REPORT No. 499

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

XII—UPPER-SURFACE AILERONS ON WINGS WITH SPLIT FLAPS

By Fred E. Weick and Carl J. Wenzinger

SUMMARY

This report covers the twelfth of a series of systematic tests being conducted by the National Advisory Committee for Aeronautics to compare different lateral control devices with particular reference to their effectiveness at high angles of attack. The present tests were made in the 7- by 10-foot wind tunnel with two sizes of upper-surface ailerons on rectangular Clark Y wing models equipped with full-span split flaps. The upper-surface ailerons were formed from the upper portions of the split trailing edges of the wings. The tests showed the effect of the upper-surface ailerons and of the split flaps on the general performance characteristics of the wings, and on the lateral controllability and stability characteristics. The results are compared with those for plain wings with ordinary ailerons of similar sizes.

With flaps neutral, the upper-surface ailerons with up-only movement gave rolling moments at angles of attack below the stall that were reasonably close to an assumed satisfactory value. The yawing moments (wind axes) were positive (favorable) with large aileron deflections but, at all except the lowest angles of attack, they were slightly negative (adverse) with small deflections. The control forces were much greater than those of ordinary ailerons of similar sizes having conventional movement. With the flaps deflected for maximum lift, the upper-surface ailerons gave control moments considerably below the value assumed to be satisfactory. The magnitudes of the positive (favorable) yawing moments were smaller than those with flaps neutral and negative (adverse) ones occurred with small aileron deflections at all angles of attack. Above the stall, flaps neutral or deflected, both sizes of upper-surface ailerons indicated poor control.

The autorotational characteristics of the wings with the flaps deflected were somewhat less favorable than with the flaps retracted.

INTRODUCTION

A series of systematic wind-tunnel investigations, one of which is covered by this report, 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, followed by wings with different plan forms, wings with high-lift devices, and also on wings with variations that affect the lateral stability. The first report of this series (reference 1, part I) deals with three sizes of ordinary ailerons, one of which is a medium-sized aileron 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 XI.

The present report covers an investigation of "upper-surface" ailerons, which appear to be one of the simplest devices for lateral control of a wing that obtains high lift by means of split flaps along the entire trailing edge. Upper-surface ailerons are formed from the upper portion of the split trailing edge of the wing, which is hinged and deflected upward for control. The split flaps increase both the lift and the drag of the wing, enabling slower speeds and steeper glides. References 2, 3, and 4 give aerodynamic characteristics of wings equipped with such flaps.

APPARATUS AND TESTS

Models.—The model wings tested were equipped with medium-sized and with long narrow upper-surface ailerons, together with full-span split flaps having medium and narrow chords, respectively. The main portion of each of the two wing models was made of laminated mahogany and the split trailing-edge portion was made of aluminum alloy. The wings had the Clark Y profile and were rectangular in plan form with a chord of 10 inches and a span of 60 inches.

The narrow-chord upper-surface ailerons were 15 percent of the wing chord wide and 60 percent of the wing semispan long. This wing model was fitted with a full-span split flap also 15 percent of the wing chord wide. (See fig. 1.)

The medium-chord upper-surface ailerons were 25 percent of the wing chord wide and 40 percent of the wing semispan long. A full-span split flap 25 percent of the wing chord wide was used in conjunction with these ailerons.

Both the ailerons and the flaps were mounted on the wings in such a manner that they could either be locked rigidly at any desired deflection or allowed to rotate freely about their respective hinge axes. The gaps between the ailerons or flaps and the wing were made as small as practicable, and then sealed with a light grease.

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 the testing of the wings in rotation, the standard force-test tripod is replaced by a special mounting that permits the model to rotate

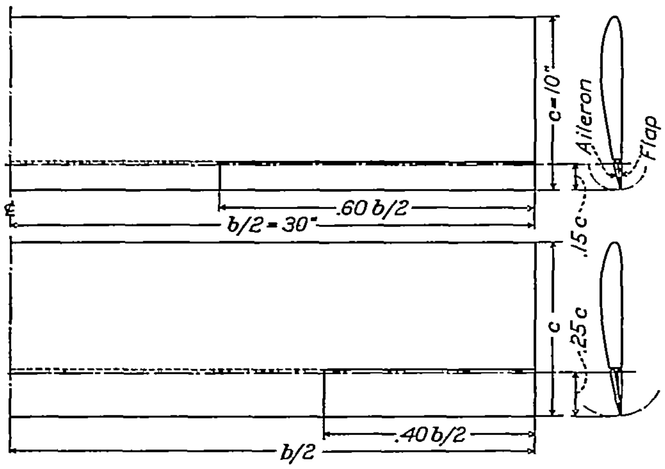

FIGURE 1.—Clark Y wings with upper-surface ailerons and split flaps.

about the longitudinal wind axis passing through the mid-span quarter-chord point. This apparatus is mounted on the balance, and rolling-moment coefficients can be read directly during forced-rotation tests. A complete description of the above-mentioned equipment is given in reference 5.

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 average Reynolds Number was 609,000, based on the wing chord of 10 inches.

The regular force tests were made with several flap deflections and 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. The force tests were also made with a sufficient number of aileron deflections, with flaps both neutral and deflected various amounts, to give data for the aileron rolling- and yawing-moment coefficients. Because of the large effect of yaw on the lateral stability, tests were made not only at 0° yaw, but also at an angle of yaw of 20°, which represents the conditions in a fairly severe sideslip.

Hinge moments of the ailerons were measured by means of the calibrated twist of a long slender torque rod extending along the hinge axis from the aileron to the balance frame outside the air stream. These moments were obtained for various aileron deflections with the flaps both neutral and deflected different amounts.

Free-autorotation tests were made to determine the angle of attack above which autorotation was self-starting with ailerons neutral. Forced-rotation tests were also made in which the rolling moment while rolling was measured at the rotational velocity corresponding to $\frac{p'b}{2V}=0.05$, the highest value likely to be obtained in gusty air, and at angles of yaw of both 0° and −20°.

The accuracy of the results presented in this report is the same as that obtained in part I of the series. It is considered satisfactory at all angles of attack except in the burbled region between 20° and 25°, where the rolling, yawing, and hinge moments are relatively unreliable due to the critical, and often unsymmetrical, condition of the burbled air flow around the wing.

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, b is the wing span, and q is the dynamic pressure. These coefficients are obtained directly from the balance and refer to the wind (or tunnel) axes. The results as given are not corrected for tunnel-wall effect.

The results of the hinge-moment tests are given about the aileron hinge axis by:

$$C_H=\frac{\text{hinge moment}}{q\,c\,S}$$

where c is the wing chord. A positive sign of C_H denotes a moment tending to make the trailing edge of the aileron move downward, and a negative sign indicates the reverse. A positive sign is given to the downward deflection of ailerons from neutral, and a negative sign to the upward deflection.

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

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

where λ is the rolling moment measured while the wing is rolling, and the other factors have the usual significance. This coefficient is used to indicate one of the critical lateral-stability 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 $\frac{p'b}{2V}=0.05$, 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.

The results of all the tests, in terms of the foregoing coefficients, are given in table I to VIII and in figures 2 to 9.

DISCUSSION IN TERMS OF CRITERIONS

For a comparison of the different lateral control arrangements, the results of the tests are discussed in terms of criterions, which are explained in detail in part I of reference 1 and briefly in the following paragraphs. In a few cases it has seemed advisable, as the result of flight tests, to modify the original form of the criterion, and where this has been done the changes are noted. By use of the criterions a comparison of the effect of the different control devices on the general performance, the lateral controllability, and the lateral stability may be made.

The ailerons used in the present tests are compared with each other by means of the criterions, under the conditions with flaps neutral and with flaps deflected in table IX. In addition, values are included from part I for the standard (medium-sized) and the long narrow ordinary ailerons on plain rectangular wings.

GENERAL PERFORMANCE

(AILERONS 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 practically the same for both wings tested with flaps neutral as for the wings with the ordinary ailerons. The maximum lift coefficient was increased from 1.27 to 2.05 with the 15 percent c flap down 60°, and from 1.26 to 2.09 with the 25 percent c flap down 45°. (See figs. 2 and 3.) These values are about what would be expected from the results of previous tests with split flaps (reference 2).

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 value of the speed-range ratio was slightly greater for the wings tested with flaps neutral than for the wings with ordinary ailerons, the differences probably being due to slight variations in the models within the accuracy of construction. With the 15 percent c flap down 60°

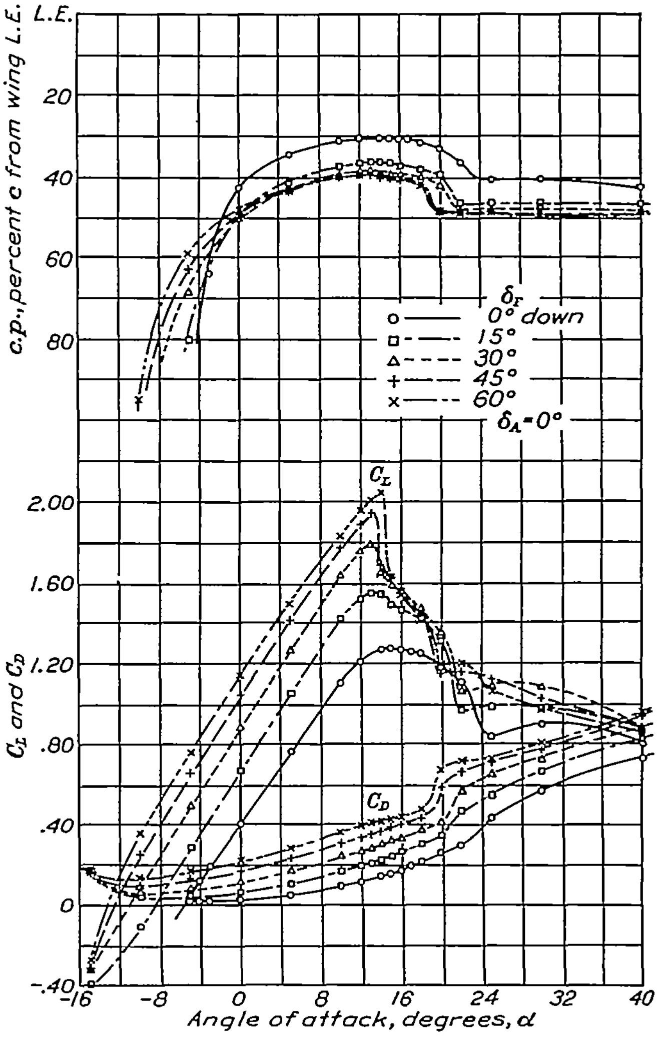

FIGURE 2.—Lift, drag, and center of pressure for wing with 0.15 c full-span split flap and 0.15 c by 0.60 $b/2$ upper-surface ailerons.

the value was increased about 61 percent, and with the 25 percent c flap down 45° the increase was about 66 percent.

