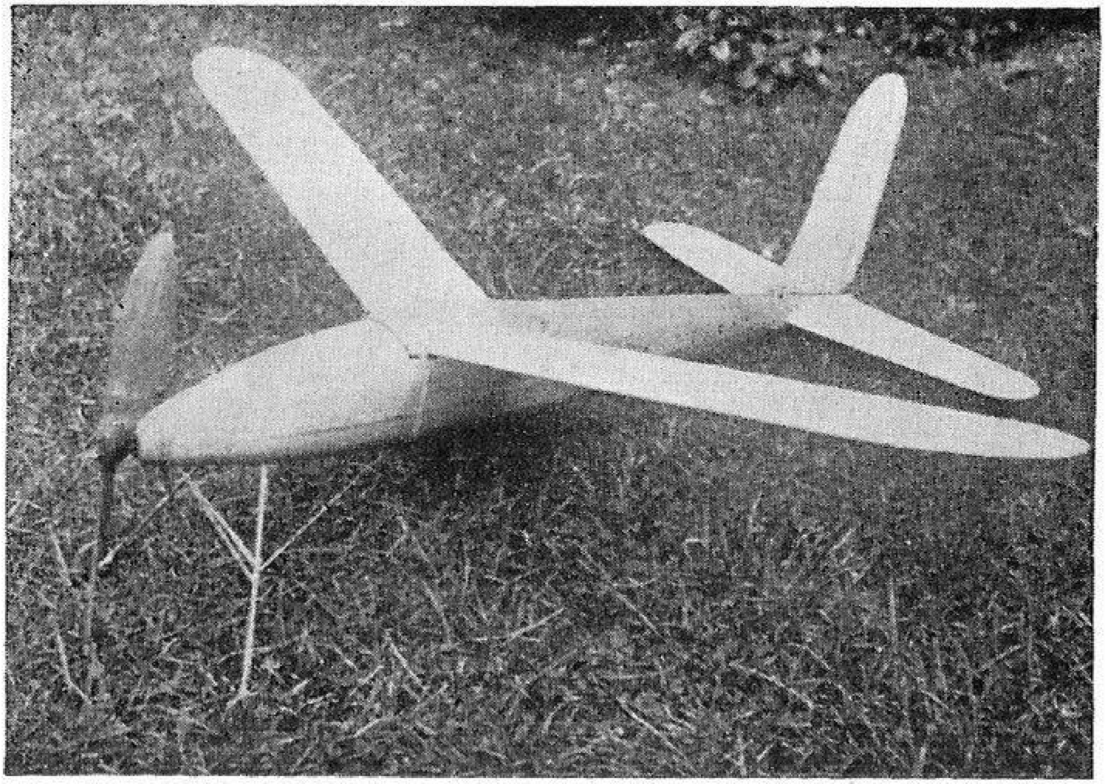

Fig. 63.—Shoulder-wing monoplane built with former and stringer construction, showing how closely the round section may be approached with this method

Rectangular fuselages may very easily be assembled on the "strut former" basis, in which the formers are built up of square or rectangular section strips of wood. In this method of construction, a side elevation of the fuselage is set out upon a board, and one fuselage side assembled on this. Without removing from the board, the second side is built flat on the top of the first, thus ensuring that each side conforms in all particulars. When removed, the builder has two perfectly flat fuselage sides which are then placed

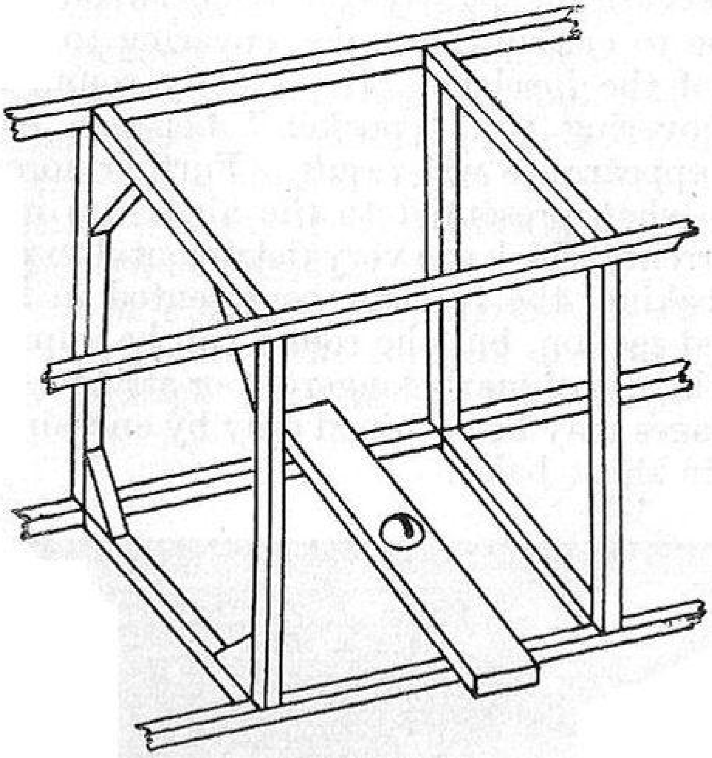

Fig. 64

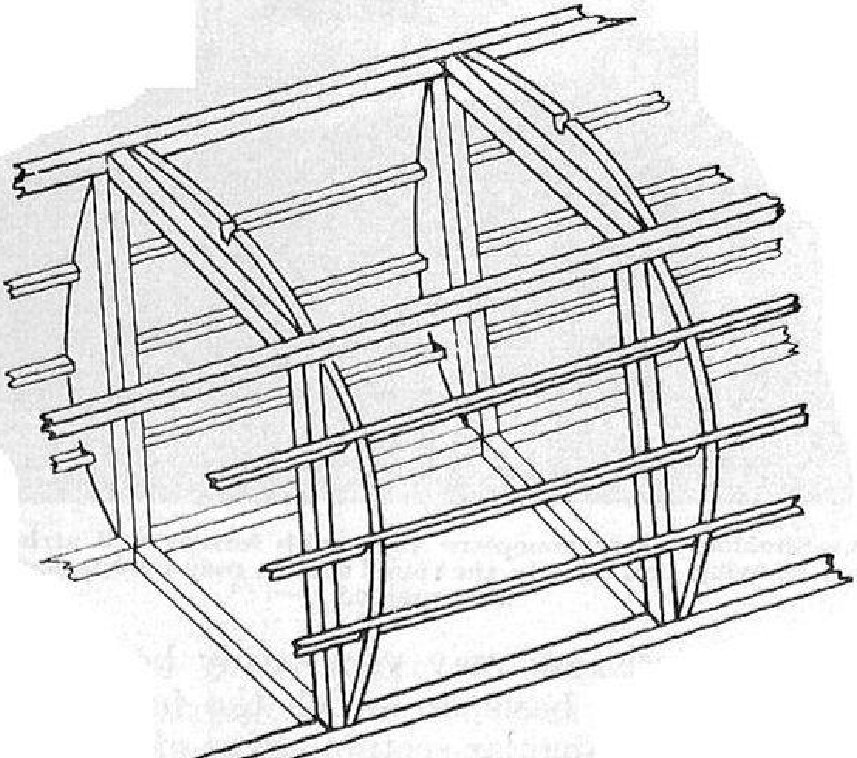

Fig. 65

in an upright position on a plan drawing and held by pieces of wood screwed to the baseboard as shown in Fig. 64.

The cross struts are then glued in, and small corner blocks affixed at intervals to maintain rigidity. It is a good plan to cut all the struts in pairs so that they may be of equal lengths. Cross-bracing is added afterwards as in the ply-former method.

This second method forms a lighter construction than the first and is ideal for simple balsa fuselages. Of course, a combination of the two may be employed. Thus the two sides may be built up and joined together by balsa or ply-formers, or oval or circular fuselages may be obtained by the strut-former construction in the manner indicated in Fig. 65. A plain rectangular fuselage is first built, and small pieces of balsa, shaped as required, are cemented to the struts. Light stringers are now affixed to maintain the shape throughout.

The possibilities of " L " section balsa for longerons should not be overlooked. The use of this will result in a very strong job, the " L " section lending itself particularly well to the accommodation of ply-formers or struts. Its greatest limitation is, of course, that it will not permit of very short

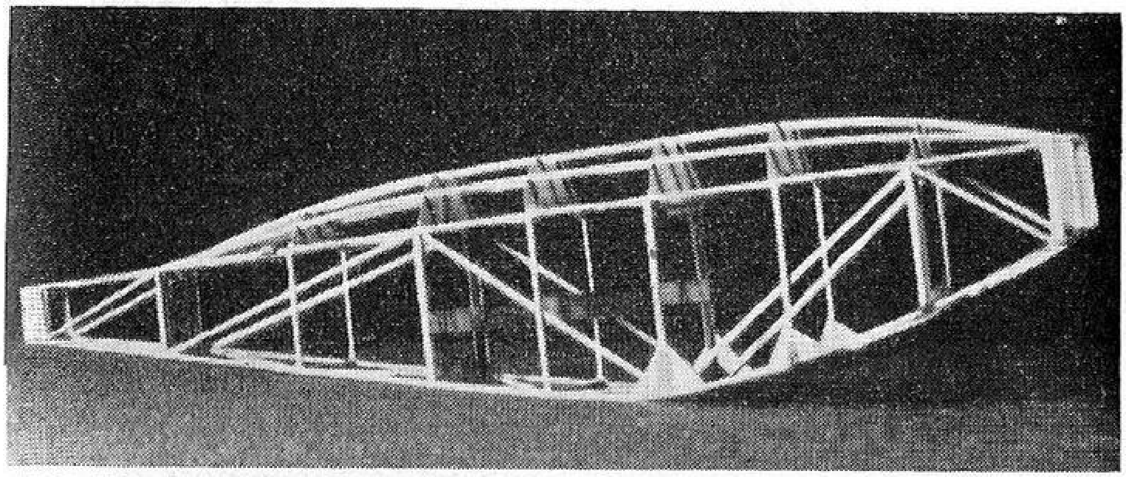

Fig. 66.—Showing a strut-former fuselage with a top decking added upon balsa formers. Note the efficient cross-bracing

or acute curves. A fuselage composed of " L " section balsa longerons and " T " section balsa vertical and cross struts is a very sound proposition.

An extremely simple formation is afforded by the method shown in Fig. 67. Here, the complete fuselage sides are cut from a sheet of 1/32nd inch or 1/16th inch balsa. Strengthening pieces are glued along the edges, and lightening holes cut at suitable points if desired. These sides may then be fixed together by cross-struts or ply-formers. Fuselages assembled by this method are extremely strong, and all necessity for cross-bracing, except on the top and bottom, is eliminated. It is not, perhaps, suitable for ply-wood construction on account of the weight involved. By forming the sides of $\frac{1}{8}$ inch balsa sheet, and sand-papering down from the centre to the edges, a convex shape may be given to the sides (Fig. 68).

A system of former construction which bids fair to supersede all others is the " wound-former " system of construction which was evolved by Mr. C. A. Rippon. In this method, the formers are made by winding and cementing strips of balsa around a detachable, cardboard former, which is cut to the

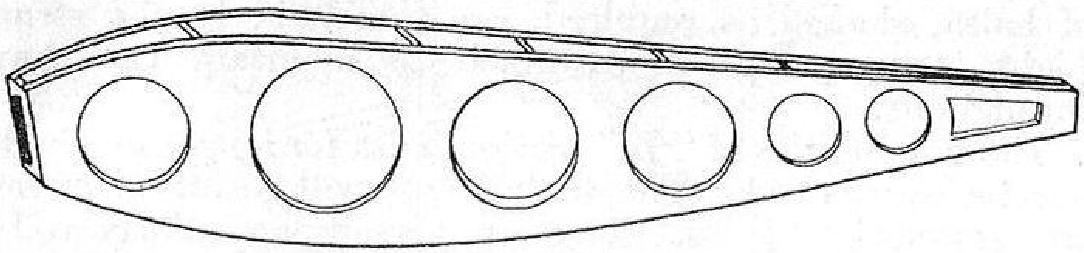

Fig. 67

desired shape of the fuselage section. As the matter is amplified in the Chapter on " G.B.3 " it will not be detailed here.

Those builders who require a certain degree of realism in their models may incorporate a cabin in the fuselage with good effect. In any case, the cabin structure should be kept as light as possible, and may either be incorporated in the design or superimposed upon a conventional fuselage. The second method probably lends itself more readily to easy construction, as a true and rigid fuselage may first be built and an extremely light cabin structure added afterwards.

The use of light stringers for top deckings is to be recommended, but it is often advantageous to carve nose-deckings

Fig. 68

from the solid balsa. This construction (Fig. 70) not only gives a clean finish, but adds greatly to the strength of the nose, and has the additional advantage of placing weight in the correct position. On any but the lightest of fuselages the nose should be reinforced in some manner, preferably with balsa blocks or even balsa panelling as shown in the photographic illustration in Fig. 71. The actual nose-former may, with advantage, be made of three-ply of $\frac{1}{8}$ inch or 3/16th inch thickness.

