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THE BOULTON AND PAUL "SIDESTRAND I"  
BOMBER AIRPLANE (BRITISH)

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THE BOULTON AND PAUL "SIDESTRAND I" BOMBER AIRPLANE (BRITISH).\*

Two Bristol "Jupiter VI" Engines.

In attempting to convey an adequate idea of the new Boulton and Paul twin-engined bomber which has recently gone into production for the Royal Air Force squadrons, two ways are open: One might concentrate on the merits of the airplane (and they are many) for the particular purpose for which it was designed, or one may approach the subject along more general lines, examining the airplane as an aircraft pure and simple, with but minor regard to its particular function as a military weapon. In the former case one would merely be describing an airplane which is a very excellent bomber, while by taking the alternative approach the merits of it as a piece of aeronautical engineering can be examined. On the whole, we believe that the majority of our readers are likely to be more interested in the general aerodynamic and structural features, and as there are certain restrictions which prevent a full discussion of the military equipment, the following notes will be devoted to the general design of the "Sidestrand," bearing in mind that the airplane has been designed as a three-seat day bomber, and that therefore certain specified loads had to be carried, loads consisting partly of equipment, partly of machine gun armament, and partly of bombs. What percentage of each is involved we are not in a

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\*From "Flight," March 29, 1928.

position to state.

### Aerodynamic Design

The readers who have followed his interesting series of articles on "Aircraft Performance" in "Flight's" monthly technical supplement "The Aircraft Engineer," will have obtained a fairly good idea of the general design policy of Mr. J. D. North, Boulton & Paul's Chief Engineer and Designer, and in examining the "Sidestrand" one looks for such features as Mr. North has advocated in his articles. Among these perhaps none was more prominent than the reduction of induced drag by having a high value of the ratio of  $\frac{\text{span}^2}{\text{weight}}$ , and a glance at the general arrangement drawings and some of the photographs (Figs. 1, 2, 3 and 4) will show that the "Sidestrand" has a very large span for its area or, as we used to say before modern airfoil theory became the fashion, high "aspect ratio." While Mr. North drew attention to the importance of large span, he also pointed out that for large airplanes it is difficult to obtain a high value of the  $\frac{\text{span}^2}{\text{weight}}$  ratio because of the increased wing weight which quickly puts a limit to the span which it is economic to employ. In the "Sidestrand," therefore, one may take it that an endeavor has been made to get the best compromise between wing structure weight and aerodynamic efficiency, and it will be of interest to examine briefly how far the wing arrangement of the "Sidestrand" may be expected to have reduced that part of the wing

drag which is due, as Mr. C. C. Walker put it, to "carrying a certain weight on a certain span at a certain speed."

The total loaded weight of the "Sidestrand" is 8850 lb. and the span is 72 ft. The value of  $\frac{\text{span}^2}{W}$  is therefore 0.518 and the monoplane value of the ratio of lift to induced drag is, at 70 M.P.H., for instance, 20.31. As the gap/span ratio of the "Sidestrand" is about 0.14, this value is increased to 25.9 for the biplane arrangement used. Thus at 70 M.P.H. the induced drag is only 342 lb., which is remarkably low and corresponds to a thrust horsepower of 64 B.H.P. only for overcoming induced drag at that speed. Since at this low speed (corresponding probably fairly well with the climbing speed of the airplane) the induced drag is a large percentage of the total wing drag, it is seen that the "high aspect ratio" wing arrangement does appear to have proved extremely beneficent. The  $\frac{\text{span}^2}{\text{weight}}$  value of 0.518 is quite high for an airplane of this weight, and in a number of airplanes this ratio only reaches a value of 0.3 or so. We believe that actually in the "Sidestrand" the extra wing weight which was the "price paid" for the higher value of  $\frac{\text{span}^2}{W}$  amounted to some 200 lb., but at that it paid to carry the extra weight.

