TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 178

T R I P L A N E T E S T S.

By C. Wieselsberger.

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These experiments were carried out for the "Automobil und Aviatik A.G." (Automobile and Aircraft Company), of Leipzig, in order to determine the aerodynamic characteristics of various triplanes, which differed in the relative positions of the wings and, more especially, in the relative incidence of the wings (decalage), in the stagger, and in the shape of the wing sections.

The tests were restricted to such dispositions as appeared constructively adapted to the plan form considered. Four different sets of wings were used in these tests, three of which had the same cross-section but differed in aspect ratio and in area. The tips of all the wings were shaped as shown in Fig. 1. The mean span of the wings, which is always given in the present article, is expressed as the quotient of the wing area divided by the chord.

The dimensions of the wings were:

Wing 1: mean span $\frac{S}{c}$ = 106 cm (41.73 in.),
chord = c = 18.4 cm (7.24 in.) (wing-section 359);

Wing 2: mean span $\frac{S}{c}$ = 115 cm (45.28 in.),
chord = c = 15.2 cm (5.98 in.) (wing-section 359);

* From Technische Berichte, Volume III, No. 7, pp. 302-308. (22nd communication from the Göttingen Aerodynamical Institute.)

Wing 3: mean span $\frac{S}{c}$ = 99 cm (38.98 in.),
chord = c = 13.8 cm (5.04 in.) (wing-section 359);

Wing 4: mean span $\frac{S}{c}$ = 106 cm (41.73 in.),
chord = c = 13.4 cm (7.34 in.) (wing-section 368).

The two wing sections, 359 and 368, are shown in Fig. 2. In addition to the tests on the five triplanes, a comparative test was also made on a biplane having the same superficial area and chord as the triplanes. Its wing dimensions were:

Wing 5 - (upper wing): mean span $\frac{S}{c}$ = 106 cm (41.73 in.),
chord = c = 26.4 cm (10.39 in.) (wing-section 359);

Wing 6 - (lower wing): mean span $\frac{S}{c}$ = 98 cm (38.58 in.),
chord = c = 22 cm (8.66 in.) (wing-section 359).

The tests were made at an air velocity of about 30 m.p.s. (98.4 ft/sec.) in the large wind tunnel. The wings used for the triplane models were first tested as monoplanes, in order that the mutual influence of the wings could be determined, in case of need, by comparison with the triplane experiments. The results of the tests (Tables I to IV) are plotted as polar diagrams in Figs. 3 to 6. The triplane models were tested in five different arrangements: A, B_1, B_2, C, and C_2, as shown in Figs. 13 to 17, while Fig. 18 shows the biplane used for comparison. The corresponding polar diagrams and curves of moments (Tables V to X) are shown in Figs. 7 to 12. The angle of attack always refers to the chord of the upper wing and the moment to the foremost point of the chord. In order to facili-

tate the consideration of the stability relations, the resultant air forces are plotted in Figs. 13 to 18.

From an inspection of the results, arrangement B_1 appears to be the best as regards lift and drag. Arrangement B_2, which is produced by altering the decalage, is inferior to arrangement B_1 in efficiency, but, on the other hand, the line of action of the air forces varies less with the change of the angle of attack. There is a similar difference between arrangements C_1 and C_2, and also between B_1 and A.

By adopting a so-called "high-speed" wing section with the C arrangements, the most favorable aerodynamic range has been shifted toward small angles of attack. These arrangements are, therefore, suitable for a high-speed airplane, while A, B_1 and B_2 will find suitable application in an airplane which must, first of all, have good climbing ability.

The biplane with the same wing area and span as the triplane is, within the practical range, not so good aerodynamically as arrangement B_1, since it has a greater induced drag, on account of the unfavorable aspect ratio of the wings.

Table I - Wing 1.

Dynamic pressure $q = 56.9$ kg/m² (11.65 lb/sq.ft.)
$S = 1950$ cm² (302.2 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.9	-3388	1042	-30.6	9.39	-31.7	4.5	-8.3
-6.0	-1400	687	-12.6	6.21	-13.2	4.8	-0.7
-4.5	-43	527	-3.9	4.76	-7.6	4.7	5.8
-3.0	1538	411	13.9	3.71	13.7	4.4	12.0
-1.4	3050	326	27.6	2.94	27.4	3.7	16.9
-0.1	4156	279	37.6	2.53	37.6	2.5	20.5
1.3	5612	295	50.7	2.66	50.6	1.3	23.3
3.0	6814	350	61.6	3.17	61.6	0.0	26.4
4.3	7960	420	71.9	3.81	71.9	-1.9	28.8
5.7	9556	511	86.5	4.63	86.4	-4.4	31.0
8.6	11358	778	102.5	7.06	102.3	-9.2	38.0
11.6	13243	1084	119.5	9.87	118.8	-15.3	42.5
14.6	13806	1411	125.0	12.8	124.0	-20.0	42.7
17.6	13438	2027	121.2	18.3	121.3	-20.0	44.2

Table II - Wing 2.

Dynamic pressure $q = 56.7$ kg/m² (11.61 lb/sq.ft.)
$S = 1750$ cm² (271.25 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.9	-2628	975	-26.5	9.84	-27.7	5.6	-10.3
-5.9	-1698	690	-17.1	7.02	-17.5	5.2	-3.3
-4.5	-488	538	-4.9	5.43	-5.3	5.0	3.4
-3.0	1148	409	11.6	4.13	11.3	4.7	11.2
-1.6	2740	310	27.6	3.12	27.5	3.8	17.5
-0.1	4068	250	41.0	2.52	41.0	2.5	21.2
1.3	5255	249	53.0	2.52	53.0	1.1	24.3
2.8	6425	293	64.8	2.95	64.9	-0.4	27.6
4.3	7515	346	75.8	3.49	75.9	-2.5	30.6
5.7	8595	437	86.6	4.40	86.6	-4.7	33.6
8.6	10758	645	108.4	6.50	108.0	-10.5	39.7
11.6	12238	915	123.4	9.23	122.3	-15.6	43.2
14.6	12302	1368	124.0	13.8	123.2	-18.8	44.4

Table III - Wing 3.

