REPORT No. 472

WIND-TUNNEL TESTS ON COMBINATIONS OF A WING WITH FIXED AUXILIARY AIRFOILS HAVING VARIOUS CHORDS AND PROFILES

By Fred E. Weick and Robert Sanders

SUMMARY

Various auxiliary airfoils having three different airfoil sections and several different chord lengths were tested in combination with a Clark Y model wing in a sufficient number of relative positions to determine the optimum with regard to certain criterions of aerodynamic performance. The airfoil sections included a symmetrical profile, one of medium camber, and a highly cambered one. The chord sizes of the auxiliary airfoils ranged from 7.5 to 25 percent of the chord of the main wing, and the span was equal to that of the main wing. The tests were made in the N.A.C.A. 5-foot vertical wind tunnel.

It was found that each of the auxiliary airfoil combinations tested, regardless of size or airfoil section, had, when located at its best position, substantially higher values of the maximum lift coefficient and of the ratio $C_{L_{max}}{}^2/C_{D_{min}}$ *than the main wing alone. The maximum values of the lift coefficient obtained, based on the total area, were very nearly the same with all the auxiliary airfoils tested. The symmetrical airfoils gave lower values of the minimum drag coefficient and higher values of the ratio* $C_{L_{max}}{}^2/C_{D_{min}}$ *than the cambered auxiliary airfoils. The highest value of the ratio* $C_{L_{max}}{}^2/C_{D_{min}}$ *was obtained with the symmetrical auxiliary having a chord length 14.5 percent of the main wing chord. The positions giving the highest values of this ratio did not vary greatly for the different auxiliary airfoils tested, except for the narrowest ones, which gave higher values in lower positions.*

Additional tests, in which the auxiliary airfoils were supported separately, were made to determine the division of air load between the auxiliary and the main wing for two representative cases. The results showed that the auxiliary airfoil took a relatively large proportion of the total load, particularly in the case of the highly cambered auxiliary at low angles of attack.

INTRODUCTION

In a previous investigation (reference 1) it was found that with an auxiliary airfoil fixed in a certain position ahead of the main wing the combination had a substantially higher value of the maximum lift coefficient (based on total area) and of the speed-range criterion, $C_{L_{max}}/C_{D_{min}}$, than either of the airfoils alone. These earlier tests were made with a single form of auxiliary airfoil now referred to as the N.A.C.A. 22. The chord was 14.5 percent of the main wing chord, and the profile was highly cambered and of medium thickness. This auxiliary airfoil was tested in a large number of positions near the front of the main wing in order to find the best location.

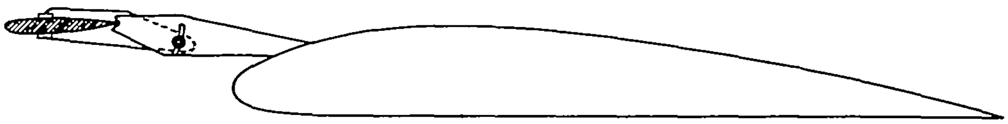
The tests described in the present report continue the investigation of fixed auxiliary airfoils to include the effect of variations in size and in airfoil section. Four sizes were tested having the original N.A.C.A. 22 section, four having a symmetrical section (N.A.C.A. 0012), and one having the Clark Y section. The lift and drag of the combinations were measured with each of the auxiliary airfoils in a sufficient number of positions ahead of the main wing to determine the optimum location. Pitching moments were then measured with each auxiliary airfoil in one or two of the best positions. Finally, the air force on the auxiliary airfoil was found for two representative combinations.

APPARATUS AND METHODS

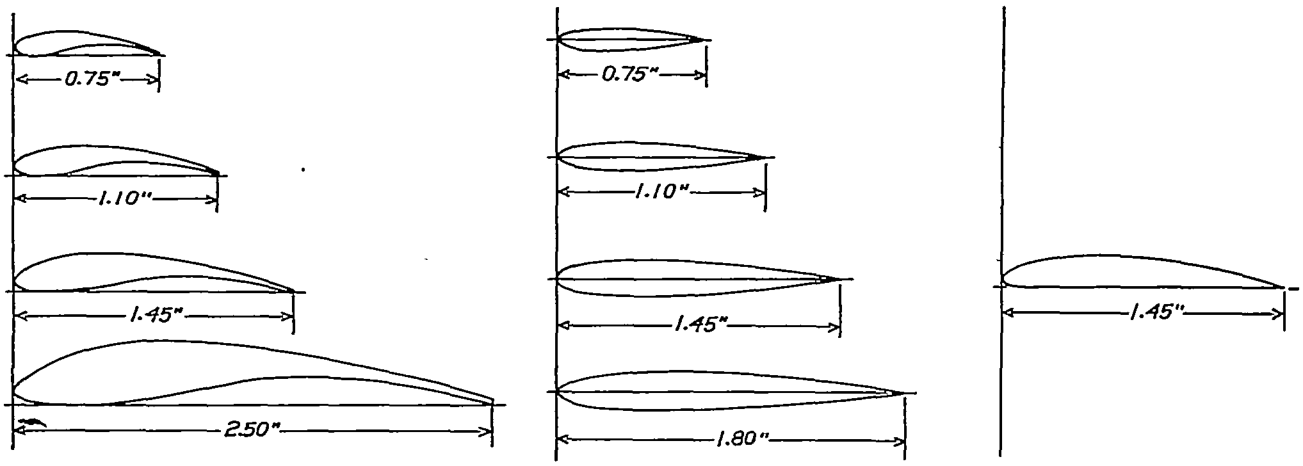
Wind tunnel.—The tests were made in the 5-foot vertical wind tunnel under essentially the same conditions as those of the original portion of the investigation (reference 1). The wind tunnel is described in detail in reference 2. A "reflection plane" and half-span model were used to permit as high a Reynolds Number as possible.

Models.—The main wing was a rectangular Clark Y airfoil, constructed of mahogany, with a 10-inch chord and a 30-inch semispan. The auxiliary airfoils, whose semispans were also 30 inches, were constructed of aluminum alloy. The chords of the auxiliary airfoils were varied until the tests indicated that the optimum range had been covered. The original highly cambered section (N.A.C.A. 22) was tested with chords of 7.5, 11, 14.5 (check on original in optimum position only), and 25 percent of the main wing chord. The symmetrical section, which was the next tested, was the N.A.C.A. 0012. This section was tested with chords of 7.5, 11, 14.5, and 18 percent of the main wing chord, the 25 percent size having been indicated as definitely too large by the tests with the original N.A.C.A. 22 section. The Clark Y section was tested with the 14.5 percent chord only. independently of the main wing. The air force on the main wing was measured in the presence of the auxiliary and subtracted from the total force to give the force on the auxiliary alone.

Tests.—The lift and drag over a range of angles of attack were measured with each of the auxiliary airfoils in a sufficient number of positions with respect



Main wing with 14.5 percent symmetrical auxiliary airfoil



ORDINATES OF AUXILIARIES

N.A.C.A. 22		
Stations, percent chord	Upper, percent chord	Lower, percent chord
0	2.88	2.88
1.25	5.40	1.09
2.5	6.48	.65
5	8.02	.28
7.5	9.11	.08
10	9.96	.00
15	11.34	.12
20	12.29	.44
30	13.35	1.46
40	13.42	3.08
50	12.60	4.78
60	11.12	5.63
70	9.15	5.79
80	6.68	4.68
90	3.95	2.67
95	2.51	1.32
100	1.13	0.00
L. E. Radius=2.00		

N.A.C.A. 0012		
Stations, percent chord	Upper, percent chord	Lower, percent chord
0	0.00	0.00
1.25	1.89	1.89
2.5	2.62	2.62
5	3.56	3.56
7.5	4.20	4.20
10	4.68	4.68
15	5.35	5.35
20	5.74	5.74
30	6.00	6.00
40	5.80	5.80
50	5.29	5.29
60	4.56	4.56
70	3.66	3.66
80	2.62	2.62
90	1.45	1.45
95	.81	.81
100	.13	.13
L. E. Radius=1.58		

CLARK Y		
Stations, percent chord	Upper, percent chord	Lower, percent chord
0	3.50	3.50
1.25	5.45	1.93
2.5	6.50	1.47
5	7.90	.93
7.5	8.85	.63
10	9.60	.42
15	10.69	.15
20	11.36	.03
30	11.70	0
40	11.40	0
50	10.52	0
60	9.15	0
70	7.35	0
80	5.22	0
90	2.80	0
95	1.49	0
100	.12	0
L. E. Radius=1.50		

FIGURE 1.—Sections of auxiliary airfoils tested.

All three sections have approximately the same thickness and form except for the camber, which varies through a large range. The cross-sectional views of the various auxiliary airfoils are shown together with a table of ordinates in figure 1. The auxiliary airfoils were supported at each end and at two intermediate positions by metal fittings, as shown in figure 2.

For obtaining the force on the auxiliary airfoil separately, fixtures were made to support the auxiliary to the main wing to determine the optimum location according to the criterion $C_{L_{max}}{}^2/C_{D_{min}}$, which was used in reference 1. The variations in position were made in the following manner. The angle δ between the chord line of the auxiliary and that of the main wing was changed about an axis through the trailing edge of the auxiliary until the angle giving the highest value of the ratio $C_{L_{max}}{}^2/C_{D_{min}}$ was determined. This procedure was repeated for various trailing-edge locations until closed contour charts of the maximum value of the ratio C_{Lmax}^2/C_{Dmin} obtained at each trailing-edge location could be drawn, showing that the position giving the highest value had been determined.

The 14.5 percent N.A.C.A. 22 auxiliary airfoil, which was the one tested in various positions in reference 1, was retested only at the best position, as a check. The results are slightly different from those of the previous tests, which is partly due to a change of the fittings supporting the auxiliary airfoil and partly to the normal experimental error. The new fittings, designed to increase the rigidity of the set-up, caused an interference effect resulting in a reduction of the maximum lift coefficient of about 3 percent (reference 3).

The pitching moments, which were obtained with a slight change in the balance arrangement, were measured for the best positions of each auxiliary airfoil.

The tests to determine the distribution of load between the auxiliary airfoil and the main wing were made with two representative auxiliary airfoils. One had the highly cambered N.A.C.A. 22 section and the other the symmetrical N.A.C.A. 0012 section, both being 14.5 percent of the main wing chord. Each of the auxiliary airfoils was tested at two different settings of the angle δ. The values of the air loads on the auxiliary airfoils must be considered as approximate, for they were obtained as the difference between two relatively large forces and the accuracy was therefore not high.

RESULTS AND DISCUSSION

The results of the simple lift and drag tests are given in tables I to IX in terms of several critical values, or criterions, of the aerodynamic characteristics. The lift and drag coefficients are based on the area of the main wing plus that of the auxiliary, and for this reason the various combinations must be compared as complete units.

CONTOURS OF PERFORMANCE CRITERIONS

The variations of four of the criterions with changes in the locations of the various auxiliary airfoils are shown by means of contour charts which serve as convenient aids to the selection of the optimum locations (figs. 3 to 10). The values on the contour charts are those obtained with the auxiliary airfoil set at the angles giving the highest value of C_{Lmax}^2/C_{Dmin} for each trailing-edge location; where two angles gave the same value within the experimental error, the choice was based on the other criterions. The values for the different angles are given in tables I to IX. The four sets of contours shown on each of the figures are for the following criterions:

a. C_{Lmax}^2/C_{Dmin}, which is the main criterion in selecting the optimum position. This is an arbitrary criterion which gives equal weight to the maximum lift coefficient and the speed-range ratio C_{Lmax}/C_{Dmin}.

b. C_{Lmax}.

c. L/D at $C_L = 0.7$, which is used as a criterion of the effectiveness in climbing flight.

d. L/D at C_{Lmax}, which gives an indication of the steepest gliding angle obtainable in unstalled flight.

