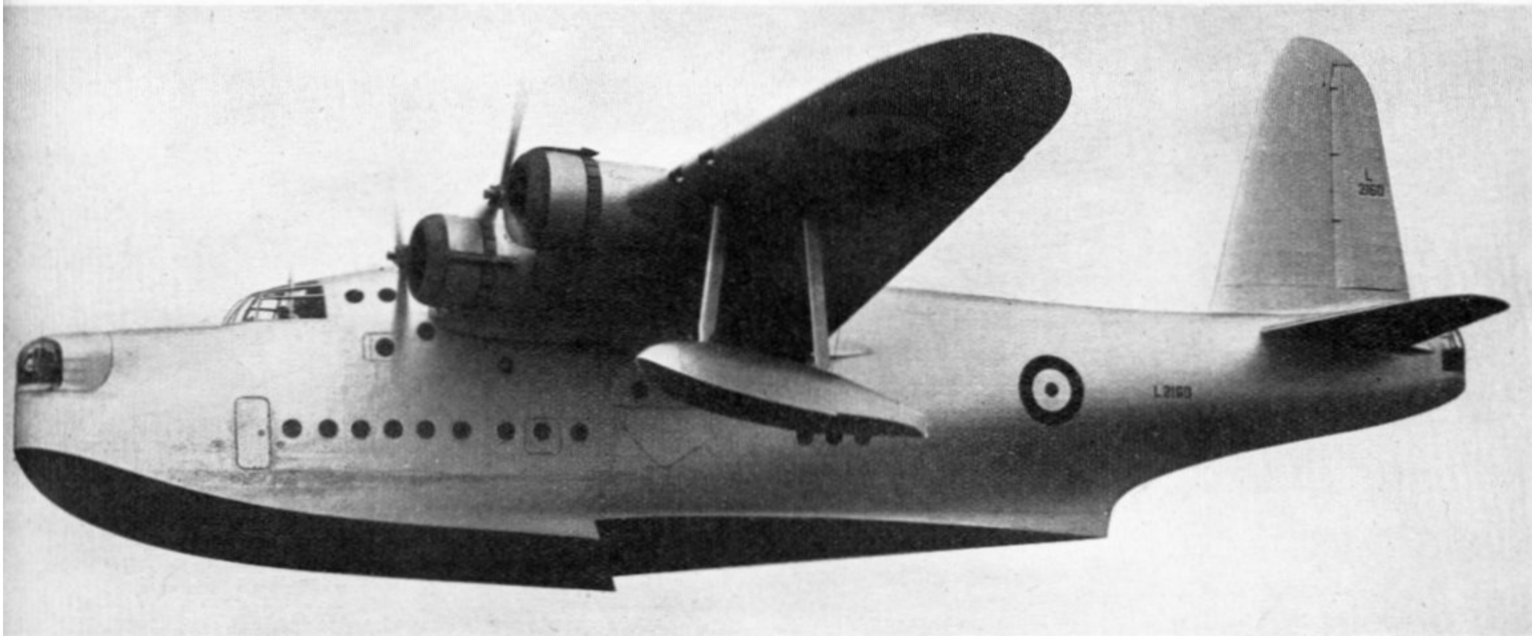
AERONAUTICAL ENGINEERING

The Sunderland Flying-boats of the Royal Air Force



FLYING-BOATS intended for service with the Royal Air Force overseas, unlike aeroplanes produced for other military purposes, have to be designed as self-contained units able to operate far from their bases for long periods. The Royal Air Force have long been working to this end.

Technical difficulties were overcome comparatively early on. Range, for instance, is obviously a primary requirement. This was not difficult to get as extra fuel tanks could always be attached to the top of the hull or slung beneath the wings. The effect of this extra load, or "overload" on the take-off was not really important as there is generally plenty of room for that purpose at sea.

Adequate seaworthiness has always been a feature of British-built flying-boats. In fact, some people have argued that too much attention has been paid to this aspect at the expense of flying performance.

