THE DEVELOPMENT OF CIVIL MARINE AIRCRAFT.

Paper read by Mr. O. E. Simmonds, M.A., A.F.R.Ae.S., (Member) before the Institution in the Lecture room of the Junior Institution of Engineers, 39, Victoria Street, London, S.W.1, on 9th March 1926, Mr. W. O. Manning in the Chair.

INTRODUCTORY.

Transmarine air services should be one of the main factors of improved conditions of transport during the next decade. Their neglect up to the present would at first seem remarkable, especially in view of the relatively slow speed of the steamship compared with the railway. The more extensive development of overland services, to trace the matter *ab initio,* has been due to the insignificant amount of money spent during the European War upon marine aircraft compared with the enormous sums expended by all the belligerents upon the landplane. Thus, not only was the technique of aeroplane design advanced far beyond that of the seaplane, but, in addition, the aeroplane designer became possessed of an almost unlimited amount of that most priceless treasure—operational data. Indeed, I shall not be unfair in saying that in 1919, when the first air lines were under consideration, the best marine aircraft available were only comparable with landplanes designed three years earlier. As a result there has become associated with seaplanes in the aeronautical mind a certain stigma of inefficiency. During the last five years, however, great strides have been made in all branches of seaplane design, and to-day, excluding the question of hull-soakage in wooden seaplanes, there is not the slightest justification for such an attitude.

This paper, which deals solely with transport aircraft, consists of a brief historical outline, a review of some of the aircraft already produced, with reference to power units, constructional methods and equipment, and, finally, a discussion of the qualities essential to a successful marine transport aircraft, with an appreciation of present achievement. By the courtesy of the various constructors, I am enabled to publish as an appendix a considerable amount of information concerning their civil marine aircraft. This data should be of service both to the designer and the operator, and will also, I hope, be of some value in defining the present standard of design.

HISTORICAL.

The first efforts in the design of civil marine aircraft in this country were inspired by the Air Ministry Competitions of 1920. In view of the fact that we had not at that time built a really successful flying boat, the brilliant idea was conceived of making the marine section a competition for amphibians; we were asked to run before we knew how to walk. Possibly a fairer way is to regard the commercial aspect of the competition as pure camouflage, the real aim being the development of a service type amphibian. Be that as it may, this amphibious blight has stricken every endeavour to design a purely marine transport aircraft, and so all our civil marine aircraft have the chagrin of carrying many pounds weight of useless structure. The only consolation is that when anyone has really wanted to purchase an amphibious civil machine, we have not been lacking in practical experience.

The first attempt to operate a marine air line in this country was made in August, 1923, when the Supermarine Aviation Works, Ltd., founded a company, now merged into Imperial Airways, to run a service of flying boats between Southampton and Guernsey. Guernsey is beyond doubt one of the most exposed harbours around the British Isles and a very unsuitable haven for any aircraft. The result has been that, in spite of heroic efforts, poor regularity has been obtained. At the present time there is a service every Wednesday, and a small number of passengers have utilised it, but in the coming summer I trust it is the intention to operate a daily service with the three machines available, two Supermarine " Sea Eagles " and the Supermarine " Swan," which awaits its trial under air line conditions.

From the designer's point of view, the service has been valuable, but there appears to be no great demand for speedier communication between the Channel Islands and the mainland.

A few air lines have operated on the Continent with marine aircraft, e.g., in the Mediterranean, in the Baltic and on the Danube. But, without a doubt, the most successful attempt at the operation of seaplanes has been made by the Scadta lines in Columbia. There we find an air line in its own element, not competing with other means of transport on highly developed routes, but serving communities which lack sufficient ground communication. A weekly service has been run from Barranquilla on the coast up the Magdalena river to Girardot, a distance of 640 miles, and in two years the machines have flown 4,521 hours, carrying 2,830 passengers and over 200 tons of mail and freight. I understand this company has paid its way—in the circumstances I see no reason to disbelieve it.

I propose now to make a brief reference to various types of marine aircraft which have been constructed for transport purposes.

A few years ago the float-seaplane was quite distinct from the boat-seaplane, but to-day the two types are less clearly defined. For the purpose of this paper I shall assume that in a float-seaplane the pontoons are fitted solely for the purpose of buoyancy and carry none of the paying load. The Savoia 55 is, therefore, a flying boat.

FLOAT-SEAPLANES.

The only British civil float-seaplane built specifically for transport purposes is the ubiquitous De Havilland 50. It will be recalled that one of these machines is on order for the Governor-General of Australia.

Probably the most extensively used machines of this type are the all-metal Junkers F.13.W. and G.24.W. Both are wide track twin-float seaplanes without wing tip floats. The wings are of the well-known Junkers monoplane type and are placed low down in the fuselage. The F.13 has a single engine, whilst the G.24 has three: both machines have very high power-loading and wing-loading.

The L.F.G. has also constructed a number of all-metal float machines, with float design similar to the Junkers. They include both monoplanes and biplanes, although they are all of the single engine tractor type. The Arkona is interesting on account of the enclosed cabin for the pilot and navigator. The Jasmund has been used for the Stettin-Copenhagen night service. Both types have high power-loadings.

In France, Breguet and Farman have seaplanes of this type. The Breguet 14.T.E. is a single engine tractor biplane and is interesting for its float arrangement, which consists of one large central float and two smaller floats either side. This machine was extensively used on the air lines in French Guiana in 1921 and 1922. The Farman is a development of the famous Goliath series, and is fitted with two Bristol " Jupiter " engines. It has a main twin-float chassis, and subsidiary wing tip floats.

BOAT-SEAPLANES.

Two interesting single engine monoplanes of this type have been built in America, the one by Kirkham and the other by Loening, and to the latter design quite a number of machines have been constructed. Both have pusher airscrews, but whilst the Loening is a high-wing semi-cantilever machine, the Kirkham has a pure cantilever wing of unusual design. Both machines have very low power-loadings, and as a consequence high speed and small paying loads.

In this country two single-engine biplane boats have been evolved, the " Sea Eagle " class, by Supermarine, and the " Viking," by Vickers. Both types, however, have so far been built only as amphibians, and even when their land chassis are removed the structure weights are clearly greater than they would be for similar machines built solely as flying boats.

The Dornier " Delphin " is a high wing semi-cantilever monoplane, and has the deck forward of the cabins very low to permit the use of a single tractor airscrew. The structure weight of this type of boat might well be expected to be somewhat high, and this is borne out by the appendices.

In France, Lioré et Olivier have a single-engine Jupiter biplane, the H.190, which, on account of its relatively high power-loading and light engine weight, carries, according to my information, the greatest paying load per h.p. of any single-engine commercial seaplane. Another machine of clean ærodynamic design is the Schreck F.B.A. type 21.H.M.T.6, which won the recent French Commercial Seaplane Competition. In this, however, in order to economise in weight and drag, the machines were not fitted with cabins.

In the twin engine class a number of Felixstowe boats have been converted for transport purposes, and details of one of these, the Short F.3, are given in the Appendices.

The only new twin engine boat in this country is the Supermarine

"Swan." She is interesting on account of her top deck-cabin, which, even though it entails additional drag, may very well be found to justify itself on account of the excellent view it gives to the crew whilst on the water. The "Swan" has probably the most commodious saloon of any flying boat yet built, and a hull of good seaworthiness. The engines, two Napier "Lions," are mounted outboard on the lower wings.

The other twin outboard engine boat is the Rohrbach R.O.III., but its suitability for open sea routes is doubtful on account of its extremely high landing speed. The first commercial boat of this type is now nearing completion in the Copenhagen works of this firm, and we may trust it will receive a trial under air line conditions, without bias or favour.

