Unsolved Aeronautical Problems

Paper read by Mr M L Bramson, A C G I (Member), before the Institution in the Lecture Room of the Junior Institution of Engineers, 39, Victoria Street, London, S W 1, on 12th October, 1926 Mr Lawrence A Wingfield in the Chair

Mr Chairman, Ladies and Gentlemen,

It is obvious that this subject is so vast and and that its nature is such, that it can only be dealt with haphazardly For that very reason it furnishes, perhaps, suitable subject matter for discussion

I propose to choose at random a limited number of unsolved aeronautical problems, to state them, one by one, with the briefest possible comments so that there may be plenty of time left for what we hope will prove an illuminating and thought-inspiring discussion

Here are the problems —

(1) The propulsion of aeroplanes with constant power at varying altitudes
(2) Jet propulsion of aeroplanes
(3) Variable wing surface aeroplanes
(4) Vertically ascending and descending flying machines
(5) Fog landings
(6) Sea-worthy flying boats
(7) The ideal aerodynamic structure , small and large
(8) The multi-engine room with ideal propeller distribution and without engine drag
(9) The super-altitude high speed transatlantic air liner with constant propulsive power and air-tight fuselage
(10) The internal combustion Turbine
(11) The Diesel Aero Engine
(12) The Elimination of fire on crash
(13) The provision at will of a steep gliding angle
(14) The establishment of public confidence in flying

(1) *The propulsion of aeroplanes with constant power at varying altitudes*

The solution of this problem involves firstly the production of a power plant capable of maintaining its power irrespective, within wide limits of the air density This part of the problem has, to a large extent, been solved by the Rateau exhaust

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driven turbo compresser and by other forms of super-chargers The exact results obtained are probably on the Secret List At any rate I havn't got them But I have it on good authority that constant engine power at air densities corresponding to altitudes of about 30,000 feet has been maintained

The second part of this problem consists in applying this constant power effectively to the surrounding thin air for the purpose of maintaining constant propulsive power This part of the problem has so far proved the most difficult A reliable variable-pitch propeller would do the trick but has so far made no public appearance This, of course, is no proof it may not exist somewhere in the world

The difficulties of designing a satisfactory variable pitch propeller are considerable Each blade has to be mounted on a bearing, the axis of rotation of which is at right angles to the propeller shaft and which must be capable of standing a centrifugal thrust of the order of 30 tons for an average case

In spite of this load the resistance offered to the operating mechanism must be low

There is the further difficulty of providing room for the operating mechanism in the space between the propeller and the engine without increasing the overhang considerably Incidentally, variable pitch propellers would, if they were reversible, provide the pilot with an efficient brake which would make exceedingly quick pull ups possible

(2) *Jet propulsion of aeroplanes*

If you follow through logically what happens in a modern aeroplane for the purpose of propelling it you get briefly the following chain of processes —

(*a*) the intermingling of atmospheric air and vapourised fuel ,
(*b*) the combustion of that mixture ,
(*c*) the transfer of the energy contained in the resulting gases through the pistons, connecting-rods and crankshaft to an airscrew ,
(*d*) the transfer, to the airscrew slipstream, of the energy supplied to the airscrew

You will notice that in this chain of processes we start with an energised gas and we finish with an energised gas It is, therefore, not unreasonable to think that it may be possible some day to bring about this transformation of heat and pressure energy contained in a small quantity of gas into kinetic energy contained in a large quantity of gas without the intermediary of an engine and airscrew

It is well known that it is possible quite efficiently to convert most of the energy released by the combustion of a fuel air mixture into kinetic energy contained in the products of combustion, merely by allowing these latter to escape through a nozzle, the cross section of which varies in such a manner that no abrupt changes of pressure take place throughout the length of the nozzle If such a nozzle be fitted to an aeroplane and directed backwards and if a quantity of fuel be burnt per second of a similar order to that consumed by an aeroengine of corresponding size the reaction obtained would, however, be quite insufficient The reason being that the propulsive efficiency of such an arrangement depends upon the ratio of jet velocity to machine velocity and is a maximum when this ratio is 2 to 1

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The problem, therefore, resolves itself into that of devising means for efficiently transferring the kinetic energy contained in a small quantity of gas having an immense velocity to a large quantity of gas (*i e*, atmospheric air), having a relatively small velocity say 300 or 400 m p h

That is the problem It is rather interesting to note that the faster aeroplanes become—the less difficult becomes the solution of this problem

(3) *Variable wing surface aeroplanes*

It is doubtful whether this problem is not obsolete It used to be thought that the only manner of combining a low landing speed with a high cruizing speed was to provide a variable wing area It is highly probable that the best possible structural realisation of such a scheme would literally outweigh all its advantages

Probably devices such as the Handley-Page slots or Fairey and de Havilland flaps, which vary the lift coefficient of the wing, will prove the best practical compromise

(4) *Vertically ascending and descending flying machines*

The nearest, and in fact the only practical approach to a satisfactory solution of this classical problem is provided by the de la Cierva Autogyro This machine does not, it is true, land and take off vertically, but an air speed of 25 m p h less the average wind velocity really gives such a low ground speed that it is doubtful whether increased safety would result from any further reduction in landing speed

The true helicopter seems to have gone out of fashion In this country the Brennan experiments have been abandoned and in France M Pescara is lying low in several senses of the word

It is highly doubtful whether a machine of this type will ever be constructed with a satisfactory performance, either from the point of view of load carried per H P , or speed

The Auto-Gyro, on the other hand, has already shown a definite advance in speed range over any hitherto known , and it will be interesting to get reliable estimates of the performance which could be expected from an Auto-Gyro with a landing speed of, say, 40 m p h

