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REPORT No. 407

THE CHARACTERISTICS OF A CLARK Y WING MODEL EQUIPPED WITH SEVERAL FORMS OF LOW-DRAG FIXED SLOTS

By FRED E. WEICK and CARL J. WENZINGER

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AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length	l	meter	m	foot (or mile)	ft. (or mi.)
Time	t	second	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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THE CHARACTERISTICS OF A CLARK Y WING MODEL EQUIPPED WITH SEVERAL FORMS OF LOW-DRAG FIXED SLOTS

By Fred E. Weick and Carl J. Wenzinger

SUMMARY

This investigation was undertaken to develop a low-drag fixed slot for an airplane wing which would avoid the complications and maintenance difficulties of the present movable-type Handley Page slot. Tests were conducted on a series of fixed slots in an attempt to reduce the minimum drag coefficient without decreasing the maximum lift coefficient or the stalling angle of the slotted wing. The tests were made in the N. A. C. A. 5-foot vertical wind tunnel on a Clark Y basic section having a 10-inch chord.

The best combination of wing and fixed slot that was developed had a maximum lift coefficient of 1.751, which was 34.6 per cent higher than that of the plain wing. The angle of attack for maximum lift was raised 9°, from 15° for the plain wing to 24° for the slotted wing. The minimum drag of the wing with fixed slot was increased 52.6 per cent above that of the plain wing, or a value about 38.8 per cent above that for a slotted wing with the movable slot closed. Fixed slots might also be used at the tips of the wings only, in which case the total drag of an average airplane would be increased very slightly, causing a loss in high speed of only 1 or 2 miles per hour.

INTRODUCTION

The wing slots in use on airplanes at the present time are usually of the automatic or controlled type, the development of which has been due mainly to Lachmann and to Handley Page. When the slot is open, the maximum lift coefficient of the wing is increased greatly and the angle of attack for maximum lift is raised considerably above that of the plain wing. With the slot open, however, the minimum drag of the wing is ordinarily more than three times as great as that of the unslotted wing. This characteristic necessitates closing the slot at low angles of attack if an appreciable loss in high speed is to be avoided. The operation of opening and closing the slots, whether or not performed automatically, requires extra mechanism with its attendant maintenance and weight.

A wing with a fixed slot would therefore appear to have certain advantages over one with a moving slot, the most important of these being greater simplicity and dependability, less weight, less maintenance, and somewhat lower cost. In the present investigation, an attempt has been made to reduce the one great disadvantage of the fixed slot, the high drag at low angles of attack.

The tests were all made using a Clark Y basic section, the shape of the fixed slot being changed systematically until it appeared that the minimum drag could not be reduced further without also reducing the maximum lift coefficient and the angle of attack at which it occurred.

APPARATUS AND TESTS

The present series of force tests was made in the N. A. C. A. vertical wind tunnel, which has a 5-foot diameter open jet. (Reference 1.) The tests were made at the same Reynolds Number as that of a series of standard controllability and stability tests being made in the N. A. C. A. 7 by 10 foot tunnel, which will include further tests with the best fixed slot found. Because the two tunnel air speeds are the same the chords of the wing models were made the same, 10 inches.

On account of the small diameter of the air stream in the vertical tunnel, a full-span wing of aspect ratio 6 could not be tested. Consequently a half-span model and "reflection plane" were used. The main wings, of Clark Y basic section, were made of laminated mahogany; the auxiliary airfoils, because of their small size, were made of aluminum alloy. The ordinates of the wooden sections were held accurate to within ±0.01 inch and those of the metal portion, to within ±0.003 inch. The metal auxiliary airfoils were supported on the main wing at each end by a thin metal plate and, in addition, a small support fastened firmly to the wooden and metal parts at mid span prevented any appreciable deflection of the nose under the applied air loads.

The drag forces were transmitted from the wing to a platform balance above the tunnel by two fine wires which passed through tubes. The lift forces were transmitted by a system of bell cranks and rigid rods to two platform balances mounted on the tunnel test floor. These two balances were so arranged that rolling moments could also be obtained if desired. A detailed description of the arrangement may be found in reference 2.

Force tests were made with the slot fixed open under various conditions, and also with the slot closed and faired with "Plasticine." Several readings were taken at angles of attack at 1° intervals to cover the region of minimum drag, and then the region of maximum lift. Tests were made also at a few intermediate angles of attack, in order to determine the shapes of the lift and drag curves.