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.

The numerical value of this criterion was about the same for the wings with flaps neutral as for the wings with ordinary ailerons. The values were greatly reduced, however, with the split flaps deflected for maximum lift, and they were less for all flap deflections tested than for the flap-neutral condition.

LATERAL CONTROLLABILITY

(CONTROLS FULLY DEFLECTED)

Rolling criterion.—The rolling criterion upon which the control effectiveness of each of the aileron arrange-

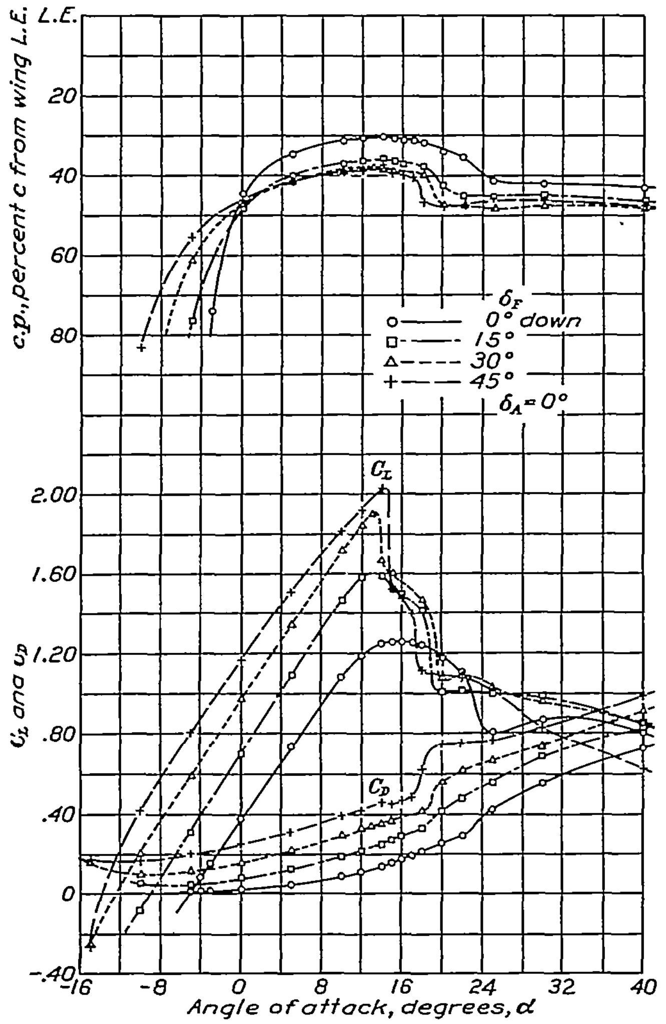

FIGURE 3.—Lift, drag, and center of pressure for wing with 0.25 c full-span split flap and 0.25 c by 0.40 b/2 upper-surface ailerons.

ments 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 of the plan form of the wing. Expressed in coefficient form for a rectangular monoplane wing, the criterion as used up to the present has been

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

where C_l is the rolling-moment coefficient about the body axis due to the ailerons. It appears desirable at this time, as the result of numerous flight observations (reference 6) obtained since the criterion was first established, to alter the form of RC slightly so that in this report

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

where C_l' is the rolling-moment coefficient about the *wind axis* due to the ailerons, and only changes appreciably in value from C_l at high angles of attack. The general form of RC, which is applicable to any wing plan form, may be found in part I of the series.

The numerical value of the criterion that is assumed to represent satisfactory control conditions is approximately 0.075, the value given by the standard ordinary ailerons with the assumed maximum deflection of ±25° at an angle of attack of 10°. (See part I, reference 1.) As a result of some recent flight tests (reference 7), it appears that a somewhat lower value of RC', 0.040 to 0.050, might be satisfactory under ordinary flight conditions. Under other conditions, particularly when controlled flight is attempted at slow speeds in extremely gusty air, it is possible that even the value of 0.075 might not be high enough for entirely satisfactory control. Further flight information would be of distinct value in clearing up present uncertainty as to what constitutes satisfactory control.

The ailerons are compared by means of the criterions given in table IX for four representative angles of attack: 0°, 10°, 20°, and 30°. The 0° angle represents the high-speed and cruising attitudes; $\alpha=10°$ represents the highest angle of attack at which satisfactory control with ordinary ailerons is obtained on plain wings; $\alpha=20°$ is the condition of greatest lateral instability for the Clark Y wing, and is probably about the greatest angle of attack obtainable in a steady glide with most present-day airplanes; and finally, $\alpha=30°$ is given only for a comparison with controls for possible future types of airplanes. The comparisons are based on an up-only deflection of 70°, the highest likely to be used, but which gave a somewhat lower rolling-moment coefficient at an angle of attack of 10° than the standard ailerons with an equal up-and-down deflection of 25°.

At $\alpha=0°$, flaps neutral, both sizes of ailerons gave values of RC' greatly in excess of that considered necessary. With flaps deflected for maximum lift, the values were reduced to slightly below that assumed as satisfactory.

At $\alpha=10°$, flaps neutral, both sizes of upper-surface ailerons gave somewhat less than the assumed satisfactory value of RC'. With flaps deflected for maximum lift, the values of RC' given by the upper-surface ailerons were about 60 percent of the assumed satisfactory values. It should be noted that, with flaps down, better rolling control could be obtained by deflecting the opposite aileron down in addition to the up-aileron (figs. 4 and 5). An equal up-and-down or a differential motion of the ailerons could be used.

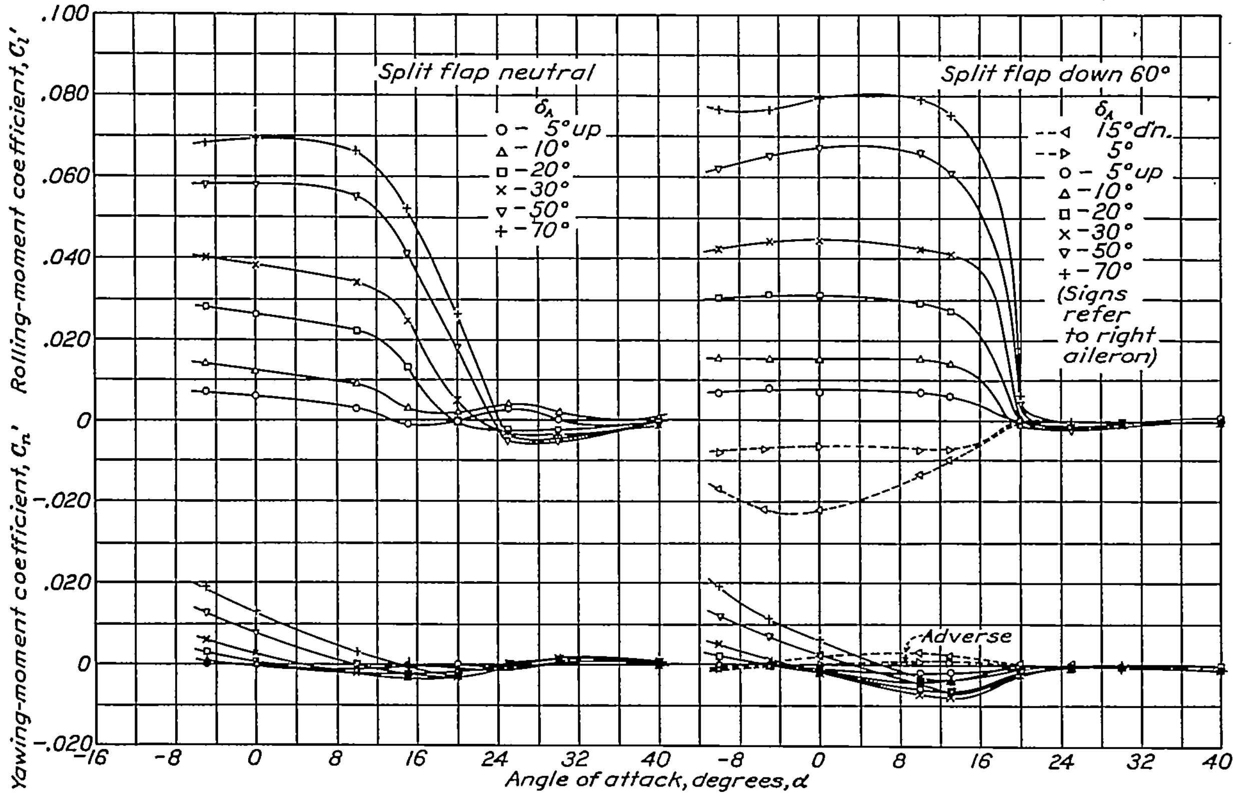

FIGURE 4.—Rolling- and yawing-moment coefficients of 0.15 c upper-surface aileron with split flap neutral, and with flap down.

