NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 417

PRESSURE DISTRIBUTION TESTS ON A SERIES OF CLARK Y BIPLANE CELLULES WITH SPECIAL REFERENCE TO STABILITY

By RICHARD W. NOYES

1932

For sale by the Superintendent of Documents, Washington, D. C.

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	s	second (or hour)	sec. (or hr.)
Force	F	weight of one kilogram	kg	weight of one pound	lb.
Power	P	kg/m/s		horsepower	hp
Speed		km/h	k. p. h.	mi./hr.	m. p. h.
		m/s	m. p. s.	ft./sec.	f. p. s.

2. GENERAL SYMBOLS, ETC.

W, Weight $= mg$

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

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

ρ, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m^{-4} s^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.

$\frac{b^2}{S}$, Aspect ratio.

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 $C_D = \frac{D}{qS}$

D_o, Profile drag, absolute coefficient $C_{D_o} = \frac{D_o}{qS}$

D_i, Induced drag, absolute coefficient $C_{D_i} = \frac{D_i}{qS}$

D_p, Parasite drag, absolute coefficient $C_{D_p} = \frac{D_p}{qS}$

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

R, Resultant force.

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

i_t, Angle of stabilizer setting (relative to thrust line).

Q, Resultant moment.

Ω, Resultant angular velocity.

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

e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, at 15° C., the corresponding number is 234,000;

or for a model of 10 cm chord 40 m/s, the corresponding number is 274,000.

C_p, Center of pressure coefficient (ratio of distance of *c. p.* from leading edge to chord length).

α, Angle of attack.

ϵ, Angle of downwash.

α_o, Angle of attack, infinite aspect ratio.

α_i, Angle of attack, induced.

α_a, Angle of attack, absolute. (Measured from zero lift position.)

γ Flight path angle.

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By RICHARD W. NOYES
Langley Memorial Aeronautical Laboratory

100179—32——1

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By Richard W. Noyes

SUMMARY

The pressure distribution data discussed in this report represent the results of part of an investigation conducted by the National Advisory Committee for Aeronautics on the factors affecting the aerodynamic safety of airplanes. The present tests were made on semispan, circular-tipped Clark Y airfoil models mounted in the conventional manner on a separation plane. Pressure readings were made simultaneously at all test orifices at each of 20 angles of attack between −8° and +90°.

The results of the tests on each wing arrangement are compared on the bases of maximum normal force coefficient, lateral stability at a low rate of roll, and relative longitudinal stability. Tabular data are also presented giving the center of pressure location of each wing.

The principal conclusions drawn from the results of these tests may be summarized as follows:

1. No biplane arrangement investigated has as high a value of maximum normal force coefficient as the monoplane, although the value for the cellule having 50 per cent positive stagger and 3° positive decalage (the lower wing at a higher angle of attack than the upper) is only 3 per cent less.

2. Unstable rolling moments due to a low rate of roll are generally decreased by the use of a gap/chord ratio of less than 1.0, positive stagger alone, or positive stagger and negative decalage.

3. Combined positive stagger and negative decalage show the greatest relative longitudinal stability below the stall.

INTRODUCTION

A review of the general problem of the aerodynamic safety of airplanes shows that the combination of flight characteristics peculiar to the conventional airplane at high angles of attack is one of the most prolific sources of danger—a situation that is directly traceable to the fact that the greatest and most sudden changes in lift and stability occur at these attitudes.

To increase the rather meager general information on airfoils operating in this angular range the National Advisory Committee for Aeronautics has conducted a comprehensive investigation of the aerodynamic characteristics of a large series of Clark Y monoplane and biplane combinations up to 90° angle of attack. This research consisted of force tests, autorotation tests, and pressure distribution tests, all made in the 5-foot atmospheric wind tunnel of the N. A. C. A. (reference 1), at a Reynolds Number of about 150,000.

The results of the force tests have been reported in references 2 and 3, the autorotation tests in reference 4, and the preliminary results of the pressure distribution tests in references 5, 6, and 7. The present report is a compilation and analysis of all the pressure distribution data given in the last three references.

Analysis of the data presented in this report covers (1) the effect of wing arrangement on maximum normal force; (2) the effect of wing arrangement on lateral stability at high angles of attack; and (3) the effect of wing arrangement on longitudinal stability.

APPARATUS AND METHODS

Apparatus.—Conventional pressure distribution test apparatus (the validity of the use of which is discussed in references 5 and 8) was used in the closed-throat atmospheric wind tunnel. A general view of the apparatus is shown in Figure 1, and a photograph of the wing models mounted vertically through a midspan "separation plane" is shown in Figure 2. The horizontal plane extended several feet upstream and downstream from the models and completely across the tunnel. Its leading edge was adjustable through a small vertical angle in order to compensate for the frictional reduction in air velocity adjacent to the plane's surface. The disk in its center was free to rotate with the wing models when their angle of attack was changed. This adjustment was possible from outside the test section while the tunnel was in operation. A clamp beneath the separation plane, protected from the air stream by a fairing, held the wing models. It was adjustable while the tunnel was shut down to allow the wings to be set in any desired biplane arrangement.

The semispan models were 5-inch chord, Clark Y airfoils with circular tips and an aspect ratio of 6. The same profile shape was maintained throughout the span and the chords of all sections lay in the

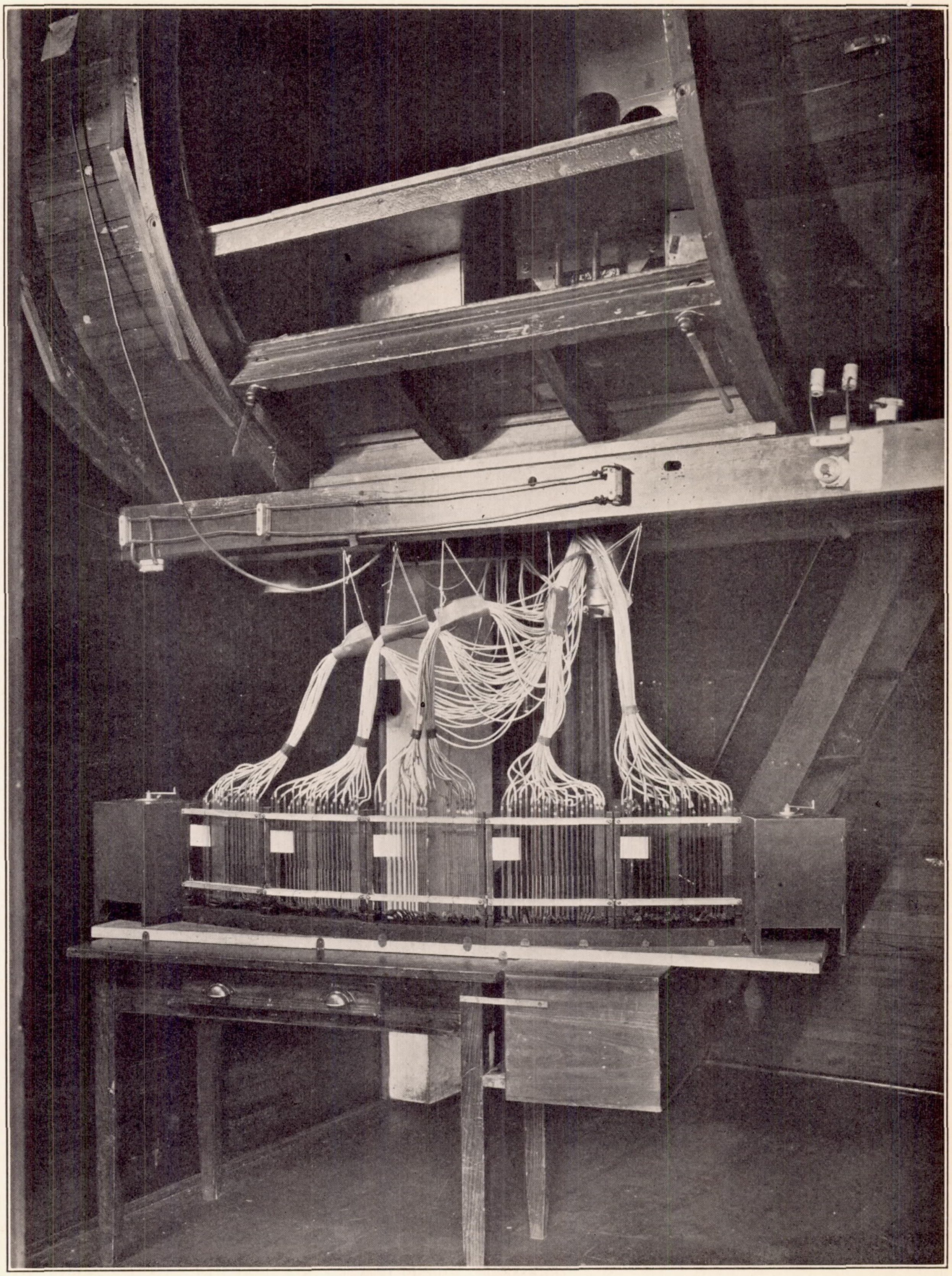

FIGURE 1.—General view of test apparatus

same plane. Figure 3 shows the plan form of the wings with test sections and orifice locations indicated. Each orifice was the end of a 0.015-inch inside diameter brass tube inlaid between the mahogany laminations of the model. The other end of each tube extended several inches beyond the butt of the wing to facilitate its connection to the manometer.

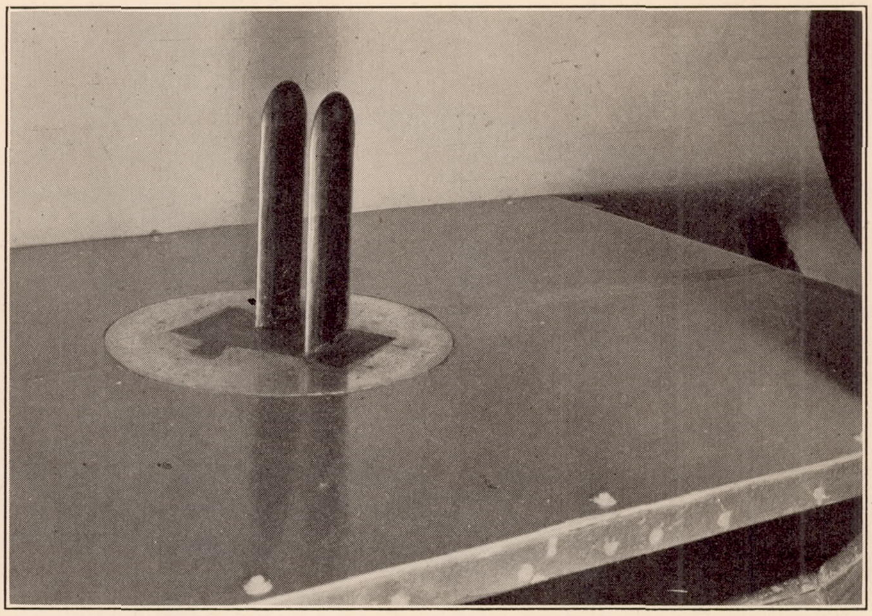

FIGURE 2.—Semispan wing models mounted on separation plane

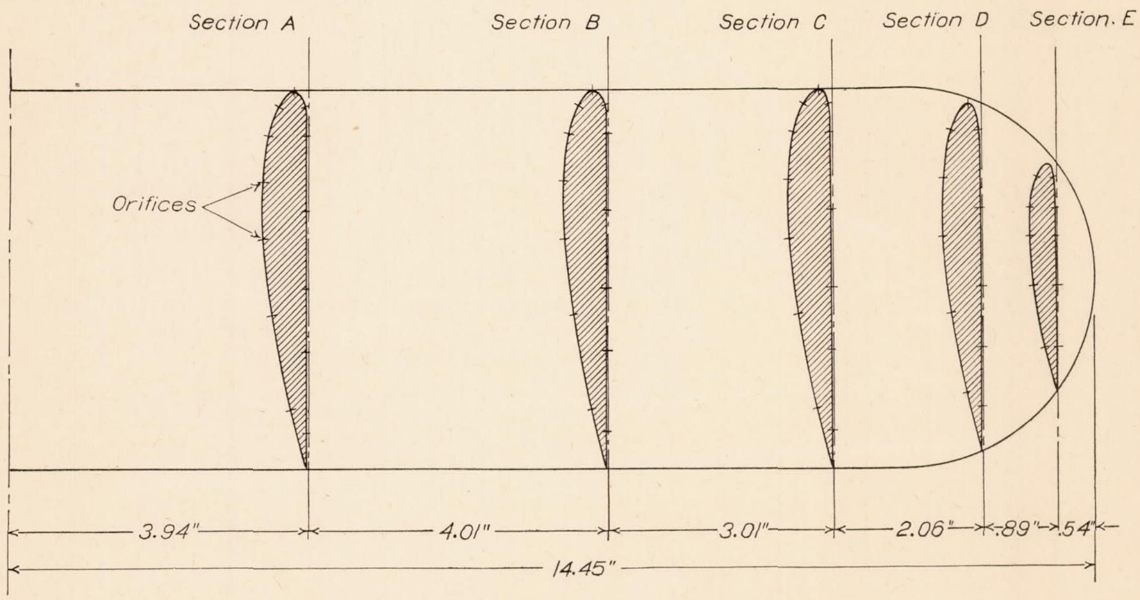

FIGURE 3.—Plan view of wing models showing profiles and orifice locations

The multiple-column alcohol manometer and rubber tubing connecting it to the inlaid brass tubes in the models are seen in Figure 1 mounted below the tunnel test section. The manometer tubes were arranged approximately on the arc of a circle at the center of which was an electric light used to expose the photostatic records. The tubes were grouped according to test sections on the models, and within each group they were so spaced that the heights of the alcohol columns formed ordinates of the section-load diagrams. Shadowgraph records of these heights were obtained on a long strip of sensitized paper stretched behind the tubes. As each record was taken it was wound on a reel in a lightproof box at one end of the manometer and a fresh length of paper unwound from a similar box at the other end.

Dynamic pressure in the test section of the wind tunnel was indicated on a separate micromanometer. This instrument was connected to a calibrated Pitot-static tube located several feet upstream where it was not affected by the presence of the models.

Tests.—A velocity survey of the air stream was made along the vertical diameter of the tunnel test section about 1 foot ahead of the models. Figure 4 shows the distribution of dynamic pressure as obtained with the models set at zero lift and reference 8 indicates that this distribution will not be changed appreciably by increasing the angle of attack. The integrated mean dynamic pressure between the limits shown was used to calibrate the "service" Pitot-static tube employed throughout the investigation to indicate the air speed in the test section.

Table I gives a complete list of the monoplane and biplane arrangements investigated. Each wing set-up was tested at angles of attack from −8° to +90° at 2° intervals in the vicinity of the stall and at larger angular steps over the remainder of the range.

The detailed test procedure followed in each case was, in general, similar to that employed in previous wind-tunnel pressure-distribution work in which all orifice pressures were recorded simultaneously. Before each run the pressure lines from the wing orifices to the manometer tubes were checked for leaks or blocking. The air was then brought up to speed, the desired angle of attack set, and the record obtained.

TABLE I

PRESSURE DISTRIBUTION TEST PROGRAM

Wing profile—Clark Y.
Tip shape—Circular.
Aspect ratio—6 (except for shorter wing of overhung combinations.)

Variable	Gap/chord	Stagger/chord	Decalage [a]	Dihedral	Sweepback	Overhang
Monoplane	Upper wing tested alone.			0	0	-------
	Lower wing tested alone.			0	0	-------
Gap	0. 50	0	0	0	0	0
	. 75	0	0	0	0	0
	1 00	0	0	0	0	0
	1. 25	0	0	0	0	0
	1. 50	0	0	0	0	0
Stagger	1	−0. 25	0	0	0	0
	1	+. 25	0	0	0	0
	1	+. 50	0	0	0	0
	1	+. 75	0	0	0	0
Decalage	1	0	−6°	0	0	0
	1	0	−3°	0	0	0
	1	0	+3°	0	0	0
	1	0	+6°	0	0	0
Dihedral	1	0	0	3° upper	0	0
	1	0	0	3° lower	0	0
Sweepback	1	0	0	0	10° upper	0
	1	0	0	0	5° upper	0
	1	0	0	0	5° lower	0
	1	0	0	0	10° lower	0
Overhang	1	0	0	0	0	+20%
	1	0	0	0	0	+40%
	1	0	0	0	0	−20%
Gap and stagger	. 75	+. 25	0	0	0	0
	. 75	+. 50	0	0	0	0
	1 25	+. 25	0	0	0	0
	1 25	+. 50	0	0	0	0
Stagger and decalage	1	+. 25	+3°	0	0	0
	1	+. 50	+3°	0	0	0
	1	+. 25	−3°	0	0	0
	1	+. 50	−3°	0	0	0
Gap and decalage	1 25	0	+3°	0	0	0
	. 75	0	+3°	0	0	0
	1. 25	0	−3°	0	0	0
	. 75	0	−3°	0	0	0
Stagger and sweepback	1	+. 25	0	0	5° upper	0
	1	+. 50	0	0	10° upper	0
	1	−. 50	0	0	10° lower	0

[a] Decalage is considered positive when the lower wing is at a larger angle of attack han the upper wing.

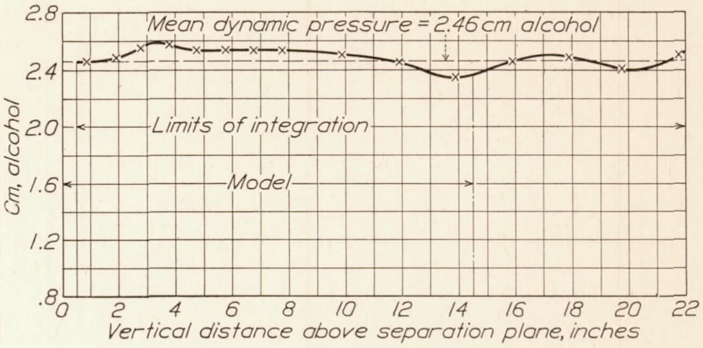

FIGURE 4.—Vertical dynamic pressure distribution 1 foot ahead of model position

RESULTS

Reduction of test data.—The results of this investigation were obtained from the recorded orifice pressures by three steps of graphical integration. First, the section normal force diagrams, which were drawn directly on the manometer records, were integrated for area and moment about the leading edge of the straight portion of the wing. The resulting section loads and section pitching moments were then plotted against span. Integration of the wing-load diagrams gave total wing normal force and bending moment about the root, and integration of the wing pitching moment curves gave total wing pitching moments. Finally, these dimensional loads and moments were reduced to coefficient form by means of the following equations.

Section normal force:

$$C_N' = \frac{N'}{qc} \tag{1}$$

where

N' = the normal load on a section of unit span

q = dynamic pressure

c = chord of the section.

Total wing normal force:

$$C_N = \frac{N}{qS} \tag{2}$$

where

N = the normal load on the whole wing

S = wing area

Cellule normal force:

$$C_{N\ cellule} = \frac{C_{N\ upper}\,S_{upper} + C_{N\ lower}\,S_{lower}}{S_{cellule}} \tag{3}$$

Wing loading ratio:

$$e = \frac{C_{N\ upper}}{C_{N\ lower}} \tag{4}$$

Cellule pitching moment about the quarter-chord point of the mean cellule chord:

$$C_{m\,c/4}=\frac{[C_N\times S\times(C_{px}'-C_{px})]_{upper}+[C_N\times S\times(C_{px}'-C_{px})]_{lower}}{S_{cellule}} \qquad (5)$$

where

C_{px}' = longitudinal distance in terms of the wing chord from its leading edge to the 25 per cent point of the chord of an imaginary airfoil lying between the upper and lower wings of the cellule at a distance from each inversely proportional to its area and bounded by planes passing through their leading and trailing edges

C_{px} = longitudinal center of pressure of the wing in terms of the chord

Longitudinal center of pressure:

$$C_{px}=\frac{M}{N} \qquad (6)$$

where

M = total pitching moment about the leading edge of the normal force over the wing

Lateral center of pressure:

$$C_{py}=\frac{L}{N} \qquad (7)$$

where

L = total bending moment about the wing root due to the normal force over the wing

Rolling moment due to roll was calculated by the strip method (reference 9) from curves of C_N' plotted against α, and reduced to coefficient form by the equation,

$$C_\lambda=\frac{\lambda}{qbS}\cos\alpha \qquad (8)$$

where

α = the angle of attack and λ is the total rolling moment due to the asymmetric distribution of normal load along the span when the assumed rate of roll is such that

$$\frac{pb}{2V}=0.05 \qquad (9)$$

In this expression

p = rate of rotation in roll in radians per second

b = span of wing in feet

V = air velocity in feet per second at center section of the wing

and the numerical measure of the rate of roll, 0.05, corresponds to the results obtained in flight tests in extremely gusty air when the airplane is held as level as possible.

Tables and figures.—The coefficients as derived from the foregoing equations are presented in graphical and tabular form. Curves of cellule, upper wing, and lower wing normal force coefficient (all plotted against angle of attack) are presented in families according to the principal cellule variables in Figures 5 to 35. The monoplane C_N curve included in each of these figures showing biplane cellule normal force is the mean curve of the two wings making up the cellule tested separately as monoplanes. The monoplane curve shown on the remaining figures is drawn through the experimental points of the particular wing (upper or lower) to which it is being compared.

Lateral stability characteristics of each wing arrangement are indicated by curves of C_λ plotted against angle of attack in Figures 36 to 46. In this series of figures, the monoplane comparison curve is, again, the mean of the two wings tested separately as monoplanes.

Curves of pitching moment about the 25 per cent point of the mean chord are given for all cellules in Figures 47 to 57.

Table II is a collection of the maxima and other important features of the foregoing curves. Tables III to XL contain all the data obtained in this research on the following characteristics of each cellule tested: (1) Normal force coefficient of the complete cellule; (2) pitching-moment coefficient of the complete cellule; (3) wing-loading ratio; (4) normal force coefficient of the individual wings of each cellule; (5) longitudinal and lateral center of pressure of each wing. (For the benefit of persons interested in the study of the effect of cellule arrangement and angle of attack on the spanload distribution of the individual wings of a biplane, tables of section normal force coefficients for all the arrangements discussed in this report are available upon request. This material is not included in the present report, because of its relatively limited general interest and because it is irrelevant to the present discussion.)

Accuracy.—A comparison of the results of repeat runs showed that a deviation of about ±2 per cent of the mean observed value of the variable may be expected in any plotted or tabulated reading presented. This error is due to factors which are typical of pressure distribution test procedure, and which are discussed in detail in reference 8.

An additional error in the biplane cellule results is due to the slight dissimilarity between the two wing models. Figure 5 shows the normal force coefficient as determined experimentally on each wing plotted against angle of attack and a curve drawn through the mean of each pair of points. The average difference between any two corresponding readings is less than 3 per cent of the mean observed value. Consequently, the probable error of each wing from an "average" wing is less than 2 per cent and therefore within the above-mentioned experimental error.

