and the Dewoitine an engine of 1,130 c.c., but these figures do not give enough data to form an accurate estimate of the difference of horse power employed for taking off and flying at full power, and it is necessary to obtain figures of the r.p.m. employed in each case before data for comparison is available. As a rough estimate it may be stated that the Clerget engine on the Dewoitine is running at 1,450 r.p.m. on the ground and at 1,650 r.p.m. when flying at 55 m.p.h. near the ground, whereas the A.B.C. engine on the "Wren" is running at 2,600 r.p.m. on the ground and 2,900 r.p.m. at 51 m.p.h. near the ground. If these assumptions are correct the maximum power used by the Dewoitine is in the order of 15 h.p., and in the case of the "Wren" the maximum used is about 8 h.p.

Any suggestions for a suitable method whereby the machine can be classified according to the maximum b.h.p. developed with a given propeller will form a useful subject for discussion.

In conclusion, it is hoped that a considerable amount of activity will be shown this year in connection with the light aeroplane, and that much useful information will be gained as a result of the trials to be held in September.

DISCUSSION.

Captain Sayers.—Re the controls of our glider, I am as curious as Major Wright is to know why this failed, but I believe there were many reasons, firstly, as with all the gliders at Itford, very little time was available for design and construction. The total time we spent on drawing was 18 hours, and total time in construction, 19 days. As originally designed it was intended to warp the wings, because it was known that trouble had been experienced with lateral control of gliders in Germany. I was going to warp them by pivoting the back spar on the centre line. I found, however, that the loads on the pivot gear were going to be very heavy, and difficult to provide for; therefore I fitted ailerons. The wings had been carefully designed so that there should be no bracing to interfere with the warp. Therefore the wings were not so rigid in torsion as they might have been.

In the second place, the ailerons were of relatively small area compared with the wing surface.

The machine was extremely clean in shape and her gliding angle good, but the added drag of a pulled-down aileron made a large addition to the resistance of the machine.

In our machine the body was very large, and the depth very much

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greater than it need have been to contain a pilot; therefore there was a very large amount of fin area; and the moments required to turn it were very large.

To what extent these various features contributed to the whole I do not know. As Major Wright says, quite large ailerons gave no appreciable effect. I am hoping to build another machine very much on the same lines in the near future, but I shall reduce the body area and rather increase the aileron area. I shall make the wings as rigid as possible, and hope I shall have no trouble.

I cordially agree with the lecturer's regret that the low-powered aeroplane has descended upon us as quickly as it has. I suppose it was inevitable, but if the development of this type leads to the abandonment of pure gliders it will be a very great misfortune. The glider is cheaper to build and less expensive to run, and leaves us free to concentrate on aerodynamic efficiency. As soon as you start to put an engine in, the thing gets complicated. It takes the matter away from pure aerodynamics. At the same time, it is obvious that you cannot make an efficient machine with 4 or 5 h.p. without sufficient aerodynamic efficiency. I hope, however, that the development of the low-powered aeroplane will not affect the development of the glider.

I am sure the lecturer is not exaggerating as to the performance that can be obtained. I suggest that in a few years there will be commercial three-seater machines flying between London and Paris at 100 m.p.h. with engines of about 1,500 c.c.

MAJOR GNOSSPELIUS.—This problem is really very big. That you can make low-powered craft is proved by these two new machines, and the fact remains that we can make something which works with very small power compared with what used to be considered a minimum. Mr. Roe used to hold the record for flying with low power. He used an 8 h.p. Jap which possibly developed more power than a 400 c.c. A.B.C. engine. His machine did not by any means fly properly—it hopped, but an 8 h.p. machine never really flew like the "Wren" does; there was no reserve power at all.

This is a hopeful indication that we have improved the shape of the machine a little. After all, the question is one of having the right shape. If you make the wrong shape you cannot fly without much horse power.

If we can fly with 4 h.p., I personally do not see why we cannot fly with a little less. People always seem to put a limit as to what one can fly with. Here comes along a machine which has something like a 1 in 18 gliding angle. Why should you not take that figure up to 1 in 25 or 1 in 30? If you have got the thing right I do not see why you should not push the figure up to anything within reason. A railway train has 1 in 100; why should not an aeroplane? If you can do this the problem becomes interesting, because it would give the cheapest transport rate in the world.

You cannot afford to go in for a £5,000 machine; the ordinary mortal can only give £500. If you show in a small thing what you can do, you can then go in for bigger ones. The low-powered aeroplane has the virtue of showing how these things should be done.

Controls is a question that rather interests me, and I think some of the gentlemen here know that I have rather strong opinions on the matter.

