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RELATIVE LIFT DISTRIBUTION IN ANY BIPLANE

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RELATIVE LIFT DISTRIBUTION IN ANY BIPLANE

A knowledge of the distribution between the upper and lower wings of the total lift of a biplane is necessary in the solution of two airplane design problems, one of an aero-structural and the other of an aerodynamic nature. In the structural analysis of a biplane cellule, the relative loading on the wings has a marked influence on the stresses in the spars. In the computation of the performance of a biplane the induced drag of the cellule is a main factor. Prandtl[1] has shown how it depends on the lift distribution, and gave particular solutions for minimum induced drag on the assumption that lift distribution is proportional to area distribution. Air Corps Information Circular No. 607, The Induced Drag of Any Biplane, gives a general solution of Prandtl's equation for any lift distribution.

Numerous wind-tunnel tests of lift distribution have been made on models of equal-span, equal-chord biplanes, with various combinations of gap/chord and stagger. With this empirical data as a basis, theoretical considerations permit a solution for biplanes with unequal spans and unequal chords and with or without decalage. In the present report, charts are derived which yield quick solutions of the general cases. Three régimes of the polar are treated—that is, 25, 50, and 90 per cent of c_a[(2)] maximum—important for the low incidence stress analysis case, for the determination of a representative value of the induced drag parabola coefficient, and for the high incidence stress analysis case, respectively. The relative loading on the upper and lower wings, e, is first given in graphical form for various values of s, the ratio of chords, and for r, the ratio of spans, equal to unity. Then a formula is derived which allows the introduction of r, less than unity. Finally, a graphical solution gives a correction to e for the effect of decalage. The variables are the ratio of the gap to the chord of the upper wing, r, s, stagger, decalage, and a, the proportion of the total lift contributed by the upper wing. The effect of variations in gap/span is considered as practically negligible, and the omission of this variable greatly simplifies the whole problem.

THE BASIC DATA

In the past eight years, quite a number of isolated and limited tests have been made of the lift distribution in equal-span, equal-chord biplanes.[3] Lately the N.A.C.A. published the results of a more systematic and comprehensive series of tests on an R.A.F. 15 biplane in which stagger and gap/chord were varied in rather wide limits. These data are plotted in Figure 1, together with some of the earlier data, in the basic form of $c_{a1}{}^1$ in function of the ratio G/c_1 of the gap to the chord of the upper wing and of the stagger. At any value of c_a of the biplane $c_a{}^1$ is equal to the lift coefficient of the upper divided by the lift coefficient of the biplane.

[1] N.A.C.A. Technical Bulletin No. 182.
[2] For symbols see pp. 5–6.
[3] See fig. 1 for references.

The main difficulty was to fair the test data, which show a wide dispersion. The N.A.C.A. data were given more weight than the older sporadic tests on smaller models at lower test velocities. Two theoretical considerations simplify the fairing. First, at larger values of G/c_1, the $c_{a1}{}^1$ values must approach unity, and this for all values of stagger. Second, when the gap is zero, the two wings coincide and $c_{a1}{}^1$ is again unity. That this is true can also be deduced when the gap is taken smaller and smaller until the lower wing passes through the upper, when the gap may be considered negative. The upper wing now becomes the lower, and we must plot values of $c_{a2}{}^1 = 2 - c_{a1}{}^1$ (as in fig. 1) on the left-hand side of $G/c_1 =$ zero. The only possible continuous function is the one which passes through $c_{a1}{}^1 =$ zero at $G/c_1 =$ zero.

With these considerations in mind and by careful cross plotting of the data for values of $G/c_1 =$ constant, the curves of Figure 1 were drawn as probably most representative of the actual conditions in an R.A.F. 15 biplane. Figures 2 and 3 incorporate similar data at other values of $c_a/c_{a\ max}$.

Values of $c^1{}_{a1}$ derived from the data on e in the Air Corps Handbook for Designers have been plotted in Figures 1 and 3 for comparison with the new data and indicate, first, that they are just as inaccurate at high as at low values of c_a, and, second, that the old experimental data had been improperly faired.

It is regretted that more extensive tests of the U.S.A. thick section No. 5 were not made, as the data observed at $G/c = 0.9$ not only do not check the R.A.F. 15 data, but the great change in $c_{a1}{}^1$ from stagger $+30°$ to zero stagger in comparison with the change from zero stagger to stagger $-30°$ appears highly improbable. Just why the relative loading at a certain c_a value should be expected to show any appreciable variation with the airfoil thickness or camber is not clear.

THE RELATIVE LOADING

The relative loading is designated by e and is the ratio of the lift coefficient of the upper to the lift coefficient of the lower wing. It is used directly in the stress analysis of wings. The present data are based on older tests on equal-span, equal-chord biplanes, but have been indiscriminately used for unequal chords and spans and for both the high and low incidence conditions. In this report empirical-theoretical data are given for 25 per cent and 90 per cent $c_{a\ max}$. for stress analysis purposes.

The relative loading can also be used to determine L_1/L, the lift of the upper wing divided by the total lift. This ratio has been designated a in A.C.I.C. No. 607. Strictly speaking, there is a different value of a all along the polar, so that the induced drag curve is the envelope of a family of parabolas. But induced drag is not an important factor at low c_a values, nor is it at high c_a values, which are outside the practical, economical flight range. However, at medium c_a values, where climbing occurs, the induced drag is a main factor, so that this report gives data on e and, hence, on a, for c_a equal to 50 per cent $c_{a\ max}$. It is intended that the parabola through this point be substituted for the above-mentioned envelope curve;

that is, that a in A.C.I.C. No. 607 be computed from values in this report of e at 50 per cent $c_{a\ max}$.

1. *Equal spans, equal chords* ($r=1$, $s=1$)

In this simplest case, when the areas of the upper and lower wings are equal, e may be found from the basic data. The lift of the biplane is the mean of the lifts of the two wings.
Since

$$A_1=A_2=\frac{A}{2}$$

$$c_{a1}+c_{a2}=2_{ca} \tag{1}$$

In a conventional biplane having equal chords and equal spans A_1 will be greater than A_2 owing to the portion of the wing cut by the fuselage. The problem is greatly simplified by neglecting this effect, which is considered negligible.

By definition,

$$c_{a1}{}^1=\frac{c_{a1}}{c_a}$$

$$c_{a2}{}^1=\frac{c_{a2}}{c_a}$$

Then,

$$c_{a2}{}^1=2-c_{a1}{}^1 \tag{2}$$

and

$$e=\frac{c_{a1}{}^1}{c_{a2}{}^1}=c_{a1}{}^1/(2-c_{a1}{}^1) \tag{3}$$

$c_{a1}{}^1$ is taken from Figures 1, 2, and 3; e is computed from equation (3) and plotted in Figures 5, 13, and 21.

2. *Equal spans, unequal chords* $\left(r=1,\ s \gtrless 1\right)$

A simple theoretical consideration permits an approximate determination of this case. In Figure 29 is represented such a biplane in which $c_2/c_1=s=0.5$. The problem is to estimate the effect of the lower on the upper wing and of the upper on the lower wing. Since the lift is directly proportional to both area and circulation and since the circulation velocity varies inversely with the distance from the disturbing wing, the same disturbance velocities result at the upper wing from the circulation around a fictitious lower wing with twice the chord (hence, twice the area of the real lower) and twice as far away from the upper as is the real lower. So, if we want to find $c_a{}^1$ for $G/c_1=1.0$ when $s=0.5$, we must take $c_{a1}{}^1$ from Figure 1[4] at $G/c_1=2.0$, since we now have to consider a biplane of equal span and equal chord but with twice the gap. Similarly, the effect of the upper on the lower can be approximated by placing a fictitious upper with half the chord of the real upper at half the real gap away from the lower. To find $c_{a2}{}^1=2-c_{a1}{}^1$, we take $c_{a1}{}^1$ from Figure 1[4], but at the original G/c_1. In general, we take $c_{a1}{}^1$ from Figure 1[4] at real $G/c_1/s$, and $c_{a2}{}^1=2-c_{a1}{}^1$ from Figure 1[4] at real G/c_1. e may then be computed as $c_{a1}{}^1/c_{a2}{}^1$. Results are plotted

[4] Or from fig. 2 or 3, as the case in point may be.

in Figures 4 to 28, inclusive. By following the same line of reasoning the same results are obtained for the case of the lower wing having a larger chord than the upper wing, $s>1$. In Figure 30, e is plotted for stagger = constant and for various values of $s<1$ and of G/c_1.

