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HIGH-LIFT AND LATERAL CONTROL CHARACTERISTICS OF AN NACA 65_2-215 SEMISPAN WING EQUIPPED WITH PLUG AND RETRACTABLE AILERONS AND A FULL-SPAN SLOTTED FLAP

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SUMMARY

A wind-tunnel investigation was made at low values of Reynolds and Mach numbers to determine the high-lift and lateral control characteristics of a semispan wing of NACA 65_2-215 airfoil section equipped with a 25-percent-chord, full-span, slotted flap and plug and retractable ailerons. The ailerons were located at the 70-percent-chord station over the outer 49 percent of the wing semispan and were fabricated in five spanwise segments.

The results of the investigation indicated that large increases in wing lift could be obtained by use of a full-span slotted flap, and also that a 15° or a 30° flap deflection would probably be more advantageous than a 45° flap deflection for best airplane climb and flight characteristics; whereas a 45° flap deflection may be more advantageous for landing or as a glide-path control.

The plug and retractable ailerons investigated produced large rolling moments in all flap conditions, and the effectiveness of both ailerons increased with increase in the flap deflection. In all flap conditions, the plug aileron was generally more effective than the retractable aileron. The yawing moments produced by both ailerons were generally favorable with the flap retracted, and became less favorable with increase in wing angle of attack or flap deflection.

A comparison of the lift data obtained on the present wing and on a previously investigated wing of similar plan form having NACA 65-210 sections showed the similarity in the incremental values of maximum lift coefficient produced by a 45° flap deflection on both wings and also showed the more advantageous lift characteristics obtained with the thicker wing used in the present investigation. In addition, the plug and retractable ailerons on the present wing generally produced larger rolling moments and more favorable yawing moments than were produced by similar ailerons at corresponding projections on the NACA 65-210 wing.

INTRODUCTION

As a solution to the high-lift and lateral-control problems presented at take-off and landing for transport airplanes and other airplanes having large wing loadings, the National Advisory Committee for Aeronautics has been investigating the characteristics of spoiler-type lateral-control devices to be used in conjunction with full-span flaps. The results of many of these investigations have been summarized in reference 1 and have indicated that, in addition to allowing for the use of full-span or almost full-span high-lift flaps, the spoiler-type, lateral-control devices also provide control at high angles of attack, favorable yawing moments, and higher reversal speeds than conventional flap-type ailerons because of the smaller wing twisting moments of spoiler-type ailerons. In addition, spoiler-type lateral-control devices provide small stick forces and an increased effectiveness when full-span flaps are deflected, particularly when a plug aileron is used. These investigations have also shown the large increases in wing lift obtainable with a full-span flap, and the generally superior lift and lateral control characteristics obtainable with a slotted-type flap. The results of other investigations performed on unswept wings having high critical speeds (references 2 to 5) showed the increase in rolling effectiveness of the spoiler-type ailerons when the Mach number was increased in the high Reynolds number range as contrasted to a decrease in rolling effectiveness obtained with conventional ailerons as the Mach number increased.

The present investigation was performed in the Langley 300 MPH 7- by 10-foot tunnel to determine the lift and lateral control characteristics of a moderately thick, low-drag, semispan wing (having NACA 65_2-215 sections) equipped with a full-span slotted flap and either a plug aileron or a retractable aileron. The present investigation is an extension of the investigations reported in references 4 to 6 and employs the same wing plan form but a thicker wing section than that used in these previous investigations. Wing lift, drag, and pitching-moment characteristics were obtained for the plain wing, and also for the wing with the flap deflected 15°, 30°, and 45° at various flap positions in order to determine the optimum-lift flap-deflected positions (that is, the flap positions at which optimum lift characteristics were obtained over the angle-of-attack range). Tests of the plug-aileron and retractable-aileron configurations were performed at various aileron projections through an angle-of-attack range with the plain-wing configuration and also with the flapped-wing configuration with the flap at various deflections in the selected optimum-lift positions.

SYMBOLS

The moments on the wing are presented about the wind axes. The X-axis is in the plane of symmetry of the model and is parallel to the tunnel free-stream air flow. The Z-axis is in the plane of symmetry of the model and is perpendicular to the X-axis. The Y-axis is mutually perpendicular to the X-axis and Z-axis. All three axes intersect at the intersection of the chord plane and the 35-percent-chord station at the root of the model.

The symbols used in the presentation of results are as follows:

C_L lift coefficient (Twice lift of semispan model/qS)

ΔC_L increment of lift coefficient

C_D drag coefficient (D/qS)

C_m pitching-moment coefficient $(M/qS\bar{c})$

C_l rolling-moment coefficient (L/qSb)

C_n yawing-moment coefficient (N/qSb)

C_{l_p} damping-in-roll coefficient; that is, rate of change of rolling-moment coefficient with wing-tip helix angle $\left(\partial C_l / \partial\left(\frac{pb}{2V}\right)\right)$

pb/2V wing-tip helix angle, radians

c local wing chord

$\bar{c}$ wing mean aerodynamic chord (2.86 ft) $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$

b twice span of semispan model (16 ft)

y lateral distance from plane of symmetry, feet

S twice area of semispan model (44.42 sq ft)

D twice drag of semispan model, pounds

M twice pitching moment of semispan model about 35-percent-chord station at root of model, foot-pounds

L rolling-moment, resulting from aileron projection, about X-axis, foot-pounds

N yawing moment, resulting from aileron projection, about Z-axis, foot-pounds

q free-stream dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

V free-stream velocity, feet per second

ρ mass density of air, slugs per cubic foot

α angle of attack with respect to chord plane at root of model, degrees

δ_f flap deflection, measured between wing-chord plane and flap-chord plane; positive when trailing edge of flap is down, degrees (fig. 2)

X distance from wing upper-surface lip to flap nose, measured parallel to wing-chord plane and positive when flap nose is ahead of lip, percent chord (fig. 2)

Y distance from wing upper-surface lip to flap nose, measured normal to wing chord plane and positive when flap nose is below lip, percent chord (fig. 2)

$$C_{L_\alpha} = \frac{\partial C_L}{\partial \alpha}$$

Subscript:

max maximum

CORRECTIONS

All the data presented are based on the dimensions of the complete wing.

The test data have been corrected for jet-boundary effects according to the methods outlined in reference 7. Blockage corrections were applied to the test data by the methods of reference 8.

MODEL AND APPARATUS

The right semispan wing model was mounted horizontally in the Langley 300 MPH 7- by 10-foot tunnel with its root section adjacent to one of the vertical walls of the tunnel, the vertical wall thereby serving as a reflection plane. The wing was constructed according to the plan-form dimensions shown in figure 1 and had an aspect ratio of 5.76 and a ratio of tip chord to root chord of 0.57. The model was constructed with neither twist nor dihedral and had an NACA 65_2-215 airfoil section (table I) from root to tip. The wing was constructed with two trailing-edge sections which were used alternately for tests of the plain-wing configuration and for tests of the flapped-wing configuration (fig. 2). No transition strips were used on the wing, and an attempt was made to keep the model surface smooth during the entire investigation.

The 25-percent-chord, full-span, slotted flap used in this investigation was built to the section dimensions presented in table I and extended from the wing root section to the 95-percent-semispan station. This flap was originally designed and constructed to conform to the contour of the thinner wing (NACA 65-210) used in the investigations reported in references 4 to 6, and, because of its availability and satisfactory aerodynamic characteristics, was used in the flap-deflected wing configurations tested in the present investigation (fig. 2). The main difference between the flap used in the present investigation and a flap that would be formed from the trailing-edge part of the NACA 65_2-215 wing is that resulting from a difference in the thickness of the wings from which these flaps are formed, since the camber and airfoil series of these wings are the same. A comparison of the wing and flap profiles is shown in figure 3 to illustrate the similarites and the differences in the various wing and flap profiles. Each of the three wing fittings supporting the flap provided for a range of flap-nose positions and flap deflections, and allowed a survey to be made for the optimum-lift flap position at each flap deflection investigated.

The plug-aileron and retractable-aileron configurations investigated are shown in figures 1 and 2. The plug aileron is a spoiler-type aileron which fits into a slot through the wing when in the neutral position and leaves this slot open when it is extended above the wing. The retractable aileron is a spoiler-type aileron (usually a circular arc) that emerges only from the upper surface of the wing without leaving an open slot through the wing. Several ailerons, each having different projections, were used in tests of both the plug-aileron and retractable-aileron configurations, and each aileron had a span equal to 49.2 percent of the wing semispan. The ailerons were fabricated from dural sheet in five equal segments and were fastened to the upper surface of the wing at the 70-percent-chord station. (See fig. 2.) Only negative aileron projections - that is, ailerons extending above the wing upper surface - were employed in the present investigation. Ailerons having projections less than -9 percent chord had no gap between the lower edge of the aileron and the wing; whereas ailerons having projections of -10 and -11 percent chord embodied gaps of 1 and 2 percent chord, respectively, between the wing and the aileron. Although the ailerons investigated did not move out of the wing profile from the neutral position as they would in a practical airplane installation (for example, the configurations of references 5, 6, and 9), the configurations investigated are believed to simulate practical airplane installations and to provide aerodynamic data representative of these installations. In simulating these aileron configurations for a full-size airplane, the plug slot shown in figure 2 was sealed at the upper and lower surfaces of the wing for the test at zero projection of the plug aileron, for all tests of the retractable-aileron configuration, and during the entire lift investigation reported herein, but was unsealed for tests of the plug-aileron configurations employing finite aileron projections.

TESTS

All tests of the plain-wing configuration were performed at a dynamic pressure of approximately 51 pounds per square foot, which corresponds to a Mach number of 0.19 and a Reynolds number of 3.7×10^6 based on the wing mean aerodynamic chord of 2.86 feet. The wing in the flap-deflected configuration was investigated at a dynamic pressure of approximately 26 pounds per square foot, which corresponds to a Mach number of 0.13 and a Reynolds number of 2.6×10^6.

All of the tests were performed through an angle-of-attack range from approximately -8° to the angle of wing stall. A number of flap-nose positions with respect to the wing upper-surface lip were investigated at each of the flap deflections obtainable (15°, 30°, and 45°) in order to determine the flap position for optimum lift characteristics. The optimum-lift flap-nose positions selected from this survey were subsequently used when the characteristics of the plug aileron and the retractable aileron were investigated. The wing-aileron lateral control characteristics were determined with ailerons of various projections (ranging from 0 percent chord to -11 percent chord) fastened to the upper surface of the wing at the 70-percent-chord line.

RESULTS AND DISCUSSION

Wing Aerodynamic Characteristics

The wing lift, drag, and pitching-moment characteristics obtained with the full-span flap at various positions with respect to the wing upper-surface lip at flap deflections of 15°, 30°, and 45° are shown in figures 4, 5, and 6, respectively. For comparison, corresponding characteristics obtained with the plain-wing configuration are also shown in each of these figures. These data show the effects on the wing aerodynamic characteristics of deflecting and locating the flap at the various positions investigated, and indicate that the flap position for small deflections is not critical, but becomes successively more critical with increase in flap deflection. Thus, the path taken by the flap at small deflections to attain a given position and deflection is not limited by the possibility of obtaining deleterious aerodynamic characteristics. The data of figures 4 to 6 also show that deflection of the full-span flap or increase in the flap deflection produced an increase in the wing lift at any given value of α and also produced an increase in the nose-down wing pitching moment at given values of C_L.

The wing aerodynamic characteristics obtained with the plain-wing configuration and with the selected optimum-lift flapped-wing configurations are shown in figure 7. Although the data of figures 4 to 6 indicate that maximum lift was not always obtained with the flap at the selected optimum-lift position at each of the flap deflections investigated, more satisfactory lift characteristics (as well as drag and pitching-moment characteristics) were generally produced with the flap at the selected positions than were produced at other flap positions. Figure 7 shows that the incremental lift produced by unit flap deflection tended to decrease as the flap deflection increased, and the values of ΔC_L produced by flap deflection at given values of α were fairly constant up to about 90 percent of $C_{L_{max}}$ but decreased at larger values of C_L because of the lower values of α for wing stall attained with increased flap deflection. A summary of the wing lift characteristics is presented in the following table:

δ_f	$(C_L)_{\alpha=0^\circ}$	$(\Delta C_L)_{\alpha=0^\circ}$	$C_{L_{max}}$	$\Delta C_{L_{max}}$
Plain wing	0.11	----	1.34	----
[a]15°	.80	0.69	2.00	0.66
[a]30°	1.27	1.16	2.22	.88
[a]45°	1.56	1.45	2.30	.96

[a]Flap at selected optimum-lift positions.