One machine that really interested me at Itford was Mr. Raynham's. His rudder was no good at all; you could push it anywhere with no effect, and he could feel no resistance on the rudder bar. If the rudder had been in air that was flying by it, it must have had a pressure when he was flying, but Raynham said he got no pressure anywhere. This therefore means that the air round the rudder must be going along with the machine. If you study the flow of air past an aerofoil, when it burbles you find that the air bounces off the nose and streams away backwards without touching the back of the aerofoil; you have no motion of air over the back of the surface. My experience is that when you try thick wings you do not get as high lift as you do in a thin one. In some sections I have tried it seemed as if you get very low lift if you have a thick wing. I think the absence of lift is a burble effect, which means that the air is leaving the back of the wing, and not following it down. It is therefore possible that it runs right away above the tail. If you use a thick wing and do not camber it underneath, you will get this effect, and that would account for the want of control that some rudders have on thick-wing machines. Probably the wing does not burble at the tips, but only in the middle.

I think this could be got over by curving the under surface, that is, putting a heavy camber underneath. All the thick wings I have tried with heavy camber have this break-away effect. If they are cambered underneath, however, you get your high lift quite strongly. I think, therefore, that the thin wing will reduce the difficulties of this control business. It really means that you blanket the rudder with thick wings.

The ailerons are associated with the rudder, and if the rudder will not work they will not. If your rudder is not effective you will have trouble with the ailerons. Ailerons alone will not do much good; you must have rudder as well. Some of the German machines have thick wings, and they seem to work, but you do not find thick wings in nature. A bird's wing is pretty thin, although heavily cambered. However, someone will no doubt soon prove me wrong, and make a thick wing which is quite good.

Regarding minimum power, we want to fly with one-man power, and I do not see why it should not be done. In 1913 I tried to make a machine like this, and failed. Acceleration will be a trouble, but I do not set a limit of 18 in 1 as your efficiency; it should be a little higher.

I should like to congratulate the lecturer very much on his performance in the "Wren." It must have been very interesting—and very nerve-racking—to fly a new type of machine that no one else has flown before. I think a test pilot's work is remarkably nerve-racking. You pay a man to test a machine, and you should therefore listen to him, and not wander away with your own opinions. You must learn from his experience. One celebrated

Admiralty expert said he was hindered by what the pilot had told him. The pilots are as near the truth as anyone can be. Light aeroplanes will come with such a rush that people will be very surprised. The motor-car would never have reached its present stage of development if makers had not been able to sell to the fool public who will buy any old thing. If we are not too much tied up with Government regulations we shall succeed in selling them.

MR. R. J. PARROTT.—I had no idea I should be asked to speak and am rather unprepared. I have given the subject very little attention but my firm are now getting rather interested and thinking about building a machine for the "Daily Mail" Motor-Glider Competition.

Regarding Major Gnosspelius's remarks concerning Mr. Roe's early experiments, I was not associated with him at the time he built his 9 h.p. machine but joined him some few months afterwards. When I first met him he was experimenting with a triplane fitted with a four-cylinder J.A.P. engine which developed about 14 h.p. It made several good straight flights, but never, as far as I can recollect, made a turn. I think this was due not so much to inability on the part of the machine, but to inexperience on the part of Mr. Roe as a pilot, as he then had but little flying experience.

With regard to the 9 h.p. J.A.P. engine, I doubt if this gave any more power than the A.B.C. engine fitted to the "Wren." It weighed 105 lbs., and had a belt-driven propeller. The propeller was four-bladed and somewhat crudely constructed.

It has taken a long time for Mr. Roe's early performance to be beaten, but perhaps the reason is that no one has been sufficiently interested in the development of very low-powered machines to make the attempt until comparatively recently.

Regarding M. Barbot's flight, his petrol consumptions are not particularly good. As far as we can see, he only averaged 30 to 35 miles to the gallon. The Avro "Baby" on one occasion remained in the air for an hour on one gallon of petrol and on a long cross-country flight, Lympne to Turin, the petrol consumption was just over 30 miles to the gallon. The "Dewoitine" machine, therefore, is not much advance on the old Baby from this point of view. The Green engine fitted to the Baby weighs about 7lbs. per h.p.

I do not think I have anything else to say except that I am looking forward to the trials in September next. The results obtained will, I am sure, be very interesting and I shall not be surprised if we approach petrol consumptions of 100 to 150 miles to the gallon.

I congratulate the lecturer on his paper, and Mr. Manning on the excellent design and performance of the "Wren."

MR. R. CHADWICK: I am very pleased to be able to take part in this discussion, though whenever I get up to speak at any of these meetings I immediately forget all I wanted to say. One of the things that appealed

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very strongly to me (perhaps because I have a budding commercial sense) was Major Gnossepelius's remarks re the public buying light aeroplanes. There is only one thing in that connection that will give trouble, and that is, when people start to fly them. I am afraid there will be some very grave difficulties then unless we can improve the ease of control of these very low powered machines, which, so far as I can see, at present requires considerable skill.