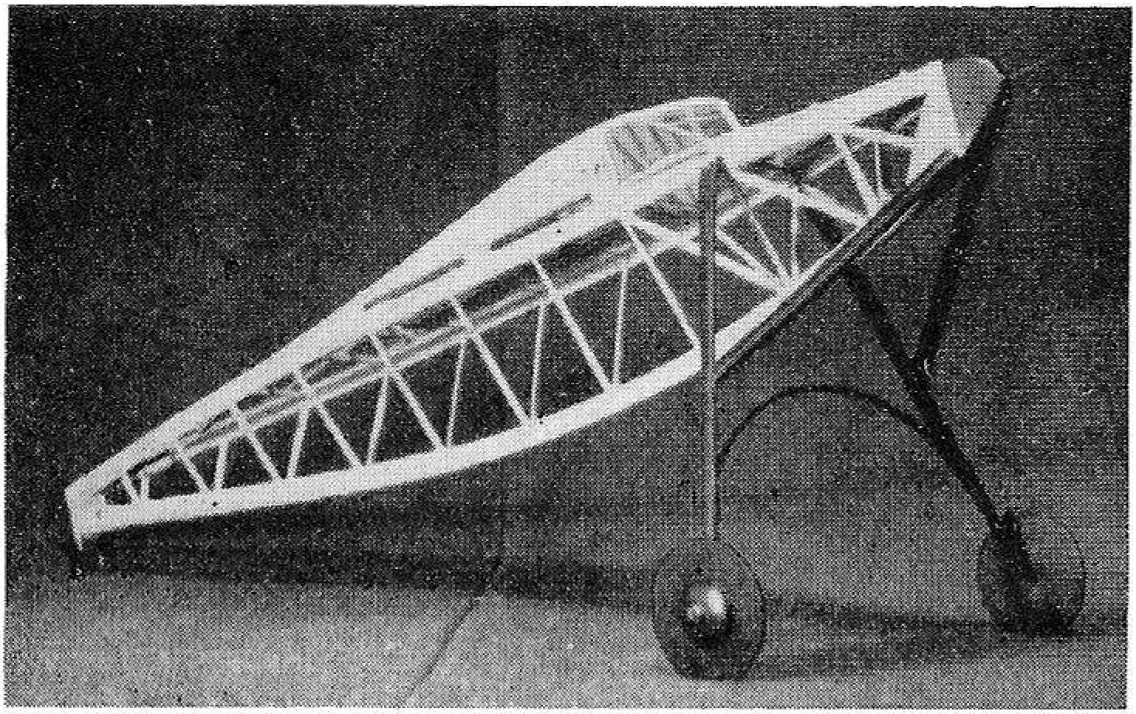

Fig. 69.—A triangular section fuselage with cabin incorporated. The slots at the base of the cabin are to accommodate the wing-fixing tongues

Special attention should be given to the points of attachment of the undercarriage, which should be reinforced with a view to distributing the landing shocks over as much of the fuselage as possible. If the stresses are too localised a broken longeron usually results. It is most important to

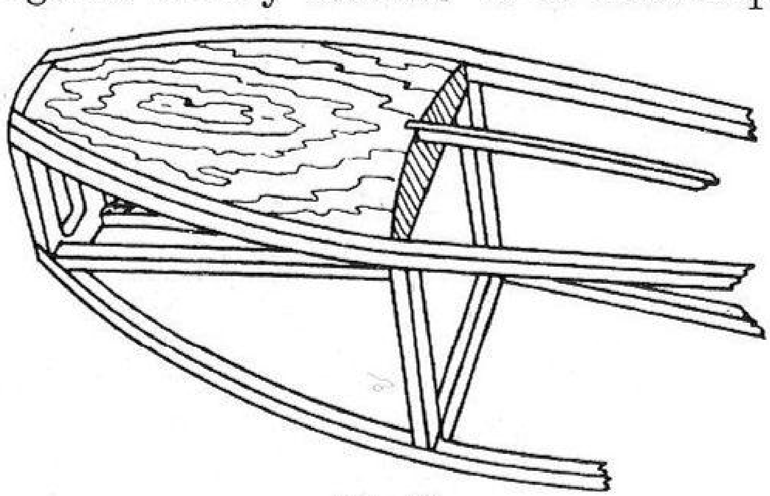

Fig. 70

attach the undercarriage at points where the fuselage formers meet the bottom longerons, and to take bracing struts from these points as in Fig. 72. In undercarriages having four fixing points, the two front legs may often be attached to the nose former quite satisfactorily.

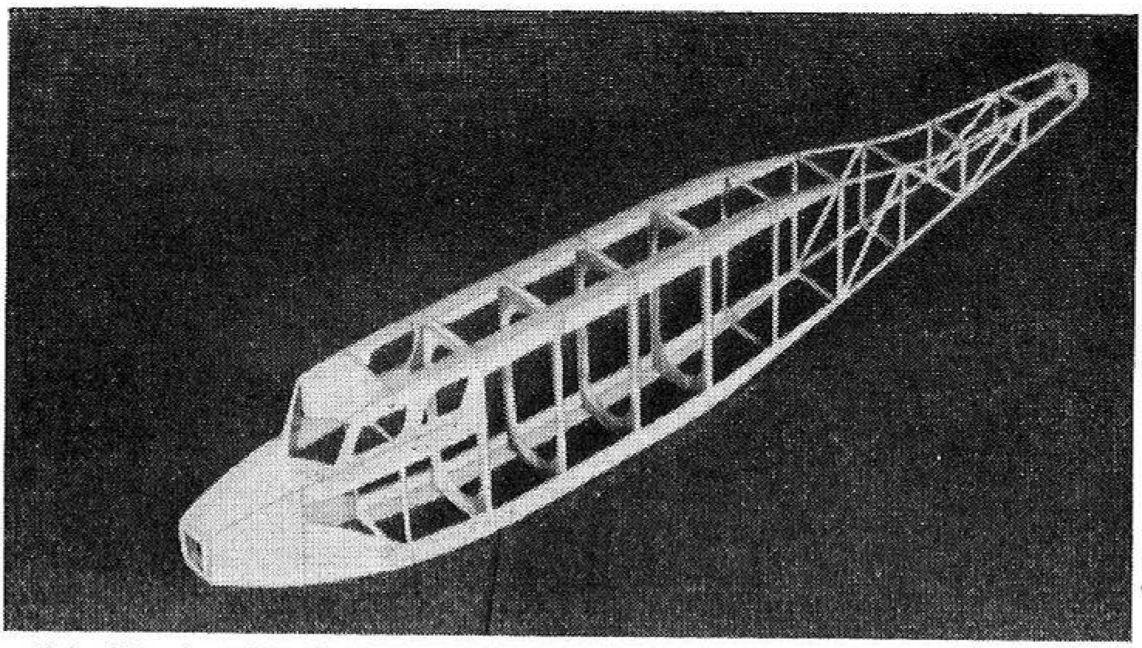

Fig. 71.—A cabin fuselage embodying both ply-former and strut-former construction. Note balsa sheet reinforcement at nose, and balsa strips cemented to longerons

A piece of fine brass tubing carried across the bottom of the fuselage, and bound to each longeron, comprises a sound undercarriage fixing (Fig. 72). Small metal clips, bound to the longerons as shown in Fig. 73, are sometimes used in the lighter models, but are apt to come adrift on the heavier types.

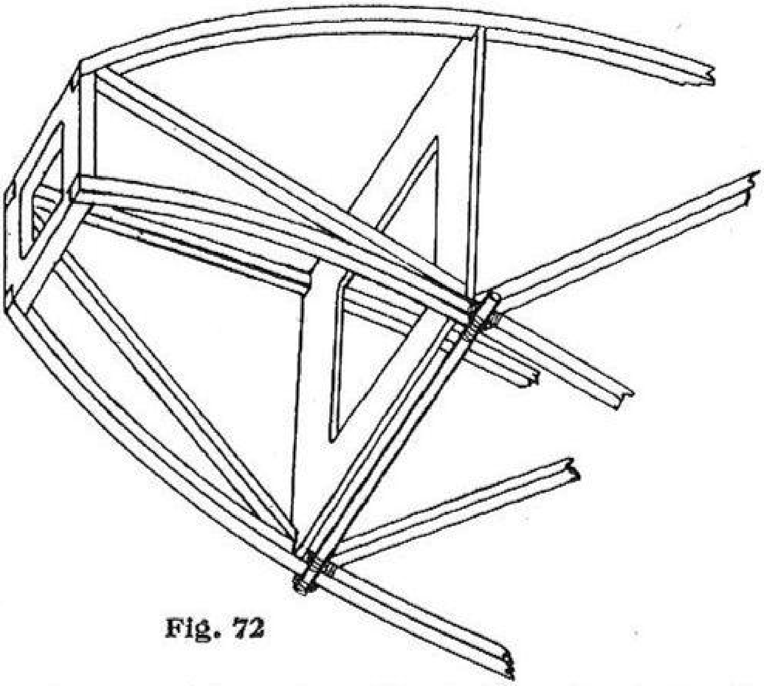

Fig. 72

The importance of keeping the tail end of the fuselage as light as possible cannot be overstressed. Nothing bespeaks bad design more than the necessity for placing the main wing far back on the fuselage in an effort to obtain correct balance. If any advice may be dogmatically given it is that of the necessity for keeping the tail light. For this purpose it may sometimes be advisable to terminate the rubber motor before the extreme end of the fuselage, but this is bad practice on account of the smaller number of turns which a short motor will accommodate. Better to design and build the fuselage correctly in the first place.

The hook for the attachment of the rubber motor at the rear end of the fuselage is often constructed of piano wire, and care should be taken in the design to ensure that sufficient room is allowed to permit the rubber to be attached without undue trouble. Rubber motors have the unhappy knack of breaking, and as this usually happens on the flying field, an easy access to the motor is advantageous. A detachable hook will often aid the easy renewal of a rubber motor, and a suggestion is given in Fig. 74. In this illustration only the sternpost of the fuselage has been shown, all longerons being omitted for the sake of clearness. Two small lengths of brass tubing are bound and soldered to the front and rear of the sternpost in the positions shown, and a piece of

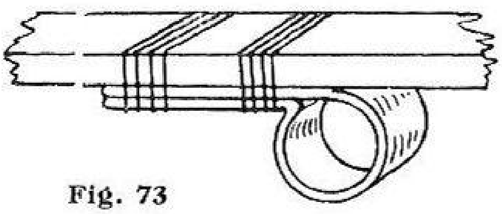

Fig. 73

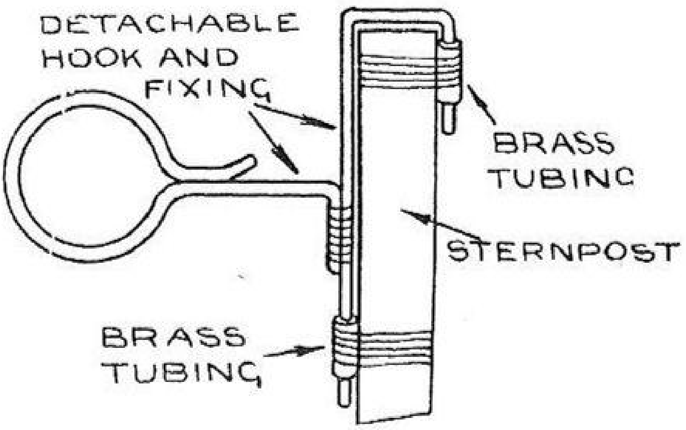

Fig. 74

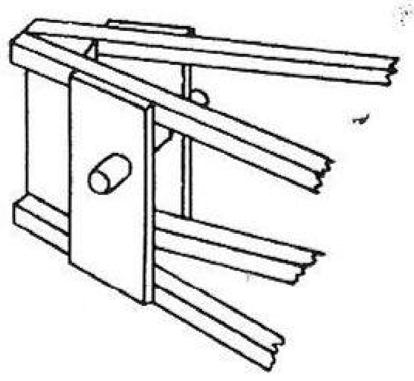

Fig. 75

piano wire, to which the rubber hook is bound and soldered, is bent to locate in the pieces of tubing. The whole is detachable by pulling upwards.

Another method, utilising a short piece of bamboo, is shown in Fig. 75. This piece of bamboo is passed through the loop of the rubber skein, and located in holes in thin plywood uprights affixed to either side of the fuselage.

For simple light-weight constructions the tail-skid may be integral with the rubber fixing hook, which is bound to the sternpost as in Fig. 76. This illustration also indicates a practical tail-skid for use when the simpler method is not possible.

In ultra-light-weight balsa fuselages the simplest form of construction is called for, and a great deal in the way of reinforcing cannot be undertaken if the weight is to be kept as low as possible. One is usually prepared to take chances with these light types which are not, in the nature of things, subject to such great flying and landing stresses as their heavier counterparts. Most of the damage is done in the actual handling of these machines, and a little judicious strengthening will often prevent annoying breakages. It should not be overlooked that the rubber bands usually

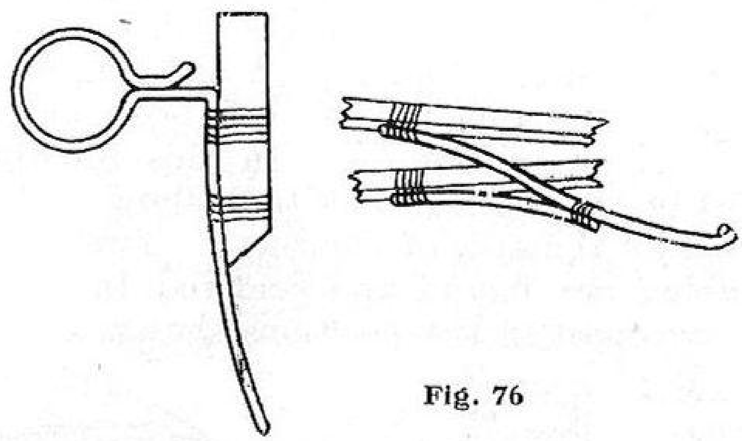

Fig. 76

employed for wing and tail fixing, exert a considerable pressure on these light structures, which may be strengthened, without much addition of weight, by means of small strips of balsa glued *on edge* along the longerons at the susceptible points (see Fig. 77). Similarly, a former or strut should always lie at the spot where the tail-fixing rubber bands will be located.

On average ultra-light-weight and light-weight machines no cross-bracing against the torsion or twist of the rubber motor need be incorporated in the fuselage. The doped covering is usually sufficient for this purpose, but should not be relied upon if the machine is to be used on wet or damp days. If much moisture is present in the air, the doped covering will slack-off considerably, and leave the fuselage practically unbraced. In any event, not a great deal of bracing should be necessary unless a very powerful, single skein motor is used, and a cross-strut here and there will usually serve the purpose. When any even number of rubber skeins is coupled together by means of gears no precaution against torsion need be taken.

In America, a much favoured method is to use a "motor stick." This usually takes the form of a balsa box spar, one end of which is rigidly attached to the nose-block. The other end of this spar carries the rear rubber hook, the whole forming a separate motor unit which is plugged into the fuselage, the free end of the spar being located in a fixing at the tail of the fuselage, but free to rotate in this. The advantages of this are that there is no torsional stress on the fuselage, and that the motor is readily accessible. Although only a very light fuselage is necessary, any saving in weight in this direction is probably nullified by the weight of the motor stick, especially as landing shocks must still be guarded against.