While on the subject of wing design, a few words concerning the method used by Mr. North and his staff in the choice of wing section may be of interest. The method was outlined by Mr. North in his series of articles to which reference has already been made, and consists in starting off with a consideration of the

operational conditions to be met, and then, taking as a basis a good streamline shape, curving its center line to give the required aerodynamic characteristics, the original streamline section being chosen of such a thickness that it will accommodate spars of sufficient depth. Thus, in any Boulton and Paul airplanes, one is not likely to find any stereotyped wing section, although some of those in use may, more or less accidentally, have a fairly close resemblance to certain "accepted" sections. Incidentally, the original streamline shape taken as the basis is generated by the generalized Joukowski theory.

The wing cellule having been carefully designed to meet the particular operational conditions of the type in question, great care is again taken in the design of fuselage and engine nacelles. In the case of the "Sidestrand," for instance, a start was made with a body of very good streamline shape, generated as in the case of the wing sections, a model of which was tested in the wind tunnel. The cockpits were then added one by one, the drag being measured after each such addition. If a certain cockpit shape or arrangement was found to add unduly to the drag, modifications were made until the figure had been reduced to what appeared to be the lowest practicable value. Take, for example, the prone gun position under the fuselage. Obviously this might easily increase the body drag to a very high figure, but by persistent experimentation the drag caused by this gun emplacement was ultimately reduced to a very low value, indeed.

The engine nacelles were the subject of similar research and the form finally chosen, which is well shown in several of our photographs, has given about as low a drag as it is possible to attain with engines placed outboard. The research included wind tunnel tests with model propellers running, and at large angles, it having been found that the "interference drag" is largely an induced drag and liable to be greater at large angles, thus affecting performance on climb, etc.

The landing gear design (Figs. 7 and 8), although perhaps more of a structural than an aerodynamic problem, also shows this striving for aerodynamic "cleanness," the landing gear of the "Sidestrand" being of remarkably low frontal area for an airplane of this size.

Altogether the Boulton and Paul "Sidestrand" is an airplane which well repays a close study, the results of the very great care taken in its aerodynamic design being reflected in the performance figures which will be found at the end of this report.

#### Structural Design

If the aerodynamic design of the "Sidestrand" is of more than usual interest, the same applies at least as much to the structural features. Although in what follows the reference is particularly to the "Sidestrand," most of the constructional details are now standard Boulton and Paul practice, and would apply fairly closely to any airplane built by that firm, since

a process of standardization without cramping the freest possible development has been evolved by the firm during the last few years.

It will be known to most of our readers that Boulton and Paul were among the very first aircraft firms in England to take up all-metal, and more particularly all-steel, construction of aircraft, and a visit to the works at Norwich, very soon reveals the fact that a very high degree of perfection has been attained, not only in the design of metal members but also, and which is, perhaps, even more important because it is a good deal more difficult, in rapid and relatively cheap manufacturing processes. Concerning the latter, but little can be said in the present article, in which we must confine ourselves to the finished results rather than go into details concerning the manner in which these results were obtained.

Earlier forms of Boulton and Paul metal fuselage construction have been described and illustrated in "Flight" from time to time, but with the present form something like finality has been attained, since certain sizes have been standardized. The basis of the new form of fuselage construction is the locked-joint circular tube, which is a relatively recent product of the firm. This type of tube is made from strip, by a special process of rolling and drawing, and the accuracy obtained is really remarkable. Not only does the tube leave the draw bench "as straight as a die," but the locked-joint seam itself is per-

fectly uniform and straight, i.e., there is no twist in the tube. This is important because of the attachment of the fittings, for which it is desirable to know exactly where the seam is going to come, and that it will be in the same place at all fittings.