Quantitatively the pitching moments as presented can be considered only approximate. The error is due to the fact that pressure distribution measurements as usually made neglect skin friction and the component of the pressure forces parallel to the chord. The neglect of these forces results in an error in the center of pressure location up to a maximum of about 3 per cent of the chord near the stall and in an error in the pitching moment of a magnitude depending on the location of the center of gravity. When the center of gravity is on the mean geometric chord, as assumed in the present report, the error in the shape of the moment curves is small enough to warrant a qualitative analysis. Quantitatively, however, the moments may be sufficiently in error to prohibit their use in stability calculations.

The Reynolds Number of the present tests was about 150,000 or 1/20 full scale. Care should therefore be exercised in applying the results to full-scale conditions, since, as indicated in reference 10, there would be appreciable changes in some of the aerodynamic characteristics if the wings had been tested at full scale. Principal among these characteristics are maximum normal force coefficient and the angle of attack at which it occurs. At full scale the maximum normal force coefficient would probably be raised somewhat and the angle of attack increased several degrees. Center of pressure and pitching moments are known to show but little change with scale and, judging from the negative slope of the full-scale Clark Y lift curve in reference 10, it is not likely that the magnitude of rolling moment due to roll would be seriously altered. There is no information covering scale effect on wing-loading ratios, but at normal angles of attack this characteristic is not likely to vary greatly with Reynolds Number.

The blocking effect or constriction of the free area of a wind tunnel by the wing model has been described in reference 3 and a method of correction developed for full-span wings supported by wires. However, owing to the very different blocking conditions existing during pressure distribution tests from those in force tests, it was not considered advisable to apply this correction to the present results.

No correction for tunnel-wall effect has been applied.

DISCUSSION

The following analysis is divided into three divisions. The first part is a detailed discussion of the effect of each cellule variable on: (*a*) Maximum normal force coefficient; (*b*) lateral stability at a low rate of roll; and (*c*) longitudinal stability. The basic wing arrangements used for comparison are the monoplane and the orthogonal biplane, the latter being defined as a biplane having wings of equal chord, a gap/chord ratio of 1.0, and no stagger, decalage, dihedral, sweepback or overhang. In the second part the data are taken as a whole and the general tendencies of the various methods of changing the orthogonal biplane arrangement are discussed relative to the three factors mentioned above. In the last section these general tendencies are collected and summarized with a view toward indicating favorable lines for future research.

DETAILED DISCUSSION

(a) **Maximum normal force**—*Monoplane* (fig. 5).—The two wings (used to make all the following biplane set-ups) tested separately as monoplanes, give the normal force coefficients shown. The maximum coefficient is greater than that of any biplane arrangement by about 3 to 18 per cent, these values indicating the approximate, practical limits to the effect of biplane interference.

Gap (figs. 6–8).—Increasing the gap/chord ratio above 1.0 increases the maximum normal force coefficient of the cellule. This is because both wings operate under progressively more favorable conditions as their distance apart is increased.

Decreasing the ratio below 1.0 tends to delay the burble of the lower wing up to about 35° angle of attack. However, it also decreases the maximum of the upper wing (owing to the greater interference from the lower wing) so that the cellule maximum normal force coefficient falls much below that of the orthogonal biplane.

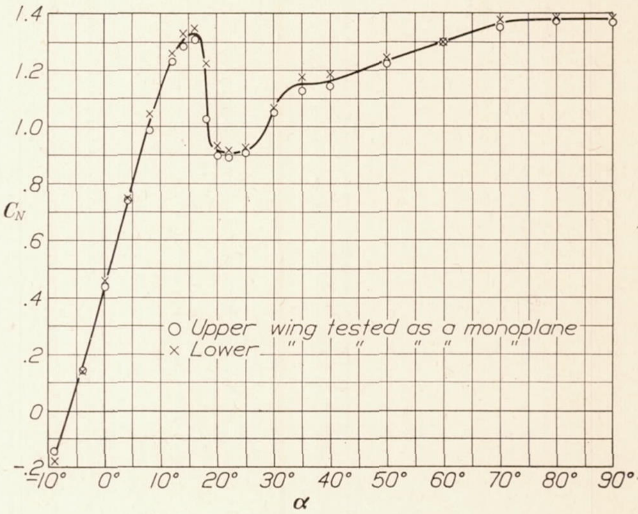

FIGURE 5.—Normal force coefficient. Clark Y monoplane. Circular tip. Aspect ratio=6

Stagger (figs. 9–11).—Positive stagger increases and negative stagger decreases the cellule maximum normal force coefficient. Increasing the positive stagger has an effect similar to increasing the gap, for it increases the distance between the wings and makes each of them behave more like a monoplane. In the extreme case of 75 per cent positive stagger, both upper and lower maximum C_N are greater than that for the monoplane. However, even in this case, the cellule maximum is less than the monoplane owing to the slot effect of the upper wing on the lower, which delays the lower wing maximum C_N until well after the upper wing has burbled.

Gap and stagger (figs. 12–14).—Increasing above 1.0 the gap of a biplane having positive stagger increases the cellule maximum normal force coefficient only when the stagger is greater than 25 per cent. Decreasing below 1.0 the gap of a biplane having positive stagger decreases the maximum normal force coefficient.

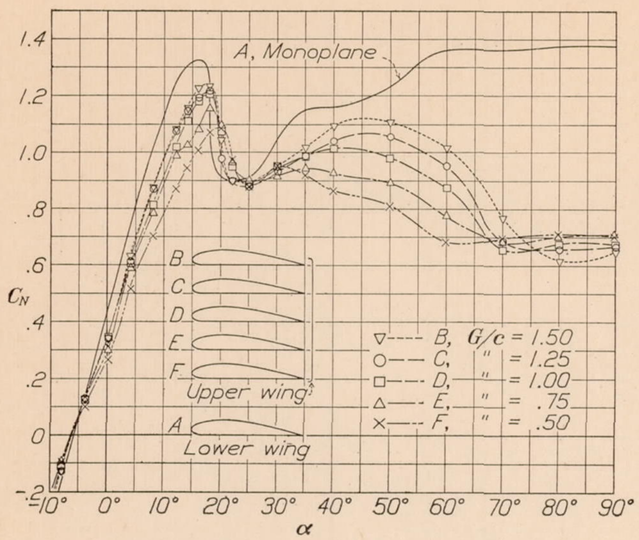

FIGURE 6.—Effect of gap on cellule coefficient of normal force

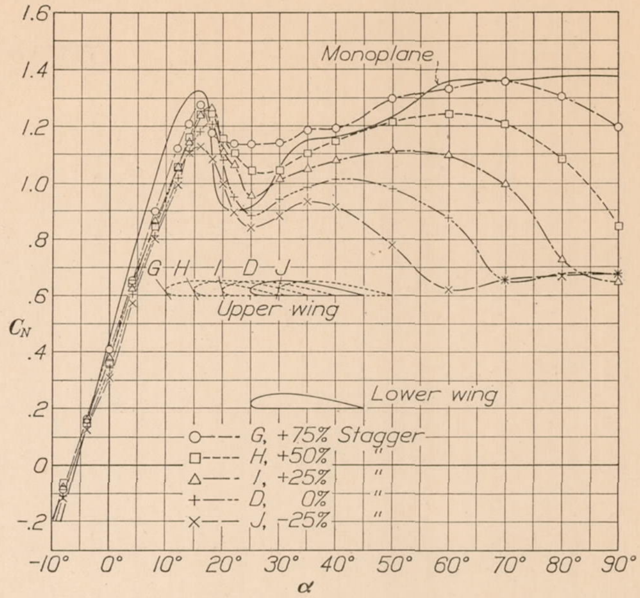

FIGURE 9.—Effect of stagger on cellule coefficient of normal force

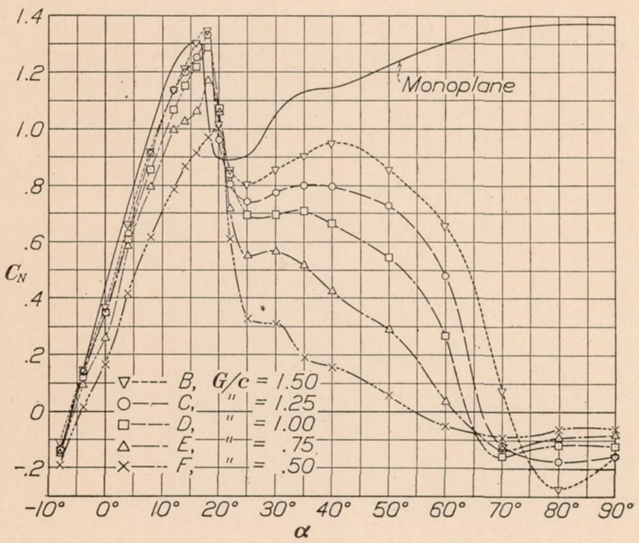

FIGURE 7.—Effect of gap on upper wing coefficient of normal force

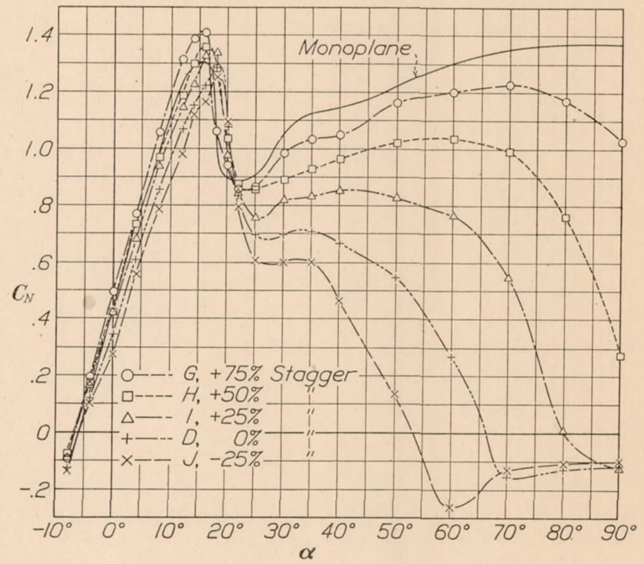

FIGURE 10.—Effect of stagger on upper wing coefficient of normal force

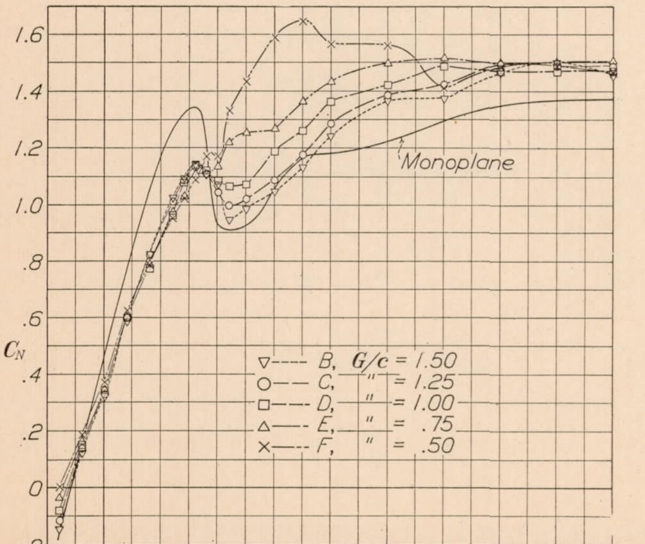

FIGURE 8.—Effect of gap on lower wing coefficient of normal force

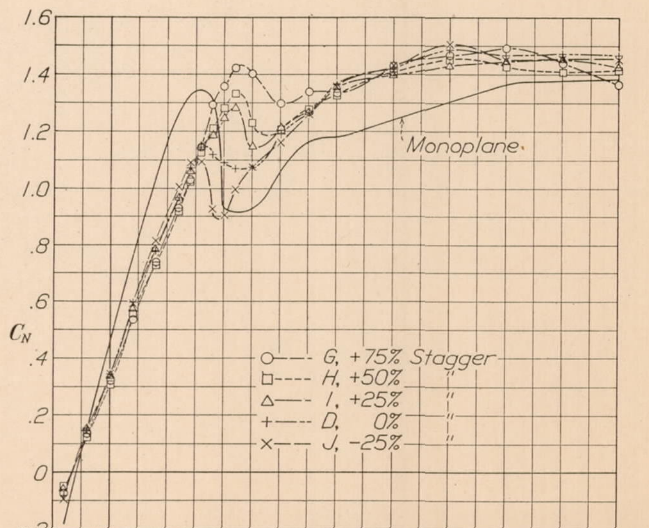

FIGURE 11.—Effect of stagger on lower wing coefficient of normal force

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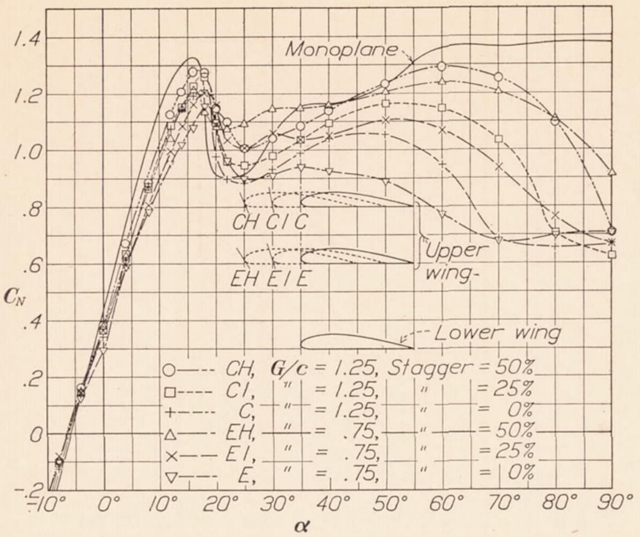

FIGURE 12.—Effect of stagger and gap on cellule coefficient of normal force

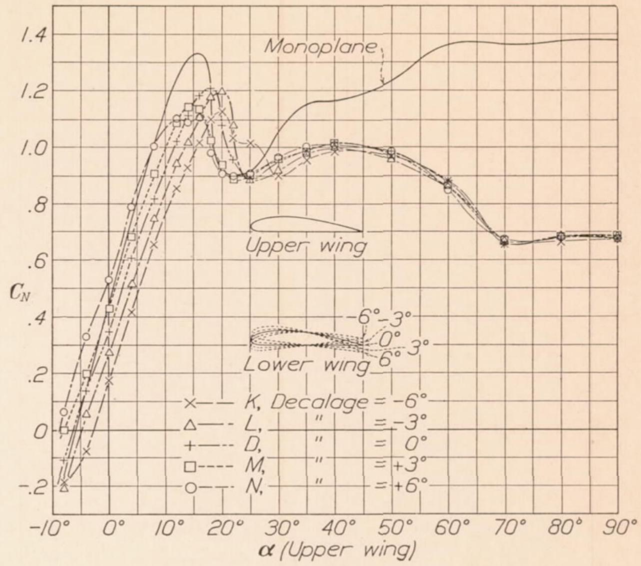

FIGURE 15.—Effect of decalage on cellule coefficient of normal force

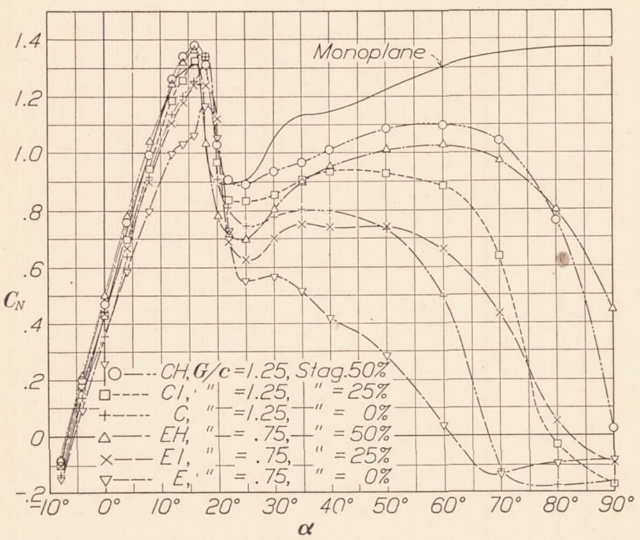

FIGURE 13.—Effect of stagger and gap on upper wing coefficient of normal force

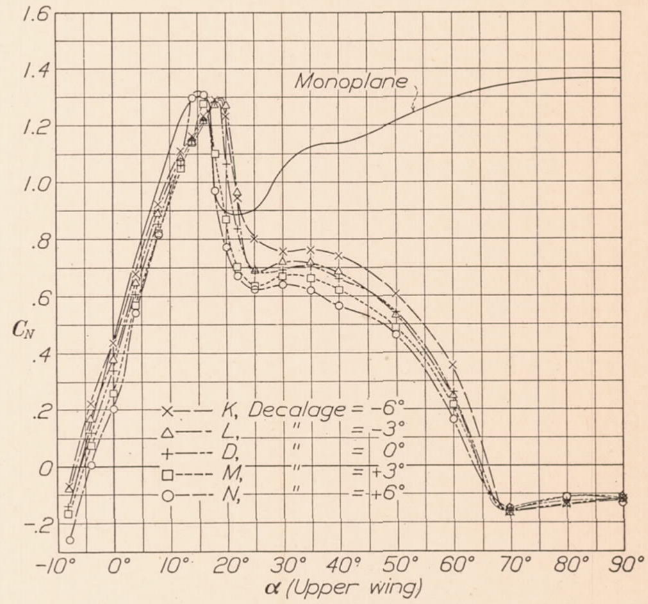

FIGURE 16.—Effect of decalage on upper wing coefficient of normal force

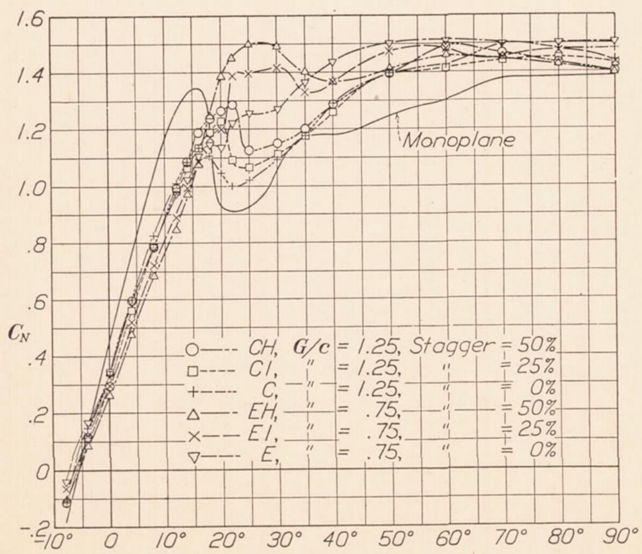

FIGURE 14.—Effect of stagger and gap on lower wing coefficient of normal force

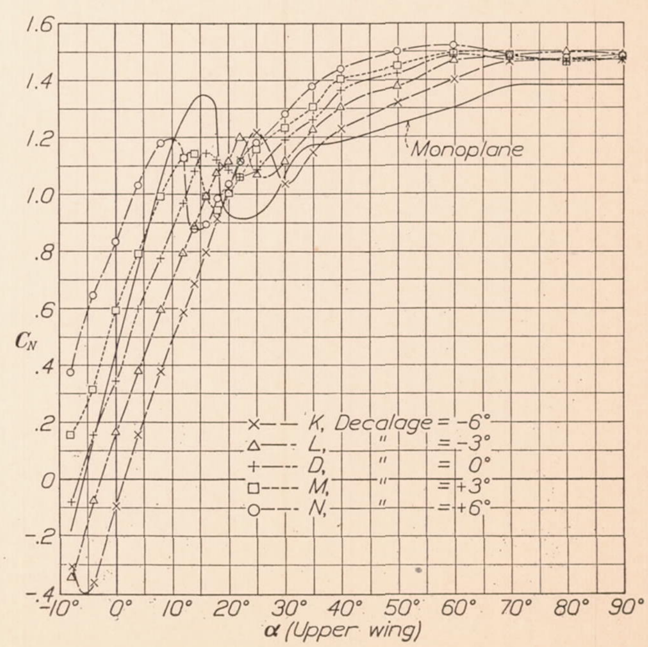

FIGURE 17.—Effect of decalage on lower wing coefficient of normal force

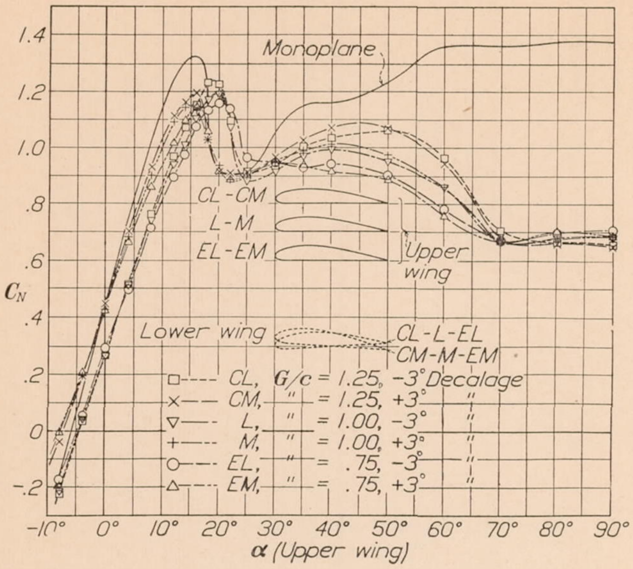

FIGURE 18.—Effect of gap and decalage on cellule coefficient of normal force

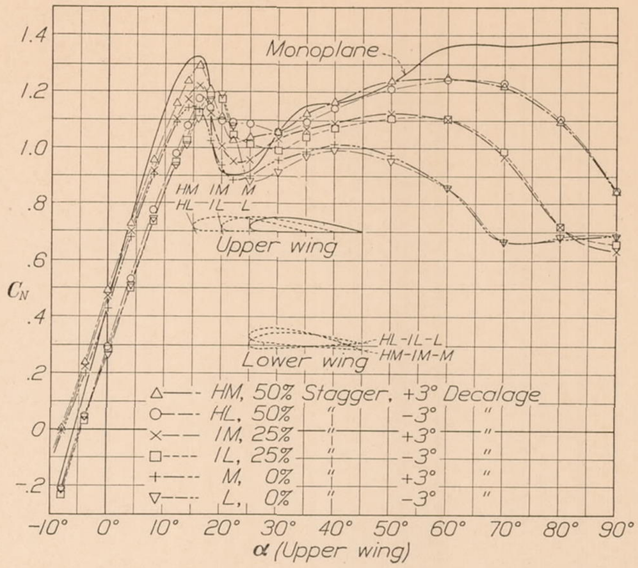

FIGURE 21.—Effect of stagger and decalage on cellule coefficient of normal force

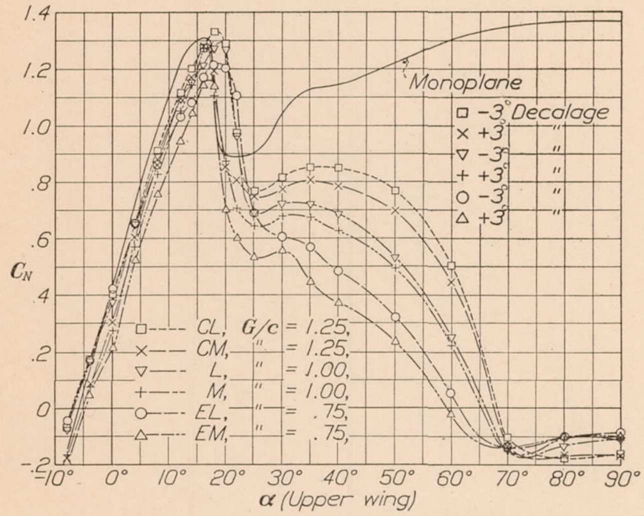

FIGURE 19.—Effect of gap and decalage on upper wing coefficient of normal force

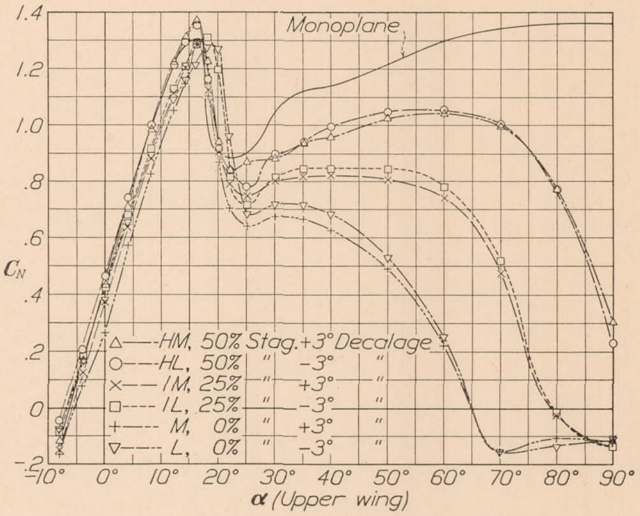

FIGURE 22.—Effect of stagger and decalage on upper wing coefficient of normal force