The extreme range of angle of attack extended from −6° to +40°, the range for any one combination depending on the stalling angle. The tests were made at a dynamic pressure of 16.37 pounds per square foot, corresponding to an air speed of 80 miles per hour

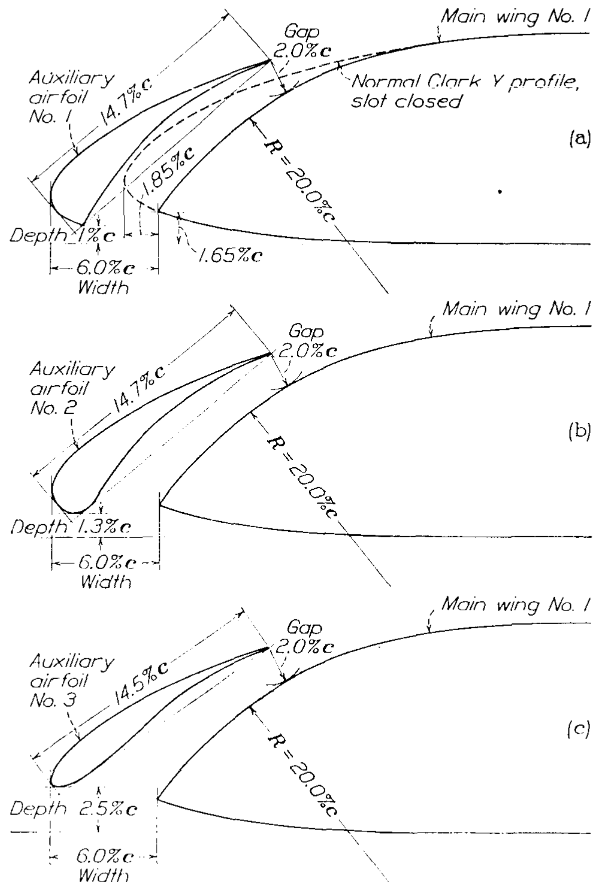

FIGURE 1.—Changes in shape of the auxiliary airfoil

at standard atmospheric conditions. The Reynolds Number based on the above test conditions and the wing chord of 10 inches was 609,000, which is about one-third of that for an ordinary small airplane while landing.

Accuracy.—The lift balances were sensitive to within ±0.06 pound, and the drag balance was sensitive to within ±0.03 pound. The angle-of-attack setting was accurate to ±0.1°, and the dynamic pressure was maintained constant to within ±0.5 per cent. A comparison of the results of check tests showed the variation between values of the maximum lift to be about ±1 per cent; the variation between the minimum drag values amounted to about ±2 per cent.

DEVELOPMENT OF SATISFACTORY FIXED SLOT

The development of the wing with a fixed slot was divided into four main parts: First, the determination of the probable best slot arrangement from the results of previous tests; second, the effect of the auxiliary airfoil shape and position; third, the effect of rounding the nose of the main wing; and fourth, the effect of moving the slot farther back from the leading edge.

1. Choice of the probable best slot arrangement.—The probable best arrangement of the auxiliary airfoil and main wing was obtained from a study of the results of a previous series of tests on a Clark Y wing with an adjustable slot. (Reference 2.) In that investigation the auxiliary airfoil was tested at 100 different locations with respect to the main wing. Tables I to V, inclusive, give the results of those tests in the form of coefficients of maximum lift and minimum drag, angle of attack for maximum lift, and ratio of maximum lift coefficient to minimum drag coefficient for each slot arrangement.

All the above four items were considered in the selection of the best slot arrangement for a wing with a fixed slot. The maximum lift coefficient and angle of attack for maximum lift determine the landing speed and stalling angle, respectively, of the airplane. The minimum drag coefficient is a measure of the high speed attainable, and the ratio of maximum lift to minimum drag gives an indication of the speed range possible.

The conditions chosen, which of necessity were a compromise, may be found in Table II. For the given auxiliary airfoil and main wing combination, the aerodynamic characteristics were:

Maximum lift coefficient = 1. 684
Angle of attack for $C_{L max}$ = 27°
Minimum drag coefficient = 0. 028
Ratio of $C_{L max}$ to $C_{D min}$ = 60. 1

The geometric characteristics, defined as in Figure 1a, were:

Slot gap = 2.0 per cent chord.
Slot depth = 1.0 per cent chord above main wing chord.
Slot width = 6.0 per cent chord.

The location of the auxiliary airfoil with respect to the main wing for the above conditions is shown to scale in the above-mentioned figure. The ordinates for the auxiliary airfoil (No. 1) are given in Table VI.

2. Effect of auxiliary airfoil shape and position.—An inspection of the shape of auxiliary airfoil No. 1 (fig. 1a) indicated that its minimum drag would probably be reduced by rounding the sharp lower edge. This edge was rounded and the auxiliary airfoil then had the shape shown in Figure 1b, the ordinates of which are given in Table VI. The slot arrangement was kept as near like that of the wing with auxiliary airfoil No. 1 as possible by keeping the trailing edge and unchanged upper surface of the auxiliary airfoil always in the same location.