An examination of the contour charts shows that no single auxiliary airfoil had the best characteristics on the basis of all the criterions. The variation of the characteristics with size, profile, and location of the

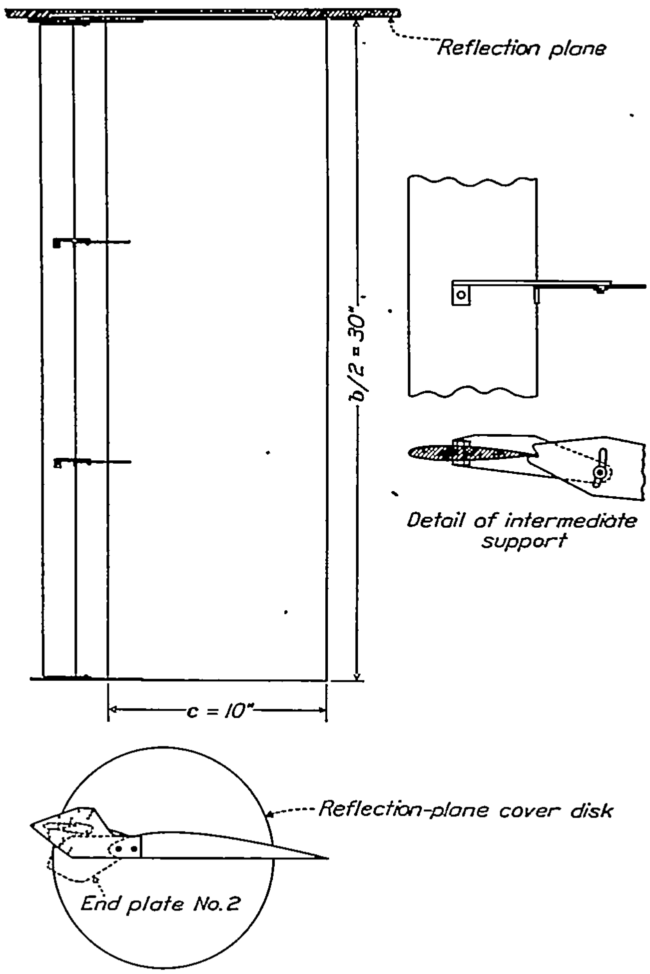
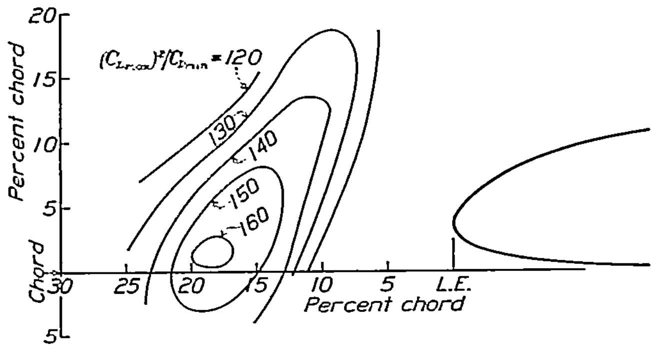


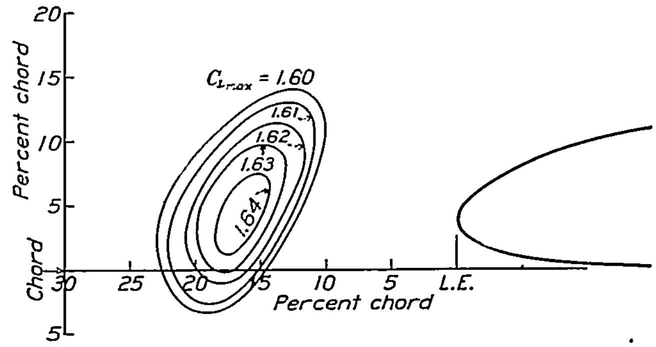
FIGURE 2.—Method of supporting auxiliary airfoils.

auxiliary is complex and requires that the data be studied in detail in order to select the best auxiliary airfoil to fulfill the requirements of any particular set of operating conditions.

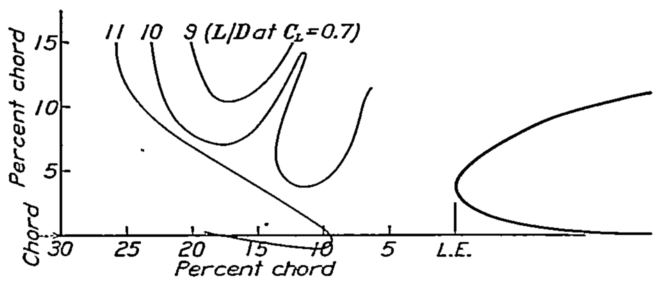
Effect of location.—In general, the location giving the highest value of the ratio C_{Lmax}^2/C_{Dmin} for any of the auxiliary airfoils was not greatly different from that giving the highest value of C_{Lmax}, being in most cases slightly lower and farther forward. The positions giving the highest values of C_{Lmax}^2/C_{Dmin} did not vary greatly with airfoil section or with size of auxiliary, except for the smallest size, which required a lower position for both the airfoil sections tested. In fact, for each size



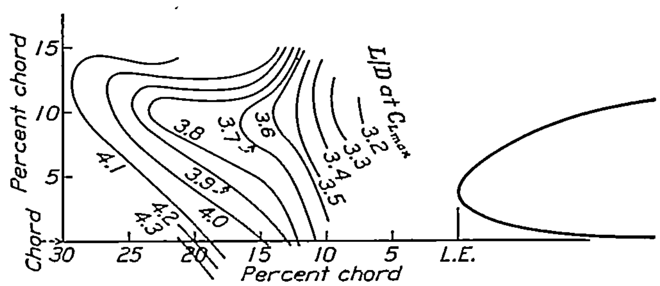
Loci of trailing-edge positions for equal values of $C_{L_{max}}{}^2/C_{D_{min}}$ obtained with a 7.5 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with a 7.5 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

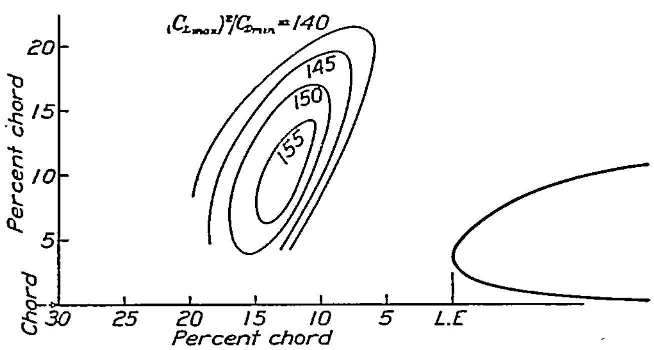


Loci of trailing-edge positions for equal values of L/D at $C_L=0.7$ obtained with a 7.5 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

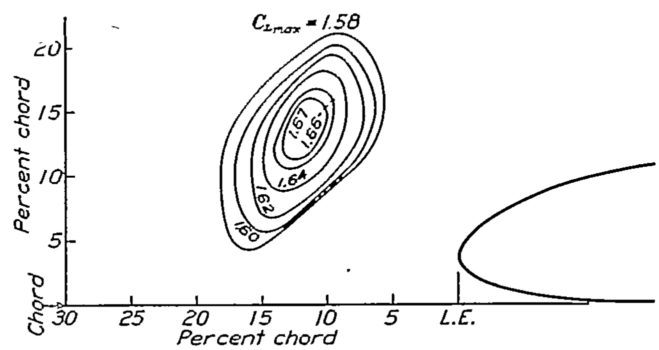


Loci of trailing-edge positions for equal values of L/D at $C_{L_{max}}$ obtained with a 7.5 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

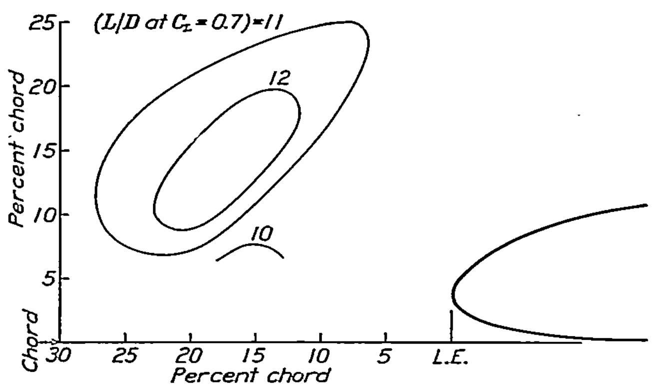
FIGURE 3.



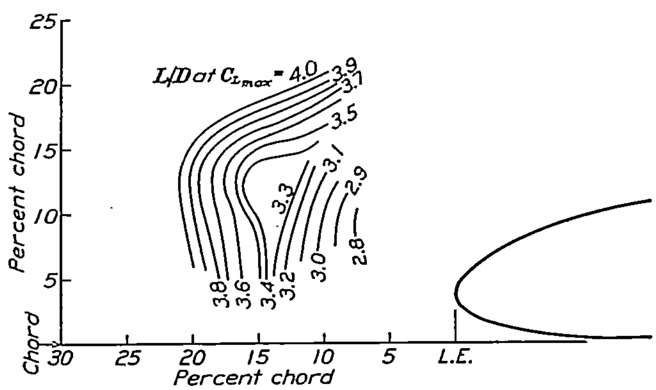
Loci of trailing-edge positions for equal values of $C_{L_{max}}{}^2/C_{D_{min}}$ obtained with an 11.0 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with an 11.0 per cent c N.A.C.A. auxiliary airfoil set at the optimum angle for each position.

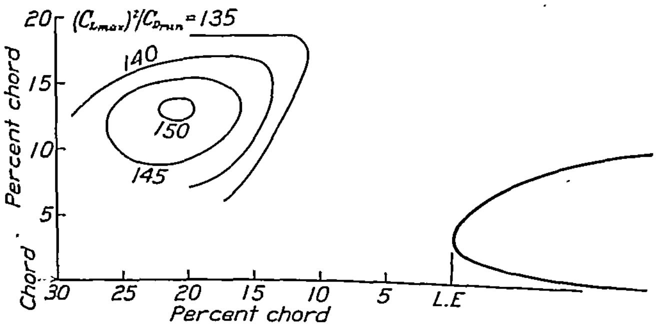


Loci of trailing-edge positions for equal values of L/D at $C_L=0.7$ obtained with an 11.0 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

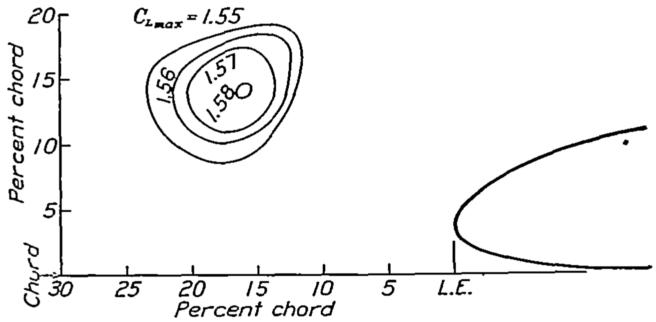


Loci of trailing-edge positions for equal values of L/D at $C_{L_{max}}$ obtained with an 11.0 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

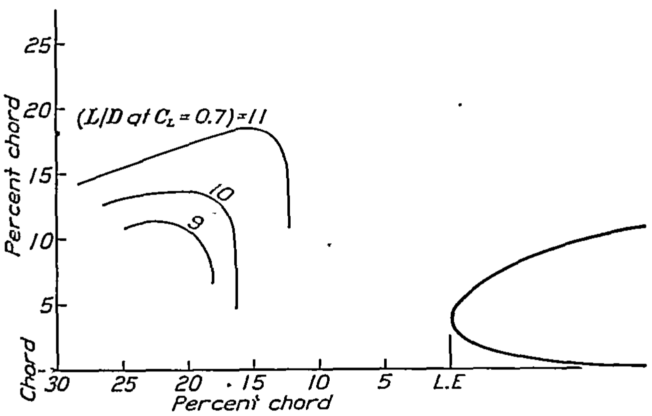
FIGURE 4.



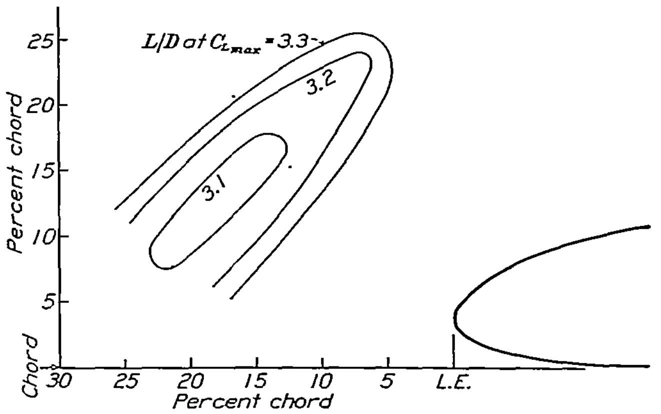
Loci of trailing-edge positions for equal values of $C_{L_{max}}^2/C_{D_{min}}$ obtained with a 25.0 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with a 25.0 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

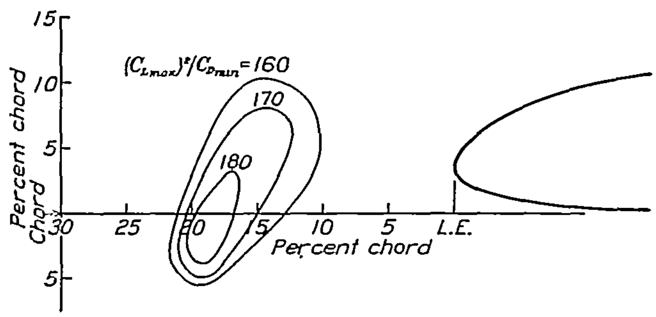


Loci of trailing-edge positions for equal values of L/D at $C_L=0.7$ obtained with a 25.0 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

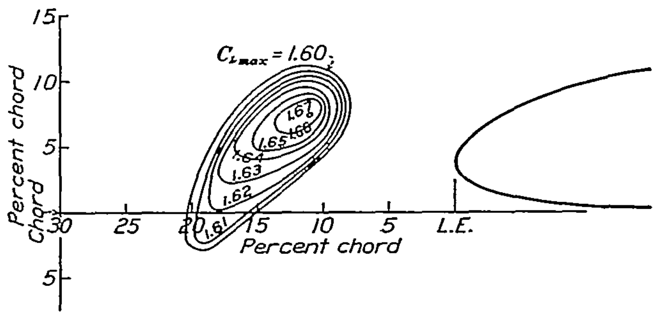


Loci of trailing-edge positions for equal values of L/D at $C_{L_{max}}$ obtained with a 25.0 percent c N.A.C.A. 22 auxiliary airfoil set at the optimum angle for each position.