The data in the preceding table and in figure 7 show that the value of $C_{L_{max}}$ produced with a 30° flap deflection was almost as large as that produced with a 45° flap deflection, even though the 45° flap deflection produced larger values of C_L over most of the angle-of-attack range. In addition, the values of drag coefficient produced at given values of C_L for flap deflections of 15° and 30° were almost the same as those produced by the plain wing, and were lower than the values of C_D produced with the 45° flap deflection. Also, as previously discussed, C_m became more negative with increase in flap deflection. From a consideration of trimmed-flight lift-drag ratios providing best climb and flight characteristics, it would therefore be concluded that a 15° or a 30° flap deflection would be more advantageous than a 45° flap deflection; whereas the 45° flap deflection (or a larger deflection) may be more advantageous for landing or as a glide-path control.

Because the wing of the present investigation was chosen mainly to give large-scale lateral-control data and had a relatively low aspect ratio, the lift, drag, and pitching-moment characteristics presented herein are not those that would be obtained on a high-aspect-ratio transport-type airplane wing. In addition, the values of the lift-drag ratio L/D obtained on the present wing $\left(\frac{L}{D} \approx 26 \text{ at } \left(\frac{L}{D}\right)_{max},\right.$ $\left. 13 \text{ at } C_L = 1.0, \text{ and } 7 \text{ at } C_L = 2.0\right)$ are not representative of the larger values of L/D that could and would be obtained on the high-aspect-ratio wings used on transport airplanes (values of $(L/D)_{max}$ of approximately 35 were obtained in the high-aspect-ratio wing investigations reported in references 10 and 11); however, the present data indicate the advantages to be gained for transport-type and other high-performance aircraft by use of a full-span flap.

A comparison of the lift data obtained in the present investigation with comparable data obtained in the investigation of the NACA 65-210 semi-span wing reported in reference 4 is presented in the following table:

Wing model	Wing configuration	C_{L_α}	$(C_L)_{\alpha=0^\circ}$	$(\Delta C_L)_{\alpha=0^\circ}$	$C_{L_{max}}$	$\Delta C_{L_{max}}$
NACA 65_2-215	Plain wing	0.077	0.11	----	1.34	----
	$\delta_f = 45^\circ$	-----	1.56	1.45	2.30	0.96
NACA 65-210 (reference 4)	Plain wing	.072	.16	----	.93	----
	$\delta_f = 45^\circ$	----	1.44	1.28	1.87	.94

These data show the similarity in the values of $\Delta C_{L_{max}}$ produced on both wings by a 45° flap deflection - a phenomenon which might be anticipated because the same flap was used in both investigations. Also shown are the more advantageous lift characteristics anticipated and obtained with the wing investigated herein - a result of the thicker wing section used on the present wing, and a phenomenon which has been noted previously (references 12 and 13).

Lateral Control Characteristics

Variation of the lateral control characteristics of the complete wing with plug-aileron projection at various angles of attack and for various flap configurations is shown in figures 8 to 11. Corresponding data obtained for various projections of the retractable aileron are shown in figures 12 to 15. The selected optimum-lift flap positions previously discussed were employed at the various flap deflections at which the plug-aileron and the retractable-aileron control characteristics were investigated.

Aileron hinge-moment characteristics were not determined in this investigation because simplified aileron configurations (fig. 2) were tested; however, the hinge-moment data presented in references 1, 5, and 6 show the magnitude and trends of the hinge moments that could be expected for various plug-aileron and retractable-aileron configurations that may be installed on the present wing if incorporated in an airplane.

Plug aileron.- The lateral-control data of figures 8 to 11 showed that the rolling effectiveness of the plug aileron was nonlinear over the projection range and generally increased with increase in aileron projection. Some of the nonlinearity results from the testing technique, as discussed later, and might not be present in an actual installation. The rolling effectiveness of the plug aileron also increased with increase in the wing angle of attack, except at large values of α and aileron projections larger than about -2 percent chord where a slight decrease in rolling effectiveness with increase in α was noted.

The ineffectiveness exhibited by the plug aileron at relatively small projections and low angles of attack for the plain-wing configuration (fig. 8) is similar to that obtained with retractable ailerons on conventional wing sections; however, this ineffectiveness of the retractable ailerons on conventional wing sections was alleviated when a slot was added behind the aileron (references 9 and 14). The plug slot on the present wing model was therefore believed to be comparatively ineffective at these low angles of attack because of the small differences in pressure that probably existed between the two wing surfaces in the vicinity of the plug slot when the flap was not deflected. This belief is substantiated by the fact that unpublished section pressure data on a similar wing section show that a reversed (unfavorable) pressure gradient across the plug slot could be obtained. At high angles of attack in the plain-wing configuration, and also with the flap deflected, the pressure difference between the upper and lower wing surfaces near the plug slot was sufficient to produce an induced flow through the plug slot and thereby increase the aileron effectiveness. Similar effects were noted at corresponding low values of Mach number in the aileron investigation reported in reference 5, but were alleviated when the Mach number was increased. Moreover, the data of references 2, 3, 5, and 6 indicate that an increase in rolling effectiveness with increase in Mach number may be expected over the entire projection range for the present wing-aileron configuration. The rolling ineffectiveness encountered at low angles of attack and low Mach numbers by the present plain-wing configuration is therefore believed to be inconsequential for a reasonably high-speed airplane because the airplane in this attitude (low α) would normally be flying at higher values of Mach number than those at which these data were obtained; also, the rolling effectiveness of the plug aileron on the aforementioned high-speed airplane is expected to vary almost linearly with aileron projection throughout the speed range in the flap-retracted condition. For airplanes of the private-owner type having low wing loadings and relatively low maximum speeds, wing sections similar to those on the present wing - or those that might give an unfavorable pressure difference, across the plug slot - probably would be unsatisfactory if a plug-aileron configuration is to be employed. For such airplanes, use of conventional wing sections would probably be desirable.

The large values of rolling-moment coefficient at small aileron projections of about -0.01c shown in figures 8 to 11 at the higher values of lift coefficient result from the sudden opening of the plug slot as well as from projection of the aileron. Because the opening of the plug slot would probably be more gradual with increase of aileron projection in an airplane installation (probably somewhat like the configuration investigated on the NACA 65-210 wing in reference 5), the resultant curves of rolling-moment coefficient against aileron projection would not exhibit such a surge in rolling effectiveness with initial aileron projection as was obtained in the present investigation, and the aforementioned curves would be more linear. It is believed, however, from the data of references 5 and 6, that no aileron ineffectiveness would be encountered with the lift flap deflected. In addition, the data of figures 8 to 11 show that at low angles of attack a slight reduction or a tendency toward a reduction in the values of rolling-moment coefficient occurred at negative aileron projections above -9.0 percent chord. At projections greater than -9.0 percent chord, a gap existed between the wing and the lower edge of the aileron, and it is believed that this gap permitted a partial pressure recovery on the wing rearward of the aileron, the pressure recovery thereby causing a loss in effectiveness. A similar effect was also noted in the investigation reported in reference 5.

The aileron effectiveness increased with increase in flap deflection; the values of C_l obtained at a flap deflection of 45° were more than twice as large as the values of C_l obtained with the plain-wing configuration. In addition, the data of figures 8 to 11 show that the plug aileron provided large rolling moments up to and even above the wing stall angle in any flap configuration.

The values of yawing-moment coefficient obtained by projection of the plug aileron on the plain-wing configuration were generally favorable (that is, having the same sign as the values of C_l) at almost all angles of attack and the values of C_n generally became more favorable with increase in aileron projection in all flap configurations. As would be expected, the values of C_n generally became less favorable with increase in the flap deflection and also with increase in the angle of attack in all flap configurations (figs. 8 to 11). The sudden surge in negative values of C_n noted for initial aileron projections at large values of α with the flap deflected probably result from the sudden opening of the plug slot (as previously discussed for the aileron effectiveness) and probably would not be encountered on a normal plug-aileron installation (reference 5). On the basis of the results obtained in the investigations reported in references 5 and 6, Mach number would be expected to have a negligible or an inconsistent effect on the yawing-moment data.

Retractable aileron.- The values of rolling-moment coefficient obtained by projection of the retractable aileron increased nonlinearly with aileron projection over most of the projection range in all flap configurations (figs. 12 to 15), but exhibited trends of reversed aileron effectiveness for small projections with the flap deflected 30° and 45°, a phenomenon usually exhibited by retractable ailerons in the flap-deflected configuration (reference 14).

In the plain-wing configuration, small aileron projections were somewhat ineffective in producing roll at low values of α, but an increase in α increased the effectiveness in this projection range. Because the data of references 2, 3, and 5 indicate that an increase in aileron effectiveness with increase in Mach number may be expected over the entire projection range for this aileron configuration, particularly for small aileron projections, it is believed that the aforementioned ineffective region of roll for small aileron projections in the flap-retracted configuration would not be encountered in flight by a reasonably high-speed airplane employing the present wing-aileron configuration. For such an airplane, flap-retracted flight would be at high speed and low angles of attack and vice versa; therefore rolling-moment coefficients probably would vary almost linearly with aileron projection.

In all flap configurations, an increase in the angle of attack usually produced an increase in the rolling moment for small aileron projections. At moderate and large aileron projections, an increase in α at low values of α produced an increase in C_l; whereas an increase in α at large values of α produced a decrease in C_l. These trends are in contrast to the decrease in effectiveness exhibited by retractable ailerons on wings having conventional sections when the angle of attack was increased (references 1 and 14). At low values of α, a constant or a slightly reduced aileron effectiveness was generally exhibited at retractable-aileron projections greater than -9 percent chord in all flap configurations. This effect was also noted and discussed for the plug-aileron configuration and is believed to result from the partial pressure recovery on the wing rearward of the aileron when a gap exists between the lower edge of the aileron and the wing surface.

The rolling effectiveness of the retractable aileron increased with increase in flap deflection and was approximately 100 percent larger at $\delta_f = 45^\circ$ than in the plain-wing configuration. (Compare fig. 12 with fig. 15.) The retractable aileron also provided large values of C_l up to and above the flap-retracted or flap-deflected wing stall angle. Because the rolling effectiveness of the retractable aileron appears very good at $\delta_f = 15^\circ$ (fig. 13) and the rolling-moment data obtained at this flap deflection do not exhibit the reversal in effectiveness for small aileron projections exhibited by the data obtained at flap deflections of 30° and 45° (figs. 14 and 15), it would appear that the retractable aileron would be a very effective and desirable lateral-control device throughout the lift range provided that the lift characteristics produced at the small flap deflections (up to approximately 15°) are acceptable.

The yawing moments produced by projection of the retractable aileron with the plain-wing configuration generally had the same sign as the rolling moments, and hence were favorable, but became less favorable with increase in flap deflection (figs. 12 to 15). The values of C_n generally became more favorable with increase in aileron projection and less favorable with increase in the wing angle of attack in all flap configurations. Although the effects of changes in Mach number were not determined in the present investigation, the data of references 5 and 6 indicate that the retractable-aileron yawing-moment characteristics presented herein would be expected to be either negligibly or inconsistently affected by such changes.

Comparison of Lateral Control Characteristics of the Plug and Retractable Ailerons

The rolling-moment characteristics of the plug aileron and the retractable aileron generally exhibited the same trends with increase in aileron projection, angle of attack, and flap deflection (figs. 8 to 11 and 12 to 15). The rolling moments produced by both ailerons in the plain-wing configuration were about the same at low values of α, but the plug aileron produced larger rolling moments than the retractable aileron at large values of α. (Compare fig. 8 with fig. 12.) With the flap deflected, the plug aileron generally produced larger rolling moments over the entire projection range than did the retractable aileron, and the tendency toward reversal of effectiveness for small projections exhibited by the retractable-aileron data at $\delta_f = 30^\circ$ and 45° was not shown by the plug-aileron data. Because of these differences in the effectiveness of the plug and retractable ailerons with flap deflected, use of the plug aileron would be more advantageous for high-performance aircraft, particularly in the high-lift flight range and at flap deflections of 30° and 45°.

Values of the helix angle $pb/2V$ generated by the wing tip in a roll were computed from the equation $\frac{pb}{2V} = \frac{C_l}{C_{l_p}}$ (where C_{l_p} is the damping-in-roll coefficient) and indicated the effectiveness of the plug and retractable ailerons investigated, particularly with flap deflected. These computations showed that a value of C_l of 0.036, which was usually exceeded at large aileron projections with the flap retracted, and easily exceeded with the flap deflected, corresponded to a value of $pb/2V$ of 0.09, based on a value of C_{l_p} (obtained from reference 15) of 0.40.

