A E R O P L A N E S, P A S T, P R E S E N T,

A N D

P O S S I B L Y F U T U R E

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A THESIS

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AIR VEHICLES OF THE PAST

The aeroplane is a natural outcome of scientific investigations. Neglecting the theory of evolution, man first acquired control over land and sea motion in various names, such as walking, swimming, sailing crude ships, by animal drawn land vessels or chariots, etc. What else was there f for him to do but to want mastery of the air? He could go on land, on sea, and under sea, so that air vehicles were logical outcome of progressive minds.

Naturally the first means of propulsion on land was obtained by hand power. Man soon learned that animals could be used with great saving of his own energy, so the development of animal drawn vehicles went on. With the introduction of machinery— most natably the steam engine— mechanically operated engines soon superseded the older constructions. The first few engines were very inefficient according to our present day standards; nevertheless they presented a marked change in methods.

This same thing happened with ships, the old galley ship being probably the best example of a combination of sail and hand power before steam engines were introduced.

Now what is more natural than to have air vehicles following the same routine? In the air we have some few distinct types which are;

1. The lighter-than-air craft
2. The helicopter
3. The ornithopter
4. The aeroplane

1. The lighter-than-air type, or balloon, was the first with which man succeeded in sustaining himself in the air for considerable periods of time. The essential elements are

(a) Space occupied by something lighter-than-air

(b) Heavier-than-air envelope.

These must be so adjusted that the lifting force is sufficient to overcome the weight of the envelope. The first of this type was non-dirigible, or merely designed for ascension and flotation in the air. This left it to the mercy of the prevailing wind, so that it was really of no practical importance for locomotion;- sometimes days had to be spent waiting on a favorable wind. It has been suggested that at different heights in the atmosphere the wind direction changes. With this verified it might be possible to rise to the height giving the best available direction, thus proceeding to the desired destination. It is recorded that balloons were used by the Chinese at the coronation of the Emperor Fo-Kien, at Pekin, in 1306, and it was there stated to be a custom, so that the first was probably much earlier.

A few years after Cavendish published his results on the weight of hydrogen (1766), Tiberius Cavalle inflated soap bubbles with this gas: they floated upward until they burst.

The first balloons are generally ascribed to the Montgolfier brothers, who produced their apparatus in 1783. Their method was to have a large paper bag with a hole at the base. They then lighted a fire of chopped straws underneath it, and, of course, the balloon soon rose. Strange to say, however, the

Montgolfiers did not realize for some time that the lifting power was due to the heating of the air, and not to the smoke.

It was a matter of only a few weeks after this that hydrogen balloons were used. These developed until it was thought expedient to have engines installed. This was a great forward stride, as the vehicle was no longer left to every whim of the wind God. So long as the engine pull was more powerful than the force of the wind the operator had control. In any ordinary wind now dirigible balloons are quite safe, as they can attain a speed of 60-miles per hour without difficulty.

Although these have been successful it is evident to a thinking man that there is very little future for the balloon. It requires costly material, has great bulk, is unwieldly and has great cost of upkeep. It affords probably a better spectacle than the aeroplane, but its usefulness is nearly at its Zenith. The common gas used was hydrogen, but due to its inflammability modern tendency is to replace this with helium making the initial cost still higher, and increasing the volume of the balloon.

2. The second type of air vehicle is the helicopter. This utilizes the lifting power of propellers so as to rise vertically. It is a heavier-than-air machine. There has always been some controversy about this type, as safety does not feel entirely satisfied with relying wholly on the engine. If the engine stopped there is really nothing to keep the machine from falling abruptly. True, the propellers themselves may be utilized for this purpose, but these are generally not suf-

ficient. With increasing dependability of engines this is becoming an increasingly important branch. It would become even more so if an arrangement could be continued for stopping quick descent. This might be accomplished by a sudden opening of a parachute, by quick opening of adjustible wings, or by blasts of air or other gas downwards. The perfection of any of these would increase the feeling of respect towards the helicopter. A continuation of this principle is given at a later part of the thesis.

The combination of the helicopter and the aeroplane is very successful relatively, as in the Bertin, and it is this combination which will probably survive all others for city use, although perhaps not for economy in full flight.

3. The third type mentioned is the ornithopter, which tries to to immitate bird action, ie. by flapping wings. It was expected that because birds have perfect mechanism that this should be aimed at in practice. However, this does not seem to fit man-made articles. Man's greates power is obtained by rotary effects, as exampled in locomotives, ships, aeroplanes, etc.

As the ornithopter follows bird and insect action it would be expected that it was the first type of heavier-than-air machine invented, History goes back a long way with attempts to make a successful one, but the first to produce sustention of any appreciable amount was Degen's in 1809, when, by vigorously flapping large very concave wings he managed to rise 54 feet in the air. He was helped in his rising by a balloon, or by counterweights passing over a pulley, which lifted 90 lbs.

The Hargrave machines of Sydney, Australia, about 1891, emplo yed a combination of the ornithopter and the aeroplane as he used the flapping wings for propulsion only.

The ornithopter so far has not proved successful; the only ones that have been so are models.

4. Our next type is the aeroplane. This has proved very suoe cessful in practice, for sizes varying from models to those carrying 8 or 9 passengers (In Britain there are aeroplanes carrying 24 people) As early as 1910, the Bregnet carried 8 passengers.

Successful aeroplanes have been in use for a long time, but the first flight of a man carrying power- propelled aeroplane was in 1890, when a machine designed by Clement Adew flew for a distance of 164 feet.

The ornithopter was a logical outcome of slow, flapping, bird flight; so there is the aeroplane the successor of quick bird soaring. This phenomenon of soaring is little understood at present, although various theories have been put forward to explain it. One view is to hold that rising currents hold the bird up; another is that the bird uses the internal energy of the wind . It is quite probable, or at least possible, that the real solution lies in combining the rising current idea with that of gliding slowly from a higher to a lower plane.

The propeller action, of course, is wholly man-made, with no analogy in nature of which the author is aware. This is probably due to its impossibility, as a propeller requires two separate parts for operation. Otherwise the whole animal would have to keep revolving at the same speed as the propeller. This animal has never yet been found, but it is clearly shown in the case of falling leaves; the whole leaf turns round rapidly, thus stopping sudden descent. This same principle is sometimes used in the helicopter;-e.i. having the propellers turned round by the force of the wind, or ascending air currents, thus retarding the descent.

The problem of indefinite soaring is one which should be investigated as thoroughly as possible, as it has been held by many very able scientists that it is practised by birds. If man could devise a machine whereby he could travel over the oceans and continents with no power except that necessay to lift him up, present day vehicles would nearly all be scrapped, thus adding still more to the scrap heap of the universe.

Gliders were used for many years before the idea of motor pre pulsion was thought of. Quite marked success with some of the latest of these was found. e.g. the Lilienthal glider of 1891, in which he performed very many successful glides of maximum length 1000 feet and maximum speed of 22 miles per hour. Probably the first real success was the experiment in California. A glider, designed by Professor Montgomery and mounted by Daniel Maloney, was raised 4000 feet by a balloon. At this height it was cut loose, and the glider began to descend, Under complete control all the time, it was finally brought to rest on the spot designated. The speed attained was estimated to reach a maximum of 68 miles an hour, which at that time was truly remarkable.

It is rather strange that after the development that has taken place in the aeroplane there should still be the interest felt in the glider, but even yet there is a great amount of work being done on this apparatus. It might be duet to the hope of discovering perfect stream-line form, with consequently a nearer approach to bird soaring, or it may be that interested amateurs with neither the capital nor the ambition for aeroplane flight are attempting to establish it as a separate machine from the aeroplane, for financial or other considerations. In spite of the successes these have made there would seem to be little future for the glides as a vehicle for the average man. It needs a height to start from, unless it be first towed, and cannot fly successfully for any great length of time. This is constantly improving, but it is not possible (or at least highly improbable) that man could ultimately attain soaring flight. Without this the glider would have to descend so often during a long trip that it would be impractical, as compared with the aeroplane. The ultimate speed is low, and does not come in accord with present day ideas.

It may be noted here that a 30-miles per hour wind on ground generally means a 50-miles per hour wind up aloft, so that this may be utilized by gliders - by first rising to an enormous height, greater then usually attempted with gliders, then employing the wind to propel them on their way.

Gliders have been of widely varying forms. The earliest ones naturally took bird form, the popular bird being the bat. Nowadays the glider follows monoplane design, and thus soaring birds. A few are biplane, and some are double monoplanes, but in general they are engineless monoplanes.

The Ader "Avion" of 1897 was one of the first aeroplanes to fly. It was of a bat-like form with twin propellers, and, judging from its great angle of incidence it must have required great power to travel at any moderate speed.

The Wright biplane of 1903 was a converted glider with a 16 H.P. motor. The pilot was placed out in front, exposed to all the winds and the cold at the height reached, It might be noted that the Wrights had no great success with their machines until after Professor Montgomery of California had published his articles on wing warping. The Wrights produced a type of working very similar to this shortly after, this being not at all like that specified in their patent. A lesson learnt, presumably, from which they profited unduly.

In 1906 the Santos-Dumont box-kite was flown. It had a long body in front with practically nothing behind the operator, and, of course, was not very stable unless flying in the same direction as the wind.

In 1907 a great many machines were put on trial. The most important of these were the Wrights, Voison, Farman, Avro, Bleriot, R.E.P. etc. It is peculiar that nearly all of the aeroplanes built round this time were of the "Canard" type, i.e. had the longitudinal stabilizing surface placed out in front of the machine. This was used by some machines as late as 1913. Probably the sight of the controls gave a heartening effect to the pilot.

The real drawback to the "Canard" type is as follows. The main surface in this is the tail surface which has to be set at a less angle of incidence than the forward stabilizing surface. This means that if the main surface is set at 5° to give lift, the forward stabilizer must be set at say 15°. This gives a very poor lift-drift ratio and consequently poor efficiency at present day speeds. With the low speeds of the first aeroplane this was not noticed so much, but as speeds increased the "Canard" type had to give way to the present model.

It was in 1908-1909 that the biggest advances were made. The triplane was a feature of 1908, but so far it has not been developed to any great extent. The Bleriot machines were greatly improved about this time, and in 1909 came in model XI which is the prototype of all his later successes. He also brought out the "parasol" type, so named because the wings are placed above the observer, giving him a clearer view of the ground.

From Bleriot's type XI to the present day there has been no marked improvement in monoplane design. Each part has been improved, as for example, shape of wings, improved building material, better engines, more efficient control, etc., but in general, the shape is the same now as the 1909 model.

Is it not rather peculiar that monoplanes should develop quickly in a few years from a very crude beginning to this Bleriot model and then stay with this form for about 15 years longer? It is an obvious deduction that this is not the best shape possible. The biplane is practically a replica of the monoplane in characteristics, so they are both treated as one. If this is not the best solution of the problem, then what is? This will be discussed a little later.