There are no less than four types built with tandem engines, the Dornier "Wal," and the Savoia S.55 as monoplanes; the C.A.M.S.33.C and the Macchi 24, as biplanes. The Dornier "Wal" is an all-metal high-wing semi-cantilever monoplane with stub floats. The passenger cabin in the forebody is comfortable but somewhat lacking in headroom. There is, however, any amount of space aft of the centre section available for freight. It is interesting to note that on his recent polar flight, Amundsen carried on these machines a load almost equal to the light weight of the machine.

The Savoia S.55 is a twin-hull thick wing monoplane, with the empennage supported on outriggers. The crew is situated in a central position in the thick wing, and accommodation is provided for six passengers in each hull. The engines are mounted in a single nacelle well about the wing. The structure is of wood, and even in the hulls three-ply is extensively used. As a design, I think this machine is of considerable interest.

The C.A.M.S. and Macchi are both wooden biplanes. The C.A.M.S. is interesting in being of a weight intermediate between the general single-engine and twin-engine classes of 6,000 and 13,000 lbs. total weight respectively.

The honour of completing the first three-engine boat goes to the French firm of Lioré et Olivier, who show the additional enterprise of fitting air-cooled engines. In this machine, the H.150, the power loading is kept low, and if the hull lines are good, which one has no reason to doubt, she should make a very useful boat for troubled waters. It is to be regretted that she is built in wood, but this can be rectified in subsequent machines. The centre engine, however, which is mounted on the top plane, does not appear to be in the happiest position.

STRUCTURE.

As is well known, the constructional methods formerly used in seaplane design are being quietly revolutionised to the exclusion of all timber, both in the marine and air structures. On account of the deplorable loss of efficiency caused by hull soakage in wooden seaplanes, metal is now becoming the accepted material of construction, and in a year or so the purchase of a wooden seaplane for transport purposes will not even be considered.

Let it not be thought, however, that the development of the wooden seaplane represents so much lost endeavour, for in timber we have tested a number of efficient designs which are only lacking in their material qualities. In addition we have a criterion on which to design our early efforts in metal construction—that they shall not be heavier than the best wooden structures, i.e., 38—40 per cent. of the total weight of the machine. And although certain optimists have proclaimed great savings, it will be seen from the appendices that this standard is just about what we are achieving. In the early future the main road of development is clear enough.

Time forbids that I should refer in detail to the various systems of metal construction initiated by Dornier, Junkers, L.F.G., Rohrbach and Short, to mention only a few; this most interesting comparison must be held over.

POWER UNITS.

The consideration of power units and their installation in float-seaplanes is so nearly identical with that of landplanes that time precludes my giving it special mention. In the flying boat the problem is very far from having a stereotyped solution, and is thus of great interest. In the single-engine boat the decision whether to instal the engine as a tractor or pusher is intimately bound up with the position of the cabin, from considerations of static balance. The quietness in the cabin of the pusher type is a great asset although clearly there are objections to having the passengers in the bows. From the points of view of resistance and longitudinal control, the pusher is certainly better than the tractor, whilst it is by no means certain that the former has a lower propeller efficiency. In both cases one has the dilemma of high thrust line or small airscrew diameter.

This latter consideration also holds good in the central tandem-engine machine, which at the moment, I regret to say, is "taboo" in this country. It is idle to talk of a 5 per cent. drop in overall efficiency as compared with the ordinary twin-engine machine, because the reduction in drag due to placing the engines behind each other counterbalances this with great facility. It has to be admitted that tolerable satisfaction, to say the least, is being given by the tandem arrangement, and I hazard the opinion that we have by no means seen the last of it. For commercial purposes its compactness and accessibility in flight are valuable assets.

In the twin outboard engine machine the one danger is damage to the propellers from water, but without undue sacrifice in other respects sufficient airscrew diameter can be obtained together with adequate water clearance. It is most essential that after starting up engines the mechanic should be able to regain his cockpit without passing through the saloon.

In the three-engine flying boat the optimum lay-out presents us with a nice problem, but the details we have already faced in the single- and twin-engine machine.

EQUIPMENT.

The equipment of a marine transport aircraft is a matter of great importance, on account of its necessary ability to remain afloat unaided for considerable periods in cases of emergency. Wireless equipment is essential, as is also an emergency aerial for use on the water. The marine equipment should consist of at least the following items:—mooring bollards, towing bridle, ground anchor, sea anchor, boat hook, bilge pump and hose. The usual air equipment will suffice. It may be of interest to note that in addition to the usual instruments, the following standard equipment is carried by the Imperial Airways' "Sea Eagle" machines on the Channel Islands route:—

	lbs.
Sea anchor and line	13
Ground anchor and line	34
Boat hook and line	4
Bilge pump and hose	8½
Complete wireless installation	134
Verey pistol	7
18 Verey cartridges	10
Reid turn indicator and accumulator	25
Malted milk	1
1 riding light	5½
Pilot's Auliff belt	1
4 kapok lifebelts	10
1 12-volt accumulator (lights)	29
Engine and cockpit covers	3
Carpet	12
4 cuspidors	1
	298 lbs.

In small machines the weight of necessary equipment is a considerable item, but as seaplanes become larger the proportion will be eased, though clearly the marine gear will have somewhat to be increased.

REQUIREMENTS.

Let us now investigate the essential characteristics of a civil marine aircraft, and endeavour to estimate the extent of present achievement.

These requirements can be discussed under the following headings, which are placed in order of importance:—

(1) Seaworthiness.
(2) Airworthiness.
(3) Efficiency.
(4) Reliability.
(7) Repairability.
(6) Longevity.
(5) Comfort.

The first four points I make are all matters of prime importance, but you must have them in some order, and the order I have chosen is probably the most logical.

(1) SEAWORTHINESS.

You will note that I have placed seaworthiness as the requirement of prime importance. Whatever characteristics a commercial seaplane may possess, she must be a good boat. In fair weather she will habitually ride at her moorings between services, and consequently the hours spent aloft will be small proportionately to those afloat. We may conveniently differentiate between the desirable characteristics at anchor and in operation. In the absence of better terms, I shall define these as the static and dynamic cases respectively, although, as I am well aware, the conditions of a boat at anchor may be quite sufficiently dynamic.

In the static case the main requirements are good forward buoyancy, adequate freeboard, and minimum strain on the structure in rough weather.

Whilst lying at anchor in smooth water, little harm can befall the worst boat, but in heavy weather our designs are subjected to severe tests. So far as pitching is concerned, the flying boat is considerably more stable than the float machine, on account of the greater length of its hull. In rolling, however, it is far more difficult to assess comparative merits, for here we have unstable machines on the one hand and those possessing varying degrees of lateral stability on the other. The normal central-hull boat, with its two wing tip floats rocks from float to float and is definitely unstable. In the slightly stable category both main types are represented, firstly, the flying boat with stub floats, with or without wing tip floats, and secondly the twin float seaplane of small track having, of necessity, subsidiary wing tip floats in addition.

In the more stable class we have twin-float and twin-hull machines and those with a single float or hull, together with large subsidiary floats placed close to the main float and rigged so that they are simultaneously buoyant. The aim in design must be twofold, to keep the wing tips out of the water, and to reduce inevitable stresses to a minimum. In a medium sea I should personally consider the stable machine best. But as the sea grows rougher we are in imminent danger of the wing tips being immersed. Here the semi-stable machine, with small wing tip floats, gives good service, for only very occasionally will they come into action and they will then afford assurance against complete capsizing. But for heavy weather, in spite of the inevitable stresses in the wing structure, it would appear that the flying boat, with adequate wing tip floats, is the seaplane least likely to suffer damage, and this clearly must be the criterion.

In the twin-float seaplane the freeboard under load is likely to be some four or five times less than that of the single-hull machine, and it is by no means impossible, therefore, for waves to break on top of the decking. The flying boat with good forward buoyancy has, on the other hand, proved herself capable of riding well in very heavy seas, whilst the size of the hull obviates any danger of swamping. A further very important point is that, with increase in size we obtain greater seaworthiness.

