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RESEARCH MEMORANDUM

EFFECTS OF A FUSELAGE ON THE AERODYNAMIC CHARACTERISTICS OF
A 42° SWEEPBACK WING AT REYNOLDS NUMBERS TO 8,000,000

By

Reino J. Salmi, D. William Conner,
and Robert R. Graham

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Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

EFFECTS OF A FUSELAGE ON THE AERODYNAMIC CHARACTERISTICS OF
A 42° SWEEPBACK WING AT REYNOLDS NUMBERS TO 8,000,000

By Reino J. Salmi, D. William Conner,
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SUMMARY

The effects of a fuselage on the low-speed aerodynamic characteristics of a sweptback wing were investigated in the Langley 19-foot pressure tunnel. Tests were made in pitch at Reynolds numbers of 3,040,000 and 8,090,000 and in yaw at Reynolds numbers of 1,720,000 and 5,300,000. The wing had an aspect ratio of 4, taper ratio of 0.625, 42° sweepback at the leading edge, and NACA 64₁-112 airfoil sections normal to the 0.273 chord line. A representative fuselage of circular cross section was tested with the wing mounted in the high-wing, low-wing, and midwing positions. Tests were made without flaps and with 18.4-percent-chord split flaps extending from 12.3 to 50 percent of the semispan.

The presence of the fuselage had negligible effect on the values of maximum lift coefficient and the slope of the lift curve. The fuselage caused a destabilizing shift in the rate of change of pitching moment with lift. This effect remained fairly constant regardless of the vertical position of the wing on the fuselage except in the high lift range for the flaps-off condition at a Reynolds number of 8,090,000, at which the effects caused by the high-wing and midwing fuselage combinations increased rapidly with lift.

The fuselage effects on the drag characteristics were small, and the vertical position of the wing had little effect except with the flaps on. The fuselage added increments to the effective dihedral and directional stability parameters $C_{l_{\psi}}$ and $C_{n_{\psi}}$ which were of the same magnitude as those observed for wings having little or no sweep. When the Reynolds number was reduced from 5,300,000 to 1,720,000, these increments in $C_{l_{\psi}}$ had unsystematic variations at moderate and high lifts.

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INTRODUCTION

The use of sweptback wings as a means of reducing compressibility effects in flight at high subsonic and supersonic speeds, has presented problems in obtaining adequate stability and control at low speeds and high lifts for any such aircraft. Simple theory and wind-tunnel tests have shown that wings with high angles of sweepback may become longitudinally unstable at the stall and may also have undesirably large positive dihedral effects in the high lift range.

Considerable data is available on the effects of interference due to design components such as fuselages and nacelles, on the longitudinal and lateral stability characteristics of unswept wings, but little data is available on the effects of any such additional bodies on the aerodynamic characteristics of wings with high angles of sweepback. Accordingly, tests were conducted to determine the aerodynamic characteristics of a 42° sweptback wing mounted on a fuselage at high-wing, low-wing, and midwing positions. The tests were made with and without split flaps at Reynolds numbers of 3,040,000 and 8,090,000 for tests in pitch and of 1,720,000 and 5,300,000 for tests in yaw. These data are presented together with corresponding wing alone data from reference 1.

COEFFICIENTS AND SYMBOLS

The data are referred to a system of axes shown in figure 1. Moments are referred to the quarter-chord point of the mean aerodynamic chord and all coefficients are based on the area of the basic wing.

- C_L lift coefficient ($Lift/qS$)
- C_D drag coefficient (D/qS)
- C_X longitudinal-force coefficient (X/qS)
- C_Y lateral-force coefficient (Y/qS)
- C_l rolling-moment coefficient (L/qSb)
- C_m pitching-moment coefficient (M/qSc)
- C_n yawing-moment coefficient (N/qSb)

- R Reynolds number $(\rho V \bar{c} / \mu)$
- M_0 free-stream Mach number (V/a)
- α angle of attack measured in plane of symmetry, degrees
- ψ angle of yaw, positive when right wing is back, degrees
- C_{l_ψ} rate of change of rolling-moment coefficient with angle of yaw, per degree $(\partial C_l / \partial \psi)$
- C_{n_ψ} rate of change of yawing-moment coefficient with angle of yaw, per degree $(\partial C_n / \partial \psi)$
- C_{Y_ψ} rate of change of lateral-force coefficient with angle of yaw, per degree $(\partial C_Y / \partial \psi)$
- ΔC_{l_ψ} increment in C_{l_ψ}
- dC_m / dC_L rate of change of pitching-moment coefficient with lift coefficient

Lift = -Z

- D drag = -X at zero yaw
- X longitudinal force
- Y lateral force
- Z vertical force
- M pitching moment
- L rolling moment
- N yawing moment
- S wing area
- b wing span
- \bar{c} mean aerodynamic chord measured parallel to plane of

symmetry $\left(\frac{2}{S} \int_0^{b/2} c^2 dy \right)$

- c local chord, parallel to plane of symmetry
- y spanwise coordinate
- q free-stream dynamic pressure $\left(\frac{1}{2}\rho V^2\right)$
- V free-stream velocity
- ρ mass density of air
- μ coefficient of viscosity
- a velocity of sound