On the other hand, that general concession to hydrodynamic cleanliness, the use of wing-tip floats to provide lateral stability on the water instead of using sea-wings, or lateral sponsons on the side of the hull, probably has had the effect of making our boats vulnerable if put down on the water with drift in rough seas. However that may be, the present tendency is to retain the wing-tip float though efforts are being made to retract it into the wing or motor-nacelle.

Another snag of the pendant wing-float, though not so generally appreciated, is its effect on the stresses in the wing.

In this connection one has to consider the effect of a wing-tip float, probably 15 ft. long and weighing 150 lb. hung on struts some 10 ft. below the wing

The time is not yet but will undoubtedly come when the hulls of flying-boats will be built of stainless steel. It will come, in fact, so soon as the plating can be used in gauges or thicknesses of such a size that local stiffening, such as by corrugation, will no longer be needed.

Problems of engine maintenance have been solved by making the flying-boats carry the necessary cranes to lift the aero-motors in and out of their mountings and by the provision of suitable built-in working platforms.

The remaining difficulty has been the provision of adequate living quarters for the crew. Wonders have been done in providing accommodation in militant flying-boats and as these got bigger so the quarters got better. Naturally for service in the tropics the crew need all the space that can be given them, because a metal flying-boat lying at anchor in tropic sun can become a pretty efficient sort of oven.

Consequently, with all these points in mind, we recently accepted with enthusiasm a chance to inspect one of the Sunderland flying-boats of which a large number have been supplied to the R.A.F. who are flying them in service at home and in the Far East. A further series is now being built.

The Sunderland is, so far as we know, the largest flying-boat in service with any Air Force in the World to-day. It is an all-metal boat seaplane with a cantilever monoplane wing and is driven by four Bristol Pegasus XXII air-cooled radials which provide a total of 4,040 h.p. for take-off and a maximum power for level flight of 3,360 h.p. at 6,250 ft. The boat is normally loaded to 45,000 lb. which on a wing area of just under 1,500 sq. ft. works out at a wing loading of 30 lb. per sq. ft.

One might imagine that at such a high wing-loading the boat would be difficult to handle. Actually, in service the boat behaves so well that the Royal Air Force habitually fly it at 50,000 lb., which is quite a reasonable weight,—in fact it comes out at something like 22 tons. The wing loading is then nearly 34 lb. per sq. ft.

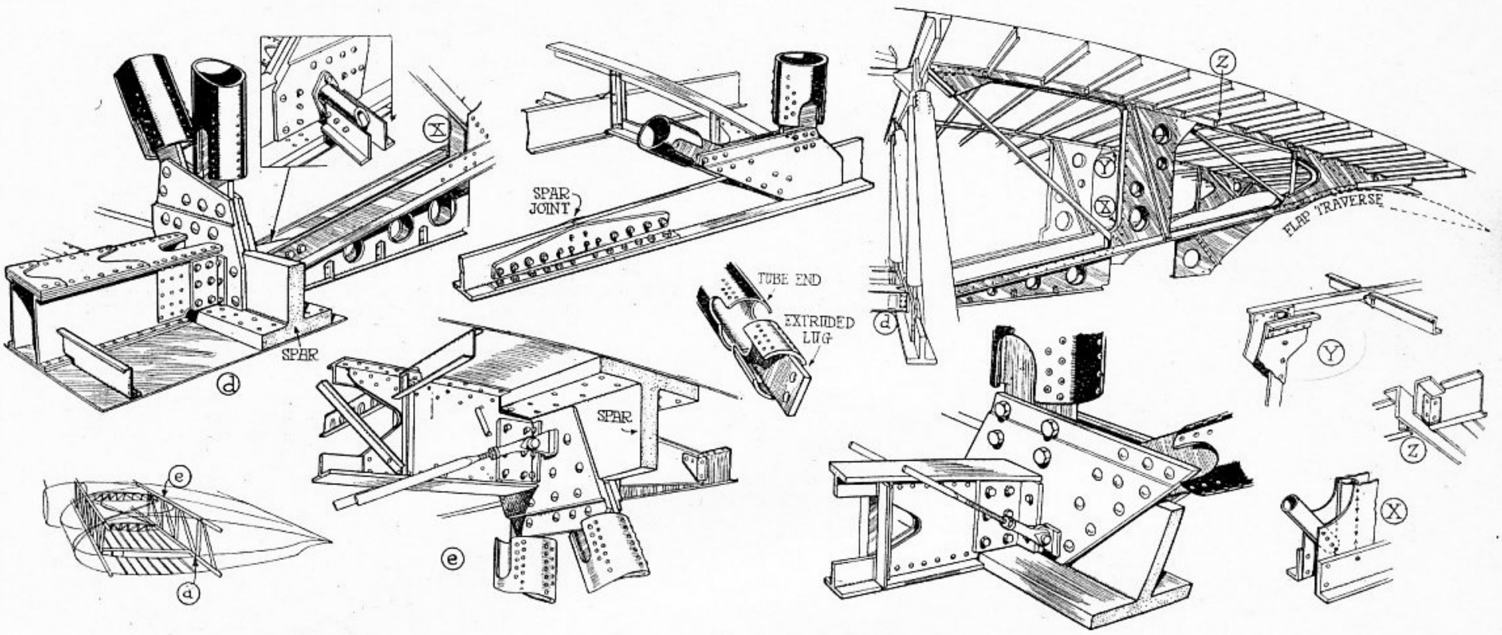
In spite of this the boat is being handled without difficulty by quite young and comparatively inexperienced pilots. In fairness to these officers we should explain that we are not suggesting that they are lacking in experience in relation to their seniority but merely that only a few years ago we should have thought that a boat of such enormous size could only be flown by pilots of many thousand hours' experience of that type of craft.

