LOW-POWERED FLYING.

Paper read by Mr. W. O. Manning, A.F.R.Ae.S., Honours Member, before the Institution at the Engineers' Club, Coventry Street, W., on 22nd February, 1924, Mr. H. B. Molesworth in the Chair.

Mr. Manning said:

As "The Wren" light aeroplane was the first of its type to fly in England, it might be as well to put on record the origin of this design.

This machine was designed originally at the end of October, 1922, and work was started on it at the beginning of February, 1923, the machine being finally finished and flown early in April the same year. It was designed for the "Daily Mail" Competition at Lympne, but it was obvious that a machine of this type which was known after its first trials to have a sufficiently good performance for the purpose would obviously have a very good chance in such a competition, and it was therefore entered. The machines which were entered at Lympne followed the lines of the first "Wren" very closely, with the exception of one or two slight alterations, which were the result of experience with the first machine. These alterations consisting principally in reducing the dihedral from 4° to 2° and swinging the wing forward so that the front edge was nearly at right angles to the centre line of the machine instead of sloping backwards as previously. This latter alteration was due to the fact that in the original machine the C.G. was somewhat far too forward. In getting out the original design for this machine, it was clear that in order to make the machine fly satisfactorily with the A.B.C. motor and C.G. engine, it was necessary to reduce all the subsidiaries of resistance to the minimum possible, and it was with this object that the wheels were half buried in the fuselage thereby surpressing the resistance of the chassis. The wheels had consequently a very narrow wheel base compared to usual practice but no trouble due to this had arisen in use.

As the C.G. of the machine is only about eighteen inches above the axle, the angle from the C.G. to the point where the wheels rest on the ground is probably about normal. It was anticipated that in the case of a bad landing or in the case of a good landing on a very rough surface that the fuselage would come in contact with the ground, but it was not expected that this would normally damage the fuselage and this expectation has been realised in practice as no structural damage of this nature has ever occurred.

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In connection with the chassis it may be pointed out that one of the functions of the rather peculiar shape of the nose of the fuselage is to prevent the machine turning over after landing. This nose was stiffened up with three-ply so as to form a broad flat skid and it would be quite safe to use it as a brake by holding the nose down with the elevator.

As great efficiency was aimed at, and as the machine was small, it appeared reasonable to make the wings of the monoplane type, and the question as to what aspect ratio could be used, was given very careful consideration. It is impossible to calculate accurately what the best aspect is under any particular set of circumstances, and the particular aspect selected is really the result of collating all the known facts and then using one's judgment.

It is clear that the higher the aspect ratio the better the L/B of the wings but if too large an aspect ratio is used the weight of the wings would increase seriously and trouble due to lack of rigidity might be expected. The aspect ratio eventually selected was 9.25 to 1.

It must of course be remembered in the design of machines of this type, the question of L/D pure and simple is not the only consideration as it is in the case of a pure glider. In the glider the performance is independent of the weight, the only effect of pushing up the weight being to increase the size of the machine if loading is to be constant. In the case of the power-driven machine, the performance is dependent on the weight divided by the L/D, which is this resistance, so that in this case, weight comes in. It therefore will not pay to put on too much weight by increasing the aspect beyond a certain amount, and, of course, biplane structure or any other of less actual efficiency, becomes possible if sufficient weight can be saved by its use.

The wings were arranged as pure cantilevers on such a design diagonal supporting struts to the very spars cannot be very satisfactorily arranged for. If they reach to anywhere and near the best point of the spar they are very long and have a bad angle. If on the other hand they are attached to the spars close in loads are seriously increased owing to negative shears, and apart from this although their angle is better they are not very effective in relieving any stresses.