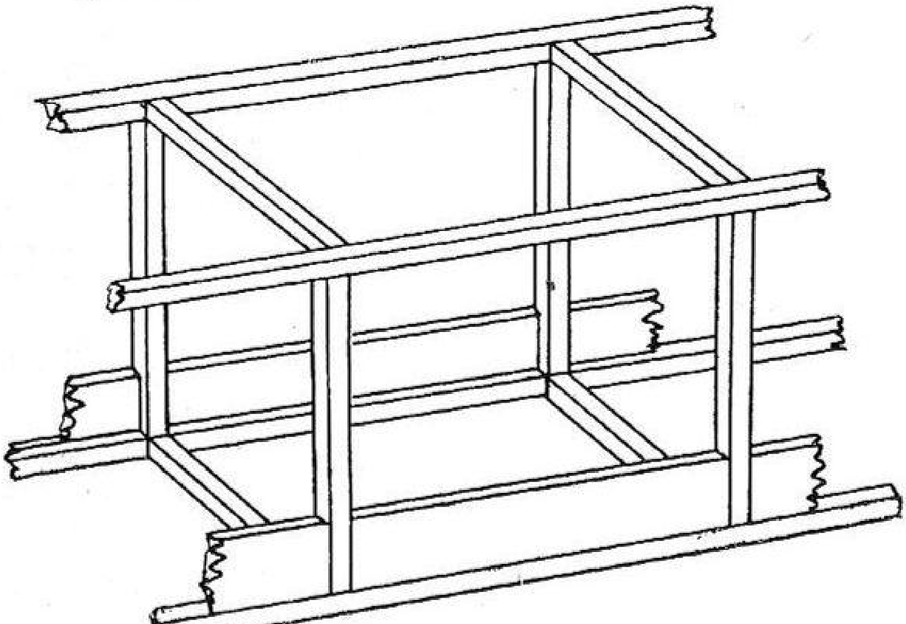

Fig. 77

Nose blocks are usually carved from one of the "hard woods," balsa sometimes being employed for the very light machines. On anything but the very lightest, however, balsa nose blocks may not prove satisfactory, the tension of the rubber motor being sufficient, in some cases, to pull the propeller shaft bush into the soft wood. This is often aggravated by any unlucky nose dives, and the bush is always apt to work loose in the housing. This, of course, destroys the correct thrust-line, and should always be borne in mind. It is common practice to utilise the piece of plywood, removed in fretting out the nose-former, as a locating piece, which is glued and pinned to the nose proper. A hardwood nose-block also adds weight to the front of a machine in a useful way.

In predetermining the centre of gravity in any fuselage, the weight and position of the undercarriage must, of course, be considered. Very light machines often have a tendency to "wallow," and this may often be cured by placing the undercarriage well forward and by using comparatively heavy wheels.

A minor point, often neglected, is the desirability of avoiding any sharp or rough edges *inside* the fuselage, which may cut or chafe the rubber motor. Always smooth off the inner edges of balsa or plywood formers with glasspaper.

In conclusion, it may be remarked that it is advisable not to design a fuselage which makes it necessary to place the tail below the line of thrust. Good machines of this type have been built by experienced builders, but it is a line-up that so often proves unsuccessful that the beginner is advised to leave it alone.

CHAPTER VI

TAIL UNITS

This term applies to the tail-plane and rudder, which, in model aeroplanes, usually form one assembly. The functions of the tail unit have been described elsewhere, and there only remains the question of actual construction.

As the rear end of a model aeroplane must be kept as light as possible, it goes without saying that the tail unit must be designed with this in mind, and a simple form of construction is, on that account, usually called for. A simple framework of bamboo or reed cane, strutted across with a few balsa ribs, will suffice for the majority of light machines. These tail frames are covered on both surfaces with paper tissue and lightly doped. Bamboo and reed cane must be bent to shape by the application of dry heat.

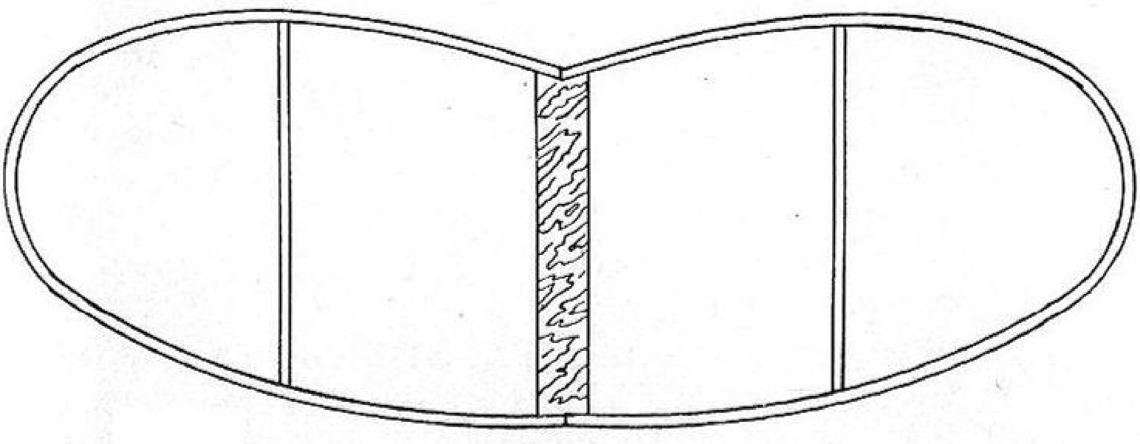

Fig. 78

If possible, this should be done over a gas flame, but care is needed not to char the wood. It will usually be impossible to avoid a slight discoloration, but this will not matter provided the wood is not burnt. Steaming is not effective, but is quite suitable for thin birch or spruce. These woods may also be curved by soaking for several hours in water, securing to the desired shape, and allowing to dry in this position.

A tail suitable for bamboo, cane, birch or spruce construction is shown in Fig. 78. In the more complicated shapes (Fig. 80) it is often advisable to make each half of the tail separately. The strips of wood from which they are to be constructed should be bound together with florists' wire, and both bent to shape in one operation. This ensures that both halves are alike.

Tails of similar outline may be made of piano-wire (Fig. 79) but are now not greatly used except for heavyweight general-purpose models. Piano-wire is rather difficult to work in long lengths, and wire frameworks for tails of over fourteen inches in length are sometimes easier to make in halves. Steel wire up to 18 S.W.G. in thickness may be straightened

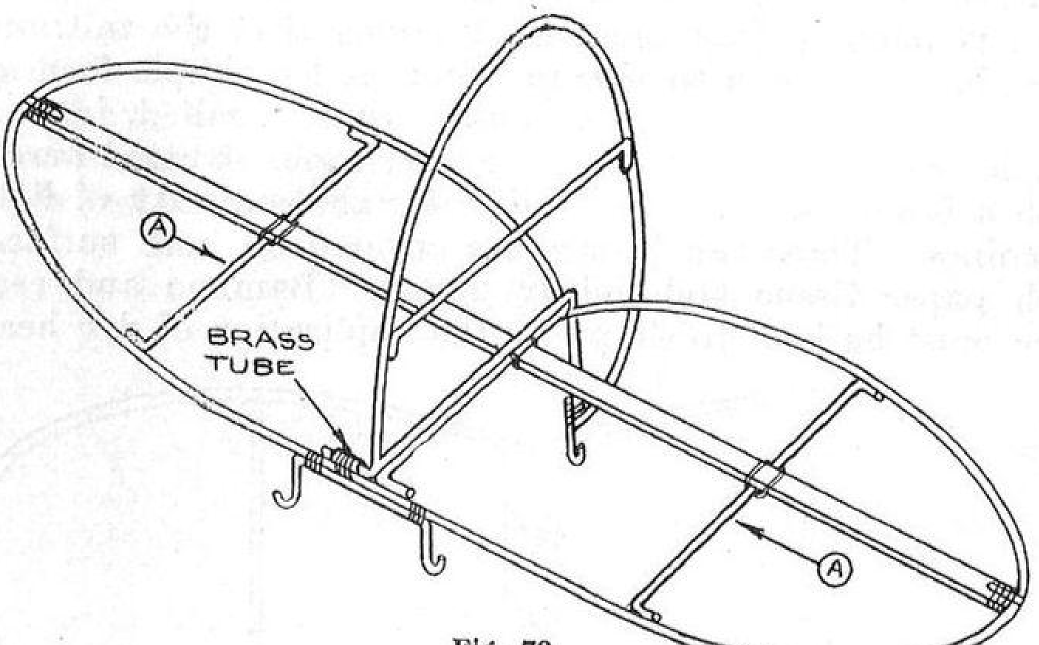

Fig. 79

by means of the tool shown in Fig. 81. This consists of a length of board, down the centre of which three nails are driven in line. A length of the wire to be straightened is uncoiled, and threaded between the nails. When sufficient of this protrudes to be firmly grasped with pliers, the wire is given a sharp pull, and will be straightened.

When making wire tail frames it is essential that the structure be flat, containing no warps or twists. All joints should be bound with florists' wire, and, before finally soldering, it should be ascertained that the framework will lie flat upon a board, touching this at all points. If cross-bracing struts are used be quite sure that these are flat, and that the two ends are bent in exactly the same plane. If this is not done, the tail will be badly warped. This illustration also shows a method of bracing a wire tail of large span by means of a balsa or spruce spar. This is secured at the ends by means of small metal clips, as shown, and bound to the cross-bracing wires.

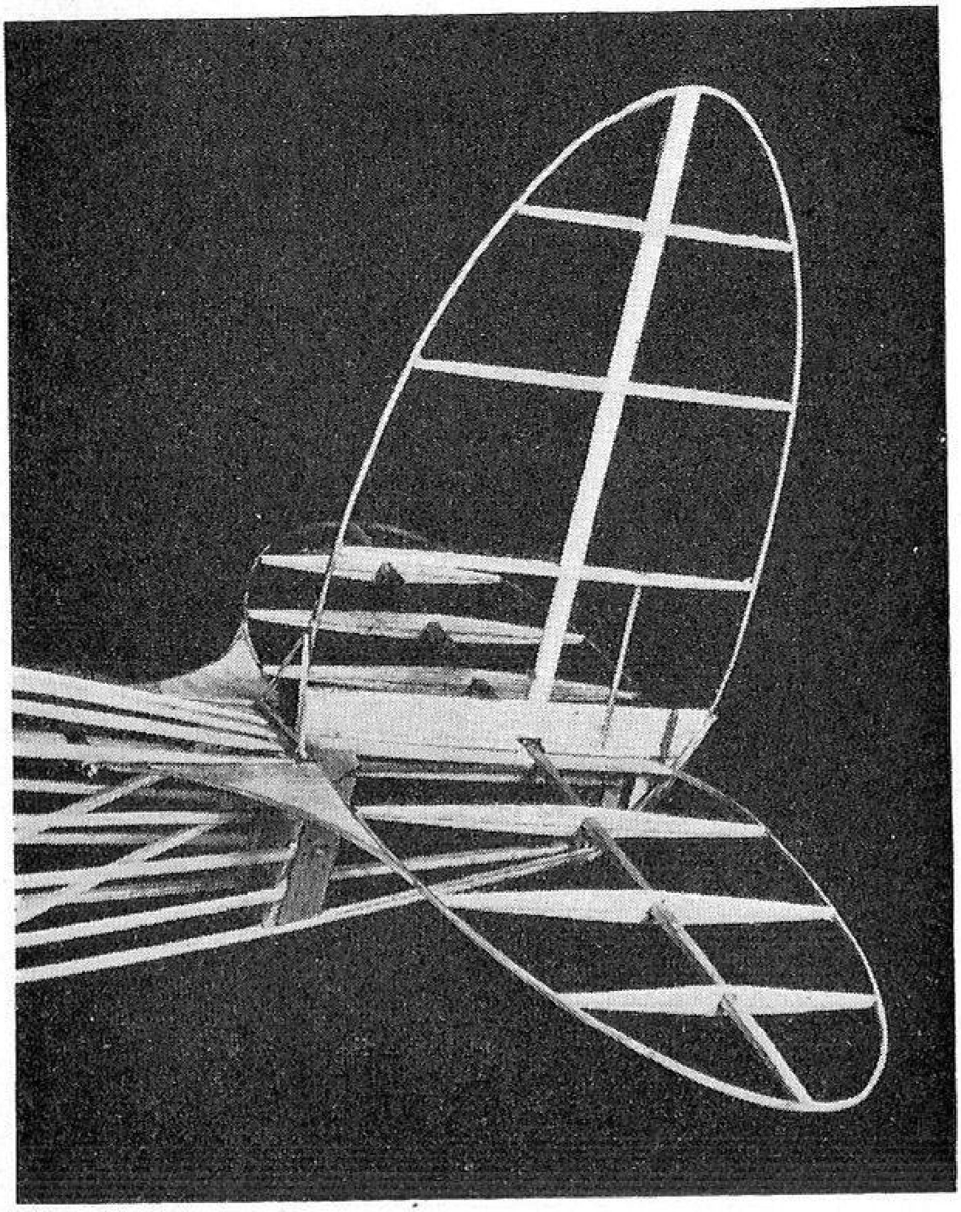

Fig. 80.—Tail unit, with centre spar inset into ribs. Tail is fixed at front by means of rubber band passed through a tube and anchoring to hooks on the tail-strakes

Tails and rudders of more complicated shapes may be constructed by the " built-up " method illustrated in Fig. 82. Any acute curves, such as occur at the tips, may be cut from sheet balsa, and balsa or spruce edges cemented in. It is possible to design quite effective shapes by using straight spars and confining all curves to the balsa inserts. The design should be marked out upon a board and the tail built flat upon this. "Built-up" tails are extremely suitable for all-balsa construction, and are surprisingly strong, especially if stiffening spars are added from tip to tip as illustrated.

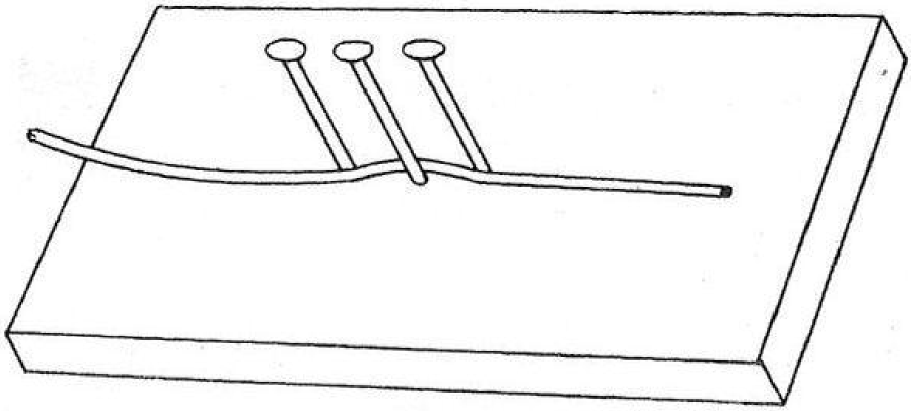

Fig. 81

Note that these spars should be placed on both sides of a negative tail, as if used on one side only, the resultant hump which the spar causes in the doped covering may transform the tail into the "lifting" variety.