THE PRESENT

Nearly every one has seen aeroplanes within the last few years, so it would be a waste of time to describe them. The prevailing types are monoplanes and biplanes, descriptions of which can be had from any aviation magazine or book. One marked tendency is to enclose everything possible — there are practically no machines of the present day which have bodies not enclosed, unless, perhaps, a few experimental ones built for economy. This makes a neater looking machine and, although increasing the weight slightly, improves the efficiency by supplying a steam line form instead of numerous stays and cross bars.

Propulsion is obtained by engine varying in H.P. from 16 to 1000 (The Napier Cub). Of what particular advantage is this variation? The automobile of today has power plants varying from about 10 H.P. to 100 H.P. approximately, but the average is fairly standard round 20 to 40 H.P.

Would it not be an asset in aeroplane design to standardize the power plants for pleasure craft in a like manner?

In the automobile the gasoline engine is the one most commonly used, but there are other types in use, e.g. electric motors and steam engines. Similarly in the aeroplane, although the gas engine is in use in most cases the steam engine also has been used. A remarkably light construction of such is that designed by Hiram Maxim in 1894. It weighed 1800 pounds without water, and developed 363 horsepower, or about 5-lbs. per horsepower. This has been considerably reduced in some of the latest French steam power plant designs.

It may be noted that most of the recent advances have been made in France. With the development of steam turbines the use of these might be advantageous due to the power obtained for light weight, but, so far, for small power they have proved quite inefficient.

The electric motor has not been applied to the aeroplane with any success, due to the weight involved, the lowest yet recorded, we believe, being in excess of 6-lbs. per horsepower. The aeroplane gasoline motor is very decidedly lower than this, varying from 1.8 to 3-lbs. per horse power generally. Various other methods have been used.

Compressed air, enclosed in steel cylinders under high pressure, has been used with models, but, on account of weight it has been practically dropped from aeroplane work. Indeed any method of creating pressure of a gas then suddenly letting it expand under a surface would make the surface rise. Thus chemical action could be used. Various other devises are discussed in the later part of the thesis.

To discuss possible future developments of the aeroplane intellignetly, and to put forth predictions requires a knowledge of the essential points of stability in design. If these are not satisfied, the aeroplane, no matter how well it may look, is doomed to failure, so that a few notes on stability here would be advisable.

The stability of an aeroplane can be divided into 3-classes

(1) Longitudinal stability.

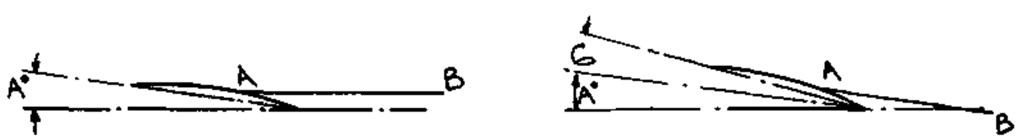
(2) Lateral stability

(3) Directional stability.

(1) <u>Longitudinal stability</u>.

This is pretty well worked out in aeroplanes. It has been understood by most, if not all, of aeroplane experimenters, and very few have overlooked it entirely.

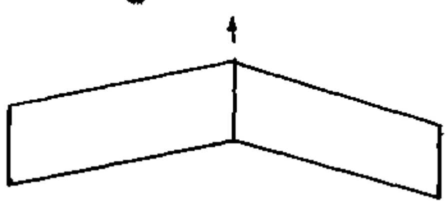
It can be explained by reference to the diagram. A is the lifting surface of the aeroplane. At the normal angle 'A'



it is sufficient to lift the whole machine. B is the tail or stabilising surface, set to produce no lift at the normal angle. If the machine were to pitch nose upwards as shown in second sketch thro' angle 'G', the center of pressure of 'A' would move forward, which will tend to increase the pitching. The tail surface B, however, comes into play. It now has an angle G and consequently a lift, tending to swing the tail upwards and restore the normal position. Similarly for a nose down effect. The total lift on A as the machine pitches nose upwards will not increase much as the speed will slow down due to the increased resistance. This is the principle mostly used in practice.

It is required that the angle of incidence of the tail surface should be set at a less angle than that of the main surface, as just explained: but it does not mean that it must be set at a less angle with respect to the center line of the machine, for the air passing the main surfaces is deflected downwards, thus altering the angle with which it meets the tail. If this deflection be sufficient the tail and main surfaces may be set at the same angle. This gives a "Relatively smaller angle of incidence".

The following method is sometimes used. If direction of motion



is as shown, and wings tipped back, then the same effect is obtained.

If the center of head resistance is above the center of gravity of the machine an end on gust will tend to throw up the nose, and during its dying away to dip the nose, thus exaggerating the movements due to the stabilising force. This is objectionable. If the center of head resistance is below the center of gravity the forces will oppose the stabilizing effect. This is dangerous. It is obvious then that the center of total head resistance of the machine should be as nearly as possible in the same horizontal line as the center of gravity.

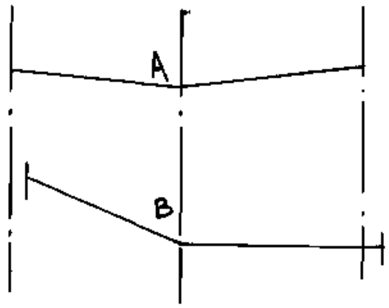
To ensure that the machine takes up its natural gliding angle if the engine were to stop it is necessary to have the center of gravity a little in advance of the center of lift, so as to give the nose-heavy effect required. If the center of gravity were behind the center of lift, the machine would slow up, turn vertical and fall straight down.

The maximum efficiency is obtained from the propeller when the thrust is horizontal. It is therefore desirable to have the thrust horizontal and a little below the center of drift to overcome the nose-heavy effect when flying. Immediately the engine stops the machine naturally takes up its gliding angle as above, leaving the pilot free from this worry.

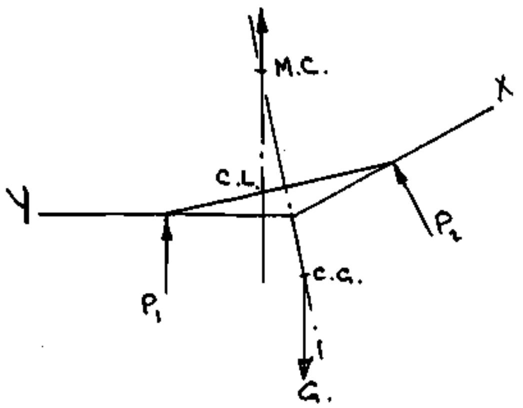
(2) Lateral stability

This is the form of stability which ensues that an even keel is attained on removal of disturbing forces. If the wings are placed with a dihedral angle, as shown, this is obtained provided that the center of gravity of the machine is not too high.

In the normal position A the machine is stable. If it is



tilted to B there is a greater length on the right than on the left side, so that there is a greater lift, the lift varying with the horizontal component of the wing surface. This therefore brings back the machine to an even keel. If the engine stops when the machine is as at B there will be a greater resistance to downward motion at the right than at the left, so we have stability as before.



If the machine tilted as shown the center of lift C L will change. The vertical line for the lift through C L will meet the center line of the machine (on which the center of gravity must lie) at M C . As before, if C.G. is below M.C. stability will result, but if it is above, the machine will capsize. If the C.G. is too low the machine acts like a pendulum, but this is not dangerous, so is preferable to the other. It will be noticed that if a gust of wind blows from the right X will be raised up and Y lowered, as X has a positive angle of incidence and Y a negative one. This could be corrected by putting a fin or vertical plane below the center of gravity. The fin could be made large enough to counteract the side force. The keel surface should be equally divided above and below the horizontal turning axis, otherwish a gust of wind would blow the heavy side over.

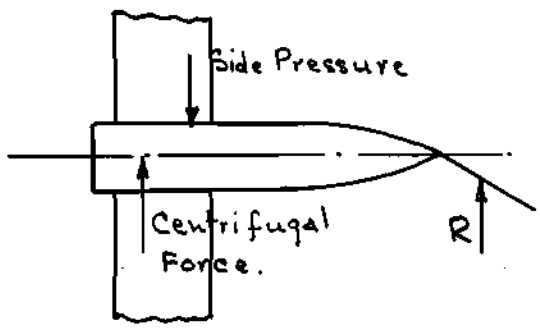
(3) Directional stability

If an aeroplane had not this stability it would be deflected from its course by every gust of wind, which is by no means a desirable feature. An end-on gust, of course, does not alter the course, but a side wind will give increased resistance to the unshielded wing. This wind also will tend to turn round the body, pins, etc.,

It is obvious, therefore, that the line of action of the total resultant side pressure must act through the center of gravity of the machine. This results in mere bodily motion sideways and eliminates the turning effect. This is a highly satisfactory state until it is realized that the center of side pressure varies with the direction of the gust. Complete balance under all conditions is therefore impossible.

If the center of side pressure is forward of the center of gravity the nose of the machine will turn with the gust, and the machine will run with the wind. This will momentarily reduce the air speed, which is dangerous, On the other hand, if the center of side pressure is behind the center of gravity the nose of the machine will turn into the wind and thus cause an instantaneous increase of speed, which is quite a safe matter. It is therefore desirable to have the latter effect I.e always to have the center of side pressure behind the C. of gravity. This could be helped by having keel surface behind.

A much more important aspect arises when the machine is turning under the action of the rudder. If the rudder is turned



as shown in sketch, a force R will act. This will make the machine move a little side-ways, thus causing a side pressure to act. The turning effect due to these two forces causes the machine to revolve, which immediately introduces the action of the centrifugal force through the center of gravity. When the three forces acting are in equilibrum the machine turns steadily and, on removal of R, the others disappear.

Suppose now that the center of side pressure is in front of the C of G. Immediately R acts the three forces tend to make the machine revolve and there are no balancing forces, so that even if R were taken away the machine would still keep revolving faster and faster. It should also be noted that as the turning increases the center of side pressure moves forward, thus increasing still more the couple applied.

This effect is obtained even without the rudder. Suppose the machine is banked, i.e. has one side risen higher than the other ,- then if it slips downwards we have the side pressure acting, and also the inertia of the machine. The turning of the machine requires more air speed for its new path, and if this is not obtainable from the machine it must be taken from gravity; thus we have the deadly spiral nose dive. It is obviously necessary then to have the side pressure kept small and to have the C. of pressure of the vertical fins behind the C. of G. of the machine. Vertical fins above the C. of G. should be avoided as they are decidedly dangerous for the reason above. It should be noted that if the fins are placed too far back a great force on the rudder will be necessary to keep equilibrium, so that some judgment should be used in determining its position.

Such then is a simple explanation of the essentials of aeroplane design. We now come to a discussion of future machines.

FUTURE

The mathematical study of aeroplanes is not an exact science, except in some very few parts the formulae used is aeroplane design are empirical: even our master matheticians are content to accept these in preference to their unproved theoretical ones. If such then is the case, is it not much better to treat this subject in the light of previous performances than to apply theoretical formulae in parts and practical knowledge at other places? Such is our method of dealing with the subject.