The dynamic case may be divided up into the following conditions: taxying, towing, taking off, landing. In taxying there is one major requirement, and that is easy turning. In the case of single engine seaplanes, it is practically essential to use a water rudder in conjunction with the air rudder in order that the aircraft shall be sufficiently manœuvrable to take care of itself in congested waterways. This is true also of multi-engine machines where the thrust lines are in the plane of symmetry of the aircraft. In all seaplanes having outboard power units, however, excellent manœuvrability in taxying is obtained, and it should certainly be possible to turn the machine on a radius equal in length to about twice the length of the hull or float. The positive lateral stability of the seaplane is certainly an asset in taxying, and I am of the opinion that the single-hull flying boat might well be given a small margin of lateral stability. This could be obtained either by means of stub floats, as in the Dornier boats, or by making the wing tip floats deeper and more acute in section of planing bottom. Of these two methods I certainly prefer the latter, because firstly, the stub floats cannot be very efficient aerodynamically, and secondly, weight would be sacrificed, because the wing tip floats would still be necessary in the static case.

In towing, the chief requirement is a good weathercock stability. The flying boat in this respect is much more amenable than the float-seaplane, and the attachment of the towline is considerably easier.

The crucial test in a seaplane's seaworthiness, however, is the act of getting off. In a civil aircraft it is almost superfluous to state that any tendency to porpoise should be eliminated. This is true not only on account of the danger of the machine being thrown into the air before flying speed is reached, but also to ensure the passengers' comfort. Conditions on the water vary so greatly that, although it has been claimed for at least one seaplane that it is non-porpoising, so far as the average machine is concerned it is safer to regard the matter as one of degree. When a seaplane porpoises it is approximately correct to assume that there is an oscillation with the main step as axis. In a boat seaplane the proximity of the passengers to the step is therefore an important point. The float-seaplane, however, with the considerable height of the cabin above the water, tends to rock the passengers more or less violently until the machine takes off. On account of the relatively short length of float on which the machine runs when it is trimmed back, porpoising is much more prevalent in float-seaplanes than in flying boats, and the discomfort of the passengers may thus assume a very serious aspect.

A requirement in itself and a safeguard against porpoising is good elevator control. With this aid a pilot can easily damp out an oscillation in its incipient stages, and in general can hold the seaplane on the water until he desires to lift it into the air. In localities which suffer from heavy ground swells a powerful elevator control becomes an absolute essential. Indeed, in such conditions, seaworthiness is likely to prove the deciding factor in tail-plane and elevator design.

Another consideration of extreme importance is the horse-power loading. This was where the early flying boats failed; they were attempting more than could reasonably be expected. Seaplanes loaded to 20 lbs. per H.P. may or may not take off well in calm water, but in a bad sea they would stand little chance of getting above the hump speed. It is thus easy enough to obtain a good paying load per horse-power at the expense of general utility. For routes across open sea I maintain that 17 lbs. per H.P. is a power-loading which should not be exceeded, and in the appendices the machines are so arranged that some idea of their serviceability in this respect may be obtainable.

Another aspect of taking off is the speed at which the machine should be designed to leave the water. In some instances this may be a secondary consideration, but in general the designer will feel that there is a certain upward limit to the getting-off speed which it will be imprudent to exceed. This limit must clearly vary considerably according to the nature and the extent of the water. Aircraft which have to operate in severe swells should have as low a take-off speed as fifty miles per hour, even for large machines, whereas those operating in calmer waters, where there is no objection to a long run, can properly be designed to take off at seventy miles per hour. That is to say, conditions may vary to such an extent that an aircraft efficiently designed for the latter conditions would require double the wing area to meet the former. In rivers the length of the run to get off may often be of importance, especially when it is necessary to take off across-stream, but in general it will be the condition of the water, and not its extent, that will be the deciding factor. Two seaplanes of the same horse-power loading, designed to take off at 50 m.p.h. and 70 m.p.h., might very well take fifteen and thirty seconds respectively to take off. This means that in the case of the more heavily loaded aircraft, compared with the other, the water forces are twice as great, and the machine is on the water twice as long. The hull must therefore be much stronger in the more highly loaded machine, and I believe this increase in weight is likely to nullify the saving due to the smaller wing altogether. It merely becomes a question, then, of whether a high air speed is essential. This does not appear to be the case, and for a general utility seaplane of between 10,000 lbs. and 20,000 lbs. total weight 55 to 60 m.p.h. seems to be the most suitable take-off speed. With increase in size, however, I certainly think this speed should be higher.

Such an increase can be tolerated from both the standpoints I have mentioned, for on the one hand large machines will not be required to operate from restricted waterways, whilst on the other, since we can successfully contend with certain conditions of sea in small seaplanes, there is no reason why with larger machines we should forgo the consequent advantages.

Whatever views may be held as to the relative merits of the boat and the float-seaplane in calm weather, I imagine no one will maintain the superiority of the float-seaplane in heavy weather. For this reason, among others, float-seaplanes will never increase very much in size, and the superiority of the flying boat for open sea work must therefore increase with time.

Landing is probably the easiest requirement to satisfy. When a seaplane is taking off the mainstep leaves a deep trough behind it, and in this the back step rides. In landing, however, it is quite possible that the aft portion of the float or hull may touch the water first, and unless this has been carefully designed the machine may be thrown heavily on to its nose. In a flying boat this would certainly not be fraught with danger, but in a float-seaplane, with its poorer righting moment, trouble may ensue.

It is regrettable that in the design of the planing bottom, the requirements of landing and taking off are somewhat inconsistent. A flat planing bottom greatly reduces the run and time to get off, but the landing shocks are likely to be severe. With a shaped bottom, in which the chines are well above the keel, the impact force in landing is greatly reduced, but we certainly lose something in taking off. In general, the planing bottoms of British machines are most shaped, and those of German machines are flattest. Our lines, however, seem nearest to the fair compromise, and even if we do err in favour of facility in landing, time may fully justify this in the ability of our machines to make forced landings in rough weather.

Of greater difficulty even than landing on a bad swell is coming down on to a glassy sea. In these circumstances it is quite possible for the most experienced pilot either to fly into the water or to make a very bad pancake landing. On routes where this condition of sea is prevalent a graduated plumb line with some means of warning the pilot could well be the means of avoiding serious crashes.

In general the take-off and landing speeds of a given seaplane vary little from each other. If, however, the maximum angle to which the machine can be trimmed back upon the water is small, it is possible that cruising conditions may prevent the wings being set at such an angle that maximum lift is obtainable when taking off. When the machine descends it can be landed on the aft portion of the hull, as previously explained, at stalling attitude. Although this is a feature of at least one foreign commercial flying boat, I regard it as bad hull design, which is not likely to be perpetuated.

Lastly, there is the important requirement of secondary buoyancy. No passenger seaplane should be entirely dependent on the watertightness of the shell of the floats or hull, and in case of holing, either during taking off or landing, bulkheads are essential. These may either take the form of a double bottom divided into a number of compartments, or the complete hull may be partitioned off by cross bulkheads.

In considering the appendices, comparisons are rendered highly difficult, especially so far as structure weight is concerned, on account of the complete disparity in the matter of seaworthiness between various machines. As seaworthiness is of such prime importance, a robust, seaworthy machine having a structure weight of 40 per cent. is infinitely better than one of less merit in this respect which has been cut down in weight by some 3 or 4 per cent. To improve marine aircraft economies must be made, but in no way should these decrease seaworthiness.

On account of its relatively poor seaworthiness, the float-seaplane can be regarded as having but a limited range of usefulness; in any event, for open sea work reliance can be placed only in the flying boat.

In an endeavour to define the degree of seaworthiness that we have there attained, I cannot do better than recall some of the recent trials which flying boats have successfully overcome. The Marquis de Pinedo flew in the Savoia S16, a small single-engine boat, from Italy to Japan and back, a distance of 35,000 miles. Amundsen was lost in the Arctic circle, but his flying boat stood up to its job and delivered him. The crew of the P.N.9 were adrift in heavy seas for nine days, but the boat survived the test undamaged.