I mention this as a point of general interest in connection with the Auto-Gyro although it can hardly be said to fall within the heading of this particular paragraph

(5) *Fog landings*

This subject was fully dealt with at a recent meeting of this Institution, and all that need be said about it now is that if progress has been made it has not been made public

I gather, however, unofficially that experiments are still proceeding with leader cables, and the present thought is to have an oval line which runs through the centre of the aerodrome I, personally, am definitely of opinion that this is an undesirable arrangement

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In designing a fog landing scheme, the purpose of which is to enable a pilot in circumstances of extreme difficulty, to land upon an aerodrome he cannot see, the first object of the designer should be the elimination of variables and the retention of those only which cannot be eliminated

Now an oval leader cable means both a variable direction and a variable curvature of the path of flight It is surely undesirable to give the pilot this added difficulty and complication, forcing him to concentrate on the steering of his machine whilst the real difficulties ought to have his exclusive attention

My suggestion is that a straight leader cable be employed four or five miles long, or even longer, and that a standard altitude be adopted In that case a pilot has only to fly in a straight line along a known compass course, occasionally checking up with the leader cable indications He can then concentrate practically all his attention upon the most important of his tasks—that of commencing his glide down at the right moment

I would respectfully submit to the authorities that they give consideration to the point of view just expressed

(6) *Sea-worthy flying boats*

This is a very difficult problem One suspects that it can only be completely solved in boats of such huge dimensions that the wing structure can be raised sufficiently above the water to prevent even large waves from reaching it It is certain that such a boat would need to have two hulls for stability (such as, for instance, projected by Professor Junkers)

It strikes one that the Auto-Gyro principle may give rise to entirely unexpected possibilities in connection with flying boats

Owing to the rotational speed of the wings and also to the fact that a very slow landing speed is hardly necessary, the total wing surface for a machine of any given size would be considerably smaller than in the case of an ordinary wing structure Furthermore, the Auto-Gyro wings have no great span and are naturally placed high above the fuselage or hull

All these factors would, it seems to me, tend to make an Auto-Gyro far more seaworthy than its present-day prototype.

(7) *The ideal aerodynamic structure large and small*

The ideal aerodynamic structure is pretty obviously a flying wing without protuberances It is clear, however, that for such a wing to constitute an aeroplane there must be room for passengers and goods inside it We are, therefore, limited to very large sizes, using a wing section thick enough to contain human beings in comfort That means a thickness of at least 6 feet Taking one of the very thickest Goettingen aerofoil sections, having a cord to thickness ratio of 6 to 1, we get a cord of 36 feet For a reasonable aspect ratio, say 7, this means a span of 252 feet and a surface of about 9,072 sq feet, and at a wing loading of 10 lb per sq foot a total weight of 90,000 lb or at least 40 tons

Machines smaller than this need a fuselage, and here the question arises which is aerodynamically the best relative position of body and wing ?

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Should the wing be attached to the bottom, the middle or the top of the fuselage? Or is the parasol arrangement the best?

(8) *The multi-engine room, with ideal propeller distribution and without engine drag*

Engines should, for preference, be out of the air stream and propellers must, of necessity, be in it It follows that, aerodynamically at any rate, it is not a good policy to put engines and propellers in the same place as is at present done universally A single experimental machine, the Parnall Possum, has proved that it is quite practicable to drive propellers at a distance from their engines, but the matter has not been pushed in this country, which is a pity As the multi-engine principle is pretty well established, any such scheme would involve a central engine room with clutch mechanism, making possible the simultaneous transmission of power from all engines to all propellers, as well as the automatic or deliberate disengagement of any one engine

(9) *The super-altitude high speed transatlantic air liner with constant propulsive power and air-tight fuselage*

This problem arises from the following considerations The effective airscrew power of an aeroplane equals the product of the drag and the speed

$$p = R \times v$$

where p = power in ft lbs per second, R = drag in lbs, and v = speed in feet per second

If it be specified that the machine should fly at the best angle of incidence (say for horizontal flight the angle of incidence corresponding to maximum $\frac{\text{lift}}{\text{drag}}$ coefficient), then the drag may be taken as constant, *i e*, the weight divided by $\frac{\text{lift}}{\text{drag}}$ coefficient

$$\text{Now the drag } R \propto v^2 \times d$$

where d = air density

By substituting above we get

$$p \propto v^3 \times d \quad \text{or}$$

$$v \propto \sqrt[3]{\frac{p}{d}}$$

From this proportionality we deduce that if p (*i e*, the propulsive power), is constant, the speed is inversely proportional to $\sqrt[3]{\text{air density}}$

This shows that for a given machine, keeping all other things constant, the speed can be increased considerably at very high altitudes Let us examine for a moment in what proportion the speed of any given machine could be increased at an altitude of, say 36,000 feet, which is the present altitude record At that altitude the air density is about 0 28 of the density at sea level

$$\text{Therefore } \sqrt[3]{\frac{1}{0\;28}} = \sqrt[3]{3\;6} = 1\;53$$

is the factor by which the speed of an aeroplane could be multiplied at 36,000 feet if the altitude of the propulsive power remained constant

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Our present speed records are of the order of 250 m p h and therefore a machine capable of this speed at sea level would be able to do 385 m p h at 36,000 feet

