# Metal-Clad Rigid Airship Development.

**A Lecture given by Mr Ralph H Upson, M S A E (Hon M I Ae E ) before the Institution in the Lecture Room of the Junior Institution of Engineers, 39, Victoria Street, London, S W 1, on 4th June, 1926 Lieut -Colonel J T C Moore-Brabazon, M C , M P , in the Chair**

THE CHAIRMAN said

GENTLEMEN —My duty to-night is to introduce to you Mr Upson, who is General Manager of the Aircraft Development Corporation of Detroit He is a bird of passage this time in one respect, because he only has a very few days in London, and consequently we are all the more lucky and grateful to him that he has come to us He is to tell us some of the new developments with regard to the airship Some of us divide ourselves into two camps over aeroplanes and airships, but if airships are a luxury to some countries, in my opinion they are a necessity to an Empire like our own, where long distances have got to be tackled and where big weights and large bales must be carried very long distances We have had disasters in the past, we will have disasters probably in the future, but do not let our faith in the big airship ever waver With America we have had a disaster in common, but in America they still have faith , they are going on developing and in our own country even with successive Governments we have not varied from seeing the necessity of building airships for this country more than for any other Consequently they go on, and soon we hope to see them in the air

Mr Upson has come here to tell us of new ideas which may be incorporated possibly in those machines which are being built—anyhow, he will introduce new thought which we will turn over in our minds, and it is, I know, your desire that I should express your gratitude to him for coming to tell us his experiences and his ideas about future airship construction (Applause )

Mr UPSON said

It is a very considerable honour to be asked to speak to you, I only regret that my talk to-night has been variously termed a Lecture and a Paper, which I think is possibly too dignified a term to cover the very informal talk I shall be obliged to give on account of what you may readily appreciate has been the very limited time available I think these informal gatherings are often more useful and have more possibilities of real value than some of the prepared Papers, so I shall be satisfied if I can tell you a few of the higher points, necessarily rather sketchy, in the development that we have been carrying on for the last five years

I have heard certain criticisms by some of your own countrymen concerning the length of time which it has taken for you to get at the actual construction of your large airships here As I understand it you have been working about two years or perhaps three, on the problem of making airships that are both bigger and better In order that no one may be discouraged as to the length of time that that has taken, I need only say that we of the Aircraft Development Corporation in Detroit (not the entire time under that name—but in effect), have been working five years on just one of those problems, merely that of making better airships, and we have only now reached a point where we are ready to begin construction on a very small demonstration unit , the larger ones must follow after the demonstration of that one

As your honourable Chairman has mentioned the matter of airship disasters, it may be of interest to know the circumstances under which the Company that I represent was actually organised As I say, the work had been under way to a certain extent before that , I had done a good deal myself in an individual capacity, and others unknown to me had been working along a line which ultimately focussed into pretty much the same thing Then the Company was actually organised for the purpose of developing a type of airship which would be thoroughly safe and economical for commercial purposes The organisation meeting took place just two weeks after our large army airship crashed and went up in flames with a loss of some thirty-four men Of course, one of the reasons that made it possible to organise at that time was the fact that one of the main objects of the whole development was improvement in the fireproof qualities of the structure

There is a good deal of misconception in some quarters as to the situation in the United States with respect to helium A good many people think we have large quantities of helium and all we need to do is to use it That is far from the case After a good many years of development—in fact, it has been going on ever since the war—we are still very far from having a supply of helium which either in quantity or price may be called commercial It is of course, possible by improvements in construction and operation of the ships themselves to use helium in such a way that it will not be wasted to any great extent, and its cost will be largely considered as part of the ship Some features tending in that direction have been developed coincidentally with the others, but even assuming that you get no loss of helium at all, that it costs nothing except the initial filling, without allowing anything for valving or for leaks or anything of that kind, all of which are bound to occur to a certain extent no matter how well it is handled, you still have very considerable disadvantages in the use of helium for commercial purposes I am not speaking of military purposes at all now

In the first place helium is very seriously deficient in lift , so far it has been impossible to get it in a quality that lifts more than about 90 per cent of good commercial hydrogen , in other words, it has 10 per cent less gross lift than hydrogen   Theoretically it may be possible eventually to get it approximately 7 per cent less than hydrogen, but that is assuming a purity which has not hitherto been obtained in other than small quantities, and it is assuming that the gas is repurified constantly to keep it up to the mark   Suppose we take it at rather a liberal figure, allowing a little for future developments, at 8 per cent less lift than hydrogen   That is the gross lift   If you subtract the weight of the structure of the ship without any passenger accommodations or useful load of any kind, it amounts to about 16 to 20 per cent of the remaining lift   Then you take out your fuel and passenger accommodations and supplies, and everything that goes with it, and your crew, and before you get through you get, as you will readily appreciate, a very serious decrease in the useful or pay-load

