NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 256

THE AIR FORCES ON A SYSTEMATIC SERIES OF BIPLANE AND TRIPLANE CELLULE MODELS

By MAX M. MUNK

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AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length	l	meter	m	foot (or mile)	ft. (or mi.)
Time	t	second	sec	second (or hour)	sec. (or hr.)
Force	F	weight of one kilogram	kg	weight of one pound	lb.
Power	P	kg/m/sec		horsepower	HP.
Speed		km/hr		mi./hr	M. P. H.
		m/sec		ft./sec	f. p. s.

2. GENERAL SYMBOLS, ETC.

W, Weight, $= mg$

g, Standard acceleration of gravity $= 9.80665$ m/sec.$^2 = 32.1740$ ft./sec.^{2}

m, Mass, $= \frac{W}{g}$

ρ, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m^{-4} sec.^{2}) at 15° C and 760 mm $= 0.002378$ (lb.-ft.$^{-4}$ sec.^{2}).

Specific weight of "standard" air, 1.2255 kg/m$^3 = 0.07651$ lb./ft.^{3}

mk^2, Moment of inertia (indicate axis of the radius of gyration, k, by proper subscript).

S, Area.

S_w, Wing area, etc.

G, Gap.

b, Span.

c, Chord length.

b/c, Aspect ratio.

f, Distance from $c.\ g.$ to elevator hinge.

μ, Coefficient of viscosity.

3. AERODYNAMICAL SYMBOLS

V, True air speed.

q, Dynamic (or impact) pressure $= \frac{1}{2} \rho V^2$

L, Lift, absolute coefficient $C_L = \frac{L}{qS}$

D, Drag, absolute coefficient $C_D = \frac{D}{qS}$

C, Cross-wind force, absolute coefficient $C_C = \frac{C}{qS}$

R, Resultant force. (Note that these coefficients are twice as large as the old coefficients L_C, D_C.)

i_w Angle of setting of wings (relative to thrust line).

i_t, Angle of stabilizer setting with reference to to thrust line.

γ, Dihedral angle.

$\rho \frac{Vl}{\mu}$, Reynolds Number, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, 0° C: 255,000 and at 15° C., 230,000;

or for a model of 10 cm chord 40 m/sec, corresponding numbers are 299,000 and 270,000.

C_p, Center of pressure coefficient (ratio of distance of $C.\ P.$ from leading edge to chord length).

β, Angle of stabilizer setting with reference to lower wing, $= (i_t - i_w)$.

α, Angle of attack.

ϵ, Angle of downwash.

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By MAX M. MUNK
Langley Memorial Aeronautical Laboratory

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

3341 NAVY BUILDING, WASHINGTON, D. C.

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REPORT No. 256

THE AIR FORCES ON A SYSTEMATIC SERIES OF BIPLANE AND TRIPLANE CELLULE MODELS

By MAX M. MUNK

SUMMARY

The air forces on the largest systematic series of biplane and triplane cellule models ever published, measured in the atmospheric density tunnel of the Langley Memorial Aeronautical Laboratory, are the subject of this report. The tests consist in the determination of the lift, drag, and moment of each individual airfoil in each cellule, mostly with the same wing section.

The magnitude of the gap and of the stagger is systematically varied; not, however, the decalage, which is zero throughout the tests. Certain check tests with a second wing section make the tests more complete, and the conclusions more convincing.

The results give evidence that the present Army and Navy specifications for the relative lifts of biplanes are good. They furnish material for improving such specifications for the relative lifts of triplanes. A larger number of factors can now be prescribed to take care of different cases.

INTRODUCTION

The investigation reported here grew out of the needs of the practice. The Bureau of Aeronautics, United States Navy Department, wanted fuller information on the share of each individual wing of a biplane and triplane cellule in the creation of the lift of the entire cellule. Not only the desired lifts but also the drag and moment of all individual wings were determined, since this could be done conveniently at the same time.

It was realized from the beginning that decalage, i. e., a difference between the angle of attack of the individual airfoils of a cellule has a major influence on the relative lift contribution of each airfoil. (Reference 1). However, the cellules anticipated for use in practice are without decalage, and it is this specialization which made the following investigation practical. Otherwise, the number of the variations would become too large, and the material presented would become too voluminous.

The method used is not novel, but is well known to most of the readers. The airfoil model, geometrically similar to an airplane airfoil, but having a rectangular plan form, is fastened to a system of balances, and is then exposed to the constant air flow of the wind tunnel. Additional airfoils are placed in the neighborhood of the airfoil undergoing the tests, so as to form the desired cellule together with this latter airfoil. These additional airfoils, however, are not in mechanical connection with the balances. The airfoil under test, by varying the position of the additional airfoil or airfoils, is thus made to play the part of any airfoil of any cellule of the series. In each case the angle of attack of the whole set of airfoils is changed by steps. The air velocity is kept constant for all tests.

The details of this interesting and important research will be found in the body of this report. The results are laid down in numerical tables, and are illustrated by diagrams attached to this report. They are further discussed to lead the reader's attention to the main features brought out.

This has, however, been restricted to the discussion of the relative lifts, i. e., of the ratio of the lift of each airfoil to the lift of the entire cellule. It is true that this report contains plenty of material suitable for elucidating other wing problems. However, the discussion of such more general questions should be extended to all material available; it should not be restricted to the following tests alone. Further, the question of the tunnel wall interference has not been entirely settled as this paper is closed. An investigation of this question of the wall influence is just under way at the Langley Memorial Aeronautical Laboratory, and the use of the material of this report on general questions referring to the wing drag is better delayed until this investigation is finished. All data given in this report are computed directly from the observations without any correction for wall effect. It is realized that there probably is a wall effect, but only a small one.

TESTS

The atmospheric density tunnel in which the tests were made, the auxiliary apparatus and the wire balance used for the tests, are described in detail in Reference 2.

The set-up was composed of rectangular airfoils measuring 4 by 24 in. (101.6 by 609.6 mm.) in plan. R. A. F. 15 wings were furnished by the Navy. They were made of bronze. Measured at two stations along the span, their ordinates showed a maximum departure of 0.003 in. (0.076 mm.) from the specified ones. U. S. A. T. S. 5 airfoils were constructed in the N. A. C. A. shops out of laminated maple and were exact up to 0.004 in. (0.102 mm). None of the airfoils had any measurable warp or twist. The specified ordinates for both profiles are given in Table 1.

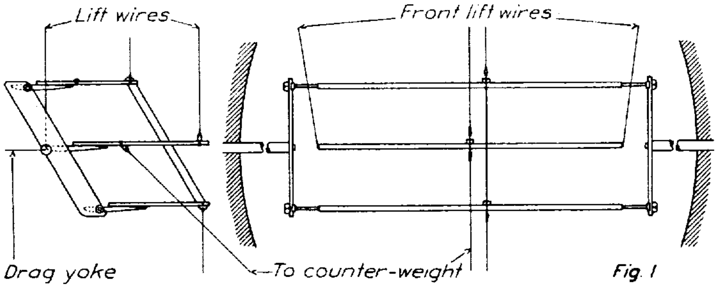

Fig. 1

Diagram showing arrangement and method of supporting wing model

The lift, drag, and pitching moment of each airfoil were measured. The air speed was 98.4 ft./sec. (30 m/sec.) throughout all tests, which corresponds to a dynamic pressure of 11.5 lb./sq. ft. (56.1 kg/m^2). It gives approximately the Reynolds Number, 206,000, with the chord as characteristic length.

The angle of attack was measured in the usual way. The absence of decalage was made certain by successively hanging an inclinometer on the wings after the wind tunnel flow was started and by adjusting the angle of attack of the fixed wing according to the readings of this inclinometer.

Supplemental tests were made to determine the wire drag and to obtain information about the interference of the side plates. This interference was found to be reasonably small.

All readings were made with the usual precision. The lift balance was read to ± 0.005 kg (0.011 lb.) exactness and could be consistently checked within an interval of that magnitude. Drags were read to 0.0001 kg (0.0002 lb.) and repeated observations disagreed by less than ±0.0003 kg (±0.0007 lb.) at minimum drag. Moments measured as forces at the end of a 30.48 cm (12 in.) arm were read exact to 0.001 kg (0.002 lb.); they could be checked within ±0.002 kg (±0.004 lb.) interval.

The angles of attack which appear in the data have not been corrected for elastic deflections. Such deflections gave rise to errors of the angle of attack up to as much as one-third degree. However, this occurred only in the neighborhood of the maximum lift, where the curve of lift coefficient versus angle of attack is relatively flat. The average error is much smaller and mostly less than 0.1°.

One single airfoil and the following 29 cellules were tested, all composed of rectangular airfoils with the aspect ratio 6.

Monoplane with R. A. F. 15 section

Biplanes with U. S. A. T. S. 5 section

Stagger	Gap/chord
30°	0. 9
0°	0. 9
+30	0. 9

Biplanes with R. A. F. 15 section

Stagger	Gap/chord
−30°	0. 6, 0. 9, 1. 2
0°	0. 6, 0. 8, 1. 0, 1. 2
+15°	0. 6, 0. 9, 1. 2
30°	0. 6, 0. 9, 1. 2

Triplanes with R. A. F. 15 section

Stagger	Gap/chord
30°	0. 6, 0. 9, 1. 2
0°	0. 6, 0. 8, 1. 0, 1. 2
+15°	0. 6, 0. 9, 1. 2
30°	0. 6, 0. 9, 1. 2

Lift, drag, and moment coefficients were calculated in the usual manner:

$$C_L = \frac{L}{qS} \qquad C_D = \frac{D}{qS} \qquad C_M = \frac{M}{qcS}$$

wherein:

L = Lift.
D = Drag.
M = Pitching moment.
M = Diving moment.
q = Dynamic pressure.
S = Wing area.
c = Wing chord.

Moment coefficients refer to the leading edges of the individual wings. They are counted negative when they are diving moments in accordance with the standards laid down in Reference 6. Within the investigated range of the angle of attack the pitching moment is generally negative. As most readers are accustomed to have positive values plotted, and as the pitching moment is counted opposite in many older publications here and abroad, the coefficient of diving moment—that is, $(-C_M)$—rather than the coefficient of pitching moment has been plotted in all diagrams.

RESULTS

The results of the biplane and triplane tests are given in Tables 2 to 41 and are illustrated by Figures 2 to 68.

In Table 2 are the lift and drag coefficients of a R. A. F. 15 airfoil as determined by tests with and without the supports for additional wings. Figure 2 contains the corresponding polar curves.

Tables 3 to 15 contain the lift, drag, and moment coefficients for each wing of the R. A. F. 15 biplane combinations for all angles of attack.

The results of the U. S. A. T. S. 5 biplane tests and the R. A. F. 15 triplane tests are presented in the same form and order in Tables 17 to 19 and 21 to 33.

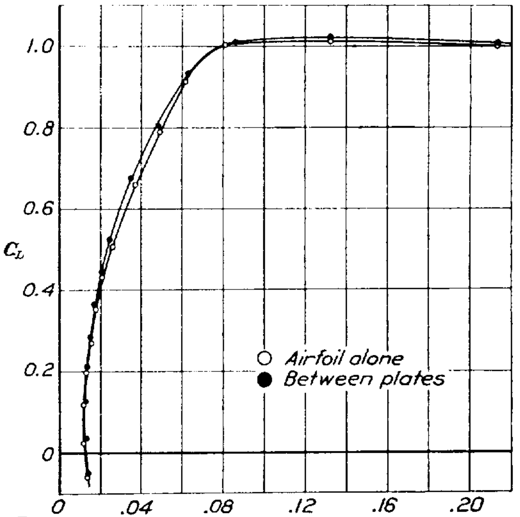

Fig. 2

Polar curve for single airfoil R. A. F. 15 measured alone and between supporting plates

Figures 3 to 15 contain the polar and moment curves of the individual wings of the R. A. F. 15 biplane cellules. Inserted into the same figures are the curves of individual lift coefficients, C_{LW}, versus cellule lift coefficient, C_{LC}. Figures 16 to 18 are the curves of relative lift versus stagger.

Figures 19 to 27 illustrate the results of the U. S. A. T. S. 5 biplane and Figures 23 to 38 those of the R. A. F. 15 triplane tests in a corresponding manner.

The relative lifts of the individual members of all the tested biplane and triplane cellules have been computed for 0.9, 0.5, and 0.25 of the maximum cellule lift coefficient. Tables 16, 20, and 34 contain the relative lifts for R. A. F. 15 biplane, U. S. A. T. S. 5 biplane, and R. A. F. 15 triplane models.

0.9 of the maximum lift coefficient is considered the upper limit of the lift coefficient for dangerous air loads occurring when the airplane is pulled out of a dive. 0.5 is considered the lower limit. The third value, 0.25 maximum lift coefficient, has been added to take care of extreme cases such as racers.

Figures 40 to 68 illustrate the positions of the centers of pressure of the individual wings plotted against the angle of attack of the cellule.

DISCUSSION

The results of the tests with all models show that there is a general tendency of the upper wing to contribute more of the lift than the lower at positive stagger and less at negative stagger. With negative lifts this is naturally reversed, since upper and lower refers primarily to the direction of the lift. This result was to be expected from theoretical considerations (Reference 3).

The variation of gap/chord causes small changes in the relative lifts at high lift coefficients and large changes at low lift coefficients. An increase of gap tends to equalize the lift of the wings over the entire range of the angle of attack. This includes also the lift contribution of the wing model of a triplane cellule. Nor does the change of the wing section of the biplane cellule upset this rule, which is natural and expected.

The middle wing of triplane cellules contributes less lift than either of the other two wings. As shown by Figures 36 to 38, it contributed less than one-third of the total lift in all tests.

The relative lift of any one airfoil may vary as much as 0.11, as the lift coefficient increases from 0.25 to 0.9 of the maximum lift coefficient. This occurred in an extreme case, with the R. A. F. biplane with −30° stagger and the gap/chord 0.6.

Figure 22 contains a curve of relative lifts at 0.9 maximum cellule lift, which for different staggers and for the U. S. A. T. S. 5 section almost coincides with the corresponding curve for the R. A. F. 15 biplane. The difference between corresponding ordinates does not exceed 2½ per cent. At lower lift coefficients the differences become larger, but do not exceed 7 per cent at 0.25 maximum cellule lift. It was, therefore, considered unnecessary to repeat the investigation of the effect of different gaps with the U. S. A. T. S. 5 section.

At large lift coefficients the two biplane wings have about equal lifts at −15° stagger.

The results of the center of pressure computations show that the ratio of gap to chord has practically no effect on the positions of the centers of pressure of the individual wings in either the biplane or triplane combinations, at normal angles of attack of flight. With increase of positive stagger in biplane cellules the centers of pressure move forward on the upper wing and backward on the lower wing, and lie nearly together at 0° stagger. In the triplane cellules there is a forward motion on the upper and middle wings and a backward motion on the lower wing with the positions nearly coincident at 0° stagger.

CONCLUSIONS

The United States Army and Navy standard relative lifts for biplanes (References 4 and 5) are plotted for comparison in Figure 39. It will be seen that the agreement is very good at high lift coefficients. In the light of the described tests the specifications appear therefore to be good.

The present Army specification for the distribution of lift in triplane cellules is illustrated in Figures 36 to 38, and plotted together with the results of the foregoing tests. The study of these figures suggests the drafting of more specialized standards for triplanes. The effects of different stagger and gap/chord ratio should be taken into account, and triplanes of different speed ranges require different specifications.

REFERENCES

1. Munk, Max M.: Beitrag zur Aerodynamik der Flugzeugtragorgane. Technische Berichte, Vol. II, No. 2, 1918.
2. Reid, E. G.: Standardization Tests of N. A. C. A. No. 1 Wind Tunnel. N. A. C. A. Technical Report No. 195, 1924.
3. Munk, Max M.: General Biplane Theory. N. A. C. A. Technical Report No. 151, 1922.
4. Engineering Division United States Army Air Service: Handbook of Instructions for Airplane Designers, fourth edition, April, 1925. Section II, Figure 1.
5. Diehl, W. S.: The Relative Loading of Biplane Wings. Bureau of Aeronautics, United States Navy Department Technical Note No. 86, 1921.
6. National Advisory Committee for Aeronautics: Nomenclature for Aeronautics. N. A. C. A. Technical Report No. 25, 1919.

FURTHER LITERATURE ON THE SUBJECT

Pannell, J. R., and Griffiths, E. A.: Experiments on Models of Biplane Wings. British Advisory Committee for Aeronautics R. and M. No. 196, 1915.

Bryant, L. W., and Jones, Miss C. N.: Biplane Effect on R. A. F. 15 Wing Section. British Advisory Committee for Aeronautics R. and M. No. 366, 1917.

Cowley, W. L., and Levy, H.: Triplane Investigation with R. A. F. 15 Section. British Advisory Commitee for Aeronautics R. and M. No. 432, 1918.

Cowley, W. L., and Levy, H.: The Contribution of the Separate Planes to the Forces on a Biplane. British Advisory Committee for Aeronautics R. and M. No. 589, 1919.

Cowley, W. L., and Lock, C. N. H.: Biplane Investigation with R. A. F. 15 Section. British Advisory Committee for Aeronautics R. and M. No. 774, 1921.

Cowley, W. L., and Jones, L. J.: Biplane Investigation with R. A. F. 15 Section, Part II. British Advisory Committee for Aeronautics R. and M. No. 857, 1922.

Cowley, W. L., Gadd, A. G., Jones, J. L., and Skan, Miss S. W.: Biplane Investigation with R. A. F. 15 Section, Part III. British Advisory Committee for Aeronautics R. and M. No. 872, 1923.

Toussaint, A.: Etudes Systematiques sur les Biplanes. Service Technique de l'Aeronautique, March, 1923.

TABLE 1

R. A. F. 15 Airfoil ordinates

Station in inches from leading edge	Upper surface	Lower surface
Inch	*Inch*	*Inch*
0.000	+0.060	+0.060
.020	.091	.039
.040	.111	.033
.080	.144	.024
.200	.202	.009
.358	.237	.000
.400	.241	+.001
.600	.266	.012
.800	.278	.021
1.000	.280	.032
1.200	.277	.041
1.400	.273	.043
1.600	.265	.041
2.000	.244	.027
2.400	.219	.013
2.800	.191	.002
2.980	.177	.000
3.200	.158	+.002
3.600	.115	.008
3.800	.088	.013
3.920	.069	.017
4.000	.032	.032

U. S. A. T. S. 5 Airfoil ordinates

Station in inches from leading edge	Upper surface	Lower surface
Inches	*Inch*	*Inch*
0.00	+0.080	+0.080
.05	.176	.000
.10	.220	−.032
.20	.296	−.072
.30	.352	−.100
.40	.400	−.120
.60	.472	−.136
.80	.524	−.140
1.20	.588	−.116
1.60	.592	−.060
2.00	.556	−.026
2.40	.492	−.012
2.80	.412	−.008
3.20	.312	−.004
3.60	.196	.000
3.80	.132	.000
4.00	.040	+.040

TABLE 2

R. A. F. 15 Airfoil—interference tests

	Airfoil alone		Between plates	
α	C_L	C_D	C_L	C_D
Degrees				
−3	−0.063	+0.0140	−0.052	+0.0141
−2	+0.022	.0121	+0.034	.0129
−1	.116	.0120	.126	.0124
0	.199	.0132	.210	.0135
+1	.270	.0157	.282	.0151
2	.352	.0178	.366	.0167
3	.432	.0203	.443	.0201
4	.506	.0261	.522	.0242
6	.659	.0370	.673	.0345
8	.790	.0490	.805	.0481
10	.915	.0617	.934	.0627
12	1.00	.0807	1.01	.0856
14	1.01	.133	1.02	.132
16	1.00	.213	1.01	.213

TABLE 3

R. A. F. 15 biplane. $G/c=0.6$. Stagger $=-30°$

α	Upper wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−4	−0.121	+0.0334	−0.015	......	......	......
−3	......	......	......	−0.058	+0.0166	−0.025
−2	......	......	......	+.002	.0167	−.045
−1	......	......	......	.090	.0157	−.065
0	......	......	......	.173	.0159	−.089
+1	......	......	......	.234	.0177	−.105
2	......	......	......	.300	.0196	−.122
3	+.224	.0199	−.089	.357	.0215	−.134
4	.278	.0256	−.096	.414	.0244	−.141
6	.396	.0347	−.129	.523	.0307	−.167
8	.504	.0524	−.161	.631	.0408	−.192
10	.606	.0710	−.182	.736	.0485	−.202
12	.711	.0898	−.195	.817	.0636	−.227
14	.810	.0952	−.200	.844	.111	−.268
16	.807	.0934	−.150	.838	.193	−.286

TABLE 4

R. A. F. 15 biplane. $G/c=0.9$. Stagger $=-30°$

α	Upper wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.072	+0.0149	−0.002	−0.084	+0.0173	−0.015
−2	−.009	.0130	−.021	−.010	.0167	−.035
−1	+.055	.0118	−.042	+.076	.0142	−.057
0	.118	.0127	−.072	.165	.0143	−.085
+1	.169	.0149	−.089	.230	.0157	−.104
2	.214	.0175	−.091	.294	.0174	−.118
3	.265	.0208	−.097	.368	.0201	−.132
4	.327	.0251	−.117	.427	.0228	−.148
6	.449	.0384	−.150	.558	.0299	−.171
8	.536	.0572	−.183	.679	.0421	−.194
10	.667	.0767	−.199	.796	.0510	−.224
12	.787	.0962	−.230	.865	.0669	−.250
14	.913	.109	−.245	.864	.108	−.269
16	.950	.130	−.256	.832	......	......
18	.891	.153	−.270	......	......	......

TABLE 5

R. A. F. 15 biplane. $G/c=1.2$. Stagger $=-30°$

α	Upper wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.058	+0.0151	−0.013	−0.092	+0.0168	−0.008
−2	.000	.0139	−.034	−.018	.0164	−.029
−1	+.084	.0125	−.053	+.070	.0144	−.056
0	.144	.0139	−.080	.163	.0149	−.078
+1	.197	.0161	−.095	.229	.0170	−.100
2	.246	.0191	−.101	.297	.0186	−.112
3	.307	.0225	−.112	.374	.0213	−.135
4	.367	.0275	−.136	.442	.0242	−.148
6	.486	.0410	−.160	.573	.0323	−.174
8	.600	.0598	−.190	.706	.0446	−.211
10	.714	.0810	−.215	.814	.0549	−.222
12	.843	.100	−.249	.897	.0710	−.253
14	.970	.118	−.280	.888	.112	−.283
16	.975	.148	−.284	.850	......	......