The yawing moments produced by projection of the plug or retractable ailerons were generally similar for all flap configurations, and exhibited the same effects produced by increase in aileron projection, angle of attack, and flap deflection.

Comparison of Lateral Control Characteristics of the Plug and Retractable Ailerons on the Present Wing with Similar Ailerons on an NACA 65-210 Wing

Comparisons were made of the lateral control characteristics produced by the plug and retractable ailerons on the NACA 65_2-215 wing of the present investigation with the corresponding characteristics produced by similar ailerons on the NACA 65-210 wing (reference 5). Some of these comparisons are presented in figures 16 and 17 for the flap-retracted and flap-deflected ($\delta_f = 45^\circ$) configurations, respectively.

At comparable values of lift coefficient in either flap configuration, the plug and retractable ailerons of the present investigation generally produced larger values of C_l at corresponding aileron projections than the plug and retractable ailerons on the NACA 65-210 wing. The plug and retractable ailerons on both wings produced nonlinear increases of C_l with aileron projection, and also produced large increases in C_l when the flap was deflected. In all flap configurations, the ailerons on the present wing produced increases in C_l with increase in α at small projections, and at moderate and large projections, produced increases in C_l with increase in α at low values of α, and decreases in C_l with increase in α at large values of α. In contrast, the plug ailerons of reference 5 generally produced an increased effectiveness in both flap configurations with increase in α, and the retractable ailerons of reference 5 generally produced an increase in effectiveness with increase in α only at small projections with the flap retracted. On both wings, the plug ailerons were usually more effective than the retractable ailerons with the flap deflected.

At comparable values of lift coefficient in either flap configuration, the plug and retractable ailerons on the present wing generally produced more favorable values of yawing-moment coefficient than similar ailerons on the NACA 65-210 wing. The yawing-moment characteristics produced by aileron projection on either wing exhibited similar effects of changes in aileron projection, angle of attack, and flap deflection.

CONCLUSIONS

A wind-tunnel investigation was made at low values of Reynolds and Mach numbers to determine the high-lift and lateral control characteristics of a semispan wing of NACA 65_2-215 airfoil section equipped with a 25-percent-chord, full-span, slotted flap and plug and retractable ailerons. The ailerons were located at the 70-percent-chord station over the outer 49 percent of the wing semispan, and were fabricated in five spanwise segments. The results of the investigation led to the following conclusions:

1. Deflection of the full-span flap or increase in the flap deflection produced an increase in the wing lift at any given angle of attack, and also generally produced an increase in the nose-down wing pitching moment and either a negligible change or a slight increase in the wing drag at given values of lift coefficient. A value of maximum lift coefficient of 1.34 was obtained with the plain wing, and values of maximum lift coefficient of 2.00, 2.22, and 2.30 were obtained with the flap deflected 15°, 30°, and 45°, respectively, at the selected optimum-flap positions.

2. On the basis of a comparison of lift, pitching-moment, and lift-drag-ratio data obtained at the various flap deflections investigated, it appears that a 15° or a 30° flap deflection would be more advantageous than a 45° flap deflection for best climb and flight characteristics; whereas the 45° flap deflection may be more advantageous for landing or as a glide-path control.

3. The rolling effectiveness of both the plug and the retractable ailerons generally increased with increase in aileron projection, except at small projections with the flap deflected 30° and 45°, where the retractable aileron exhibited trends of reversed rolling effectiveness. In all flap configurations, the rolling effectiveness of both ailerons at moderate and large projections increased with increase in the wing angle of attack α at low values of α, and decreased with increase in α at large values of α; for small aileron projections, increase in α increased the aileron effectiveness. The rolling effectiveness of both ailerons increased with increase in the flap deflection and was more than twice as large with the flap deflected 45° as with the flap neutral. Both ailerons also provided large rolling moments up to and above the wing stall. In the plain-wing configuration at large values of α, and with the flap deflected at all values of α, the plug aileron was generally more effective than the retractable aileron.

4. The plug and the retractable ailerons produced similar yawing-moment characteristics. The yawing moments of both ailerons were generally favorable in the plain-wing configurations; and in all flap configurations, the wing yawing moments generally became more favorable with increase in aileron projection and less favorable with increase in wing angle of attack and flap deflection.

5. At comparable values of lift coefficient with the flap retracted or deflected the plug and retractable ailerons on the NACA 65_2-215 wing of the present investigation generally produced larger values of rolling moment and more favorable values of yawing moment than were produced by similar ailerons at corresponding projections on a previously investigated wing of similar plan form having NACA 65-210 sections. In addition, the rolling-moment and yawing-moment characteristics produced by aileron projection on either wing generally exhibited similar effects of changes in aileron projection, flap deflection, and angle of attack.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va., January 28, 1949

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TABLE I.- ORDINATES FOR AIRFOIL AND FLAP

(All dimensions given in percent of wing chord)

NACA 65_2-215 airfoil

Upper Surface		Lower Surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
.406	1.170	.594	-1.070
.645	1.422	.855	-1.282
1.132	1.805	1.368	-1.591
2.365	2.506	2.635	-2.134
4.848	3.557	5.152	-2.925
7.342	4.380	7.658	-3.532
9.841	5.069	10.159	-4.035
14.848	6.175	15.152	-4.829
19.863	7.018	20.137	-5.426
24.882	7.658	25.118	-5.868
29.904	8.123	30.096	-6.179
34.927	8.426	35.073	-6.366
39.952	8.569	40.048	-6.427
44.976	8.522	45.024	-6.332
50.000	8.271	50.000	-6.065
55.021	7.815	54.979	-5.625
60.039	7.189	59.961	-5.047
65.053	6.433	64.947	-4.373
70.062	5.572	69.938	-3.628
75.065	4.638	74.935	-2.848
80.063	3.653	79.937	-2.061
85.055	2.649	84.945	-1.303
90.040	1.660	89.960	-.626
95.020	.744	94.980	-.112
100.000	0	100.000	0

L.E. radius: 1.505
Slope of radius through L.E.: 0.0844

Slotted flap

Upper Surface		Lower Surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
.28	.92	.28	-.41
.56	1.19	.56	-.62
1.12	1.56	1.12	-.88
1.69	1.80	1.69	-1.00
2.25	1.99	2.48	-1.03
3.38	2.22	4.98	-.83
4.50	2.33	7.48	-.63
5.61	2.38	9.98	-.44
7.00	2.40	12.48	-.27
9.00	2.35	14.98	-.12
11.00	2.16	17.48	.01
12.51	1.91	19.99	.10
15.01	1.50	22.49	.12
17.51	1.10	25.00	0
20.00	.71		
22.50	.34		
25.00	0		

L.E. radius: 0.80
Slope of radius through L.E.: 0.35

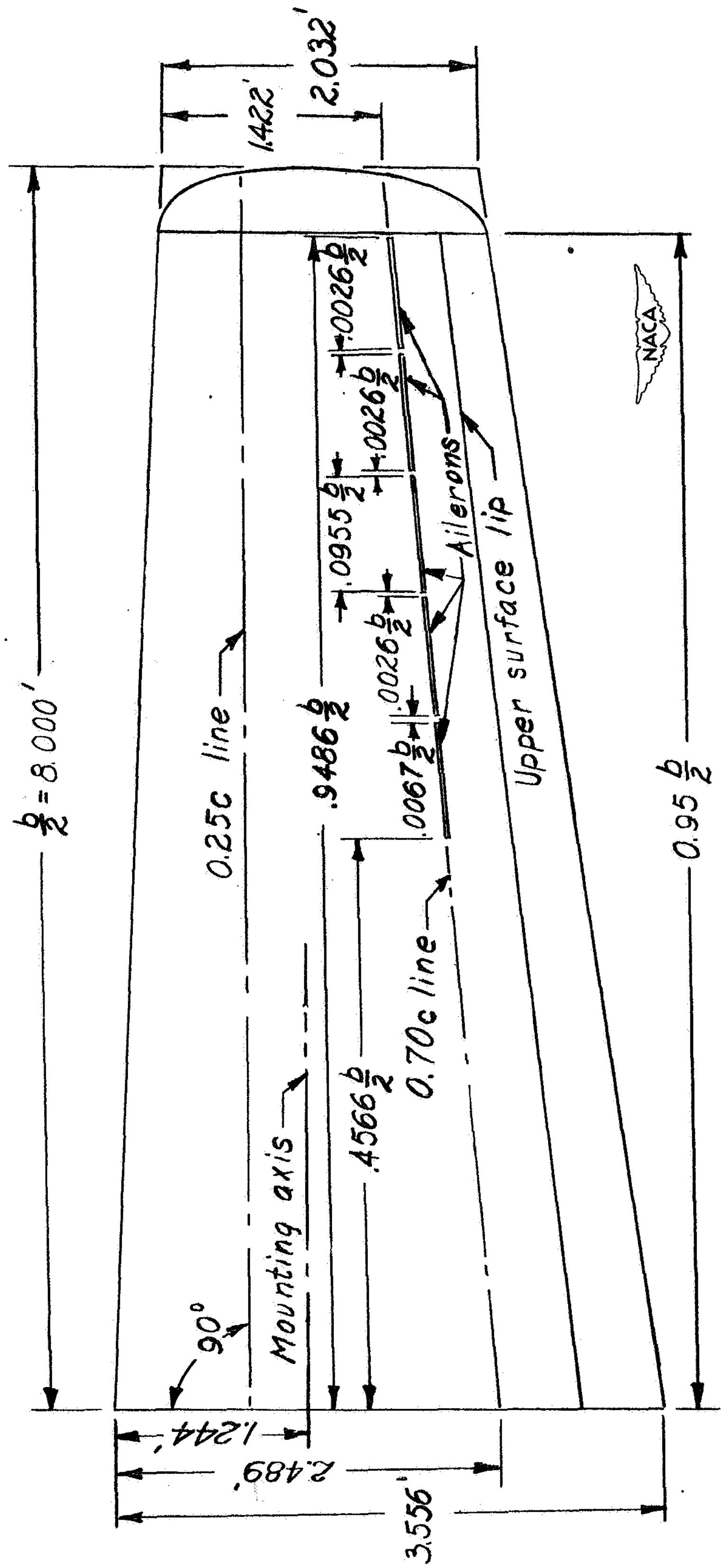
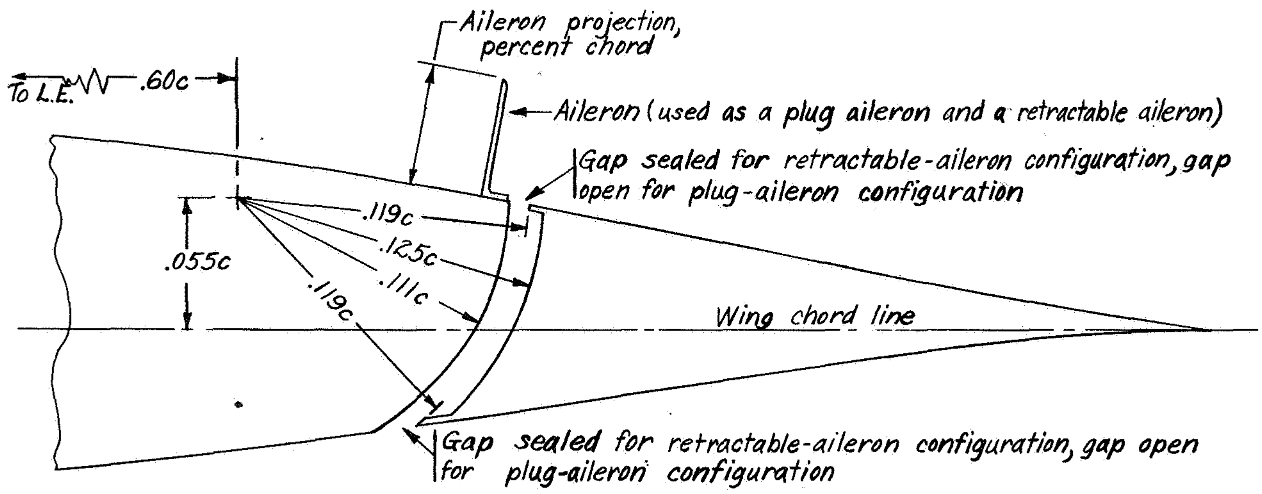
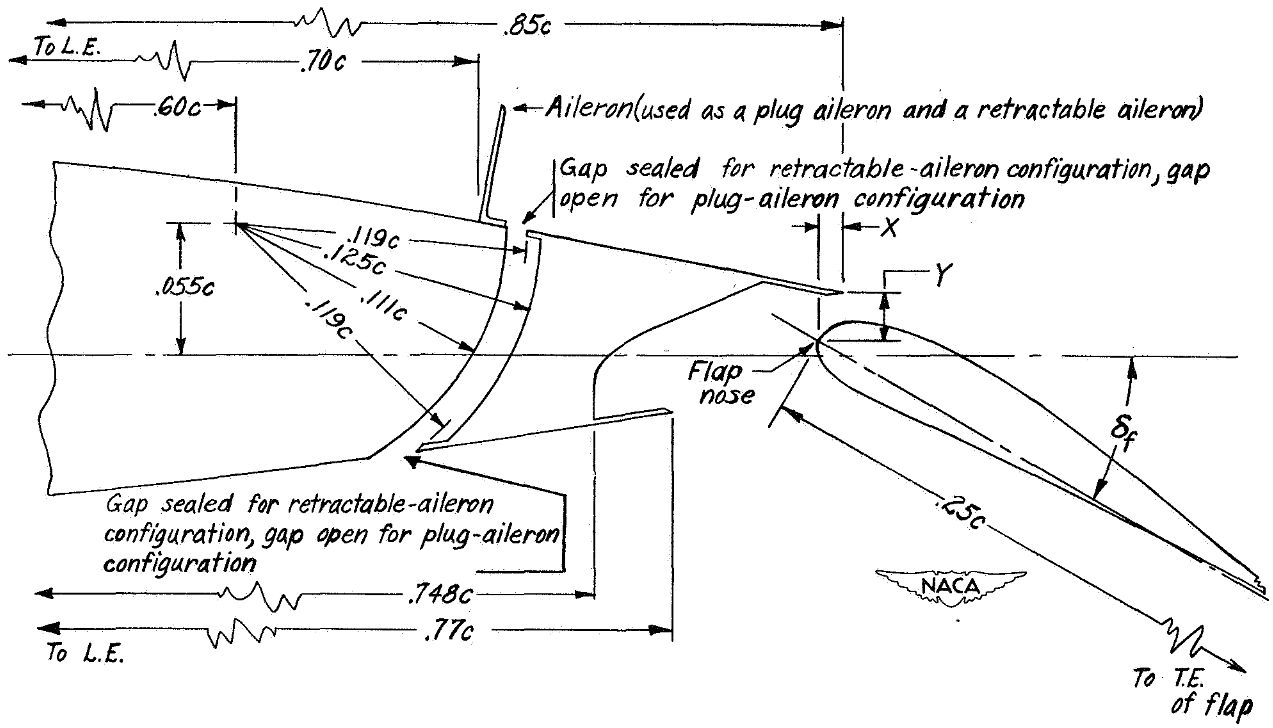