Personally, I am not quite in agreement with some of the speakers, because I think you require an engine of moderately high power to propel a machine of sufficiently robust construction to be handled and kept in trim by the ordinary man who wants to buy and fly an aeroplane. If you have *very* low power, it means very light construction, and the machine is easily damaged. Also a good reserve of power is of considerable assistance in helping one out of difficulties when flying.

From a scientific point of view, of course, it is most important that we should experiment with the minimum power machine, not so much from the aspect of the light aeroplane itself as from the data which we shall obtain which may be applied to large type machines, so that we can evolve machines of sufficiently low petrol consumption—that is to say, sufficiently efficient to cross the Atlantic and carry a reasonable percentage of useful load such as mails (and females).

Major Gnosspelius dwelt rather on the question of the thick wing (having in mind, I presume, the Cantilever Monoplane type). Many of us are thinking a great deal about that type of wing, on account of its obvious efficiency and the clean lines which it enables one to obtain in the layout of the complete aeroplane and which should enable us to develop very satisfactory L/D figures for aircraft. With the very small aeroplane, however, I think the biplane is well worth considering, because you can make the wing structure very light and stiff, so that when using the ailerons you do not warp the wing the wrong way, while you benefit from the improved elevator control which you get with the narrow chord. I think that the improved L/D of the thin wing probably compensates for the additional resistance of the necessary bracing, and therefore the biplane is worth considering when looking into the design of a low-powered aeroplane.

With regard to the "Wren," I think with everyone else that it is a very excellent design indeed, and altogether wonderful, and makes us realise what the possibilities of the low-powered machine are. I feel quite in agreement with the lecturer's figures of the possible performance of this type of aircraft, and perhaps with Captain Sayers', although he seems a little optimistic. I wish to thank the lecturer and the Institution for the opportunity of taking part in this discussion.

Dr. Hankin: With regard to the lecturer's suggestion that intermittent use of controls may be of advantage, it is of interest to recall the fact that such method of control is used by vultures. For steering in the horizontal plane, the vulture rotates the wing-tip of the wing that becomes the inside wing during the turn. The rotation is not a pulling down of the trailing edge as in the movement of an aileron. It is a depression of the leading edge of the wing-tip. As soon as this occurs the air begins to press on the upper surface of the wing-tip quills, thereby pressing them downwards, thus giving the appearance of a depression of the wing-tip. This pressure on the wing-tip results in a force that tends to produce banking in the sense required for the turn. No sooner is this depression produced than the wing-tip is rotated back to its normal position. The total time required for the manœuvre is a little over two seconds as a rule. It is usually only after the wing-tip has returned to its normal position that the steering effect is apparent. One or two such steering movements may be made by the bird when describing a circle about 50 metres in diameter.*

Major Gnosspelius has referred to the possibility of the rudder, under certain conditions, being blanketed by its having to work in a region of dead or disturbed air. No flying animals ever run any such risk. They may use the tail in checking a turn but never for producing one. In dragon-flies steering is produced by rotation of the whole wing. In flying-fishes a muscle exists whose action is to pull down the leading edge of the wing. This is probably used to produce camber, or to add to it if it exists, in the wing that becomes the inside wing during the turn. Speed of this wing is thereby checked and steering results. In birds, when in gliding flight, rotation of the whole wing may occur for steering, but, at least in the larger birds, rotation of the wing-tip is the more important adjustment used for this purpose. In bats steering is produced by rotation downwards of the part of the wing membrane supported by the first two digits. By this means camber and consequent checking of speed of the inside wing is produced. In the flying reptiles known as pterodactyls there was provision for rotation at the wrist joint, and this adjustment probably played a part in steering movements. In flying lizards, the wing membrane is supported on elongated ribs. Dissection of these animals led me to believe that they steer by retiring and increasing camber of the inside wing. Similarly in flying squirrels there is no possibility of wing-tip rotation as their wrist joint is outside the wing membrane. The wing membrane extends along the arm as far as this joint only. The consequent restriction of their power of steering is a possible reason for the low development of their power of flight.

It is noteworthy that in none of these methods of steering is any use made of a vertical plane. Among living flying animals the only instance of vertical planes to be found is offered by the tail fin and the upturned wing-tips of the flying-fish. It is of interest to notice that in this animal the arrangement of the supporting surfaces and fins resembles, to a notable extent, that of an inherently stable model glider designed some years ago by Professor Bairstowe.

Should any attempt be thought of to introduce bird control into low-

* See "Animal Flight," pp. 68 and 115.

powered aeroplanes, it should be borne in mind that the rotatable wing-tip is much larger than an aileron. In the Sarus (*Grus antigone,* a species of crane), for example, the total area of one wing was found to be 628 square inches. The rotatable part of this (the wing-tip) measured 225 square inches. The length of the wing was 47 inches.