Indeed, of late progress has been so noteworthy that on the completion of a recent flight around the British Isles of four Supermarine " Southamptons " the Air Ministry issued an official report which concluded thus :—

" Both cruises have shown that under conditions of weather which must throughout be considered distinctly bad, the ' Southampton ' flying boats are capable of keeping the air and carrying out such observations as visibility will permit. What is more important, it demonstrates that a programme, once having been drawn up, it can be adhered to practically independent of the weather. Refuelling at sea was carried out on all occasions without a hitch, and, provided a certain amount of shelter is available when the flying boats are not flying, it has been demonstrated that they can function successfully, quite separately and independently of their land bases."

In these words the Air Council has set its " hall mark " on the seaworthiness of the flying boat.

(2) AIRWORTHINESS.

Second only in importance to seaworthiness is airworthiness. Considerations in this respect fall naturally under two headings—structural and aerodynamic.

With the possible exception of the wing covering, which needs to be strong to withstand the water, the conditions of strength in seaplanes are so nearly identical with those of land-planes, as far as the air structure is concerned, that no special reference appears necessary. The general requirements for certificates of airworthiness are identical for land-planes and seaplanes.

Airworthiness from the aerodynamic point of view comprises stability, controllability, and performance. It must be admitted that in general seaplanes have exhibited no spectacular qualities so far as stability is concerned, and of the two types boat seaplanes have been the worse. This is quite unnecessary if only the machine is designed as a seaplane, without landplane standards being introduced; for we are faced with this fact that the hydrodynamic design necessitates some 40 per cent. of the hull length being placed forward of the centre of gravity, and a special consideration of seaplane stability, both longitudinal and directional, becomes essential. In both respects the long forebody is a destabilising factor, but a small increase in the areas of the stabilising surfaces is an adequate remedy. For tail plane area it is hard to fix a safe minimum on account of the large possible variation of the movement of the centre of pressure of the main plane. So far as fin and rudder area is concerned a good general rule is not to have the non-dimensional co-efficient of fin volume $\frac{S_F \times l_F}{2\ s\ S}$ less than .025

where S = total wing area,

s = semi-span,

S_F = fin and rudder area,

l_F = length from centre of gravity to centre of pressure of fin and rudder, assumed at .33 C.

(l) m n.
(s) t u.
C (for chord).

I have heard it suggested that no flying boat has yet been sufficiently stable. This is not borne out by facts, for, to mention only one case, the Supermarine " Swan " has been consistently regarded by pilots as a standard of stability which many landplanes might look up to with profit.

With the advent of the thick aerofoil special care is necessary in design, for frequently these sections have inordinately large movements of the centre of pressure, and unless tail-plane design is treated commensurately longitudinal instability is inevitable.

To sum up, instability is no more to be tolerated in a seaplane than a landplane; it is highly objectionable and quite unnecessary, as recent designs prove.

In control no difficulty exists. By balancing the control surfaces the loads required on the part of the pilot are sufficiently light, even in large machines. I do think, however, that all passenger carrying aircraft of over 7,000 lbs. gross weight should have their tail planes adjustable in flight. In certain designs provision has been made for relieving the pilot of a proportion of the elevator load, but this is almost a negative advantage. What is required is more longitudinal control in case of emergency. I feel satisfied that at least one of the serious disasters to civil aircraft might have been avoided had there been sufficient support from the tail when the centre of gravity moved backwards under the influence of a similar movement by the passengers.

Another important aspect of control is the maintenance of an adequate reserve with all possible combinations of thrust. Some seaplanes have suffered from considerable change in trim engines on and off. This may easily occur on trial flights due to an unexpected flow around the tail, but the trouble can usually be rectified by the application of a little ingenuity.

The condition, however, which appears most sorely to try the average multi-engine seaplane is the failure of one outboard engine. In the three-engine machine this is clearly less serious than in the twin-engine seaplane, but even in the latter case adequate control can be provided, as is evidenced in the case of the Supermarine " Southampton," whose ability to fly on one engine and turn against one engine is now well-known.

So far as performance is concerned, we have only to consider the requisite minima for safety under the present heading; the importance of good performance is dealt with under efficiency. The minimum requirement which embraces every other essential is a speed-range of 30 miles per hour. Aircraft without this, cruise and climb at speeds much too near the stall to be safe. Given this speed-range, the sea-plane will have a tolerable climb and ceiling, and even in rough weather the machine will be safe to fly at cruising speed. In the past the absence of such a margin has given many a pilot harrowing experiences, but in future the probability is that the seaplane without a margin of speed-range above that quoted will be rejected from the standpoint of efficiency.

(3) EFFICIENCY.

Having passed the eliminating tests of seaworthiness and airworthiness, let us now face the crux of the matter—efficiency. To some minds this is not a word which can legitimately be associated with seaplanes. Indeed, I was appalled to read in General Brancker's paper* that, whilst the D.H.34 carries 3.1 lbs. of paying load per horse-power and the Handley-Page W.8 3.85 lbs., the Supermarine " Sea Eagle " can only muster 2.19 lbs. Are we to understand from this that, taking the figures for the two single-engine machines, the landplane as a type is really 41 per cent. more efficient than the seaplane?

Investigation shows that although the D.H.34 with a Napier " Lion " engine has 440 normal H.P., and the " Sea Eagle," with a Rolls-Royce " Eagle IX. " 75 less, the total weight of the power plant is slightly less in the case of the D.H.34, on account of the relatively lighter weight of the Napier " Lion " engine. Assume this weight to be 1,250 lbs. in each case, then we obtain the following figures for the weight of the power plant per horse-power.

" D.H.34 "	2.84 lbs.
" Sea Eagle "	3.43 lbs.

That is, the D.H.34 has already gained .59 lbs. per H.P. towards its paying load.

The pilot, his instruments, and wireless installation, totalling about 350 lbs., is a constant load to be carried in both machines. Here again the D.H.34, with its higher H.P. gains, and to the extent of .16 lbs. per H.P. We, therefore, arrive at this interesting result that of the .91 lbs. per H.P. that represent the efficiency of the D.H.34 above the " Sea Eagle," .75 lbs. per H.P. are dependent solely on the choice of the power unit.

The " Sea Eagle " was designed as an amphibian, and even when she is used as a flying boat and the land chassis is removed, extra structure weight is involved in addition to the chassis operating gear, which is necessarily a fixture.

We may justifiably conclude, therefore, that with the same type of engine the " Sea Eagle," if designed as a flying boat solely, would be about as efficient as the D.H.34. This may be expressed more generally that, given the same power units, the efficiency expressed in paying load per horse-power, is approximately equal for passenger landplanes and flying boats.

If the D.H.34 had been designed around the " Eagle IX.," and the " Sea Eagle " around the Napier " Lion " with, as before, constant power-loading it would have been interesting to note what conclusions would have been drawn as to the relative efficiencies of the two types. In saying that, I am confident that General Brancker will not begrudge me taking full advantage of this opportunity of placing the flying boat in happier perspective.

From considerations of seaworthiness we have already fixed the power-loading and the landing speed. The aim must be, therefore, to obtain this power for minimum weight, and the necessary lift with minimum drag.

---

* The Journal of the Royal Aeronautical Society, Nov., 1925.

There is also, of course, the fertile field of structure weight, which, although difficult to till, offers a rich harvest. The problem of power plant efficiency as it affects seaplanes, differs little from that of the aeroplane, and no special reference is necessary. The reduction of drag, although it is a panacea for aeronautical inefficiency, has a number of special applications in seaplane design.