TABLE 6

R. A. F. 15 biplane. $G/c=0.6$. Stagger $=0°$

α	Upper wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.066	+0.0169	0.000	+0.003	+0.0140	−0.039
−2	−.001	.0140	−.025	.065	.0132	−.061
−1	+.067	.0116	−.047	.096	.0131	−.085
0	.126	.0116	−.053	.146	.0150	−.091
+1	.183	.0115	−.073	.194	.0175	−.097
2	.254	.0129	−.084	.234	.0198	−.118
3	.314	.0152	−.112	.290	.0232	−.129
4	.373	.0185	−.118	.335	.0273	−.137
6	.488	.0244	−.125	.433	.0374	−.149
8	.605	.0395	−.161	.532	.0506	−.177
10	.730	.0532	−.190	.620	.0623	−.192
12	.838	.0669	−.223	.700	.0741	−.214
14	.912	.0834	−.230	.765	.0983	−.238
16	.911	.173	−.218	.799	.178	−.282

TABLE 7

R. A. F. 15 biplane. $G/c=0.8$. Stagger $=0°$

α	Upper wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.055	+0.0161	−0.012	−0.040	+0.0137	−0.026
−2	−.018	.0139	−.024	+.002	.0125	−.047
−1	+.056	.0120	−.060	.059	.0118	−.061
0	.115	.0121	−.075	.112	.0129	−.086
+1	.160	.0130	−.080	.162	.0150	−.097
2	.236	.0144	−.098	.208	.0171	−.112
3	.299	.0174	−.117	.264	.0201	−.126
4	.350	.0208	−.128	.320	.0240	−.128
6	.472	.0308	−.155	.422	.0340	−.154
8	.606	.0460	−.199	.527	.0473	−.186
10	.731	.0625	−.214	.621	.0590	−.211
12	.845	.0776	−.236	.706	.0680	−.221
14	.931	.102	−.264	.756	.0975	−.242
16	.942	.142	−.269	.796	.173	−.283

TABLE 8

R. A. F. 15 biplane. $G/c=1.0$. Stagger $=0°$

α	Upper wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.061	+0.0130	−0.015	−0.060	+0.0143	−0.027
−2	−.006	.0104	−.033	−.001	.0120	−.049
−1	+.063	.0090	−.055	+.064	.0113	−.069
0	.129	.0095	−.071	.129	.0125	−.087
+1	.182	.0105	−.089	.177	.0145	−.101
2	.248	.0120	−.103	.231	.0167	−.115
3	.319	.0153	−.122	.293	.0197	−.121
4	.380	.0213	−.140	.355	.0238	−.140
6	.509	.0326	−.166	.465	.0342	−.164
8	.639	.0487	−.191	.567	.0465	−.186
10	.770	.0655	−.210	.672	.0583	−.208
12	.889	.0815	−.225	.757	.0686	−.227
14	.968	.109	−.262	.808	.101	−.250
16	.988	.161	−.311	.833	.170	−.281

TABLE 9

R. A. F. 15 biplane. $G/c=1.2$. Stagger=0°

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.066	+0.0147	−0.015	−0.055	+0.0148	−0.016
−2	−.001	.0121	−.033	+.015	.0132	−.041
−1	+.074	.0107	−.064	.080	.0118	−.066
0	.144	.0113	−.076	.149	.0126	−.082
+1	.197	.0128	−.084	.203	.0148	−.094
2	.267	.0148	−.111	.257	.0163	−.105
3	.333	.0180	−.121	.325	.0193	−.122
4	.402	.0225	−.139	.378	.0233	−.135
6	.531	.0342	−.175	.501	.0335	−.165
8	.666	.0504	−.206	.620	.0471	−.191
10	.786	.0675	−.232	.730	.0597	−.207
12	.897	.0837	−.261	.815	.0705	−.235
14				.860	.105	−.258
16				.874	.178	−.298

TABLE 10

R. A. F. 15 biplane. $G/c=0.6$. Stagger=+15°

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.057	+0.0180	0.000	+0.017	+0.0119	−0.038
−2	+.013	.0158	−.025	.085	.0117	−.060
−1	.096	.0142	−.049	.137	.0125	−.078
0	.159	.0133	−.070	.178	.0136	−.090
+1	.226	.0117	−.079	.213	.0154	−.091
2	.289	.0125	−.107	.257	.0177	−.106
3	.354	.0152	−.108	.312	.0213	−.120
4	.419	.0181	−.120	.366	.0269	−.131
6	.552	.0274	−.151	.462	.0398	−.150
8	.688	.0396	−.184	.554	.0546	−.192
10	.807	.0520	−.206	.654	.0702	−.206
12	.916	.0656	−.218	.737	.0833	−.235
14	.952	.0914	−.242	.803	.100	−.248
16	.901	.129	−.245	.877	.145	−.272

TABLE 11

R. A. F. 15 biplane. $G/c=0.9$. Stagger=+15°

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.052	+0.0150	−0.003	−0.034	+0.0144	−0.023
−2	+.024	.0138	−.030	+.038	.0130	−.044
−1	.108	.0135	−.053	.103	.0128	−.065
0	.178	.0136	−.074	.160	.0139	−.074
+1	.238	.0137	−.094	.209	.0157	−.091
2	.307	.0152	−.099	.257	.0181	−.097
3	.379	.0177	−.121	.316	.0207	−.116
4	.450	.0205	−.133	.374	.0254	−.129
6	.584	.0304	−.162	.480	.0380	−.160
8	.717	.0440	−.189	.588	.0527	−.182
10	.865	.0622	−.220	.681	.0680	−.211
12	.970	.0783	−.251	.775	.0813	−.229
14	1.04	.108	−.270	.861	.100	−.248
16	1.01	.147	−.293	.923	.144	−.263

TABLE 12

R. A. F. 15 biplane. $G/c=1.2$. Stagger=+15°

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.055	+0.0174	−0.012	−0.043	+0.0150	−0.012
−2	+.021	.0161	−.033	+.032	.0144	−.033
−1	.110	.0159	−.063	.102	.0143	−.055
0	.191	.0170	−.093	.164	.0159	−.082
+1	.249	.0173	−.105	.220	.0176	−.094
2	.326	.0180	−.120	.270	.0192	−.103
3	.400	.0206	−.132	.339	.0221	−.124
4	.468	.0245	−.145	.395	.0260	−.140
6	.609	.0356	−.175	.502	.0373	−.160
8	.751	.0503	−.212	.623	.0525	−.181
10	.896	.0693	−.241	.711	.0695	−.221
12	1.01	.0874	−.278	.811	.0833	−.241
14	1.05	.122	−.303	.908	.107	−.250
16	1.03	.178	−.334	.960	.149	−.291

TABLE 13

R. A. F. 15 biplane. $G/c=0.6$. Stagger=+30°

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.020	+0.0162	−0.020	+0.016	+0.0123	−0.036
−2	+.057	.0153	−.041	.075	.0125	−.060
−1	.145	.0145	−.067	.116	.0134	−.061
0	.216	.0152	−.079	.152	.0163	−.084
+1	.295	.0156	−.103	.192	.0193	−.082
2	.364	.0174	−.116	.231	.0231	−.099
3	.438	.0192	−.130	.276	.0260	−.100
4	.500	.0221	−.144	.329	.0309	−.117
6	.639	.0298	−.176	.423	.0446	−.143
8	.787	.0428	−.208	.510	.0615	−.167
10	.912	.0552	−.234	.602	.0778	−.191
12	.997	.0779	−.228	.686	.0936	−.212
14	1.00	.124	−.291	.783	.115	−.238
16	.951		−.292	.906	.157	−.279

TABLE 14

R. A. F. 15 biplane. $G/c=0.9$. Stagger=+30°

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.052	+0.0156	−0.013	−0.028	+0.0132	−0.030
−2	+.028	.0161	−.027	+.041	.0128	−.047
−1	.120	.0158	−.058	.093	.0125	−.063
0	.208	.0166	−.099	.147	.0144	−.071
+1	.272	.0177	−.098	.202	.0168	−.087
2	.351	.0197	−.132	.241	.0197	−.094
3	.422	.0220	−.139	.300	.0228	−.109
4	.499	.0262	−.158	.353	.0280	−.120
6	.640	.0359	−.197	.452	.0412	−.154
8	.794	.0511	−.236	.556	.0572	−.185
10	.898	.0658	−.234	.662	.0748	−.200
12	1.03	.0832	−.248	.756	.0900	−.230
14	1.08	.130	−.312	.862	.110	−.256
16	1.05	.215	−.356	.964	.144	−.294

TABLE 15

R. A. F. 15 biplane. $G/c=1.2$. Stagger $=+30°$

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−3	−0.055	+0.0147	−0.016	−0.040	0.0152	−0.009
−2	+.032	.0149	−.048	+.032	.0157	−.044
−1	.122	.0145	−.071	.090	.0153	−.062
0	.214	.0153	−.095	.152	.0167	−.080
+1	.275	.0165	−.105	.213	.0189	−.092
2	.358	.0186	−.134	.257	.0219	−.103
3	.434	.0214	−.142	.320	.0251	−.117
4	.505	.0249	−.167	.374	.0297	−.137
6	.659	.0356	−.199	.489	.0424	−.161
8	.820	.0518	−.240	.600	.0594	−.191
10	.948	.0671	−.226	.709	.0759	−.216
12	1.05	.0864	−.252	.811	.0906	−.244
14	1.08	.137	−.326	.913	.110	−.267
16	1.06	.226	−.358	.974	.148	−.288

TABLE 16

R. A. F. 15 biplanes.

	90% $C_{LC\,max}$					50% $C_{LC\,max}$					25% $C_{LC\,max}$				
G/c	90% $C_{LC\max}$	C_{LU}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$	50% $C_{LC\max}$	C_{LU}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$	25% $C_{LC\max}$	C_{LU}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$
Stagger = −30°															
0.6	0.752	0.698	0.806	0.464	0.536	0.418	0.350	0.485	0.418	0.582	0.209	0.145	0.268	0.351	0.649
0.9	.807	.755	.850	.470	.530	.449	.387	.501	.435	.565	.224	.186	.256	.421	.579
1.2	.841	.810	.877	.480	.520	.468	.423	.508	.454	.546	.234	.215	.252	.460	.540
Stagger = 0°															
0.6	0.771	0.840	0.700	0.545	0.455	0.429	0.452	0.398	0.531	0.469	0.214	0.213	0.217	0.495	0.505
0.8	.783	.857	.712	.546	.454	.435	.461	.411	.528	.472	.218	.222	.206	.519	.481
1.0	.820	.885	.754	.540	.460	.456	.478	.430	.526	.474	.228	.234	.222	.513	.488
1.2	.837	.873	.800	.521	.479	.465	.483	.445	.521	.479	.233	.241	.222	.520	.480
Stagger = +15°															
0.6	0.801	0.890	0.705	0.557	0.443	0.445	0.478	0.408	0.539	0.461	0.223	0.221	0.223	0.498	0.502
0.9	.873	.958	.785	.548	.452	.485	.528	.438	.547	.453	.243	.262	.224	.538	.462
1.2	.900	.995	.800	.554	.446	.500	.543	.454	.544	.456	.250	.271	.226	.545	.455
Stagger = +30°															
0.6	0.838	0.988	0.682	0.591	0.409	0.466	0.573	0.362	0.613	0.398	0.233	0.277	0.189	0.595	0.405
0.9	.914	1.05	.780	.574	.426	.508	.591	.418	.586	.414	.254	.287	.211	.576	.424
1.2	.923	1.05	.795	.567	.433	.512	.588	.434	.575	.425	.256	.292	.217	.571	.429

TABLE 17

U. S. A. T. S. 5 biplane. $G/c=0.9$. Stagger $=-30°$

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−9				−0.004	+0.0132	−0.124
−7	+0.064	+0.0144	−0.178	+ .119	.0165	−.158
−5	.165	.0161	−.223	.246	.0217	−.182
−3	.268	.0209	−.254	.369	.0278	−.207
−1	.380	.0284	−.281	.489	.0358	−.237
0	.441	.0345	−.290	.548	.0400	−.244
+1	.493	.0409	−.313	.607	.0444	−.253
2	.554	.0473	−.326	.670	.0490	−.277
3	.609	.0562	−.347	.729	.0542	−.275
4	.670	.0658	−.354	.787	.0590	−.294
6	.783	.0857	−.384	.900	.0695	−.322
8	.895	.109	−.415	.999	.0800	−.348
10	1.01	.135	−.442	1.07	.0865	−.354
12	1.13	.162	−.468	1.09	.0999	−.346
14	1.22	.185	−.478	1.02	.120	−.329
16	1.25	.203	−.480	.958	.143	−.312
18	1.17	.216	−.425			
20	1.09	.223	−.423			

TABLE 18

U. S. A. T. S. 5 biplane. $G/c=0.9$. Stagger $=0°$

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−9	−0.026	+0.0257	−0.088	+0.040	+0.0036	−0.144
−7	+.091	.0242	−.118	.158	.0074	−.162
−5	.205	.0248	−.133	.272	.0139	−.192
−3	.325	.0279	−.169	.379	.0229	−.208
−1	.452	.0333	−.199	.486	.0330	−.243
0	.508	.0370	−.208	.536	.0385	−.252
+1	.574	.0412	−.238	.591	.0448	−.264
2	.635	.0464	−.250	.645	.0523	−.282
3	.697	.0520	−.255	.695	.0589	−.288
4	.758	.0556	−.279	.750	.0665	−.302
6	.887	.0734	−.308	.858	.0825	−.320
8	1.01	.0921	−.336	.956	.0960	−.348
10	1.13	.113	−.366	1.03	.113	−.365
12	1.21	.132	−.381	1.06	.124	−.367
14	1.23	.158	−.381	1.06	.139	−.351
16	1.22	.174	−.363	1.02	.158	−.341

TABLE 19

U. S. A. T. S. 5. biplane. $G/c=0.9$. Stagger $=+30°$

	Upper wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M
Degrees						
−9	+0.097	+0.0165	−0.125	+0.003	+0.0074	−0.099
−7	.229	.0180	−.157	.102	.0096	−.122
−5	.363	.0215	−.193	.203	.0154	−.148
−3	.504	.0264	−.232	.300	.0234	−.168
−1	.646	.0332	−.275	.395	.0347	−.192
0	.724	.0377	−.281	.447	.0418	−.213
+1	.804	.0428	−.305	.496	.0490	−.231
2	.890	.0486	−.323	.544	.0571	−.239
3	.965	.0553	−.359	.585	.0658	−.249
4	1.03	.0624	−.381	.635	.0755	−.261
6	1.18	.0774	−.415	.725	.0945	−.284
8	1.29	.0936	−.428	.823	.115	−.314
10	1.34	.114	−.426	.921	.136	−.335
12	1.35	.139	−.416	1.03	.160	−.370
14	1.31	.168	−.399	1.12	.182	−.393
16	1.25	.190	−.383	1.15	.207	−.398
18	1.15	.212	−.365	1.15	.231	−.395
20				1.16	.262	−.401

TABLE 20

U. S. A. T. S. 5 biplanes.

	90% C_{LC} max.					50% C_{LC} max.					25% C_{LC} max.				
G/c	90% C_{LC} max.	C_{LU}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$	50% C_{LC} max.	C_{LU}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$	25% C_{LC} max.	C_{LU}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$
Stagger $=-30°$															
0.9	1.01	0.975	1.05	0.481	0.519	0.562	0.507	0.620	0.450	0.550	0.281	0.233	0.328	0.415	0.585
Stagger $=0°$															
0.9	1.03	1.07	1.00	0.518	0.482	0.575	0.562	0.583	0.493	0.507	0.287	0.257	0.317	0.447	0.553
Stagger $=+30°$															
0.9	1.10	1.32	0.868	0.604	0.396	0.609	0.757	0.463	0.620	0.380	0.305	0.387	0.221	0.638	0.363

TABLE 21

R. A. F. 15 triplane. $G/c=0.6$. Stagger = −30°

	Upper wing			Middle wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−4	−0.083	+0.0179	−0.002	−0.105	+0.0182	−0.012	----	----	----
−3	----	----	----	−.056	+.0170	−.036	−0.065	+0.0174	−0.025
−2	----	----	----	----	----	----	+.005	.0180	−.042
−1	----	----	----	----	----	----	.083	.0171	−.059
0	----	----	----	----	----	----	.161	.0173	−.093
+1	----	----	----	----	----	----	.232	.0186	−.110
2	----	----	----	----	----	----	.277	.0199	−.121
3	+.201	+.0185	−.083	----	----	----	.345	.0222	−.133
4	.242	.0227	−.087	+.248	+.0212	−.088	.401	.0246	−.141
5	.290	.0285	−.096	.304	.0238	−.112	----	----	----
6	.329	.0334	−.113	.352	.0291	−.118	.511	.0320	−.155
8	.418	.0502	−.146	.434	.0409	−.138	.616	.0385	−.171
10	.541	.0723	−.172	.514	.0517	−.148	.715	.0474	−.208
12	.638	.0930	−.193	.602	.0609	−.165	.786	.0637	−.222
14	.744	.115	−.223	.680	.0622	−.176	.800	.113	−.247
16	.846	.126	−.233	.689	.0702	−.159	.756	.183	−.288
18	.868	.146	−.249	----	----	----	----	----	----

TABLE 22

R. A. F. 15 triplane. $G/c=0.9$. Stagger = −30°

	Upper wing			Middle wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.035	+0.0135	−0.012	−0.075	+0.0163	−0.010	−0.083	+0.0164	−0.012
−2	+.002	.0127	−.032	−.025	.0143	−.023	−.014	.0162	−.029
−1	.062	.0122	−.048	+.013	.0126	−.037	+.070	.0158	−.058
0	.109	.0129	−.063	.102	.0134	−.066	.158	.0159	−.084
+1	.154	.0146	−.077	.157	.0154	−.084	.226	.0170	−.102
2	.200	.0168	−.084	.202	.0177	−.091	.286	.0170	−.110
3	.248	.0201	−.102	.245	.0205	−.094	.354	.0195	−.122
4	.289	.0240	−.105	.293	.0237	−.106	.421	.0221	−.132
6	.400	.0373	−.139	.405	.0333	−.131	.543	.0296	−.160
8	.499	.0543	−.166	.503	.0467	−.159	.662	.0375	−.187
10	.599	.0761	−.191	.600	.0605	−.168	.773	.0488	−.214
12	.695	.0972	−.223	.723	.0737	−.186	.830	.0673	−.217
14	.809	.121	−.238	.825	.0808	−.203	.803	.105	−.247
16	.929	.150	−.267	.842	.109	−.310	.771	----	−.260
18	.964	.168	−.272	----	----	----	----	----	----

TABLE 23

R. A. F. 15 triplane. $G/c=1.2$. Stagger = −30°

	Upper wing			Middle wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.049	+0.0137	−0.014	−0.061	+0.0125	−0.015	−0.089	+0.0164	−0.009
−2	+.002	.0127	−.026	−.009	.0131	−.040	−.015	.0153	−.032
−1	.079	.0123	−.060	+.069	.0135	−.058	+.073	.0142	−.060
0	.136	.0134	−.076	.135	.0142	−.085	.161	.0147	−.085
+1	.185	.0155	−.083	.189	.0159	−.086	.226	.0155	−.096
2	.235	.0180	−.094	.238	.0186	−.104	.294	.0160	−.104
3	.283	.0210	−.102	.291	.0214	−.109	.368	.0182	−.122
4	.340	.0258	−.125	.358	.0256	−.127	.436	.0211	−.141
6	.456	.0397	−.161	.466	.0363	−.150	.569	.0303	−.175
8	.561	.0565	−.175	.579	.0523	−.176	.692	.0399	−.201
10	.669	.0791	−.211	.690	.0677	−.200	.799	.0553	−.229
12	.769	.101	−.239	.798	.0822	−.231	.887	.0752	−.258
14	.878	.124	−.269	.899	.0977	−.253	.852	.112	−.275
16	.984	.149	−.285	.905	.127	−.268	.828	----	−.297
18	1.01	.183	−.308	----	----	----	----	----	----

TABLE 24

R. A. F. 15 triplane. $G/c=0.6$. Stagger = 0°

α	Upper wing			Middle wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.050	+0.0162	−0.008	+0.010	+0.0135	−0.031	+0.017	+0.0114	−0.045
−2	+.006	.0147	−.017	.058	.0140	−.047	.078	.0126	−.067
−1	.073	.0135	−.031	.093	.0145	−.059	.129	.0139	−.081
0	.134	.0141	−.060	.124	.0156	−.067	.178	.0163	−.093
+1	.185	.0145	−.071	.153	.0171	−.078	.221	.0197	−.104
2	.255	.0161	−.086	.200	.0187	−.086	.260	.0229	−.110
3	.310	.0183	−.097	.242	.0207	−.095	.312	.0266	−.124
4	.365	.0212	−.118	.278	.0231	−.100	.360	.0301	−.133
6	.478	.0286	−.145	.356	.0298	−.111	.446	.0401	−.155
8	.587	.0399	−.165	.425	.0382	−.122	.530	.0517	−.176
10	.700	.0539	−.193	.500	.0470	−.129	.610	.0632	−.192
12	.808	.0690	.210	.565	.0545	−.143	.685	.0721	−.215
14	.917	.0859	−.237	.651	.0625	−.148	.740	.0869	−.217
16	.946	.116	−.254	.716	.0883	−.168	.780	.152	−.250
18				.762		−.293	.838	.232	

TABLE 25

R. A. F. 15 triplane. $G/c=0.8$. Stagger = 0°

α	Upper wing			Middle wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	0.042	+0.0149	−0.009	−0.007	+0.0133	−0.026	−0.007	+0.0126	−0.031
−2	+.022	.0138	−.032	+.054	.0139	−.049	+.064	.0139	−.057
−1	.090	.0132	.047	.098	.0144	−.056	.122	.0145	−.078
0	.156	.0142	.068	.141	.0159	−.070	.175	.0161	−.095
+1	.209	.0149	.086	.177	.0178	.077	.221	.0196	−.109
2	.278	.0173	.098	.224	.0195	−.085	.269	.0225	−.115
3	.338	.0197	−.117	.279	.0222	−.103	.324	.0255	−.126
4	.398	.0234	−.130	.323	.0251	−.111	.370	.0296	−.139
6	.513	.0325	−.161	.414	.0331	−.124	.469	.0390	−.155
8	.627	.0460	−.183	.497	.0431	−.147	.559	.0504	−.180
10	.756	.0612	−.204	.581	.0544	−.150	.650	.0624	−.198
12	.857	.0774	−.218	.666	.0646	−.169	.732	.0717	−.212
14	.980	.0981	−.245	.749	.0758	−.184	.785	.0891	−.220
16	1.01	1.33	−.268	.821	.112	−.213	.817	.157	−.267
18	1.01			.866	.184	−.250	.855	.230	