The results of the tests on the wing model with the above rounded auxiliary airfoil are given in Table VII. The maximum lift coefficient was reduced slightly and the minimum drag coefficient of the combination was increased a small amount from the values of the first combination. These changes therefore gave a somewhat lower ratio of $C_{L_{max}}$ to $C_{D_{min}}$. The angle of attack for maximum lift was unaffected.

An auxiliary airfoil was then designed that in itself would have a relatively low minimum drag. This auxiliary airfoil (No. 3) with the corresponding slot arrangement is shown in Figure 1c. The upper surface, which was unchanged for all three of the auxiliary airfoils, and the trailing edge were kept in the same location as that used for auxiliary airfoils Nos. 1 and 2. The ordinates for this auxiliary airfoil are given in Table VI.

The test results of the wing with auxiliary airfoil No. 3 are given in Table VII. The maximum lift coefficient was reduced considerably and the minimum drag coefficient was the same as that of the wing with auxiliary airfoil No. 1. The ratio of $C_{L_{max}}$ to $C_{D_{min}}$ was the lowest of all three of the combinations tested. The angle of attack for maximum lift was decreased by 3°.

The conclusion may be drawn from the results of the foregoing tests that reducing the minimum drag of the auxiliary airfoil does not necessarily cause a reduction in the minimum drag of the wing-slot combination, but may actually cause an increase. A decrease in the maximum lift coefficient and in the angle of attack for maximum lift may also occur. The results indicated that the reduction in the minimum drag of the auxiliary airfoil was not the proper line of attack to pursue in reducing the minimum drag of the wing-slot combination. It appeared that the sharp lower edge of auxiliary airfoil No. 1 was probably advantageous in that the air could break away from it and flow on to the main wing with the least disturbance. The next step was therefore an attempt to reduce the minimum drag of the wing and auxiliary airfoil by reducing the drag of the combination as a whole.

The next slot was designed in a wing having an over-all contour of a Clark Y, which has a relatively low minimum drag coefficient. The slot was cut through the wing in such a manner that at low angles of attack the air would flow past with as little disturbance as possible. The auxiliary airfoil No. 1 was used together with main wing No. 1 cut off to form main wing No. 2 as shown by Figure 2, with a sharp nose on the main wing portion. The test results for this condition of the slotted wing are given in Table VIII, first line below "Slot closed." It will be seen that the maximum lift coefficient has remained nearly the same as that of the best previous slot, but the angle of attack for maximum lift was reduced from 27° to 24°. The minimum drag coefficient was decreased appreciably from the best previous value and the ratio of $C_{L_{max}}$ to $C_{D_{min}}$ was increased, indicating that the new slot arrangement was a step in the right direction.

3. Effect of rounding nose of main wing.—The most promising way to reduce the minimum drag still further appeared to be by rounding the sharp leading edge of the main wing. This was done in successive steps, the largest radius of curvature being 2.5 per cent of the total wing chord. (See fig. 2.) The results of the tests of these arrangements are listed in Table VIII. It will be noted that the maximum lift coefficient was increased appreciably by the first small rounding of the sharp leading edge but that further rounding had little effect. No effect was noticeable on the angle of attack for maximum lift. As the nose radius of the main wing No. 2 was increased,

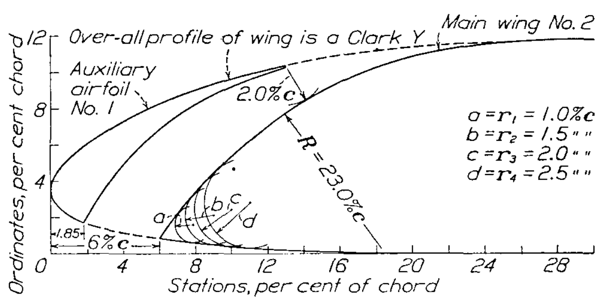

FIGURE 2.—Changes in shape of nose of main wing. Slot through Clark Y wing

the minimum drag of the slotted wing decreased at first to a certain point and then increased again. The ratio of $C_{L_{max}}$ to $C_{D_{min}}$ also increased to a certain point and then decreased again with increased rounding of the nose of the main wing. The best over-all characteristics of this slotted wing were obtained when the nose of the main wing was rounded by a radius of 2 per cent of the total wing chord. (See Table VIII) It may therefore be stated that rounding the nose of the main wing by a radius of about 2 to 3 per cent of the chord produces a favorable effect on the aerodynamic characteristics of the fixed slot combination.