It should be noted that a secondary effect has been neglected. The curvature of the streamlines at the upper wing due to the presence of the fictitious lower is less than that due to the true lower. As a consequence the increase in lift of the upper in presence of the real lower is greater than in the presence of the fictitious lower. But the negative curvature of the streamlines at the lower due to the fictitious upper is greater than that due to the real upper, and the lift of the lower decreases more slowly in presence of the real upper than in the presence of the fictitious upper. Since we have a slight increase in both numerator and denominator, the value of the quotient e is not greatly changed, and the method of this section of the report gives a good approximation to actuality.

3. *Unequal spans, unequal chords* $\left(r \gtrless 1,\ s \lessgtr 1\right)$

For the solution of this case, it is assumed that the portion of the upper wing directly above the shorter lower wing is affected in the same manner as if b_1 were equal to b_2 (that is, as if r were 1) and that the overhanging portion of the upper span is unaffected. Then, e for $r<1$ becomes

$$e_{r<1}=\frac{r\,c_{a1}{}^1+(1-r)}{c_{a2}{}^1}$$

$$=\frac{rc_{a1}{}^1}{c_{a2}{}^1}+\frac{1-r}{c_{a2}{}^1}$$

$$e_{r<1}=r\,e(r=1)+\frac{1-r}{2-c_{a1}{}^2} \tag{4}$$

When the span of the lower wing is greater than the span of the upper, r is greater than unity, and we have

$$e_{r>1}=r.e(r=1)\left[1-\frac{r-1}{c_{a2}{}^1+r-1}\right] \tag{4^1}$$

THE EFFECT OF DECALAGE

The relative loading

$$e_d=\frac{c_{a1d}}{c_{a2d}}$$

when decalage is introduced into the cellule can be evaluated by writing the expressions for the numerator and denominator in terms of the decalage δ, mean slope of the biplane lift curve $\frac{dc_a}{d\alpha}$, the ratio $\frac{L_1}{L}=a$, and the values of $c_{a1}{}^1$ and $c_{a2}{}^1$ for $\delta=$ zero.

Thus,

$$e_d = \frac{c_{a1d}}{c_{a2d}} = \frac{c_{a1}{}^1 ca + \delta \frac{dc_a}{d\alpha} c_{a1}{}^1 \left(\frac{A_2}{eA_1 + A_2} \right)}{c_{a2}{}^1 ca - \delta \frac{dc_a}{d\alpha} c_{a2}{}^1 \left(\frac{eA_1}{eA_1 + A_2} \right)} \tag{5}$$

This is derived by considering that the total decalage is distributed between the two wings in inverse proportion to the portion of the total lift which each carries. The angle of attack of the upper thus changes by an amount $\frac{A_2}{eA_1 + A_2} \times \delta$, and the lift coefficient changes by $c_{a1}{}^1 \frac{dc_a}{d\alpha}$ times that amount. $c_{a1}{}^1 ca$ is equal to the lift coefficient, c_{a1} of the upper when no decalage is present. But

$$\frac{eA_1}{eA_1 + A_2} = a = \frac{L_1}{L}.$$

Substituting and simplifying,

$$e_d = e \left[\frac{1 + \delta \frac{dc_a}{d\alpha} \frac{(1-a)}{c_a}}{1 - \delta \frac{dc_a}{d\alpha} \cdot \frac{a}{c_a}} \right]$$

This can also be written

$$\frac{e_d}{e} = \left[\frac{1 + \frac{\delta(1-a)}{c_{a\,max.} \times \text{per cent } c_{a\,max.}}}{1 - \frac{\delta . a}{c_{a\,max.} \times \text{per cent } c_{a\,max.}}} \right] \tag{7}$$

A mean value of $\frac{dc_a}{d\alpha}$ for biplanes of 0.000175 has been assumed, and equation (7) plotted in Figure 28 for values of decalage of $\pm 2°$ in function of $c_{a\,max.}$ times per cent $c_{a\,max.}$ and a. It was necessary in the determination of a to use the value of the relative loading, e, when δ was zero. This introduces an error of ± 2 per cent in extreme cases. If this error is considered too great, a second approximation may be made, taking

$$a = \frac{e_d A_1}{e_d A_1 + A_2} \tag{8}$$

A third approximation is entirely unnecessary.

SYMBOLS

The following symbols are used in this paper:

$A = A_1 + A_2$.

A_1 = Effective area of upper wing.
A_2 = Effective area of lower wing.
} These areas include 50 per cent of fuselage and 25 per cent of nacelles.

a = Portion of total lift contributed by upper wing.

b_1 = Span of upper wing.

b_2 = Span of lower wing.
c_1[5] = Chord of upper wing—(mean aerodynamic).
c_2[5] = Chord of lower wing—(mean aerodynamic).
c_a = Lift coefficient of the biplane.
c_{a1} = Lift coefficient of the upper wing in the biplane.
c_{a2} = Lift coefficient of the lower wing in the biplane.
} lbs./sq. ft./m. p. h.
$c_{a1}{}^1 = c_{a1}/c_a$.
$c_{a2}{}^1 = c_{a2}/c_a$.
$e = c_{a1}/c_{a2}$.
$e_d = e$ decalage.
G[5] = Gap (aerodynamic).
L = Lift of the biplane.
L_1 = Lift of the upper wing in the biplane.
r = Span ratio, b_2/b_1.
s = Chord ratio, c_2/c_1.
Stagger [5] = Angle measured between a line connecting the third points of the mean aerodynamic chords of the upper and lower wings, and a line perpendicular to the mean aerodynamic chord of the upper wing.
δ = Angle of decalage.

DETERMINATION OF "*e*"

The value of "*e*," the relative efficiency of the upper wing with respect to the lower wing, for the four possible combinations of chords, spans, and decalage, is obtained in the manner indicated for each case.

Case I.—Equal spans, equal chords, no decalage.
$r = 1$.
$s = 1$.
e is taken directly from Figures 5, 13, or 21, as the case may be.

Case II.—Equal spans, unequal chords, no decalage.
$r = 1$.
$s \gtrless 1$.
e is taken directly from Figures 4 to 27, as the case may be.

Case III.—Unequal spans, unequal chords, no decalage.
$r \gtrless 1$.
$s \gtrless 1$.

1. Determine e for $r = 1$ from Figures 4 to 27, as the case may be.
2. Determine $c_{a1}{}^1$ from Figures 1, 2, or 3, as required.
3. Determine e for $r \gtrless 1$ from the following relations:

$$a.\ e(r<1) = r \cdot e(r=1) + \frac{1-r}{2-c_{a1}{}^1}$$

$$b.\ e(r>1) = r \cdot e(r=1)\left[1 - \frac{r-1}{1-c_{a1}{}^1+r}\right]$$

Case IV.—Case I, II, or III, with decalage.
1. Determine e for no decalage as above.
2. Calculate a for no decalage from $a = \frac{eA_1}{eA_1 + A_2}$.