That is not all   Hydrogen will burn , that furnishes one of its principal disadvantages, and also one of its principal advantages   From the very fact that it will burn, you can use it for part of the fuel, and I understand that that is also contemplated with your development here   Hydrogen in proper quantity can be burned with the liquid fuel in order to keep the ship approximately in balance and increase its range of action from 20 to 30 per cent   In one way that is really one of the factors, one of the characteristics of hydrogen making for safety because it does increase the reserve cruising range, not only on account of the extra fuel that can be carried, but on account of the gas itself being useful for fuel   Putting everything together, you get this as a final result   with a ship of a range of size which is now contemplated—take, for instance, the " Los Angeles," which we are operating now   formerly the ZR3—if you want to make the greatest possible distance, you can just about double the distance with hydrogen that would be possible with helium at equal speed   Figured on a basis of pay-load, in many cases it would be quite in the range of commercial feasibility to carry considerably more than double the pay-load with hydrogen than with helium, other conditions being equal   In almost all cases it is at least double, and in many cases three and four times the amount of pay-load   So that for commercial purposes we are not at all ready to scrap hydrogen, and the situation to-day is really not very far different from what it was at the time I speak of, when one of the main desirable features we wanted to work out was to get a ship which was enough fireproof in its own structure, in the container within which the gas was to be placed, to make it to all intents and purposes just as safe with hydrogen as with helium   To give just a crude example   you are not afraid to ride in a motor-car with petrol, providing it is safely contained in a metal tank , you are not afraid to live near a large storage tank of illuminating gas   provided it is in a metal tank of proper construction   It is rather an unsightly thing usually, but no one is ever afraid it will blow up   In the same way, the metal airship should be to all intents and purposes perfectly safe for ordinary commercial use whether used with hydrogen or helium

Now the next thing of course, is to get such a ship   It was fairly clear before we went very far that duralumin, a material now available in commercial grades, had very good qualifications for the purposes   On a time test it was far stronger than the ordinary fabrics weight for weight , it was very much more positive and determinate in its physical characteristics , it was not subject to such irregular and uncertain deductions for the length of time that the load was on it and for exposure and so on. It is true that duralumin does corrode to a certain extent, but we are learning several practical ways now to protect it which seems to be very satisfactory. As long as the surface is protected we know that it is of indefinite life. The fabric, on the other hand, no matter how well it is protected by any dope or varnish preparation, or anything through which light rays can filter, is still affected by the actinic rays which strike through and not only deteriorate the coating, but the fabric itself. Even supposing that the fabric itself is not affected to any appreciable extent until the coating is destroyed, it is a very difficult if not impossible procedure to scrape off the old coating and put on fresh in the case of fabric. In the case of duralumin there is a great deal of lee-way in the way it can be handled, and as long as there is anything at all to keep away the moisture it is perfectly good. In other words the sun-rays have little or no effect.

Given the fundamental physical qualities which make it theoretically possible to design a satisfactory all-metal airship, it was a problem then of getting the material arranged in much a way that one could utilise these qualities. One of the most fundamental principles which was early employed in working out the development to a practical point was the assumption that the covering should be made an essential part of the structure; in other words, let us not consider it as a covering at all, but in a similar category to the plating on a steamship. Take away the plating from a metal steamship and what do you have left? You have left the frame you say. But the frame by itself is nothing; it won't even carry the loads of operation even assuming that it would hold water. It is not structurally self-sufficient. Of course neither is the *plating* sufficient by itself, but the two together make the structure of the ship, and it is in a similar way that we work out the structure of the metalclad airship. It is a combination of the two, both of which contribute their proper functions to the whole.