The power-driven aeroplane of today has only been on the market successfully for a very few years. It is as yet only in its infancy, and is still regarded in some quarters, as a clever experimental piece of work: fortunately this feeling is not prevalent in intellectual circles. But we think the public should realise that the aeroplane is the probable vehicle of the future, or at least, some branch of power driven heavier-than-air machine will surely supercede the present day locomotive, street cars, automobile, etc.

For a long time after the introduction of aeroplanes the mere mention of the subject was sufficient to bring an icy chill to the back of the listener, with thoughts immediately conjured up of a dare-devil pilot steering a shaky monstrosity skywards, and the sudden dropping to earth from a tremendous height, with direful results. This feeling is still surpris - ingly popular. The same sentiments were felt at the intro- duction of the steam locomotive and the automobile, though, of course, in a much less degree. But these feelings show the inertia of the public- it takes a long time for a new idea to soak in.

One of the main enemies of aeroplane advance is this same trait of fear, which, to a certain extent, is a habit of mind. As an example, during the first few years of the automobile it was looked on as a death-dealing instrument: as a matter of fact, comparing the passenger- miles of auto, and horse drawn vehicles the latter is responsible f for far more fatalities than the former. Such is the case with the aeroplane and the auto. Except in cases of warfare the aeroplane has far fewer fatalities per passenger- mile than the automobile, but to say so to an auto. driver merely gets a pittying look. To see of an aeroplane crash in the papers is quite an event, and to lift up one without seeing three or four auto. crashes is also quite an event. Familiar- ity with ordianary travel soon breeds contempt of its danger. Thus, although tens of thousands of people are killed per year by autos, no more is thought of riding in one than is walking round a block. If the aeroplane were brought more into public notice with actual statistics on accidnets as com- pared with other modes of travel it would very quickly pick up trade and popularity. This does not mean, however, that the aeroplane is not dangerous. It is, but relatively it is not.

There are some very sound reasons for predicting that air vehicles are the means of locomotion of the future:— these are as follows.

(1) Initial cost of light aeroplane is much less than that of motor car.

(2) Upkeep per mile of travel is less.

(3) Higher speed is obtained for same power.

With a light plane of type explained in (9) 82 miles per hour was obtained.

(4) The automobile operates on one plane only, but the air has an infinite number of planes, thus congestion would be avoided to a great extent.

(5) The wear and tear of roads would be less, thus road upkeep expenses would fall, and therefore those taxes paid by private auto. owners would practically be eliminated. Of course, commercial cars might still be in use, and these would have to bear the burden of road upkeep. The amount per person would be very little more than now.

(6) The weight necessary for passenger carrying is decidedly reduced from autos, which weigh from 1000 lbs. upwards, neglecting passengers, while the light monoplanes go from 200-lbs. up. It is true that the motor car is used for more than one or two passengers, but very often, as with coupés it is used for this purpose only.

(7) Similar to (2), but not quite the same; the gasoline and oil consumption per mile with good soaring light plane would be much less than with auto. With an English light plane 87½ miles per gallon of fuel was obtained. Automobiles give generally 20 miles to the gallon, although some give a little more.

(8) Increased safety. This has already been explained.

(9) Increased comfort. There would be comparatively little dust or exhaust gases from vehicles in front.

(10) Increased pleasure in surrounding scenery. Is it not true that we enjoy the view from the top of a mountain better than from the bottom?

(11) Great cleanliness of the atmosphere due to practical elimination on ground level of the refuse of gasoline motors.

(12) With more advanced knowledge of bird action and on internal and external characteristics of the wind, it is probable, and, indeed, a certainty, that nearer approach of aeroplane flight to bird soaring can be reached with corresponding loss in fuel or increase in economy.

(13) With the type of aeroplane the author has designed, aeroplanes could be used in cities, letting house tops act as landing and starting fields, instead of having autos. strewn all round the business centers. Instead of this, they could be parked at the side of the street as autos, are at present, as street cars would to a great extent be out-of-date.

(14) Due to the various factors maintained, an increase in health would come naturally.

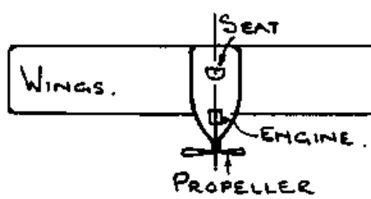
These reasons could be kept up for a long time, but enough has been said to show why aviation is the probable future mode of travel.

We now come to the design of aeroplanes.

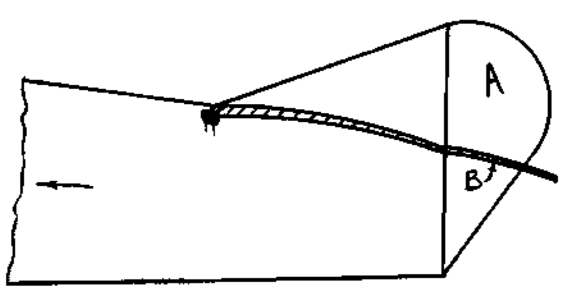
The first requisite is wings, if an attempt at soaring is to be made. (Later on we will discuss designs neglecting wings)
Since wings are a necessity, let them first of all be as simple as possible. i.e. let there be only one plane. Also will be required a place for the pilot to sit. (In the first case, for simplicity, we neglect any passengers). To have him sitting down in the open would be unpleasant, so we shall cover him up much as is done in the present aeroplane. The result is as an aeroplane minus the tail. The shape of the body will be much like a shell, back first. It was formerly

thought that having a pointed front was an advantage in reducing air resistance, but this has been proved a fallacy. The reason for this is possibly that the body carries in front of it a cone of air which remains there just as an integral part of the body, thus doing away with the necessity of having a pointed nose. There has to be a means of propulsion. Let us take for this a small gasoline engine of light weight, and a propeller. This propeller can be put either at the front or the rear of the machine, but for the first design it is desirable to have it at the rear. The reason for this will be plain when the reversing gear is explained.

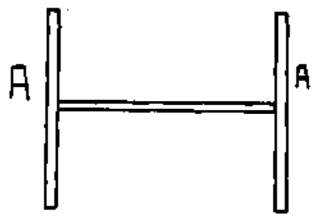
We now have the result shown.



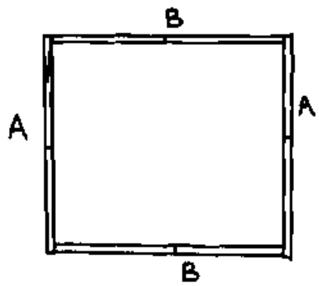
To control the machine we must have a rudder and an elevator. This is where standard practice is very decidedly changed and improved. With the present day aeroplane the controls are as shown. The small vertical plane A is the rudder, which gives the directional control, while B is the elevator. Now instead of having one plane A, let there be two, some little distance apart, and let these be of triangular form. We then have something like this, looking from the rear.

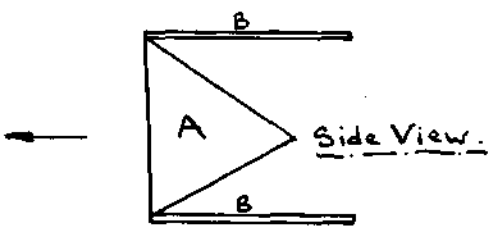


Similarly, instead of B, let two horizontal planes be



used, with the same distance between them as the height of plane A. We then have this, a square looking from the back, or tail of machine. From the side we see A.A. as triangle similarly from above we see B.B. as triangles. It should

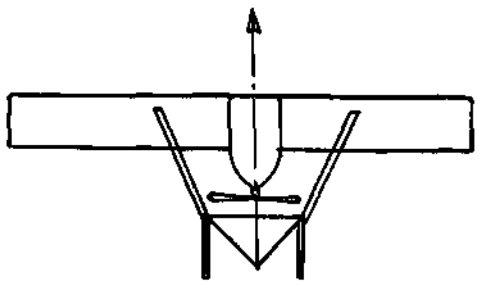




be borne in mind that bi-planes have been developed mainly to give a greater lifting power per sq.foot of horizontal area, and thus reduce the gross weight per sq. foot of surface. It is then evident that if the four surfaces are used as rudders a more efficient tail lifting surface is obtained. As these are not so far from the main planes and center of gravity as is usual, a greater force would be needed to hold them in position when turning or climbing, but with two planes as A A, the force on each would be halved and would counteract this effect.

If we now fasten these to the machine we get the following result. The method of fastening them to the machine is of no consequence in the meantime. They would probably have to be fastened to the body, but for convenience we show them

fixed to the wings.



The machine is now a pusher monoplane. Suppose running gear engine necessities such as oil, gasoline, etc. are added, we are now ready to start. What advantage, you may ask, has this increased control area given? The reasons are these.

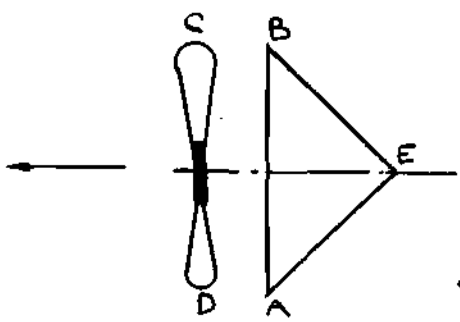
If the aeroplane is going to move forward, the four triangular plates are open, as shown above. With the engine started the machine would move forward, and at the right time the B plates would be moved upwards slightly, and the aeroplane would rise from the ground. Now all these triangles are such that they can either be moved separately, or the two A's or two B's moved together. If the direction needs to be changed, A is used. Not if all four are moved inwards till they meet, the result is a closed hollow square pyramid. The propeller is continually turning, but the air from it is being pushed into the pyramid, so that instead of pushing forward, the propeller is pushing the machine backwards: if a quick stop is required once the machine has touched the ground, the pyramid can be formed and the aeroplane stopped practically at once. This is a decided asset.

If the plane were moving at its maximum speed in the air and it came suddenly on to some obstacle like a church tower it would be able to slow down the machine sufficiently to turn away or turn upwards. Care should be taken, however, on slowing down in the air that the speed does not get below the minimum speed, otherwise the aeroplane would drop. This could be rectified by turning the machine vertically and using it as helicopter. Then again a sudden slowing down is dangerous while in the air, so perhaps after all it would not be advisable to use it much when at a height.

If automobiles were built without brakes what havoc would be wrought: no car could go at a greater speed than one or two miles per hour in a city, otherwise an accident would be bound to take place at street corners. If we wanted to stop at some particular place we would need to shut off the engine or put it into neutral, and coast along until the machine stopped. This would be an intolerable state of affairs and, to us, is laughable. Yet this is the case with the modern aeroplane. It has no brakes, and is allowed to coast until it stops. The method of stopping is to "bank" the plane, or lower the tail, thus giving a greater head resistance. With ordinary planes this is not sufficient to stop it within an ordinary seven-acre field. With some of the best light planes recently tested at Lympne, in Britain, they managed to stop in 70-yards, or about 210 feet, and to rise in 210 yards or 630 feet, these are quite exceptional. A good bit more could be accomplished in this direction by a raising of the rear controls, thus allowing a greater banking effect on the ground; unless exceptionally great banking were made it would not be equivalent in any way to the effect of the reversing control already described. Care must be taken that the raising of the controls does not give more keel surface above than below the longitudinal line of motion.

