Reprinted from
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October 28, 1936

The EMPIRE FLYING BOATS

SHORT BROTHERS (ROCHESTER AND BEDFORD) LTD.,
Seaplane Works - - Rochester, Kent

Telephone: Chatham 2261. Telegrams: "Seaplanes, Rochester."

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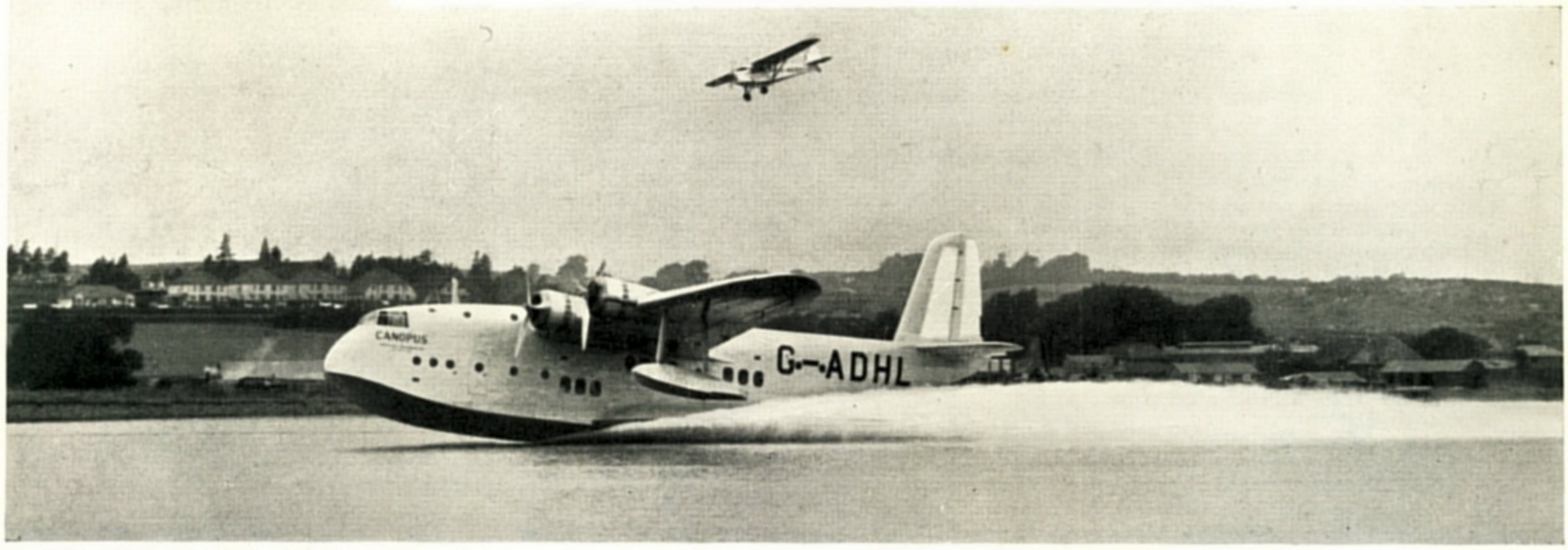
OUR EMPIRE FLYING-BOATS

By C. G. G.



THE FIRST AWAY.—Here the "Canopus," the first of the Empire Flying-Boats, (four 900 h.p. Bristol Pegasus motors), is seen alighting on the Medway after its first test flight. No photographs at close quarters were got in the air because none of the photographic machines could keep pace with the startling speed of the new ship.

OUR EMPIRE FLYING-BOATS are collectively the biggest and boldest experiment, one might almost call it gamble, that has ever been taken in connection with British Civil Aviation. And yet when one sees the way in which all the Short flying-boats of the past have come up to calculations, and have generally bettered them, one can hardly regard the boats themselves as an experiment, or call the use of them a gamble.

Nevertheless, in ordering 28 flying-boats of 18 tons weight apiece before the first of them had flown, the Directors of Imperial Airways Ltd. were certainly taking a bold step in the right direction.

Naturally the ordinary person has no idea of the cost of such boats, but ever since flying began there has always been a sort of axiom that the price of an aeroplane is roughly £1 per 1 lb., so a twenty-ton boat must cost something in the region of £45,000. And thirty of those is a very nice order in any line of business. The directors of Imperial Airways could only justify such an order by showing to their critics that Short Brothers had never yet let them down.

In giving this order the Directors of Imperial Airways have also demonstrated their confidence in the company's own Technical Department and in their Technical Adviser, Major R. H. Mayo, who together were responsible for working out, from figures which are only possessed by Imperial Airways Ltd., the precise type of craft which would be needed to meet the requirements of our Empire air routes in the light of those figures.

The experiences of the pilots and crews of Imperial air-liners, both flying-boats and land-planes, all the way from England to Australia and England to South Africa have been embodied in the specification. The figures for mails, passengers and freight, calculated from the firm's years of experience and projected forward for years to come, entered likewise into the specification. All that is known of existing motors and of motors which are being developed had to be taken into consideration.

All that is known about the handling of big boats to-day, and all that can be prophesied about the uses of automatic pilots, controlled blind landings, homing radio devices and such aids to simplified but more strenuous flying by day and night was put into the demands made by Major Mayo and the other technicians of Imperial Airways.

The big idea is that the boats may be not only the best things in the air when they start out on their regular work but the best for so far ahead that our Empire Flying-Boat services may still compete with those of other nations when the World awakens to the possibilities of big flying-boats and demands them in quantities,—for Civil Aviation is only beginning to-day to see dimly what flying-boats will do in the future to increase peace and goodwill all over the World, and to build up commerce and the wealth and welfare of nations.

We have been fortunate in persuading the chief men of the Short firm to set down something of what they know about and what they have done in producing this great fleet.

Mr. Oswald Short, the head of the firm, has written on how the boats came into being. Mr. Arthur Gouge, the firm's chief engineer, who is recognised as one of the World's leading designers of flying-boats, has explained why these boats are as they are. Mr. A. E. Bibby, who is in charge of construction, tells how these big craft are put together in the workshops. And Mr. Lankester Parker, who learned water-flying on Windermere in 1913, flew in the Royal Naval Air Service during the War 1914-18, has flight-tested every Short landplane and/or seaplane since that time,—and still looks as if he were in his early thirties,—gives some hints on how these big ships have to be handled, compared with the little boats of the past.

To all of them our readers will be grateful for the first-hand information which they have so freely given.

Although the history of the Short firm has been told several times in this paper this seems to be rather a time at which to repeat something of that history.

The first activities of the Short Brothers as aeronautical engineers consisted in being official constructors of balloons to the Aero Club of Great Britain. The balloon-builders were the two younger brothers Eustace and Oswald. The third brother, Horace, who had been a mining engineer in Mexico, and had done engineering of one sort or another all over the World, was at that time the right-hand man of the Honourable Sir Charles Parsons, the inventor, or at any rate the protagonist, of the steam turbine. And Horace Short had more to do with producing that first amazing little turbine-driven ship the *Turbinia* than anybody,—except perhaps Sir Charles Parsons himself.

When flying began, and when Wilbur Wright brought his first machine over to France to demonstrate it in 1908, Horace Short, who had only just left Sir Charles Parsons to join his brothers in London, went over to France with, I believe, Mr. Griffith Brewer, who was the Wright Brothers' patent agent in this country, and thereupon made up his mind to start building aeroplanes as the Wrights' agent.

The Short Brothers' factory at that time was in two or three railway arches under the Battersea end of Battersea Railway Bridge. I well remember them there starting to do their first aeroplane work in 1909.

The Aero Club, not then Royal, shortly afterwards made up its mind to do something or other about flying, and took a patch of ground—most of it marshes—at Leysdown on the Isle of Sheppey, where they put up some aeroplane sheds. And there the Short Brothers established their first aeroplane factory.

By 1910 Mr. Frank McClean, now Sir Francis, had bought what is now the R.A.F. Aerodrome at Eastchurch. All the aeroplanes of the Aero Club were shifted to the new site, and the Short Brothers put up a real aeroplane factory. They only shifted from there during the War when the R.N.A.S. took over the whole aerodrome and all the buildings, which made a move to Rochester worth the while of the Short Brothers.

The first Short seaplane, on floats, was built in about 1911 at Eastchurch and was tried out in Sheerness Harbour and round the coast of the Isle of Sheppey. The brothers only took to building big flying-boats after the War.

One thing which I always consider is immensely to the credit of the Short Brothers is that when the War stopped and all the orders for aeroplanes were cut off, they were ready to start in making barges and boats, from which they proceeded to making bus-bodies in enormous quantities.

The proudest boast of Mr. Oswald Short, who is now the head of the firm, is that at no time had they less men on their pay-roll at Rochester than they had during the boom time during the War. That is one of the finest examples of sound commerce and good management that I have ever come across.

The long succession of successful Short flying-boats is guarantee enough that the Empire boats are going to be worthy of the people who make them. Therefore, the chief interest in their future will lie in how they behave in regular service,—making all due allowance for the fact that Imperial Airways Ltd. know considerably more about how to run an air line as an almost self-supporting proposition than do any other aircraft operators in the World.

The project of running our Imperial air-lines entirely by flying-boats is as bold a conception as is the design of the boats themselves. If they succeed, as I am sure that they will do, they will alter the whole World's opinion of British commercial aircraft.

All nations admit that our war-machines are equal to and generally superior to those of any other nation, but, in spite of the excellent records of Imperial Airways, both financially and from the point of view of the safety of its passengers, there is no doubt that, taking them all round, British commercial aeroplanes of the larger or air-line sizes are regarded as a joke all over the World. And the joke is not made any less piquant by the fact that the Imperial air-liners run very closely to schedule,—chiefly because the schedule times are so low.

Only a few weeks ago we published a letter from a South African aircraft operator saying just what he thought of British aeroplanes. And, when South African Airways wanted to equip themselves with fast and thoroughly reliable passenger machines they went and bought German monoplanes because there was nothing in this country in the same category for passenger capacity and performance.

Somewhat as the result of this, people in the British Dominions steadily hold the belief that British aeroplanes cannot compete with those of other nations. As Mr. C. W. A. Scott said in a speech recently, South Africans always decry British Civil Aviation. He said that British machines are not so bad as some foreign newspapers would try to make them out to be, but in spite of that British commercial aviation is right down whereas it should be right up.

If, as we know they will, the Empire flying-boats can raise the reputation of British air transport as a whole, they will be well worth the money which their building and operation will cost the taxpayers of the Empire. Sir Francis Shelmerdine, Director-General of Civil Aviation, has stated that the speed of the Empire Boats is 199 m.p.h. That will probably become more than 200 m.p.h. by the time they have been tuned up. And that will put them among the fastest, as well as being the biggest, air transport machines in the World.

THE FIRST AWAY.—The crew of the "Canopus": (left to right) Mr. E. Crowson (engineer); Mr. T. Vallett (Marconi Co.); Major H. G. Brackley, D.S.O., D.S.C., Air Superintendent of Imperial Airways Ltd.; Mr. F. Hards (flight engineer); Mr. W. Bell (radio operator); Mr. C. E. M. Adams (station superintendent); S. G. Long (first officer) and Capn. F. J. Bailey (to command the "Canopus" in the Mediterranean).

The Beginning of the Empire Flying-Boats

By H. Oswald Short, F.R.Ae.S.

WHEN the first of the Empire Flying-Boats, the *Canopus*, flew on July 4 last and proved itself entirely successful it was a proud day for everyone who had worked on the design and construction of the machine, from our General Manager, Mr. Gouge, down to the young boys who had, sometimes in most uncomfortable positions, held the dollies for the riveters. Lying on the stringers inside a hull for hours on end is not like lying on a feather bed!

The exigencies of the position in the Aircraft Industry created by the great expansion of the Royal Air Force, forced us to use a certain percentage of unskilled labour on the building of these commercial flying-boats. Credit is due to this unskilled labour, but more credit to those very skilled foremen, leading hands, and first-class workmen, who with ever-watchful eye and much patience directed and controlled energy lacking experience to such effect that there were few blemishes to detect in the workmanship even in the first machine.

Such blemishes offend only the eye, and not the mind which is concerned with the reliability of a structure, because that mind, or the many minds concerned with the vital points in design and the operations of construction, have made the processes fool-proof.

As the Chairman of the Company watching the progress of the Empire Flying-Boat from its inception, I feel that I cannot express in adequate words my admiration for those who did the work and bore in varying degrees the great responsibility which the venture entailed. To mention all their names is impossible.