TABLE 26

R. A. F. 15 triplane. $G/c=1.0$. Stagger = 0°

α	Upper wing			Middle wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.037	+0.0149	−0.010	−0.003	+0.0161	−0.034	−0.027	+0.0134	−0.023
−2	+.032	.0143	−.034	+.056	.0124	−.047	+.049	.0136	−.052
−1	.106	.0143	−.055	.109	.0129	−.061	.118	.0138	−.072
0	.173	.0159	−.082	.158	.0149	−.073	.167	.0157	−.091
+1	.225	.0176	−.086	.200	.0167	−.097	.219	.0183	−.098
2	.295	.0201	−.111	.248	.0186	−.094	.273	.0210	−.114
3	.354	.0228	−.131	.303	.0212	−.107	.331	.0239	−.123
4	.419	.0271	−.146	.352	.0248	−.117	.387	.0278	−.137
6	.546	.0374	−.165	.452	.0340	−.153	.492	.0373	−.156
8	.667	.0520	−.201	.550	.0462	−.158	.591	.0491	−.182
10	.787	.0678	−.225	.645	.0592	−.169	.682	.0613	−.206
12				.732	.0707	−.200	.771	.0713	−.219
14	.997	.104	−.257	.828	.0854	−.209	.830	.0923	−.223
16	1.02	.142	−.307	.885	.128	−.244	.866	.154	−.271
18	1.01			.919			.892	.230	

TABLE 27

R. A. F. 15 triplane. $G/c=1.2$. Stagger=0°

	Upper wing			Middle wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.003	+0.0145	−0.016	−0.007	+0.0136	−0.030	−0.036	+0.0152	−0.022
−2	+.034	.0129	−.038	+.068	.0133	−.051	+.035	.0150	−.046
−1	.107	.0125	−.061	.132	.0143	−.078	.108	.0156	−.066
0	.178	.0142	−.080	.181	.0161	−.095	.173	.0176	−.088
+1	.237	.0161	−.095	.225	.0189	−.109	.226	.0204	−.102
2	.306	.0179	−.117	.283	.0216	−.114	.283	.0230	−.113
3	.374	.0215	−.130	.341	.0248	−.132	.347	.0259	−.130
4	.441	.0256	−.138	.387	.0285	−.141	.402	.0298	−.140
6	.566	.0363	−.170	.500	.0378	−.159	.509	.0395	−.161
8	.693	.0511	−.208	.596	.0506	−.175	.617	.0512	−.187
10	.814	.0689	−.223	.702	.0643	−.201	.710	.0630	−.206
12	.934	.0872	−.247	.793	.0774	−.224	.799	.0732	−.232
14	1.03	.112	−.267	.883	.0952	−.244	.817	.0975	−.245
15	1.04	.134	−.282						
16	1.05	.156	−.296	.922	.137	−.263	.868	.161	−.295
18				.927			.886	.233	

TABLE 28

R. A. F. 15 triplane. $G/c=0.6$. Stagger=+15°

	Upper wing			Middle wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−4				0.000	+0.0141	−0.033			
−3	−0.049	+0.0235	−0.006	+.049	.0139	−.047	+0.009	+0.0111	−0.042
−2	+.022	.0163	−.031	.097	.0147	−.065	.068	.0114	−.053
−1	.102	.0142	−.059	.133	.0156	−.067	.113	.0128	−.074
0	.161	.0122	−.066	.155	.0174	−.073	.158	.0142	−.084
+1	.232	.0120	−.085	.176	.0190	−.071	.194	.0168	−.092
2	.294	.0129	−.094	.228	.0208	−.087	.225	.0188	−.096
3	.356	.0164	−.104	.264	.0243	−.102	.270	.0221	−.110
4	.411	.0186	−.116	.303	.0278	−.104	.321	.0264	−.123
6	.542	.0274	−.147	.382	.0357	−.124	.407	.0384	−.145
8	.670	.0395	−.172	.458	.0461	−.136	.487	.0517	−.159
10	.797	.0550	−.197	.543	.0588	−.155	.570	.0690	−.180
12	.914	.0690	−.174	.622	.0671	−.171	.650	.0828	−.202
14	.975	.0923	−.236	.700	.0794	−.182	.715	.0948	−.218
16	.973	.130	−.250	.770	.102	−.199	.778	.119	−.244
18	.898	.165	−.256	.857	.154	−.240	.832	.186	−.278
20							.876	.262	−.320

TABLE 29

R. A. F. 15 triplane. $G/c=0.9$. Stagger=+15°

	Upper wing			Middle wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.046	+0.0142	−0.012	+0.006	+0.0137	−0.028	−0.023	+0.0131	−0.021
−2	+.031	.0131	−.034	.068	.0134	−.058	+.045	.0124	−.038
−1	.116	.0121	−.059	.119	.0138	−.066	.103	.0129	−.060
0	.187	.0132	−.076	.158	.0166	−.076	.154	.0143	−.079
+1	.248	.0141	−.100	.197	.0183	−.084	.200	.0164	−.095
2	.323	.0151	−.110	.245	.0199	−.080	.239	.0182	−.097
3	.387	.0203	−.125	.298	.0235	−.106	.288	.0212	−.109
4	.456	.0232	−.139	.346	.0274	−.119	.344	.0248	−.120
6	.592	.0341	−.167	.444	.0371	−.142	.440	.0372	−.141
8	.728	.0488	−.203	.534	.0497	−.158	.530	.0508	−.168
10	.862	.0671	−.234	.634	.0653	−.183	.627	.0680	−.195
12	.982	.0843	−.258	.724	.0785	−.206	.718	.0813	−.210
14	1.06	.112	−.272	.817	.0932	−.224	.802	.0936	−.233
16	1.05	.160	−.306	.906	.154	−.328	.819	.124	−.238
18				.957	.255	−.288	.865	.197	−.281

TABLE 30

R. A. F. 15 triplane. $G/c=1.2$. Stagger = +15°

α	Upper wing			Middle wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.057	+0.0146	−0.019	−0.003	+0.0139	−0.026	−0.043	+0.0143	−0.021
−2	+.016	.0133	−.045	+.045	.0130	−.046	+.031	.0141	−.045
−1	.105	.0121	−.066	.079	.0138	−.059	.102	.0141	−.066
0	.182	.0133	−.088	.164	.0163	−.083	.158	.0156	−.088
+1	.243	.0144	−.103	.209	.0183	−.092	.206	.0176	−.086
2	.323	.0158	−.123	.257	.0203	−.095	.260	.0199	−.102
3	.394	.0188	−.138	.321	.0240	−.115	.316	.0227	−.110
4	.465	.0232	−.156	.378	.0281	−.133	.374	.0270	−.126
6	.601	.0347	−.187	.486	.0390	−.157	.480	.0393	−.156
8	.746	.0500	−.224	.591	.0528	−.179	.587	.0537	−.179
10	.886	.0686	−.214	.701	.0699	−.210	.698	.0704	−.209
12	1.00	.0872	−.279	.800	.0848	−.233	.784	.0837	−.235
14	1.06	.117	.298	.902	.104	−.252	.855	.0987	−.240
16	1.05	.170	−.333	.978	.144	−.277	.889	.134	−.263
18	....	....	....	1.01	.229	−.336	.907	.215	−.318

TABLE 31

R. A. F. 15 triplane. $G/c=0.6$. Stagger = +30°

α	Upper wing			Middle wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.014	+0.0165	−0.016	+0.052	+0.0127	−0.042	−0.009	+0.0112	−0.029
−2	+.063	.0166	−.036	.097	.0121	−.048	+.042	.0099	−.044
−1	.151	.0147	−.058	.128	.0130	−.057	.079	.0102	−.057
0	.216	.0142	−.077	.158	.0146	−.061	.124	.0119	−.069
+1	.299	.0147	−.104	.189	.0166	−.064	.166	.0148	−.073
2	.370	.0158	−.107	.250	.0190	−.073	.201	.0181	−.079
3	.438	.0147	−.120	.279	.0226	−.084	.239	.0220	−.086
4	.500	.0195	−.133	.312	.0267	−.094	.287	.0269	−.107
6	.648	.0273	−.177	.394	.0371	−.109	.376	.0405	−.130
8	.790	.0400	−.198	.476	.0516	−.141	.453	.0540	−.150
10	.930	.0528	−.227	.555	.0643	−.143	.535	.0748	−.167
12	1.02	.0738	−.250	.643	.0785	−.165	.615	.0902	−.190
14	1.05	.120	−.265	.763	.0988	−.181	.700	.109	−.218
16	1.00	.....	−.295	.887	.131	−.210	.769	.130	−.228
18	....	....	....	.955	.177	−.265	.844	.166	−.268

TABLE 32

R. A. F. 15 triplane. $G/c=0.9$. Stagger = +30°

α	Upper wing			Middle wing			Lower wing		
	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.023	+0.0152	−0.014	+0.009	+0.0124	−0.030	−0.002	+0.0124	−0.024
−2	+.063	.0150	−.053	.065	.0108	−.051	+.037	.0114	−.042
−1	.154	.0169	−.084	.120	.0109	−.060	.085	.0111	−.055
0	.227	.0143	−.089	.164	.0129	−.073	.133	.0127	−.067
+1	.305	.0148	−.106	.206	.0152	−.078	.181	.0155	−.075
2	.384	.0165	−.129	.257	.0177	−.092	.220	.0185	−.083
3	.458	.0192	−.143	.311	.0214	−.102	.268	.0219	−.097
4	.529	.0222	−.156	.360	.0265	−.111	.325	.0271	−.113
6	.674	.0313	−.192	.458	.0386	−.143	.418	.0396	−.140
8	.825	.0469	−.217	.560	.0549	−.170	.505	.0557	−.163
10	.962	.0634	−.256	.656	.0737	−.183	.596	.0710	−.180
12	1.07	.0862	−.281	.758	.0857	−.202	.667	.0846	−.197
14	1.12	.138	−.319	.879	.107	−.245	.755	.101	−.213
16	1.08	....	−.357	.973	.141	−.262	.828	.124	−.230
18	....	....	....	....	....	....	.898	.165	−.260

TABLE 33

R. A. F. 15 triplane. $G/c=1.2$. Stagger $=+30°$

	Upper wing			Middle wing			Lower wing		
α	C_L	C_D	C_M	C_L	C_D	C_M	C_L	C_D	C_M
Degrees									
−3	−0.035	+0.0146	−0.016	−0.009	+0.0148	−0.022	−0.026	+0.0136	−0.019
−2	+.057	.0147	−.043	+.048	.0118	−.045	+.037	.0116	−.035
−1	.148	.0134	−.073	.109	.0115	−.060	.093	.0127	−.058
0	.216	.0140	−.095	.161	.0129	−.076	.153	.0151	−.080
+1	.290	.0149	−.099	.210	.0153	−.080	.204	.0183	−.092
2	.369	.0168	−.123	.264	.0177	−.093	.249	.0207	−.101
3	.449	.0201	−.143	.328	.0217	−.108	.310	.0231	−.111
4	.523	.0236	−.164	.382	.0264	−.123	.359	.0283	−.125
6	.682	.0343	−.194	.495	.0393	−.154	.463	.0410	−.152
8	.832	.0504	−.229	.605	.0557	−.191	.566	.0582	−.182
10	.970	.0671	−.270	.716	.0720	−.215	.665	.0740	−.210
12	1.08	.0879	−.283	.835	.0878	−.242	.752	.0884	−.221
14	1.12	.143	−.330	.953	.110	.264	.858	.109	−.248
16	1.07			1.02	.152	−.284	.922	.136	−.247
18							.941	.198	−.287

TABLE 34.—R. A. F. 15 triplane.

Stagger $=-30°$

		C_{LU}	C_{LM}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LM}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$
$G/c=0.6$	90% $C_{LC\text{ max.}}=0.688$	0.650	0.619	0.795	0.316	0.300	0.384
	50% $C_{LC\text{ max.}}=.383$	.313	.339	.500	.272	.295	.433
	25% $C_{LC\text{ max.}}=.191$	.138	.165	.272	.241	.288	.471
$G/c=0.9$	90% $C_{LC\text{ max.}}=.765$	.720	.745	.831	.314	.324	.362
	50% $C_{LC\text{ max.}}=.425$	.370	.384	.526	.290	.302	.408
	25% $C_{LC\text{ max.}}=.212$	.184	.186	.270	.288	.292	.420
$G/c=1.2$	90% $C_{LC\text{ max.}}=.819$	.768	.800	.888	.312	.326	.362
	50% $C_{LC\text{ max.}}=.455$	.412	.428	.520	.302	.314	.384
	25% $C_{LC\text{ max.}}=.228$	.208	.214	.258	.304	.313	.383

Stagger $=0°$

		C_{LU}	C_{LM}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LM}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$
$G/c=0.6$	90% $C_{LC\text{ max.}}=0.755$	0.894	0.635	0.742	0.394	0.280	0.326
	50% $C_{LC\text{ max.}}=.420$	.476	.350	.436	.378	.278	.344
	25% $C_{LC\text{ max.}}=.210$	.216	.181	.240	.343	.288	.369
$G/c=0.8$	90% $C_{LC\text{ max.}}=.825$	.955	.733	.778	.386	.296	.318
	50% $C_{LC\text{ max.}}=.458$	.510	.406	.456	.371	.296	.333
	25% $C_{LC\text{ max.}}=.229$	.240	.207	.240	.349	.302	.349
$G/c=1.0$	90% $C_{LC\text{ max.}}=.852$	.956	.786	.805	.374	.308	.318
	50% $C_{LC\text{ max.}}=.473$	.522	.436	.467	.368	.307	.325
	25% $C_{LC\text{ max.}}=.237$	.253	.222	.239	.356	.312	.332
$G/c=1.2$	90% $C_{LC\text{ max.}}=.864$	.958	.815	.812	.370	.314	.316
	50% $C_{LC\text{ max.}}=.480$	.520	.454	.466	.361	.315	.324
	25% $C_{LC\text{ max.}}=.240$	.252	.233	.232	.352	.324	.324

Stagger $=+15°$

		C_{LU}	C_{LM}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LM}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$
$G/c=0.6$	90% $C_{LC\text{ max.}}=0.773$	0.957	0.670	0.692	0.413	0.289	0.298
	50% $C_{LC\text{ max.}}=.430$	.528	.373	.394	.408	.288	.304
	25% $C_{LC\text{ max.}}=.215$	.246	.199	.205	.380	.305	.315
$G/c=0.9$	90% $C_{LC\text{ max.}}=.837$	1.01	.752	.745	.401	.300	.299
	50% $C_{LC\text{ max.}}=.465$	.565	.424	.415	.405	.304	.291
	25% $C_{LC\text{ max.}}=.232$	.273	.222	.211	.392	.319	.289
$G/c=1.2$	90% $C_{LC\text{ max.}}=.883$	1.02	.818	.803	.387	.308	.305
	50% $C_{LC\text{ max.}}=.490$	.568	.457	.448	.386	.311	.303
	25% $C_{LC\text{ max.}}=.245$	.276	.235	.226	.376	.320	.304

Stagger = +30°

		C_{LU}	C_{LM}	C_{LL}	$\frac{C_{LU}}{C_{LC}}$	$\frac{C_{LM}}{C_{LC}}$	$\frac{C_{LL}}{C_{LC}}$
G/c=0.6	90% $C_{LC\ max.}$=0.802	1.04	0.702	0.657	0.434	0.292	0.274
	50% $C_{LC\ max.}$= .446	.613	.378	.353	.457	.282	.261
	25% $C_{LC\ max.}$= .223	.296	.202	.170	.442	.302	.256
G/c=0.9	90% $C_{LC\ max.}$= .865	1.09	.796	.698	.420	.305	.275
	50% $C_{LC\ max.}$= .480	.624	.426	.383	.433	.296	.271
	25% $C_{LC\ max.}$= .240	.312	.217	.186	.434	.302	.264
G/c=1.2	90% $C_{LC\ max.}$= .908	1.09	.855	.775	.402	.314	.284
	50% $C_{LC\ max.}$= .504	.623	.462	.429	.411	.306	.283
	25% $C_{LC\ max.}$= .252	.310	.232	.212	.410	.307	.283

TABLE 35

Centers of pressure in per cent of chord on a R. A. F. 15 biplane

	Stagger −30°						Stagger 0°							
G/c	0.6		0.9		1.2		0.6		0.8		1.0		1.2	
α	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing
Degrees														
−1			−76.3	−75.0	−63.1	−80.0	−70.2	−88.5			−87.3		−86.5	−82.5
0		−51.5	−61.0	−51.5	−55.5	−47.9	−42.0	−62.4	−65.1	−76.7	−55.0	−67.4	−52.8	−55.0
+1		−44.8	−52.7	−45.2	−48.2	−41.8	−39.9	−50.0	−50.0	−59.9	−48.9	−57.0	−42.6	−46.3
2		−40.5	−42.3	−40.0	−40.9	−37.6	−33.0	−50.2	−41.5	−53.6	−41.5	−49.6	−41.4	−40.7
3	−39.6	−37.4	−36.5	−35.9	−36.4	−36.0	−35.6	−44.5	−39.0	−47.6	−38.1	−41.2	−36.2	−37.4
4	−34.4	−34.1	−35.7	−34.7	−37.0	−33.4	−31.7	−41.5	−36.6	−40.0	−36.8	−39.3	−34.6	−35.7
6	−32.5	−31.9	−33.3	−30.7	−32.9	−30.4	−25.6	−34.2	−32.8	−36.4	−32.6	−35.2	−33.0	−32.9
8	−31.8	−30.4	−34.0	−28.6	−31.5	−30.0	−26.6	−33.2	−32.8	−34.5	−29.8	−32.8	−31.1	−30.8
10	−29.9	−27.6	−29.7	−28.2	−30.0	−27.4	−26.1	−30.9	−29.3	−33.9	−27.3	−31.0	−29.7	−28.4
12	−27.3	−28.0	−29.1	−29.2	−29.4	−28.4	−27.0	−30.6	−28.1	−31.4	−25.4	−30.1	−29.3	−28.9
14	−24.7	−31.7	−27.0	−31.2	−28.9	−31.9	−25.5	−31.1	−28.5	−32.0	−27.2	−31.0		−30.1
16	−18.8	−33.3	−27.0		−29.1		−23.6	−34.5	−28.5	−34.7	−31.3	−33.1		−33.5
18			−30.2											

TABLE 36

Centers of pressure in per cent of chord on a R. A. F. 15 biplane

	Stagger +15°						Stagger +30°					
G/c	0.6		0.9		1.2		0.6		0.9		1.2	
α	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing
Degrees												
−1	−51.0	−56.9	−49.1	−63.0	−57.3	−54.9	−46.2	−52.5	−48.4	−67.8	−58.2	−68.9
0	−44.0	−50.5	−41.6	−46.2	−48.7	−50.0	−36.6	−55.2	−47.5	−48.4	−44.4	−52.6
+1	−35.0	−42.7	−39.5	−43.5	−42.2	−42.7	−34.9	−42.7	−36.0	−43.0	−38.2	−43.1
2	−37.0	−41.1	−32.1	−37.6	−36.7	−38.7	−31.8	−42.6	−37.5	−38.8	−37.3	−39.9
3	−30.4	−38.4	−31.8	−36.6	−32.9	−36.4	−29.6	−36.1	−33.0	−36.2	−32.7	−36.5
4	−28.7	−35.7	−29.5	−34.4	−31.0	−35.4	−28.8	−35.4	−31.6	−33.9	−33.0	−36.5
6	−27.4	−32.3	−27.8	−33.2	−28.8	−31.8	−27.6	−33.6	−30.7	−33.9	−30.2	−32.8
8	−26.8	−34.0	−26.4	−30.9	−28.3	−29.0	−26.5	−32.5	−29.8	−33.2	−29.4	−31.7
10	−25.6	−31.4	−25.5	−30.9	−26.9	−31.0	−25.8	−31.5	−26.1	−30.2	−23.9	−30.4
12	−23.9	−31.7	−26.0	−29.6	−27.6	−29.8	−23.0	−30.7	−24.3	−30.0	−24.1	−30.0
14	−25.6	−30.9	−26.3	−28.6	−28.8	−27.6	−29.0	−30.3	−29.0	−29.7	−30.8	−29.3
16	−27.2	−30.8	−28.8	−28.4	−32.1	−30.2		−30.4	−33.1	−30.5	−33.3	−29.2

TABLE 37

Centers of pressure in per cent of chord on a U. S. A. T. S. 5 biplane of $G/c=0.9$

Stagger	−30°		0°		+30°	
α	Upper wing	Lower wing	Upper wing	Lower wing	Upper wing	Lower wing
Degrees						
−5	----------	−75.3	−65.8	−71.1	−53.6	−73.5
−3	−95.1	−56.4	−52.2	−55.2	−46.2	−56.1
−1	−74.2	−48.6	−44.1	−48.3	−42.7	−48.7
0	−65.9	−44.5	−40.9	−47.1	−38.9	−47.6
+1	−63.3	−41.6	−41.4	−44.6	−37.9	−46.5
2	−58.7	−41.3	−39.3	−43.6	−36.3	−43.8
3	−56.7	−37.6	−36.5	−41.3	−37.1	−42.4
4	−52.6	−37.3	−36.7	−40.1	−36.8	−40.9
6	−48.8	−35.7	−34.6	−37.0	−35.1	−38.9
8	−46.0	−34.8	−33.4	−36.0	−33.2	−37.8
10	−43.9	−33.2	−32.3	−35.1	−31.8	−36.0
12	−41.1	−31.8	−31.5	−34.1	−30.8	−35.6
14	−39.0	−32.1	−30.8	−32.6	−30.2	−34.6
16	−38.0	−32.5	−29.8	−32.6	−30.4	−34.1
18	−36.1	----------	----------	----------	−31.3	−34.0

TABLE 38

Centers of pressure in per cent of chord on R. A. F. 15 triplane

	Stagger −30°								
G/c	0.6			0.9			1.2		
α	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing
Degrees									
−2	----------	----------	----------	----------	----------	----------	----------	----------	----------
−1	----------	----------	−71.1	−77.4		−82.9	−76.0	−84.0	−82.2
0	----------	----------	−57.8	−57.8	−64.7	−53.1	−55.9	−63.0	−52.9
+1	----------	----------	−47.4	−50.0	−53.5	−45.2	−14.9	−45.5	−42.5
2	----------	----------	−43.5	−41.8	−44.9	−38.4	−39.8	−43.5	−35.2
3	----------	----------	−38.4	−41.0	−38.2	−34.4	−35.9	−37.3	−33.0
4	−35.8	−35.3	−35.1	−36.2	−36.1	−30.6	−36.6	−35.4	−32.9
6	−34.2	−33.4	−30.3	−34.6	−32.2	−29.5	−35.2	−32.0	−30.7
8	−34.7	−31.7	−27.7	−33.1	−31.5	−28.5	−31.1	−30.3	−29.1
10	−36.4	−28.7	−29.1	−31.6	−27.9	−27.9	−31.4	−28.9	−28.7
12	−30.0	−27.4	−27.1	−31.8	−25.7	26.2	−30.9	−29.0	−29.2
14	−29.7	−26.1	−30.8	−29.3	−24.8	−30.8	−30.6	−28.2	−32.3
16	−27.5	−23.3	−37.1	−28.3	−36.9	----------	−28.6	−29.6	----------
18	−28.6	----------	----------	−28.1	----------		−27.6		----------