The methods just described are suitable for lifting tails, which may be assembled in exactly the same manner, except, of course, that ribs of "lifting" section are used

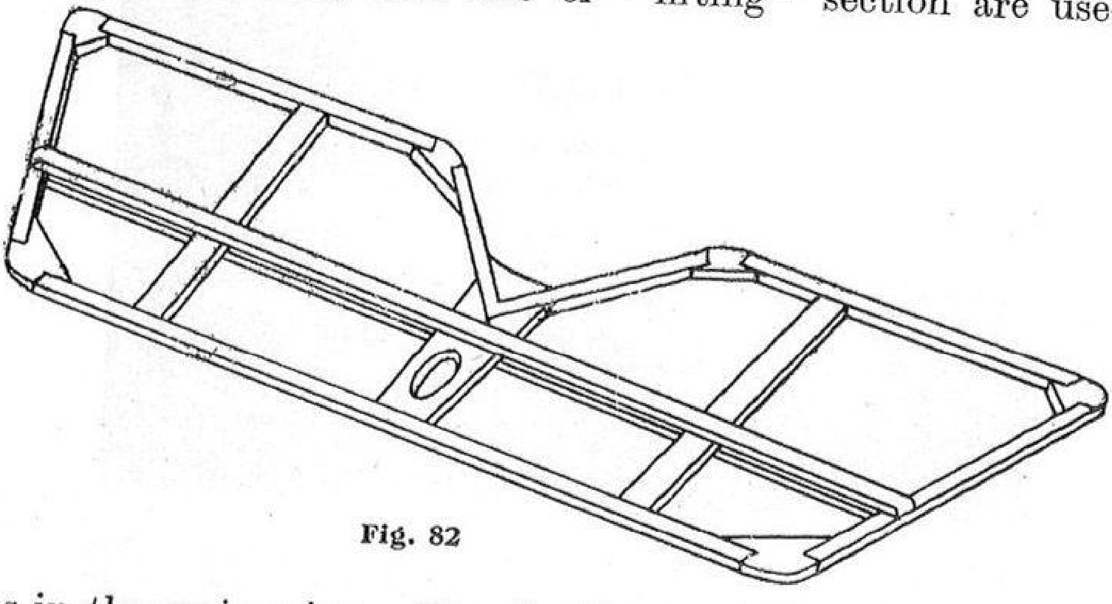

Fig. 82

as in the main wing. Usually the aerofoil section need not be of such high lift as that employed in the main wing. Lifting tails are really small wings, and, therefore, any system applicable to main wings may be utilised. A modification of these methods is, however, advisable, as,

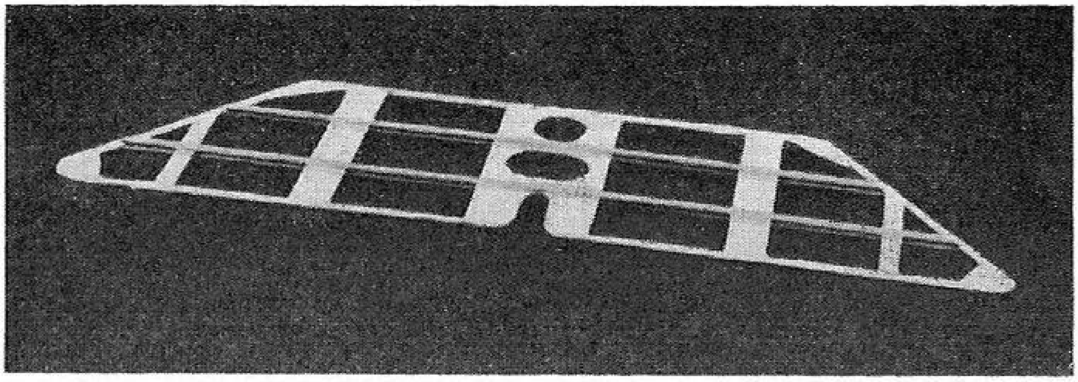

Fig. 83.—Built-up tail plane of all balsa construction, incorporating two main spars

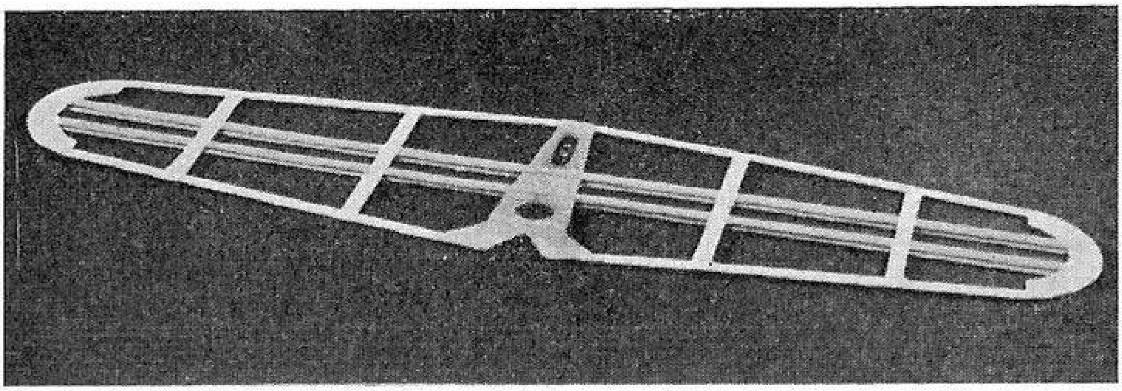

Fig. 84.—All-balsa, built-up tail plane. Note semi-circular tips of sheet balsa and twin main spars

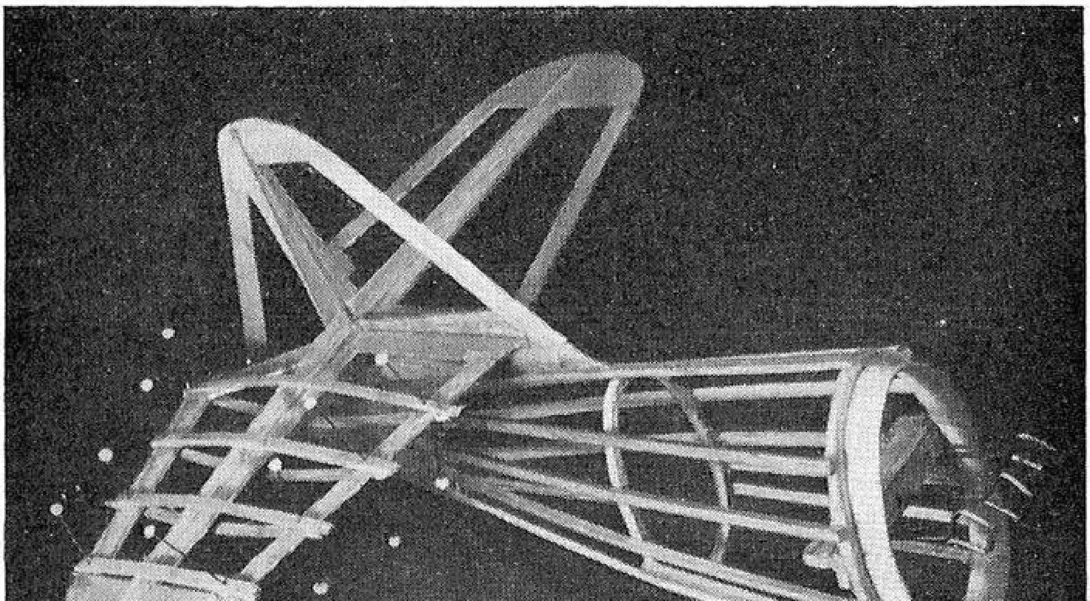

Fig. 85.—Tail unit forming part of detachable end of fuselage. Note method of making the ribs

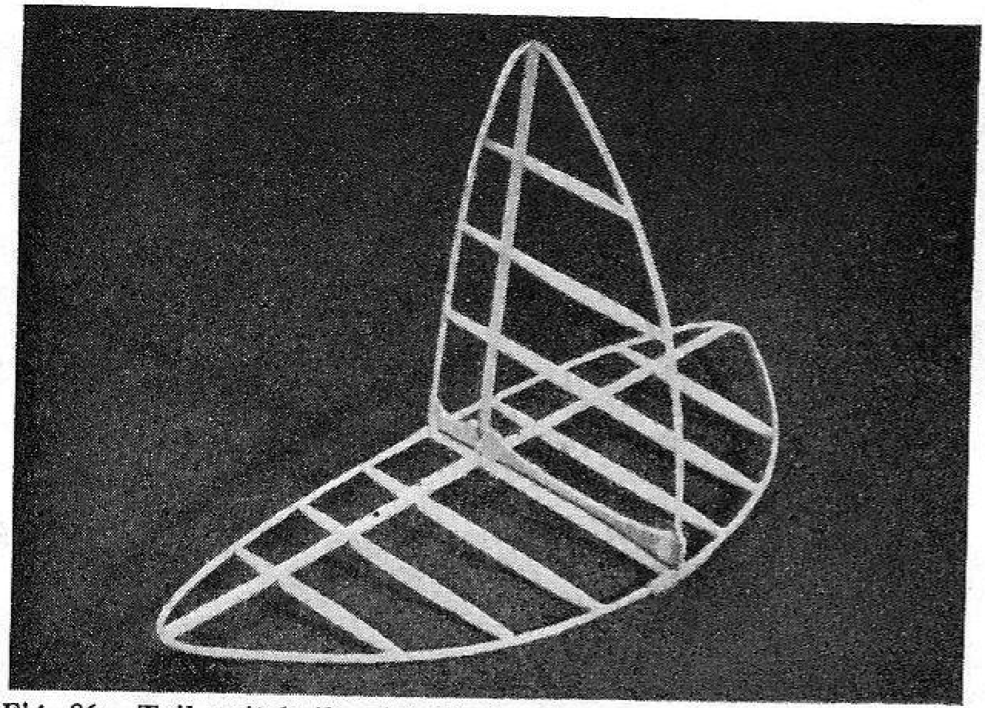

Fig. 86.—Tail unit built with birch edges, and balsa spars passing through balsa ribs

owing to the shorter span, the stresses are much less, and it is extremely important to keep the tail light.

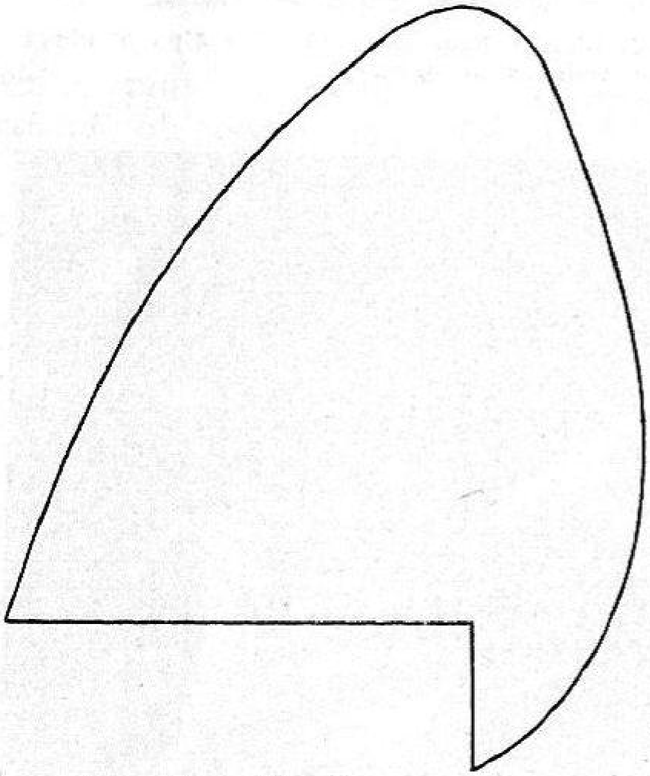

Fig. 87

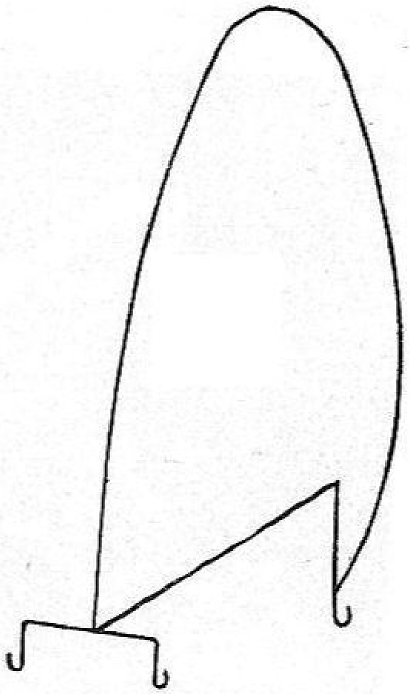

Fig. 88

Rudder fins will, of course, be constructed to be in keeping with the tails with which they will be employed, and no detailed description should be necessary. However, a very finished appearance may be given to the rear of the machine by shaping the lower part of the rudder to carry on the lines of the fuselage (Fig. 87). This also provides a very convenient point at which to fix a small hook ; a rubber band being attached between this and the tail-skid. By this system, not only is the one end of the rudder secured, but the tail itself is also held down. A simple form of fixing the rudder at the front is shown in Fig. 88, by means of a wire saddle which is secured to the fuselage by a rubber band.