[5] The chords, gap, and stagger used are the mean aerodynamic values, although the physical mean arithmetic values would be more nearly correct. This deviation is warranted by the fact that differences are negligible, and the necessity of dealing with two sets of values is eliminated.

3. Determine $\frac{e_d}{e}$ from Figure 28.
4. Calculate e_d from equation (3) (first approximation).
5. Recalculate a from $a=\frac{e_d A_1}{e_d A_1+A_2}$.
6. Determine $\frac{e_d}{e}$ from Figure 28.
7. Calculate e_d from equation 6 (second approximation). (For use in charts of A.C.I.C. 607, the second approximation for a must be used.)

EXAMPLES

The lift distribution in representative biplane cellules is solved in the following according to the formulas and charts of this paper.

Case I.—Equal spans, equal chords, no decalage.

Span—Upper wing	=40 ft. (b_1)
Span—Lower wing	=40 ft. (b_2)
Chord—Upper wing	=60 in. (c_1)
Chord—Lower wing	=60 in. (c_a)
Gap	=60 in. (G)
Stagger	=+15 deg.
$r=b_2/b_1$	=1
$s=c_2/c_1$	=1
$G/c_1=60/60$	=1

From Figure 5, $e=1.193$ (low incidence).
From Figure 13, $e=1.251$ (high incidence).
From Figure 21, $e=1.210$ (For determination of equivalent monoplane span).

Case II.—Equal spans, unequal chords, no decalage.

Span—Upper wing	=40 ft. (b_1)
Span—Lower wing	=40 ft. (b_2)
Chord—Upper wing	=60 in. (c_1)
Chord—Lower wing	=30 in. (c_2)
Gap	=60 in. (G)
Stagger	=+15 deg.
$r=b_2/b_1$	=1
$s=c_2/c_1=30/60$	=0.5
$G/c_1=60/60$	=1

From Figure 10, $e=1.121$ (for low incidence).
From Figure 18, $e=1.150$ (for high incidence).
From Figure 26, $e=1.132$ (for determination of equivalent monoplane span).

Case III.—Unequal spans, unequal chords, no decalage

Span—Upper wing	=40 ft. (b_1)
Span—Lower wing	=20 ft. (b_2)
Chord—Upper wing	=60 in. (c_1)
Chord—Lower wing	=30 in. (c_2)
Gap	=60 in. (G)
Stagger	=+15 deg.
$r=b_2/b_1=20/40$	=0.5
$s=c_2/c_1=30/60$	=0.5
$G/c_1=60/60$	=1

From Figure 10, $e(r=1)=1.121$ (for low incidence).
From Figure 1, $c_{a1}{}^1=1.090$ (for equal chords and equal spans).

$$e(r<1)re(r=1)+\frac{1-r}{2-c_{a1}{}^1}$$

$$=0.5\times1.121+\left(\frac{1-0.5}{2-1.090}\right)$$

$$=0.560+\frac{0.5}{0.910}$$

$$=.560+0.549$$

$e(r<1)=1.109$ for the low incidence condition.

The value of e for the high-incidence condition and for the determination of the equivalent monoplane span may be determined in the same manner by the use of the proper charts.

Case IV.—Case I, II, or III, with decalage.

Area upper wing $=200$ sq. ft. (A_1)
Area lower wing $=45$ sq. ft. (A_2) (includes 50 per cent fuselage and 25 per cent nacelles)
Span upper wing $=40$ ft. (b_1)
Span lower wing $=20$ ft. (b_2)
Chord upper wing $=60$ in. (c_1)
Chord lower wing $=30$ in. (c_2)
Gap $=60$ in. (G)
Stagger $=+15$ deg.
Decalage $=+1.5$ deg.

The above characteristics are identical with Case III, decalage excepted.

$e=1.109$ (no decalage) (from Case III, low incidence)

$$a=\frac{eA_1}{eA_1+A_2}$$

$$=\frac{1.109\times200}{(1.109\times200)+45}=\frac{221.8}{221.8+45}=\frac{221.8}{266.8}$$

$a=0.832$

$\frac{e_d}{e}=1.46$ (from fig. 28 at $c_a=0.0008=25$ per cent $c_{a\ max}$.)

$e_d=1.109\times1.46=1.620$ (first approximation)

$$a=\frac{e_dA_1}{e_dA_1+A_2}=\frac{(1.62\times200)}{1.62\times200+45}$$

$$=\frac{324}{324+45}=\frac{324}{369}=0.878$$

$\frac{e_d}{e}=1.48$ (from fig. 28 at $c_a=0.0008$, 25 per cent $c_{a\ max}$.)

$e_d=1.48\times1.109=1.642$ (second approximation).

The value of e_d for the high-incidence condition and for the determination of the equivalent monoplane span may be determined in a like manner, using the proper value of e and c_a in Figure 28.

SUMMARY

With experimental data on special biplane cellules as basis, the empirical-theoretical method of this paper permits the general solution for the lift distribution in any biplane. The determination of the relative loading e for stress-analysis work is rationalized, and the effect of actual lift distribution on induced drag can be found from the data of this paper in conjunction with the charts of a previous report, A.C.I.C. 607, on The Induced Drag of Any Biplane. The introduction of the variable gap/span into this problem is held to be unnecessary and undesirable. Sweep back, dihedral, and taper may be eliminated from the problem by dealing with mean aerodynamic chords of the two wings and with a mean value of the gap. It is believed that the data of this paper, although based solely on R.A.F. 15 biplane tests, may be considered valid for biplanes with airfoils of other thicknesses and cambers, at least until further systematic tests have been made which show differences due to airfoil section greater than the probable error of any one measurement.