TABLE 39

Centers of pressure in per cent of chord on R. A. F. 15 triplane

	Stagger 0°											
G/c	0.6			0.8			1.0			1.2		
α	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing
Degrees												
−2	−28.3	−81.0	−85.9	----------	−90.7	−89.0	----------	−84.0	----------	----------	−75.0	----------
−1	−42.5	−63.5	−62.8	−52.3	−57.2	−64.0	−51.8	−56.0	−61.0	−57.0	−59.1	−61.1
0	−44.8	−54.0	−52.2	−43.6	−49.6	−54.4	−47.4	−46.2	−54.5	−45.0	−52.5	−50.9
+1	−38.4	−51.0	−47.0	−41.2	−43.5	−49.3	−38.2	−48.5	−44.7	−40.1	−48.4	−45.1
2	−33.6	−42.8	−42.2	−35.1	−37.8	−42.6	−37.5	−37.8	−41.6	−38.1	−40.2	−39.8
3	−31.2	−39.1	−39.5	−34.5	−36.8	−38.8	−36.9	−35.2	−37.0	−34.6	−38.6	−37.3
4	−32.4	−35.9	−36.8	−32.7	−34.3	−37.5	−34.8	−33.2	−35.3	−31.2	−36.3	−34.7
6	−30.3	−31.1	−34.6	−31.4	−29.9	−33.0	−30.2	−33.7	−31.6	−30.0	−31.7	−31.5
8	−28.1	−28.6	−33.1	−29.2	−29.6	−32.1	−30.2	−28.7	−30.7	−30.0	−29.4	−30.2
10	−27.6	−25.7	−31.4	−27.1	−25.8	−30.5	−28.6	−26.2	−30.2	−28.6	−28.6	−29.0
12	−26.1	−25.4	−31.4	−25.5	−25.5	−29.0	----------	−27.4	−28.5	−26.5	−28.3	−28.9
14	−26.0	−22.9	−29.3	−25.2	−24.7	−28.2	−25.9	−25.4	−27.0	−26.0	−27.7	−28.5
16	−26.9	−23.6	−31.3	−26.5	−26.0	32.1	−30.0	−27.5	−31.0	27.0	−28.5	−32.9
18	----------	----------	----------	----------	−28.4			----------	----------	−28.1		----------

TABLE 40

Centers of pressure in per cent of chord on R. A. F. 15 triplane

	Stagger +15°								
G/c	0.6			0.9			1.2		
α	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing
Degrees									
−2		−67.0	−77.9		−85.3	−88.3			
−1	−57.8	−50.4	−65.5	−50.8	−55.5	−58.3	−62.8	−71.7	−64.8
0	−44.0	−47.1	−53.2	−40.7	−48.1	−51.3	−48.4	−50.7	−56.3
+1	−36.6	−40.3	−47.5	−40.3	−42.6	−47.5	−42.4	−44.0	−46.5
2	−32.0	−38.0	−42.5	−34.1	−32.5	−40.4	−37.9	−36.8	−39.1
3	−29.2	−38.5	−40.6	−32.2	−35.5	−37.7	−34.9	−35.5	−34.6
4	−28.2	−34.2	−38.2	−30.5	−34.3	−34.9	−33.5	−35.4	−33.6
6	−27.4	−32.3	−35.5	−28.4	−31.8	−31.9	−31.0	−32.2	−32.3
8	−25.7	−29.6	−32.5	−27.9	−29.4	−31.6	−30.0	−30.2	−30.4
10	−24.8	−28.1	−31.4	−27.2	−28.8	−31.0	−27.6	−29.9	−29.9
12	−19.2	−27.4	−30.9	−26.4	−28.4	−29.2	−27.8	−29.2	−30.0
14	−24.4	−26.1	−30.4	−25.8	−27.5	−29.1	−28.1	−28.1	−28.1
16	−25.8	−25.9	−31.2	−29.0	−36.2	−29.0	−31.3	−28.4	−29.6
18	−28.2	−27.8	−33.1		−29.0	−31.8		−32.7	−34.2

TABLE 41

Centers of pressure in per cent of chord on R. A. F. 15 triplane

	Stagger +30°								
G/c	0.6			0.9			1.2		
α	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing	Upper wing	Middle wing	Lower wing
Degrees									
−2	−58.0	−49.5		−85.5	−78.5		−75.5	−93.8	−94.7
−1	−38.4	−44.5	−72.1	−54.5	−50.0	−64.7	−49.1	−55.0	−62.4
0	−35.6	−38.6	−55.6	−39.2	−44.5	−50.3	−44.0	−47.2	−52.3
+1	−31.7	−33.9	−44.0	−34.8	−37.9	−41.5	−34.2	−38.1	−45.1
2	−28.8	−29.1	−39.1	−33.5	−35.6	−37.6	−33.3	−35.1	−40.4
3	−27.3	−30.0	−35.8	−31.2	−32.7	−36.1	−31.8	−32.8	−35.7
4	−26.6	−29.1	−37.4	−29.4	−30.7	−34.6	−31.4	−32.1	−34.7
6	−27.3	−27.5	−34.4	−28.4	−31.4	−33.3	−28.4	−31.0	−32.7
8	−25.1	−29.5	−32.9	−26.4	−30.3	−32.0	−27.5	−31.4	−32.0
10	−24.6	−25.7	−31.1	−26.7	−27.8	−30.1	−28.0	−30.0	−31.5
12	−24.6	−25.5	−30.6	−26.4	−26.6	−29.4	−26.3	−29.0	−29.4
14	−28.0	−25.0	−30.9	−28.6	−27.9	−28.1	−29.5	−27.8	−28.9
16		−23.7	−29.0		−27.0	−27.7		−27.8	−26.7
18		−24.9	−31.3			−28.7			−30.1

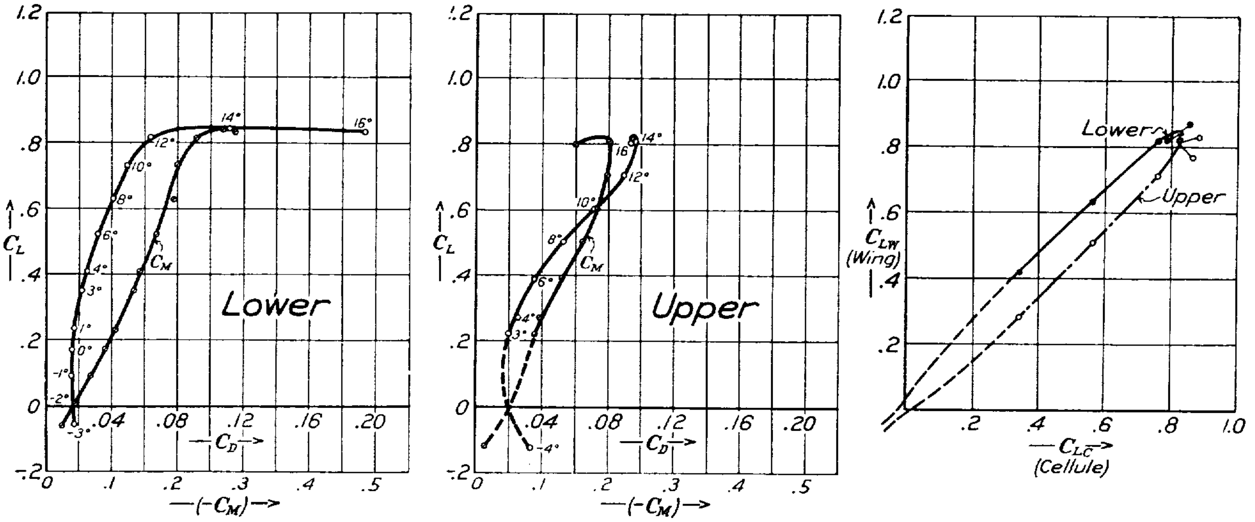

FIG. 3.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=0.6$; Stagger $-30°$

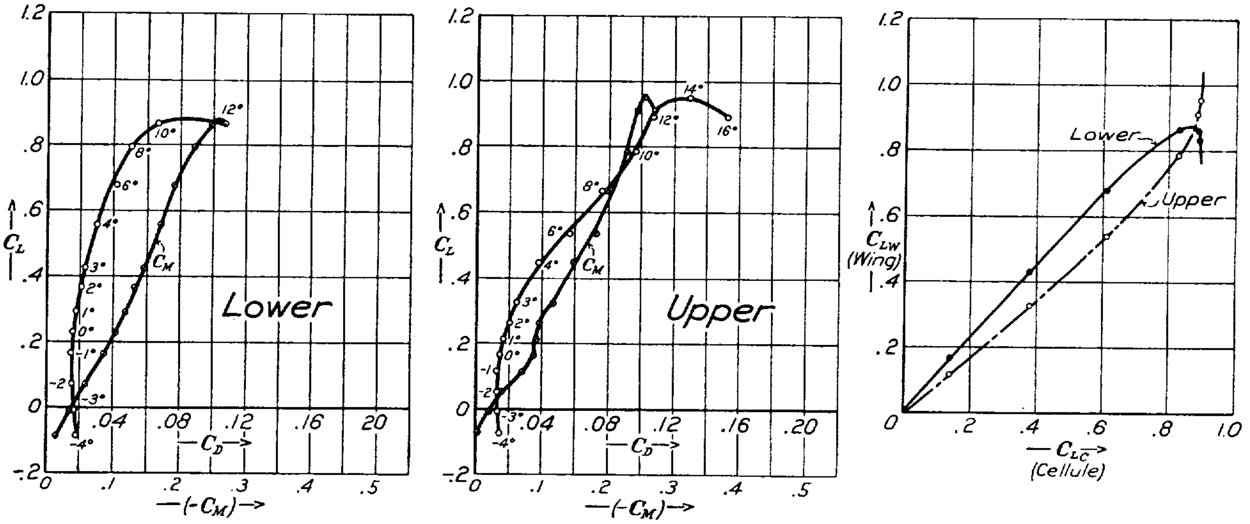

FIG. 4.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=0.9$; Stagger $-30°$

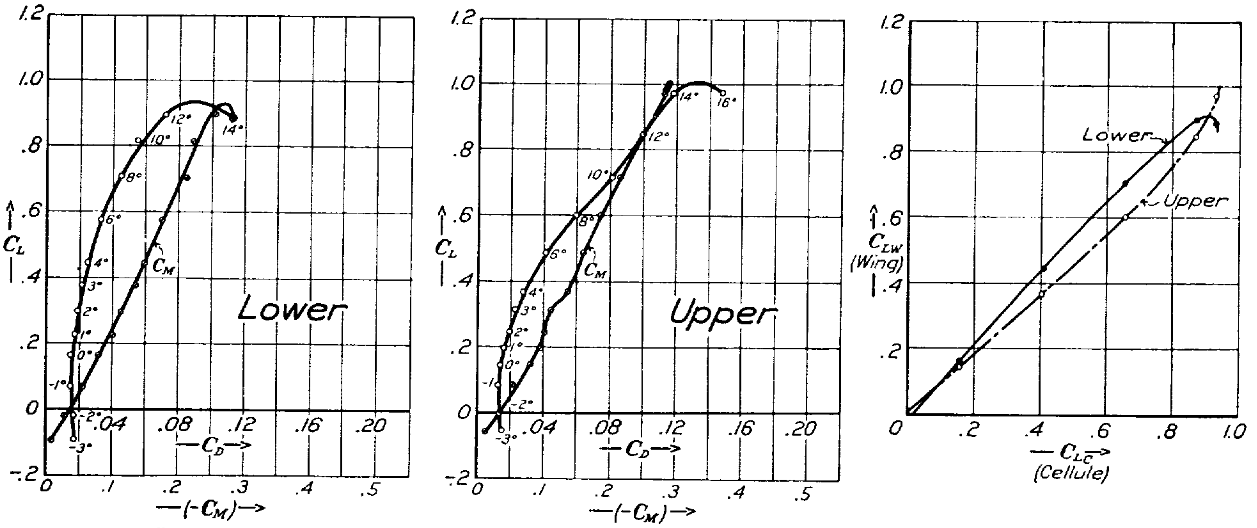

FIG. 5.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=1.2$; Stagger $-30°$

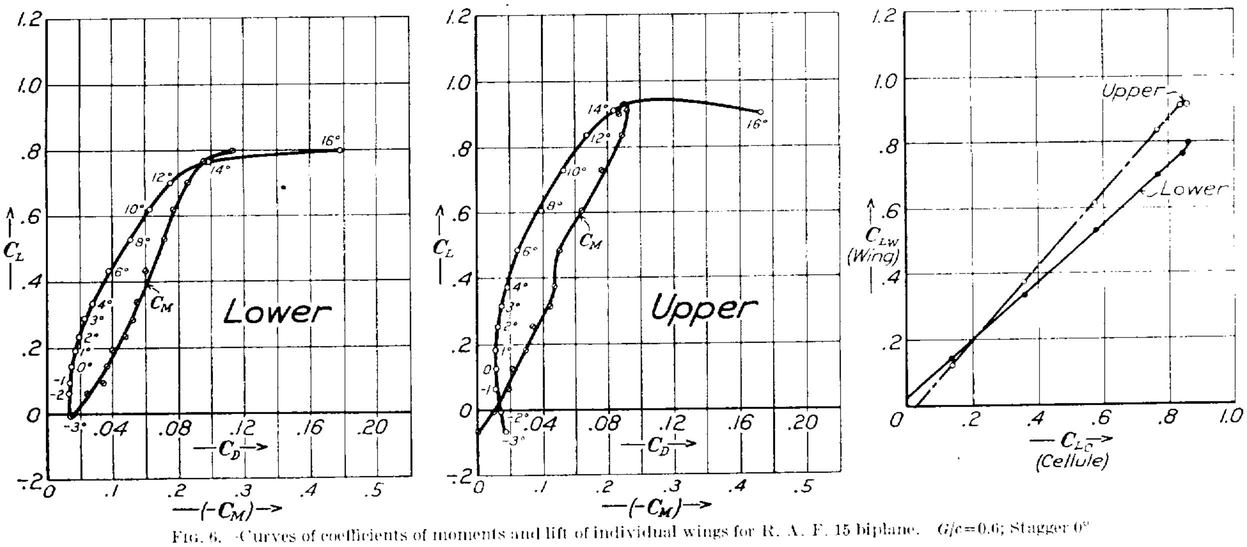

FIG. 6.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=0.6$; Stagger 0°

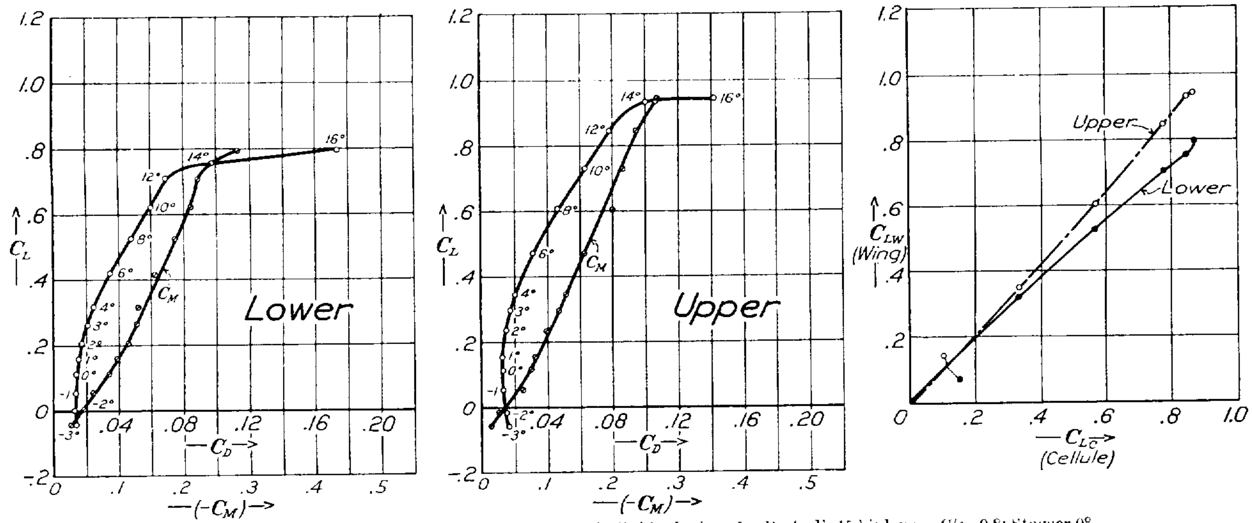

FIG. 7.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=0.8$; Stagger 0°

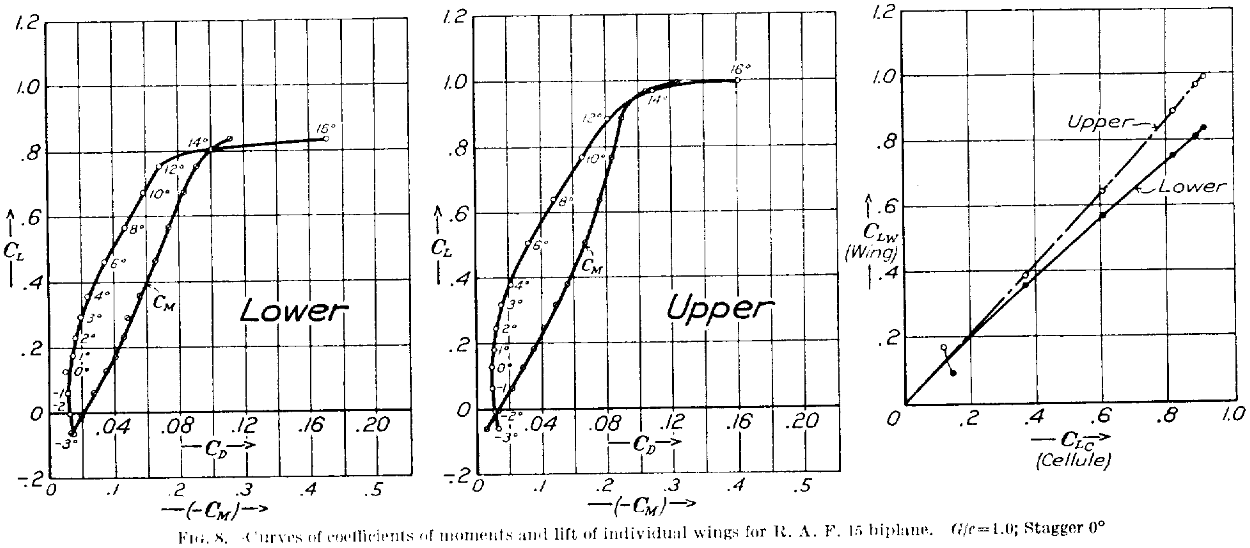

FIG. 8.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=1.0$; Stagger 0°

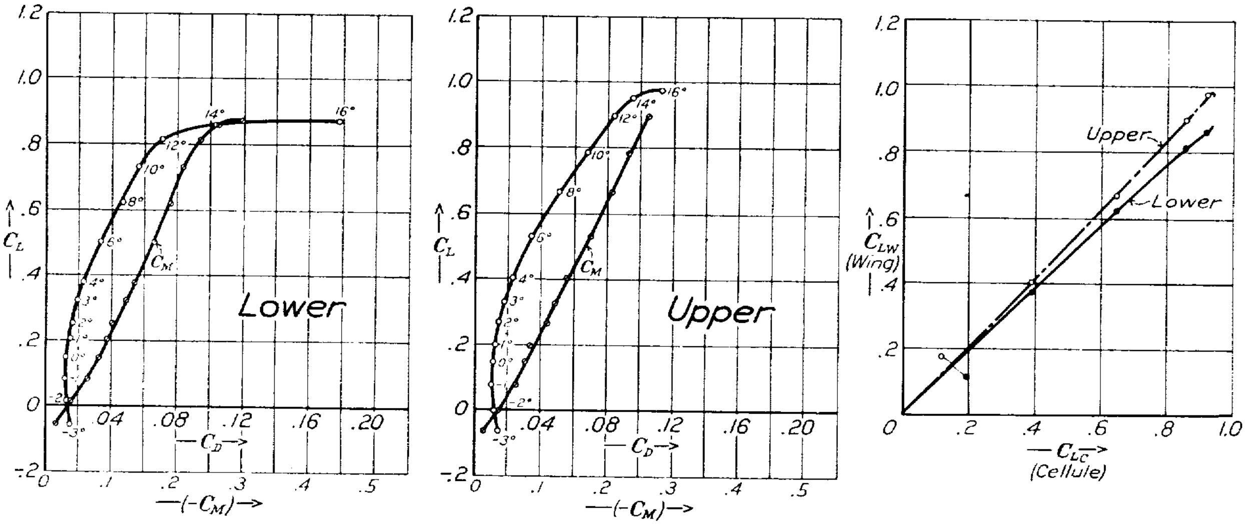

FIG. 9.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. G/c=1.2; Stagger 0°

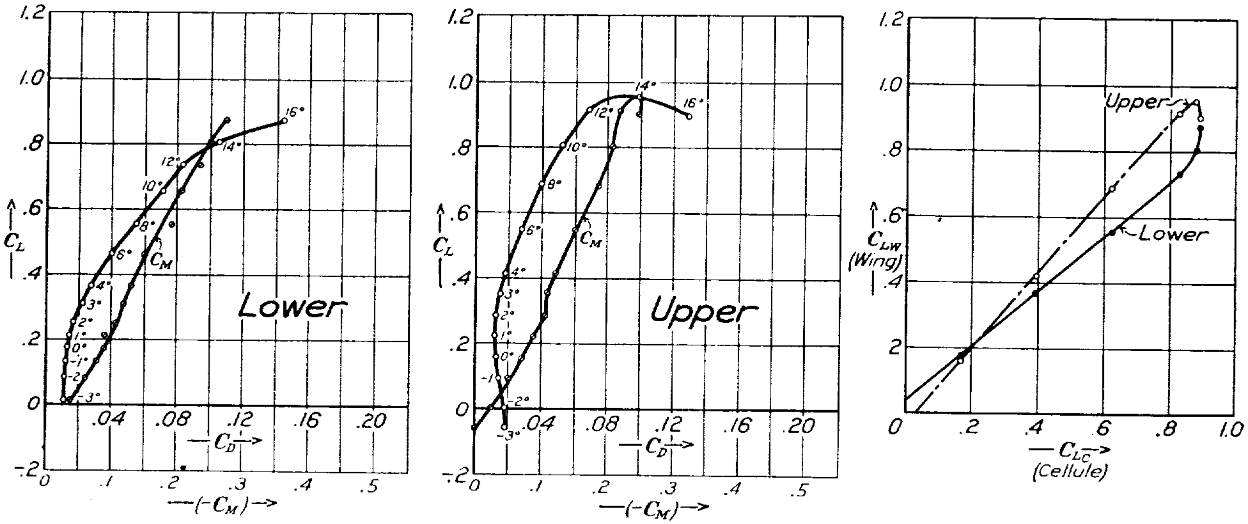

FIG. 10.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. G/c=0.6; Stagger +15°