Having evolved an eminently satisfactory type of tube for longerons and struts, standardized in a certain number of sizes, the next step was to design a neat type of fitting for the attachment of struts to longerons. How the problem was ultimately solved is indicated in Figure 5. A tubular "pad" of magnesium alloy, fitting snugly over the tubular longeron,\* and with flat faces machined on the outside, gave the solution. Bolts pass through "pad" and longeron vertically and horizontally (being, of course, slightly staggered in relation to each other), the strut ends being attached to the bolt heads and the bracing wires to sheet steel links or wiring plates in the manner shown. The bolts themselves are of duralumin, and bushes are interposed between them and the walls of the longerons to increase the bearing area. The arrangement will be clear from Figure 5. By the employment of magnesium alloy "pads" and duralumin bolts, the weight of the fuselage fittings is kept down to a very low figure, while certainly the locked-joint tubes, of high-grade steel, are lighter than any drawn tube could be. The result is a structurally very economical construction. We regret that we have no figures relating to the bare structure weight of the "side-strand" but knowing the amount of equipment carried, and the



difference between tare weight and gross weight, it is fairly obvious that the aircraft structure must be a very low percentage.

If the fuselage structure is unusually interesting, the wing structure is no less so, although showing perhaps, a less noticeable departure from Boulton and Paul's previous forms of wing structure. We believe we are correct in stating that this firm was among the pioneers of rolled steel strip wing spar construction, at least in its efficient modern form using high-tensile steels. And it is certainly the first British firm to standardize a scheme of construction by which all conceivable manner and sizes of wings may be built from standardized parts.

Of the Boulton & Paul method of manufacturing steel spars, nothing need be said here. Suffice it to point out that manufacturing processes have been evolved which allow of both rapid and cheap production. What is of interest is the system of standardizing certain spar flanges, webs and fittings in a manner which gives a sufficient number of combinations to meet well-nigh every possible demand without having to go to the expense of making special rollers and dies. A few of the standardized combinations of webs and flanges are shown diagrammatically in Figure 6. It will be seen that, with three standard webs, and six standard flanges, 18 different spars are produced, giving quite a wide range. Add to this the fact that further variety may be added by a change of material, even to a change from steel

to duralumin, and it will be obvious that the range immediately available is very wide.

Incidentally, the accuracy of production is within 0.01 in., thus ensuring complete interchangeability, which is even more important from the point of view of mass production than repairs. It might here be mentioned that all Boulton & Paul strip is formed in the soft state, and hardened and tempered after forming.

The rib design is very simple, and consists of channel flanges and tubular distance pieces forming the girder webs. This applies to the normal rib. At points where heavier stresses have to be withstood, modified forms are used, also of channel section, but with larger channels, and with channel section distance pieces. Several types are shown in Figure 6.

The attachment to the spars of internal drag struts and interplane struts is effected via bridge pieces in such a manner as to impose no crushing stresses on the thin-walled spars, the loads being taken either on the bridge pieces or on bolts passing through the distance tubes in the spars.

Without being a very detailed description of the construction of "Sidestrand," the above notes should give a general idea of the types of structure employed. In the absence of an explanation of the internal arrangement of the fuselage, which would necessitate a reference to equipment of a military nature, about which nothing may be said, we must confine ourselves to stating

that the load of bombs forming the raison d'etre of the airplane is carried inside the fuselage instead of outside. In this way a great deal of air resistance must be saved, and doubtless this fact has contributed materially towards the good performance attained.

The Bristol "Jupiter VI" engines are mounted on the lower wing, the supporting structure being rather neatly triangulated in a manner to avoid torque reaction stresses being transmitted to the wing spars in the form of bending moments (Fig. 5). The engines are hung on swivelling mounts which greatly facilitate inspection. The gasoline tanks are situated in the fuselage, and number three in all, a front main, a rear main, and a service tank. The full tankage is 260 gallons, of which 35 gallons represent an overload to be used for long flights or some such special occasion, the normal capacity being 225 gallons, of which 65 gallons in the service tank, 90 gallons in the front main tank, and 70 gallons in the aft main tank.