So far, so good, from the standpoint of theory. But then there comes the matter of actually putting it into practical form. We found considerable difficulty in applying the principle at first. It was very difficult, for example, to get for the smaller sizes, or even for moderate sizes of airship, a guage of material thin enough to compare with the plating round a steamship in proportion to the loads that it had to carry. As a matter of fact on simple proportion, it worked out as an almost prohibitively thin skin. That made it necessary, for the smaller sizes at least, to allow a certain proportion of the weight for what you might call mere covering purposes, so that you would have something substantial to handle and deal with, and which would not be so subject to local injury. That requirement necessitated, or at least made very desirable, a re-design of the entire hull in such a way that the amount of surface would be reduced to a minimum. At that time the ordinary idea for a rigid airship was to have a fineness ratio (length divided by diameter) of between 8 and 10. The Shenandoah was 8·7 approximately. The Los Angeles appeared soon after with a ratio of 7·3, an improvement, but not enough to make a really substantial difference from the standpoint of weight. I had an idea, and other people had too, I think, that with a proper design of curve, one could make an efficient ship very much shorter and more compact. Of course, we had had the example of non-rigids which approximated a fineness ratio of five which were fairly satisfactory, but were supposed to have quite a high resistance It was found, however, that most of the resistance was parasite in nature, due to cables and car and various things About that time also the thick section wing began to come into favour for aeroplanes, and it was rather astonishing the results that were being obtained from very thick wing sections, so that just by analogy and one thing and another we figured we ought to be able to design a rigid airship hull which might have as low a fineness ratio as say $3\frac{1}{2}$ to 4 , our first attempt was $3\frac{1}{2}$ Based on more or less fundamental data, a study of the effect of slight changes in the shape, making use of the hydrodynamics of a perfect fluid, and then going back and figuring the results of skin friction and turbulence, and also a study of the forms of fast swimming fish and cetaceans, an improved curve was evolved We call it the E-H curve, because it is a combination of elliptical and hyperbolic curves with definite equations The one part of the curve which was not susceptible of any rigid mathematical analysis, the tail, we made in several different forms of varying fineness One was carried out to an extreme point , then there were three other styles that were progressively shorter and more rounded The one that was next to the shortest came out best, everything considered That gave it a fineness ratio in the end of approximately 2 8, or less than 3 The first tests were made in the Navy wind tunnel at Washington , by the extrapolation method used in that tunnel, for full-scale conditions, the resistance figured out substantially less than that of the Shenandoah hull, which had a fineness ratio approximately three times greater Of course, there was a good deal of question immediately as to whether we could depend on that result, but even though we should add 100 per cent to indicated figure for resistance, it still showed that the thing could be done without great sacrifice

The next objection was that the low fineness hull would be unstable It was claimed that we could not stabilise it , it would “ spin like an egg and be uncontrollable ” So it was, rather poor in stability, with the ordinary old-style types of surfaces This idea about the instability of the low fineness ratio had rather good support also from experience that had been had with one of those non-rigids that I spoke of which was extremely poor in stability and almost uncontrollable at times Of course, pilots blamed it on the most conspicuous difference from previous ships and said “ Well, the low fineness ratios are no good ” So then we had an entirely different problem, that of stabilising the ship Again from fundamental considerations it appeared entirely reasonable to suppose that a ship of that kind could be stabilised satisfactorily, and again, by means of a close study of the proportions, dimensions and arrangement, we have been able not only to set a satisfactory stability and control, but to effect a very great improvement over anything that had appeared up to that time The comparison with the Shenandoah for example, which incidentally was a very good representation of airship styles at that time, worked out something like this

At small angles of yaw—take for instance, some particular angle like 4 degrees, which is a fair average of what you are liable to meet with in actual operation—the transverse resultant force on the Shenandoah, with fins on, crosses the axis at a point well in advance of the nose This is what we will call the centre of pressure for that particular angle of pitch

With the new hull at the same angle, other conditions being entirely the same, the force came almost back to the maximum section of the hull, and in addition was considerably greater, that is the aerodynamic lift with neutral surfaces was considerably greater, at the same time the unstable moment very much less Some of the various dynamic characteristics in free flight were equally favourable The way it was done was almost entirely by a study of the detail of the fins and controls, that is by entirely throwing out the old ones and going back to first principles, and considering that there were several different variables all of which had to be set just right to get the results , in other words we forgot about having had four fins, we forgot about their having to be put at a certain approximate position on the hull—the old idea was to put them back as far as possible to get the greatest lever arm—we forgot about the idea of making them a certain approximate length and so on , we forgot about all that old stuff and started all over again, simply with this to go by, that we had to stabilise that ship with some kind of fins We assumed that we had to have fins on that ship, but we did not know where to put them, how many of them to put on , we did not know where to put them longitudinally or circumferentially , we did not know how big to make them, what shape to make them , we did not know how long or how wide to make them , we did not know what proportion between the movable and fixed surfaces would give the best results, and so on Now, of course, we tried to get as near to some of these many variables as possible by analytical means, and there again hydrodynamical methods came to the rescue and provided a means of doing as much work of this preliminary nature in a few weeks' time as would otherwise take months in the wind tunnel Then we made three different styles of fin surfaces to start with, and eliminated one factor very early in the study, that is we found very soon that eight fins were a great deal better than four, and then gradually narrowed it down and tried many different styles of the eight-unit type until we finally had the shape and the size and the position both circumferentially and longitudinally that gave a very close approach to the absolute maximum of efficiency Just by being willing to throw out the old fins and make a fresh start has made all the difference between a ship that was not so very stable and one which is unprecedentedly good Now, of course, you must not assume that that particular arrangement is going to apply as it stands to some other shape of hull It is all fitted in with the hull , in the same way that the frame and the plating co-operate structurally, the fins and the hull co-operate aerodynamically to produce the result