The Section Leader and his seventy draughtsmen and schedulers produced 12,000 drawings and untold schedules of materials in the short space of a few months. All had to be correct or the jig-saw puzzle would not have gone together. The venture was that of building twenty-eight very large flying-boats of a new type without having tested the first model.

Like most other aircraft designers and constructors we would have preferred to have had the necessary time to build and try-out a prototype before going into mass production. We argued on this line when we were first negotiating the contract with Imperial Airways Ltd. Such contracts must involve penalties for failure to reach performance, or for delays in delivery, and all manufacturers know how even little teething-troubles can affect the latter.

We were, however, apprised of a condition which was of National importance in connection with the further and rapid development of Empire air routes and we were finally convinced, not unwillingly, that we must take our share of the risks in the bold scheme of this development with which Imperial Airways, with the support of the Air Ministry, was determined to proceed.

When once the decision was made and work started I was conscious of a confidence on the part of those who bore the main responsibility which grew as the machines grew. It was not that there was any doubt in our minds that the Empire flying-boat would be a creditable production, the responsibility lay in the close guarantee of performance and delivery dates, and the fact that if anything went wrong in this connection the whole vast organisation in course of preparation by Imperial Airways Ltd. would be upset.

In a case like this where there is so much at stake the first flight is a particularly interesting event, but there is no anxiety. The machine is to be flown at a weight of about 1½ tons below full weight. Lankester Parker takes the pilot's seat, and one minute later he has left the buoy with all engines running. His take-off is cautious but does not exceed 17 seconds. Climbing steadily he takes a wide turn and heads directly for the open water of Gillingham Reach where there is room for all eventualities.

How long will he be away? If he returns in a few minutes there will be something wrong of major or minor importance.

ON THE JOB.—Inside the big erecting shop in Short Brothers factory at Rochester. The hull of the "Canopus" is in the middle. The gantries in which nine other hulls are being built are out of the picture on the right, which gives some idea of the size of the shop.

As it happens he is away longer than we expected. Is this a good omen or a bad one? Has he been forced to come down out there?

As these thoughts are at least going through my mind the machine appears again over Rochester Castle, it flies over the Works, makes a steep climbing turn, by which time it is a few miles away. It is now heading in our direction again, losing height. The next moment Parker is doing a roar past close to the jetty. It is a pilot's way of indicating to those below that all is well,—and Gouge is observed to light a cigarette.

When the pilot steps ashore after such a first trial flight it is a rule that no comments shall be made aloud. This is necessary because strangers may be present, and any little fault announced (those teething troubles) will grow by rumour into a disaster. However, to my whispered,—"Well, John?" Parker replies,—"Nothing wrong."

The next day a man in the City walked into a stockbroker's office and said he wanted to sell all his shares in Short Brothers because he had heard that the Empire boat was a failure!

It is not necessary, apparently, to await the first trials of a particular type of aircraft before condemning it, because some weeks before the *Canopus* was flown certain members of the House of Commons arose in due turn and declared to Parliament and the whole World for permanent record in Hansard that however good these new boats in course of construction might prove to be, they could not possibly be expected to compare with the latest American flying-boats and *other* foreign "*seaplanes.*"

This incident represents the peculiar aptitude of the British for advertising British goods abroad.

Actually the cruising speed of the Empire flying-boat is considerably above the guaranteed speed undertaken in the contract, and about four miles per hour faster than the optimum speed the forecast of which was never mentioned outside our technical staff.

This increase of speed beyond the most careful calculations and wind-tunnel tests may indicate a scale effect in favour of bigger machines.

Some people love the controversy of aeroplanes versus flying-boats. In my humble opinion both types will be shaking hands with each other long after we are dead and gone.

At the present moment it would seem that the flying-boat for the long journeys to and from the outposts of the British Empire has an advantage in the size to which it can be built *without loss of speed* due to considerations of the necessary space for landing and take off. For travel involving many days' journey the travelling public will demand greater and greater comfort and competing methods of travel will vie with each other in giving comfort with the highest possible speed that is attainable with that condition.

CRUISING COMFORT.—Inside the promenade saloon of the "Canopus." Through the door can be seen, past the midship cabin, the steward's pantry and into the forward compartment.

In both types of aircraft where four or more motors are used, there is little danger of forced landing, but the flying-boat will always be better for alighting at sea than will the aeroplane. On the other hand there are pilots, including Sir Alan Cobham, who have told me that they would rather face a forced landing with a flying-boat than with an aeroplane on some of the land over which they have had to fly, stretching for hundreds of miles.

As regards comfort, space in the cabin is a factor of great importance. It would seem that flying-boats will advance in size more rapidly than the aeroplane. I am assured by those who know more than I do about the technical side of the question that a flying-boat of 100 tons is not an impossible position. The chassis for an aeroplane of that size would add nothing to the space and comfort of the fuselage but would be necessarily of great weight.

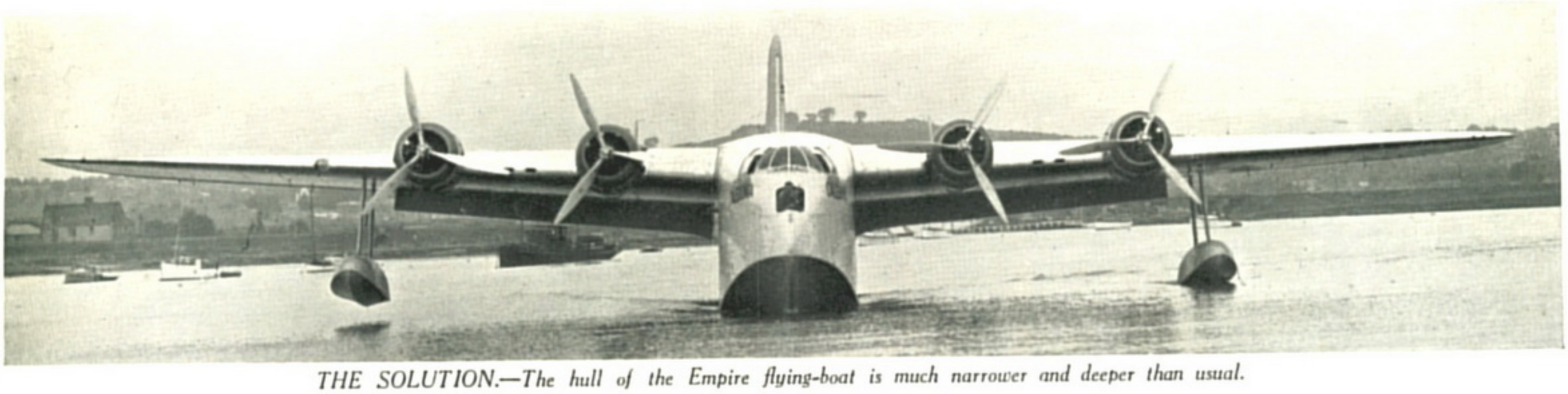
In fact we are reaching a point where fuselage-cum-chassis is heavier than hull plus wing-tip floats in very large machines.

["Aeroplane" photograph

THE MEN BEHIND THE JOB.—Mr. Oswald Short, Chairman, seated in the middle; on his right Mr. Arthur Gouge, General Manager and Chief Designer; on his left Mr. J. Lankester Parker, Test Pilot. Standing left to right, Mr. C. P. Lipscomb, Assistant Chief Designer; Mr. W. C. Jackson, Assistant Chief Designer; Mr. A. G. Parks, Chief Draughtsman; Mr. W. Browning, Head of Stress Office; Mr. W. Newnham, Foreman-in-charge.

Some Problems of Big Boat Design

By Arthur Gouge, B.Sc., F.R.Ae.S.



THE SOLUTION.—The hull of the Empire flying-boat is much narrower and deeper than usual.

THE EMPIRE BOAT was designed for Imperial Airways Limited to their own specification. This specification calls for very luxurious accommodation for passengers and also specified the cubic feet of space that each passenger should occupy. In addition to this, the boat is to be equipped for a considerable volume of mails and luggage.

Also, on some stages of the route it may be necessary to carry both chairs and bunks, therefore, space is to be allowed in which these articles may be stored when not actually in use.

The foregoing roughly determines the volume of the boat.

The necessity for having an adequate clearance between the propeller-tips and the water-surface determines the height of the plane above the water.

In a modern flying-boat, where one obviously desires to put the airscrew axis fairly near the centre of the wing, the height of the wing above the water is determined by the sum of half the propeller-diameter plus the water clearance.

One is therefore faced with the need for a wing being considerably higher from the water than the top of the hull of a normal flying-boat. But when we take into account the volume it is desired this boat shall have, it is found that the top of the hull is only just under the wing and in the design of the Empire Boat it was considered that a far lower drag could be obtained by continuing the hull up to the top of the wing surface than by building the wing on a neck.

This gave us rather more volume than we required but we were able to fix the cantilever wings onto the hull in a very much better fashion than would be possible if the top of the hull were just underneath the wings.

We used this extra available volume to increase the cubic feet per passenger, and were able to give the crew a small separate compartment in the top of the hull, also enabling us to accommodate the mails.

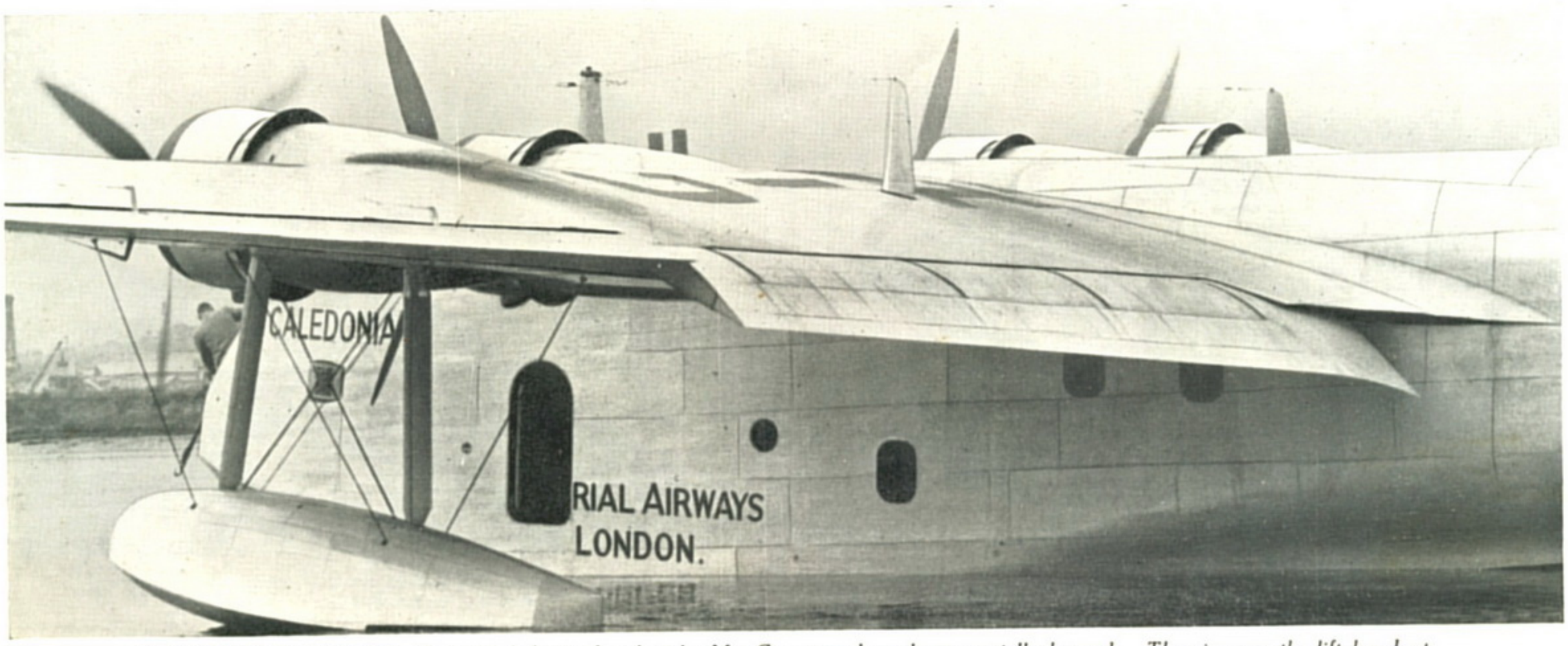
Perhaps one of the most difficult problems in the design of this boat was the planing-bottom of the hull. In order to get as high a performance and as low a hull-weight as possible, a decision was made in the early stages of the design that we would make a drastic reduction in the beam of this hull as compared with a normal British-type flying-boat hull. This involved an enormous amount of experimental work on the tank, but finally we were able to reduce the beam some 18 ins. below its original size.