The landing gear of the "Sidestrand" is of simple two-wheeled type, with oleo-pneumatic telescopic "legs" of somewhat unusual design. A long stroke is one of the features of this "leg," and it is quite remarkable to see the "Sidestrand" taxiing at high speed across rough ground, the airplane itself remaining steady, while the "legs" are telescoping in and out, the wheels moving up and down with the uneven surface. In place of a sectional drawing of the actual "leg," which would have to

be of a highly technical nature, we publish a diagrammatic representation which will serve to illustrate the general principle upon which the "leg" is designed (Fig. 8).

The lower portion of the "leg" is filled with air (pumped in at an initial pressure of 125 lb./sq.in.), and the upper part with oil, a floating diaphragm separating the air from the oil. A piston is attached to, and moves up and down with, the lower part of the leg. This piston has in its head a valve seat and a spring-loaded hollow-stem valve. This hollow or cylindrical stem is provided with ports, so that when the valve opens, the oil can pass through from one side of the piston to the other. In the valve head is a small leak hole. This, of course, permits oil to pass through under all conditions.

When the "leg" is subjected to a load, the air is compressed by the upward movement of the lower half. If the movement is a relatively gentle one, oil merely leaks through the small leak hole in the valve head. When a certain speed of travel is reached, however, the valve opens against the action of its spring, and the oil is then permitted to flow through the ports in the valve stem, from the space above the piston to the space below it. The size of leak hole and ports has been carefully proportioned so as to give, in conjunction with the compressed air and the pneumatic tire, a deflection diagram of the right shape. In taxiing, the damping of the oil is such as to prevent any tendency to bouncing, and the airplane travels along on an

even keel, although on rough ground the wheels may be seen to be moving up and down rapidly, following the irregularities of the ground. The small air vent pipe shown may possibly pass a small amount of oil during the travel of the "leg," but its chief function is to avoid the formation of an air lock while the "leg" is being filled with oil. The jack shown in the diagrams and in Figure 7 can be used for extending the "leg," or for tire changing, etc., as well as for relieving the "legs" of load when the airplane is standing in a shed for long periods.

Specifications

Length . . . . .	40 ft. 8 in.
Span . . . . .	72 " 0 "
Areas:	
Total wing areas . . . . .	943.5 sq.ft.
Ailerons . . . . .	142.0 "
Stabilizer . . . . .	68.6 "
Elevators . . . . .	50.7 "
Fins . . . . .	11.0 "
Rudder . . . . .	31.8 "

The main dimensions of the "Sidstrand I" are shown in Figure 1. The weight of the airplane light, is 5275 lb. (2400 kg), and the load carried is 3575 lb. (1625 kg), giving a total loaded weight of 8850 lb. (4025 kg).

Wing loading  $\frac{8850}{944} = 9.37$  lb./sq.ft. (45.9 kg/m<sup>2</sup>)

Power " (on normal power of 450 B.HP. per engine)

$\frac{8850}{900} = 9.84$  lb./HP. (4.47 kg/HP)

"Wing Power" = 0.95 HP./sq.ft. (10.25 HP/m<sup>2</sup>)

#### Performance

Speed at ground level, 125 M.P.H. (201 km/h).

Speed at 5000 ft. (1525 m), 130 M.P.H. (209 km/h).