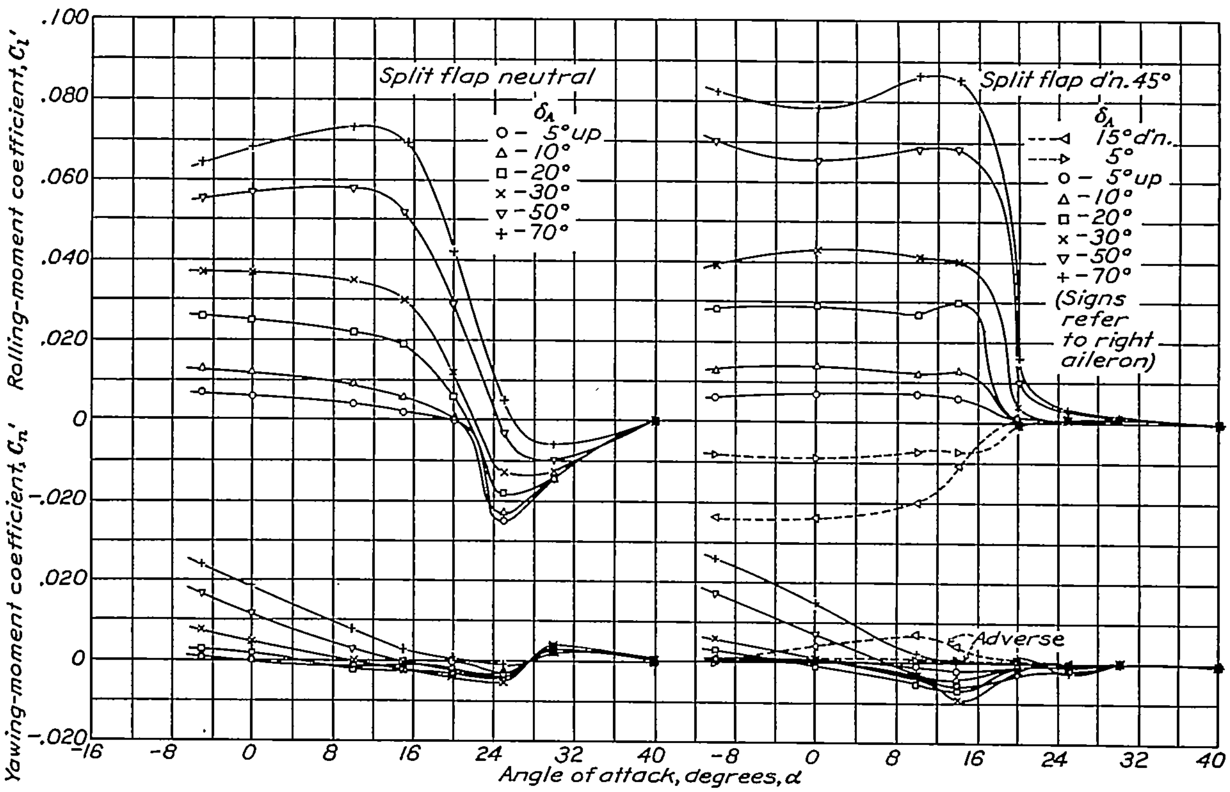

FIGURE 5.—Rolling- and yawing-moment coefficients of 0.25 c upper-surface aileron with split flap neutral, and with flap down.

At $\alpha = 20°$, flaps neutral, the values of RC' given by the upper-surface ailerons were less than half of the assumed satisfactory value, but were slightly higher than the values given by the ordinary ailerons. With flaps deflected for maximum lift the values of RC' were so low as to make the ailerons ineffective as a source of rolling moments.

At $\alpha = 30°$, flaps neutral or down, the values of RC' given by the upper-surface ailerons were practically zero. The long narrow ordinary ailerons with equal up-and-down deflection, used on the plain rectangular wing, gave a higher value of RC' than any of the other arrangements. (See also part I.)

Lateral control with sideslip.—If a wing is yawed appreciably, a rolling moment is set up that tends to raise the forward tip. The magnitude of this rolling moment is always greater at very high angles of attack than the available rolling moment due to ordinary ailerons. The highest angle of attack at which the aileron can balance the rolling moment due to 20° yaw has been tabulated for all the ailerons tested, as a criterion of control with sideslip. As previously mentioned, 20° yaw represents the conditions in a fairly severe sideslip. The upper-surface ailerons (flaps neutral) gave rolling control against the effect of 20° sideslip up to angles of attack 1° or 2° lower than for the ordinary ailerons of similar sizes. With flaps deflected for maximum lift, the angle of attack at which the upper-surface ailerons gave control against the sideslip was 2° lower than when the flaps were in the neutral position.

Yawing moment due to ailerons.—The magnitude and even the direction of the yawing moment desirable from ailerons have not been definitely determined up to the present time. It was thought in the past, particularly with reference to acrobatic flying and probably also with reference to most ordinary maneuvers, that to the pilot the maneuvers would seem as if they occurred about the airplane, or body, axes. For a highly maneuverable or acrobatic airplane, therefore, it was thought that complete independence of the three aerodynamic controls about the body axes would probably be a desirable feature. Recent flight tests made in an investigation of several lateral control devices (reference 6) indicate that the yawing action of the ailerons as observed by the pilot is that which would be expected from the yawing moments occurring about the *wind axes*, not those about the body axes. It is hoped that a continuation of this investigation, in which some of the most promising ailerons and spoilers developed in the series of wind-tunnel tests on lateral control devices are being tested in flight, will give sufficient information on yawing moments to settle the question as to the amount of yawing moment desirable for various flying conditions. The indication is, at the present time, that zero or very small yawing moments about the *wind axes* are desirable for acrobatic flying and possibly for flying in general, but that yawing moments of such a sense that they tend to retard the low wing in a turn definitely improve the lateral control at angles of attack above the stall. From the results of the above-mentioned flight tests, it is believed desirable in the present report to give the yawing-moment coefficient in the criterion table about the wind axes (C_n'), rather than about the body axes (C_n) as in previous reports of this series. The yawing moments are often negative with respect to the wind axes but at the same time positive with respect to the body axes. The signs of the yawing-moment coefficient as given in the tables and figures are in agreement with the N.A.C.A nomenclature in which yawing moments tending to produce clockwise rotation are regarded as positive. The concept of positive yawing moments as moments that aid the roll (generally termed "favorable") and negative moments as those that oppose the roll (generally termed "adverse") is also used throughout except as regards the aileron when deflected downward. The aileron being at the right wing tip then tends to produce roll in a counterclockwise direction and the coefficients therefore have signs opposite to those of the up-aileron at the same tip.

At angles of attack below the stall both sizes of upper-surface ailerons (flaps neutral) gave positive (favorable) yawing moments with large aileron deflections but at medium and high angles of attack they gave very small negative (adverse) moments with small deflections. Just above the stall the yawing moments were negative (adverse) even with large deflections. These characteristics are definitely better than those of corresponding sizes of ordinary ailerons. With flaps down for maximum lift, the magnitudes of the positive (favorable) yawing moments were smaller than those with flaps neutral, and negative (adverse) yawing moments occurred with small aileron deflections at practically all angles of attack.

LATERAL STABILITY

(AILERONS 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. With the split flaps neutral the limiting angle of attack was the same as for the wings without flaps, but with the split flaps deflected for maximum lift the limiting angle was reduced 3° to 4°.

Stability against rolling caused by gusts.—Test flights have shown that in severe gusts a rolling velocity may be attained such that $\frac{p'b}{2V} = 0.05$. Consequently, the rolling moment of a wing due to rolling at this value of $\frac{p'b}{2V}$ gives a measure of one factor affecting lateral-stability characteristics in rough air. In the present case, the angle of attack 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. As in the case of the angle of attack above which autorotation was self-starting, the angle of instability while rotating with $\frac{p'b}{2V}=0.05$ was the same for the wings with split flaps neutral as for the wings without flaps. With flaps deflected for maximum lift at 0° yaw (fig. 6), the angle of attack for initial instability was 4° lower than for the wings with flaps neutral.

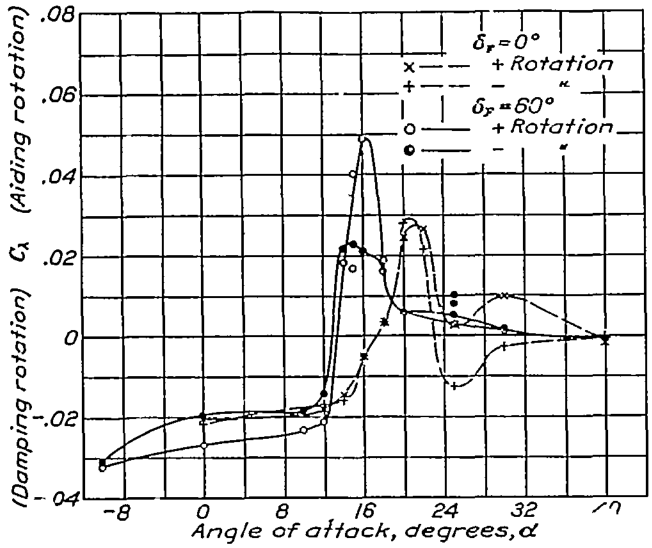

FIGURE 6.—Rolling-moment coefficient due to rolling at $\frac{p'b}{2V}=0.05$ for wing with 0.15 c full-span split flap neutral, and with flap down. 0° yaw.

