REPORT ON THE STRENGTH OF THE WINGS OF CAPTURED GERMAN AEROPLANES.

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SUMMARY.—Stress calculations were made on the following machines :—
Two-seater biplanes : Albatross C.III., Aviatik 1916, L.V.G. 1916, Rumpler 1916.
Single-seater scouts : Albatros, D.I., Halberstadt.
The general conclusion arrived at from examination of the wings of various German machines and from calculations is that, as regards the main spars, German machines are decidedly below British machines in strength ; as regards the general structure of the wings, including ribs, drag struts, drag wiring, trailing edges, &c., there does not seem to be any decided difference in the strength and stiffness. The leading portions of the wings of German machines are perhaps in general rather stiffer than those of British machines.

At the request of the Air Board various captured machines have been inspected at the Agricultural Hall, Islington, and at the Southern Aircraft Depôt, Farnborough, and particulars taken for the purpose of enabling an opinion to be formed as to their strength. In several instances the machines examined were either identical with, or very similar to, the machines of which particulars have been given in recent numbers of the French periodical " L'Aérophile," and use has accordingly been made of the information there found.

It may be stated at once that the conclusions arrived at as a result of calculation and inspection do not indicate that the wings of British aeroplanes are less strong than those of German aeroplanes, but rather, as regards the main spars at least, point to the reverse being the case.

On the other hand, it is probable that the leading portions of the wings of German machines are in general rather stiffer than those of British machines : the desirability of following the practice adopted by the Germans in certain of their machines, of covering over the upper surface of the leading portion of the wing with three-ply wood, appears to be worthy of serious consideration, from the points of view of stiffness and durability.

The leading particulars of the machines which came under examination, together with drawings of the wing section, and a line diagram of the lift girder, are given in the appended figure. Corresponding particulars for S.E.5 have been added for comparison purposes. The wing sections adopted by the Germans are in striking contrast with those adopted by the British in two respects, namely, camber and thickness. The German sections are, without exception, of the high lift type generally associated with low efficiency; coupled with this the under surface camber is so considerable that the thickness of section and consequent depth of spar are much smaller than generally obtains with wing sections of British design. The areas of the various sections and their moduli for bending under lift are given in the figure, and enable a comparison of the spars as to their resistance to compression and bending to be made. Comparing, for instance, the spars (assumed solid) of the Albatros scout with the spars of S.E.5, the former have moduli of 1·67 in.^{3} and 1·34 in.^{3}, front and rear respectively, as against 2·23 in.^{3} and 1·17 in.^{3} for the latter. It should be noticed that the greatest span in the Albatros scout lift girder is 120 in., as compared with only 87 in. for S.E.5.

In this connection it may be mentioned that in the German machines under consideration failure of the spars would probably occur under the compressive stress due to end load combined with bending. The direct stress is always much smaller than the bending stress, the ratio of the two varying roughly from $\frac{1}{2}$ to $\frac{1}{5}$.

For each machine stress calculations have been made to find the loading on the wings corresponding with the breaking point of the spars. In what follows the ratio of this loading to the normal net loading on the wings in steady horizontal flight will be referred to as the "breaking load factor." It was assumed, in accordance with the conclusions arrived at in T.938 ("On the Possible Loading of the Wings and Body of a High Speed Aeroplane in Flight"), that the front spar would be most heavily stressed when the centre of pressure was furthest forward and the angle of incidence the critical angle, while the rear spar would be most heavily stressed when the centre of pressure was at 0·5 of the chord from the leading edge.

Reference to the tables given in T.938 shows that, in the case of the particular machine for which the calculations were made, the wing load factor corresponding with maximum loading on the front spar is 10·8 (*see* Table 3), whereas the load factor corresponding with maximum loading on the rear spar is 6·7 (*see* Table 1). The ratio of these two load factors is 1·6; for present-day machines it is considered that the ratio will, in general, lie between unity and rather less than two, according to the various characteristics of the machine.

The breaking load factors actually specified for British machines are believed generally to be the same for both front and rear spars (centre of pressure at 0·3 of the chord for the front spar and 0·5 of the chord for the rear spar). It probably often happens, therefore, that in British machines the real factor of safety is greater for rear than for front spars. The magnitude of the breaking load factor specified for the wings ranges from about 4 for large machines heavy on the controls to 6 or more for light, easily controlled machines.