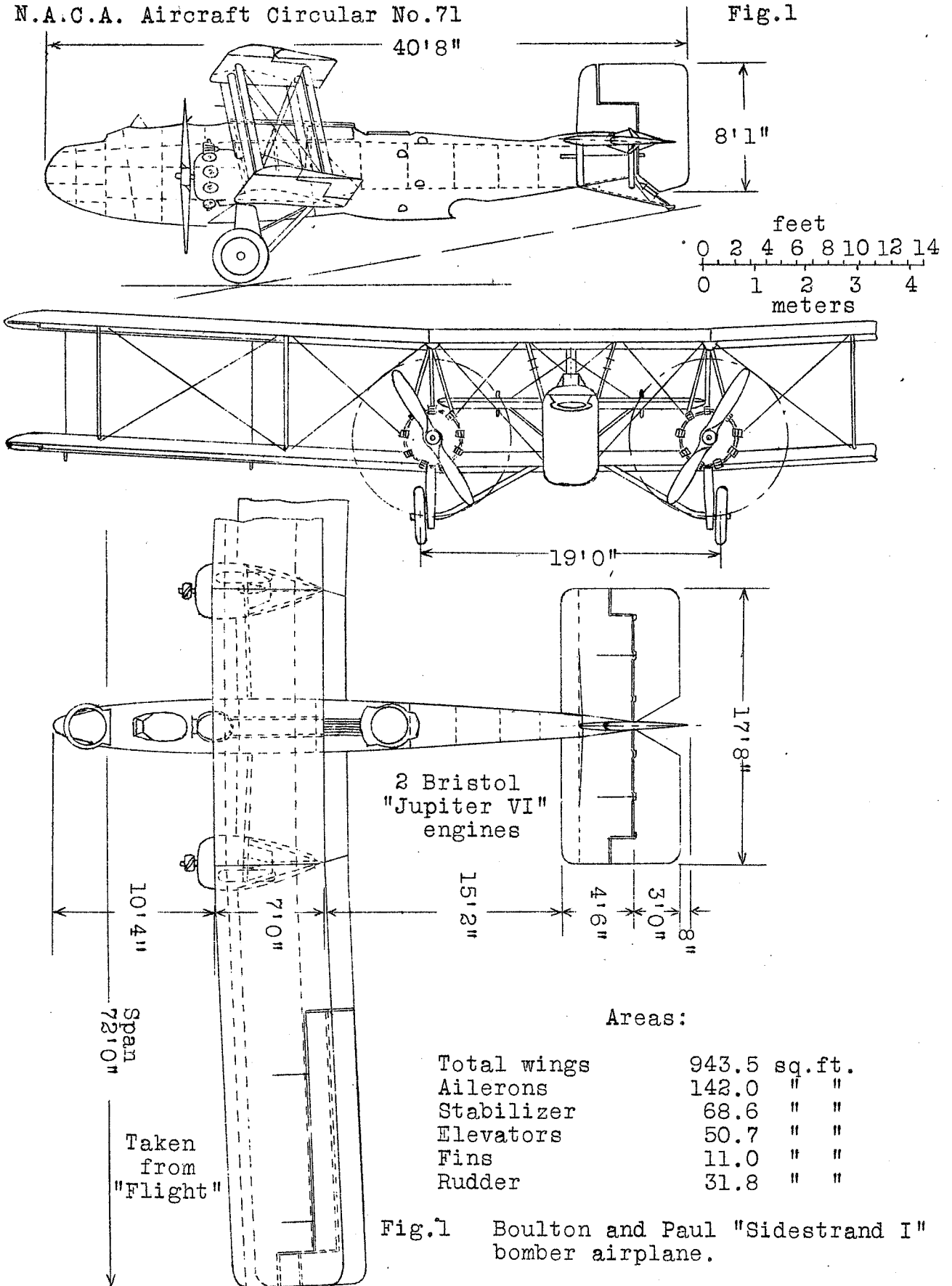


Fig.1 Boulton and Paul "Sidestrand I" bomber airplane.

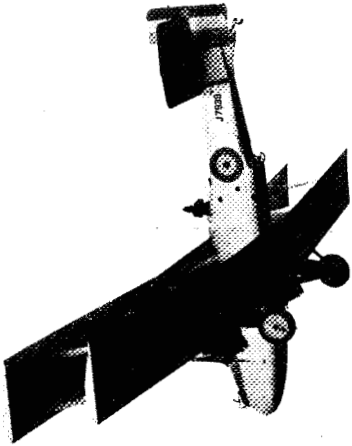


Fig. 4 The "Sidestrand I" in flight showing the large span and clean lines.