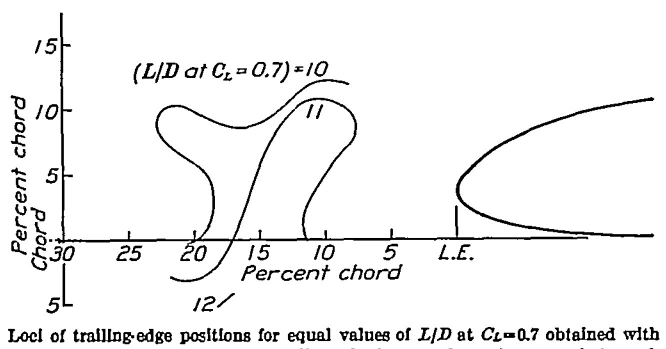
FIGURE 5.



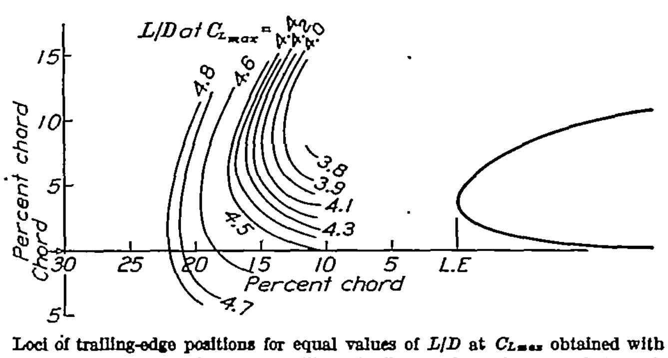
Loci of trailing-edge positions for equal values of $C_{L_{max}}^2/C_{D_{min}}$ obtained with a 7.5 percent c N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with a 7.5 percent c N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

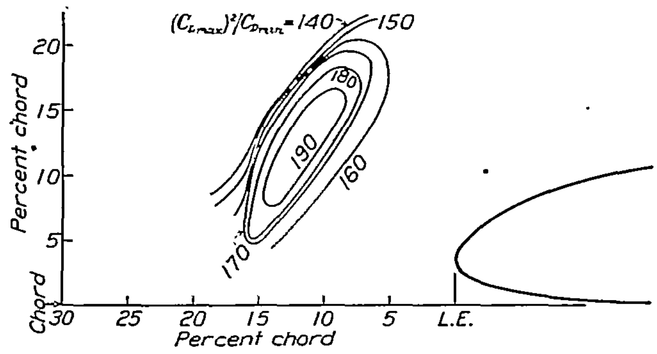


Loci of trailing-edge positions for equal values of L/D at $C_L=0.7$ obtained with a 7.5 percent c N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

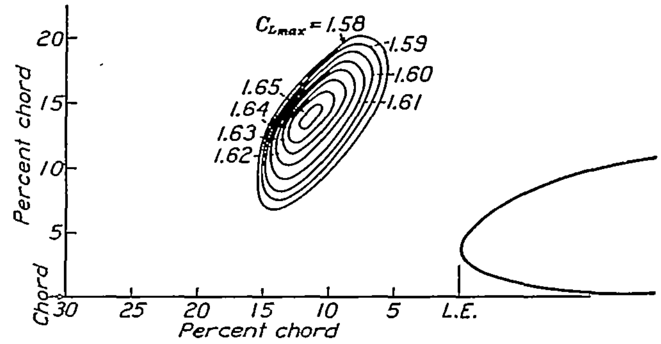


Loci of trailing-edge positions for equal values of L/D at $C_{L_{max}}$ obtained with a 7.5 percent c N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

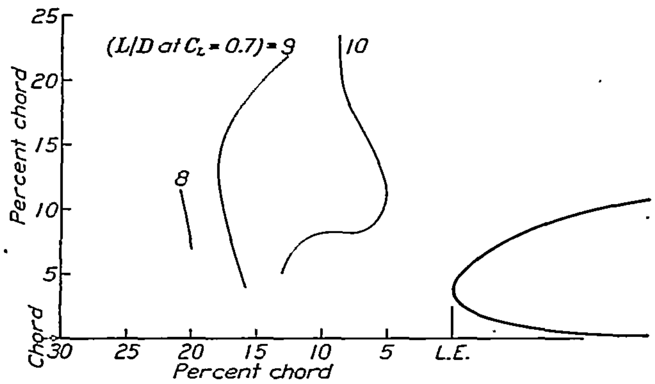
FIGURE 6.



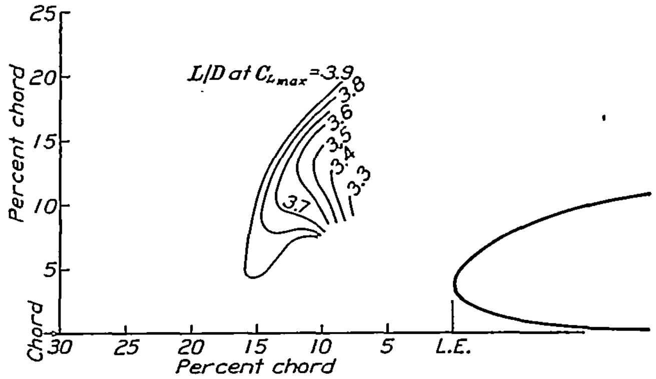
Loci of trailing-edge positions for equal values of $C_{L_{max}}{}^2/C_{D_{min}}$ obtained with an 11.0 percent *c* N.A.C.A 0012 auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with an 11.0 percent *c* N.A.C.A 0012 auxiliary airfoil set at the optimum angle for each position.

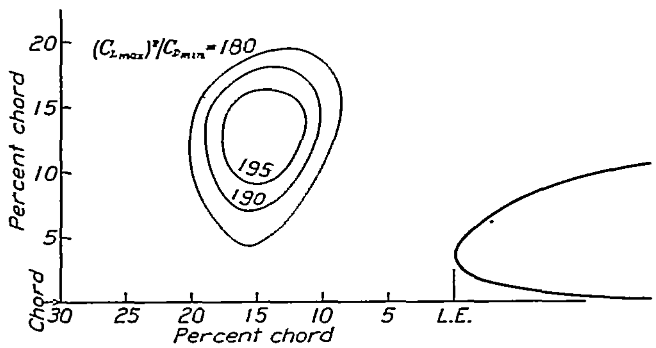


Loci of trailing-edge positions for equal values of *L/D* at $C_L=0.7$ obtained with an 11.0 percent *c* N.A.C.A 0012 auxiliary airfoil set at the optimum angle for each position.

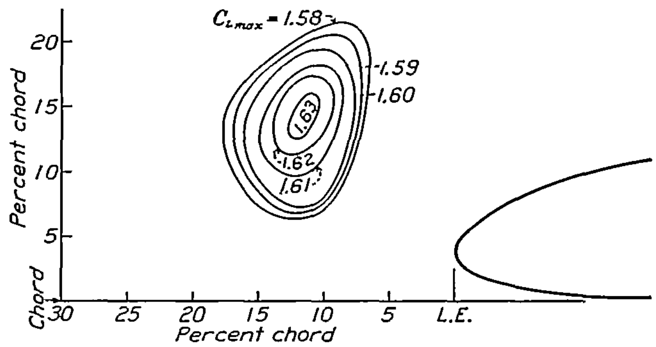


Loci of trailing-edge positions for equal values of *L/D* at $C_{L_{max}}$ obtained with an 11.0 percent *c* N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

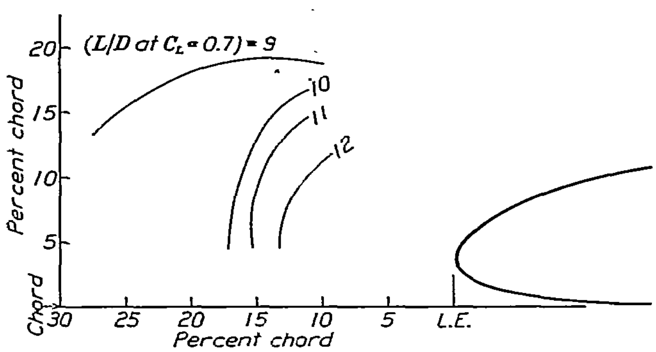
FIGURE 7.



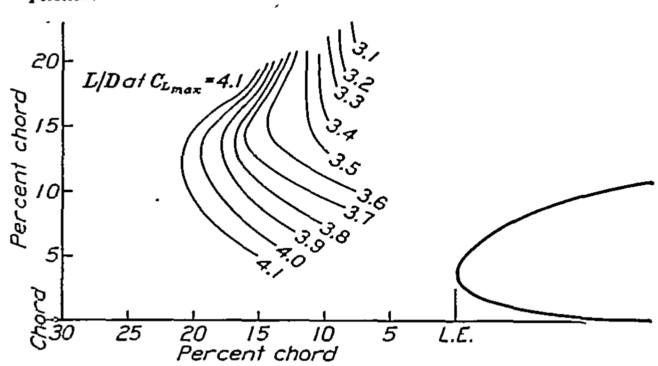
Loci of trailing-edge positions for equal values of $C_{L_{max}}{}^2/C_{D_{min}}$ obtained with a 14.5 percent *c* N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with a 14.5 percent *c* N.A.C.A 0012 auxiliary airfoil set at the optimum angle for each position.

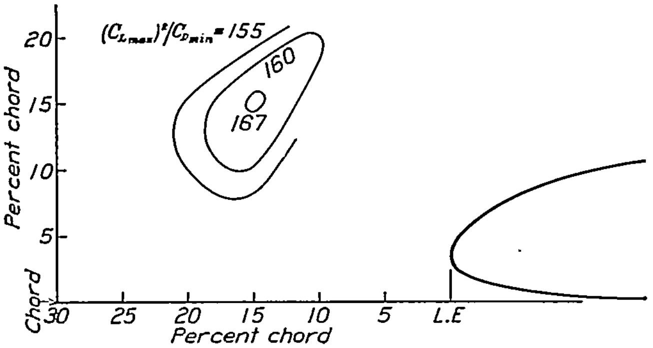


Loci of trailing-edge positions for equal values of *L/D* at $C_L=0.7$ obtained with a 14.5 percent *c* N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

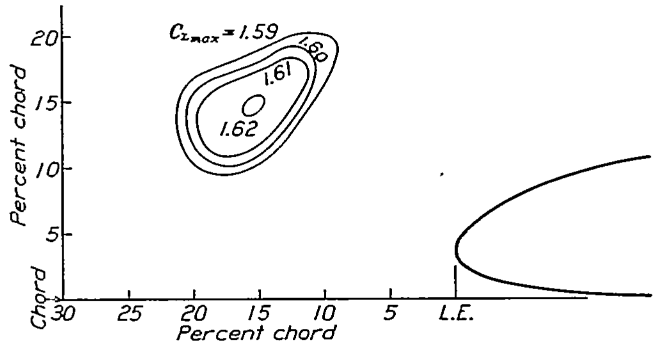


Loci of trailing-edge positions for equal values of *L/D* at $C_{L_{max}}$ obtained with a 14.5 percent *c* N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

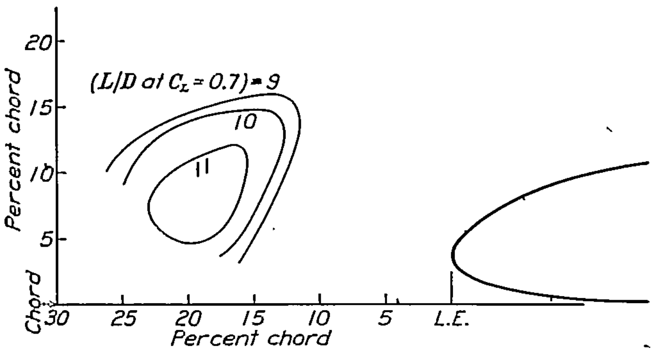
FIGURE 8.