This has had, as was expected, a marked effect on the weight of the hull, and also on the performance of the boat.

In order to get the boat to run stable at high speeds on the water when taking off and landing, we found that we had to lengthen both the forebody and the afterbody over what would be the normal length in a standard British boat.

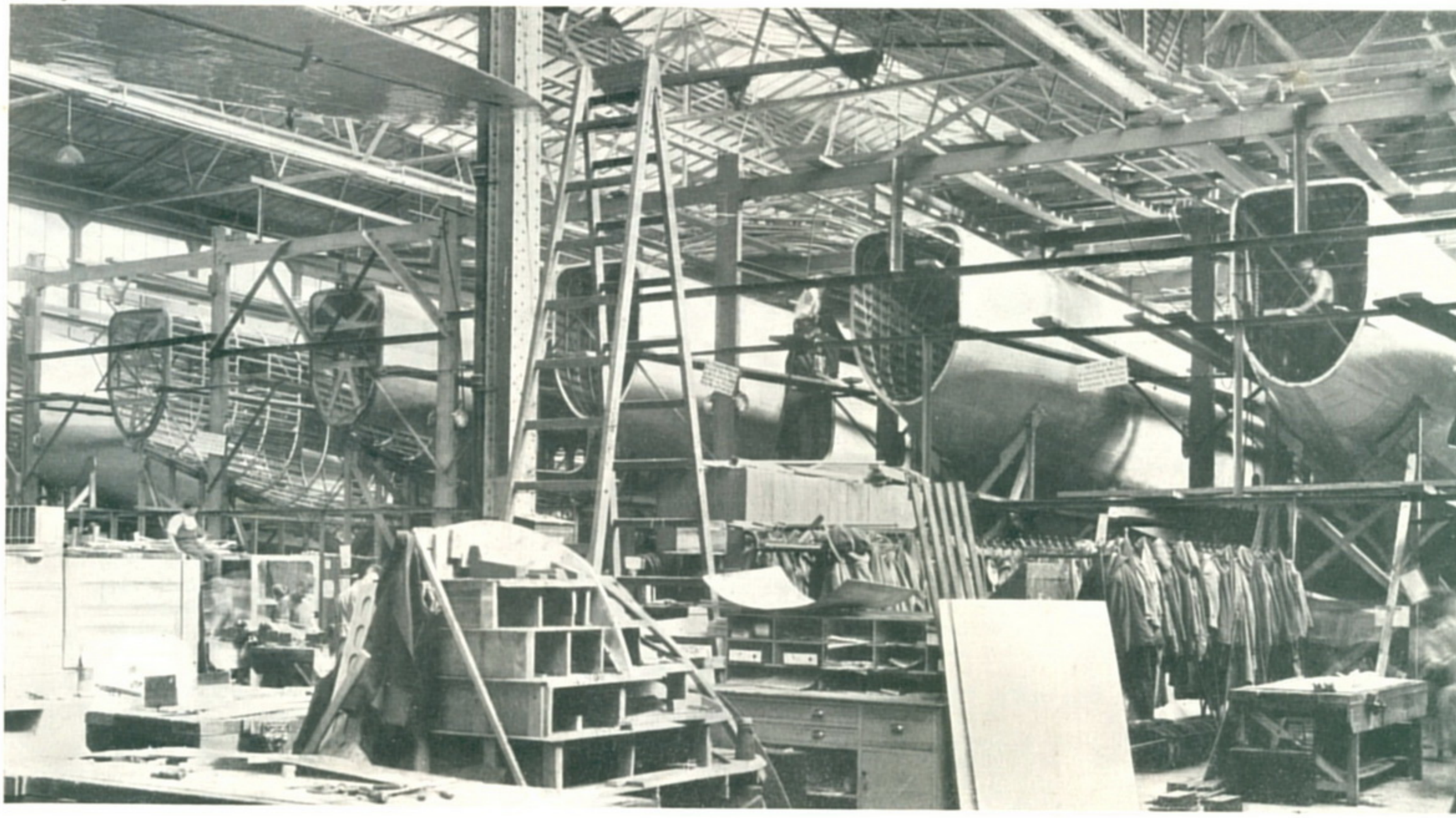
The particular type of flap which is used on the Empire Boat was designed with two objects in view—(1) to decrease the landing speed—(2) to help the take-off. If one is to achieve the latter, it is obvious that the flap must not increase the drag out of

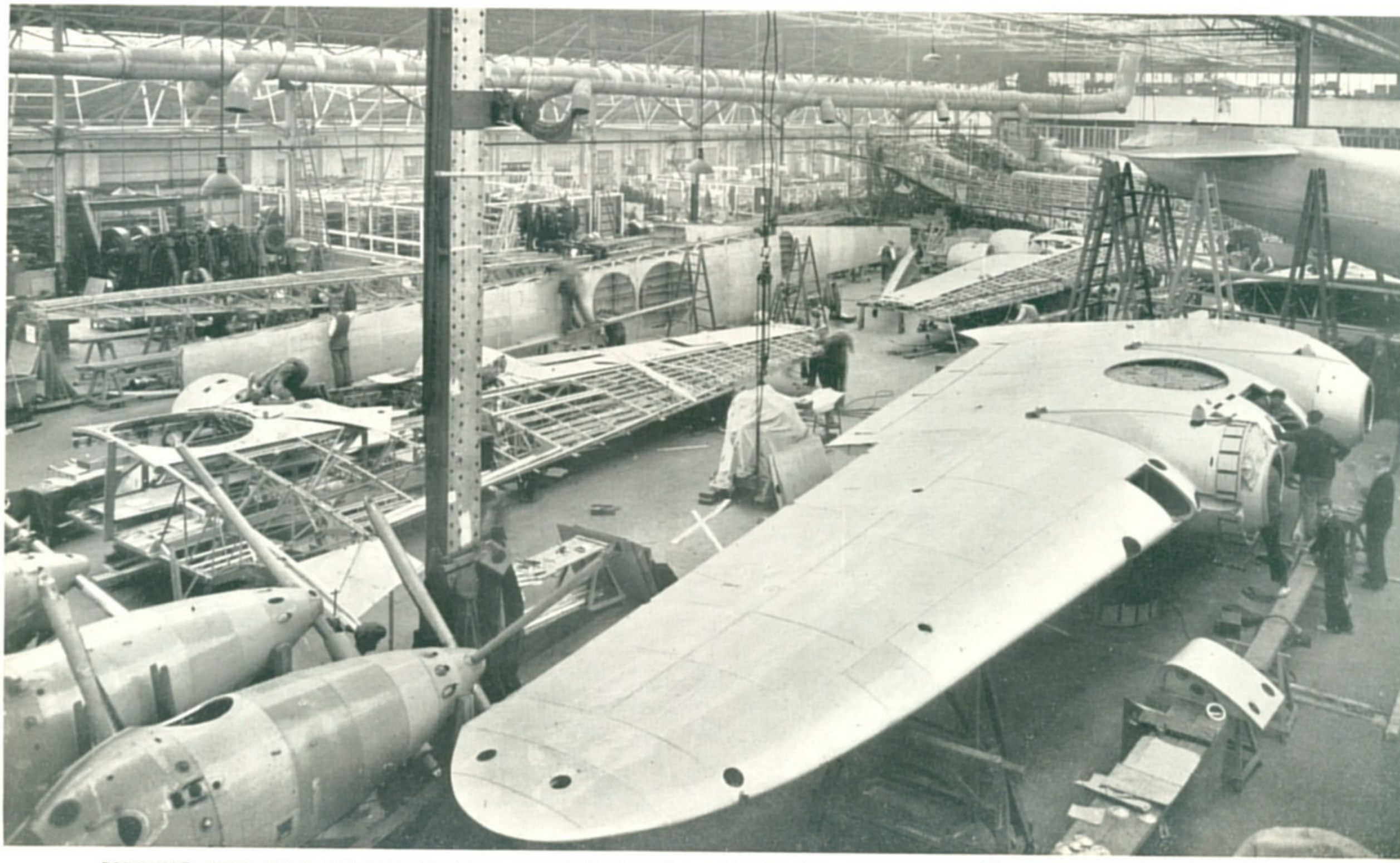
(Continued on page 11)



ONE-THIRD INCREASE.—The special flaps referred to by Mr. Gouge are here shown partially lowered. They increase the lift by about 30 per cent. and reduce the alighting speed by from 10 to 12 m.p.h.