Coming back more nearly to the subject of metal clad construction, the result of all these aerodynamic tests established without any question of a doubt that the short, compact shape could be satisfactorily used, so that was out of the way It made a considerable saving in weight for the smaller sized ships, and permitted not only building a large ship of the metal-clad type, not only a medium sized one, but it permitted building an extremely small one The demonstration ship that we are building first is one of only 200,000 cubic feet, just the same size as the fabric non-rigids that are being operated by the Army at the present time This ship is not only rigid, but a metal-clad rigid

Coming to the structural part of the design, it was considered at first by many an almost insuperable difficulty to figure out the intricate maze of stresses that were to be carried in a metal-clad airship, and the fear was well founded In the Zeppelin type of ship or the conventional rigid ship, and in that I include all rigid ships which consist of a frame covered with fabric, in any of them you have a very high degree of redundancy on account of the fact that you have wires running through and wires running round, and they all hook up with each other and with the compression members to produce a very highly redundant structure The reason it is redundant is, of course, that there are so many members and wires running around in different directions Now off-hand you would say nothing could be more redundant that a metal-clad ship which carries its share of the stresses in the plating itself, because there you have the equivalent of an infinite number of wires which carry stresses in any and all directions that they happen to want to go in, and are reinforced by compression members which in their turn take stresses along predetermined lines Strangely enough, however, the approach to the extreme in that respect has been in effect a simplification There are two ways to simplify a structure from a stress analysis standpoint one is to reduce the number of elements to the very minimum which makes a statically determinate structure of it , the other is to multiply them so much that they in effect produce a uniform material In other words, if you increase your number of parts to such an extent that your material to a large extent closes in on itself and becomes perfectly uniform, so that the stresses can be carried in any direction, then you can go back to first principles and consider what direction that stress is going to be carried on I do not know whether that is perfectly clear, but that is the way it works Here is a good example Take, for instance, an ordinary beam, say a 2 × 4 wooden beam such as is used in a wooden house construction, and subject it to bending You might think off-hand, that stresses in that member are going to shoot around in all directions, but they do not You have certain loads and pulls on that beam that require the stresses to go in certain directions even though they can be carried in any direction, but when you limit in any way the direction in which stresses can be carried but at the same time have a multiplicity of members which *can carry them*, then you are up against it, because you have neither the one thing nor the other That is where most of the complications come in I hardly need to say it is not child's play to work out the plot of stresses over the whole of the metal-clad airship hull , it is a very arduous difficult undertaking, but it is susceptible of very close analysis, that is the thing I am trying to bring out It is susceptible of very close analysis not only on account of the arrangement of the material, but the definiteness of its physical characteristics, making up a structural unit, which has a perfectly definite elasticity, co-efficient of expansion and other characteristics

The stresses in the actual ship were first worked out by purely analytical methods but then, to be thoroughly safe on it, we repeated the same kind of experiments, that is, experiments for a similar purpose as the aerodynamic ones We thought we were on the right track, the premises and steps in the analysis seemed reasonable, and were checked in various ways by "backdoor methods," but we still wanted a practical test on something that would prove out the theory and formulæ in some practical way on the actual structure as a whole For that it was insufficient to take members by themselves, because if you want to know how strong a girder is, you can make a section of it and break it, in the same way you can treat a beam or a wire or anything else that is a component part of the structure, but none of these tests gave the sum total of effect of all the inter-reactions of stresses on the structure as a whole Some of you are familiar with the method of testing airships by what is known as the "water-model" The water-model in its fundamental essence is simply a scale model made out of the same kind of material, everything in proper proportion, which is then hung upside down and filled with water

The weight of the water pulls downward all over in proportion to its volume and the forces which represent the weight of the structure of the ship and its contents are carried by cables running up to levers or pulleys Thus you get the reverse condition from that existing in the actual airship in which the gas lift acts upwards and all your weights act by gravity downward In other words the weight of the water is a volume factor the same as the lift of the gas, and that permits the test to be made on the structure of the ship as a whole All water-model tests that I knew of previously, were made on the "natural size" of the water-model, one thirtieth the linear dimensions of the full-sized ship The purpose of choosing that particular size is to get such a size that you can use the same envelope material that was usually employed on non-rigids But here was a case where we were not satisfied with a test which would put the same stress on the material We wanted a test which would overload it in the same way that you sand-load an aeroplane wing, and if you are loading it to destruction, you are not satisfied to put on what you expect in normal flight, you want to get an increased weight, you want to keep on increasing the weight on the upturned wing until it breaks and see what happens In the same way we wanted an overload test on the airship You cannot do that from a standpoint of direct lift and load of an actual airship, because your gas will only lift in proportion to its volume, but here by choosing a different size, which in this case was approximately 1/14th instead of 1/30th, we got the equivalent of overloading the ship approximately five times, and that was severe enough to give us a good big load factor, and at the same time it accomplished another incidental purpose of practically eliminating any effect of the stiffness of the material to normal movement, that is the stiffness normal to the surface which is almost nothing on the full-sized ship, and, in comparison to the stresses existing in the model, was also practically nothing in the model If we had used the same stresses as in the full-sized ship, then the stiffness of the material would have been an appreciable factor, at least it would have been a factor which tended in the other direction We wanted to be sure of keeping it on the safe side