Dynamic pressure q = 56 9 kg/m² (11.65 lb/sq.ft.)
S = 1330 cm² (195.3 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.9	-1927	726	-26.9	10.2	-28.0	5.8	-10.5
-6.0	-1350	512	-17.4	7.14	-18.1	5.3	-2.7
-4.5	-294	392	-4.1	5.47	-4.5	5.1	4.4
-3.0	895	295	12.5	4.12	12.3	4.8	12.4
-1.4	2093	218	29.2	3.04	29.2	3.8	18.5
-0.1	3057	173	42.7	2.41	42.7	2.5	22.1
1.4	3898	187	54.5	2.60	54.5	1.3	25.1
2.8	4755	215	66.5	3.00	66.6	-0.5	28.8
4.3	5600	266	78.0	3.72	78.4	-2.4	31.7
5.8	6415	316	89.5	4.42	89.5	-5.1	34.5
8.7	8010	481	112.0	6.71	111.5	-10.8	40.7
11.7	8910	673	124.5	9.48	123.7	-16.6	43.6
14.7	8880	967	124.0	13.5	123.3	-19.1	44.4

Table IV - Wing 4.

Dynamic pressure q = 56.9 kg/m² (11.65 lb/sq.ft.)
S = 1960 cm² (303.8 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.8	-5025	1079	-45.0	9.67	-45.9	2.6	-12.7
-5.9	-2838	482	-25.4	4.31	-25.6	1.6	0.4
-4.5	-417	196	-3.7	1.76	-3.8	1.5	4.8
-3.0	838	145	7.5	1.31	7.4	1.7	7.8
-1.4	2074	148	18.5	1.34	18.5	1.8	10.9
0.0	3220	170	28.8	1.52	28.8	1.5	13.4
1.4	4357	214	39.0	1.93	39.0	0.9	16.3
2.8	5600	275	50.0	2.50	50.3	-0.2	19.2
4.4	6812	347	60.3	3.08	61.2	-1.7	22.0
5.7	8015	443	71.7	3.97	71.9	-3.5	25.0
8.7	10158	695	90.9	6.23	90.3	-8.0	30.0
11.6	11608	1033	103.9	9.28	103.3	-12.6	33.8
14.6	11637	1694	104.4	15.2	104.3	-12.4	37.5

Table V - Triplane A

Dynamic pressure q = 56.8 kg/m² (11,63 lb/sq.ft.)
S = 4960 cm² (768.8 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.8	-5360	2481	-19.0	8.81	-20.1	5.9	-3.2
-5.9	-1845	1681	-6.5	5.96	-7.1	5.3	3.7
-4.5	355	1367	1.2	4.84	0.9	4.9	7.5
-3.1	2850	1098	10.0	3.89	9.8	4.3	11.9
-1.7	5175	950	18.3	3.36	18.2	3.7	15.1
-0.2	7180	855	25.4	3.03	25.4	2.8	18.2
1.2	9835	866	34.8	3.07	34.9	1.8	21.4
2.6	12205	958	43.4	3.40	43.4	0.8	24.5
4.0	14160	1090	50.2	3.86	50.5	-0.5	26.0
5.5	16235	1315	57.6	4.65	57.8	-1.9	28.2
8.3	20322	1920	72.1	6.80	73.0	-5.2	32.0
11.2	24348	2555	86.2	9.05	86.1	-9.8	34.6
14.1	28015	3538	99.7	12.5	99.0	-14.5	36.8
17.0	30888	4589	109.5	16.2	108.5	-19.3	38.0
20.0	31370	5797	111.2	20.5	110.0	-21.6	37.4

Table VI - Triplane B

Dynamic pressure q = 57.1 kg/m² (11.7 lb/sq.ft.)
S = 4960 cm² (768.8 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.8	-5836	2578	-20.5	9.06	-22.1	3.8	4.4
-5.9	-2210	1859	-7.8	6.52	-8.9	4.9	9.0
-4.5	198	1417	0.7	4.96	-0.1	5.0	10.3
-3.1	2730	1137	9.6	4.11	8.9	5.4	11.8
-1.7	5396	985	19.0	3.46	18.4	5.6	12.9
-0.3	7870	872	27.6	3.06	27.4	5.5	13.2
1.2	10193	877	35.9	3.08	35.6	5.3	13.3
2.6	12558	958	44.1	3.36	44.1	4.9	13.4
4.0	14650	1104	51.6	3.89	51.5	4.3	12.8
5.5	16548	1253	58.2	4.40	58.4	3.4	12.0
8.3	20880	1858	73.5	6.52	73.8	1.4	11.1
11.2	24825	2532	87.5	8.90	87.9	-1.8	7.9
14.1	28238	3302	99.2	11.6	99.9	-5.8	5.0
17.0	30610	4494	108.0	15.8	109.0	-9.0	6.2
20.0	31080	5736	109.3	20.2	111.0	-10.8	4.8

Table VII - Triplane B

Dynamic pressure q = 57.6 kg/m² (11.8 lb/sq.ft.)
S = 4960 cm² (768.8 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.9	-4925	2357	-17.4	8.33	-18.8	4.2	3.3
-6.0	-868	1690	-3.1	5.98	-4.1	5.4	6.3
-4.6	1615	1418	5.7	5.02	4.9	5.8	7.8
-3.1	4208	1204	14.9	4.25	14.3	6.0	8.8
-1.7	6700	1090	23.7	3.86	23.2	6.1	10.0
-0.3	9142	1053	32.3	3.73	32.1	6.0	10.4
1.2	10928	1047	38.6	3.71	38.5	5.4	10.9
2.6	13858	1066	49.1	3.78	49.0	4.6	9.3
4.0	15972	1305	56.5	4.62	56.5	4.1	9.7
5.4	17942	1520	63.5	5.39	63.6	3.2	8.9
8.3	22058	2128	78.1	7.55	78.5	0.7	7.6
11.2	25790	2896	91.1	10.2	91.8	-2.5	5.7
14.1	28460	3865	100.9	13.7	101.9	-5.8	5.8
17.0	30815	5006	109.1	17.7	111.1	-9.2	7.0
20.1	29375	6625	103.8	23.5	106.1	-9.0	7.7