How They Are Built

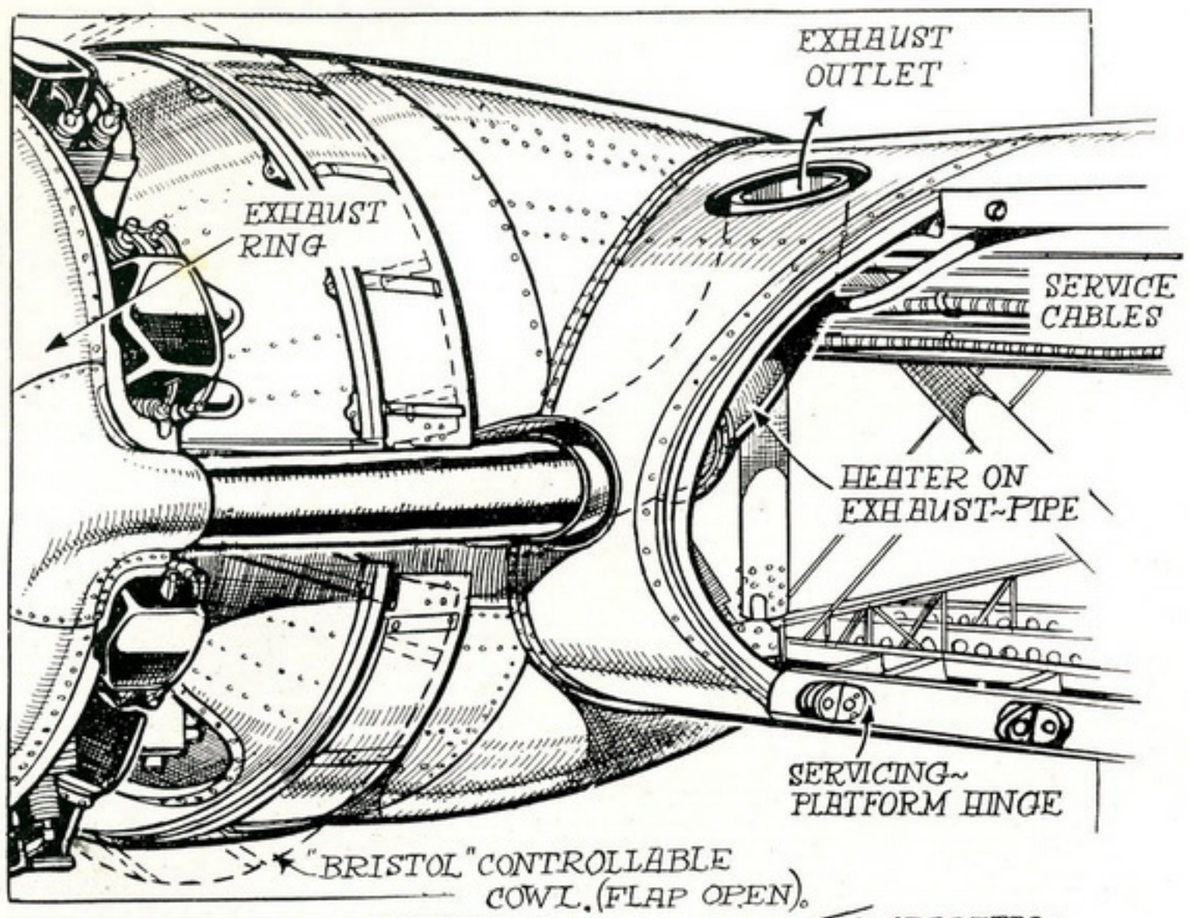


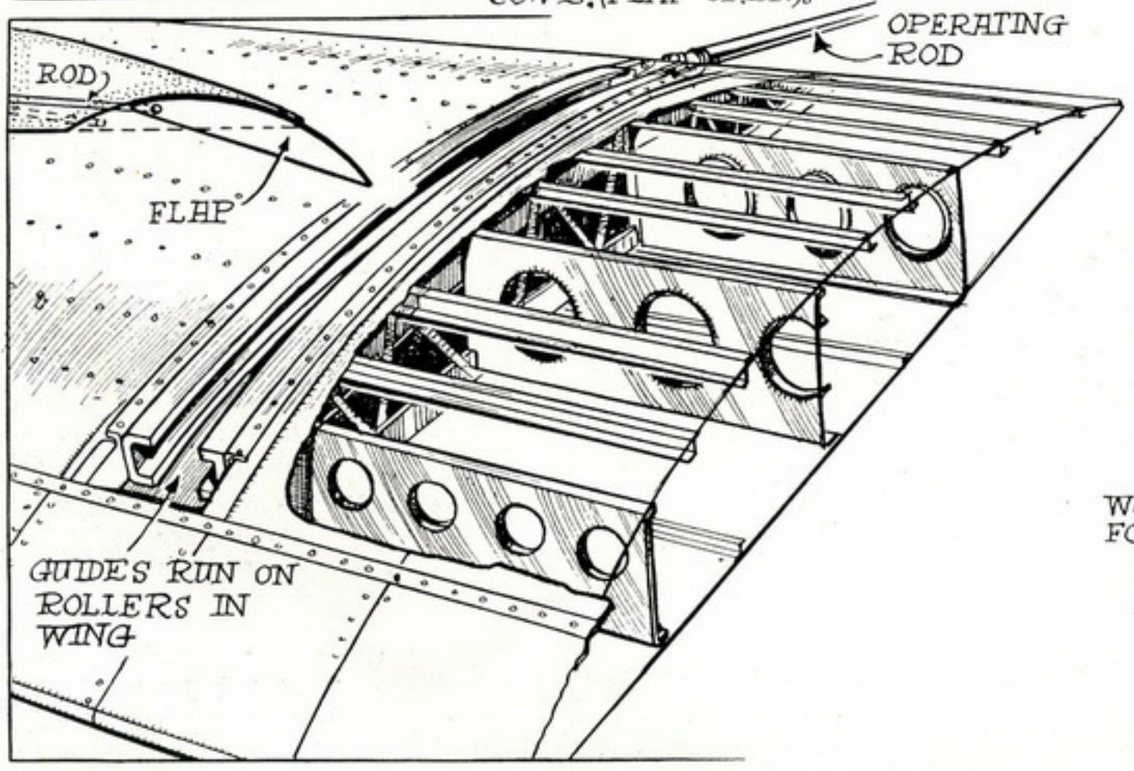


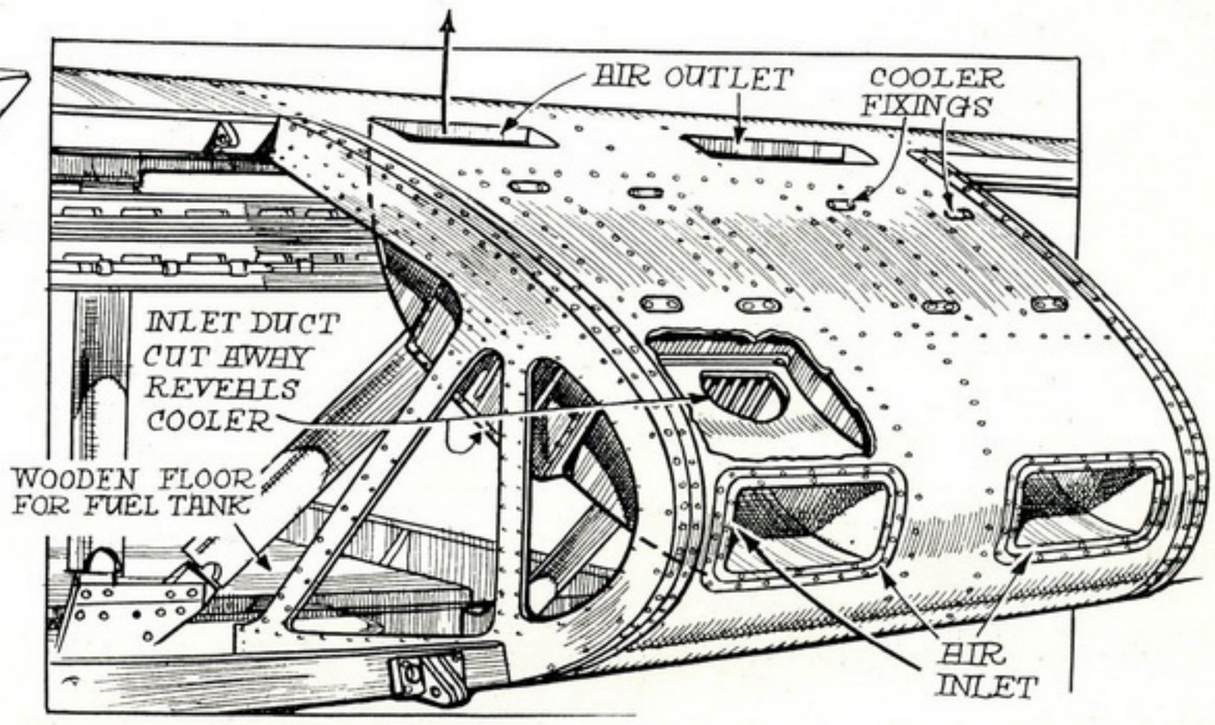
PUTTING THE BITS TOGETHER.—Top, some of the hulls being plated in the row of gantries. The sterns are built separately. Bottom, another view of the big erecting shop. The circular hole in the wing is for one of the flat-topped and bottomed cylindrical fuel-tanks.

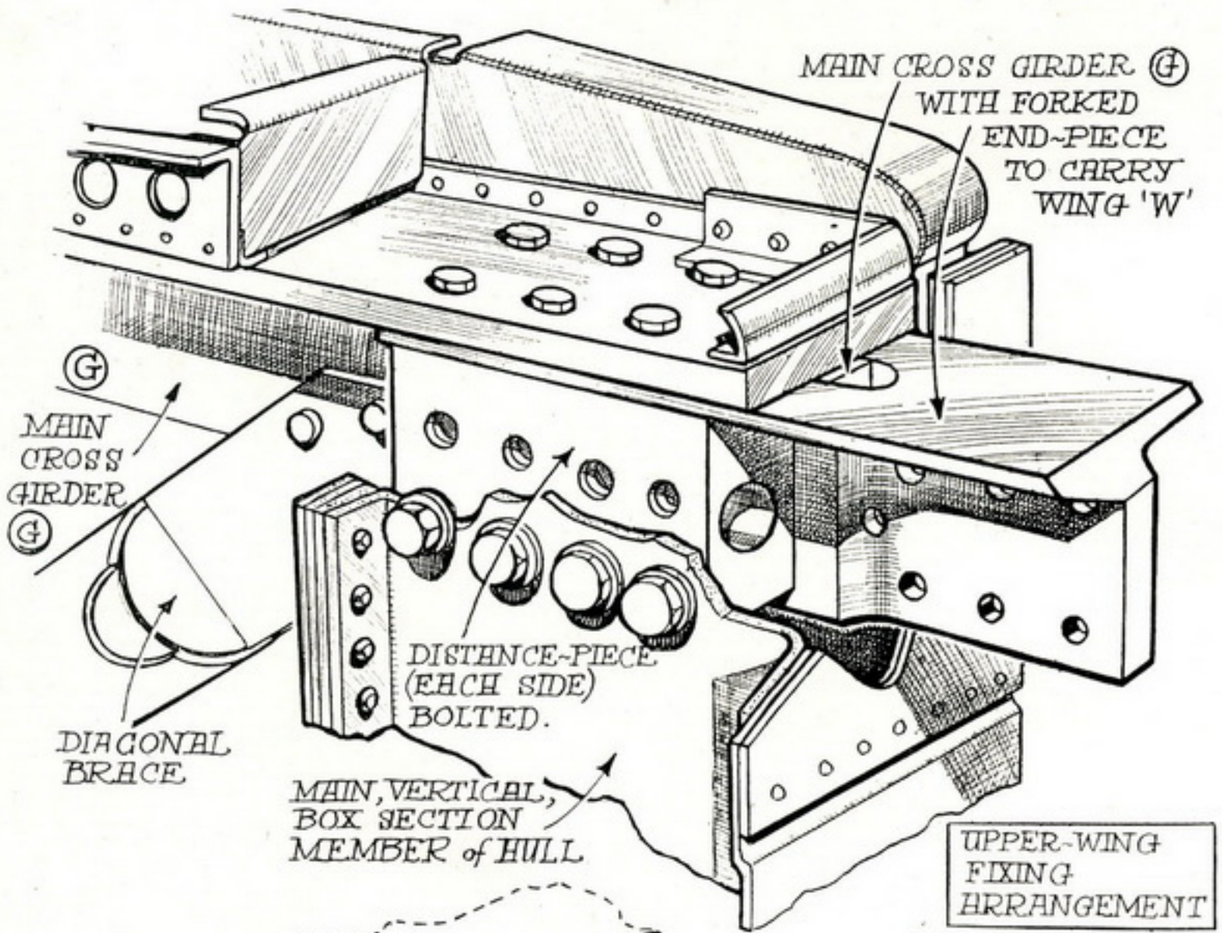
Details of the Structure of the Empire Flying-boats

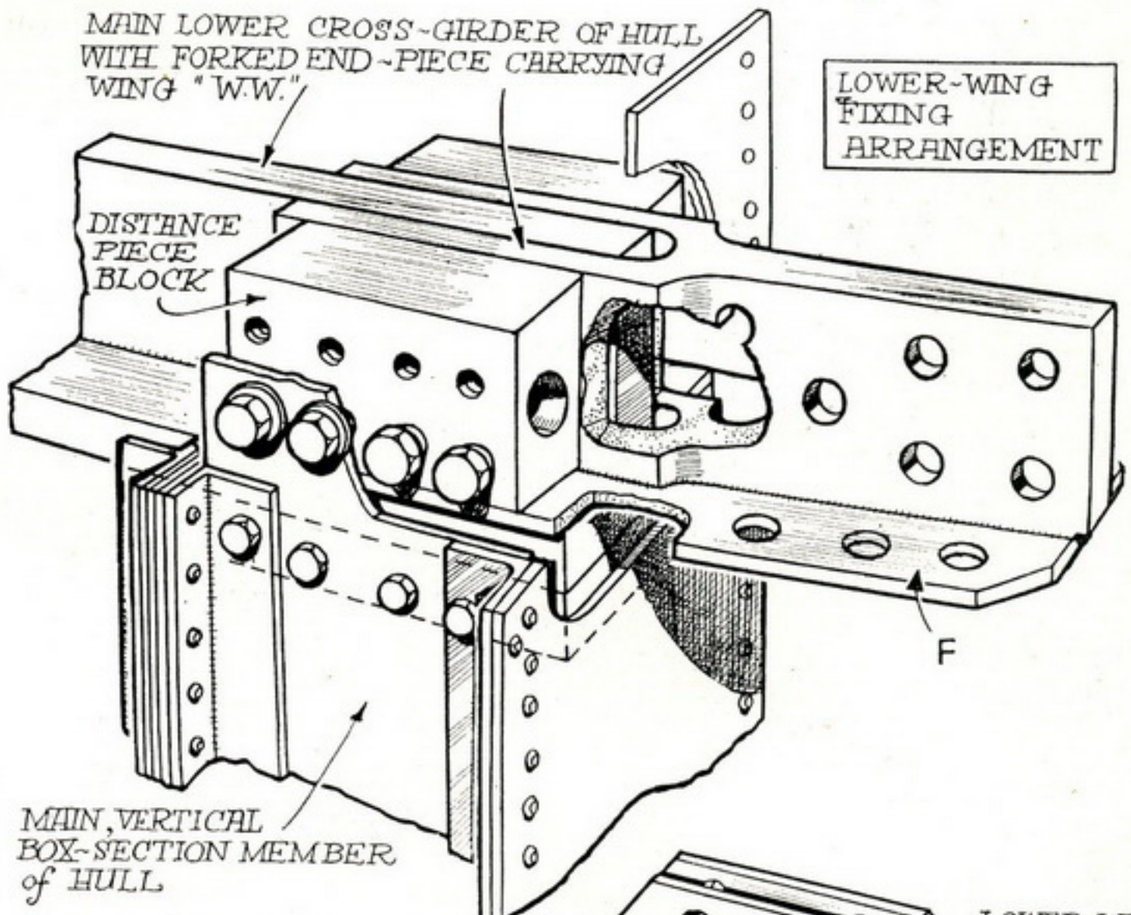
Built by Short Bros. (Bedford and Rochester), Ltd., for Imperial Airways Ltd.