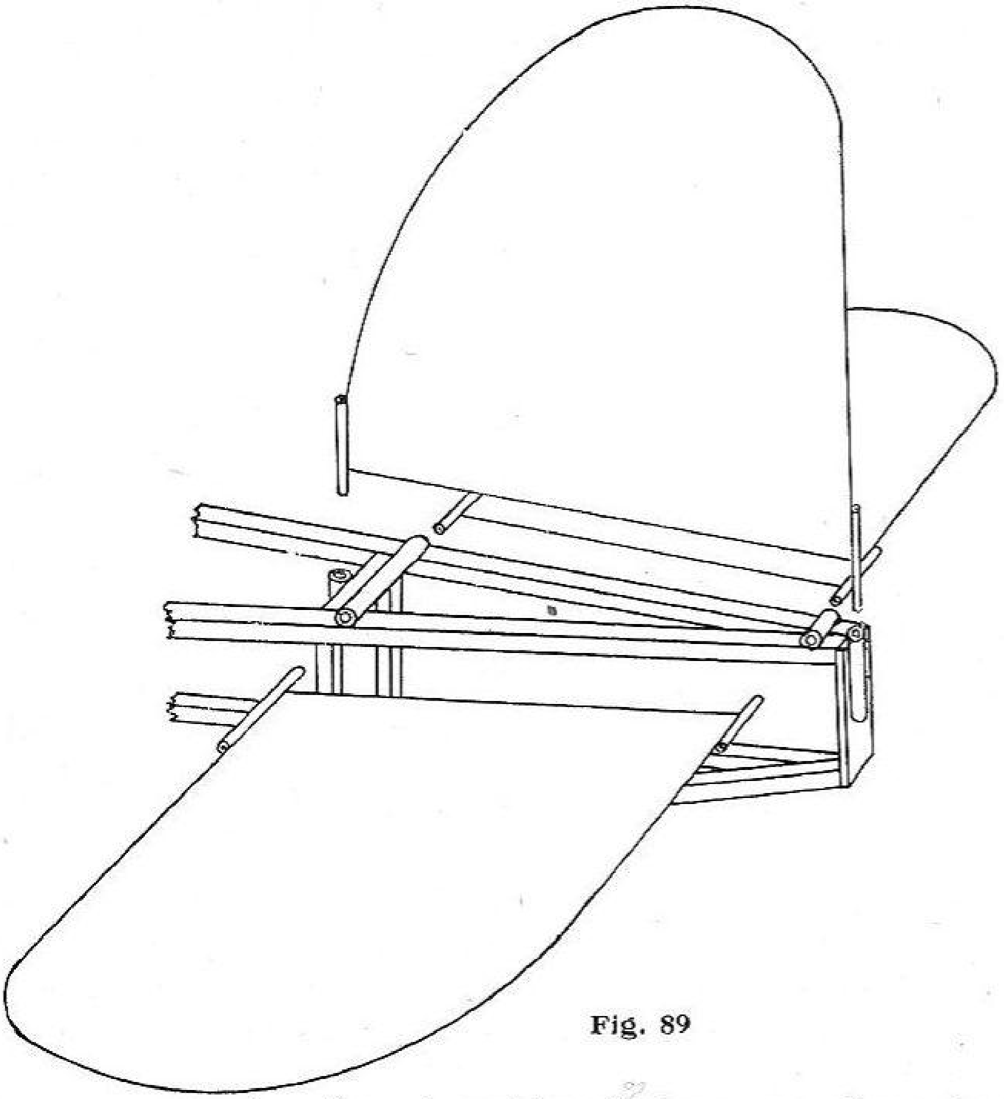

Fig. 89

Some types of tail and rudder fixings are given in the chapters devoted to the construction of the several machines described in this book, and should form a sufficient variety for our purpose.

The actual size of the tail required for any given machine will depend upon several factors, one of which is the distance at which the leading edge of the tail plane is located from the trailing edge of the wing. Generally speaking, a tail set at an average distance from this point (an average distance being approximately two and a half times the wing chord) need possess about one-quarter of the main wing area. The rudder may be one-third of the tail area. As the distance between the wing and tail increases, the size of the tail plane may be lessened. This distance has, of course, its limits, as, if we are to be governed by the fuselage formula, the longer the machine the greater the cross-sectional area of the fuselage must be. We may thus reach a point where the fuselage becomes much too unwieldy for the wing span.

Some constructors prefer to make the vertical fin and each half tail as separate units, which may be affixed to the fuselage by the plug and socket method. It is possible to obtain from the model aeroplane supply stores telescopic celluloid tubing which lends itself very well to a simple adaptation of this system. This celluloid tubing is supplied in sizes from 1/32nd inch diameter upwards, and its application is shown in Fig. 89. It will be seen that short pieces of tube are cemented to the top longerons of the fuselage at suitable points, and that lengths of tube of smaller diameter are cemented to each half wing. As the smaller tubing is of a size just sufficient to be a slide-in fit in the larger, the tail may be securely held by plugging these tubes one within the other. If the socket-tube is split along its length on the upper side, a tighter fit may be obtained.

The rudder is secured in a similar manner, except that the celluloid tubing is cemented in a vertical position. This is an extremely good method, and the ingenious constructor will at once see possible applications to the fixing of the main plane itself.

The necessity for accuracy need not be pointed out. It is especially required that the tail surfaces be flat and unwarped, as the detrimental effect will be much exaggerated by the fact that the tail is operating through the leverage of the fuselage.

The advisability of an adjustable rudder on a model may be discounted on two grounds. Adjustable parts usually mean added weight, which is particularly undesirable at the tail end of a model aeroplane. Movable tails are also liable to be accidentally knocked out of adjustment, with disastrous effect if the machine is launched without the defect being noticed. Anything which may so easily upset the trim of a model is to be avoided, especially as the small amount of rudder adjustment necessary may be given by simply warping the tail in the desired direction.

The same objections hold good in the case of trimmers on the rudder fin and elevators on the tail plane. However, if some light-weight system can be evolved which will provide a rigid fixing in any position, these refinements may be incorporated. In any case, they should be designed in such a manner that, once adjusted, they become a permanent feature in the line-up of the aeroplane, or, failing this, some locating system should be embodied which will enable an exact duplication of adjustment to be attained at all times.

CHAPTER VII

UNDERCARRIAGES

Although the duties of the undercarriage on model aeroplanes are to assist in the "take-off" and the landing, it would be incorrect to say that the undercarriage does nothing when the model is in the air. It certainly does nothing useful, in fact, all its "activities" are detrimental to the machine's performance. First, the weight forms a load which the wings must carry, and, secondly, the resistance of the undercarriage to forward motion through the air adds still more to the drag which the thrust must counteract.

Could we dispense with the undercarriage, our models would give us far better performance on less power, but as such a course is not advisable, let us consider how we may lessen the evils and, if possible, use them to our advantage.

We cannot construct an undercarriage which has no weight, so we must do the next best thing and make the structure as light as possible. On the light-weight machines this presents few difficulties, as the landing and "take-off" stresses are very small, and a simple structure will usually suffice. The heavier machines present greater difficulties, as not only is the undercarriage called upon to bear the increased weight of the model in landing, but this weight is moving comparatively fast. Actually, for a machine of given weight, the landing stresses go up as the square of the speed, i.e., at twice the speed four times the stress is imposed on the landing gear. This complicates the undercarriage construction on heavy-weight models, until, as in the case of racing machines, it becomes one of the chief problems of design.

The light-weight or duration class of model is, however, the type with which constructors seem most concerned, and none of the problems which confront the designer of speed machines need trouble them. All that is required is a construction which is light, reasonably rigid, and capable of absorbing small landing shocks.

The position at which the undercarriage may be fixed to the fuselage has a bearing on the machine's performance. By placing the undercarriage well forward of the centre of

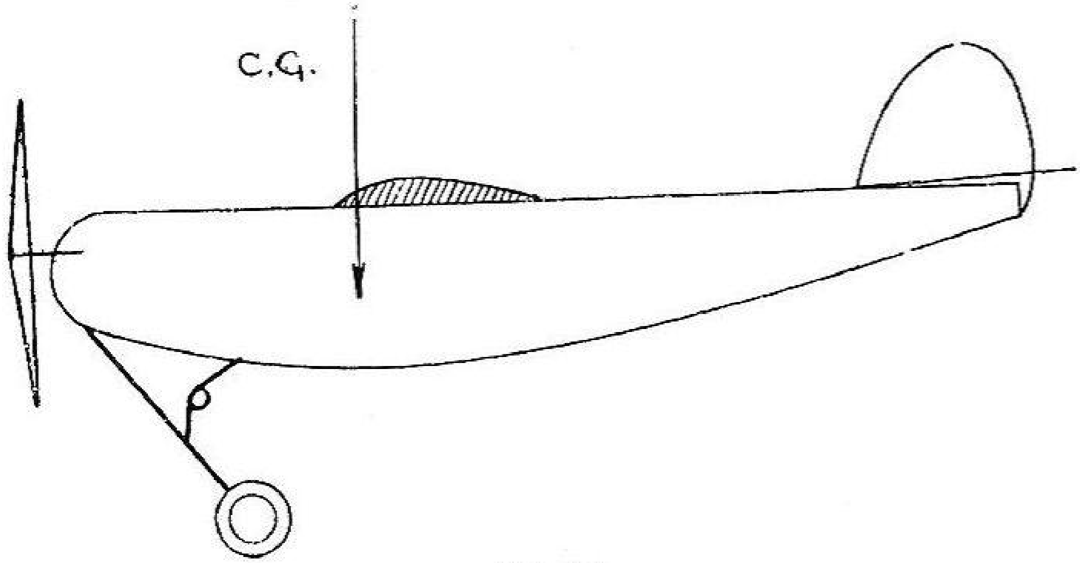

Fig. 90

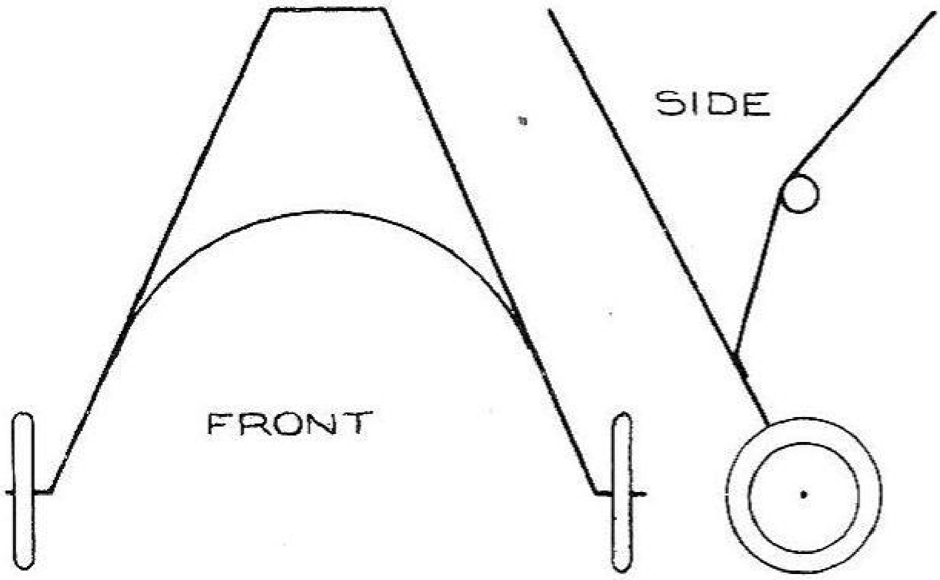

Fig. 91

gravity, the weight may be utilised in a useful manner as an aid to obtaining the correct balance of the aeroplane. At the same time, the position of the wheels in relation to the centre of gravity has a marked effect on the ability of the machine to take off from the ground. If the wheels are situated very far forward, it will be more difficult for the tail to rise and for the machine to assume the correct take-off attitude. The wheels may be placed in front of the centre of gravity, but only sufficiently ahead to ensure that the machine does not topple over on to its nose in landing.

We see, then, that although the weight must be well forward, it is desirable that the wheels themselves are not too much so. It would appear from this that some form of construction is needed in which the weight of the usual springing device is situated in front of the wheels. Fig. 90

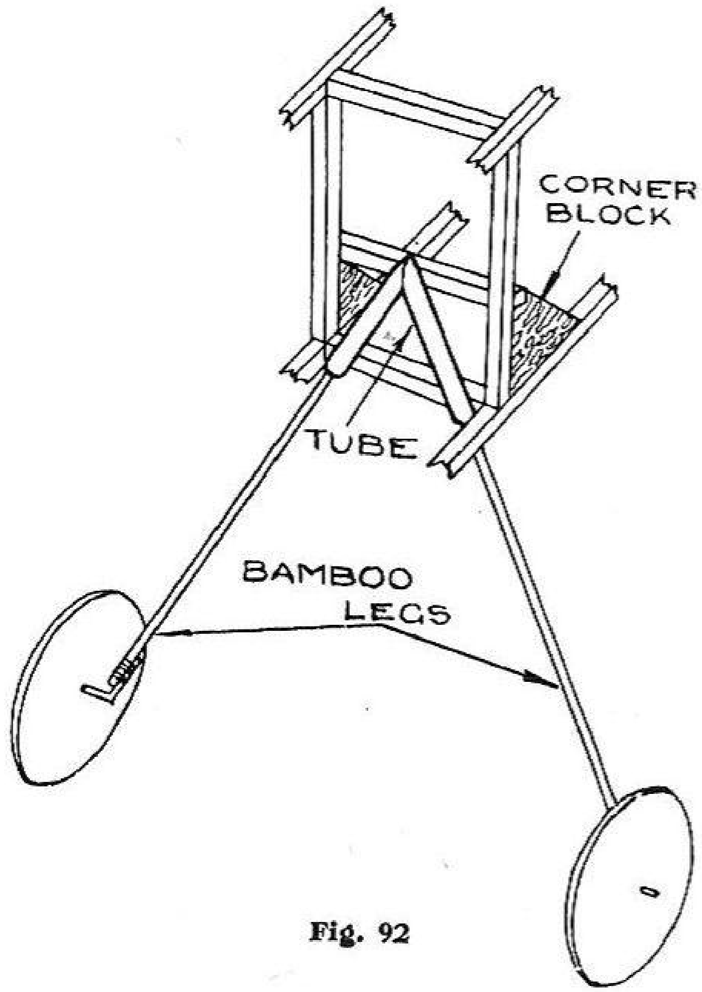

Fig. 92

illustrates a popular type of undercarriage for straightforward light-weight models. In this drawing the arrangement is somewhat different from that usually employed for this type, as the front struts are affixed to the nose former, and the wheels "swept back" to the desired position. It will be understood, of course, that this does not alter the position at which the weight of the wheels themselves will act; it is only the weight of the springing which is brought forward. This allows the main plane to be situated a little nearer to the nose of the fuselage.

The construction of this type of undercarriage is too simple to need much description. It is made of piano wire of 18 or 20 S.W.G., and the legs are cross-braced in the manner shown in the front elevation in Fig. 91. In this instance, a curved cross-bracing wire is used, which, though rigid enough for the purpose of bracing, is not so liable to entangle itself in grass as a straight wire situated lower down.

Only very simple undercarriages are needed on the light-weight class of machines, and a suggestion is given in Fig. 92. In this construction the legs are of thin bamboo, and no springing is incorporated other than that of the bamboo itself. The legs are a push-in fit in tubes which are bound and cemented to the bottom longerons, and braced at the tops with struts. These tubes may be of celluloid (similar to that mentioned in the chapter on tail units), or may be constructed of rolled cartridge paper or gummed paper tape. Only one piece of tube is made, this being bent into a " V " to provide two sockets. The bamboo legs may be withdrawn from the tubes for ease in transit.

Although so simple, this type of structure is quite efficient, and may even be used on balsa models of eight ounces in weight, if a little attention is paid to strength. This applies especially to some form of bracing of the tubes within the fuselage.