The importance of speed is not so much the decrease in time for a given journey, but the consequent reduction in fuel consumption. Nor is this by any means a matter of minor importance. Let us consider the case of two flying boats of equal weight, each fitted with three Napier " Lion " engines, on a 500 miles flight. The one shall have a cruising speed of 100 m.p.h., whilst the other, at the same engine revolutions, we will assume to cruise at 85 m.p.h. A fair average figure for the consumption at cruising throttle of the Napier Lion is 25 gallons per hour, so we obtain total fuel consumptions of 375 gallons and 441 gallons for the two machines respectively. By using the faster machine, therefore, an operating Company would save 15 per cent. on its fuel bill, or about 5 per cent. on the total operational expenses. It would also mean that between overhauls carried out after 250 hours flying, the faster machine would make 25 double trips whilst the other would complete only 21. But these economies by no means complete the story, for in addition to reducing costs, we have effected a potential increase in revenue, as the weight of fuel saved, some 500 lbs., is now available to increase the paying load.

How, then, can resistance be reduced? This again is a hardy annual, but from the particular standpoint of this paper, there is one step we should take in the early future, viz., the development of the monoplane flying boat. It is generally admitted now that the thick wing monoplane is no heavier than the biplane, whilst, as I have shown previously,* the absence of wing bracing may easily effect a reduction of 15 per cent. in the total drag of a seaplane of clean aerodynamic design. This does not mean, however, that there is no future for the biplane seaplane, for in spite of the aerodynamic handicap under which it labours compared with the monoplane, the biplane has in the past not served us badly. Indeed, I find that were we enabled to attempt new world's records with a certain Supermarine biplane flying boat, the following measure of success would be obtainable :—

Of 39 existing World's Records for Seaplanes this machine could capture 32, and in addition could create

Four new World's Records in classes not previously successfully attempted.

But this happy possibility does not entitle us to neglect the monoplane type. Whatever method of construction be adopted, the design of the all-metal monoplane wing involves problems which in this country we have barely commenced to solve. On the Continent the technique of metal wing construction is being steadily developed, and there are already several designers who appear to have evolved satisfactory methods of construction. Whether we are able in future to draw upon this fund of information or not, I do hope more encouragement will be given to us to develop this type of

---

* The Journal of the Royal Aeronautical Society, December, 1925, p.642.

machine.

Let us now look at this question of efficiency from the quantitative standpoint. I have no doubt that some of the performance figures given in the Tables have been compiled in an atmosphere not exactly of gross pessimism, but I think the weights may be assumed to be of reasonable accuracy, and it is in these that here we are primarily interested.

In spite of the difficulties involved in making useful comparisons, two easily obtainable figures are at any rate of some value—the ratio between paying load and total weight; and the paying load in terms of the horse-power. Unfortunately, both these figures can be very misleading for the most efficient machines on these bases are likely to be those that are overloaded and underpowered. If, however, the importance of wing loading, and in particular power loading is borne in mind, comparisons of some usefulness are obtained.

In Tables 3 and 4 these two figures are given for a number of civil seaplanes on a 300 mile flight, together with the effect of an alteration in this distance. It may be argued that the time factor should somehow be included, but provided the cruising speed is not less than 80 m.p.h. it is probable that time in itself is not of very great importance; in other respects time is represented in the figures. Those who are interested will be able to glean for themselves many interesting facts from a close study of the Appendices, but I must content myself here with making references to a few outstanding points only. Firstly, have we made any improvement in the last five years in our two index figures? Some deduction can be made from the Air Ministry Competition Amphibians, which, without their landing gear but with 130 lbs. of wireless apparatus might have another 200 lbs. placed to their paying loads. For the Supermarine which carried most load, our indices would be 13.0 and 2.1; these compared with similar more recent machines are not very good. Again, take the Short F.3, and compare it with a boat of about the same power-loading, the Rohrbach. We obtain for the two machines respectively 18.0 and 3.27, 26.9 and 5.02, so that even allowing for the difference in power-loading, we have made substantial progress.

A comparison of float seaplanes and flying boats indicates immediately the relative heaviness of the structure in the case of the float seaplanes. As a result the paying load is not so good; the Farman Goliath with the very great advantage of 5.1 per cent. and .73 lbs./H.P. gained on the power-plant, has indices almost identical with those of the " Swan," corrected to the same power-loading.

This brings out also the value of air-cooled engines from the point of view of efficiency. To obtain a direct comparison between the two types of engine, I have worked out the indices for the " Swan " fitted with Bristol " Jupiter " engines. For the same power-loading as the Napier " Lion " machine the total weight will be 12,500 lbs., a reduction of 1,210 lbs. On the credit side the structure weight will be reduced by 480 lbs., the power unit weight by 890 lbs., and there will be a further saving of 100 lbs. on fuel. This gives a total reduction in weight of 1,470 lbs., so the " Jupiter "

Swan can carry 260 lbs. more paying load than the "Lion" aircraft, in spite of its being a smaller machine. The advantage is brought out forcibly in the index figures, for whilst the water-cooled engines permit a paying load of 3.39 lbs. per H.P. and 21.7 per cent. of the total weight, the use of the air-cooled power units increases these figures to 4.06 and 25.9 respectively, a very substantial advance. These results are calculated on the Jupiter Series IV. engine, so with the approval of the Series VI. engine for civil aircraft, they will be capable of still further improvement.

If the view is taken that 16 lbs. per H.P. is a fair and reasonable power-loading for a commercial flying boat the above figures indicate an efficiency not only that we can guarantee but upon which we can already improve. It is simple enough to obtain bigger loads by increasing the power-loading and sacrificing seaworthiness, but real gain is not to be obtained by this method. Our opportunity in the immediate future of improving the index figures lies chiefly with the air-cooled engine, and duralumin construction.

(4) RELIABILITY.

Intimately bound up with efficiency is reliability. High efficiency, in a good paying load per horse power, and a meritorious figure for percentage of useful load to total weight, is useless if it entails unreliable operation. Reliability has now come to refer almost exclusively to the power unit, and this is clearly a problem in itself. But in one respect seaplane design has been responsible for a certain amount of unreliability in the power unit on account of overloading. Machines with a speed range of about 30 m.p.h. having to operate in bad weather inevitably fly for long periods at full throttle and clearly the same degree of engine reliability cannot be expected as in a machine where the revolutions are reduced. There is also considerable wear and tear on the engine of an overloaded seaplane when taking off. The time to take the air is long, and hence for a considerable period the machine may suffer intermittent retardations due to waves. Not only does this affect the power unit itself, but it also subjects the engine-mounting to severe stresses which through the wearing of attachments, may in turn set up vibration. This again involves worse stresses, and so the vicious circle continues.

When small seaplanes traverse large expanses of open sea the perils of unreliability of the power unit are great. This fact was vividly brought home in the recent French Seaplane Competitions in the Mediterranean, when of five competing machines no less than two, together with their crews of five, were lost without trace. The risks they were running were heightened by the absence of wireless aboard, but even granted this aid failure of the power unit may have dire results. It is conceivable that a flying boat plying between two sheltered waterways in its endeavour to maintain a high degree of regularity on the service, might meet in the open seas conditions which could be fatal during landing. But as a general rule one might expect to land successfully, and the matter then becomes a question purely of seaworthiness, as understood of a boat.

The remedy is thought at present to lie with the multi-engine machine. So far as the twin-engine machine is concerned we appear to have been perhaps even more successful with flying boats than with landplanes. It is largely on account of the inability of the latter to keep in the air on one engine that we have the present craze for three-engine machines. Several the probable life of the machine as a matter of considerable importance. The light alloys are likely to give longer service than wood, and what we have to discover is firstly the best way to use them with length of service flying boats, however, can put up quite creditable performances in this respect. The tandem propellor arrangement gives excellent results in the case of the failure of the aft engine; should the front engine fail the outlook may not be better than it is for the twin outboard engine machine. But, as I have previously mentioned, even the latter has given satisfactory results in the case of one engine failing. With the three-engine machine, therefore, the reliability should be distinctly good.

