DISCUSSION.

Lieutenant de Vaisseau Jacques Bos (Air Attaché to the French Embassy) :—I should like to say on behalf of M. De Woitine how very sorry M. De Woitine is not to be able to be present to-night, and, on my own behalf, that although I am not a technical man, after having heard the paper I understand your aims and your difficulties. I should like also to say that (using M. De Woitine's own views) an exchange of ideas can be very helpful, and I consider that such papers as this will enable all to make real progress.

M. Gaston Montfort (President of the French Chamber of Commerce in London, and representing Messrs, Schneider, of Le Creusot) :—It gives me great pleasure to be here, but, like Lieutenant Bos, I am not a technical man; in fact, the only connection I have with the paper is that my firm has been mentioned therein. We have been one of the pioneers of the alloy metals as used in the fabrication of all-metal planes. We have had a little trouble in working out our alferium (as we call our new alloy), but have now got out of our difficulties, and our alloy is more and more widely used in the manufacture of aeroplanes and propellers.

Major Nerincx (Military Attaché to the Belgian Embassy) :—I should like to say that I was very much looking forward to hearing M. De Woitine in French, and of course we all agree that it would have been a greater pleasure if he had been present. I should like, however, to say that these exchanges of views of the different countries in technical matters are very helpful.

Major H. C. Davidson (Assistant Military Attaché, American Embassy) :—I do not feel competent to express an opinion on this subject, not having had enough technical experience. I was very much interested, however, to notice that M. De Woitine mentions the factor of safety 16, and would like to ask him if this factor is now prescribed for single seater airplanes in France.

Some of our authorities in the United States have been trying to have the factor of safety for single seaters raised to 15. This high factor was recommended after one of our pilots had carried out some accelerometer tests and obtained readings of approximately 7 g.

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MR. J. D. NORTH (Messrs. Boulton & Paul) :—It gives me special pleasure to be here to-night by courtesy of the Institution of Aeronautical Engineers to join in the welcome to M. De Woitine and to hear his interesting account of his work and that of other French constructors in metal aeroplanes. In 1919 my firm exhibited at the Paris Show their first all-metal aeroplane, and since that time we have actively developed this work. We have observed with care, so far as it was possible for us to do, the work carried on in other countries as well as in England, and I am interested to observe in how many cases M. De Woitine's experience has led him to the same conclusions as ourselves.

I would draw special attention to the paragraph, " Enfin la creation du prototype . . . dependra." Design, structurally economical, has been achieved, and we have now for some years been addressing ourselves to systemisation. I do not find the figure of 1½ million francs excessive for tooling up. I gather this refers to special tools, rather than machine tools, as stated in the translation.

M. De Woitine is kind enough to refer in gracious terms to the work of my firm, but I would assure him that our efforts have not been limited to steel girder work. During the first few years of our development work, the use of duralumin for structural members was rigorously prohibited by the Air Ministry, and we were thus bound to solve all our problems in steel, even those to which steel was least adaptable. This was accomplished in several designs, the structural weight of which compared favourably with wood. It is true that these machines were day bombers (circ. 4,000 kgs.), but I cannot agree that the problem was easier than with the fighter class. On the contrary, these twin machines with their extensive and complicated equipment offered, I believe, more difficult problems than the fighter. M. De Woitine is, however, in error in imagining that the fighter has not been produced in steel.

The specific properties of steel compare favourably with duralumin. The effective compression strength of the former is realised as a minimum at 65 tons per sq. inch (about 1,000 kgs. sq. m.), while that of duralumin is, according to our experience, 15 tons per sq. inch (about 23 kgs.), equal to a steel only just over 40 tons per sq. inch (about 60 kgs.) in effective compression strength. The difference between these figures for duralumin and those given by M. De Woitine is probably due to the adoption of a different criterion. The comparative figures for steel and duralumin, however, hold good. It is true that higher figures are occasionally realised in duralumin, but similarly higher figures are obtained in steel, e.g., up to 80 tons per sq. inch (125 kgs. sq. mm.). The specific elasticity of the two materials is substantially the same. Duralumin, although it has a high fatigue range on ordinary tests, is particularly susceptible to failure by reverse bending. Practically all fatigue failures in duralumin which I have seen have been due to reverse bending being set up by vibration of the structure. M. De Woitine refers to the replacement of " des portion fatiguees de poutre." I should be glad to know what types of failure he has experienced.