Breaking load factors for the front and rear spars of various German machines with the position of centre of pressure at 0·3 and 0·5 of the chord respectively, are given in the figure on the line diagrams of the lift girders, the portion of the spar to which the factor applies being indicated. The least breaking load factor obtained for each machine is set out below :—

	Front spar. C.P. at ·3 chord.	Rear spar. C.P. at ·5 chord.
Albatros CIII. (two-seater) – – –	6·0	2·8
Aviatik ,, – – –	4·7	2·5
L.V.G. ,, – – –	3·3	2·9
Rumpler ,, – – –	4·6	2·5
Albatros Scout DI. (single-seater)– –	3·4	2·0
Halberstadt ,, – –	3·9	3·6

The magnitude of the factor is surprisingly small. It would seem that, if breakages of German machines in flight are not to be frequent, either they must be not so controllable as British machines, or German pilots must be very cautious in their handling of them, or that there are other factors, not taken account of in the calculations, tending materially to increase the strength of the wings.

The calculations were made in the usual manner, ignoring the strength added to the wing due to minor ribs and fabric, an addition which is not easily calculable, and is, moreover, small compared with the strength of the spars, and decreases with the life of the machine.

There is one point of difference which would appear to indicate a greater strength above the calculated strength in the German wings than in British wings. Comparison of the German wing sections with S.E.5 wing section shows the distance of the leading edge below the straight line through the spar centres to be greater (except in the case of the Albatros) for the German sections than for S.E.5 (R.A.F. 15) section. The effect of this, as regards bending under lift forces, will be, for a given size of nose piece, to add more to the stiffness of the leading portion of the wings than if the leading edge were on the line joining the spar centres ; the stiffness will be still more increased when the upper surface of the leading portion of the wing is covered with three-ply wood, as in the Albatros and Halberstadt machines. In these machines, however, the distance from the nose of the wing to the line joining the spar centres is much about the same

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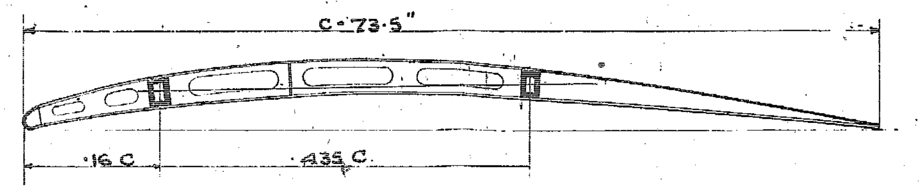
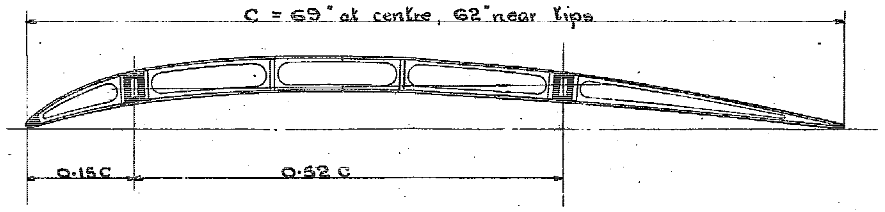
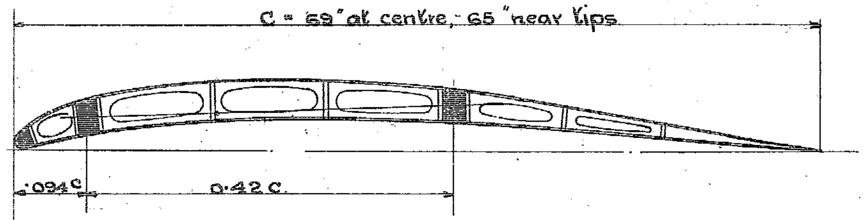
Machine	Weights fully loaded lbs.	Wing area sq. ft.	Spans Upper	Spans Lower	Stagger	Spar sections: Area (sq. ins.) Front	Spar sections: Area (sq. ins.) Rear	Spar sections: Lift modulus $(ins.)^3$ Front	Spar sections: Lift modulus $(ins.)^3$ Rear	Engines
Aviatik (2 seater) 1916. (see also l'Aérophile. Oct. 1916).	2840	430	41'-1"	35'-6"	none	2.8 (hollow) 4.4 (solid)	2.45 (hollow) 3.7 (solid)	1.52 (hollow) 1.8 (solid)	0.78 (hollow) 1.41 (solid)	170 H.P. Mercedes
L.V.G. (2 seater) 1916. (see also l'Aérophile Nov. 1916).	2850	404	42'-3"	37'-3"	none	3.3 (hollow) 4.4 (solid)	3.1 (hollow) 4.2 (solid)	1.8 (hollow) 2.02 (solid)	1.54 (hollow) 1.77 (solid)	Ditto.
Rumpler (2 Seater) 1916. (see also l'Aérophile. Dec. 1916.)	2780	382	40'-3"	36'-3"	none	4.7	4.8	2.14 (solid)	1.9 (solid)	Ditto.
Albatros C.III. (2 Seater) 1916. (see also l'Aérophile. Jan. 1917)	3000	407	38'-7"	36'-7"	none	3.8	4.35	1.75 (solid)	2.1 (solid)	Ditto.
Albatros (2 Seater) (British Number G.19, at the Agricultural Hall, Islington, June 1917)		446	41'-6"	37'-6"	none	2.6	4.26	1.68 (hollow)	2.6 (hollow)	Ditto.
Albatros Scout D.I. 1916. (at Farnborough June 1917). (see also l'Aérophile. Feb. 1917. & Flight. June 28th 1917)	2000 (?)	268	28'-3"	26'-5"	none	3.54 (assumed solid)	3.36	1.67 (solid)	1.34 (solid) 1.67 (with auxiliary spar)	Ditto.
Halberstadt Scout (at Farnborough June 1917) Particulars supplied by the R.A.F.	2000 (?)	252	29'-0"	27'-7"	25°	2.1 (solid) 1.1 (I section)	3.28 (solid) 1.66 (I section)	0.70 (solid) 0.56 (I sec).	1.06 (solid) 0.82 (I sec).	120 H.P. Argus.
S.E.5. 1917.	1950	251	28'-0"	28'-0"	23°	2.73	1.6	2.23 (I section)	1.17 (I sec)	H.P. 150-200 Hispano Suiza.