Table VIII - Triplane C

Dynamic pressure q = 56.7 kg/m² (11.61 lb/sq.ft.)
S = 4970 cm² (770.3 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.8	-6925	2454	-24.6	8.70	-25.6	5.0	4.3
-5.9	-2528	1409	-9.0	5.00	-9.4	4.1	6.3
-4.5	-178	1072	-0.6	3.80	-0.9	3.8	7.0
-3.1	2060	915	7.3	3.24	7.2	3.6	8.8
-1.7	4642	801	16.5	2.84	16.4	3.1	9.9
-0.2	7180	776	25.5	2.75	25.5	2.5	10.8
1.2	9458	808	33.6	2.84	33.6	1.7	11.0
2.6	11665	890	41.4	3.16	41.7	0.6	11.0
4.0	13850	1031	49.2	3.62	49.3	-0.7	10.2
5.5	15798	1207	56.0	4.28	56.6	-2.1	9.3
8.4	19945	1743	70.8	6.19	70.9	-5.6	7.7
11.2	23860	2475	84.8	8.78	84.5	-9.7	5.7
14.1	27025	3594	95.9	12.8	95.6	-13.3	7.2
17.1	29000	5132	103.0	18.4	103.4	-15.2	9.1
20.1	28370	6654	100.7	23.6	102.3	-14.9	9.8

Table IX - Triplane C

Dynamic pressure q = 56.8 kg/m² (11.63 lb/sq.ft.)
S = 4970 cm² (770.3 sq.in.)

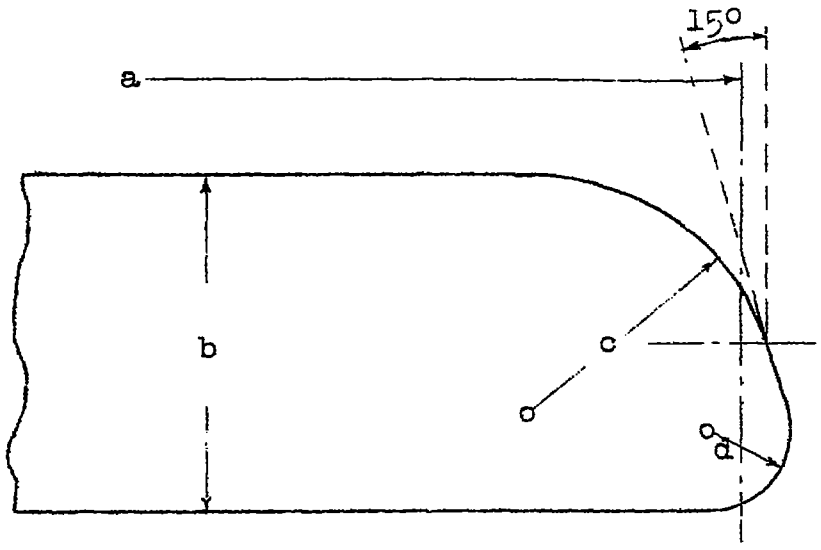
Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.3	-6788	2411	-24.1	8.55	-25.3	3.6	3.4
-5.9	-2688	1433	-9.5	5.09	-10.2	3.6	4.2
-4.5	-598	1316	-2.1	4.32	-2.6	4.0	5.3
-3.1	1800	1035	6.4	3.68	6.0	4.3	6.7
-1.7	4527	923	16.1	3.27	15.8	4.4	8.3
-0.2	7055	881	25.0	3.12	24.9	4.2	8.8
1.2	9405	908	33.4	3.22	33.3	3.8	9.2
2.6	11788	942	41.8	3.34	38.3	3.0	8.7
4.0	13792	1055	49.2	3.74	49.2	2.0	7.8
5.5	15890	1375	56.4	4.70	56.6	1.4	7.6
8.4	20064	1847	71.0	6.54	71.3	-1.6	5.4
11.2	23645	2562	83.9	9.00	84.0	-4.9	3.2
14.1	26802	3672	95.0	13.0	95.6	-7.8	5.2
17.1	28832	5357	102.4	19.0	103.7	-10.8	8.6
20.1	28468	6635	101.0	23.5	103.2	-11.5	7.1

Table X - Biplane D.

Dynamic pressure q = 57.0 kg/m² (11.67 lb/sq.ft.)
S = 4960 cm² (738.8 sq.in.)

Angle of attack	Lift L g	Drag D g	Coef.of lift C_L	Coef.of drag C_D	Coef.of normal force C_n	Coef.of tangential force C_t	Coef.of moment C_m
-8.8	-6625	2751	-23.3	9.70	-26.6	5.5	-2.7
-5.9	-3096	1904	-10.9	6.72	-11.6	6.0	3.4
-4.5	-970	1555	-3.4	5.48	-3.9	5.2	6.6
-3.0	1605	1257	9.1	4.43	6.0	4.8	9.7
-1.6	4590	1092	16.2	3.85	16.2	4.3	14.5
-0.2	6550	943	23.1	3.33	23.2	3.4	14.4
1.2	8840	879	31.2	3.11	32.4	2.4	15.9
2.6	11310	916	39.3	3.23	40.7	1.2	18.0
4.1	13330	1034	47.0	3.65	49.4	0.1	19.6
5.6	15400	1250	54.3	4.42	55.2	-1.3	19.7
8.4	19600	1793	69.2	6.35	70.0	-4.6	21.7
14.1	27400	3415	96.7	12.1	94.2	-13.5	23.5
17.0	30950	4316	109.0	15.2	109.0	-19.4	22.5
20.0	32750	5443	115.5	19.2	115.0	-23.6	21.8

Figs. 1 & 2



a=Mean span $\frac{S}{c}$

b=184 mm(7.24 in.)
c=132 " (5.20 ")
d= 44 " (1.73 ")

