TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 443

# WIND-TUNNEL RESEARCH COMPARING LATERAL CONTROL DEVICES, PARTICULARLY AT HIGH ANGLES OF ATTACK

## VII. HANDLEY PAGE TIP AND FULL-SPAN SLOTS WITH AILERONS AND SPOILERS

By Fred E. Weick and Carl J. Wenzinger
Langley Memorial Aeronautical Laboratory



Washington
January, 1933

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 443

# WIND-TUNNEL RESEARCH COMPARING LATERAL CONTROL DEVICES, PARTICULARLY AT HIGH ANGLES OF ATTACK

## VII. HANDLEY PAGE TIP AND FULL-SPAN SLOTS WITH AILERONS AND SPOILERS

By Fred E. Weick and Carl J. Wenzinger

## SUMMARY

This report is the seventh in a series of systematic tests in which various lateral control devices are compared with particular reference to their effectiveness at high angles of attack. The present tests were made with ordinary ailerons and different sizes of spoilers on rectangular Clark Y wing models with Handley Page tip and full-span slots. The tests, which were made in the 7 by 10 foot wind tunnel of the National Advisory Committee for Aeronautics, showed the effect of the control devices on the general performance of the wings as well as on the lateral control and lateral stability characteristics.

It was found that the wing with Handley Page tip slots and certain combinations of the ailerons and properly located spoilers had satisfactory damping in roll and satisfactory rolling control with no adverse yawing moments at angles of attack up through 30°. With the full-span slot the conventional ailerons alone did not give rolling control of an assumed satisfactory amount at angles of attack above 10° (maximum lift occurred at 26°), but when combined with spoilers satisfactory rolling moments were obtained with no adverse yawing moments. Large spoilers tested as the sole means of lateral control on both the wing with tip slots and that with the full-span slot gave in both cases a moderate amount of rolling control at all angles of attack, together with favorable yawing moments which were extremely large, possibly too large.

## INTRODUCTION

A series of systematic wind-tunnel investigations is being made by the National Advisory Committee for Aeronautics in order to compare various lateral control devices. The various devices are given the same routine tests to show their relative merits in regard to lateral controllability and their effect on the lateral stability and on airplane performance. They are being tested first on rectangular Clark Y wings of aspect ratio 6, then on wings with different plan forms, wings with high lift devices, and also on wings with such variations as washout and sweepback, which affect lateral stability. The first report of this series (reference 1, Part I) deals with three sizes of ordinary ailerons, one of these a medium-sized one taken from the average of a number of conventional airplanes and used as the standard of comparison throughout the entire investigation. Other work that has been done in this series is reported in reference 1, Parts II to VI. In these tests the only control devices that affected the lateral stability were ordinary and slotted ailerons arranged to float and floating wing-tip ailerons.

The present report covers two of the series of investigations comparing lateral control devices. The first is on a wing with Handley Page tip slots, which improve the lateral stability at high angles of attack. The second is on the same wing fitted with a full-span slot, which extends the range of angles of attack below the stall and increases the maximum lift coefficient, and which therefore requires that the ailerons give greater values of the rolling-moment coefficient at the high angles of attack in order to provide the same degree of lateral control. The form of the slat and its location with the slot open, which are the same for both the tip and full-span slots, were taken directly from the optimum results of previous tests. (Reference 2.)

The length of the tip slots was taken as that which gave damping in roll to the highest angle of attack. In tests described in reference 3, this length was 50 per cent of the semispan. The slots were assumed to be automatic in action, being closed at the low angles of attack and open at an angle of attack of 10° or above.

The wing with both tip and full-span slots was tested with the standard average-sized ailerons and with these same ailerons rigged up 10° when neutral in order to improve the yawing moments. (See reference 1, Part III.) In addition, tests were made with the ailerons combined with spoilers and interceptors, and large spoilers were tested alone as the sole means of lateral control.

## APPARATUS

Model.- The wing model, which was constructed of laminated mahogany, was basically a Clark Y airfoil 10 inches in chord and 60 inches in span. (Fig. 1.) The slats were made of aluminum alloy and were attached to the main wing by means of small metal clips. The specified ordinates for both the main airfoil and the slat are given in Table I; the models were constructed to within ±0.005 inch of those values.

The spoilers were the same ones tested previously under reference 1, Part V, being thin metal plates hinged in such a manner as to be flush with the surface of the airfoil when closed. The medium-sized spoilers, 0.07 c high, were hinged at the rear so that the hinge moment could be balanced against that of the ailerons to give a small control force. (Fig. 2.) The best location of the hinge axis back of the leading edge was found in previous tests. (Reference 1, Part V, and reference 4.) This location was far enough back of the slot so that the spoiler could be operated with the slot open or closed. The length of the spoiler in the case with the tip slot was made the same as that of the slot - 50 per cent of the semispan.

With the full-span slot the medium-sized spoilers were made the same length as for the first tests on a plain wing, 40 per cent of the semispan. (Reference 1, Part V.) As shown in Figure 2, they were located with the outer tips 20 per cent of the semispan inboard from the tip of the wing. This was the position that gave the highest rolling moment at the angle of attack of maximum lift in the preliminary tests, the results of which are given in Figure 3.

An interceptor, which is considered here as a small spoiler intended essentially to close off the slot at high angles of attack, was proportioned as closely as possible to the latest form of Handley Page interceptor, as illustrated in references 5 and 6. (Front position, fig. 4.) Inasmuch as previous N.A.C.A. tests (reference 4) had indicated that better results might be expected with the interceptor located farther back from the slot, tests were also made with it in the rear location as shown in Figure 4. In both positions it would be covered by the slat when the slot was closed. These interceptors were tested only with the tip slots for they were thought too small to give the degree of control assumed satisfactory with the full-span slot.

The large spoiler used alone is shown in Figure 5. It is located entirely to the rear of the slot and would operate independently of the slot whether it were open or closed.

Wind tunnel.- All the present tests were made in the N.A.C.A. 7 by 10 foot open-jet wind tunnel. In this tunnel the model is supported in such a manner that the forces and moments at the quarter-chord point of the mid section of the model are measured directly in coefficient form. For autorotation tests, the standard force-test tripod is replaced by a special mounting that permits the model to rotate about the longitudinal wind axis passing through the midspan quarter-chord point. This apparatus is mounted on the balance, and the rolling-moment coefficient can be read directly during the forced-rotation tests. A complete description of the above equipment is given in reference 7. TR-412 - Harris, 1931

## TESTS

The tests were conducted in accordance with the standard procedure, and at the dynamic pressure and Reynolds Number employed throughout the entire series of investigations on lateral control. (Reference 1.) The dynamic pressure was 16.37 pounds per square foot, corresponding to an air speed of 80 miles per hour at standard density, and the Reynolds Number was 609,000, based on the chord of the basic airfoil section.

The regular force tests were made at a sufficient number of angles of attack to determine the maximum lift coefficient, the minimum drag coefficient, and the drag coefficient at $C_L = 0.70$, which is used to give a rate-of-climb criterion. Free-autorotation tests were made to determine the angle of attack above which autorotation was self-starting with all controls neutral. Forced-rotation tests were also made in which the rolling moment was measured while the wing was rolling at the rotational velocity corresponding to $\frac{p'b}{2V} = 0.05$, the highest rate likely to be obtained in gusty air, and at angles of yaw of both $0^\circ$ and $-20^\circ$.

The accuracy of the results in this report is the same as that in Part I (reference 1) except for angles of attack above the burble. It is considered satisfactory at all angles of attack for the wing with both tip and full-span slots, whereas with the plain wing accurate measurements could not be made just beyond the stall.

Assumed control movements.- The force tests were made with a sufficient number of spoiler and aileron deflections to give data for the four types of aileron movement used in the tests with the plain wing (reference 1, Part I): equal up-and-down, average differential (No. 1), extreme differential (No. 2), and upward movement only. The relative displacements of the two ailerons are given in Figure 6 and the assumed control linkages in Figure 7. In the case in which spoilers and ailerons are used in combination, the maximum deflection of the spoiler is taken as $90^\circ$ and the movement is considered proportional to that of the up aileron.

The maximum deflection of the large spoiler when used alone is also assumed to be $90^\circ$ for the present tests. Although the previous tests of this spoiler on a plain wing indicated no appreciable gain from deflections above $60^\circ$, the present tests with the Handley Page slots showed a definite increase in rolling moment from $60^\circ$ to $90^\circ$.

## RESULTS

Coefficients.- The force-test results are given in the form of absolute coefficients of lift and drag and of the rolling and yawing moments:

$$C_L = \frac{\text{lift}}{q\ S}$$

$$C_D = \frac{\text{drag}}{q\ S}$$

$$C_l' = \frac{\text{rolling moment}}{q\ b\ S}$$

$$C_n' = \frac{\text{yawing moment}}{q\ b\ S}$$

where $S$ is the total wing area with slots closed, $b$ is the wing span, and $q$ is the dynamic pressure. The coefficients as given above are not corrected for tunnel-wall effect. They are obtained directly from the balance and refer to the wind (or tunnel) axes. In special cases in the discussion where the moments are used with reference to body axes, the coefficients are not primed. Thus the symbols for the rolling and yawing moment coefficients about body axes are $C_l$ and $C_n$.

The results of the forced-rotation tests are given, also about the wind axes, by a coefficient representing the rolling moment due to rolling:

$$C_\lambda = \frac{\lambda}{q\ b\ S}$$

where $\lambda$ is the rolling moment measured while the wing is rolling, and the other factors have the usual significance. This coefficient may be used as a measure of the degree of lateral stability or instability of a wing under various rolling conditions. In the present case, it is used to indicate the characteristics of a wing when it is subjected to a rolling velocity equal to the maximum likely to be encountered in controlled flight in very gusty air. This rolling velocity may be expressed in terms of the wing span as

$$\frac{p'b}{2\ V} = 0.05$$

where $V$ is the air speed at the center section of the wing, and $p'$ is the angular velocity in roll about the wind axis.

Tables.- The complete results of the tests for the wing with tip slots are given in Tables II to V, inclusive. Tables II and III give the values of $C_L$, $C_D$, $C_l'$, and $C_n'$ for all control deflections and for $0^\circ$ and $-20^\circ$ yaw, respectively. Table IV gives values of $C_\lambda$ at $\frac{p'b}{2V} = 0.05$, and values of $\frac{p'b}{2V}$ over the first part of the free-autorotation range for $0^\circ$ yaw with the ailerons neutral. Table V gives values of $C_\lambda$ at $\frac{p'b}{2V} = 0.05$ with $-20^\circ$ yaw. In like manner the results obtained with the full-span slot are given in Tables VI to IX.

## DISCUSSION IN TERMS OF CRITERIONS

## SECTION I. TIP SLOTS

A series of criterions was developed in Part I (reference 1) for the purpose of comparing the effect of various ailerons or other lateral control devices on the general performance of an airplane, on its lateral controllability, and on its lateral stability. The ailerons and spoilers used in the present tests with their various movements are compared with each other by means of these criterions in Table X. In addition, values are included from reference 1 for the ailerons on a plain unslotted wing.

### General Performance

### (Controls Neutral)

Wing area required for desired landing speed.- The value of the maximum lift coefficient is used as a criterion of the wing area required for the desired landing speed, or conversely for the landing speed obtained with a given wing area. The value of the maximum lift coefficient was slightly lower with the tip slots than with the plain unslotted wing, but, as shown in Figure 8, the lift coefficient with the slotted wing is maintained at a relatively high value up to a much higher angle of attack, and has a second peak as high as the first at an angle of attack of $32^\circ$.

When it was decided to make tests on the tip-slotted wing with the ailerons deflected up 10° when neutral to improve the yawing moments, it was thought that possibly the effect of the tip slot in delaying the stall would eliminate the loss in maximum lift accompanying the 10° upward deflections on both ailerons of a plain wing. The tests showed, however, that the tip slots did not help in this respect. The maximum lift coefficient with the ailerons rigged up was, as in the case of the plain wing, 6 per cent lower.

Speed range.- The ratio $C_{L_{max}}/C_{D_{min}}$ is a convenient figure of merit for comparison of the relative speed range obtained with various wings. The minimum drag coefficient in this ratio has been taken as the value for the plain wing, the slot being assumed closed and the resultant wing of perfect form for the high speed. The value of $C_{L_{max}}/C_{D_{min}}$ is slightly lower for the wing with tip slots than for the plain wing on account of the lower values of $C_{L_{max}}$. It is still lower with the ailerons rigged up 10° when neutral.

Rate of climb.- In order to establish a suitable criterion for the effect of the wing and the lateral control devices on the rate of climb of an airplane, the performance curves of a number of types and sizes of airplanes were calculated, and the relation of the maximum rate of climb to the lift and drag curves was studied. This investigation showed that the L/D at $C_L = 0.70$ gave a consistently reliable figure of merit for this purpose. Inasmuch as the slots are assumed closed at this lift coefficient and the wing form is assumed perfect, the value of this criterion is the same for the wing with tip slots as for the plain wing.

## Lateral Controllability

### (Maximum Assumed Control Deflection)

Rolling criterion.- The rolling criterion upon which the control effectiveness of each of the aileron arrangements is judged is a figure of merit that is designed to be proportional to the initial acceleration of the wing tip, following a deflection of the ailerons from neutral, regardless of the air speed or the wing plan form of an airplane. Expressed in coefficient form for a rectangular monoplane wing, the criterion becomes

$$RC = \frac{C_l}{C_L}$$

where $C_l$ is the rolling-moment coefficient about the body axis due to the ailerons. The numerical value of this expression that has been found to represent satisfactory control conditions is approximately 0.075. A more detailed explanation of RC and its more general form, which is applicable to any wing plan form, is given in Part I.

The comparison of the ailerons on the basis of this criterion is given in Table X at four representative angles of attack; namely, 0°, 10°, 20°, and 30°. The first angle, 0°, represents the high-speed attitude; $\alpha = 10°$ represents the highest angle of attack at which entirely satisfactory control with ordinary ailerons can be maintained; $\alpha = 20°$ represents the condition of greatest instability in rolling for the plain unslotted Clark Y wing, and is probably the greatest attainable angle of attack with most present-day airplanes in a steady glide; and finally, $\alpha = 30°$ is representative of the highest angles of attack at which the present wing with tip slots has satisfactory control and stability.

At $\alpha = 0°$ all the control devices tested gave more control than necessary, the lowest being nearly double the assumed satisfactory value. At this angle of attack the slots are assumed closed and the condition the same as for the plain wing.

At $\alpha = 10°$ the slots are assumed open and all the plain aileron arrangements gave reasonably close to the assumed satisfactory value of RC, 0.075. This condition is also true for the large spoiler alone and the combined ailerons and interceptor with the latter in its original position. The combinations of ailerons and spoilers, including the interceptor in its rear position, gave rolling-control criterions in excess of the satisfactory value. A more rigorous comparison could, therefore, be made by decreasing the control sizes or deflections to give approximately the satisfactory value of RC at $\alpha = 10°$, but this has not been done because of the added complications.

At $\alpha = 20^\circ$, which represents the highest angle of attack that can be maintained by an average airplane in a glide, the plain ailerons operating behind the slot did not give satisfactory values of RC with any of the four movements. The highest value, about 80 per cent of the satisfactory, was given by the average differential movement with standard rigging and by equal up-and-down movement with the ailerons rigged up $10^\circ$ when neutral. (The actual maximum position of the ailerons in both of these cases is exactly the same.) The extreme differential and up-only movements, which gave the highest values of RC with the plain wing, gave definitely lower values with the wing having tip slots.

The interceptor in its original location combined with ailerons decreased the rolling moments slightly as compared with the ailerons alone at an angle of attack of $20^\circ$ for the equal up-and-down and the average differential movements, but increased them slightly when used with the extreme differential and up-only movements. In no case, however, did the combination give values as high as those obtained with the ailerons alone having the average differential movement. When moved back from the slot to become what is here considered a small spoiler, the effect of the interceptor was greatly increased and a satisfactory value of RC was obtained with equal up-and-down aileron movement. (This is the only movement listed in Table X, but the maximum deflections corresponding to the other movements were tested and the data are given in Tables II and III.) This improvement substantiates the results of reference 3 and shows that the proper action is to spoil the smooth flow over the upper surface of the wing rather than to intercept the air flowing through the slot.

The 0.07 c high spoiler when combined with the equal up-and-down or the average differential movement gave substantially greater than the assumed satisfactory value of RC at an angle of attack of $20^\circ$, but gave a value that is just satisfactory with the extreme differential movement. The large spoiler alone gave 91 per cent of the assumed satisfactory value.

At the extreme angle of attack of $30^\circ$ every control combination tested on the wing with tip slots gave more than one-half the satisfactory value of RC, a great improvement over the values obtained without the slots. Satisfactory values were given by the spoiler and aileron combinations with equal up-and-down or average differential movement of the ailerons. The large spoiler alone gave three-fourths of the satisfactory value.

Lateral control with sideslip.- If a wing is yawed 20°, a rolling moment is set up that tends to raise the forward tip with a magnitude that is greater at very high angles of attack than the available rolling moment due to conventional ailerons. The limiting angle of attack at which the ailerons can balance the rolling moment due to 20° yaw represents the greatest angle of attack that can be held in an average sideslip. This angle is tabulated for all the aileron and spoiler arrangements as a criterion of control with sideslip.

With the wing-tip slots and ailerons alone the equal up-and-down deflection gave control against 20° yaw to the same angle of attack as the same aileron on the plain wing, namely 20°, but the extreme differential and up-only movements gave control to substantially higher angles of attack, 32° and 33°, respectively. In addition, the interceptors in their original location did not affect this angle of attack, but when moved back increased it slightly. The 0.07 c high spoilers and ailerons gave control up to high angles of attack with all the aileron movements, the angle being 38° with both the average and the extreme differential movements. The large spoiler alone gave control up to an angle of attack of 34°.