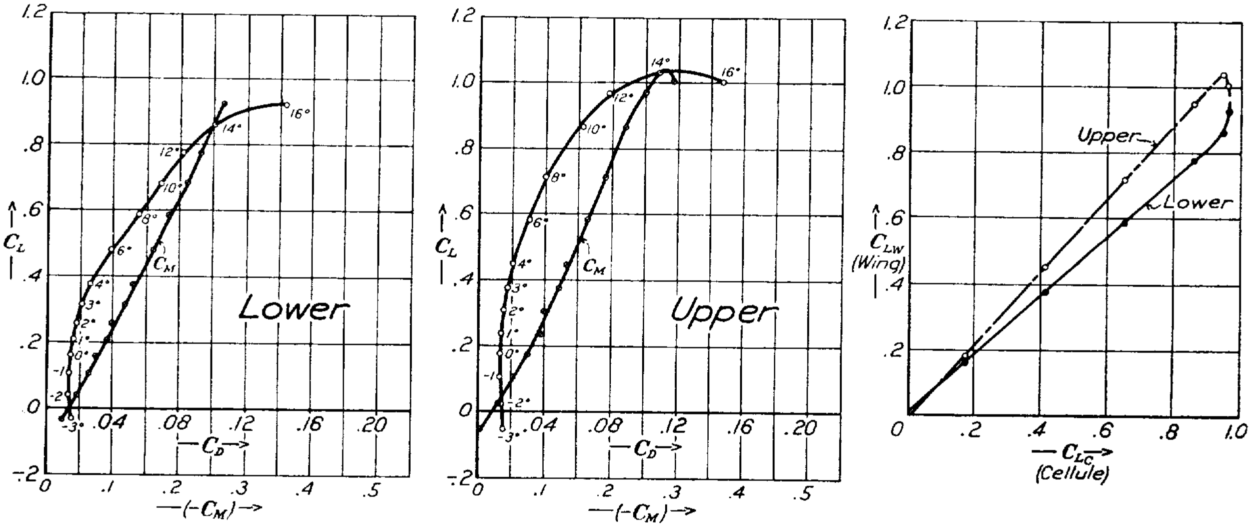

FIG. 11.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. G/c=0.9; Stagger +15°

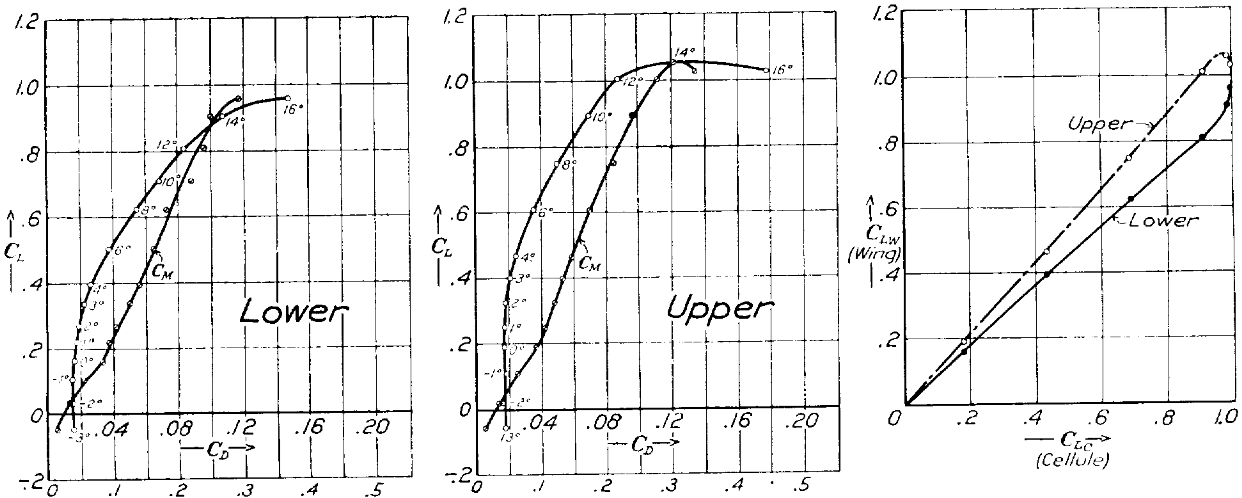

FIG. 12.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=1.2$; Stagger +15°

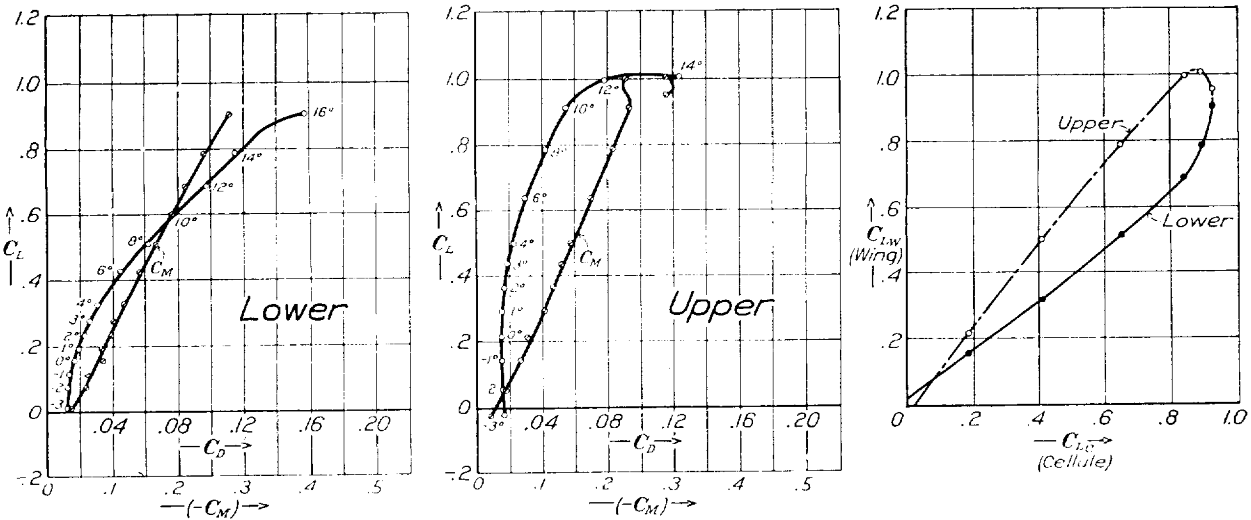

FIG. 13.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=0.6$; Stagger +30°

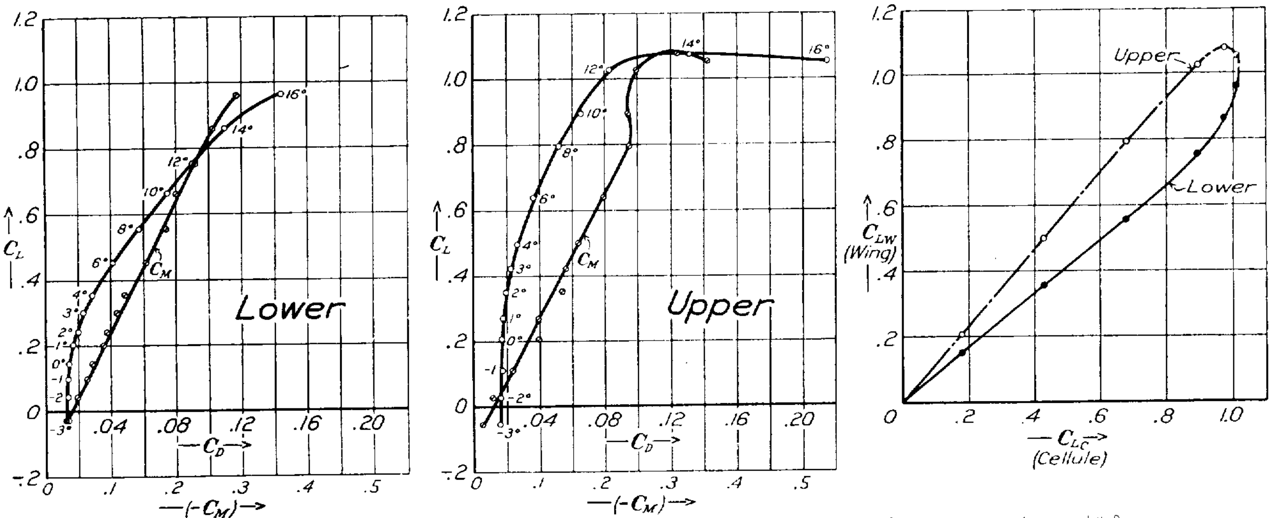

FIG. 14.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. $G/c=0.9$; Stagger +30°

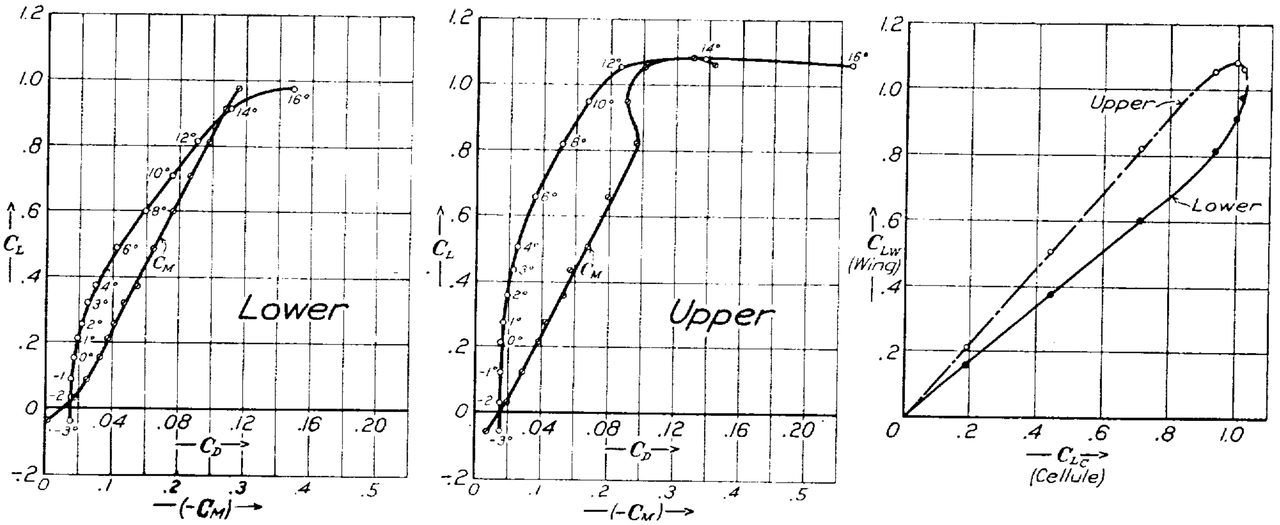

FIG. 15.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 biplane. G/c=1.2; Stagger +30°

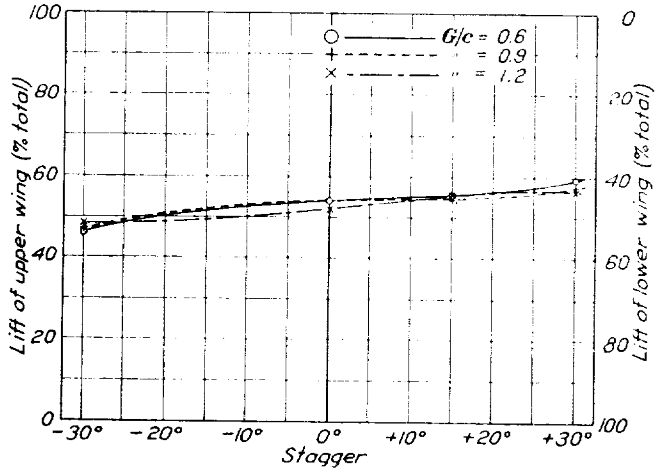

FIG. 16.—R. A. F. 15 biplane relative lift at 0.9 maximum lift

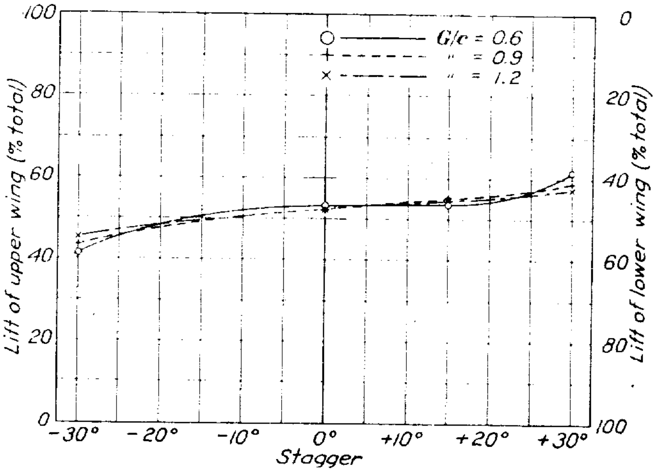

FIG. 17.—R. A. F. 15 biplane relative lift at 0.5 maximum lift

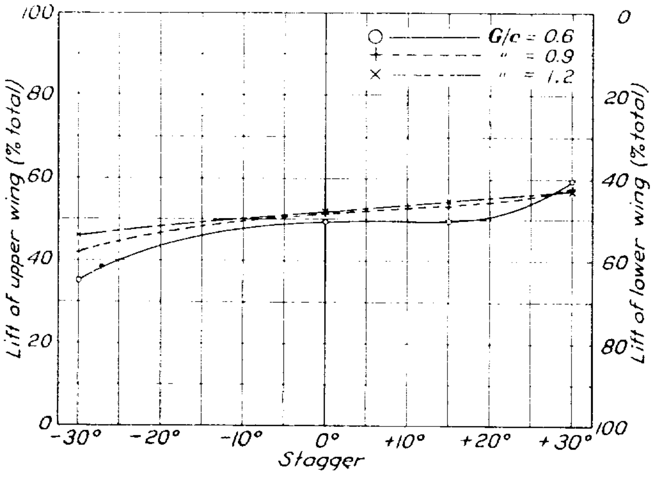

FIG. 18.—R. A. F. 15 biplane relative lift at 0.25 maximum lift

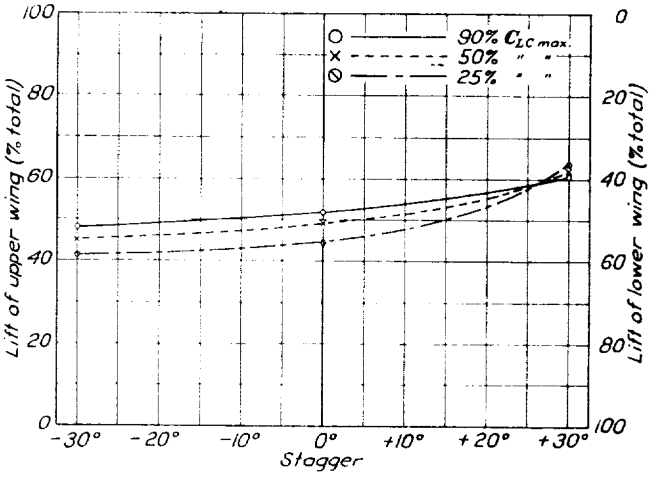

FIG. 22.—U. S. A. T. S. 5 biplane. G/c=0.9

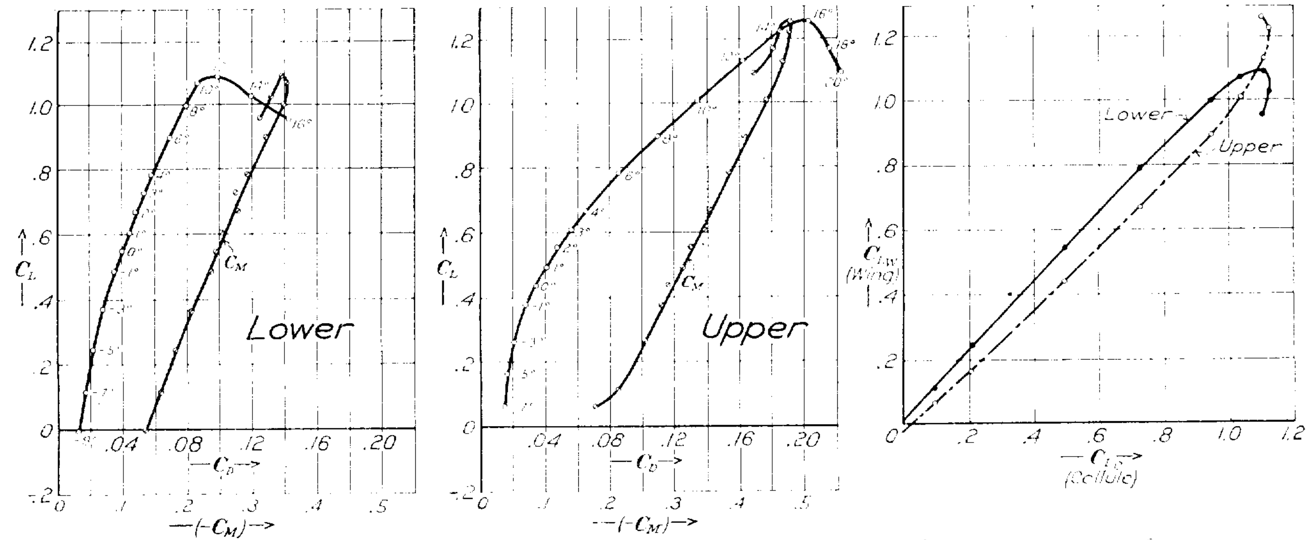

FIG. 19. Curves of coefficients of moments and lift of individual wings for U. S. A. T. S. 5 biplane. G/c=0.9; Stagger −30°

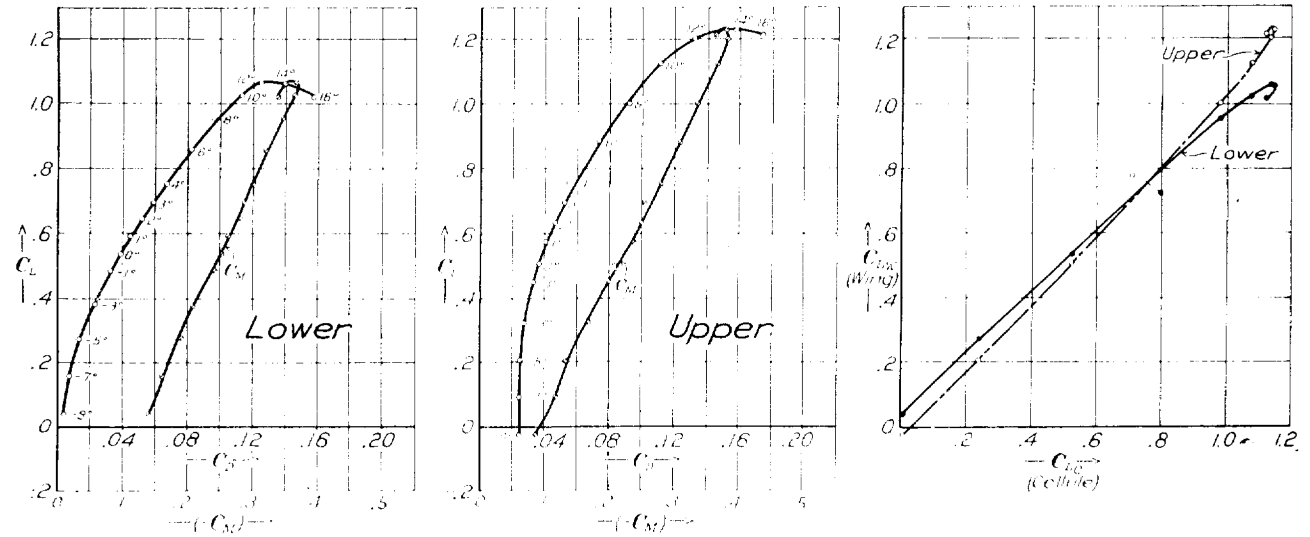

FIG. 20. Curves of coefficients of moments and lift of individual wings for U. S. A. T. S. 5 biplane. G/c=0.9; Stagger 0°

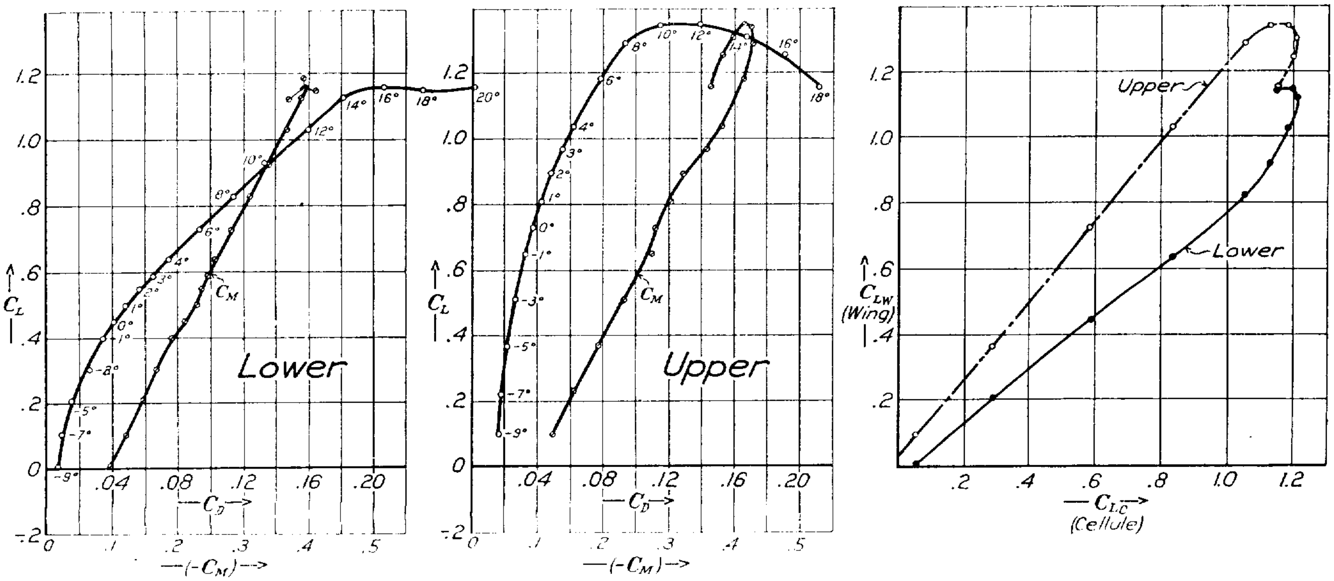

FIG. 21. Curves of coefficients of moments and lift of individual wings for U. S. A. T. S. 5 biplane. G/c=0.9; Stagger +30°

