DISCUSSION.

MR. PARROT: I have listened with great interest to Capt. Liptrot's paper; he has covered the subject very thoroughly and he has not left much material for discussion. I have had a very considerable experience in the use of three-ply in aircraft construction, and I propose to mention a few points in connection with the use which I trust will be of interest.

The greatest disadvantage with the use of three-ply is its vulnerability to moisture. Its reliability in this respect depends to a very great extent on the care which is exercised in its construction, and also in the materials employed. Not only does this apply to the careful selection of timber, but to a greater extent of the substance used as the jointing medium. The B.E.S.A. Specifications demand a soaking test of not less than three hours in boiling water. The ordinary commercial three-ply will not stand this test, and my experience is that three-ply which even does successfully pass the test is not altogether suitable for certain purposes. It is possible, however, to obtain three-ply which to all intents and purposes can be described as absolutely waterproof. I recently tested some birch three-ply samples submitted by a British firm that withstood successfully the following tests:—Boiling continuously for 55 hours, soaking in sea water for three weeks. At the end of this time the plies showed no signs of opening or coming unstuck; when dry, however, they were badly warped. In spite of the apparent immunity of three-ply from failure by soaking tests, it does fail in actual practice. I believe this is due to internal stresses set up by alternate wetting and drying. I have witnessed a case which tends to bear out this idea. On a scrap heap were a pair of old three-ply seaplane floats, the inspection covers of which had been removed. I was surprised to find on examining them that whereas the plies of the decks and upper parts of the sides had become completely unstuck, the floats were half-full of rain water and perfectly tight, the three-ply bottoms and lower parts of the sides were completely saturated with moisture, but the plies were not separated.

Quite a number of designers still favour three-ply for fuselage construction, as Captain Liptrot has pointed out. It lends itself to simple and cheap construction and offers many temptations, but I do not consider that now that the aeroplane is becoming a real engineering job that it should be used for this purpose, especially for machines destined to be used in the Tropics. The box girder type of construction either of wood or steel is I am convinced much more durable in any climate. I know of two aeroplanes which were stored together for a long time in a very leaky Bersonneau Hangar; one was a German Halberstat machine and the other an ordinary Avro Training Machine. The Halberstat fuselage was of thin three-ply semi-monocoque construction. It eventually sagged until the middle part completely collapsed and rested on the ground. The Avro machine, in which, of course, the

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fuselage is of the ordinary box girder type, in the same period suffered no ill effects whatever, and was eventually reconditioned and is in service to-day.

A theory has been advanced that the failure of three-ply under tropical conditions is due to a bacteriological decomposition of the jointing substance. As ox blood is one of the constituents there may be something in the theory.

Three-ply used to be employed in the construction of seaplane floats, it never gave satisfaction, and I am pleased to say that all new floats are now being constructed of two or three skins of mahogany rivetted together.

Three-ply is extensively employed in rib construction, and for this purpose it seems to be fairly satisfactory, as the wing structure is almost hermetically sealed by the wing covering, and consequently the three-ply does not suffer to any extent.

Three-ply lends itself very well for the construction of instrument boards, decking, etc., and all such parts as may be widely described as the furniture of an aeroplane. A very nice mahogany faced three-ply can be obtained for this purpose.

I think the time is not far distant when the use of three-ply will be confined to such parts, especially in military and naval aircraft.

In connection with the motor gliders, it unfortunately appears inevitable that three-ply must enter largely into the construction. In Avro machines three-ply of only .8 mm. in thickness was extensively employed.

Very thin three-ply has been and is still employed as a wing covering by some constructors. Personally, I do not consider this worth while. To adequately protect it, it should be covered by fabric and doped, and if one has to go to this trouble, why use it at all?

MR. OSWALD: I wish to join with the others in thanking the lecturer for his excellent paper. Until quite recently where three-ply has been used in a design, the estimation of the strength of the three-ply has been done a good deal by instinct. The lecturer has supplied us with figures dealing with the strength of three-ply in tension and in bending which will give us a more satisfactory basis of design than instinct has been.

I notice that the standard taken for moisture content is oven-dried. What is the temperature of the oven there?

In connection with three-ply monocoque construction it seems to me that the amount of labour required will put up the price very much, and for a long time that will be a factor against the use of three-ply. Even apart from the labour, great care must be taken to have the face plies arranged at right angles to the others, and unless you have careful supervision, that may not be the case. $2\frac{1}{2}$ in. tape also has to be wound on with an overlap of $\frac{1}{4}$ in., and that, it seems to me, will take a very long time and careful supervision.

Of course, there is this advantage in three-ply when used for the monocoque construction, especially for large passenger machines—that you have freedom of movement, which is certainly an advantage over the ordinary box type. From that point of view, although the cost may be higher, the three-ply monocoque construction may hold its own against the box girder type.

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MR. ELLIOTT : There are just two points I wish to mention.

First, with regard to the fact of three-ply panels always going at the edges. I have not very much experience of three-ply, but quite a short time ago I saw a panel where the face-ply had quite a big bubble. Perhaps the lecturer can explain this.