APPARATUS AND TESTS

Model

The wing and fuselage (fig. 2) were constructed of laminated mahogany, lacquered and sanded to an aerodynamically smooth finish. The wing has a sweepback angle of 42.05° along the leading edge and has NACA 64₁-112 sections normal to the 0.273 chord line. The 0.273 chord line of the swept wing, is the quarter-chord line of a straight wing panel which has been rotated 40° about the quarter-chord point of the root chord. The aspect ratio is 4, taper ratio, 0.625, and the tips are rounded in plan form and cross section beginning at 97.5 percent of the semispan. There is no geometric dihedral or twist.

The fuselage is circular in cross section and tapers to a point at each end. The maximum diameter, which is constant at the wing intersection, is equal to 40 percent of the wing chord (measured at the plane of symmetry), and the fineness ratio is 10.2. The center portion of the fuselage has removable blocks to permit the mounting of the wing at high-wing, low-wing, and midwing positions with 2° incidence between the wing chord plane and the fuselage center line. No fillets were used at the wing-fuselage juncture for any wing position.

The split flaps were fabricated of sheet steel and extended from 12.3 to 50 percent of the wing semispan. The center gap was maintained to facilitate flap deflection. The flap chord is 18.4 percent of the local wing chord. The flap deflection measured from the lower surface of the wing and in a plane normal to the hinge line is 60° .

Tests

The model was tested in the Langley 19-foot pressure tunnel and was mounted on a two-support system for the pitch tests (figs. 3(a) and 3(b)) and on a single support for the yaw tests (fig. 3(c)). In the low-wing fuselage combination the top of the yaw support was shielded by the same fairing used for the wing alone tests (reported in reference 1). The pitch tests were made at Reynolds number values of 3,040,000 ($M_0 = 0.069$) and 8,090,000 ($M_0 = 0.190$). The tests were made with and without split flaps. Stall characteristics were studied by means of wool tufts attached to the upper surface of the wing beginning at 20 percent of the wing chord. The lateral-stability parameters were obtained from tests through an angle-of-attack range of yaw angles of 0° and 15° , at Reynolds number values of 1,720,000 ($M_0 = 0.10$) and 5,300,000 ($M_0 = 0.12$). Tests through a yaw range of -10° to 25° angle of yaw were made with flaps off at 15° angle of attack and with flaps on at 14.2° angle of attack at a Reynolds number of 5,300,000.

CORRECTIONS TO DATA

The same corrections, applied to the fuselage-off data of reference 1 and discussed therein, have been applied to the fuselage-on data. These corrections account for model support and interference effects, and for model blocking and jet-boundary effects. No jet-boundary corrections were applied to the rolling-moment, yawing-moment, and lateral-force coefficients.

RESULTS AND DISCUSSION

Aerodynamic Characteristics in Pitch

The lift, drag, and pitching-moment characteristics of the wing mounted on a fuselage at the high-wing, low-wing, and midwing positions and of the wing alone, with and without flaps, are presented in figures 4 to 7. The variation of dC_m/dC_L with lift coefficient is shown in figure 8.

Lift and stalling characteristics.- Figures 4(a) and 5(a) show that at a Reynolds number of 8,090,000 the presence of the fuselage had very little effect on the maximum lift coefficient and the slope of the lift curve. The Reynolds number of the data for the wing

alone with flaps on is 6,080,000, but the tests of reference 1 show that in the range of Reynolds numbers from 6,080,000 to 8,090,000 there is negligible scale effect on the aerodynamic characteristics of the wing. Figure 6(a) shows that at a Reynolds number of 3,040,000 the fuselage effects were also negligible. No data were obtained at the lower Reynolds number for the wing alone with flaps on. Visual observations of wool tufts attached to the upper surface of the wing showed that the presence of the fuselage had no effects on the stalling characteristics of the wing except for a small rough area at the wing-fuselage juncture of the low-wing combination. The fuselage effects may differ considerably when the air flow over the wing is changed by devices such as leading-edge flaps.

Pitching-moment characteristics.- Figures 4(a) and 5(a) show that at a Reynolds number of 8,090,000 and at a C_L of 0.1 the presence of the fuselage displaced the pitching-moment curves of the wing by increments in C_m varying from -0.006 to -0.013 with flaps off and -0.021 to -0.027 with flaps on for the high-wing to low-wing fuselage combination, respectively. Figure 8 shows that the fuselage produced a positive change in dC_m/dC_L of about 0.02 with flaps off and 0.03 with flaps on at a Reynolds number of 8,090,000 except in the range of lift coefficients above 0.3 for the flaps off condition, where the midwing and high-wing fuselage combinations caused rapidly increasing values of dC_m/dC_L with C_L . The pitching-moment curves of figures 6 and 7 show that the increments in dC_m/dC_L at a Reynolds number of 3,040,000 were of approximately the same magnitude as those in the low lift range at the higher Reynolds number.