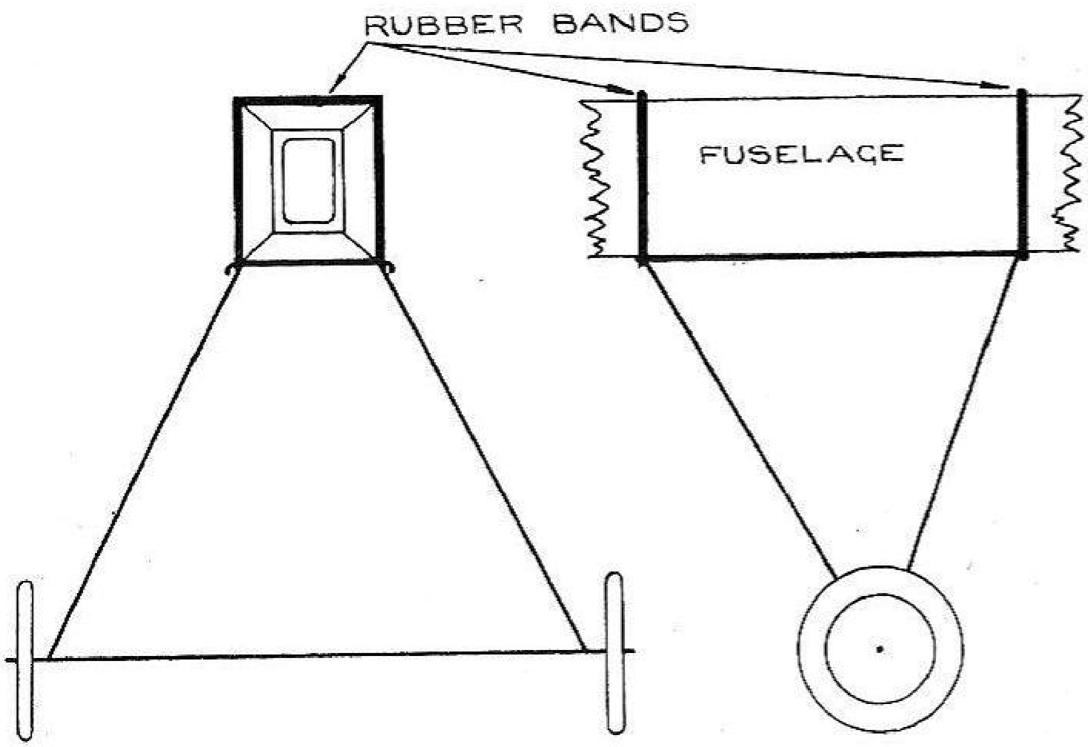

Fig. 93

A detachable type of undercarriage, used with success in America, and suitable for machines of the light-weight class, is shown in Fig. 93. This is a separate structure of piano wire, and does not depend on the fuselage for rigidity, being attached only by rubber bands which provide the springing. An additional feature is that the undercarriage may be moved along the fuselage, and should help considerably in obtaining the correct trim of the machine.

Another American type will be seen in Fig. 94. Here, the actual undercarriage is rigid, all the spring being obtained by

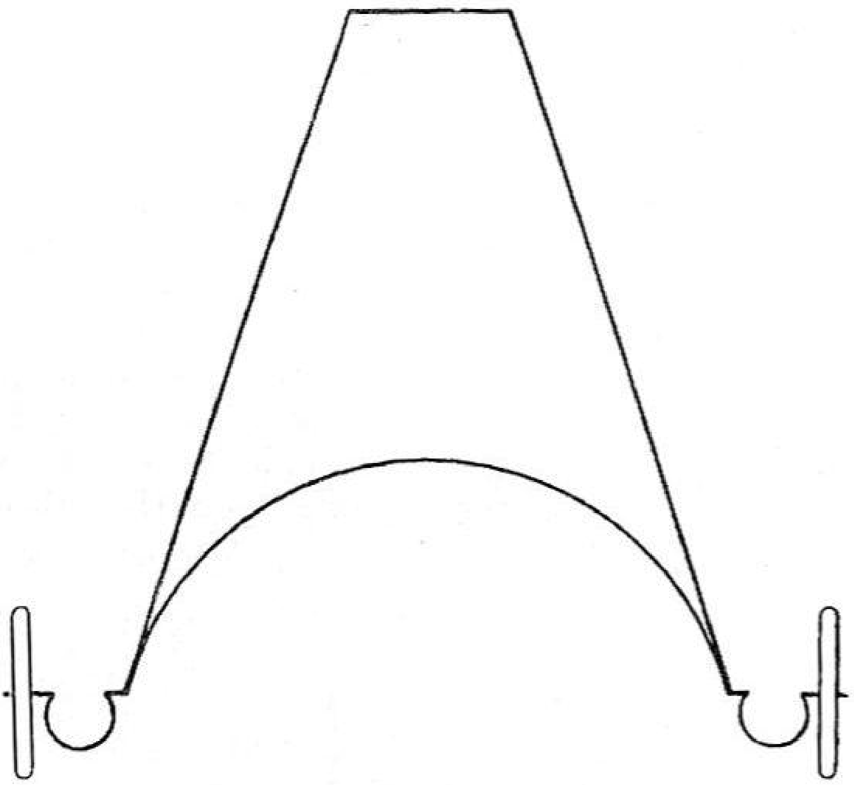

Fig. 94

bending the axle into a " C " shape, close up to the wheels. This is quite efficient for models up to four ounces ; a suitable gauge of wire being 20 S.W.G.

This undercarriage, in an altered form, is depicted in Fig. 95, where the " C " spring is replaced by a short spiral spring. This is wound from 20 S.W.G. piano wire, and the wheel axle is sweated into one end. The undercarriage leg is secured, in like manner, to the other end of the spring, a short length of " free " spring being left between. It is interesting to note that a strengthened edition of this undercarriage has been used with success on a model of 24 ozs. weight !

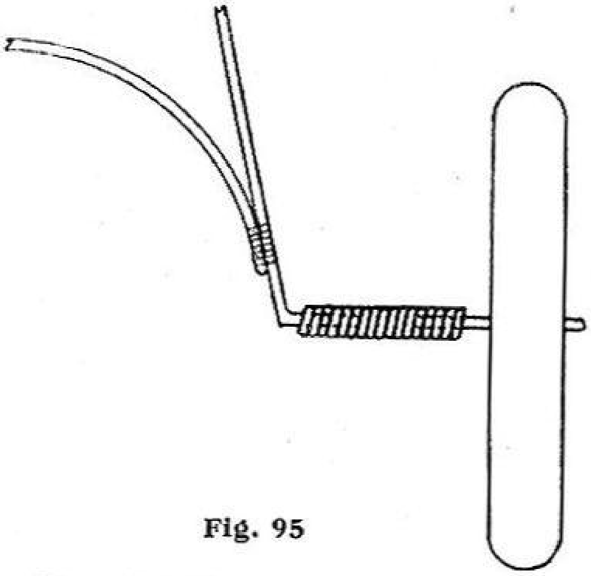

Fig. 95

Although the system of springing the wheels at the axles may appear rather a makeshift job, it has the advantage that the legs may be made rigid and to any desired shape or section. Thus, a very realistic appearance may be given to the undercarriage; a particularly good feature in scale or semi-scale work.

Fig. 96 illustrates part of such a "scale" undercarriage, with an imitation "oleo leg" carved from solid balsa. Springing is effected by simply securing the wheel axle to the rigid leg by means of rubber bands.

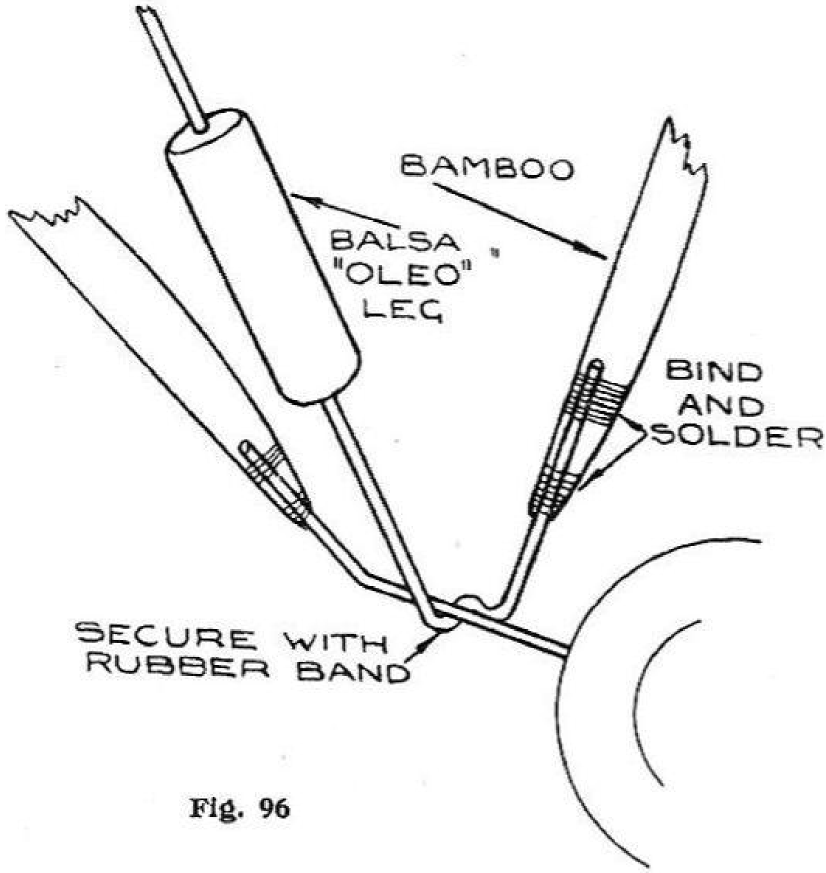

Fig. 96

The wire undercarriage has many merits, one of which is its low resistance or drag, yet many constructors of lightweight or medium-weight models prefer to use something a little more elaborate. Several good systems are in operation;

one of the most successful of which is shown in Fig. 97. In this, the rear legs are of bamboo, suitably shaped to a streamlined section, the front legs being paper tubes. These tubes are made by rolling stout cartridge paper around a wooden former, one side of the paper being coated with "Seccotine" or gum to ensure rigidity when set. Elastic bands pass through these hollow front legs and are anchored

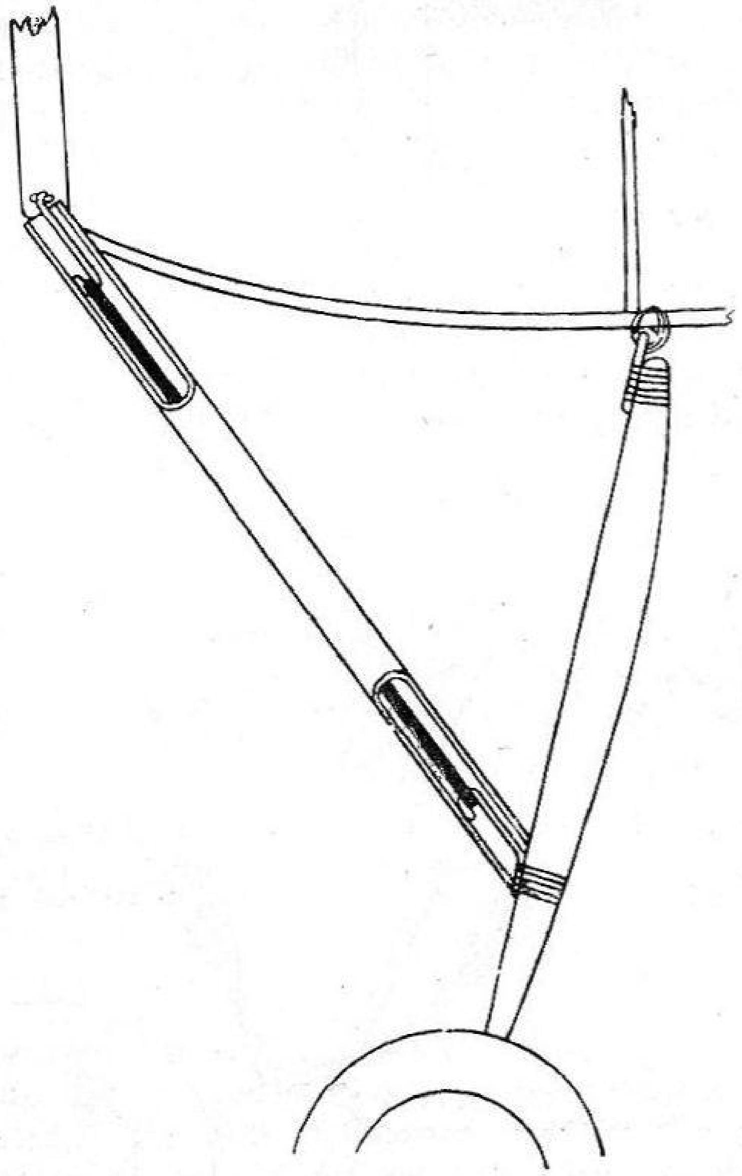

Fig. 97

to hooks suitably situated on the rear legs and the fuselage, as shown in the drawing. The tube has been shown with a portion cut away at each end, so that the hooks and rubber bands may be visible. The rubber bands (indicated by a thick line in the drawing), being always in tension, hold the structure rigid, while the front legs prevent it from collapsing in a forward direction.

When the model lands, the rear legs are knocked backwards, which movement, however, is checked by the pull of the rubber bands concealed in the front legs. As the amount of springing may be regulated by the number of rubber bands used, it is possible to obtain an undercarriage which is rigid enough for rise-off-ground flights, yet resilient enough to absorb considerable landing shocks.