Now suppose we go up to very great altitudes—and this of course is possible so long as we can maintain our power Say, for the sake of argument, 52,000 feet or 10 miles The air density at this altitude is about 0 16 The ratio of increase in speed would therefore be

$$\sqrt[3]{\frac{1}{0\ 16}} = \sqrt[3]{6\ 25} = 1\ 84$$

If the speed at sea level, therefore, were 250 m p h , the speed at an altitude of 10 miles would be about 460 m p h Obviously at such altitudes an airtight fuselage and a reliable oxygen and pressure supply would be required We are, of course, as yet at some distance away from the complete solution of this fascinating possibility , but surely the prospect of flying from London to New York in 6½ hours is sufficiently attractive to stimulate the imagination and efforts of aeronautical engineers

(10) *The Internal Combustion Turbine*

The solution of this difficult problem is of particular importance to aeronautical engineers

It would constitute an intermediate step between existing practice and jet propulsion It would mean a tremendous reduction in weight per B H P , and it should mean the reduction to one, of the number of moving parts in the Prime mover proper There are two schools of thought on this subject

One advocates intermittent combustion at constant volume, thermodynamically corresponding to the Otto cycle The other advocates continuous combustion at constant pressure, thermodynamically corresponding to the Diesel cycle

I personally consider that the latter is the only principle worth considering

The principal three difficulties are as follows

(1) To construct a rotor with vanes which will stand subjection to a gas jet which is almost a flame at a temperature of the order of 600 to 700 degrees Cent and at jet velocities of the order of half-a-mile per sec

(2) To construct rotors which will stand peripheral speeds of half that order

(3) To provide and drive a suitable air compressor of adequate capacity without introducing such complications as would nullify the simplification obtained elsewhere

The I C T if really made practicable would doubtless do for aircraft what the Steam Turbine has done for ships

(11) *The Diesel Aero Engine*

I may possibly incur the displeasure of one of our most brilliant engineering companies by including the Diesel aero engine in a list of unsolved problems

I have done so however with no malice aforethought, and I am willing, and should in fact be delighted, to be effectively contradicted on this score Perhaps someone will do so in the course of the discussion

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As I see it there are four great advantages to be gained by the complete solution of this problem

Firstly, the use of crude oil will render flying safer because, although curiously oil has a lower ignition temperature than petrol, yet being less volatile it does not give rise to the formation of highly inflammable pockets of air and vapour mixtures which are probably responsible for most petrol fires

Secondly, it will render flying more economical because crude oil is cheaper than petrol, and because the thermal efficiency of the Diesel cycle can be made higher than that of the Otto cycle

Thirdly, it will enable more paying load to be carried for a given radius of action, or conversely it will make possible a longer radius of action for a given paying load

Fourthly, it will introduce simplification by eliminating electrical ignition systems

(12) *The Elimination of Fire on Crash*

There is no type of accident which is more terrifying to contemplate than a crash followed by fire It brings up visions of agonised passengers or crew half mutilated, pinned under debris and waiting for the flames to get them One cannot imagine any subject more calculated to stimulate the imagination and intense efforts of engineers

Five or six years ago the Air Ministry organised a safety fuel tank competition Somebody won it and prizes were paid with good Treasury money But so far as one has been able to discover no action was taken And people still burn to death in this country as a result of crashes which would hardly hurt them at all but for the fire

There is an aeronautical research committee R and M which recommends placing petrol tanks on the top wings of biplanes and the practice is now being more and more generalised But this is by no means a guarantee against burst petrol tanks and something far more definite is possible and should be done towards the elimination of fire on crash

(13) *The Provision at Will of a Steep Gliding Angle*

This problem is a modern one because it only arises in connection with machines having a high $\frac{\text{lift}}{\text{drag}}$ ratio At all reasonable flying speeds such machines have adsurdly flat gliding angles, a fact which is greatly appreciated by the pilot in so far as it enables him to choose a forced landing ground from a very great area in relation to his height But from the point of view of the approach to a landing ground which is surrounded by obstacles that same flat gliding angle may frequently prove disastrous and at any rate renders the approach far more difficult

A satisfactory device for temporarily spoiling the aerodynamic finesse of the machine, such as for instance, the old Sopwith air brakes, would in such circumstances be of great value I believe the Sopwith device became unpopular because pilots who did not properly understand their effect used them with suicidal results

But properly used such air brakes would be invaluable for the purpose of getting into a confined field by diving on it with the air brakes on and therefore without an appreciable increase in speed

(14) *The Establishment of Public Confidence in Flying*

This problem is or should be at the root of all the others which I have mentioned and in fact every problem connected with the progress of aviation

The progress of a new science such as aeronautics is bound up in a vicious circle Proper progress cannot take place without extensive public support and confidence Public support and confidence will not be forthcoming until extensive technical progress has been made And in this connection technical progress means improved safety more than anything else

I would therefore put it to the members of this Institution that it is our duty to the public, to aviation and to ourselves, to see to it that there shall be no unnecessary lag between invention and application

I am naturally aware that delays do sometimes originate in official places and that such delays are generally beyond the control of the active members of the industry But let us counter such delays by endeavouring to create a strong public interest in aviation and strong public indignation when accidents occur which could and should have been avoided

DISCUSSION

CHAIRMAN (Mr Wingfield) We have listened to an extraordinarily interesting lecture Many of Mr Bramson's problems appeal most strongly to the imagination, particularly the possibility of flying from England to New York in six and a half hours I would remind you, that it has not been infrequent in the past for even the most wildest romantic dreams of the most romantic novelists to come with the passage of time first within the bounds of possibility and then into the realm of actual fact We have only to think of the works of Jules Verne, such as " Round the World in Eighty Days," for an example In some of this week's newspapers it was reported that certain people in Russia are about to attempt to fly to the moon in a rocket fired out of a cannon pursuing the method suggested by Mr H G Wells I remember reading a story in I think, the *Strand Magazine*, about a man who proposed to fly by rising in the air in a kind of dirigible which had the power to detach itself from the earth's gravitating pull By simply standing still the dirigible could then make a complete circle of the earth in twenty-four hours The speed of Mr Bramson's future aeroplane is at least equal to that of my dirigible