The principal result of the exhaustive water-model tests, covering a period of about five months, during which the model was inflated most of the time, was that we could not tell any difference from the calculated results, it checked almost exactly At first we thought we had found a place where it did not There was a series of little wrinkles that indicated an excessive shear stress at one portion of the model that we had not figured and which had not shown up in the calculations, and we thought at first that the calculations had gone wrong in some way, but we found the trouble was simply this we had not taken the stresses at enough different points The preliminary calculations covered only the equator and the bottom and the top all the way along, and this was in between where we considered at first it was not necessary to go We figured if we got four different points around the ship, that would be enough to fair in the rest, but it was not so There was a spot in there that got a little beyond the limit and showed it , as soon as we had worked it out for that particular place, it showed in the calculated figures exactly where it should have been expected

There is one other feature of the construction that I suppose I should mention, but I want to leave as much time as possible for discussion The ship is designed as a rigid structure at all times, that is, it is entirely non-deformable, which is one of the main essentials for a metal-clad hull , if you allowed it to deflect to any appreciable degree you would simply be " sunk," because the material won't stand a lot of moving around, particularly considering the fact that you cannot strain or distort the circular section, the transverse section, without also changing the longitudinal dimensions too , and with a double curved surface like that, it is simply impossible to change both at once, and have your material hang together, even though you can take a piece of it and bend it in one direction almost indefinitely. That is one of the main essentials to make it absolutely rigid , in that respect it will be far more rigid than the rigids of the present day, that is, there will be less deflection of the ship as a whole It still leaves one problem to be taken care of, or rather two related problems one of them is the stiffening of the surface locally against the wind pressures and tendencies to vibrate and so on , the other is to utilise the strength of the plating to as great an extent as possible in unusual weather conditions such as destroyed the Shenandoah

Now the usual method of stiffening the surface locally against aerodynamic forces and vibrations is, of course, by either corrugating or by a multiplicity of ribs We had to discard both of these methods in the case of the airship hull , corrugations are not good because they spoil the flow of stress in the other direction, a multiplicity of ribs adds too much to the weight and expense of construction. So this is the way it is done

The present type of rigid has a series of openings leading into the air space in the hull, so distributed that the internal pressure averages about zero In other words, for a ship of this kind you would get a little suction around the centre, and a little pressure from the outside at the nose and tail On the metal-clad ship we simply do this instead of making the internal pressure correspond with the zero point, we make it correspond with a certain positive range of pressure by taking in the air supply from the proper portion of the outside pressure curve In other words it averages a positive pressure when under power in one respect similar to the non-rigid, but in another respect very different, because normally it is the function only of its motion through the air In other words as you build up speed and require more local support for your plating, you get it by the natural flow of air as induced by the speed itself

I would like to throw the meeting open for discussion now, if I may (Applause )

COMMANDER BURNEY Colonel Moore-Brabazon and Gentlemen —I am certain I shall only be expressing the feeling of the meeting if I say we have been very delighted to listen to Mr Upson's Lecture this evening, and it has been one of very great interest to everybody who is working on airship construction Like all pioneers who put forward new ideas I am sure that he will expect criticism, and I hope he will be able to give us a reply to such criticisms as we may have because owing to the shortness of the time that we have had to-night, there are, of course, many features which have only been sketched on rather lightly

I do not profess to have been able to follow the whole of the constructional features put before us, but it seems to me that there are three fundamental points which have been dealt with