This method is suitable for quite heavy machines, and has actually been used with great success on a petrol-engined

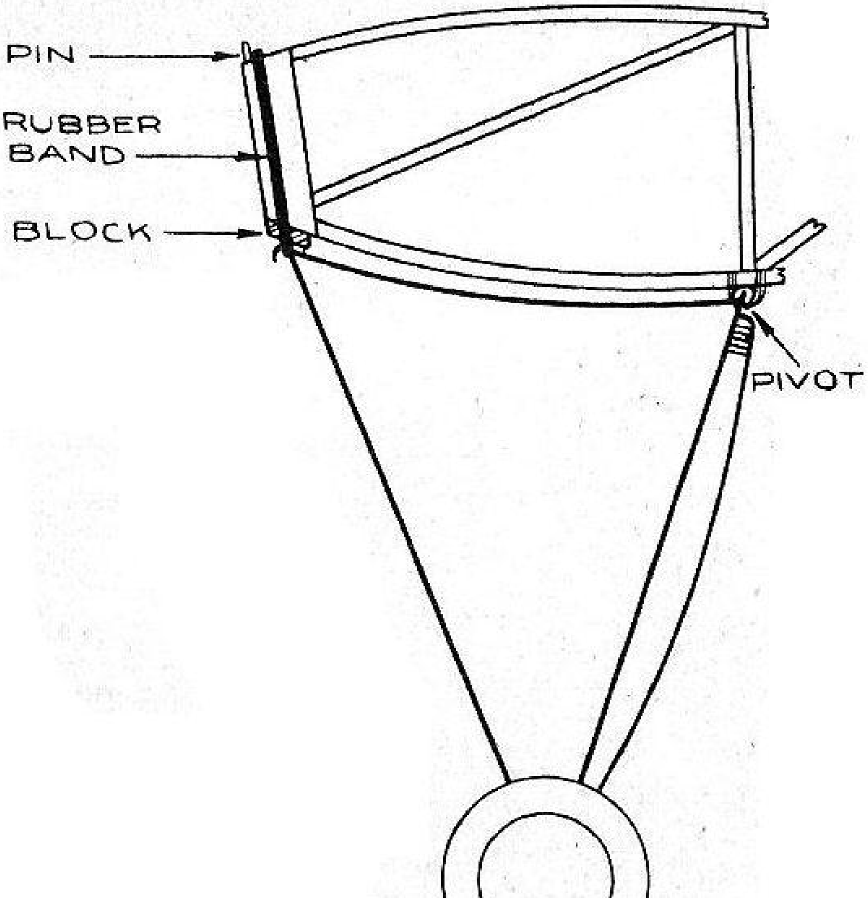

Fig. 98

model. In this case, the hollow legs were constructed of birch three-ply, steamed to shape around a wooden former, and bound with silk and doped. Also the rubber bands were attached between sliders which operated within the ends of the tubes.

In this undercarriage, most of the weight lies in front of the wheels, which is, as we have seen, a desirable feature. It may be constructed in various weights to suit the class of aeroplane to which it may be fitted ; in short, it is a most useful arrangement.

It must be remembered that model 'planes " fly " or glide to the ground at a flat angle. Unlike the full-sized aeroplane, there is no " flattening-out " of the machine just before alighting. A model undercarriage, therefore, need only " give " in a backward direction ; that is, against the direction of the landing impact.

An undercarriage which fulfils these conditions may be

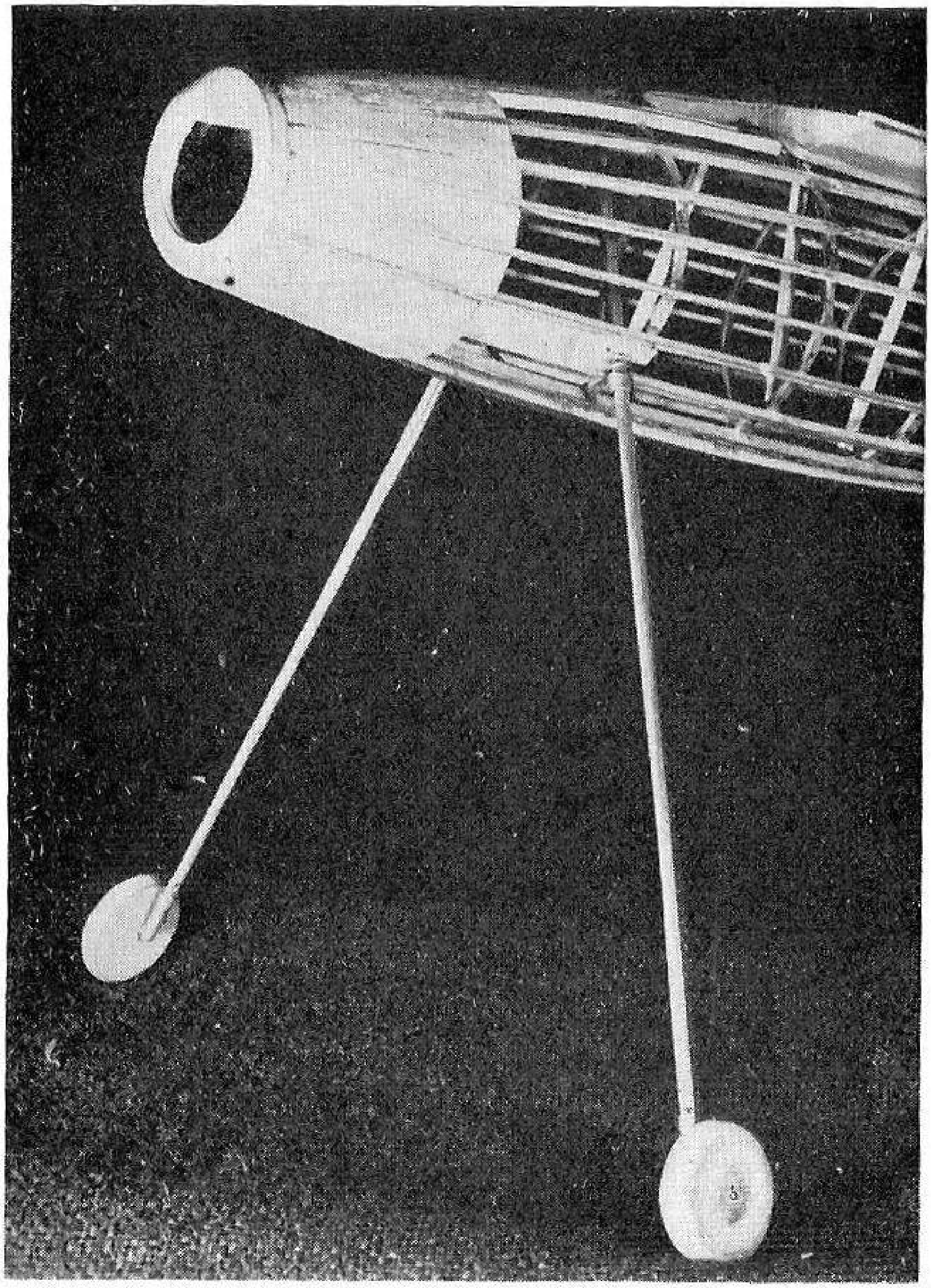

Fig. 99.—Undercarriage for light-weight machine. The bamboo legs pivot in slots in the fuselage, while the tops of the legs are secured to the top decking with rubber bands

constructed on the bell-crank principle, and is suitable for models of four ounces weight and upwards. The illustration in Fig. 98 is practically self-explanatory. It will be seen that the undercarriage is pivoted at the top of the rear legs ; an elastic band, passed over the nose of the fuselage, allowing

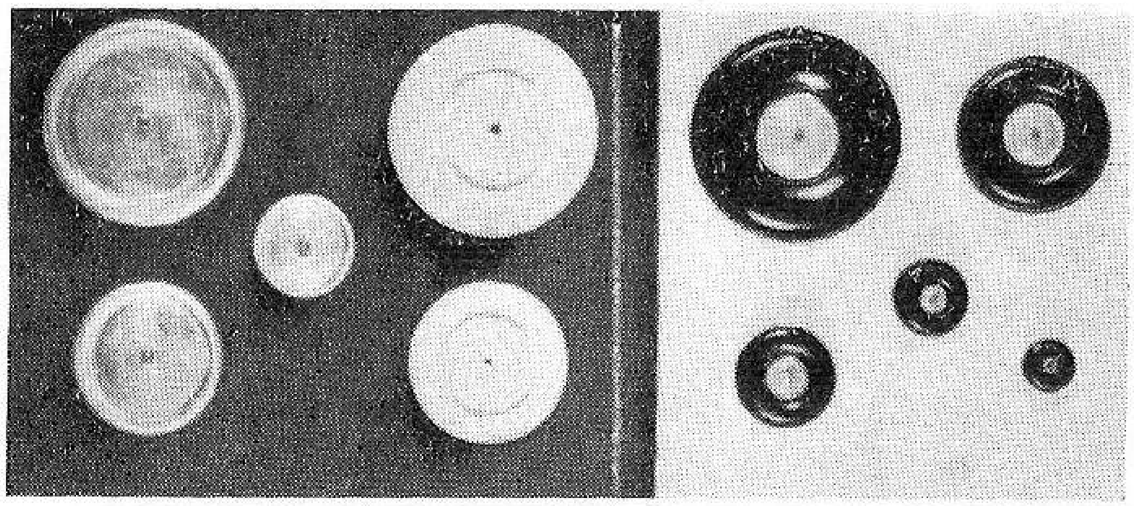

Fig. 100

the undercarriage to spring backwards on this pivot. The legs must, of course, be cross-braced, and it is advisable to glue and pin a small piece of hard wood under the nose of the fuselage, to withstand the small impact when the undercarriage returns to position. The small block is shown in

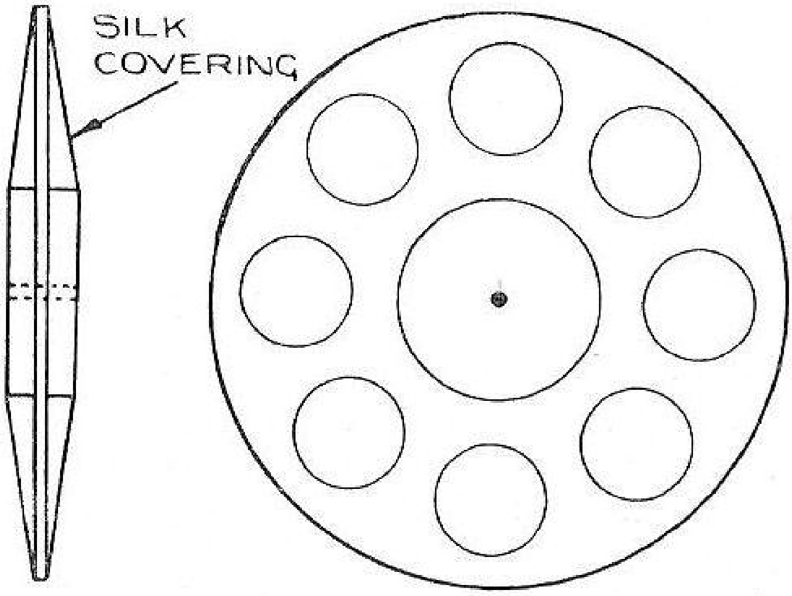

Fig. 101

the drawing, together with one of two pins placed in the top of the nose former to locate the rubber band.

Although, in its lighter forms, this is quite a suitable arrangement for light-weight machines, it may be used quite successfully on the heaviest models. It may be of all-wire construction, or bamboo legs may be incorporated, as shown in the drawing. This is another good type for scale model undercarriages, as the structure is rigid and may be made to any desired shape.

There are so many types of wheels which may be purchased from the model supply stores that it hardly seems worth while to make these oneself. Wheels may be obtained in celluloid, aluminium and turned balsa. Some of these commercial wheels are shown in Fig. 100.

Those constructors who may wish to make their own, may

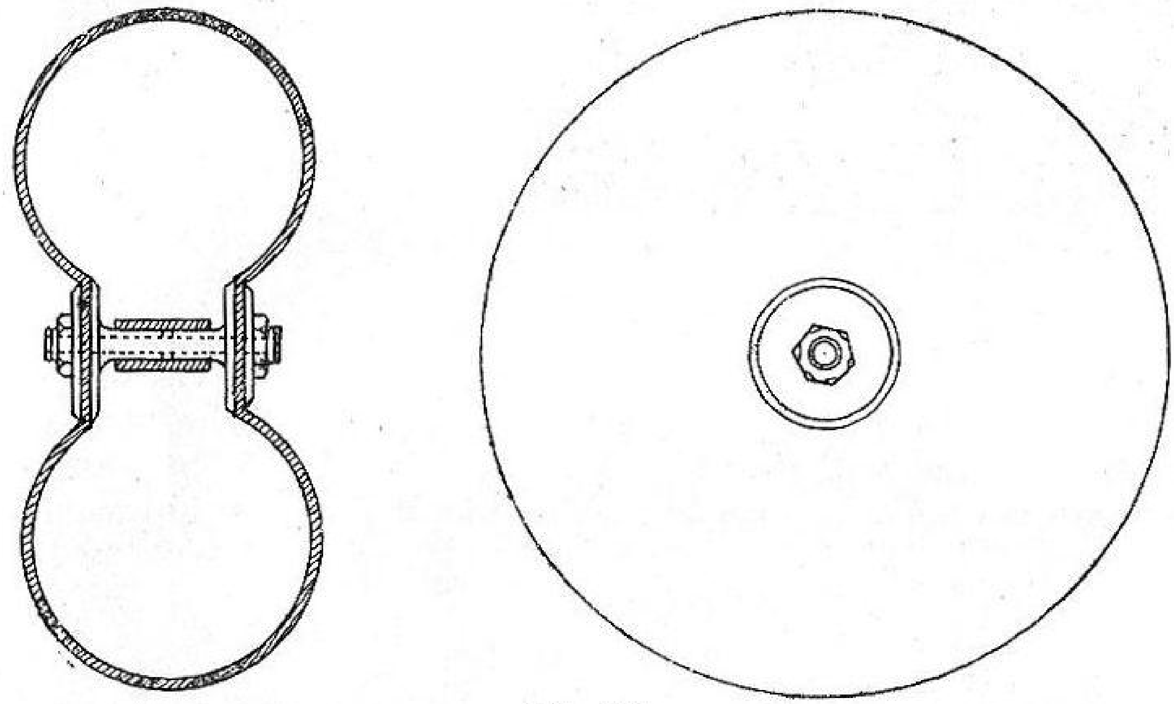

Fig. 102

do so to the plan suggested in Fig. 101. Plywood or balsa discs, suitably lightened by fretting, form the basis, to the sides of which smaller discs of $\frac{1}{4}$ inch plywood are glued. The whole is then covered with silk and doped, and the spindle hole drilled and bushed with brass tubing.

We are indebted to Mr. A. M. Willis for the following excellent method of making pneumatic wheels for heavy-weight models. Fig. 102 illustrates this very clearly, and the construction should present no difficulties to those fortunate enough to have access to a lathe.

A brass bush is made with two collars turned on it as shown. The outer ends of this bush are threaded up to the collars, and the bush itself drilled through from end to end to form the spindle hole. Next, a small hole is drilled through the centre of the shaft, at a right-angle to the spindle hole, and a piece of rubber tubing is forced over one of the collars on to the centre of the bush. This forms the air valve.