The meeting is now thrown open for discussion

SQUADRON LEADER DEH HAIG *Re* jet propulsion of aeroplanes, I think Mr Bramson will have some difficulty in starting his aeroplane He may be able to make something out of jet propulsion after getting up speed, but it seems to me that it will take most of Europe to start in

With regard to variable wing surfaces, we must not forget that when you use some of these devices there is quite a lot of useless weight that you have to carry at other times than getting off or landing, and that goes very much against making use of such devices

Concerning fog landings I am rather tied There is a device for making fog landings which is getting on very well and as far as I know is successful Mr Bramson objects to the oval cable That was adopted because of the expense of laying down a great length of cable I would like to point out that the oval cable is not really an oval, it has one long flat side which comes down to the centre of the aerodrome, and the rest of the path is laid out in a suitable gentle turn If you cross this leader cable at any reasonable height you can pick it up by the device provided on the machine, which is very much more simple to do than a straight cable unless you are at right angles to it

Referring to problem No 9, I think there are two difficulties which Mr Bramson has not mentioned (1) Wind speed at height The normal speed will help you at some heights, but defeat you at others (2) Heating is also a very difficult problem, you cannot very well keep the inside of the cabin warm enough at this height

Regarding the Diesel engine, I cannot say much about this, but one of the points to consider is the weight per H P One is always asked this

No one has taken into account the amount of fuel consumed compared with other engines You cannot take the engine as a separate unit, you must consider the thing as a whole The problem has been fairly well overcome, and we hope to see some of these engines in use in the fairly near future

With regard to fire on crash, I do not think it is fully realised that the chief trouble is not the petrol but the oil If you pour petrol on to a cylinder it won't catch fire, but you get a hot flame if oil and petrol are combined

Re landing speed, that has been done on one of the recent machines that has been very fully described I mean Hills' machine, of course

CAPT TYMMS I think that the only point on which I feel qualified to speak is fog landings

I do not quite agree with Squadron Leader Haig on some of his arguments concerning the oval or straight cable He referred to a leader cable device which is supposed to be satisfactory but on which he is not permitted to speak I do not know whether he is referring to the R A F leader cable That has been fully described before the Royal Aeronautical Society, and hence may be regarded as public property As far as we have been told, the system is satisfactory in model form, experiments on the full scale are being undertaken at Farnborough, and it is the present intention to lay the cable in oval form

Mr Bramson's suggestion that the cable should be laid straight has been made by one or two people recently, and I am beginning to think it is the right thing to do

Squadron Leader Haig says it will require a much greater length of cable than in oval form, I do not think that is so, one side of the oval has to run the whole length of the landing ground That means that one side has to be much more

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than a mile long, and the total length cannot be much less than five miles, whereas a five miles' straight run should be sufficient with DF wireless D F W/T will give the aircraft's position within two or three miles In other words, with a straight run at right angles to the normal direction of arrival you could guarantee to bring a machine within the range of the cable

Objections have been made that when the machine comes to the end of the straight length of cable, there is no indication to the pilot as to how to get back This, however, raises no serious difficulty, as the pilot has only to turn through 180 degrees As to the exact indication of the point at which the pilot has to start losing height, or at which he may land, there are several ways in which it might be done For example, I see no reason why the cable should not be enclosed at certain points in a metal sheath, thus interrupting the magnetic field in that vicinity

It can be done accoustically also, though I cannot give details Suffice it to say that it can be done automatically

Experiments are now being carried out at Croydon with Neon tubes laid just below the surface of the ground, with a view to their use in conjunction with the leader cable , we are at present trying to get a suitable glass covering for the tubes to permit machines to taxi over them with safety Experiments have shewn that Neon light can be seen through some 300 feet of fog, when the observers were at some height above the fog they could see the actual tubes It was very much like observation through water As they came lower down, they lost the tubes but saw a red pool of light on the surface of the fog Coming still lower, they lost the red glow, but at about 150 feet, while in the fog, the lights became visible again

With regard to air sickness, which was referred to by the Chairman, I was hoping to hear somebody's views about the effect of noise in the cabins of civil aircraft—as to whether noise is responsible to a certain extent for air sickness Silencing of cabins is one of the problems which the Civil Aviation Department is investigating, and personally I should be very glad to hear if anyone here has any suggestions

Note —Since the above discussion, I have had further talks on the subject of the leader cable and understand that there is a considerable technical difficulty in arranging for the return of the current in a straight cable, without disturbing the regularity of the field, which of course, is essential to the solution of the problem

COLONEL BELAIEW It seems to me that now, as the speed of the aeroplane has increased, the solution of the problems which are before us might be more or less found in ballistics Take problem No 9—the super-altitude high speed transatlantic air liner with constant propulsive power , that problem is exactly the one which was tackled and to a certain extent perhaps solved by the flight of the projectile of the Big Bertha

I do feel that there is something in common between the flight of an aeroplane and the flight of a projectile, and I would like to draw your attention to the solution of certain problems which were attempted in connection with ballistics

Regarding the relative position of the fuselage on the wings, I think again that that question could perhaps also be considered from the point of view of the

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relative position of the centre of gravity and the centre of resistance We ought to tackle these problems from the point of view of ballistics, and it should be applied here to a certain extent