With 20° yaw, the wings with split flaps neutral, like the wings with ordinary ailerons, had an angle of attack for initial instability 6° or 7° lower than that with 0° yaw. With the wings with split flaps deflected for maximum lift, the angle for initial instability was shifted to negative values so that the wings showed a distinct tendency, at all normal angles of attack, to increase an initial rate of rotation in roll when the direction of motion of the roll and the yaw were of the same sign. (See fig. 7.) This characteristic might be expected to impair the lateral stability of airplanes equipped with split flaps.

The preceding criterion shows the critical range below which the stability is such that any rolling is damped out, and above which instability exists. The remaining lateral-stability criterion, maximum C_λ, indicates the degree of the maximum instability. All the rotation tests showed somewhat unsymmetrical conditions in the two directions of rotation, and the maximum value of C_λ found with any angle of attack in either direction of rotation is used as the criterion. At 0° yaw, the wings with split flaps neutral had the same maximum tendency to autorotate as the wings with ordinary ailerons but, with split flaps down for maximum lift, this tendency was increased somewhat.

The maximum autorotational moment at 20° yaw is of importance for 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 for the wings having split flaps neutral and for the wings with ordinary ailerons, increased slightly with the narrow-chord flaps deflected for maximum lift and decreased slightly for the medium-chord flaps.

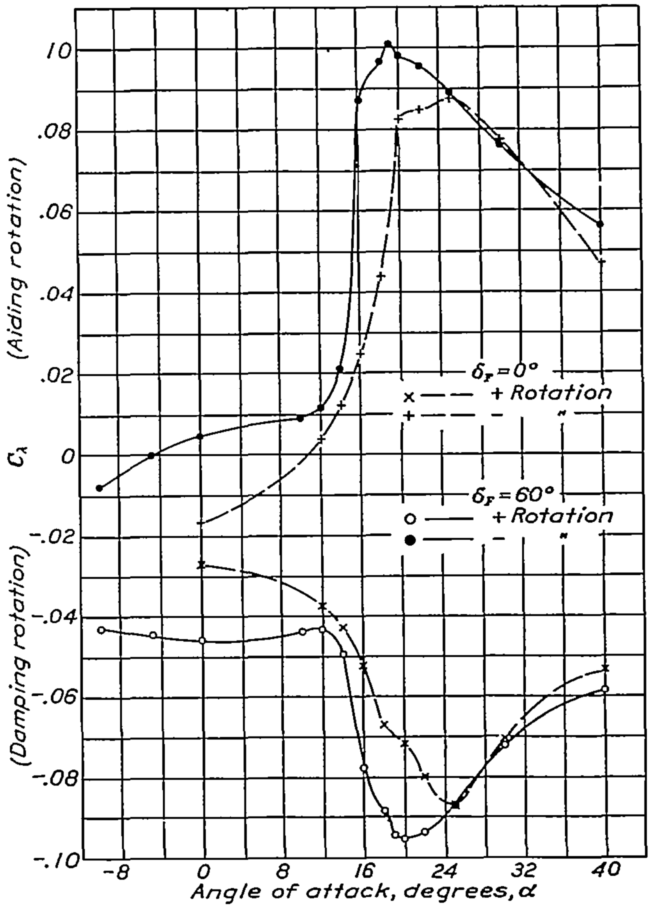

FIGURE 7.—Rolling-moment coefficient due to rolling at $\frac{p'b}{2V}=0.05$ for wing with 0.15 c full-span split flap neutral, and with flap down. −20° yaw.

CONTROL FORCE REQUIRED

The hinge-moment coefficients for the two sizes of upper-surface ailerons are plotted in figures 8 and 9 for both the flap-neutral and flap-deflected conditions. A control-force criterion, with which the various lateral control devices are compared in regard to the control-stick force required to attain the assumed maximum deflections, is based on a control-stick movement of ±25° and is independent of air speed. This criterion is

$$CF=\frac{Fl}{qcSC_L}=\frac{C_H}{C_L}\left(\frac{\delta_A}{25}\right)$$

ment are about three times as great as those of ordinary ailerons of corresponding sizes with equal up-and-down movement (split flaps neutral). Compared with the ordinary ailerons having an up-only movement of 70°, however, the values of CF for the upper-surface ailerons are about the same. (See part I, reference 1.) These values are much too high for practical operation, and an investigation of methods for reducing the hinge moments of upper-surface ailerons is now under way in the 7- by 10-foot wind tunnel.

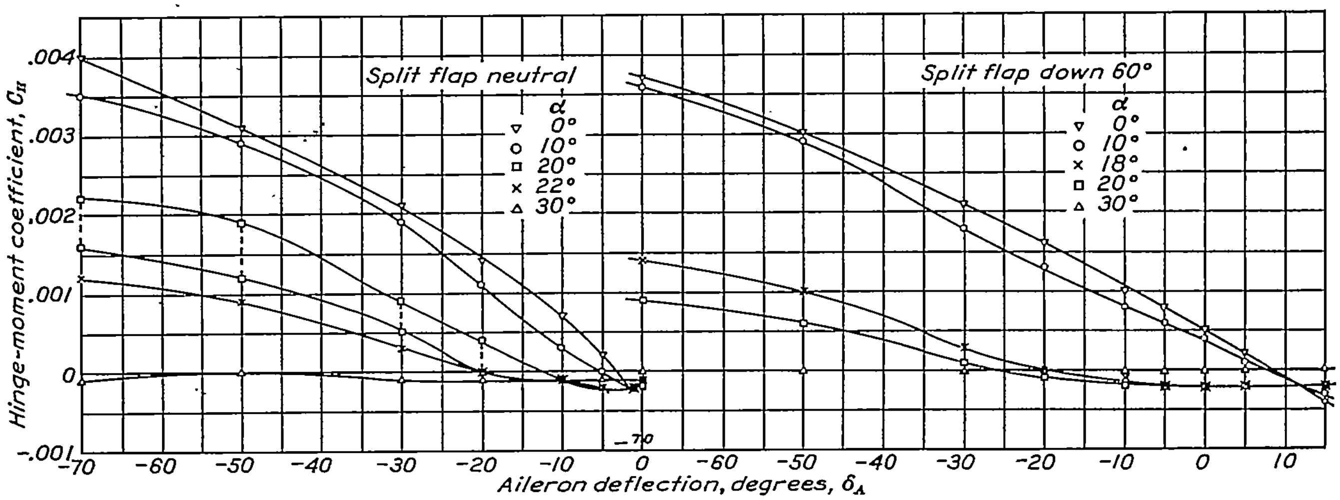

FIGURE 8.—Hinge-moment coefficients of 0.15 c upper-surface aileron with split flap neutral, and with flap down.

where F is the force applied at the end of the control lever of length l, and $\delta_A/25$ is the gear ratio between the aileron and the control lever.

Values of CF are given in the table of criterions (table IX) for the two sizes of upper-surface ailerons with split flaps both neutral and deflected for maximum lift, and for the two corresponding sizes of ordinary ailerons. At $\alpha=0°$ and $\alpha=10°$, the values of CF for the upper-surface ailerons with up-only move-

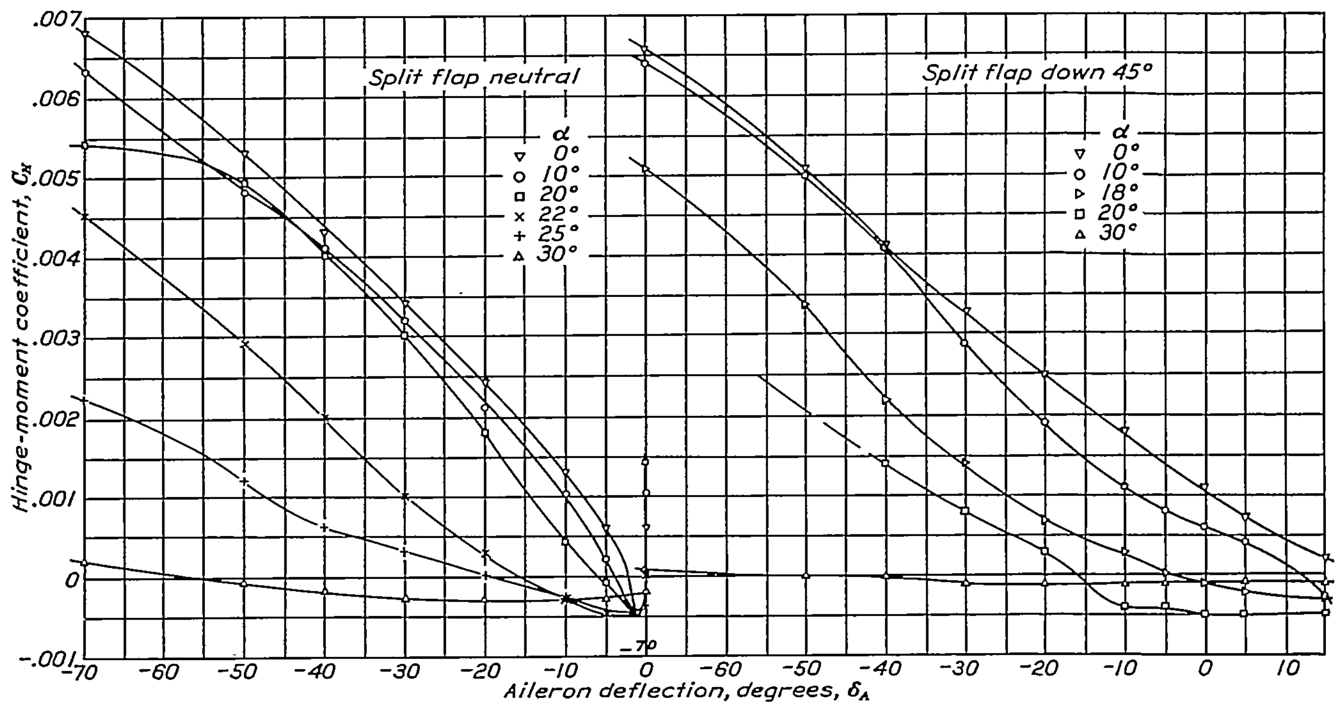

FIGURE 9.—Hinge-moment coefficients of 0.25 c upper-surface aileron with split flap neutral, and with flap down.