Drag characteristics.- The results indicate that the effects of fuselage position on the drag characteristics are small for the wing without flaps but are appreciable when the split flaps are on. The drag of the plain wing without flaps was increased about 0.0040 throughout the lift range for all wing-fuselage combinations. With flaps on the increment in drag due to the fuselage in the low-wing combination was about the same as with flaps off, but in the midwing combination it was zero and in the high-wing combination it was negative. There was no appreciable scale effect on the increments in drag.

Aerodynamic Characteristics in Yaw

The lateral-stability parameters C_{l_ψ} , C_{n_ψ} , and C_{y_ψ} are presented in figures 9 and 10 as functions of lift coefficient for the three wing-fuselage combinations and the wing alone, with and without split flaps. Increments in C_{l_ψ} due to changes in the

vertical location of the fuselage are given in figure 11. The aerodynamic characteristics through a yaw range at a constant angle of attack near maximum lift are presented in figures 12 and 13.

Effective-dihedral parameter.- Figure 11 shows that at a Reynolds number of 5,300,000 and with the flaps off, the presence of the fuselage in the midwing combination caused no change in the effective-dihedral parameter $C_{L\psi}$ at zero lift, but that the high-wing and low-wing positions added increments in $C_{L\psi}$ equal to 0.00065 and -0.00065, respectively. The increments in $C_{L\psi}$ due to the fuselage decreased linearly with increasing lift coefficient up to values of lift coefficient of about 0.7. With the flaps on, the high-wing and low-wing positions produced almost constant increments in $C_{L\psi}$ through the lift range, equal to about 0.00050 and -0.00030, respectively, and the midwing position had no effect.

The increments in $C_{L\psi}$ produced by the various wing positions, tend to become irregular in the high lift range due to the unsteady conditions associated with initial separation over the wing tips. A comparison of this data with corresponding data from reference 2 shows that the increments in $C_{L\psi}$ produced by the fuselage for various vertical locations of the 42° sweptback wing are approximately of the same order as have been measured on wings having little or no sweep.

Reducing the Reynolds number from 5,300,000 to 1,720,000 caused the increments in $C_{L\psi}$ to be shifted in a positive direction at low lifts with flaps off, for the high-wing and low-wing combinations, but did not effect $\Delta C_{L\psi}$ at zero lift for the midwing combination. With flaps on, the high-wing and low-wing positions had values of $\Delta C_{L\psi}$ approximately equal to those at the higher Reynolds number, whereas the midwing position had a more negative value. All combinations showed unsystematic variation of $\Delta C_{L\psi}$ at moderate and high lifts.

Figures 9 and 10 show that the scale effect on $C_{L\psi}$ with the fuselage on is the same as was noted in reference 1, in that reducing the Reynolds number from 5,300,000 to 1,720,000 considerably reduced the linear range of the variation of $C_{L\psi}$ with C_L .

Directional-stability parameters.- The effect of the fuselage on directional-stability parameter $C_{n\psi}$ of the wing alone is

indicated by the almost constant unstable increment through the lift range as shown in figures 9 and 10. Varying the vertical location of the wing had little effect on the magnitude of the increment in $C_{n\dot{\psi}}$, although it may be observed that the midwing position caused the smallest increment in $C_{n\dot{\psi}}$, with and without flaps. There was no Reynolds number effect on the increment in $C_{n\dot{\psi}}$ in the range of lift coefficient up to the beginning of the wing stall.

Characteristics through a yaw range.- The tests at high angles of attack through an extended yaw range (figs. 12 and 13) reveal that the fuselage interference effects at small yaw angles continued with little change to the highest angle of yaw tested. The reversals in C_n at high angles of yaw that appeared in the wing-alone tests of reference 1 were also evident with the fuselage on. The fuselage effected a constant positive increment in $C_{y\dot{\psi}}$ which had a maximum value of 0.0025 for the wing in the midposition.

SUMMARY OF RESULTS

The principal results from an investigation of the effects of a fuselage on a 42° sweptback wing are as follows:

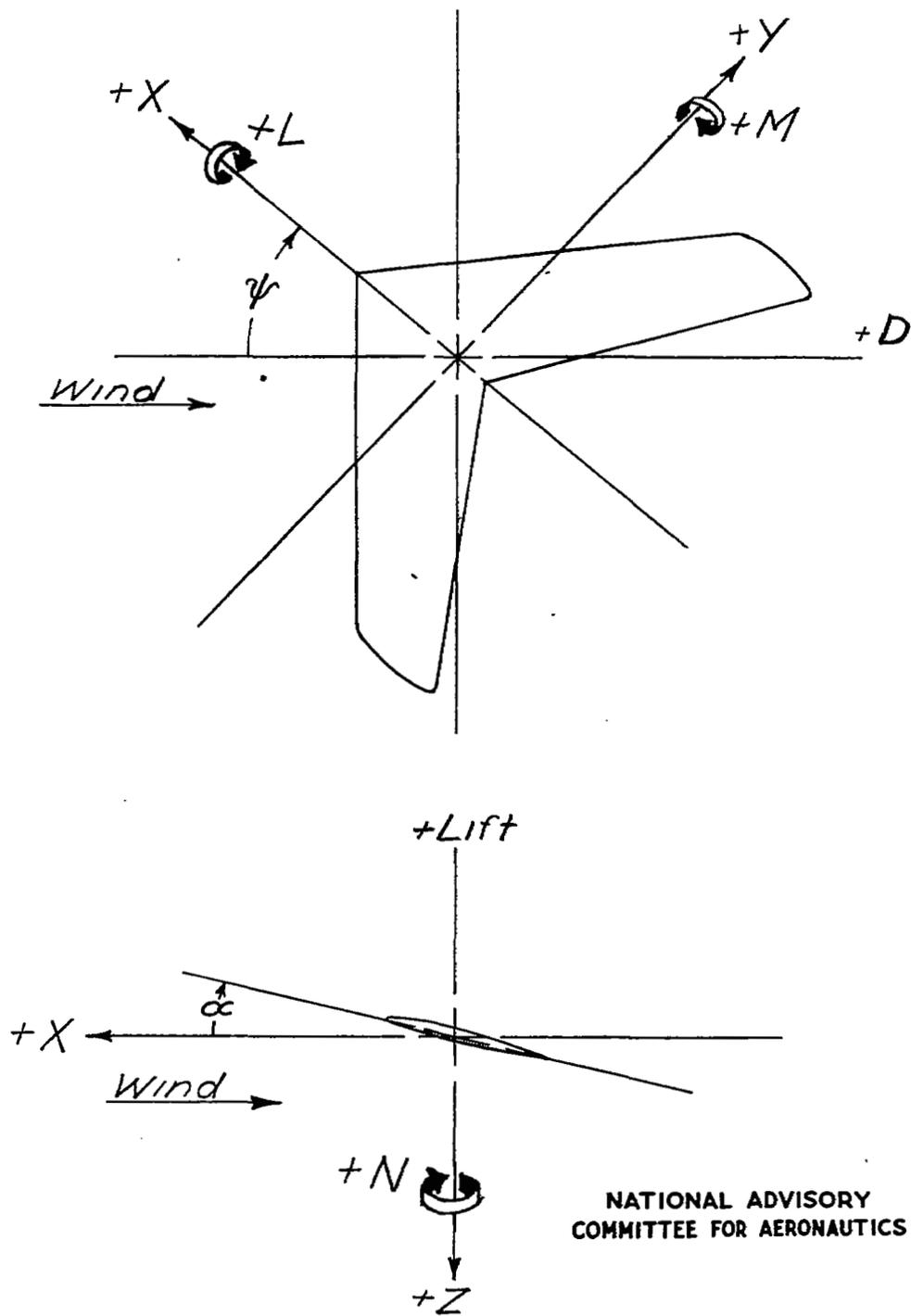
1. The presence of the fuselage had negligible effect on the values of maximum lift coefficient and the slope of the lift curve.
2. The fuselage caused a destabilizing shift in the rate of change of pitching moment with lift. This effect remained fairly constant regardless of the vertical position of the wing on the fuselage except for the flaps-off condition at a Reynolds number of 8,090,000, at which the effects caused by the high-wing and midwing fuselage combinations increased rapidly with lift.
3. The effects of fuselage position on the drag characteristics were small for the wing without flaps but were appreciable when the split flaps were on.
4. The fuselage added increments to the effective-dihedral and directional-stability parameters $C_{l\dot{\psi}}$ and $C_{n\dot{\psi}}$ which were of the same magnitude as observed for wings having little or no sweep.

5. When the Reynolds number was reduced from 5,300,000 to 1,720,000, the increments in $C_{L\beta}$ had unsystematic variations at moderate and high lifts.