Firstly there was the difference in length diameter ratio which was developed primarily to reduce the area of the outer cover It is quite true, and it bears out the work we have been doing upon the same lines, that there is no difficulty in getting down to a very much greater length diameter ratio—or rather less length diameter ratio—than normally employed I was also interested to hear Mr Upson had been doing a great deal of work on water-models, because we also have gone to water-models for the same reason, and when one gets down to investigation of the actual resistance, I quite agree with what he says that there is very little difference between a ratio of three and a ratio of say up to 4½ Where I do rather disagree with him is that there are other considerations which must be taken into account when one is dealing with a large ship I quite agree that on small ships it is feasible to go on a small length diameter ratio, but if one is building a very much bigger ship, say of the five million type, there are other practical considerations which come in which have to be given very serious consideration, and it was those considerations which led us to a 5½ to one ratio But if one takes a form of construction which necessitates a length diameter ratio of say three to one, then I think one can only get comparison in the structural efficiency of that type of design if one compares it with a vessel designed on the same length diameter ratio of the more normal Zeppelin structure, because obviously there is a very considerable inherent gain in structural efficiency in going to a small length diameter ratio and I do not think it is quite accurate to draw too many conclusions from a comparison in actual structural efficiency when comparing the three to one ratio with an eight to one ratio , that is the first point

The second point I would raise is that in so far as I have understood the form of construction, it would seem that the determining feature of the ship must be the maximum local compressive stress, because the capacity of the design, the maximum local compressive stress would seem to be dependent upon the internal pressure and the thickness of the material, or the outer covering Therefore, if it is dependent upon those two features, instead of designing a vessel from two points of view, the structure of the vessel firstly from the local stresses it has to take, and secondly from the aerodynamic or more than constructional stresses it has to take, it would seem from a cursory point of view that unless the envelope layers were made up in variations of thicknesses, and a considerable variation of thicknesses to take such aerodynamic stresses as you get at the tail and the fins, and features of that kind, the determining factor would be the local compressive stress in every case Therefore in comparing it with a design in which one is able to separate out those two features, one is arbitrarily confined by having to meet that one point, instead of as in the more normal point, being able to have a flexible type of construction which allows you to put in such strength as you require for aerodynamic stresses and for local stresses For instance, in the vessel that we are now building the actual weight of the structure, that is the girders themselves longitudinal, transverse, frames and so forth, is just under one-fifth of the displacement , it is about 12½ per cent of the total weight

MR UPSON You do not include wires ?

COMMANDER BURNEY No I take the actual weight I take the proportion of the wires and the outer cover to do the other features If one considers it upon that basis, it would seem that to get the highest efficiency one would begin to crowd their outer cover into such forms and such spaces throughout the ship that you would eventually come back to the type of structure which is termed the Zeppelin type, leaving the cover as it is left in that case to be your bare cover for reduction of resistance and so forth It would seem from a cursory consideration that a type of vessel of the metal-clad type as suggested by Mr Upson would be heavier in structural weight that a vessel built under the normal conditions , at the same time I would not for a moment say that the extra weight might not be justified by increased safety and increased capacity to resist fire and so forth I am not arguing upon that line, but primarily upon the basis of structure

The third consideration which I will put is that, if you have a structure of that type in which you are dependent upon the whole outer surface and on pressure within that outer cover for your security, it is very difficult to meet conditions such as one has to meet in the normal type of a deflated gasbag which might take place owing to enemy fire, or something of that character, and I should be interested to know how that condition is to be met

The points I have raised as I say, are criticisms more to give Mr Upson the opportunity to make clearer to us the features that he has illustrated, and I will only conclude by congratulating him on having done some very fine and exceedingly interesting development work, and I wish him all success in his efforts (Applause )

MR UPSON Commander Burney brought up so many points that I should have started taking notes before I am afraid if I put off answering until others have spoken I will forget most of them

With regard to the comparisons between fineness ratios I had not expected anyone to draw any unwarranted conclusions at all I was merely bringing out certain rather striking facts to show the same thing Commander Burney has stated, the short fineness ratio was feasible from a standpoint at least of resistance and stability The matter of accommodating the fineness ratio to the structure is a considerably different kind of problem As I have already pointed out the small and middle-sized ships practically demand a rather low fineness ratio, one which would reduce to the minimum the amount of material used in the surface It is true that from a structural standpoint you can afford and should have rather longer fineness ratios for the larger sizes There is no use in my trying to give definite figures on that subject, because personally, I have not worked it out from a quantitative standpoint, but this much can be said that the bigger you get the ship, the more serious becomes the effect of the diameter , no matter what the details of the design may be the diameter has a fundamental effect on the weight particularly with large sizes and especially in this case when we get up to the sizes where the plating is practically all useful for structural effect The latter is partly a matter of definition—but the diameter will be a factor at any rate before we get to the size of ship that you are building now I think it averages round three to four million, before you begin to consider the weight of the skin entirely as a structural part of the ship Then anything beyond that will make desirable, to a certain extent, an increase in fineness ratio, and a variation in surface gauge over the hull Another thing also affects fineness ratio, and that is the number of compartments that you want That, of course, depends on the use to which the ship is to be put very largely, and there again we cannot draw any hard and fast line, but only the general tendency As a mere personal opinion, I would be surprised to see any ship built in the future, no matter what size, exceed the fineness ratio of 4½ to 5, because the advantages of keeping it down are very great

