COMMERCIAL AIRSHIP DESIGN.

Paper read by Commander F. L. M. Boothby, C.B.E., before the Institution, at the Engineers' Club, Coventry Street, W., on Friday, 17th October, 1924, Sir Charles Bright, F.R.S.E., M.Inst.C E., F.R.Ae.S., in the Chair.

A letter from AIR VICE-MARSHAL SIR W. SEFTON BRANCKER, regretting his unavoidable absence from the meeting, was read, and in his opening remarks SIR CHARLES BRIGHT said:—

I feel that this Institution owes a very great debt of gratitude to Commander Boothby for having selected this particular audience for reading his paper, for Commander Boothby has read many papers and delivered many addresses on aeronautical subjects, and can command practically any audience he wishes at any time. I feel that this is the right audience, because it is necessary that the Institution of Aeronautical Engineers should carry on its good work of disseminating useful and valuable reports of papers read before its members. That is one of the chief ways in which the science and practice of aeronautics can be kept at its fullest activity, in readiness for a time of increased production of aircraft. The total number of Service machines available at this date is approximately only 550, as compared with about 22,000 at the end of 1918, and it is of vital importance that British air supremacy should be regained.

So far as the airship is concerned, I have always believed in this for long distances, both for civil and military purposes, and I now have much pleasure in calling upon Commander Boothby.

COMMANDER BOOTHBY said:—

It is useless to expect airship-owning firms to start running regular lines till they are convinced that the aeronautical engineers can provide them with airships that will attract passengers.

Airships will not attract passengers till they are safe, and till the fares can be low enough to bring them within the means of the average individual. Our commercial airship must fulfil the following requirements:—

(1) It must be structurally strong.
(2) It must be safe against fire.
(3) It must be very controllable in any weather.
(4) It must be cheap to run.

Experience with earlier airships of the R.33 type and others have shown that ample strength can be obtained when half the total displacement is devoted to the hull and engines. The new commercial Zeppelin, Z.R.3, has this proportion. With increase in size it is possible to allot a smaller proportionate weight to the hull and engines while keeping the same strength.

As to the type of airship—whether rigid or semi-rigid—for commercial purposes, it is too early to form a definite opinion. My personal preference lies with the semi-rigid, anyhow for the smaller sizes. The new Parseval type, for instance, consists of a keel the whole length of the ship supported by gas-bags, as in the Zeppelin type, but divided longitudinally as well as transversely. They are under steel nets and over all goes an outer cover, leaving a six-inch space between it and the gas-bags all round, which is very suitable for filling with inert gas. The upkeep of such an airship should be simple and cheap, and the whole of the metal-work under compressive loads is easily kept under supervision, which is not the case in the rigid type. The advantages and disadvantages of the two types are so nicely balanced, that till a ship of each type, of similar size, and employed on the same service, has been tested over a long period, it will not be possible to reach a decision, but it may be accepted that both types are perfectly capable of running an airship service quite efficiently.

Safety against fire.

The first and most pressing need is the abolition of petrol. There are always petrol fumes hanging about in large airships, and in hot climates the evaporation is serious. The most direct and simple way, of course, is to fit engines of the heavy-oil Beardmore type. A second way is to use hydrogen drawn from the gas-bags in conjunction with a heavy fuel in the ordinary engine, and the third way is to gasify crude oil, by a new process shortly to be introduced to the public by an inventor, a well-known petroleum expert.

Before considering the merits of these three systems, we have to consider another point, namely, the protection of the hydrogen against fire by putting a layer of inert gas round it. Various methods have been suggested from time to time, such as double-walled gas-bags containing nitrogen or ammonia gas. Here we meet the difficulty that when the airship rises the protective gas will expand and blow off into the atmosphere, and there is no means of replacing it. It has been proposed to insert ballonnets into each gas-bag into which the inert gas would flow as it expanded, but in that case it would push out hydrogen and make the ship heavy. The double-walled gas-bags are also of undue weight. By far the simplest and most efficient means appears to be to utilise the exhaust gases for protective purposes. There is an ample and constant supply of these which have only to be cleaned and cooled below boiling point, so as not to hurt the fabric, and then turned into the ring space between the gas-bag and outer cover. The ordinary doped outer cover should be quite gas-tight enough to contain it. We need only deal with a portion of the exhaust gas, such as can be dealt with by the weight of apparatus we can afford to carry, and a large part of the cooling is done in the ring space. First we can use the gas for cooking, as at present, and then for warming the living spaces. If it requires further cooling it can be passed between metal plates let in flush with the side in the slip stream of the propeller and finally expanded into the ring space.