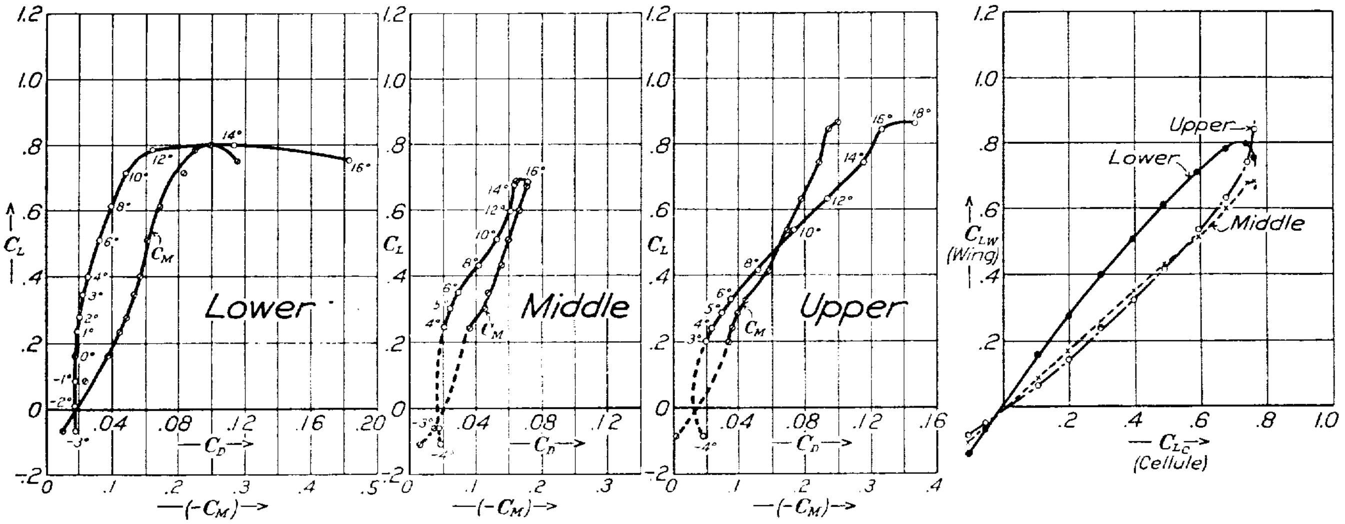

FIG. 23.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c—0.6; Stagger —30°

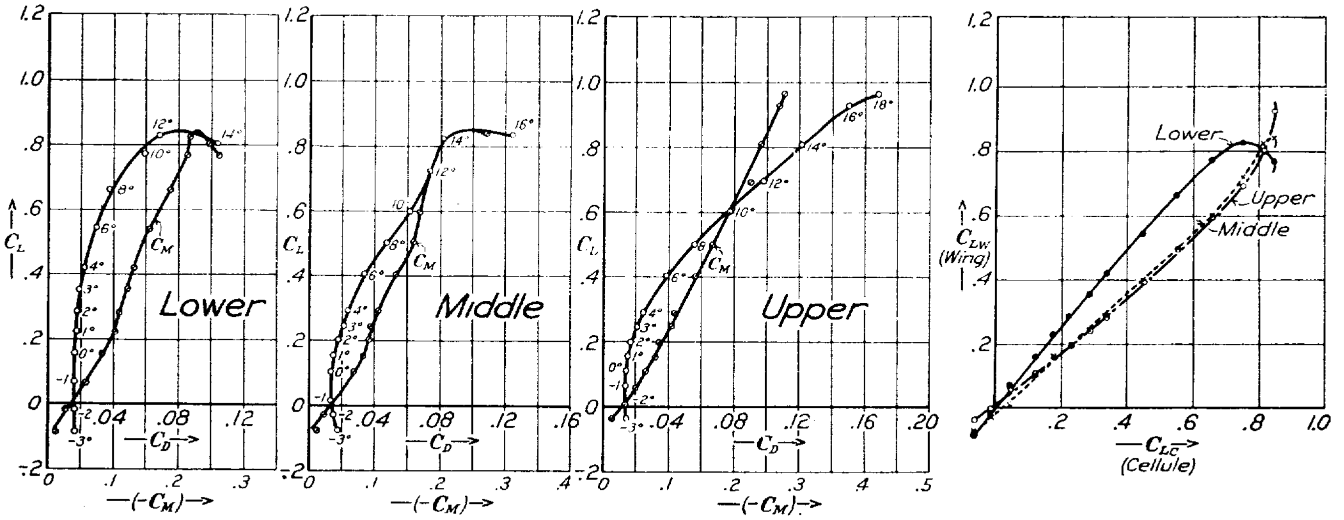

FIG. 24.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c—0.9; Stagger—30°

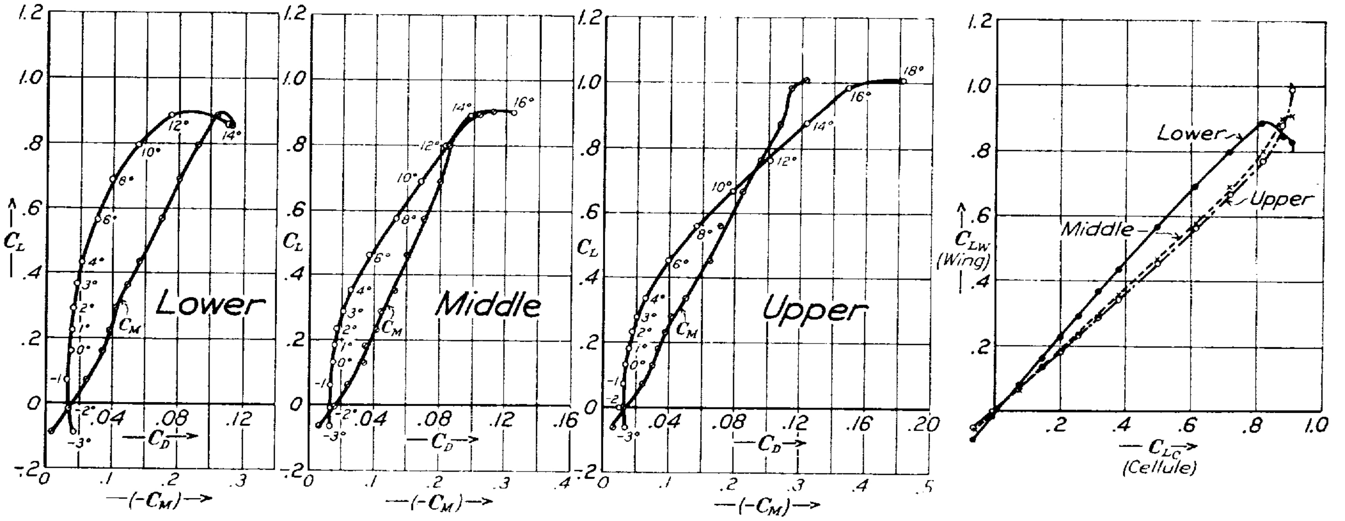

FIG. 25.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c—1.2; Stagger—30°

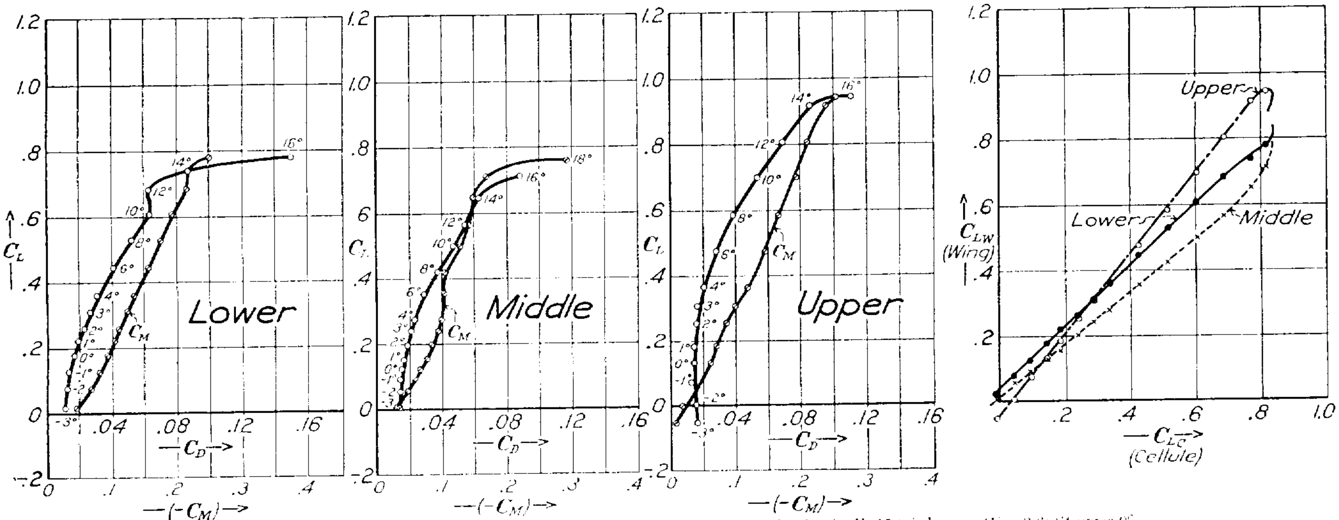

FIG. 26.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c = 0.6; Stagger 0°

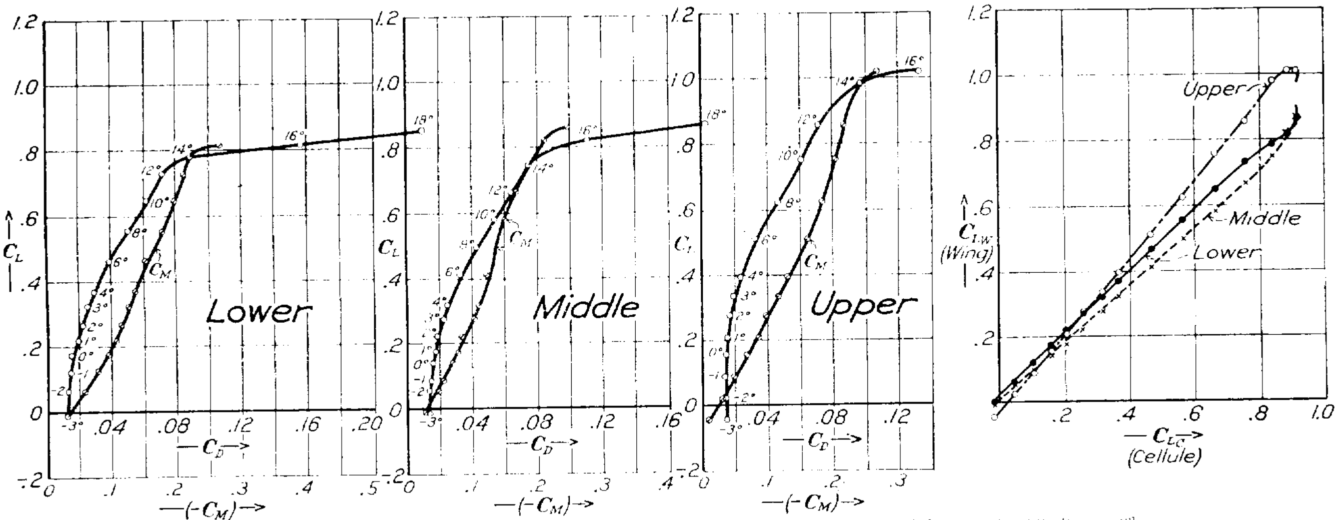

FIG. 27.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c = 0.8; Stagger 0°

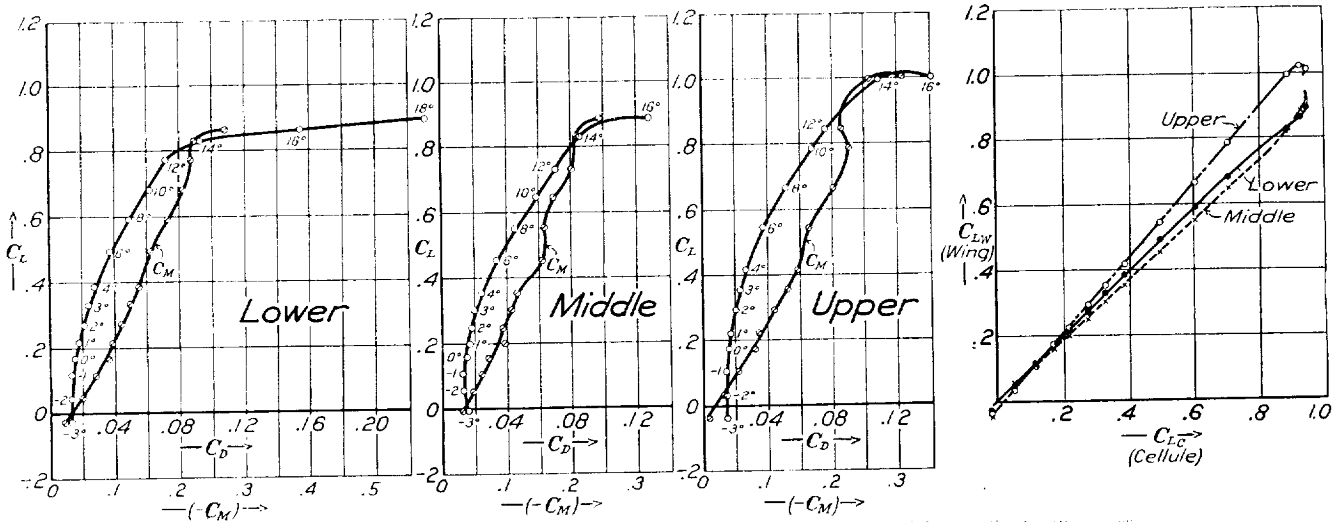

FIG. 28.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c = 1.0; Stagger 0°

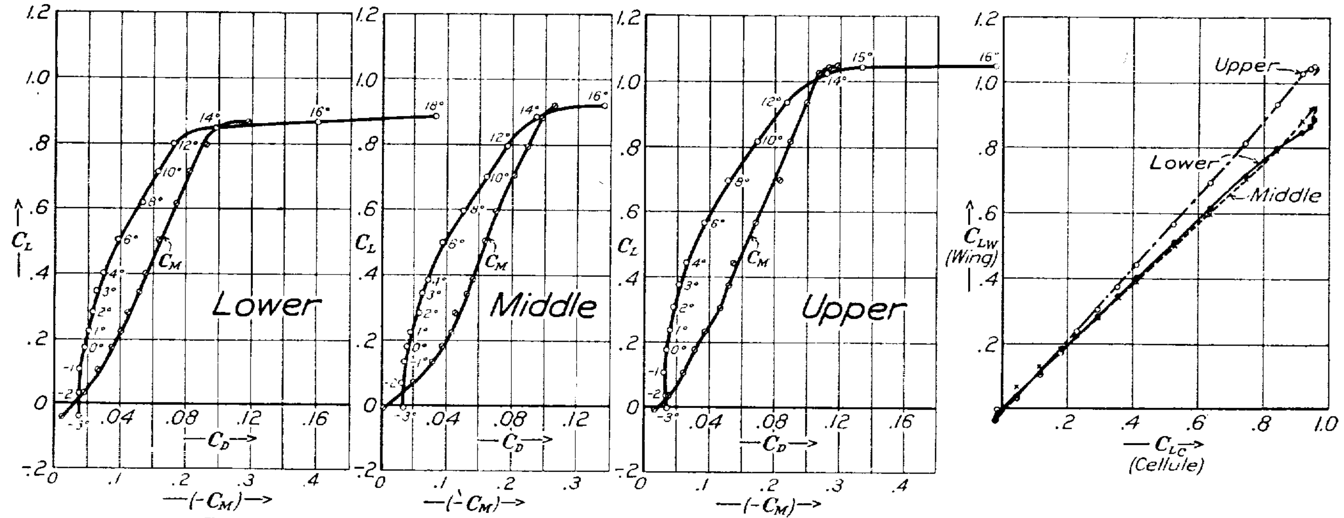

FIG. 29.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c=1.2; Stagger 0°

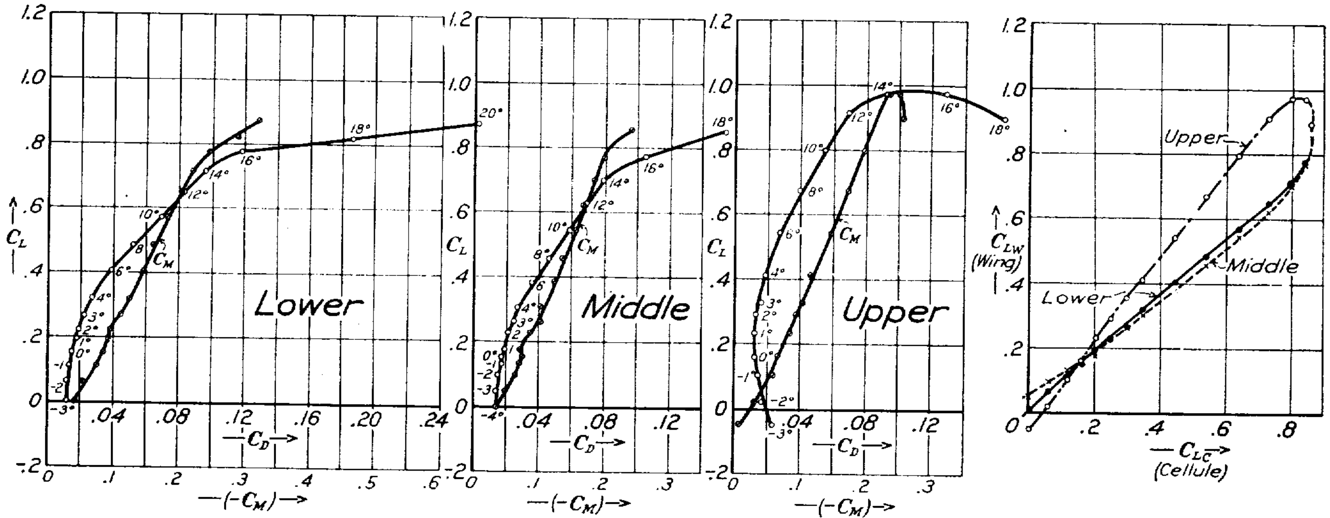

FIG. 30.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c=0.6; Stagger +15°

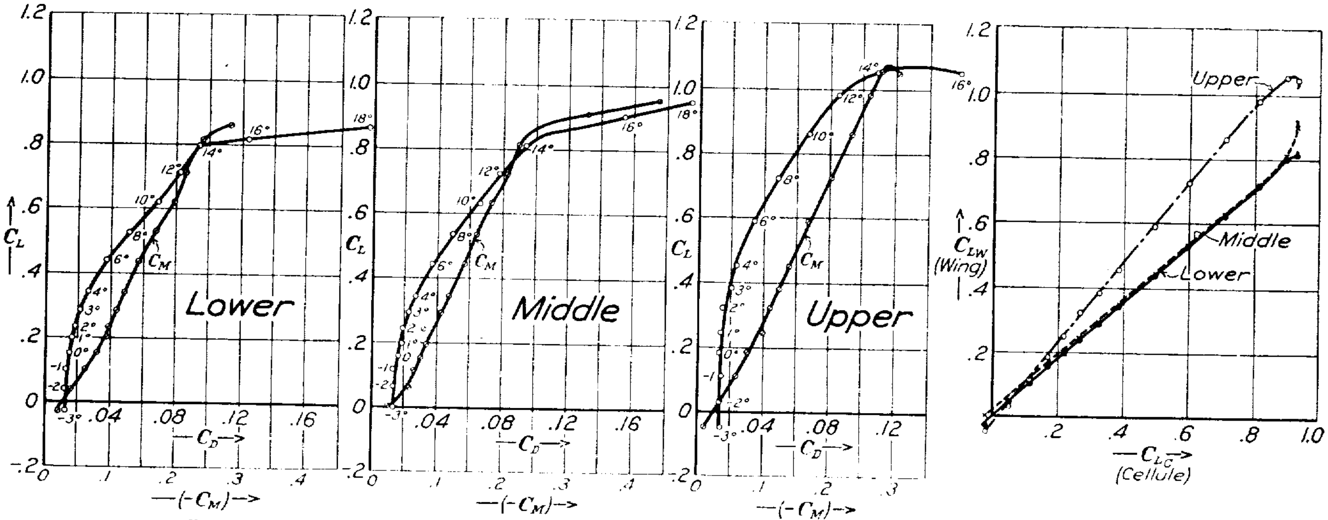

FIG. 31.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c=0.9; Stagger +15°

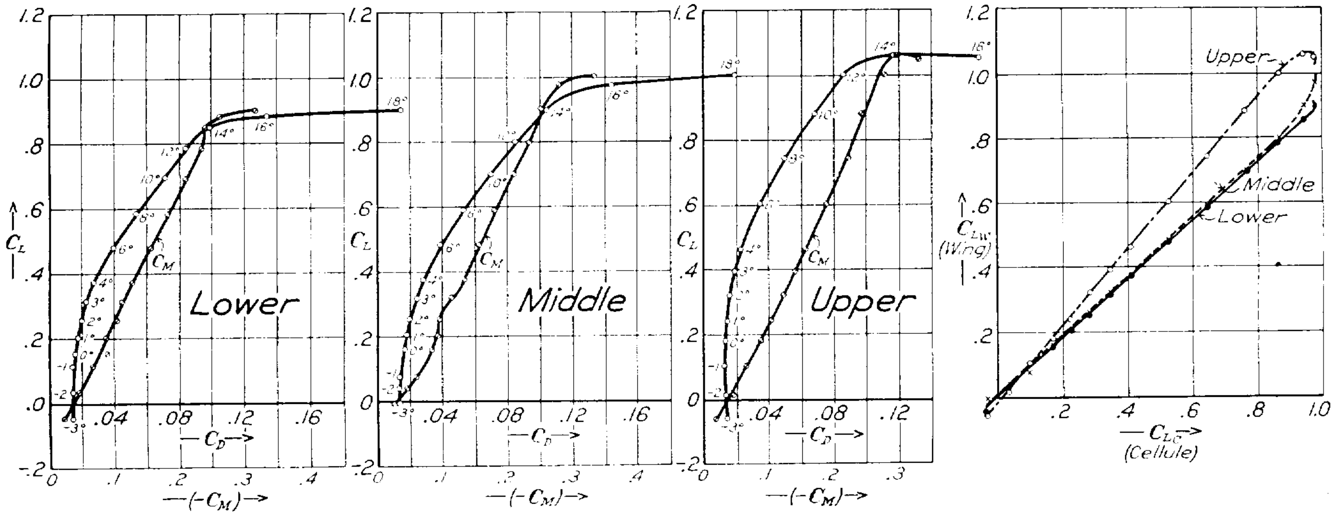

FIG. 32.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c=1.2; Stagger +15°

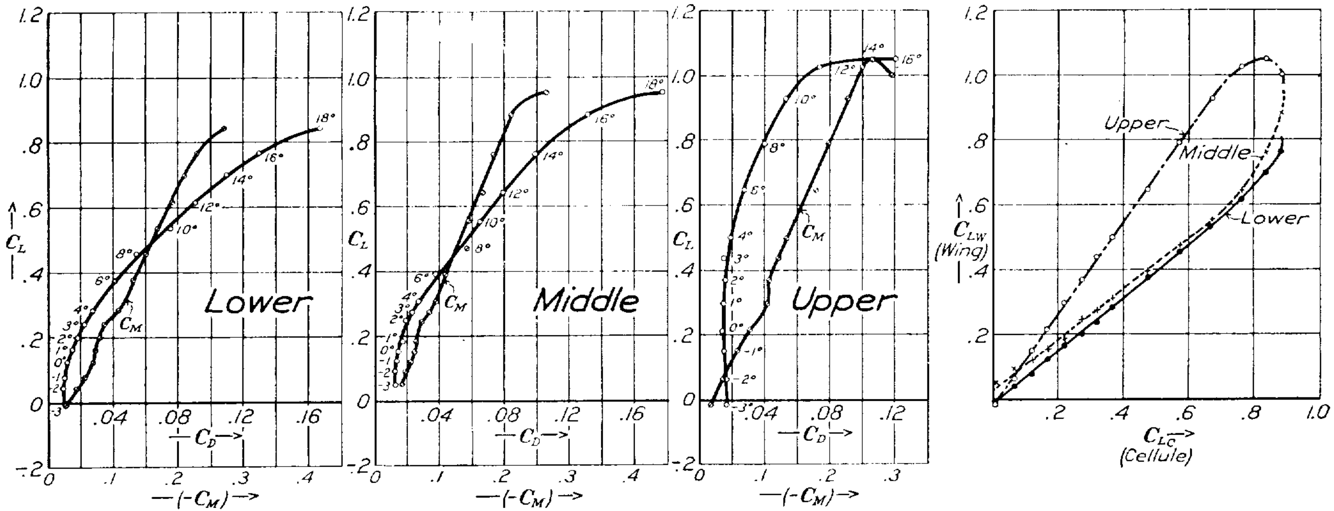

FIG. 33.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c=0.6; Stagger +30°

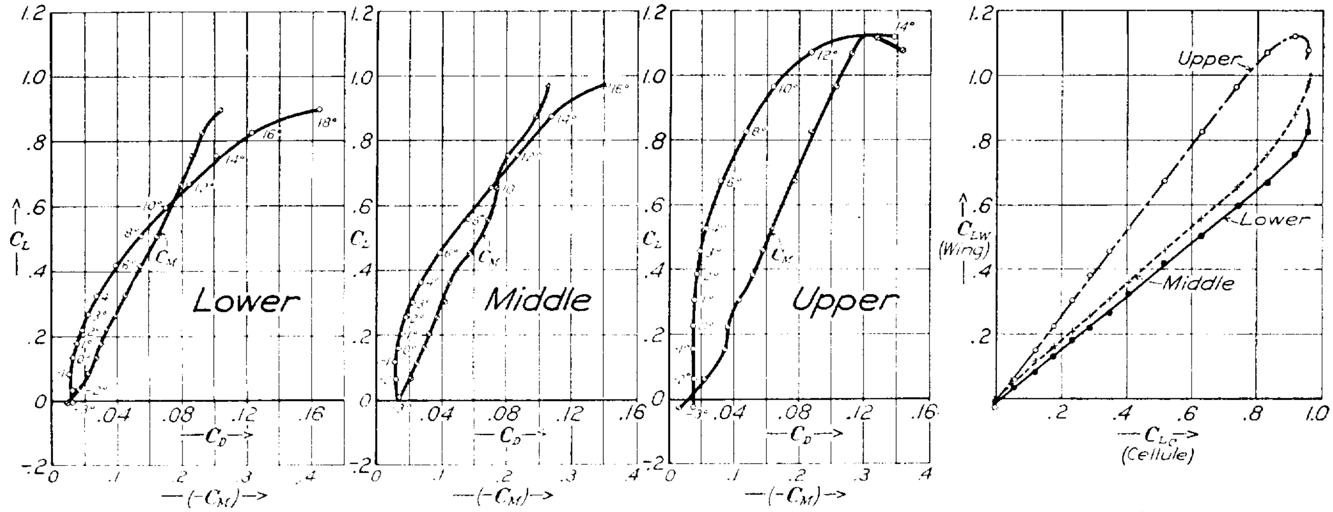

FIG. 34.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. G/c=0.9; Stagger +30°

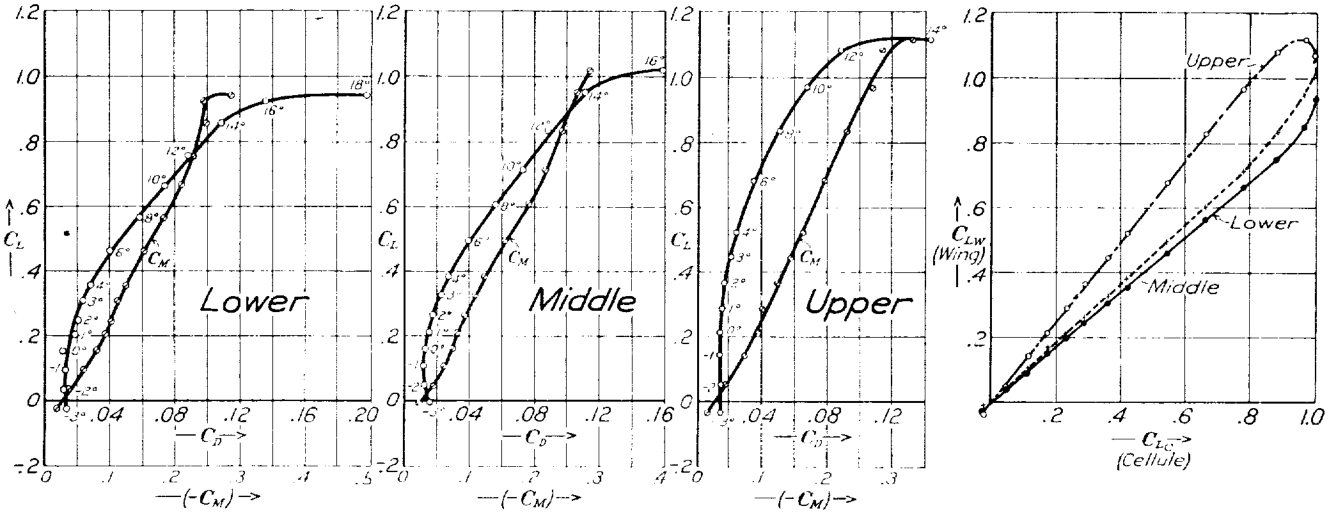

FIG. 35.—Curves of coefficients of moments and lift of individual wings for R. A. F. 15 triplane. $G/c=1.2$; Stagger +30°

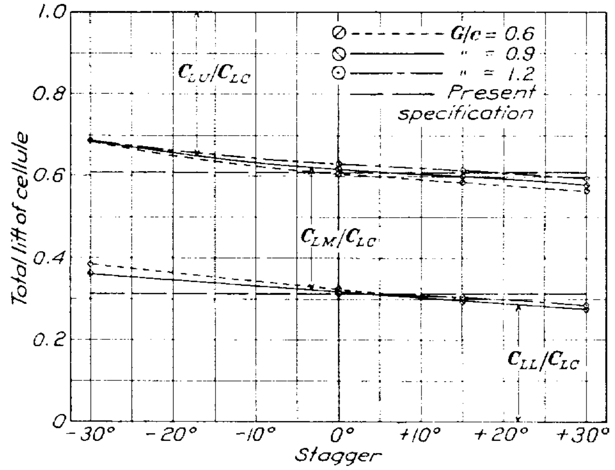

FIG. 36.—R. A. F. 15 triplane relative lift at 0.9 maximum lift

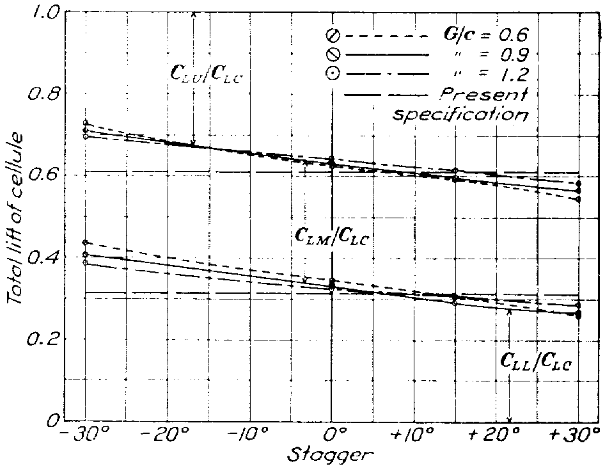

FIG. 37.—R. A. F. 15 triplane relative lift at 0.5 maximum lift