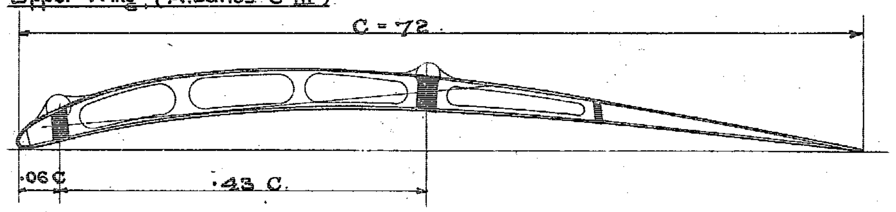
Wing Section. (Scale 1/10).

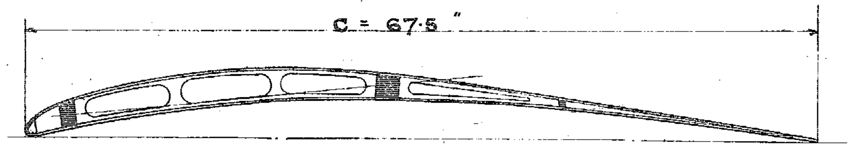




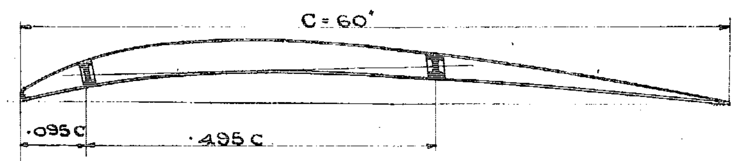


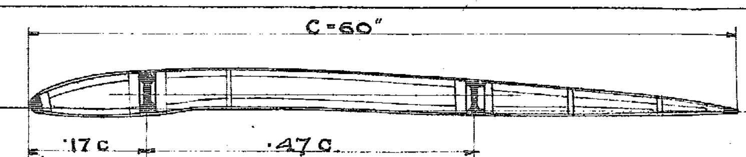
Upper Wing (Albatros C III)



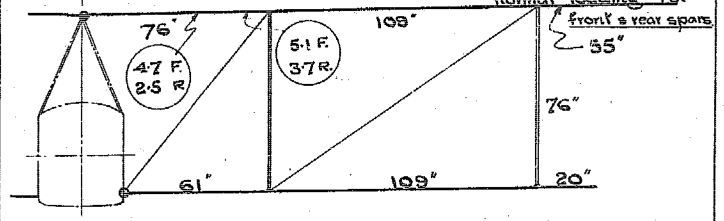


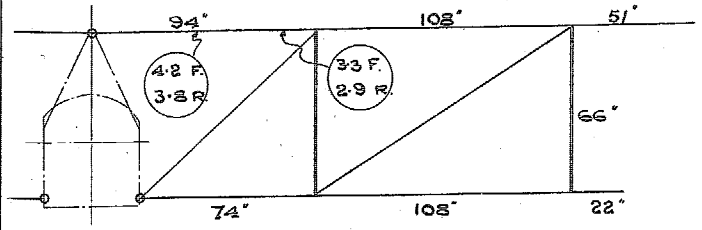
Lower Wing (Albatros C III).