There appears to be no particular difficulty in connection with controls of such machines, and a rudder of ample size should be arranged for, and if ordinary practice is followed in connection with elevators and rudders, no trouble need be expected from either of these directions. These small machines have, however, shown one rather important characteristic. Owing probably to the high degree of lateral damping, they do not put one wing down suddenly when stalled, and certain machines of this type, including the "Wren," have been stalled repeatedly without anything whatever happening. This feature unquestionably is very important from a point of view of safety. I think, personally, that it would be advisable to keep to the two-cylinder engine as far as possible. This engine has the advantage of extreme simplicity and can be overhauled, the valves ground, and cylinders cleaned, etc., at very small cost. An objection one sometimes hears to the use of this

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type, is that if one plug failed a large proportion of the power vanishes, but this is equally true of any small engine which is likely to be fitted in such machines. Such engines are not likely in any case to have a greater number of cylinders than four, and as a counterpoise to the above, it is clear that as there are twice as many plugs in the latter engine as there are in the two-cylinder type, the risk of failure of one of them is twice as great. In a small engine of this type, the irregularity of the torque does not seem to have an appreciable detrimental effect on the propeller, and I think that it would be quite possible to drive a propeller satisfactorily with a single cylinder only.

Air-cooling has been used exclusively on these small engines so far and has worked quite well and although it might be possible to produce a cleaner machine with a water-cooled engine and wing radiators it is doubtful whether the additional complication and expense is worth the possible gain.

There is another point to which attention may be directed in connection with engines and that is the question of gearing driven by the propeller. The French custom in all their light machines is to run the propeller at not more than 1,700 r.p.m., and they either use a larger engine than we do and drive direct or else they use a high-speed engine and gear down, and they seldom use a propeller less than five feet in diameter. At Lympne several machines were fitted with propellers turning up to over 3,000 revs. per minute and about four feet in diameter, much to the astonisment of some of the Frenchmen who found it hard to believe that such an arrangement had any appreciable efficiency.

I believe that at Lympne the only reason why certain engines were geared was owing to the designers desiring to get more power than could be obtained at a speed practicable for the propeller. Some of the designs used were stated to give their maximum power at 5,000 r.p.m. or so.

There is a good deal to be said for the small-diameter, high-speed propeller. Though it is obvious that apart from increase of power a geared propeller may be considerably more efficient this is not the only point to consider though it is clearly a most important one.

The high-speed, direct-driven propeller is much lighter than the " Wren " propeller, weighs 1 lb. 11 ozs., and the arrangement is much simpler. Lightness is also assisted by the absence of a gear box. The small diameter of the high-speed propeller also may enable some resistance to be saved; with its use the wheels may possibly be put in the fuselage while with a slow-speed propeller a higher chassis, which could be heavier and of greater resistance than the alternative, may have to be used. It is not a bad general rule when considering two alternative methods of doing something, and if the arguments in favour of each are so balanced as to make it difficult to know which to adopt, adopt the simplest.

The question of instruments for these small machines deserves some consideration, and in this connection it may be stated that the speed indicator used on the " Wren " was slightly heavier than the engine mounting. Very

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much lighter instruments could and should be provided, and full-size machines would also benefit from a reduction in the weight obtained.

It was possibly due to the effects of the late war that over a period of from say, 1913 to 1922, or nine years, there was practically no improvement in the aerodynamical efficiency of the aeroplane. Engines, of course, improved enormously and the improved performances of machines at the end of the war were almost entirely due to the engine.

More recently the possibility of improving the aerodynamical efficiency of the aeroplane had occurred to several people in this country but it was not until the results of the German experiments with gliders were known that these ideas began to take concrete shape. Possible lines of improvement were clearly indicated by the glider trials at Itford in 1922 and these were followed by the highly successful trials of light aeroplanes at Lympne last year, of which it can be said that nearly every well-known designer in this country produced a machine for this competition and that every machine represented a marked advance in aerodynamical efficiency on anything previously produced in this country.

One of the immediate results of this development is that it is now beyond question possible to produce a training machine for the Air Force which in first cost, cost of upkeep, cost of fuel and oil, etc., will save the Air Force many thousands a year, as the items enumerated above will probably not be more than one-third of the present cost, and the principal object of this year's competition is to produce such a machine.

While the Lympne competition may be stated to have shown the way and proved the possibility of improved efficiency, this year's competition represents an unitarian development of the information obtained.