4. Effect of moving slot farther back.—The slot was moved back farther from the leading edge of the wing in an attempt to reduce the minimum drag of the wing to a still lower value than was obtained with the above fixed slot. The new slot had the same general geometric characteristics. Auxiliary airfoil No. 1–A was formed from auxiliary airfoil No. 1 by adding "Plasticine" to the under surface. Main wing No. 3 was formed by altering the shape of main wing No. 2 to a section having a sharp nose. (See fig. 3 for details of this slot.)

The first test was made with the sharp nose on the main wing. The results showed the minimum drag to be the same as that of the best foregoing fixed slot combination for similar conditions. (Table VIII.)

The nose of the main wing was then rounded successively to a maximum radius of curvature of 3 per cent of the whole wing chord (fig. 3), and tested for five intermediate nose curvatures.

The results of the tests are given in Table VIII under the heading: Auxiliary Airfoil No. 1-A, and

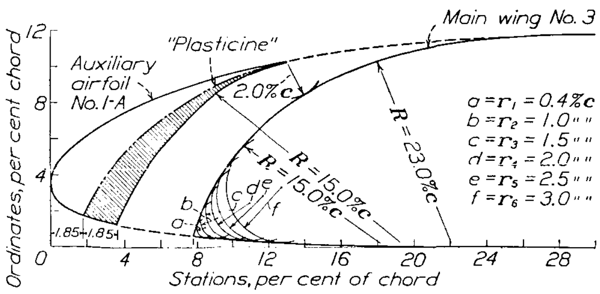

FIGURE 3.—Changes in shape of nose of main wing. Slot moved back in Clark Y wing

Main Wing No. 3. The maximum lift coefficient obtained by rounding the nose of the main wing in this arrangement was about the same as that of the wing with the best fixed slot obtained so far. (Main wing No. 2 and auxiliary airfoil No. 1.) The angle of attack for maximum lift remained the same as before, 24°. The minimum drag of this fixed slot combination decreased to a certain value and then increased again as before with increase in the rounding of the nose of the main wing. The lowest minimum drag coefficient, however, was slightly higher and the ratio of $C_{L\max}$ to $C_{D\min}$ was slightly lower than for the wing with the best fixed slot so far obtained. Placing the slot farther back from the leading edge of the wing within the range of the tests may be said to have no appreciable effect on the aerodynamic characteristics. Since reference 3 showed that little was to be gained by moving the slot back still farther, the best slot of those tested was taken as a sufficiently close approach to the best obtainable.

DISCUSSION

The best fixed slot combination is drawn to scale in Figure 4a. The lift and drag coefficients of both the plain and slotted wings are plotted against angle of attack in Figure 4b. It will be seen that at a given angle of attack up to the stalling angle of the plain wing, the lift of the slotted wing is somewhat lower and the drag is higher than the corresponding values for the plain wing. Beyond this angle, however, and up to the stall of the slotted wing the drag of the slotted wing is lower than that of the plain wing.

The maximum lift coefficient given by the slotted wing was 1.751 (Table VIII) compared with 1.297 for the plain wing—an increase of 34.6 per cent. An increase of 21.8 per cent has been obtained in some earlier tests made by Lachmann (reference 3) on a Göttingen 422 wing equipped with a fixed slot near the leading edge.

In a previous series of tests made at this laboratory (reference 2) on a Clark Y wing with a movable type of slot, the highest maximum lift coefficient obtained was 1.835 (Table II) compared with 1.297 for the plain wing. These values gave an increase in the maximum lift of 41.5 per cent. The coefficients, however, were computed on the basis of the area of the original wing. Figured on the actual plan-form area with the slot open, the maximum lift coefficient becomes 1.660, an increase over the plain wing of only about 28 per