Mr. J. Lankester Parker, whose experience of testing large flying-boats must be unequalled in England, and probably in the World, told me something, while I was down looking over the Sunderland, which backs up this feature of easy handling in an interesting way. Recently, he had been discussing with other pilots the take-off of large landplanes.

The narrowest way of Rochester aerodrome gives a run of 800 yards. There was some debate about whether it was enough. During the discussion Mr. Parker bethought himself of the 22-ton Sunderlands which he takes off and puts down on the Medway above Rochester bridge without trouble. So he laid a ruler on the large-scale map of the river which hangs in his office. He then discovered that he has been taking off and putting down large flying-boats, for all these years, the Sunderland included, from a piece of water whereon in no usable direction does the run exceed 800 yards.

This, as the stockbrokers say, is a bull point for a favourite argument of ours. In spite of their high wing-loading, the Sunderlands all have the Gouge dragless flap. This is an ingenious retractable portion of the underside trailing edge of the wing which can be slid backwards and downwards when taking off and alighting. The effect is not only to increase the Maximum Lift Coefficient (C_L) of the wing, but also to increase its area without a very large increase of drag. Consequently the alighting speed is very much less than one would expect from the wing loading.

In general form the Sunderland is a military version of the Empire flying-boat but curiously enough in spite of its greater depth through the fuselage and greater weight, the Sunderland is just over a foot shorter in the span and 3 ft. shorter over all.



WING DETAILS.—Sketches of some of the interesting structural features of the wing of the Sunderland.

The first thing that strikes a visitor on board is the general air of spaciousness. The door in the port side opens into a metal-floored compartment in which the most conspicuous object is the solid-seeming windlass to deal with the anchor chain or mooring gear.

In the extreme nose is a power-driven twin-gun turret. This can be slid backwards into the hull to provide an open cockpit for the handling of marine gear during the mooring operations. The sliding back of the turret also allows the erection of a mooring bollard on an extremely stout post. In the air this post is taken down and stowed inside the hull. Also when this is out of the way and the turret pushed forward into firing position, the nose portion of the hull can be opened up to provide a position for the bomb aimer.

Turning round to go aft one is faced by a flight of steps which lead up to what one might call the flight bridge, or pilots' compartment. Here are two seats side-by-side and in front of them are the normal stick-and-wheel controls and on the floor beyond them the adjustable rudder-bars. Between the seats and in front of the instrument board is the pulpit or battery of throttles and mixture controls. The Exactor hydraulic system of transmission is used for these.