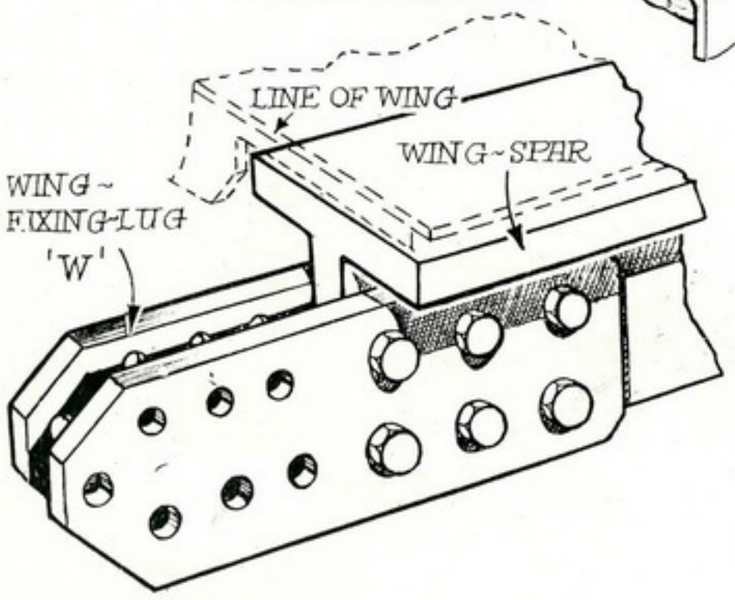


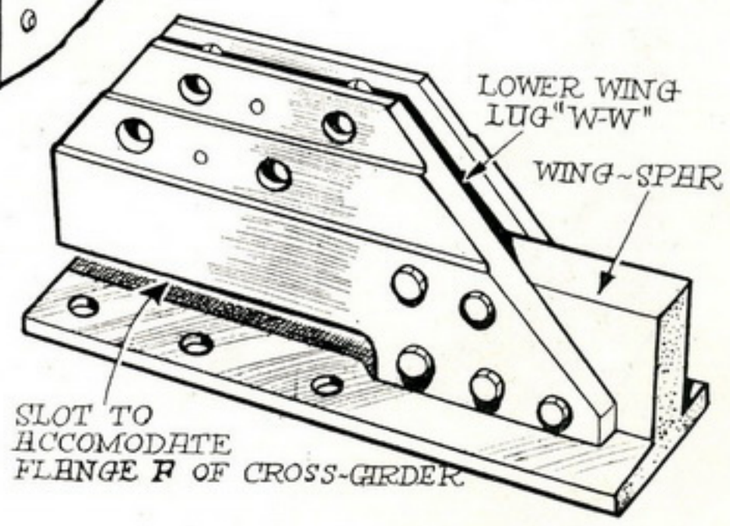












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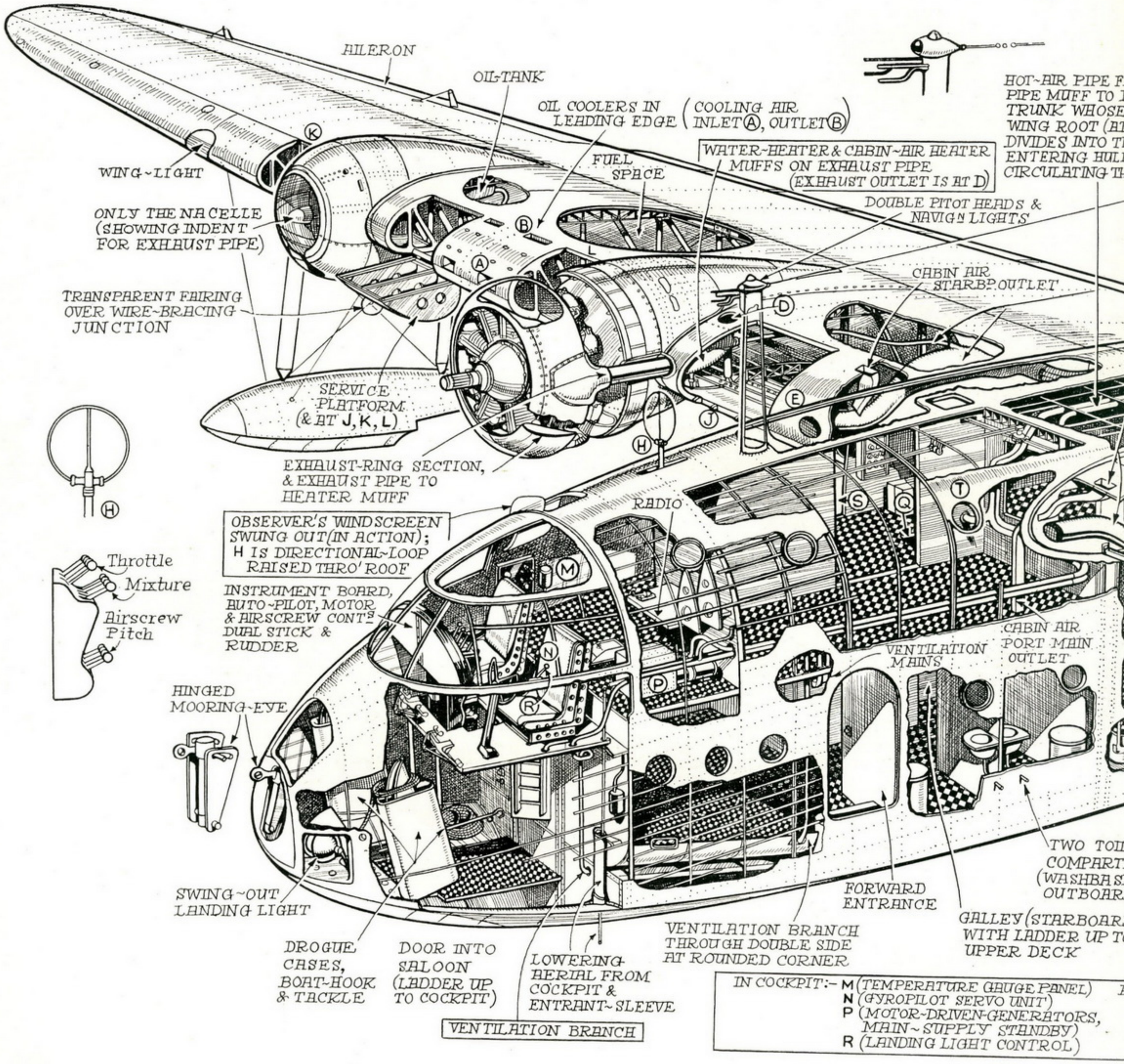
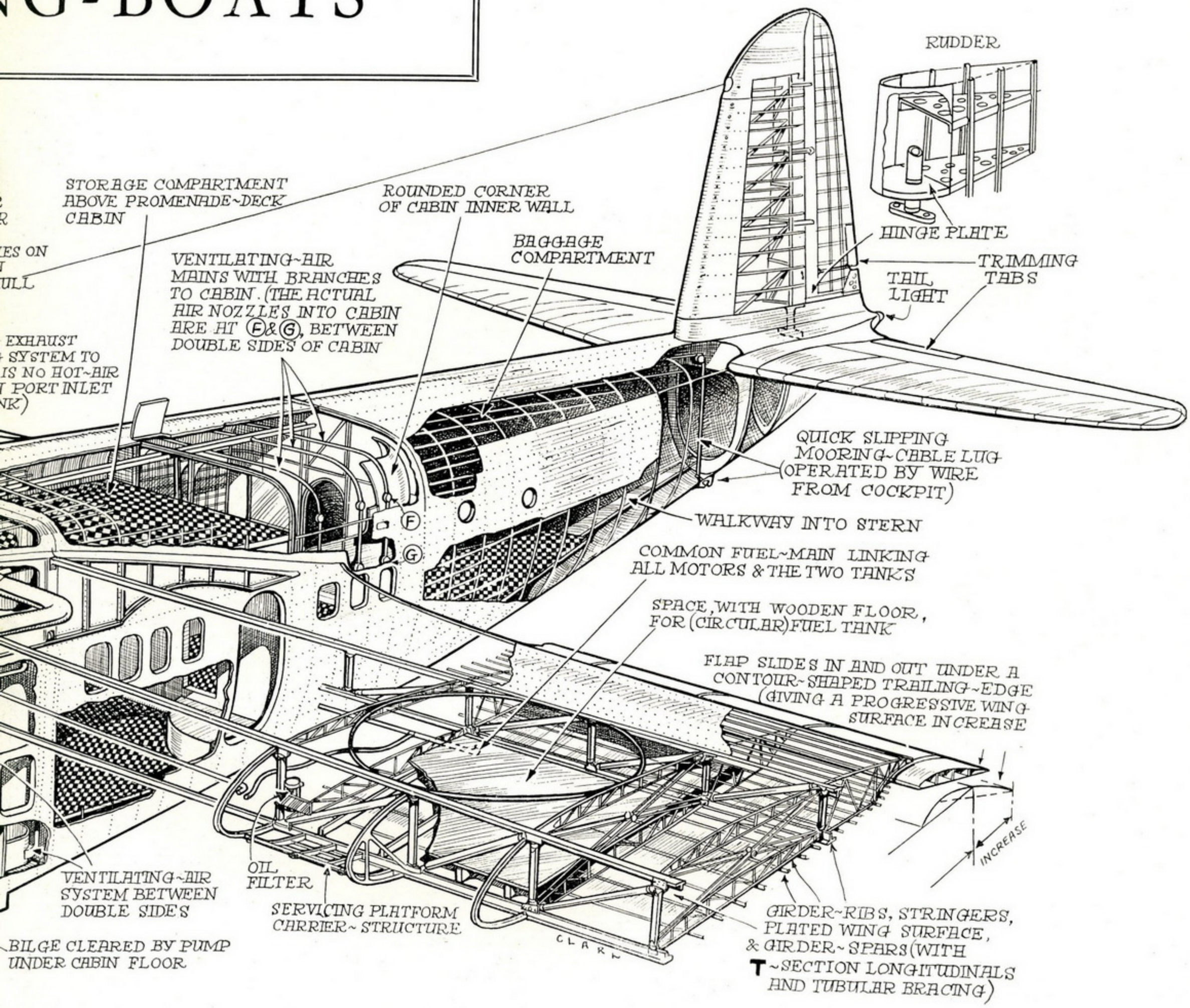
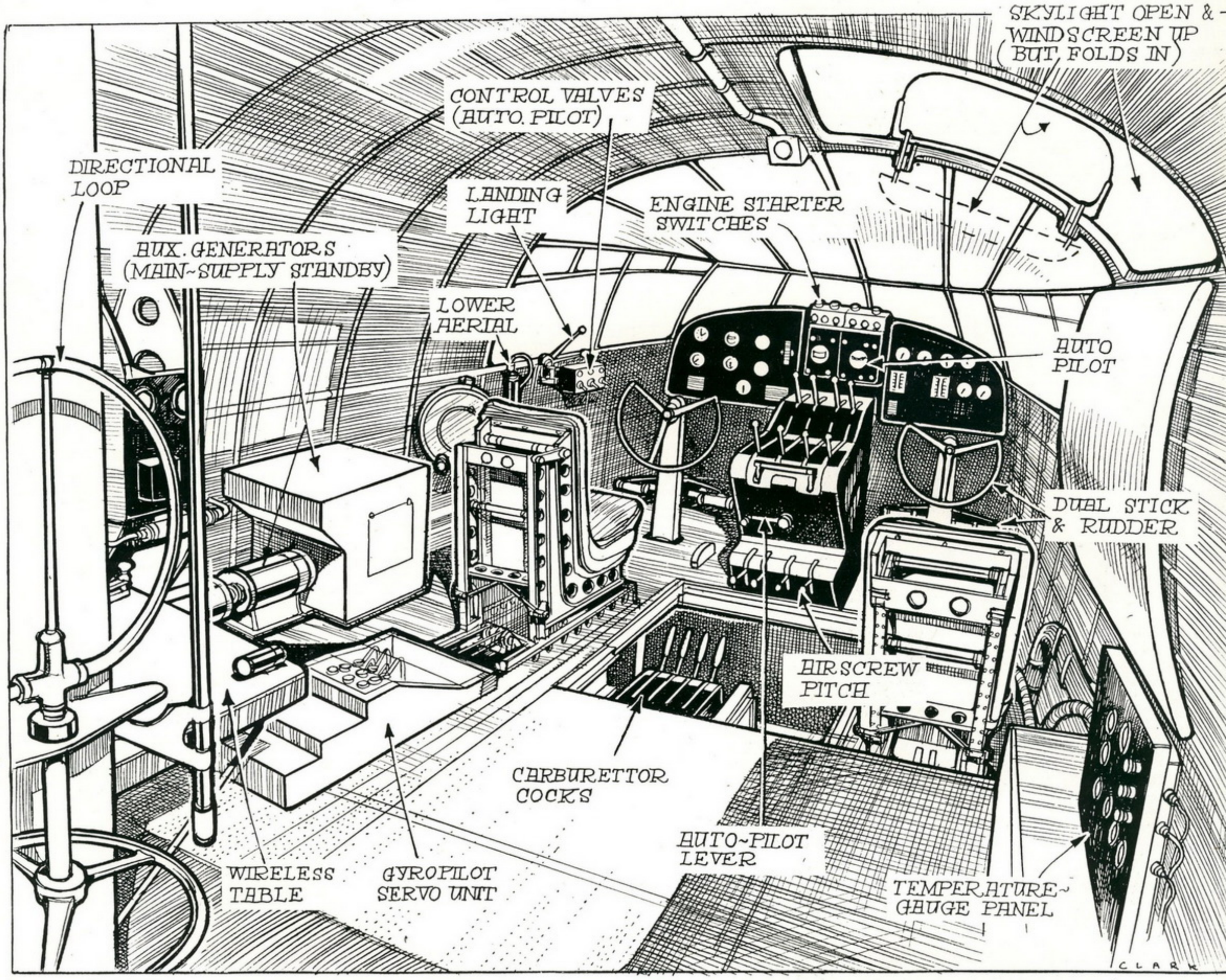