In regard to the weight as influenced by the metal-clad construction, at first we were fully prepared, and considered it would be necessary to make considerable sacrifices in that direction in order to obtain the other more obvious advantages of the metal construction In principle, the idea at first was similar to the one we have now, that is, considering the rather radical nature of the design we wished to build the first ship about as small as it could be made, and have a satisfactory demonstration for some useful purpose Our first guess—it was not much more than a guess —was 1,600,000 cubic feet The design of that ship was worked out to a point where we began to get a fairly good idea of the weights, and we found to our surprise that it was coming out more efficient from the standpoint of useful lift than the somewhat larger Shenandoah That is as far as we went with that design, because we soon came to the conclusion that if we could beat the Shenandoah on percentage of useful lift with a ship somewhat smaller, we could in all probability build a ship with a fair useful lift percentage, which would be good for demonstration purposes, with a far smaller size , so the result has been this 200,000 cubic feet size which compares very favourably from a lift standpoint with the non-rigids of equal size Now it must be admitted that the metal by itself adds a considerable weight in that size of ship In other words, if we had not made these other improvements in the shape of the hull, in the form and size of the fins, and various refinements in the car structure and girders and so on, if we had left all those supplementary improvements out, we would be handicapped quite a bit with the extra weight of the covering or plating But taking everything into consideration it is very favourable By reducing the power plant and fuel weight to represent in proportion to give an equal speed and range to what is being obtained now with the same sized ship, I think we would have a slightly better percentage of carrying capacity

Now it is somewhat surprising, the lightness that is possible in view of the fact that the ship is so much stronger than preceding types In other words, the ship that we are building will have strength or airworthiness at least eight times greater than the Shenandoah, and again I want to say I am not particularly criticising the Shenandoah, because it was a very good, well-made ship of the general style that was being made at that time, of similar construction to your own R34 for example If we were satisfied with an equal strength in these new ships, the structure could be made considerably lighter Here is one of the reasons You have in the conventional rigid type of ship, first Outer Cover, say the weight including the dope, tape etc , is 6 ozs per sq yd Next you have shear wires, call it 2 ozs per sq yd Then you have the gas pressure wires, and cord netting, say 2 ozs per sq yd Then you have the gas cell fabric itself, which is possibly 6 ozs That gives you 16 ozs per sq yd Now the 8/1000 duralumin sheet that we are using on this particular ship is not much more than that (about 20 ozs complete with seams etc ) Add to that the safeguarding by various refinements in design, such as the decrease in fineness ratio and other factors, and you will readily see how it is done The result is a hull plating that serves all of these purposes and does each one of them apparently in a better way, particularly with regard to the strength It is as if every one of layers of the ordinary rigid was able to transmit stress in any direction it might be called up to carry it It is not like wires For instance, suppose you imagine a whole series of square wires laid side by side , of course for equal materials the strength in this direction would be about the same roughly as a similar thickness of sheet, but the strength in the other direction would be nothing In order to get the strength in both directions you would have to add another equal layer at right angles, and even then it would not take the shear loads

SQUADRON-LEADER BALDWIN I should like to know what form of local strengthening you have

MR UPSON That is another point which Commander Burney mentioned in regard to the compressive stresses In our calculations we allow nothing at all for the sheet in respect to carrying compressive stresses, absolutely nothing We assume that the sheet carries only tensile stresses and shear Of course the shear really works into tension if you take it in the right direction The girders, regular compressive members, are assumed to carry all the compressive load, although there is good reason to believe that under the actual conditions of operation the sheet will carry a very appreciable amount of compressive load

THE CHAIRMAN On behalf of us all I offer you our very sincere thanks, not only for the material for thought contained in your address, but for the way you have given it to us After all, a Paper is always a Paper, and anybody who can talk to us as you have done to-night gives us added pleasure because of the intimate way in which your thoughts are conveyed to us

Having tested most of the methods of getting up in the air I consider the airship is the only gentleman's way of travelling My own experience in English airships is that you sit in comfort, you have no noise you ring a bell for anything you want to eat or drink, you gaze quietly out on to the scenery, and you can talk That is a thing you are never able to do in an aeroplane, and after all, in long journeys it is rather tiresome to be almost by yourself , the noise is so bad you can have no form of converse with anybody else But apart from that, what I would like to know from Mr Upson is, when is it going to be finished ? We have all talked about airships for such a long time, and I want to see the new type up in the air, whether it is from America or France I do not think we need have a ratio of five to one—the old ones of five to one looked like a very coarse sort of fish I wish you would, however, let us know when you think America is going to deliver this, and when it is going to be finished, and that Commander Burney would tell us when he thinks his is going to be finished , I think we should then leave this meeting looking forward at any rate to seeing more airships in the air (Applause )