The view from up here is very good and is improved by the fact that all the windows are flat. And, by making the flat surfaces into comparatively small panels, quite a good streamline shape has been obtained. In one window in front of each pilot is a circular cutting device so that he can make himself an exit in emergency.

Behind the pilots and a large hanging curtain is the space provided for the navigator and radio-operator. There is a large chart table on the starboard side and an armchair which slides out of the way beneath it. On the port side is the radio-operator's desk. Our eye was caught here by a looking glass placed so that the operator can watch the meters on the bulkhead behind him.

On the starboard side behind the navigator's table is the flight engineer's compartment. Here between the centre-section spars are all the various cocks and gauges for the control of the fuel supply. There is also a ladder from this compartment to the galley beneath.

The chain hoist for the removal or replacement of the motors is neatly stowed away here. The engineer also has the responsibility of looking after the steam-boiler heated by the exhaust which warms the incoming fresh air.

The fuel is normally carried outside the hull in the wings between the spars. There are three drum-shaped tanks each side of the hull. In an emergency 52 per cent. of the fuel can be jettisoned.

If we go forward again and down the stairs from the pilots' compartment we find that the lavatory is on the starboard side and that on the port is a passageway which leads to the wardroom. There is room in this passageway to hang coats, overalls, or oilskins. Two large suit-cases are also stowed here. In the wardroom are two bunks and a table.

Immediately aft is the galley. As already mentioned there is a ladder from here to the flight engineer's compartment above. The galley is well provided with storage space, an ice chest for food, cooking equipment, a sink and draining board.

The galley is also used as a drogue operating station. The only means at present approved or provided for slowing down flying-boats on the water is to heave overboard a drogue, that is a long canvas bucket without a bottom, on a length of rope. The drag of towing this through the water provides an effective brake. There are opening windows or ports in each side of the galley and a container below for the drogue and its rope so that all this gear can be handled conveniently.

Behind the galley are two compartments for the crew. Both have two bunks, one each side. In the first compartment the crew have to share the space with the main bomb load. A very ingenious system is provided to get the bombs out of here into the air but it cannot be described in detail. Provision is also made in the port side of the hull for the removal of two large panels so that a complete spare aero-motor can be taken on board.

There is a metal roof to the galley and on top of this are stored the smoke-floats. These make a heavy smoke when dropped on the water and so provide useful information about the direction and force of the wind. Access to the storage place of these floats is by man-hole from the engineers' compartment or by cat-walk from the midship gun positions.

Behind the second crew's compartment are the two platforms for the midship guns. The cat-walk from these to the metal roof over the galley has previously been mentioned. Normally, the openings for the midship guns are closed by neatly fitting hatches, but these can be taken inside and the gun is erected on a pillar mounting. Some protection from the slipstream is provided by a cowling on the forward side.

A cat-walk along the bottom of the hull leads one to the power-driven gun-turret in the tail. Sitting up here one was impressed by the attention given to details. Besides having his own man-sized electric light, the gunner is kept warm or cool by an individual supply of fresh air (warm or cold), the amount of which he can regulate. On the way up one passes the hatch in the bottom of the hull which can be lifted to provide an opening for the camera.

Large numbers of these boats have been sent out to the East and so all the port-holes or window-lights are provided with curtains. A system of cowls has also been worked out to improve the interior ventilation when afloat.

Aerodynamics

Aerodynamically, the layout of the Sunderland differs but little from that of the Empire boat. The form of the hull has been modified to meet military requirements. The installation, for instance of a gun-turret in the extreme stern, has modified the shape of the hull around the tailplane and fin. There is also some departure from the rectangular cross-section of the Empire boat.

The most interesting feature of the Sunderland is the novel form of the bottom of the hull. As Mr. H. M. Garner disclosed in his lecture at the conference of the Lilienthal-Gesellschaft last October, a great deal of drag is caused by the steps which are necessary on the bottom of the hull to provide a good take-off. He then indicated that there was a very good chance of fairing the main step in, or at any rate of making the discontinuity on the bottom of a hull of such form as to reduce the air drag very considerably.

This has not been done on the Sunderland. The main step is of V shape in plan with the apex of the V pointing aft. This is probably to improve stability and prevent porpoising. Instead of ending in a second or rear step the planing bottom terminates in a vertical knife-edge which sweeps up into the rounded portion of the hull which extends out to the tail.