Yawing moment due to ailerons.- The desirable yawing moment due to ailerons varies to some extent with the type of airplane that is being considered. For a highly maneuverable military or acrobatic machine, complete independence of the controls as they affect the turning moments about the various body axes is no doubt a desirable feature. On the other hand, for large transport airplanes and for machines to be operated by relatively inexperienced pilots, a favorable yawing moment of the proper magnitude would probably be an appreciable aid to safe flying. Finally, it is obvious that a yawing moment tending to turn the airplane out of its normal bank is never desirable.

With the ailerons alone the yawing moments were about the same with the slotted wing as with the plain unslotted wing, the adverse yawing moments at high angles of attack being greater than could be overcome with an average rudder. The adverse yawing moments were reduced considerably but not entirely eliminated by rigging the ailerons up 10° when neutral. They could be entirely eliminated by rigging the ailerons up further, but this would require a rather large sacrifice in a lower maximum lift coefficient and a higher minimum drag coefficient.

The yawing moments were not improved by the addition of the interceptor in its original position at any of the usual angles of attack through 20°, but definitely favorable yawing moments were obtained at an angle of attack of 30°. With the rearward position, however, substantially favorable yawing moments, with no adverse ones with any deflection, were obtained at all angles of attack at which the slot would be open (assumed as 10° and above).

The combination of the 0.07 c high spoiler and the ailerons gave large favorable yawing moments, with no adverse ones, at all angles of attack whether the slot was assumed open or closed. The large spoiler alone gave very large, possibly too large, favorable yawing moments at all angles of attack. In this connection, the desirable magnitude of the favorable yawing moment is not known within a reasonable degree of accuracy, and flight tests to establish this point would be highly desirable.

## Lateral Stability

## (Controls Neutral)

Angle of attack above which autorotation is self-starting.- This criterion is a measure of the range of angles of attack above which autorotation will start from an initial condition of practically zero rate of rotation. The limiting angle of attack was raised from 18° for the plain Clark Y wing to 33° for the wing with tip slots, which puts it well above the range of angles of attack that can be maintained by average conventional airplanes.

Stability against rolling caused by gusts.- Test flights have shown that in severe gusts a rolling velocity such that $\frac{p'b}{2V} = 0.05$ may be obtained. Consequently, the rolling moment of a wing due to rolling at this value of $\frac{p'b}{2V}$ gives a measure of its stability characteristics in rough air. In the present case, the angle at which this rolling moment becomes zero is used as a more severe criterion than the previously mentioned angle at which autorotation is self-starting, to indicate the practical upper limit of the useful angle-of-attack range. With 0° yaw, the angle of attack for initial instability is 32° for the wing with tip slots as compared with 17° for the plain unslotted wing; but with 20° yaw the angle is increased only a small amount, from 11° to 14°, by means of the slots.

The above criterion shows the critical range below which stability is such that any rolling is damped out, and above which instability exists. The last criterion, maximum $C_\lambda$, indicates the degree of this instability. With 0° yaw, the slotted wing had a much weaker tendency to autorotate, and the maximum tendency occurred at a very high angle of attack - about 40°. As shown in Figure 9, the damping in roll is practically zero for a very small range of angles of attack near 20°. As shown by the results of reference 3, the damping at this point can be increased if desired, by lengthening the slots slightly.

The maximum autorotational moment with 20° yaw is of importance only in the condition in which the airplane is skidded and the forward wing tip is rolled upward or the rear tip downward by means of a gust. This autorotational moment, which is large with the plain Clark Y wing, is reduced somewhat by means of the tip slots; but of greater importance is the fact that it does not occur except at angles of attack above the range that can be maintained by the average airplane.

## Control Force Required

The hinge moments were not measured in the tests with the slots because it was thought that they should not differ greatly from the moments for the same ailerons and spoilers on the plain wing given in reference 1, Part V. Those results show that with the proper combinations of spoilers and ailerons, it is possible to obtain very small control forces.

## SECTION II. FULL-SPAN SLOT

Criterions similar to those used in the previous section are given for the wing with the full-span slot in Table XI.

### General Performance

### (Controls Neutral)

Wing area required for desired landing speed.- The value of the maximum lift coefficient was increased from 1.27 with the unslotted Clark Y wing to 1.83 with the full-span slot. (Fig. 10.) With the ailerons rigged up 10° when neutral, the value was 5 per cent lower.

Speed range.- With the slot assumed closed and the wing of perfect form at the angle of attack for minimum drag, the ratio $C_{L_{max}}/C_{D_{min}}$ was 44 per cent higher for the fully slotted wing than for the plain wing and 51 per cent higher for the fully slotted wing than for the one with tip slots covering 50 per cent of the span. The value of the speed-range ratio was somewhat lower with the ailerons rigged up 10° when neutral.

Rate of climb.- Inasmuch as the slots are assumed closed for the climbing condition and the wing is assumed to be of perfect Clark Y form, the rate of climb would be the same with the full-span slot as with the plain unslotted wing.

### Lateral Controllability

### (Maximum Assumed Control Deflection)

Rolling criterion.- At the angle of attack of 0° with the slot assumed closed, conditions are the same as for the unslotted wing. At this angle of attack all the devices tested gave more control than necessary.

At $\alpha = 10^\circ$ with the slot open, all of the plain aileron arrangements and also the large spoilers alone gave very close to the assumed satisfactory value of RC of 0.075. The combinations of ailerons and spoilers gave values greatly in excess of the satisfactory value with all four aileron movements.

At $\alpha = 20^\circ$, which represents the highest angle of attack which can be obtained by an average airplane in a glide, but which is well below the stall with the full-span slot, none of the plain aileron arrangements gave satisfactory values of RC, the values ranging between one-half and two-thirds of the satisfactory value. With all movements except the equal up-and-down, the ailerons alone gave less control on the fully slotted wing than on the plain wing, which is stalled at this angle of attack. The 0.07 c high spoiler when combined with the ailerons with either equal up-and-down or average differential movements gave greater than the assumed satisfactory value of RC at $\alpha = 20^\circ$. The values with the extreme differential and up-only movements were not quite satisfactory. These conditions indicate that the downward aileron movement is more effective on a fully slotted wing than on a plain wing. The large spoiler alone gave about four-fifths of the assumed satisfactory value of RC.

At $\alpha = 30^\circ$, which is beyond the stall of the slotted wing, none of the control combinations tested gave values of RC which were entirely satisfactory, but some approached it fairly closely. The highest value, 92 per cent of the assumed satisfactory RC, was obtained with the 0.07 c spoilers combined with the ailerons with the average differential movement. The large spoiler alone gave about the same amount of control at 30° as at 20°.

<u>Lateral control with sideslip</u>.- The maximum angle of attack at which the ailerons alone would balance the rolling moment due to 20° yaw ranged from a minimum of 27°, or just above the stall of the completely slotted wing, to a maximum of 32°; the combined spoilers and ailerons gave control up to somewhat higher angles of attack, 35° being obtained with the up-only movement. Control was also obtained up to an angle of 35° with the large spoiler alone.

<u>Yawing moment due to controls</u>.- With the ailerons alone the yawing moments were about the same with the full-span slot as with the unslotted wing. The adverse yawing moments above the stall of the fully slotted wing were greater than can be overcome with an average rudder. The adverse yawing moments were eliminated below the stall and reduced above the stall by rigging the ailerons up 10°

when neutral; but the values above the stall were still unsatisfactorily high. The spoiler-aileron combination gave rather large favorable yawing moments at all angles of attack, with no adverse ones. The same is true for the large spoiler alone, but in that case the so-called favorable values were extremely large, possibly too large for satisfactory control.

## Lateral Stability

### (Controls Neutral)

Angle of attack above which autorotation is self-starting.- The limiting angle was raised from 18° for the unslotted Clark Y wing to 25° for the Clark Y wing with a full-span slot. This value is above the limiting angle of attack which can be maintained in a glide with an average conventional airplane, but is slightly below the angle of attack for maximum lift of the fully slotted wing.

Stability against rolling caused by gusts.- With 0° yaw the angle of attack for initial instability with a rolling velocity such that $\frac{p'b}{2V} = 0.05$ was the same as the self-starting value, 25°. This value was 17° for the unslotted wing and 32° for the wing with tip slots covering half the span. With 20° yaw the angle was increased from 11° for the plain wing and 14° for the wing with tip slots to 19° for the wing with a full-span slot.

At 0° yaw the fully slotted wing had a maximum autorotational tendency (value of $C_\lambda$) which was definitely lower than the average values measured for the plain unslotted wing. It was about the same as the lowest measured for several plain unslotted wings which vary throughout a fairly wide range because of inaccuracies of form, even though built within close limits to the same dimensions. With the fully slotted wing the maximum value of $C_\lambda$ occurred at a high angle of attack, about 35°. (Fig. 11.) At 20° yaw the value of $C_\lambda$ was about the same for the fully slotted wing as for the plain unslotted one.

## CONCLUSIONS

### SECTION I. TIP SLOTS

1. The general performance of the wing with tip slots was slightly poorer than that of the plain wing.

2. Ordinary ailerons gave somewhat greater rolling control at high angles of attack on the slotted wing than on the plain wing, but it was below the assumed satisfactory value, and the adverse yawing moments were not reduced.

3. Rigging the ailerons up 10° gave improved yawing moments but slightly poorer general performance.

4. The Handley Page type interceptor was found to give much more favorable rolling and yawing moments when it was moved back a certain distance from the slot and became in effect a small spoiler.

5. The 0.07 c high spoiler when combined with the ailerons gave rolling control in excess of the assumed satisfactory value, together with favorable yawing moments at all angles of attack through 30°.

6. The large spoiler alone gave a moderate amount of rolling control, together with extremely large favorable yawing moments, possibly too large.

7. The Clark Y wing model with Handley Page tip slots as tested had no autorotational tendency below an angle of attack of 32°.

### SECTION II. FULL SPAN SLOT

1. The general performance of the wing with full-span slot was improved considerably over that of the unslotted wing and that of the wing with tip slots.

2. Ordinary ailerons gave rolling control definitely below the assumed satisfactory value at angles of attack well below the stall of the fully slotted wing. Fairly large adverse yawing moments occurred with equal up-and-down deflection, but these were reduced somewhat by the differential movements.

3. Rigging the ailerons up 10° when neutral eliminated the adverse yawing moments below the stall but not above.

4. Satisfactory rolling control at angles of attack up to the stall of the slotted wing was given by spoilers combined with ailerons having equal up-and-down or average differential movement. The control was within close limits of the assumed satisfactory value several degrees beyond the stall.

5. The large spoiler alone gave a moderate amount of rolling control, together with extremely large favorable yawing moments, possibly too large.

6. The wing with full-span slot had autorotational tendencies at angles of attack above 25°, but the maximum autorotational tendency was definitely lower than the average for plain Clark Y wings.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 25, 1932.

## REFERENCES


1. Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack.

   I. Ordinary Ailerons on Rectangular Wings. T.R. No. 419, N.A.C.A., 1932, by Fred E. Weick and Carl J. Wenzinger.

   II. Slotted Ailerons and Frise Ailerons. T.R. No. 422, N.A.C.A., 1932, by Fred E. Weick and Richard W. Noyes.

   III. Ordinary Ailerons Rigged Up 10° When Neutral. T.R. No. 423, N.A.C.A., 1932, by Fred E. Weick and Carl J. Wenzinger.

   IV. Floating Tip Ailerons on Rectangular Wings. T.R. No. 424, N.A.C.A., 1932, by Fred E. Weick and Thomas A. Harris.

   V. Spoilers and Ailerons on Rectangular Wings. T.R. No. 439, N.A.C.A., 1932, by Fred E. Weick and Joseph A. Shortal.

   VI. Skewed Ailerons on Rectangular Wings. T.R. No. 444, N.A.C.A., 1932, by Fred E. Weick and Thomas A. Harris.

2. Wenzinger, Carl J., and Shortal, Joseph A.: The Aerodynamic Characteristics of a Slotted Clark Y Wing as Affected by the Auxiliary Airfoil Position. T.R. No. 400, N.A.C.A., 1931.

3. Weick, Fred E., and Wenzinger, Carl J.: Effect of Length of Handley Page Tip Slots on the Lateral-Stability Factor, Damping in Roll. T.N. No. 423, N.A.C.A., 1932.

4. Weick, Fred E., and Wenzinger, Carl J.: Preliminary Investigation of Rolling Moments Obtained with Spoilers on Both Slotted and Plain Wings. T.N. No. 415, N.A.C.A., 1932.

5. Alston, R. P.: Stalled Flight Tests on a Bristol Fighter Fitted with Auto Control Slots and Interceptors. R. & M. No. 1338, British A.R.C., 1930.

6. Lachmann, G. V.: Control Beyond the Stall. Jour. Roy. Aero. Soc., Vol. XXXVI, No. 256 (Apr., 1932), pp. 276-338.

7. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 412, N.A.C.A., 1931.

TABLE I. ORDINATES OF CLARK Y WING WITH HANDLEY PAGE SLOTS

| Basic Clark Y | | | Cut-off Clark Y | | | Slat | | |
|---|---|---|---|---|---|---|---|---|
| Per cent basic chord | | | Per cent basic chord | | | Per cent slat chord | | |
| Station | Upper | Lower | Station | Upper | Lower | Station | Upper | Lower |
| 0 | 3.50 | 3.50 | 0 | - | - | 0 | 11.60 | 11.60 |
| 1.25 | 5.45 | 1.93 | 1.85 | 1.65 | 1.65 | 1.25 | 15.80 | 7.24 |
| 2.50 | 6.50 | 1.47 | 2.50 | a | 1.47 | 2.50 | 17.70 | 4.56 |
| 5.00 | 7.90 | .93 | 5.00 | a | .93 | 5.00 | 19.85 | .00 |
| 7.50 | 8.85 | .63 | 7.50 | a | .63 | 7.50 | 21.00 | 1.30 |
| 10.00 | 9.60 | .42 | 10.00 | a | .42 | 10.00 | 21.60 | 2.43 |
| 15.00 | 10.69 | .15 | 13.00 | 10.07 | - | 15.00 | 22.55 | 4.60 |
| 20.00 | 11.36 | .03 | 15.00 | 10.69 | .15 | 20.00 | 23.15 | 6.35 |
| 30.00 | 11.70 | 0 | 20.00 | 11.36 | .03 | 30.00 | 23.20 | 9.27 |
| 40.00 | 11.40 | 0 | 30.00 | 11.70 | 0 | 40.00 | 22.10 | 10.94 |
| 50.00 | 10.52 | 0 | 40.00 | 11.40 | 0 | 50.00 | 20.05 | 11.66 |
| 60.00 | 9.15 | 0 | 50.00 | 10.52 | 0 | 60.00 | 17.25 | 11.35 |
| 70.00 | 7.35 | 0 | 60.00 | 9.15 | 0 | 70.00 | 13.78 | 10.14 |
| 80.00 | 5.22 | 0 | 70.00 | 7.35 | 0 | 80.00 | 10.00 | 7.73 |
| 90.00 | 2.80 | 0 | 80.00 | 5.22 | 0 | 90.00 | 5.68 | 4.38 |
| 95.00 | 1.49 | 0 | 90.00 | 2.80 | 0 | 95.00 | 3.52 | 2.12 |
| 100.00 | .12 | 0 | 95.00 | 1.49 | 0 | 100.00 | 1.20 | 0 |
| | | | 100 | .12 | 0 | | | |

Leading edge radius = 1.50

[a]Use radius of 20.00 from station 1.85 to station 13.00 and corresponding ordinates

TABLE II. FORCE TESTS. 10 BY 60 INCH CLARK Y WING WITH 50 PER CENT b/2

HANDLEY PAGE TIP SLOTS OPEN AT ALL ANGLES OF ATTACK - PLAIN AILERONS

Yaw = 0° R.N. = 609,000 Velocity = 80 m.p.h.

| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | α | -5° | 0° | 5° | 10° | 15° | 17° | 18° | 19° | 20° | 22° | 25° | 30° | 31° | 32° | 40° | 50° | 60° |
| δ up | δ dn. | Ailerons locked - Neutral | | | | | | | | | | | | | | | | | |
| 0° | 0° | $C_L$ | -0.040 | 0.313 | 0.728 | 0.986 | | 1.182 | 1.176 | 1.145 | 1.065 | 1.045 | 1.110 | 1.185 | 1.206 | 1.208 | 1.073 | 0.885 | 0.718 |
| 0° | 0° | $C_D$ | .057 | .037 | .057 | .089 | | .196 | .219 | .239 | .324 | .353 | .419 | .525 | .555 | .575 | .774 | .938 | 1.091 |
| Equal up-and-down | | | | | | | | | | | | | | | | | | | |
| 20° | 20° | $C_l'$ | | .058 | | .063 | 0.061 | | .047 | | .046 | .042 | .037 | .028 | | .022 | .011 | | |
| 20° | 20° | $C_n'$ | | -.003 | | -.015 | -.021 | | -.024 | | -.027 | -.026 | -.028 | -.029 | | -.030 | -.021 | | |
| 25° | 25° | $C_l'$ | | .070 | | .071 | .070 | | .056 | | .054 | .051 | .047 | .037 | | .031 | .015 | | |
| 25° | 25° | $C_n'$ | | -.008 | | -.017 | -.024 | | -.027 | | -.031 | -.031 | -.033 | -.036 | | -.036 | -.026 | | |
| 30° | 30° | $C_l'$ | | .078 | | .079 | .074 | | .059 | | .056 | .055 | .054 | .045 | | .037 | .019 | | |
| 30° | 30° | $C_n'$ | | -.002 | | -.019 | -.025 | | -.028 | | -.031 | -.032 | -.036 | -.042 | | -.041 | -.030 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | | | |
| 10° | 8½° | $C_l'$ | | .032 | | .031 | .028 | | .022 | | .027 | .019 | .016 | .010 | | .006 | .004 | | |
| 10° | 8½° | $C_n'$ | | -.001 | | -.007 | -.010 | | -.012 | | -.014 | -.014 | -.014 | -.015 | | -.014 | -.010 | | |
| 20° | 13° | $C_l'$ | | .052 | | .054 | .053 | | .044 | | .045 | .040 | .035 | .028 | | .020 | .011 | | |
| 20° | 13° | $C_n'$ | | .000 | | -.010 | -.016 | | -.019 | | -.023 | -.023 | -.024 | -.025 | | -.024 | -.017 | | |
| 30° | 15° | $C_l'$ | | .069 | | .064 | .062 | | .055 | | .058 | .054 | .050 | .042 | | .035 | .020 | | |
| 30° | 15° | $C_n'$ | | .002 | | -.011 | -.017 | | -.021 | | -.025 | -.026 | -.028 | -.031 | | -.031 | -.024 | | |
| 35° | 15° | $C_l'$ | | .075 | | .069 | .066 | | .057 | | .060 | .057 | .053 | .046 | | .040 | .027 | | |
| 35° | 15° | $C_n'$ | | .004 | | -.009 | -.016 | | -.019 | | -.024 | -.024 | -.027 | -.031 | | -.031 | -.025 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | | | |
| 10° | 7° | $C_l'$ | | .030 | | .028 | .025 | | .020 | | .024 | .017 | .014 | .009 | | .004 | .003 | | |
| 10° | 7° | $C_n'$ | | -.001 | | -.006 | -.009 | | -.011 | | -.012 | -.012 | -.012 | -.013 | | -.012 | -.008 | | |
| 20° | 12° | $C_l'$ | | .051 | | .051 | .050 | | .041 | | .045 | .037 | .034 | .026 | | .019 | .011 | | |
| 20° | 12° | $C_n'$ | | .000 | | -.010 | .015 | | -.017 | | -.021 | -.021 | -.023 | -.024 | | -.023 | -.016 | | |
| 30° | 14° | $C_l'$ | | .067 | | .059 | .059 | | .053 | | .056 | .051 | .049 | .041 | | .034 | .020 | | |
| 30° | 14° | $C_n'$ | | .003 | | -.009 | -.015 | | -.019 | | -.021 | -.022 | -.025 | -.028 | | -.027 | -.021 | | |
| 40° | 11½° | $C_l'$ | | .077 | | .069 | .066 | | .058 | | .046 | .058 | .056 | .048 | | .041 | .033 | | |
| 40° | 11½° | $C_n'$ | | .007 | | -.006 | -.012 | | -.016 | | -.025 | -.021 | -.024 | -.027 | | -.027 | -.025 | | |
| 50° | 7° | $C_l'$ | | .061 | | .071 | .067 | | .062 | | .049 | .058 | .059 | .052 | | .044 | .019 | | |
| 50° | 7° | $C_n'$ | | .012 | | .000 | -.007 | | -.012 | | -.019 | -.015 | -.018 | -.023 | | -.023 | -.015 | | |
| Up-only | | | | | | | | | | | | | | | | | | | |
| 10° | 0° | $C_l'$ | | .021 | | .018 | .016 | | .012 | | .017 | .008 | .006 | .003 | | .001 | .003 | | |
| 10° | 0° | $C_n'$ | | .000 | | -.003 | -.005 | | -.006 | | -.007 | -.006 | -.007 | .007 | | .007 | .006 | | |
| 20° | 0° | $C_l'$ | | .036 | | .035 | .034 | | .029 | | .034 | .025 | .022 | .016 | | .015 | .008 | | |
| 20° | 0° | $C_n'$ | | .002 | | -.005 | -.008 | | -.010 | | -.012 | -.012 | -.013 | -.014 | | -.014 | -.010 | | |
| 30° | 0° | $C_l'$ | | .054 | | .043 | .041 | | .039 | | .030 | .037 | .036 | .031 | | .030 | .018 | | |
| 30° | 0° | $C_n'$ | | .005 | | -.004 | -.007 | | -.010 | | -.012 | -.012 | -.015 | -.017 | | -.019 | -.015 | | |
| 40° | 0° | $C_l'$ | | .064 | | .053 | .050 | | .046 | | .043 | .046 | .044 | .038 | | .036 | .031 | | |
| 40° | 0° | $C_n'$ | | .009 | | -.001 | -.006 | | -.009 | | -.015 | -.012 | -.014 | -.017 | | -.018 | -.019 | | |
| 50° | 0° | $C_l'$ | | .072 | | .062 | .058 | | .053 | | .042 | .050 | .051 | .046 | | .042 | .017 | | |
| 50° | 0° | $C_n'$ | | .012 | | .001 | -.004 | | -.008 | | -.014 | -.010 | -.013 | -.017 | | -.018 | -.013 | | |
| 60° | 0° | $C_l'$ | | .078 | | .069 | .065 | | .060 | | .048 | .052 | .055 | .052 | | .048 | .017 | | |
| 60° | 0° | $C_n'$ | | .016 | | .005 | -.002 | | -.006 | | -.013 | -.008 | -.012 | -.016 | | -.018 | -.012 | | |
| Down-only | | | | | | | | | | | | | | | | | | | |
| 0° | 5° | $C_l'$ | | .010 | | .010 | .008 | | .013 | | .009 | .003 | .000 | -.003 | | -.005 | .001 | | |
| 0° | 5° | $C_n'$ | | -.001 | | -.003 | -.004 | | -.004 | | -.005 | -.004 | -.004 | -.004 | | -.004 | -.004 | | |
| 0° | 10° | $C_l'$ | | .016 | | .017 | .016 | | .018 | | .016 | .007 | .005 | .002 | | -.001 | .001 | | |
| 0° | 10° | $C_n'$ | | -.001 | | -.005 | -.007 | | -.008 | | -.009 | -.008 | -.008 | -.008 | | -.007 | -.007 | | |
| 0° | 20° | $C_l'$ | | .022 | | .029 | .026 | | .017 | | .019 | .012 | .009 | .006 | | .001 | .001 | | |
| 0° | 20° | $C_n'$ | | -.004 | | -.011 | -.014 | | -.014 | | -.016 | -.015 | -.016 | -.016 | | -.015 | -.012 | | |
| 0° | 30° | $C_l'$ | | .029 | | .039 | .033 | | .021 | | .018 | .015 | .012 | .008 | | .002 | -.001 | | |
| 0° | 30° | $C_n'$ | | -.007 | | -.016 | -.018 | | -.020 | | -.020 | -.020 | -.021 | -.024 | | -.023 | -.016 | | |

A

TABLE II. (Cont'd) FORCE TESTS. 10 BY 60 INCH CLARK Y WING WITH 50 PER CENT b/2

HANDLEY PAGE TIP SLOTS OPEN AT ALL ANGLES OF ATTACK - PLAIN AILERONS

Yaw = 0° R.N. = 609,000 Velocity = 80 m.p.h.

| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 NEUTRAL POSITION RIGGED UP 10° | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | α | -5° | 0° | 7° | 10° | 15° | 17° | 18° | 19° | 20° | 22° | 25° | 30° | 31° | 32° | 40° | 50° | 60° |
| $\delta_A$ up | $\delta_A$ dn. | Ailerons locked - Neutral rigged up 10° | | | | | | | | | | | | | | | | | |
| 0° | 0° | $C_L$ | -0.150 | 0.200 | 0.891 | 0.892 | 1.088 | 1.090 | 1.090 | 1.070 | 1.055 | 0.965 | 1.038 | 1.105 | 1.120 | 1.133 | 1.028 | 0.872 | 0.718 |
| 0° | 0° | $C_D$ | .066 | .037 | .053 | .073 | .134 | .168 | .187 | .206 | .255 | .314 | .371 | .474 | .498 | .514 | .724 | .903 | 1.055 |
| Equal up-and-down (From rigged up 10°) | | | | | | | | | | | | | | | | | | | |
| 20° | 20° | $C_l'$ | | .067 | | .057 | .058 | | .051 | | .055 | .048 | .048 | .040 | | .035 | .031 | | |
| 20° | 20° | $C_n'$ | | .003 | | -.008 | -.014 | | -.017 | | -.025 | -.022 | -.025 | -.028 | | -.028 | -.022 | | |
| 25° | 25° | $C_l'$ | | .075 | | .069 | .066 | | .057 | | .060 | .057 | .053 | .046 | | .040 | .027 | | |
| 25° | 25° | $C_n'$ | | .004 | | -.009 | -.016 | | -.019 | | -.024 | -.024 | -.027 | -.031 | | -.031 | -.025 | | |
| 30° | 30° | $C_l'$ | | .084 | | .081 | .077 | | .084 | | .050 | .061 | .060 | .051 | | .045 | .034 | | |
| 30° | 30° | $C_n'$ | | .005 | | -.011 | -.018 | | -.023 | | -.031 | -.027 | -.029 | -.034 | | -.035 | -.040 | | |
| Extreme differential No. 2 (From rigged up 10°) | | | | | | | | | | | | | | | | | | | |
| 10° | 7° | $C_l'$ | | .035 | | .031 | .031 | | .026 | | .031 | .021 | .019 | .015 | | .013 | .008 | | |
| 10° | 7° | $C_n'$ | | .002 | | -.004 | -.007 | | -.009 | | -.010 | -.010 | -.012 | -.013 | | -.012 | -.010 | | |
| 20° | 12° | $C_l'$ | | .059 | | .047 | .045 | | .043 | | .045 | .039 | .039 | .035 | | .033 | .020 | | |
| 20° | 12° | $C_n'$ | | .005 | | -.002 | -.007 | | -.010 | | -.015 | -.015 | -.018 | -.021 | | -.022 | -.017 | | |
| 30° | 14° | $C_l'$ | | .070 | | .058 | .055 | | .050 | | .042 | .048 | .048 | .042 | | .040 | .031 | | |
| 30° | 14° | $C_n'$ | | .005 | | -.003 | -.008 | | -.012 | | -.019 | -.015 | -.018 | -.022 | | -.023 | -.022 | | |
| 40° | 11½° | $C_l'$ | | .074 | | .064 | .061 | | .055 | | .045 | .051 | .054 | .047 | | .045 | .019 | | |
| 40° | 11½° | $C_n'$ | | .013 | | .001 | -.003 | | -.006 | | -.015 | -.011 | -.014 | -.016 | | -.019 | -.014 | | |
| 50° | 7° | $C_l'$ | | .073 | | .065 | .062 | | .056 | | .047 | .049 | .052 | .049 | | .046 | .017 | | |
| 50° | 7° | $C_n'$ | | .018 | | .006 | .001 | | -.004 | | -.011 | -.006 | -.009 | -.014 | | -.015 | -.011 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 COMBINED WITH HANDLEY PAGE 3 PER CENT c BY 50 PER CENT b/2 INTERCEPTOR AT USUAL LOCATION ON WING. INTERCEPTOR UP 90° | | | | | | | | | | | | | | | | | | | |
| Equal up-and-down | | | | | | | | | | | | | | | | | | | |
| 20° | 20° | $C_l'$ | | .058 | | .064 | .065 | | .055 | | .048 | .045 | .052 | .063 | | .062 | .036 | | |
| 20° | 20° | $C_n'$ | | -.003 | | -.014 | -.019 | | -.021 | | -.025 | -.019 | -.020 | -.024 | | -.022 | -.022 | | |
| 25° | 25° | $C_l'$ | | .069 | | .071 | .073 | | .063 | | .051 | .049 | .057 | .070 | | .065 | .040 | | |
| 25° | 25° | $C_n'$ | | -.002 | | -.016 | -.023 | | -.025 | | -.029 | -.023 | -.024 | -.029 | | -.029 | -.027 | | |
| 30° | 30° | $C_l'$ | | .078 | | .060 | .076 | | .063 | | .051 | .052 | .060 | .075 | | .068 | .044 | | |
| 30° | 30° | $C_n'$ | | -.002 | | -.018 | -.024 | | -.026 | | -.031 | -.026 | -.028 | -.035 | | -.034 | -.032 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | | | |
| 10° | 8½° | $C_l'$ | | .032 | | .031 | .035 | | .034 | | .029 | .031 | .037 | .052 | | .045 | .030 | | |
| 10° | 8½° | $C_n'$ | | -.001 | | -.007 | -.009 | | -.010 | | -.014 | -.009 | -.010 | -.013 | | -.009 | -.013 | | |
| 20° | 13° | $C_l'$ | | .058 | | .056 | .057 | | .052 | | .043 | .042 | .051 | .062 | | .059 | .036 | | |
| 20° | 13° | $C_n'$ | | .000 | | -.010 | .015 | | -.016 | | -.021 | -.015 | -.015 | -.019 | | -.018 | -.018 | | |
| 30° | 15° | $C_l'$ | | .068 | | .063 | .063 | | .057 | | .050 | .049 | .057 | .072 | | .066 | .044 | | |
| 30° | 15° | $C_n'$ | | .002 | | -.010 | -.015 | | -.017 | | -.023 | -.018 | -.019 | -.024 | | -.023 | -.024 | | |
| 35° | 15° | $C_l'$ | | .073 | | .068 | .066 | | .059 | | .051 | .050 | .057 | .075 | | .068 | .050 | | |
| 35° | 15° | $C_n'$ | | .004 | | -.009 | -.015 | | -.016 | | -.022 | -.016 | -.017 | -.024 | | -.023 | -.026 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | | | |
| 10° | 7° | $C_l'$ | | .031 | | .029 | .033 | | .033 | | .027 | .029 | .036 | .050 | | .044 | .031 | | |
| 10° | 7° | $C_n'$ | | .000 | | -.006 | -.008 | | -.008 | | -.012 | -.007 | -.007 | -.011 | | -.007 | -.012 | | |
| 20° | 12° | $C_l'$ | | .052 | | .053 | .056 | | .051 | | .043 | .041 | .050 | .062 | | .059 | .036 | | |
| 20° | 12° | $C_n'$ | | .000 | | -.009 | -.015 | | -.016 | | -.021 | -.015 | -.016 | -.019 | | -.018 | -.018 | | |
| 30° | 14° | $C_l'$ | | .068 | | .063 | .063 | | .057 | | .049 | .049 | .059 | .072 | | .066 | .044 | | |
| 30° | 14° | $C_n'$ | | .003 | | -.010 | -.015 | | -.017 | | -.023 | -.017 | -.019 | -.023 | | -.022 | -.024 | | |
| 40° | 11½° | $C_l'$ | | .076 | | .070 | .067 | | .062 | | .054 | .050 | .056 | .071 | | .068 | .055 | | |
| 40° | 11½° | $C_n'$ | | .007 | | -.006 | -.012 | | -.014 | | -.019 | -.014 | -.014 | -.019 | | -.018 | -.025 | | |
| 50° | 7° | $C_l'$ | | .079 | | .073 | .069 | | .066 | | .060 | .053 | .054 | .058 | | .056 | .039 | | |
| 50° | 7° | $C_n'$ | | .012 | | .000 | -.006 | | -.009 | | -.014 | -.008 | -.009 | -.012 | | -.012 | -.015 | | |
| Up-only | | | | | | | | | | | | | | | | | | | |
| 10° | 0° | $C_l'$ | | .021 | | .018 | .023 | | .024 | | .019 | .022 | .027 | .044 | | .041 | .028 | | |
| 10° | 0° | $C_n'$ | | .001 | | -.003 | -.004 | | -.004 | | -.006 | -.002 | -.001 | -.005 | | -.002 | -.008 | | |
| 20° | 0° | $C_l'$ | | .037 | | .035 | .039 | | .037 | | .030 | .028 | .039 | .053 | | .054 | .033 | | |
| 20° | 0° | $C_n'$ | | .002 | | -.004 | -.007 | | -.007 | | -.011 | -.005 | -.006 | -.008 | | -.009 | -.012 | | |
| 30° | 0° | $C_l'$ | | .053 | | .043 | .043 | | .042 | | .037 | .035 | .046 | .062 | | .060 | .043 | | |
| 30° | 0° | $C_n'$ | | .005 | | -.003 | -.005 | | -.007 | | -.011 | -.006 | -.007 | -.012 | | -.011 | -.015 | | |
| 40° | 0° | $C_l'$ | | .062 | | .052 | .050 | | .049 | | .043 | .037 | .045 | .062 | | .062 | .053 | | |
| 40° | 0° | $C_n'$ | | .009 | | -.001 | -.004 | | -.008 | | -.010 | -.004 | -.004 | -.010 | | -.009 | -.019 | | |
| 50° | 0° | $C_l'$ | | .069 | | .062 | .058 | | .057 | | .053 | .045 | .047 | .052 | | .052 | .037 | | |
| 50° | 0° | $C_n'$ | | .013 | | .002 | -.003 | | -.005 | | -.006 | -.004 | -.004 | -.007 | | -.008 | -.012 | | |
| 60° | 0° | $C_l'$ | | .076 | | .070 | .066 | | .065 | | .061 | .052 | .054 | .052 | | .053 | .035 | | |
| 60° | 0° | $C_n'$ | | .017 | | .005 | -.001 | | -.003 | | -.007 | -.003 | -.004 | -.006 | | -.007 | -.012 | | |

TABLE II (Cont'd) FORCE TESTS. 10 BY 60 INCH CLARK Y WING WITH 50 PER CENT b/2
HANDLEY PAGE TIP SLOTS OPEN AT ALL ANGLES OF ATTACK - PLAIN AILERONS
Yaw = 0° R.N. = 609,000 Velocity = 80 m.p.h.

| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 COMBINED WITH 3 PER CENT c BY 50 PER CENT b/2 SPOILER LOCATED BACK FROM SLOT SPOILER UP 90° | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | α | -5° | 0° | 5° | 10° | 15° | 17° | 18° | 19° | 20° | 22° | 25° | 30° | 31° | 32° | 40° | 50° | 60° |
| | $\delta_A$ up | $\delta_A$ dn. | Equal up-and-down | | | | | | | | | | | | | | | | | |
| | 10° | 10° | $C_l'$ | | .033 | | .049 | .056 | | .061 | | .056 | .052 | .062 | .074 | | .067 | .038 | | |
| | 10° | 10° | $C_n'$ | | .002 | | .003 | .000 | | -.003 | | -.010 | -.009 | -.009 | -.015 | | -.013 | -.015 | | |
| | 20° | 20° | $C_l'$ | | .055 | | .075 | .080 | | .077 | | .068 | .062 | .071 | .083 | | .079 | .044 | | |
| | 20° | 20° | $C_n'$ | | .000 | | -.004 | -.009 | | -.013 | | -.019 | -.018 | -.017 | -.024 | | -.024 | -.024 | | |
| | 25° | 25° | $C_l'$ | | .067 | | .085 | .090 | | .085 | | .076 | .068 | .075 | .088 | | .087 | .048 | | |
| | 25° | 25° | $C_n'$ | | .000 | | -.006 | -.013 | | -.016 | | -.023 | -.022 | -.021 | -.028 | | -.029 | -.028 | | |
| | 30° | 30° | $C_l'$ | | .075 | | .088 | .089 | | .084 | | .075 | .072 | .078 | .091 | | .089 | .052 | | |
| | 30° | 30° | $C_n'$ | | .000 | | -.008 | -.015 | | -.018 | | -.025 | -.026 | -.025 | -.034 | | -.035 | -.033 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | | | | |
| | 35° | 15° | $C_l'$ | | .070 | | .074 | .079 | | .079 | | .074 | .070 | .077 | .094 | | .093 | .059 | | |
| | 35° | 15° | $C_n'$ | | .006 | | .001 | -.005 | | -.008 | | -.016 | -.016 | -.016 | -.023 | | -.024 | -.027 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | | | | |
| | 50° | 7° | $C_l'$ | | .075 | | .072 | .077 | | .077 | | .070 | .060 | .066 | .077 | | .073 | .048 | | |
| | 50° | 7° | $C_n'$ | | .013 | | .007 | .002 | | -.002 | | -.008 | -.007 | -.006 | -.013 | | -.013 | -.017 | | |
| Up-only | | | | | | | | | | | | | | | | | | | | |
| | 60° | 0° | $C_l'$ | | .071 | | .066 | .072 | | .072 | | .067 | .054 | .058 | .068 | | .069 | .045 | | |
| | 60° | 0° | $C_n'$ | | .017 | | .012 | .007 | | .005 | | -.002 | -.001 | .001 | -.006 | | -.007 | -.015 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 COMBINED WITH 7 PER CENT c BY 50 PER CENT b/2 REARWARD-HINGED SPOILER | | | | | | | | | | | | | | | | | | | | |
| $\delta_S$ | $\delta_A$ up | $\delta_A$ dn. | Equal up-and-down | | | | | | | | | | | | | | | | | |
| 90° | 25° | 25° | $C_l'$ | | .090 | | .118 | .128 | | .118 | | .100 | .090 | .088 | .091 | | .087 | .044 | | |
| 90° | 25° | 25° | $C_n'$ | | .012 | | -.001 | -.008 | | -.015 | | -.022 | -.023 | -.022 | -.031 | | -.033 | -.032 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | | | | |
| 90° | 35° | 15° | $C_l'$ | | .078 | | .103 | .114 | | .108 | | .098 | .087 | .092 | .100 | | .094 | .055 | | |
| 90° | 35° | 15° | $C_n'$ | | .015 | | .006 | .001 | | -.006 | | -.015 | -.017 | -.016 | -.025 | | -.027 | -.030 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | | | | |
| 90° | 50° | 7° | $C_l'$ | | .067 | | .087 | .098 | | .098 | | .088 | .074 | .077 | .078 | | .077 | .045 | | |
| 90° | 50° | 7° | $C_n'$ | | .017 | | .012 | .007 | | .001 | | -.007 | -.008 | -.007 | -.013 | | -.016 | -.019 | | |
| Up-only | | | | | | | | | | | | | | | | | | | | |
| 90° | 60° | 0° | $C_l'$ | | .056 | | .075 | .086 | | .088 | | .077 | .064 | .067 | .070 | | .070 | .040 | | |
| 90° | 60° | 0° | $C_n'$ | | .017 | | .014 | .010 | | .004 | | -.003 | -.003 | -.003 | -.009 | | -.011 | -.015 | | |
| 45° | 10° | 0° | $C_l'$ | | .050 | | .065 | .075 | | .078 | | .070 | .054 | .061 | .067 | | .067 | .029 | | |
| 45° | 10° | 0° | $C_n'$ | | .016 | | .013 | .011 | | .006 | | .000 | .000 | -.001 | -.006 | | -.009 | -.011 | | |
| 45° | 20° | 0° | $C_l'$ | | .057 | | .076 | .086 | | .088 | | .078 | .062 | .068 | .072 | | .073 | .035 | | |
| 45° | 20° | 0° | $C_n'$ | | .016 | | .012 | .008 | | .004 | | -.003 | -.003 | -.003 | -.009 | | -.012 | -.015 | | |
| 45° | 30° | 0° | $C_l'$ | | .057 | | .078 | .090 | | .093 | | .084 | .070 | .074 | .080 | | .081 | .044 | | |
| 45° | 30° | 0° | $C_n'$ | | .016 | | .012 | .008 | | .003 | | -.004 | -.005 | -.005 | -.011 | | -.014 | -.019 | | |
| 60° | 20° | 0° | $C_l'$ | | .061 | | .079 | .091 | | .092 | | .083 | .066 | .070 | .076 | | .075 | .037 | | |
| 60° | 20° | 0° | $C_n'$ | | .018 | | .013 | .009 | | .004 | | -.003 | -.004 | -.004 | -.009 | | -.012 | -.016 | | |
| 60° | 40° | 0° | $C_l'$ | | .057 | | .077 | .089 | | .092 | | .083 | .068 | .076 | .085 | | .089 | .056 | | |
| 60° | 40° | 0° | $C_n'$ | | .018 | | .014 | .011 | | .006 | | -.001 | -.002 | -.003 | -.010 | | -.014 | -.023 | | |
| 60° | 60° | 0° | $C_l'$ | | .055 | | .075 | .084 | | .086 | | .077 | .063 | .067 | .071 | | .072 | .043 | | |
| 60° | 60° | 0° | $C_n'$ | | .019 | | .015 | .011 | | .006 | | -.001 | -.002 | -.002 | -.007 | | -.010 | -.016 | | |
| 30° | 10° | 0° | $C_l'$ | | .043 | | .060 | .069 | | .072 | | .065 | .050 | .060 | .062 | | .062 | .027 | | |
| 30° | 10° | 0° | $C_n'$ | | .015 | | .012 | .011 | | .005 | | -.001 | -.002 | -.002 | -.007 | | -.009 | -.011 | | |
| 30° | 20° | 0° | $C_l'$ | | .049 | | .070 | .079 | | .082 | | .072 | .057 | .064 | .068 | | .068 | .034 | | |
| 30° | 20° | 0° | $C_n'$ | | .014 | | .010 | .008 | | .003 | | -.004 | -.004 | -.005 | -.010 | | -.012 | -.016 | | |
| 15° | 10° | 0° | $C_l'$ | | .033 | | .051 | .062 | | .064 | | .057 | .045 | .052 | .054 | | .054 | .022 | | |
| 15° | 10° | 0° | $C_n'$ | | .010 | | .009 | .007 | | .003 | | -.004 | -.004 | -.003 | -.007 | | -.009 | -.010 | | |
| SPOILER ALONE (FORWARD-HINGED) 10 PER CENT c BY 60 PER CENT b/2 | | | | | | | | | | | | | | | | | | | | |
| Up-only | | | | | | | | | | | | | | | | | | | | |
| 10° | 0° | 0° | $C_l'$ | | .009 | | .030 | .044 | | .045 | | .034 | .022 | .018 | .007 | | .001 | .002 | | |
| 10° | 0° | 0° | $C_n'$ | | .005 | | .006 | .005 | | .000 | | -.004 | .001 | -.001 | .000 | | .001 | -.002 | | |
| 20° | 0° | 0° | $C_l'$ | | .030 | | .039 | .052 | | .053 | | .043 | .030 | .033 | .031 | | .024 | .002 | | |
| 20° | 0° | 0° | $C_n'$ | | .010 | | .008 | .005 | | .001 | | -.004 | .000 | -.002 | -.005 | | -.004 | -.004 | | |
| 40° | 0° | 0° | $C_l'$ | | .045 | | .058 | .067 | | .064 | | .058 | .044 | .047 | .048 | | .048 | .012 | | |
| 40° | 0° | 0° | $C_n'$ | | .015 | | .012 | .008 | | .005 | | -.001 | .001 | -.001 | -.006 | | -.008 | -.006 | | |
| 60° | 0° | 0° | $C_l'$ | | .068 | | .073 | .084 | | .082 | | .073 | .059 | .063 | .065 | | .066 | .024 | | |
| 60° | 0° | 0° | $C_n'$ | | .021 | | .017 | .014 | | .010 | | .004 | .003 | .001 | -.004 | | -.006 | -.007 | | |
| 90° | 0° | 0° | $C_l'$ | | .028 | | .050 | .071 | | .097 | | .104 | .086 | .081 | .077 | | .075 | .079 | | |
| 90° | 0° | 0° | $C_n'$ | | .023 | | .023 | .020 | | .018 | | .014 | .005 | -.001 | .001 | | -.004 | -.013 | | |

TABLE III. FORCE TESTS. 10 BY 60-INCH CLARK Y WING WITH 50 PER CENT b/2
HANDLEY PAGE TIP SLOTS OPEN AT ALL ANGLES OF ATTACK - PLAIN AILERONS AND SPOILERS

Yaw = -20° R.N. = 609,000 Velocity = 80 m.p.h.

| $\delta_S$ | $\delta_A$ up | $\delta_A$ dn. | α | -10° | -5° | 0° | 5° | 10° | 15° | 18° | 19° | 20° | 22° | 25° | 30° | 32° | 33° | 34° | 40° | 50° | 60° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 | | | | | | | | | | | | | | | | | | | | | |
| Ailerons locked - Neutral | | | | | | | | | | | | | | | | | | | | | |
| | 0° | 0° | $C_L$ | -0.297 | -0.046 | 0.268 | 0.592 | 0.898 | | 1.178 | 1.208 | 1.165 | 1.125 | 1.082 | 1.140 | 1.142 | 1.145 | 1.132 | 1.074 | 0.905 | 0.725 |
| | 0° | 0° | $C_D$ | .103 | .058 | .039 | .050 | .083 | | .189 | .217 | .280 | .349 | .390 | .492 | .539 | .582 | .573 | .711 | .898 | 1.068 |
| | 0° | 0° | $C_l'$ | .008 | -.002 | -.005 | -.007 | -.007 | | -.042 | -.050 | -.061 | -.063 | -.068 | -.073 | -.073 | -.074 | -.073 | -.063 | -.050 | -.045 |
| | 0° | 0° | $C_n'$ | .005 | .002 | .002 | .002 | .004 | | .009 | .007 | .008 | .018 | .026 | .035 | .040 | .042 | .045 | .047 | .048 | .052 |
| Equal up-and-down | | | | | | | | | | | | | | | | | | | | | |
| | 25° | 25° | $C_l'$ | | | .070 | | .067 | 0.070 | .069 | | .061 | .055 | .053 | .048 | .043 | | | .008 | | |
| | 25° | 25° | $C_n'$ | | | -.004 | | -.016 | -.022 | -.024 | | -.027 | -.027 | -.033 | -.034 | -.035 | | | -.026 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | | | | | |
| | 35° | 15° | $C_l'$ | | | .074 | | .070 | .070 | .072 | | .070 | .064 | .065 | .065 | .059 | | | .021 | | |
| | 35° | 15° | $C_n'$ | | | .004 | | -.009 | -.014 | -.018 | | -.022 | -.023 | -.029 | -.035 | -.038 | | | -.028 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | | | | | |
| | 50° | 7° | $C_l'$ | | | .073 | | .076 | .077 | .082 | | .080 | .072 | .073 | .075 | .072 | | | .039 | | |
| | 50° | 7° | $C_n'$ | | | .011 | | .000 | -.006 | -.010 | | -.014 | -.024 | -.023 | -.030 | -.034 | | | -.030 | | |
| Up-only | | | | | | | | | | | | | | | | | | | | | |
| | 60° | 0° | $C_l'$ | | | .071 | | .075 | .077 | .082 | | .062 | .074 | .075 | .078 | .075 | | | .044 | | |
| | 60° | 0° | $C_n'$ | | | .016 | | .005 | -.002 | -.005 | | -.010 | -.019 | -.018 | -.025 | -.029 | | | -.028 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 NEUTRAL RIGGED UP 10° | | | | | | | | | | | | | | | | | | | | | |
| Ailerons locked - Neutral rigged up 10° | | | | | | | | | | | | | | | | | | | | | |
| | 0° | 0° | $C_L$ | -.410 | -.149 | .163 | | .820 | 1.044 | 1.101 | 1.130 | 1.084 | 1.000 | 1.010 | 1.065 | 1.090 | 1.092 | 1.090 | 1.050 | | |
| | 0° | 0° | $C_D$ | .123 | .066 | .040 | | .070 | .114 | .166 | .189 | .254 | .314 | .358 | .452 | .491 | .511 | .529 | .672 | | |
| | 0° | 0° | $C_l'$ | .015 | .005 | -.001 | | -.003 | -.012 | -.037 | -.044 | -.053 | -.057 | -.060 | -.066 | -.067 | -.068 | -.070 | -.066 | | |
| | 0° | 0° | $C_n'$ | .006 | .003 | .001 | | .003 | .006 | .007 | .007 | .005 | .017 | .023 | .030 | .035 | .037 | .038 | .047 | | |
| Equal up-and-down (From rigged up 10°) | | | | | | | | | | | | | | | | | | | | | |
| | 25° | 25° | $C_l'$ | | | .074 | | .070 | .070 | .072 | | .070 | .064 | .065 | .065 | .059 | | | .021 | | |
| | 25° | 25° | $C_n'$ | | | .004 | | -.009 | -.014 | -.018 | | -.022 | -.023 | -.029 | -.035 | -.038 | | | -.028 | | |
| Extreme differential No. 2 (From rigged up 10°) | | | | | | | | | | | | | | | | | | | | | |
| | 50° | 7° | $C_l'$ | | | .063 | | .068 | .072 | .075 | | .072 | .066 | .067 | .070 | .068 | | | .047 | | |
| | 50° | 7° | $C_n'$ | | | .016 | | .006 | .001 | -.002 | | -.006 | -.018 | -.013 | -.019 | -.023 | | | -.027 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 COMBINED WITH HANDLEY PAGE 3 PER CENT c BY 50 PER CENT b/2 INTERCEPTORS AT USUAL LOCATION ON WING. INTERCEPTOR UP 90° | | | | | | | | | | | | | | | | | | | | | |
| Equal up-and-down | | | | | | | | | | | | | | | | | | | | | |
| 90° | 25° | 25° | $C_l'$ | | | .072 | .069 | | .073 | .069 | | .070 | .055 | .052 | .050 | .045 | | | .030 | | |
| 90° | 25° | 25° | $C_n'$ | | | -.003 | -.016 | | -.021 | -.020 | | -.020 | -.023 | -.024 | -.023 | -.023 | | | -.020 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | | | | | |
| 90° | 35° | 15° | $C_l'$ | | | .074 | .071 | | .073 | .071 | | .074 | .060 | .061 | .065 | .062 | | | .043 | | |
| 90° | 35° | 15° | $C_n'$ | | | .005 | -.008 | | -.013 | -.013 | | -.013 | -.017 | -.021 | -.023 | -.025 | | | -.022 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | | | | | |
| 90° | 50° | 7° | $C_l'$ | | | .074 | .076 | | .079 | .080 | | .083 | .068 | .070 | .075 | .072 | | | .055 | | |
| 90° | 50° | 7° | $C_n'$ | | | .012 | .000 | | -.005 | -.006 | | -.004 | -.015 | -.016 | -.020 | -.021 | | | -.021 | | |
| Up-only | | | | | | | | | | | | | | | | | | | | | |
| 90° | 60° | 0° | $C_l'$ | | | .070 | .073 | | .080 | .083 | | .083 | .066 | .071 | .069 | .071 | | | .054 | | |
| 90° | 60° | 0° | $C_n'$ | | | .016 | .004 | | .000 | .000 | | .003 | -.009 | -.010 | -.015 | -.017 | | | -.017 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 COMBINED WITH 3 PER CENT c BY 50 PER CENT b/2 SPOILER LOCATED BACK FROM SLOT SPOILER UP 90° | | | | | | | | | | | | | | | | | | | | | |
| Equal up-and-down | | | | | | | | | | | | | | | | | | | | | |
| 90° | 25° | 25° | $C_l'$ | | | .071 | | .070 | .076 | .087 | | .076 | .072 | .060 | .062 | .062 | | | .047 | | |
| 90° | 25° | 25° | $C_n'$ | | | -.001 | | -.010 | -.014 | -.014 | | -.014 | -.022 | -.019 | -.015 | -.018 | | | -.027 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 COMBINED WITH 7 PER CENT c BY 50 PER CENT b/2 REARWARD-HINGED SPOILER | | | | | | | | | | | | | | | | | | | | | |
| Equal up-and-down | | | | | | | | | | | | | | | | | | | | | |
| 90° | 25° | 25° | $C_l'$ | | | .078 | | .085 | .103 | .123 | | .119 | .106 | .101 | .083 | .078 | | | .058 | | |
| 90° | 25° | 25° | $C_n'$ | | | .011 | | .003 | -.005 | -.008 | | -.015 | -.024 | -.028 | -.031 | -.023 | | | -.035 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | | | | | |
| 90° | 35° | 15° | $C_l'$ | | | .072 | | .081 | .094 | .112 | | .113 | .100 | .103 | .091 | .084 | | | .062 | | |
| 90° | 35° | 15° | $C_n'$ | | | .018 | | .010 | .004 | -.001 | | -.007 | -.017 | -.024 | -.021 | -.022 | | | -.034 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | | | | | |
| 90° | 50° | 7° | $C_l'$ | | | .073 | | .078 | .091 | .110 | | .111 | .098 | .094 | .087 | .084 | | | .060 | | |
| 90° | 50° | 7° | $C_n'$ | | | .024 | | .016 | .011 | .005 | | -.001 | -.011 | -.015 | -.013 | -.017 | | | -.029 | | |
| Up-only | | | | | | | | | | | | | | | | | | | | | |
| 90° | 60° | 0° | $C_l'$ | | | .068 | | .073 | .085 | .103 | | .106 | .083 | .092 | .081 | .062 | | | .056 | | |
| 90° | 60° | 0° | $C_n'$ | | | .028 | | .020 | .016 | .010 | | .004 | -.005 | -.011 | -.008 | -.012 | | | -.023 | | |
| SPOILER ALONE (FORWARD-HINGED) 10 PER CENT c BY 60 PER CENT b/2 | | | | | | | | | | | | | | | | | | | | | |
| Up-only | | | | | | | | | | | | | | | | | | | | | |
| 90° | 0° | 0° | $C_l'$ | | | .028 | | .050 | .071 | .097 | | .104 | .088 | .081 | .077 | .075 | | | .079 | | |
| 90° | 0° | 0° | $C_n'$ | | | .023 | | .023 | .020 | .018 | | .014 | .005 | -.001 | .001 | -.004 | | | -.013 | | |

