DISCUSSION.

COMMANDER BOOTHBY: I have very little to say except to agree with the lecturer's views. I think he has placed his finger on a point of the greatest importance, namely, to put pressure inside the airship outer cover, which I believe would ensure an additional factor of safety. Non-rigid airships retain their form entirely by this means, and there is no reason why it should not be utilised to support rigid airships likewise. When we put pressure inside the cover I hope that pressure in future airships will be maintained by inert gas, drawn from the exhaust of the motors, which, besides protecting the hydrogen from fire, will keep the fabric of the gasbags moist—a most desirable point. It should be possible to get a rigid airship properly stream-lined by maintaining pressure in a correctly-shaped outer cover, if it is not convenient to make the metal hull itself of the exact form desired.

Another point made by the lecturer is the advantage in the reduction in the number of longitudinal girders, and this is a very strong argument for the semi-rigid airship, which is a type I very much favour, seeing it has only one longitudinal girder.

With reference to the wires between the gasbags, the new Parseval design allows of these being slack, the result being obtained by modifying the shape of the gasbags, and that system will overcome the trouble mentioned by the lecturer to a very large extent if it can be embodied in the rigid type as well as in the semi-rigid, for which it was originally designed.

MR. MANNING (Chairman): I am afraid I cannot pretend to any particular knowledge of this interesting subject, so I must ask for indulgence if my remarks are somewhat trite.

I was much interested in the lecturer's remark that it would be considered unsafe to fly a certain machine at full speed close to the ground. I presume that if the airship was flying at full speed close to the ground there was a possibility of failure, as the stresses arising would therefore be just about the failing point of the structure. I gather that the additional weight of about four tons, referred to by the lecturer, would double the strength of the structure and that this is regarded as adequate. That means a factor of safety of only 2, which appears to be somewhat low.

With regard to stresses on airship frameworks in general, I have not been able to look up the records, but I seem to remember that some years ago there was an investigation in America on the subject of lattice girders under compression loads in connection with the failure of the Quebec Bridge. Now, in that investigation it was, I believe, shown that the distribution of stresses inside such girders was very irregular. It appeared that the unavoidable imperfections of workmanship seriously altered the distribution

of the stresses in the various longitudinal and bracing members. I should like to know whether any experiments of that sort have been carried out on ordinary Zeppelin type lattice girders, and with what results.

It should be quite possible to measure the stresses on the various members of an airship while it is in flight by the aid of strain indicators. This has been done on railway bridges, etc.

The lecturer gave a general list of conditions under which stress assumptions were taken, one case being where the airship in straight flight meets a sudden change in the direction of the wind, and another where the elevators are suddenly thrown over to the maximum angle.

It is obviously possible that a gust might occur at the moment when the rudders or elevators are thrown over, stresses might be then considerably increased.

Re pin joints. It is obvious that in structures under compression load pin joints will increase the stresses on them. I take it that pin joints may possibly necessitate an increase in the section of some of these members, and therefore add to their weight.

I would like to congratulate Colonel Richmond on an exceedingly interesting paper, which is a valuable addition to the papers we have had on scientific subjects. I feel certain that the question of airships, which has until recently been very much in the future, has now become of particular importance, and I think it is necessary for us and other institutions connected with the science of aeronautics to pay more attention to airships than we have done recently. I have enjoyed the paper exceedingly, as I am sure we all have. A paper of this kind, which looks on the question of airship structures from a different point of view to that of aeroplane design, enables us to consider the use of materials from a new aspect, and I am quite certain that the liaison between the two branches of aeronautics will be bound to be to the advantage of both.

MR. COX: One portion of this paper interested me more than any other, namely, the question of the use of models in connection with stresses.

Colonel Richmond points out that considerable work has been done on determining the theory of calculating stresses on certain assumptions, and he suggests that these assumptions require further testing by experiments either on models of the framework or on an actual airship. I do not know whether there are any insuperable difficulties in the way, but it seems to me that it might be possible to obtain the stresses themselves, as well as the assumptions, from models. It is the first thing one considers—whether work could be done on the model scale from the point of view of stresses, just as it was from aerodynamics. There is no analogy between the use of models in determining aerodynamic pressures and in determining stresses, but the success of the one method makes one hopeful that there may be success in the other.

I should like Colonel Richmond to tell us whether there has been any work done with models in this connection in England. I am sure that, considering the number of people who have dealt with the question of stresses in airships,

the idea of getting data from the model standpoint must have occurred very early in their minds. That being so, it would seem that there must be some very great difficulties, as, so far as my knowledge goes, there has been no work yet published in this connection. I would like to know what the difficulties are or what is the reason why there has not been any work of this kind.

A most successful way would be by the aid of polarised light, as carried out in America. There are several experts in that method in this country, and it does not strike one as a particularly expensive method of research.

I should hope, now that the Directorate of Research is being reorganised, that some work might be instituted in this direction.

COLONEL RICHMOND'S REPLY.