Thought of in terms of big flying-boats and the usual British arrangement of two steps the arrangement certainly seems novel. But when one recalls the shape of the earlier American flying-boats, particularly the NC flying-boats which made the first crossing of the Atlantic, one can see that this single main step and vertical stern is a logical development of earlier practice. Practically all seaplane floats have single main steps and a vee-shaped planing bottom which ends in a stern-post.

The idea seems to work well in practice. And in fact, the Sunderland is faster than the Empire flying-boat. Anybody who is interested in this particular subject would do well to look up our report of Mr. Garner's lecture in THE AEROPLANE of November 16, 1938, and to study the pictures.

While on the aerodynamic aspects we might draw attention to the skill with which the control surfaces have been designed so that they can be easily handled without servo-controls.

The Structure

Generally speaking, the structure of the Sunderland is that of the Empire Boat. The skin plating of the wings and hull is all assembled with "joggled" joints and countersunk riveting to make the skin as smooth as possible.

The hull and wings are plated with Alclad Na 24 ST, or in the later types with Alclad Na 23 ST. Much Hiduminium RR 56 is used in the structure of the hull and wings.

The wing is built around a main box-spar. This consists of two girder members joined with sturdy transverse members and the whole cross-braced in the transverse plane with steel tie-rods.

The girder members themselves have flanges of extruded light alloy which are machined to the proper taper and form on a specially constructed milling machine. The webs of these girders are made of diagonal struts built up of extruded tubes and extruded sections ingeniously designed so that only a simple machining operation is needed to make suitable connecting pieces.

To ensure interchangeability the wings are assembled to a master centre-section. Because of the large amount of light steel girder work in this jig it is known in the works as the "Westminster" jig.

The main trusses or girder members of the centre-section are also built to a master jig and are then sent back to the Frame Shop for incorporation in the main spar-frames. By virtue of this arrangement rigid control is ensured and as a result in spite of the enormous size of the wings they can be assembled to the boat with the minimum of trouble.

The metal-plated gouge flaps which fit so snugly beneath the trailing edge of the wing are driven electrically. A Rotax high-speed motor drives a series of screw-jacks through shafting.

The flaps are carried by a series of rollers on arms which project from the wing into the flap. These rollers run in curved channels built into the flaps. The grooves in which the rollers run have to be machined with great accuracy, as any "flats" on the surface would cause them to jam. These curved channels are milled out of solid bar after this has been bent to shape.

As with the Empire Boats, the hulls are built in a gantry, the right way up and plated in position, much as a ship is built, but whereas work on most ships begins with the laying of the keel from which the frames or ribs are built up, in the building of the Sunderland and the Empire Boats the frames are built first in horizontal jigs. These jigs are of very simple form and really consist of large tables on which the "lines" have been laid out. When the frames are complete they are lifted out and put in a gantry. A keel and keelsons are then built in and the Z-shaped stringers, to which the plating is riveted, are put in place.

The motor-nacelles are of straightforward shell construction, built around circular frames. The mounting ring of the Bristol Pegasus is bolted directly to the stiff circular channel of light alloy which forms the nose of the nacelle. To add the necessary stiffness, strong radial ribs are built into the nose of the nacelle.

The fuel tanks are of the same successful design as used in the Empire Boat. The simple design of drum used, in which the flat top and bottom discs are tied together by steel tie-rods, results in an extraordinarily low weight per gallon of capacity. In the Empire Boats we believe that this figure worked out at about .3 lb. per gallon.

The fuel tanks are carried in the motor-nacelles, but the oil-coolers are in the leading edges of the wing, where by a suitable arrangement of inlet and outlet slots a steady stream of cooling air is available at a low cost in drag.

An interesting feature of the motor installation is the auxiliary power unit driven by a small petrol motor which is mounted in the leading edge of the starboard wing. This provides the power necessary for refuelling, pumping out the bilges or charging the batteries.

The wing-tip floats are built of light alloy in the usual way, with keelsons and transverse frames and a skin of light alloy sheet. Each watertight compartment is provided with means for pumping out the bilge water.