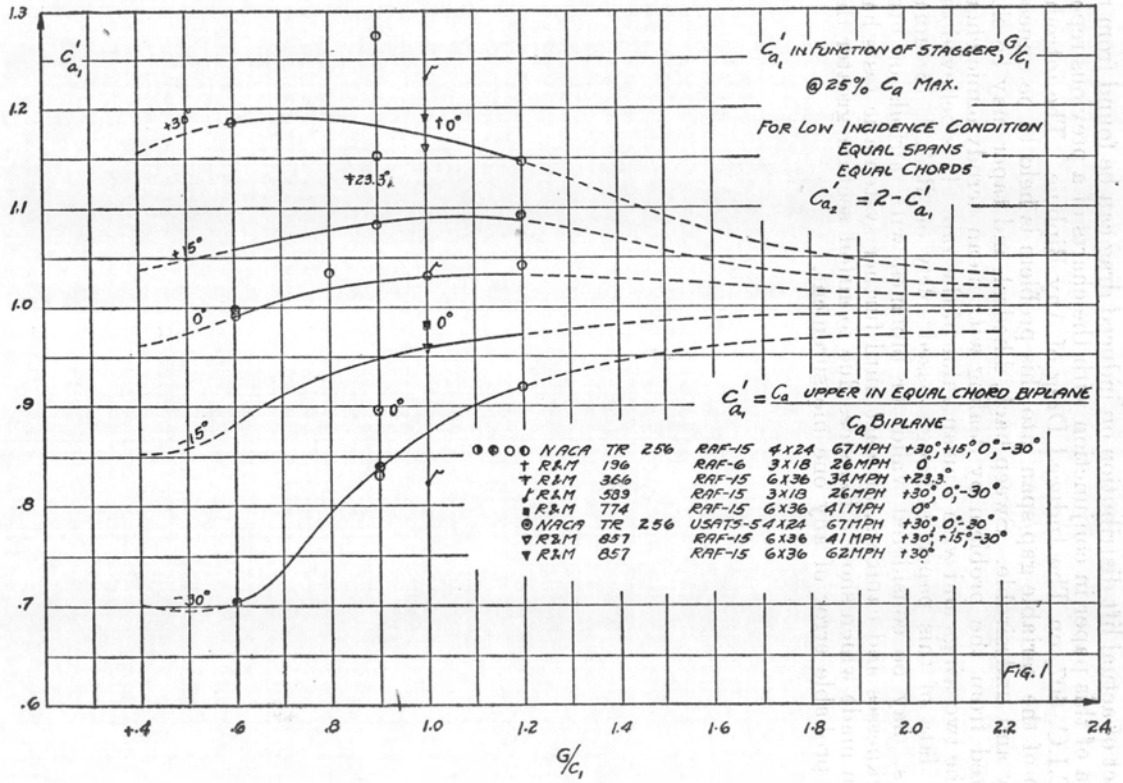

C'_{a_1} IN FUNCTION OF STAGGER, G/C_1
@ 25% C_a MAX.
FOR LOW INCIDENCE CONDITION
EQUAL SPANS
EQUAL CHORDS
$C'_{a_2} = 2 - C'_{a_1}$
$C'_{a_1} = \frac{C_a \text{ UPPER IN EQUAL CHORD BIPLANE}}{C_a \text{ BIPLANE}}$
NACA TR 256 RAF-15 4x24 67MPH +30°, +15°, 0°, -30°
R&M 196 RAF-6 3x18 26MPH 0°
R&M 366 RAF-15 6x36 34MPH +23.3°
R&M 589 RAF-15 3x18 26MPH +30°, 0°, -30°
R&M 774 RAF-15 6x36 41MPH 0°
NACA TR 256 USATS-54 4x24 67MPH +30°, 0°, -30°
R&M 857 RAF-15 6x36 41MPH +30°, +15°, -30°
R&M 857 RAF-15 6x36 62MPH +30°
+30°
+0°
+23.3°
+15°
0°
0°
0°
-15°
-30°
FIG. 1
C'_{a_1}
G/C_1
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4

FIGURE 1

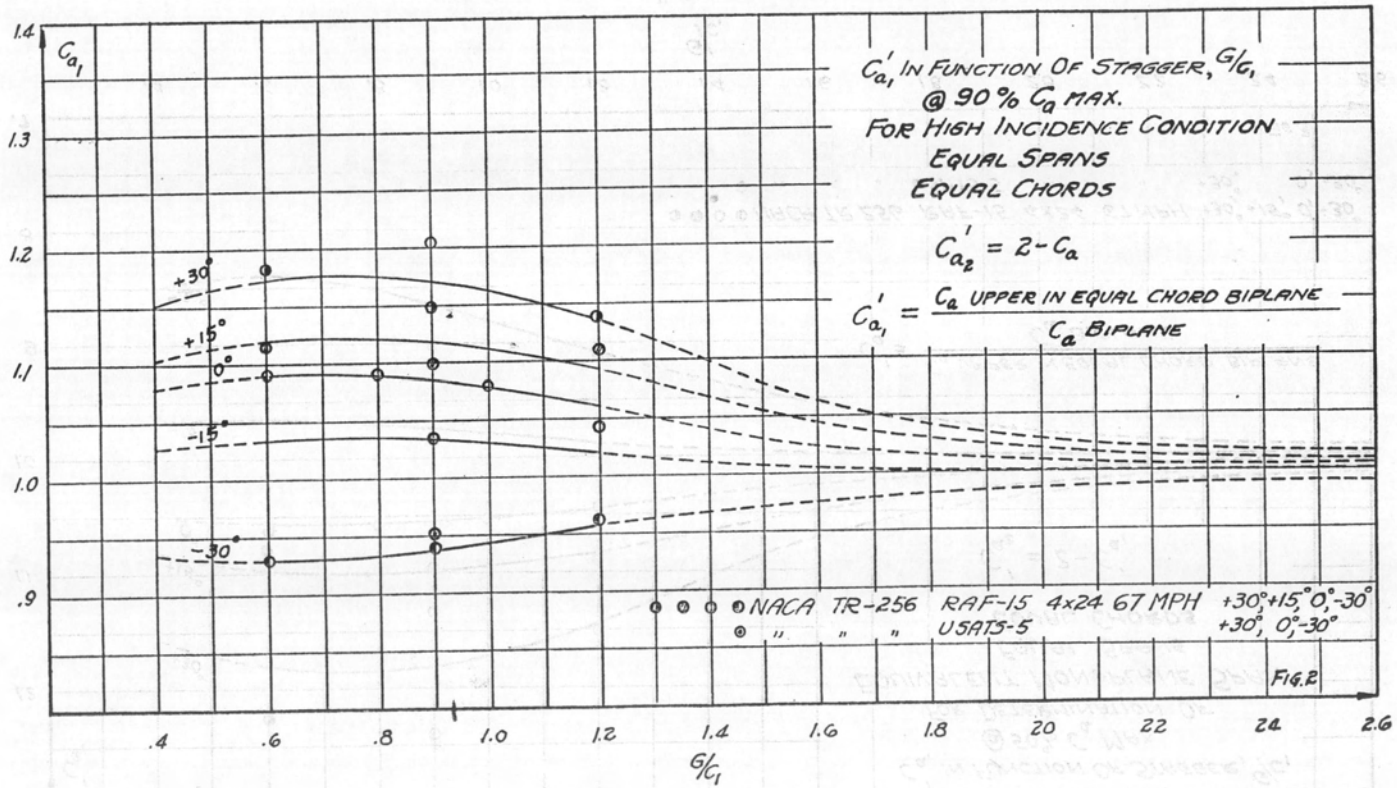

C_{a_1}
C_{a_1}' IN FUNCTION OF STAGGER, G/C₁
@ 90 % C_a MAX.
FOR HIGH INCIDENCE CONDITION
EQUAL SPANS
EQUAL CHORDS
$C_{a_2}' = 2 - C_a$
$C_{a_1}' = \frac{C_a \text{ UPPER IN EQUAL CHORD BIPLANE}}{C_a \text{ BIPLANE}}$
+30°
+15°
0°
-15°
-30°
NACA TR-256 RAF-15 4x24 67 MPH +30°,+15°,0°,-30°
" " " USAT5-5 +30°, 0°,-30°
FIG.2
1.4
1.3
1.2
1.1
1.0
.9
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
G/C₁

