THE POSITION OF THE AIRSHIP IN AERIAL TRANSPORT.

Paper read by Lieut.-Commander C. D. Burney, C.M.G., M.P., R.N. (Retd), before the Institution, at the Engineers' Club, Coventry Street, W.1, on 24th April, 1925. Lieut.-Colonel J. T. C. Moore-Brabazon, M.C., M.P., in the Chair.

COMMANDER BURNEY said :

With the exception of the construction and trial flight of the Z.R.3, recently built by the Zeppelin Company, of Germany, to the order of the U.S. Government, there has been so little actual operation of airships that from the commercial point of view it is only possible to indicate the performance of a modern airship embodying the latest developments in design.

Since only last month Dr. Eckener gave a full description of the capabilities of the Z.R.3, I propose to direct attention rather to the new improvements in design which have been incorporated in the 5,000,000 cub. ft. ship now being built by the Airship Guarantee Company for the British Government, and the effect they will have in relation to the contemplated mail and passenger service between this country and New Zealand.

The principal departures from existing practice may be divided into four main sections :—

(1) Streamline design—with pilot car in nose of vessel.
(2) New method of anchoring, necessitating new type of mooring mast and mooring gear.
(3) Development of hydrogen-kerosene engine.
(4) Structural design of hull and wiring.

The first three sections, being of more general interest, I shall describe in some detail; in regard to the hull structure I will say only that research and experimental work on the new type have given grounds for satisfaction.

Taking first the streamline type of ship. This new design marks an advance on previous work in the attainment of complete streamline form by the

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elimination, so far as possible, of all external projections from the envelope. To this end all passenger cars, control cars, and observation posts will be situated inside the hull, leaving only the four engine cars suspended below it. Experiments in the wind tunnel at the National Physical Laboratory show that these improvements greatly reduce the head resistance and thereby tend to increase the speed of the vessel by about 20 per cent.

It must not be assumed that the reduction in resistance is only that obtained by the subtraction of the resistance of the control car as an independent unit, or of an engine car as an independent unit. It has been found that a much greater total effect is produced upon the resistance of the ship as a whole by disturbing the streamline in the front part of the vessel. After all obstructions which might deflect and disturn the streamline flow are removed from that part of the vessel which is in front of the maximum diameter, the actual improvement will be considerably greater than would be obtained if the same number of obstructions of the same kind were removed from the after part of the vessel.

As soon as this effect is realised it is evident that all improvement in design must tend towards a perfectly clean shape for the foremost part of the vessel, and therefore it is essential that arrangements should be made to eliminate the control car from the normal position. The best alternative position is the nose of the ship, but there was a difficulty in utilising this space for the control car so long as the type of mooring mast known as the Air Ministry type was to be used for mooring the ship. This type of mooring mast necessitated a strengthened nose to take the fitting which connected with the mooring mast. A new type of mooring mast was accordingly devised, which freed the nose space for the purpose of providing room for the control and observation car. At the same time this new design had the advantage of holding the ship from two points instead of from only one point.

This development brings out quite clearly that the design of the ship and the design of the mooring arrangements are interdependent, and therefore any policy of commercial development should, if it is to be efficient and satisfactory, contain the condition that control and direction of the bases should be in the same hands as the control and direction of the ships themselves.

Another factor which has been carefully considered in regard to the development of a standard type of mooring mast has been the desirability of developing a type which would be equally suitable for land work and for sea work. It may be said that the two most important functions of airships for the British Empire are in connection with the development of aerial communications, and in relation to the provision of an auxiliary reconnaissance force that could, in time of national emergency, co-operate with the British Fleet.

So far as experiments with mooring masts have beeen carried out it has

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been found that before the final connection between the moving ship and the fixed mast is made the ship should be controlled by a triangulated system of wires. In the Air Ministry type of mooring this is attained by utilising side guys dropped from the ship and secured to bollards, perhaps a thousand feet from the base of the mast. Obviously such a system cannot be used when it is desired to moor an airship to a naval vessel, for the simple reason that fixed points at a radius of a thousand feet from the base of a floating mast will not be available.

In the new type of mooring mast the triangulated system is obtained by having position of attachment for the side guys borne by two arms, capable of being swung horizontally on a revolving platform at the top of the mast.

This system has a further advantage: the whole system may be rotated. Thus, the difficulty of providing for the case in which the airship approaches a floating base at an angle relative to the floating vessel is overcome by the simple rotation of the system to accommodate the line of approach of the airship.

Other subsidiary advantages are inherent in the design, but the main advance that has been made is, firstly, that it makes possible the construction of an airship having the minimum of resistance and therefore the maximum radius of action, and, secondly, it standardises the type of mooring mast both for shore stations and for floating bases

One of the most interesting ancillary advantages is the possibility of having two gangways, one on either side of the ship, for the embarkation and disembarkation of passengers. From the practical point of view when handling a large number of passengers this is of some importance, as it allows one gangway to be used for those coming off and the other for those going on board the ship, thus lessening the wait at the mast-head; also by this arrangement the total net weight of passengers in the ship is not disturbed, which allows the ballasting conditions at the mast to be more easily controlled.