One of the last points which the lecturer raised was the question of fire and the cause of it In this connection I think we should approach the Institution of Chemical Engineers, for that to a certain extent is a problem where the chemical engineer comes in I think there are several chemical bodies in this country who could be approached, and who would be very glad to offer their services, or sit on a Committee in conjunction with our Institution and other bodies who are interested, in order to consider and decide what might be done to deal with this problem of fire There might be some chemical solution to the question, such as the carrying of some chemical extinguisher which could be automatically released when necessity arose

CAPTAIN SAYERS Mr Bramson has presented us with a number of problems on which one could talk at almost any length, and I feel very much tempted to do so I will, however, touch upon the points which are uppermost in my mind

Mr Bramson says that the problem of maintaining engine power within wide limits is being solved to a considerable extent This is quite true so far as the exhaust driven type of supercharger is concerned—within certain limits On recent tests made in America with an engine driven compressor it was found that at an altitude of 20,000 feet, 12½ per cent of the engine output was absorbed by the compressor, and in fact the efficiency of a supercharger of any type decreases very rapidly as the intake pressure falls Your efficiency would be under 50 per cent , and you would want over 50 per cent of your engine power to drive your supercharger at the extreme heights of which Mr Bramson appears to be thinking

The propeller problem is going to be very much more serious than the one of merely changing pitch If you maintain sea level power at altitude your airscrew diameter should increase with the increase in air-speed to maintain airscrew efficiency If it does not the airscrew r p m must increase, or else you must use a heavily over-pitched airscrew running at a poor value of V/nD The variable diameter propeller is going to be a serious problem

With regard to an ideal aerodynamic structure, it is quite obvious that if you can get rid of everything but your wings you can increase your efficiency At the same time, the actual necessity of providing a body is not so serious as the results of what you have to put inside it If you could have a closed streamline body you could make one 27 feet long, of 20 square feet cross section, for about 18 lbs resistance at 150 m p h , but you cannot do that

You have to put an engine in that body, and it is usually too big to go into a nice streamline nose The engine requires intake air, and you have to give egress for the exhaust Both the intake and the exhaust disturb the air flow round your body The pilot has to have his head out of the body Finally, your passengers want air inside the body, and that has to be ventilated All these mean irregularity in the flow over the body

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If you scrap your body and use Mr Bramson's arrangement you still have to provide holes for these various purposes, and the effect of these will be to increase resistance

Actually, the average aeroplane body has a resistance of about five times as high as any streamline you could make if you had not to put anything needing air supplies inside it

Regarding the question as to where the wings should be attached to the body of a monoplane, the best place is at the top of the fuselage and close to it In any case, your body is going to slow up the air in its immediate vicinity The wing owes its whole lifting effect to the fact that the air velocity under it is retarded and over it is accelerated, and it seems obvious that the place for the body is the one where it will least disturb this state of affairs

The effect of the relative position of body and wing is of decreasing importance as speed rises, consequently there is little practical advantage in the high-wing type for high speed machines *The majority of commercial monoplanes with* the exception of the Junkers use the high wing The low wing of the Junkers is according to Dr Junkers used on account of structural consideration, but in the case of the little Junkers cabin three seater with a 60 h p engine, the high wing was adopted as aerodynamic considerations became of greater importance than the structural advantages of the low wing arrangement

MR C G GREY I was discussing these problems with a high authority the other day, and he said that one of the aeronautical problems that required solving was the removal of most of the senior designers in the aircraft industry Then some of the juniors might get a chance He said that there is much need for new ideas, which may come from junior members of the design staffs of the big factories

As for the questions which have been raised this evening, Captain Tymms touched on the question of silence in the cabin of an aeroplane Nobody seems, as far as I have yet gathered, to have said anything about the cause of what seems to me most of the noise, that is, the slipstream You can silence an engine, but I am pretty sure that the real noise comes from the slipstream All the streamlined struts, and the leading edges of the planes, and the fuselage itself, within the radius of the action of the airscrew are continually being hit sideways by the bunch of air which is carried round by each blade of the screw

I think one of the unsolved problems is to turn out some method of using pusher screws instead of tractors If you can get the screw out of the way of these obstructions it seems to me that you will get a more efficient and quieter machine

One of Mr Bramson's points concerns vertically ascending and descending flying machines, and there you come up against fresh problems If you *could* get such a machine it would take a lot more handling than a machine taking off an aerodrome You would have to be mighty nippy on your controls to avoid getting the machine blown into your garden wall

With regard to seaworthy flying boats, a point arises that is worth considering Years ago Mr Pemberton Billing invented the idea of a motor boat with detachable wings He wanted to build a flying boat in which the hull was of very large size, and coupled to the wings by a sort of big quick-release gear His idea was to alight in Southampton Water, leave the wings at moorings, and then come alongside the dock as a motor boat

The idea is worth considering when you come to the large size flying boats, because many a pilot has been forced to land on the sea and has been wrecked by the action of the waves on his own wings When we do get to the point of having serious passenger-carrying flying boats this idea is worth considering from the designer's point of view, because a flying boat is an awkward thing to handle in a crowded harbour

As to the ideal aerodynamic structure, many people like the idea of a flying wing without anything else attached If you are going to have a flying wing without any body you have to have " twiddling " wing tips By the time you have all those things tacked on to your wing tips you may have something which is not so much more efficient than an ordinary aeroplane with a body, tail, etc Captain Hill's machine is very interesting as an experiment, but if everybody had started by building Pterodactyls, and then someone had come along with a normal aeroplane, such as we know to-day, everyone would have sat up and said " What a nice new idea ! " It is quite possible that the ideal structure may be very much like the aeroplane we have now Also it is probable that the Creator knew something about aerodynamics when He designed a bird