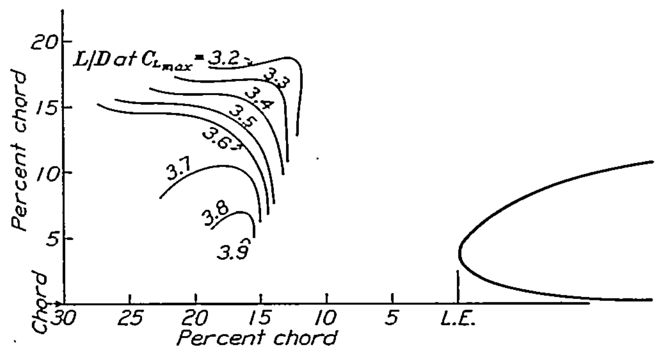
Loci of trailing-edge positions for equal values of $C_{L_{max}}^2/C_{D_{min}}$ obtained with an 18.0 percent *c* N.A.C.A 0012 auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with an 18.0 percent *c* N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

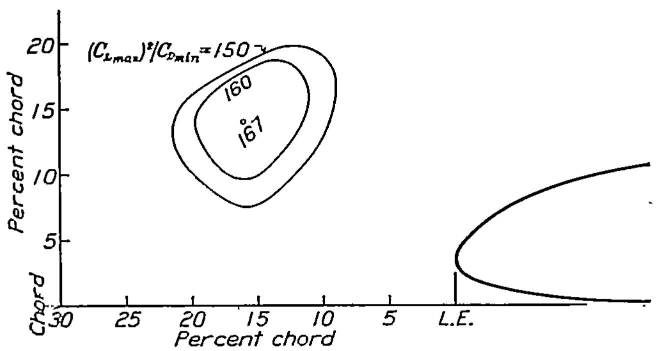


Loci of trailing-edge positions for equal values of L/D at C_L=0.7 obtained with an 18.0 percent *c* N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

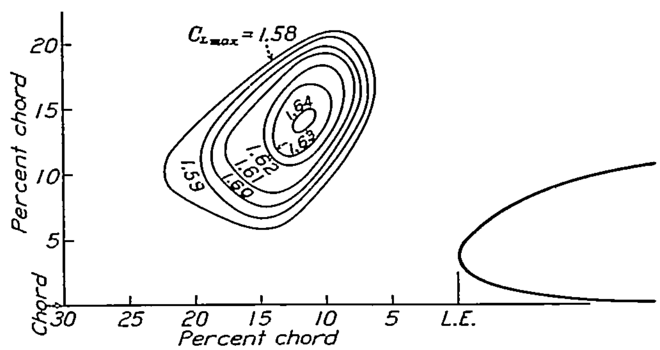


Loci of trailing-edge positions for equal values of L/D at $C_{L_{max}}$ obtained with an 18.0 percent *c* N.A.C.A. 0012 auxiliary airfoil set at the optimum angle for each position.

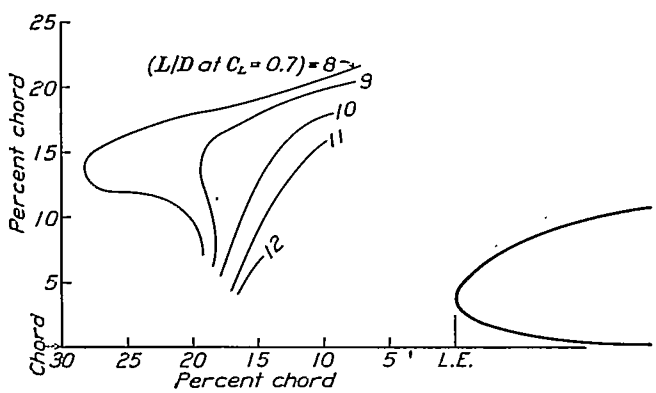
FIGURE 9



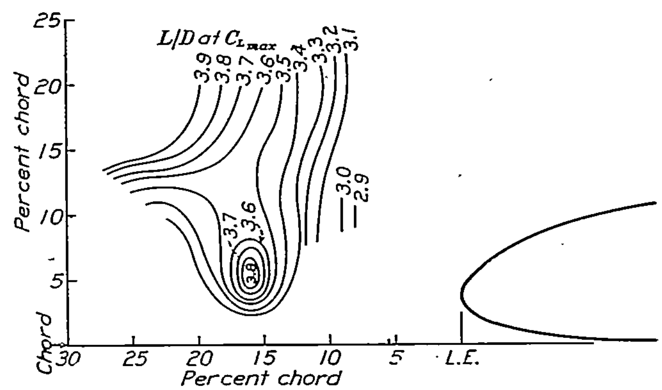
Loci of trailing-edge positions for equal values of $C_{L_{max}}^2/C_{D_{min}}$ obtained with a 14.5 percent *c* Clark Y auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of $C_{L_{max}}$ obtained with a 14.5 percent *c* Clark Y auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of L/D at C_L=0.7 obtained with a 14.5 percent *c* Clark Y auxiliary airfoil set at the optimum angle for each position.



Loci of trailing-edge positions for equal values of L/D at $C_{L_{max}}$ obtained with a 14.5 percent *c* Clark Y auxiliary airfoil set at the optimum angle for each position.

FIGURE 10.

of auxiliary airfoil except the extreme 7.5 and 25 percent sizes, and for each of the three airfoil sections, a position with the trailing edge 14 percent ahead of the nose and 12 percent above the chord line of the main wing gave a value of $C_{L_{max}}$ within 2 percent and a value of the ratio $C_{L_{max}}^2/C_{D_{min}}$ within 5 percent of the maximum value obtained for the particular auxiliary airfoil at any position. The best angle δ was within 3° of zero for all medium-sized auxiliary airfoils, regardless of section.

In most cases, moving the auxiliary airfoil closer to the main wing than the position giving the highest value of the ratio $C_{L_{max}}^2/C_{D_{min}}$ gave a slight increase in the value of L/D in the climbing range and at the same time a decrease in the value of L/D near maximum lift, both of which result in an increase in the range of possible gliding angles. Considering this fact, together with the similar condition in regard to the maximum lift coefficient, and also the structural requirements, the optimum position would seem to be somewhat closer to the main wing than the position giving the highest ratio of $C_{L_{max}}^2/C_{D_{min}}$. No rigid general rule can be drawn, however, for the details of each case must be considered separately.

Effect of size.—A comparison of the results for the different sized auxiliary airfoils as given on the contour charts shows that for any one airfoil section there was no great change in the values of the criterions with change in size within the range covered, if the values taken are for each size in its best position. The maximum lift coefficients obtained with the auxiliary airfoils of all sizes and sections, set at the value of δ which gave the highest value of the ratio $C_{L_{max}}^2/C_{D_{min}}$, were all within 2 percent (or approximately within the experimental error) of the value 1.64, except for the value with the 25 percent auxiliary airfoil, which was within 4 percent. With the highly cambered N.A.C.A. 22 section the smaller auxiliary airfoils had slightly higher values of the ratio $C_{L_{max}}^2/C_{D_{min}}$ than the larger ones, but the entire range was only 7 percent. With the symmetrical section the variation of the maximum value of the ratio $C_{L_{max}}^2/C_{D_{min}}$ with size was about twice as great, the highest value being obtained with the medium size and the lowest values with the extreme sizes.

The values of the climb criterion, L/D at $C_L=0.7$, were nearly the same for all sizes, but were slightly greater for the smallest size than for the others. The smallest sized auxiliary airfoils, unfortunately, also gave definitely higher values of the criterion of steep glides, L/D at $C_{L_{max}}$, than the others. The variation among the larger sizes was very small.

Effect of auxiliary airfoil section.—Although the auxiliary airfoils of all sizes and sections gave approximately the same values of the maximum lift coefficient, the minimum drag coefficients were found to be decidedly lower with the auxiliary airfoils of symmetrical section than with the cambered ones, so that higher values of the ratio $C_{L_{max}}^2/C_{D_{min}}$ were obtained with them. The cross plots for the three different sections with the 14.5 percent chord indicated that the highest values of the ratio obtained with each varied consistently with the camber, the value with the symmetrical N.A.C.A. 0012 auxiliary airfoil being 199, that for the Clark Y being 166, and that for the highly cambered N.A.C.A. 22, being 154. The value of 199 obtained with the 14.5 percent symmetrical auxiliary airfoil was the highest found in the investigation.

The values of L/D at $C_L=0.7$ were approximately the same for the symmetrical and for the highly cambered sections, but the values of L/D at $C_{L_{max}}$ were slightly lower with the highly cambered sections.

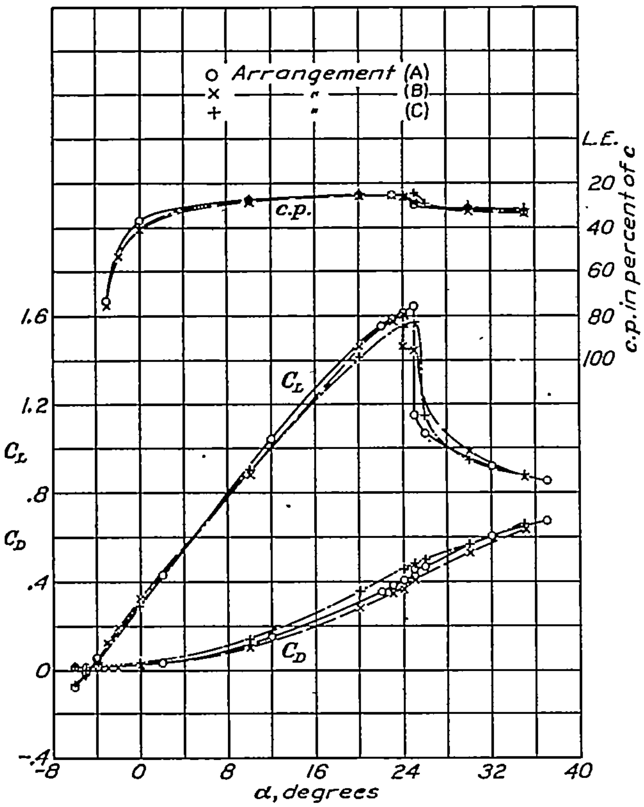
LIFT, DRAG, AND CENTER-OF-PRESSURE CURVES FOR OPTIMUM POSITIONS

Curves of lift, drag, and center-of-pressure coefficients against angle of attack are given in figures 11 to 19 for each of the auxiliary airfoils in one or more of the optimum positions, selected mainly on the basis of the ratio $C_{L_{max}}^2/C_{D_{min}}$. In addition, values of the pitching-moment coefficients for all the angles of attack measured are given in table X. The values of center-of-pressure positions were computed on the basis of the main wing chord and the values of C_m on the basis of the main wing chord and the combined area.

The numerical value of C_m at zero lift for the combination with the 14.5 percent Clark Y auxiliary airfoil was found to be 14 percent less than the value for the plain Clark Y wing alone. With the symmetrical auxiliary airfoil having the 11 percent chord the value was the same as for the plain wing, but it became greater if the size of the auxiliary was either increased or decreased from the 11 percent point. The highly cambered N.A.C.A. 22 auxiliary airfoils gave somewhat smaller negative values than the plain Clark Y wing, the values decreasing as the size of the auxiliary was increased. If C_m is plotted against C_L the curve will not in any case be a straight line, but will have a definite bend in the neighborhood of the 5° angle of attack.