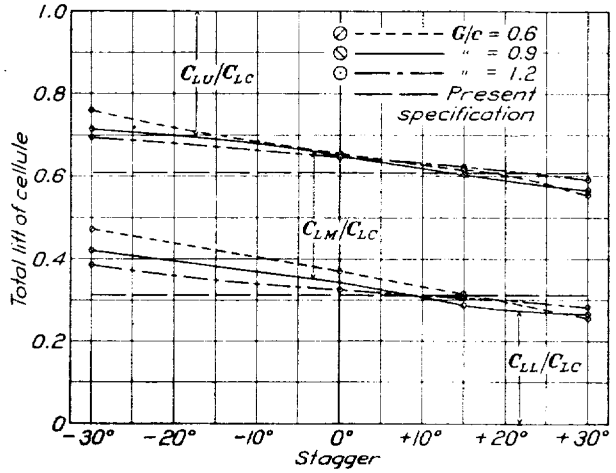

FIG. 38.—R. A. F. 15 triplane relative lift at 0.25 maximum lift

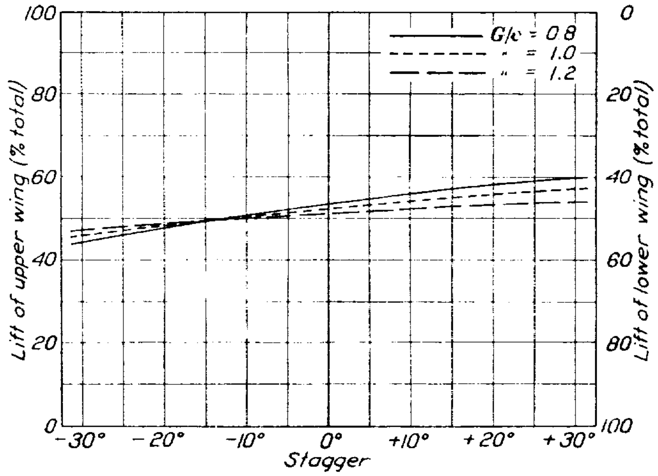

FIG. 39.—Relative lifts of biplane wings for all lift coefficients: Army standard.

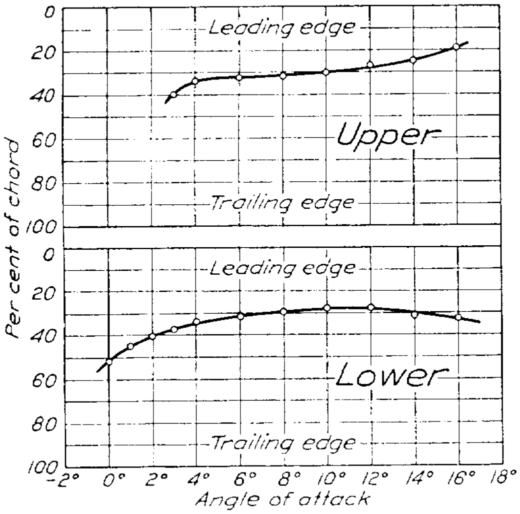

FIG. 40.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.6; Stagger −30°

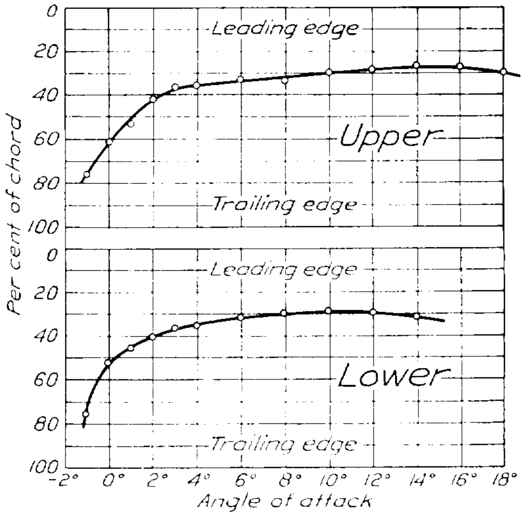

FIG. 41.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.9; Stagger −30°

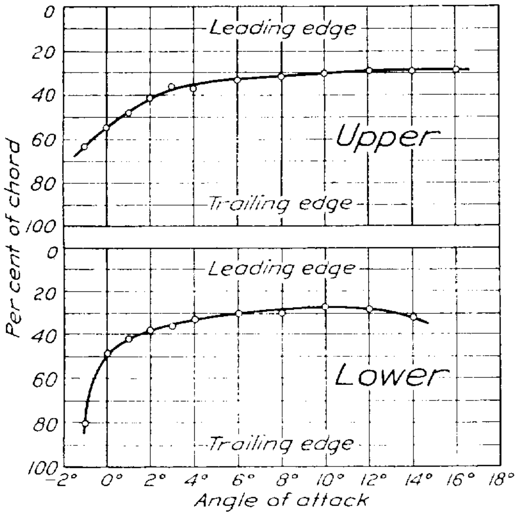

FIG. 42.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=1.2; Stagger −30°

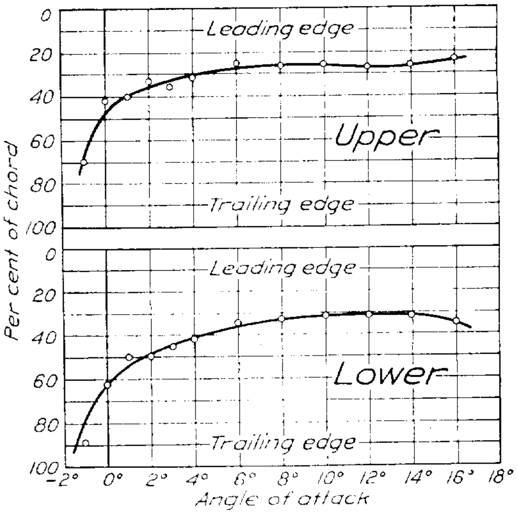

FIG. 43.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.6; Stagger 0°

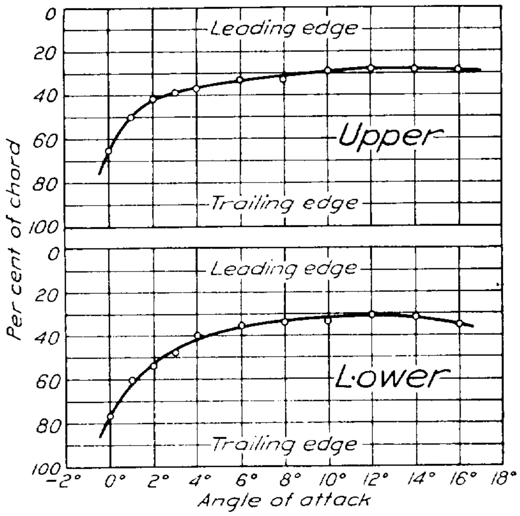

FIG. 44.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.8; Stagger 0°

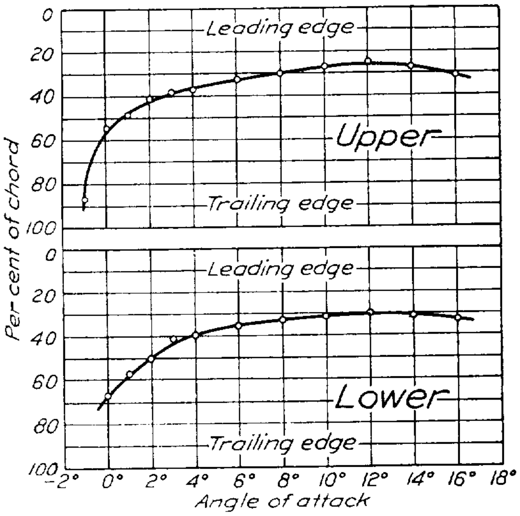

FIG. 45.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=1.0; Stagger 0°

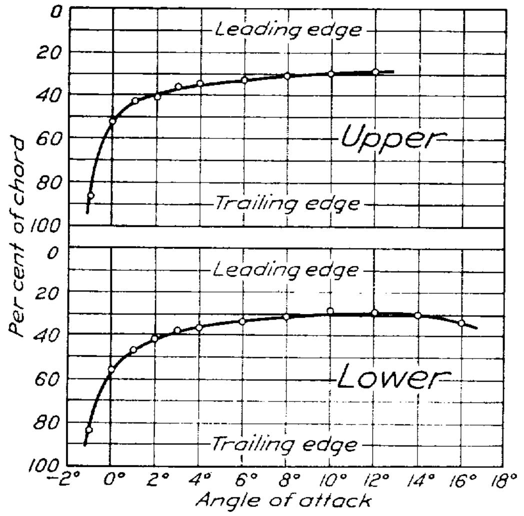

FIG. 46. Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=1.2; Stagger 0°

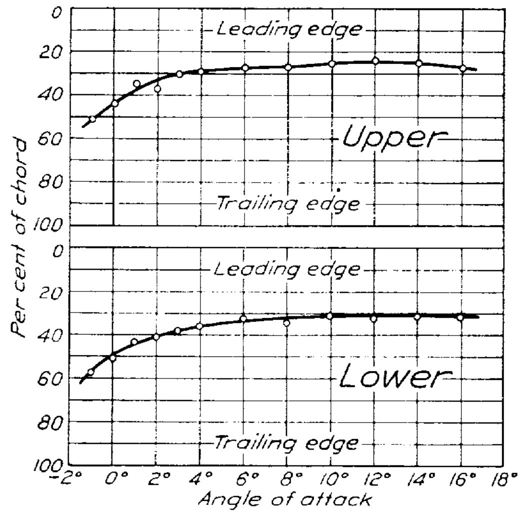

FIG. 47. Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.6; Stagger +15°

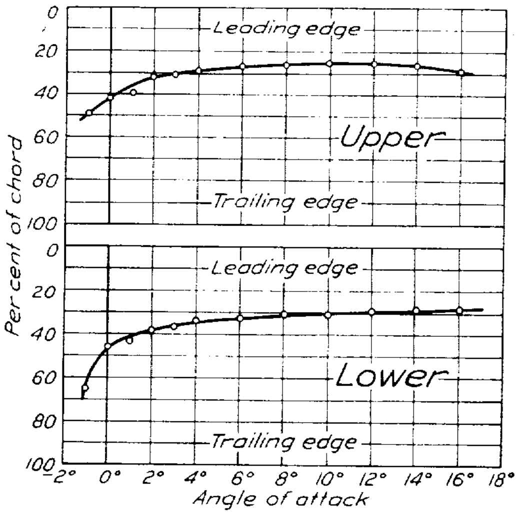

FIG. 48.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.9; Stagger +15°

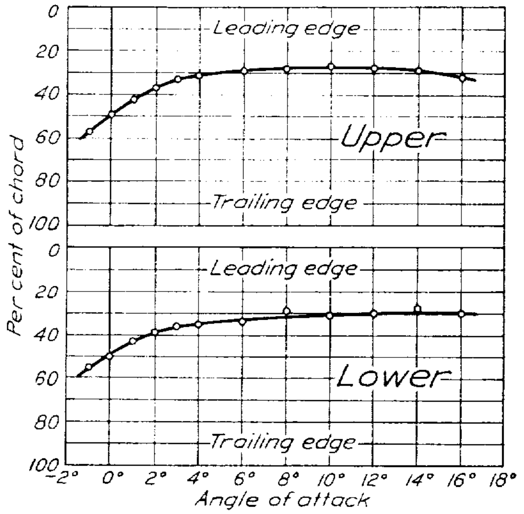

FIG. 49.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=1.2; Stagger +15°

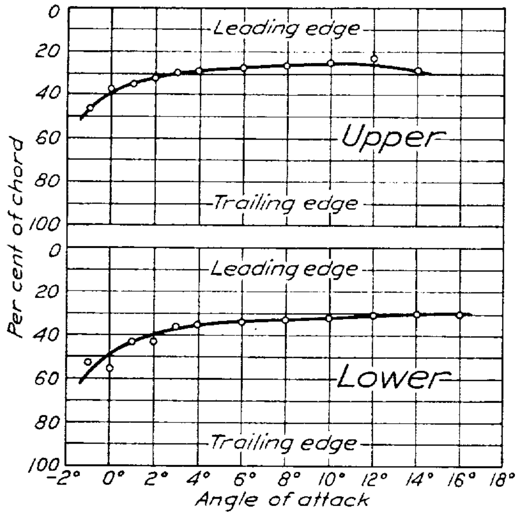

FIG. 50.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.6; Stagger +30°

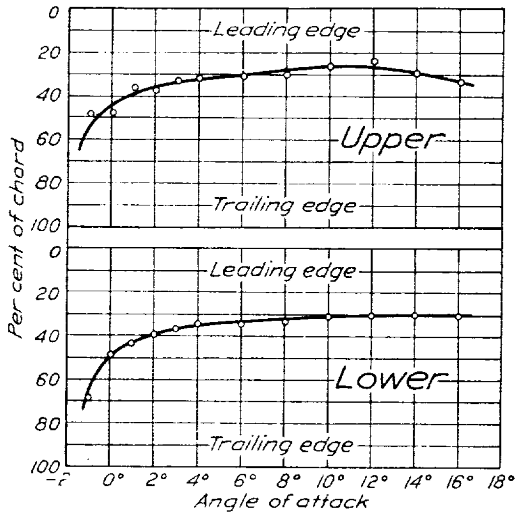

FIG. 51.—Centers of pressure in per cent of chord for R. A. F. 15 biplane. G/c=0.9; Stagger +30°

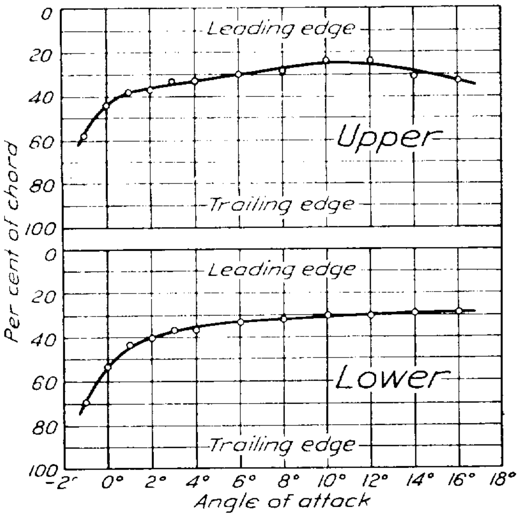

FIG. 52.—Centers of pressure in per cent of chord for R. A. F; 15 biplane. G/c=1.2 Stagger +30°