One possible method of reducing the control force might be to rig the upper-surface ailerons up a small amount when neutral and to provide them with an ordinary differential movement, although this might cause a small increase of minimum drag. A preliminary investigation indicated that this method was not very promising and other arrangements which appear more satisfactory are being investigated in the wind tunnel.

With the split flaps deflected for maximum lift, the values of *CF* for the upper-surface ailerons at $\alpha=0°$ and 10° are reduced to nearly the same as those of the ordinary ailerons with equal up-and-down movement, on account of the reduced speed at the same angle of attack.

It will be noted that for approximately the same rolling control the values of *CF* are considerably smaller for the long narrow ailerons than for the medium ailerons.

CONCLUSIONS

1. With the split flaps neutral, the upper-surface ailerons gave values of the rolling criterion *RC'* reasonably close to the assumed satisfactory value at angles of attack below the stall. With the flaps deflected for maximum lift, the rolling control was considerably below the assumed satisfactory value, but might be sufficient under ordinary flight conditions. Above the stall, little or no rolling control was indicated with the flaps either neutral or down.

2. At angles of attack below the stall both sizes of upper-surface ailerons (flaps neutral) gave positive (favorable) yawing moments with large deflections but with small deflections at all except the lowest angles of attack they gave small negative (adverse) yawing moments. Just above the stall the yawing moments were negative (adverse) even with large deflections. With the flaps deflected for maximum lift the magnitudes of the positive (favorable) yawing moments were smaller than those with flaps neutral, and negative (adverse) ones occurred with small aileron deflections at all angles of attack.

3. The control forces required to operate upper-surface ailerons with up-only deflection would be too great for practical use.

4. The autorotational tendencies of both wings were somewhat greater with the flaps deflected than with them retracted. With the flaps deflected and the wings yawed, a tendency to rotate in one direction was shown throughout the entire usable angle-of-attack range, a characteristic that might be expected to result in some impairment of the lateral stability of airplanes equipped with split flaps.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *June 8, 1934.*

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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 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.
   VII. Handley Page Tip and Full-Span Slots with Ailerons and Spoilers. T.N. No. 443, N.A.C.A., 1933, by Fred E. Weick and Carl J. Wenzinger.
   VIII. Straight and Skewed Ailerons on Wings with Rounded Tips. T.N. No. 445, N.A.C.A., 1933, by Fred E. Weick and Joseph A. Shortal.
   IX. Tapered Wings with Ordinary Ailerons. T.N. No. 449, N.A.C.A., 1933, by Fred E. Weick and Carl J. Wenzinger.
   X. Various Control Devices on a Wing with a Fixed Auxiliary Airfoil. T.N. No. 451, N.A.C.A., 1933, by Fred E. Weick and Richard W. Noyes.
   XI. Various Floating Tip Ailerons on Both Rectangular and Tapered Wings. T.N. No. 458, N.A.C.A., 1933, by Fred E. Weick and Thomas A. Harris.
2. Weick, Fred E., and Harris, Thomas A.: The Aerodynamic Characteristics of a Model Wing Having a Split Flap Deflected Downward and Moved to the Rear. T.N. No. 422, N.A.C.A., 1932.
3. Wenzinger, Carl J.: The Effect of Partial-Span Split Flaps on the Aerodynamic Characteristics of a Clark Y Wing. T.N. No. 472, N.A.C.A., 1933.
4. Wenzinger, Carl J.: Wind-Tunnel Measurements of Air Loads on Split Flaps. T.N. No. 498, N.A.C.A., 1934.
5. 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.
6. Weick, F. E., Soulé, H. A., and Gough, M. N.: A Flight Investigation of the Lateral Control Characteristics of Short Wide Ailerons and Various Spoilers with Different Amounts of Wing Dihedral. T.R. No. 494, N.A.C.A., 1934.
7. Soulé, Hartley A., and Wetmore, J. W.: The Effect of Slots and Flaps on Lateral Control of a Low-Wing Monoplane as Determined in Flight. T.N. No. 478, N.A.C.A. 1933.

TABLE I.—FORCE TESTS. CLARK Y WING WITH 0.15c BY 0.60 $\frac{b}{2}$ UPPER-SURFACE AILERON AND 0.15c FULL-SPAN SPLIT FLAP

(Values are given for one aileron at right wing tip)