TABLE IV

ROTATION TESTS. 10 BY 60 INCH CLARK Y WING WITH 50 PER CENT b/2
HANDLEY PAGE TIP SLOTS

$C_\lambda$ is given for forced rotation at $p'b/2V = 0.05$ (+) Aiding the rotation
(-) Damping the rotation

$p'b/2V$ values are for free rotation

Yaw = 0° Velocity = 80 m.p.h. R.N. = 609,000

| | α | 0° | 12° | 16° | 18° | 19° | 20° | 21° | 22° | 25° | 26° | 30° | 32° | 33° | 34° | 35° | 36° | 40° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ailerons locked - Neutral at 0° | | | | | | | | | | | | | | | | | | |
| (+) Rotation (clockwise) | $C_\lambda$ | -.0243 | -.0218 | -.0083 | -.0056 | -.0013 | -.0012 | -.0118 | -.0168 | | -.0173 | -.0073 | .0007 | | | .0030 | | .0094 |
| | $\frac{p'b}{2V}$ | | | | | | | | | | | | .056 | .147 | | .359 | | .479 |
| (-) Rotation (counter-clockwise) | $C_\lambda$ | -.0243 | -.0207 | -.0098 | -.0085 | -.0005 | .0006 | -.0105 | -.0168 | | -.0148 | -.0088 | .0042 | | | .0070 | | .0090 |
| | $\frac{p'b}{2V}$ | | | | | | | | | | | | .076 | .348 | | .395 | | .490 |
| Ailerons locked - Neutral rigged up 10° | | | | | | | | | | | | | | | | | | |
| (+) Rotation (clockwise) | $C_\lambda$ | -.0246 | -.0233 | -.0062 | -.0074 | -.0018 | -.0006 | -.0058 | -.0174 | -.0182 | | -.0082 | -.0012 | | .0042 | | .0018 | .0072 |
| | $\frac{p'b}{2V}$ | | | | | | | | | | | | | .080 | | .190 | | .406 |
| (-) Rotation (counter-clockwise) | $C_\lambda$ | -.0216 | -.0200 | -.0100 | -.0114 | .0018 | .0016 | -.0058 | -.0140 | -.0150 | | -.0092 | .0042 | | .0062 | | .0034 | .0070 |
| | $\frac{p'b}{2V}$ | | | | | | | | | | | | .054 | .141 | | .338 | | .406 |

TABLE V

ROTATION TESTS. 10 BY 60 INCH CLARK Y WING WITH 50 PER CENT b/2
HANDLEY PAGE TIP SLOTS

$C_\lambda$ is given for forced rotation at $p'b/2V = 0.05$ (+) Aiding the rotation
(-) Damping the rotation

Yaw = -20° Velocity = 80 m.p.h. R.N. = 609,000

| | α | 0° | 12° | 14° | 16° | 18° | 20° | 22° | 23° | 25° | 28° | 30° | 35° | 40° | 45° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ailerons locked - Neutral at 0° | | | | | | | | | | | | | | | |
| (+) Rotation (Clockwise) | $C_\lambda$ | -0.0300 | -0.0355 | -0.0430 | -0.0550 | -0.0460 | -0.0465 | -0.0510 | -0.0645 | -0.0735 | -0.0770 | -0.0775 | -0.0665 | -0.0535 | -0.0540 |
| (-) Rotation (Counter-clockwise) | $C_\lambda$ | -.0120 | -.0050 | .0000 | .0100 | .0360 | .0435 | .0285 | .0300 | .0440 | .0505 | .0555 | .0370 | .0760 | .0640 |
| Ailerons locked - Neutral rigged up 10° | | | | | | | | | | | | | | | |
| (+) Rotation (Clockwise) | $C_\lambda$ | -.0284 | -.0330 | -.0358 | -.0450 | -.0593 | -.0434 | -.0478 | -.0588 | -.0688 | | -.0728 | -.0658 | -.0534 | |
| (-) Rotation (Counter-clockwise) | $C_\lambda$ | -.0146 | -.0056 | -.0030 | .0044 | .0200 | .0400 | .0238 | .0270 | .0420 | | .0520 | .0644 | .0758 | |

# TABLE VI

## FORCE TESTS. 10 BY 60 INCH CLARK Y WING WITH HANDLEY PAGE FULL-SPAN SLOT OPEN AT ALL ANGLES OF ATTACK -- PLAIN AILERONS AND SPOILERS

Yaw = 0° R.N. = 609,000 Velocity = 80 m.p.h.

| PLAIN AILERONS 25 PER CENT. c BY 40 PER CENT b/2 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | α | -5° | 0° | 5° | 8° | 10° | 15° | 20° | 24° | 25° | 28° | 30° | 35° | 40° | 50° | 60° |
| $\delta_A$ up | $\delta_A$ dn. | | Ailerons locked - Neutral | | | | | | | | | | | | | | |
| 0° | 0° | $C_L$ | -0.017 | 0.293 | 0.636 | 0.700 | 0.932 | 1.332 | 1.668 | | 1.818 | 1.830 | 1.455 | 1.258 | 1.148 | 0.966 | 0.796 |
| 0° | 0° | $C_D$ | .086 | .050 | .054 | .061 | .092 | .151 | .236 | | .340 | .360 | .475 | .623 | .753 | .899 | 1.018 |
| Equal up-and-down | | | | | | | | | | | | | | | | | |
| 20° | 20° | $C_l'$ | | | | | .063 | | .061 | 0.056 | | .019 | .015 | .015 | .006 | | |
| 20° | 20° | $C_n'$ | | | | | -.015 | | -.027 | -.029 | | -.031 | -.029 | -.025 | -.020 | | |
| 25° | 25° | $C_l'$ | | .065 | | | .067 | | .072 | .068 | | .027 | .024 | .018 | .008 | | |
| 25° | 25° | $C_n'$ | | -.004 | | | -.017 | | -.032 | -.035 | | -.036 | -.035 | -.029 | -.025 | | |
| 30° | 30° | $C_l'$ | | .077 | | | .076 | | .084 | .078 | | .035 | .031 | .022 | .011 | | |
| 30° | 30° | $C_n'$ | | -.004 | | | -.019 | | -.035 | -.039 | | -.041 | -.040 | -.033 | -.028 | | |
| Average differential No. 1 | | | | | | | | | | | | | | | | | |
| 10° | 8½° | $C_l'$ | | .027 | | | .028 | | .028 | .023 | | -.002 | .000 | .003 | .000 | | |
| 10° | 8½° | $C_n'$ | | -.002 | | | -.007 | | -.014 | -.014 | | -.017 | -.014 | -.012 | -.009 | | |
| 20° | 13° | $C_l'$ | | .047 | | | .050 | | .052 | .044 | | .015 | .015 | .014 | .005 | | |
| 20° | 13° | $C_n'$ | | -.001 | | | -.011 | | -.021 | -.023 | | -.026 | -.023 | -.020 | -.015 | | |
| 30° | 15° | $C_l'$ | | .064 | | | .061 | | .070 | .068 | | .032 | .030 | .023 | .014 | | |
| 30° | 15° | $C_n'$ | | .001 | | | -.011 | | -.024 | -.028 | | -.031 | -.031 | -.024 | -.021 | | |
| 35° | 15° | $C_l'$ | | .068 | | | .066 | | .073 | .073 | | .038 | .035 | .029 | .019 | | |
| 35° | 15° | $C_n'$ | | .003 | | | -.010 | | -.023 | -.028 | | -.031 | -.031 | -.027 | -.024 | | |
| Extreme differential No. 2 | | | | | | | | | | | | | | | | | |
| 10° | 7° | $C_l'$ | | .026 | | | .027 | | .026 | .023 | | -.005 | -.001 | .003 | .001 | | |
| 10° | 7° | $C_n'$ | | -.002 | | | -.007 | | -.012 | -.014 | | -.016 | -.013 | -.012 | -.009 | | |
| 20° | 12° | $C_l'$ | | .048 | | | .050 | | .053 | .045 | | .014 | .014 | .014 | .006 | | |
| 20° | 12° | $C_n'$ | | -.001 | | | -.011 | | -.022 | -.024 | | -.026 | -.024 | -.021 | -.016 | | |
| 30° | 14° | $C_l'$ | | .064 | | | .060 | | .070 | .066 | | .033 | .030 | .024 | .014 | | |
| 30° | 14° | $C_n'$ | | .001 | | | -.011 | | -.025 | -.029 | | -.032 | -.032 | -.026 | -.022 | | |
| 40° | 11½° | $C_l'$ | | .072 | | | .066 | | .072 | .070 | | .040 | .035 | .030 | .024 | | |
| 40° | 11½° | $C_n'$ | | .006 | | | -.007 | | -.020 | -.025 | | -.029 | -.028 | -.025 | -.024 | | |
| 50° | 7° | $C_l'$ | | .077 | | | .069 | | .075 | .074 | | .045 | .038 | .026 | .012 | | |
| 50° | 7° | $C_n'$ | | .011 | | | -.002 | | -.015 | -.020 | | -.024 | -.025 | -.019 | -.015 | | |
| Up-only | | | | | | | | | | | | | | | | | |
| 10° | 0° | $C_l'$ | | .016 | | | .017 | | .018 | .016 | | -.010 | -.005 | .002 | .000 | | |
| 10° | 0° | $C_n'$ | | -.001 | | | -.004 | | -.008 | -.009 | | -.011 | -.009 | -.007 | -.005 | | |
| 20° | 0° | $C_l'$ | | .033 | | | .033 | | .036 | .033 | | .005 | .007 | .010 | .005 | | |
| 20° | 0° | $C_n'$ | | .001 | | | -.005 | | -.013 | -.015 | | -.017 | -.015 | -.013 | -.010 | | |
| 30° | 0° | $C_l'$ | | .048 | | | .040 | | .051 | .052 | | .024 | .021 | .020 | .013 | | |
| 30° | 0° | $C_n'$ | | .004 | | | -.004 | | -.014 | -.019 | | -.021 | -.021 | -.017 | -.014 | | |
| 40° | 0° | $C_l'$ | | .057 | | | .049 | | .057 | .059 | | .033 | .028 | .027 | .023 | | |
| 40° | 0° | $C_n'$ | | .008 | | | -.002 | | -.012 | -.016 | | -.020 | -.021 | -.018 | -.018 | | |
| 50° | 0° | $C_l'$ | | .068 | | | .058 | | .065 | .065 | | .038 | .034 | .022 | .011 | | |
| 50° | 0° | $C_n'$ | | .012 | | | .001 | | -.011 | -.015 | | -.019 | -.019 | -.014 | -.011 | | |
| 60° | 0° | $C_l'$ | | .072 | | | .065 | | .071 | .074 | | .046 | .040 | .023 | .010 | | |
| 60° | 0° | $C_n'$ | | .016 | | | .004 | | -.009 | -.014 | | -.018 | -.019 | -.013 | -.011 | | |
| Down-only | | | | | | | | | | | | | | | | | |
| 0° | 0° | $C_l'$ | | .005 | | | .007 | | .006 | .004 | | .002 | .005 | .006 | .000 | | |
| 0° | 0° | $C_n'$ | | .000 | | | -.002 | | -.002 | -.002 | | -.001 | -.002 | -.003 | -.002 | | |
| 0° | 10° | $C_l'$ | | .011 | | | .014 | | .014 | .012 | | -.009 | .005 | -.004 | -.003 | | |
| 0° | 10° | $C_n'$ | | -.002 | | | -.005 | | -.008 | -.008 | | -.010 | -.006 | -.006 | -.004 | | |
| 0° | 20° | $C_l'$ | | .018 | | | .027 | | .024 | .022 | | -.005 | .012 | -.003 | -.005 | | |
| 0° | 20° | $C_n'$ | | -.006 | | | -.011 | | -.015 | -.016 | | -.016 | -.015 | -.011 | -.008 | | |
| 0° | 30° | $C_l'$ | | .026 | | | .037 | | .031 | .027 | | -.006 | .0100 | -.006 | -.008 | | |
| 0° | 30° | $C_n'$ | | -.009 | | | -.017 | | -.023 | -.024 | | -.022 | -.021 | -.016 | -.012 | | |