FIGURE 2

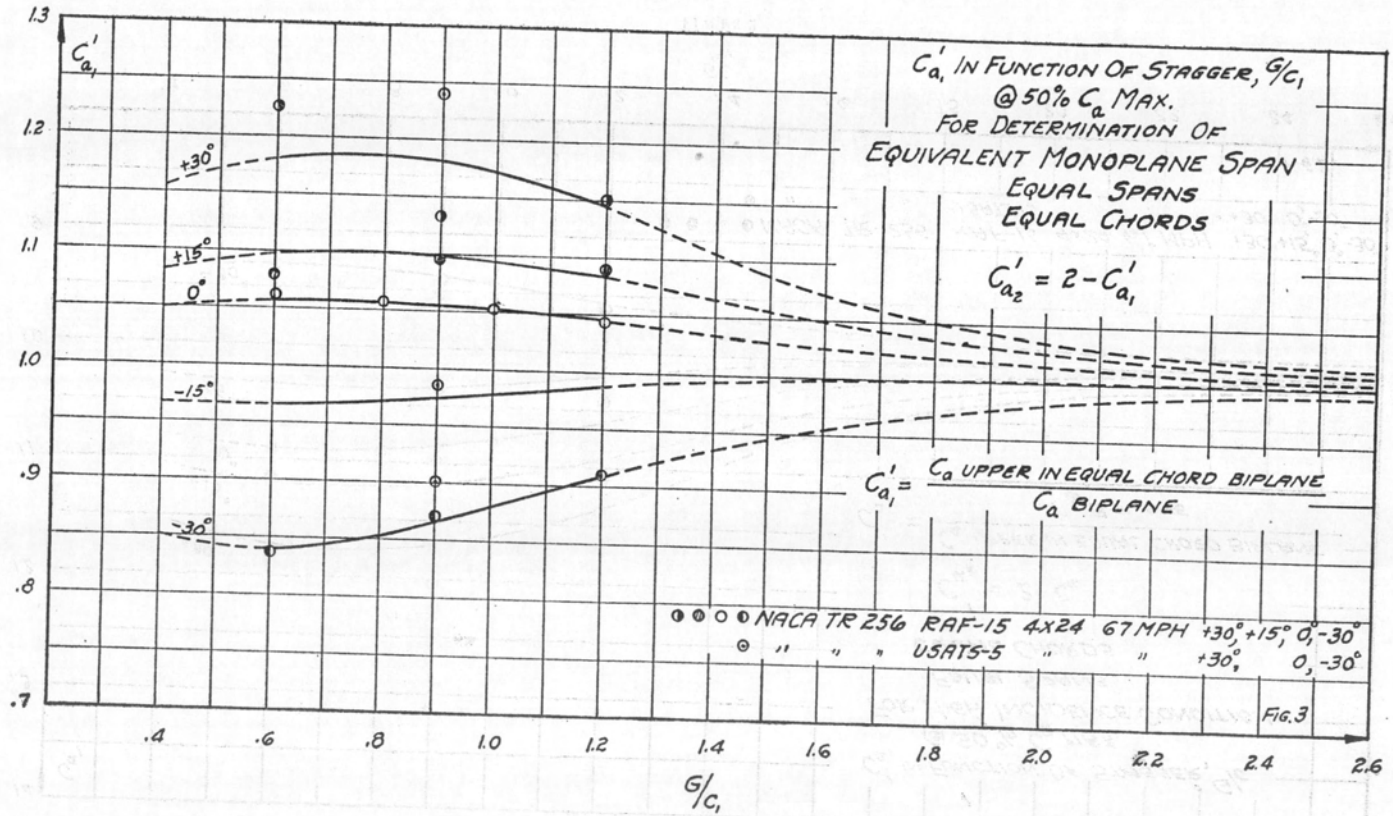
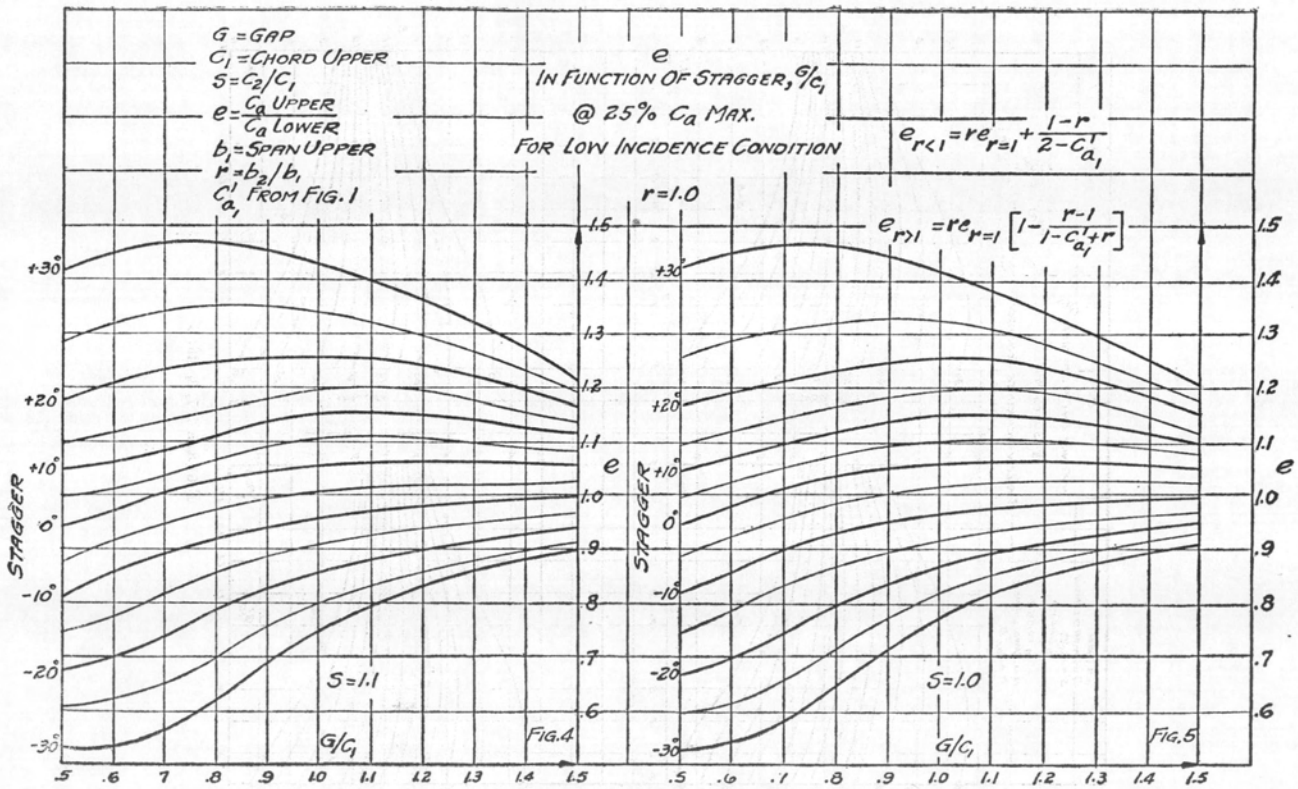
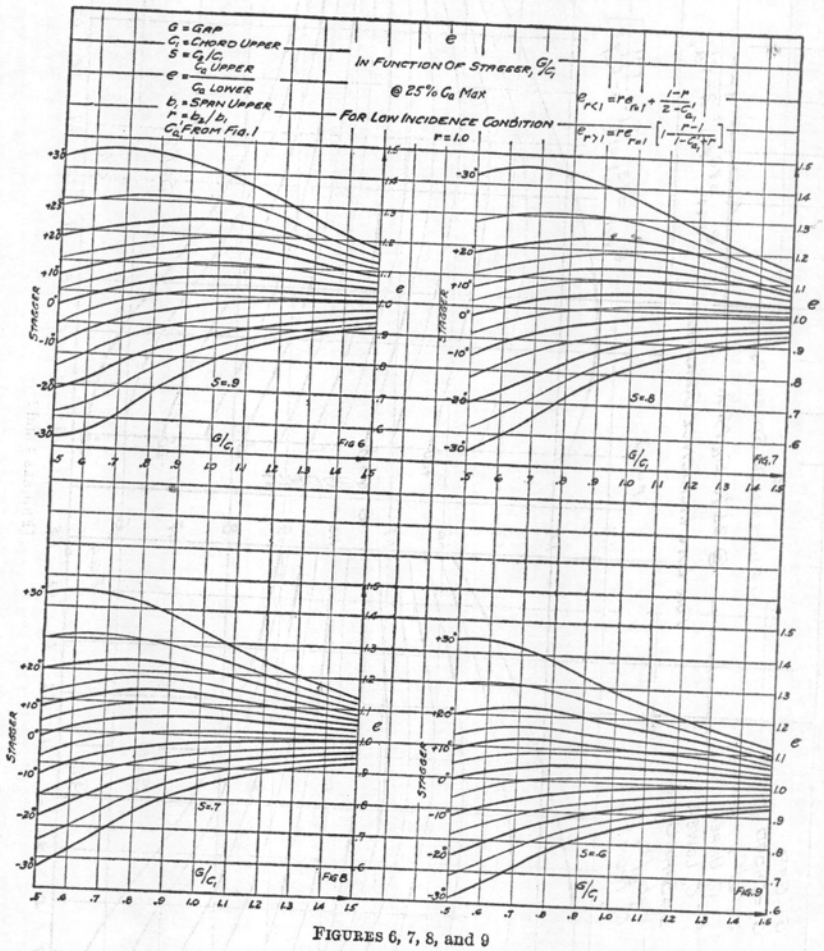