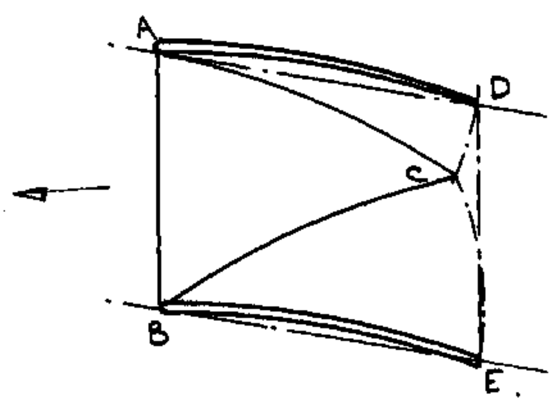
But quick stopping is not the only function of this apparatus. It can be proved that if instead of a square pyramid, a hemisphere is used, the backward velocity attained would be 33 1/3%, but 20% could be expected with good shapes.

<u>A proof of this is as follows</u>.



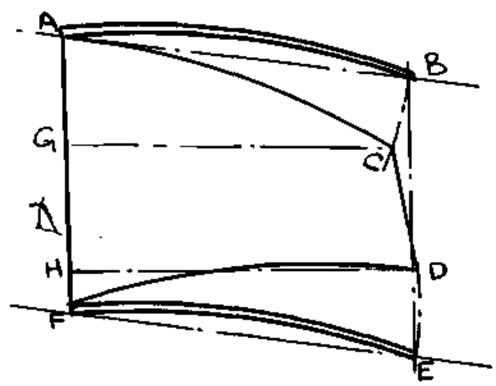
ABE = pyramid
Assume AB > CD. CD = propeller
If ABE were a semi-sphere, and machine moving forward at ten feet/sec. with controls open; let us close these and see what happens. Let the backward speed = X feet/sec. The relative velocity of air and machine is now (10-X) feet/sec.. The air is completely reversed and brought to

a standstill, if perfect mechanism. For maximum efficiency $X = \frac{1}{2V}$ where V = relative volume of air and machine .·. 10 - X = V.·. For maximum efficiency, $\frac{10 - X}{2} = X$.·. 3X = 10. or X = 33 1/3% of forward maximum speed. But this shape of reversing mechanism does not conform to best practice in aeroplane design. The elevators should not be plane triangles , otherwise the lifting power of these would be very greatly reduced, so that it is advisable to modify this by using curved surfaces like the main wings. The rudders are not extraordinary, and if made of plane surfaces would be no great change, as they do no lifting, The shape would now be this.



Side elevation

C would be approximately mid-way between D and E, so that each elevator would move nearly the same amount. The curved surfaces AD and BE could be made of standard design for tail surfaces. The curve BC is made in such a way that when BE is fully closed it will coincide with BC. Similarly for AC. The chords AD and BE would be set at a smaller angle of incidence than the main lifting surface, for longitudinal stability, as explained in chapter relating to that branch. Although this design is all right from a theoretical point of view, the probability is that either the elevators or the rudders would be too small, as it would be presuming too much to assume that they should be equal. If the rudders are too small compared with the elevators the difficulty can be got over in the following manner. If AB and FE were



similar, as in the first case, then CG and DH, the perpendiculars on to the swivel AF would not be equal in length and on closing the rudders the points C on each would not touch. This could be rectified by having AB longer than FE such that when fully closed B & E will lie on a plane parallel to AF. If the elevators need to be made longer than the rudders the same process could be followed.

We have now settled the shape to a certain extent, so we can proceed to the calculation, using approximate weights. For these it would be advisable to use figures similar to those in use for materials, structures, etc., as it is the intention of the author to make his predictions on present day perfection, and not on some fanciful figures which may never be realized.

The motor decided on for first consideration is the Darracq, which weighs 66-lbs. and develops 35 H.P. The decision was made on account of lightness. Other machines can be designed with a heavier and more powerful engine, wt. of engine = 66-lbs. With oil, gasoline, etc. for say 3-hours journey the weight would probably be brought up to round 130-lbs. Weight of propeller and hub equal 10-lbs. Total engine weight = 140-lbs. for 3-hours journey. Gross weight = weights of engine + passenger + seating + body + wings + instruments + landing gear + controls + reversing gear.

According to C. D. Hanscom in Kent's Mechanical Engineer's Handbook the following figures give approximate values.
Weight of body 9-lbs.
Wt. of wings with bracing = 1-lb./sq.ft.
This is for a plane heavier than ours, so we can assume .8-lbs./ sq.ft.
Weight of equipment = 4% of gross weight.
Weight of landing gear = 6% (maximum) of gross weight.
Weight of tail structure including pins and rudders equal 1.2 (maximum) lbs./sq.foot.

Gross weight = 140 + 160 +10 + 10 + wings + 10% of gross weight + tail structure.

Assume that the machine lifts 7-lbs. per sq.ft. of wing area. (The Bristol monoplane lifts 8.9-lbs. and the Loening M 8 monoplane lifts 9.9 lbs. /sq.ft., so 7-lbs. per sq. ft. is a reasonable assumption)

Assume tail structure weighs 20-lbs. ∴ .9Gross weight equal 140 + 160 + 10 + 10 + (.8 x $\frac{\text{Gr. Wt.}}{7}$) + 20 = 340 + .11 Gr. Wt..

∴ Gross weight = $\frac{340}{.79}$ = 430 lbs.

This includes passenger of 160 lbs. weight ∴ net weight engine, oil, gasoline for 3 hrs. = 270 lbs.

It will be realized that this is cutting very close to the limits attainable, so, for safety and to pacify any scoffers we shall raise the gross weight to 460 lbs., or an increase of 30 lbs. over our calculated weight. Surely this accounts for more than the slight errors due to inaccuracy in average figures of aeroplanes.

From the figures given above, the wing area = $\frac{460}{7}$ = 66 sq.ft. approx. wt. of wings = 66 x .8 = 53 lbs. If aspect ratio = 7 then 7 d^2 = 66 ∴ d^2 = 9.43. ∴ d = 3.07' Span = 7x 3.07 equal 21.5'. ∴ Wing is $21\frac{1}{2}$ feet x 3 feet.

∴ Wing area = 21.5 x 3 = 64.5 sq.feet.

∴ Lift = $\frac{460}{64.5}$ = 7.1 lbs./sq.ft.

This is a light monoplane, and to carry 7.1 lbs/sq.ft. is perhaps asking too much of the flimsy wings, so we shall increase the wing area to 80 sq. feet. This increases the wt. of wings to 63-lbs.

If aspect ratio = 7

$7\ d^2 = 80 \qquad d^2 = \frac{80}{7} = 11.43\ . \qquad$ i. $d = 3.38'$

Wing span = 3.38 x 7 = 23.7'

∴ Wing is <u>24 feet x 40 inches.</u>

This gives a lift of $\frac{460 + 10}{80} = 5.9$ lbs./sq.ft., The gross weight has to be increased to 470 lbs. due to increase in wing area. The lift /horse power = $\frac{470}{35} = 13.4$ lbs., The lift obtainable in some British light planes is 80 lbs. per H. P., so no difficulty would be experienced in obtaining 13.4 lbs./H.P.

It should be taken into account that the British and the French are some years in advance of America in light plane design.

Lift = Ky AV^2 = $>$ 470 lbs.

Where Ky = Coefficient for the machine

A = area of wings.

V = relative velocity in feet /sec. of wind and machine

Ky is nearly independent of A & V if the angle of incidence remain constant.

Lift = L = Ky AV^2

Drift = D = $K_x AV^2$

From" Aeroplane Design"

by F. S. Barnwell, for a load of 5.9 lbs./sq.ft.

Ky for a monoplane = .00207 for minimum speed.

$\therefore$ L = .00207 x 80 x V^2 = 480 lbs. say.

$\therefore$ V^3 = 2900 $\therefore$ V = 53.8 ft/sec.

$\therefore$ minimum speed = 37½ miles per hour.

It may seem that the high aspect ration is unnecessary - it was chosen for economy in flight. Less fuel would be necessary for this machine then with a 5 ; 1 aspect ratio. The latter is the average for monoplanes, and gives a higher velocity acquired due to the lessened head resistance. It is obvious that either one could be chosen, depending on the ultimate result desired.

The author has decided, for first estimate, to compare with monoplanes already designed and verified as to speed,

The Midwest light Monoplane.

Wing span 24 feet.

Length overall 15 feet and 2 inches.

Wing chord 40"

Wing section similar to Martin No. 2

Wing area 80 sq. ft.

Weight empty 230 lbs.

Cruising range 300 miles.

<u>The Avia Light Monoplane</u>

Span 31 feet.   Length 18 feet.

Wing area 114 sq. feet. Useful load 220 lbs.

Weight with 16 H.P. Vaslin Motor 275 lbs.

Total weight 495 lbs. Wt. of fuel 35 lbs.

Cruising range 3 to 4 hours.

High speed 74 miles / hour.

With a gross wt. of 495 lbs. and a motor of only 16 H.P. this machine attains a speed of 74 miles/hour. If the gross weight be reduced to 470 lbs. and the power increased to 35 H.P. it would seem fairly plausible to assume that the speed would be increased very appreciably.

The resistance varies approximately as the square of the velocity, so if the resistance at 74 miles per hour for e each plane is the same, then the speed obtainable with the larger engine would be $74 \times \sqrt{\frac{35}{16}} = 110$ M.P.H. As a matter of fact the resistance of the Avia would probably be greater than that of the other due to its larger wing area and tail. However, even if this speed were not realized, and only 100 M.P.H. could be got, it would be quite sufficient for the purpose for which it was designed. But this is all the function required of an aeroplane, — being able to rise off the ground and to fly at a reasonable pace towards the desired destination.

Another sample of this nature is the German monoplane "Udet Collbri", the general information on which is as follows:

Span 32 feet 10 inches. Height 6 feet.

Length 18 feet. Wing area 135 sq. feet.

Weight empty 330 lbs.

Weight loaded 550 lbs.

Wing loading 4.1 lbs./sq.ft.

Engine 500 CC Douglas.

Fuel capacity 4 hours.

Speeds 75 to 31 miles/hour.

Climb to 3300 feet in 8 minutes.

Range's. 300 miles.

Power loading 30 lbs./H.P.

Now we come to the helicopter principle. This is, by having propellers or other rotating elements on verticle axes, to enable the machine to rise perpendicularly to the ground. The helicopters of today are of many and varied designs. The main drawback seems to be that no reliance can be put on the machine if the engine were to stop; with some the enormous propellers act as the safeguard against falling, while with one of the best (the Berliner), the lifting screws are on the wings and tail of the machine, which is in reality a combination of aeroplane and helicopter. It is of practically standard triplane design except for the lifting screws.