Here being heavier than air it will accumulate at the bottom, and the air will be forced out through lightly-loaded valves into the trunks for leading away hydrogen gas when valved, being taken down to the bottom of the trunk below the hydrogen gas valve by a duct. When all the air is forced out, exhaust gas will follow by the same route and fill the trunks, finally escaping into the atmosphere. This is all plain sailing so long as the airship is climbing or flying horizontally; if she dives at more than about 50 feet per minute the whole supply of exhaust gas could not make up for the shrinkage, and it is necessary to admit air to the top of the airship again, either through automatic valves or by pumping it in from the slip stream of the propellers in the usual way. It is argued by some that it is unnecessary to supply this gas protection, as a Zeppelin has already been struck by lightning in flight without harm, and the metal framework or net gives sufficient protection. That may be so, but it does not provide for the case of spontaneous combustion from oily waste left in the ring space, or from the accidental firing of a Verey light into the gas-bags, etc., which the layer of exhaust gas has been proved capable of doing. It only fails where a stream of incendiary bullets is concentrated on one spot from a machine-gun, when hydrogen may be carried by the hose effect into the open air and ignited there; but one does not expect to meet with a machine-gun firing incendiary bullets at close range in a commercial ship. In any case I feel convinced of the importance of supplying inert gas to the exhaust trunks of the airship. Steps are now taken to see that an explosive mixture of hydrogen and air does not remain in the trunks, by scouring them with air, but as soon as a hydrogen gas-valve is opened an explosive mixture *must* be formed. The hydrogen passing out into the atmosphere is a good conductor of electricity, and if any atmospheric discharge does travel down it, it is better that it should find a mixture of hydrogen and exhaust gas at the bottom than a mixture of hydrogen and air. Nothing would happen in the first case; the second would involve a violent explosion in the trunk—which may account for the loss of the Dixmude. Having in mind the desirability of using the exhaust gas for protective purposes let us glance further at the types of heavy fuel engines available.

While the use of the Beardmore type engine removes our petrol trouble it does not provide the greatest possible economy in running. In an airship, for every ton of liquid fuel consumed 33,000 cubic feet of hydrogen have to be got rid of to keep the airship in trim. This hydrogen is a valuable fuel.

In 1 lb. of hydrogen (which is about 190 cubic feet) there are approximately 62,000 British thermal units compared to some 19,000 in one pound of petrol. Previously it was necessary to blow this hydrogen into the atmosphere, and waste it, in order to keep the ship in trim. The Eastern Asiatic Oil Company and Mr. Ricardo carried the tests on with kerosene, getting the consumption down to .35 lbs. per b.h.p. hour. Since then, by a slight modification in the original process, an engine has been run on gas oil. Using these heavy oils the engines will doubtless require frequent cleaning, but if they will run for 50 hours non-stop it is sufficient for our purpose. The engines should be specially designed for rapid dismantling. The war-time Maybach was very good in this respect, it being possible to lift the cylinders in flight and have the engine running again within four hours, and this can doubtless be repeated. Under this system, using gas oil, we require 350 lbs. of liquid fuel, costing £1, and 5,000 cubic feet of hydrogen, costing £1 5s., total £2 5s., per 1,000 h.p. per hour. Compare this with the cost of running on petrol alone, when the fuel for 1,000 h.p. hour would cost £5 17s., plus 7,000 cubic feet of gas wasted, costing £1 15s., total £7 12s.

A new process of using crude oil commercially has recently been introduced. This oil only costs 3½d. per gallon as compared to 5d. for gas oil and 10d. for kerosene. I am not at liberty to describe the process as the inventor has not yet published his system. A plant using this process is working in London, so it has reached the practical stage. Suffice to say that crude oil is put into a generator which weighs about 50 lbs. for an engine requiring 60 gallons of fuel an hour. The crude oil is converted into gas which is cooled and cleaned. If used in the ordinary engine without a supercharger, 78 per cent. of the maximum h.p. is obtainable. The consumption is about .6 lbs. per h.p. hour. Using hydrogen in conjunction with this gas, full power can be obtained from the engine, and the consumption drops to about .45 lbs. per h.p. hour, so that for our 1,000 h.p. unit we should require 450 lbs. of liquid fuel, costing 14s. 7d., and 6,400 cubic feet of hydrogen, £1 12s., Total £2 6s. 7d. per 1,000 h.p. hour. Thus this process is not quite so economical as the last as regards cost, whilst the extra weight of liquid fuel required, which amounts to about a ton per 1,000 h.p. unit per 24 hours, reduces the amount of paying load which can be carried.