At present, however, many of the designs used at Lympne can only be produced in small sizes and although the results obtained there are of enormous value, there are many problems to be solved before we can produce a commercial machine weighing, say, 10,000 lbs., and capable of cruising at 100 m.p.h., with a gliding angle at that speed of one in fourteen, say, which would represent a horsepower of, say, 250 or a horsepower loading of 40.

That such results and better will eventually be obtained, I have not the slightest doubt, and when light, single-seater aircraft are produced with a gliding angle of, say, 20 to 25 and of such a form that they can be constructed in a large size with excessive structive weight such results will be in sight.

There is a certain amount of opinion which considers that experiment with pure gliders as the method of experiment. I do not agree with this. Apart from the practical difficulties such as difficulty of access to suitable hills, infrequency of suitable winds, the type of development is not what is wanted. As pointed out previously L/D is of vital importance to a good glider and weight is not, especially wing weight which does not add to the stresses on any part. The tendency expected is that wing efficiency would be improved by using enormous aspect ratios and that is exemplified by German practice. As low-powered single-seater aeroplanes, such machines would probably be

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improved by reducing the aspect ratio as the weight saved would more than compensate for the reduction in efficiency. It is also probable that the best fuselage forms developed by the gliding method would be quite unsuitable for the addition of an engine and propeller.

Light aeroplanes can on the other hand be flown from any suitable aerodrome and the choice seems to lay between experimenting with such machines or with models in an aerial tunnel. There is not probably much difference in expense between these methods and although measurements can be made more accurately in a tunnel the light aeroplane tests are not subject to certain possible errors of an unknown magnitude which may occur in tunnel work. Controls can be tested in flight and any difficulties in connection with them can be more easily discovered and overcome.

It was clearly shown at the Lympne trials that one of the most important attributes of these light aircraft is their safety in operation, and the safety of any aeroplane is very closely wrapped up with the question of low landing speeds. If one assumes that every landing is going to be made on a perfect aerodrome and that the pilot will always do his part in a perfect manner, there is no reason why the landing speed of aircraft should not be anything one likes. Practically speaking, engines sometimes fail, and landings have to be made across country and pilots occasionally make errors of judgment, and it is then that the low landing speed comes in. If a smash is inevitable it is not unfair to assume that the chance of injury to any occupant of the aircraft would vary as the amount of kinetic energy contained in his body at the moment the machine hits the ground, and therefore varies as the square of his velocity at this moment. That is to say, if a smash occurs at 25 miles per hour the chance of serious injury is one-fourth of what it would be at 50 miles an hour, or one may say that any injuries would be only one-fourth as serious.

Another point which makes for safety is that referred to previously; that is, that these machines can be so designed as to be capable of being stalled without the usual sideslip and nose-dive which generally accompanies this manœuvre on the ordinary machine. More fatalities have probably been due to this peculiarity of ordinary aircraft than to any other cause. A pilot takes a machine off an aerodrome; when he has reached a height of, say, 100 ft., climbing rapidly, and cannot land in the aerodrome without turning, the engine either loses revolutions or stops. The pilot, anxious to save his machine, turns quickly, loses flying speed, and stalls, the result being generally fatal.

Light aircraft should be entirely free from this trouble.

Those who remember the early days of aeroplanes will remember the early Anzani Blériot. This machine, which possibly had a top speed of about 5 miles an hour and a low speed of 28, was certainly very safe to fly. I have seen many smashes in such machines, but never one in which the pilot was hurt. If he was thrown out, and he often was if he made a bad landing, he was never seriously hurt, but, in fact, the usual injury might be described

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as a slight shaking. When Blériot started fitting 50 h.p. Gnome engines into these machines he flattened out the camber of the wings at the same time, and put the landing speed up to possibly 40 m.p.h. The result to the pilot was that if he was thrown out he generally either broke his neck or suffered from very severe concussion.

The fact that modern machines with high landing speed do not cause more fatal accidents is due to the greater skill of the modern pilot. Really bad landings are scarce, and a landing which is bad nowadays would have been considered as passable 12 years ago. It is almost unheard of for a modern pilot to bring a machine into a modern aerodrome and to crash on landing unless some extraordinary mishap has occurred. Such smashes were not uncommon in the early days.