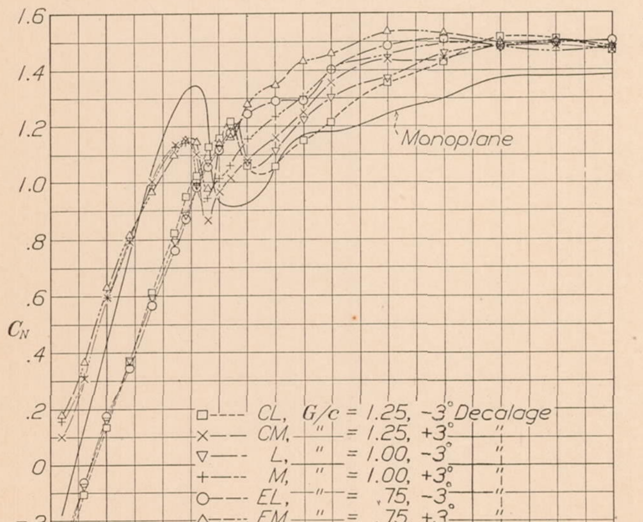

FIGURE 20.—Effect of gap and decalage on lower wing coefficient of normal force

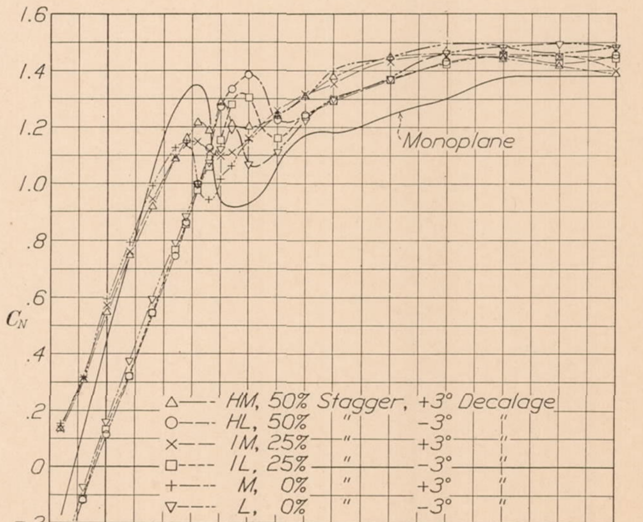

FIGURE 23.—Effect of stagger and decalage on lower wing coefficient of normal force

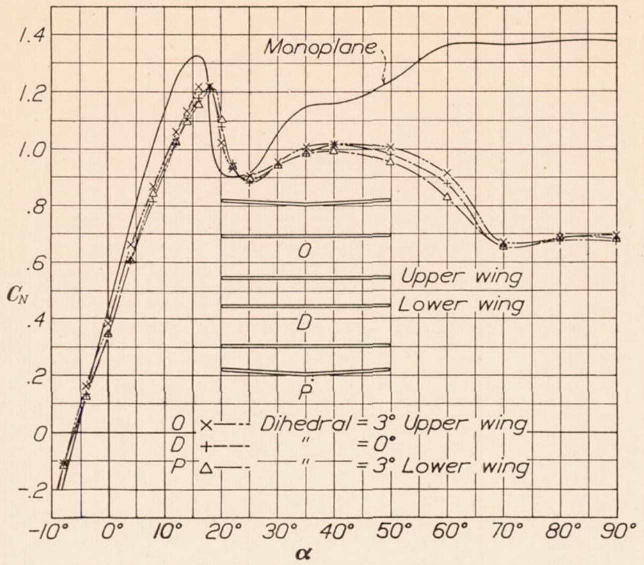

FIGURE 24.—Effect of dihedral on cellule coefficient of normal force

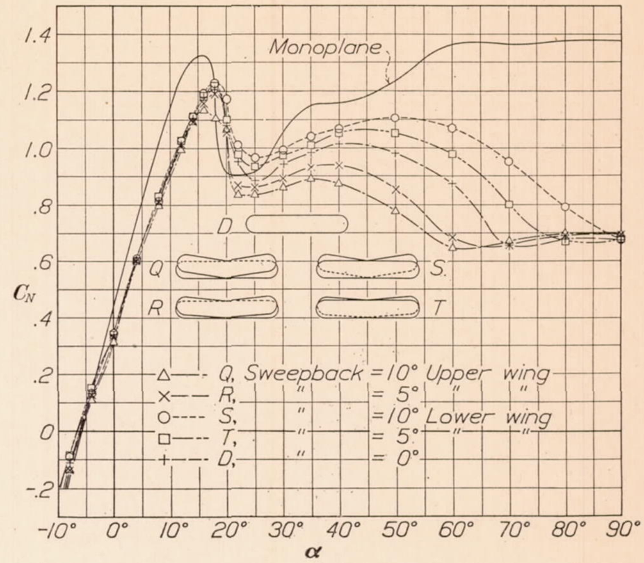

FIGURE 27.—Effect of sweepback on cellule coefficient of normal force

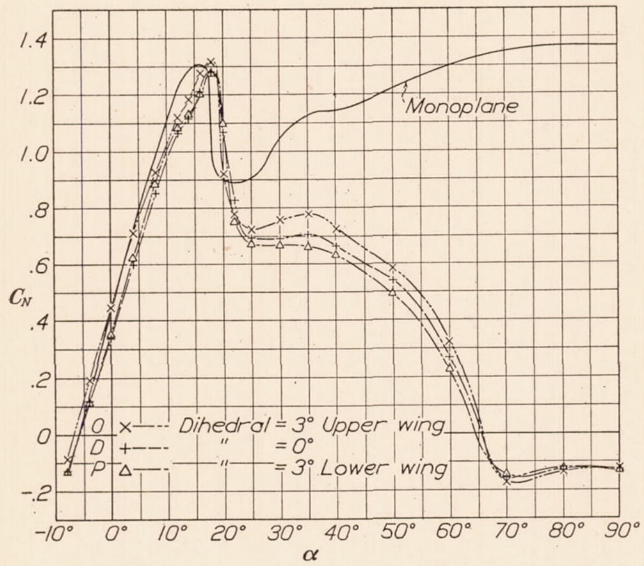

FIGURE 25.—Effect of dihedral on upper wing coefficient of normal force

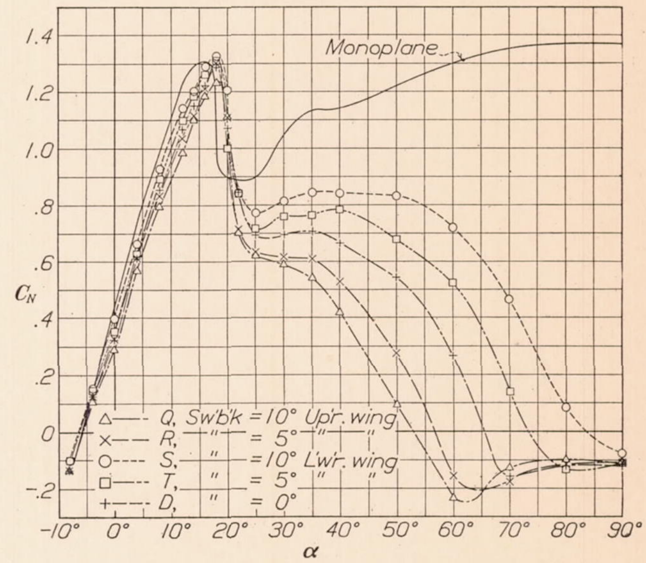

FIGURE 28.—Effect of sweepback on upper wing coefficient of normal force

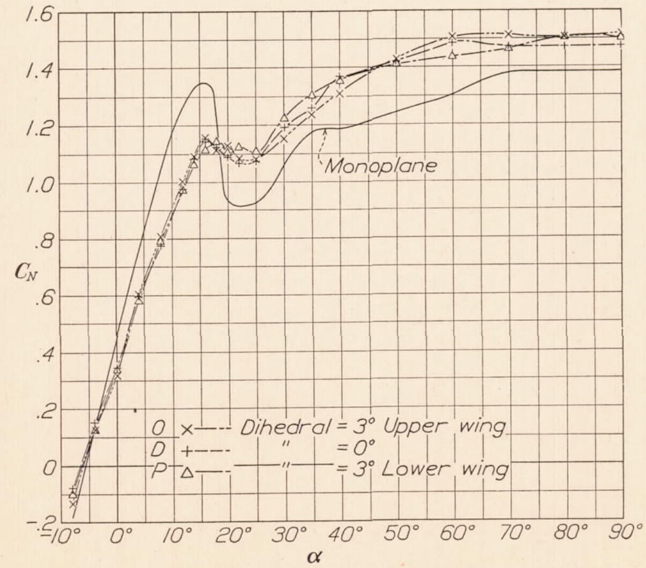

FIGURE 26.—Effect of dihedral on lower wing coefficient of normal force

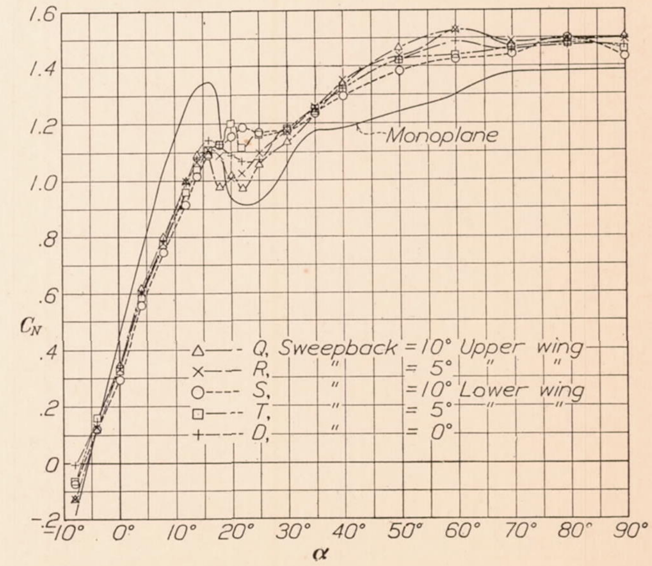

FIGURE 29.—Effect of sweepback on lower wing coefficient of normal force

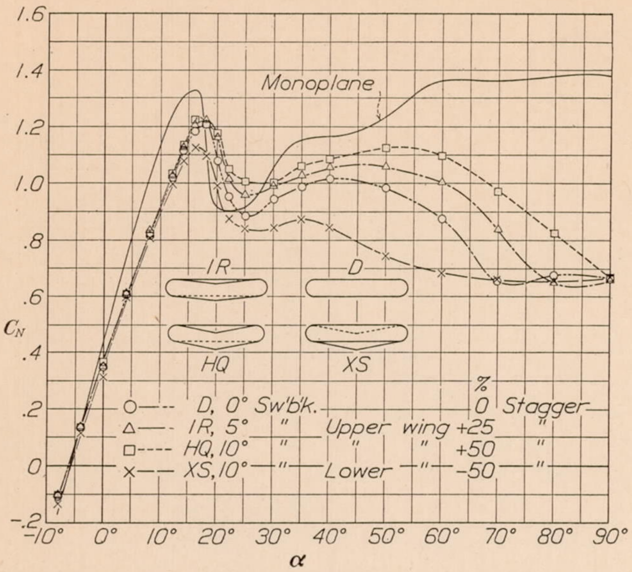

FIGURE 30.—Effect of stagger and sweepback on cellule coefficient of normal force

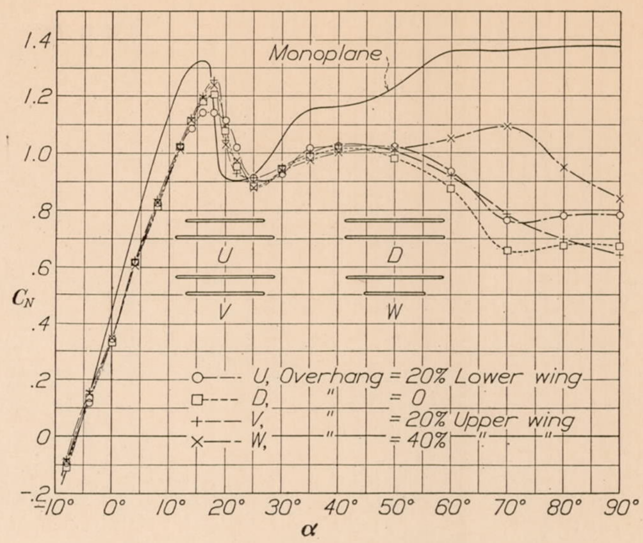

FIGURE 33.—Effect of overhang on cellule coefficient of normal force

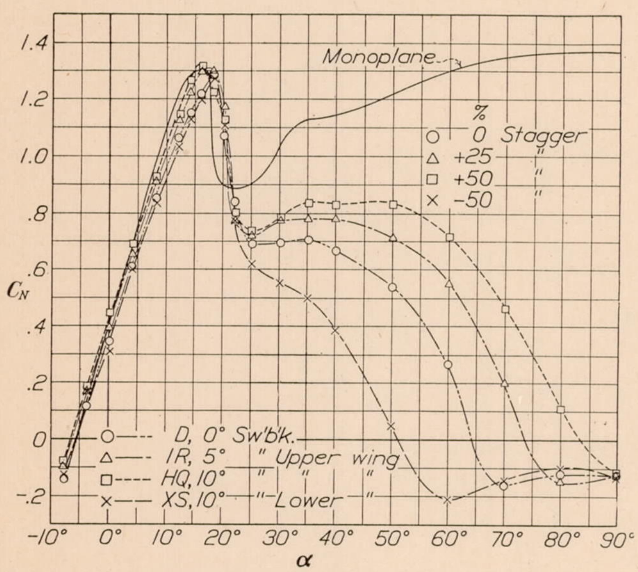

FIGURE 31.—Effect of stagger and sweepback on upper wing coefficient of normal force

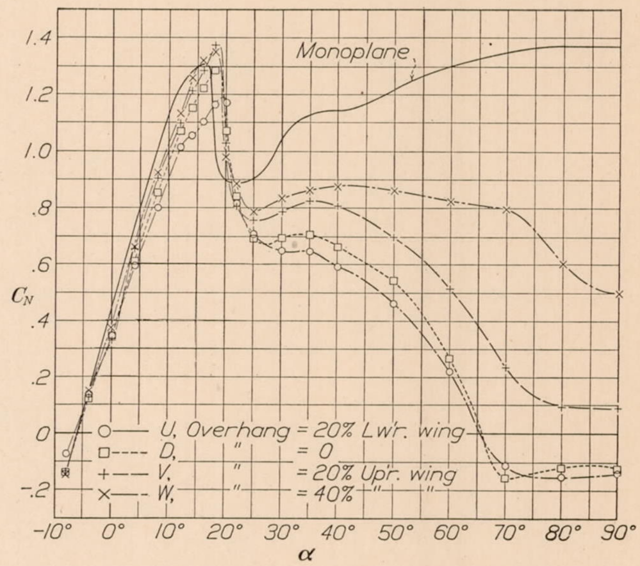

FIGURE 34.—Effect of overhang on upper wing coefficient of normal force

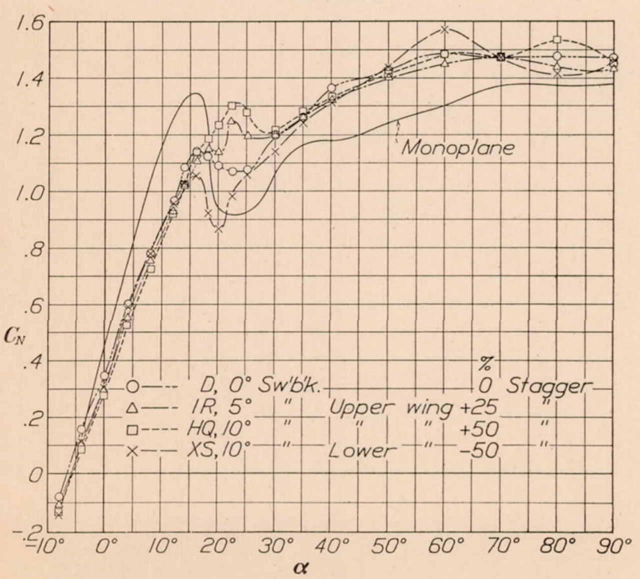

FIGURE 32.—Effect of stagger and sweepback on lower wing coefficient of normal force

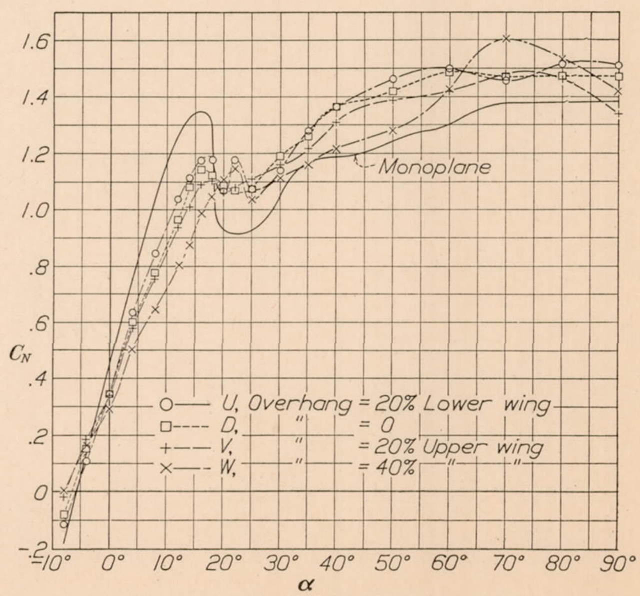

FIGURE 35.—Effect of overhang on lower wing coefficient of normal force

Decalage (figs. 15–17).—The angles of zero and maximum normal force of the lower wing of a biplane cellule having decalage are displaced from those of the orthogonal biplane approximately the amount of the decalage. The upper wing shows a small angular displacement in the opposite direction at low angles of attack and a shift similar to the lower wing at high angles. This latter displacement is not sufficient, however, to cause the maxima of both wings to occur simultaneously, with the result that the cellule maximum normal force is decreased (as compared to the orthogonal arrangement) for all values of decalage tested.

Decalage and gap (figs. 18–20).—Changing the gap of a biplane having ± 3° decalage increases the maximum normal force coefficient of the cellule when the gap is increased above 1.0 and decreases it when reduced below 1.0.

Decalage and stagger (figs. 21–23).—Positive decalage alone causes a reduction in the angle of maximum normal force on the lower wing, but positive stagger tends to increase it. These effects practically cancel each other, within the range of these tests, causing the lower wing to burble at approximately the same angle that it does in an orthogonal biplane. The separate effect of the two variables on the angle of attack of the upper wing maximum is to reduce it slightly in both cases. Inasmuch as the latter point occurs just after the burble of the lower wing in the orthogonal combination, the net result on a cellule having positive decalage and positive stagger is to increase its maximum normal force coefficient. This increase is great enough so that at +3° decalage and +50 per cent stagger, the cellule maximum C_N is only 3 per cent less than that of the monoplane.

Negative decalage and positive stagger both tend to delay the burble of the lower wing and cause the stalling angle of the upper wing to occur progressively sooner. Consequently, the lower wing reaches its maximum from 3° to 9° later than the upper, causing a low maximum normal force for the cellule and poor division of load between the wings.

Dihedral (figs. 24–26).—Dihedral has practically no effect on the coefficient of normal force.

Sweepback (figs. 27–29).—The effect of sweepback on either the upper or the lower wing is, in general, similar to the effect of stagger. The magnitude of the changes in maximum normal force are equivalent to those that would be produced by an amount of stagger corresponding to the mean stagger of the sweptback wing relative to the straight wing.

Sweepback and stagger (figs. 30–32).—Comparison of the results of combined sweepback and stagger with those of sweepback and stagger tested separately (figs. 27 to 29 and 9 to 11, respectively) shows that the mean stagger is again the principal factor governing the normal force characteristics of the cellule. Within the range of these tests a mean positive stagger of only 25 per cent was obtained, an amount that does not materially raise the maximum normal force coefficient.

Overhang (figs. 33–35).—Slight improvement in the cellule maximum normal force coefficient results from positive overhang. This increase is due to the combined effect of the reduction in area of the lower wing, which is adversely affected by biplane interference, and to an improvement in the upper wing maximum C_N.

(b) **Lateral stability.**—If the condition be assumed that an airplane is taking off or landing at a high angle of attack over an obstacle of sufficient size to cause considerable turbulence, in the air blowing over it, the inherent lateral stability of the machine becomes an important factor from the standpoint of safety. These conditions can be approximated for the purpose of stability calculations by assuming an angle of attack giving $C_{N_{max}}$ and an instantaneous disturbance causing a rate of roll such that $\frac{pb}{2V}=0.05$.

The influence of the different biplane variables on the first of these two conditions is of importance only in its relation to the angle at which lateral instability begins. (See General Discussion.) In the present case, the conditions affecting the range and magnitude of the unstable rolling moments due to the rate of roll specified will be discussed.