Fig. 1 Wing 1

Section 359

Section 368

Fig. 2

Figs. 3 & 4

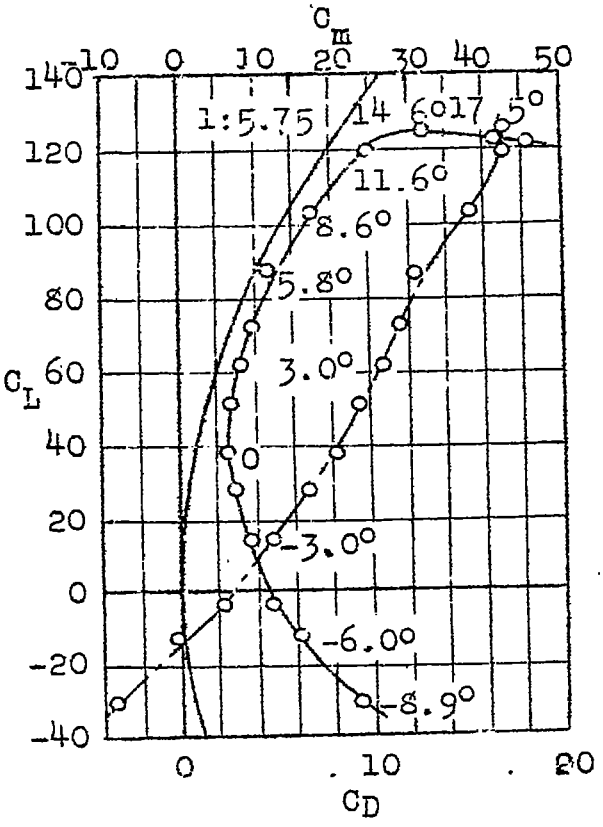


Fig. 3 Wing 1 Section 359

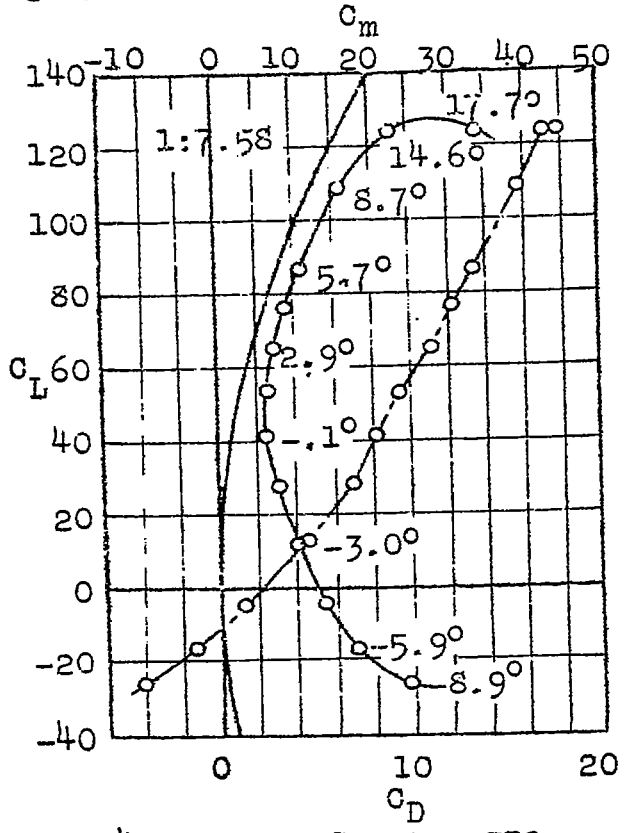


Fig. 4 Wing 2 Section 359

Figs. 5 & 6

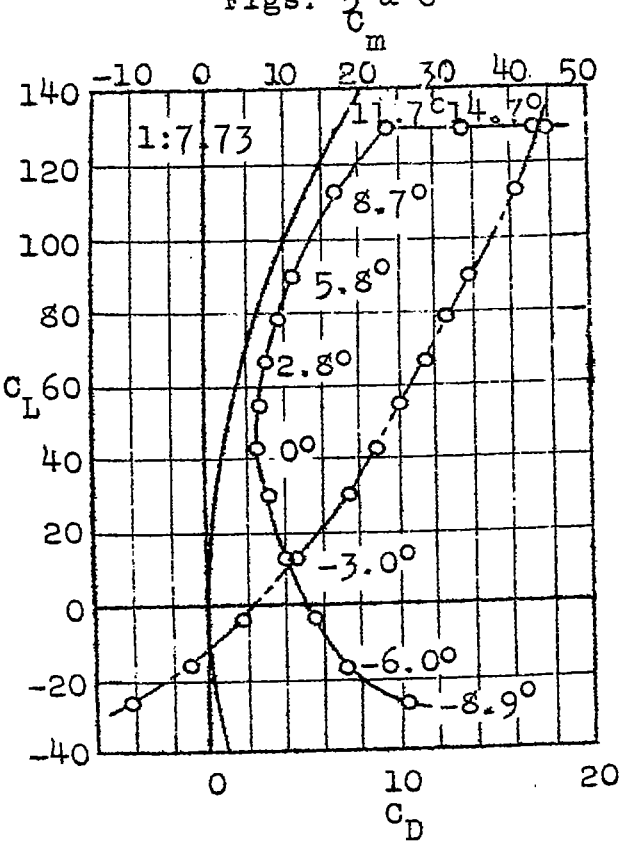