One of the main objections is the tremendous power necessary to lift the machine against the resistance of the wing area and body. Would it not be a decided advantage if the whole triplane could be turned on end, and let the wings pierce the air instead of presenting a blank wall to it? This of course is not practical with any of the modern types, but with the design submitted a few pages before the tail is not long enough to present any difficulty. Wheels or skids could be placed behind the rudders so that the machine could stand nose up. The chord of the wings was made 40 inches, and the total length would be under 8-feet. One difficulty in using this construction is that the propeller most efficient for taking the aeroplane horizontally would not be the best for vertical flight. A compromise would have to be made.

The Berliner Helicopter weighs 1950 lbs. with pilot and fuel for 20 minutes flight, and has a 220 H.P. engine. (Taken from the Mid-November issue of Mechanical Engineering of 1924). The two air screws are 15 feet diameter and turn at 560 R.P.M. We see some difficulty in the size of propellers. If they were to be greatly reduced in size the efficiency would fall, but it would materially help our case. It is obvious that the Berliner gives a lift of about 9 lbs./H.P. The other design would need a lift of about $\frac{470}{35}$ or 13.4 lbs./H.P.

The resistance to vertical motion is greatly decreased so that a higher rate that 9-lbs./H.P. could be expected. The very high rate of 13.4 lbs./H.P. might not be reached at the same rate fo speed as the Berliner, but a little sacrifice of a few feet/sec. in vertical flight is of very little consequence when the extreme simplicity and economy are considered.

If Damblanc's helicopter had not been wrecked before its figures were verified we might have been tempted to take his calculations to show the possibility or our own. Whith his machine, the gross weight = 2640 lbs., and the power of the engines = 110 H.P..

$\therefore$ Lift = $\frac{2640}{110}$ = 24 lbs./H.P. This is a result far in excess of what would be required for our own design, but of course his propellers would be much more efficient due to their enormous sizes. Damblanc estimated his initial climbing speed at 10 ft./sec.

The various other helicopters are of too complicated a design to be at all a commercial success, although they may be more effective for their purpose.

If we assume that our design could be used as a helicopter we can perform a few calculations to see what might be expected with regard to speed, etc. Let the propeller be

4 feet in diameter. Taking as our authority "Mechanical Engineering", Table 3, page 740 of the Mid-November, 1934, issue, we have the following.

Horse power available. = 35.

This is our total, but all of this is not wanted for lifting so we can assume that the R.P.M. are throttled down to 900.

Take $\frac{T}{P} \times Dn = 940$ (Figure from table).

$\therefore \quad \frac{470}{P} \times 4 \times 15 = 940. \quad \therefore \quad P = 30$ H.P.

P = power required

N = revs. per second.

T = thrust to be overcome.

D = dia. of propeller.

V = velocity in feet/sec/

From table, $\frac{V}{nD} = .269$ for $\frac{T}{P} \times Dn = 940$.

$\therefore \quad V = .269 \times 15 \times 4 = 16.14$ feet/ second.

$\therefore$ Our machine can climb vertically at a speed of 16 feet per second. This is rather doubtful, as the propeller is so small that the figures used would probably not apply too closely. However, it gives an idea of what might be expected in this line.

It is one of the essential principles in vertical flight that the propellers should be large, while with horizontal flight very large propellers are usually avoided. The dia. of a 4 feet chosen is possibly too small for vertical flight, but if it were increased to 8 feet great advantages would ensue in flying upwards. If this be too big for the R.P.M. of the motor it could be geared down by a simple chain and sprockets to the required speed. The size of rudders and elevators would then have to be slightly increased, although not necessarily to 8 feet square.

These figures above have been worked out for vertical flight only. It is the general practice of helicopters to rise in a vertical direction without any preliminary side motion or f forward flight. With the combination helicopter and aeroplane the lifting power would be very appreciably increased by first running along the ground and attaining a horizontal velocity. This would have the same effect as rising on a steep angle after leaving the ground. With our design this matter is easily attainable, as we only need to rest the machine at an angle with respect to the horizontal or vertical. The thrust of the propeller could be resolved into its horizontal and vertical components, the horizontal part accelerating the machine along the ground until the lift is sufficient to raise the machine. This method of rising in a very steep angle would probably give better results for this type of aeroplane than vertical flight, as it would very likely be more stable, and much more easily brought into the horizontal plane in the air. There might be some difficulty in determining the various factors for stabiltiy for this combination but we have no doubt that a way could be found ultimately. It is evident that with an angle to the vertical of about 10° the lifting power due to the propellers is approx. its vertical lifting power x cos 10°; but to this must be added the lift due to the vertical component of the wind pressure of the wings, which may be quite considerable with favorable wing shapes. Since sin 10° = .1737 there must be quite a big force pulling horizontally. The best angle could be obtained by trial of the machine. With 15° to vertical, loss of lift $< 3\%$ & horizontal component 25% of lift. The righting of the aeroplane in the air would be more readily accomplished with the four steering planes than with the two ordinarily present so no fear need be held on this account. It must be taken into account however that on changing from horizontal to vertical motion the center of pressure on the wings is moved slightly forwards at first and the aeroplane tends to turn over If the center of pressure coinsides with the center of gravity then the aeroplanes would spin round a horizontal axis through this point. If the center of pressure is below the center of gravity we capsize probably. The variation required for the two perpendicular motions might be obtained by calculation: if not, it could be rectified by having movable weights, although this practice is by no means to be recommended. If the pilot wanted to loop-the-loop the same difficulty would be found with this aeroplane as with any other, except that due to its nearness to the C.Pressure the tail structure would have to be altered.

Stability is maintained in the same manner as shown in a previous chapter, nothing extraordinary having taken place in this line.

For economy, and reasons explained later, ailerons have been left out of consideration.

We have now completed the rough design of the machine, and we set down our estimates of the probable results.

Wing span ---- 24 feet.

Chord -------- 40 inches.

Wing area----- 80 sq. ft.

Gross weight including passenger of 160 lbs, oil and gasoline for 3-hours.------ 470 lbs.

Lift = 5.9 lbs./sq.ft.

Power lift = 13.4 lbs./H.P/

Net weight = 216 to 246 lbs., without passenger oil or fuel.

Actually calculated, net wt. = 216 lbs.

Total length under 8 feet.

Probable speed range = 37½ to 100 miles per hour forwards. (With the quick stopping device the minimum speed need not be very low).

Maximum speed backwards = 22 miles /hour.

Vertical velocity = 16 ft./ sec. calculated.

Probably only 10 ft./ sec. in reality.

Power necessary for this climbing = 30 H.P.

Power of engine = 35 H.P.

Wt. of engine, dry = 66 lbs.

Two cylinder Darracq type.

It must be admitted that this conforms fairly closely to standard design in the matter of lift, weight, etc., but it will be seen that there is a general all round improvement due to its lightness, high horse power for a given wt., and its quick rising, stopping and reversing principle.

We might show a few figures to derive the probable space necessary to stop the machine after touching the ground.

Assume that the speed on alighting is 25 miles per hour. This is quite within reason as it will have been stopped slightly before touching ground. On touching assume that the engine is suddenly accelerated up to its maximum; 22 miles per hour is obtainable backwards.

We have then to find out what distance would be traversed forward before the machine would come to rest.

22 miles /hr. = 32.3 feet/sec.

Resistance must be R, where R x 32.3 = 35 x 550.

$\therefore$ R = 597 lbs. This R is due to tail alone. With half of wings, etc., assume minimum of R 600 lbs.

Now force = Mass x acceleration.

$\therefore$ 600 x 32.3 = 470 x α

$\therefore$ α = 41.2 feet/sec^2.

25 miles /hr. = 36.7 ft./ sec.

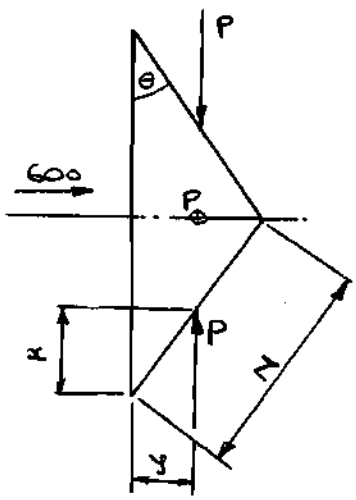
$\therefore$ Time to come to rest = $\frac{36.7}{41.2}$ = .89 seconds.

$\therefore$ Distance traveled = $\frac{1}{2}$ x 41.2 x $.89^2$ = 16.4 feet.

$\therefore$ After touching ground all the space necessary for running is < 20 feet. This is a most marked advantage over the ordinary plane, which requires from 200 yards upward to start and about 80 yards to 240 feet upwards to stop. How many accidents would have been avoided had this been fitted before? If a pilot stops within 20 feet of a hedge he generally imagines he has just escaped from Kingdom come. How would he feel if he only touched ground there?

At the recent light aeroplane meeting at Lympne, England, the first prizes for quick starting and stopping were given for approximately 210 yards and 70 yards respectively. These are very exceptional, the general numbering much higher than this.

The resistance we found to be about 600 lbs. It may seem that this is a tremendous force and would be beyond the operator's control in handling. Sufficient leverage could be brought into play however to enable him to move each control. As he only moves two at a time the resistance offered to the first two would be considerably less than this, and it is only with the last two that the big pressure would be required.



When closed there would be four forces P acting to counterbalance the resistance. Let θ = angle shown.

∴ Each force accounts for 150 lbs.

∴ If P is in the center of pressure of the triangle, we have, 150 x X equals P x Y.

If P is in the center of pressure of triangles, then both forces act through one point.

$\therefore \frac{Y}{X} = \tan \theta$.

$\therefore 150 \times X = P \times X \tan \theta$

$\therefore P = \frac{150}{\tan \theta}$

The larger θ is the smaller is the force,P so that a suitable value can be found from this equation.

Now if P does not act through the C. P. of the triangles, then 150 x X = P x Y but $\frac{Y}{X}$ is not = tanθ . If it is a triangle then the center of pressure is 1/3 of the height from the base. If P is set at say ½ the height, then

$$150 \times \frac{H}{3} \cos \theta = P \times \frac{H}{2} \sin \theta$$

$$\therefore 50 \cos \theta = \frac{P}{2} \sin \theta$$

$$\therefore P = \frac{100}{\tan \theta}$$

It can be seen that as P is pushed farther away from the hinge towards the open the smaller becomes the force necessary.

Thus at the apex, $150 \times \frac{N}{3} \cos\theta = P \times N \sin\theta$

$\therefore P = \frac{50}{\tan\theta}$, which is the minimum value of P.

It would therefore seem desirable to have the forces placed so as to act through the apex: on second thought, the additional leverage will be found to exactly counterbalance this advantage so it merely comes to a debate on which would be preferable high leverage and low pressure or low leverage with high pressure.