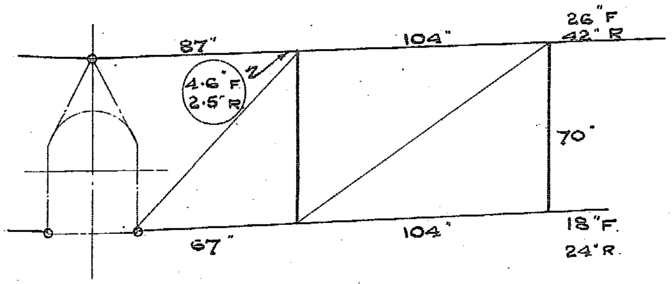


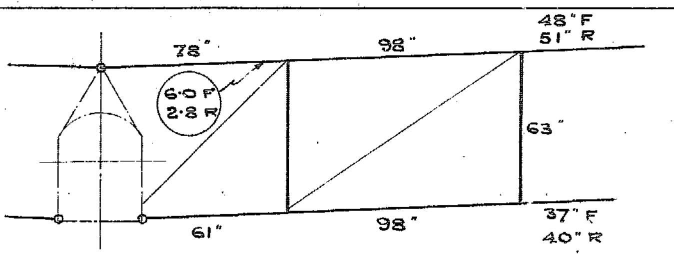


Lift Girder (Scale 1/50) Figs inside circles are breaking load factors for normal loading for front & rear spars

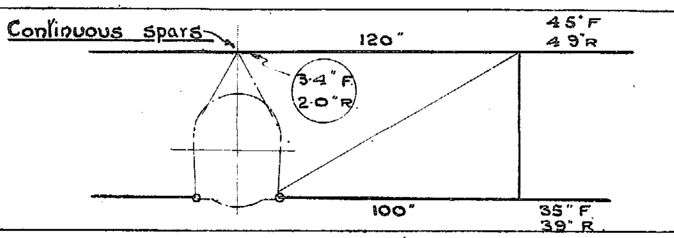


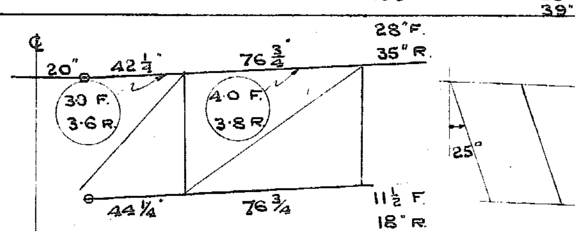


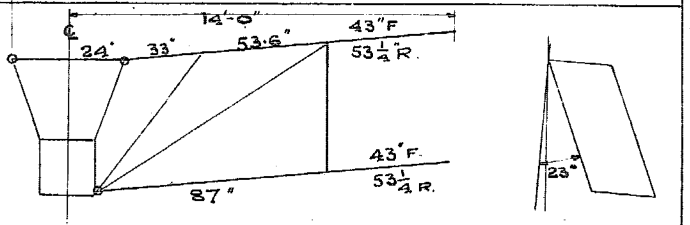




NOTE Small circles indicate pin joints in spars.







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as in S.E.5. It is not considered that any superiority the German wings may have as regards stiffness of the leading portion is of sufficient magnitude to affect the conclusion that the wing structure as a whole is not so strong as that of British machines. But the use of three-ply wood over the upper surface of the leading portion adds a considerable local strength and stiffness to the wing at a part where the effect of wear and tear is generally most marked.

It will be noticed that the breaking load factors for the rear spars of the German machines are, in general, much less than for the front spars. Whether or not this is in accordance with equality of factor of safety for the front and rear spars of the various machines cannot be definitely stated ; the probability is that for the larger machines at least it is right that the breaking load factor should be considerably less for rear than for front spars. As mentioned above, the requirements for British machines put the strength of the rear spar on the safe side in this respect.

The spars of German machines appear generally to be glued and bound with fabric. Some small increase in strength might be expected as a result, but no data as to its magnitude are available. The failing stress employed in working out the factors of safety for the spars was in all cases 5,500 lbs. per square inch.

The Albatros and Halberstadt machines, especially the former, have both spars located well forward, giving, with the three-ply wood over the nose, a stiff leading portion and a rather flexible trailing portion. This latter is, however, to some extent stiffened up in the Albatros machines by means of a light auxiliary spar running parallel to and behind the main spars, and forming (on the upper wing) the hinge attachment of the ailerons. The forward position of the spars would appear to be necessitated by the employment of a wing section whose trailing portion is so thin that the rear spar has to be placed not far behind the middle of the wing, in order that it may be of sufficient depth ; consequently the front spar is placed as far forward as possible so as to give the maximum distance between the spars, which is desirable from the point of view of obtaining a stiff drag girder.

As regards the drag girder, the drag struts are commonly made of circular steel tube extending from front to rear spars. It is considered that this form of construction has advantages from the point of view of durability over the built up construction, involving the use of three-ply wood, which is sometimes adopted.