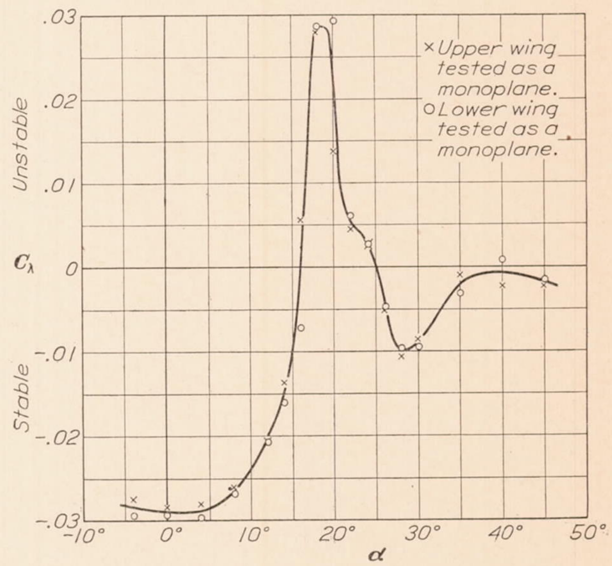

FIGURE 36.—Rolling moment due to roll at $\frac{pb}{2V}=0.05$. Clark Y monoplane. Circular tip. Aspect ratio=6

Monoplanes (fig. 36).—Comparison of the critical points of the curve shown with corresponding force test data given in reference 3 (Table III) shows an agreement within 2° of the angles of attack for $C_\lambda=0$ as determined by the two methods of test. The lack of complete agreement is probably due to the difference in results obtained by application of the strip method of calculation of lateral stability to force test data and pressure distribution data. Assumption of uniform span loading was made in the force tests, but pressure distribution data allow a more accurate determination of the true span loading. Consequently, results from the pressure distribution tests take into account the delay in burble of the tips beyond the angle of maximum normal force on the wing as a whole and, therefore, consistently give slightly larger angles of initial neutral stability than calculations based on force tests. The upper limit of the range of instability is likewise raised above force test calculations owing to the normal load increasing again at the center of the wing before it does so at the tips.

A comparison of Figure 36 with corresponding autorotation results (from reference 4, figs. 31 and 32) shows relatively close agreement of the angles of attack of stable autorotation at $\frac{p\,b}{2\,V}=0.05$ as determined by these two methods of test. The pressure distribution results are considered more reliable, however, because the lowest value of $\frac{p\,b}{2\,V}$ obtained in the autorotation tests was about 0.20 and interpolation of the curve of rotation against angle of attack from this point to $\frac{p\,b}{2\,V}=0$ is, at best, very uncertain.

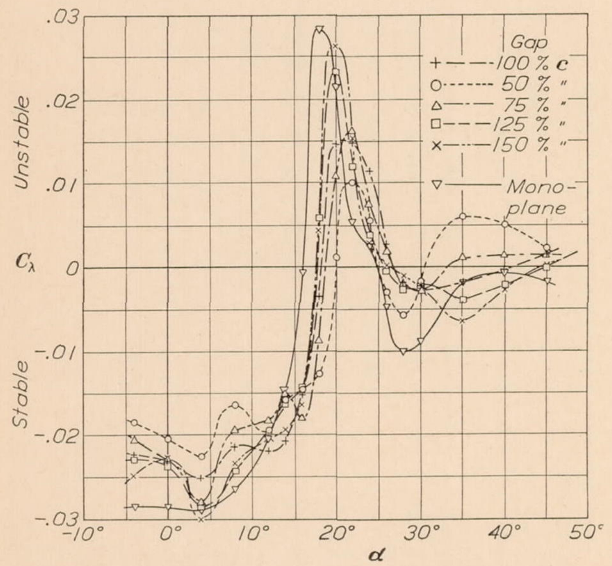

FIGURE 37.—Effect of gap on rolling moment due to roll at $\frac{pb}{2V}=0.05$

Gap (fig. 37).—The most important feature to note is that progressive reduction in gap causes a general decrease in the range and magnitude of the unstable rolling moments. This effect is due to the increasing tendency of the upper wing to maintain the flow over the lower as the gap is lessened. At the same time, however, the burble of the upper wing becomes more rapid so that in the region from gap/chord = 1.00 to gap/chord = 0.75 the improvement due to the lower wing is just offset by the greater instability of the upper.

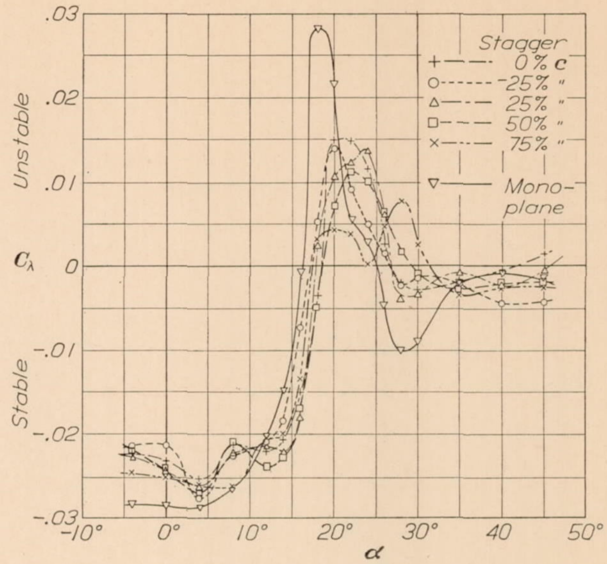

FIGURE 38.—Effect of stagger on rolling moment due to roll at $\frac{pb}{2V}=0.05$

Stagger (fig. 38).—Separation of the burble points of the two wings by either positive or a small amount of negative stagger reduces maximum instability. However, above 25 per cent positive stagger this separation causes a distinct prolongation of the range of instability. At +75 per cent the separation is so marked that there are two peaks of unstable moment, one at the burble of the upper wing and a second, greater one, when the flow over the lower wing breaks down.

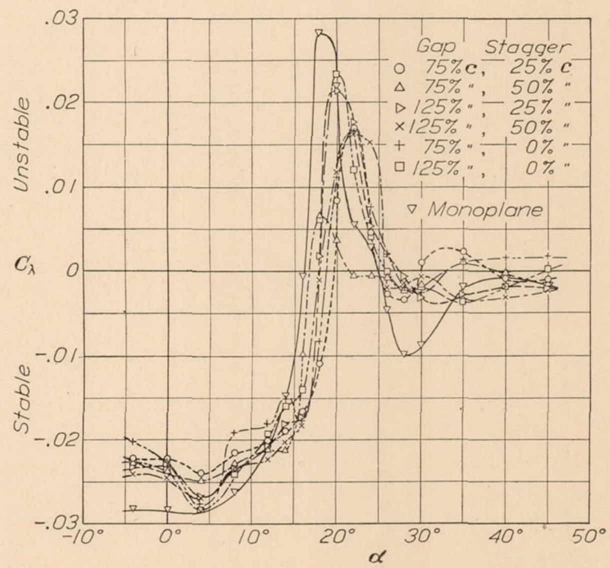

FIGURE 39.—Effect of combined gap and stagger on rolling moment due to roll at $\frac{pb}{2V}=0.05$

Gap and stagger (fig. 39).—As compared with the orthogonal biplane, the high degree of instability associated with a gap/chord ratio of 1.25 is partially

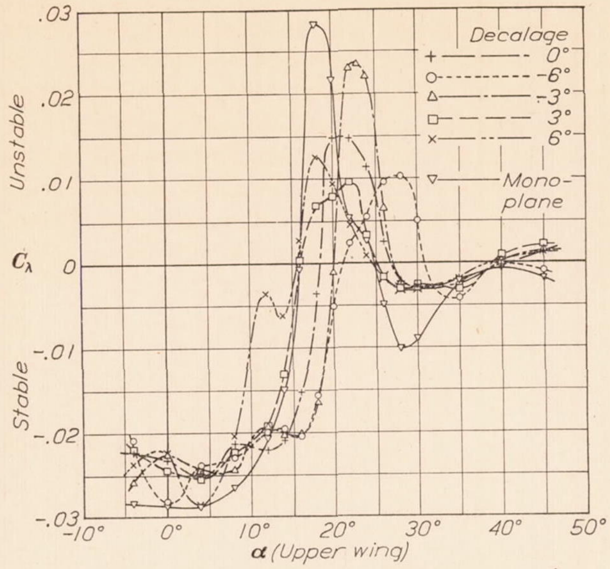

FIGURE 40.—Effect of decalage on rolling moment due to roll at $\frac{pb}{2V}=0.05$

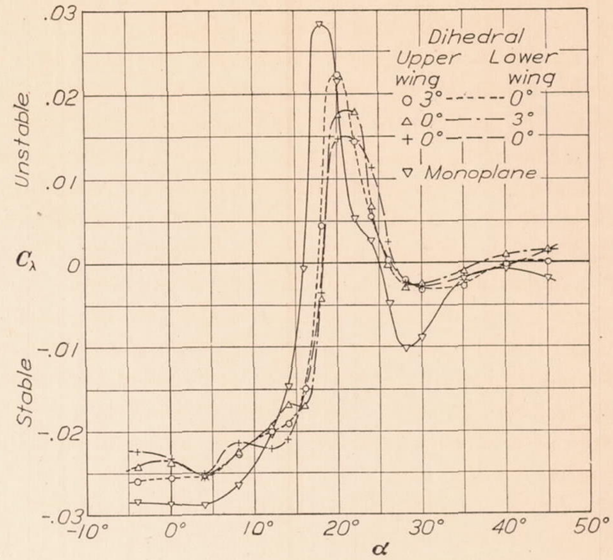

FIGURE 43.—Effect of dihedral on rolling moment due to roll at $\frac{pb}{2V}=0.05$

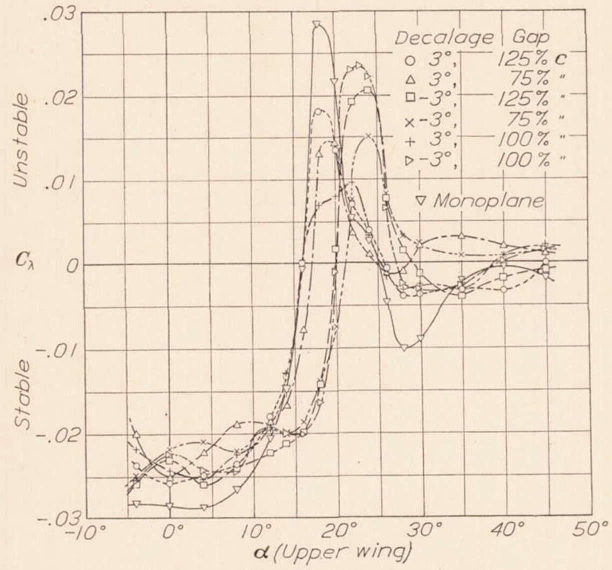

FIGURE 41.—Effect of combined decalage and gap on rolling moment due to roll at $\frac{pb}{2V}=0.05$

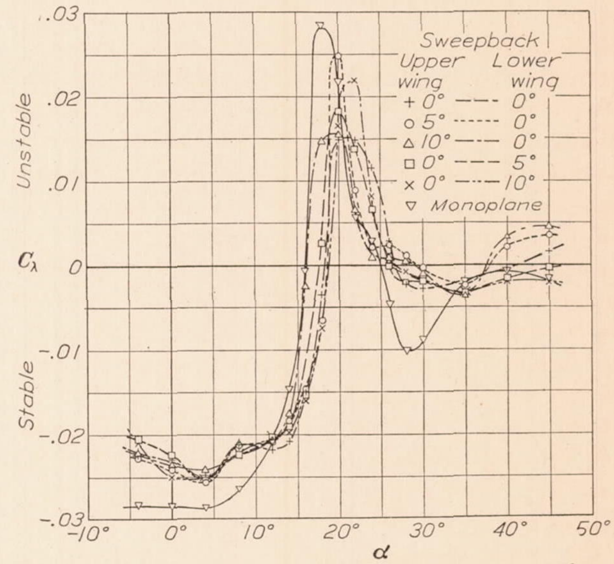

FIGURE 44.—Effect of sweepback on rolling moment due to roll at $\frac{pb}{2V}=0.05$

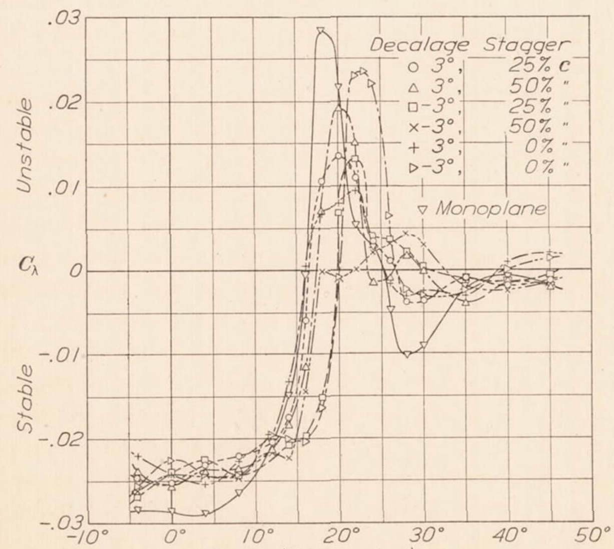

FIGURE 42.—Effect of combined decalage and stagger on rolling moment due to roll at $\frac{pb}{2V}=0.05$

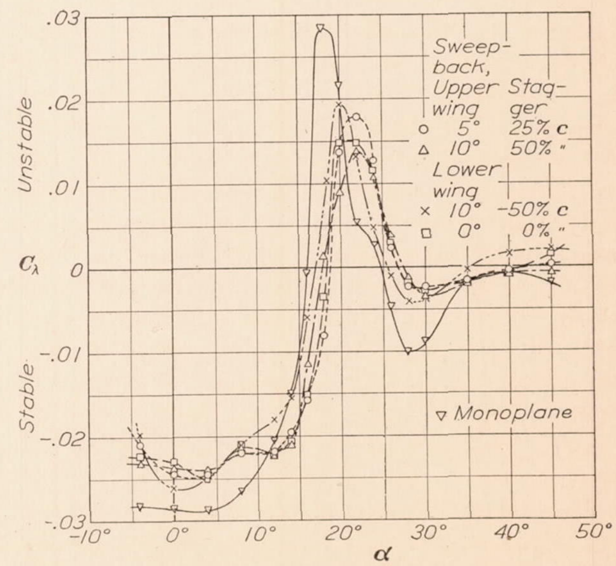

FIGURE 45.—Effect of combined sweepback and stagger on rolling moment due to roll at $\frac{pb}{2V}=0.05$

mitigated by 25 per cent positive stagger and wholly so by 50 per cent stagger. Reducing the gap to 75 per cent of the chord and staggering the wings +25 per cent has practically no influence on the characteristics of the orthogonal biplane. However, increasing the stagger to 50 per cent reduces maximum instability by more than one-half. The range of instability is small for this biplane arrangement but occurs at a slightly lower angle than for the previous cases.

Decalage (fig. 40).—The principal effect of this variable is displacement of the range of instability owing to the displacement of the normal force curve of the lower wing. Except for the −3° setting of the lower wing, all the cases of decalage show a decrease in maximum instability. The one case in which an increase is shown can be explained by the fact that the burble of both wings occurs at practically the same angle. This concentration of the factors leading to instability has the advantage, however, of noticeably reducing the unstable range.

Decalage and gap (fig. 41).—Gap apparently is the governing factor in regard to magnitude of instability. Decalage in the cellule causes its characteristic angular displacement of the unstable range.

Decalage and stagger (fig. 42).—As pointed out in the discussion of the normal force characteristics of this combination of cellule variables (figs. 21 to 23), +3° decalage and +50 per cent stagger cause C_N maximum of both wings to occur at virtually the same angle. This condition was excellent from the standpoint of small biplane interference, but coincidence of maximum normal force entails coincidence of the burble of the two wings. The result is that this combination is quite unstable over a small angular range. Wide separation of the points of maximum normal force, as obtained with −3° decalage and +50 per cent stagger, has the opposite effect, giving this biplane arrangement the smallest maximum instability of any cellule investigated.

Dihedral (fig. 43).—This variation on the orthogonal biplane increases the maximum unstable rolling moment slightly.

Sweepback (fig. 44).—The simple analogy that the effect of sweepback is equivalent to the effect of the mean stagger of the sweptback wing is not so apparent when stability is considered as when only normal force characteristics are compared. In the case of 5° sweepback on the upper wing, the effective negative stagger is about 10 per cent, which is just sufficient to put the burble of each wing at the same angle of attack. Hence, strong instability occurs over a relatively short range. (Compare with fig. 38 and its discussion.) At 10° sweepback the burble of the lower wing is distinctly prior to that of the upper. This condition produces instability over a wide range, but the maximum degree of instability is only slightly greater in magnitude than that of the orthogonal arrangement.

Sweepback and stagger (fig. 45).—As with sweepback alone, the general characteristics are very similar to those of a biplane cellule having stagger equivalent to the mean stagger of the sweptback wing. There appears to be little choice between combinations having one wing sweptback a certain amount alone or having the same degree of sweepback and having sufficient stagger to make the wing tips come approximately vertically over each other.

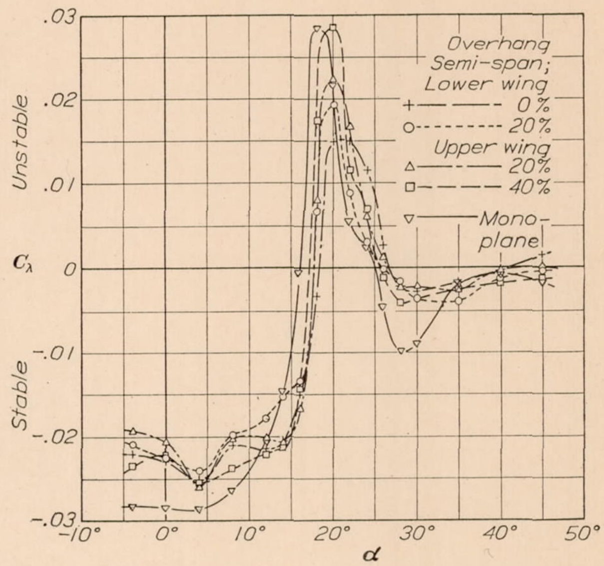

FIGURE 46.—Effect of overhang on rolling moment due to roll at $\frac{pb}{2V}=0.05$

Overhang (fig. 46).—From this figure it is apparent that any form of overhung biplane is less desirable than the orthogonal biplane. The reason for this condition apparently is due to the intermediate nature of overhung combinations between the very unstable monoplane (see fig. 36) and the biplane. Negative 20 per cent overhang is slightly preferable to the same amount of positive overhang because the upper wing, whose burble is much more rapid than the lower, exerts a smaller influence on the cellule in this case than in positively overhung combinations.

(c) **Longitudinal stability.**—The scope of the present investigation is insufficient to attempt a quantitative discussion of the effects of the various wing combinations on the longitudinal stability of a complete airplane because of the great effect upon pitching moment of such factors as the center of gravity location, chord components of force, and the pitching moments of the tail surfaces. If, however, we assume a constant geometric location of the center of gravity relative to each wing system (as defined by equation (5) in the present case) and tail surfaces adequate to maintain balance at normal angles of attack, the pitching moment curve of each cellule about an axis through the assumed center of gravity affords a basis for a discussion of certain qualitative relations between the characteristics of the various wing systems. Such a comparison is made below, the axis chosen being the 25 per cent point of the mean cellule chord, although any other axis would give the same relative results.

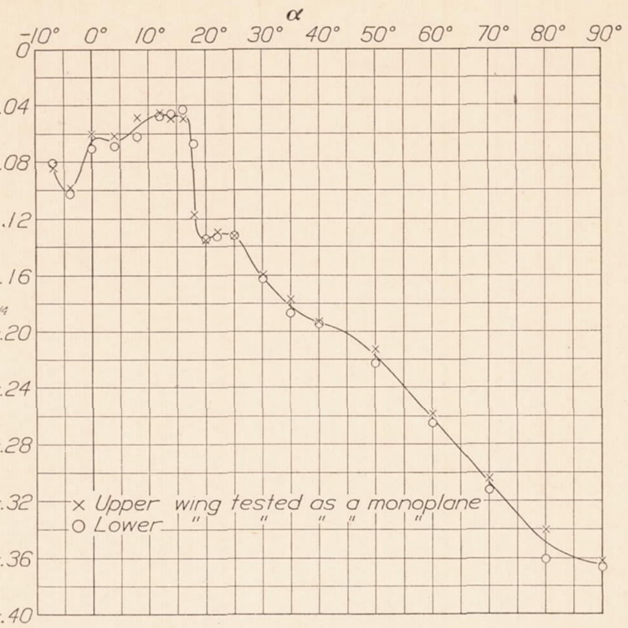

FIGURE 47.—Pitching moment about the quarter-chord point. Clark Y monoplane. Circular tip. Aspect ratio=6

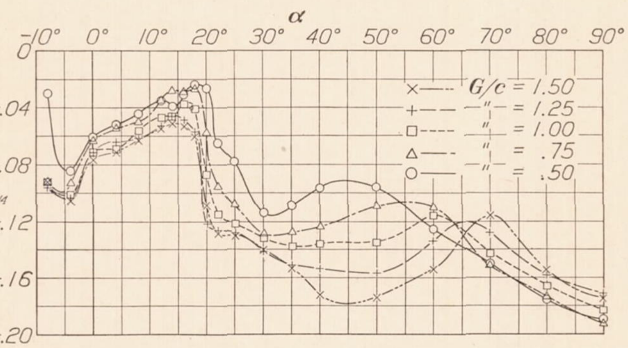

FIGURE 48.—Effect of gap on pitching moment about the quarter-chord point

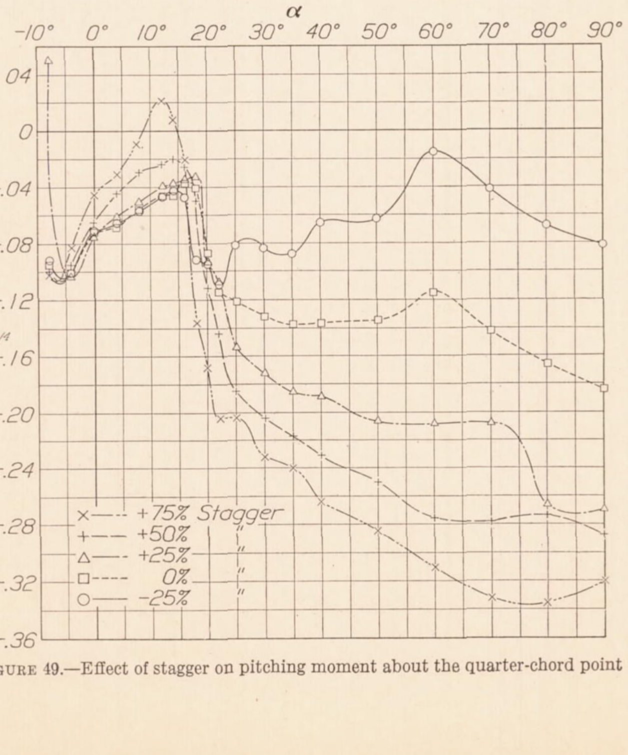

FIGURE 49.—Effect of stagger on pitching moment about the quarter-chord point

Monoplane (fig. 47).—Comparison of this curve with those for the unstaggered biplane combinations in the subsequent figures shows the monoplane to have a steeper negative slope to its pitching-moment curve at high angles of attack, and therefore a stronger tendency toward longitudinal stability in this region than any of the biplanes.