Fig. 5 Wing 3 Section 359

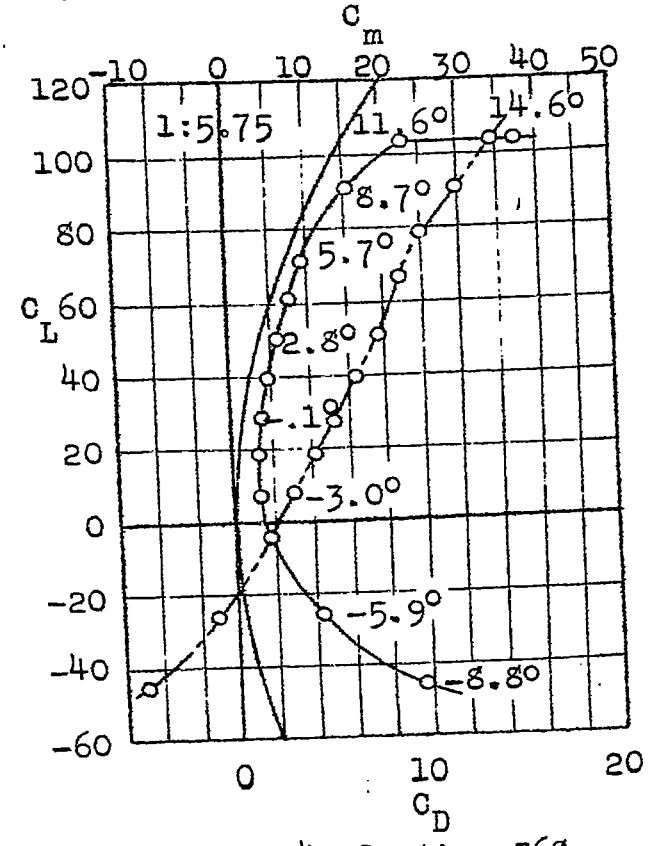


Fig. 6 Wing 4 Section 368

Figs. 7 & 8

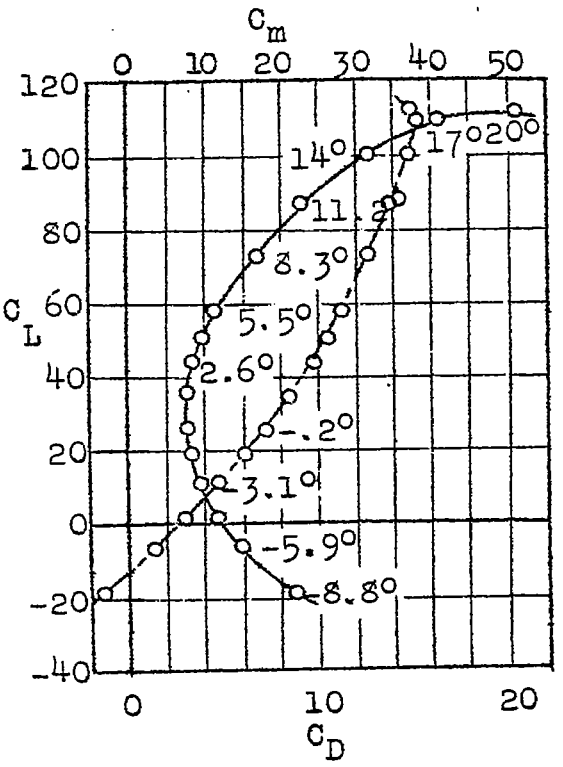


Fig. 7 Triplane A

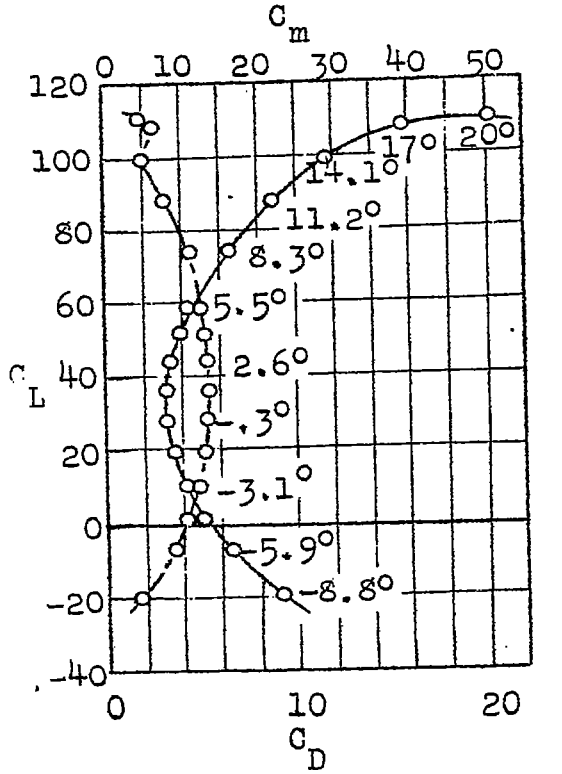


Fig. 8 Triplane B_1

Figs. 9 & 10

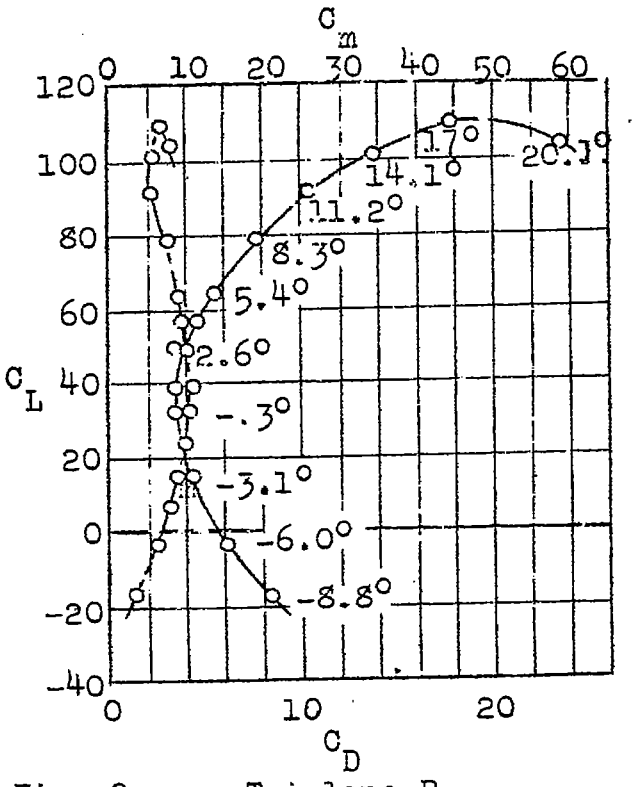