"Flight" photographs

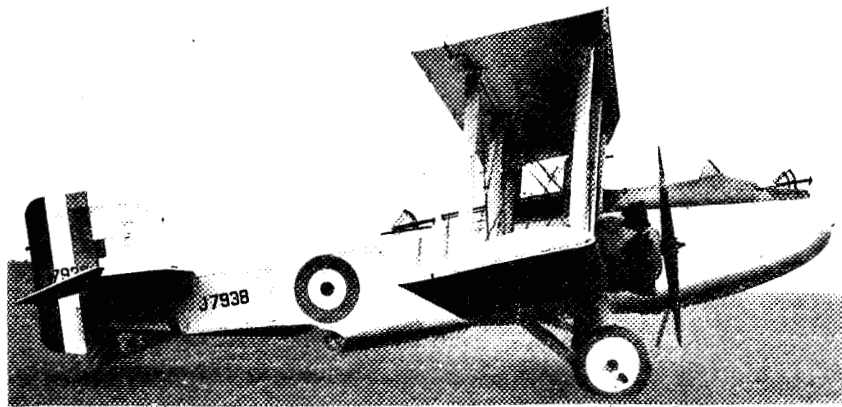


Fig. 2 Side view of the Boulton & Paul "Sidestrand I". Note the three gun positions, and more particularly that for the aft gunner firing under the tail.

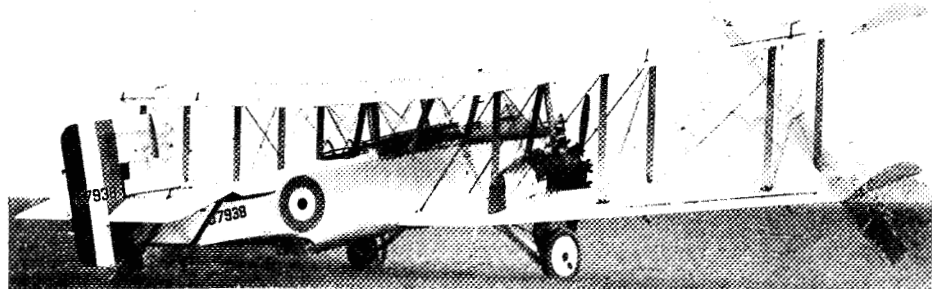
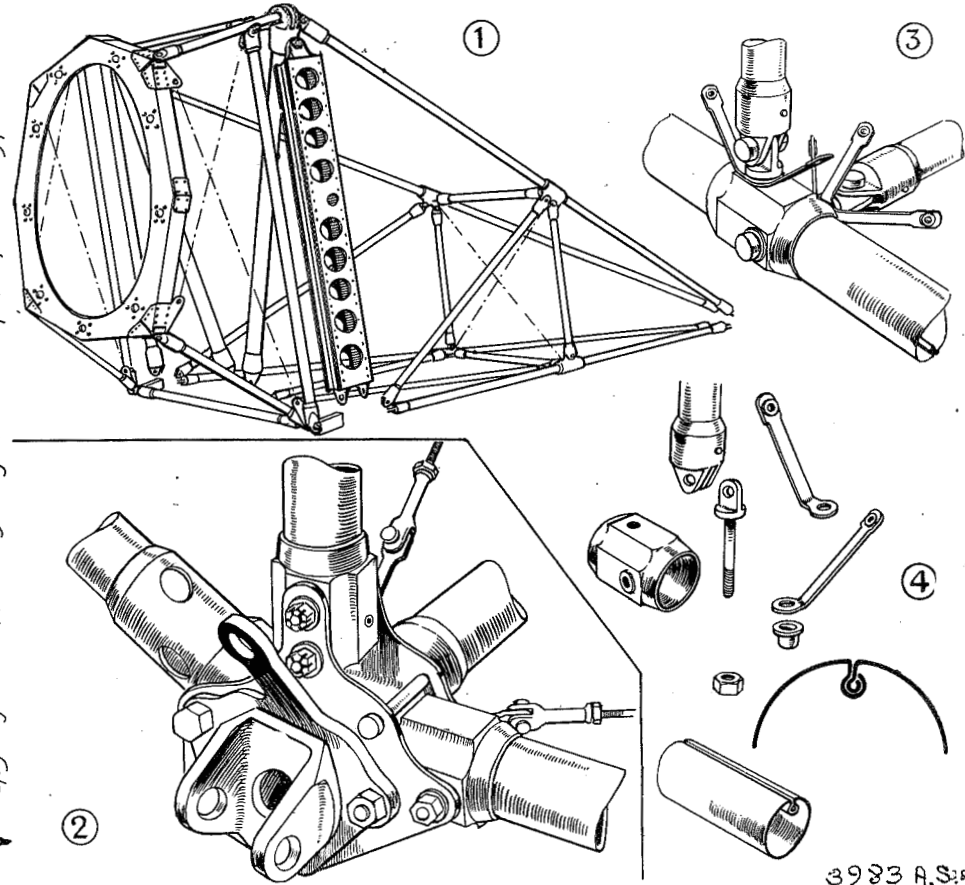