Gap (fig. 48).—Below the stall, the slopes of the curves for all ratios are essentially the same as the monoplane. Above the stall, increasing the gap increases both the range and steepness of the stable slope to the curve.

Stagger (fig. 49).—A small amount of either positive or negative stagger has little effect on the slope of the pitching-moment curve below the stall. Increasing the stagger above +25 per cent very rapidly increases the unstable slope to the curve in this region, owing to the strong stalling moment of the upper wing.

Above the stall a negatively staggered biplane shows very poor stability characteristics. In fact it is highly probable that neutral stability or possibly unstable pitching moments would exist above 22° angle of attack in a complete airplane having this wing arrangement. Positive stagger, on the other hand, produces

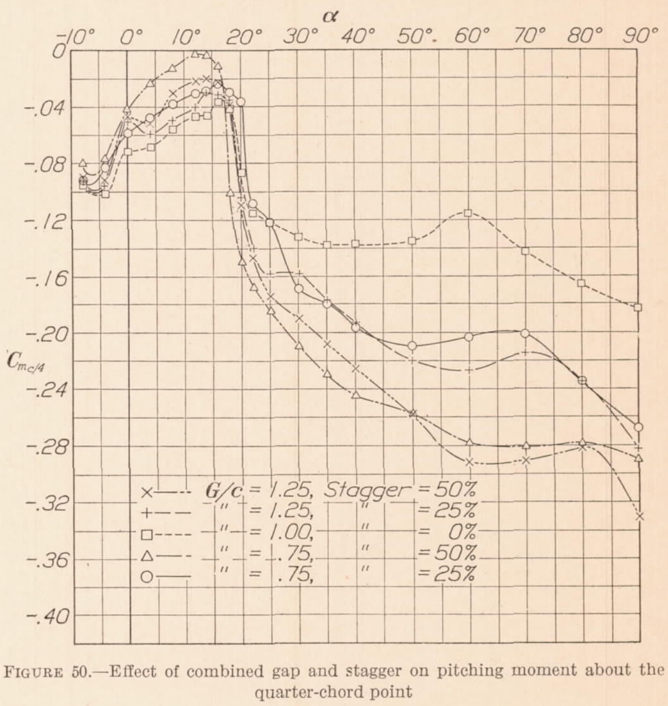

FIGURE 50.—Effect of combined gap and stagger on pitching moment about the quarter-chord point

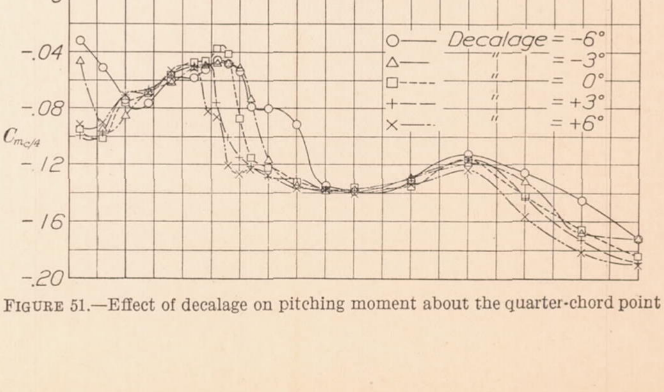

FIGURE 51.—Effect of decalage on pitching moment about the quarter-chord point

in this range positive stability equal to or greater than that of the monoplane.

Gap and stagger (fig. 50).—The characteristics of these combinations follow very closely those for similar amounts of stagger at a gap/chord ratio of 1.0.

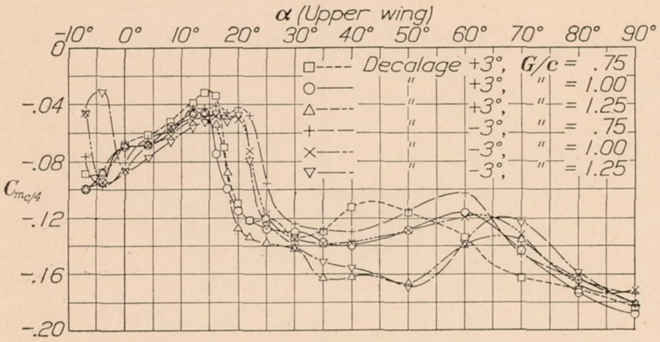

FIGURE 52.—Effect of combined decalage and gap on pitching moment about the quarter-chord point

Decalage (fig. 51).—This variable has no effect on longitudinal stability below the stall. Above the stall, +6° or −6° decalage has a tendency to reduce the abruptness of the familiar nosing-down action accompanying burbling of the wings. This characteristic is due to the marked separation of the stalling points of the two wings and the resulting prolongation of the range during which the center of pressure of the cellule is moving back. Beyond this range the pitching-moment curve for biplanes having any amount of decalage between +6° and −6° does not differ appreciably from that of the orthogonal arrangement.

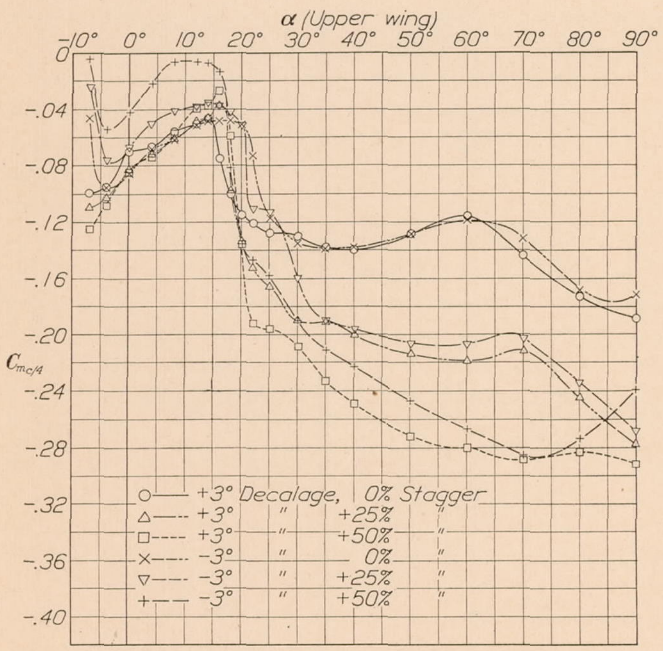

FIGURE 53.—Effect of combined decalage and stagger on pitching moment about the quarter-chord point

Decalage and gap (fig. 52).—Throughout the range of angle of attack tested the only marked influence of decalage is to shift the stalling angle in a manner similar to the shift when the gap equals the chord. Otherwise, the curves fall in groups whose characteristics follow, in general, the corresponding cellules having no decalage.

Decalage and stagger (fig. 53).—Negative decalage has a distinct tendency to reduce the unstable slope of the cellule pitching-moment curves below the stall for all degrees of stagger. It also reduces the magnitudes of the cellule diving moments in this range to such on extent that at −3° decalage and +50 per cent stagger both the slope and the magnitude are the smallest of

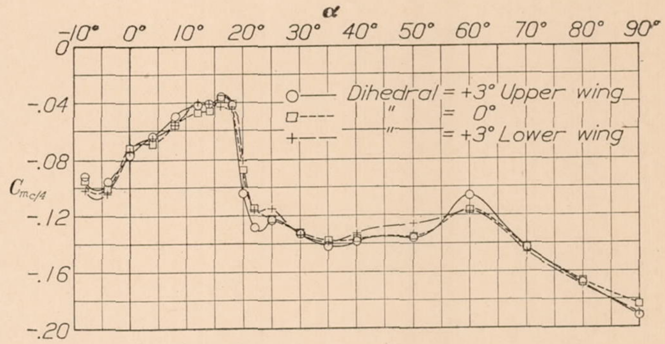

FIGURE 54.—Effect of dihedral on pitching moment about the quarter-chord point

any cellule investigated. Positive decalage increases the slope of the pitching-moment curve as the stagger is increased, but its effect is less than in the preceding case. Above the stall all the cases investigated have characteristics very similar to those of cellules having corresponding amounts of stagger alone.

Dihedral (fig. 54).—Dihedral up to 3° on either wing has practically no influence on the pitching moment characteristics of an orthogonal biplane

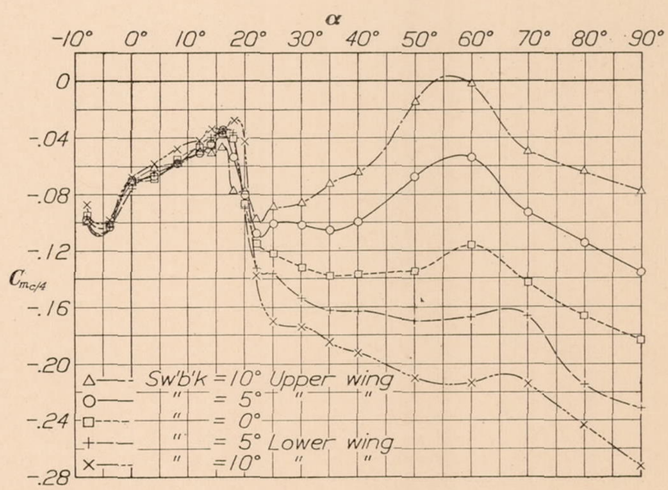

FIGURE 55.—Effect of sweepback on pitching moment about the quarter-chord point

Sweepback (fig. 55).—Below the stall the slope of the curves for all the arrangements tested differ only slightly from that of the orthogonal biplane. This feature of the curves agrees closely with the curves of pure stagger (fig. 49) of an amount equal to the mean effective stagger of the sweptback wing.

Above the stall, sweepback on the upper wing shows a greater divergence of the pitching-moment curve from that of the orthogonal biplane than a corresponding amount of negative stagger. Consequently, even a small degree of sweepback on the upper wing alone would be likely to be distinctly harmful to longitudinal stability at high angles of attack.

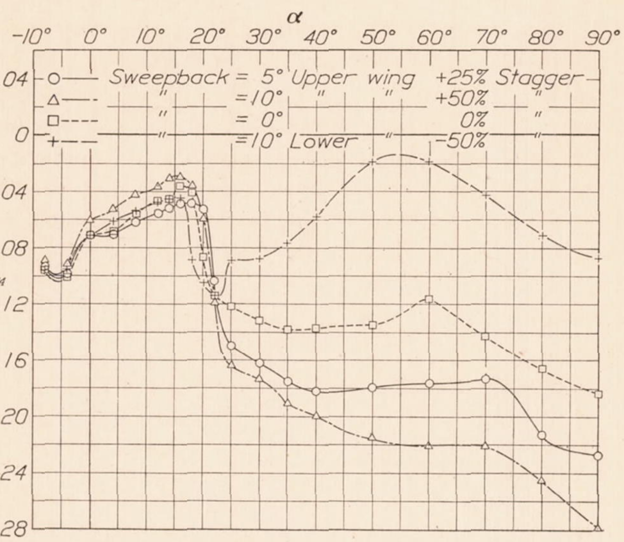

FIGURE 56.—Effect of combined sweepback and stagger on pitching moment about the quarter-chord point

Sweepback and stagger (fig. 56).—The pitching moment of a biplane cellule having sweepback of either the upper or lower wing and also having stagger is essentially the same as that of a cellule having an equivalent amount of mean stagger obtained by sweepback alone.

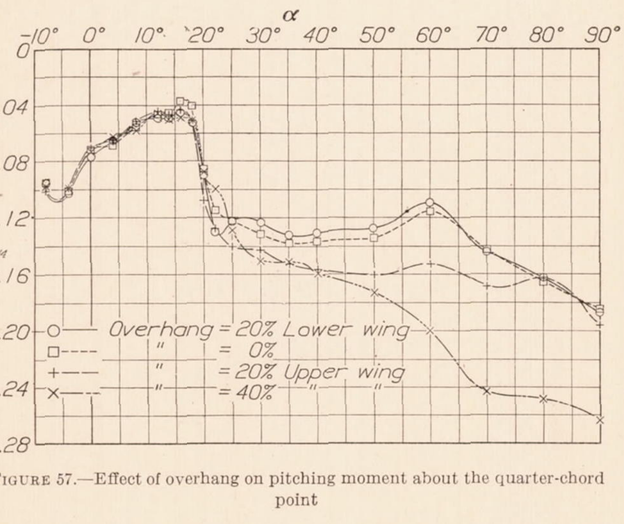

FIGURE 57.—Effect of overhang on pitching moment about the quarter-chord point

Overhang (fig. 57).—At low angles of attack positive or negative overhang has no influence on the pitching-moment curve of the orthogonal biplane. Above the stall the characteristics of positively overhung combinations approach those of the monoplane as the overhang increases. Negative overhang up to 20 per cent has practically no effect in this region.

GENERAL DISCUSSION

(a) **Maximum normal force.**—Table II gives a collection of certain of the aerodynamic characteristics of all the wing systems investigated. A study of these data in view of the foregoing detailed discussion of each cellule variable reveals certain general tendencies in the variation of the tabulated characteristics. For instance, increasing (1) the gap/chord ratio above 1.0, (2) the effective positive stagger, or (3) positive overhang of a biplane decreases the mutual interference between the wings and tends to make the maximum normal force coefficient of the cellule approach that of the monoplane. With a gap/chord ratio of 1.0, change in stagger is the most effective single factor influencing this characteristic. However, if +50 per cent stagger is used with a gap/chord ratio of 1.25 (cellule CH) the interference is still less. Finally, if +3° decalage is used with +50 per cent stagger (cellule HM) the normal force curve of the lower wing is shifted so that it nearly coincides with that of the upper wing, producing a cellule maximum normal force that is only 3 per cent less than the monoplane and is the highest value obtained on all the biplane arrangements tested. Gap/chord ratios below 1.0, negative effective stagger, or use of decalage without stagger, definitely increases mutual wing interference and reduces maximum normal force.

From an inspection of Columns 2 and 3, the conclusion may be drawn that the interference of the circulation of air about the lower wing on the circulation about the upper wing is sufficient to reduce the maximum normal force coefficient of the latter (as compared to the monoplane) for all unstaggered biplane combinations having a gap/chord ratio of 1.0. Closer proximity of the wings, negative stagger, or negative overhang increases this interference. Conversely moving the wings farther apart or using positive overhang improves the operating conditions of the upper wing to the extent that it attains a greater maximum normal force coefficient than the monoplane. The optimum point of separation beyond which the characteristics of the upper wing begin to reapproach those of the monoplane, apparently has not been reached in the scope of the present tests except in the case of overhang.

The interference effect of the upper wing on the lower may be compared to that of a leading-edge slot on an ordinary airfoil. Thus, in all cases, decreasing the gap/chord ratio to less than 1.0, or using positive stagger, tends to maintain the flow over the lower wing to very high angles and large values of normal force coefficient.

The angle of attack for maximum normal force (column 4) is seen to be virtually coincident with the angle for initial lateral instability (column 5) except for the biplane cellules having 6° positive decalage (N) or +50 per cent stagger with 3° negative decalage (HL). In each of these cases the angular interval of safety between maximum lift and the beginning of lateral instability is due to wide separation of the stalling points of the component wings in the cellules. However, it should be noted from Figures 40 and 42 that, although these cellules do not reach true neutral equilibrium until the angle of attack specified in Column 5, they have only a very slight degree of stability for 3° or 4° below this point.

(b) **Lateral stability.**—Columns 7 and 8 give the initial range of lateral instability and the maximum value of unstable rolling moment due to roll. Close correlation of these characteristics with each other or the other criteria given in the table is not possible, but a few very general relationships can be noted.

The average range of lateral instability is a little less than 9°. In nearly all cases of cellules having a very much larger range, initial instability is due to the upper wing burbling first while the lower wing continues to maintain lift and a stabilizing influence on the combination. For this reason such wing arrangements usually have relatively small values of maximum instability, but, owing to the fact that the instability which does exist depends primarily on the sharpness and extent of the burble of the upper wing, all cellules do not follow this rule.

The geometric relation between the wings best suited to obtain the combination of a short range of instability and a small maximum instability, is a gap/chord ratio less than 1. An apparently outstanding exception to this rule is the combination having a gap/chord ratio of 0.75 and −3° decalage (EL). It will be noticed from Figure 41, however, that this cellule is only very slightly unstable over the last 15° of the curve.

A second method for obtaining a short range of instability is the use of +50 per cent stagger and +3° decalage. This cellule (HM) shows the closest coincidence of the normal force curves of its component wings and consequently the minimum dispersion in angle of attack of the negative slope to these curves. However, this very condition produces a magnitude of maximum lateral instability that is greater than the average.

If the range of instability is of secondary importance and only the maximum value of unstable rolling moment is considered, separation of the normal force curve of the

TABLE II

SUMMARY OF AERODYNAMIC CHARACTERISTICS

Key letter	Cellule variable						1	2	3	4	5	6	7	8
	Gap/chord	Stagger/chord	Decalage	Dihedral	Sweepback	Overhang	$C_{N_{max}}$ cellule	$C_{N_{max}}$ upper	$C_{N_{max}}$ lower	Angle of attack at $C_{N_{max}}$, degrees	Angle of attack at initial $C_\lambda=0$, degrees	Angle of attack at final $C_\lambda=0$, degrees	Range of initial instability, degrees	Maximum unstable C_λ at $\frac{pb}{2V}=0.05$
A	Monoplane (average)			0	0	----------	1.329	----------	----------	16	16	25	9	0.0288
B	1.50	0	0	0	0	0	1.240	1.349	1.150	17	18	26	8	.0264
C	1.25	0	0	0	0	0	1.218	1.333	1.136	18	18	26	8	.0232
D	1.00	0	0	0	0	0	1.205	1.287	1.142	18	18	27	9	.0151
E	.75	0	0	0	0	0	1.157	1.167	(a)	18	19	27	8	.0163
F	.50	0	0	0	0	0	1.090	1.004	(a)	20	20	25	5	.0102
G	1	.75	0	0	0	0	1.276	1.414	1.430	16	17	31	14	.0077
H	1	.50	0	0	0	0	1.255	1.360	1.333	17	19	29	10	.0111
I	1	.25	0	0	0	0	1.269	1.348	1.280	18	18	27	9	.0138
J	1	−.25	0	0	0	0	1.128	1.250	1.104	16	17	27	10	.0139
CH	1.25	.50	0	0	0	0	1.285	1.379	1.288	17	18	25	7	.0161
CI	1.25	.25	0	0	0	0	1.265	1.345	1.227	18	18	27	9	.0214
EH	.75	.50	0	0	0	0	1.217	1.360	[b] 1.500	16	17	21	4	.0065
EI	.75	.25	0	0	0	0	1.205	1.240	[b] 1.418	18	19	25	6	.0168
K	1	0	−6°	0	0	0	1.126	1.290	1.216	20	21	31	10	.0103
L	1	0	−3°	0	0	0	1.192	1.300	1.195	20	20	27	7	.0235
M	1	0	+3°	0	0	0	1.149	1.290	1.148	15	16	25	9	.0096
N	1	0	+6°	0	0	0	1.105	1.328	1.190	12	15	25	10	.0125
CL	1.25	0	−3°	0	0	0	1.240	1.331	1.215	20	20	29	9	.0205
CM	1.25	0	+3°	0	0	0	1.195	1.290	1.151	16	16	26	10	.0182
EL	.75	0	−3°	0	0	0	1.159	1.220	(a)	20	21	[c] 45+	[c] 24+	.0151
EM	.75	0	+3°	0	0	0	1.142	1.160	(a)	16	17	25	8	.0145
HM	1	.50	+3°	0	0	0	1.292	1.370	[b] 1.283	16	17	23	6	.0193
HL	1	.50	−3°	0	0	0	1.181	1.357	1.385	17	[d] 22	32	10	.0044
IM	1	.25	+3°	0	0	0	1.221	1.290	1.151	16	17	27	10	.0135
IL	1	.25	−3°	0	0	0	1.189	1.313	1.318	19	20	31	11	.0132
O	1	0	0	3° UP.	0	0	1.230	1.320	1.156	17	18	26	8	.0223
P	1	0	0	3° LR.	0	0	1.212	1,277	1.140	18	18	26	8	.0182
Q	1	0	0	0	10° UP.	0	1.135	1.231	1.100	16	16	29	13	.0156
R	1	0	0	0	5° UP.	0	1.194	1.302	1.112	18	19	29	10	.0248
S	1	0	0	0	10° LR.	0	1.228	1.326	1.182	18	19	27	8	.0218
T	1	0	0	0	5° LR.	0	1.219	1.313	1.197	18	18	26	8	.0183
IR	1	.25	0	0	5° UP.	0	1.225	1.310	[b] 1.248	18	19	27	8	.0179
HQ	1	.50	0	0	10° UP.	0	1.224	1.324	1.310	18	18	27	9	.0139
XS	1	−.50	0	0	10° LR.	0	1.125	1.269	1.051	17	17	26	9	.0194
U	1	0	0	0	0	−20%	1.143	1.185	1.190	17	18	26	8	.0193
V	1	0	0	0	0	+20%	1.254	1.373	1.100	18	18	27	9	.0224
W	1	0	0	0	0	+40%	1.240	1.349	1.147	18	17	26	9	.0287

[a] Maximum normal force coefficient occurs at a very high angle and is not well defined.

[b] No well-defined maximum. The normal force coefficient continues to increase above the values given after only a slight loss in lift.

[c] Only very slightly unstable above 30° angle of attack.

[d] Only very slightly stable above 18° angle of attack.

upper and lower wings is desirable. This condition can best be obtained by use of +50 to +75 per cent stagger at a gap/chord ratio of 1.00 (cellules H and G), +50 per cent stagger at a gap/chord ratio of 0.75 (cellule EH), or +50 per cent stagger combined with −3° decalage (cellule HL), the last-mentioned arrangement being the most favorable.

(c) **Longitudinal stability.**—Quantitative comparison of the various wing arrangements on the score of longitudinal stability is impossible from the present data. However, a general review of all the pitching-moment curves reveals normal slopes below the stall except for combinations having a large amount of stagger or positive stagger combined with negative decalage. In the former case, abnormally large tail surfaces would probably be required to maintain longitudinal balance. In the latter case the opposite condition exists, these cellules showing the smallest unstable pitching moments below the stall of any wing system tested.

Above the stall, the monoplane or a biplane having 40 per cent positive overhang or at least +25 per cent effective stagger, with or without small variations in gap/chord ratio or decalage, gives better than average stability. A very small gap/chord ratio or negative effective stagger has the opposite effect.

SUGGESTIONS FOR FUTURE RESEARCH

From the preceding outline of the general effects of wing arrangement on the efficiency and stability of the lifting system of an airplane, certain lines for future investigation suggest themselves. Table I shows a considerable field to have been covered in the present research, but the intervals between test points have necessarily been so large that more detailed investigation of limited portions of the field would be likely to reveal wing combinations that are better than any tested thus far. Omitting, for practical reasons, consideration of the improved characteristics of such abnormal biplanes as those having gap/chord ratios greater than 1.50, more than 75 per cent stagger, or a combination of these features, the arrangements that indicate the least loss in maximum lift due to biplane interference are those having combined positive stagger and positive decalage. Slight increases in either stagger or decalage or both, with or without an increase in gap, might produce a biplane equal to the monoplane in maximum lift.