C'_{a_1} IN FUNCTION OF STAGGER, G/C1
@ 50% C_a MAX.
FOR DETERMINATION OF
EQUIVALENT MONOPLANE SPAN
EQUAL SPANS
EQUAL CHORDS
$C'_{a_2} = 2 - C'_{a_1}$
$C'_{a_1} = \frac{C_a \text{ UPPER IN EQUAL CHORD BIPLANE}}{C_a \text{ BIPLANE}}$
NACA TR 256 RAF-15 4x24 67 MPH +30°, +15°, 0°, -30°
" " " USATS-5 " " +30°, 0, -30°
FIG. 3
+30°
+15°
0°
-15°
-30°
1.3
1.2
1.1
1.0
.9
.8
.7
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
G/C1

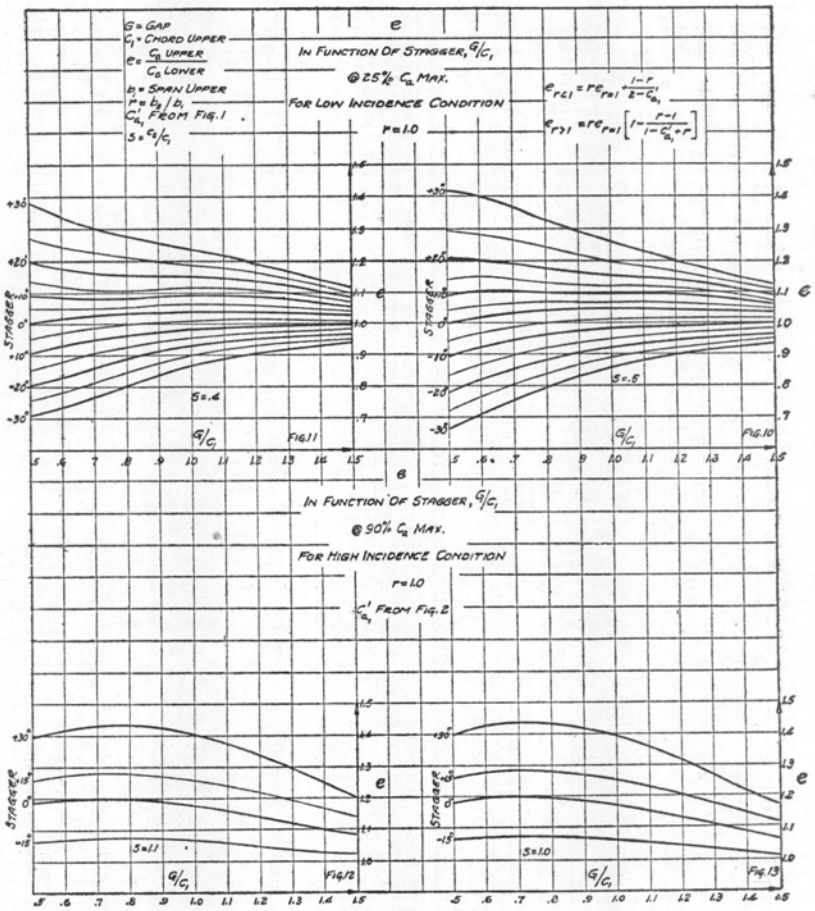
FIGURE 3



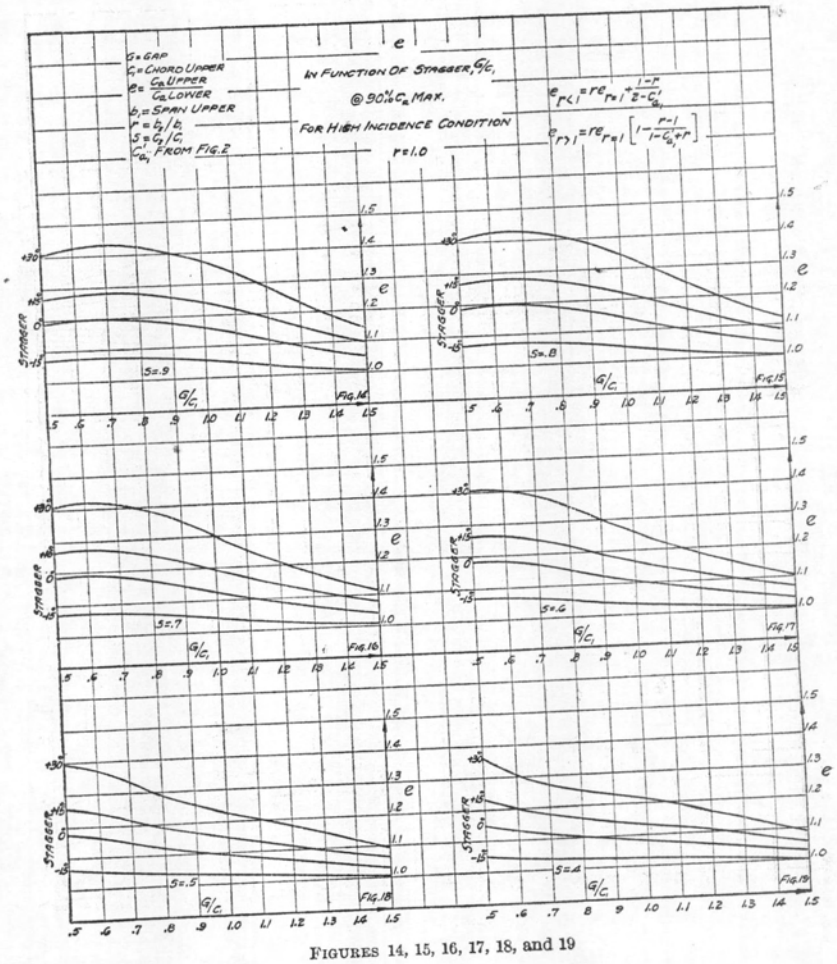
[FIGURES 4 and 5



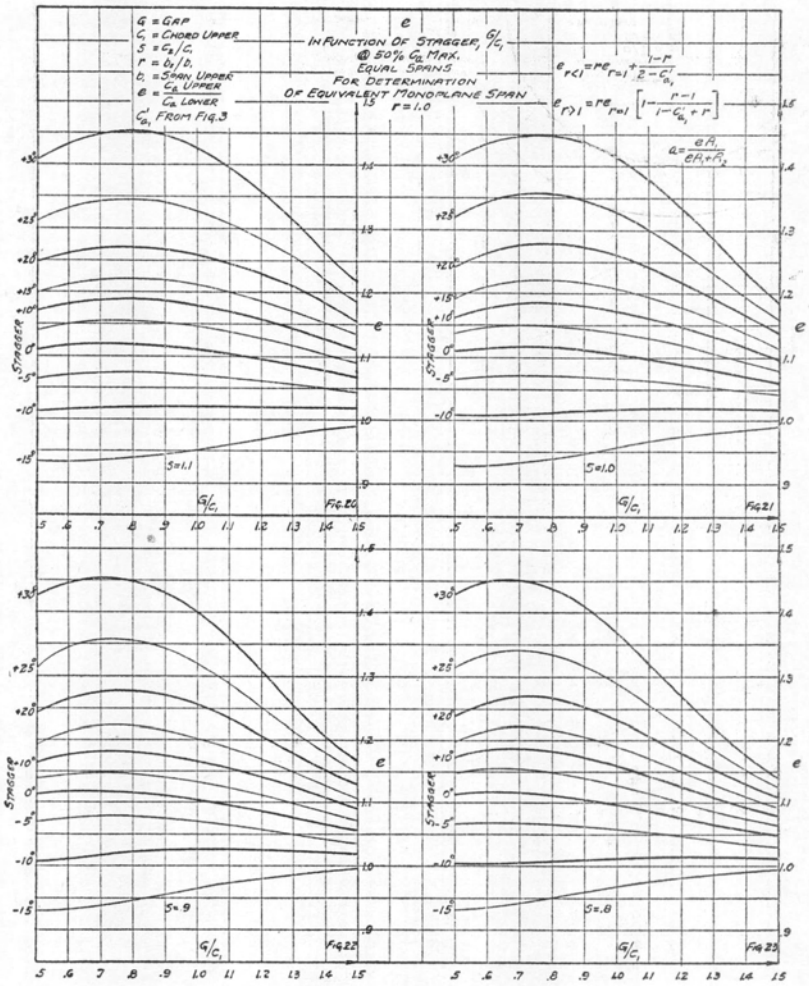
FIGURES 6, 7, 8, and 9



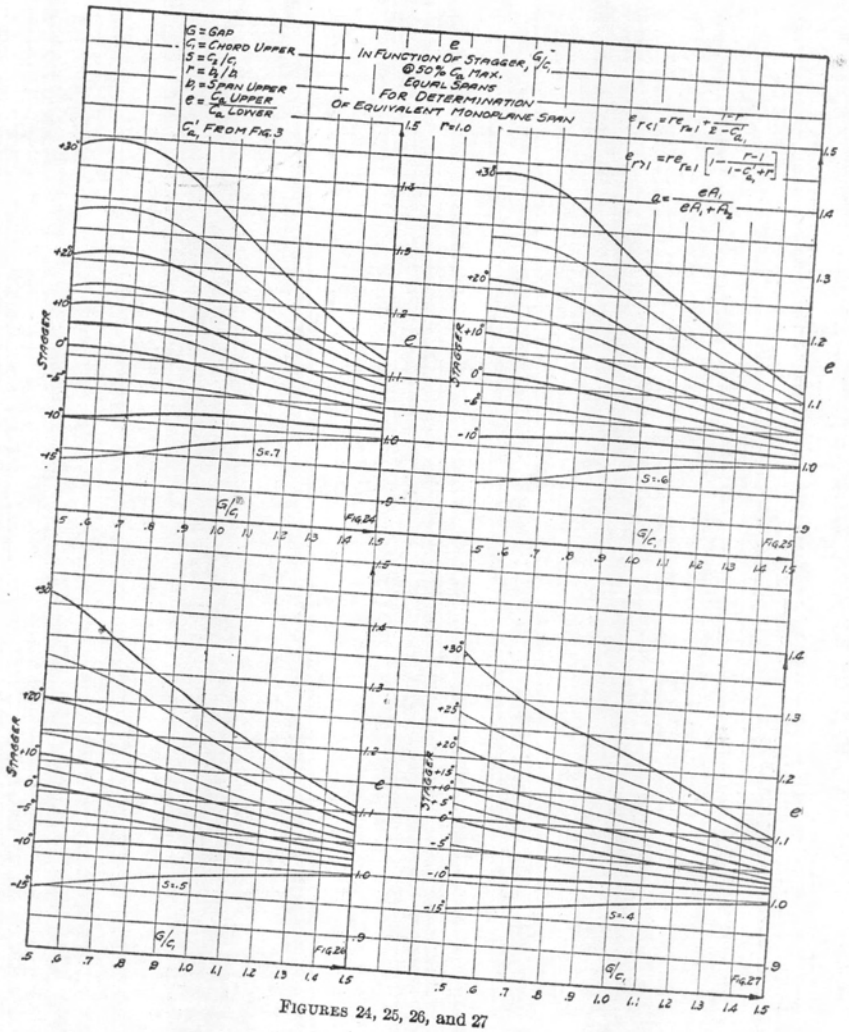