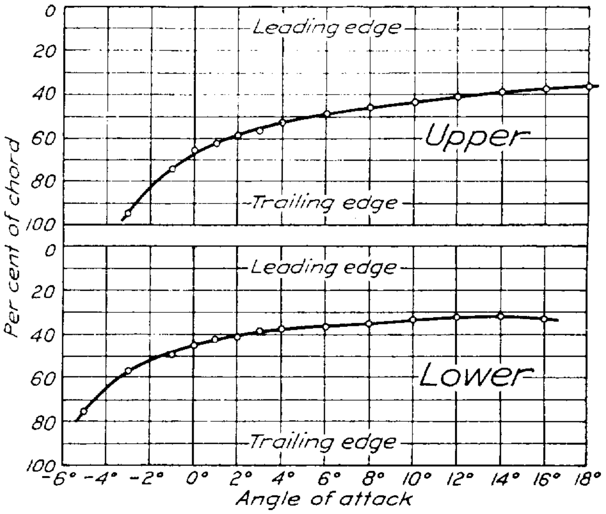

FIG. 53.—Centers of pressure in per cent of chord for U. S. A. T. S. 5 biplane. G/c=0.9; Stagger −30°

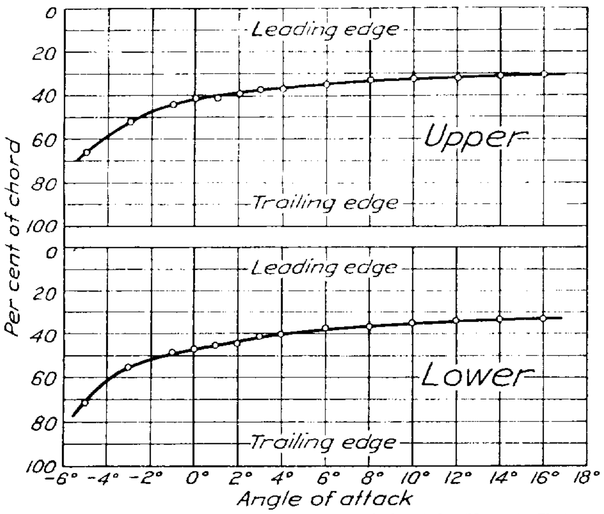

FIG. 54.—Centers of pressure in per cent of chord for U. S. A. T. S. 5 biplane. G/c=0.9; Stagger 0°

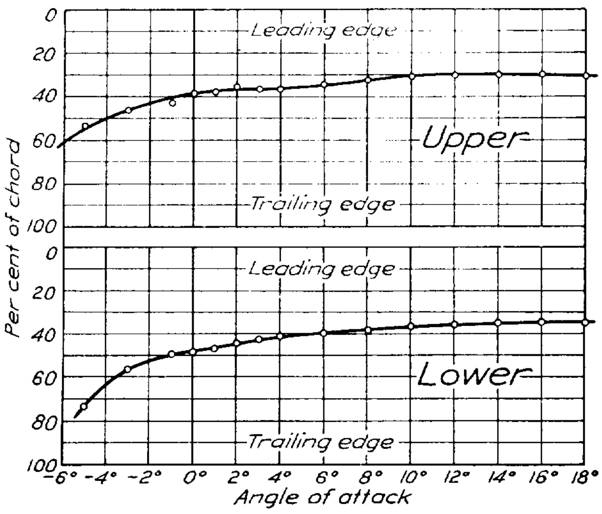

FIG. 55.—Centers of pressure in per cent of chord for U. S. A. T. S. 5 biplane. G/c=0.9; Stagger +30°

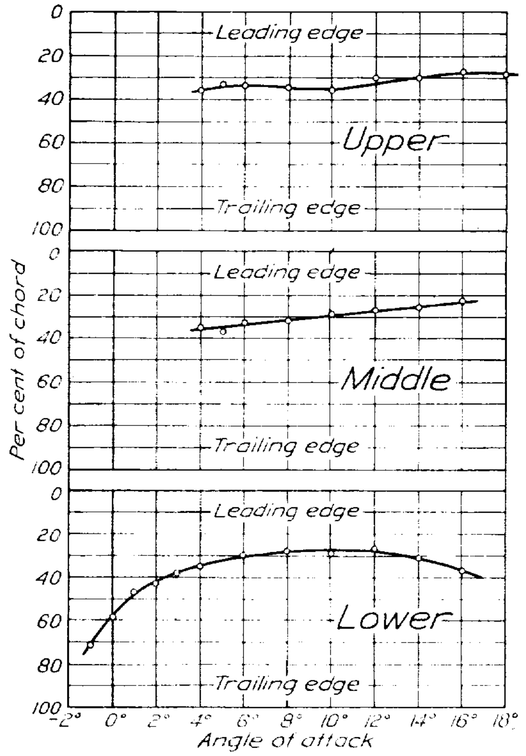

FIG. 56.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. $G/c=0.6$; Stagger −30°

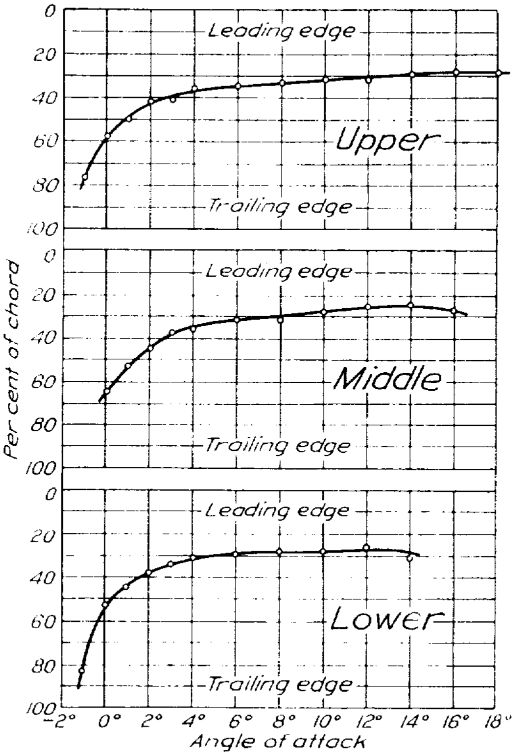

FIG. 57.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. $G/c=0.9$; Stagger −30°

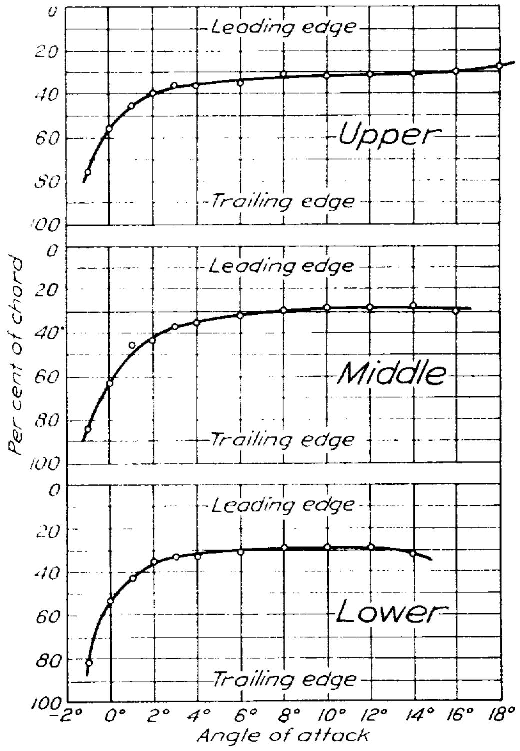

FIG. 58.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. $G/c=1.2$; Stagger −30°

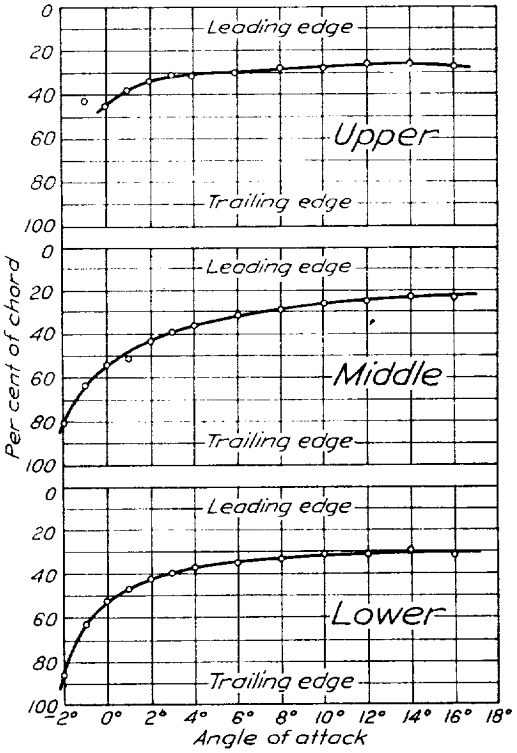

FIG. 59.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. $G/c=0.6$; Stagger 0°

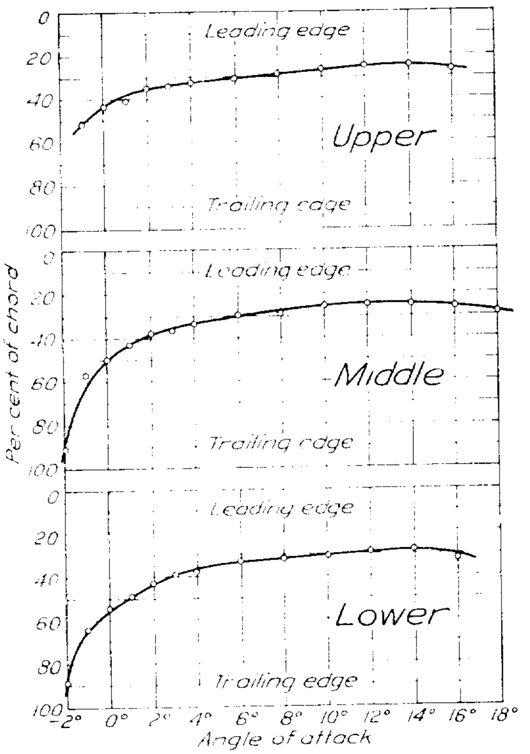

FIG. 60.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=0.8; Stagger 0°

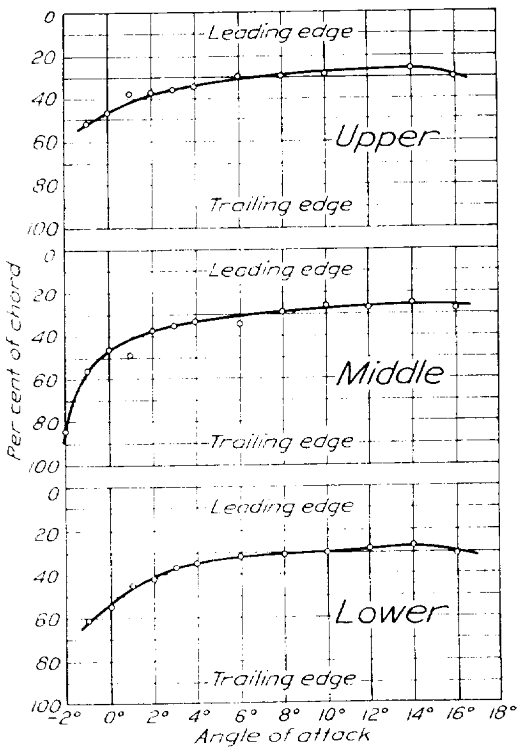

FIG. 61.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=1.0; Stagger 0°

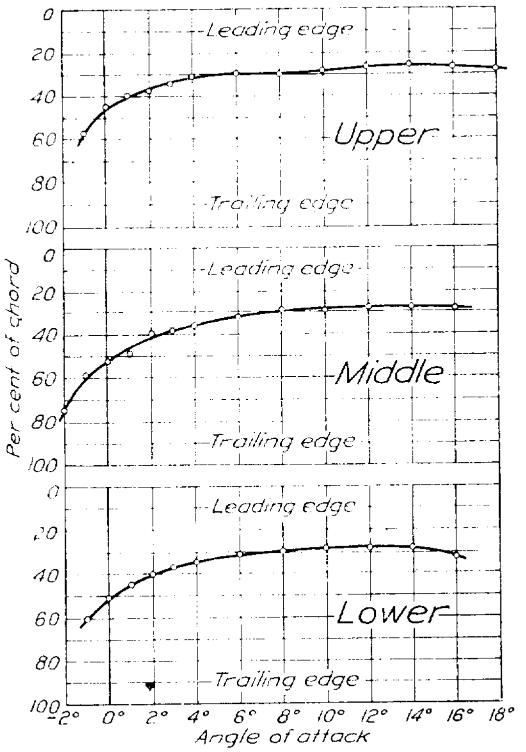

FIG. 62.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=1.2; Stagger 0°

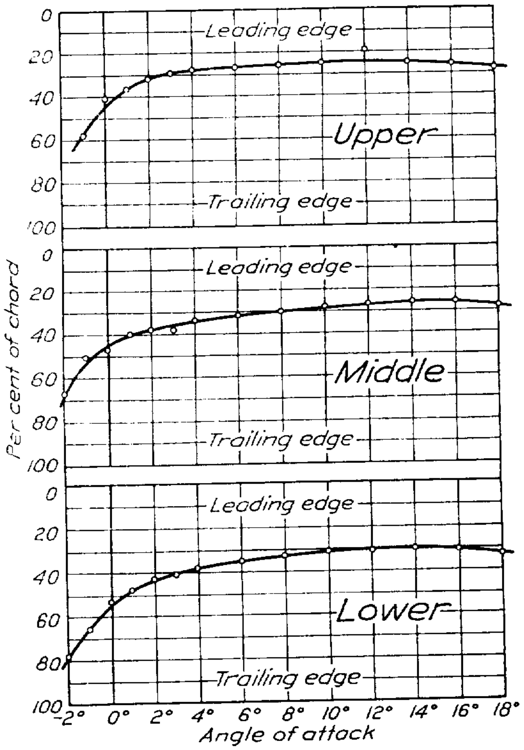

FIG. 63.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=0.6; Stagger +15°

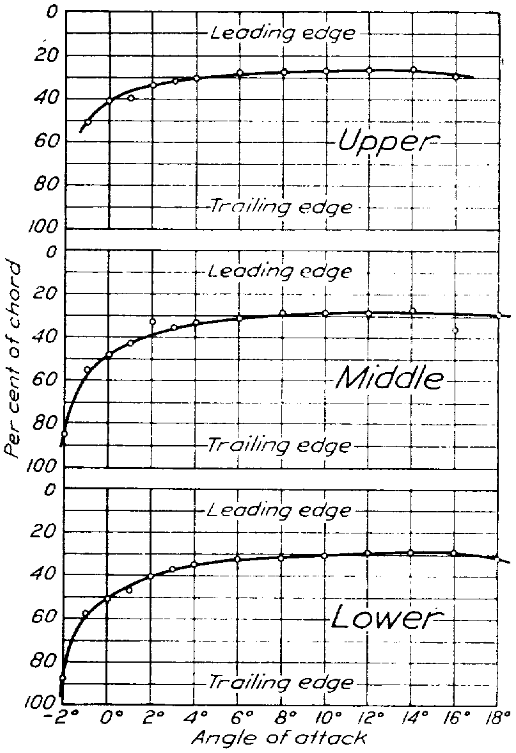

FIG. 64.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=0.9; Stagger +15°

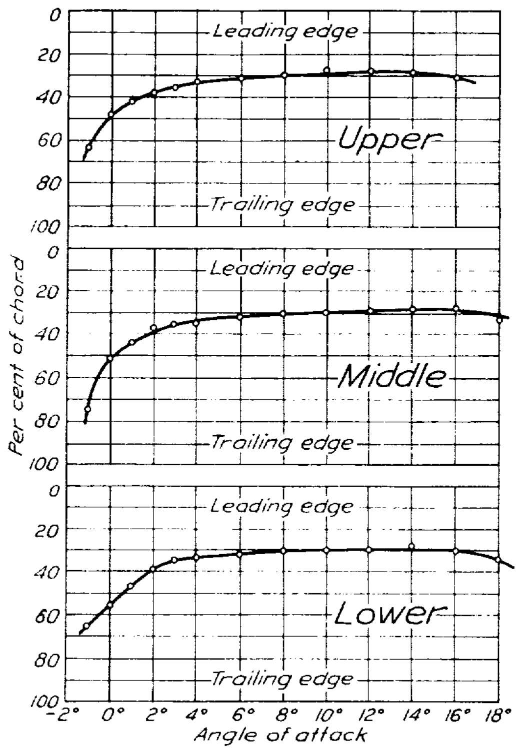

FIG. 65.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=1.2; Stagger +15°

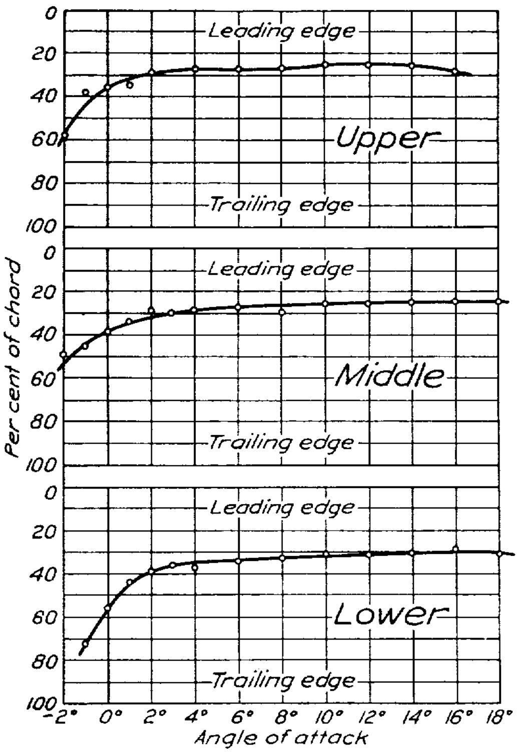

FIG. 66.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=0.6; Stagger +30°

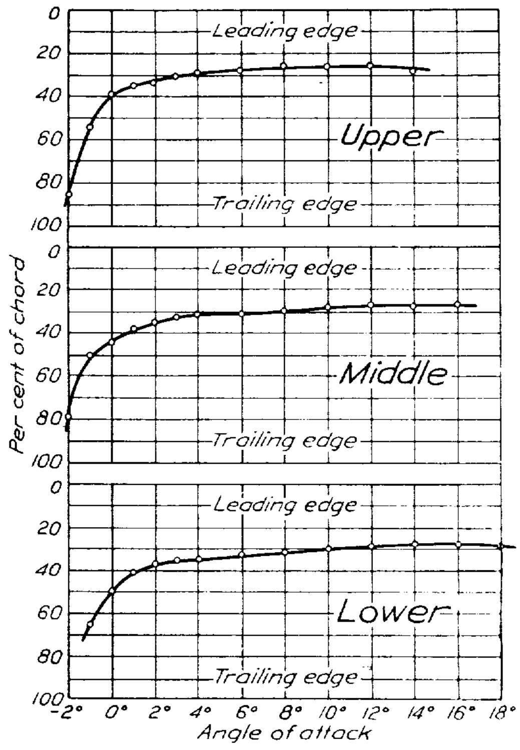

FIG. 67.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. G/c=0.9; Stagger +30°

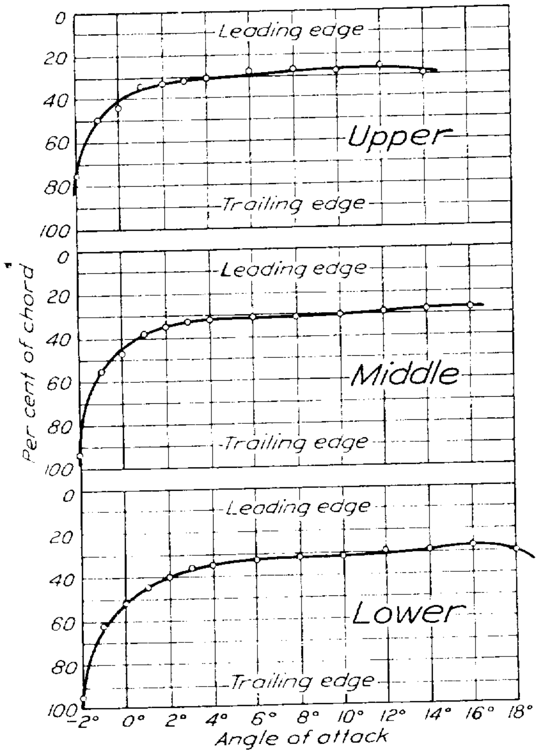

FIG. 68.—Centers of pressure in per cent of chord for R. A. F. 15 triplane. $G/c=1.2$; Stagger +30°

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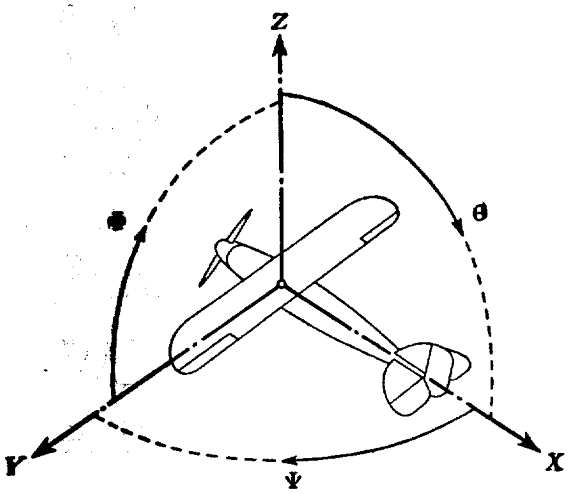

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	**rolling**	L	$Y \longrightarrow Z$	roll	Φ	u	p
Lateral	Y	Y	**pitching**	M	$Z \longrightarrow X$	pitch	Θ	v	q
Normal	Z	Z	**yawing**	N	$X \longrightarrow Y$	yaw	Ψ	w	r

Absolute coefficients of moment

$$C_L=\frac{L}{qbS}\quad C_M=\frac{M}{qcS}\quad C_N=\frac{N}{qfS}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter.
p_e, Effective pitch
p_g, Mean geometric pitch.
p_s, Standard pitch.
p_v, Zero thrust.
p_a, Zero torque.
p/D, Pitch ratio.
V', Inflow velocity.
V_s, Slip stream velocity.

T, Thrust.
Q, Torque.
P, Power.
(If "coefficients" are introduced all units used must be consistent.)
η, Efficiency $= T\,V/P$.
n, Revolutions per sec., r. p. s.
N, Revolutions per minute., R. P. M.
Φ, Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 HP = 76.04 kg/m/sec. = 550 lb./ft./sec.
1 kg/m/sec. = 0.01315 HP.
1 mi./hr. = 0.44704 m/sec.
1 m/sec. = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg.
1 kg = 2.2046224 lb.
1 mi. = 1609.35 m = 5280 ft.
1 m = 3.2808333 ft.