The multi-engine room scheme is one of the most fascinating problems in aircraft design, and if you can get something like a respectable gear-drive it looks like a way out of very many difficulties

Perhaps some of you who really know something about engineering can give some sort of idea of what is the lowest weight per H P you can get to with an indirect drive This is a very old problem Long before the War Mr Howard Wright was working on indirect drives He said that everyone went wrong because they ran their engines at what speed they could and then geared down from the engine to the screw His idea was that you ought to gear up your engine to the shaft and use a high-speed flexible shaft, like a dentist's drill, and gear down from that at the airscrew end

What is hanging up the indirect drive at the moment is the weight of the transmission

MR BRAMSON'S REPLY TO THE DISCUSSION

I am most grateful to you all for having made such varied and numerous contributions to the discussion It is always a test of whether it has been worth while to come, to see the number and length of the contributions afterwards

Squadron-Leader Haig made the very just remark that, assuming every problem in connection with jet propulsion to have been solved, you stilll have in front of you the enormous one of how to start the thing going, because at a standstill the efficiency would be nil I think the idea of having an ordinary engine to start with would hardly meet the case I thought that the weight of wing mechanisms, flaps, slots, etc , had now been brought down to such figures that their incorporation was nevertheless justified, but that of course depends to a large

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extent on the relative importance which you attach to safety and economy, and in this connection I am very much of the opinion that safety is the only true form of economy in aviation, because without it you cannot get any paying load whatever

Squadron-Leader Haig also mentioned fog landing schemes, and Capt Tymms was kind enough to agree with me I think that if you develop the oval cable into a straight line leading to the aerodrome, the total length required will be found to be of the same order in both cases Speaking as a pilot, if I were flying down along a straight line and was about to throttle down I might have the necessary courage and conviction, but not if I had an oval line

The question of guiding machines into the effective field of the leader cable was I think, completely dealt with by Capt Tymms If a cable were laid down in a straight line at right angles to the usual course of the arriving aeroplane, the pilot, knowing that the line was, say, north-south, would zig-zag east-west towards the direction in which he was told to go by wireless telephone

Regarding high wind velocity at heights, I did not know this was as much as 100 m p h but even if it were, and the figures I mentioned were attained, it would only amount to the same percentage reduction of speed as we have to face now

With regard to the Diesel engine, weight per H P is not a true criterion You have to start with certain assumptions as to flight duration and then find out, in comparing two different engines, what is the sum of the weight of the necessary fuel and of the engine, and you will then get a true comparison

Concerning the question of fire, there is something I, personally, have only just realised—that the ingition temperature of oil is very much lower than that of petrol Whether fires actually do occur due to ignition of oil I do not know, but if you have only oil on board the flame is likely to remain local so that in spite of the low ignition temperature of oil it is, in the absence of petrol, relatively safe

Referring to Capt Hill's machine, I think everyone admired the fact that he had got so thoroughly into the scheme " in one go " It was his first effort, and I think it was a remarkable one

Capt Tymms dealt very fully with fog landings, and I thought that one of the most interesting facts he gave us was that direction finding can now be done with an accuracy of two to three miles He also spoke of the possibility of flying in a straight line and then turning 180 degrees and finding it again I have some experience of that in skywriting when dotting i's and crossing t's With a machine that I know I can do it with my eyes closed

Capt Tymms told us about the Neon tubes This is of extreme interest I have always been accustomed to think that the complete fog landing scheme would involve under-carriages capable of absorbing sufficient energy to allow a machine to glide down at an angle of incidence corresponding to the minimum rate of vertical descent, assuming that the pilot was unable to see the ground

So far as air sickness is concerned, I do not know what causes it, but judging from what one can feel in one's inside, it is a matter of momentary acceleration I have made some experiments on a boat in finding out by walking along the deck, the place that seems to be the centre of oscillation If you are there you don't get sick, because angular motions do not affect you Curiously enough, passenger boats generally seem to be so arranged that the dormitories are well forward where the effect is worst, and round about the centre you find engines and kitchens and every possible thing that you can't get at The effect of noise in regard to sickness is a subject worth investigating The problem might arise in connection with finding suitable positions for engines on large passenger aircraft

Colonel Belaiew made some comparisons between aeroplanes and projectiles, between aerodynamics and ballistics, and said that the comparison suggests itself more and more as greater speed is attained Although one knows, that the air forces acting on projectiles have to be considered, at the same time I think that from a mathematical and an aerodynamical point of view the two sciences are distinct and separate, because usually projectiles move at a speed greater than that of sound, whereas aeroplanes do not For that reason I do not think we could use this comparison when dealing with aircraft

Colonel Belaiew mentioned that the question of preventing fire in aeroplanes on crashing might be dealt with by chemical engineers, and this is, of course, a chemical engineering problem I have recently been in touch with people who considered they were the proprietors of the most efficient fire extinguisher in the world They have produced a kind of foam by means of a viscous liquid, in which carbon dioxide bubbles are in suspension The foam serves the purpose of keeping that gas round the burning matter It is possible to extinguish in a very short time big chemical fires which defy extinction by any other means At the same time, I believe the apparatus is too heavy to be carried on aircraft I think the main trouble is the petrol tank It is definitely possible to design tanks which won't burst on crashing, and it seems a crying shame that regulations have not yet been made to make such tanks compulsory at any rate on civil machines