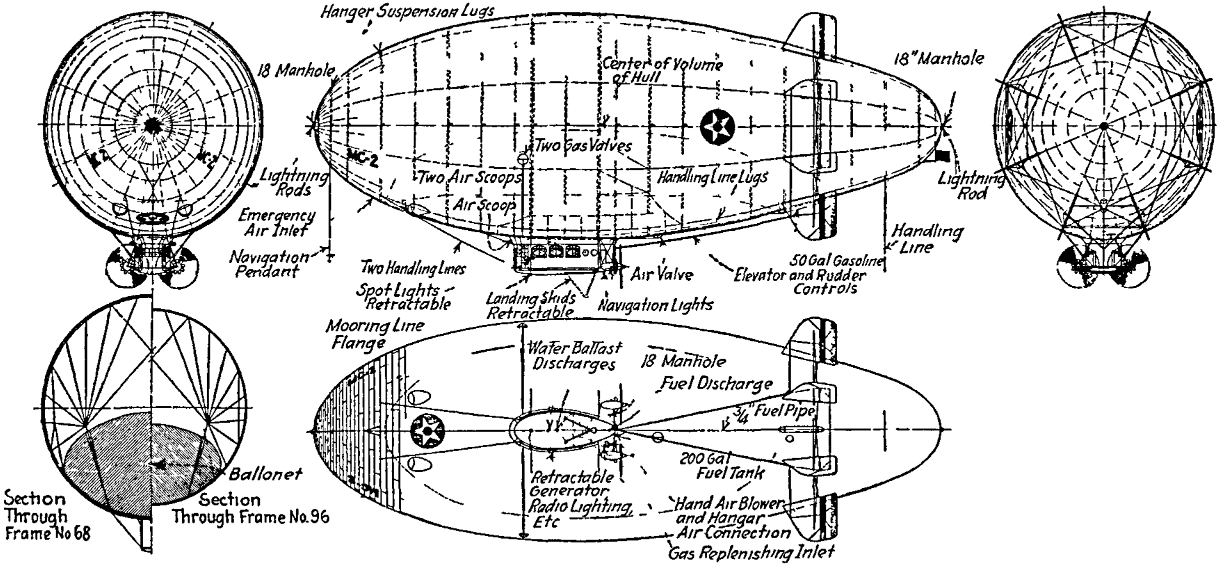
Mr UPSON I am afraid I shall have to leave the answer to one of your questions But about the fish, this is a little hobby of mine One ordinarily gets the impression that a fast swimming fish is long and slim Of course, there are fish which really are comparatively long and slim which travel quite fast We cannot fathom all of the reasons that the Maker might have had for making fish and other animals as He did, but we do know that some of the fastest swimming fish, like the tunny fish for example, and particularly the large-sized ones, and particularly cetaceans like porpoises and whales, which are more nearly in line with the dimensions that we are considering, are many of them of comparatively low fineness ratio, and even lower than what might be supposed by a cursory glance at the fish itself Suppose, starting with an airship hull, we take the car and the fins off and make a fish out of it If you extend the tail far back and put a regular fish's tail on the end, and then put a mouth forward, it immediately gives you the impression of quite a lengthening of the form, does it not, and yet the major part of it is exactly the same In trying to get anything from analysis of fish shapes you have to take into account the various other things it has to do besides go through the water, and also the means which it has available for propulsion control and so on If the usual fish's propulsion and directional control was put right behind the blunt tail, for example, it would be in an area of dead water where it would be very ineffective for the purpose , the tail has to be further back where it will get a clear sweep of the water flowing past it Also the fish needs certain organs for " refueling " and various things, and he has to have part of his power plant well back so that he does not require too long a " shaft " Putting everything together you soon see that certain parts of the fish, particularly the head and tail are not necessarily concerned with economising the resistance According to the wind tunnel tests they are clearly not necessary

Now about when it will be done—I am very sorry, but that is the one question that I do not believe I can answer It sounds very haphazard to answer it that way, but we are really going on the principle that as long as there is no war going on, or no immediate necessity for this ship, there are things that are a great deal more important than the time of delivery We want to put the quality and safety of the construction always first In order words, I do not like to make any promise of when it will be done at all, but I hope it will be some time next year

THE CHAIRMAN It has been started ?

MR UPSON We are just starting and hope to be ready some time next year

THE CHAIRMAN Thank you very much, Mr Upson (Applause )



General Scheme of the Metal-clad Airship designed by Mr Ralph Upson
(Reproduced by courtesy of " *The Aeroplane* ")