Fig. 9 Triplane B_2

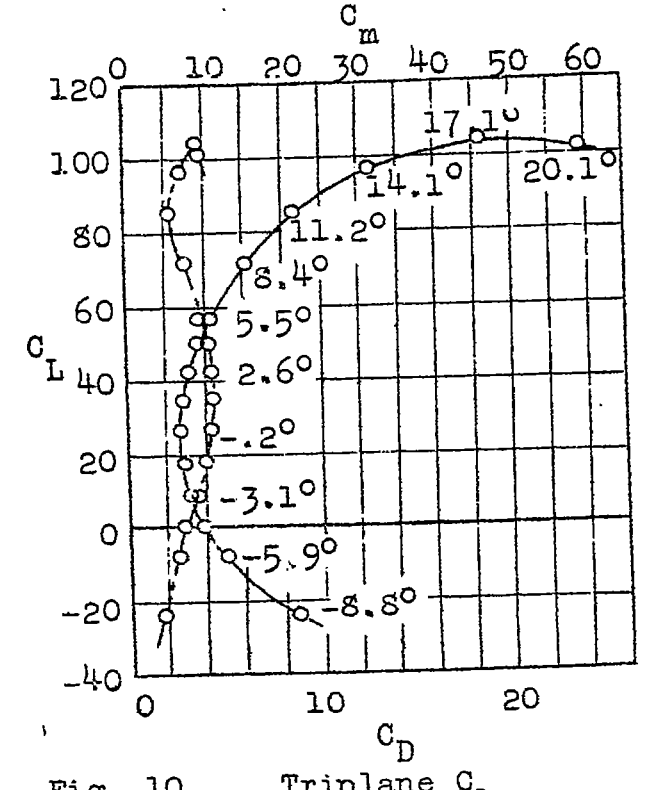


Fig. 10 Triplane C_1

Figs. 11 & 12

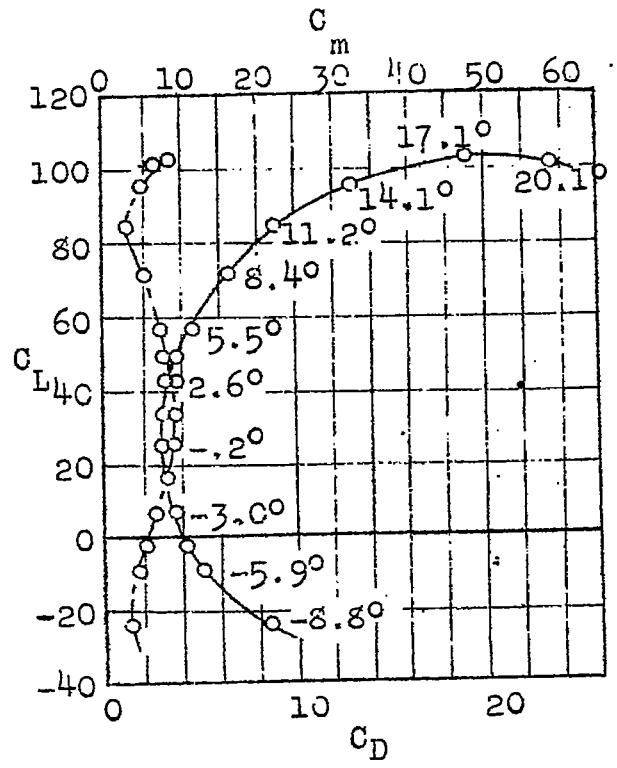


Fig. 11 Triplane C_2

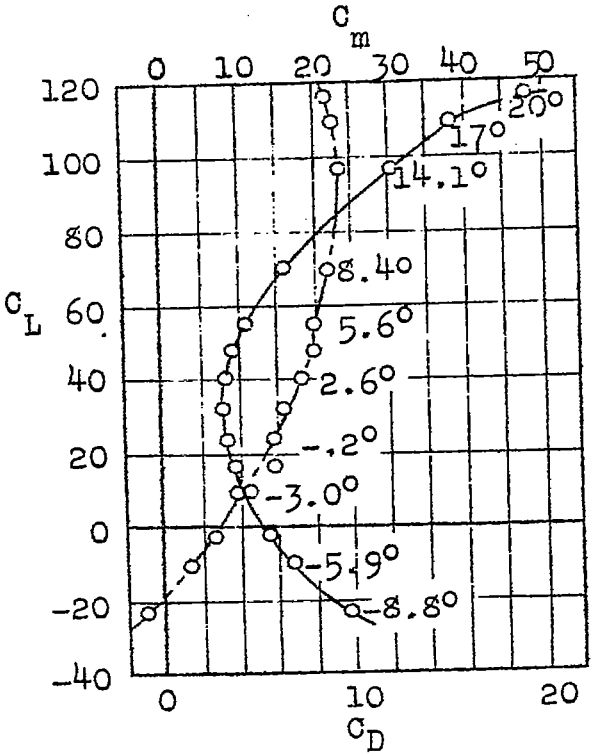
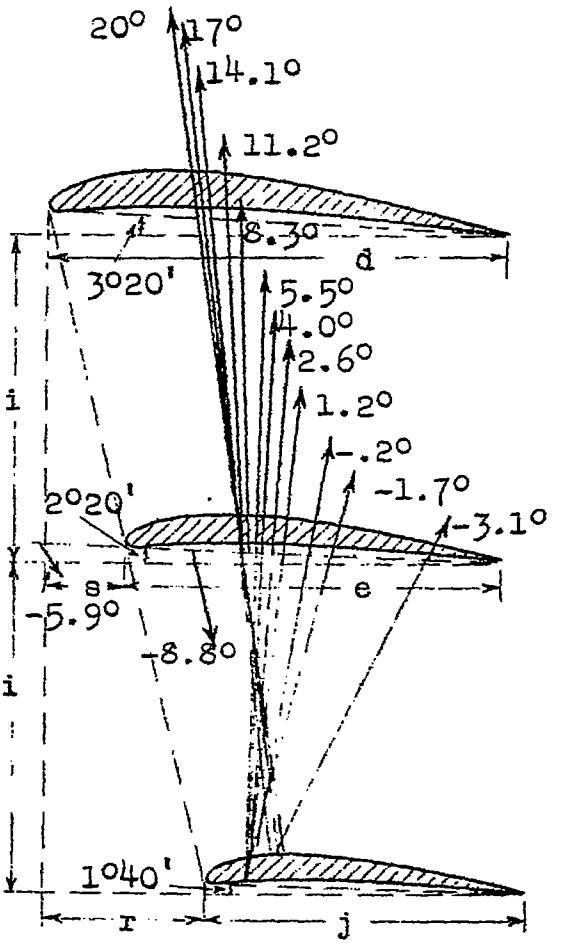