Of perhaps greater interest are cellules showing a tendency toward improved lateral stability. Along this line positive stagger combined with negative decalage shows the greatest promise. Reduction of the gap of such cellules or the introduction of sweepback on both wings should continue to improve conditions sufficiently to warrant a much more detailed investigation of the combined effects of these variables.

Good longitudinal stability usually exists in laterally stable combinations, but it is apparent that high maximum normal force does not go with the other favorable characteristics. Consequently, it would be of considerable interest to determine the best cellule from the standpoint of stability and then attempt to compensate for the loss of lift on the upper wing by use of flaps or slots.

CONCLUSIONS

1. Within the range of this investigation the changes given in the following table from the orthogonal, circular-tipped, Clark Y biplane tend appreciably to reduce mutual wing interference and raise the maximum normal force coefficient of the cellule. The particular cellule cited in each class is the best wing arrangement tested.

Wing arrangement (orthogonal except as specified)	$C_{N_{max}}$	Percentage increase over orthogonal
Orthogonal biplane	1.205	0.0
Overhang=+20%	1.254	4.1
Stagger=+75%	1.276	5.9
Gap/chord=1.25, Stagger =+50%	1.285	6.6
Decalage= +3°, Stagger =+50%	1.292	7.2
Monoplane	1.329	10.3

2. Reduction in the range of initial lateral instability is best accomplished by use of gap/chord ratios distinctly less than 1.0.

3. Reduction in the magnitude of maximum lateral instability is best accomplished by use of positive stagger at a gap/chord ratio of not more than 1.0, or positive stagger in combination with negative decalage.

4. For the same location of the center of gravity with respect to the mean chord combined positive stagger and negative decalage shows the greatest relative longitudinal stability below the stall.

5. Strong longitudinal stability above the stall is best obtained by use of positive stagger in combination with any other variable.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., *October 15, 1931.*

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TABLE III

CLARK Y CIRCULAR-TIPPED MONOPLANES, 5-INCH CHORD, ASPECT RATIO=6

α	Wing No. 2 (Upper of Biplane Cellules)				Wing No. 1 (Lower of Biplane Cellules)			
	C_N	$C_{m\ c/4}$	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	C_{px}	C_{py}
Degrees								
−8	−0.118	−0.084	0.314	0.450	−0.181	−0.081	−0.197	0.460
−4	.142	−.098	.944	.428	.136	−.103	1.010	.432
0	.436	−.060	.388	.434	.456	−.071	.406	.430
4	.739	−.061	.332	.436	.749	−.069	.341	.449
8	.987	−.048	.299	.449	1.043	−.062	.309	.443
12	1.230	−.045	.286	.456	1.260	−.048	.288	.453
14	1.282	−.048	.287	.461	1.330	−.046	.284	.458
16	1.309	−.049	.287	.472	1.349	−.043	.282	.470
18	1.027	−.117	.364	.516	1.222	−.067	.305	.506
20	.898	−.135	.399	.514	.931	−.134	.393	.511
22	.890	−.129	.394	.513	.916	−.133	.396	.510
25	.905	−.132	.395	.492	.926	−.132	.393	.493
30	1.049	−.159	.401	.485	1.062	−.163	.410	.485
35	1.127	−.177	.407	.484	1.174	−.187	.408	.481
40	1.141	−.193	.418	.477	1.184	−.195	.414	.478
50	1.220	−.213	.425	.476	1.243	−.223	.429	.477
60	1.300	−.258	.448	.478	1.301	−.265	.454	.481
70	1.350	−.304	.475	.478	1.379	−.312	.477	.481
80	1.372	−.340	.498	.479	1.382	−.361	.512	.482
90	1.369	−.362	.514	.475	1.383	−.367	.516	.483

TABLE IV

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=1.50$

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.108	−0.571	0.473	−0.142	−0.424	0.470	−0.125	−0.092	0.760
−4	.145	.968	.451	.125	1.105	.414	.135	−.105	1.160
0	.368	.442	.451	.322	.497	.441	.345	−.076	1.142
4	.660	.352	.449	.606	.372	.450	.634	−.071	1.090
8	.921	.318	.448	.827	.327	.454	.876	−.063	1.114
12	1.134	.297	.460	1.029	.306	.460	1.083	−.055	1.102
14	1.213	.293	.461	1.095	.296	.463	1.157	−.051	1.108
16	1.303	.288	.468	1.150	.298	.473	1.230	−.053	1.133
18	1.349	.290	.478	1.115	.308	.491	1.233	−.060	1.209
20	1.015	.364	.507	1.075	.342	.496	1.046	−.108	.943
22	.851	.383	.531	.949	.403	.508	.900	−.129	.897
25	.802	.374	.506	.988	.413	.503	.898	−.130	.812
30	.852	.373	.492	1.044	.418	.482	.950	−.140	.816
35	.903	.376	.492	1.133	.420	.480	1.020	−.153	.796
40	.950	.380	.492	1.241	.426	.476	1.098	−.172	.765
50	.852	.354	.491	1.365	.440	.471	1.110	−.174	.624
60	.659	.280	.511	1.375	.458	.476	1.019	−.154	.479
70	.074	−.971	1.055	1.463	.471	.478	.771	−.116	.051
80	−.272	.461	.386	1.501	.494	.471	.616	−.155	−.181
90	−.161	.511	.342	1.458	.519	.469	.649	−.175	−.110

TABLE V

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=1.25$

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.138	−0.409	0.438	−0.117	−0.611	0.545	−0.127	−0.096	1.180
−4	.136	.987	.484	.140	1.024	.413	.138	−.104	.972
0	.350	.444	.464	.330	.480	.443	.340	−.072	1.061
4	.631	.347	.452	.599	.361	.450	.615	−.064	1.053
8	.912	.317	.452	.823	.325	.460	.868	−.062	1.110
12	1.135	.293	.458	1.012	.308	.464	1.077	−.053	1.121
14	1.200	.288	.460	1.088	.293	.461	1.147	−.046	1.103
16	1.250	.285	.465	1.136	.297	.467	1.193	−.049	1.100
18	1.333	.286	.476	1.103	.310	.481	1.218	−.057	1.208
20	.906	.374	.527	1.045	.377	.498	.976	−.122	.867
22	.803	.379	.530	1.000	.400	.499	.901	−.126	.803
25	.741	.366	.504	1.021	.414	.497	.881	−.128	.726
30	.772	.362	.500	1.090	.430	.480	.932	−.141	.708
35	.799	.353	.495	1.179	.435	.477	.998	−.151	.677
40	.795	.350	.495	1.287	.428	.471	1.040	−.154	.618
50	.725	.320	.498	1.388	.439	.472	1.055	−.157	.522
60	.477	.190	.520	1.424	.459	.474	.950	−.134	.335
70	−.121	.934	.247	1.495	.474	.471	.686	−.128	−.081
80	−.180	.495	.333	1.490	.492	.464	.655	−.158	−.121
90	−.161	.543	.322	1.490	.514	.468	.665	−.172	−.108

TABLE VI

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=1.00$

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.139	−0.329	0.422	−0.080	−1.113	0.554	−0.110	−0.095	1.738
−4	.120	1.019	.445	.153	.964	.410	.136	−.101	.784
0	.344	.439	.448	.343	.479	.432	.344	−.072	1.004
4	.610	.347	.451	.600	.379	.442	.605	−.069	1.017
8	.853	.314	.448	.778	.326	.454	.815	−.056	1.093
12	1.067	.288	.456	.966	.308	.460	1.020	−.047	1.102
14	1.150	.283	.460	1.080	.298	.462	1.113	−.046	1.064
16	1.220	.275	.469	1.142	.288	.467	1.181	−.037	1.069
18	1.287	.272	.468	1.120	.298	.476	1.205	−.041	1.147
20	1.070	.311	.514	1.089	.350	.491	1.079	−.087	.982
22	.840	.339	.550	1.067	.394	.498	.951	−.115	.788
25	.693	.350	.509	1.073	.413	.495	.884	−.122	.646
30	.694	.333	.508	1.191	.423	.478	.943	−.132	.582
35	.708	.327	.505	1.260	.426	.472	.986	−.138	.562
40	.666	.298	.511	1.362	.425	.474	1.015	−.137	.489
50	.542	.233	.511	1.421	.447	.466	.981	−.135	.381
60	.268	−.033	.568	1.486	.456	.470	.877	−.116	.180
70	−.158	.540	.316	1.470	.476	.467	.656	−.143	−.108
80	−.120	.536	.264	1.472	.499	.464	.677	−.166	−.081
90	−.123	.501	.257	1.470	.520	.467	.674	−.184	−.084

TABLE VII

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=0.75$

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.151	−0.202	0.419	−0.039	−2.72	0.725	−0.095	−0.093	3.86
−4	.092	1.140	.494	.163	.883	.424	.128	−.093	.564
0	.258	.432	.463	.341	.476	.429	.300	−.062	.756
4	.583	.322	.449	.595	.364	.447	.590	−.055	.980
8	.795	.308	.449	.781	.317	.451	.788	−.050	1.018
12	.995	.262	.455	.976	.311	.452	.988	−.035	1.018
14	1.028	.263	.463	1.026	.292	.460	1.027	−.028	1.002
16	1.059	.263	.469	1.108	.290	.465	1.083	−.029	.955
18	1.167	.262	.475	1.147	.284	.468	1.157	−.027	1.016
20	1.051	.273	.499	1.138	.331	.480	1.096	−.058	.923
22	.714	.328	.549	1.220	.360	.475	.966	−.095	.585
25	.549	.315	.531	1.252	.395	.478	.901	−.108	.438
30	.563	.304	.520	1.269	.429	.481	.918	−.129	.444
35	.512	.251	.516	1.366	.438	.476	.942	−.128	.375
40	.420	.195	.526	1.435	.438	.471	.929	−.124	.293
50	.286	.008	.544	1.498	.442	.469	.891	−.110	.191
60	.035	−2.40	.890	1.513	.455	.467	.774	−.110	.023
70	−.137	.482	.323	1.498	.473	.466	.680	−.152	−.092
80	−.099	.500	.252	1.500	.498	.468	.701	−.174	−.066
90	−.088	.513	.252	1.503	.521	.466	.708	−.193	−.058

TABLE VIII

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=0.50$

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.193	−0.054	0.413	0.006	20.2	0.730	−0.094	−0.030	32.2
−4	.012	5.915	.913	.190	.772	.413	.101	−.084	.063
0	.162	.432	.488	.374	.496	.430	.268	−.061	.433
4	.413	.285	.481	.624	.389	.440	.518	−.052	.663
8	.616	.260	.458	.790	.355	.449	.704	−.044	.780
12	.787	.246	.473	.955	.326	.449	.870	−.035	.824
14	.869	.248	.475	1.022	.326	.456	.945	−.039	.850
16	.918	.237	.483	1.090	.318	.459	1.004	−.031	.842
18	.970	.231	.481	1.176	.305	.461	1.072	−.024	.825
20	1.004	.230	.493	1.175	.310	.468	1.090	−.026	.854
22	.610	.285	.556	1.338	.330	.471	.974	−.065	.456
25	.324	.264	.678	1.436	.354	.469	.880	−.077	.226
30	.305	.192	.598	1.593	.402	.499	.950	−.114	.191
35	.189	−.089	.646	1.649	.422	.482	.920	−.109	.115
40	.156	−.379	.645	1.569	.437	.478	.863	−.097	.099
50	.054	−1.63	.840	1.565	.437	.475	.810	−.096	.035
60	−.054	.976	.162	1.414	.456	.469	.681	−.126	−.038
70	−.094	.522	.245	1.485	.469	.469	.696	−.150	−.063
80	−.062	.514	.179	1.487	.498	.470	.711	−.176	−.042
90	−.063	.400	.145	1.469	.517	.468	.703	−.191	−.043

TABLE IX

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=0.75

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.096	−0.805	0.423	−0.076	−0.996	0.542	−0.086	−0.102	1.265
−4	.196	.771	.447	.130	.931	.416	.163	−.083	1.508
0	.494	.396	.444	.321	.509	.444	.408	−.046	1.539
4	.770	.346	.442	.533	.396	.448	.652	−.031	1.446
8	1.055	.309	.448	.738	.351	.458	.897	−.009	1.430
12	1.312	.271	.449	.930	.330	.461	1.121	.021	1.411
14	1.385	.287	.454	1.029	.314	.461	1.207	.008	1.345
16	1.410	.301	.468	1.142	.309	.458	1.276	−.020	1.234
18	1.059	.352	.532	1.295	.307	.464	1.177	−.136	.818
20	.941	.371	.523	1.357	.299	.468	1.149	−.168	.694
22	.857	.375	.504	1.421	.313	.475	1.139	−.204	.602
25	.868	.376	.497	1.402	.319	.495	1.135	−.204	.619
30	.982	.389	.488	1.298	.411	.445	1.140	−.232	.755
35	1.031	.395	.482	1.339	.411	.444	1.185	−.240	.770
40	1.048	.415	.477	1.334	.435	.464	1.191	−.264	.785
50	1.162	.420	.472	1.429	.441	.465	1.296	−.285	.813
60	1.199	.432	.471	1.465	.458	.463	1.332	−.311	.817
70	1.226	.439	.470	1.491	.471	.466	1.359	−.332	.822
80	1.169	.442	.477	1.438	.489	.465	1.304	−.335	.812
90	1.024	.408	.481	1.362	.508	.468	1.193	−.321	.751

TABLE X

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=0.50

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.076	−0.985	0.413	−0.051	−1.678	0.595	−0.064	−0.100	1.491
−4	.176	.813	.429	.120	1.115	.424	.148	−.095	1.467
0	.415	.420	.441	.307	.532	.441	.361	−.065	1.352
4	.732	.332	.443	.553	.386	.450	.643	−.045	1.323
8	.971	.307	.447	.723	.343	.456	.847	−.030	1.345
12	1.188	.293	.453	.915	.321	.458	1.052	−.024	1.299
14	1.299	.283	.457	1.022	.315	.463	1.161	−.020	1.270
16	1.358	.282	.466	1.125	.309	.459	1.242	−.026	1.208
18	1.280	.291	.490	1.207	.303	.467	1.244	−.050	1.061
20	1.033	.342	.526	1.280	.303	.476	1.157	−.112	.806
22	.874	.374	.530	1.331	.300	.483	1.103	−.144	.656
25	.857	.364	.501	1.228	.396	.481	1.043	−.185	.698
30	.890	.369	.485	1.202	.436	.474	1.046	−.204	.740
35	.930	.374	.481	1.275	.433	.472	1.103	−.217	.729
40	.966	.377	.479	1.327	.435	.468	1.147	−.231	.728
50	1.021	.384	.475	1.407	.440	.465	1.214	−.250	.726
60	1.036	.390	.477	1.450	.459	.466	1.243	−.276	.713
70	.992	.379	.482	1.428	.474	.468	1.210	−.278	.694
80	.761	.305	.489	1.409	.494	.468	1.085	−.274	.540
90	.275	−.023	.511	1.413	.510	.469	.844	−.288	.195

TABLE XI

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=0.25

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.093	−0.654	0.440	−0.066	−1.241	0.577	−0.080	−0.050	1.410
−4	.163	.865	.449	.153	.962	.430	.158	−.104	1.065
0	.417	.428	.443	.339	.503	.435	.378	−.076	1.230
4	.678	.341	.446	.572	.383	.445	.625	−.062	1.187
8	.939	.308	.448	.785	.335	.453	.862	−.051	1.195
12	1.142	.289	.455	.966	.311	.458	1.054	−.040	1.180
14	1.225	.282	.458	1.061	.305	.460	1.143	−.038	1.154
16	1.328	.275	.463	1.144	.302	.463	1.236	−.036	1.161
18	1.338	.275	.475	1.184	.292	.472	1.261	−.033	1.130
20	.973	.343	.526	1.245	.301	.481	1.109	−.094	.782
22	.839	.358	.540	1.280	.304	.486	1.060	−.108	.656
25	.755	.356	.497	1.148	.404	.493	.952	−.154	.658
30	.816	.355	.496	1.207	.425	.477	1.012	−.173	.677
35	.830	.351	.484	1.265	.435	.471	1.048	−.186	.656
40	.849	.347	.486	1.305	.432	.470	1.077	−.189	.650
50	.825	.336	.490	1.394	.443	.468	1.110	−.207	.592
60	.765	.300	.491	1.429	.457	.467	1.097	−.209	.536
70	.544	.199	.506	1.449	.477	.471	.997	−.208	.375
80	.001	47.500	1.925	1.450	.492	.471	.725	−.266	.001
90	−.127	.466	.270	1.422	.512	.471	.648	−.270	−.089

TABLE XII

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=−0.25

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.136	−0.313	0.411	−0.094	−0.911	0.518	−0.115	−0.092	1.448
−4	.103	1.211	.449	.153	.968	.404	.128	−.101	.672
0	.274	.488	.454	.342	.498	.436	.308	−.071	.801
4	.554	.376	.453	.596	.364	.445	.575	−.066	.930
8	.786	.327	.445	.816	.320	.455	.801	−.057	.963
12	.980	.298	.458	1.006	.301	.458	.993	−.048	.975
14	1.119	.284	.459	1.089	.290	.463	1.104	−.043	1.027
16	1.162	.281	.468	1.095	.298	.483	1.128	−.048	1.061
18	1.250	.269	.473	.925	.379	.492	1.088	−.092	1.351
20	1.094	.279	.501	.903	.400	.495	.998	−.095	1.211
22	.793	.353	.538	.995	.415	.486	.894	−.110	.796
25	.609	.336	.523	1.072	.410	.501	.840	−.082	.568
30	.600	.319	.526	1.161	.420	.481	.880	−.084	.516
35	.602	.312	.526	1.260	.425	.475	.931	−.088	.478
40	.465	.254	.540	1.357	.427	.474	.911	−.066	.343
50	.135	.371	.735	1.424	.441	.473	.779	−.063	.095
60	−.261	.515	.356	1.503	.462	.468	.621	−.015	−.174
70	−.131	.557	.313	1.451	.473	.468	.660	−.042	−.090
80	−.109	.555	.278	1.453	.501	.466	.672	−.068	−.075
90	−.101	.529	.259	1.453	.515	.467	.676	−.082	−.070

TABLE XIII

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=1.25$; STAGGER/CHORD=0.50

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.087	−0.816	0.437	−0.188	−0.526	0.486	−0.102	−0.089	0.737
−4	.200	.750	.428	.126	1.052	.437	.163	−.092	1.588
0	.470	.393	.446	.294	.489	.448	.382	−.047	1.599
4	.755	.339	.447	.590	.374	.452	.673	−.050	1.281
8	.992	.309	.447	.777	.325	.454	.885	−.031	1.276
12	1.260	.289	.451	.992	.310	.460	1.126	−.022	1.270
14	1.340	.281	.456	1.081	.308	.460	1.210	−.020	1.240
16	1.379	.284	.465	1.181	.291	.464	1.280	−.023	1.167
18	1.311	.291	.499	1.237	.284	.473	1.274	−.039	1.062
20	1.028	.347	.541	1.267	.295	.488	1.148	−.109	.812
22	.905	.383	.528	1.288	.311	.499	1.097	−.147	.703
25	.888	.370	.497	1.125	.410	.477	1.007	−.174	.789
30	.933	.383	.487	1.150	.426	.473	1.042	−.190	.811
35	.965	.397	.478	1.200	.428	.473	1.083	−.208	.804
40	1.009	.394	.482	1.289	.434	.470	1.149	−.226	.783
50	1.082	.403	478	1.393	.446	.468	1.238	−.259	.776
60	1 096	.402	.475	1.490	.464	.468	1.293	−.292	.735
70	1.040	.391	.481	1.465	.474	.469	1.253	−.291	.710
80	.758	.303	.498	1.435	.497	.471	1.097	−.282	.528
90	.026	−1.545	1.660	1.400	.511	.469	.713	−.331	.019

TABLE XIV

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=1.25$; STAGGER/CHORD=0.25

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.100	−0.639	0.413	−0.114	−0.591	0.487	−0.107	−0.092	0.876
−4	.172	.831	.450	.115	1.116	.398	.144	−.096	1.495
0	.429	.412	.445	.299	.489	.429	.364	−.050	1.435
4	.692	.337	.448	.561	.381	.429	.627	−.059	1.233
8	.942	.310	.446	.781	.329	.434	.862	−.049	1.206
12	1.189	.287	.445	.988	.312	.434	1.089	−.041	1.201
14	1.252	.279	.450	1.061	.294	.437	1.157	−.030	1.179
16	1.324	.281	.457	1.137	.291	.442	1.231	−.032	1.166
18	1.340	.283	.468	1.187	.287	.451	1.264	−.035	1.130
20	.966	.366	.510	1.227	.300	.461	1.096	−.104	.788
22	.832	.362	.513	1.092	.390	.480	.962	−.140	.762
25	.830	.383	.497	1.066	.416	.482	.948	−.158	.779
30	.849	.369	.491	1.112	.413	.478	.981	−.158	.763
35	.903	.376	.491	1.175	.425	.476	1.039	−.177	.768
40	.931	.380	.487	1.259	.428	.469	1.095	−.193	.740
50	.927	.375	.483	1.398	.440	.469	1.163	−.220	.663
60	.882	.352	.492	1.411	.460	.470	1.147	−.227	.624
70	.634	.252	.504	1.439	.478	.470	1.037	−.215	.441
80	−.033	.246	−.534	1.450	.496	.473	.708	−.234	−.023
90	−.173	.432	.294	1.430	.527	.474	.628	−.283	−.121

TABLE XV

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=0.75$; STAGGER/CHORD=0.50

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.081	−0.772	0.455	−0.106	−0.550	0.494	−0.093	−0.080	0.764
−4	.213	.709	.439	.081	1.341	.421	.147	−.077	2.628
0	.495	.375	.444	.262	.554	440	.379	−.042	1.890
4	.775	.323	.445	.474	.392	.455	.625	−.024	1.635
8	1.038	.293	.445	.683	.354	.463	.861	−.013	1.521
12	1.239	.278	.450	.844	.332	.462	1.042	−.003	1.468
14	1.319	.271	.457	.971	.320	.462	1.145	−.004	1.358
16	1.360	.267	.469	1.073	.317	.462	1.217	−.012	1.267
18	1.030	.319	.521	1.242	.312	.457	1.136	−.101	.829
20	.778	.339	.536	1.383	.308	.463	1.081	−.150	.562
22	.711	.343	.517	1.438	.311	.469	1.074	−.168	.495
25	.688	.328	.510	1.495	.326	.475	1.093	−.185	.460
30	.799	.347	.496	1.488	.364	.468	1.144	−.210	.537
35	.896	.357	.490	1.400	.420	.463	1.148	−.230	.640
40	.948	.376	.486	1.364	.444	.460	1.156	−.245	.695
50	1.010	.377	.477	1.410	.454	.465	1.210	−.258	.716
60	1.025	.388	.480	1.456	.461	.471	1.241	−.279	.704
70	.970	.369	.481	1.446	.477	.471	1.208	−.282	.671
80	.794	.311	.491	1.422	.499	.472	1.108	−.279	.558
90	.445	.187	.491	1.393	.517	.472	.919	−.291	.319