Concerning the advantages of monocoque construction over the box girder, the lecturer referred to the necessity for elaborate fairing of the latter. It seems to me that in most of the machines of to-day, where the rectangular fuselage is fitted, they do not trouble to fair off, because, I presume, they are putting on frontal area, and, as we know, are increasing the surface friction.

MR. H. B. MOLESWORTH : I notice that in these tables there is no mention of willow, which is extremely tough and durable.

MR. W. O. MANNING : I agree with the speaker who said that the rectangular fuselage is best. I do not think there is very much object in rounding off. A square fuselage is much more economical.

Have any improvements been made during the last few years in glue? I could show you a sample of three-ply I have in my office which was made six years ago and which was used in connection with a certain seaplane. There is now no glue whatever between the plies. It is probable that since then certain improvements have been made. If so it would be interesting to know.

Re buckling; this is important, and I have no doubt it is due to the cause stated by Mr. Parrott. Some of us cover the leading edge with three-ply, which with high-lift cambers seems to pay, as it retains their form, but in these cases it is practically impossible to prevent buckling. It bends very badly.

The tables are exceedingly interesting, but I should like him to add some information as to the sheer strength of three-ply.

In conclusion, it has occurred to me that in certain cases three-ply of spruce would be good. Has this been tried, and with what result?

CAPTAIN LIPTROT'S REPLY TO THE DISCUSSION.

MR. PARROTT raised the point as to the non-permanence of three-ply structures, but I do not think that objection holds good with a properly made three-fly fuselage. I know an old war-type three-ply fuselage which was made in 1917, and to-day is still flying in perfectly good condition. I will admit the difficulty of buckling where you have a flat-sided fuselage with a big panel, but this is doubtless due to the fact that the ply-wood used has not been correctly proportioned as to core and total thickness.

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MR. OSWALD raised the question of difficulty of manufacture, but my own opinion is that the three-ply fuselage is not a difficult manufacturing proposition. We must remember that the fittings are simplified, and although the actual time of assembly may be increased, the whole of the labour employed on the fuselage shows a distinct saving of time. The three-ply braced fuselage is better, because it retains its alignment. In reply to Mr. Oswald's other inquiry, ordinary steam ovens are used for drying, with a temperature of 100 deg. cent.

Re taping—this is most essential. What I have tried often to get done is that the ply-wood manufacturers should put on the fabric cover when the plywood is made in the press. Unfortunately, the plywood manufacturers will not look at this proposition, as it involves too much work. It means money and time for the aircraft constructor to put on the fabric, and it is not a nice job to spread fabric over a big three-ply panel.

Replying to MR. ELLIOTT'S remarks re streamline, I agree that a straight-sided fuselage as usual, but why should you not have this in three-ply?

In reply to MR. MOLESWORTH'S question, I did not include willow because we have not used it in this country.

MR. MANNING inquires about glue. That has been a very difficult question. In the past, English manufacturers have used many kinds of glue of the ox-blood variety, and later the casein cement, which is the best. In America they use casein, which is giving satisfaction, but if you look at English plywood you will often find on splitting one of the panels off that there is a space in the attachment of the two panels where they have not properly spread the glue. This is entirely a question of manufacture. If casein cements are properly used, the plywood will hold, but in spite of this it must be properly protected, particularly in tropical climates, where there are great changes of temperature and humidity between day and night. The stresses thus brought about are enough to cause failures, which usually start at the edges; that is why the edges should be taped. If three-ply is made up with the ox-blood cement, bacteriological action may come in and lead to breaking up of the adhesion between the plies.

Regarding Mr. Manning's query re spruce, one great advantage of the use of three-ply in a fuselage of the semi-monocoque type is that only small panellings are required, and the panels can therefore be cut from timber that would not ordinarily be accepted for aircraft work. In such cases I think spruce ply-wood would be quite satisfactory, particularly for those parts of the fuselage which are not highly stressed.

In conclusion, my own opinion is that the semi-monocoque does merit attention. It is a good production proposition, is permanent, and stands up well in use, but if any of you take up the method, I would say :—

First of all remember that the skin must have a big proportion of its grain longitudinally in respect to the length of the fuselage.

Secondly, in the semi-monocoque, using longerons and bulkheads, it is not difficult to stiffen up the skin itself by disposing the longerons and bulkheads properly. If you put the skin on in several layers yourself, using veneer

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instead of three-ply, always put cotton sheeting between the plies, since it greatly increases the strength of the panels. It takes time, but it is well worth while. In making joins in the three-ply, take care to make a proper scarf join and thoroughly protect it, either by fabric or a plywood cover strip. Butt joints should not be used.

Another point which is sometimes overlooked is the weakening of the top side of the fuselage where a cockpit occurs. Do not forget that longerons require stiffening at all cockpits.

Watch the local reactions at bulkheads. Design bulkheads to take the bending moment applied by lift wires.

To get uniform results, very careful manufacture is necessary, and the whole of this operation should be watched throughout.

A very hearty vote of thanks to Captain Liptrot for his interesting paper brought the meeting to a close, the Chairman remarking that the paper would form a valuable contribution to the subject of three-ply.

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