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

α		−15°	−10°	−5°	−4°	−3°	0°	5°	10°	13°	14°	15°	16°	17°	18°	20°	22°	25°	30°	40°
	δ_A	AILERON AND FLAP NEUTRAL																		
C_L	0°	--------	--------	0.048	0.119	0.190	0.406	0.763	1.100	--------	1.271	1.274	1.262	1.260	1.252	1.186	1.115	0.840	0.900	0.805
C_D	0°	--------	--------	.015	.015	.016	.024	.051	.096	--------	.141	.159	.179	.197	.217	.259	.297	.440	.568	.738
RIGHT AILERON UP—FLAP NEUTRAL																				
C_l'	5°	--------	--------	0.007	--------	--------	0.006	--------	0.003	--------	--------	−0.001	--------	--------	--------	0.000	--------	0.003	0.000	0.000
C_n'	5°	--------	--------	.000	--------	--------	.000	--------	.000	--------	--------	.000	--------	--------	--------	.000	--------	−.001	.001	.001
C_l'	10°	--------	--------	.014	--------	--------	.012	--------	.009	--------	--------	.003	--------	--------	--------	.002	--------	.004	.002	.001
C_n'	10°	--------	--------	.001	--------	--------	.000	--------	−.001	--------	--------	.000	--------	--------	--------	−.001	--------	−.001	.001	.000
C_l'	20°	--------	--------	.028	--------	--------	.026	--------	.022	--------	--------	.013	--------	--------	--------	.000	--------	−.002	−.002	.000
C_n'	20°	--------	--------	.003	--------	--------	.001	--------	−.002	--------	--------	−.002	--------	--------	--------	−.002	--------	.000	.001	.001
C_l'	30°	--------	--------	.040	--------	--------	.038	--------	.034	--------	--------	.024	--------	--------	--------	.005	--------	−.003	−.003	−.001
C_n'	30°	--------	--------	.006	--------	--------	.003	--------	−.002	--------	--------	−.003	--------	--------	--------	−.003	--------	.000	.002	.000
C_l'	50°	--------	--------	.058	--------	--------	.058	--------	.055	--------	--------	.041	--------	--------	--------	.018	--------	−.005	−.005	.000
C_n'	50°	--------	--------	.013	--------	--------	.008	--------	.000	--------	--------	−.002	--------	--------	--------	−.003	--------	.000	.001	.000
C_l'	70°	--------	--------	.068	--------	--------	.069	--------	.036	--------	--------	.052	--------	--------	--------	.026	--------	−.003	−.004	−.001
C_n'	70°	--------	--------	.019	--------	--------	.013	--------	.003	--------	--------	.000	--------	--------	--------	−.003	--------	.000	.001	.000
RIGHT AILERON UP—FLAP DOWN 15°																				
C_L	0°	−0.398	−0.111	0.282	--------	--------	0.671	1.054	1.419	1.549	1.541	1.485	1.462	--------	1.413	1.305	0.963	0.986	0.980	0.867
C_D	0°	.164	.039	.040	--------	--------	.062	.104	.167	.207	.223	.245	.269	--------	.305	.342	.470	.548	.666	.830
C_l'	30°	--------	.046	.042	--------	--------	.043	--------	.041	--------	.035	--------	--------	--------	--------	.009	--------	−.001	−.001	.000
C_n'	30°	--------	.011	.006	--------	--------	.002	--------	−.003	--------	−.004	--------	--------	--------	--------	−.004	--------	−.001	.000	.000
C_l'	70°	--------	.079	.070	--------	--------	.074	--------	.075	--------	.067	--------	--------	--------	--------	.029	--------	.002	−.001	−.001
C_n'	70°	--------	.026	.017	--------	--------	.011	--------	.000	--------	−.001	--------	--------	--------	--------	−.004	--------	−.001	−.001	.000
RIGHT AILERON UP—FLAP DOWN 30°																				
C_L	0°	−0.329	0.089	0.492	--------	--------	0.883	1.263	1.636	1.791	1.652	1.586	1.554	--------	1.462	1.348	1.063	1.083	1.080	0.887
C_D	0°	.161	.060	.079	--------	--------	.114	.168	.241	.284	.301	.323	.341	--------	.375	.412	.563	.652	.720	.801
C_l'	30°	--------	.041	.042	--------	--------	.044	--------	.043	.040	--------	--------	--------	--------	--------	.008	--------	.000	.001	.000
C_n'	30°	--------	.008	.004	--------	--------	.001	--------	−.004	−.005	--------	--------	--------	--------	--------	−.003	--------	.000	−.001	.000
C_l'	70°	--------	.081	.073	--------	--------	.077	--------	.079	.075	--------	--------	--------	--------	--------	.026	--------	.001	.001	.000
C_n'	70°	--------	.025	.016	--------	--------	.009	--------	.000	−.002	--------	--------	--------	--------	--------	−.003	--------	.000	−.001	.000
RIGHT AILERON UP—FLAP DOWN 45°																				
C_L	0°	−0.334	0.246	0.655	--------	--------	1.040	1.410	1.767	1.944	1.676	1.618	1.567	--------	1.447	1.138	1.160	1.110	1.025	0.873
C_D	0°	.162	.095	.121	--------	--------	.167	.228	.306	.350	.363	.384	.399	--------	.427	.587	.662	.696	.771	.940
C_l'	30°	--------	.042	.043	--------	--------	.046	--------	.044	.041	--------	--------	--------	--------	--------	.001	--------	.001	.000	.000
C_n'	30°	--------	.007	.004	--------	--------	.001	--------	−.005	−.006	--------	--------	--------	--------	--------	−.002	--------	.001	−.001	.000
C_l'	70°	--------	.081	.075	--------	--------	.079	--------	.079	.075	--------	--------	--------	--------	--------	.005	--------	.001	.000	−.001
C_n'	70°	--------	.022	.014	--------	--------	.008	--------	.004	−.003	--------	--------	--------	--------	--------	−.001	--------	−.004	.000	−.001
RIGHT AILERON NEUTRAL—FLAP DOWN 60°																				
C_L	0°	−0.278	0.354	0.762	--------	--------	1.133	1.487	1.833	2.012	2.050	1.605	1.543	--------	1.434	1.191	1.200	1.062	0.971	0.841
C_D	0°	.169	.129	.163	--------	--------	.214	.279	.359	.407	.410	.424	.440	--------	.469	.663	.720	.718	.803	.958
RIGHT AILERON UP—FLAP DOWN 60°																				
C_l'	5°	--------	0.007	0.008	--------	--------	0.007	--------	0.007	0.006	--------	--------	--------	--------	--------	0.000	--------	−0.001	0.000	0.001
C_n'	5°	--------	.000	.000	--------	--------	−.001	--------	−.002	−.002	--------	--------	--------	--------	--------	−.001	--------	.000	.000	−.001
C_l'	10°	--------	.015	.015	--------	--------	.015	--------	.015	.014	--------	--------	--------	--------	--------	−.001	--------	−.001	.000	.000
C_n'	10°	--------	.000	.000	--------	--------	−.001	--------	−.004	−.004	--------	--------	--------	--------	--------	−.001	--------	.000	−.001	−.001
C_l'	20°	--------	.030	.031	--------	--------	.031	--------	.029	.027	--------	--------	--------	--------	--------	.000	--------	−.002	−.001	.000
C_n'	20°	--------	.002	.000	--------	--------	−.002	--------	−.006	−.007	--------	--------	--------	--------	--------	−.002	--------	−.001	−.001	−.001
C_l'	30°	--------	.042	.044	--------	--------	.044	--------	.042	.041	--------	--------	--------	--------	--------	.001	--------	−.001	.000	.000
C_n'	30°	--------	.005	.001	--------	--------	−.002	--------	−.007	−.008	--------	--------	--------	--------	--------	−.002	--------	−.001	−.001	−.001
C_l'	50°	--------	.062	.065	--------	--------	.067	--------	.066	.061	--------	--------	--------	--------	--------	.004	--------	−.002	.000	.000
C_n'	50°	--------	.012	.007	--------	--------	.002	--------	−.004	−.007	--------	--------	--------	--------	--------	−.002	--------	−.001	−.001	−.001
C_l'	70°	--------	.076	.076	--------	--------	.079	--------	.079	.075	--------	--------	--------	--------	--------	.006	--------	.000	.000	.000
C_n'	70°	--------	.019	.011	--------	--------	.006	--------	−.003	−.004	--------	--------	--------	--------	--------	.000	--------	−.001	−.001	−.001
RIGHT AILERON DOWN—FLAP DOWN 60°																				
C_l'	5°	--------	−0.008	−0.007	--------	--------	−0.006	--------	−0.007	−0.007	--------	--------	--------	--------	--------	0.000	--------	−0.001	0.000	0.000
C_n'	5°	--------	−.001	.000	--------	--------	.000	--------	.001	.001	--------	--------	--------	--------	--------	.000	--------	−.001	.000	.000
C_l'	15°	--------	−.017	−.022	--------	--------	−.022	--------	−.013	−.010	--------	--------	--------	--------	--------	.000	--------	−.001	−.001	−.001
C_n'	15°	--------	−.001	.001	--------	--------	.002	--------	.003	.002	--------	--------	--------	--------	--------	.000	--------	−.001	.000	−.001

TABLE II.—FORCE TESTS. CLARK Y WING, WITH 0.15c BY 0.60 $\frac{b}{2}$ UPPER-SURFACE AILERON AND 0.15c FULL-SPAN SPLIT FLAP

(Values are given for one aileron at right wing tip)

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

α		−15°	−10°	−5°	−4°	−3°	0°	5°	10°	12°	14°	15°	16°	17°	18°	20°	22°	25°	30°	40°
	δ_A	AILERON AND FLAP NEUTRAL																		
C_L	0°			0.036	0.099	0.162	0.354	0.678	0.979	1.074	1.143	1.167	1.192	1.192	1.190	1.192	1.041	0.926	0.918	0.822
C_D	0°			.019	.019	.019	.024	.049	.088	.106	.123	.135	.148	.164	.184	.236	.354	.440	.548	.700
C_l'	0°			−.006	−.006	−.006	−.009	−.009	−.013	−.019	−.016	−.032	−.034	−.042	−.066	−.087	−.064	−.104	−.104	−.058
C_n'	0°			.001	.001	.002	.002	.003	.006	.008	.010	.012	.014	.015	.017	.019	.033	.041	.054	.045
		RIGHT AILERON UP—FLAP NEUTRAL																		
C_l'	70°			0.065			0.065		0.063			0.061				0.057		0.036	0.018	−0.002
C_n'	70°			.017			.012		.001			−.003				−.004		−.014	−.009	−.002
		AILERON NEUTRAL—FLAP DOWN 60°																		
C_L	0°	−0.228	0.300	0.662			1.003	1.327	1.643	1.740	1.822	1.830	1.818		1.360	1.235	1.190	1.150	1.055	0.900
C_D	0°	.151	.111	.141			.182	.238	.306	.334	.359	.367	.380		.533	.595	.639	.716	.809	.961
C_l'	0°	−.011	−.014	−.017			−.018	−.018	−.019	−.021	−.015	−.021	−.043		−.102	−.108	−.105	−.101	−.086	−.060
C_n'	0°	.005	.003	.003			.004	.006	.009	.011	.012	.016	.020		.019	.035	.041	.049	.054	.051
		RIGHT AILERON UP—FLAP DOWN 60°																		
C_l'	70°		0.066	0.070			0.071		0.070				0.058			0.039		0.021	0.006	−0.001
C_n'	70°		.020	.016			.010		−.002				−.003			−.011		−.006	−.002	−.001

TABLE III—ROTATION TESTS. CLARK Y WING WITH 0.15c FULL-SPAN SPLIT FLAP

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\begin{cases}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{cases}$

Aileron neutra

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

	α	−10°	−5°	0°	10°	12°	14°	16°	18°	19°	20°	22°	25°	30°	40°
FLAP NEUTRAL—YAW=0°															
(+) Rotation (clockwise)	C_λ			−0.020		−0.018	−0.015	−0.006	0.003		0.024	0.026	0.003	0.010	−0.002
(−) Rotation (counterclockwise)	C_λ			−.022		−.017	−.016	−.005	.003		.028	.022	−.013	−.003	−.001
FLAP DOWN 60°—YAW=0°															
(+) Rotation (clockwise)	C_λ	−0.032		−0.027	−0.023	−0.021	0.018	0.049	0.019		0.006		0.003	0.001	−0.001
(−) Rotation (counterclockwise)	C_λ	−0.031		−.020	−.018	−.015	.022	.021	.016		.006		.003	.001	.001
FLAP NEUTRAL—YAW=−20°															
(+) Rotation (clockwise)	C_λ			−0.028		−0.038	−0.043	−0.053	−0.067		−0.072	−0.080	−0.087	−0.071	−0.054
(−) Rotation (counterclockwise)	C_λ			−.017		.004	.012	.025	.044		.082	.085	.087	.077	.046
FLAP DOWN 60°—YAW=−20°															
(+) Rotation (clockwise)	C_λ	−0.043	−0.045	−0.046	−0.044	−0.044	−0.050	−0.078	−0.088	−0.094	−0.095	−0.094	−0.086	−0.072	−0.058
(−) Rotation (counterclockwise)	C_λ	−.008	0	.005	.009	.012	.021	.087	.097	.101	.098	.096	.089	.076	.056

TABLE IV.—HINGE-MOMENT COEFFICIENTS. CLARK Y WING WITH 0.15c BY 0.60 $\frac{b}{2}$ UPPER-SURFACE AILERON AND 0.15c FULL-SPAN SPLIT FLAP

(C_H is given for one aileron at right wing tip)