Fig. 3 Three-quarter rear view of the "Sidestrand I". The careful streamlining of the engine nacelle is apparent.

Fig. 5 Details of the "Sidestrand I". 1, engine mountings for the Bristol Jupiter designed to avoid receiving torque reaction loads as bending moments on the wing spars.

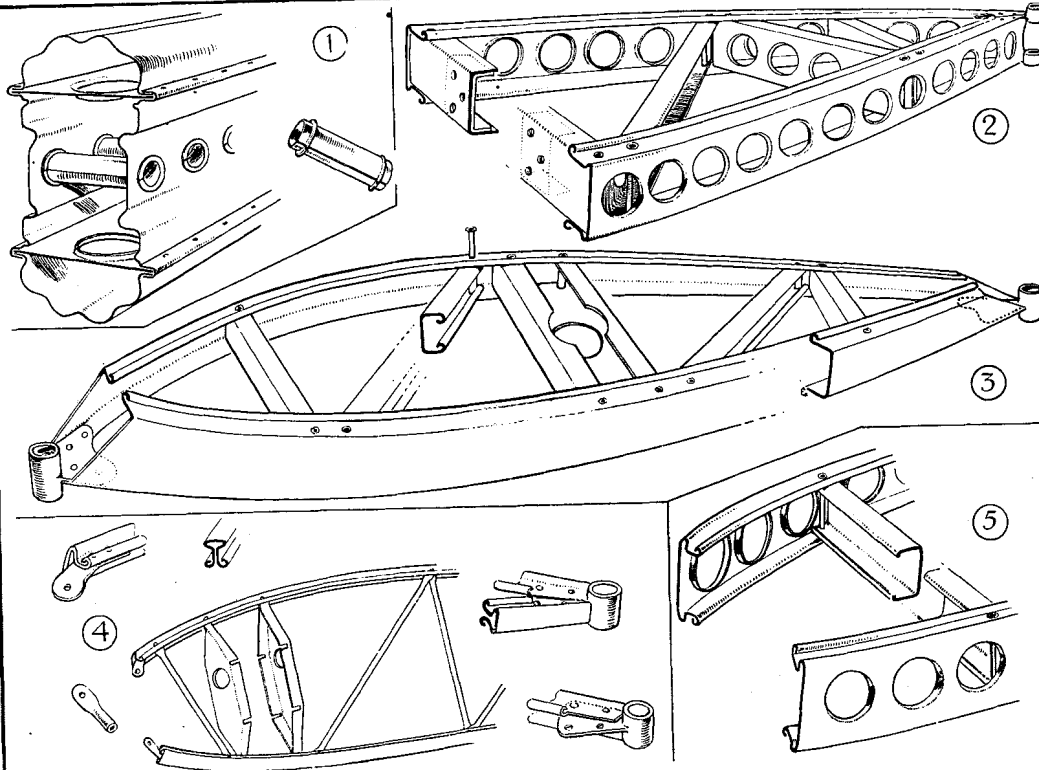
A typical fuselage joint is illustrated in 3. A disassembly of this structure is shown in 4. Note particularly the locked-joint tube longeron and the magnesium alloy pad with flat faces for the fittings.