(5) COMFORT.

In this connection the float seaplane when once in the air has precisely the same qualities as the landplane, but as I have pointed out under seaworthiness, the take off in certain circumstances can be distinctly unpleasant. Flying boats have more roomy saloons than other types since the beam of the hull to satisfy water requirements is greater than the width of an average fuselage. So far as noise and ventilation are concerned, seaplanes and landplanes are subject to equal disabilities.

It must be admitted that compared with the steamship, we in common with all other heavier-than-air craft, are likely to suffer from restricted passenger accommodation for several years to come. With the advent, however, of flying boats approaching 100,000 lbs. in weight we shall be able to avail ourselves of the wings and the problem will then assume a different complexion.

It is of prime importance in a passenger aircraft that freight should be stowed in a separate compartment. It is unreasonable to expect passengers to pay first class fare and ride in a glorified guard's van. Indeed, this objectionable practice has prejudiced many a passenger on the present cross-channel air lines. It is perfectly simple to provide an easily removable partition with attachment fittings at various points along the length of the saloon, and if the separate luggage compartments are sufficient only for personal baggage, something of this nature should be provided. In the flying boat we are not likely to have to resort to this expedient, and so far as marine aircraft are concerned my remarks, therefore, apply only to the float seaplane.

A further consideration in the comfort of passengers is ease of embarkation. It is unwise to ask passengers to clamber up ladders—proper companion ways must be provided. This applies equally whether passengers go aboard from a jetty or are taken out to the seaplane in surface craft. In the latter case the use of a pontoon equipped with stairways up to deck level will considerably facilitate the transference of the passengers from the launch to the seaplane.

(6) LONGEVITY.

I fear that this is a matter which up to the present has been crowded out of consideration on account of more pressing demands. In the future I feel confident that, when discussing the comparative merits of various aircraft preparatory to making purchases, operating companies will regard in view, and secondly the best way to protect and preserve them. In respect of the former consideration, the retention of the circular hull, which is a feature of the all British metal flying boats, is probably wise. Cambered plates are likely to stand up to their work better than the flat sheets which are a feature of some Continental designs, although clearly the cost of the former is likely to be slightly higher. Whether this increased cost is justified, time will prove.

The danger of corrosion, especially with the light alloys, may always be present, but it would appear well established that the protective coatings of paint, varnish, etc., that we have applied have not been in vain. To cite only one example, several all-metal Junkers monoplanes have been in constant use on the Scadta lines in Columbia since 1921.

(7) REPAIRABILITY.

Ease of repair is another advantage which metal has over wood. The removal of a damaged plate and the rivetting in of a new one is clearly a less lengthy and, therefore, a cheaper job than the replanking of a wooden hull. A typical instance of the improvements we are likely to effect is to be found in the easily detachable leading and trailing edges in the Rohrbach design.

CONCLUSION.

My general conclusion from the foregoing appreciation of detailed achievement is that the modern seaplane is worthy of greater consideration in air transport. Owing to the terms of its agreement with the Air Council Imperial Airways is obliged to operate a marine service, but its interest lies almost entirely in the landplane. It does not require great brilliance of mind to discover other marine routes where the prospects from every standpoint would be brighter than on the Channel Islands service, and if only a small part of the thought and consideration that are given to the landplane services of Imperial Airways were transferred to the marine side such a route would soon be found. Indeed, Mr. Cobham, whom I believe has no special love for the seaplane, writes from Africa in this manner: "As far as I can judge, nearly all the great commercial air routes up to the present are really seaplane jobs. . . . If I had time I could mention dozen fine commercial air routes, but they would all be seaplane jobs."*

But in the long run it will not have mattered greatly that Imperial Airways neglected the sea.

As soon as we have completed an all-metal flying-boat of about 50,000lb. gross weight there are numerous shipping lines that will be ready to run such machines in conjunction with their services. At first the aircraft will only be allowed to ply on coasting and short sea routes, but as soon as they have acquitted themselves with credit a wider field of operation will be available. Whereas the chief assets of a railway company are fixtures, almost all the capital of a steamship company is in its vessels, and so the

---

* "The Aeroplane," January 20th, 1926.

gradual absorption of aircraft into a commercial fleet presents no major economic difficulty. For, instead of replacing all obsolete vessels by surface craft, a proportion of aircraft would be introduced. As I see it, this is the main direction in which the future of the flying boat lies, and we should develop it with this end in view.

Before I close, I would like to express my gratitude to the constructors who have supplied me with such a generous amount of data for publication in the Appendices. These are a milestone marking the position we have at present reached and a finger-post pointing the way to future progress. I have endeavoured to employ the information given me without bias or partiality, and in this, at any rate, I trust I have been successful.

I am also indebted to Mr. E. H. Mansbridge, B.Sc., for his valuable assistance in the compilation of the Tables.

If this paper shall in any way help to remove some of the doubts and suspicions which have clustered around the seaplane and to promote faith in its possibilities and prospects, I am more than satisfied. Finally, I may affirm my confidence that the day of the seaplane is coming, is, indeed, near at hand, and in that day marine aircraft will be recognised as one of the speediest and safest methods of world transport.

NOTES ON THE TABLES.

(1) The machines are arranged in order of power loading. (See "Seaworthiness.")

(2) As the aim of the Tables is to compare designs, hull soakage is not included in the structure weight of wooden machines.

(3) Machines built as amphibians have had all amphibian gear removed in computing structure weight in order to obtain more accurate comparisons.

(4) All figures are calculated on the basis of a 300-mile flight at cruising speed, and the effect on paying load of each additional 100 miles is indicated.

(5) Disposable load includes crew, equipment and paying load—not fuel.

(6) Table I. indicates the maximum number of crew and passengers for which provision is made. In other Tables, aircraft of less than 10,000lb. gross weight are assumed to require one pilot only; above that weight allowance is made for a second member of the crew.

(7) It will be noted that considerable disparity exists between the weight of accommodation and equipment for the various machines. As in some instances items naturally falling under these headings may be fixtures and thus become included in structure weight, no attempt has been made to reduce the weights under these two headings to a standard figure. All machines carry wireless equipment, flying instruments and marine gear, although the weights of these items vary considerably.

(8) In Tables III. and IV. the complete list of component weights is given in terms of normal horse power, and as percentages of total weight respectively. By this means, comparisons of enhanced value are obtainable, since inefficient components of each machine can readily be seen and their bearing on the final index figures gauged.

DETAILS OF CIVIL MARINE AIRCRAFT.

TABLE 1. MAIN PARTICULARS.