FIGURES 10, 11, 12, and 13



FIGURES 14, 15, 16, 17, 18, and 19



FIGURES 20, 21, 22, and 23



FIGURES 24, 25, 26, and 27

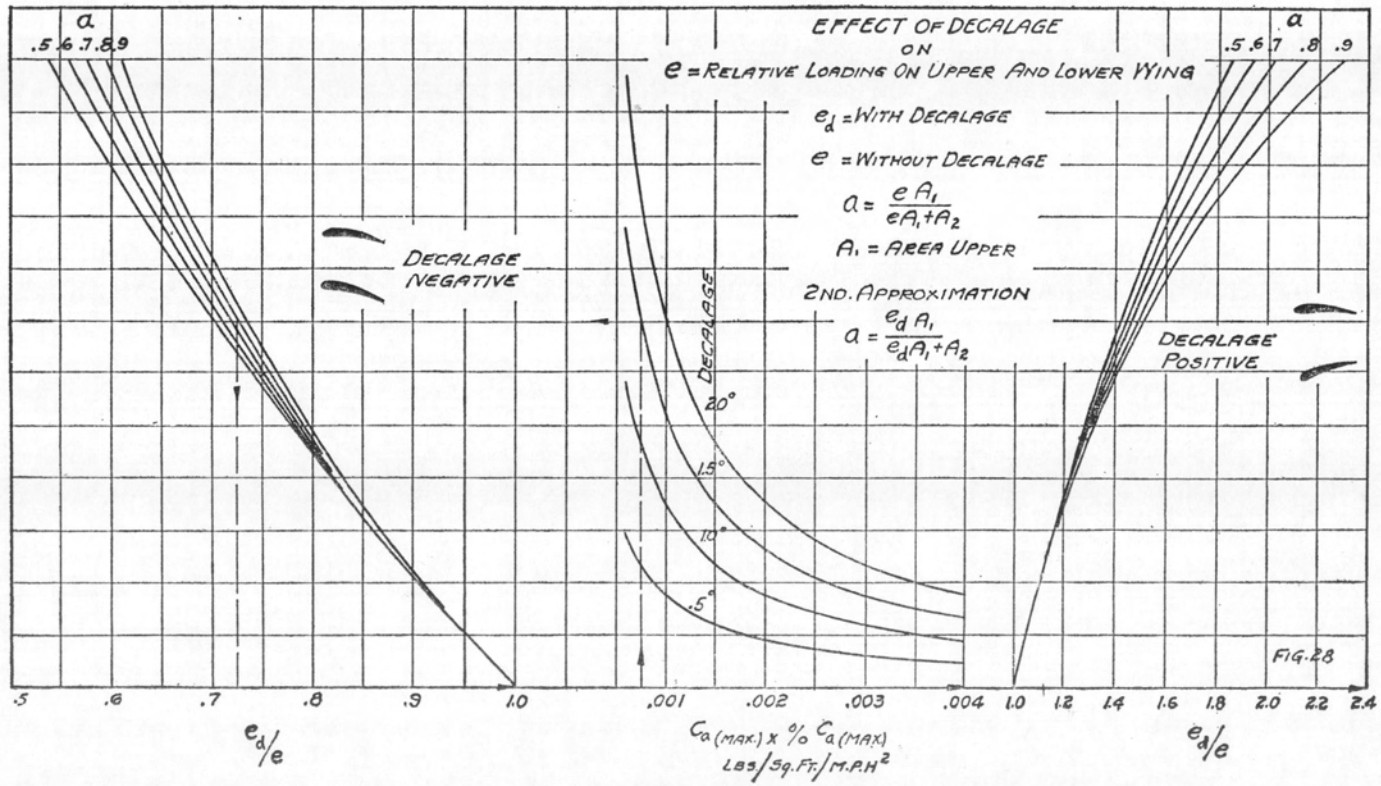

EFFECT OF DECALAGE
ON
e = RELATIVE LOADING ON UPPER AND LOWER WING
e_d = WITH DECALAGE
e = WITHOUT DECALAGE
$a = \frac{e A_1}{e A_1 + A_2}$
A_1 = AREA UPPER
2ND. APPROXIMATION
$a = \frac{e_d A_1}{e_d A_1 + A_2}$
a
.5 .6 .7 .8 .9
DECALAGE NEGATIVE
DECALAGE POSITIVE
DECALAGE
20°
1.5°
1.0°
.5°
FIG. 28
.5 .6 .7 .8 .9 1.0
.001 .002 .003 .004
1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
e_d/e
$C_{a\,(MAX.)} \times \%\ C_{a\,(MAX)}$
LBS/SQ.FT./M.P.H.^{2}