The cantilever tail unit is built like that of the Empire Boat.

SPECIFICATION

WEIGHTS.—Empty, 28,290 lb.; Crew, 1,400 lb.; Fuel, 11,400 lb.; Oil, 830 lb.; Disposable, 16,410 lb.; Loaded, 45,700 lb.; Max. overload, 49,870 lb.; Wing loading, 30 lb. per sq. ft.; Power loading, 11.05 lb. per h.p.; Span loading, 3.6 lb. per sq. ft.

PERFORMANCE.—(At 45,700 lb.)—Max. speed, 210 m.p.h. at 6,250 ft.; Cruising speed on 65% power, 178 m.p.h. at 5,750 ft.; Stalling speed at sea-level, 80 m.p.h.; Take-off, 23 secs. with 10 m.p.h. wind; Normal range, 1,670 sea-miles; Max. range, 2,500 sea-miles; Initial rate of climb, 1,200 ft. per min.; Service ceiling, 20,500 ft.

SUPPLIERS OF ACCESSORIES

Accles and Pollock Ltd. (stainless and mild steel tubes); Amal Ltd. (pressure-reducing valves); Bakelite Ltd. (Bakelite sheet); Birmingham Battery and Metal Co. Ltd. (copper tube); Bell's Asbestos and Eng. Supplies Co. Ltd. (Asbestos goods); Birmabright Ltd. (birmabright tubes); James Bright and Co. Ltd. (Duralumin, bar, sheet and tubes, etc.); Bowden Engineers Ltd. (Bowden clips); The Breeze Corp. of Gt. Britain Ltd. (electrical fittings).

The Bristol Aeroplane Co. Ltd. (engines); The British Aluminium Co. Ltd. (aluminium sheet, tubes and ingots); British Celanese Ltd. (Celastoid sheeting); British Insulated Cables Ltd. (electric cables); British Thomson-Houston Ltd. (electrical equipment); Brown Bros. Ltd. (AGS parts); Bruntons (Musselburgh) Ltd. (streamline wires and tie rods); Callender's Cable and Construction Co. (electric cables); L. Cameron and Son (Camloy sheet); The Cork Mfg. Co. (Langite sheets and cork floats).

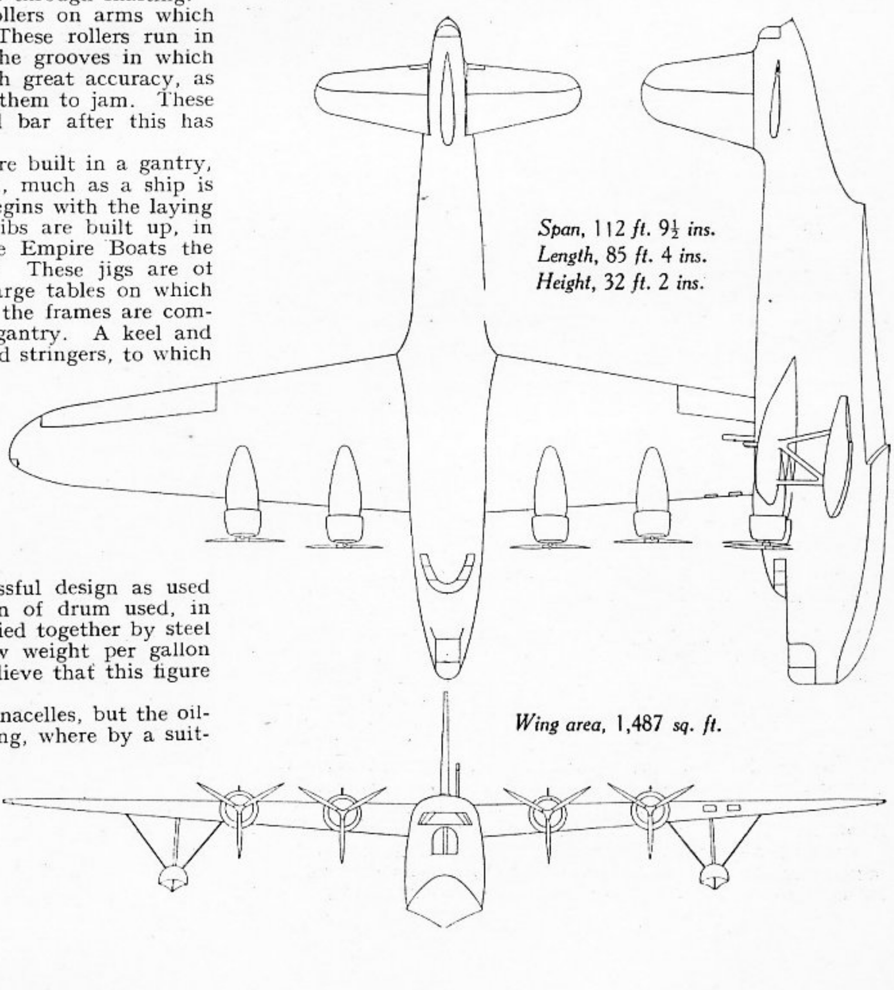
Cornercroft Ltd. (pressings); Dashwood Engineering Ltd. (machined parts, bolts, etc.); De Bergue Patents Ltd. (patent rivets); The Dunlop Rubber Co. Ltd. (tyres and wheels); Ellison Insulations Ltd. (Tufnol bars and tubes); Exactor Control Co. Ltd. (throttle controls); Firth-Vickers Stainless Steels Ltd. (stainless steel bars); Flexo Plywood Industries Ltd. (aircraft plywood); Gallay Ltd. (heaters); J. J. Habershon and Sons (stainless steel and carbon steel sheets and strips).