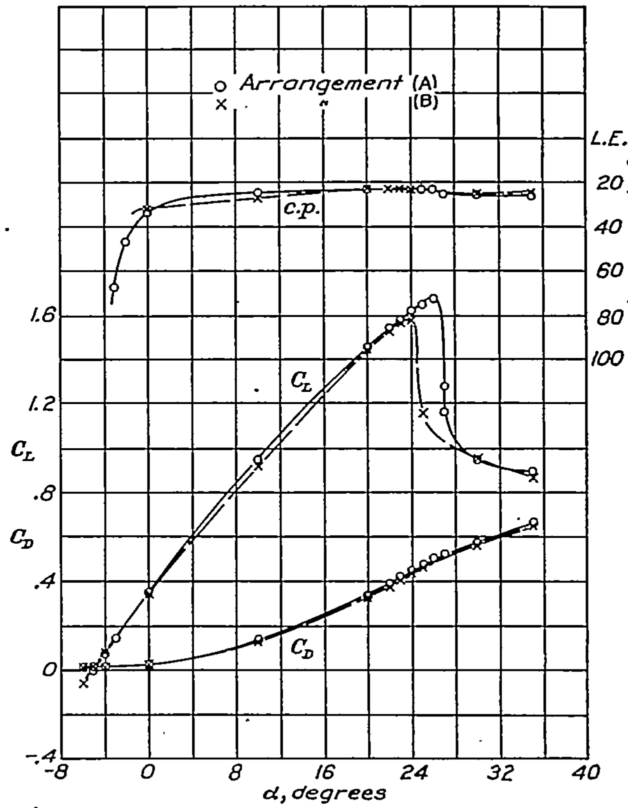
DIVISION OF AIR LOAD BETWEEN MAIN WING AND AUXILIARY AIRFOIL

The results of the tests to show the division of the air load between the main wing and the two selected auxiliary airfoils are shown in figure 20. The load on the auxiliaries is divided into normal and chord components and these are given in terms of the total lift on the main wing plus the auxiliary. The auxiliary airfoil having the symmetrical section sustained in the neighborhood of one fifth of the total load throughout the entire angle-of-attack range tested. The highly cambered N.A.C.A. 22 auxiliary airfoil sustained about the same portion of the total load at the high lift coefficients, but a higher proportion if the angle of attack was reduced. At $\alpha=0°$ the lowest angle of attack which could be obtained with the set-up



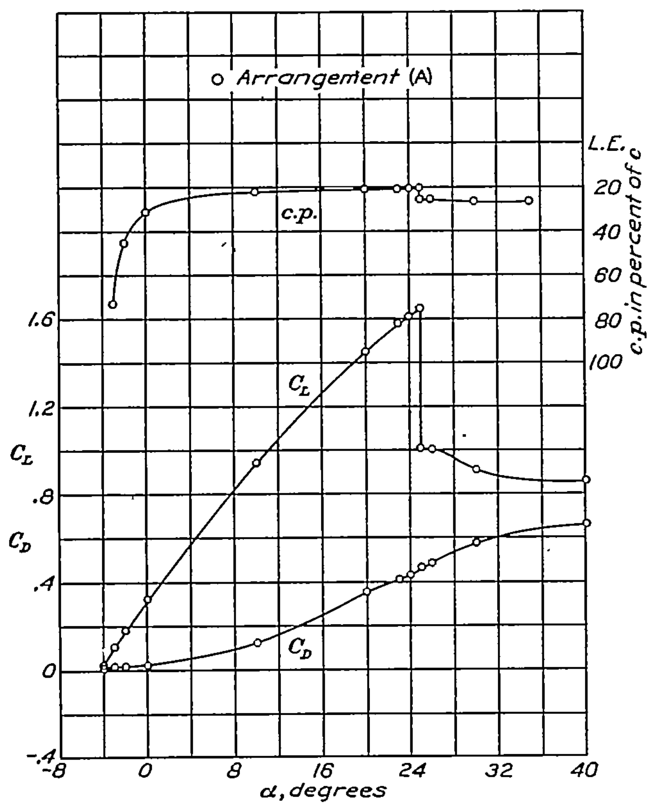
(A) Aux. T.E. 16.0 percent ahead of L.E., 4.5 percent above chord, δ=5°.
(B) Aux. T.E. 19.3 percent ahead of L.E., 2.5 percent above chord, δ=2½°.
(C) Aux. T.E. 11.1 percent ahead of L.E., 7.4 percent above chord, δ=10°.

FIGURE 11.—Characteristics with N.A.C.A. 22, 7.5 percent chord auxiliary.



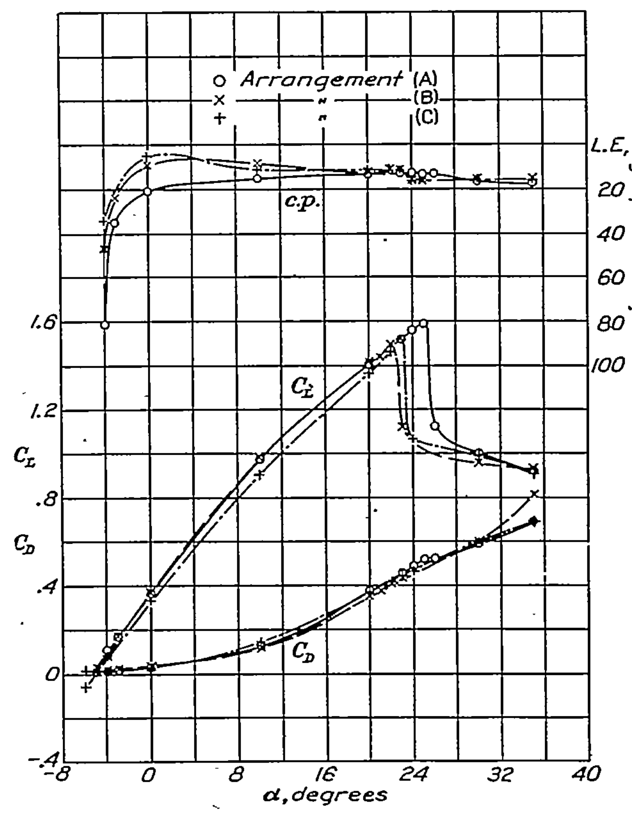
(A) Aux. T.E. 11.5 percent ahead of L.E., 14.0 percent above chord, δ=0°.
(B) Aux. T.E. 16.0 percent ahead of L.E., 4.5 percent above chord, δ=2½°.

FIGURE 12.—Characteristics with N.A.C.A. 22, 11.0 percent chord auxiliary.



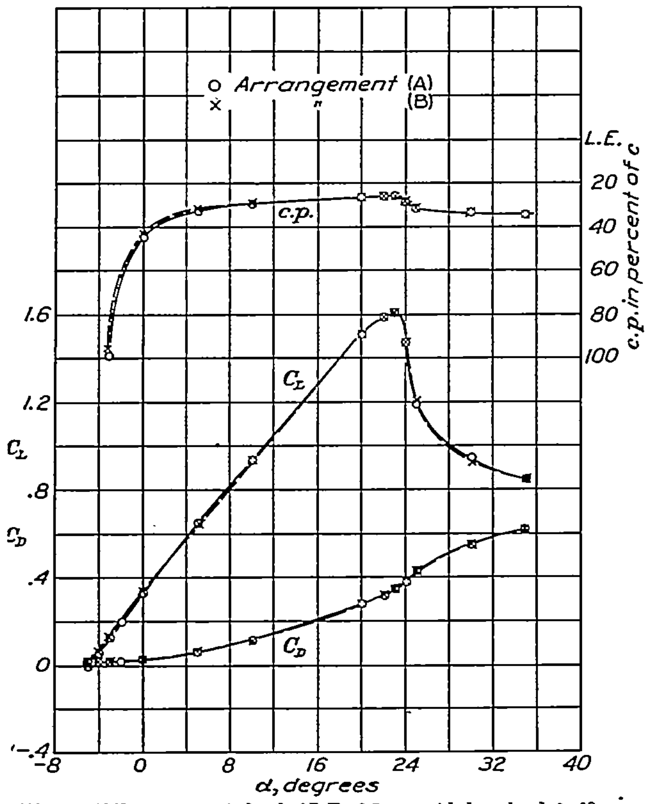
(A) Aux. T.E. 15.2 percent ahead of L.E., 12.0 percent above chord, δ=0°.

FIGURE 13.—Characteristics with N.A.C.A. 22, 14.5 percent chord auxiliary.

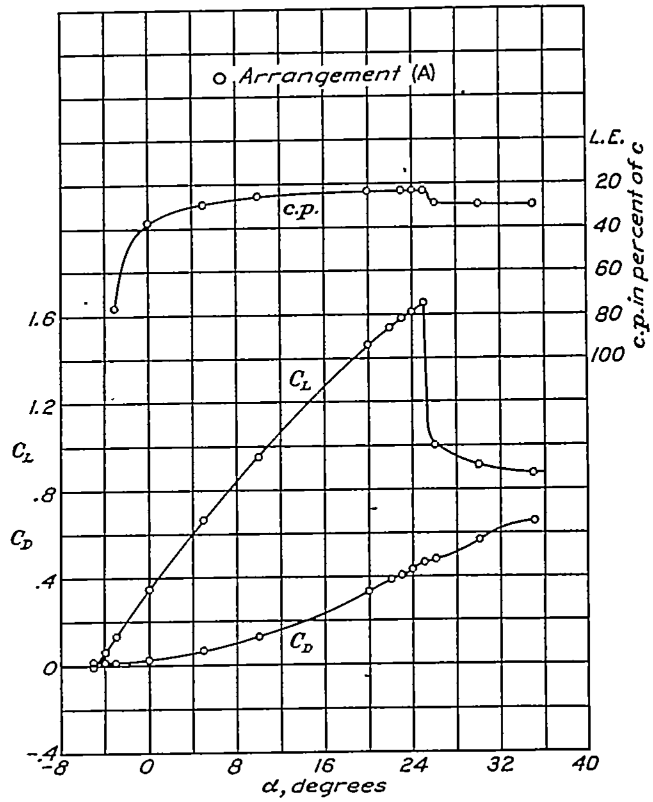


(A) Aux. T.E. 16.0 percent ahead of L.E., 14.0 percent above chord, δ=0°.
(B) Aux. T.E. 27.5 percent ahead of L.E., 14.0 percent above chord, δ=0°.
(C) Aux. T.E. 21.2 percent ahead of L.E., 8.8 percent above chord, δ=2½°.

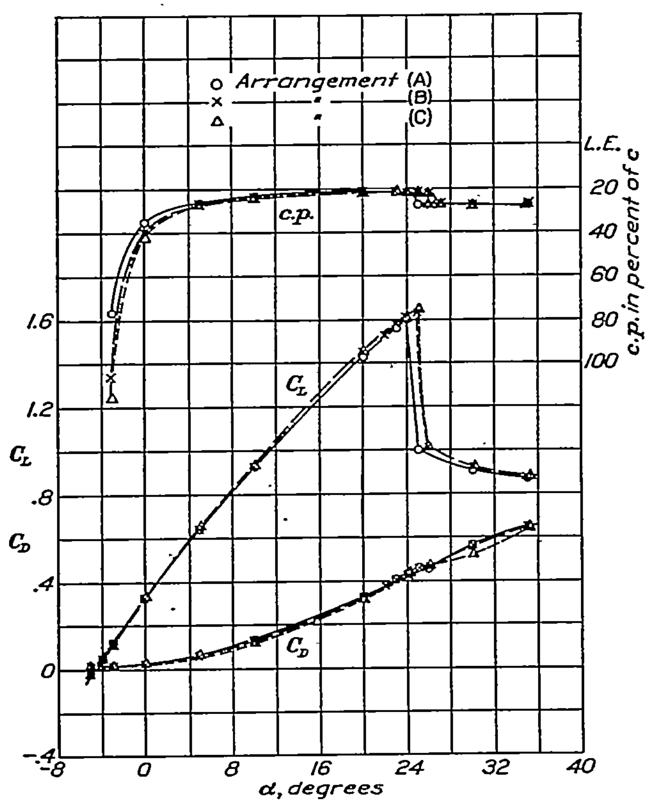
FIGURE 14.—Characteristics with N.A.C.A. 22, 25.0 percent chord auxiliary.



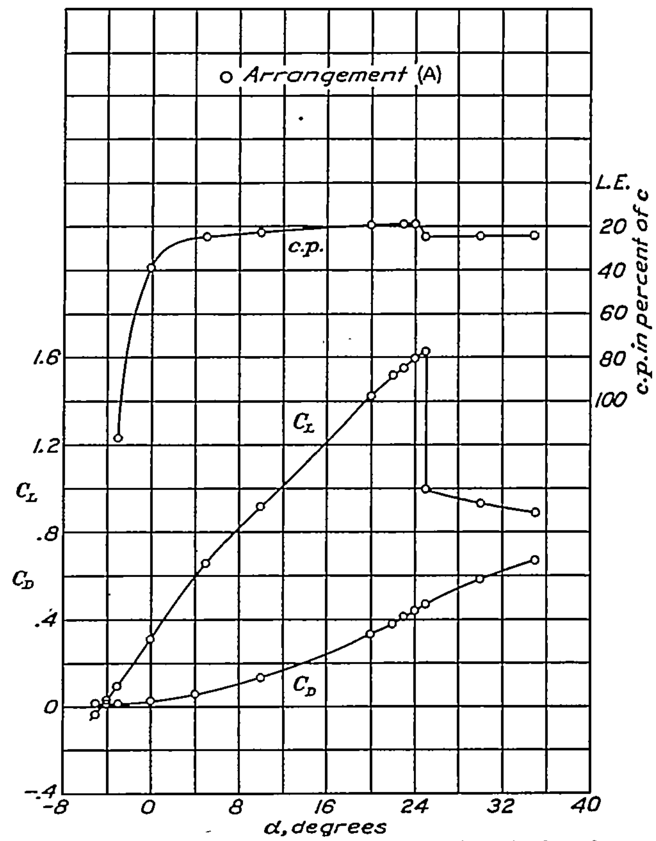
(A) Aux. T.E. 19.3 percent ahead of L.E., 2.5 percent below chord, δ=0°.
(B) Aux. T.E. 19.3 percent ahead of L.E., 2.5 percent below chord, δ=2½°.
FIGURE 15.—Characteristics with N.A.C.A. 0012, 7.5 percent chord auxiliary.