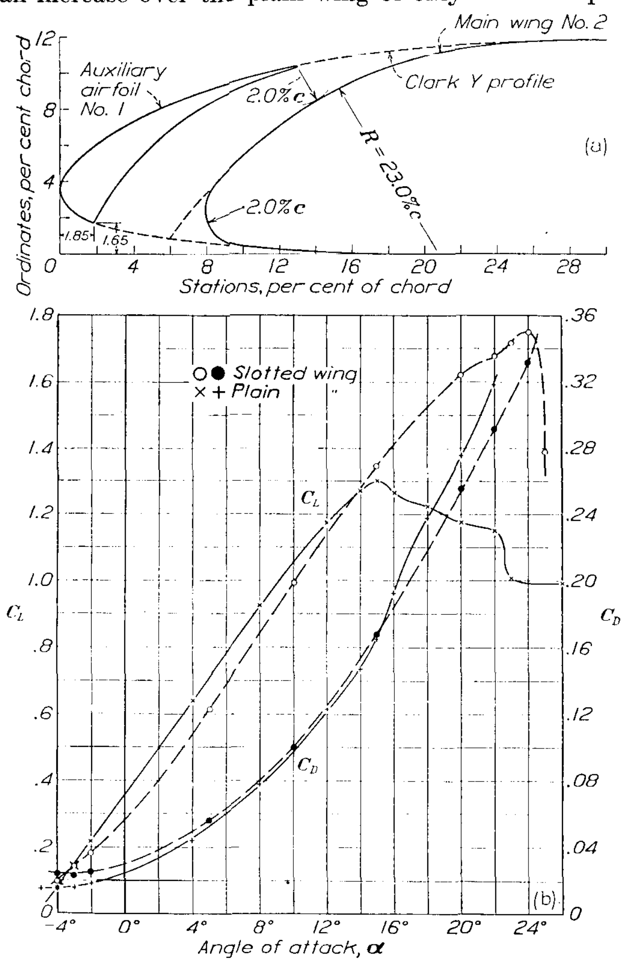

FIGURE 4.—Characteristics of Clark Y wing with best fixed slot

cent. It appears, therefore, that the present fixed slot has a greater effect on the maximum lift. The angle of attack for maximum lift has been increased 9° (from 15° to 24°) with the fixed slot, compared with an increase of 13° (from 15° to 28°) obtained with the movable slot giving the highest maximum lift coefficient.

The minimum drag coefficient of the wing with fixed slot was 0.0229 (Table VIII) compared with 0.0150 for the plain wing, giving an increase of 52.6 per cent.

The results previously mentioned of the tests on the Göttingen 422 slotted wing showed an increase in the minimum drag coefficient of about 85 per cent over the value for that plain wing. If the minimum drag value of the plain Clark Y wing is increased by 10 per cent to correspond with the minimum drag of a wing with movable type of slot closed (reference 4), the increase in minimum drag of the wing with fixed slot then becomes 38.8 per cent of the value for the wing with movable slot closed.

It is interesting to consider the effect of placing the best fixed slot in an ordinary Clark Y wing of an average airplane. Judging by the speed range ratio ($C_{L_{max}}/C_{D_{min}}$) of 76.4 for the slotted wing as compared with 86.4 for the plain wing, it might be expected that an airplane with the slotted wing would have a smaller actual ratio of maximum to minimum speeds. If, however, the entire airplane is unchanged except for the addition of the fixed slot, the speed range is not reduced. The drag of the rest of the airplane is much greater than that of the wing alone at high speed, and the relative decrease in the maximum speed would be appreciably smaller than the reduction in the minimum speed which is dependent almost entirely on the wing alone.

Although the speed range would thus be increased by the fixed slot if the wing area were held constant, it would not be increased if the minimum speeds were kept the same. If the area of the plain Clark Y wing were enlarged to give the same minimum speed as with the fixed slot, and the rest of the airplane could be left unchanged, the maximum speed would be slightly higher with the plain wing. When the extra weight of the larger wing and the extra tail size are taken into account, the higher speed with the plain wing would be very slight if existent at all. For airplanes having low landing speeds and excessively large wings the fixed slot enables the attainment of the desired minimum speed with a smaller wing and little if any loss in high speed.

The foregoing discussion deals with a fixed slot extending along the entire span of the wing. Fixed slots might also be used at the tips of the wings only, say the outer 40 per cent of the semispan, for improving lateral stability and control at the high angles of attack. With this arrangement, the increase in drag would be very small compared to the total drag of an average airplane so that the maximum speed of the airplane would be decreased by only one or two miles per hour.

CONCLUSIONS

1. A maximum lift coefficient of 1.751, an angle of attack for maximum lift of 24°, and a minimum drag coefficient of 0.0229 were obtained for a Clark Y wing with the best fixed slot developed, compared with the corresponding values of 1.297, 15°, and 0.0150 for the plain wing.

2. Fixed slots might be used at the wing tip only to improve lateral stability and control at large angles of attack, in which case the maximum speed of the average airplane would be decreased by only one or two miles per hour.