Replying to Commander Boothby, the only point which requires an answer is his reference to the semi-rigid; we are watching this with a jealous eye. So far the best semi-rigids that have been built are the P.V. 27 of 1,200,000 cub. ft. and the Roma of 1,1000,000 cub. ft. The rigid airships have reached a size of $2\frac{1}{2}$ million cub. ft., and my own impression is that the difficulties of semi-rigid construction are bound to increase very greatly with size. In semi-rigid construction you rely on the fabric to take the tension and the keel to take the compression, and I think you would develop great fabric difficulties in big semi-rigids.

With regard to horizontal bending, which we know is very serious at considerable speeds on large ships, there is nothing to take the compression side of the bending, because the keel, as regarded in plan, is practically on the neutral axis. That is one of the difficulties which I foresee, but one keeps a fairly open mind, because it remains for these large airships to be built and for one to see then how they behave.

I was very interested in Dr. Thurston's remarks. He referred to the help that aeroplane designers can give us, and he also referred in that connection to metal construction.

You may remember that I said how very much I welcomed a broadening of the field of those who consider airship design, and hoped it would be lifted out of any atmosphere of close secrecy, and there is no doubt that the aeroplane designers can help us very much, especially in this question of metal construction. I cannot tell Dr. Thurston any of the results obtained on new metal airship girders, as nothing has yet been done, and such calculations as we have been able to make on these girders have been based on the work already done on metal aeroplanes.

He mentioned the question of structure loads. If he will turn to my paper, and especially Fig. 2, he will find there the static bending moments on the structure of a certain airship of 2 million cub. ft. capacity. The

maximum top curve is given as 400 tons feet, and if he scales that off and compares it with all the other curves he will get some idea of the distribution of loading under all conditions. I feel that is the best way to deal with the subject.

I was rather amused to hear Dr. Thurston refer to the " poor bored passengers " on airships, because he is paying the airship a great compliment in that respect, as the motion of an airship in flight is steady and comfortable almost to the extent of being monotonous.

Regarding a knowledge of the loads, there again he has, I think, supported my contention that that is one of the fundamentals of the problem—to investigate aerodynamic stresses, and the way in which we must approach the question is to get a very correct idea on the full-scale airship of the distribution in a particular manœuvre, so that in future we can work out the stresses due to other manœuvres direct from work on the model.

Re the orders to commanders and what Dr. Thurston said regarding what they did during the war, I can reply to him by a somewhat tragic illustration. The L.71 was delivered to this country under the terms of the Peace Treaty, and it happened to fall to my lot to go to Germany and to be concerned in the arrangements for her delivery. I came in contact with Commander Heinen, one of the best Zeppelin pilots, who has since gone to America, and whose great airmanship saved the " Shenandoah." L.27 is a sister ship of the " Dixmude." She is extremely lightly constructed, and was built for flying at a great height in order to avoid aeroplanes. Heinen said: " Do not attempt to drive her at full speed near the ground." I am afraid that what happened in the case of the " Dixmude " was that she found herself in a particular combination of conditions where the commander took the fatal risk of driving her at full speed while at a low altitude or in gusty weather. I do not know, but that is my theory.

Mr. Cox raises the question of models. The great difficulty in model work is to produce a comparable deflection of the various joints, that is to say, elasticity comes into account. If you are loading with water to represent the gas pressures you have to carry out a certain geometrical relationship which will not necessarily give strains comparable with those produced in the full-sized structure.

Another difficulty is to measure the strain in a large number of small members. The whole question is one of difficulty, though not insuperable, but the fact remains that so far it has not been attempted in this country.

Mr. Manning referred to my remarks re a weight of 4 tons added to the strength of the ship, and said that would mean there was only the dangerously low factor of safety of 2. In presuming, however, that the ship is under the worst conditions, a factor of safety of 2 would mean 8 or 10 under normal conditions, and that is comparable practice with aeroplane design. Even then, if you like to increase the factor to 3 you have still 35 odd tons to play with, and with 35 tons of load you have a vehicle which is capable of doing something to improve and speed up communication in a way that no other vehicle can do.

Regarding irregularity of manufacture, some experiments on Zeppelin girders have recently been carried out in America. I cannot give you the figures because that would be trespassing on the publication R.38 prize competition paper by the American designers. This will be published shortly.

Re pin joints, I did not suggest using pin joints, but said they would simplify the question of stress calculations. I said that both ends of the longitudinals should be provided with a lug and socket joints, to make them virtually continuous.

Re gusts; whatever may be the stresses we may guess at as arising from gusts (as, for example, those which are illustrated in one of the curves I have given), they must be considered in conjunction with any other possible load. These curves are not meant to be taken separately: the designer must estimate what combination of conditions may exist simultaneously.

I thank you all for your attention to a somewhat dry and long-winded paper.

The meeting closed with a very hearty vote of thanks to Colonel Richmond for his interesting paper.

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