Steel spars suitable for biplane structure are, in my experience, in most

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cases lighter than duralumin, since we get the full benefit of the greater specific strength. These spars are quickly and economically made, though the technique of their design and manufacture is complicated. M. De Woitine will, I think, be surprised to know that we harden and temper these spar sections after forming in lengths up to 75 feet, producing parts thereby of interchangeable accuracy, i.e., within a few thousandths of an inch. I would also add that we obtain a shear stress of over 30 tons per sq. inch in our rivets, which are of alloy steel, and that the weight of rivets in steel parts compares quite well with duralumin parts. It is perhaps not necessary to state that the design and material of these rivets have been carefully studied, and that they are specially made.

Although we prefer to use steel for the primary structure (e.g., the spars, fuselage, longerons, interplane struts, engine mountings, etc.) it is our regular practice to use duralumin for the secondary structure (ribs, leading and trailing edges, etc.). This combination gives, I believe, the most economical results from all standpoints.

The difference in the value of the two materials is easily taken into account in stressing. There are, I think, many more serious difficulties in stressing than that, particularly in the multiple-redundant types of structure, such as multi spars and skin wings, which he favours. I would also make the point of different and load variable apparent E of constituent members in such structures. Perhaps M. De Woitine would enlarge on this point. M. De Woitine takes his stand with the cantilever-metal skin school. I must not take up time to discuss this point. I will agree that if this is to be the ultimate aim (and I am far from conceding that it is), then duralumin is indicated, as the heavy variations of stress are more easily dealt with in the simpler forms permissible with duralumin. Steel does not lend itself to taper construction, and is, of course, quite impracticable as a covering. I would say one thing—that the figures 2.15 (10.5 kgs.) and 1.64 (8 kgs.) lbs. per sq. foot seem heavy to one accustomed to biplane construction for fighters, and dimensional theory certainly does not indicate reduction of weight with increase of size, but the contrary.

As the ordinary biplane type of construction is particularly adaptable for steel spars, I am always anxious that my preference for that type should be sound, because, as Mr. Harry Brearly once said: "The danger of research is that we tend to find what we are looking for." I cannot help feeling that Dr. Rohrbach's advocacy of heavy loading for large seaplanes is unconsciously due to the fact that without heavy loading his system of construction would be impossible.

I must, in conclusion, say how much I appreciate M. De Woitine's paper and kindness in giving us the benefit of his experience. The two curses of aviation to-day are too much secrecy and too little flying. Before the war there was a very free interchange of ideas among those engaged in all branches of aeronautical work, and I wish there was more of the same spirit to-day. We cannot altogether blame ourselves in this matter. The heavy hand of the Official Secrets Act is on us. Our honourable and gallant Chairman would do yeoman service to the cause of aeronautical engineering if he could somewhat mitigate its pressure.

CAPTAIN SAYERS :—I should like to express my thanks to the Institution for having persuaded M. De Woitine to give us this paper. He has set out here some of the considerations that have led to duralumin construction in France. It is rather a curious fact that on the Continent—in France, in particular—the lighter alloys have been used and steel has been neglected. In Germany there has been the tendency to mix them, and in this country it has been prohibited to use duralumin. M. De Woitine refers, in one place, to one of the causes of this fact, and I do not want to go into details, but the actual reason lies in the absence of spruce forests in Europe. After the next war there will be no spruce to build aeroplanes; we very nearly emptied the spruce forests in North America during the last war, and with another war the possibilities are that the supplies would end, so we turned to steel. France has concentrated on duralumin because she has large amounts of aluminium ore in the country, and a great deal less steel. Germany has used both metals, because she possesses both steel and aluminium and large supplies of raw material. People in this country are now turning their attention to duralumin, but steel is mainly favoured because of our experience with this material on a regular basis. In England we must be prepared to use metal, because during a war we could not get wood, as the demand for that wood will certainly exceed the supply.