If it is decided to have a high leverage then it would be foolish to obtain it by placing P at the apex. The calculations shown above would be equally applicable if the leverage were obtained in the control lever with P acting through the center of pressure of the triangles. The increased P would give the same thing as the increased leverage. Thus with a reduction of force of 2:1 or an increase of leverage of 100%,

$P_1 = \frac{150}{\tan\theta} \div 2.$ or $\frac{75}{\tan\theta}$

With $\theta = 45^\circ$, $P_1 = 75$ lbs., which is easily obtainable

P_1 = force on lever before being increased to P by leverage reduction. P of course, as before is at center of pressure and is = $\frac{150}{\tan\theta}$.

With P at center of pressure a much stronger construction for the same weight of material is obtained, as bending movements are reduced to a minimum. Even with this, however, a fairly strong construction would be required.

The most notable immediate effects of this is that city dwellers could use aeroplanes, if houses were built with flat roofs. This only takes care of the landing, and to use roofs we must be able to get off into the air in as small a space. The helicopter principle already explained does away with the necessity for a starting field.

It is surely then no great step from this to the prediction that aviation will be the main method of travel in the near future. Even if the design submitted is not workable for some reason or other not noticed by the designer it is evident that very shortly a successful design will be manufactured which will serve the same purpose.

All these figures have been worked out for a monoplane. The same process would be employed in calculating the various factors for a biplane. Indeed it would seem preferable to have a biplane, as this would allow a reduction in wing spread. If the span were reduced from 24 feet to 18 feet great economy in space would be entailed, which is very desirable for our purpose.

Let us consider now what would happen if we used a biplane instead of a monoplane.

As we have already calculated the weights for a monoplane the gross weight will be readily found for a biplane. Gross wt. of biplane = wt. of monoplane - wt of monoplane wing + wt. of biplane wing + additional struts. = 470 minus 64 + two wings + struts. For ordinary biplanes the load per sq. ft. of wing surface varies from $4\frac{1}{4}$ to 13 lbs. It would seem reasonable to take 5-lbs./sq.ft. for our case, as this is easily obtained. Wt. per sq.foot = 7-lbs. for biplanes. Struts weigh less than 20-lbs.

$\therefore$ Gross weight $= \frac{426}{.86} =$ 496 lbs.

$\doteq$ 500 lbs.

This includes pilot, fuel, oil, etc.. Leaving out these three we have, Net weight = 275 lbs.

(For the monoplane the corresponding wt. was 235 lbs.

The area of the wings from the above $= \frac{\text{Gross wt}}{5} =$ 100 sq.ft.

If the upper and lower wings are of equal shape and area, we have then 50 sq. feet for each plane. If aspect ratio = 7 as before, $7d^2 = 50$. $\therefore d = 2.67$ feet. $7d = 18.7$ ft.

$\therefore$ Wing spread = $18\frac{3}{4}$ feet

" chord = 2' 8" = 32"

Lift per sq. foot = 5-lbs.

Lift = $K_y AV^2$ = 500 lbs.

Units as before.

For 5 lbs./sq.ft. K_y maximum = .00149 at 58 ft./sec.

$\therefore$ For minimum velocity V

$500 = .00149 \times 100 \times V^2$

$\therefore V^2 = \frac{5}{.00149} = 3350$

$\therefore$ V = 57.8 ft./sec.

= 40 miles /hr.

$\therefore$ Minimum velocity = 40 miles /hour. The maximum velocity w will probably be about the same as that calculated for the monoplane, i.e. 100 miles / hour. The result for the biplane now obtained are the following:

Wing area —— 100 sq.feet.

" span ——— $18\frac{3}{4}$ feet.

" chord ——— 32 inches.

Lift ————— 5 lbs./ sq.ft.

Power lift——— 14.3 lbs. /H.P.

Minimum speed—— 40 miles / hour.

Cross weight—— 500 lbs., including pilot of 160 lbs., oil and gasoline for 3-hours. journey.

Net weight = 250 to 280 lbs., including pilot, oil and fuel.

Total length under 7 feet.

The other figureswill be the same as for monoplane.

Compare these figures with those of the biplane built by Lieut. D. B. Phillips.

Wing spread 18 feet.

Speed developed 115 miles per hour.

Cruising speed 90 miles per hour.

Has Lawrence 3-cylinder 60 H.P. radial engine.

Fuel for 4-hours at full throttle or 5½ hours at cruising speed

450 miles cruising radius.

Landing speed 50 miles per hour.

Weight, less engine,	305 lbs.
" of engine	175 lbs.
" " pilot	180 lbs.
" " fuel	120 lbs.
Total weight carried	780 lbs.
Wing section U.S.A.	27.
Upper wing	36"
Chord, lower wing,	30"

Climb 600 ft./min. to ceiling at 12,000 ft.

Factor of safety 6.

Gasoline capacity 22½ gallons.

Oil " 9 quarts.

Mr. Fasig and Mr. Turner of Wilbur Wright Field designed a light biplane with the following characteristics.

76 cu. in. Indian Chief engine, fitted with a Thor reduction gear.

Span 18 feet. Chord 40". Area 119 sq. ft.

Took off at 30-35 M.P.H.

Weighed 475 lbs. gross.

Wing loading 4 lbs./sq.ft.

Power " 23 lbs./H.P.

Mr. Snyder's machine is as follows:

Biplane. Span 21' 7" Chord 3' 9".

Area 147 sq. ft. Weight empty 314 lbs.

Wt. full 500 lbs.

Engine was Indian chief running at 2500 R.P.M.

Chain driven reduction gear to 1200 R.P.M. at propeller.

It can be seen that our own design compares favorably with these, and these have been tested out.

It would perhaps be advantageous to see to what extent light planes can go. Mr. Mix of Chicago designed a biplane, the dimensions of which are as follows:

Span 12 ft. Area 84 sq.ft.

Gross weight 360 lbs.

Indian 8-valve racing motor, driving propeller direct at 2700 R.P.M.

With a small machine of this sort aerial navigation becomes as auto. driving. The area occupied is just the same as that for an auto, and it could stop just as quickly with our special device. It is much easier handled, as one man could lift it were such a thing desired. If the wings were made removable the whole machine could be parked inside the house.

One German plane has wings which can be removed and hitched to the side in two minutes by one man. What an asset in stormy weather if no garage is available! No more tiresome spreading out of the wing and body covers and lashing of controls at the slightest sign of rain.

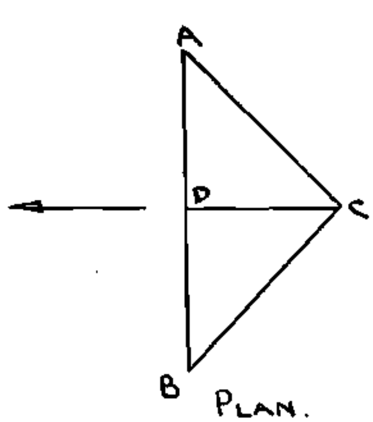
It would now be beneficial to calculate the size of rudders & elevators approximately.

(1) We shall first consider the monoplane. According to Kent's Mechanical Engineer's Handbook, an average of 8 monoplanes was taken, and it was found that the horizontal tail surfaces consisted of 14.8% of wing area. The wing area of monoplanes was 80 sq. ft.

$\therefore$ Area in horizontal tail surfaces $= 80 \times \frac{14.8}{100}$

equal 11.8 sq. feet.

This is in two pieces, so each would have say 6 sq.ft.



AB is 4-feet, or the same size as the propeller. $\therefore$ DC $= \frac{6}{\frac{1}{2}\times 4} =$ 3 feet. This assumes that the triangle form is used. Any other shape would be calculated in much the same way. From the same table, the area in the vertical tail surfaces = 6.1%

of wing area = .061 x 80 = 4.88 sq. ft. If triangles are used, then each is 4 x 1.22 feet. The two horizontal tail surfaces are 3-feet long and the vertical ones about 1¼ feet. These obviously would not do, so we can take an average and make each approximately 2½ feet long. It must be observed that the upper horizontal tail surface is longer than the lower as shown on a previous page, so 2½ feet for these is the mean of the two.

(2) For single seater biplanes, the area in horizontal tail surfaces = 11.8% of wing area = $\frac{11.8}{100}$ x 100 = 11.8 sq.ft. as before.

∴ Same size of horizontal tail surfaces would do here, Area in vertical tail surfaces = 4.4% of wing area equal .044 x 100 = 4.4 sq. ft.

This gives two triangles of 4 feet x 1.1 feet. A compromise for the biplane would therefore be triangles of 4' x 2' .05' or 4' x(2' + ½")apt. This would obviously not do, as the triangles would just barely close, which would require an infinitely great force to do. It must then be obvious that the tail surfaces would have to be increased for the biplane up to what they were for the monoplane, as this is about the minimum which could be used. Of course, this has all been done assuming that the base of the square pyramid is equal to the dia. of the propller, but this is not necessary;

the area of the tail surfaces could be made lower by reducing the size of the base and keeping the height the same. In this way the calculated biplane tail surface sizes could be accommodated at the expense of a slight loss in quick stopping. This reduction would lessen the force on the controls and lighten the whole rear end, which is a desirable matter.

Sofar we have settled a few of the points in the rough design of a monoplane and biplane, using a single propeller driven by a small 35 H.P. engine.

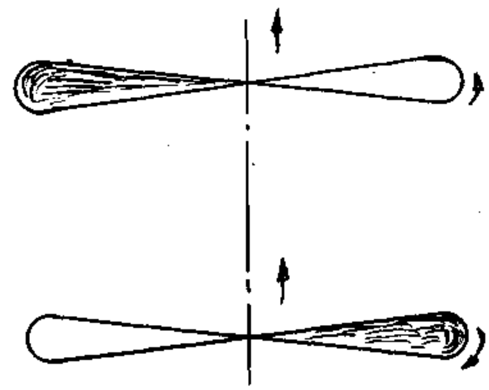
When aviation was in its infancy it was the general thing to have all planes low powered for the simple reason that that was all that was available, Being underpowered they were dangerous; so that it was customary to add more power, forgetting entirely the light plane. This was the easiest way out, but in the last year or two economy and common sense have taken a hand, and light planes of 10 to 20 H.P. have been developed with remarkable success. It is in this cheap article that commercial success will ultimately be attained.

If we want more power then 35 H.P. and thus greater speed, we can increase the power of the engine and use two propellers. It is the general practice in aeroplane work where two propellers are used, to have twin engines. In helicopter however, it is quite often the case that two propellers are run from the same engine.

With some, the propellers are a distance apart and are driven by chain or belt on vertical axes, while others are on the same axis. If the engine used were of the ordinary fixed type and the propellers rotated in the same direction, then there would be a tendency for the machine to turn round. This would be balanced in a great degree by any wing surfaces opposing the motion, but this disturbing force is not at all desirable.

This is overcome in practice by having one wing "washed in" i.e. by increasing the angle of incidence; the other wing may be "washed out" or decreased. The increased lift due to the "wash-in" exactly counterbalances the tendency to rotate.