	FLYING BOATS.													FLOAT SEAPLANES.			
Type	Air Yacht	H150	Viking IV.	21.Hm. T.6	Vulture	Sea Eagle	Wal	Swan	33 C	H190	F3	R.O. III.	Delphin	14 T2	Goliath	Arkona	Jasmund
Constructor	Loening	Lioré et Olivier	Vickers	Schreck	Vickers	Supermarine	Dornier	Supermarine	C.A.M.S.	Lioré et Olivier	Short	Rohrbach	Dornier	Breguet	Farman	L.F.G.	L.F.G.
Monoplane or Biplane	Mono	Bi.	Bi.	Bi.	Bi.	Bi.	Mono.	Bi.	Bi.	Bi.	Mono.	Mono.	Bi.	Bi.	Bi.	Mono.	Mono.
Approx. Date of Construction	1921	1925	1921	1925	1924	1922	1922	1924	1922	1925	1920	1925	1921	1920	1922	1922	1922
Materials of Construction	Composite	Wood	Wood	Wood	Wood	Wood	Metal	Wood	Wood	Wood	Wood	Metal	Metal	Metal	Wood	Metal	Metal
Engines, No. and Type	1 Liberty	3 Jupiter	1 Napier	1 Lorraine	1 Napier	1 Napier	2 Rolls-Royce	2 Napier	2 Hispano	1 Jupiter	2 Rolls-Royce	2 Rolls-Royce	1 B.M.W.	1 Renault	2 Jupiter	1 B.M.W.	1 B.M.W.
Total Normal Horse-power....	400	1200	440	450	440	440	730	880	550	400	700	730	240	300	800	185	185
Wing Area .... sq. ft.	385	1470	635	575	828	620	1120	1272	995	692	1430	785	550	549	1732	388	430
Normal Accommodation: Crew	1	2	1	2	1	1	2	2	2	2	2	3	2	1	2	2	2
Ditto Passengers	4	12	6	4	6	7	11	10	4	6	8	12	5	3	12	4	4
Power Loading, lbs. per H.P...	10.15	12.2	13.62	14.3	14.78	14.78	15.4	15.6	16.46	17.1	18.18	18.7	22.5	14.33	16.0	21.97	23.24
Wing loading, lbs. per sq. ft.....	10.55	9.95	9.45	11.2	7.85	10.5	10.0	10.78	9.1	9.9	8.98	17.4	9.8	7.84	7.4	10.48	10.0
Maximum Speed (Sea Level) m.p.h.	135	112	111	118	105	99	115	105	120	102.5	95	124	100	105	105	105	105
Cruising Speed (Sea Level) m.p.h.	115	93	90	100	85	84	97	87	100	87	75	112	78	90	87	87	87
Rate of Climb (Sea Level) ft. per min.	1000	560	765	657	555	540	470	510	475	320	500	600	390	483	510	410	450
Landing Speed (Sea Level) m.p.h.	52	56	52.5	59.5	48	56	53	58	56	56	51	68	52.5	48	47	56	56
Kl. Max (Deduced)	.765	.624	.67	.615	.67	.659	.70	.63	.57	.615	.678	.74	.70	.67	.655	.655	.627
Speed Range ....m.p.h.	83	56	58.5	58.5	57	43	62	47	64	46.5	44	56	47.5	57	58	49	49

TABLE 2. COMPONENT WEIGHTS. (LBS.)

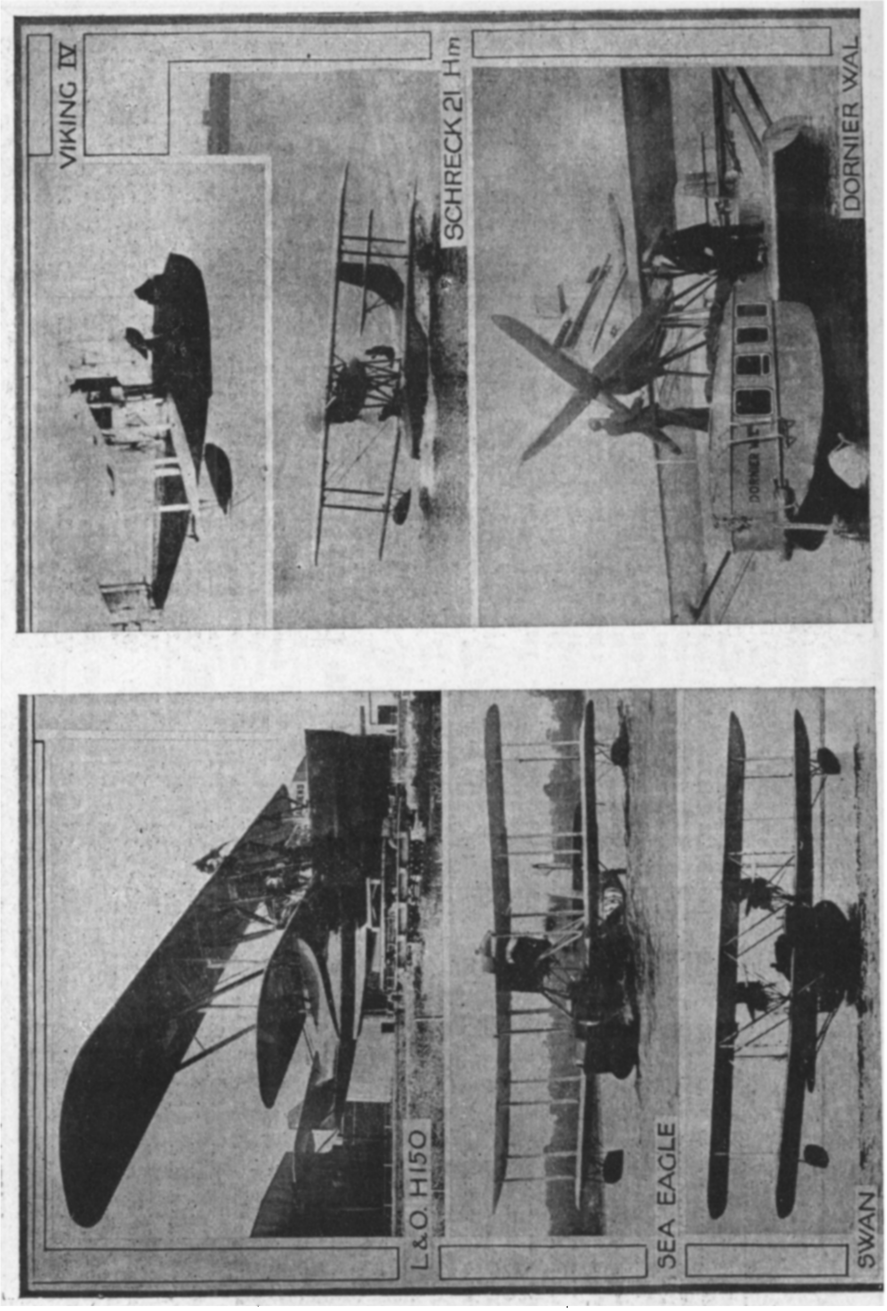
Type	Air Yacht	H.150	Viking IV.	21 Hm. T6.	Vulture	Sea Eagle	Wal	Swan	33C.	H190	F3.	R.O. III.	Delphin	14T2.	Goliath	Arkona	Jasmund
Weight fully loaded	4059	14650	6000	6445	6500	6500	11250	13710	9050	6840	12700	13670	5400	4300	12800	4060	4300
Power Plant	920	2646	1394	1302	1415	1284	2410	2600	2100	992	2921	2480	965	1148	1786	750	750
Fuel Oil and Tanks	550	1941	695	849	703	864	1075	1640	1499	719	1253	996	457	497	1292	571	552
Structure	1400	5450	2208	2275	2571	2546	4748	5439	3310	2560	5404	5300	2401	1652	5780	1675	1720
Accommodation	153	225	72	143	100	150	330	435	110	134	160	600	242	90	331	88	132
Disposable Load..............	1036	4388	1631	1876	1711	1656	2687	3596	2031	2435	2962	4294	1335	913	3611	976	1146
Crew	180	360	180	180	180	180	360	360	180	180	360	360	180	180	360	180	180
Equipment	195	513	175	213	175	235	305	254	420	437	315	260	290	220	288	218	218
Paying Load	661	3515	1276	1483	1356	1241	2022	2982	1431	1818	2287	3674	865	513	2963	578	748
Variation in Paying Load per 100 Miles	172	650	215	283	215	280	340	538	500	234	418	302	145	166	432	185	185

TABLE 3. COMPONENT WEIGHTS. (LBS. PER H.P.)