A sectioned view of one of the thirty twenty-ton flyin
Rochester) Ltd., for Imperial Airways Ltd., to be used
and on to New Zealand, from England to South Afri
States. Two were already fl

NG-BOATS



which are to be built by Short Bros. (Bedford and British Empire Air Routes, from England to Australia possibly from England to Canada and the United the end of October 1936.



THE PILOT'S CABIN AND SOME STRUCTURAL DETAILS

ON BOARD.—Above is seen the Captain's Bridge, which is at the front end of the upper deck that runs forward from the rear spar. There is so much room in the pilot's cabin that the old term "pilot's cockpit" seems no longer applicable. The drawing is largely self-explanatory, but one or two points can be enlarged upon.

The opening in the roof on the starboard side is normally closed by a hatch which is shown hanging down inside in the drawing. For purposes of navigation the hatch is opened and the small windscreen is swung up so that the navigator can take his observations.

The large opening in the deck between the pilot's seats provides access to the lower deck, which is cut off by a bulkhead from the passengers at this point.

Forward in the nose is the mooring compartment where all the marine gear is stored so that it is rather more than the chain locker of a ship. Details of this compartment are clearly shown in the big drawing on the preceding pages.

In the left-hand corner of the picture above is seen the retractable loop for the directional radio. This loop is normally carried inside the cabin to save drag, and is only lifted when in use.

To save the captain and first officer as much physical labour as possible an automatic pilot is carried. The mounting for this can be seen on the left. It is driven by compressed air and can be made not only to keep the machine on a level straight course, but also to fly in turns, in climbs or glides.

The keyboard, like the manual of an organ, in the middle of the cabin contains the throttles for the four motors, the mixture controls and the controls for the variable pitch airscrew.

On page 7 are shown some of the more interesting details and components. The general features of the structure are also shown in the photographs elsewhere in the paper.

At the top of page 7 is a typical motor-mounting for one of the four 900 h.p. Bristol Pegasus XC motors. The controllable flaps, like Dog Toby's frill around the trailing edge of the cowling, can be deflected outwards to suck extra air past the cylinders when the boat is climbing and when the air speed is consequently reduced.

The service platform which normally turns up to continue the profile of the leading edge has been taken away to make the picture clearer.

Immediately below the drawing of the motor is a section of the new trailing-edge flap which has been specially developed for the Empire Boat. It brings down the alighting speed by 10 to 12 m.p.h. The inset diagram explains how the flap normally lies under the trailing-edge. When it is pushed down the flap moves backwards, thus increasing the area. It also continues the contour of the upper surface of the wing.

The collection of drawings at the bottom of page 7 illustrate the straightforward way in which the wings are attached to the hull. For the sake of clearness only the upper and lower joints for one main spar are shown. The main members of the big girders of the wings consist, as explained more fully elsewhere, of extruded sections of light alloy. These lend themselves to the simple form of fastening shown.

(Continued from page 5)

proportion to the increase in lift. Therefore a design of flap was evolved which gained this increase in lift in two ways—(1) by increasing the area of the main planes and (2) by angle of flap.

At the same time continuity of the top surface of the aerofoil is not disturbed.—It is not necessary in the ordinary flying-boat to use the flap as an air-brake.

The practical results of the application of this flap are that the lift coefficient of the wing is increased about 30%, with a corresponding reduction in landing speed of from 10 to 12 m.p.h. There is no change in trim for any angle of flap and the pilots invariably use full flap for landing.

The best take-offs are effected with about one-half of the flap in operation. Application of more flap than this results in a longer take-off, although this flap is of a low-drag type.

This is very interesting inasmuch as it brings out the fact that resistance is almost equally as important as lift coefficient when considering the application of high-lift devices as applied to the take-off of flying-boats.

After a considerable amount of thought and experiment, it was finally decided to build the wing structure on two main lift-trusses of the ordinary N-girder type and to take the drag and torsion loads by means of a stressed skin between the two lift trusses,—of course a portion of the torsion goes in the two lift trusses.

The reason for deciding on these two lift-trusses of the N girder form was two-fold—

(1) because the stresses in all normal flying cases can be accurately determined in all the members (it is normal flying that this boat will do for 95% of its life), and

(2) because the experimental work and research that was done in connection with these wings led us to believe that it is the lightest form of structure for a boat of this magnitude.

How the Big Boats are Built

By A. E. Bibby

A. E. Bibby

At the beginning of the construction of these boats, the design being entirely different from anything we had done at these Works before, new ideas on the Works side had to be evolved. As you know, both the hull and the plane are produced with a dead-clean surface, i.e., counter-sunk riveting and joggle-plated, so that there are no projections on either the jointing, sheeting or rivet-heads. The lay-out of the Works also had to be altered to suit the new methods of construction.

The hulls are built in gantries, the keels laid on keelboards and the frames then assembled to the keel and top backbone of the gantry.

Perhaps the most important part of the hull structure is the centre sections to which are attached the two main-plane spar-frames. These are located by interchangeability jigs which are kept in position until the hull-sheeting around this centre section is finally riveted.

As we have at the moment nine hulls being assembled on the floor at one time, the problem of labour has been most difficult—there are only a limited number of skilled hands used to our class of work available, and the result has been that we have had to train quite a large percentage of our personnel into the various methods used in the construction of these hulls.

The hull is finished in the gantry complete with all internal decoration,—i.e., the walls inside are upholstered before leaving the gantry. The tail portion of the hull is manufactured in a similar way, in a gantry, but in another part of the Works.

As soon as the hull is drawn from the gantry to be got ready for erection to the planes, the tail portion is then riveted onto the main hull to complete the hull structure.

The main plane is assembled on the floor, complete with engines and all equipment, so as to make the floor-space required for final assembly of the machine as small as possible, and the delay as little as possible. It is approximately three weeks from the time of fitting the planes to the launching, as all final connections have to be made,—i.e. petrol system, controls, etc., after the wings are erected.

The main-plane spar-booms are large extrusions of angular "T" section, which have a constant taper from wing-root to wing-tip. Another of our problems was to get a machine capable of tapering the wing-spar booms to accurate dimensions,—this was got over by purchasing a large milling machine with a 10-ft. 6-in. travelling table. It took quite a time

["Aeroplane" photograph

AT ANCHOR.—The "Caledonia," the second of the Empire flying-boats, has extra tanks to give specially long range. D.H. variable-pitch airscrews, cooling gills on the cowlings of the 900 h.p. Bristol Pegasus XC motors, trailing-edge flaps and sprung wing-tip floats are all clearly shown.

to get the men used to machining to the limits required, but they are now going through in a time suitable to the requirements of our delivery programme.

These spar-booms are then taken to a truss assembly-jig in which the operations of drilling the biscuit-plates and drift-struts are carried out. They are then removed from the table and taken under a riveting machine worked by compressed air, and the whole truss is riveted at one time.

The main planes are then taken to an interchangeability jig, representing the centre section of the machine, and all drift-struts, stiffeners and sheeting are assembled while attached to this jig. The spar (now being in box formation) is taken from the jig and movable trestles, for the fitting of leading edge and trailing edge, engine nacelles, wing-tip end, ailerons and flaps.

When these are fitted it is again moved forward to a position for installing the engines, exhaust manifolds and cowling.—I would explain here that the engines, cowling and exhaust manifolds are assembled on a separate jig and are handled on to the wing nacelle as a complete unit.

While these operations are going on, the nosing nacelles, tail-plane, etc., in fact all the components to complete the machine, are made in separate shops to interchangeability jigs.

On both these sections we have had only a small nucleus of experienced hands, and approximately 80% of the people employed on these parts have had to be trained in the work.

The construction of the tail-plane calls for a type of spar-boom different from that used on the plane. It is an extrusion of cruciform formation and is tapered on a milling machine in parallel steps. These are then assembled in a similar manner to the main plane spars, i.e. they are formed on a separate jig to the elevation assembly.

They are then put onto another interchangeability jig for the fitting of drag members, nosing ribs, hinged ribs for elevators, etc., and sheeting, in a similar manner to the assembly of the machine. The same remarks apply to elevator, rudder, fin, ailerons and flaps.

The petrol-tanks are permanently fixed inside the main-plane spars, and are circular in formation, petrol-tightness being obtained by jointing material and De Bergue riveting.

The oil-tanks are of semi-D formation, and are constructed in a similar manner. They fit inside the engine nacelles immediately aft of the rear engine fixing-plate.

All the external sheeting on the whole of the boat has got to be taken down after fitting and drilling for rivets, and sent to the anodising bath. After anodising the plates are riveted to their positions on the various components.

The problem of getting the various parts, i.e. the parts made in the Machine Shop, Tank Shop, etc., to come through in their right sequence to suit the production programme, is perhaps the most difficult one to control. The sequence of parts manufactured in the various shops is arranged by a Production Office, and the detail manufacturing shops work to this programme as nearly as possible.

The difficulties of a Works Manager in producing these machines is nothing to the joy he experiences in pushing one out of the doors, down the slipway, and seeing it take off on its first flight.

The Technique of Flying the Empire Boats

By J. Lankester Parker, A.F.R.Ae.S.

THE Empire Boat is deserving of rather more than ordinary publicity, and, prejudiced as I certainly am, I still retain the reputation of being a hard critic. Judge it by any standard you will, it is really good. It has a splendid take-off, good climb, is fast and quiet, and, what is still important even in 1936, to my mind, is easy to fly with *any* two engines switched off. All of which encourages me to attempt to do that which I find so difficult, to outline something of the technique needed to handle successfully this type of craft.

J. L. Parker.

Starting Up

This sounds a simple operation and usually is, but it has to be done by the crew (wheel chocks and ground staff can't help here). Except in rare conditions where the boat is moored by the stern it will ordinarily be necessary to leave the buoy immediately two engines are started. Confined waterways and cold engines must be respected. I therefore usually start the outermost engines first to get the maximum control with the minimum of speed.

The tendency will be for the flying-boat to progress slowly into wind, and should the wind be strong and some obstruction not far ahead, it is advisable to get another engine running quickly to assist in the turn.

Another point to be remembered is that the engines cannot be "run up" to check the revs. as is done with a land machine, so great care must be taken that the power is there when opening up for the take-off.