Capt Sayers mentioned that turbo compressors have only partially solved the problem of maintaining constant power, and that the loss at 30,000 feet was 12½ per cent The proper test, of course, as to whether it is justifiable to carry a turbo compressor is, firstly, the question what do you want to use the aeroplane for ? If for military purposes it may be economical to adopt a complication for the purpose of getting a few more thousand feet ceiling I would like Capt Sayers either now or later to let us know at what density he considers that the gain in power due to the turbo compressor only just compensates for the loss of power due to driving it, and due to the extra drag corresponding to its weight That would seem to give us an indication of what is the possible limit

CAPT SAYERS I do not think there is any limit , it is subject to considerations of weight You can get up to 20,000 feet and then start your climb from there You do not get constant power At 20,000 feet you start as if you were running an ordinary aeroplane over sea level

MR BRAMSON Capt Sayers also mentioned the question of the ideal aerodynamic structure, and referred to the imperfections and so on which the presence of the engine imposes on the fuselage shape I would put it to him that that again is very largely due to the fact that the propeller is put so close to the engine at the present moment It is not that there is no room to put an engine inside the fuselage,

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but that it has to be in one particular place in relation to the propeller, and if that condition were eliminated by the adoption of some device to drive the propeller at a distance the aerodynamical problem might be affected in a very favourable manner I can hardly imagine that in a big aeroplane the pilot's windscreen, although its surface is placed at right angles to the line of flight, would involve a serious percentage of the loss

CAPT SAYERS It is a great loss on a good streamline If you take a really streamline body and put 1/20th of its cross section on a wind screen, you double its resistance You cannot get a clean nose with an aeroplane , all you can do is to streamline the tail

MR BRAMSON Captain Sayers also mentioned the question of the best place for the wings, and said that the German constructors obviously thought that the wing attached to the top of the fuselage was the best Junkers, however, swears by their old scheme

CAPT SAYERS That is entirely for structural reasons

MR BRAMSON Capt Sayers made a very interesting point that the function of an aerofoil is to slow down the stream under it and accelerate that above it, and therefore if one puts the wing on top of the fuselage the effect is to slow down the airstream near the fuselage, that is, where it has been slowed down already That seems simple, and the most recent knowledge on the behaviour and effect of the boundary layer seems to bear out Capt Sayer's views

Mr Grey's first problem consists in removing designers If you removed them by air that would in some vague manner constitute an aeronautical problem, otherwise I would call it an industrial problem—not that of preventing them from exercising their industry, but of making our aircraft industry choose the right people for doing the job As a matter of fact, I think Mr Grey may, very occasionally be inclined to be a little pessimistic

The problem of silence to which Mr Grey referred is to a large extent coupled with propeller problems I do not know what are the percentages in practice, but a great deal of the trouble is due to air noise Mr Grey suggests that pushers would get over it to a large extent Well, now, with the big twin-engined machines on Imperial Airways there is no propeller slipstream going round the body, and yet the noise is very considerable , I therefore do not know to what extent that would influence noise

Mr Grey says it might increase the efficiency of propellers if they had not got to pump back on to big bodies, wings, etc At the same time, it seems probable that the advantages of putting wings and body in virgin air would be very great, because, obviously, propellers should be placed in positions where their slipstreams are free, and where they do not destroy the good qualities of the aerofoil that carries them

The flying boat which can shed its wings seems a very interesting proposition

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Capt Sayers dealt with the ideal aerodynamic structure, and I think it is high time we knew something about it

All the complications which Mr Grey mentioned in a bodiless aeroplane might outweigh the advantages of having no body They were not very much in evidence as possibilities in Hill's machine, but a question which affects the problem very much is—to what extent will the small accessories, wing, tip ailerons, etc , affect the wing compared with the extent to which bodies affect the wing ?

The design of birds is not altogether based on the same considerations as the design of an aeroplane Birds never carry passengers, but that is not the only point which one could make for the purpose of showing that Nature is not always the most perfect engineer For instance, there is no animal in existence which has a wheel, and yet the wheel has produced practically everything in modern engineering

The multi-engine room is a fascinating possibility What the lowest weight per H P is I do not know I worked with Mr Constantinesco, and he invented some hydraulic transmission schemes in which high pressures were employed , we did not then get down below a value which would mean that the total weight per H P would be increased about 50 per cent

The meeting closed with a very hearty vote of thanks to Mr Bramson for his extremely interesting paper

ADDITIONAL WRITTEN DISCUSSION FROM CAPTAIN SAYERS

October 15*th*, 1926

DEAR MR BRAMSON,

I am sorry that I did not notice it earlier, but I find that your computations of the speed which will be attained at heights in your recent paper is rather misleading In your introductory remarks you suggest that you are considering the case of a machine always flying at the same L/D, and therefore with constant drag

Accordingly you assume $R \propto v^2 \times \rho$, in other words, you imply constant drag coefficient, which is in accordance with the initial suggestion But you neglect the essential governing factor upon which all aeroplane performances depend—the necessary equality of lift and weight Your expression for the variation of speed with altitude, or rather density, is correct for an airship kept always in static equilibrium, but not for any aircraft whose lift is dynamic except under limited special conditions as an approximation If an aeroplane maintains constant L/D and constant weight, then drag and thrust are constant and power varies directly with speed That is nothing is to be gained by changing density But to reach this condition the wing area or characteristic must be changed with change of density in order to keep both L and D constant If you take the case of the aeroplane at constant incidence, and constant K_L and K_D, then —

$$L \propto K_L \rho V^2$$
$$D \propto K_D \rho V^2$$

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Hence with change in ρ to maintain constant L

$$V \propto \sqrt[2]{\frac{1}{\rho}}$$

and D also remains constant if this condition is fulfilled In your 52,000 ft case, where $\rho = 16$, V at 52 000 ft is $\sqrt[2]{\frac{1}{16}} = 2\ 5$ times V at sea level, or 625 m p h for the 250 m p h machine, and 2 5 times the power is necessary