(A) Aux. T.E. 11.5 percent ahead of L.E., 14.0 percent above chord, δ=2½°.
FIGURE 16.—Characteristics with N.A.C.A. 0012, 11.0 percent chord auxiliary.



(A) Aux. T.E. 16.0 percent ahead of L.E., 14.0 percent above chord, δ=2½°.
(B) Aux. T.E. 11.5 percent ahead of L.E., 14.0 percent above chord, δ=0°.
(C) Aux. T.E. 11.5 percent ahead of L.E., 14.0 percent above chord, δ=−2½°.
FIGURE 17.—Characteristics with N.A.C.A. 0012, 14.5 percent chord auxiliary.



(A) Aux. T.E. 16.0 percent ahead of L.E., 14.0 percent above chord, δ=0°.
FIGURE 18.—Characteristics with N.A.C.A. 0012, 18 percent chord auxiliary.

used, approximately half the total load was taken by the N.A.C.A. 22 auxiliary airfoil.

CONCLUSIONS

1. Each of the auxiliary airfoil combinations tested, regardless of size or airfoil section, gave, in the best positions, substantially higher values of $C_{L_{max}}$ and of the ratio $C_{L_{max}}^2/C_{D_{min}}$ than the main wing alone.

2. The maximum values of C_L obtained, based on the total area, were very nearly the same with all the auxiliary airfoils tested.

3. The symmetrical auxiliary airfoils gave lower values of the minimum drag coefficient and higher values of the ratio $C_{L_{max}}^2/C_{D_{min}}$ than the auxiliary airfoils having other sections, the highest value of the ratio $C_{L_{max}}^2/C_{D_{min}}$ being obtained with the 14.5 percent symmetrical auxiliary airfoil.

4. The positions giving the highest values of the ratio $C_{L_{max}}^2/C_{D_{min}}$ did not vary greatly for the auxiliary airfoils of different sizes and sections tested, except for the smallest size, which required a lower position.

5. In most cases within the range of the tests, moving the auxiliary airfoil closer to the main wing than the position giving the highest value of the ratio $C_{L_{max}}^2/C_{D_{min}}$ gave a slight increase in the value of L/D in the climbing range and a decrease in the value of L/D near maximum lift, thus giving a dual increase in the range of possible flight angles.

6. The air load on the 14.5 percent symmetrical auxiliary airfoil was about one fifth the total air load on the combination at all angles of attack; the proportional air load on the highly cambered auxiliary airfoil was about the same at the high values of the lift coefficient, but approximately half the total air load at low values of the lift coefficient.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., *June 10, 1933.*

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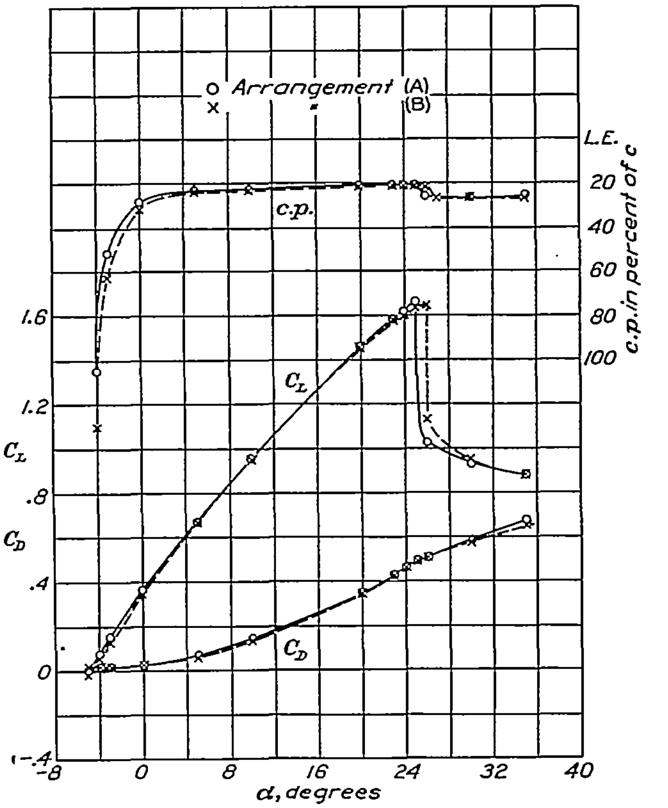
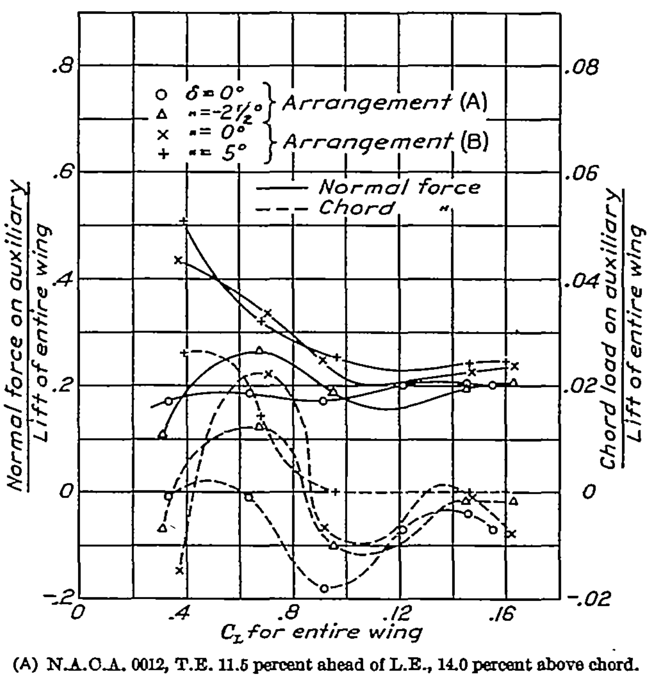
2. Wenzinger, Carl J., and Harris, Thomas A.: The Vertical Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 387, N.A.C.A., 1931.
3. Weick, Fred E., and Noyes, Richard W.: Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. X. Various Control Devices on a Wing with a Fixed Auxiliary Airfoil. T.N. No. 451, N.A.C.A., 1933.



(A) Aux. T.E. 16.0 percent ahead of L.E., 14.0 percent above chord, δ=2½°.
(B) Aux. T.E. 11.5 percent ahead of L.E., 14.0 percent above chord, δ=0°.
FIGURE 19.—Characteristics with Clark Y, 14.5 percent chord auxiliary.



(A) N.A.C.A. 0012, T.E. 11.5 percent ahead of L.E., 14.0 percent above chord.
(B) N.A.C.A. 22, T.E. 15.2 percent ahead of L.E., 12.0 percent above chord.
FIGURE 20.—Normal and chord components of the force on 14.5 percent chord auxiliary airfoils.

TABLE I.—CHARACTERISTICS AND CRITERIONS FOR AN N.A.C.A. 22, 7.5 PERCENT AUXILIARY WITH A CLARK Y WING

Position of T.E. of auxiliary airfoil		δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for $C_L=0.7$	$\frac{L}{D}$ for $C_{L_{max}}$
Ahead	Above								
Percent c	*Percent c*	*Degrees*			*Degrees*				
16.0	14.0	5	0.0187	1.458	21	78	114	11.1	4.42
		7½	.0185	1.462	21	79	116	10.0	4.27
		12½	.0185	1.478	21	80	118	7.6	4.06
11.5	14.0	2½	.0188	1.560	24	84	130	10.4	3.84
		5	.0188	1.602	25	85	137	10.4	3.61
		7½	.0185	1.602	25	87	139	10.1	3.54
		10	.0196	1.620	25	83	134	8.9	3.47
		12½	0199	1.602	25	81	129	8.6	3.37
27.5	14.0	0	.0184	1.400	20	76	107	10.8	5.19
		2½	.0170	1.374	22	79	109	13.0	4.07
		5	.0187	1.390	20	74	103	11.7	4.81
21.2	8.8	0	.0201	1.415	23	70	100	12.1	3.94
		2½	.0185	1.420	23	77	109	14.0	3.86
		5	.0180	1.415	23	79	111	12.1	3.74
		7½	.0191	1.510	22	79	119	10.8	4.18
		10	.0201	1.563	23	78	122	10.0	3.74
		12½	.0199	1.551	23	78	121	18.4	3.96
16.0	4.5	2½	.0160	1.523	21	95	145	12.1	4.62
		5	.0174	1.646	25	95	157	10.9	3.85
		7½	.0168	1.605	24	96	153	10.0	3.96
7.5	9.6	0	.0204	1.563	25	77	120	10.0	3.45
		2½	.0199	1.563	26	79	123	9.9	3.21
		5	.0204	1.522	25	75	114	9.9	3.24
10.7	0.0	0	.0185	1.401	24	76	106	11.3	3.80
		5	.0157	1.340	23	86	114	11.3	3.79
		7½	.0163	1.380	24	85	117	11.8	3.69
		12½	.0166	1.323	23	80	106	11.3	3.66
19.3	−2.5	−5	.0218	1.628	23	75	121	14.0	4.92
		0	.0177	1.620	24	92	149	11.1	4.33
		2½	.0171	1.615	24	94	153	10.6	4.39
		5	.0177	1.598	24	91	145	10.6	4.19
11.1	7.4	0	.0196	1.640	25	84	137	9.7	3.82
		5	.0185	1.618	25	87	141	10.3	3.58
		7½	.0182	1.605	25	88	142	9.3	3.48
		10	.0191	1.575	25	83	130	8.9	3.26

TABLE II. CHARACTERISTICS AND CRITERIONS FOR AN N.A.C.A. 22, 11.0 PERCENT AUXILIARY WITH A CLARK Y WING

Position of T.E. of auxiliary airfoil		δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for $C_L=0.7$	$\frac{L}{D}$ for $C_{L_{max}}$
Ahead	Above								
Percent c	*Percent c*	*Degrees*			*Degrees*				
7.50	22.5	−5	0.0172	1.470	22	85	126	12.5	4.26
		−2½	.0161	1.480	22	92	136	11.5	4.08
		0	.0172	1.492	22	87	129	10.8	3.94
16.0	18.9	−5	.0203	1.435	21	71	102	12.3	4.60
		0	.0169	1.452	21	86	124	12.5	4.27
		2½	.0169	1.465	21	87	128		4.30
		5	.0185	1.474	21	80	117	11.9	3.97
16.0	14.0	−5	.0201	1.481	22	74	109	14.0	4.32
		0	.0172	1.532	22	89	136	13.5	4.14
		2½	.0172	1.571	23	91	143	13.7	3.79
		5	.0183	1.610	24	88	142	12.7	3.41
11.5	14.0	−5	.0209	1.650	25	79	130	10.9	3.69
		0	.0183	1.678	26	92	154	10.9	3.34
		2½	.0183	1.660	26	91	151	10.9	3.22
		5	.0191	1.610	25	84	136	10.9	3.20
27.5	14.0	−5	.0211	1.395	20	66	93	13.5	5.03
		0	.0185	1.410	20	76	107	10.9	4.70
		2½	.0182	1.420	20	78	111	10.8	4.44
		5	.0185	1.426	20	77	111	10.9	4.34
21.2	8.8	0	.0180	1.510	21	84	127	13.7	4.47
		2½	.0182	1.558	22	86	134	12.3	4.15
		5	.0180	1.545	22	86	132	13.2	3.99
16.0	4.5	−5	.0225	1.605	23	72	115	15.9	4.34
		0	.0175	1.580	23	90	143	8.9	3.97
		2½	.0167	1.584	24	95	150	9.0	3.56
		5	.0178	1.571	24	88	138	9.0	3.58
7.5	9.6	−5	.0215	1.542	25	72	111	10.1	3.20
		−2½	.0201	1.525	25	76	116	9.7	3.27
		0	.0191	1.480	27	78	115		2.79
		5	.0209	1.425	25	68	97	13.7	2.85
11.1	7.4	−5	.0225	1.648	25	73	121	12.7	3.77
		0	.0190	1.597	25	84	134	12.1	3.47
		5	.0172	1.558	26	91	141	10.9	3.03
		7½	.0175	1.520	25	87	132	10.9	3.07

TABLE III. CHARACTERISTICS AND CRITERIONS FOR AN N.A.C.A. 22, 14.5 PERCENT AUXILIARY WITH A CLARK Y WING

Position of T.E. of auxiliary airfoil		δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for $C_L=0.7$	$\frac{L}{D}$ for $C_{L_{max}}$
Ahead	Above								
Percent c	*Percent c*	*Degrees*			*Degrees*				
15.2	12.0	0	0.0177	1.650	25	93	154	8.0	3.56