3. For airplanes having low landing speeds and excessively large wings the fixed slot enables the attainment of the desired minimum speed with a smaller wing and little if any loss in high speed.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *August 27, 1931.*

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TABLE I

SLOTTED CLARK Y WING RESULTS

MOVABLE TYPE SLOT

R. N.=609,000 10-inch chord—c. 80 m. p. h.

Test No.	Gap [1] per cent c.	Depth [1] per cent c.	Width [1] per cent c.	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$ degrees	$C_{D_{min}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$
0	Plain wing			1.297	15.0	0.015	86.4
1	1.5	3.5	3.4	1.519	23.0	.027	56.2
2	1.5	3.5	6.0	1.527	19.0	.021	72.7
3	1.5	3.5	9.0	1.355	15.0	.024	56.4
4	1.5	3.5	12.0	1.073	10.0	.031	34.6
5	1.5	3.5	15.0	1.041	25.0	.037	28.2
6	1.5	1.0	3.4	1.290	29.0	.029	44.5
7	1.5	1.0	6.0	1.671	25.0	.028	59.7
8	1.5	1.0	9.0	1.645	21.0	.031	53.1
9	1.5	1.0	12.0	1.421	16.0	.037	38.4
10	1.5	1.0	15.0	1.164	21.0	.044	26.5
11	1.5	−1.5	3.4	1.248	35.0	.048	26.0
12	1.5	−1.5	6.0	1.635	32.0	.043	38.0
13	1.5	−1.5	9.0	1.781	27.0	.039	45.7
14	1.5	−1.5	12.0	1.621	21.0	.046	35.2
15	1.5	−1.5	15.0	1.302	14.0	.057	22.8
16	1.5	−4.0	3.4	1.298	41.0	.064	20.3
17	1.5	−4.0	6.0	1.582	39.0	.058	27.3
18	1.5	−4.0	9.0	1.820	32.0	.052	35.0
19	1.5	−4.0	12.0	1.757	24.0	.054	32.5
20	1.5	−4.0	15.0	1.558	19.0	.064	24.3

[1] Terms defined in Figure 1a.

TABLE II

SLOTTED CLARK Y WING RESULTS

MOVABLE TYPE SLOT

R. N.=609,000 10-inch chord—c. 80 m. p. h.

Test No.	Gap per cent c.	Depth per cent c.	Width per cent c.	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$ degrees	$C_{D_{min}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$
0	Plain wing			1.297	15.0	0.015	86.4
21	2.0	3.5	3.4	1.482	24.0	.035	42.3
22	2.0	3.5	6.0	1.630	21.0	.024	67.9
23	2.0	3.5	9.0	1.451	16.0	.023	63.1
24	2.0	3.5	12.0	1.200	18.0	.028	42.8
25	2.0	3.5	15.0	1.100	19.0	.037	29.7
26	2.0	1.0	3.4	1.292	30.0	.032	40.4
27	2.0	1.0	6.0	1.684	27.0	.028	[1] 60.1
28	2.0	1.0	9.0	1.736	22.0	.029	59.8
29	2.0	1.0	12.0	1.500	17.0	.037	40.5
30	2.0	1.0	15.0	1.239	21.0	.043	28.8
31	2.0	−1.5	3.4	1.249	36.0	.051	24.5
32	2.0	−1.5	6.0	1.542	34.0	.044	35.1
33	2.0	−1.5	9.0	1.805	27.0	.039	46.3
34	2.0	−1.5	12.0	1.705	22.0	.046	37.1
35	2.0	−1.5	15.0	1.440	16.0	.056	25.7
36	2.0	−4.0	3.4	1.295	42.0	.069	18.8
37	2.0	−4.0	6.0	1.565	40.0	.061	25.6
38	2.0	−4.0	9.0	1.675	35.0	.055	30.5
39	2.0	−4.0	12.0	[2] 1.835	28.0	.051	36.0
40	2.0	−4.0	15.0	1.635	21.0	.064	25.6

[1] Probable best fixed slot arrangement. [2] Highest $C_{L_{max}}$ obtained.

TABLE III

SLOTTED CLARK Y WING RESULTS

MOVABLE TYPE SLOT

R. N.=609,000 10-inch chord—c. 80 m. p. h.

Test No.	Gap per cent c.	Depth per cent c.	Width per cent c.	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$ degrees	$C_{D_{min}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$
0	Plain wing			1.297	15.0	0.015	86.4
41	2.5	3.5	3.4	1.329	26.0	.030	44.3
42	2.5	3.5	6.0	1.657	23.0	.024	69.0
43	2.5	3.5	9.0	1.599	19.0	.023	69.5
44	2.5	3.5	12.0	1.300	18.0	.028	46.4
45	2.5	3.5	15.0	1.183	18.0	.036	32.9
46	2.5	1.0	3.4	1.253	31.0	.035	35.8
47	2.5	1.0	6.0	1.586	30.0	.031	51.1
48	2.5	1.0	9.0	1.780	24.0	.029	61.4
49	2.5	1.0	12.0	1.645	19.0	.035	47.0
50	2.5	1.0	15.0	1.293	22.0	.041	31.5
51	2.5	−1.5	3.4	1.270	37.0	.056	22.7
52	2.5	−1.5	6.0	1.510	35.0	.048	31.5
53	2.5	−1.5	9.0	1.769	27.0	.040	44.2
54	2.5	−1.5	12.0	1.818	24.0	.043	42.3
55	2.5	−1.5	15.0	1.580	18.0	.054	29.3
56	2.5	−4.0	3.4	1.290	44.0	.077	16.8
57	2.5	−4.0	6.0	1.520	41.0	.067	22.7
58	2.5	−4.0	9.0	1.641	36.0	.056	29.3
59	2.5	−4.0	12.0	1.804	25.0	.050	36.1
60	2.5	−4.0	15.0	1.733	22.0	.059	29.4