Figure 1.- Plan form of right-semispan-wing model equipped with spoiler-type ailerons and a full-span slotted flap.



(a) Aileron configuration on the plain wing.



(b) Aileron configuration with flap deflected.

Figure 2.– Schematic drawing of plug–aileron and retractable–aileron configurations tested on semispan wing.

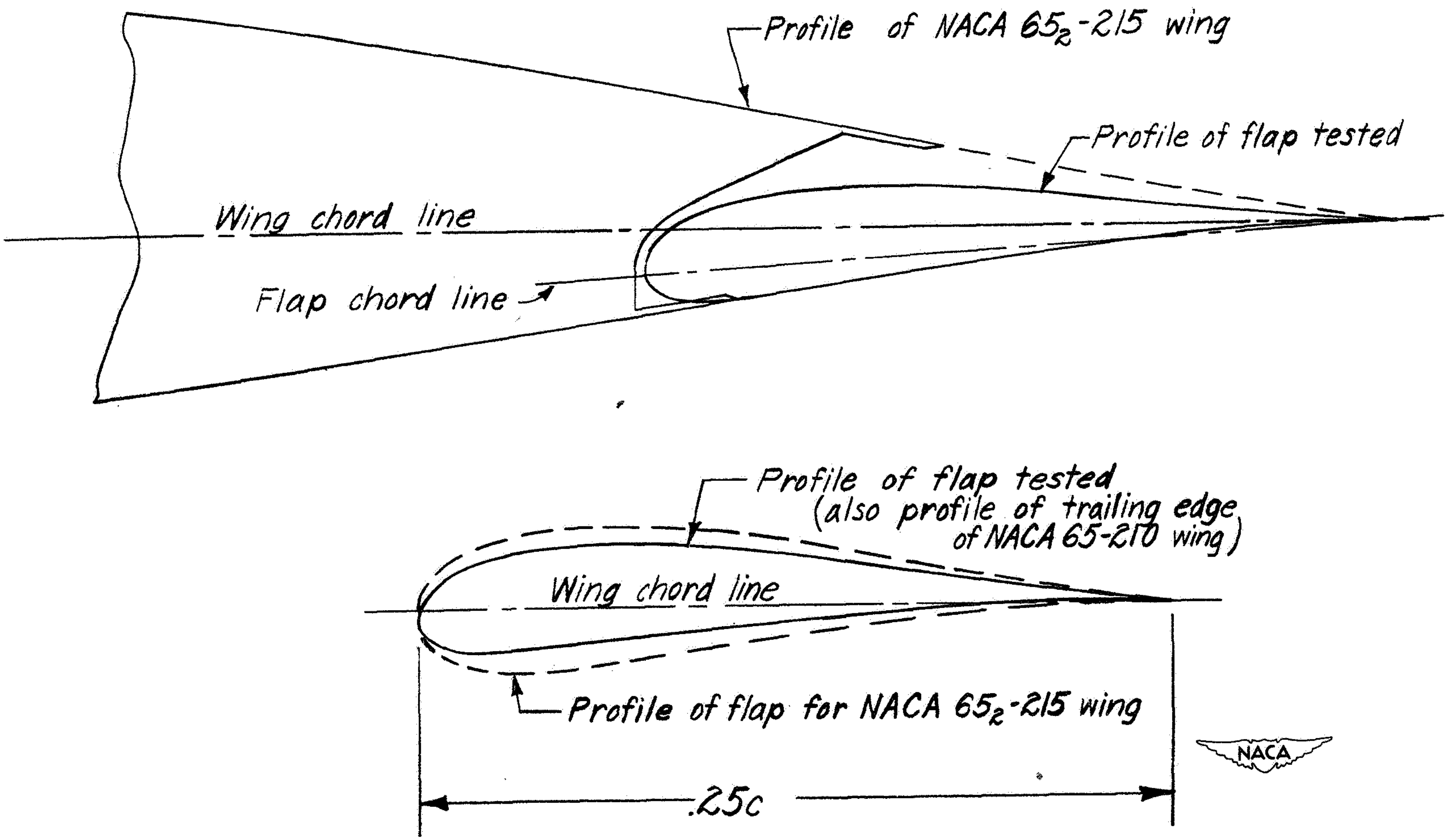


Figure 3.– Comparison of profiles of NACA 65_2-215 wing and a flap for this wing with profile of flap used in present investigation.

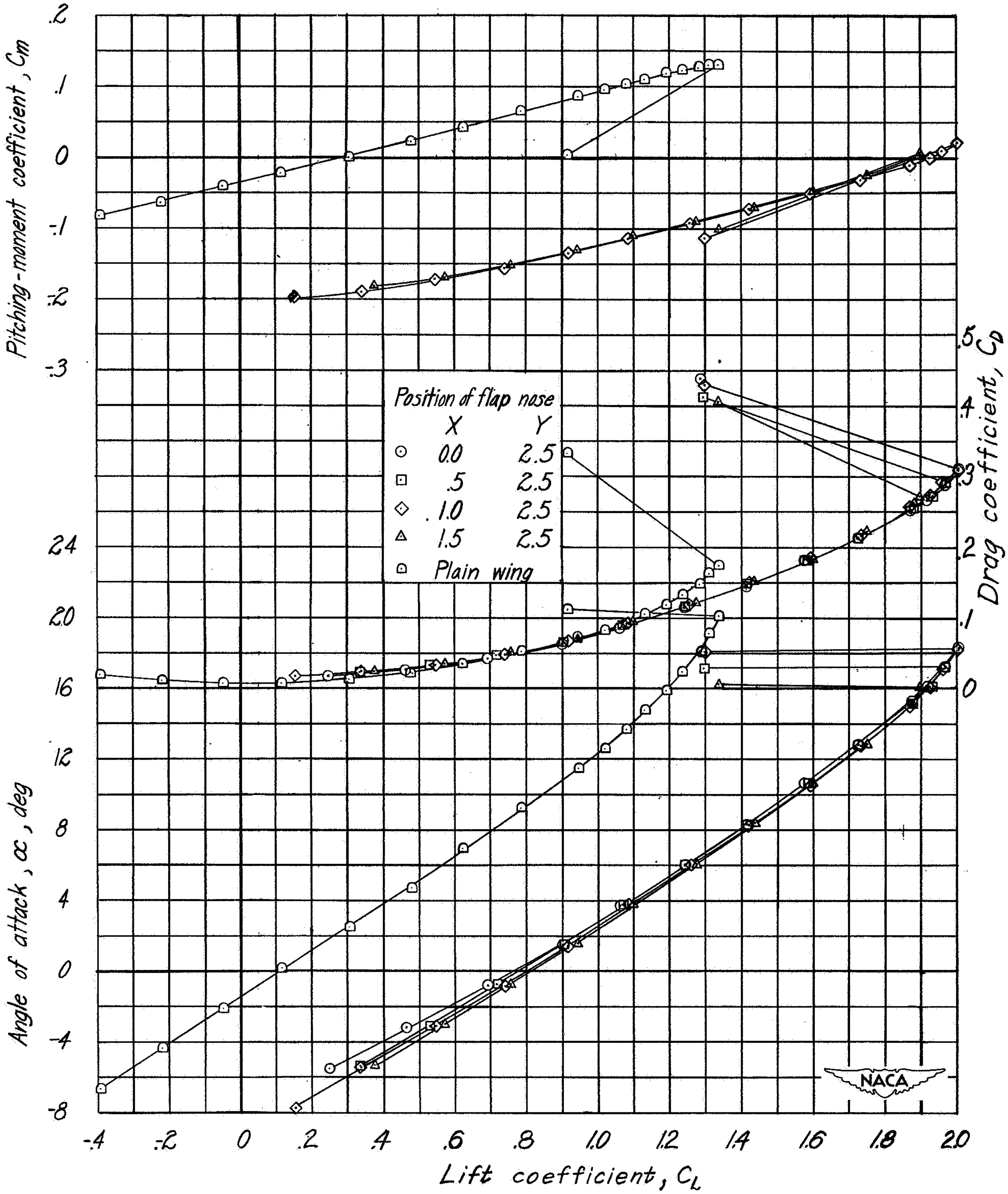


Figure 4.– Aerodynamic characteristics of wing for various positions of flap nose. $\delta_f = 15^{\circ}$.