TABLE IV. CHARACTERISTICS AND CRITERIONS WITH N.A.C.A. 22, 25 PERCENT AUXILIARY FOR EACH POSITION TESTED

Position of T.E. of auxiliary airfoil		δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for $C_L=0.7$	$\frac{L}{D}$ for $C_{L_{max}}$
Ahead	Above								
Percent c	*Percent c*	*Degrees*			*Degrees*				
7.5	22.5	−7½	0.0238	1.575	25	66	105	11.9	3.24
		−5	.0186	1.504	24	81	122	11.3	3.12
		0	.0163	1.416	21	87	124	10.0	3.25
16.0	18.9	−5	.0209	1.562	24	75	117	11.7	3.55
		−2½	.0188	1.574	24	84	133	12.3	3.42
		0	.0180	1.550	24	86	133	11.1	3.19
		5	.0180	1.527	24	85	130	9.6	2.85
16.0	14.0	−5	.0207	1.656	26	80	133	10.4	3.27
		−2½	.0185	1.620	25	87	141	11.3	3.30
		0	.0162	1.592	25	98	156	10.4	3.07
		2½	.0178	1.568	25	88	138	9.5	2.98
		5	.0178	1.510	24	85	128	8.1	2.87
11.5	14.0	−5	.0206	1.576	25	77	121	13.2	3.21
		−2½	.0176	1.528	24	87	133	11.5	3.19
		0	.0169	1.470	23	87	128	9.9	3.11
		5	.0169	1.365	21	81	111	8.6	3.05
27.5	14.0	−5	.0200	1.510	23	75	114	----------	3.85
		0	.0156	1.498	22	96	144	10.9	3.71
		2½	.0179	1.534	23	86	131	12.1	3.75
		5	.0179	1.487	22	83	124	11.1	3.39
21.2	8.8	−5	.0211	1.603	25	76	122	10.8	3.49
		0	.0182	1.556	24	86	134	12.1	3.34
		2½	.0168	1.516	23	90	137	9.0	3.41
		5	.0168	1.480	23	98	144	8.3	3.08
16.0	4.5	−5	.0207	1.516	25	73	112	11.1	3.43
		−2½	.0169	1.470	24	87	128	10.1	3.46
		0	.0155	1.405	23	90	127	10.3	3.44
		5	.0155	1.281	20	83	106	9.5	3.55

TABLE V. CHARACTERISTICS AND CRITERIONS FOR AN N.A.C.A. 0012, 7.5 PERCENT AUXILIARY WITH A CLARK Y WING

Position of T.E. of auxiliary airfoil: Ahead	Position of T.E. of auxiliary airfoil: Above	δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for $C_L=0.7$	$\frac{L}{D}$ for $C_{L_{max}}$
Percent c	*Percent c*	*Degrees*			*Degrees*				
16.0	14.0	0	0.0163	1.402	20	86	121	10.8	4.93
		5	.0155	1.418	20	91	130	11.3	4.80
		7½	.0152	1.428	20	94	134	9.2	4.65
		12½	.0166	1.434	20	84	120	8.3	4.35
11.5	14.	0	.0161	1.438	21	89	129	10.6	4.57
		5	.0166	1.500	22	90	136	9.5	4.17
		7½	.0164	1.520	22	93	141	8.9	4.12
		10	.0169	1.545	23	91	141	8.4	3.84
		12½	.0180	1.590	24	88	140	7.4	3.53
21.2	8.8	−2½	.0169	1.401	20	81	114	10.3	4.90
		0	.0150	1.383	19	92	128	11.5	5.47
		2½	.0152	1.390	20	91	127	10.6	4.83
		5	.0161	1.420	20	88	125	10.4	4.91
16.0	4.5	0	.0155	1.646	24	106	175	10.9	4.35
		2½	.0149	1.621	23	109	176	10.4	4.45
		5	.0152	1.609	23	106	170	9.9	4.36
		7½	.0160	1.637	24	102	167	9.5	4.07
7.5	9.6	−2½	.0153	1.580	24	103	163	10.9	3.85
		0	.0147	1.545	23	105	162	10.1	3.89
		5	.0158	1.582	25	100	158	8.9	3.35
10.7	0.0	−2½	.0146	1.475	22	101	149	11.9	4.71
		0	.0138	1.470	22	106	157	10.6	4.50
		2½	.0133	1.403	22	105	148	9.5	4.28
		5	.0133	1.407	21	106	149	9.7	4.53
19.3	−2.5	−2½	.0158	1.622	23	103	166	13.0	4.88
		0	.0141	1.610	23	114	184	11.7	4.74
		2½	.0139	1.610	23	116	186	10.9	4.68
		5	.0144	1.600	23	111	178	10.1	4.57
11.1	7.4	−5	.0182	1.660	25	91	151	11.9	4.17
		−2½	.0172	1.670	25	97	162	11.5	3.80
		0	.0172	1.636	25	95	156	10.6	3.67
		5	.0172	1.608	24	94	150	10.4	3.91
20.0	2.1	0	.0160	1.540	22	96	147	11.3	4.87
		5	.0155	1.570	22	101	159	10.0	4.68
		7½	.0155	1.570	22	101	159	9.6	4.61
16.0	−1.5	−2½	.0163	1.602	23	98	157	11.9	4.75
		0	.0152	1.590	23	105	166	11.3	4.65
		2½	.0152	1.582	23	104	165	10.1	4.54
		5	.0152	1.570	23	103	162	9.9	4.41
18.6	−7.1	−2½	.0169	1.570	23	93	146	12.5	4.85
		0	.0163	1.571	23	96	152	12.1	4.82
		2½	.0163	1.512	23	93	140	10.9	4.61
		5	.0163	1.482	22	91	135	10.6	4.72
21.8	−2.8	−2½	.0172	1.570	22	91	143	12.3	5.06
		0	.0161	1.573	22	98	154	11.1	4.97
		2½	.0169	1.570	22	93	146	10.1	4.86
		5	.0169	1.590	23	94	150	9.5	4.49

TABLE VI. CHARACTERISTICS AND CRITERIONS FOR AN N.A.C.A. 0012, 11.0 PERCENT AUXILIARY WITH A CLARK Y WING

Positions of T.E. of auxiliary airfoil: Ahead	Positions of T.E. of auxiliary airfoil: Above	δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for C_L=0.7	$\frac{L}{D}$ for $C_{L_{max}}$
Percent c	*Percent c*	*Degrees*			*Degrees*				
7.5	22.5	−5	0.0153	1.400	20	91	128	12.5	4.98
		0	.0151	1.413	20	94	132	10.1	4.67
		5	.0158	1.426	20	90	129	8.4	4.26
16.0	18.9	0	.0151	1.392	20	92	128	10.8	4.73
		5	.0153	1.408	20	92	130	8.9	4.46
		10	.0151	1.395	20	92	129	9.1	4.42
16.0	14.0	0	.0157	1.413	20	90	127	10.4	4.74
		2½	.0148	1.410	21	95	134	9.7	4.47
		5	.0159	1.461	20	91	130	8.9	4.41
11.5	14.0	0	.0143	1.568	23	110	172	10.0	3.95
		2½	.0143	1.656	25	116	192	9.5	3.58
		5	.0143	1.618	25	113	183	8.6	3.60
		10	.0162	1.614	25	100	161	7.9	3.22
21.2	8.8	0	.0156	1.432	20	92	132	11.1	4.92
		5	.0169	1.508	21	89	135	9.1	4.42
		10	.0164	1.531	22	93	143	8.1	3.89
		12½	.0164	1.536	22	94	144	7.9	3.83
16.0	4.5	0	.0143	1.560	22	109	170	11.3	4.46
		2½	.0140	1.562	22	112	174	9.3	4.27
		5	.0136	1.558	23	114	178	9.0	3.90
		7½	.0144	1.527	22	106	162	8.5	4.00
7.5	9.6	−5	.0157	1.546	24	99	152	12.5	3.65
		−2½	.0154	1.540	24	100	154	10.4	3.53
		0	.0152	1.535	25	101	155	9.3	3.25
		5	.0152	1.468	24	97	142	7.8	3.14
11.1	7.4	−5	.0172	1.610	23	94	151	11.7	4.25
		−2½	.0164	1.598	23	97	156	11.7	4.13
		0	.0156	1.571	23	101	159	10.1	3.96
		5	.0172	1.561	24	91	142	8.4	3.48

TABLE VII. CHARACTERISTICS AND CRITERIONS FOR AN N.A.C.A. 0012, 14.5 PERCENT AUXILIARY WITH A CLARK Y WING

Positions of T.E. of auxiliary airfoil: Ahead	Positions of T.E. of auxiliary airfoil: Above	δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for C_L=0.7	$\frac{L}{D}$ for $C_{L_{max}}$
Percent c	*Percent c*	*Degrees*			*Degrees*				
7.5	22.5	0	0.0151	1.443	21	96	138	10.0	4.23
		5	.0149	1.556	24	104	162	7.6	3.34
		7½	.0154	1.575	25	102	161	6.9	3.08
16.0	18.9	−5	.0159	1.390	20	87	122	12.3	4.90
		−2½	.0149	1.400	21	94	132	12.1	4.42
		0	.0141	1.408	21	100	140	10.6	4.27
		2½	.0149	1.443	21	97	140	9.2	4.13
		5	.0146	1.460	21	97	139	8.3	4.07
16.0	14.0	0	.0129	1.501	22	116	175	11.5	4.15
		2½	.0129	1.603	24	124	199	9.2	3.67
		5	.0131	1.603	24	122	196	8.8	3.58
		7½	.0134	1.593	24	119	190	7.9	3.38
11.5	14.0	−2½	.0139	1.651	25	119	196	11.7	3.65
		0	.0137	1.639	25	120	196	11.1	3.53
		5	.0137	1.613	25	118	190	8.1	3.26
27.5	14.0	0	.0149	1.333	19	89	119	11.5	5.02
		5	.0146	1.370	20	94	129	8.9	4.32
		7½	.0164	1.434	21	87	125	7.9	3.96
21.2	8.8	−5	.0164	1.408	20	86	121	12.5	5.12
		0	.0149	1.485	21	100	148	11.1	4.54
		2½	.0157	1.540	22	98	151	9.5	4.17
		5	.0167	1.534	22	92	141	8.5	4.02
16.0	4.5	−5	.0159	1.550	22	97	151	12.5	4.56
		−2½	.0129	1.537	22	119	183	12.7	4.38
		0	.0126	1.520	22	121	184	10.8	4.15
		5	.0126	1.490	22	118	176	8.3	3.92
7.5	9.6	−7½	.0159	1.504	23	94	142	13.0	3.90
		−5	.0146	1.513	24	103	156	12.3	3.61
		−2½	.0146	1.466	23	100	147	10.9	3.58
		0	.0152	1.440	25	95	137	8.8	3.00
		5	.0156	1.400	25	90	126	7.3	2.79
11.1	7.4	−5	.0154	1.605	24	104	167	12.5	3.91
		−2½	.0142	1.542	23	109	167	11.9	3.96
		0	.0142	1.518	23	107	162	9.9	3.73
		5	.0144	1.480	23	103	153	8.2	3.51

TABLE VIII. CHARACTERISTICS AND CRITERIONS FOR AN N.A.C.A 0012, 18 PERCENT AUXILIARY WITH CLARK Y WING

Position of T.E. of auxiliary airfoil: Ahead	Position of T.E. of auxiliary airfoil: Above	δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for $C_L=0.7$	$\frac{L}{D}$ for $C_{L_{max}}$
Percent c	*Percent c*	*Degrees*			*Degrees*				
7.5	22.5	0	0.0159	1.473	22	93	136	9.5	3.77
		2½	.0159	1.578	25	99	157	8.0	3.14
		5	.0159	1.565	25	98	154	7.1	3.09
		7½	.0161	1.531	24	95	146	6.5	2.96
16.0	18.9	0	.0152	1.440	21	95	136	10.8	4.09
		2½	.0161	1.485	22	92	136	8.5	3.75
		5	.0161	1.488	22	92	137	8.2	3.65
		7½	.0166	1.580	24	95	150	6.6	3.15
		10	.0169	1.530	23	89	139	6.2	3.87
		12½	.0174	1.552	24	88	137	6.1	2.91
16.0	14.0	−2½	.0157	1.560	23	99	155	11.7	4.05
		0	.0155	1.621	25	104	169	11.1	3.48
		2½	.0152	1.550	23	102	158	8.3	3.59
		5	.0157	1.575	24	100	158	7.8	3.32
11.5	14.0	0	.0164	1.600	25	98	156	10.4	3.33
		2½	.0162	1.590	25	98	156	8.0	3.15
		5	.0164	1.580	26	96	152	7.4	3.01
27.5	14.0	0	.0156	1.337	19	86	114	11.3	4.82
		5	.0156	1.395	20	89	125	8.0	4.21
		7½	.0164	1.426	21	87	124.	7.4	3.69
21.2	8.8	−2½	.0166	1.470	21	89	130	11.7	4.51
		0	.0156	1.544	22	99	153	11.3	3.71
		2½	.0166	1.513	22	91	138	9.2	3.99
		5	.0176	1.510	22	86	130	7.5	3.83
16.0	4.5	−2½	.0157	1.483	22	95	141	12.1	4.21
		0	.0149	1.488	22	100	149	11.1	4.02
		2½	.0142	1.468	22	103	152	8.8	3.91
		5	.0144	1.418	21	99	140	11.9	3.92