MR. OSWALD :—I have great difficulty in taking part in this discussion, as I agree with so many of the arguments and conclusions of the lecturer.

One was recently engaged on the mechanical design of a flying boat hull built of duralumin. This machine has now been produced, and gives every satisfaction. The hull has come out as light as a similar wooden hull which had been subject to several years' refinement in design. The constructors are confident that with further experience the duralumin hull can be made much lighter than the wooden hull.

The initial difficulties involving exact design and draughtsmanship, before putting the job in the shops, having been overcome, the man-hours of production will be considerably less than for a wooden hull.

Duralumin construction for flying boat hulls has also the outstanding advantage that it entirely eliminates the serious increase in weight due to the soakage which takes place in wooden hulls.

A certain pilot once said he had never come across a flying boat hull which did not leak. Once this pilot has had experience with duralumin hulls he will probably amend his statement.

I would like most heartily to thank the lecturer for his most interesting paper.

MR. COATES :—I was in the Department of the Air Service concerned with safety and stability during the war, and in it I became a very firm believer in the future of duralumin, and I pointed this out very frequently to my chiefs. I pointed out that with duralumin of elastic limit to 14 tons to a square inch, fighters could be safely built.

One of the heartbreaking things was the way in which duralumin was persistently ignored during the war, and I remember going over with Dr. Rosenhain, alloys of his which came up to 20 tons to the square inch, and came to the conclusion that metal construction had a future here. A metal wing covering of thin alloy showed when pierced with a revolver bullet (making a hole four times as long as wide) that the metal stood much more strain than before; this is owing to the fact that the alloy is hardened and temporarily strengthened by sudden blows.

They would insist, during the war, on using steel alone for fighters. I told them that that could not be done. They said that if you had 26 tons elastic limit you would have sufficient strength. I endeavoured to explain that it was otherwise.

May I mention that the best steel wire I saw just stood a factor of 7 in the National Physical Laboratory?

I agree with M. De Woitine that metal allows of pneumatic rivets (female labour) in the work, but one experiment of mine showed a great danger. In an experiment done by the Steel Wing Company for me, 45-ton steel was riveted by soft 18-ton rivets, and then tested in tension. The 18-ton rivets were hardened to 85 tons by the pneumatic riveting, and tore through the 45-ton sheet like paper, and when a hole was made of the full length of the rivet the head of the rivet snapped off like glass. The fact that pneumatic rivets are so small (1/16th of an inch) that on forging they rise to 85-ton stall and this spot hardens, is one of the extra difficulties. I was much in touch with that question, and should like to know if the difficulty of riveting aluminium alloys has been overcome. I have, of course, referred to experiences of seven years ago.

One further question I would like to put for the benefit of people like myself is, that someone should turn the factor of kilograms per centimetre into tons per square inch, for the benefit of the English, and should give the unit of thickness of metal as mentioned in the paper.

Of course, duralumin has very greatly improved, but I should like to ask one other question. It is stated that duralumin is a solid solution; but with a solid solution you get all kinds of workings, and different strengths with different forgings. Are you getting nearer a decent alloy?

I notice that the factor of safety of the author, in metal, is 16. This I heartily agree with. We used to have normally a factor of 6 or 7 in wood, but it was really much higher. First of all we neglected many sources of strength, for example, the mutual support of the spars, otherwise it would have been lighter. Secondly, we did not allow for the parts that the ribs supported. Thirdly, wood is a structure of varying strength, so we always took the lowest estimate of its strength, in fact, when we reported a factor of safety of 7 it was really 10 or 11. As an instance, I reported on a fuselage of Vickers that the factor of safety was only 5. They maintained that it was 8. Very probably they were right, and our normal factor of 7 was an actual factor of 11 for a weak structure.