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

δ_A	15°	5°	0°	−5°	−10°	−20°	−30°	−50°	−70°
α	FLAP NEUTRAL								
0°	------	------	−0.0002	0.0002	0.0007	0.0014	0.0021	0.0031	0.0040
10°	------	------	−.0001 −.0002	0	0.0003	.0011	.0019	.0029	.0035
20°	------	------	−.0002	−.0002	−.0001	.0004 0	.0009 .0005	.0019 .0012	.0022 .0016
22°	------	------	−.0001 −.0002	−.0002	−.0001	0	.0003	.0009	.0012
25°	------	------	−.0001 −.0002	−.0001	−.0001	.0002	.0004	.0009	.0010
30°	------	------	−.0001 −.0002	−.0001	−.0001	−.0001	−.0001	0	−.0001
	FLAP DOWN 60°								
0°	−0.0004	0.0002	0.0005	0.0008	0.0010	0.0016	0.0021	0.0030	0.0037
10°	−.0003	.0001	.0004	.0006	.0008	.0013	.0018	.0029	.0036
18°	−.0002	−.0002	−.0002	−.0002	−.0001	0	.0003	.0010	.0014
20°	−.0002	−.0002	−.0002	−.0002	−.0002	−.0001	.0001	.0006	.0009
30°	0	0	0	0	0	0	0	0	0

TABLE V.—FORCE TESTS. CLARK Y WING WITH 0.25c BY 0.40$\frac{b}{2}$ UPPER-SURFACE AILERON AND 0.25c FULL-SPAN SPLIT FLAP

(Values are given for one aileron at right wing tip)

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

α		−15°	−10°	−5°	−4°	−3°	0°	5°	10°	12°	14°	15°	16°	17°	18°	20°	22°	25°	30°	40°
	δ_A	AILERON AND FLAP NEUTRAL																		
C_L	0°	------	------	0.011	0.082	0.155	0.367	0.737	1.081	1.185	1.254	1.257	1.250	1.251	1.242	1.170	1.103	0.800	0.865	0.805
C_D	0°	------	------	.016	.015	.016	.021	.048	.091	.113	.134	.154	.172	.188	.208	.247	.285	.423	.548	.723
		RIGHT AILERON UP—FLAP NEUTRAL																		
C_l'	5°	------	------	0.007	------	------	0.006	------	0.004	------	------	0.002	------	------	------	0.000	------	−0.025	−0.016	0.000
C_n'	5°	------	------	.001	------	------	.000	------	.000	------	------	.000	------	------	------	.000	------	−.003	.003	.001
C_l'	10°	------	------	.013	------	------	.012	------	.009	------	------	.006	------	------	------	.001	------	−.023	−.016	.000
C_n'	10°	------	------	.001	------	------	.000	------	−.001	------	------	−.001	------	------	------	−.002	------	−.003	.003	.000
C_l'	20°	------	------	.023	------	------	.025	------	.022	------	------	.019	------	------	------	.006	------	−.018	−.016	.000
C_n'	20°	------	------	.003	------	------	.002	------	−.002	------	------	−.002	------	------	------	−.003	------	−.004	.004	.000
C_l'	30°	------	------	.037	------	------	.037	------	.035	------	------	.030	------	------	------	.012	------	−.013	−.013	.000
C_n'	30°	------	------	.008	------	------	.005	------	.000	------	------	−.002	------	------	------	−.004	------	−.005	.003	.000
C_l'	50°	------	------	.055	------	------	.057	------	.058	------	------	.052	------	------	------	.029	------	−.003	−.010	.000
C_n'	50°	------	------	.017	------	------	.012	------	.003	------	------	.000	------	------	------	−.002	------	−.004	.001	.001
C_l'	70°	------	------	.034	------	------	.068	------	.073	------	------	.069	------	------	------	.012	------	.005	−.006	.000
C_n'	70°	------	------	.024	------	------	.019	------	.008	------	------	.003	------	------	------	.001	------	−.001	.002	.000
		RIGHT AILERON UP—FLAP DOWN 15°																		
C_L	0°	------	−0.090	0.311	------	------	0.701	1.090	1.462	1.530	1.591	1.523	1.498	------	1.418	1.016	1.020	1.005	0.985	0.850
C_D	0°	------	.056	.053	------	------	.078	.124	.186	.213	.243	.270	.290	------	.322	.419	.479	.559	.691	.828
C_l'	30°	------	.042	------	------	------	.039	------	.043	------	.010	------	------	------	------	.020	------	.027	−.001	−.001
C_n'	30°	------	.012	------	------	------	.003	------	−.002	------	−.004	------	------	------	------	−.006	------	−.004	.000	.001
C_l'	70°	------	.073	------	------	------	.074	------	.035	------	.083	------	------	------	------	.046	------	.022	.001	.000
C_n'	70°	------	.031	------	------	------	.016	------	.005	------	.001	------	------	------	------	−.001	------	−.002	−.001	.000
		RIGHT AILERON UP—FLAP DOWN 30°																		
C_L	0°	−0.353	0.200	0.593	------	------	0.973	1.344	1.713	1.843	1.663	1.600	------	------	1.462	1.080	1.090	1.030	0.960	0.855
C_D	0°	.159	.095	.117	------	------	.157	.217	.289	.325	.345	.366	------	------	.416	.559	.614	.604	.739	.913
C_l'	30°	------	.047	------	------	------	.042	------	.044	------	------	------	------	------	------	.004	------	.002	.000	.001
C_n'	30°	------	.010	------	------	------	.001	------	−.004	------	------	------	------	------	------	−.002	------	−.002	.000	−.001
C_l'	70°	------	.081	------	------	------	.077	------	.087	------	------	------	------	------	------	.019	------	.003	.001	−.001
C_n'	70°	------	.029	------	------	------	.014	------	.002	------	------	------	------	------	------	.001	------	−.002	−.001	−.001
		RIGHT AILERON NEUTRAL—FLAP DOWN 45°																		
C_L	0°	−0.273	0.420	0.805	------	------	1.163	1.510	1.838	1.953	2.087	1.581	1.526	1.463	1.175	1.100	1.160	1.125	0.955	0.815
C_D	0°	.173	.163	.200	------	------	.246	.306	.387	.417	.456	.446	.463	.479	.624	.744	.744	.724	.824	.983

TABLE V.—FORCE TESTS. CLARK Y WING WITH 0.25c BY 0.40$\frac{b}{2}$ UPPER-SURFACE AILERON AND 0.25c FULL-SPAN SPLIT FLAP—Continued

α		−15°	−10°	−5°	−4°	−3°	0°	5°	10°	12°	14°	15°	16°	17°	18°	20°	22°	25°	30°	40°
RIGHT AILERON UP—FLAP DOWN 45°																				
C_l'	5°	--------	0.008	--------	--------	--------	0.007	--------	0.007	--------	0.006	--------	--------	--------	--------	0.001	--------	0.001	0.001	0.000
C_n'	5°	--------	.000	--------	--------	--------	.000	--------	−.001	--------	−.002	--------	--------	--------	--------	−.001	--------	−.001	.000	−.001
C_l'	10°	--------	.013	--------	--------	--------	.014	--------	.012	--------	.013	--------	--------	--------	--------	.001	--------	.001	.001	.000
C_n'	10°	--------	.001	--------	--------	--------	.000	--------	−.003	--------	−.004	--------	--------	--------	--------	−.001	--------	.000	.000	−.001
C_l'	20°	--------	.028	--------	--------	--------	.029	--------	.027	--------	.030	--------	--------	--------	--------	.001	--------	.001	.001	.000
C_n'	20°	--------	.003	--------	--------	--------	−.001	--------	−.005	--------	−.007	--------	--------	--------	--------	−.001	--------	−.001	.000	−.001
C_l'	30°	--------	.039	--------	--------	--------	.043	--------	.041	--------	.040	--------	--------	--------	--------	.004	--------	.000	.001	.000
C_n'	30°	--------	.006	--------	--------	--------	.001	--------	−.004	--------	−.009	--------	--------	--------	--------	−.002	--------	.000	.000	.000
C_l'	50°	--------	.070	--------	--------	--------	.065	--------	.068	--------	.068	--------	--------	--------	--------	.010	--------	.003	.001	.000
C_n'	50°	--------	.017	--------	--------	--------	.007	--------	−.003	--------	−.008	--------	--------	--------	--------	−.003	--------	−.002	.000	.001
C_l'	70°	--------	.082	--------	--------	--------	.078	--------	.086	--------	.085	--------	--------	--------	--------	.016	--------	.003	.002	.000
C_n'	70°	--------	.026	--------	--------	--------	.015	--------	.002	--------	.000	--------	--------	--------	--------	.002	--------	−.003	.000	.000
RIGHT AILERON DOWN—FLAP DOWN 45°																				
C_l'	5°	--------	−0.008	--------	--------	--------	−0.009	--------	−.0007	--------	−0.007	--------	--------	--------	--------	0.000	--------	0.001	0.001	0.000
C_n'	5°	--------	.000	--------	--------	--------	.001	--------	.001	--------	.001	--------	--------	--------	--------	.000	--------	−.001	0000	.001
C_l'	15°	--------	−.024	--------	--------	--------	−.024	--------	−.020	--------	−.011	--------	--------	--------	--------	.001	--------	.000	.001	.000
C_n'	15°	--------	.000	--------	--------	--------	.004	--------	.007	--------	.004	--------	--------	--------	--------	.001	--------	−.001	.001	.000

TABLE VI.—FORCE TESTS. CLARK Y WING WITH 0.25c BY 0.40 $\frac{b}{2}$ UPPER-SURFACE AILERON AND 0.25c FULL-SPAN SPLIT FLAP