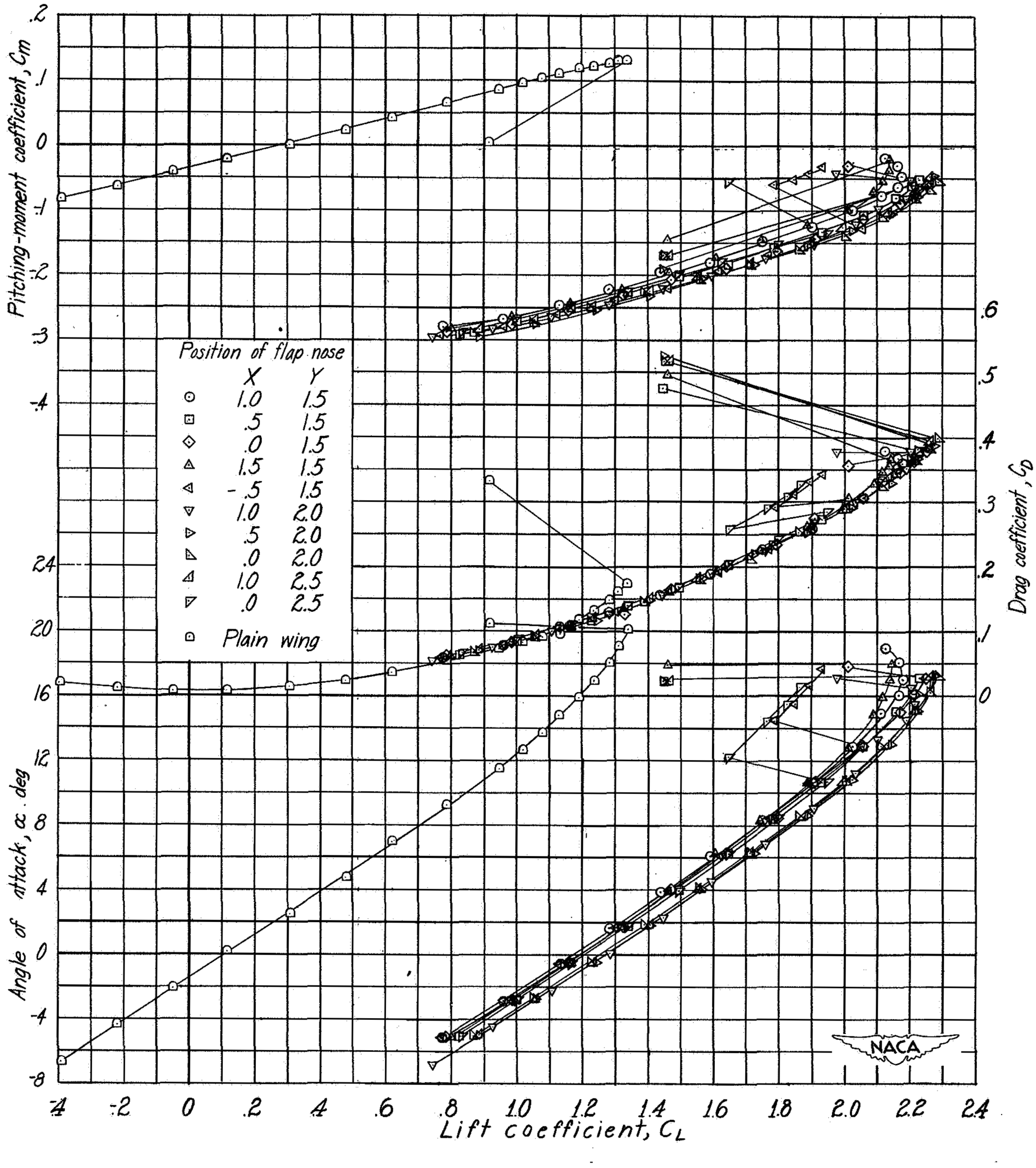


Figure 5.— Aerodynamic characteristics of wing for various positions of flap nose. $\delta_f = 30^{\circ}$.

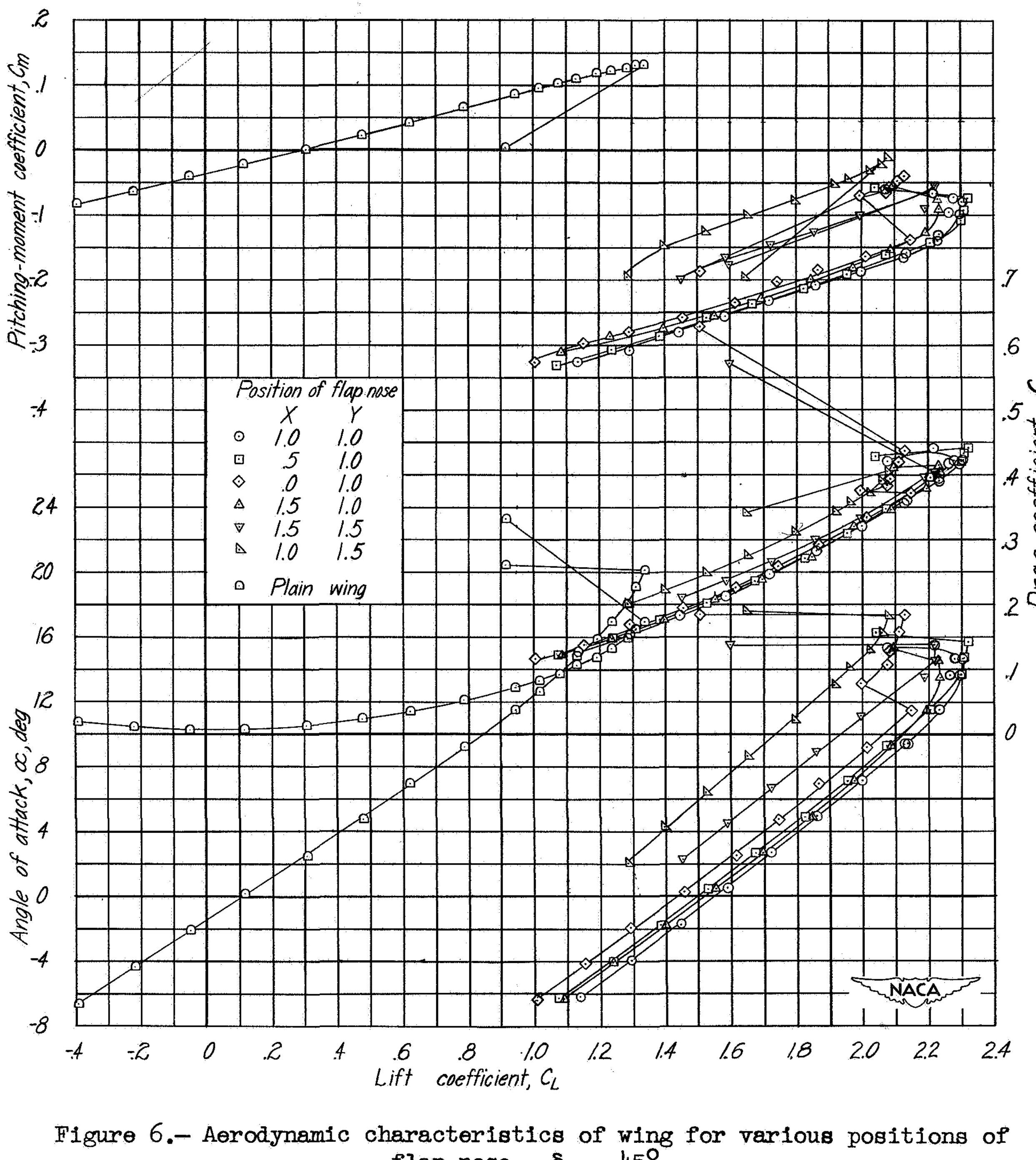


Figure 6.– Aerodynamic characteristics of wing for various positions of flap nose. $\delta_f = 45^{\circ}$.

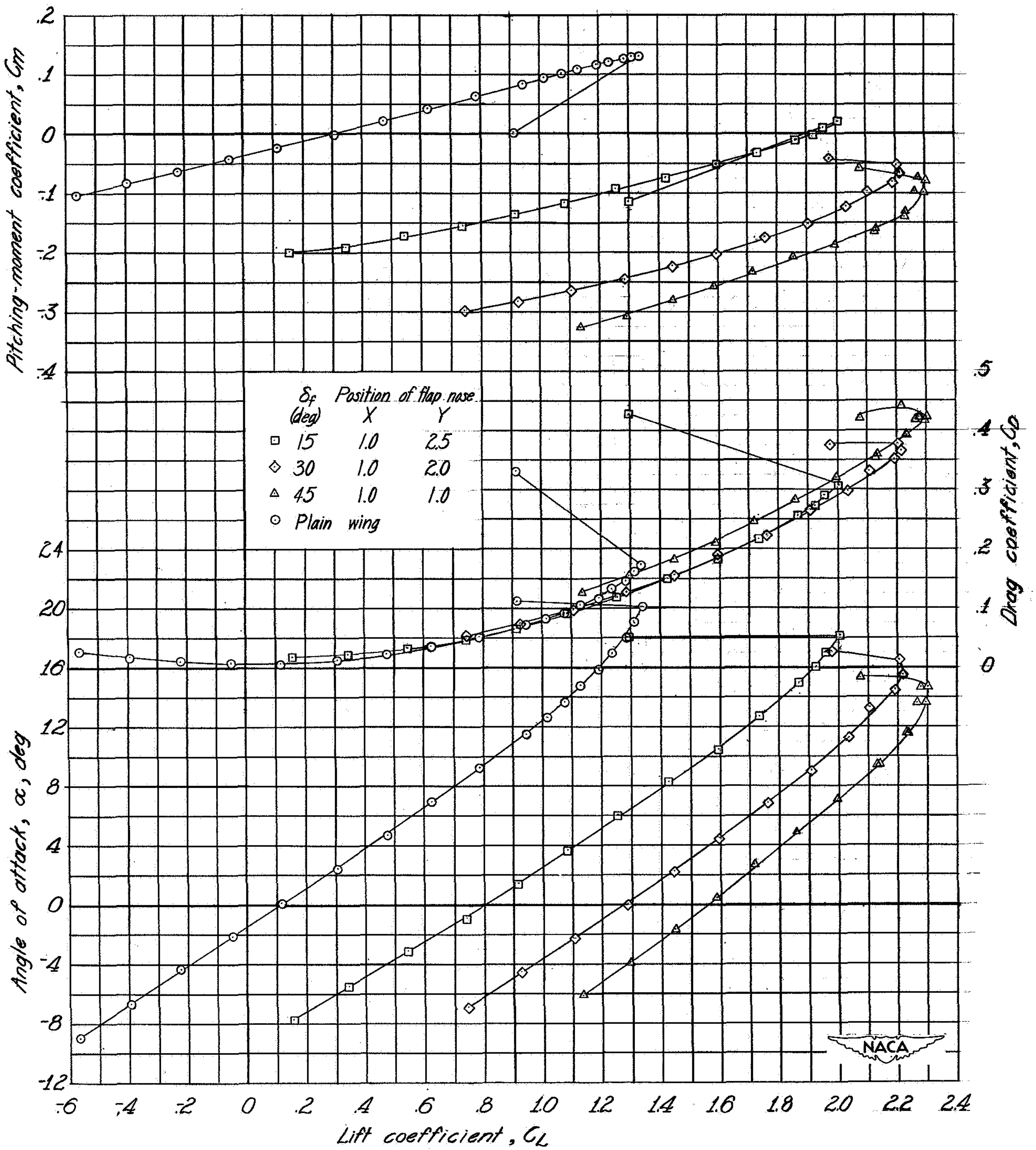


Figure 7.– Aerodynamic characteristics of the wing for selected optimum-lift flap positions and for plain wing.

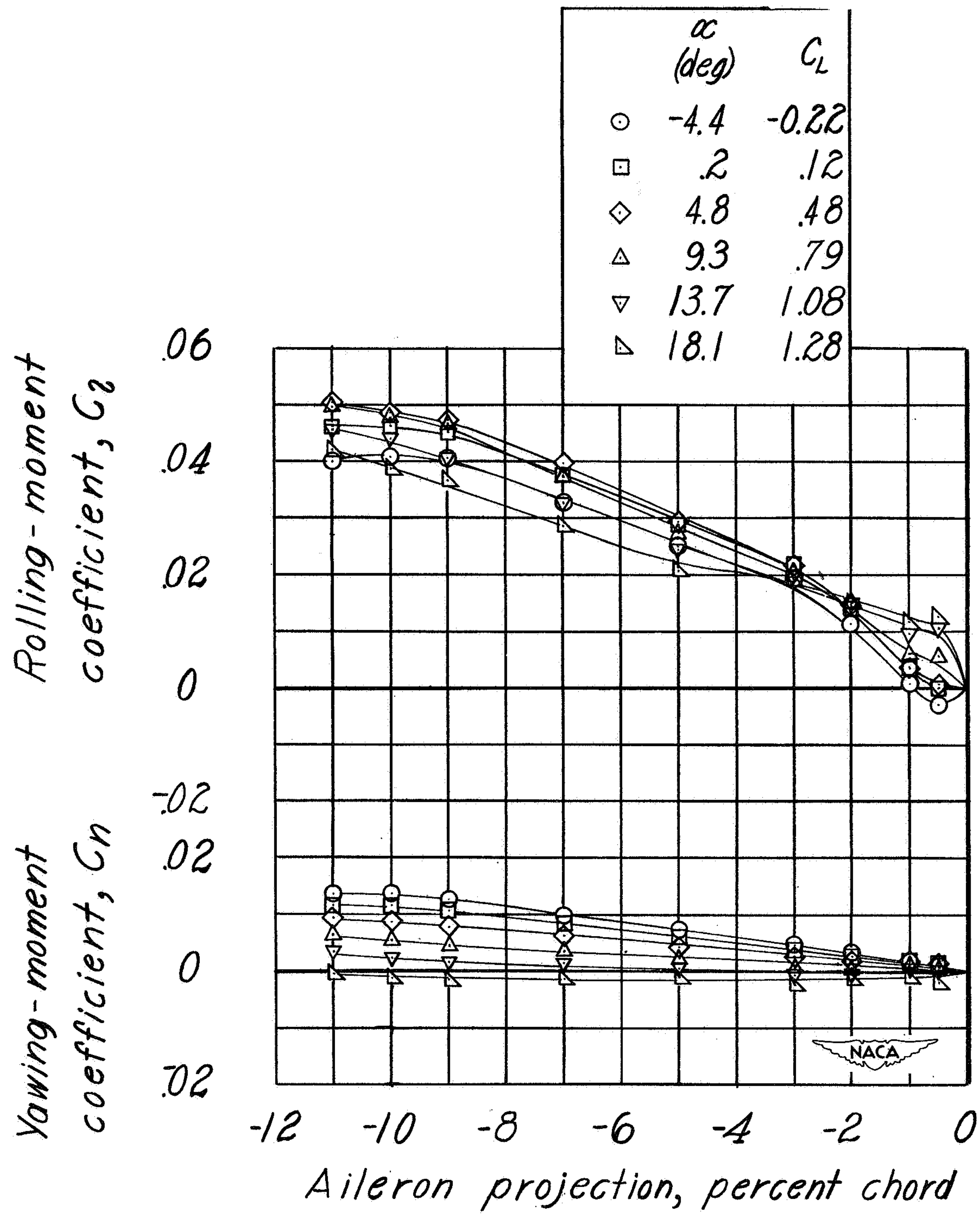


Figure 8.– Variation of lateral control characteristics of complete wing with projection of plug aileron. Plain-wing aileron configuration.