It is obvious that for proper equilibrium the propellers should revolve in opposite directions. For both propellers to give a forward motion they must be set so that the blade angles are opposite in value, as shown in sketch.



To apply this principle to our aeroplane necessitates (1) That one of the propellers at least be at the back so that the reversing gear may operate perfectly. (2) That they cannot be on the one shaft; one can either be

Driven by belts, chains, or gearing, which involves additional weight.

(3) If there is one at the front then it must be considerably smaller than the rear one, or it must have a clutch.

The explanation of these facts is simple,

(1) is self explanatory. If one were not at the back then the current of air going through the propeller would very likely be considerably diverted from its course before it reached the rudders, etc., and the stopping power would be greatly reduced. If very quick stopping were not required as, for instance, where landing space were available, then placing the propeller in front might be desirable, as it would greatly reduce the pressure on the controls, and would allow a reduction in weight of the rear members.

(2) is obvious.

(3) follows from (1). If the front propeller were as big as the rear one then there would be a greater force pulling forward than there would be pushing backward, (unless the engine were stopped), so the machine would keep on running forward along the ground. To remove this difficulty the forward one could have a clutch which would be released on reaching ground, thus allowing only the back one to operate; or the front propeller could be made smaller than the rear one so that the backward pull is much the greater.

It should be noted that far quicker and better control can be obtained with this triangular form than usually, if if the propeller is at the back. The full force of the air coming from the propellers plays on the rudders or elevators, so that the slightest movement of either would result in a big force on the tail.

If the rear propeller were to act in the same horizontal line as the center of lift, then the other propeller would give the thrust necessary to pull the nose heavy machine up to its normal level while flying. It has already been explained in chapter on stability why the resultant propeller thrust should be below the center of lift. The amount obtained in this manner may be excessive, but the center lines of the propellers could be moved to any desired place by suitable driving mechanism. Since the clutch would only be used on stopping it could have a device for holding it in position while flying, thus relieving the pilot of anxiety in this respect. But it would seem that if it is to be used for this purpose only it would probably be discarded, and the engine stopped for landing, trusting that the closed tail surfaces would offer great enough resistance without the help of a propeller. The landing distance in this case would have to be increased.

For stopping by banking, (as in present-day aeroplanes), the area exposed to the air for this purpose is roughly the (area of wings x sin θ) + resistance of body, tails, etc.. The latter is negligible for our very rough calculations, so the former gives $R \propto 100 \times \sin 15^\circ$ say.

$\theta = 15^\circ$ = angle of incidence.

100 = wing area in sq.ft.

$\therefore$ 1 R $\propto$ 26 sq. feet, for 15° angle..

R = resistance to motion.

Instead of offering a plane surface to divert the air through ($15^{\circ} \times 2$) we now offer a closed area of 16 sq.feet + this resistance already obtained.

(It will be noted that if angle of incidence is 15° the wind will be diverted roughly 30° for a flat surface. For the curved surface of an aeroplane wing this is not so, but we assume the surface flat for our calculations).

The air in the one case is driven downwards, while in the other the direction is forwards with resultant reaction backwards.

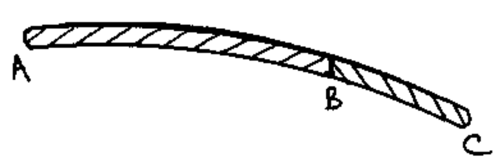
The probability is that the resistance to forward motion would be increased many fold, and the increase in resistance varies inveresly as the distance required for stopping. The exact amount of resistance is unobtainable until the aeroplane has been actually drawn and built, but this merely indicates the trend of thought.

After all our other assumptionsit is now quite in order to take up the case of the aeroplane where the reversing gear does not completely close. Unless reversibility is required, or very quick stopping essential, it ought to be quite sufficient to close it only partly. This would allow a stronger rear end for the same weight, and would allow a greater leaverage for the same hand movement on the controls, thus making the pilot's job easier physically.

If we have each triangle moved inwards for 15° there should be approximately the same resistance as that offered a plane of the same area sloping upwards at 15°, so that by varying the angle we can stop in the distance required, from 20 feet upwards to the present day requirement.

We have an analogy to this in the automobile.- either it can be stopped within 20 feet by the emergency brake or it can be allowed to coast until motion ceases. This finishes the design of the first type.

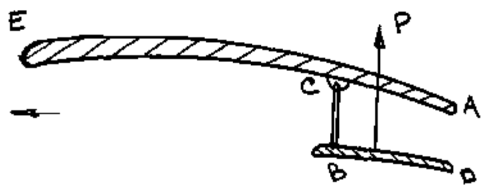
In all of our previous work we have left out the ailerons which play such a big part in aeroplane control. It was not our intention to do so from our machine, the putting off merely being for the reason that we are now in a much better position to discuss and understand more clearly any alteration. We shall deal a little more thoroughly with this.



A B C is a wing section.
B C is aileron which is hinged to the main surface at B. By moving C up and down we can get increased drift or increased lift, whichever we want. As a matter of fact, both positions give increased drift, but the

ratio $\frac{\text{lift}}{\text{drift}}$ is all we want. The aileron on the other wing is operated in the opposite direction to this one, so that it is easy to gain lateral control.

After all we have said, however, on quick stopping, it is obvious that relying on a sloping shape to give resistance is not the best thing to do. The following is a suggested construction for special ailerons.



Let the main surface be continued its full length, and let the aileron be entirely separate wing, smaller than usual, and located below the main surface. If it is in its proper position it acts as a small lifting surface. If we now want resistance on the one side we can pull P upwards and close the end of the wing, i.e. D moves to A. It will be obvious that the increase in resistance is tremendous, very many times what is usually attained. The other aileron at the same time would be moved in the opposite direction, giving increased lift.

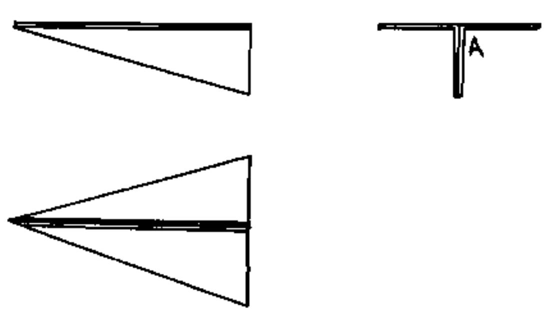
The greatly increased resistance might not be necessary, so the area of the aileron could be cut down, thus increasing its strength. At the same time if the resistance is wanted large, the area of the rear controls for quick stopping need not be so large as the ailerons could be used for this purpose, (assuming that they can be moved in opposite or in the same directions). If the rear controls are kept the same area, then they need not be entirely closed to stop, thus again reducing the weight and the force necessary by the pilot.

It is obvious that by a little judicious planning we can get a very efficient combination between these two retarding mechanisms.

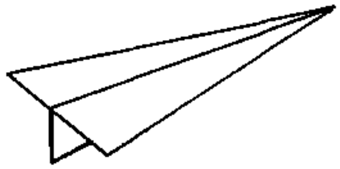
The advantages are very evident. Our whole construction is now of a machine unlike any yet attempted. As with all radical inventions the oppositions to its use will be very strong, but if due consideration be given to it very decided merits, it will be realized that it represents a big stride towards better aeroplanes.

We have a few cases in mind where imagination plays a stronger part than reason.--- flights of fancy with enough common sense behind them to avoid the ludicrous.

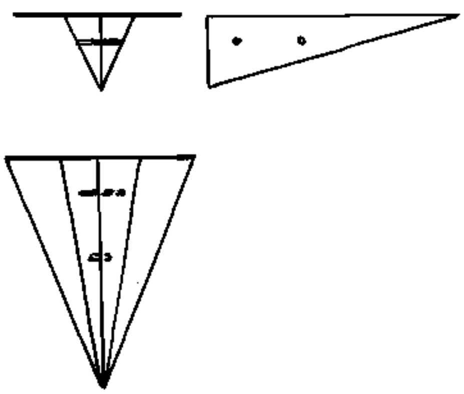
For this last fifteen years or more it has been common practice for youngsters to make paper gliders or darts abo t 8 to 12 inches long in the following shape approximately. Some are



joined at A while others are quite loose here. The only difference seems to be that the loose ones have not the same



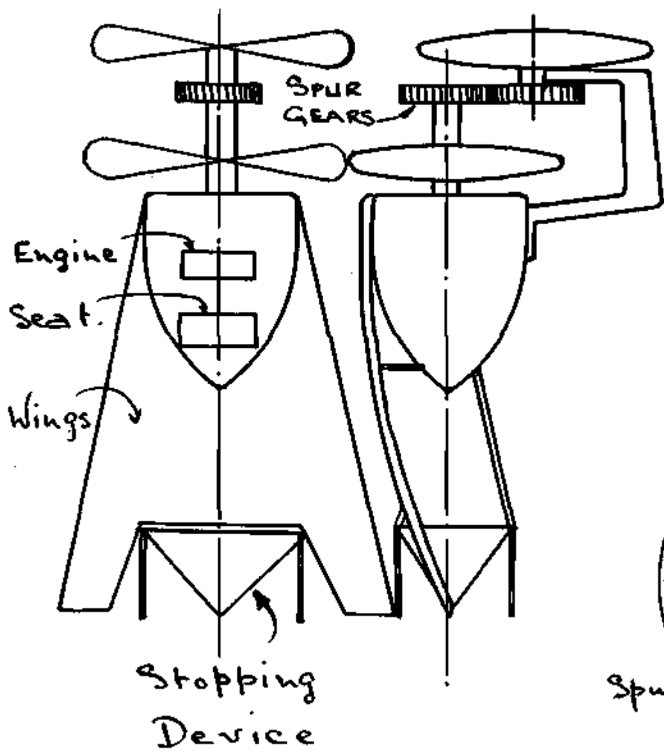
stability nor do they glide so far as those that are fixed. It may be that if a few stays or struts were provided to keep the sides a fixed distance apart that the gliding would be improved. e.g. see sketch!This certainly goes against



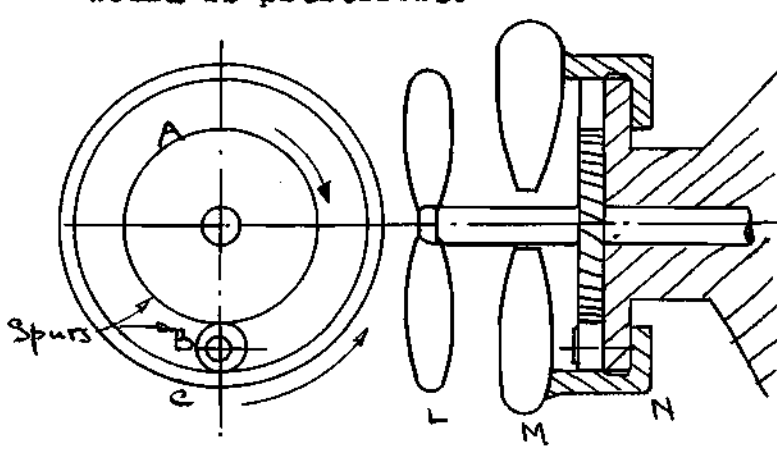
common glider practice, but it must be admitted that most aeroplane workers are very averse to leaving standard practice for the simple reason that they know the present designs work. If a few original ideas were proved workable the inertia of the public, and even of the aeroplane experts, would slowly be overcome until these new ideas took their place beside, or completely superseded, the old ones. The aeroplane has passed through various stages of this, e.g. the old bat-like form was changed to the box-like type, then the biplane, triplane and monoplane, etc., The wings of all these differed to some extent, so it should not come as a shock to change them still a little more.