TABLE VI. (Cont'd) PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2

NEUTRAL RIGGED UP 10°

| $\delta_S$ | $\delta_A$ up | $\delta_A$ dn. | α | -5° | 0° | 5° | 6° | 10° | 15° | 20° | 24° | 25° | 26° | 30° | 35° | 40° | 50° | 60° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Ailerons locked - Neutral rigged up 10° | | | | | | | | | | | | | | |
| | 0° | 0° | $C_L$ | -.115 | .184 | .537 | | .850 | 1.248 | 1.582 | 1.735 | 1.643 | | 1.413 | 1.189 | 1.112 | .947 | .793 |
| | 0° | 0° | $C_D$ | .094 | .051 | .046 | | .078 | .130 | .204 | .288 | .306 | | .435 | .569 | .709 | .837 | .938 |
| | | | | Equal up-and-down (From rigged up 10°) | | | | | | | | | | | | | | |
| | 20° | 20° | $C_l'$ | | .059 | | | .053 | | .064 | .060 | | .039 | .027 | .023 | .014 | | |
| | 20° | 20° | $C_n'$ | | .002 | | | -.008 | | -.022 | -.026 | | -.039 | -.029 | -.024 | -.020 | | |
| | 25° | 25° | $C_l'$ | | .068 | | | .066 | | .073 | .073 | | .038 | .035 | .029 | .019 | | |
| | 25° | 25° | $C_n'$ | | .003 | | | -.010 | | -.023 | -.028 | | -.031 | -.031 | -.027 | -.024 | | |
| | 30° | 30° | $C_l'$ | | .077 | | | .076 | | .080 | .078 | | .040 | .038 | .029 | .024 | | |
| | 30° | 30° | $C_n'$ | | .003 | | | -.012 | | -.026 | -.031 | | -.033 | -.033 | -.029 | -.028 | | |
| | | | | Extreme differential No. 2 (From rigged up 10°) | | | | | | | | | | | | | | |
| | 10° | 7° | $C_l'$ | | .028 | | | .027 | | .030 | .027 | | .000 | .003 | .008 | .004 | | |
| | 10° | 7° | $C_n'$ | | .001 | | | -.004 | | -.011 | -.013 | | -.014 | -.013 | -.011 | -.009 | | |
| | 20° | 12° | $C_l'$ | | .051 | | | .043 | | .054 | .053 | | .025 | .022 | .002 | .001 | | |
| | 20° | 12° | $C_n'$ | | .004 | | | -.005 | | -.016 | -.020 | | -.023 | -.022 | -.018 | -.015 | | |
| | 30° | 14° | $C_l'$ | | .064 | | | .055 | | .062 | .063 | | .035 | .031 | .027 | .024 | | |
| | 30° | 14° | $C_n'$ | | .007 | | | -.004 | | -.015 | -.019 | | -.024 | -.023 | -.020 | -.020 | | |
| | 40° | 11½° | $C_l'$ | | .068 | | | .061 | | .066 | .067 | | .040 | .035 | .024 | .011 | | |
| | 40° | 11½° | $C_n'$ | | .011 | | | .001 | | -.012 | -.017 | | -.020 | -.021 | -.016 | -.012 | | |
| | 50° | 7° | $C_l'$ | | .066 | | | .060 | | .068 | .068 | | .043 | .037 | .021 | .008 | | |
| | 50° | 7° | $C_n'$ | | .016 | | | .005 | | -.007 | -.011 | | -.013 | -.016 | -.010 | -.009 | | |
| | | | | PLAIN AILERONS 25 PER CENT c BY 40 PER CENT b/2 COMBINED WITH REAR-HINGED SPOILER 7 PER CENT c BY 40 PER CENT b/2 | | | | | | | | | | | | | | |
| $\delta_S$ | $\delta_A$ up | $\delta_A$ dn. | | Equal up-and-down | | | | | | | | | | | | | | |
| 90° | 25° | 25° | $C_l'$ | | .091 | | | .109 | | .141 | .145 | | .141 | .061 | .044 | .030 | | |
| 90° | 25° | 25° | $C_n'$ | | .010 | | | -.004 | | -.019 | -.025 | | -.028 | -.029 | -.032 | -.030 | | |
| | | | | Average differential No. 1 | | | | | | | | | | | | | | |
| 90° | 35° | 15° | $C_l'$ | | .085 | | | .097 | | .132 | .143 | | .139 | .099 | .052 | .039 | | |
| 90° | 35° | 15° | $C_n'$ | | .015 | | | .003 | | -.012 | -.018 | | -.022 | -.029 | -.028 | -.028 | | |
| | | | | Extreme differential No. 2 | | | | | | | | | | | | | | |
| 90° | 50° | 7° | $C_l'$ | | .088 | | | .090 | | .123 | .130 | | .127 | .093 | .046 | .034 | | |
| 90° | 50° | 7° | $C_n'$ | | .021 | | | .009 | | -.004 | -.010 | | -.014 | -.020 | -.021 | -.020 | | |
| | | | | Up-only | | | | | | | | | | | | | | |
| 15° | 10° | 0° | $C_l'$ | | .027 | | | .050 | | .086 | .093 | | .091 | .059 | .030 | .020 | | |
| 15° | 10° | 0° | $C_n'$ | | .006 | | | .005 | | .000 | -.004 | | -.006 | -.010 | -.013 | -.012 | | |
| 30° | 10° | 0° | $C_l'$ | | .044 | | | .057 | | .089 | .098 | | .098 | .064 | .032 | .021 | | |
| 30° | 10° | 0° | $C_n'$ | | .010 | | | .006 | | .001 | -.004 | | -.006 | -.010 | -.013 | -.012 | | |
| 30° | 20° | 0° | $C_l'$ | | .051 | | | .066 | | .099 | .108 | | .106 | .070 | .037 | .025 | | |
| 30° | 20° | 0° | $C_n'$ | | .010 | | | .005 | | -.003 | -.007 | | -.009 | -.013 | -.016 | -.017 | | |
| 45° | 10° | 0° | $C_l'$ | | .054 | | | .062 | | .094 | .104 | | .103 | .068 | .035 | .022 | | |
| 45° | 10° | 0° | $C_n'$ | | .012 | | | .008 | | .001 | -.003 | | -.005 | -.009 | -.013 | -.012 | | |
| 45° | 20° | 0° | $C_l'$ | | .058 | | | .070 | | .104 | .112 | | .110 | .074 | .040 | .027 | | |
| 45° | 20° | 0° | $C_n'$ | | .013 | | | .007 | | .002 | -.006 | | -.008 | -.013 | -.016 | -.016 | | |
| 45° | 30° | 0° | $C_l'$ | | .064 | | | .072 | | .111 | .120 | | .119 | .080 | .045 | .032 | | |
| 45° | 30° | 0° | $C_n'$ | | .015 | | | .007 | | -.003 | -.008 | | -.010 | -.015 | -.019 | -.019 | | |
| 60° | 20° | 0° | $C_l'$ | | .064 | | | .075 | | .106 | .115 | | .114 | .077 | .041 | .027 | | |
| 60° | 20° | 0° | $C_n'$ | | .014 | | | .008 | | -.002 | -.005 | | -.009 | -.013 | -.016 | -.016 | | |
| 60° | 40° | 0° | $C_l'$ | | .071 | | | .076 | | .110 | .125 | | .124 | .088 | .051 | .040 | | |
| 60° | 40° | 0° | $C_n'$ | | .018 | | | .010 | | .000 | -.005 | | -.008 | -.015 | -.019 | -.022 | | |
| 60° | 60° | 0° | $C_l'$ | | .081 | | | .084 | | .114 | .122 | | .123 | .086 | .046 | .031 | | |
| 60° | 60° | 0° | $C_n'$ | | .025 | | | .014 | | .003 | -.002 | | -.006 | -.012 | -.015 | -.016 | | |
| 90° | 60° | 0° | $C_l'$ | | .083 | | | .086 | | .116 | .126 | | .128 | .087 | .047 | .032 | | |
| 90° | 60° | 0° | $C_n'$ | | .025 | | | .014 | | .002 | -.004 | | -.007 | -.013 | -.016 | -.016 | | |
| | | | | FORWARD-HINGED SPOILER ALONE 10 PER CENT c BY 60 PER CENT b/2 | | | | | | | | | | | | | | |
| | | | | Up-only | | | | | | | | | | | | | | |
| 10° | 0° | 0° | $C_l'$ | | .006 | | | .015 | .034 | .049 | | .045 | | .011 | | -.005 | | |
| 10° | 0° | 0° | $C_n'$ | | .002 | | | .005 | .004 | .000 | | -.002 | | -.002 | | -.001 | | |
| 20° | 0° | 0° | $C_l'$ | | .034 | | | .037 | .053 | .067 | .076 | .076 | | .052 | | .002 | | |
| 20° | 0° | 0° | $C_n'$ | | .010 | | | .008 | .005 | .001 | -.005 | -.006 | | -.013 | | -.004 | | |
| 40° | 0° | 0° | $C_l'$ | | .056 | | | .059 | .072 | .089 | .099 | .100 | | .071 | | .016 | | |
| 40° | 0° | 0° | $C_n'$ | | .018 | | | .013 | .010 | .005 | .000 | -.002 | | -.010 | | -.001 | | |
| 60° | 0° | 0° | $C_l'$ | | .066 | | | .070 | .083 | .100 | .114 | | .115 | .087 | | .025 | | |
| 60° | 0° | 0° | $C_n'$ | | .022 | | | .017 | | .009 | .004 | | .001 | -.007 | | -.012 | | |
| 90° | 0° | 0° | $C_l'$ | | .070 | | | .078 | .092 | .109 | .122 | | .126 | .095 | | .036 | | |
| 90° | 0° | 0° | $C_n'$ | | .026 | | | .022 | .019 | .014 | .009 | | .006 | -.003 | | -.013 | | |

TABLE VII. FORCE TESTS. 10 BY 60 INCH CLARK Y WING WITH HANDLEY PAGE FULL-SPAN SLOT OPEN AT ALL ANGLES OF ATTACK - PLAIN AILERONS AND SPOILERS

Yaw = -30° R.N. = 609,000 Velocity = 80 m.p.h.

| $\delta_S$ | $\delta_A$ up | $\delta_A$ dn. | $\alpha$ | -5° | 0° | 5° | 10° | 15° | 20° | 24° | 25° | 28° | 30° | 35° | 40° | 50° | 60° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT $\frac{b}{2}$ | | | | | | | | | | | | | | | | | |
| | | | Ailerons locked - Neutral | | | | | | | | | | | | | | |
| | 0° | 0° | $C_L$ | -0.068 | 0.250 | 0.564 | 0.852 | 1.222 | 1.533 | 1.684 | 1.691 | 1.638 | 1.488 | 1.317 | 1.128 | 0.963 | 0.816 |
| | 0° | 0° | $C_D$ | .088 | .050 | .053 | .085 | .138 | .204 | .269 | .283 | .326 | .448 | .597 | .719 | .872 | .981 |
| | 0° | 0° | $C_l'$ | .008 | -.007 | -.011 | -.013 | -.011 | -.019 | -.035 | -.038 | -.037 | -.056 | -.078 | -.083 | -.057 | -.052 |
| | 0° | 0° | $C_n'$ | .003 | .002 | .003 | .004 | .007 | .014 | .021 | .023 | .024 | .032 | .045 | .049 | .051 | .055 |
| | | | Equal up-and-down | | | | | | | | | | | | | | |
| | 25° | 25° | $C_l'$ | | .066 | | .068 | | .072 | .068 | | .051 | .036 | .020 | .011 | | |
| | 25° | 25° | $C_n'$ | | -.003 | | -.016 | | -.030 | -.032 | | -.032 | -.037 | -.035 | -.023 | | |
| | | | Average differential No. 1 | | | | | | | | | | | | | | |
| | 35° | 15° | $C_l'$ | | .070 | | .071 | | .076 | .077 | | .065 | .050 | .037 | .023 | | |
| | 35° | 15° | $C_n'$ | | .004 | | -.009 | | -.023 | -.027 | | -.029 | -.037 | -.038 | -.026 | | |
| | | | Extreme differential No. 2 | | | | | | | | | | | | | | |
| | 50° | 7° | $C_l'$ | | .071 | | .078 | | .083 | .086 | | .053 | .061 | .055 | .035 | | |
| | 50° | 7° | $C_n'$ | | .012 | | .000 | | -.016 | -.022 | | -.026 | -.029 | -.037 | -.028 | | |
| | | | Up-only | | | | | | | | | | | | | | |
| | 60° | 0° | $C_l'$ | | .068 | | .075 | | .081 | .087 | | .056 | .068 | .055 | .038 | | |
| | 60° | 0° | $C_n'$ | | .016 | | .006 | | -.010 | -.017 | | -.030 | -.026 | -.032 | -.024 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT $\frac{b}{2}$. NEUTRAL RIGGED UP 10° | | | | | | | | | | | | | | | | | |
| | | | Ailerons locked - Neutral rigged up 10° | | | | | | | | | | | | | | |
| | 0° | 0° | $C_L$ | -.149 | .146 | .461 | .761 | 1.133 | 1.444 | 1.592 | 1.580 | 1.520 | 1.438 | 1.244 | 1.115 | .945 | .792 |
| | 0° | 0° | $C_D$ | .091 | .050 | .045 | .071 | .119 | .162 | .241 | .270 | .294 | .409 | .553 | .683 | .892 | 1.026 |
| | 0° | 0° | $C_l'$ | .013 | -.005 | -.008 | -.010 | -.007 | -.016 | -.030 | -.046 | -.063 | -.050 | -.080 | -.080 | -.058 | -.048 |
| | 0° | 0° | $C_n'$ | .004 | .002 | .002 | .004 | .006 | .012 | .018 | .019 | .020 | .028 | .042 | .052 | .053 | .055 |
| | | | Equal up-and-down (From rigged up 10°) | | | | | | | | | | | | | | |
| | 25° | 25° | $C_l'$ | | .070 | | .071 | | .076 | .077 | | .065 | .050 | .037 | .023 | | |
| | 25° | 25° | $C_n'$ | | .004 | | -.009 | | -.023 | -.027 | | -.029 | -.037 | -.038 | -.026 | | |
| | | | Differential No. 2 (From rigged up 10°) | | | | | | | | | | | | | | |
| | 50° | 7° | $C_l'$ | | .063 | | .069 | | .075 | .079 | | .077 | .055 | .056 | .034 | | |
| | 50° | 7° | $C_n'$ | | .010 | | .007 | | -.007 | -.012 | | -.015 | -.019 | -.027 | -.025 | | |
| PLAIN AILERONS 25 PER CENT c BY 40 PER CENT $\frac{b}{2}$ COMBINED WITH REAR-HINGED SPOILERS 7 PER CENT c BY 40 PER CENT $\frac{b}{2}$ | | | | | | | | | | | | | | | | | |
| $\delta_S$ | $\delta_A$ up | $\delta_A$ dn. | Equal up-and-down | | | | | | | | | | | | | | |
| 90° | 25° | 25° | $C_l'$ | | .071 | | .070 | | .087 | .085 | | .077 | .026 | -.033 | -.060 | | |
| 90° | 25° | 25° | $C_n'$ | | .012 | | .003 | | -.003 | -.001 | | .003 | .005 | .018 | .026 | | |
| | | | Average differential No. 1 | | | | | | | | | | | | | | |
| 90° | 35° | 15° | $C_l'$ | | .073 | | .073 | | .090 | .087 | | .082 | .033 | -.019 | -.050 | | |
| 90° | 35° | 15° | $C_n'$ | | .019 | | .010 | | .004 | .005 | | .006 | .007 | .013 | .024 | | |
| | | | Extreme differential No. 2 | | | | | | | | | | | | | | |
| 90° | 50° | 7° | $C_l'$ | | .072 | | .072 | | .091 | .093 | | .089 | .040 | -.005 | -.030 | | |
| 90° | 50° | 7° | $C_n'$ | | .024 | | .017 | | .012 | .011 | | .011 | .011 | .015 | .022 | | |
| | | | Up-only | | | | | | | | | | | | | | |
| 90° | 60° | 0° | $C_l'$ | | .069 | | .069 | | .092 | .091 | | .089 | .042 | .000 | -.029 | | |
| 90° | 60° | 0° | $C_n'$ | | .029 | | .022 | | .018 | .018 | | .017 | .015 | .019 | .025 | | |
| FORWARD-HINGED SPOILERS ALONE 10 PER CENT c BY 60 PER CENT $\frac{b}{2}$ | | | | | | | | | | | | | | | | | |
| | | | Up-only | | | | | | | | | | | | | | |
| 90° | 0° | 0° | $C_l'$ | | .024 | | .035 | .050 | .068 | .078 | | .078 | .044 | | -.035 | | |
| 90° | 0° | 0° | $C_n'$ | | .027 | | .029 | .029 | .027 | .028 | | .028 | .025 | | .035 | | |

TABLE VIII. ROTATION TESTS. 10 BY 60 INCH CLARK Y WING WITH HANDLEY PAGE FULL-SPAN SLOT

$C_\lambda$ is given for forced rotation at $p'b/2V = 0.05$ { (+) Aiding the rotation; (-) Damping the rotation }

$p'b/2V$ values are for free rotation

Yaw = 0° Velocity = 80 m.p.h. R.N. = 609,000

| | α | 0° | 12° | 16° | 20° | 22° | 24° | 25° | 26° | 27° | 30° | 32° | 35° | 40° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Ailerons locked - Neutral at 0° | | | | | | | | | | |
| (+) Rotation (clockwise) | $C_\lambda$ | -0.0243 | -0.0238 | -0.0278 | -0.0248 | | -0.0148 | | 0.0117 | 0.0152 | 0.0140 | 0.0097 | 0.0110 | 0.0095 |
| | $\frac{p'b}{2V}$ | | | | | | | 0.214 | | | .403 | | .458 | .543 |
| (-) Rotation (counter clockwise) | $C_\lambda$ | -.0245 | -.0246 | -.0260 | -.0200 | | -.0125 | | .0160 | .0168 | .0190 | .0188 | .0208 | .0160 |
| | $\frac{p'b}{2V}$ | | | | | | | .086 | | | .387 | | .465 | .582 |
| | | | | Ailerons locked - Neutral rigged up 10° | | | | | | | | | | |
| (+) Rotation (clockwise) | $C_\lambda$ | -.0238 | -.0233 | -.0281 | -.0258 | -0.0243 | | -.0016 | .0092 | .0152 | .0130 | .0110 | .0062 | .0084 |
| | $\frac{p'b}{2V}$ | | | | | | | | | | .372 | | .437 | .533 |
| (-) Rotation (counter clockwise) | $C_\lambda$ | -.0305 | -.0220 | -.0257 | -.0225 | -.0210 | | -.0135 | .0145 | .0175 | .0180 | .0180 | .0150 | .0150 |
| | $\frac{p'b}{2V}$ | | | | | | | .071 | | | .372 | | .449 | .533 |

TABLE IX. ROTATION TESTS. 10 BY 60 INCH CLARK Y WING WITH HANDLEY PAGE FULL-SPAN SLOT

$C_\lambda$ is given for forced rotation at $p'b/2V = 0.05 \begin{cases} (+) \text{ Aiding the rotation} \\ (-) \text{ Damping the rotation} \end{cases}$

Yaw = -20° Velocity = 80 m.p.h. R.N. = 609,000

| | α | 0° | 12° | 16° | 18° | 20° | 22° | 23° | 24° | 25° | 26° | 28° | 30° | 32° | 35° | 40° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ailerons locked - Neutral at 0° | | | | | | | | | | | | | | |
| (+) Rotation (clockwise) | $C_\lambda$ | -.0318 | -.0376 | -.0393 | -.0403 | -.0443 | | -.0493 | -.0516 | -.0438 | -.0383 | -.0393 | -.0408 | -.0448 | -.0553 | -.0636 |
| (-) Rotation (counter clockwise) | $C_\lambda$ | -.0140 | -.0065 | -.0075 | -.0030 | .0025 | | .0145 | .0272 | .0295 | .0362 | .0608 | .0710 | .0778 | .0875 | .0800 |
| | | Ailerons locked - Neutral rigged up 10° | | | | | | | | | | | | | | |
| (+) Rotation (clockwise) | $C_\lambda$ | -.0263 | -.0328 | -.0348 | | -.0410 | -.0438 | | | -.0488 | -.0418 | -.0416 | -.0448 | -.0463 | -.0653 | -.0643 |
| (-) Rotation (counter clockwise) | $C_\lambda$ | -.0190 | -.0085 | -.0110 | | -.0012 | .0050 | | | .0260 | .0290 | .0477 | .0658 | .0690 | .0795 | .0870 |