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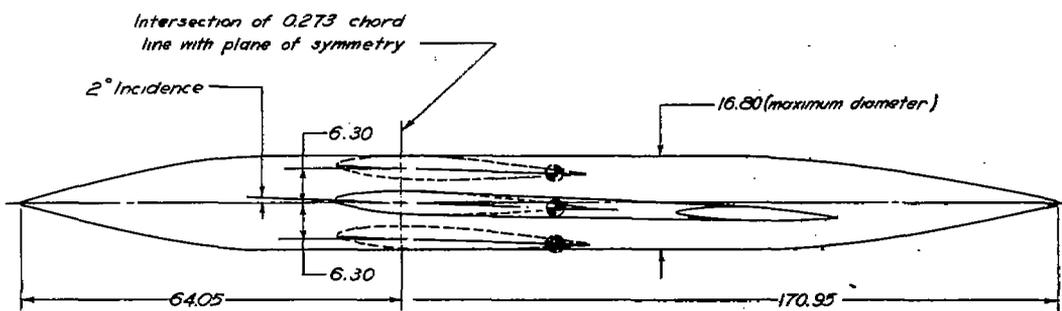
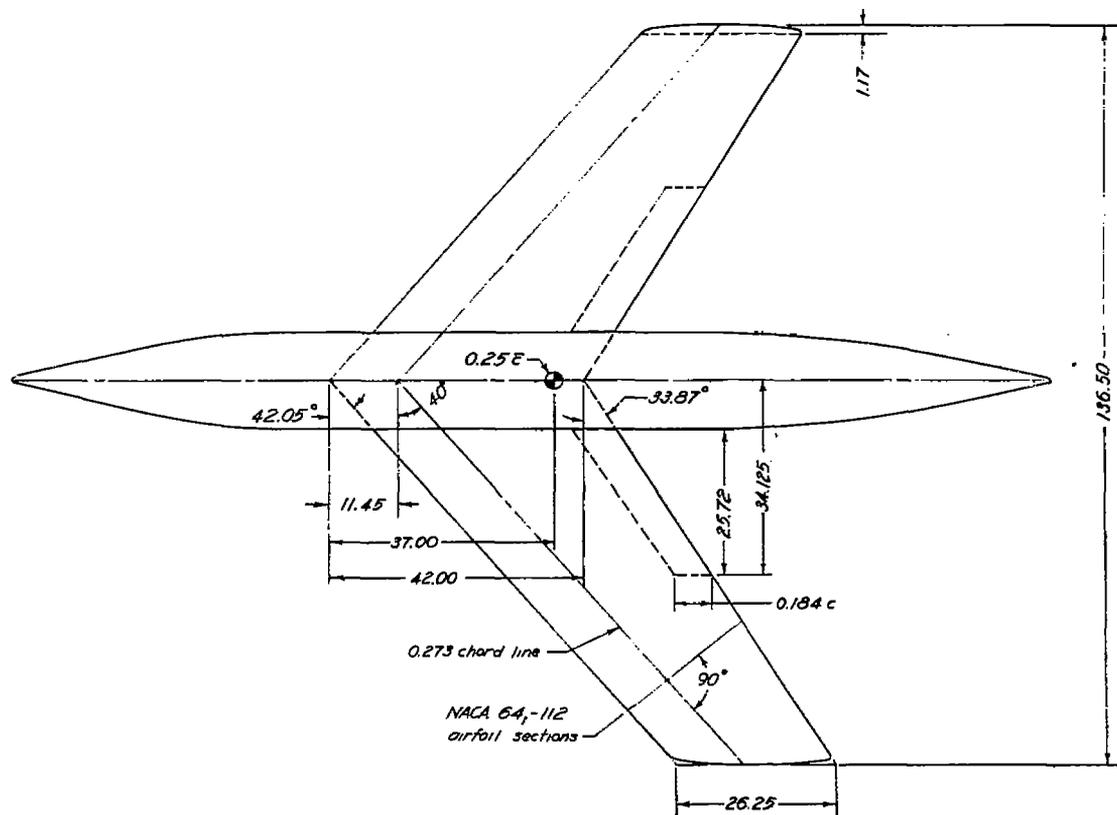
REFERENCES

1. Neely, Robert H. and Conner, D. William: Aerodynamic Characteristics of a 42° Swept-Back Wing with Aspect Ratio 4 and NACA 64₁-112 Sections at Reynolds Numbers from 1,700,000 to 9,500,000. NACA RM No. L7D14, 1947.
2. House, Rufus O., and Wallace, Arthur R.: Wind-Tunnel Investigation of Effect of Interference on Lateral-Stability Characteristics of Four NACA 23012 Wings, an Elliptical and a Circular Fuselage and Vertical Fins. NACA Rep. No. 705, 1941.



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Figure 1.- System of axes used.



FUSELAGE ORDINATES			
Distance behind fuselage nose	Fuselage diameter	Distance behind fuselage nose	Fuselage diameter
0	0.20	112.00	16.80
18.00	9.84	122.00	16.32
22.05	11.80	132.00	14.90
27.39	13.80	142.00	12.52
34.56	15.60	151.20	9.46
42.35	16.60	162.00	4.78
48.00	16.80	170.95	0

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Figure 2.- Geometry of 42° sweptback wing and fuselage. Aspect ratio = 4.01; taper ratio = 0.625; area = 4643 sq in.; \bar{c} = 34.7 in. No dihedral or twist. (All dimensions in inches.)