(Values are given for one aileron at right wing tip)

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

α		−15°	−10°	−5°	−4°	−3°	0°	5°	10°	12°	14°	15°	16°	17°	18°	20°	22°	25°	30°	40°
	δ_A	AILERON AND FLAP NEUTRAL																		
C_L	0°	--------	--------	0.000	0.064	0.132	0.320	0.651	0.957	1.052	1.115	1.148	1.163	1.173	1.181	1.176	0.996	0.955	0.922	0.813
C_D	0°	--------	--------	.020	.019	.019	.022	.044	.083	.099	.119	.129	.141	.156	.176	.226	.354	.419	.536	.683
C_l'	0°	--------	--------	−.006	−.006	−.007	−.008	−.009	−.014	−.020	−.025	−.031	−.035	−.045	−.057	−.083	−.099	−.111	−.099	−.058
C_n'	0°	--------	--------	.002	.002	.002	.002	.003	.006	.008	.010	.011	.013	.015	.016	.020	.023	.033	.053	.043
RIGHT AILERON UP—FLAP NEUTRAL																				
C_l'	70°	--------	--------	0.064	--------	--------	0.066	--------	0.072	--------	--------	0.075	--------	--------	--------	0.074	0.049	--------	0.035	−0.002
C_n'	70°	--------	--------	.021	--------	--------	.017	--------	.007	--------	--------	.002	--------	--------	--------	.000	−.007	--------	−.012	.001
AILERON NEUTRAL—FLAP DOWN 45°																				
C_L	0°	−0.185	0.353	0.699	--------	--------	1.020	1.333	1.642	1.748	1.848	1.867	1.833	1.543	1.295	1.220	1.180	1.122	1.035	0.862
C_D	0°	.160	.140	.168	--------	--------	.212	.265	.333	.363	.392	.405	.405	.446	.568	.622	.674	.739	.832	.993
C_l'	0°	−.012	−.016	−.018	--------	--------	−.019	−.016	−.018	−.021	−.021	−.013	−.035	−.087	−.107	−.104	−.099	−.096	−.079	−.057
C_n'	0°	.007	.005	.005	--------	--------	.006	.008	.010	.011	.013	.014	.020	.025	.026	.036	.042	.049	.053	.051
RIGHT AILERON UP—FLAP DOWN 45°																				
C_l'	70°	--------	0.071	--------	--------	--------	0.070	--------	0.077	--------	0.077	--------	--------	0.083	--------	0.046	--------	0.037	0.010	−0.002
C_n'	70°	--------	.027	--------	--------	--------	.020	--------	.006	--------	.004	--------	--------	.001	--------	−.009	--------	−.004	−.002	−.002

TABLE VII.—ROTATION TESTS. CLARK Y WING WITH 0.25c FULL-SPAN SPLIT FLAP

C_λ is given for forced rotation at $\frac{p'b}{2V}=0.05\left\{\begin{matrix}(+)\text{ aiding rotation}\\(-)\text{ damping rotation}\end{matrix}\right.$

Aileron neutral

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

	α	−10°	−5°	0°	10°	12°	14°	16°	17°	18°	20°	21°	22°	24°	25°	30°	40°
FLAP NEUTRAL—YAW=0°																	
(+) Rotation (clockwise)	C_λ			−0.022		−0.019	−0.016	−0.003		0.007	0.037		0.048		0.002	−0.002	−0.002
(−) Rotation (counter-clockwise)	C_λ			−.021		−.019	−.016	−.005		.007	.040		.023		.005	−.001	−.002
FLAP DOWN 45°—YAW=0°																	
(+) Rotation (clockwise)	C_λ	−0.032		−0.027	−0.023	−0.023	0.015	0.047	0.040	0.014	0.004			0.002		0	−0.001
(−) Rotation (counter-clockwise)	C_λ	−.031		−.018	−.016	−.016	.022	.057	.026	.012	.007			.004		.002	.001
FLAP NEUTRAL—YAW=−20°																	
(+) Rotation (clockwise)	C_λ			−0.026		−0.036	−0.040	−0.048		−0.060	−0.067		−0.073		−0.082	−0.076	−0.053
(−) Rotation (counter-clockwise)	C_λ			−.014		.001	.008	.019		.039	.060		.093		.083	.074	.047
FLAP DOWN 45°—YAW=−20°																	
(+) Rotation (clockwise)	C_λ	−0.042	−0.046	−0.046	−0.044	−0.044	−0.047	−0.075		−0.085	−0.080	−0.078	−0.076	−0.078		−0.069	−0.050
(−) Rotation (counter-clockwise)	C_λ	−.007	.002	.007	.011	.011	.020	.080		.084	.088	.090	.088	.083		.072	.055

TABLE VIII.—HINGE-MOMENT COEFFICIENTS. CLARK Y WING WITH 0.25c BY 0.40 $\frac{b}{2}$ UPPER-SURFACE AILERON AND 0.25c FULL-SPAN SPLIT FLAP

(C_H is given for one aileron at right wing tip)

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

δ_A	15°	5°	0°	−5°	−10°	−20°	−30°	−40°	−50°	−70°
α	**FLAP NEUTRAL**									
0°			0.0006 −.0005	0.0006	0.0013	0.0024	0.0034	0.0043	0.0053	0.0068
10°			.0010 −.0005	.0002	.0010	.0021	.0032	.0041	.0048	.0063
20°			.0014 −.0005	−.0001	.0004	.0018	.0030	.0040	.0049	.0054
22°			0 −.0005	−.0005	−.0003	.0003	.0010	.0020	.0029	.0045
25°			−.0004		−.0003	0	.0003	.0006	.0012	.0022
30°			−.0002	−.0003	−.0003	−.0003	−.0003	−.0002	−.0001	.0002
	FLAP DOWN 45°									
0°	0.0002	0.0007	0.0011	0.0014	0.0018	0.0025	0.0033	0.0041	0.0051	0.0066
10°	−.0003	.0004	.0006	.0003	.0011	.0019	.0029	.0041	.0050	.0064
18°	−.0003	−.0002	−.0001	0	.0003	.0007	.0014	.0022	.0034	.0051
20°	−.0005	−.0005	−.0005	−.0004	−.0004	.0003	.0008	.0014		
30°	−.0001	−.0001	−.0001	−.0001	−.0001	−.0001	−.0001	0	0	.0001

TABLE IX.—CRITERIONS SHOWING RELATIVE MERITS OF AILERONS

Subject	Criterion	Ailerons 0.15c by 0.60 b/2			Ailerons 0.25c by 0.40 b/2		
		Ordinary	Upper-surface	Upper-surface	Ordinary	Upper-surface	Upper-surface
			(Flap neutral)	(Flap down 60°)		(Flap neutral)	(Flap down 45°)
		Standard 25° up, 25° dn.	Up-only 70°	Up-only 70°	Standard 25° up, 25° dn.	Up-only 70°	Up-only 70°
Wing area or minimum speed	$C_{L_{max}}$ $\delta_A=0°$	1.222	1.274	2.050	1.270	1.257	2.087
Speed range	$C_{L_{max}}/C_{D_{min}}$ $\delta_A=0°$	76.4	83.3	134.0	79.4	81.5	135.6
Rate of climb	L/D at $C_L=0.70$ $\delta_A=0°$	15.9	15.4	4.52	15.9	15.9	3.82
Lateral controllability	RC $\alpha=0°$	.220	.170	.070	.206	.185	.067
	RC $\alpha=10°$	.068	.060	.043	.074	.068	.047
	RC $\alpha=20°$	.015	.022	.005	.033	.035	.014
	RC $\alpha=30°$	.043	−.004	0	.009	−.007	.002
Lateral control with sideslip	Maximum α at which ailerons will balance C_l' due to 20° yaw.	19°	18°	16°	20°	18°	16°
Maximum yawing moments due to ailerons (wind axes). (+) Favorable; (−) Adverse	C_{n_A}' $\alpha=0°$	---- −0.006	0.013 0	0.006 [b]−.002	---- −0.007	0.019 0	0.015 [b]−.001
	C_{n_A}' $\alpha=10°$	---- [b]−.014	.002 [b]−.002	---- [c]−.007	---- −.018	.008 [b]−.002	.002 [b]−.005
	C_{n_A}' $\alpha=20°$	---- −.019	0 [c]−.003	0 [b]−.002	---- −.023	.001 [c]−.004	.002 [d]−.003
	C_{n_A}' $\alpha=30°$	---- −.023	[a].002 0	---- [a]−.001	---- −.015	[b].004 ----	0 0
Lateral stability ($\delta_A=0°$)	α for initial instability in rolling	18°	18°	14°	18°	18°	15°
	α for initial instability at $p'b/2V=0.05$: Yaw=0°	17°	17°	13°	17°	17°	13°
	Yaw=20°	10°	10°	−5°	11°	11°	−6°
	Maximum unstable C_λ at $p'b/2V=0.05$: Yaw=0°	0.028	0.028	0.049	0.048	0.048	0.057
	Yaw=20°	.087	.087	.101	.093	.093	.090
Control force required	CF $\alpha=0°$	.010	.027	.009	.017	.052	.016
	CF $\alpha=10°$	.003	.009	.005	.006	.016	.010
	CF $\alpha=20°$	.003	.005	.003	.006	.013	.012
	CF $\alpha=30°$	.003	0	0	.007	.001	0

[a] [b] [c] [d] Where the maximum yawing moment occurred below maximum deflection the letters indicate the deflection of the up aileron as follows: [a]=10°, [b]=20°, [c]=30° [d]=50°.