I have often been asked what effect tide has on the take-off and landing. The answer is very simple, it merely alters the direction and speed of the wind. A "sausage" mounted on a boat drifting freely with the tide would give a true direction and speed of the wind in relation to the water, which is obviously the important fact. Landing in no wind onto a stream running at four knots is the same as landing in a four-knot wind onto still water.

Getting Back to Moorings

It is of course well known that a flying-boat generally lies to wind and a ship to tide. Very strong tides or winds will modify this rule, but it always holds good to some extent. This raises some problems.

When tide and wind are in the same direction there is no difficulty in departing from or picking up moorings, nor in coming alongside with a suitable launch. When the wind and tide are in opposite directions, whether to approach moorings up wind or up tide has to be decided.

The snag in approaching against the wind (with the tide) is that the buoy will be rigid, that is the sinker chain will be fully extended in the direction of one's travel by the tide. Drogues will be ineffective for the same reason, but because the flying-boat is travelling naturally into wind it will be very controllable directionally.

The snag in approaching with the wind is the difficulty of keeping course without opening up the engines, which will tend to increase speed. Also, when the mooring is picked up, the flying-boat will swing through 180 deg. into wind, but this is of no consequence.

The real difficulties arise when wind and tide are across each other. Under these circumstances it is quite impossible for the bows of the flying-boat to be held near the buoy for the bowman to pick up. The best that can be done is for the bows to drift sideways across the buoy, and because the sinker chain will be fully extended down tide as mentioned before, it will be a comparatively rigid affair and demand considerable quickness with the mooring-pole.

Once moored under these circumstances it will surprise some people to know that such is the "tacking" effect of the hull that the mooring cable or buoy is sometimes at an angle of 45 degrees astern of the hull. The flying-boat is in fact sailing into both wind and tide.

The load on the mooring cable will then be considerable and may necessitate severing the cable when getting under way.

In these conditions too, coming alongside with a motor launch will be impossible in the ordinary way, as the bows of the boat must be kept into tide. But given a suitable boat and a skilled skipper contact can always be made.

The major difference in handling one of these cleaner, faster and, more important still, larger flying-boats on the water is due to their momentum,—the way they carry.

Speed must be reduced to a minimum well before reaching the mooring. As you know, hydroplanes, such as Scott-Paine's boats, come to rest by falling through the surface almost as soon as the throttle is closed, but the *Queen Mary* carries on for miles. This is partially due to the fact that one skims the surface and the other is a displacement vessel,

Interior Pictures

INSIDE THE BIG BOATS.—Top left,—A quartette in the main cabin. Top right,—The promenade deck—and the step up to the door on the right. Middle left,—The smoking room. Lower right,—Upper and lower sleeping-bunks. Bottom left,—A quiet corner.

but the main factor is, I feel, just size and weight. The weight per square inch of cross sectional area is so different.

The increase of size does not seem to increase the take-off run,—except that the take-off speed may be higher due to the much greater wing-loadings used in the larger craft.

The alighting run is undoubtedly extended because the total resistance of the air and water per unit weight is less in the larger (and cleaner) flying-boat (a square inch bar of steel a foot long will have a much slower sinking speed in deep water than one of similar section but ten times the length, provided it proceeds end first). But the alighting run in the largest boats so far built is not excessive, and gadgets such as flaps can be used to reduce it.

I do not think a large boat should be put down faster than is necessary, but I am sure that basically the larger the boat the faster it can alight with comfort.

Although possibly the strains and stresses on the hull-bottom are at a maximum at the highest speeds when alighting on a sea, the shock transmitted to the occupants reaches its peak much later on in the alighting run, probably at the point where planing ceases and "falling through the surface" begins, coupled with the reducing air support.

Seaworthiness

I feel there can be no doubt, other things being equal, that the larger the boat the larger the sea it can operate from, but of course alighting speeds and many other factors come in. High alighting speed is a handicap when taking off from or alighting on a swell in little wind, but is probably a big advantage in the reverse conditions, namely, a gale of wind blowing up a nasty chop.

Then again, the actual sea that a given boat can take off from may be limited by airscrew clearance, damage to flaps or tail-plane, whereas it might be capable of alighting onto and drifting in, indefinitely, a very much bigger sea.

In commercial aviation anyway it should never be necessary to take off from rough water, but it is highly important that an alighting can be made, should it be forced on one, in a rough sea: it is perhaps even more important that a boat should be able to remain afloat even in very rough seas, as it is quite possible that in the event of a forced alighting in the middle of an ocean in good weather, bad weather might overtake the craft before rescue was possible.

This is a very good argument for the modern heavily-wing-loaded boats, as with their relatively small wings, they much more nearly approach the ideal, expounded in THE AEROPLANE, of jettisoning the wings and turning the hull into a life-boat.

In full flight these big boats are very like any other aeroplane to fly, they have the same essential controls but of course the response is slower. This slowness of response can at first be mistaken for lack of control, and in consequence the test pilot will need a longer time to make up his mind.

He can prove the effectiveness of the rudder by cutting out an outboard motor at slow speed. A level alighting with the C.G. moved to one side will prove the power of the ailerons at slow speed. Full load trials with the C.G. on the forward and aft limits will help to confirm his opinion of the elevator.

With flaps, automatic boost over-ride, variable-pitch airscrews, and all the gadgets pertaining to the automatic pilot, plus a few odd fuel-cocks and so on, the cockpit appears to be most complicated on first acquaintance, and the pilot is certainly kept busy for a few minutes at take-off and alighting; but when once the function of the levers is understood, a good memory is all that is needed. What I mean is, that it is no good having flaps unless one remembers to put them out and so on.

If a big machine had the same characteristics in performance as its small brother, there is a height from which it could not be put down in the event of sudden engine failure, simply because there would not be enough time to rotate the mass to gliding angle and then to alighting angle. Fortunately the increase of speed of these modern boats is increasing the time factor by the good old square law.

What surprises me is how long it takes the Empire Boat to settle down to its top speed of about 200 m.p.h. If one is climbing at 180 m.p.h. an increase of speed to 190 m.p.h. will cause a loss of height for some time, followed by a period of level flight, then a climb again. And so on. Previously I had always thought that one could dive to the level speed in a few seconds but this is not so, for though the forward acceleration is achieved quickly it is only at the expense of a downward one.

Before closing I think you will be interested to know that the special flaps on the Empire Boat reduce the landing speed by about 12 m.p.h. and make no noticeable difference to trim.

["Aeroplane" photograph.

ON TEST.—Mr. Parker flying an Empire Boat at Rochester.

SIDE ELEVATION.—The relative proportions of the hull to which Mr. Gouge refers in his article are here clearly shown.

Outside and Inside the Empire Boat

By Thurston James

WHEN IMPERIAL AIRWAYS LTD., some three years ago, decided with the blessing of the British Government to link the Empire by a series of all-red routes, as opposed to those which passed over the territory of other countries, they thereby substituted harbours for airports. That made necessary a new type of flying-boat. Nothing like it existed at the time, but it had to be produced if the all-red routes were to be used.

Therefore Imperial Airways Ltd. set about producing an ideal specification for the passenger-carrying flying-boat, in the light of aeronautical knowledge then existing and in the light of what the Bristol Aeroplane Co. Ltd. thought they could do in the way of power plants.

A number of specifications were drawn up to find the most efficient compromise between conflicting requirements. Not only had the ideal specification to include all the operating benefits to be obtained by making use of the latest aeronautical ideas, but also such points as the staff of Imperial Airways, scattered up and down the World, had found to be desirable. And after the specification was composed a number of tentative designs had to be got out.

After much deliberation one of these designs, towards the end of the list, was selected and to it Short Brothers (Rochester and Bedford) Ltd. produced as solution the formula of the Short Empire Flying-boat. This formula is going quite definitely to set a new fashion in the design of flying-boats.

It looks so right to you and me that neither of us being experts could imagine an 18-ton four-motored flying-boat being built any other way. But other engineers and designers, who have yet to go and do likewise, are, in their more expansive moments at any rate, quite unstinting in their admiration of the whole job.

And, after all, such admiration really is justified in the light of what the Short Boat does on the total 3,160 h.p. of its four Bristol Pegasus X C motors at 5,500 ft. It carries 8,200 lb. of payload (including a crew of 5,—which is why it pays to ship light stewards) at 200 m.p.h. On a total power of 2,400 h.p. it cruises at 165 m.p.h.

The external simplicity of the design conceals an immense complexity of detail. In producing the designs for the Empire flying-boats, the particular drawing office on that particular job at Rochester, put in a total of 150,000 man-hours. One has to remember here that this work included the designing of two-and-a-half sets of wings,—not because there was anything wrong with the first lot, but because of the variety of fuel systems required for the various types of boats.

The perfectly standard boat has one nice big fuel-tank in each wing and that does for 700 odd miles, but for trans-Atlantic routes and other extended stages quite a row of tanks along the wing is necessary.

Flying Flats

No pictorial representation that one has seen really gives an idea of the size of the Empire Boat. To say that the inside is 17 ft. from the bottom of the hull to the top of the wing will probably not bring home the capacity of the hull much more. The vastness of the craft becomes more obvious when you wander about a smoking-room as large as a room in a modern flat and rather higher than some, and then hear a member of the crew walking about above on the upper deck.

Then, with that in your mind, consider the fact that there are three more cabins, two of them even bigger and both of them longer and that all of them are being pushed through the air at up to 200 m.p.h. Then you begin to see what Shorts have achieved.

And this boat, together with another twenty-seven like it, is being built without there ever having been a prototype. The reasons for this have been explained by Mr. Oswald Short in his article. But a great deal of valuable experience was gained with the Short Scion Senior, which though a landplane, was by way of being a half-scale model of the Empire flying-boat.

Apart from what Mr. Gouge has said about the considerations which actually governed the layout of the Empire Boat, Short Brothers are naturally not yet ready to release detailed information about the aerodynamic design of the Boat. Nothing more can therefore be said about the design of wing

The span and area will be found in the specification which follows hereafter and shows that the wing-loading works out at 27 lb. per square foot. The consequently high landing speed, which such loading would entail, has been lowered some ten to twelve miles an hour by a new form of flap developed specially for the Boat.

Here again experimental results were obtained from a flying model. A special wooden wing was built and fitted to a Short Scion. Photographs of this machine and some notes on the flap appeared in this paper on April 8, 1936.

Some Technical Points

The structure of the wings and the process of building them have been briefly outlined elsewhere. Technically the most interesting thing about the wings is the use of extrusions in Hiduminium R.R.56 alloy. Extruded tubes and sheets of the same material are also used.

The extrusions for the flanges of the wing-girders are supplied to the required section and with the flanges set over the appropriate amount. But they require machining to the necessary taper.

This is done on a special form of milling machine as explained by Mr. Bibby. But besides being tapered these sections have also to be twisted. No way of doing this on the machine has yet been devised, and the operation has to be done by hand.

These extrusions are linked with vertical and diagonal tubular struts of R.R.56 alloy into which tongued fittings, machined from Hiduminium, are fixed by tubular rivets. The girders so formed are then linked by compression ribs, built up girder-fashion from more extruded sections. In place of webs between the top and bottom ribs, swaged rods provide the necessary cross-bracing.

The top and bottom surface between the spars is then covered with a stressed skin of Alclad. This is stiffened on the inside with "Z"-section stringers which run the length of the wing. The nose and trailing edges are similarly sheeted.

All the skin-plates are fixed in position with countersunk rivets and all joints, whether running along or across the wing, are "joggled." As a result the outer surface is perfectly smooth.

The ailerons, of the Frise type, are mounted on inset hinges. The ailerons have a metal-covered nose forward of the spar but are covered with fabric back to the trailing edge. They are worked in a perfectly ordinary way by swaged rods.

How the Flaps Work

Between the inner ends of the ailerons and the hull are the special flaps. These have a circular upper surface and are flat underneath. They are built entirely of metal, including the covering.

They are supported by special roller bearings working in curved tracks and move extremely easily. Each flap is worked by a screw-jack with a stroke of some 30 ins. These jacks are turned by a shaft which runs at 500 r.p.m. This consists of a number of sections linked by Mollart universal joints.

Both shafts are coupled to a Rotax electric motor of ½ h.p. which runs at 6,000 r.p.m. This pushes the flaps down in 60 secs. and brings them home in 90. The interesting thing about this mechanical equipment is that it is some 40 lb. lighter than any equivalent hydraulic system.

Each wing is bolted directly to four fittings on the side of the hull. Details of these are shown in the sketches which appear elsewhere.