TABLE X. CRITERIONS SHOWING RELATIVE MERITS OF CONTROLS FOR WING WITH TIP SLOTS

| Subject | Criterion | Plain ailerons 25 per cent chord by 40 per cent semi-span (assumed standard size) Plain wing[h] | | | | Plain ailerons Tip slots 0.50 b/2 long | | | | Plain ailerons Neutral rigged up 10° Tip slots | | Plain ailerons Interceptor 0.03 c by 0.50 b/2 Tip slots | | | | Plain ailerons. Spoiler 0.03 c by 0.50 b/2 at 0.08 c location. Tip slots | Plain ailerons. Spoiler 0.07 c by 0.50 b/2 Tip slots | | | | Spoiler 0.10c by 0.50 b/2 - Tip slots |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Standard 25° up 25° dn. | Differential No. 1 35° up 15° dn. | Differential No. 2 50° up 7° dn. | Up-only 60° | Standard 25° up 25° dn. | Differential No. 1 35° up 15° dn. | Differential No. 2 50° up 7° dn. | Up-only 60° | Standard 25° up 25° dn. | Differential No. 2 50° up 7° dn. | Standard 25° up 25° dn. | Differential No. 1 35° up 15° dn. | Differential No. 2 50° up 7° dn. | Up-only 60° | Standard 25° up 25° dn. | Standard 25° up 25° dn. | Differential No. 1 35° up 15° dn. | Differential No. 2 50° up 7° dn. | Up-only 60° | Up-only 90° |
| Wing area or minimum speed | Maximum $C_L$ | 1.270 | 1.270 | 1.270 | 1.270 | 1.208 | 1.208 | 1.208 | 1.208 | 1.133 | 1.133 | 1.208 | 1.208 | 1.208 | 1.208 | 1.208 | 1.208 | 1.208 | 1.208 | 1.208 | 1.208 |
| Speed range | Max. $C_L$/min. $C_D$ ($\delta_A$ & $\delta_S = 0°$) | 79.4 | 79.4 | 79.4 | 79.4 | 75.5 | 75.5 | 75.5 | 75.5 | 66.6 | 66.6 | 75.5 | 75.5 | 75.5 | 75.5 | 75.5 | 75.5 | 75.5 | 75.5 | 75.5 | 75.5 |
| Rate of climb | L/D at $C_L$ = 0.70 ($\delta_A$ & $\delta_S = 0°$) | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 17.1 | 17.1 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 |
| Lateral controllability | RO α = 0° Slot closed | 0.204 | 0.202 | 0.214 | 0.198 | 0.204 | 0.202 | 0.214 | 0.198 | 0.249 | 0.220 | [g]0.204 | [g]0.202 | [g]0.214 | [g]0.198 | [g]0.304 | 0.204 | 0.172 | 0.171 | 0.135 | 0.135 |
| | RO α = 10° Slot open | .076 | .074 | .074 | .072 | .074 | .071 | .071 | .062 | .078 | .070 | .074 | .070 | .073 | .069 | .086 | .119 | .102 | .065 | .073 | .074 |
| | RO α = 20° | .038 | .051 | .055 | .054 | .057 | .051 | .050 | .046 | .061 | .045 | .054 | .053 | .057 | .055 | .074 | .095 | .091 | .078 | .069 | .068 |
| | RO α = 30° | .017 | .005 | .003 | .003 | .043 | .047 | .047 | .045 | .050 | .045 | .063 | .065 | .047 | .040 | .076 | .079 | .084 | .063 | .054 | .056 |
| Lateral control with side slip | Maximum α at which controls will balance $C_l$' due to 20° yaw | 20° | 20° | 21° | 22° | 20° | 24° | 31° | 33° | 24° | 32° | 21° | 21° | 32° | 33° | 24° | 34° | 38° | 38° | 38° | 34° |
| Yawing moments due to controls | $C_n$ α = 0° Slots closed | −.007 | 0.002<br>[b]−.003 | 0.010<br>[b]−.002 | 0.016 | −.007 | 0.008<br>[b]−.003 | 0.010<br>[b]−.002 | 0.016 | [c]0.002 | 0.016 | [g]<br>[g]−.007 | [g]0.002<br>[g]−.003 | [g]0.010<br>[g]−.002 | [g]0.016<br>[g] | [g]<br>[g]−.007 | [c]0.002 | 0.007 | 0.010 | 0.013 | 0.017 |
| (+) Favorable (−) Unfavorable | $C_n$ α = 10° Slots open | −.004 | .004<br>[b]−.008 | .015<br>[b]−.001 | .019 | −.004 | .005<br>[a]−.003 | .012<br>[a]−.001 | .016 | .003 | .017 | −.003 | .003<br>[a]−.001 | .013<br>[a]−.001 | .017 | [a].012 | .022 | [d].023 | [e].035 | [e].037 | .035 |
| | $C_n$ α = 20° | −.010 | [b]−.007 | .008<br>[b]−.006 | .013<br>[a]−.003 | −.010 | [c]−.006 | [a]−.008 | .005<br>[a].001 | [c]−.004 | .006<br>[d]−.003 | −.010 | [c]−.006 | .008<br>[c]−.006 | .015 | [a].010 | .014 | [d].022 | [e].033 | [e].037 | .037 |
| | $C_n$ α = 30° | −.008 | −.008 | [b]−.007 | .002<br>[b]−.004 | −.012 | [b]−.006 | .006<br>[b]−.008 | .013<br>[b].005 | −.004 | .018<br>−.003 | [a].014 | .017 | [e].019 | [e].023 | [a].025 | .019 | [d].023 | [e].027 | [e].034 | .038 |
| Lateral stability ($\delta_A$ & $\delta_S$ = 0°) | α for initial instability in rolling | 18° | 18° | 18° | 18° | 33° | 33° | 33° | 33° | 33° | 33° | 38° | 33° | 33° | 33° | 33° | 33° | 33° | 33° | 33° | 33° |
| | α for initial instability at p'b/2V = 0.05, Yaw = 0° | 17° | 17° | 17° | 17° | 32° | 32° | 33° | 32° | 32° | 32° | 32° | 32° | 32° | 32° | 32° | 32° | 32° | 32° | 32° | 32° |
| | Ditto Yaw = 20° | 11° | 11° | 11° | 11° | 14° | 14° | 14° | 14° | 15° | 15° | 14° | 14° | 14° | 14° | 14° | 14° | 14° | 14° | 14° | 14° |
| | Maximum unstable $C_\lambda$ at p'b/2V = 0.05, Yaw = 0° | .048 | .048 | .048 | .048 | [f].009 | [f].009 | [f].009 | [f].009 | [f].007 | [f].007 | [f].009 | [f].009 | [f].009 | [f].009 | [f].009 | [f].009 | [f].009 | [f].009 | [f].009 | [f].009 |
| | Ditto Yaw = 20° | .093 | .093 | .093 | .093 | .076 | .078 | .076 | .076 | .076 | .076 | .076 | .076 | .076 | .076 | .076 | .076 | .078 | .076 | .076 | .078 |

[a] to [e] Where the maximum yawing moment occurred below maximum deflection, the letters indicate the deflection of the up aileron as follows: a = 10°, b = 15°, c = 20°, d = 30°, e = 40°.

[f] Value at α = 40°. Maximum not yet reached.

[g] Ailerons alone deflected for this condition.

[h] Data from Reference 1, Parts I and V.

TABLE XI. CRITERIONS SHOWING RELATIVE MERITS OF CONTROLS FOR WING WITH FULL-SPAN SLOTS

| Subject | Criterion | Plain ailerons 25 per cent chord by 40 per cent semispan (assumed standard size) Plain wing[e] | | | | Plain ailerons full-span slot | | | | Plain ailerons Neutral rigged up 10°. Full-span slot | | Plain ailerons with spoiler 0.07 c by 0.40 b/2. Full span slot | | | | Spoiler 0.10 c by 0.60 b/2. Full span slot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Standard 25° up 25° dn. | Differential No.1 35° up 15° dn. | Differential No.2 50° up 7° dn. | Up-only 60° | Standard 25° up 25° dn. | Differential No.1 35° up 15° dn. | Differential No.2 50° up 7° dn. | Up-only 60° | Standard 25° up 25° dn. | Differential No.2 50° up 7° dn. | Standard 25° up 25° dn. | Differential No.1 35° up 15° dn. | Differential No.2 50° up 7° dn. | Up-only 60° | Up-only 90° |
| Wing area or minimum speed | Maximum $C_L$ ($\delta_A$ and $\delta_S = 0°$) | 1.270 | 1.270 | 1.270 | 1.270 | 1.830 | 1.830 | 1.830 | 1.830 | 1.735 | 1.735 | 1.830 | 1.830 | 1.830 | 1.830 | 1.830 |
| Speed range | Max. $C_L$/min. $C_D$ ($\delta_A$ and $\delta_S = 0°$) | 79.4 | 79.4 | 79.4 | 79.4 | 114.2 | 114.2 | 114.2 | 114.2 | 103.0 | 103.0 | 114.2 | 114.2 | 114.2 | 114.2 | 114.2 |
| Rate of climb | L/D at $C_L$ = 0.70 ($\delta_A$ and $\delta_S = 0°$) | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 17.1 | 17.1 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 |
| Lateral controllability | RC $\alpha = 0°$ Slot closed | 0.204 | 0.203 | 0.214 | 0.196 | 0.204 | 0.202 | 0.214 | 0.196 | 0.249 | 0.220 | 0.207 | 0.174 | 0.128 | 0.135 | 0.135 |
| | RC $\alpha = 10°$ Slot open | .075 | .074 | .074 | .072 | .074 | .072 | .073 | .069 | .078 | .069 | .115 | .108 | .091 | .089 | .076 |
| | RC $\alpha = 20°$ | .038 | .061 | .055 | .064 | .047 | .046 | .045 | .043 | .043 | .041 | .083 | .077 | .070 | .065 | .059 |
| | RC $\alpha = 30°$ | .017 | .005 | .003 | .002 | .026 | .033 | .031 | .050 | .032 | .028 | .068 | .069 | .062 | .058 | .058 |
| Lateral control with side slip | Maximum $\alpha$ at which controls will balance $C_l'$ due to 20° yaw | 20° | 20° | 21° | 22° | 27° | 29° | 31° | 32° | 29° | 30° | 32° | 33° | 34° | 35° | 35° |
| Yawing moments due to controls (+)Favorable (-)Unfavorable | $C_n$ $\alpha = 0°$ Slot closed | -.007 | 0.002 b-.005 | 0.010 b-.002 | 0.016 | -.007 | 0.002 b-.005 | 0.010 b-.002 | 0.016 | c0.002 | 0.016 | 0.001 | 0.006 | 0.012 | 0.013 | 0.017 |
| | $C_n$ $\alpha = 10°$ Slot open | -.004 | .004 b-.003 | .013 b-.001 | .018 | -.005 | .002 b-.002 | .010 b-.002 | .015 a-.001 | .002 | .015 | .015 | .019 | .025 | .029 | .035 |
| | $C_n$ $\alpha = 20°$ | -.010 | b-.007 | .008 b-.006 | .013 a-.003 | -.005 | .005 a-.003 | .012 b-.003 | .016 a-.001 | .005 | d .016 -.001 | .030 | c.033 | .039 | .042 | .061 |
| | $C_n$ $\alpha = 30°$ | -.008 | -.008 | b-.007 | .002 b-.004 | -.018 | b-.013 | c-.014 | .004 b-.010 | c-.011 | .005 a-.010 | .015 | .025 | .030 | .033 | .045 |
| Lateral stability ($\delta_A$ and $\delta_S$ = 0°) | $\alpha$ for initial instability in rolling | 18° | 19° | 18° | 18° | 25° | 25° | 25° | 35° | 25° | 25° | 25° | 25° | 25° | 25° | 25° |
| | $\alpha$ for initial instability at p'b/2V = 0.05 Yaw = 0° | 17° | 17° | 17° | 17° | 25° | 25° | 25° | 25° | 25° | 25° | 25° | 25° | 25° | 25° | 25° |
| | Ditto Yaw = 20° | 11° | 11° | 11° | 11° | 19° | 19° | 19° | 19° | 21° | 21° | 19° | 19° | 19° | 19° | 19° |
| | Maximum unstable $C_{l_A}$ at p'b/2V = 0.05 Yaw = 0° | .049 | .048 | .048 | .048 | .021 | .021 | .021 | .021 | .018 | .018 | .021 | .021 | .021 | .021 | .021 |
| | Ditto Yaw = 20° | .093 | .093 | .093 | .093 | .088 | .088 | .088 | .088 | .087 | .087 | .088 | .088 | .088 | .088 | .088 |

a to d Where the maximum yawing moment occurred below maximum deflection, the letters indicate the deflection of the up aileron as follows: a = 10°, b = 15°, c = 20°, d = 5°.
e Data from Reference 1, Parts I and V.

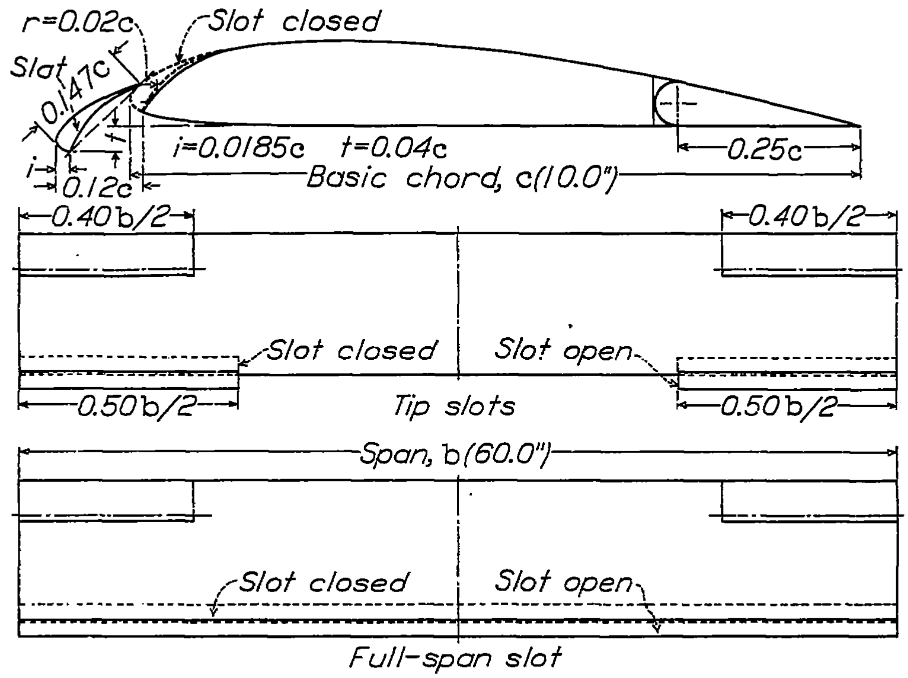


Fig. 1 Details of Clark Y wing with Handley Page slots and ordinary ailerons.

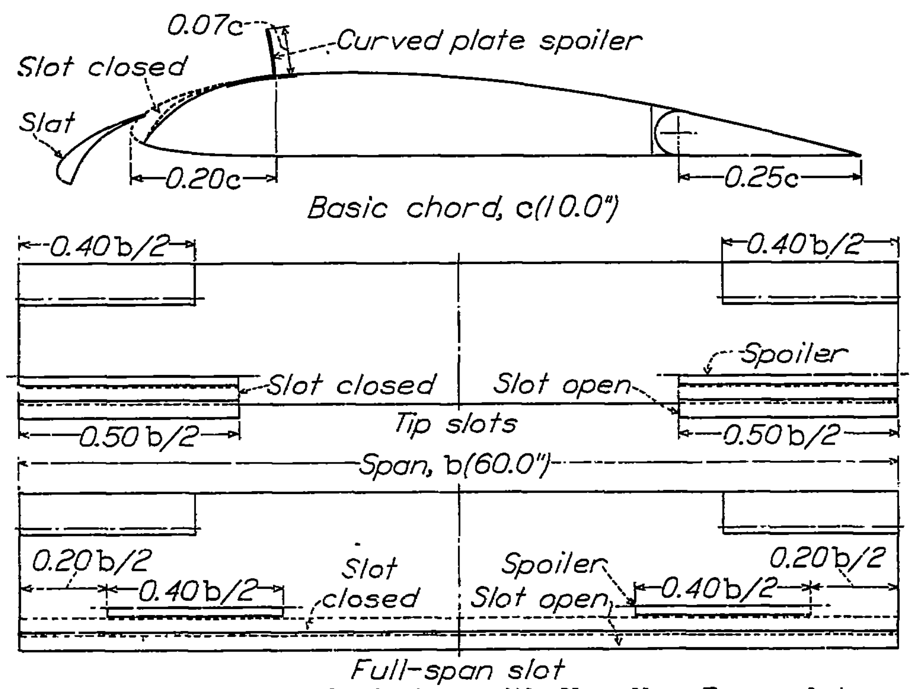


Fig. 2 Details of Clark Y wing with Handley Page slots, ordinary ailerons, and rear hinged spoilers.

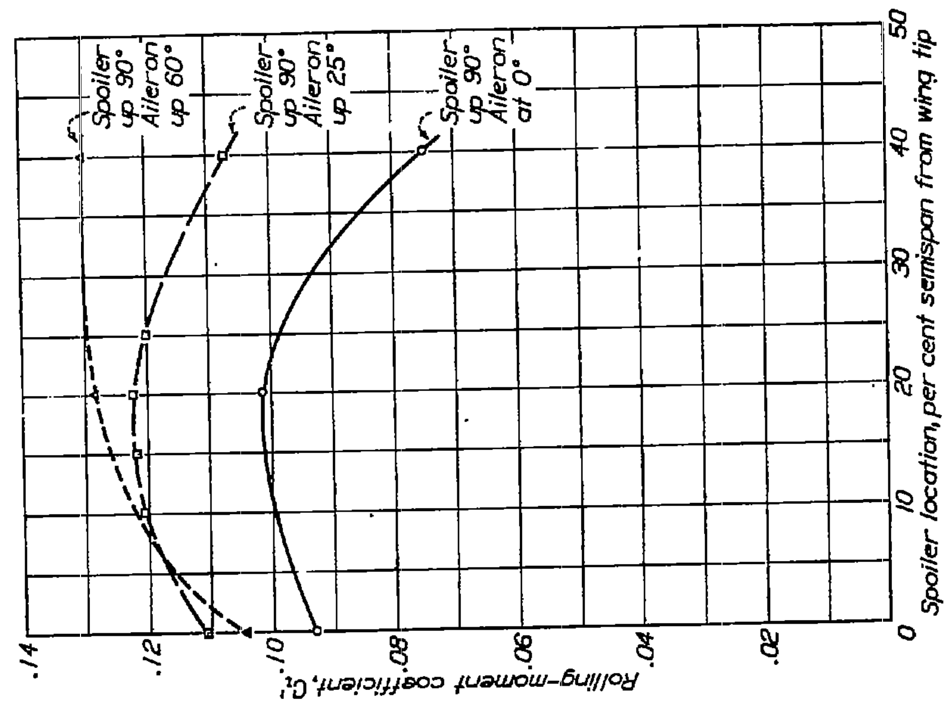


Fig. 3 Effect on $C'_{l_{max.}}$ of spoiler location along span of wing with full-span slot and medium ailerons.

