The only really important point to watch in setting out the controls is the amount of give and take in the cables which results from levers of uneven lengths—and hence, from trying to get a gear ratio with levers, or from leading a cable on to a lever at an angle other than 90 degrees.

This trouble is caused by one cable moving more nearly parallel to itself than the other, and is particularly noticeable in elevator controls where the cables are usually crossed. If the cable be tightened up so that there is no backlash in neutral, it will slack off when the control is fully over, and if then tightened up, will be very much too tight in neutral.

When wheel control is used, and the cables have to go a certain distance fore and aft before branching out to the wings, it is necessary virtually to crank the axis tube of the column in order to arrange for the cable to intersect the axis about which the control pillar rotates. Otherwise, moving the pillar fore and aft will tighten and slacken the aileron cables.

Short of making every lever a quadrant, there does not seem to be any way of avoiding backlash with levers, but with care it can be restricted to a negligible amount.

It should be possible to take out and replace any cable without cutting it or making a slice in position.

The speed of erection is governed largely by the number of men who can work on the machine, and it is no use getting too many on, or they merely get in each other's way. Therefore, if for no other reason, such as replacements which are practically necessary, we should eliminate splicing on erection, and all that is necessary to do this is to so design fairleads and pulley boxes that the cable can be removed intact.

Where the cable passes through such a part as an end rib, the hole should be large enough to pass the splice.

DISCUSSION.

MR. H. B. MOLESWORTH (Chairman).—I have listened with the greatest interest to this very instructive paper, and should like to make a few remarks on a certain point which has struck me, not necessarily in regard to aeroplane construction, but concerning cross-bracing. Some years ago I was inspecting the construction of viaducts for the Uganda railway, the piers of which consisted of four heavy uprights braced together, these being cross-braced at the intersections of the struts and ties with the uprights. There was some difficulty with regard to the horizontal cross-bracing, as to holding it up. The cross-braces were very long, and I wrote home and suggested that the cross-braces should be entirely omitted, because when you get four sides all braced, it is unnecessary

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to in any way cross-brace the intersections of the struts, because you get a brace in at the top and another at the bottom. The structure therefore is complete without them. Any other cross-bracing is not only redundant, but likely to put incommutable stresses on the stucture. Now, this is what Mr. Tinson says: "If bracing wires are 'uncut,' no cross-bracing is required."

With regard to the fairing of the fuselage, the wider you get the longerons apart, the less strain on them you have. In other words, it comes down to commonsense—the deeper the girder, the less stress on the booms and bracing.

MAJOR D. C. M. HUME.—It is my particular job in life to find fault with expert designers, and therefore it gives me very great pleasure to say how I respect their work. At the same time, I feel in the present instance some diffidence in approaching a discussion upon a paper dealing with land machines, for I am chiefly concerned with seaplanes. I have always known the seaplane had its troubles, and I am glad to find that land machines too have their difficulties.

Firstly, re cross-bracing, which our Chairman has touched upon. He very happily made the point still more clear to everybody that in a complete four-sided braced structure there is no need for panel-bracing; but I would point out to those who are considering this special specification, that it is for a fighter. The question of "shot away" is therefore foremost. If there is one thing the enemy will shoot at, it is the fuselage, and therefore the risk of getting a "shot-away" factor in the fuselage is higher in this part than in any other part of the structure. Cross-bracing here is therefore essential. Cases have occurred where cross-bracing has been regarded by the designer as a redundant ornament, and therefore he has not always given it due consideration.

I realise the difficulties in making openings and passage-ways in this form, and except in certain purely experimental seaplanes, this has furnished a comparatively strong argument for the Monocoque construction. A seaplane body generally has to have ample communication by means of a big passage-way. The Monocoque, therefore, has its points. It can be made of almost ideal strength in every direction required. There is one feature I have found of great use in an open type of body, and it might work in the braced type, that is, to make the internal flying controls all of one unit, which can be rapidly assembled outside the machine proper, and, if necessary, in the mock-up. It requires the minimum of fitting up. In erection there is often a great deal of time wasted by getting things to fit together inside, rather than making them independent units which can be put in as a whole.

The lecturer touched upon the adjustable tail as being required—which will be, and is, a matter for great thought. If you get to large machines (and I do not see why land machines should not get bigger), the method of moving the tail begins to be complicated, and will need the particular attention of the designer in the near future. If you have a large tail, it is beyond a man's power to move it in the time required, and it therefore needs some special method to deal with it. It will, I think, compel the attention of several aircraft designers in the near future.