TABLE IV

SLOTTED CLARK Y WING RESULTS

MOVABLE TYPE SLOT

R. N.=609,000 10-inch chord—c. 80 m. p. h.

Test No.	Gap per cent c.	Depth per cent c.	Width per cent c.	$C_{L_{max}}$	$\alpha_{C_{L_{max}}}$ degrees	$C_{D_{min}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$
0	Plain wing			1.297	15.0	0.015	86.4
61	3.0	3.5	3.4	1.305	28.0	.031	42.1
62	3.0	3.5	6.0	1.675	25.0	.028	59.8
63	3.0	3.5	9.0	1.690	20.0	.026	65.0
64	3.0	3.5	12.0	1.398	21.0	.027	51.7
65	3.0	3.5	15.0	1.258	20.0	.035	35.9
66	3.0	1.0	3.4	1.270	33.0	.038	33.4
67	3.0	1.0	6.0	1.518	32.0	.033	46.0
68	3.0	1.0	9.0	1.762	26.0	.030	58.8
69	3.0	1.0	12.0	1.719	20.0	.033	52.0
70	3.0	1.0	15.0	1.398	15.0	.040	34.9
71	3.0	−1.5	3.4	1.285	39.0	.063	20.4
72	3.0	−1.5	6.0	1.505	38.0	.051	29.5
73	3.0	−1.5	9.0	1.644	33.0	.042	39.2
74	3.0	−1.5	12.0	1.800	25.0	.040	45.0
75	3.0	−1.5	15.0	1.672	20.0	.050	33.4
76	3.0	−4.0	3.4	1.262	45.0	.083	15.2
77	3.0	−4.0	6.0	1.431	43.0	.071	20.2
78	3.0	−4.0	9.0	1.660	39.0	.057	29.1
79	3.0	−4.0	12.0	1.659	23.0	.051	32.5
80	3.0	−4.0	15.0	1.758	24.0	.058	30.3

TABLE V

SLOTTED CLARK Y WING RESULTS

MOVABLE TYPE SLOT

R. N.=609,000 10-inch chord—c. 80 m. p. h.

Test No.	Gap per cent c.	Depth per cent c.	Width per cent c.	$C_{L_{max}}$	$\alpha C_{L_{max}}$ degrees	$C_{D_{min}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$
0	Plain wing			1.297	15.0	0.015	86.4
81	3.5	3.5	3.4	1.285	28.0	.031	41.5
82	3.5	3.5	6.0	1.647	26.0	.027	61.0
83	3.5	3.5	9.0	1.760	22.0	.025	70.4
84	3.5	3.5	12.0	1.517	16.0	.027	56.2
85	3.5	3.5	15.0	1.324	20.0	.035	37.8
86	3.5	1.0	3.4	1.255	34.0	.042	29.9
87	3.5	1.0	6.0	1.476	33.0	.036	41.0
88	3.5	1.0	9.0	1.747	28.0	.032	54.5
89	3.5	1.0	12.0	1.790	22.0	.034	52.6
90	3.5	1.0	15.0	1.512	16.0	.040	37.8
91	3.5	−1.5	3.4	1.283	41.0	.067	19.1
92	3.5	−1.5	6.0	1.451	38.0	.055	26.4
93	3.5	−1.5	9.0	1.627	34.0	.044	37.0
94	3.5	−1.5	12.0	1.780	26.0	.041	43.4
95	3.5	−1.5	15.0	1.752	21.0	.049	35.8
96	3.5	−4.0	3.4	1.230	45.0	.085	14.5
97	3.5	−4.0	6.0	1.481	42.0	.076	19.5
98	3.5	−4.0	9.0	1.641	39.0	.060	27.4
99	3.5	−4.0	12.0	1.635	34.0	.053	30.8
100	3.5	−4.0	15.0	1.711	22.0	.057	30.0

TABLE VI.—ORDINATES FOR AUXILIARY AIRFOILS CLARK Y WING WITH FIXED SLOT

[Values in per cent auxiliary airfoil chord]