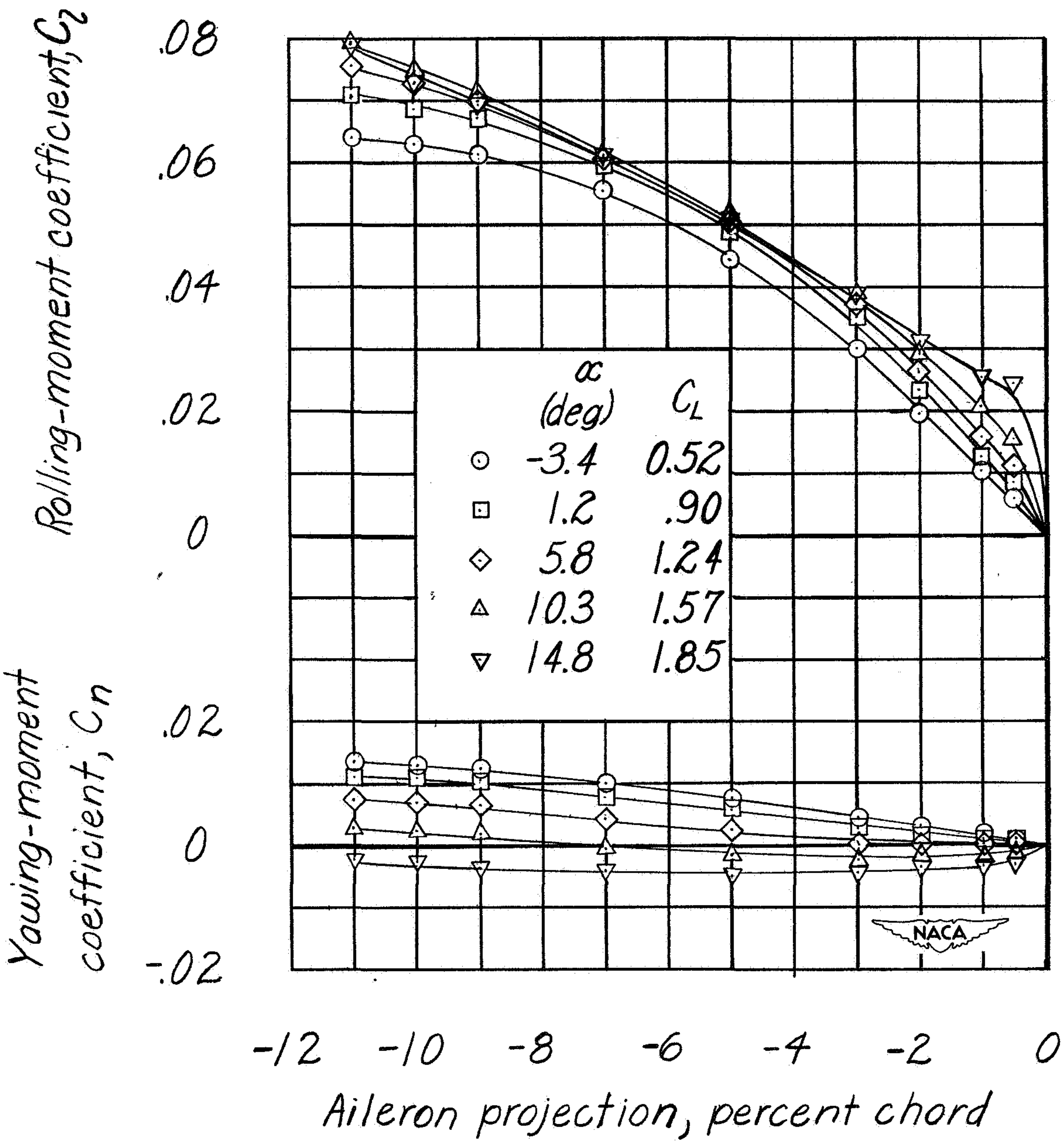


Figure 9.– Variation of lateral control characteristics of complete wing with projection of plug aileron. $\delta_f = 15^o$; X = 1.0; Y = 2.5.

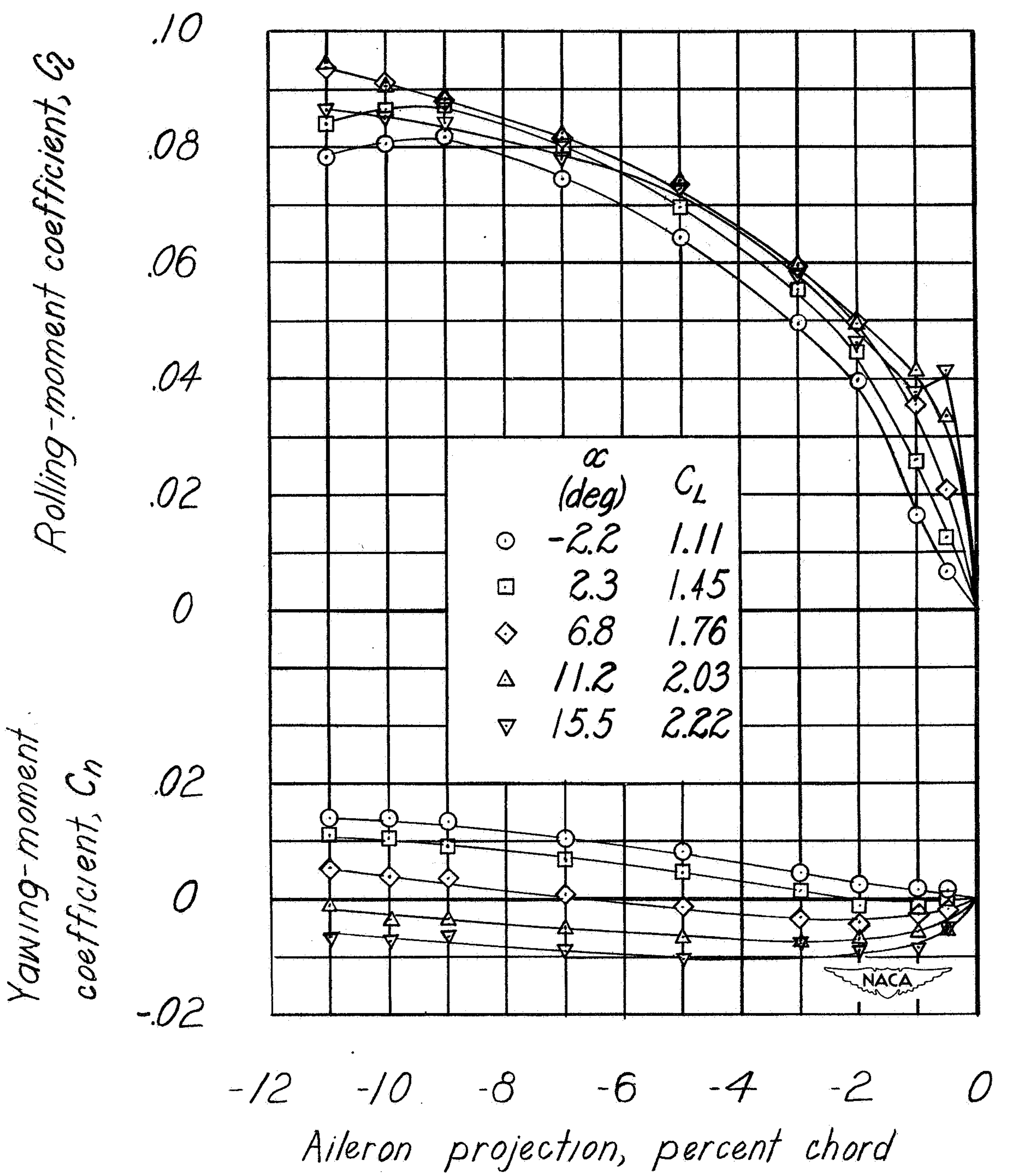


Figure 10.– Variation of lateral control characteristics of complete wing with projection of plug aileron. $\delta_f = 30^o$; X = 1.0; Y = 2.0.

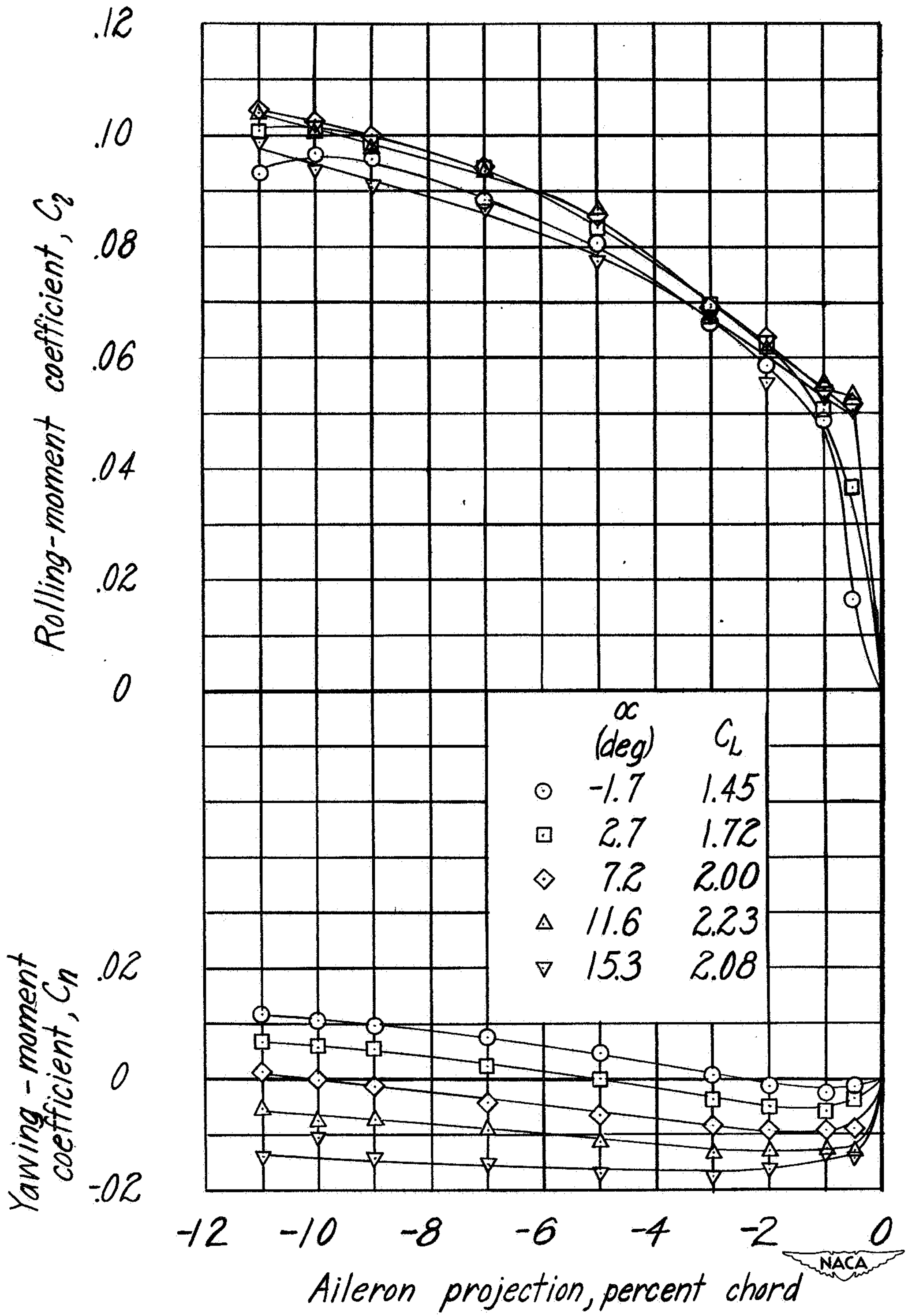


Figure 11.- Variation of lateral-control characteristics of complete wing with projection of plug aileron. $\delta_f = 45^{\circ}$; X = 1.0; Y = 1.0.