TABLE XVI

CLARK Y CIRCULAR-TIPPED BIPLANE, $G/c=0.75$; STAGGER/CHORD=0.25

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m c/4}$	e
Degrees									
−8	−0.102	−0.503	0.438	−0.066	−1.242	0.555	−0.084	−0.090	1.545
−4	.163	.772	.455	.120	.964	.427	.142	−.083	1.358
0	.433	.378	.449	.297	.484	.440	.365	−.059	1.458
4	.665	.320	.449	.519	.378	.452	.592	−.048	1.282
8	.897	.288	.452	.721	.336	.460	.809	−.038	1.246
12	1.103	.274	.453	.890	.318	.464	.997	−.031	1.239
14	1.180	.267	.460	.996	.310	.462	1.088	−.029	1.184
16	1.239	.258	.470	1.086	.303	.460	1.162	−.024	1.141
18	1.237	.257	.483	1.170	.300	.455	1.204	−.030	1.057
20	1.120	.256	.524	1.198	.298	.459	1.159	−.037	.933
22	.685	.332	.551	1.387	.303	.475	1.036	−.108	.494
25	.623	.319	.516	1.397	.322	.483	1.010	−.121	.446
30	.697	.313	.509	1.418	.394	.483	1.058	−.169	.492
35	.748	.310	.502	1.329	.432	.468	1.039	−.180	.563
40	.737	.313	.501	1.365	.441	.467	1.051	−.197	.540
50	.735	.297	.497	1.473	.448	.464	1.104	−.210	.499
60	.659	.251	.495	1.484	.456	.468	1.072	−.204	.444
70	.430	.139	.510	1.449	.473	.472	.939	−.202	.297
80	.051	−.908	.943	1.472	.489	.474	.762	−.236	.035
90	−.092	.550	.203	1.432	.512	.475	.669	−.269	−.064

TABLE XVII

CLARK Y CIRCULAR-TIPPED BIPLANE, DECALAGE=−6°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m c/4}$	e
Degrees									
−8	−0.064	−0.893	0.453	−0.308	0.277	0.554	−0.186	−0.032	0.208
−4	.216	.681	.432	−.368	.225	.470	−.076	−.051	−.587
0	.438	.408	.439	−.092	−.612	.445	.174	−.074	−4.760
4	.680	.339	.449	.153	.839	.460	.417	−.076	4.445
8	.928	.313	.450	.379	.414	.456	.654	−.060	2.450
12	1.114	.297	.451	.587	.358	.453	.851	−.057	1.900
14	1.168	.290	.459	.687	.334	.457	.928	−.052	1.700
16	1.230	.279	.465	.799	.321	.454	1.015	−.046	1.540
18	1.290	.282	.472	.912	.310	.456	1.101	−.049	1.414
20	1.237	.293	.489	1.015	.304	.457	1.126	−.053	1.218
22	.949	.352	.558	1.117	.306	.457	1.033	−.080	.850
25	.807	.372	.539	1.216	.301	.466	1.012	−.080	.664
30	.761	.354	.501	1.037	.349	.488	.899	−.091	.735
35	.764	.342	.500	1.144	.426	.477	.954	−.134	.667
40	.745	.332	.497	1.228	.427	.473	.987	−.139	.607
50	.610	.277	.508	1.320	.437	.467	.966	−.130	.462
60	.362	.103	.543	1.400	.448	.461	.881	−.112	.258
70	−.148	.716	.301	1.462	.468	.468	.657	−.126	−.101
80	−.133	.612	.306	1.467	.481	.464	.667	−.145	−.091
90	−.117	.487	.265	1.467	.504	.466	.675	−.173	−.080

TABLE XVIII

CLARK Y CIRCULAR-TIPPED BIPLANE, DECALAGE=−3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m c/4}$	e
Degrees									
−8	−0.076	−0.782	0.437	−0.347	0.207	0.499	−0.211	−0.046	0.219
−4	.170	.831	.428	−.071	−1.041	.476	.050	−.095	−2.395
0	.377	.447	.451	.163	.858	.427	.270	−.086	2.310
4	.650	.348	.449	.376	.443	.431	.513	−.069	1.729
8	.891	.313	.452	.595	.362	.452	.743	−.062	1.497
12	1.086	.292	.455	.794	.322	.455	.940	−.051	1.368
14	1.140	.290	.456	.884	.312	.449	1.014	−.049	1.290
16	1.216	.282	.465	.997	.305	.455	1.107	−.048	1.220
18	1.276	.282	.472	1.074	.301	.460	1.175	−.048	1.188
20	1.270	.288	.482	1.114	.297	.471	1.192	−.051	1.140
22	.962	.341	.558	1.196	.299	.474	1.079	−.073	.804
25	.692	.361	.511	1.070	.395	.493	.881	−.117	.646
30	.720	.344	.500	1.114	.430	.484	.917	−.135	.646
35	.720	.328	.499	1.228	.429	.474	.974	−.139	.586
40	.686	.306	.503	1.302	.431	.473	.994	−.138	.527
50	.532	.244	.521	1.376	.438	.470	.954	−.129	.387
60	.251	.004	.572	1.463	.454	.472	.857	−.119	.172
70	−.155	.630	.305	1.486	.469	.467	.666	−.132	−.104
80	−.132	.502	.258	1.498	.496	.466	.683	−.168	−.088
90	−.111	.591	.264	1.482	.509	.466	.686	−.172	−.075

TABLE XIX

CLARK Y CIRCULAR-TIPPED BIPLANE, DECALAGE=+3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.165	−0.248	0.432	0.156	0.991	0.403	−0.004	−0.099	−1.059
−4	.077	1.478	.470	.318	.549	.434	.197	−.095	.242
0	.263	.473	.476	.593	.387	.437	.428	−.070	.443
4	.571	.362	.458	.792	.339	.452	.681	−.067	.722
8	.828	.309	.455	.990	.313	.457	.909	−.056	.835
12	1.052	.293	.457	1.129	.300	.463	1.090	−.050	.932
14	1.142	.285	.463	1.141	.299	.481	1.142	−.048	1.000
16	1.282	.275	.468	.990	.368	.505	1.136	−.075	1.296
18	1.104	.302	.512	.941	.400	.506	1.023	−.100	1.174
20	.872	.333	.550	1.003	.407	.505	.937	−.115	.869
22	.707	.344	.539	1.060	.416	.498	.884	−.121	.666
25	.640	.336	.514	1.156	.423	.485	.898	−.128	.554
30	.674	.321	.504	1.233	.422	.479	.954	−.130	.546
35	.669	.314	.508	1.305	.429	.479	.987	−.138	.512
40	.626	.290	.512	1.403	.431	.474	1.013	−.140	.446
50	.493	.207	.509	1.450	.443	.470	.972	−.129	.340
60	.222	−.132	.575	1.495	.461	.475	.859	−.116	.148
70	−.153	.510	.316	1.488	.471	.469	.668	−.144	−.103
80	−.107	.534	.249	1.462	.507	.466	.678	−.173	−.073
90	−.116	.506	.279	1.484	.524	.469	.684	−.189	−.078

TABLE XX

CLARK Y CIRCULAR-TIPPED BIPLANE, DECALAGE=+6°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.255	−0.070	0.429	.0376	0.515	.0419	0.061	−0.091	−0.678
−4	.009	10.360	1.181	.646	.388	.432	.328	−.090	.014
0	.208	.534	.478	.851	.345	.446	.530	−.070	.245
4	.545	.373	.457	1.033	.318	.450	.789	−.069	.528
8	.820	.316	.451	1.181	.293	.465	1.001	−.053	.694
12	1.080	.289	.449	1.128	.301	.491	1.104	−.050	.960
14	1.301	.277	.450	.879	.396	.501	1.090	−.082	1.480
16	1.315	.271	.472	.896	.411	.494	1.106	−.086	1.466
18	.974	.329	.515	.986	.415	.498	.980	−.120	.987
20	.777	.343	.530	1.035	.425	.486	.906	−.126	.750
22	.675	.338	.528	1.116	.416	.481	.896	−.123	.605
25	.628	.317	.508	1.181	.429	.479	.905	−.127	.531
30	.643	.312	.507	1.279	.431	.473	.961	−.136	.503
35	.623	.291	.508	1.378	.431	.472	1.001	−.138	.452
40	.570	.266	.511	1.442	.438	.470	1.006	−.140	.395
50	.468	.179	.508	1.499	.451	.467	.984	−.134	.312
60	.168	−.277	.581	1.519	.471	.471	.844	−.124	.111
70	−.147	.514	.308	1.488	.487	.471	.671	−.157	−.099
80	−.108	.484	.257	1.467	.513	.467	.680	−.181	−.074
90	−.127	.497	.283	1.476	.529	.465	.675	−.190	−.086

TABLE XXI

CLARK Y CIRCULAR-TIPPED BIPLANE, G/c=1.25; DECALAGE=−3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.069	−1.002	0.462	−0.380	0.232	0.489	−0.225	−0.046	0.182
−4	.179	.818	.423	−.105	.615	.449	.037	−.031	−1.705
0	.402	.426	.451	.137	.992	.452	.270	−.086	2.935
4	.655	.359	.449	.369	.472	.439	.512	−.077	1.775
8	.914	.317	.451	.612	.367	.457	.763	−.066	1.492
12	1.118	.299	.458	.823	.319	.455	.971	−.056	1.359
14	1.200	.289	.462	.950	.311	.456	1.075	−.052	1.263
16	1.275	.285	.468	1.024	.297	.463	1.150	−.046	1.243
18	1.331	.289	.477	1.129	.297	.466	1.230	−.052	1.180
20	1.289	.293	.486	1.159	.286	.478	1.224	−.048	1.112
22	.973	.355	.545	1.215	.297	.479	1.094	−.079	.800
25	.766	.378	.510	1.058	.395	.499	.912	−.125	.724
30	.815	.367	.498	1.058	.423	.477	.937	−.140	.770
35	.852	.362	.491	1.151	.430	.475	1.002	−.151	.740
40	.850	.356	.496	1.217	.431	.477	1.034	−.155	.699
50	.767	.334	.505	1.355	.450	.475	1.061	−.168	.566
60	.504	.213	.542	1.430	.457	.472	.967	−.138	.353
70	−.105	1.165	.127	1.518	.476	.475	.707	−.123	−.069
80	−.179	.483	.338	1.510	.489	.469	.666	−.159	−.119
90	−.162	.504	.276	1.469	.525	.476	.654	−.181	−.110

TABLE XXII

CLARK Y CIRCULAR-TIPPED BIPLANE, G/c=1.25; DECALAGE=+3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.175	−0.207	0.421	0.100	1.452	0.399	−0.037	−0.100	−1.750
−4	.086	1.378	.484	.310	.523	.438	.198	−.089	.277
0	.304	.456	.466	.593	.380	.441	.449	−.070	.513
4	.606	.362	.454	.795	.337	.449	.701	−.069	.763
8	.860	.328	.453	1.003	.300	.455	.932	−.058	.857
12	1.096	.286	.457	1.133	.297	.465	1.115	−.047	.966
14	1.172	.292	.460	1.151	.288	.475	1.162	.047	1.018
16	1.284	.291	.461	1.105	.309	.491	1.195	−.055	1.162
18	1.191	.293	.506	.866	.397	.505	1.029	−.089	1.375
20	.854	.369	.530	.968	.409	.505	.911	−.128	.882
22	.804	.376	.534	1.016	.415	.497	.910	−.134	.792
25	.745	.368	.504	1.075	.428	.485	.910	−.139	.693
30	.773	.359	.502	1.161	.423	.482	.967	−.142	.665
35	.803	.356	.501	1.251	.441	.477	1.027	−.163	.642
40	.783	.344	.499	1.356	.437	.472	1.070	−.163	.578
50	.697	.309	.503	1.440	.452	.468	1.069	−.167	.484
60	.446	.169	.530	1.440	.470	.475	.943	−.140	.310
70	−.131	.823	.259	1.486	.483	.474	.678	−.136	−.088
80	−.167	.516	.344	1.486	.501	.469	.660	−.164	−.112
90	−.168	.515	.295	1.469	.526	.469	.651	−.181	−.114

TABLE XXIII

CLARK Y CIRCULAR-TIPPED BIPLANE, G/c=0.75; DECALAGE=−3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.046	−1.535	0.376	−0.299	0.012	0.483	−0.173	−0.077	0.154
−4	.175	.763	.444	−.065	−1.397	.503	.055	−.098	−2.693
0	.421	.397	.459	.173	.826	.435	.297	−.081	2.430
4	.648	.334	.451	.345	.462	.447	.497	−.064	1.876
8	.859	.306	.448	.570	.372	.454	.715	−.059	1.505
12	1.030	.281	.460	.760	.320	.464	.895	−.043	1.355
14	1.082	.280	.466	.869	.314	.459	.976	−.044	1.246
16	1.170	.272	.470	.982	.307	.462	1.076	−.041	1.192
18	1.217	.276	.476	1.052	.308	.465	1.135	−.046	1.156
20	1.201	.271	.489	1.117	.304	.469	1.159	−.043	1.076
22	1.106	.290	.515	1.178	.293	.472	1.142	−.048	.938
25	.689	.349	.538	1.242	.349	.480	.966	−.096	.555
30	.603	.313	.514	1.290	.413	.481	.947	−.124	.467
35	.567	.275	.522	1.293	.436	.474	.930	−.128	.438
40	.484	.218	.532	1.400	.445	.472	.942	−.130	.346
50	.320	.059	.561	1.487	.446	.471	.904	−.115	.215
60	.053	−1.846	.888	1.513	.459	.471	.783	−.103	.035
70	−.140	.517	.292	1.486	.470	.470	.673	−.146	−.094
80	−.102	.552	.243	1.496	.489	.472	.697	−.164	−.068
90	−.088	.590	.197	1.505	.500	.474	.709	−.174	−.058

TABLE XXIV

CLARK Y CIRCULAR-TIPPED BIPLANE, G/c=0.75; DECALAGE=+3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.197	−0.137	0.410	0.179	0.822	0.415	−0.009	−0.089	−1.100
−4	.047	2.015	.533	.365	.515	.430	.206	−.089	.129
0	.211	.483	.472	.631	.388	.438	.421	−.068	.335
4	.521	.341	.456	.812	.341	.452	.667	−.061	.642
8	.753	.309	.451	.965	.311	.455	.859	−.052	.780
12	.940	.275	.455	1.097	.301	.462	1.019	−.039	.858
14	1.039	.269	.455	1.150	.289	.470	1.095	−.032	.902
16	1.141	.265	.460	1.143	.294	.482	1.142	−.034	.998
18	1.139	.250	.493	.977	.394	.496	1.058	−.070	1.165
20	.699	.328	.531	1.129	.397	.492	.914	−.110	.619
22	.604	.330	.544	1.160	.418	.490	.881	−.121	.520
25	.530	.296	.525	1.274	.418	.503	.902	−.120	.416
30	.554	.269	.528	1.343	.440	.478	.949	−.134	.412
35	.448	.214	.539	1.430	.443	.472	.939	−.130	.313
40	.371	.135	.536	1.459	.434	.470	.915	−.112	.254
50	.235	−.098	.581	1.533	.453	.466	.884	−.116	.153
60	−.022	3.084	−.168	1.526	.467	.469	.754	−.134	−.014
70	−.139	.470	.282	1.495	.488	.469	.678	−.163	−.093
80	−.101	.552	.219	1.500	.500	.465	.701	−.172	−.067
90	−.104	.551	.219	1.480	.520	.471	.687	−.184	−.070

TABLE XXV

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=+0.50; DECALAGE=+3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.119	−0.425	0.418	0.128	1.083	0.389	0.005	−0.125	−0.929
−4	.169	.820	.454	.306	.531	.430	.238	−.108	.552
0	.431	.409	.454	.544	.398	.441	.488	−.084	.793
4	.712	.338	.445	.742	.354	.449	.727	−.074	.960
8	.985	.308	.449	.916	.330	.458	.951	−.057	1.076
12	1.222	.287	.457	1.090	.310	.465	1.156	−.039	1.121
14	1.310	.285	.461	1.160	.306	.468	1.235	−.037	1.130
16	1.370	.278	.470	1.213	.295	.471	1.292	−.027	1.130
18	1.228	.300	.510	1.187	.306	.488	1.208	−.059	1.035
20	.939	.363	.535	1.283	.314	.495	1.111	−.137	.732
22	.840	.377	.508	1.210	.403	.468	1.025	−.192	.694
25	.869	.370	.490	1.201	.420	.490	1.035	−.196	.723
30	.880	.373	.486	1.238	.427	.473	1.059	−.208	.710
35	.935	.377	.481	1.310	.442	.470	1.123	−.233	.713
40	.957	.381	.483	1.373	.445	.465	1.165	−.249	.697
50	1.024	.392	.470	1.449	.452	.463	1.237	−.272	.706
60	1.040	.389	.478	1.460	.462	.470	1.250	−.280	.712
70	.995	.375	.482	1.442	.485	.469	1.219	−.288	.689
80	.770	.312	.495	1.415	.503	.470	1.093	−.283	.544
90	.299	.073	.544	1.388	.513	.475	.844	−.292	.215

TABLE XXVI

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=+0.50; DECALAGE=−3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.043	−1.531	0.515	−0.377	0.214	0.481	−0.210	−0.004	0.114
−4	.207	.741	.431	−.118	−.498	.470	.045	−.054	−1.755
0	.461	.396	.449	.115	1.146	.443	.293	−.042	4.010
4	.741	.338	.445	.321	.512	.443	.531	−.022	2.310
8	1.003	.305	.449	.547	.379	.455	.775	−.006	1.831
12	1.215	.296	.455	.743	.349	.459	.979	−.006	1.635
14	1.297	.291	.460	.861	.332	.460	1.079	−.007	1.505
16	1.357	.284	.471	.994	.321	.457	1.176	−.013	1.365
18	1.159	.330	.496	1.128	.318	.462	1.144	−.081	1.026
20	.914	.361	.535	1.272	.313	.460	1.093	−.136	.718
22	.844	.372	.540	1.333	.304	.469	1.089	−.149	.633
25	.783	.364	.500	1.385	.305	.479	1.084	−.158	.565
30	.895	.369	.485	1.223	.406	.478	1.059	−.190	.731
35	.940	.374	.483	1.240	.434	.468	1.090	−.211	.758
40	.995	.380	.477	1.292	.437	.465	1.144	−.223	.770
50	1.049	.392	.477	1.370	.443	.463	1.210	−.247	.765
60	1.059	.400	.482	1.430	.447	.468	1.245	−.267	.740
70	1.010	.390	.485	1.449	.470	.467	1.230	−.285	.697
80	.773	.307	.496	1.429	.489	.468	1.101	−.274	.541
90	.234	−.060	.525	1.452	.507	.471	.843	−.240	.161

TABLE XXVII

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/ CHORD=+0.25; DECALAGE=+3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.151	−0.243	0.429	0.138	1.027	0.376	−0.006	−0.110	−1.094
−4	.122	1.013	.459	.327	.518	.421	.225	−.103	.373
0	.374	.418	.458	.572	.388	.440	.473	−.083	.654
4	.640	.338	.451	.761	.346	.451	.701	−.073	.841
8	.892	.310	.451	.943	.318	.455	.918	−.062	.947
12	1.112	.288	.454	1.091	.304	.463	1.102	−.049	1.018
14	1.202	.283	.457	1.141	.302	.473	1.172	−.046	1.054
16	1.290	.280	.465	1.151	.296	.483	1.221	−.037	1.120
18	1.126	.321	.501	1.116	.354	.490	1.121	−.098	1.010
20	.910	.349	.537	1.098	.389	.491	1.004	−.134	.828
22	.796	.366	.512	1.107	.408	.494	.953	−.153	.719
25	.750	.358	.498	1.162	.420	.485	.956	−.166	.645
30	.803	.353	.485	1.259	.441	.477	1.031	−.190	.638
35	.822	.345	.487	1.317	.434	.472	1.068	−.191	.625
40	.819	.345	.489	1.355	.439	.473	1.087	−.201	.605
50	.809	.331	.487	1.437	.448	.468	1.123	−.214	.563
60	.745	.297	.497	1.455	.466	.466	1.100	−.219	.511
70	.478	.177	.511	1.455	.481	.466	.967	−.212	.329
80	−.025	2.270	−.563	1.458	.494	.470	.717	−.245	−.017
90	−.131	.446	.262	1.400	.527	.473	.635	−.278	−.093

TABLE XXVIII

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=+0.25; DECALAGE=−3°

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.086	−0.715	0.436	−0.373	0.254	0.493	−0.230	−0.024	0.231
−4	.181	.809	.435	−.113	−.531	.472	.034	−.076	−1.603
0	.429	.412	.450	.134	1.010	.438	.282	−.067	3.200
4	.681	.343	.447	.319	.503	.444	.500	−.050	2.132
8	.921	.315	.450	.546	.375	.449	.734	−.041	1.688
12	1.130	.296	.456	.769	.338	.451	.950	−.038	1.470
14	1.202	.289	.462	.854	.328	.454	1.028	−.035	1.410
16	1.279	.285	.470	.980	.317	.453	1.130	−.038	1.305
18	1.313	.287	.476	1.060	.311	.456	1.187	−.041	1.238
20	1.199	.286	.514	1.158	.303	.462	1.179	−.050	1.035
22	.815	.362	.533	1.280	.307	.465	1.048	−.111	.637
25	.720	.362	.510	1.305	.306	.476	1.013	−.113	.552
30	.818	.353	.493	1.163	.416	.484	.991	−.160	.703
35	.845	.360	.495	1.240	.441	.468	1.043	−.190	.681
40	.845	.361	.495	1.297	.436	.471	1.071	−.196	.651
50	.846	.341	.488	1.370	.445	.469	1.108	−.206	.618
60	.785	.308	.497	1.425	.453	.462	1.105	−.207	.550
70	.527	.190	.506	1.450	.471	.471	.989	−.203	.363
80	−.013	4.262	−.980	1.450	.486	.471	.718	−.234	−.009
90	−.136	.462	.284	1.445	.506	.468	.655	−.267	−.094

TABLE XXIX

CLARK Y CIRCULAR-TIPPED BIPLANE, DIHEDRAL =+3° ON UPPER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.084	−0.761	0.430	−0.132	−0.503	0.501	−0.108	−0.092	0.637
−4	.192	.712	.444	.128	1.065	.411	.160	−.096	1.500
0	.448	.433	.457	.318	.465	.447	.383	−.076	1.410
4	.712	.333	.452	.608	.362	.454	.660	−.064	1.172
8	.926	.298	.458	.804	.318	.454	.865	−.050	1.152
12	1.120	.283	.464	1.002	.299	.462	1.061	−.042	1.118
14	1.182	.281	.471	1.090	.292	.463	1.136	−.041	1.084
16	1.276	.276	.471	1.156	.285	.467	1.216	−.036	1.102
18	1.320	.277	.478	1.112	.292	.485	1.216	−.042	1.188
20	.920	.352	.526	1.130	.350	.486	1.025	−.104	.813
22	.778	.388	.530	1.084	.387	.489	.931	−.128	.718
25	.726	.347	.509	1.082	.411	.484	.904	−.123	.671
30	.754	.342	.501	1.152	.421	.475	.953	−.134	.654
35	.776	.336	.503	1.234	.425	.473	1.005	−.142	.628
40	.726	.312	.507	1.310	.427	.470	1.018	−.139	.554
50	.586	.253	.521	1.424	.440	.472	1.005	−.136	.411
60	.324	−.040	.573	1.504	.453	.470	.914	−.106	.216
70	−.170	.554	.316	1.510	.472	.468	.670	−.143	−.113
80	−.132	.483	.308	1.504	.494	.467	.686	−.168	−.088
90	−.125	.444	.286	1.512	.518	.468	.694	−.192	−.083