Fig. 12 Biplane for comparison

Fig. 13



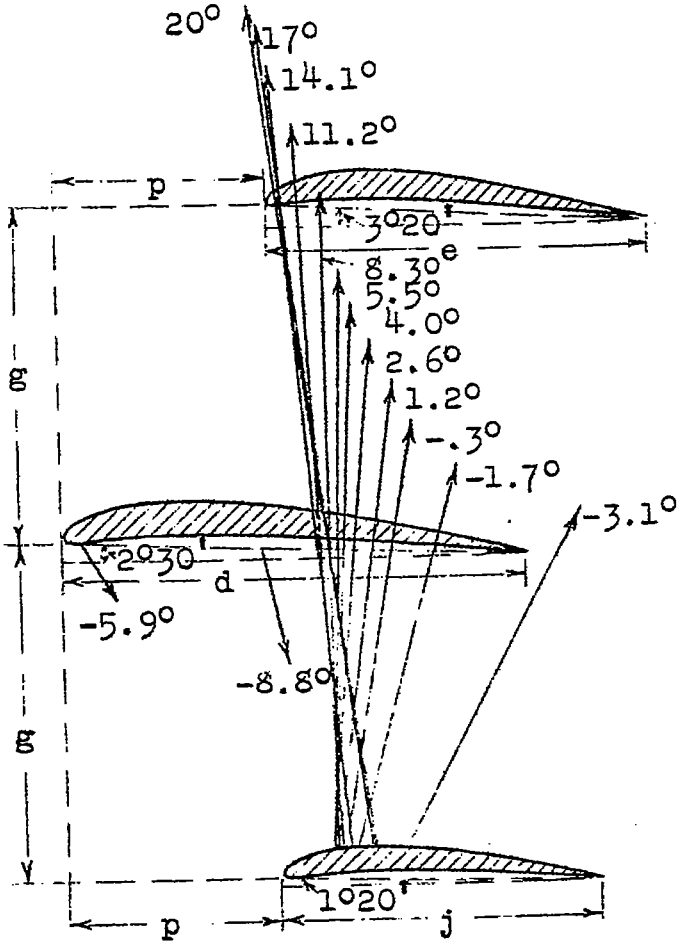
d=184 mm(7.24 in.)
i=135.5 mm(5.33 in.)
r= 64 mm(2.52 in.)

e=152 mm(5.98 in.)
j=128 " (5.04 ")
s= 31 " (1.22 ")

Upper wing: Span 106 cm(41.73 in.) Chord 18.4 cm(7.24 in.)
Middle " " 115 " (45.28 ") " 15.2 " (5.98 ")
Lower " " 99 " (38.98 ") " 12.8 " (5.04 ")
Total area 4960 cm^2(768.8 sq.in.)

Fig. 13 Triplane A

Fig. 14

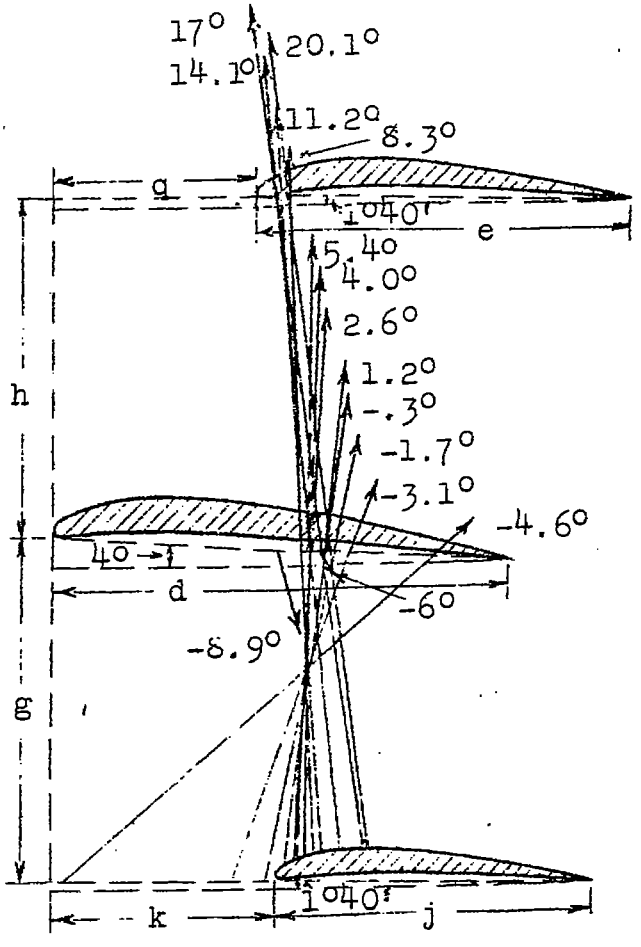


d=184 mm(7.24 in.) p=84 mm(3.31 in.) e=152 mm(5.98 in.)
g=140 " (5.51 ") j=128 " (5.04 ")

Upper wing: Span 115 cm(45.28 in.) Chord 15.2 cm(5.98 in.)
Middle " " 106 " (41.73 ") " 18.4 " (7.24 ")
Lower " " 99 " (38.98 ") " 12.8 " (5.04 ")
Total area 4960 cm^2(768.8 sq.in.)

Fig. 14 Triplane B_1

Fig. 15

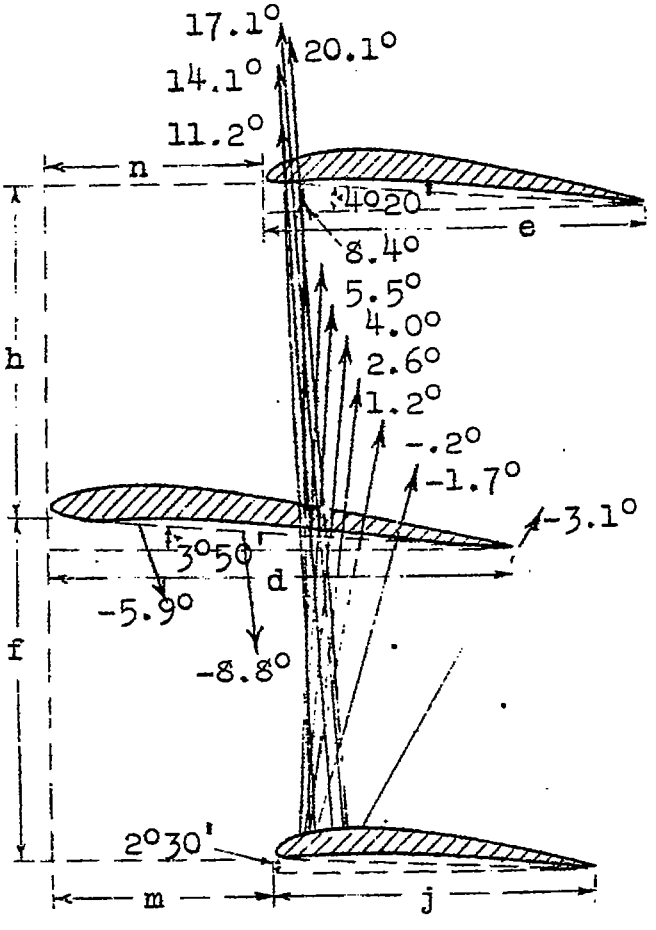


d=184 mm(7.24 in.) q=81 mm(3.19 in.) e=152 mm(5.98 in.)
g=140 " (5.51 ") h=137 " (5.39 ")
j=128 " (5.04 ") k= 89 " (3.50 ")

Upper wing: Span 115 cm(45.28 in.) Chord 15.2 cm(5.98 in.)
Middle " " 106 " (41.73 ") " 18.4 " (7.24 ")
Lower " " 99 " (38.98 ") " 12.8 " (5.04 ")
Total area 4960 cm^2(768.8 sq.in.)