I would suggest that the lecturer is taking a slightly pre-war view in the matter of chassis, when he suggests it is advisable to keep the V so that the load is equal in each V. I say this because he has there premised that he is using a rubber shock-absorber. Nowadays a chassis will never be dependent upon rubber to take the shock. Oleo is almost universal at the moment.

There is a point in stability that occurs to me, worth noting by anybody who has to do a fighter design. A fighter should be neutrally stable on all axes. As an example, take the Brandenburgh monoplane: that machine is very lively, and neutrally stable on all axes.

I do not think our lecturer has said a wiser thing than drawing attention to the necessity of considering the controls from the very start of the design. they can give more trouble than anything else, except, possibly, c.g. In seaplanes, if they are wrong at the start they always keep you busy for perhaps three subsequent types. It is not unusual for certain firms to affect a hinged pulley, under the idea that it is self-lining: it is so, but only provided that you can true up the whole of your control system sufficiently tight so as to avoid droop at the pulley hinge. Sloppy controls, using hinged pulleys, are indefinite, and demand a lot of extraneous work in lifting pulleys and taking up slacks ere ever the pilot gets into real touch with his control surfaces.

I am glad to see that the lecturer touched upon the question of fireproof bulkheads—a most important thing. Only last week we had one of our best test pilots' life saved by a fireproof bulkhead.

I would like to leave with those interested in this class of design, the possibility of washing out (especially for commercial work) the cable lengths for controls, and substituting surface rods. You can carry the rod in stores conveniently as a spare, and put it in very quickly.

The lecturer ties himself down fairly safely on the tolerance of c.g. I only wish everyone would do that.

He has rightly pointed out something which I think should be written in large letters of gold and hung in every designer's office: "It always weighs more!" This is one of the most important sentences in his paper. I remember once making a boat tail which was of some importance, and that tail weight was estimated, with every conceivable thing in it, even down to the glue, and five per cent. was added to the total for material variation, and the result was only just about 3 lbs. wrong; but the work entailed was considerable, and perhaps barely justified as far as the one job was concerned. It showed me, however, that the degree of optimism allowable on weight was very low. That little sentence—"It always weighs more"—is very much to be commended.

MR. TINSON'S reply to the discussion:

In answer to the Chairman's remarks on cross-bracing, regarding which Major Hume has also spoken, I should like to say that while agreeing that in theory cross-bracing may be redundant, in practice it is usually found to be otherwise, as without it there is a danger of lack of rigidity.

I am glad Major Hume has mentioned the Monocoque, because I consider it the right thing to have, both for efficiency and from the point of view of cost.

I should like to ask, however, if it is possible to design a Monocoque for a given strength. A braced fuselage can be designed with a knowledge of what it will stand. Is it possible to design a Monocoque for a given strength without having to make one and test it to actually find out whether it is strong enough, or too strong, or what its strength really is?

Major Hume has mentioned the advantage of unit design for seating and controls, and I entirely agree with him. From a commercial point of view I am convinced it is the right thing to try and make each component a complete unit in itself.

Regarding undercarriages, in the whole of this paper I have not mentioned the Oleo gear, partly because I know nothing about it, and also for the reason that at the third lecture of the Institution, Mr. Dowty will speak about that very subject, and tell us all he knows.

Major Hume has referred to a fighter having to be of neutral stability, which, of course, is correct. I have not mentioned much about stability in this paper, because I am endeavouring to review the structural design of an aeroplane. The whole subject is so big that it is impossible for me to do more than select one type around which to centralise my remarks.

With regard to the remark that my view of the c.g. position is the right one, exactly the same thing was said when this lecture was given at Hamble, but I have found that some designers do not give nearly as much thought to this question as they should. I consider that the c.g. of the machine should always be regarded with a considerable sense of its importance, since a relatively small shift of c.g., and the modification of the tail plane incidence caused thereby may result in decreased longitudinal stability owing to the displacement of the righting-moment curve. It is also a fact that shift of c.g. resulting from an additional passenger in a small machine has a most marked effect on lateral and directional stability, but the reason for this is not entirely clear.

My remark regarding weight has also been specially commented upon, and is certainly another important thing for all designers to bear in mind.

The Chairman proposed a hearty vote of thanks to Mr. Tinson, which was seconded by Major Hume, and the meeting then closed.