Mr. Oswald says they have built seaplane duralumin hulls lighter than wood, and I offer my hearty congratulations on this achievement. During the war I had the privilege of Major Linton Hope's friendship, and make no breach of confidence in saying that he also favoured duralumin.

MR. RINGWOOD :—I would like to point out an inaccuracy in the paper —that fighters have not been constructed entirely in steel in this country. This has already been done; in fact, all makes of Siskin, and some others, are entirely of steel now.

MR. S. H. EVANS :—I note that the author, in common with most metal enthusiasts, claims certain advantages for this type of construction on the score of structure weight, but does not offer us any comparative statistics, such as percentage ratios of total weight. I believe that Mr. North, representing the steel construction school in this country, claims a figure as low as 25 per cent. for structure weight, as against the more usual 30-36 per cent. attained in the wooden machine. Such a low figure for the steel machine appears extremely good, but I should like to see it backed up with a complete weight analysis before condemning the composite machine on this count alone. Structure weight as here defined includes all necessary fixed furnishings in the fuselage, such as seats, safety belts, engine mountings and cowling, etc., etc.; in other words, the complete "flying structure"—not merely the primary frame—is intended. This is a well recognised Air Ministry grouping, and is capable of very little misinterpretation. Could M. De Woitine give us such a corresponding analysis for one of his latest duralumin types, say his Monoplane Fighter? The weight comparison of the three types—wood, steel and duralumin—should prove more interesting than general statements.

Whilst I am in thorough agreement with the author's belief in duralumin construction, and particularly that school which believes in the stressed duralumin skin type as the ultimate goal, I find myself at issue with his aerodynamic pessimism. I do not believe we have reached anything approaching finality in aerodynamic refinement and development; the slotted wing is only just beginning to emerge from the chrysalis stage, and optimum wing and body combinations are not yet given the attention they deserve. I submit that present-day aerodynamic design has not kept step with our present knowledge of this subject.

Finally, I am not at all clear about the author's strength factors. M. De Woitine cites such figures as 16 and 18 derived from static testing; if these figures are comparable with English load factors of C.P. forward, they appear unnecessarily high, from the weight point of view, but I imagine the form of test is very different from our own, and further information would be acceptable.

I beg to add my appreciative thanks to M. De Woitine for presenting the French view here to-night. The Institution also is to be congratulated on maintaining this annual liaison with the Continental engineer. These outside points of view are very welcome and worthy of our best support.

MR. BRAMSON :—Concerning the technical point of polar curves—a system that is very little used in this country—I think that once you have taken the trouble to realise what the polar curve is, you will find no better way of comparing aerofoils. They contain more essential information than the lift incidence curves, and I think that they convey a better picture.

M. De Woitine says that neither engines nor wings give much scope for the reduction of weight. Now, a different way of reducing weight entirely is by reducing the drag. Any given reduction of drag gives you an equivalent result ten times that reduction in weight for a machine with a lift drag-ratio of 10/1. The points that rise to one's mind are the elimination of the undercarriage, and of obstacles in the propeller slipstream. Cooling always increases the drag very much. The wing surface radiators used by the Americans are the only exception. Any drag is as bad as increased weight in the ratio mentioned, and therefore wing-surface radiators are probably superior even to air cooling.

The inter-action between wings and fuselage and airscrew needs investigation. What is the effect of a corkscrew type of airflow on a wing designed for efficiency in a uniform flow of air? What is known about it?

Another question is the metal thicknesses required to resist tearing. What are the minimum thicknesses practicable either in duralumin or in steel? I should be glad to have the opinions of M. De Woitine and others on that subject.

MR. J. D. NORTH :—I have been specifically asked to reply to two questions. Firstly, the structure weight.

I would say at once that the term structure weight is very misleading, since it has so many interpretations. We divide the aeroplane up into power unit, the military load and the structure weight. The dividing line between military load and structure weight is hard to fix. For example, the Air Ministry will include safety belts in the structure. The economy due to the use of metal construction and high grade materials may be anything up to 5 per cent. of the gross weight. Structure weight percentage cannot be used to compare one aeroplane with another except under the most rigid conditions. The point which was made with regard to the very high load factors mentioned by M. De Woitine is, I think, a further instance of the dangers of comparison. Load factors have no meaning apart from the methods of determining loads. This difference accounts for the discrepancy in the load factors between English and Continental machines.