High Duty Alloys Ltd. (aluminium alloy sheets, etc.); The Hoffmann Manufacturing Co. Ltd. (ball and roller bearings); Wm. Jessop and Sons Ltd. (stainless steel bars, forgings, sheets, etc.); Lissen Ltd. (machining special parts); Manganese Bronze and Brass Co. Ltd. (Oilite bushes); John Marston Ltd. (oil-coolers); May and Baker Ltd. (Rhodoid); M.R.C. Ltd. (Teleflex controls); The Mollart Engineering Co. Ltd. (ball joints).

Northern Aluminium Co. Ltd. (aluminium alloy sheets, bars, etc., and extrusions); S. E. Opperman Ltd. (machining and assembly); Power Flexible Tubing Co. Ltd. (Avioflexus tubing); Renold and Coventry Chain Co. Ltd. (chain); Reynolds Tube Co. Ltd. (aluminium alloy sheets, tubes, bars, extrusions, etc.); Robertson Coolers Ltd. (oil-coolers); Rotax Ltd. (electrical equipment); Rotherham and Sons Ltd. (drain taps, etc.).

George Salter and Co. Ltd. (springs); Serck Radiators Ltd. (radiator tubes); Superflexit Ltd. (Superflexit tubes); Simmonds Aerocessories Ltd. (Simmonds nuts); Skefko Ball Bearing Co. Ltd. (ball and roller bearings); Smiths Aircraft Instruments (instruments); Smith's Stamping Works Ltd. (light alloy stampings); Sperry Gyroscope Co. Ltd. (shock absorbers and Sperry equipment); Spring Washers Ltd. (spring washers); Sterling Metals Ltd. (castings); J. Stone and Co. Ltd. (light alloy rivets and Elektron castings).

Tecalemit Ltd. (greasers); Technical Rubber Co. Ltd. (petrol-resisting rubber); H. Terry and Co. Ltd. (Anglepoise lamps); Triplex Safety Glass Co. Ltd. (aero glass); Tuck and Co. Ltd. (packing rings); Vokes Ltd. (oil-cleaner); The Weston Electrical Instrument Co. Ltd. (pyrometers); Whitely Products Ltd. (rubber cord); Wilkinson Rubber Linatex Ltd. (Linatex rubber).



Span, 112 *ft.* 9½ *ins.*
Length, 85 *ft.* 4 *ins.*
Height, 32 *ft.* 2 *ins.*

Wing area, 1,487 *sq. ft.*