Now obtain an ordinary rubber ball, and make two small holes in positions exactly opposite each other. The bush is now located in these holes, in the manner illustrated, and secured with nuts and washers from the outside. The rubber ball thus becomes a tyre, which is inflated through the spindle hole with a cycle pump, the other end of the hole

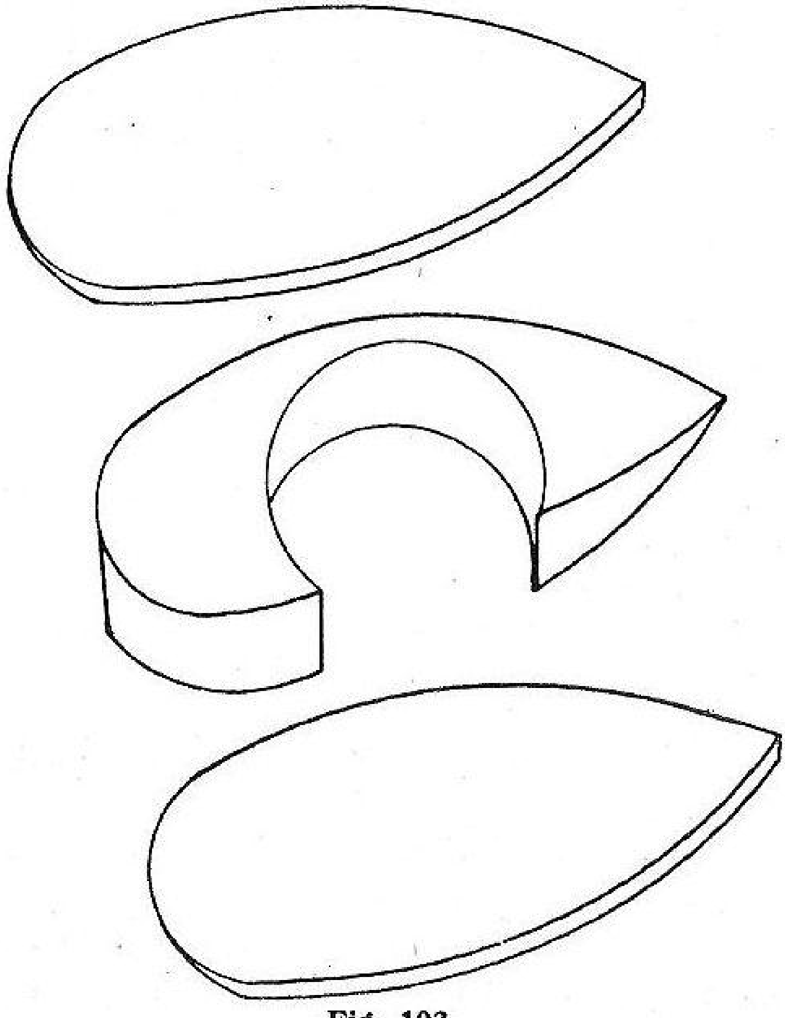

Fig. 103

being stopped with the finger during the process. Wheels of this type have been used with great success on the heaviest petrol models.

Similar wheels, though not of the pneumatic types, may be made with sponge rubber "golf practice balls." Do not buy the very light kind, but those of fair solidity, made from "close grained" sponge rubber. The method of manufacture is similar to that just described, except that no provision need be made for inflation. A wheel of about 1½ inches diameter may be made in this manner.

It is sometimes the practice to streamline the wheels of a model by means of "spats." These are used more for the sake of appearance than for any actual aerodynamic value; the speed of model 'planes usually being too low for "spats" to be of any value. Possibly, from a flying point of view, they are a handicap, yet they undoubtedly give a finished look to a model, especially one with any pretensions to "scale" appearance.

Celluloid spats may be purchased, but as they are often difficult to obtain, they are usually carved from balsa. The most suitable method is shown in "exploded" view in Fig. 103, and consists in making a centre piece of ½ inch or ¾ inch balsa and gluing sides on afterwards. The whole is then sand-papered to shape, and the wheel spindle inserted through the sides.

In designing any undercarriage, care must be taken to ensure that the legs are long enough to enable the propeller to clear the ground when the machine is alighting at its *natural gliding angle.* This usually means that the legs will have to be longer than is desirable from the point of view of weight and drag, but this cannot be avoided. Also see that sufficient track width is given between the wheels, especially on models of large span.

The effect of the side area of wheels should not be overlooked, as this has a considerable influence on a machine's behaviour owing to the lever effect of the undercarriage legs. Large wheels will usually have to be offset by a large rudder fin.

It must be borne in mind that slightly heavier wheels than are ordinarily necessary may be used to lower the centre of gravity, and the pendulum effect of these will often correct for any tendency to "wallow" which a machine may possess.

CHAPTER VIII

COVERING, DOPING and FINISHING

Although the various materials which are commonly used for covering model aeroplane structures have been dealt with in Chapter II, a few remarks on the actual covering process may be helpful.

The extensive use of balsa wood for model frameworks is reflected in the almost exclusive use of paper tissue as a covering for the light-weight models. Balsa structures are seldom silk covered, as the weight and strength of silk is not usually required in machines of the all-balsa type. However, medium-weight all-balsa 'planes may be very satisfactorily covered with Japanese silk, especially if the wood has been used with a scientific regard for strength.

For the lighter frameworks, as used on ultra-light weight and duration models, the light Japanese tissue papers are required. These may be stuck to the structure with cellulose cement, dope, or a dextrine mounting paste. The latter is probably the best.

If tissues are held up to the light a " grain " will be seen running across the paper. In covering, always apply the tissue with this grain running in the direction of the greatest length. For instance, in covering a wing the grain should run from wing-root to wing-tip and not across the chord. The reason for this is that under the action of dope the paper contracts more *across* the grain than *with it,* and a better finished job is possible if the tissue is used as stated.

Much bad and wrinkled covering is caused through an attempt to cover too much of the structure at once. On small wings this may be successful, but for spans of over 24 inches the wings should be covered in sections, the wing ribs forming convenient anchorages for the paper. It is usually helpful to cover the under-surfaces first. Light tissue paper cannot be applied very tightly, but this does not matter greatly as dope has a considerable tightening effect on paper. The chief concern is to apply the paper evenly, without tight and loose places.

Medium-weight models may be successfully covered with bamboo paper, which may be affixed with mounting paste or Seccotine. Bamboo paper is not suitable for extremely light and fragile structures as it absorbs a considerable quantity of dope, and will therefore contract a great deal, either warping or breaking the framework. It should be applied with the same regard to the grain as is necessary with the lighter papers.

Covering models neatly with Japanese silk is no simple task, the great difficulty lying in obtaining an even tension on the silk. This must be applied firmly and evenly; not too tightly, but without tight and slack places. If these exist the dope will cause the silk to wrinkle at the slack points. Silk should be applied damp, and the greatest length should run parallel with the selvedge edge, in the same manner as the grain of tissue paper. The most suitable adhesive is Seccotine, but, as already mentioned, Scotch glue may be used. Dextrine mounting paste is also excellent.

Unlike paper, Japanese silk may be applied in quite large pieces, in fact, it is desirable to cover as much framework as is convenient at one time. This is possible because silk may be freely pulled and manipulated, and portions may be lifted and restuck as many times as may be necessary. This is impossible with paper, as its frail nature does not allow of much manipulation.

The purposes of doping tissues and fabrics are to render them airproof, to tighten or contract them, and, to a certain extent, to make them less vulnerable to weather conditions. The base of dopes is cellulose, which is obtained from cotton, wood pulp and similar substances of vegetable origin. Dopes are of two types: *cellulose acetate* dopes and *nitro* dopes, the former, in a diluted state, being that generally employed for model work. Nitro dopes are of a heavier nature, take longer to dry and do not contract to the same extent as cellulose acetate dopes. These latter have considerable powers of contraction, but are susceptible to changes in humidity. This means that doped coverings will tighten greatly under the influence of dry warmth, but will slacken out if subjected to moisture, such as is present in the air on damp days.

Doping with clear acetate dope should be done in a warm, dry room, at a temperature of not less than 70 degrees F. If moisture is present in the air, or the covering is not perfectly dry, white patches will appear on the doped surface. This is known as "blushing," and may sometimes be rectified by again doping the covering under dry conditions.

Paper tissues contract considerably more than silk, as the fibres of the paper definitely shrink. Pure silk, on the other hand, cannot be shrunk by water or dopes, but is tightened by the shrinkage of the actual dope itself which soaks into the fibres and draws them closer together.

It is advisable to apply at least one coat of clear acetate dope before using coloured dope, which is obtainable in a variety of colours and also in aluminium. Several thin applications are preferable to one or two heavy coats, and these applications should be left to dry naturally and not hastened by excessive artificial heat.

On extremely light frameworks, the application of even one coat of acetate dope is often sufficient to warp the structure. In these cases a nitro dope may be used. *Banana oil* is the most common nitro dope for our purpose. and is very suitable for doping such things as light tail units. Extremely light, paper-covered models, especially those used for indoor flying, need not be doped at all; the paper being sprayed with water and left to dry. This has a considerable tightening effect, in fact, all paper covering should be treated in this manner before doping.

It should be remembered that nitro dopes and cellulose acetate dopes will not mix, although a coat of nitro dope may be applied over dry acetate dope. This is often desirable, as the outer coating is then not so affected by conditions of the atmosphere. Do not, however, apply acetate dope over coloured nitro dope, as this will dissolve and blister the first coating.

On any but the lightest of models at least two coats of dope should be applied. The heavier machines may require as many as six thin applications, usually three of clear dope and three of coloured.

Wings which have become warped in the making or covering may usually be straightened out by doping and allowing to set whilst secured to a flat board. The wing building jig illustrated in Fig. 53 may be used for this purpose. Thin strips of wood may be tacked to the jig, to lightly grip the leading and trailing edges of the wing. The wing is first doped and then gently forced between the wooden strips which will hold the edges of the wing flat upon the boards until the dope is set. Small weights, placed at suitable intervals, will also aid in keeping the wing in position. It must be remembered, however, that if a wing structure is built badly out of truth this method will only hold the wing true whilst the doped covering is tight. On damp days the covering will slacken, and the wing will, in all probability, resume the warped shape to which it was constructed.

Models intended for indoor flying must be of the lightest possible weight, and for this reason *microfilm* covering has been evolved. This method really consists of using the dope itself for a covering, no silk or paper tissue being utilised. There are several formulae for the manufacture of microfilm, as although clear acetate dope may be used, a special preparation gives the better results. Two popular American formulae are given :—

No. 1 Collodion .. .. ½ ounce.
Cresol Phosphate .. .. .. 8 drops.
Add to the above mixture :—
Ethyl Actate .. .. .. 8 drops.
(If too sticky add a little collodion : If does not form, add a little ethyl).

No. 2 3 parts Collodion.
1 part liquid Ether.

Microfilm mixtures may also be purchased ready made.

The procedure for using microfilm is as follows :—

Obtain a shallow dish, preferably of rectangular shape, and about six inches wide and ten inches long. Next, construct a wire frame, as shown in Fig. 104 ; six inches long and four inches wide. The handle of this frame should be set at an angle to enable the frame to lie flat upon the bottom of the dish, with the handle protruding.

Now fill the dish with water, at a temperature of about 70 degrees F., and submerge the wire frame, letting it lie upon the bottom of the dish. A small quantity of the microfilm mixture is now dropped into the water, and will spread itself as a thin film upon the surface. With some mixtures, a more even film is obtained by dropping the microfilm liquid from a height of about two feet.

In a few seconds the microfilm will be set, and may be lifted from the water by raising the wire framework from beneath. Without touching with the hands, the film is now placed upon the wing or fuselage structure, the edges of which have been lightly smeared with rubber solution as an adhesive. As the dampness evaporates, the microfilm will contract upon the framework and form an even covering.

Wire tails and rudders are invariably covered with oil-proofed silk, which may be stuck to the framework with cellulose cement, Seccotine or Scotch glue. Oiled silk, as it is usually called, has, however, a slippery surface, and is, for that reason, rather difficult to fix tightly with adhesives ; the material slipping from its stretched condition before the glue or cement is set. A better method is to sew the fabric to the wire frame. Care must be taken not to distort the wire framework by pulling the silk too tightly, which will result in a permanent warp.

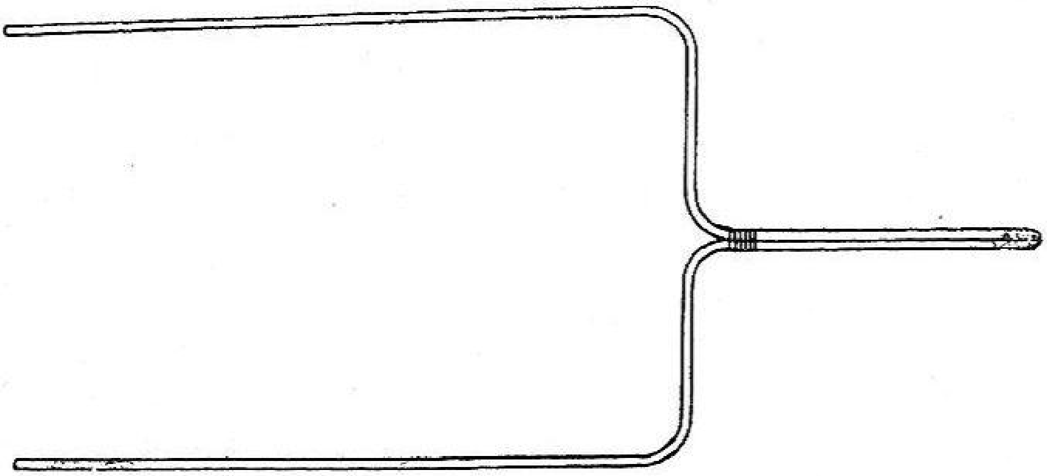

Fig. 104

For some reason a prejudice exists in the minds of some model builders against finishing a model with some form of decoration. This may be because attempts are often made to improve a badly-finished machine by the application of paint ; which attempts are seldom successful. Paint, especially of the cellulose variety, also adds much weight if used lavishly. However, a well-made machine deserves a handsome finish, and may often be rendered still more attractive by the use of a little decoration. Moderation seems to be the watchword, and one should be careful not to overdo things.

Very pleasing effects may be obtained by picking out the edges of fuselage and wings with a suitable colour. For instance, a cream doped aeroplane will look very well outlined in green, especially if the colours are separated by a thin black line. Aluminium and blue or aluminium and orange are also extremely pleasing ; two shades of one colour give a restrained and tasteful finish. Light and dark blue are particularly effective.

Ultra-light-weight or duration 'planes will not usually be decorated, as all superfluous trimmings will be avoided. Medium-weight or heavy-weight machines, on the other hand, may be treated as suggested. Cellulose lacquers are suitable for silk-covered machines, but should be used sparingly on account of the weight. Poster colours are better for paper-covered models, being lighter in weight, but ordinary water colour will not "cover" well on doped surfaces.