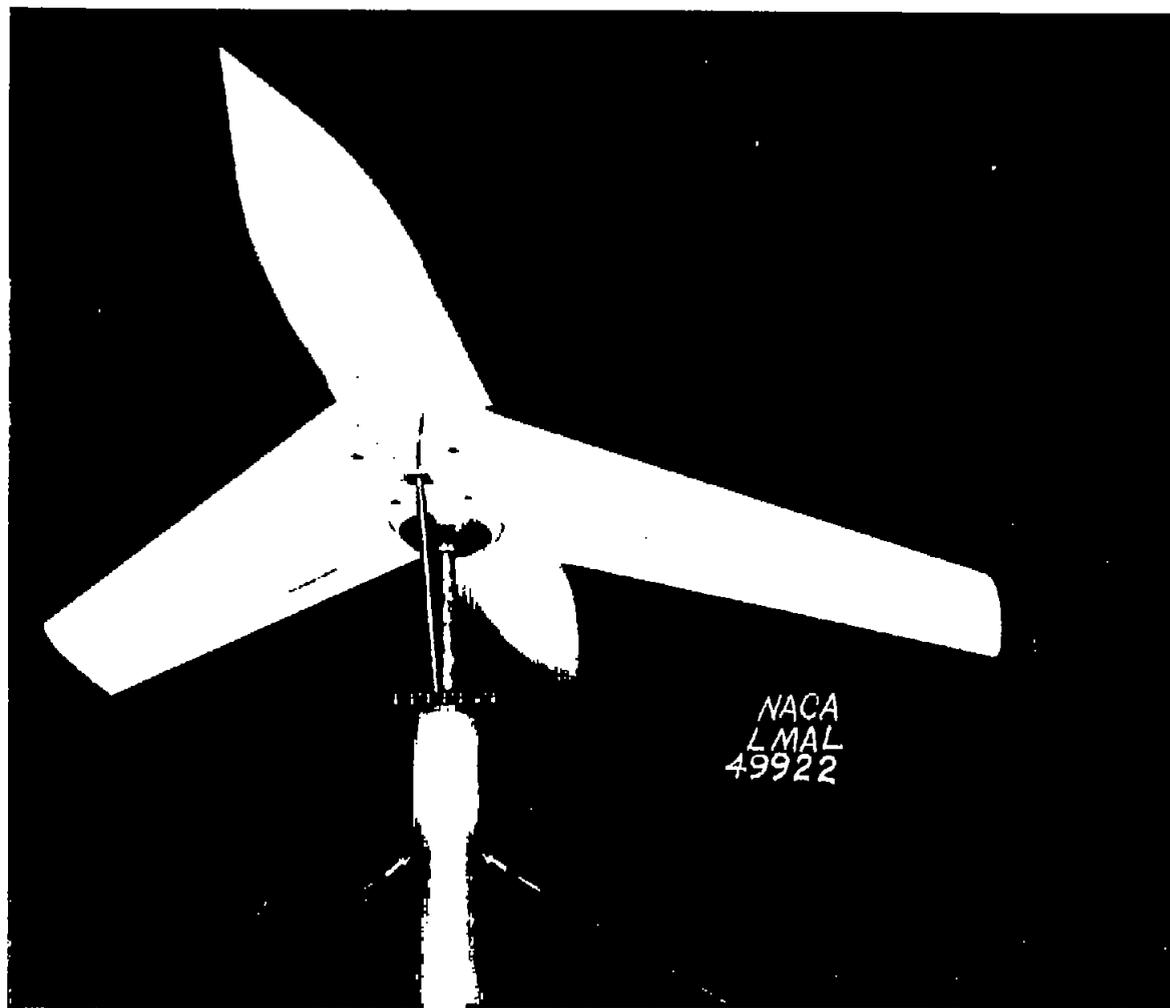
(a) High-wing fuselage combination on pitch supports.

Figure 3.- The 42° sweptback wing and fuselage mounted for testing in the Langley 19-foot pressure tunnel.