Taking your expression $V \propto \sqrt[3]{\frac{1}{\rho}}$ you obtain a lower speed in the ratio of

$$\frac{\sqrt[3]{\frac{1}{\rho}}}{\sqrt[2]{\frac{1}{\rho}}} = \sqrt[6]{\rho}$$

and the lift at the same incidence will be only

$$(\sqrt[6]{\rho})^2 \times \text{Weight } (= \sqrt[3]{\rho}\ W)$$

This is the reciprocal of your speed expression—*i e*, to meet your speed variation at constant L/D the weight of the machine must change inversely with the speed For $\rho = 16$ Your speed increase of 1 84 involves increasing weight in the ratio of $\frac{1}{1\ 84} = 54$

In the case of a machine flying high up in its speed range—well away from landing speed and much above the speed of best L/D—it is nearly true that K_D is constant for fairly large changes in K_L

If the assumed 250 m p h machine at sea level has a reasonable landing speed, this approximation would apply to it fairly and it would reach nearly the speed given by you at altitude So far as present possibilities go it could not weigh much more than 5 lbs per H P to reach that speed, and therefore could barely carry fuel to reach 52,000 ft and then fly any distance If however, you take the case of a machine carrying enough load to be useful and still landing at a reasonable speed, the gain in speed at high altitude will be considerably less than this, assuming constant power

For long distance flights, on which alone high altitude flights are promising, the weight of fuel to be carried is the crucial consideration The minimum weight of fuel for a given distance is almost entirely dependent on drag The total energy expended on any journey is D × L where D is drag and L is length of journey For fuel of fixed calorific value, the total energy per lb is constant, and given equal overall efficiency of power plant and airscrew, all machines having equal drag will use the same weight of fuel to cover the same distance, quite independently of speed Therefore for long distance flights the maximum ratio of L/D is essential in order to keep down fuel weight Landing speed is necessarily limited

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in any practical transport service At constant density, there is a definite ratio between landing speed and speed of best L/D for any given design For the average decently designed aeroplane of to-day, the speed of maximum L/D is from 1 4 to 1 6 times landing speed

If you fix landing speed as high as 100 m p h you cannot exceed a speed of 160 m p h at standard density unless you quite appreciably increase the total fuel consumed per mile—otherwise sacrifice either range or useful load

But if you decrease density the speed of maximum L/D varies as $\sqrt[2]{\frac{1}{\rho}}$ Drag remains constant, time-rate of expenditure of energy, or power, increases with speed, but fuel consumed per mile does not—assuming, of course, that engine and airscrew efficiency can be maintained

Consider a normal commercial machine (say, loaded to 15 lbs /H P), landing at 60 m p h with a maximum L/D of, say, 9 at 96 m p h Assume 3 lbs /H P for power plant and for structure, and one for pilot and navigation instruments You have 8 lbs disposable load Assume that you are willing to use 7 of these for fuel and 1 for urgent mails or the like The effective thrust H P loading is 28 4 lbs , and with an airscrew efficiency of 80 per cent the B H P loading at cruising speed is 22 7 (That is engines are asked to give 2/3 maximum output cruising) If you take the fuel and oil consumption at 6 lbs /H P hour, 7 lbs of fuel per H P gives you a range of $\frac{7}{6}$ or 11 66 hours, and an extreme range of about 1,120 miles Suppose you transport the same machine to an altitude where the density is 1/4 of that at sea level At the same incidence, etc , the speed of best L/D becomes twice as great—192 m p h , the cruising H P is doubled, and efficiencies remaining the same, the fuel consumption per hour is doubled But as you cover the total distance in half the time your total fuel is unchanged, and you have doubled your speed for nothing

Practically of course, you will have doubled your power plant weight which in this case would wipe out the whole available pay load and some of your fuel as well, but actually the process may in time permit of considerable increase in cruising speed at a reduced cost

If you try to double the speed at standard density conditions your power will have to increase at some rate intermediate between the second and third power of speed The lower rate cannot be achieved, but if it could your fuel consumption per mile would increase directly with speed, and your power plant weight as the square so that you can not go far along this road In practice one would fly somewhere between the speed of minimum power and that of maximum L/D to compromise between power plant weight and minimum fuel weight, if one went out for a combination of high speed and long range by operating at extreme altitude But what could be done in this way can only be settled when fuel details of a practical power plant are known, and the particular conditions as to load to be carried and range to be covered are fixed

There are very distinct possibilities of increasing speed of aerial transport by operation at extreme altitude, but very few indeed of decreasing its cost

Yours sincerely,

W H SAYERS.

MR BRAMSON'S REPLY TO CAPTAIN SAYERS

DEAR CAPTAIN SAYERS,

Many thanks for your letter of October 15th

I fully realised that the estimates given in my paper of possible increases in speed at high altitudes were very rough approximations and I am obliged to you for pointing out that they were in fact too rough

The assumption of constant drag coefficient does not hold good as you point out at economical angles of incidence when the lift coefficient has to be varied

I think that your letter is so interesting and is in fact a model of the very kind of contribution which my sketchy paper was intended to rouse, that I intend, with your permission, to have this correspondence included in the minutes of proceedings of our Institution If there is some technical objection to this course I shall propose that it be published in the monthly circular to members

With many thanks for your taking the trouble to write me such a thorough and lucid letter on this fascinating subject

I remain, Yours sincerely,

M L BRAMSON

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