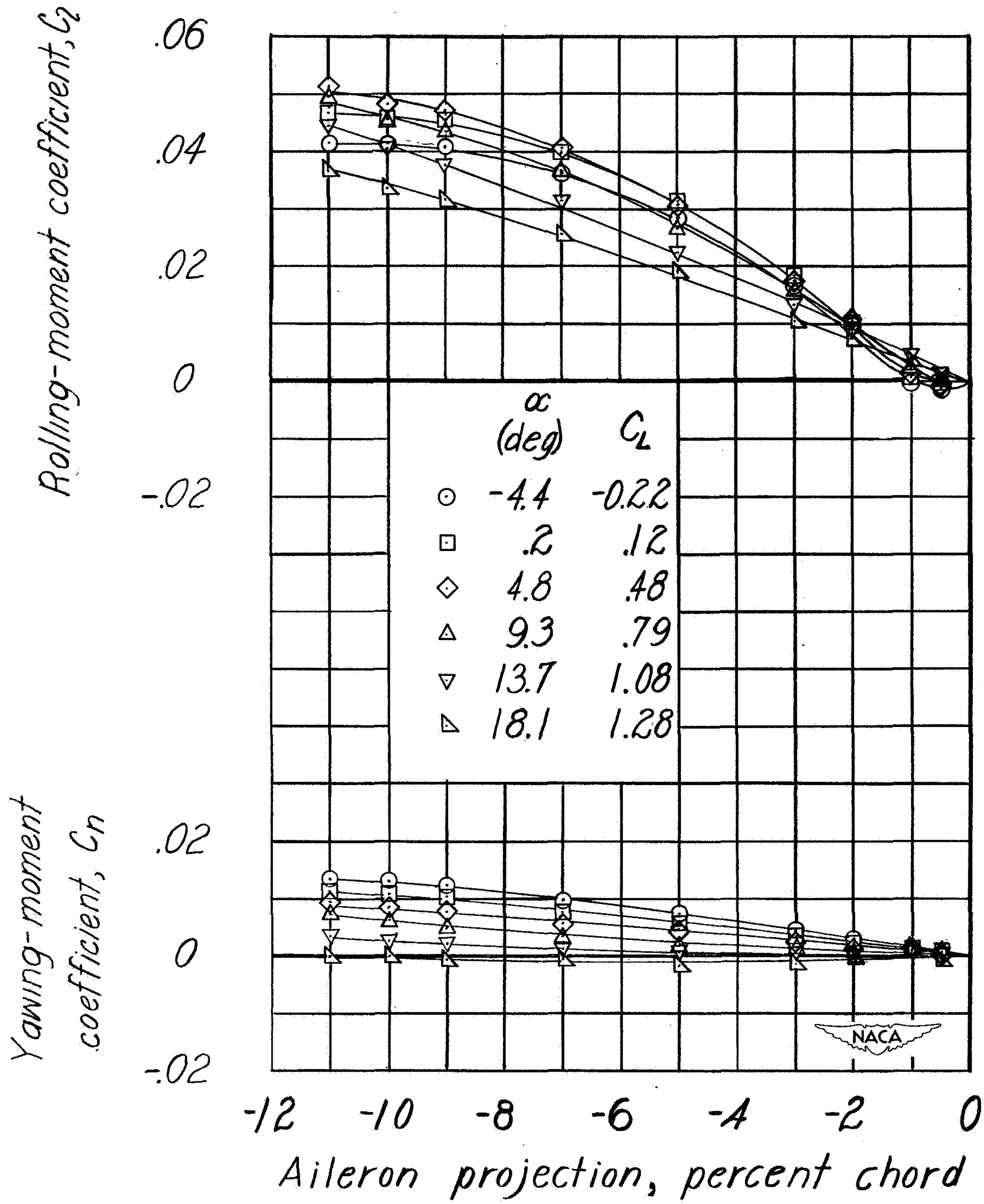


Figure 12.– Variation of lateral control characteristics of complete wing with projection of retractable aileron. Plain-wing aileron configuration.

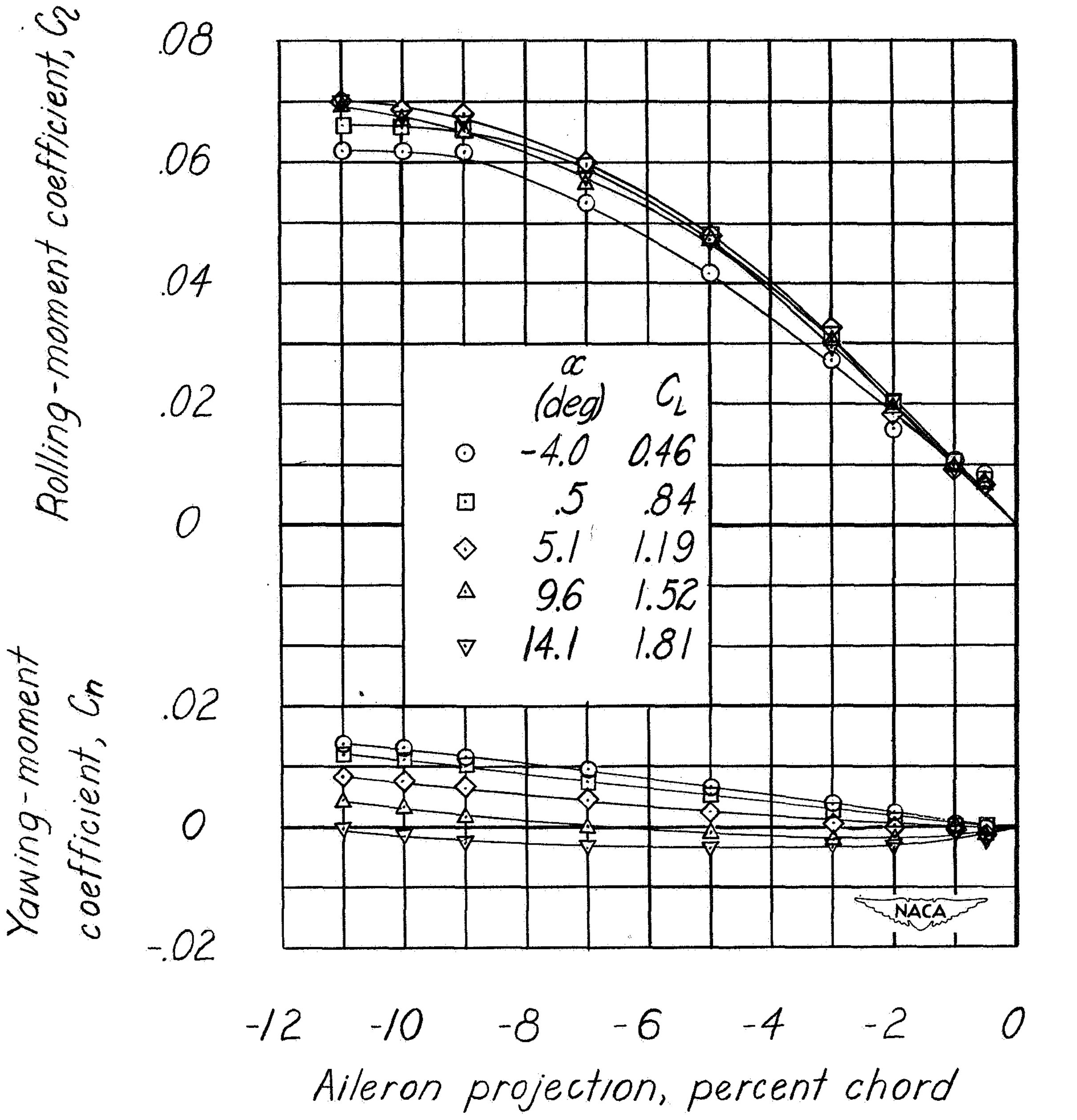


Figure 13.– Variation of lateral control characteristics of complete wing with projection of retractable aileron. $\delta_f = 15^\circ$; X = 1.0; Y = 2.5.

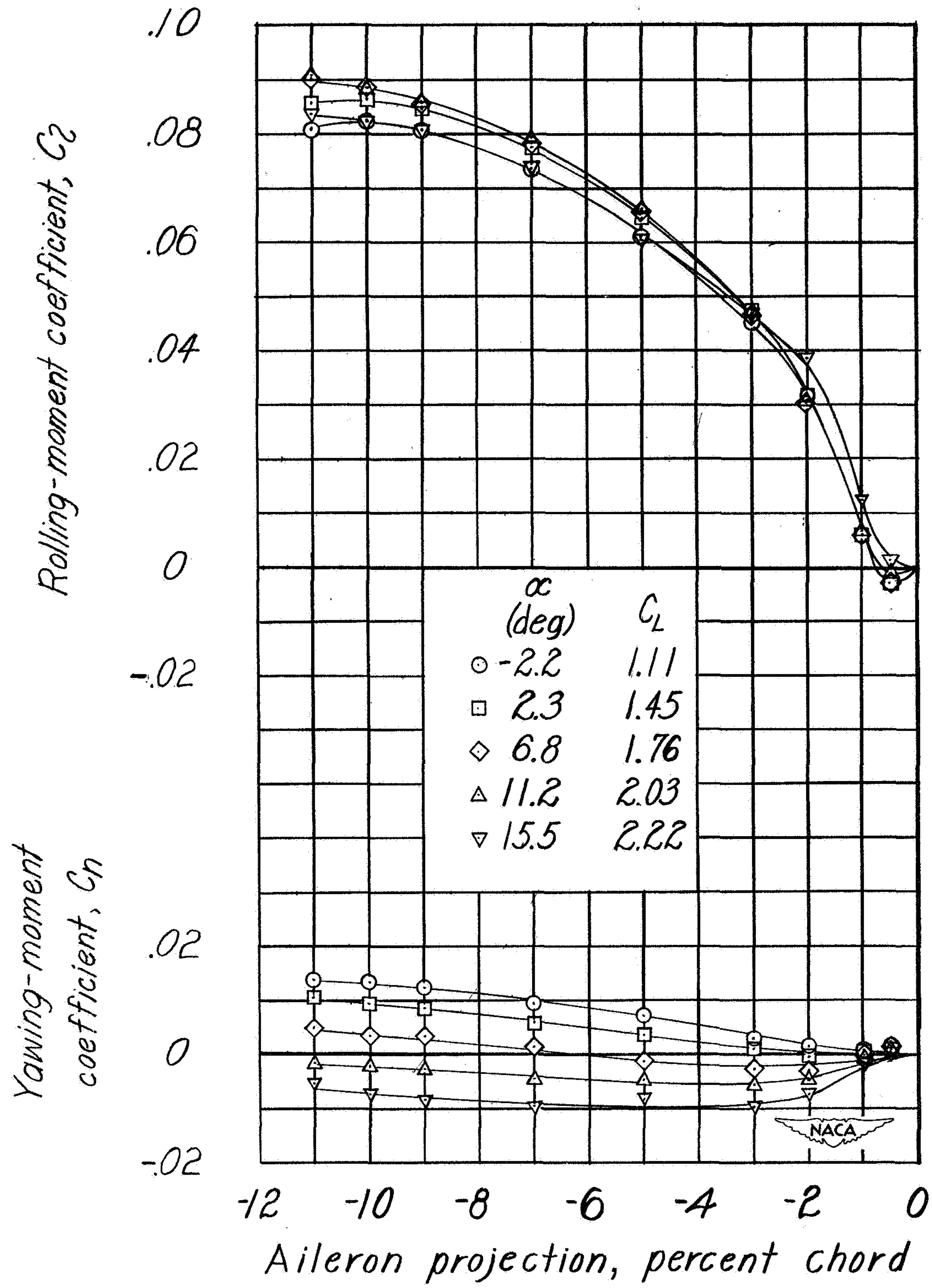


Figure 14.- Variation of lateral control characteristics of complete wing with projection of retractable aileron. $\delta_f = 30^{\circ}$; X = 1.0; Y = 2.0.