MR. HOWARD-FLANDERS: Regarding Mr. A. V. Roe's early work, I was associated with him in the construction of the 9 h.p. machine, but I do not believe the 9 h.p. engine gave 9 h.p. It vibrated in the most appalling way—nearly throwing one out of the seat at full power. The airscrews and transmission were inefficient, and the control arrangements crude and inconvenient, but I believe that if that machine were rebuilt and fitted with normal controls, a good pilot could get circuits out of it.

I well remember the very grave difficulties under which this work was carried on. At first the police wanted to stop us from flying in the early morning over Lea Marshes because we were endangering the public. After Bleriot had flown the Channel they also wanted to prevent us from flying on account of the obstruction caused to traffic owing to all passing vehicles stopping to watch us.

MR. TILGHMAN RICHARDS: I must congratulate Mr. Manning and the lecturer on the very fine performance of the "Wren." One feels, however, that instead of this paper being a forecast of the future it should really be the result of about five years' work. Everything seems to have stood still since the war. All the factors which go to make a light aeroplane have been known for years past. Now we suddenly apply this knowledge, and I hope that in the end we shall produce something really revolutionary in light aircraft.

I agree for once with Major Gnosspelius that the present L/D ratios are in no way what we should look for, and it is rather interesting to note that the troubles which are cropping up with these light machines are very much what have been the trouble with light machines for some years. We have really very little data to go upon, and I wonder sometimes whether we are on the right lines at all in pushing a "petrified ornithopter" through the air by means of a propeller.

It also sounds funny to an engineer to talk about kicking a thing round. Kicking may be quite correct on a soaring bird, but there does not seem to be any reason why we should accept this form of control on rigid machines.

I would like to utter a word of warning as to the use of the Peyret type controls, particularly for gliders. I used this before the war, and where you have a lightly loaded machine which has any amount of control surface, the system is quite safe, but not in the hands of a learner. You must have 25 degrees movement for ailerons control and another 25 degrees for the elevator control, and in the hands of a novice it is quite possible that you get no control on one side and a great deal on the other. This type of control needs to be used with great caution except for very light loading and with

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ample control surfaces. If stops limiting the movement of controls to 25 degrees were used, it would prevent the control surfaces getting to a dangerous angle, but I am afraid that these stops would baulk a beginner, and would probably be carried away in a tight corner.

The Chairman (Mr. W. O. Manning).—Regarding the control surfaces of the "Wren," these were designed on the usual basis of aeroplane practice, and seemed efficient. It is quite possible by pulling down a large aileron to its maximum angle to double the resistance of a small machine like this, and thereby run the risk of a stall if the machine is not dived to some extent. That is what the lecturer meant by advising that controls should be worked more rapidly. This is probably the best way of correcting the trouble.

With regard to the rudder, I am afraid I do not agree with Major Gnosspelius, but time will show whether he is correct. I am sure the absence of rudder control is more due to absence of dihedral than anything else. I think it is hardly plausible to assume that there was anything like bad order in the region of Raynham's rudder. Major Gnosspelius may be right, but I do not think he is. Another point is that the diameter of the slipstream in that case is probably in the neighbourhood of three feet. As the engine is about 30 feet away it is sufficient to bring the slipstream away altogether; you cannot therefore rely on the slipstream to improve the rudder control.

SQUADRON-LEADER WRIGHT'S REPLY TO THE DISCUSSION.

(Major Gnosspelius.) Re his suggestion that the rudder does not work, in the case of the "Wren" we have T.64 span put up nearly 70 per cent., and I think he will agree that this is a span that ought not to allow the rudder to work, yet the "Wren" rudder works very well.

Regarding Government support, I think there will be no difficulties whatever put in the way of developing low-powered aircraft, but that every encouragement will be given. (Applause.)

(Mr. Parrott.) Referring to M. Barbot's petrol consumptions; all the time the machine was at Lympne the petrol was pouring out of the carburettor, and he said "Let it run." Nevertheless, the Avro "Baby" was the first machine to show what could be done towards really economical flying. I am only sorry that we have taken two years to follow it.

(Mr. Chadwick.) I think that a light machine with low power can be made quite sufficiently robust. In the case of the "Wren" you can run it over rough roads quite well.

With regard to the elevator control, this appears to be one of the most easy controls to obtain on this type, and we can get a good control below stalling speed while we cannot get it on larger machines.

Dr. Hankins's remarks are extremely interesting, and are my views on the matter in every way.

(Mr. Richards.) I think his point regarding controls has been replied to by Mr. Manning.

A very hearty vote of thanks to the lecturer was proposed by the Chairman and passed unanimously, and the meeting then closed.

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