Stations	Auxiliary No. 1		Auxiliary No. 2		Auxiliary No. 3	
	Ordinates		Ordinates		Ordinates	
	Upper	Lower	Upper	Lower	Upper	Lower
0	11.60	11.60	7.84	7.84	2.88	2.88
1.25	15.80	7.24	13.10	4.06	5.40	1.09
2.50	17.70	4.56	15.02	2.44	6.48	0.65
5.00	19.85	0.00	16.91	0.68	8.02	0.28
7.50	21.00	1.30	18.10	0.10	9.11	0.08
10.00	21.60	2.43	18.78	0.00	9.96	0.00
15.00	22.55	4.60	19.90	1.62	11.34	0.12
20.00	23.15	6.35	20.55	3.71	12.29	0.44
30.00	23.20	9.27	20.80	7.03	13.35	1.46
40.00	22.10	10.94	20.00	9.03	13.42	3.08
50.00	20.05	11.66	18.38	10.12	12.60	4.78
60.00	17.25	11.35	15.68	9.89	11.12	5.63
70.00	13.78	10.14	12.70	9.08	9.15	5.79
80.00	10.00	7.73	9.08	6.97	6.68	4.68
90.00	5.68	4.38	5.16	3.92	3.95	2.67
95.00	3.52	2.12	3.20	1.90	2.51	1.32
100.0	1.20	0	1.20	0	1.13	0

TABLE VII

AERODYNAMIC CHARACTERISTICS

CLARK Y WING WITH FIXED SLOT

Effect of changing auxiliary airfoil shape

R. N.=609,000 10-inch chord—c. 80 m. p. h.

	$C_{L_{max}}$	$\alpha C_{L_{max}}$ degrees	$C_{D_{min}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$
Slot closed	1.297	15.0	0.0150	86.4
Auxiliary airfoil No. 1			Main Wing No. 1	
Sharp nose	1.684	27.0	0.0280	60.1
Auxiliary airfoil No. 2			Main wing No. 1	
Sharp nose	1.660	27.0	0.0290	57.2
Auxiliary airfoil No. 3			Main wing No. 1	
Sharp nose	1.570	24.0	0.0280	56.0

TABLE VIII

AERODYNAMIC CHARACTERISTICS

CLARK Y WING WITH FIXED SLOT

(Whole profile is Clark Y)

Effects of rounding nose of main wing and moving slot back

R. N.=609,000 10-inch chord—c. 80 m. p. h.

	$C_{L_{max}}$	$\alpha C_{L_{max}}$ degrees	$C_{D_{min}}$	$\frac{C_{L_{max}}}{C_{D_{min}}}$
Slot closed	1.297	15.0	0.0150	86.4
	Slot cut in Clark Y wing			
	Auxiliary airfoil No. 1		Main wing No. 2	
Sharp nose	1.655	24.0	0.0235	70.4
Rounded 1.0 per cent c	1.720	24.0	.0238	72.2
Rounded 1.5 per cent c	1.722	24.0	.0225	73.3
Rounded 2.0 per cent c	1.751	24.0	.0229	[1] 76.4
Rounded 2.5 per cent c	1.740	24.0	.0233	74.6
	Slot moved back			
	Auxiliary airfoil No. 1-A		Main wing No. 3	
Sharp nose	1.672	24.0	0.0235	71.2
Rounded 0.4 per cent c	1.700	24.0	.0235	72.3
Rounded 1.0 per cent c	1.714	24.0	.0235	73.0
Rounded 1.5 per cent c	1.719	24.0	.0232	73.2
Rounded 2.0 per cent c	1.718	24.0	.0232	73.2
Rounded 2.5 per cent c	1.738	24.0	.0235	75.9
Rounded 3.0 per cent c	1.750	24.0	.0238	73.5

[1] Best fixed slot.

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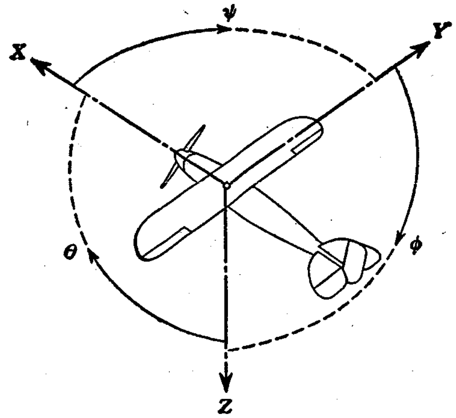

Positive directions of axes and angles (forces and moments) are shown by arrows

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 $= \sqrt[5]{\frac{\rho V^5}{P n^2}}$.
η, Efficiency.
n, Revolutions per second, r. p. s.
Φ, Effective helix angle $= \tan^{-1}\left(\frac{V}{2\pi r n}\right)$

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.