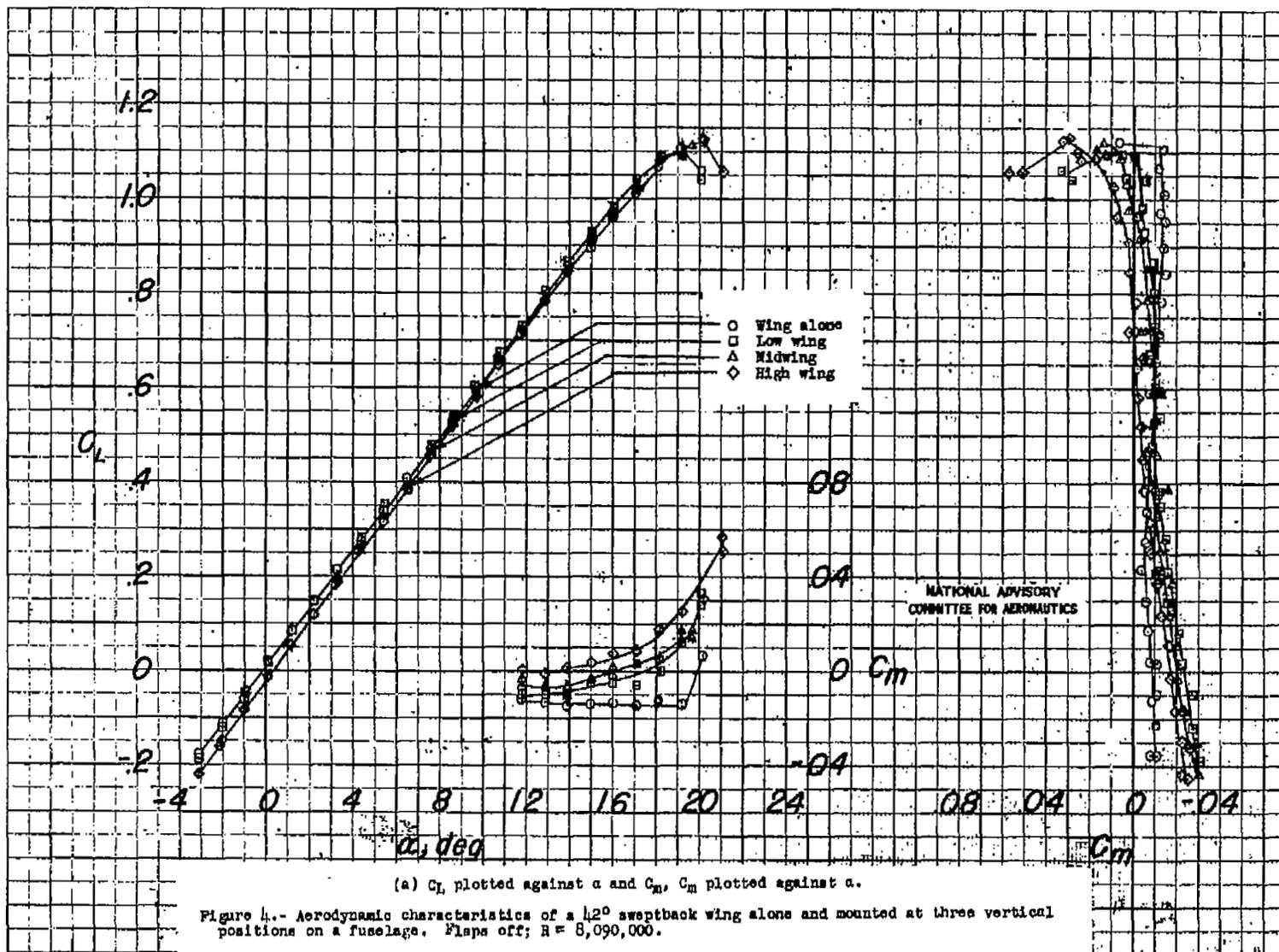
(b) Pitch support details.

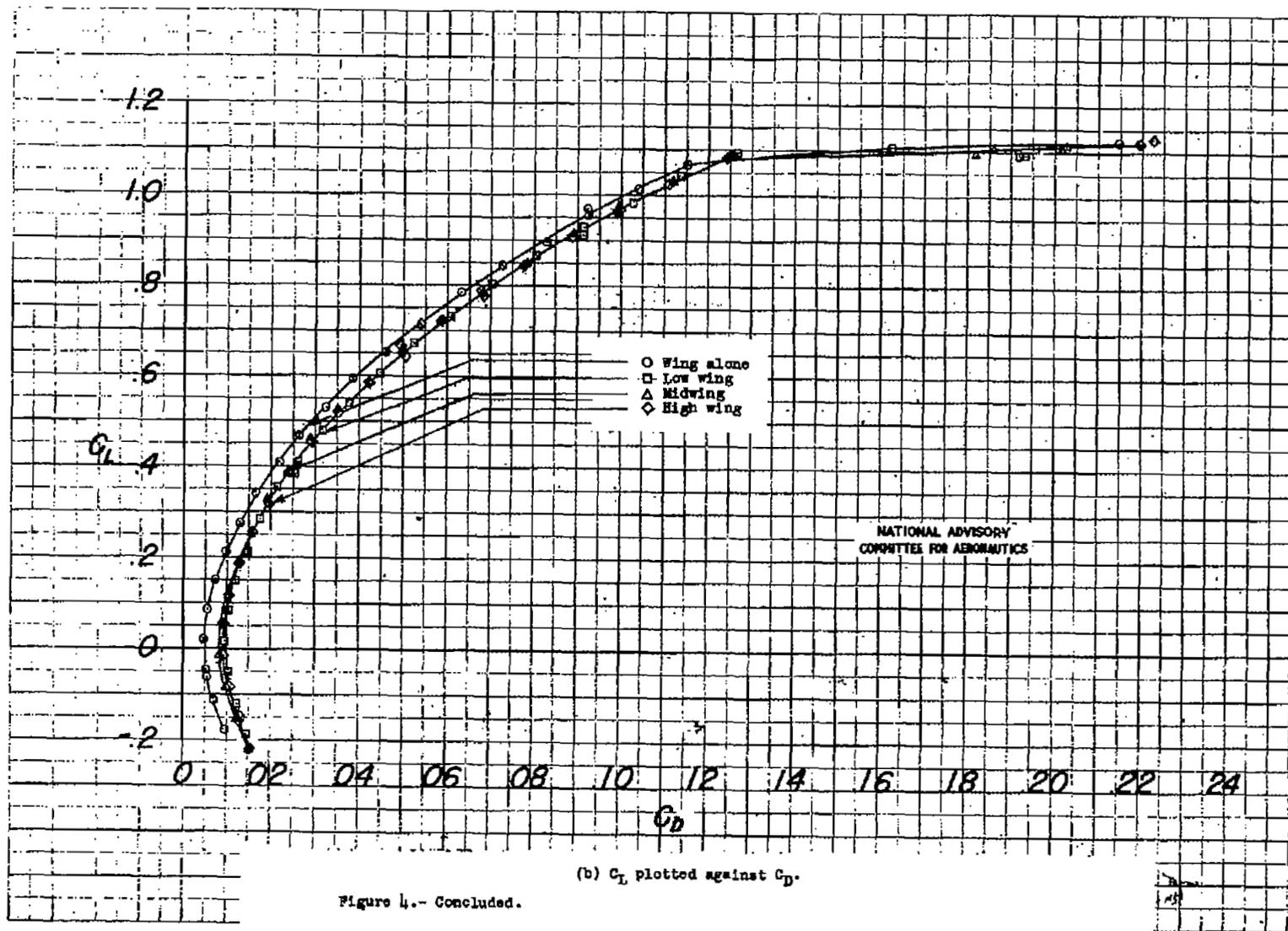
Figure 3.- Continued.