TABLE IX. CHARACTERISTICS AND CRITERIONS FOR A CLARK Y, 14.5 PERCENT AUXILIARY WITH A CLARK Y WING

Position of T.E. of auxiliary airfoil: Ahead	Position of T.E. of auxiliary airfoil: Above	δ	$C_{D_{min}}$	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$	$\frac{(C_{L_{max}})^2}{C_{D_{min}}}$	$\frac{L}{D}$ for $C_L=0.7$	$\frac{L}{D}$ for $C_{L_{max}}$
Percent c	*Percent c*	*Degrees*			*Degrees*				
7.5	22.5	0	0.0156	1.460	25	94	137	11.7	3.06
		2½	.0164	1.470	25	90	132	10.1	2.91
		5	.0174	1.571	25	90	142	7.3	3.05
		7½	.0179	1.555	24	87	135	6.7	3.08
16.0	18.9	0	.0164	1.446	21	88	128	11.7	4.14
		5	.0172	1.502	22	87	131	8.0	3.65
		7½	.0182	1.532	23	84	129	7.2	3.38
16.0	14.0	0	.0159	1.612	24	101	163	11.7	3.73
		2½	.0157	1.616	24	103	166	9.6	3.51
		5	.0162	1.622	25	100	163	8.2	3.23
11.5	14.0	−2½	.0178	1.665	26	93	156	11.7	3.35
		0	.0170	1.647	26	97	159	11.1	3.27
		2½	.0170	1.631	26	96	157	9.2	3.21
		5	.0165	1.608	26	97	157	7.6	2.96
27.5	14.0	0	.0169	1.390	20	82	114	11.9	4.51
		5	.0172	1.443	21	84	121	8.4	3.99
		7½	.0182	1.475	21	81	120	7.7	3.91
21.2	8.8	0	.0182	1.542	22	85	131	11.7	4.27
		5	.0180	1.578	23	88	138	8.5	3.71
		7½	.0180	1.565	23	87	136	7.4	3.57
		10	.0178	1.587	24	89	141	6.9	3.30
		12½	.0193	1.536	23	79	122	6.5	3.25
16.0	4.5	−2½	.0177	1.562	23	88	138	12.1	4.06
		0	.0167	1.548	23	93	144	11.5	3.81
		2½	.0169	1.502	22	94	142	9.3	3.94
		5	.0159	1.480	22	93	138	7.4	3.77
7.5	9.6	−5	.0218	1.500	26	69	103	11.9	2.99
		−2½	.0192	1.470	26	77	113	11.3	2.84
		0	.0192	1.443	26	75	108	11.1	2.75
		5	.0192	1.400	24	73	102	6.7	2.84

TABLE X. CHARACTERISTICS OF A CLARK Y WING WITH VARIOUS AUXILIARIES IN THEIR MOST PROMISING POSITIONS

NO AUXILIARY

α (degrees)	C_L	C_D	C_m 0.25c of main wing
−4	0.047	0.016	−0.077
−3	.111	.015	−.076
−2	.188	.017	−.076
0	.331	.022	−.076
10	.934	.092	−.067
13	1.169	.127	−.065
14	1.222	.140	−.064
15	1.260	.150	−.064
16	1.295	.162	−.064
17	1.333	.180	−.069
18	1.319	.204	−.078
19	1.295	.224	−.086
20	1.275	.250	−.094
30	.911	.552	−.168

N.A.C.A. 22, 25.0 PERCENT AUXILIARY

T.E. of auxiliary 0.16c ahead, 0.14c above, $\delta=0°$

α (degrees)	C_L	C_D	C_m 0.25c of main wing
−5	−0.032	0.024	−0.047
−4	.061	.017	−.033
−3	.145	.018	−.015
0	.363	.038	.016
10	1.015	.129	.100
20	1.412	.370	.165
23	1.521	.444	.194
24	1.555	.476	.196
25	1.590	.507	.199
26	1.114	.535	.147
30	.995	.582	.100
35	.935	.685	.089

N.A.C.A. 0012, 14.5 PERCENT AUXILIARY

T.E. of auxiliary 0.115c ahead, 0.14c above, $\delta=0°$

α (degrees)	C_L	C_D	C_m 0.25c of main wing
−5	−0.040	0.017	−0.094
−4	.035	.016	−.089
−3	.100	.017	−.081
0	.310	.022	−.040
5	.664	.061	−.013
10	.954	.132	.004
20	1.468	.333	.045
23	1.578	.411	.051
24	1.630	.439	.053
25	1.660	.469	.055
26	1.685	.495	.058
27	1.000	.496	−.025
30	.937	.554	−.026
35	.889	.642	−.026

N.A.C.A. 22, 7.5 PERCENT AUXILIARY

T.E. of auxiliary 0.150c ahead, 0.045c above, $\delta=5°$

α (degrees)	C_L	C_D	C_m 0.25c of main wing
−6	−0.084	0.020	−0.071
−5	−.019	.018	−.064
−4	.046	.018	−.059
−3	.117	.019	−.055
0	.305	.029	−.036
10	.916	.121	−.025
20	1.474	.311	−.004
23	1.578	.381	−.001
24	1.632	.405	.000
25	1.191	.444	−.056
30	.968	.553	−.072
35	.876	.647	−.088

T.E. of auxiliary 0.212c ahead, 0.088c above, $\delta=2\frac{1}{2}°$

α (degrees)	C_L	C_D	C_m 0.25c of main wing
−6	−0.061	0.020	−0.051
−5	.023	.017	−.028
−4	.091	.017	−.008
0	.332	.028	.065
10	.903	.144	.126
20	1.361	.367	.193
22	1.463	.417	.205
23	1.518	.445	.213
24	1.064	.464	.114
30	.989	.595	.114
35	.903	.695	.107

T.E. of auxiliary 0.115c ahead, 0.14c above, $\delta=-2\frac{1}{2}°$

α (degrees)	C_L	C_D	C_m 0.25c of main wing
−5	−0.039	0.018	−0.097
−4	.031	.017	−.093
−3	.095	.017	−.086
0	.306	.023	−.054
5	.664	.055	−.016
10	.955	.128	−.001
20	1.461	.322	.042
24	1.631	.429	.051
25	1.660	.457	.049
26	1.696	.484	.052
28	1.010	.464	−.029
30	.929	.551	−.033
35	.894	.637	−.030

T.E. of auxiliary 0.193c ahead, 0.025c below, $\delta=2\frac{1}{2}°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−4	0.054	0.017	−0.068
−3	.122	.017	−.061
−2	.196	.019	−.056
0	.321	.024	−.050
10	.887	.106	−.028
20	1.469	.288	−.012
23	1.585	.350	−.010
24	{1.618 1.450	} .374	{−.018 −.015
25	1.418	.415	−.040
30	.993	.534	−.080
35	.870	.629	−.096

T.E. of auxiliary 0.275c ahead, 0.14c above, $\delta=0°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.009	0.019	−0.035
−4	.061	.017	−.013
−3	.145	.017	.002
0	.349	.026	.055
10	.965	.114	.164
20	1.397	.343	.190
22	1.480	.391	.203
23	1.516	.415	.207
24	1.111	.447	.113
25	1.043	.474	.110
30	.960	.585	.109
35	.934	.691	.115

T.E. of auxiliary 0.16c ahead, 0.14c above, $\delta=2\frac{1}{2}°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.023	0.016	−0.090
−4	.049	.016	−.079
−3	.127	.017	−.065
0	.335	.024	−.033
5	.660	.069	−.011
10	.960	.137	.010
20	1.460	.335	.054
23	1.590	.410	.061
24	1.620	.442	.063
25	1.048	.469	−.021
30	.931	.572	−.021
35	.882	.656	−.019

TABLE X. CHARACTERISTICS OF A CLARK Y WING WITH VARIOUS AUXILIARIES IN THEIR MOST PROMISING POSITIONS—Continued

N.A.C.A. 22, 11.0 PERCENT AUXILIARY

T.E. of auxiliary 0.115c ahead, 0.14c above, $\delta=0°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.050	0.023	−0.062
−4	.045	.019	−.054
−3	.111	.018	−.047
−2	.185	.019	−.041
0	.320	.025	−.027
10	.929	.133	.004
20	1.460	.331	.032
25	1.653	.466	.036
26	1.682	.496	.035
27	1.072	.509	−.041
30	.997	.564	−.041
35	.903	.655	−.050

T.E. of auxiliary 0.16c ahead, 0.045c above, $\delta=2\frac{1}{2}°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−6	−0.063	0.023	−0.075
−5	−.018	.017	−.062
−4	.048	.017	−.052
0	.327	.027	−.024
10	.900	.127	.000
20	1.436	.322	.030
22	1.529	.374	.036
23	1.568	.399	.037
24	1.591	.433	.031
30	.963	.559	.035
35	.945	.643	.043

N.A.C.A. 22, 14.5 PERCENT AUXILIARY

T.E. of auxiliary 0.15c ahead, 0.12c above, $\delta=0°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−4	0.010	0.024	−0.051
−3	.105	.018	−.050
−2	.182	.019	−.040
0	.325	.023	−.021
10	.942	.124	.026
20	1.450	.356	.063
23	1.582	.407	.073
24	1.610	.434	.076
25	1.650	.465	.079
25	1.080	.466	−.003
26	1.014	.484	−.009
30	.909	.574	−.013
35	.861	.661	−.013

N.A.C.A. 0012, 7.5 PERCENT AUXILIARY

T.E. of auxiliary 0.193c ahead, 0.025c below, $\delta=0°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.027	0.017	−0.093
−4	.044	.016	−.084
−3	.112	.016	−.083
0	.325	.023	−.062
5	.633	.052	−.042
10	.920	.103	−.040
20	1.498	.277	−.034
22	1.577	.316	−.027
23	1.605	.341	−.025
24	1.381	.365	−.056
25	1.210	.431	−.088
30	.944	.530	−.095
35	.856	.617	−.109

T.E. of auxiliary 0.193c ahead, 0.025c below, $\delta=2\frac{1}{2}°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.022	0.016	−0.089
−4	.048	.015	−.085
−3	.112	.016	−.078
0	.324	.022	−.059
5	.626	.055	−.041
10	.920	.106	−.040
20	1.492	.284	−.030
22	1.592	.323	−.028
23	1.616	.344	−.026
24	1.558	.376	−.035
25	1.200	.425	−.076
30	.950	.534	−.093
35	.862	.615	−.103

N.A.C.A. 0012, 11.0 PERCENT AUXILIARY

T.E. of auxiliary 0.115c ahead, 0.14c above, $\delta=2\frac{1}{2}°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.020	0.015	−0.079
−4	.055	.015	−.071
−3	.120	.015	−.061
0	.331	.023	−.042
5	.654	.067	−.028
10	.963	.135	−.008
20	1.480	.335	.023
23	1.594	.413	.025
24	1.630	.438	.027
25	1.660	.466	.027
26	1.013	.483	−.048
30	.920	.566	−.054
35	.875	.654	−.055

N.A.C.A. 0012, 18.0 PERCENT AUXILIARY

T.E. of auxiliary 0.16c ahead, 0.14c above, $\delta=0°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.040	0.016	−0.108
−4	.030	.015	−.097
−3	.093	.015	−.085
0	.312	.022	−.013
5	.670	.057	.005
10	.933	.134	.023
20	1.446	.333	.079
23	1.565	.406	.088
24	1.590	.439	.091
25	.973	.458	.000
30	.910	.573	.004
35	.870	.659	.009

CLARK Y, 14.5 PERCENT AUXILIARY

T.E. of auxiliary 0.115c ahead, 0.14c above, $\delta=0°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.010	0.018	−0.071
−4	.059	.017	−.062
−3	.135	.017	−.051
0	.357	.025	−.024
5	.705	.058	.008
10	.973	.141	.016
20	1.473	.352	.056
24	1.619	.458	.063
25	1.654	.490	.064
26	1.630	.522	.064
27	1.042	.516	−.014
30	.967	.567	−.018
35	.896	.663	−.019

T.E. of auxiliary 0.16c ahead, 0.14c above, $\delta=2\frac{1}{2}°$

α	C_L	C_D	C_m 0.25c of main wing
Degrees			
−5	−0.003	0.017	−0.061
−4	.065	.017	−.051
−3	.151	.018	−.041
0	.369	.027	−.012
5	.690	.069	.011
10	.965	.146	.021
20	1.471	.351	.063
23	1.590	.432	.072
24	1.630	.460	.073
25	1.656	.490	.074
26	1.018	.503	−.010
30	.944	.593	−.013
35	.944	.680	−.009