TABLE XXX

CLARK Y CIRCULAR-TIPPED BIPLANE, DIHEDRAL =+3° ON LOWER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0.131	−0.398	0.455	−0.102	−0.910	0.531	−0.117	−0.102	1.284
−4	.111	1.107	.468	.128	1.122	.429	.120	−.104	.867
0	.353	.438	.466	.336	.489	.441	.345	−.074	1.050
4	.624	.345	.451	.580	.370	.449	.602	−.065	1.077
8	.887	.306	.448	.792	.330	.453	.840	−.056	1.120
12	1.081	.277	.456	.972	.300	.460	1.027	−.040	1.112
14	1.132	.278	.460	1.061	.297	.462	1.097	−.041	1.067
16	1.202	.277	.463	1.111	.297	.468	1.157	−.043	1.081
18	1.277	.278	.468	1.140	.296	.475	1.209	−.045	1.119
20	1.099	.307	.492	1.103	.341	.480	1.101	−.081	.995
22	.750	.356	.530	1.121	.386	.487	.936	−.116	.669
25	.673	.333	.506	1.108	.406	.496	.891	−.115	.607
30	.669	.318	.500	1.220	.431	.476	.945	−.134	.548
35	.662	.316	.503	1.303	.430	.469	.983	−.139	.508
40	.632	.286	.499	1.351	.429	.466	.992	−.133	.468
50	.493	.208	.500	1.406	.445	.465	.951	−.126	.350
60	.225	−.084	.508	1,433	.464	.466	.829	−.117	.157
70	−.146	.507	.331	1.461	.474	.466	.658	−.146	−.100
80	−.124	.499	.298	1.502	.496	.464	.689	−.170	−.083
90	−.130	.476	.294	1.498	.523	.465	.684	−.190	−.087

TABLE XXXI

CLARK Y CIRCULAR-TIPPED BIPLANE, SWEEPBACK=10° ON UPPER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
-8	-0.137	-0.398	0.405	-0.132	-0.593	0.495	-0.135	-0.100	1.038
-4	.104	1.162	.486	.115	1.192	.405	.110	-.102	.903
0	.290	.481	.472	.332	.488	.430	.311	-.072	.873
4	.568	.350	.456	.619	.363	.458	.594	-.062	.917
8	.794	.321	.445	.801	.324	.451	.798	-.058	.991
12	.986	.300	.451	.997	.299	.455	.992	-.050	.990
14	1.100	.289	.447	1.089	.294	.458	1.095	-.052	1.010
16	1.182	.282	.450	1.088	.289	.473	1.135	-.047	1.086
18	1.231	.262	.451	.975	.361	.471	1.103	-.078	1.263
20	1.110	.259	.443	1.010	.379	.433	1.061	-.078	1.100
22	.700	.356	.496	.967	.407	.495	.834	-.098	.725
25	.619	.336	.498	1.054	.416	.486	.837	-.089	.588
30	.589	.319	.485	1.129	.422	.478	.860	-.086	.522
35	.540	.287	.486	1.240	.419	.475	.890	-.073	.435
40	.418	.241	.482	1.331	.434	.472	.875	-.065	.314
50	.092	-.542	.283	1.462	.434	.465	.777	-.015	.063
60	-.238	.643	.517	1.528	.455	.467	.644	-.002	-.156
70	-.127	.526	.288	1.469	.473	.465	.671	-.050	-.087
80	-.099	.638	.264	1.485	.491	.466	.693	-.064	-.067
90	-.115	.572	.324	1.498	.511	.466	.692	-.079	-.077

TABLE XXXII

CLARK Y CIRCULAR-TIPPED BIPLANE, SWEEPBACK=5° ON UPPER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
-8	-0.137	-0.400	0.394	-0.133	-0.570	0.493	-0.135	-0.099	1.030
-4	.123	1.047	.491	.122	1.145	.396	.123	-.105	1.008
0	.322	.445	.458	.337	.477	.435	.330	-.070	.955
4	.611	.353	.449	.604	.366	.444	.608	-.067	1.012
8	.838	.318	.443	.789	.324	.455	.814	-.059	1.062
12	1.040	.292	.453	.991	.304	.463	1.016	-.051	1.049
14	1.117	.287	.455	1.065	.292	.465	1.091	-.045	1.049
16	1.215	.282	.455	1.112	.272	.473	1.164	-.035	1.092
18	1.302	.278	.459	1.086	.303	.491	1.194	-.054	1.199
20	1.110	.272	.470	1.005	.380	.460	1.058	-.081	1.104
22	.715	.356	.519	1.022	.405	.488	.869	-.108	.700
25	.635	.334	.499	1.096	.411	.493	.865	-.101	.580
30	.616	.312	.495	1.170	.421	.474	.893	-.102	.526
35	.610	.298	.489	1.255	.426	.471	.933	-.106	.486
40	.528	.266	.490	1.350	.429	.469	.939	-.100	.391
50	.272	.016	.477	1.434	.439	.466	.853	-.068	.190
60	-.158	.935	.522	1.529	.459	.465	.686	-.054	-.103
70	-.173	.479	.329	1.486	.470	.464	.657	-.093	-.117
80	-.112	.560	.261	1.495	.493	.463	.692	-.115	-.075
90	-.109	.521	.273	1.496	.516	.463	.694	-.136	-.073

TABLE XXXIII

CLARK Y CIRCULAR-TIPPED BIPLANE, SWEEPBACK=10° ON LOWER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
-8	-0.102	-0.585	0.453	-0.074	-0.875	0.470	-0.088	-0.087	1.379
-4	.151	.858	.466	.121	1.129	.427	.136	-.099	1.248
0	.398	.423	.455	.294	.514	.446	.346	-.068	1.352
4	.666	.339	.452	.557	.372	.447	.612	-.058	1.196
8	.930	.306	.450	.745	.336	.450	.838	-.048	1.250
12	1.143	.293	.449	.916	.316	.456	1.030	-.042	1.249
14	1.200	.278	.459	1.011	.303	.457	1.106	-.034	1.187
16	1.291	.279	.461	1.093	.300	.456	1.192	-.035	1.181
18	1.326	.275	.470	1.130	.290	.460	1.228	-.028	1.173
20	1.207	.280	.506	1.151	.296	.456	1.179	-.043	1.046
22	.843	.370	.518	1.182	.359	.447	1.013	-.138	.713
25	.770	.363	.523	1.165	.413	.447	.968	-.170	.661
30	.812	.367	.515	1.175	.424	.442	.994	-.174	.691
35	.845	.356	.515	1.238	.434	.446	1.042	-.185	.682
40	.841	.353	.519	1.296	.434	.446	1.069	-.192	.650
50	.830	.344	.524	1.384	.442	.453	1.107	-.210	.600
60	.720	.308	.555	1.422	.455	.460	1.071	-.214	.506
70	.465	.204	.659	1.441	.473	.462	.953	-.214	.322
80	.085	-.368	.800	1.499	.491	.466	.792	-.244	.057
90	-.075	.584	.041	1.430	.515	.468	.677	-.273	-.053

TABLE XXXIV

CLARK Y CIRCULAR-TIPPED BIPLANE, SWEEPBACK=5° ON LOWER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
-8	-0.099	-0.574	0.446	-0.065	-1.399	0.520	-0.082	-0.096	1.524
-4	.146	.915	.454	.160	.934	.439	.153	-.104	.912
0	.356	.452	.460	.326	.500	.440	.341	-.076	1.092
4	.630	.343	.456	.582	.376	.448	.606	-.065	1.082
8	.895	.314	.449	.772	.334	.455	.834	-.058	1.160
12	1.100	.287	.462	.960	.309	.461	1.030	-.045	1.146
14	1.188	.280	.460	1.039	.300	.463	1.114	-.040	1.142
16	1.263	.273	.470	1.109	.295	.469	1.186	-.035	1.140
18	1.313	.276	.476	1.127	.294	.470	1.219	-.037	1.165
20	1.002	.352	.495	1.197	.305	.476	1.101	-.090	.837
22	.841	.362	.544	1.114	.388	.466	.978	-.133	.755
25	.715	.361	.517	1.159	.392	.455	.937	-.136	.617
30	.760	.346	.508	1.190	.426	.459	.975	-.154	.638
35	.764	.336	.510	1.255	.430	.459	1.010	-.162	.608
40	.785	.322	.505	1.321	.428	.459	1.053	-.163	.594
50	.680	.285	.518	1.422	.439	.465	1.051	-.170	.478
60	.521	.198	.548	1.439	.462	.469	.980	-.167	.362
70	.140	-.303	.919	1.468	.473	.465	.804	-.166	.095
80	-.132	.509	.252	1.479	.495	.466	.674	-.215	-.089
90	-.108	.459	.292	1.459	.517	.467	.676	-.252	-.074

TABLE XXXV

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=+0.25; SWEEPBACK=5° ON UPPER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
-8	-0.095	-0.676	0.421	-0.108	-0.687	0.528	-0.102	-0.094	0.880
-4	.170	.820	.450	.107	1.202	.413	.139	-.099	1.588
0	.396	.433	.451	.295	.502	.438	.346	-.072	1.342
4	.653	.352	.451	.554	.383	.452	.604	-.071	1.180
8	.911	.311	.444	.751	.342	.455	.831	-.062	1.211
12	1.125	.292	.452	.928	.319	.463	1.027	-.056	1.214
14	1.226	.287	.453	1.030	.306	.466	1.128	-.052	1.190
16	1.298	.279	.458	1.104	.301	.470	1.201	-.049	1.175
18	1.300	.281	.474	1.149	.295	.477	1.225	-.049	1.132
20	1.172	.279	.509	1.140	.304	.488	1.156	-.053	1.028
22	.775	.367	.519	1.248	.313	.494	1.012	-.104	.621
25	.723	.351	.497	1.194	.409	.468	.959	-.150	.605
30	.775	.347	.503	1.200	.428	.462	.988	-.163	.645
35	.782	.349	.500	1.266	.434	.460	1.024	-.175	.618
40	.782	.339	.495	1.325	.439	.458	1.054	-.182	.590
50	.713	.299	.484	1.402	.446	.458	1.058	-.180	.508
60	.552	.221	.474	1.450	.461	.457	1.001	-.177	.381
70	.200	-.111	.329	1.475	.478	.460	.838	-.174	.136
80	-.146	.513	.342	1.443	.502	.463	.649	-.213	-.101
90	-.124	.474	.256	1.436	.517	.462	.656	-.228	-.086

TABLE XXXVI

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=+0.50; SWEEPBACK=10° ON UPPER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
-8	-0.076	-0.864	0.411	-0.132	-0.491	0.513	-0.104	-0.089	0.575
-4	.185	.769	.453	.086	1.401	.427	.136	-.092	2.150
0	.448	.402	.451	.276	.525	.445	.362	-.061	1.623
4	.691	.338	.447	.523	.376	.451	.607	-.053	1.321
8	.928	.302	.451	.724	.339	.462	.826	-.043	1.282
12	1.148	.288	.450	.918	.316	.465	1.033	-.037	1.250
14	1.262	.279	.451	1.010	.308	.470	1.136	-.031	1.250
16	1.318	.272	.454	1.129	.300	.470	1.224	-.030	1.167
18	1.222	.272	.468	1.189	.295	.474	1.205	-.037	1.029
20	1.126	.288	.461	1.230	.303	.478	1.178	-.060	.915
22	.800	.392	.485	1.300	.296	.487	1.050	-.120	.615
25	.737	.356	.474	1.275	.392	.459	1.006	-.164	.578
30	.787	.354	.471	1.214	.423	.466	1.001	-.174	.648
35	.838	.354	.462	1.281	.435	.473	1.060	-.191	.655
40	.830	.361	.462	1.336	.432	.470	1.083	-.200	.621
50	.832	.346	.444	1.415	.445	.473	1.124	-.216	.588
60	.713	.294	.421	1.485	.461	.466	1.099	-.221	.480
70	.461	.207	.340	1.480	.474	.462	.971	-.221	.311
80	.109	-.355	.027	1.537	.494	.468	.823	-.246	.071
90	-.119	.528	.259	1.450	.518	.475	.666	-.279	-.082

TABLE XXXVII

CLARK Y CIRCULAR-TIPPED BIPLANE, STAGGER/CHORD=−0.50; SWEEPBACK=10° ON LOWER WING

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0. 125	−0. 446	0. 441	−0. 143	−0. 449	0. 455	−0. 134	−0. 096	0. 874
−4	. 114	1. 022	. 478	. 113	1. 134	. 471	. 114	−. 095	1. 010
0	. 310	. 473	. 470	. 309	. 489	. 439	. 310	−. 072	1. 004
4	. 605	. 349	. 464	. 590	. 351	. 453	. 598	−. 061	1. 026
8	. 834	. 319	. 461	. 781	. 307	. 458	. 808	−. 054	1. 068
12	1. 032	. 296	. 465	. 958	. 291	. 457	. 995	−. 048	1. 076
14	1. 129	. 290	. 462	1. 028	. 283	. 457	1. 079	−. 045	1. 097
16	1. 195	. 287	. 471	1. 051	. 280	. 466	1. 123	−. 045	1. 137
18	1. 269	. 270	. 485	. 923	. 367	. 446	1. 096	−. 089	1. 375
20	1. 111	. 288	. 490	. 868	. 406	. 450	. 990	−. 105	1. 282
22	. 776	. 363	. 515	. 980	. 421	. 446	. 878	−. 115	. 792
25	. 619	. 346	. 532	1. 062	. 414	. 433	. 841	−. 089	. 583
30	. 552	. 330	. 548	1. 140	. 431	. 458	. 846	−. 088	. 485
35	. 501	. 299	. 572	1. 243	. 430	. 457	. 872	−. 077	. 403
40	. 384	. 215	. 607	1. 310	. 439	. 461	. 847	−. 058	. 293
50	. 044	−1. 380	1. 935	1. 440	. 450	. 467	. 742	−. 019	. 031
60	−. 211	. 650	. 245	1. 573	. 473	. 467	. 681	−. 019	−. 134
70	−. 149	. 555	. 366	1. 469	. 480	. 464	. 660	−. 043	−. 102
80	−. 105	. 555	. 221	1. 415	. 510	. 475	. 655	−. 071	−. 074
90	−. 138	. 508	. 252	1. 468	. 531	. 469	. 665	−. 087	−. 094

TABLE XXXVIII

CLARK Y CIRCULAR-TIPPED BIPLANE, OVERHANG=−20%

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0. 072	−0. 907	0. 440	−0. 115	−0. 680	0. 543	−0. 096	−0. 095	0. 626
−4	. 134	. 939	. 425	. 108	1. 290	. 409	. 120	−. 103	1. 241
0	. 348	. 450	. 444	. 341	. 493	. 446	. 344	−. 077	1. 021
4	. 593	. 349	. 441	. 634	. 362	. 451	. 616	−. 066	. 936
8	. 799	. 314	. 442	. 844	. 318	. 460	. 825	−. 053	. 948
12	1. 010	. 291	. 447	1. 037	. 306	. 467	1. 026	−. 050	. 975
14	1. 051	. 294	. 459	1. 112	. 297	. 468	1. 087	−. 049	944
16	1. 101	. 289	. 465	1. 175	. 292	. 471	1. 142	−. 046	. 937
18	1. 162	. 290	. 481	1. 178	. 300	. 488	1. 140	−. 053	. 988
20	1. 169	. 293	. 499	1. 066	. 372	. 427	1. 112	−. 090	1. 096
22	. 815	. 373	. 494	1. 178	. 386	. 436	1. 018	−. 130	. 692
25	. 708	. 341	. 505	1. 071	. 419	. 464	. 910	−. 123	. 660
30	. 649	. 322	. 480	1. 140	. 425	. 475	. 925	−. 124	. 568
35	. 646	. 310	. 481	1. 279	. 427	. 466	1. 016	−. 133	. 506
40	. 590	. 277	. 485	1. 363	. 430	. 466	1. 022	−. 131	. 433
50	. 460	. 184	. 480	1. 462	. 445	. 465	1. 020	−. 128	. 314
60	. 220	−. 122	. 464	1. 498	. 451	. 469	. 935	−. 110	. 147
70	−. 114	. 627	. 289	1. 457	. 477	. 468	. 764	−. 144	−. 078
80	−. 153	. 478	. 294	1. 514	. 489	. 468	. 780	−. 163	−. 101
90	−. 140	. 481	. 298	1. 510	. 519	. 468	. 782	−. 187	−. 093

TABLE XXXIX

CLARK Y CIRCULAR-TIPPED BIPLANE, OVERHANG=+20%

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0. 136	−0. 413	0. 432	−0. 020	−5. 321	0. 627	−0. 085	−0. 101	6. 800
−4	. 128	1. 008	. 481	. 185	. 788	. 438	. 154	−. 099	. 692
0	. 327	. 449	. 465	. 336	. 471	. 431	. 331	−. 070	. 973
4	. 655	. 340	. 458	. 580	. 373	. 445	. 622	−. 065	1. 130
8	. 902	. 307	. 458	. 752	. 322	. 445	. 836	−. 052	1. 200
12	1. 097	. 282	. 468	. 937	. 308	. 448	1. 026	−. 045	1. 170
14	1. 211	. 279	. 469	1. 010	. 309	. 453	1. 125	−. 047	1. 200
16	1. 286	. 277	. 477	1. 090	. 298	. 458	1. 200	−. 044	1. 180
18	1. 373	. 282	. 480	1. 100	. 303	. 465	1. 254	−. 052	1. 250
20	1. 026	. 338	. 536	1. 060	. 369	. 467	1. 041	−. 108	. 968
22	. 805	. 378	. 550	1. 078	. 393	. 483	. 926	−. 128	. 748
25	. 754	. 373	. 522	1. 110	. 420	. 478	. 911	−. 141	. 679
30	. 784	. 355	. 522	1. 160	. 425	. 480	. 951	−. 143	. 675
35	. 824	. 351	. 520	1. 217	. 434	. 477	. 999	−. 153	. 677
40	. 806	. 341	. 531	1. 310	. 432	. 478	1. 029	−. 156	. 615
50	. 697	. 320	. 555	1. 390	. 447	. 475	1. 004	−. 161	. 501
60	. 515	. 275	. 665	1. 420	. 456	. 478	. 917	−. 153	. 363
70	. 232	. 255	. 984	1. 480	. 477	. 475	. 784	−. 169	. 157
80	. 094	. 050	1. 539	1. 463	. 486	. 483	. 699	−. 163	. 064
90	. 089	. 558	1. 409	1. 339	. 522	. 469	. 642	−. 196	. 066

TABLE XL

CLARK Y CIRCULAR-TIPPED BIPLANE, OVERHANG=+40%

ALL OTHER DIMENSIONS ORTHOGONAL

α	Upper wing			Lower wing			Cellule		
	C_N	C_{px}	C_{py}	C_N	C_{px}	C_{py}	C_N	$C_{m\ c/4}$	e
Degrees									
−8	−0. 143	−0. 345	0. 443	0. 003	36. 00	−1. 615	−0. 089	−0. 097	−47. 70
−4	. 139	1. 001	. 440	. 167	. 813	. 417	. 150	−. 099	0. 832
0	. 376	. 441	. 464	. 294	. 505	. 430	. 346	−. 073	1. 280
4	. 657	. 350	. 458	. 505	. 369	. 430	. 602	−. 063	1. 301
8	. 926	. 313	. 457	. 645	. 337	. 440	. 823	−. 058	1. 436
12	1. 131	. 289	. 468	. 803	. 310	. 438	1. 011	−. 046	1. 410
14	1. 257	. 288	. 468	. 875	. 307	. 445	1. 118	−. 050	1. 438
16	1. 321	. 286	. 478	. 978	. 300	. 447	1. 195	−. 049	1. 352
18	1. 349	. 287	. 486	1. 049	. 299	. 455	1. 240	− 050	1. 286
20	. 980	. 366	. 508	1. 109	. 307	. 460	1. 028	−. 088	. 885
22	. 884	. 388	. 505	1. 147	. 318	. 465	. 983	−. 100	. 770
25	. 787	. 367	. 527	1. 038	. 410	. 476	. 880	−. 129	. 759
30	. 833	. 376	. 526	1. 111	. 425	. 478	. 936	−. 150	. 750
35	. 863	. 365	. 530	1. 161	. 423	. 468	. 975	−. 151	. 742
40	. 875	. 368	. 550	1. 218	. 425	. 466	1. 002	−. 159	. 718
50	. 860	. 380	. 567	1. 280	. 433	. 468	1. 016	−. 173	. 672
60	. 825	. 373	. 600	1. 427	. 458	. 463	1. 048	−. 200	. 578
70	. 793	. 423	. 618	1. 603	. 467	. 453	1. 093	−. 243	. 494
80	. 603	. 470	. 767	1. 535	. 485	. 466	. 948	−. 248	. 393
90	498	. 542	. 847	1. 420	. 519	. 461	. 838	−. 263	. 351

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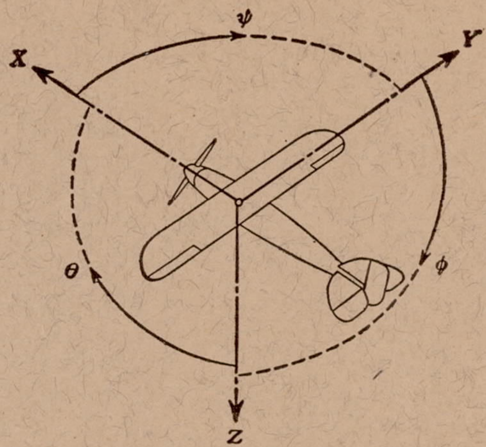

Positive directions of axes and angles (forces and moments) are shown by arrows

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

$$C_l=\frac{L}{qbS} \qquad C_m=\frac{M}{qcS} \qquad C_n=\frac{N}{qbS}$$

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

4. PROPELLER SYMBOLS

D, Diameter.
p, Geometric pitch.
p/D, Pitch ratio.
V', Inflow velocity.
V_s, Slipstream velocity.
T, Thrust, absolute coefficient $C_T=\frac{T}{\rho n^2 D^4}$
Q, Torque, absolute coefficient $C_Q=\frac{Q}{\rho n^2 D^5}$
P, Power, absolute coefficient $C_P=\frac{P}{\rho n^3 D^5}$.
C_S, Speed power coefficient $=\sqrt[5]{\frac{\rho V^5}{Pn^2}}$.
η, Efficiency.
n, Revolutions per second, r. p. s.
Φ, Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 hp = 76.04 kg/m/s = 550 lb./ft./sec.
1 kg/m/s = 0.01315 hp
1 mi./hr. = 0.44704 m/s
1 m/s = 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.