As much as can be said about the lines of the hull appears in Mr. Gouge's article. The structure follows along well-proved lines. There are a large number of closely spaced frames linked with closely pitched longitudinal stringers of "Z"-section. These are covered with Alclad sheeting and an absolutely smooth surface is got in the same way as on the wings.

The tail unit is built into the stern of the hull. The structure of the fixed tail-plane resembles that of the wings except that, instead of the skin covering between the spars, the latter are linked by a number of diagonal tubes. The nose is covered with metal and the middle section with fabric.

The elevator is built much like the ailerons and in the same way, the trailing edge is covered with fabric. The fin is built like the tail-plane and the rudder is covered with fabric. Both the rudder and the elevators are provided with trimming tabs. These are set by simple mechanical control from the cockpit.

When the boat is at rest on the water it is balanced by floats just outboard of the outer motors. These floats are built along the usual Short lines and are divided into a number of watertight compartments. Provision is made for extracting any bilge water through connections in the upper surface to which a hand-pump can be fitted.

Sprung Floats

Each float is carried on a pair of struts in tandem depending from the main spars. These are braced laterally with a pair of streamlined rods on each side. To prevent undue torsional loads being transmitted to the wing by shocks when the floats are struck by a large wave or moving fast through broken water, a special form of shock-absorber is placed between the cross-bracing wires between struts.

This allows the float to move backwards some 4 ins. and the shocks are absorbed by rubber in compression. The system has already proved its use on another monoplane flying-boat built by the firm. The arrangement has the additional advantage of absorbing any oscillations which might arise from the pendulum effect of so large a mass being hung so far below the wing.

Power is supplied by four Bristol Pegasus X.C motors which drive four de Havilland three-bladed variable-pitch airscrews, 12 ft. 9 ins. in diameter, through a reduction ratio of .5/1. These run on fuel to Air Ministry specification D.T.D. 230.

The motors provide a maximum power of 790 h.p. at 2,600 r.p.m. at 5,500 ft., and 910 h.p. at 2,475 r.p.m. for take-off. They are carried on short nacelles built out from the front spar.

The fuel capacity of the boats varies according to the duties for which each is intended. The first machine, *Canopus*, has a normal range in still air of about 760 miles when carrying a payload

plus crew of five equal to 8,200 lb. (3.65 tons). Fuel for this range is carried in two tanks of 325 gallons capacity each.

The big size of the wing makes possible the building of fuel-tanks in a really economical shape. The tanks for the Empire boats are just cylindrical drums rather wide for their height.

They are made of anodically treated Duralumin and have a cruciform baffle which divides the tank into four equal communicating quadrants. The tanks are De Bergue riveted and the flat top and bottom surfaces are tied together with tubular rods. They are carried on wooden floors in the wings and bolted down into position.

The oil coolers are carried in ducts in the leading edge, as shown in the sketches.

The interior decoration of the passengers' quarters has been designed for Imperial Airways by Mr. Brian O'Rorke and the work done by L. A. Rumbold and Co., except for the special adjustable chairs which have been installed by Imperial Airways. These can be set at any angle between that suitable for reclining and sitting bolt upright. They have been produced by Imperial Airways after two years of experiments. They are upholstered with Moseley's "Float-on-Air" cushions.

The passenger accommodation of the big boat is divided into four main sections. Right in the nose is the smoking cabin, 10 ft. long by 8 ft. wide and nearly 7 ft. high. There is a door in the port side. A hatch in the forward bulkhead gives access into the mooring cabin in the nose.

The floor and walls are of the bottle-green colour now much in evidence and in this particular cabin the ceiling is white.

Behind it is the midship cabin, 10 ft. wide by 6 ft. 6 ins. long and 8 ft. high. Joining the two is a white-painted passage on the starboard side of which is the steward's white-painted pantry. The two lavatories are on the port side.

Behind the midship cabin is the so-called promenade cabin because of the large amount of floor space left free between the chairs and the port side of the boat. The main door is in that wall at the back of the cabin. There is thus plenty of room for people coming in and out through that door to move down the whole length of the boat.

The promenade cabin is the largest. It is 13 ft. long, 9 ft. wide and 7ft. 9 ins. high. The after cabin is 10 ft. long, 8 ft. 6 ins. wide and 9 ft. high.

The three last cabins are furnished with grey carpets and dove-grey ceilings. Walls and chairs are in the standard bottle-green. The various lighter fittings and fastening strips have all been finished in a pleasing opalescent finish by British Anodising Ltd.

In the bulkhead at the back of the after cabin is a hatch-way into the enormous after hold. Access to this from outside is by a two-section door in the starboard wall. Normally the lower portion is used. But by taking up the top part of the door as well a whole radial engine can be shipped.

Provision is made to mount a temporary derrick on the side of the hull and with this the motor can be lifted onto a block and pulley. The latter runs along an overhead rail into the hold.

The boat is provided with two entirely separate ventilating systems. Each passenger has a controllable punka-louvre so that he can control the supply for his own immediate wants in the way of cold fresh air.

The second ventilating system is under control of the Captain. Fresh air is taken in through the wing in the same way as in the other system, but passes through a radiator to ducts which have their outlets arranged down near the floors of the cabin.

The radiator is supplied with steam produced in a boiler built around the exhaust pipe of one of the motors. In this way the fullest possible advantage is taken of the enormous latent heat of water. If a supply of hot air is not wanted the radiator can be by-passed and the cabins supplied with fresh air only.

Except for the very large ducts which are of aluminium sheet, the air is taken through ducts which are built up from doped fabric. Strips of fabric are laid onto suitable formers and doped in place.

When the material has set, the formers can be removed and an extremely light and effective tube is obtained. Ordinary foundry cores serve very satisfactorily as they can be broken up without much trouble.

The only communication between the crew's quarters and the passengers' quarters is by way of a tubular ladder which runs vertically up at one end of the steward's pantry. This takes one up the whole of the 17 ft. out on top of the wing or one can step off half-way onto the upper deck.

Here one is in the middle of everything and as there is no upholstery to hide the works, the immense complexity of the accessory installations is apparent.

Behind in the centre section of the wing is the space for mail and freight. Still farther aft behind this is the space for the storage of bunks and bedding. Actual access to this storage space is obtained through a hatch in the promenade cabin.

As one moves forward along the upper deck there is a space for the mail on the port side. Then comes the Marconi radio equipment with the retractable loop aerial and the full direction-finding equipment. The short and medium-wave transmitter works on wave-lengths of 16.9 to 75 metres and 600 to 1,100 metres. The output on the former is 100 watts and on the latter 120 watts.

By means of the vee-shaped Di-pole aerial on top of the wing and hull, the operator can "listen through" while transmitting. When his key is not depressed he is connected to the receiver and so can pick up any calls, in between the sending of his own signals.

The receiver works on 15 to 75 metres and on 600-2,000 metres. The direction-finder also works on the latter wave-band.

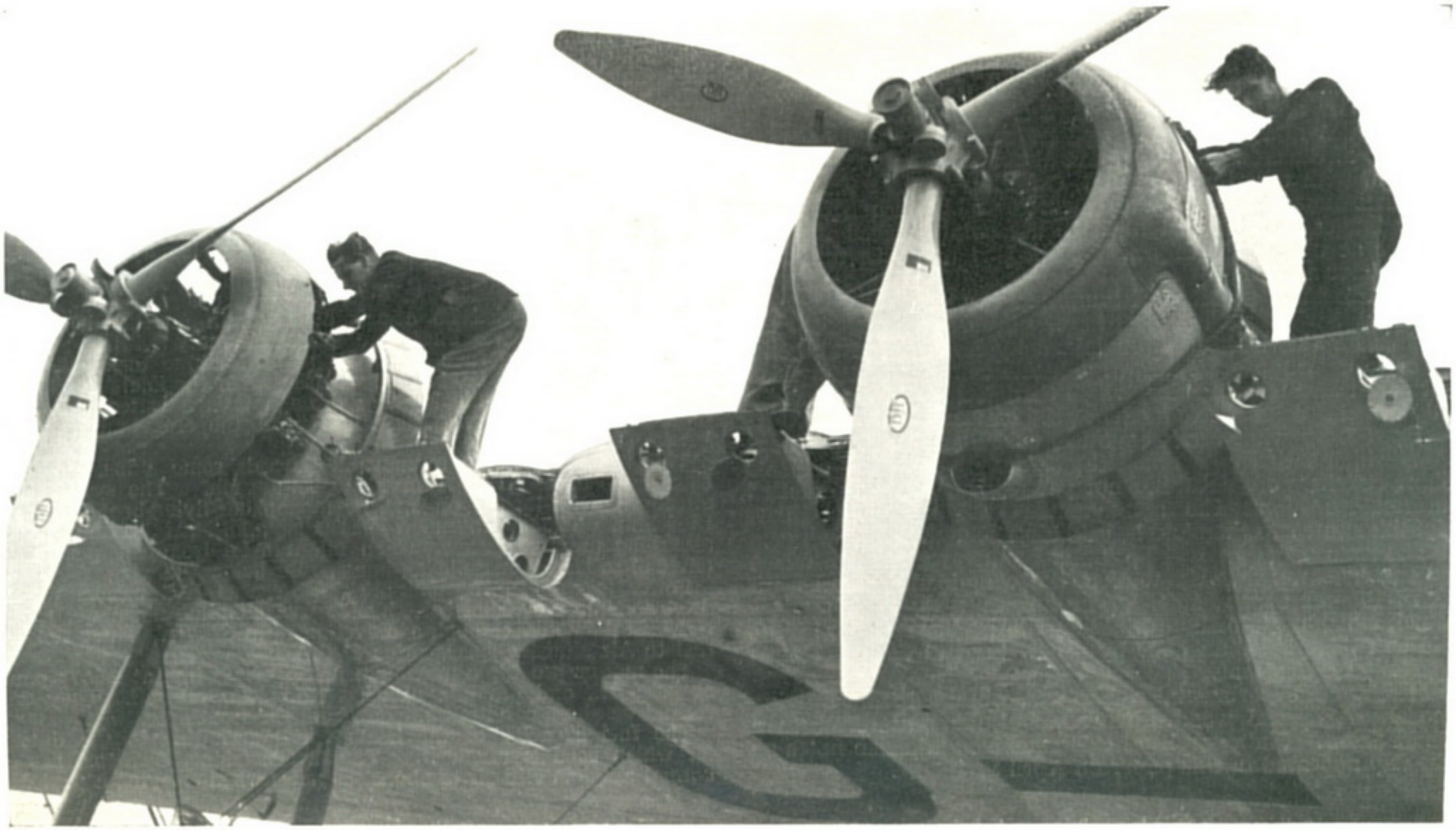
On the left is the mounting for a Sperry automatic pilot and then the two pilots' seats with all the controls in front of them. Between the seats is the hatch which leads to the forward chain locker where all the marine gear is stowed.

Exactor hydraulic controls link the throttles in the cockpit with the carburetters. There is a full range of Smith's Aircraft Instruments with the new coloured dials, also a new Husun P.4 L compass.

Each boat is provided with two Harley searchlights, one in the port side of the nose for taxying on the water and another in the starboard wing. Both have Osram lamps.

Specification

DIMENSIONS.—Span, 114 ft. (34.75 m.). Length overall, 88 ft. (26.82 m.). Height overall to top of fin, 31 ft. 9¾ ins. (9.70 m.). Wing area, 1,500 sq. ft. (139 sq. m.).

WEIGHTS (Standard Boat).—Weight empty, 24,000 lb. (10,900 kg.). Petrol (600 gallons), 4,560 lb. (2,070 kg.). Oil (44 gallons), 400 lb. (182 kg.). Equipment, 3,340 lb. (1,515 kg.). Payload plus crew (5), 8,200 lb. (3,720 kg.). Weight loaded, 40,500 lb. (18,380 kg.).

PERFORMANCE (Standard Boat).—Maximum speed, 200 m.p.h. (322 km. per hr.) at 5,500 ft. (1,680 m.). Maximum cruising speed, 165 m.p.h. (266 km. per hr.) (510 h.p. per motor). Minimum flying speed, 73 m.p.h. (118 km. per hr.). Rate of climb at sea-level (coarse pitch), 950 ft. per min. (4.8 m. per sec.). Absolute ceiling, 20,000 ft. (6,100 m.). Time to take-off, 21 secs. Normal range in still air, 760 miles (1,220 km.).