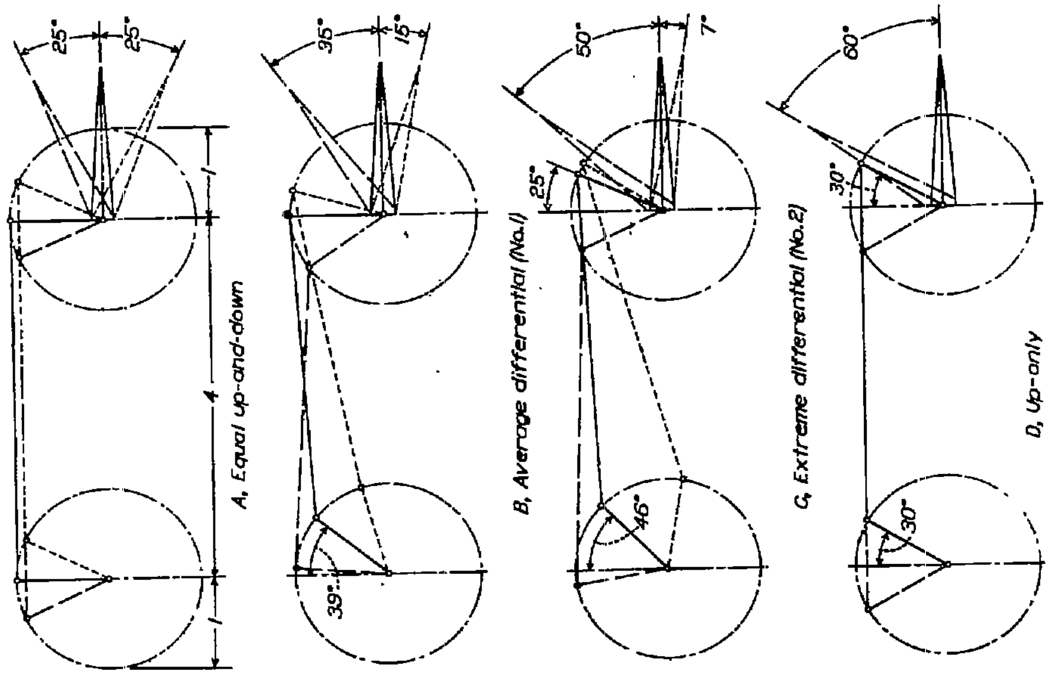


Fig. 7 Aileron linkage systems, assumed maximum deflections.

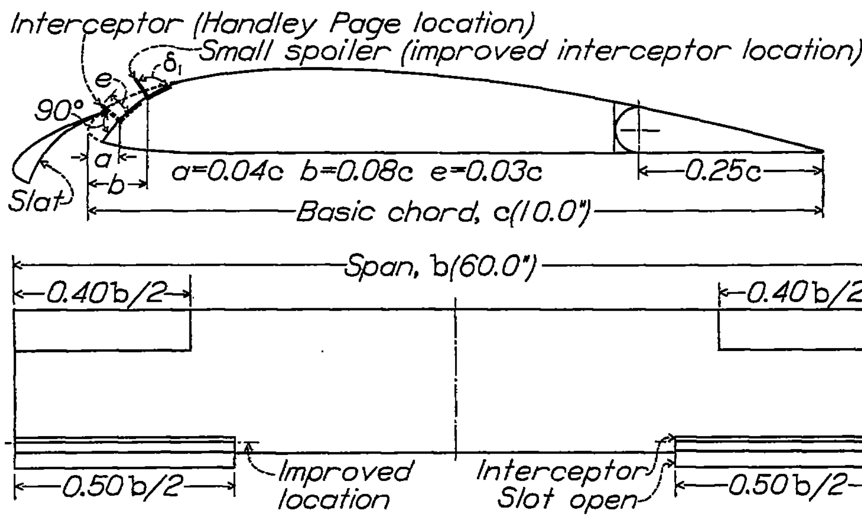


Fig.4 Details of Clark Y wing with ordinary ailerons, interceptors, and Handley Page tip slots.

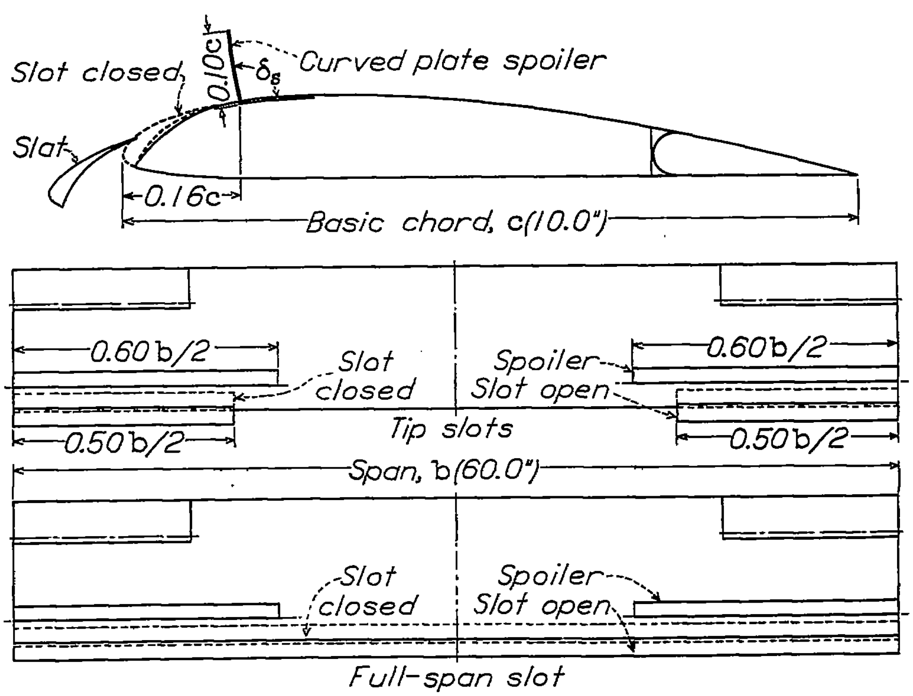


Fig. 5 Details of Clark Y wing with Handley Page slots and large spoiler.

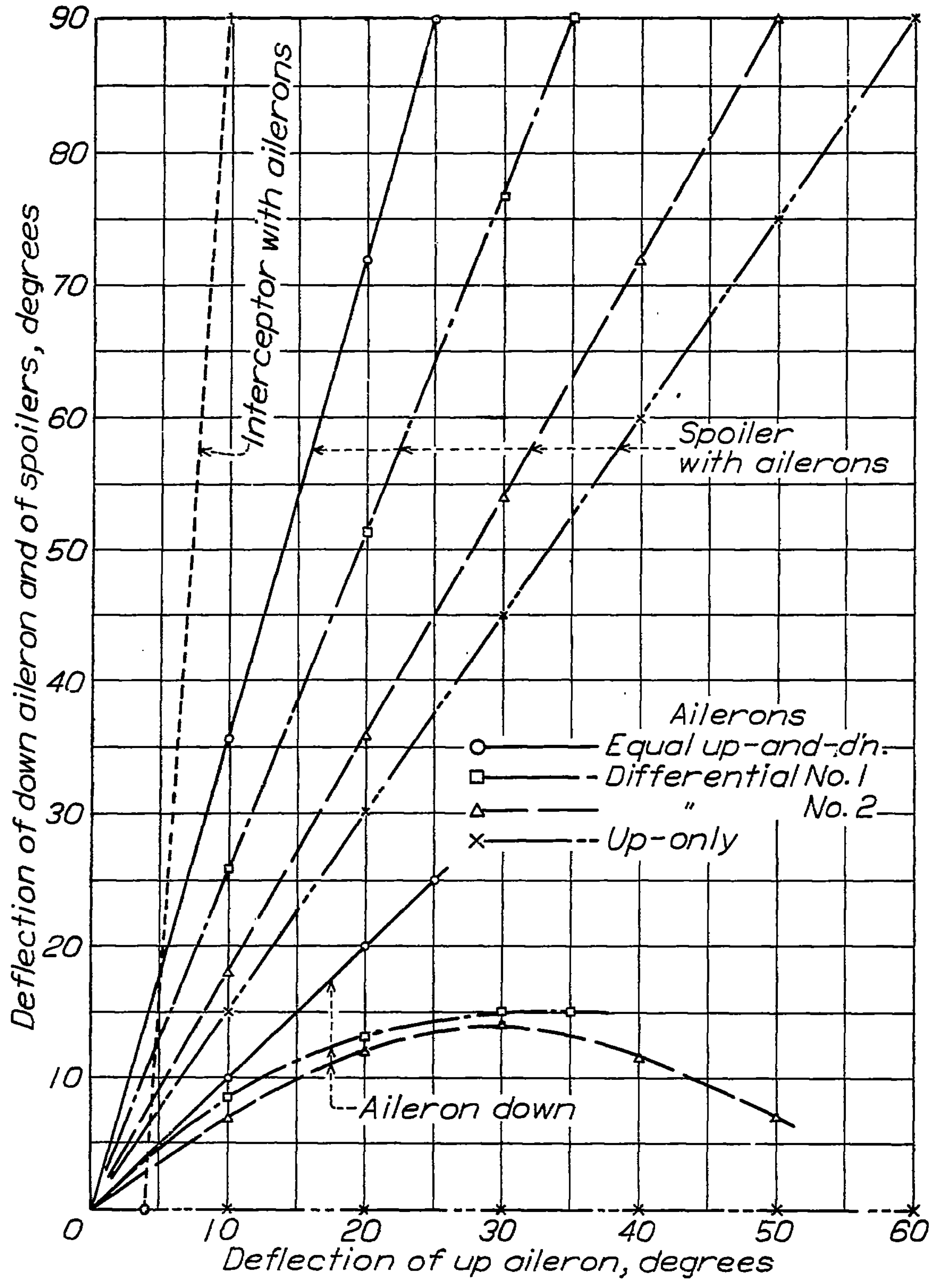


Fig. 6 Assumed movements of control surfaces.

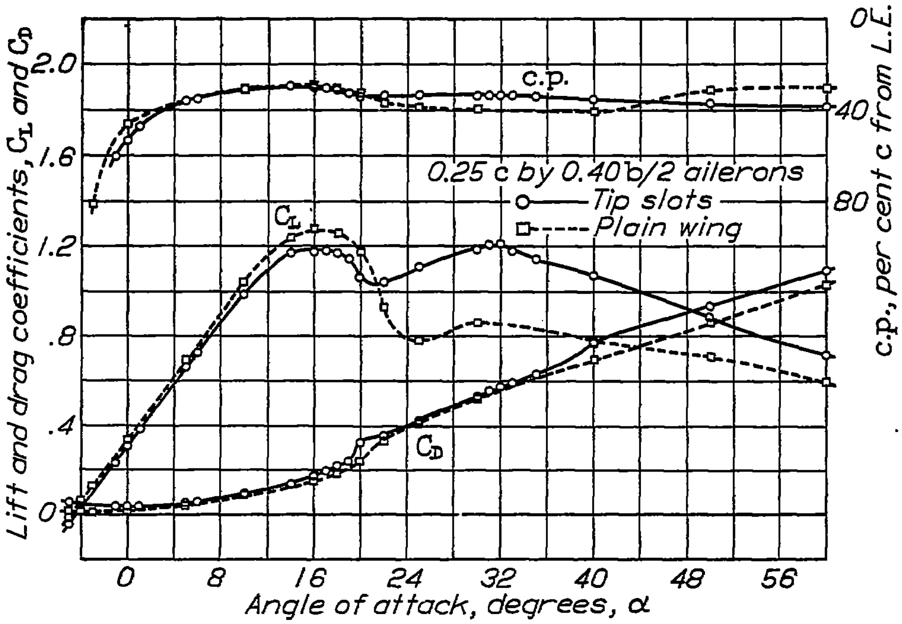


Fig. 8 Lift, drag, and center of pressure for Clark Y wing with 50 per cent b/2 tip slots and for plain wing. Yaw = 0°

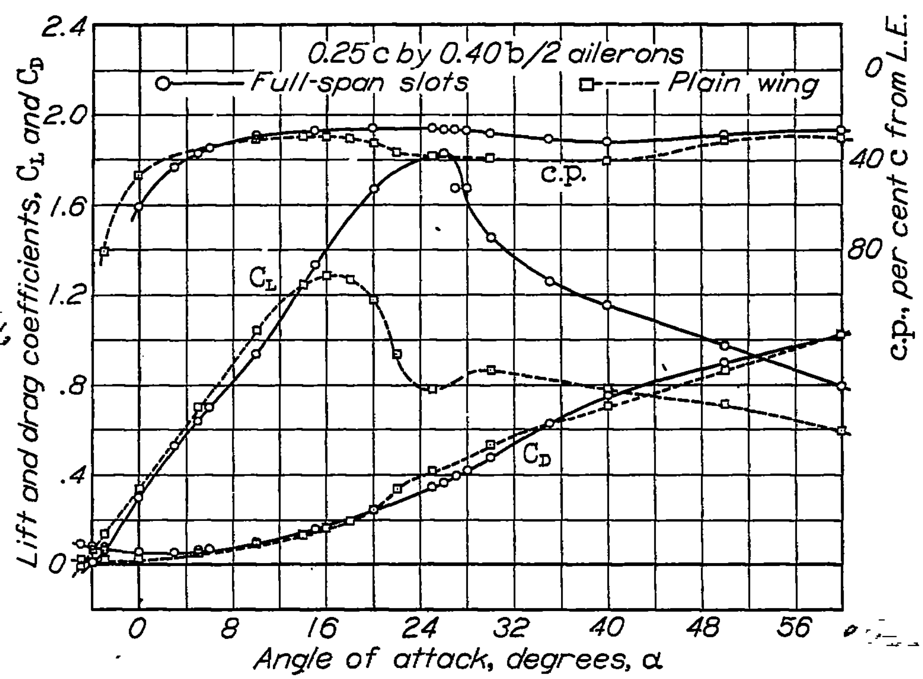


Fig. 10 Lift, drag, and center of pressure for Clark Y wing with full-span slot and for plain wing. Yaw = 0°

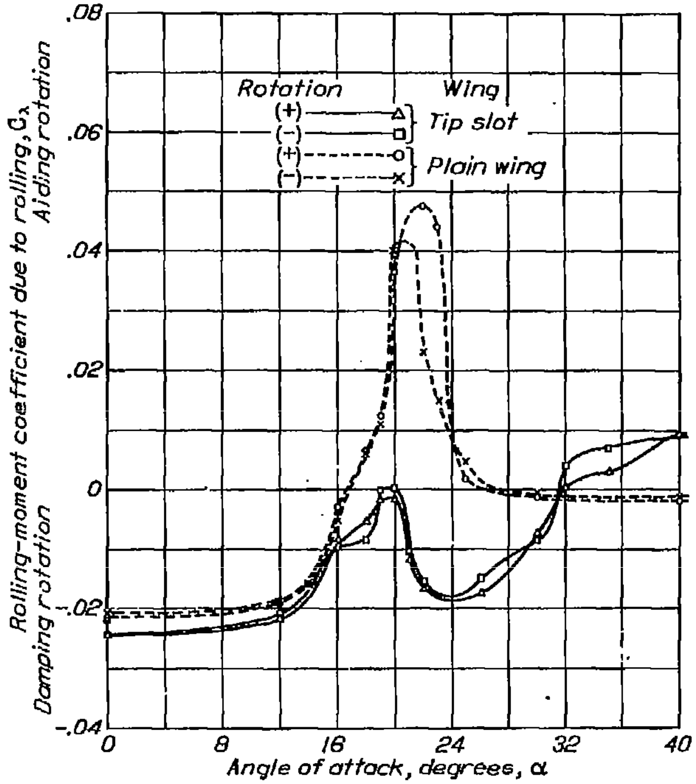


Fig. 9 Rolling-moment coefficients due to rolling at $\frac{p'b}{2V} = 0.05$ and yaw = 0° for Clark Y wing with 50 per cent b/2 tip slots and for plain wing.

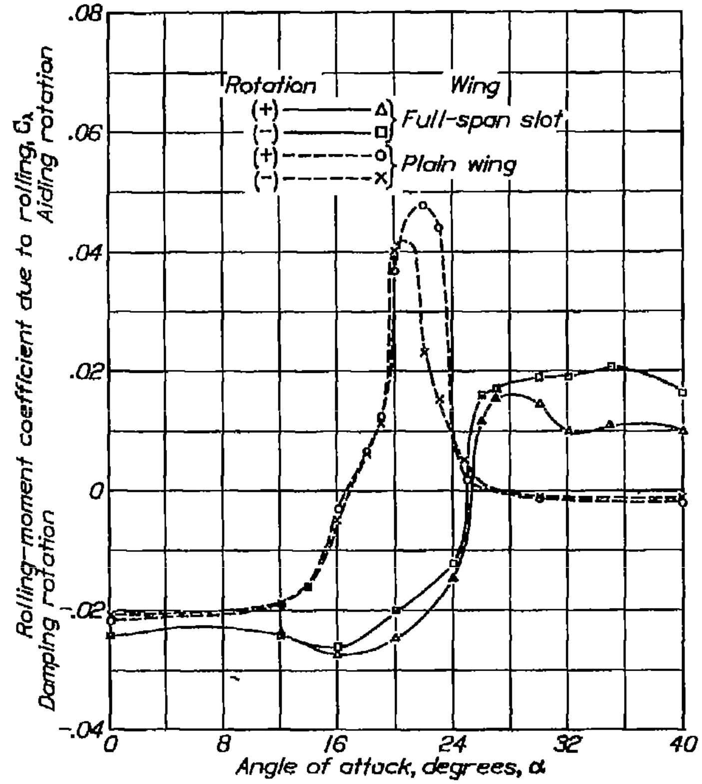


Fig.11 Rolling-moment coefficients due to rolling at $\frac{p'b}{2V} = 0.05$ and yaw = 0° for Clark Y wing with full-span slot and for plain wing.