FIGURE 28

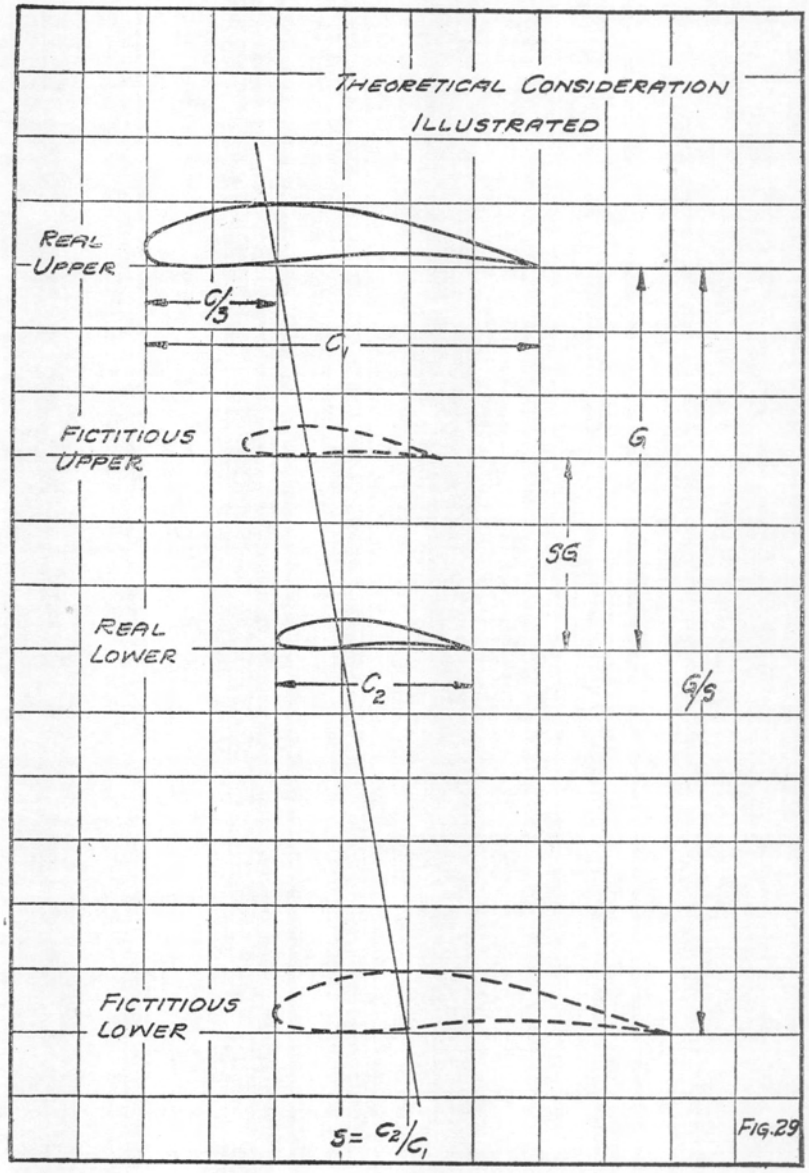

THEORETICAL CONSIDERATION
ILLUSTRATED
REAL
UPPER
C/S
C1
FICTITIOUS
UPPER
G
SG
REAL
LOWER
C2
G/S
FICTITIOUS
LOWER
S= C2/C1
FIG.29

FIGURE 29

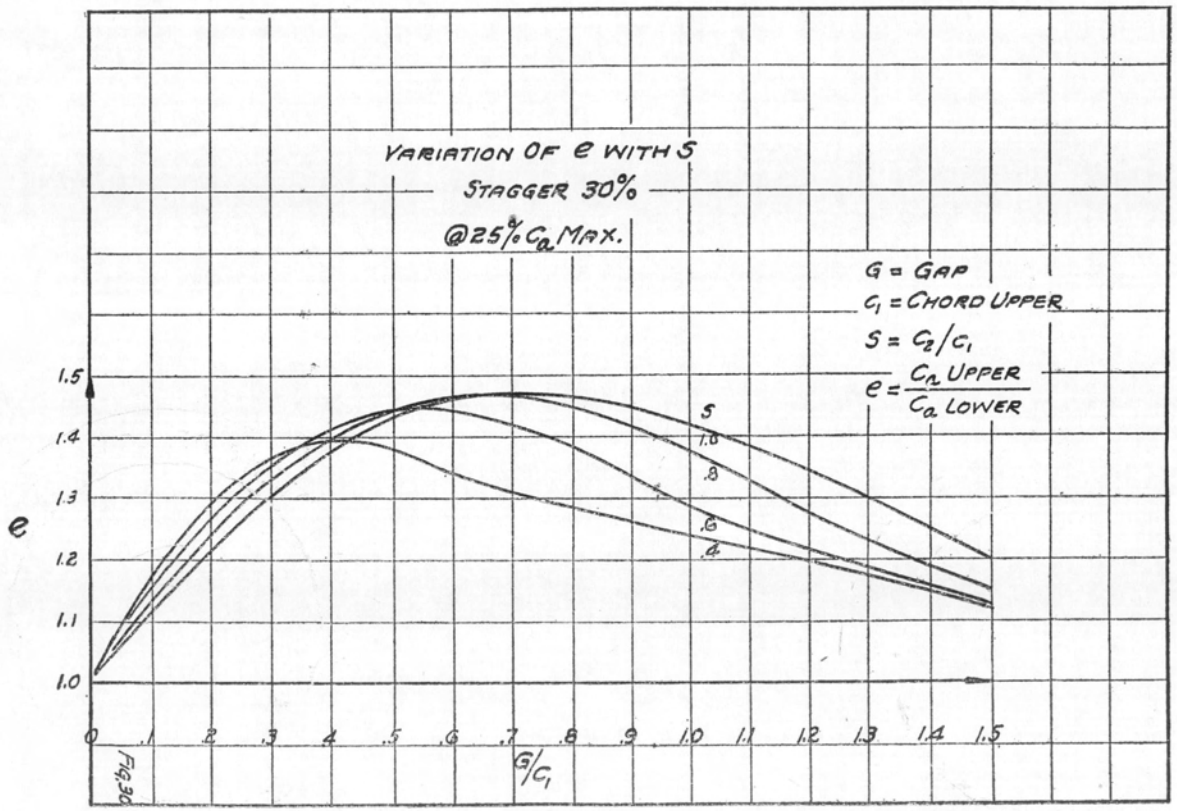

VARIATION OF e WITH S
STAGGER 30%
@25% Ca MAX.
G = GAP
C1 = CHORD UPPER
S = C2/C1
e = Ca UPPER / Ca LOWER
S
1.0
.8
.6
.4
e
1.5
1.4
1.3
1.2
1.1
1.0
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
G/C1
FIG.30

FIGURE 30