There are other possibilities of this process, however. It is customary for airships to carry about 10-15 per cent. of their total lift in the form of water ballast. Suppose we substitute crude oil. When it is required to use it as ballast, instead of throwing it overboard, we can make it into gas, which can be stored till required for use in the engines, and this gas is slightly lighter than air. We have thus got rid of our dead weight and yet have the fuel. The extra weight involved in this system is the generator, and diaphragms in two or three gas-bags to allow of the crude oil gas being stored there, replacing the hydrogen as used in the engines. A ton should cover the total extra weight involved, in a ship like the Z.R.3, a sacrifice well worth making in view of the increased radius of action obtainable. Of course, this process of discharging ballast is slow, perhaps half a ton an hour could be reached, but in a sudden emergency the whole supply of crude oil could be discharged overboard, just like water ballast. Sudden emergencies should generally be dealt with by the use of swivelling propellers, which in my view should be fitted in all commercial ships.

It is sometimes pointed out that as airships increase in size, the smaller proportionate horse power is required to drive them at a given speed, and consequently the effect of swivelling propellers decreases as size increases, which is true. Nevertheless I think that they are always worth fitting for navigational and economic reasons. I believe we can meet with disturbed air, when rudders and elevators are little use, and if caught in down draught the ability to be able to apply the equivalent of five tons of ballast by means of your engines in a ship of the Z.R.3 type is most useful. The same effect could be got by dropping water ballast, but this can only be done a limited number of times, while swivelling propellers can be applied as often as necessary. They are also available for ascent in a violent up-draught, when a ship might be carried up and lose a lot of irreplaceable gas. They are also useful for working down through low clouds when it might be dangerous to dive a long ship through them. On the economic side we can imagine a ship without swivelling propellers, lying at her mooring mast with a full load and full of gas. Starting with a small initial lift she will put her helm up and force herself up to her safe flying height (which may be taken at 3 times the ship's length) by means of her engines and elevators. If we take this to be 2,000 feet the ship will blow off 6 per cent. of her gas in so doing, which is entirely wasted. In an 80-ton ship this would amount to 158,000 cubic feet, cost £39 10s. With swivelling propellers this gas need not have been taken on board, as no initial lift is necessary for leaving the mooring mast.

In considering the design of commercial airships due weight must be given to the important question of working them with the smallest number of men, as this is of even greater importance in the air than it is on the sea. Thus in British and German Naval airships two men were allowed for each engine besides an engineer officer, and there were nine other officers and men.

By simplification of design it should be possible to reduce this to one man per engine and an engineer officer; one man looking after two engines in normal flight. Again, in the control car was a helmsman, a man for the elevator controls, and an officer for navigating, etc. In small airships one man could, and frequently did, perform all these duties for long periods. There is no reason why he should not do so in large ships if suitable relay gear is designed for operating the controls.

Also we might follow the practice of some merchant ships and put our control position aft. In the streamline fins fitted in recent practice, ample room can be provided for rudder and elevator controls, so avoiding the long leads of wire and the necessary arrangements for taking up the slack.

What is now wanted is some process of manufacturing hydrogen with the

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airship's own resources. Sitting on the sea there is plenty of hydrogen in the water around, if some reasonably light electrolytic process can be found. Perhaps some system of cracking oil may meet our requirements, but it is a point that requires the earnest consideration of every aeronautical who wishes to see the empire linked up by real commercial aircraft at the earliest possible date.

DISCUSSION.

Sir Charles Bright :—Commander Boothby gives out so much useful information in a very modest way, that I do not think there is any fear of our overdoing our expression of gratitude. I propose a very hearty vote of thanks to Commander Boothby for his interesting paper.

The vote of thanks was seconded by Mr. Molesworth and passed with acclamation, and the discussion then proceeded.

Commander Hunsaker :—I should like to express my appreciation of what Commander Boothby has done in taking us back through 18 years of historical development, and also projecting us about 16 years ahead. If the next 16 years are as fruitful as the past 18, airships should become a very useful part of our civilisation.

Captain Sayers :—I think it is an extremely good sign that the Institution of Aeronautical Engineers, whose members are mostly concerned with aeroplanes, should every now and then be stirred up to the recollection of the fact that there have been such things as airships in the past, and are likely to be more in the future.

I have had nothing to do with airships, and my main interest is in aeroplanes, but at the same time I do not know how anyone with any reasonable understanding of the characteristics of the two can imagine for a moment that the aeroplane is going to supersede the airship, or the airship the aeroplane. The esential difference between the two is, that for a given speed the weight per h.p. of the aeroplane is constant, and that the bigger you make the aeroplane, the less the proportion of your useful load becomes; whereas, with an airship, the bigger it is the less h.p. you require per ton for a given speed. That means that if you want to carry large loads over a long distance you can do it by the use of the big airship, but if you want to carry a really large load on an aeroplane you find you cannot do so. It therefore comes out

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