After the unquestioned success of roughly made paper gliders of the form shown, is it not possible that man-carrying sizes should prove of as much value ? When compared with models of the same size made in standard glider form (monoplane usually), it can be seen that the standard one has possibly a little more stability due to its relatively complicated design and controls, but the other makes up for this in its smoothness of flight and speed attained. Each comes to rest gracefully and without jar.

The design for man carrying size, of course, would have to be altered to suit the conditions imposed on it. Since the span is relatively small, to overcome the tendency to turn round due to the rotation of the propeller, the "wash-in" would have to be increased beyond reasonable limits, thus reducing the $\frac{\text{lift}}{\text{drift}}$ ratio. It would then seem advisable to use the two propellers rotating in opposite directions.



The construction might be as shown above. This would entail a very frail and relatively expensive support for the front propeller, so the following would be preferable.

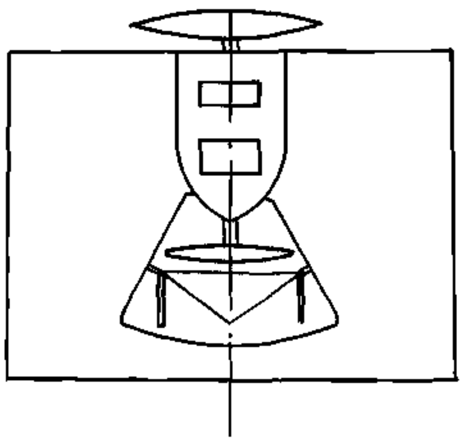


Have the shaft driving the front propeller operated directly from the engine. (Radical Type). To it would be fastened spur gear A, which meshes with a second spur gear B revolving round a stationary axis in an extension of the engine casing. This in turn is in gear with an annular ring C which must therefore revolve in the opposite direction to A. To C is attached the wings of the propeller M. It should be noted that C revolves more slowly than A, ∴ M must be increased in size. M is prevented from coming off by the ring behind N.

The author does not suggest for a minute that this is the best construction possible. He only wishes to show that two propellers on the one shaft are quite within reason.

With this general construction the head resistance would be considerably reduced, thus allowing a greater speed but less efficiency in gliding.

As a combination helicopter and aeroplane this would probably offer as many advantages as would be possible in one machine, due to its lightness, rigidity, compactness, speed acquired, etc.. On the other hand the span is so short that the lift may not be big enough at ordinary speeds to keep the machine in horizontal flight unless a very large angle of incidence were obtainable. This could be varied at will, and the machine could be moving horizontally although the propeller may be tilted at 20° to the horizontal, but as the efficiency of the propeller is a minimum when the thrust is horizontal this is not desirable. Also with the increased angle of incidence there would be increased drift, thus lowering the speed of the machine and consequently the $\frac{\text{lift}}{\text{drift}}$ ratio. The lift would possibly increase but not so much proportionately as the drift, so $\frac{L}{D}$ falls. In that case we would increase the aspect ratio a little. It might be advantageous to have one of the propellers at the back. The construction would then be as

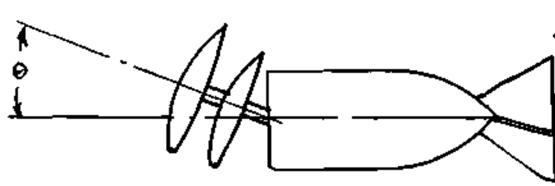


shown. This is also a very light, compact strong aeroplane, and it would probably be much more efficient than the last mentioned. It should be borne in mind that in the last two cases the areas of the rudders and elevators would have to be increased due to their closeness to the center of gravity of the machine. It will be noticed that birds have long narrow wings for fast soaring, and short broad ones for slow flapping flight. The divergences of each type, however, are so great that we are led to think that actual shape is of little consequence so long as the aspect ratio is kept constant.

We now come to a much better mechanical construction than any yet shown.

The form most favorable to progress through the air is the elongated pear-like form, blunt end foremost. Then let us make a body of this type. For propulsion, as there are no wings, we must have two propellers. First let us consider the case of both propellers in front. We have a very compact machine, but we have absolute dependency on the engine, which must therefore be of a very high grade. To ensume that the machine is absolutely dependable it would be advisable to run it at a much smaller speed than its maximum. This always keeps a certain reserve in hand for emergencies. Since there is no wing surface to support the machine, the propellers would have to be tilted at an angle to the horizontal, thus applying horizontal and vertical pulls. It is then a combination helicopter and aeroplane. By having the angle to the horizontal increased to its maximum of 90° we have the complete helicopter.

Since the propeller thrust is nefer horizontal, (and therefore less efficient), it might be possible to have it permanently set at an angle to the body, this angle being the minimum that the propeller would require to be set at to lift the machine from the ground. If θ = angle of thrust to horizontal



then lift = thrust x sin θ

If the weight of the machine and pilot is about 330 lbs. then the thrust obtainable would have to be a great deal more, (if a reasonable speed is required) unless the machine is set at a very steep angle. This would entail a much more powerful engine than with the aeroplanes already described, thus bringing up the weight. But an increase of even 200 lbs. in weight would still keep the machine in the light air vehicle class.

If the thrust were set permanently as shown, the air resistance of the body would be greatly decreased. Mechanical difficulties would come in here which would probably overcome the benefits received. It can be seen that if it were set so, the resistance to motion horizontally would be decreased, but vertically would be increased very slightly. As the vertical motion is only a few feet/sec., the added resistance would be negligible when the great resistance due to horizontal flight is so greatly reduced.

The propeller sizes would need to be large as already explained in the chapter on helicopters.

As there is no gliding action, ordinary rudders and elevators could be used, a reversing mechanism being practically useless in the air. If in addition to flying this were so fashioned that it could be used for land travel, then the reversing gear would play a big part in its functions. As a matter of fact this machine would make a very presentable substitute for the automobile, but as this thesis deals only with aviation that branch will not be expanded.

The second one to be considered is where the propellers are set at opposite ends of the body. The mechanical construction would be easier as the annular gear of the other type would be eliminated. There would be a little difference in cost, and the engine power would probably be the same. The rear propeller would give a lifting power to the rear end which is not so readily attainable with the former construction, thus adding still more to the advantages of the latter.

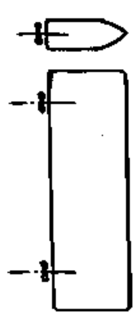
So far the discussion of these two types has only been for horizontal and vertical flight, but now there comes the question of stopping. How can we stop safely with this machine? There is no gliding slowly to earth here. This is the one real difficulty that would be found in realizing our design as a commercial vehicle.

It might be accomplished by having the body of a very light aluminum structure, and, instead of having the covering fixed, have it made in the general form of a parachute, folded up to give the same elongated pear like form. When descent is required the propeller could be tilted upwards, and thus also the nose, and the parachute could be opened. This would only need to be done if the engine had absolutely stopped; if not, then it could be revolved at a slightly less spedd than required to lift the machine, thus regulating the speed of dropping. It would seem that this gives a reasonable solution of the difficulty.

An extension of the pear-like construction principle leads us to the question, "Why should the body not turn round?" If some method were found to hold the engine stationary there would be no reason why the whole machine should not turn. As the construction is that of a surface of revolution, little resistance to turning would be experienced: in addition, the many stabilizing force for the ordinary plane would be greatly reduced. With a rotary engine the cylinders could be fastened directly to the propellers and body, thus leaving only the difficulty of holding the crankshaft. The pilot of course would have to be put in a non-revolving chair. Either he could be supported by roller bearings, the rollers running in a groove in the body, or else he could be attached in some way to the stationary crankshaft.

This can be carried a step further. Why have a body at all? Let the body be replaced by big wings rotating round the pivot at the center of gravity. In this we can have a minimum of mechanism with a maximum of output.

We now come to a few designs for which the author is not responsible. One of these is to have the body and wing as one piece. That is, to have the wing thick enough so as to have the pilot, passengers and engine all inside it, as shown.



The design seen was of this general form, with the lower side practically of the same shape as the upper. This of course, is not practical, as little lift would be obtained. If the body were shaped like a wing, this construction might be possible .

Another type is to have a rocket motion, i.e. to be propelled forward by blasts of dynamite or other means. This may seem absurd at first glance, but it has been proved successful with models and with instrument carrying sizes. It is frequently used to find out the properties of the upper layers of air. round the earth. It has even been proposed to shoot a man in one of these to the moon, by having successive discharges when the force of the last had been spent. A professor of one of our foremost colleges asked if any one would be willing to make the attempt—— he had about 20 answers in the affirmative. Some dare-devils would do anything. We do not know yet if a means of returning to earth has been found. A much more reasonable idea is being worked on in France at present. To stop sudden descent chemical means is used to give out quick blasts of gases below the machine. So far it has proved fairly successful. If it were absolutely reliable for this purpose, what then would prevent it from being used a s a means of propulsion? In this respect it resembles the last design closely.

Quite a lot of work lately has been done on pilotless aeroplanes, with remarkable success. A successful fleet of these might cheapen transportation if the cost of operating were found to be less than the gasoline and oil, and the pilot's pay. Otherwise there seems to be little in this except in warfare. If other aeroplanes were very dangerous it would have a greater scope, but with the safety now attained little future can be expected with the pilotless aeroplane, at least, as a passenger carrying vehicle. It is interesting to note, however, that if an aeroplane goes high enough into the air the density of this falls so also must the resistance to flight. Thus with a steep pitch of the propeller enormous speeds may be accomplished, providing the necessary oxygen requirements for pilot and passengers are available. Why not have a variable pitch propeller to operate at the various heights reached?

Although it may not be claimed as a pure air vehicle, still the following is undoubtedly one taking passengers through the air. A train, surrounded by steel hoops, and carrying its passengers, is supported high in the air at the first station. The next station is merely a short tunnel, which is composed of a great No. of insulated wires running round a dia. a little larger than the steel hoops on the train. As the current is switched on in the second station and off at the first a force is created pulling the train towards the second station or solenoid. Similarly, as it passes (2) the 3rd is switched on and 2 off. The speed attained would be enormous, but so also would the cost. This has been tried, we believe, with a model, and has given satisfactory results, though not what was anticipated.

The preceding designs are a few of those in which many people are interested. We feel sure that one will survive as a successful venture.