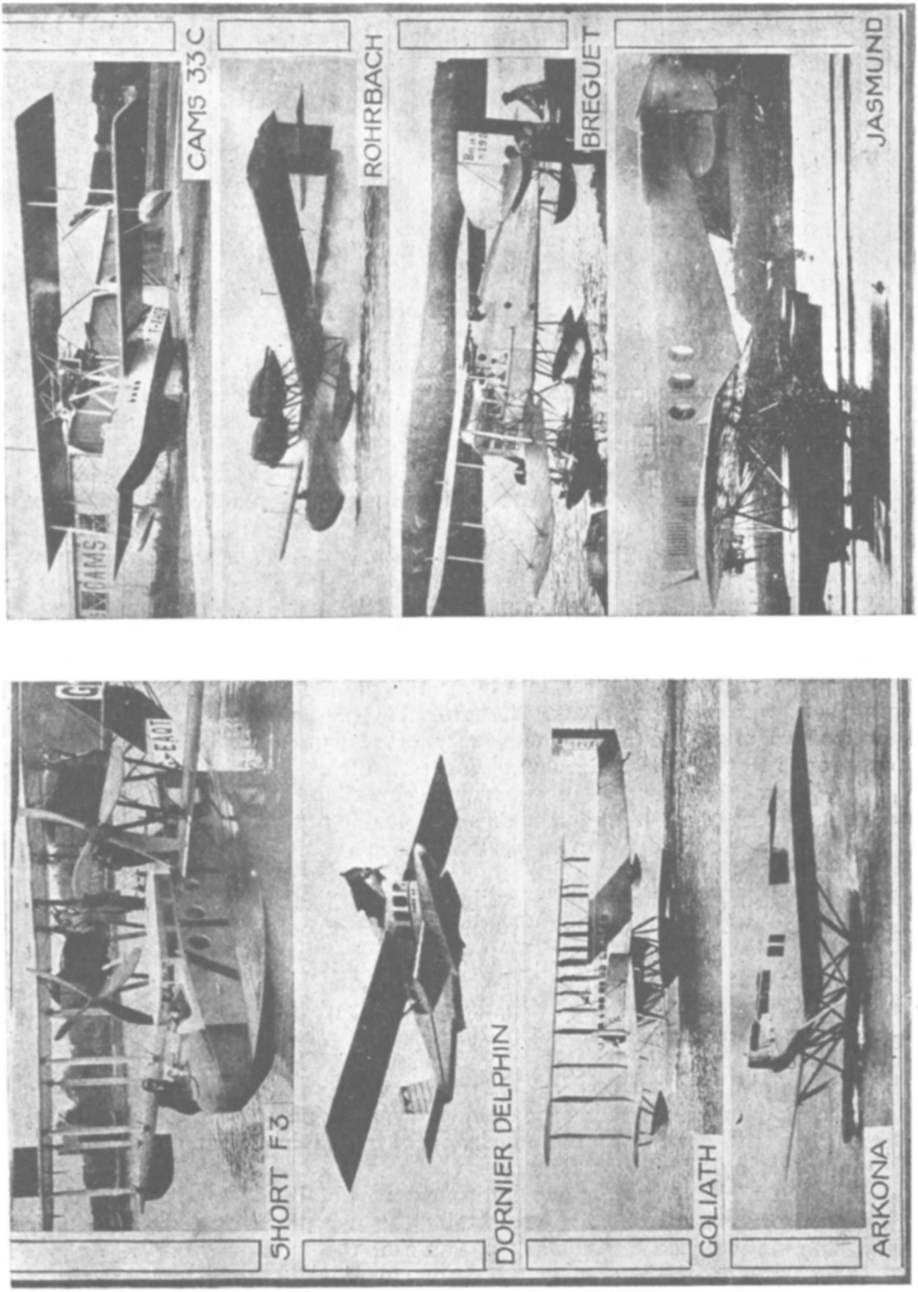
	FLYING BOATS.													FLOAT SEAPLANES.			
Type	Air Yacht	H150	Viking IV.	21 Hm. T6	Vulture	Sea Eagle	Wal	Swan	33C.	H190	F3.	R.O. III.	Delphin	14T2.	Goliath	Arkona	Jasmund
Fully Loaded	10.15	12.2	13.63	14.3	14.78	14.78	15.4	15.6	16.46	17.1	18.18	18.7	22.5	14.33	16.0	21.97	23.24
Power Plant	2.30	2.21	3.16	2.90	3.22	2.92	3.30	2.96	3.82	2.48	4.18	3.40	4.01	3.82	2.23	4.05	4.05
Fuel, Oil and Tanks..........	1.38	1.62	1.58	1.89	1.60	1.96	1.47	1.87	2.72	1.80	1.79	1.37	1.90	1.66	1.62	3.09	2.99
Structure	3.50	4.54	5.02	5.05	5.84	5.80	6.50	6.18	6.02	6.40	7.74	7.25	10.02	5.51	7.24	9.06	9.30
Accommodation	.38	.18	.16	.32	.23	.34	.45	.50	.20	.33	.23	.81	1.01	.30	.41	.48	.71
Disposable Load.............	2.59	3.65	3.71	4.17	3.89	3.76	3.68	4.09	3.70	6.09	4.24	5.87	5.56	3.04	4.50	5.29	6.19
Crew	.45	.30	.41	.40	.41	.41	.49	.41	.33	.45	.52	.49	.75	.60	.45	.97	.97
Equipment....................	.49	.43	.40	.47	.40	.53	.42	.29	.76	1.09	.45	.36	1.21	.73	.35	1.18	1.18
Paying Load	1.65	2.92	2.90	3.30	3.08	2.82	2.77	3.39	2.61	4.55	3.27	5.02	3.60	1.71	3.70	3.14	4.04
Variation in Paying Load per 100 miles	.43	.54	.49	.63	.49	.64	.47	.61	.91	.59	.60	.41	.61	.55	.54	1.0	1.0
Accommodation per Passenger, lbs.	38.2	18.75	12.0	36.7	16.6	21.4	30.0	43.5	27.5	22.3	20.0	50.0	48.4	30.0	27.6	22.0	33.0

TABLE 4. COMPONENT WEIGHTS. (% OF TOTAL WEIGHT.)

Type	Air Yacht	H150	Viking IV.	21 Hm. T6.	Vulture	Sea Eagle	Wal	Swan	33C.	H190	F3.	R.O. III.	Delphin	14T2.	Goliath	Arkona	Jasmund
Power Plant	22.6	18.1	23.2	20.2	21.8	19.7	21.4	19.0	23.2	14.5	23.0	18.1	17.8	26.7	13.9	18.5	17.4
Fuel, Oil and Tanks..........	13.6	13.3	11.6	13.2	10.8	13.3	9.6	12.0	16.6	10.5	9.9	7.3	8.5	11.6	10.1	14.0	12.8
Structure	34.5	37.2	36.8	35.4	39.6	39.2	42.2	39.6	36.6	37.4	42.5	38.8	44.5	38.4	45.1	41.2	40.0
Accommodation	3.8	1.5	1.2	2.1	1.5	2.3	2.9	3.2	1.2	2.0	1.3	4.4	4.5	2.1	2.6	2.2	3.1
Disposable load	25.5	29.9	27.2	29.1	26.3	25.5	23.9	26.2	22.4	35.6	23.3	31.4	24.7	21.2	28.3	24.1	26.7
Crew	4.4	2.5	3.0	2.8	2.8	2.8	3.2	2.6	2.0	2.6	2.8	2.6	3.3	4.2	2.8	4.4	4.2
Equipment	4.8	3.4	2.9	3.3	2.7	3.6	2.7	1.9	4.6	6.4	2.5	1.9	5.4	5.1	2.3	5.4	5.1
Paying Load	16.3	24.0	21.3	23.0	20.8	19.1	18.0	21.7	15.8	26.6	18.0	26.9	16.0	11.9	23.2	14.3	17.4
Variation in Paying Load per 100 Miles	4.2	4.4	3.6	4.4	3.3	4.3	3.2	3.9	5.5	3.4	3.3	2.2	2.7	3.9	3.4	4.6	4.3



Civil Marine Aircraft.
Some of the Machines referred to in the Paper.
(Reproduced by courtesy of "Flight")



Civil Marine Aircraft.
Some of the Machines referred to in the Paper.
(Reproduced by courtesy of "Flight")