Fig. 15 Triplane B_2

Fig. 16

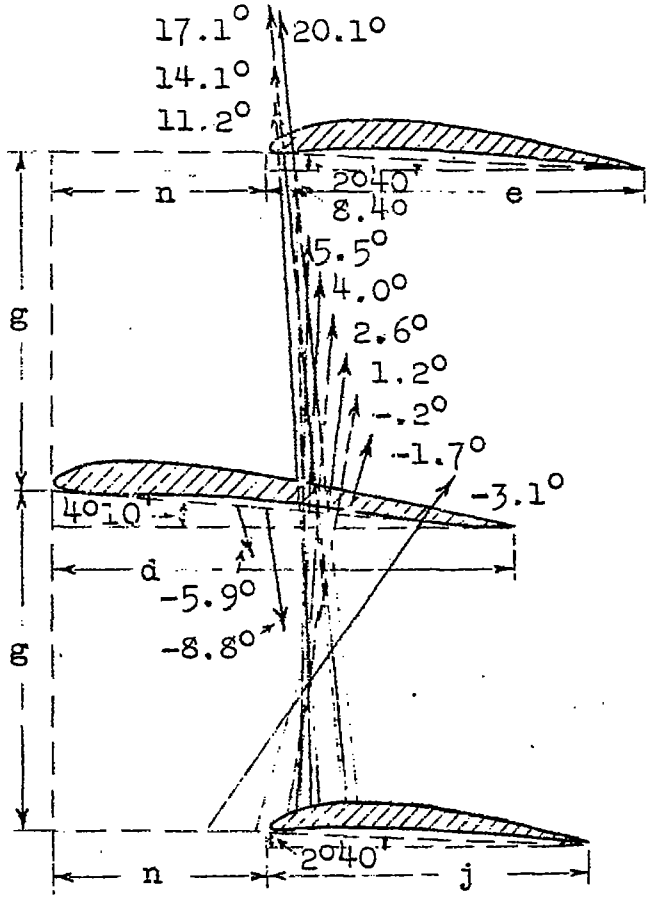


d=184 mm(7.24 in.) n=86 mm(3.39 in.) e=152 mm(5.98 in.)
f=141 " (5.55 ") h=137 " (5.39 ")
j=128 " (5.04 ") m= 88 " (3.46 ")

Upper wing: Span 115 cm(45.28 in.) Chord 15.2 cm(5.98 in.)
Middle " " 106 " (41.73 ") " 18.4 " (7.24 ")
Lower " " 99 " (38.98 ") " 12.8 " (5.04 ")
Total area 4970 cm^2(770.3 sq.in.)

Fig. 16 Triplane C_1

Fig. 17

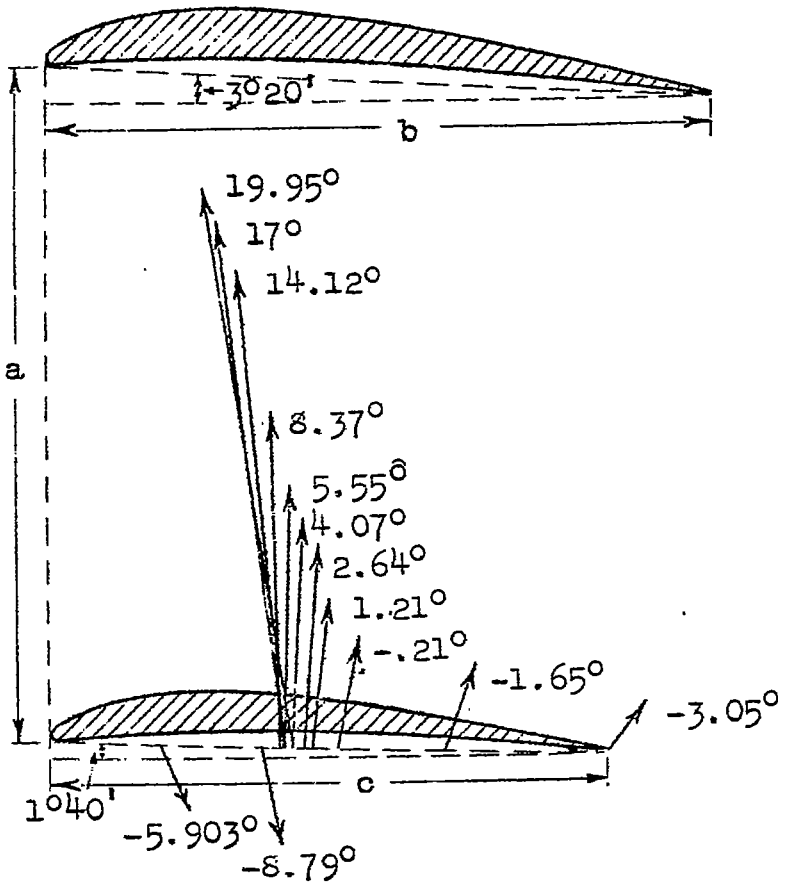


d=184 mm(7.24 in.) n=86 mm(3.39 in.) e=152 mm(5.98 in.)
g=140 " (5.51 ") j=128 " (5.04 ")

Upper wing: Span 115 cm(45.28 in.) Chord 15.2 cm(5.98 in.)
Middle " " 106 " (41.73 ") " 18.4 " (7.24 ")
Lower " " 99 " (38.98 ") " 12.8 " (5.04 ")
Total area 4970 cm^2(770.3 sq.in.)

Fig. 17 Triplane C_2

Fig. 18



a=278 mm(10.94 in.)c=220 mm(8.66 in.) b=264 mm(10.39 in.)

Upper wing: Span 106 cm(41.73 in.) Chord 26.4 cm(10.39 in.)
Lower " " 98 " (38.58 ") " 22.0 " (8.66 ")
Total area 4960 cm^2(768.8 sq.in.)

Fig. 18 Biplane D