The next development, namely the introduction of the hydrogen-kerosene engine, is not claimed as being entirely new, since as far back as 1913, the Airship Department of Messrs. Vickers, Ltd., were engaged in preliminary experiments in this direction. Owing, no doubt, to the many other problems which had to be faced at that time, no very practical result was obtained.

The advantages of the engine are twofold: firstly, by utilising hydrogen, which would otherwise be expelled from the airship in order to compensate for the weight of fuel used, it is possible to economise in fuel consumption in two directions: each pound weight of hydrogen contains some 40,000 B.T.U.'s as compared with 20,000 B.T.U.'s of kerosene, and as the ratio of the lift of hydrogen to its weight is approximately 14 to 1, we immediately

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obtain a reduction in the amount of kerosene required, by one-seventh. Secondly, other conditions allow of the saving of fuel to be still greater, since a heat cycle can be employed in the engine which gives a higher thermal efficiency than would otherwise be possible.

It may be as well to expand this point in some detail. The use of hydrogen as a partial fuel in an internal-combustion engine has been shown to give an efficiency as high as that ever obtained with a Diesel engine.

A Diesel engine derives its high efficiency (meaning low fuel consumption per horse power) from its high compression. It is, however, well known that unless the fuel is injected well before the piston reaches the top of its travel it is not possible to obtain low fuel consumption combined with high-power output in a given sized cylinder.

The combination of high compression and early injection of fuel results in pressures in the cylinder from 50 per cent. to 100 per cent. greater than those in a carburettor-type engine giving the same power in the same sized cylinder.

The carburettor-type engine can only work with a relatively rich mixture. It being common knowledge that when the fuel supply is cut down relatively to the air supply, as, for instance, when a smaller jet is put in the carburettor, the engine is liable to fire back through the inlet valve. This effect is due to slow burning of the diluted fuel vapour of the previous combustion lighting up the fresh charge as it enters the cylinder.

By admitting at the same time as the diluted fuel vapour one-fifteenth part of its weight of hydrogen, the burning of the fuel is greatly accelerated. No firing back occurs and the quantity of liquid fuel can be still further reduced while the air throttle remains wide open.

The result of this weakening or further diluting of the fuel with air is that the efficiency of the engine is increased, the loss of heat to the cylinders and in exhaust gases being much reduced.

The pressure in the cylinder is naturally less and likewise is the power output of a given cylinder, though at maximum efficiency with hydrogen the power is no less than that of the Diesel engine when working at its maximum efficiency and the *maximum pressure* given by the combustion with hydrogen is not much more than half as great as for the Diesel engine.

For these considerations it is seen that there is a fundamental reason for the Diesel engine being heavier than an engine of the same output and efficiency using hydrogen as a partial fuel.

If examples can be cited of a Diesel engine being lighter, then the only conclusion is that the materials of which it is composed are more highly

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stressed, and assuming equal merit in the two designs and equal quality of manufacture, then the hydrogen engine will give more reliable service.

We are now in a position to consider the effect upon the performance of a vessel embodying these developments as compared with one of the same size which does not, and the result is very striking. Briefly, with the same capacity to carry a useful load, the radius of action of the vessel is exactly doubled. From a careful analysis it is expected that the Airship Guarantee Company's vessel will be able to carry 140 passengers and seven tons of mail at an average speed of 70 m.p.h. for a distance of 3,500 miles.

It must be remembered in making calculations of this kind it is necessary to analyse the temperature conditions upon the route that it is proposed to operate, otherwise a considerable over-estimate of performance might be made. For instance, if a mooring station was to be situated at Baghdad, there are conditions of temperature and barometric pressure that would reduce the lift of the vessel some 13 to 15 tons, in comparison with the "standard" conditions adopted as a basis of calculation in England.

It is easy to visualise, therefore, that a development of this character must necessarily imply a reconsideration of the route between England and New Zealand. In order to fly from England to New Zealand with a full load in the shortest possible time, only three intermediate stations need be made, and subject to commercial considerations, these stopping places should be as nearly as possible upon the arc of a great circle drawn between England and New Zealand. It will be found that the most favourable positions are Baghdad, Colombo, and Freemantle or Perth, in Australia. Operating upon such a route it should be possible to average a speed of 70 m.p.h. if the top speed of the airship is about 90 m.p.h. Under these conditions the time taken would be as follows:—

England—Bagdad	... ...	37 hours.
Bagdad—Colombo	... ...	41 hours.
Colombo—Perth	... ...	51 hours.
Perth—Wellington	... ...	38 hours.

The total time between England and Australia would, of course, be increased by the duration of time taken to Bagdad and Colombo for refuelling, but it would seem possible that the trip to Freemantle should be made in about 6½ days.

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