On the question of the thickness of material which may be used without tearing, the limitations on thickness of material are not due to considerations of tearing, but to considerations of stability. Tearing is due to local concentrations of stress, which is a matter of bad design. The solution of the problems due to instability is the essence of metal construction design. Material has been used down to .007 in. thick, but if we use both steel and duralumin in our construction, .012 in. should be as thin a material as we need.

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COLONEL BELAIEW (Vice-Chairman):—Much splendid work has been done and is being done with regard to duralumin by the National Physical Laboratory, but that refers not only to duralumin, but to other alloys, and I feel sure that there is a great future for the alloys which Dr. Rosenhain and his colleagues are patiently and steadily working out. I would like to say that Dr. Rosenhain and Professor Carpenter would be only too glad to give any information with reference to such alloys if requested by anyone present.

Of course, aluminium is considered as a French metal, being first prepared, if I am not mistaken, by St. Claire de Ville. It may be interesting from a military point of view, because St. Claire de Ville was the father of Colonel St. Claire de Ville, the inventor of the famous 75 m.m. gun, to which all the Allies are indebted, so you will see that all these things are coupled.

I must remark on the shyness of M. De Woitine with regard to the heat treatment of steel. Well, I would like to say that before the War I had the privilege of visiting the steel works at Creusot, and I should certainly not feel shy if I were in his place—the actual working of the steel there was really remarkable.

There is another point with regard to heat treatment, and I would like to draw the attention of the Institution to Mr. Low's paper before the Iron and Steel Institute on "The Influences of Man on Heat Treatment," and to that of Mr. Charpy on "Forging." Further, if you were present at Mr. Fokker's lecture before the Institution you will agree that there are possibilities in metal construction for steel, and not for light alloys only.

MR. RINGWOOD:—I have much pleasure in proposing a vote of thanks for this very unusual paper, and also the rather unusual remarks in the discussion, which I am sure M. De Woitine would have enjoyed had he been here. I am very sorry that the paper has had to be dealt with in his absence, and we should be glad to extend a welcome to him should he come to this country.

CAPTAIN SAYERS:—I would like to second the vote of thanks to the lecturer. Aeronautical engineers of English nationality frequently find themselves at a loss to understand the motives of some of their foreign friends, and papers of this kind enable us to understand these matters and appreciate many things which otherwise seem incomprehensible. I consider that papers of this kind are among the most useful of those presented to this Institution, and that the organisers should be thanked for arranging for it.

MR. GLASS:—I would like to propose a vote of thanks to our official Chairman, Colonel Moore-Brabazon, and much regret that he could not give us more of his time. He, however, left us a perfect Vice-Chairman, and a very capable authority on the subject, in Colonel Belaiew, and for his able work in reading the French portion of the paper and conducting the discussion, I propose a hearty vote of thanks.

The vote of thanks was seconded by Mr. Oswald and passed with acclamation.

CHAIRMAN :—I have enjoyed every moment of this evening, but am sorry that M. De Woitine was unable to be here. Our grateful thanks are due to him for having provided us with such a valuable paper.

The proceedings then closed.

Note.—It is much regretted that it has not been possible to include comments or a reply from M. De Woitine on the discussion on his paper, owing to the fact that he has not yet responded to the Institution's requests for such. As, therefore, the publication of the paper could not be longer delayed, it was decided to issue it minus the reply to the discussion.

We have received for review a copy of "TRANSPORT AVIATION", a book published in New York. The book deals with Aviation from a commercial standpoint, and with the progress made in all countries. The price per copy, including postage in Great Britain, is 12/6d, and it is obtainable from The Simmons-Boardman Publishing Co., 34, Victoria Street, London, S. W. 1.

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