All pilots to-day are used to flying machines which may be considerably faster than 100 miles an hour, and naturally consider machines with top speeds of, say, 70 miles an hour slow.

In fact, it is common to hear that nothing less than 100 m.p.h. is any good for cross-country flying and that light aircraft will be in practical use until such speeds are attained. I do not agree. Let us consider what sort of machine would be suitable for, say, a ranch-owner in Australia who desires to use it for supervising his ranch, involving journeys of say 40 miles each. We may assume that he has just taken a course of tuition and has had little real experience of flying and that the ranch does not provide good landing grounds and that any emergency landing ground will be very poor. A very low landing speed is clearly here of optimum importance, as even if this invokes a top speed of only 60 miles an hour, or less, he will save an enormous amount of time over his present method of transport even in a wind up to 40 m.p.h. Let us not forget that the old Maurice Farman was once one of the best and most used across country, with a top speed of about 54 m.p.h.

There are numerous other possible uses for light aircraft. In Canada machines of usual type are extensively employed for mapping by photography, patrolling forest land for fires, sending parties to fight fires, etc. For these purposes high performance is not required, and it is certain that aircraft can now be produced which will do the work at a much less cost than the machines which they have in use at present. There is, however, one difficulty with Canadian requirements, which is that in many districts the only landing places available are lakes or rivers, and before full advantage of the new developments can be taken it will be necessary to produce a light seaplane.

The development of a light seaplane will present many new problems. Compared with the ordinary seaplane it will unquestionably have to be much more efficient aerodynamically, but its engine power must be sufficient to enable the machine to get over what is known as the hump speed. This speed in the ordinary seaplane usually occurs at about 25 knots. It occurs on all floats and boats so far designed, and although by careful design the resistance at this point may be reduced, the minimum power with which a seaplane may be fitted depends on the amount of power which is necessary to pull the machine over this hump.

In the case of a hull of the Linton-Hope type, with a getting-off speed of about 80 knots this hump resistance is roughly 175 lbs. in 1,000 lbs., and to this must, of course, be added the aerodynamical resistance of the machine to get the total resistance. 50 knots, which is about 57 miles per hour, would possibly be about the cruising speed of a light seaplane, and is much too high for the getting-off speed, which might be 30 knots. This latter figure would bring the hump speed of the latter down to, say, 15 knots on a similar design of hull.

These figures are much lower than anything which has so far been tried, but there is no reason to believe that any serious difficulty would arise. The aerodynamical design would present more difficulties. Seaplanes of small size have always been less efficient than the equivalent land machine, while the structive weight has also been greater owing to the weight of floats, etc., and the indications point to the impossibility of getting what is wanted with existing types. Possibly a monoplane flying-boat might be developed which would possess the desired features, but the actual design of such a machine is rather outside the scope of this paper.

Apart from the possibilities of light aircraft coming into extensive use in this country there are undoubtedly considerable possibilities in the Colonies and also in such countries as the Argentine. The fathers of the present owners of large ranches and farms made their visits of inspection on horseback at an average speed of possibly 7 to 8 miles an hour. Many of the present owners probably use Ford motor-cars and average 10 to 12 miles an hour. The sons of the present owners will probably use light aircraft and will average 40 to 50 miles an hour, and the saving of time will be considerable. I am informed that in the Argentine there are ranches which require a journey of 50 to 60 miles to be made by the owners or manager for one round of inspection.

But before a market can be created in districts like these, it will be necessary to educate the populace in the possibilities of modern light aircraft, and this will take several years. Types specially developed for the requirements of each country may also be necessary.

I should like to say in conclusion that to my mind the demonstrated fact that improved aerodynamical efficiency is obtainable is a most important landmark.

It remains for us to apply this knowledge of larger machines and to try and overcome the very great structural and other difficulties which will arise. At the same time even better results than those reached at Lympne are undoubtedly possible and should be obtained. The prize money already given has produced results out of all proportions to the cash value of the prizes. Further progress could be stimulated by the same method.