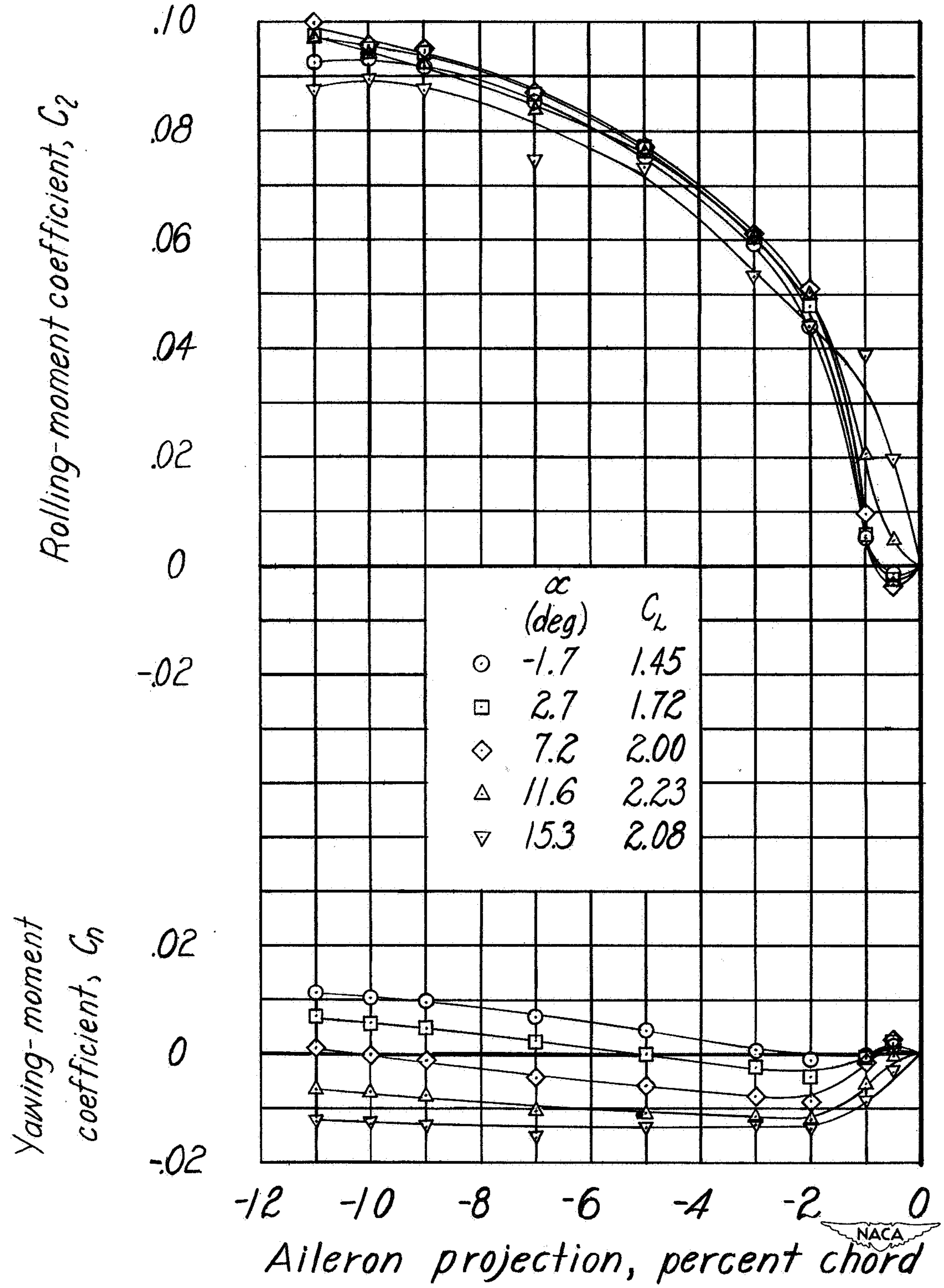


Figure 15.– Variation of lateral control characteristics of complete wing with projection of retractable aileron. $\delta_f = 45^{\circ}$; X = 1.0; Y = 1.0.

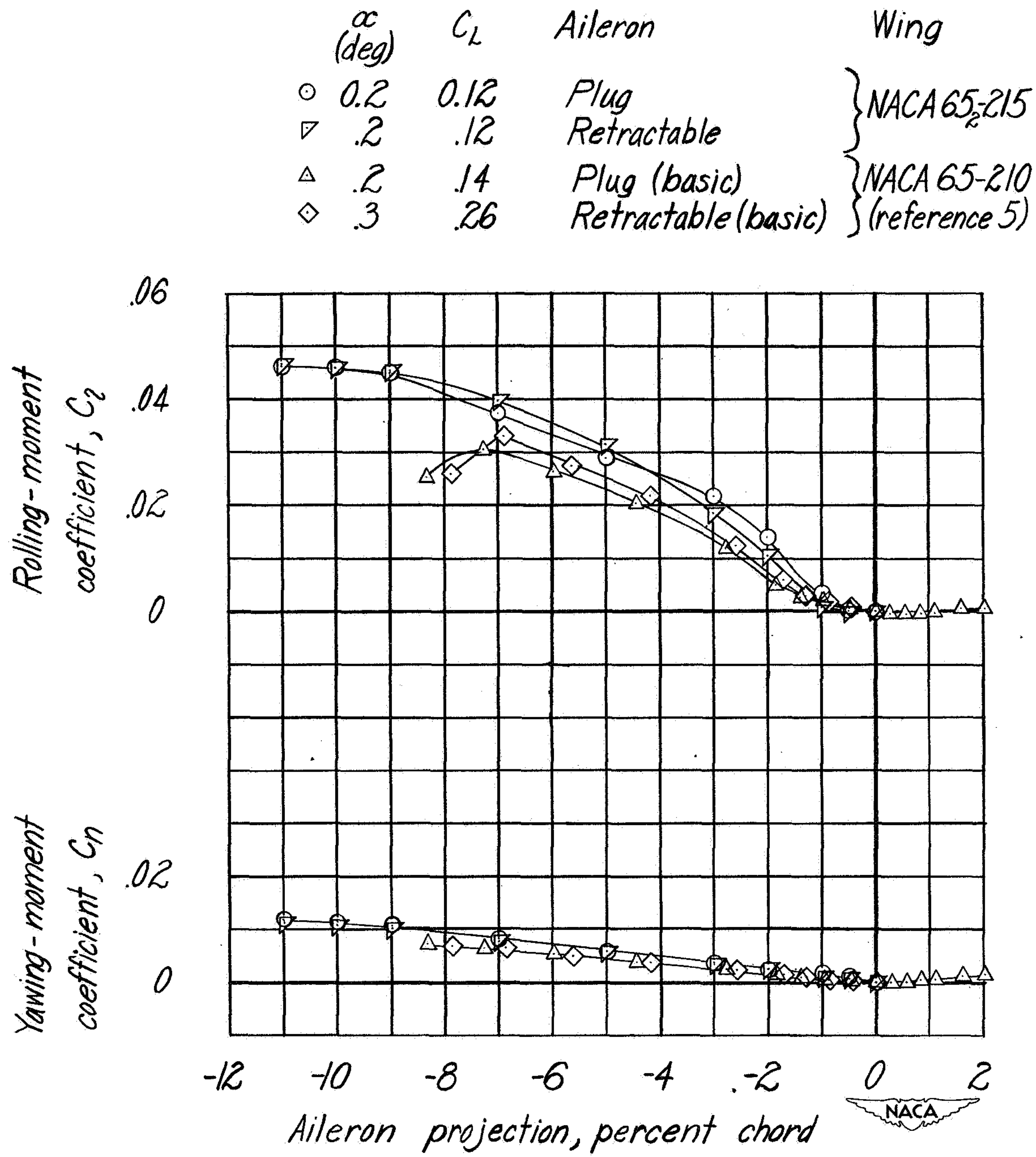


Figure 16.– Comparison of lateral control characteristics of plug and retractable ailerons on present wing (NACA 65_2-215) and on wing of reference 5 (NACA 65-210). Full-span flap retracted.

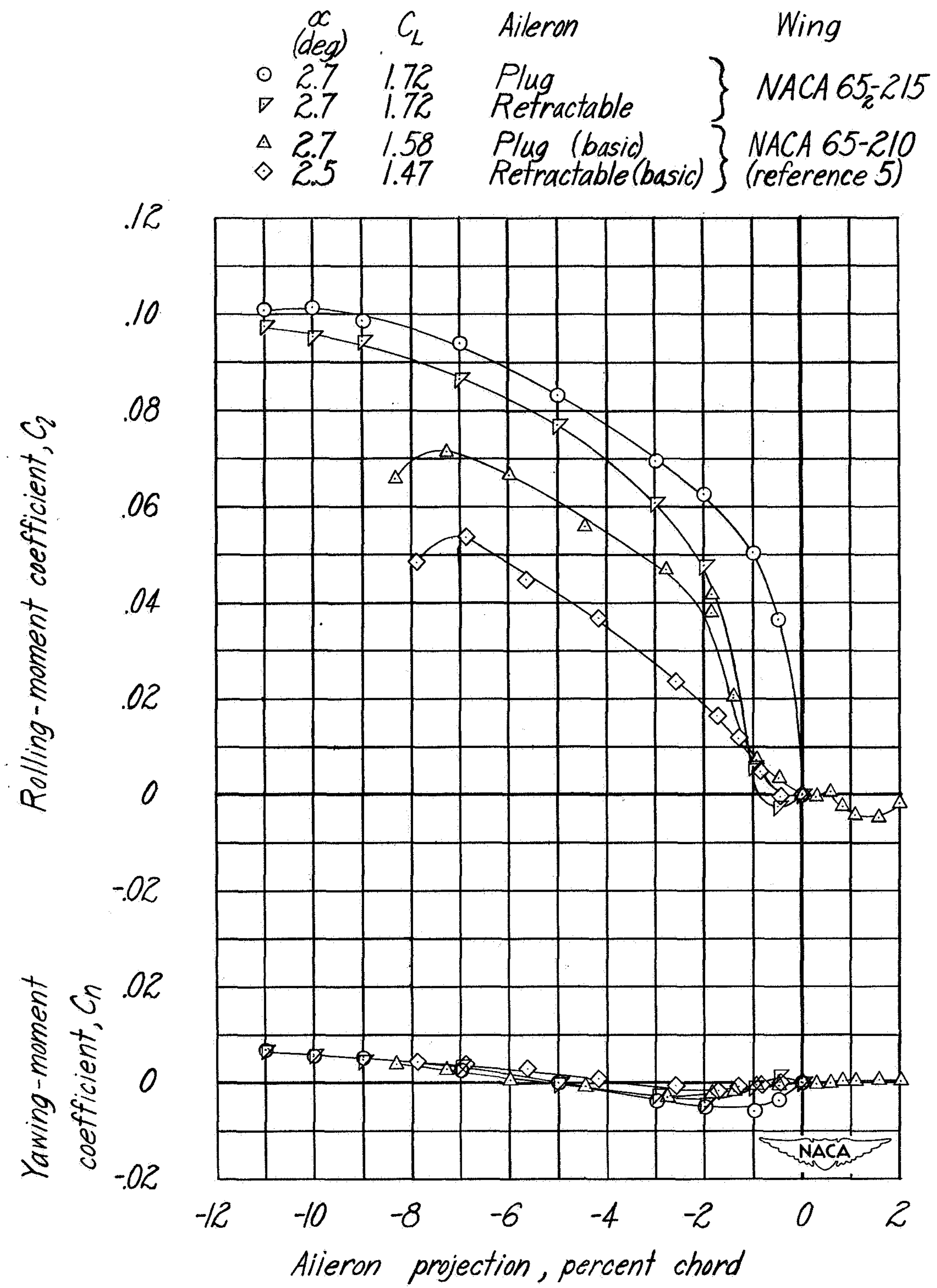


Figure 17.- Comparison of lateral control characteristics of plug and retractable ailerons on present wing (NACA 65_2-215) and on wing of reference 5 (NACA 65-210). Full-span flap deflected 45°.