A slightly different fuselage joint is shown in 2.



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Fig. 6 Some of the constructional details of the wings of the "Sidestrand I" 1, is a spar section with inset showing the distance-tube bracing the web walls together. A standard wing rib is shown in 4. The attachment to the spars is by means of the notched plates shown, the notches fitting over the spar flanges along the lines of rivets. A somewhat stronger form of rib, used at points where concentrated loads occur, is illustrated in 2, while 3 shows a rudder rib. Further details are illustrated in sketch 5.

Fig. 7 One of the landing gear "legs" of the "Sidestrand I". The streamline fairing has been removed to show the arrangement.

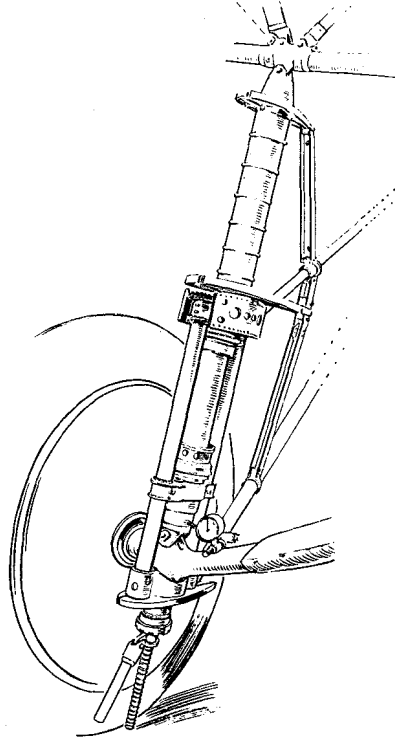
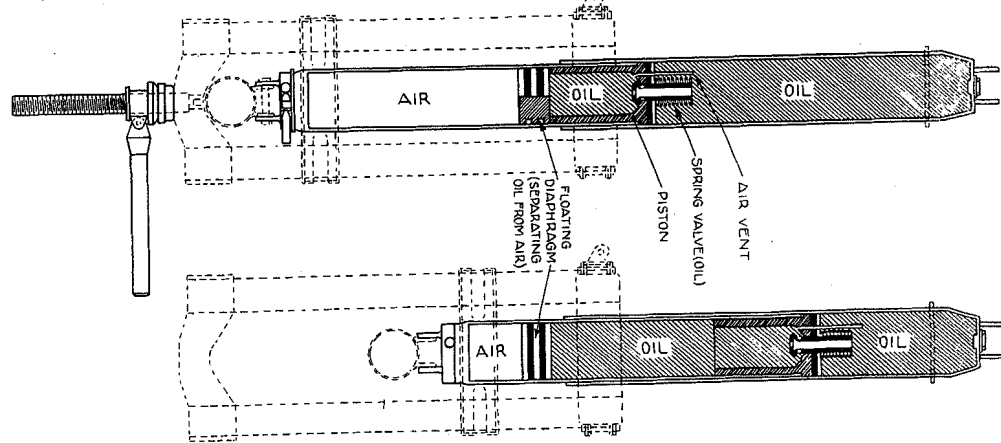


Fig. 8 Diagrammatic representation of a landing gear "leg" of the Boulton and Paul "Sidestrand I". The valve has a leak hole in its head, and ports in the tubular stem.



Figs. 6, 7, 8