(c) Low-wing fuselage combination on yaw support.

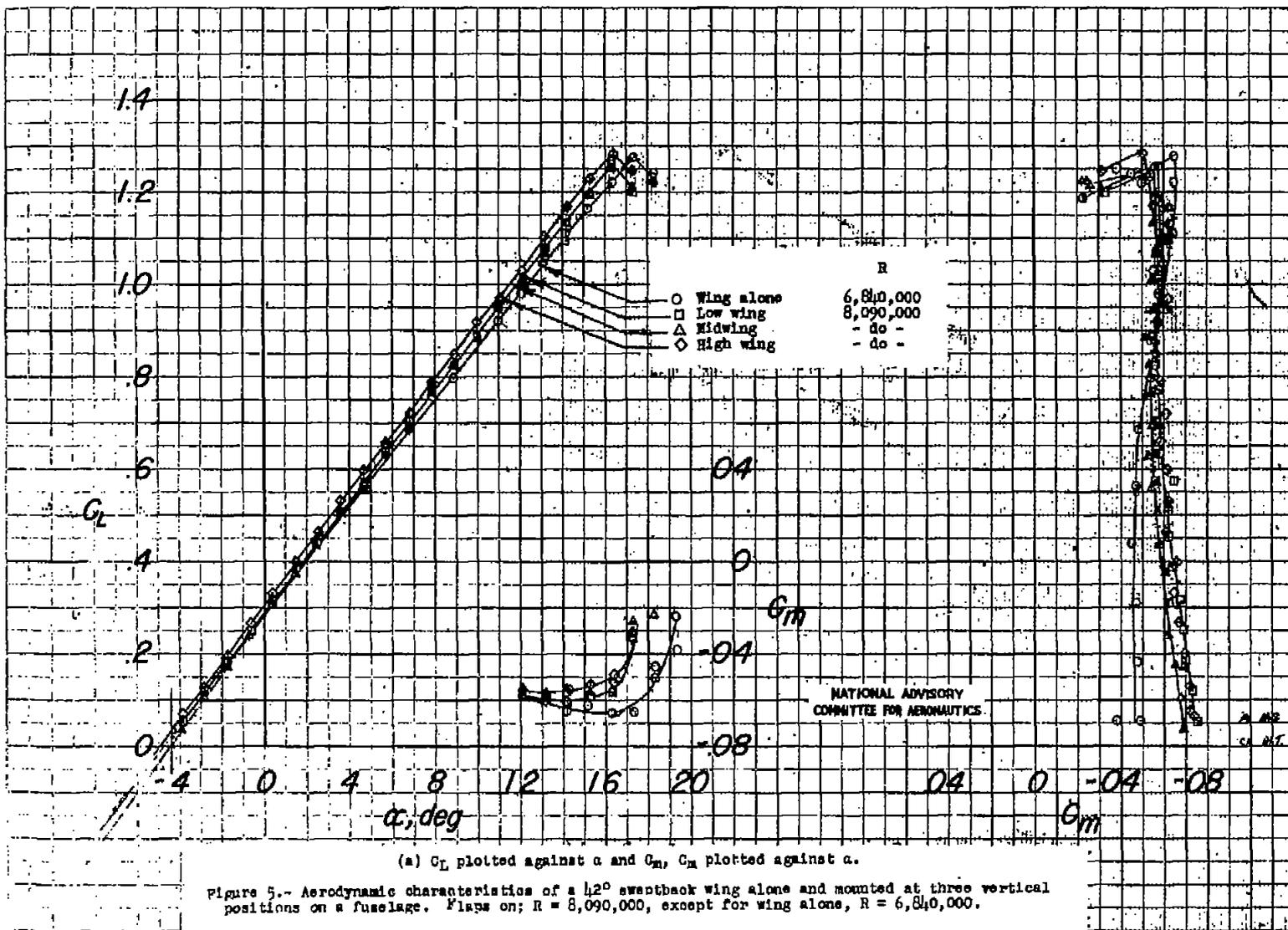
Figure 3.- Concluded.

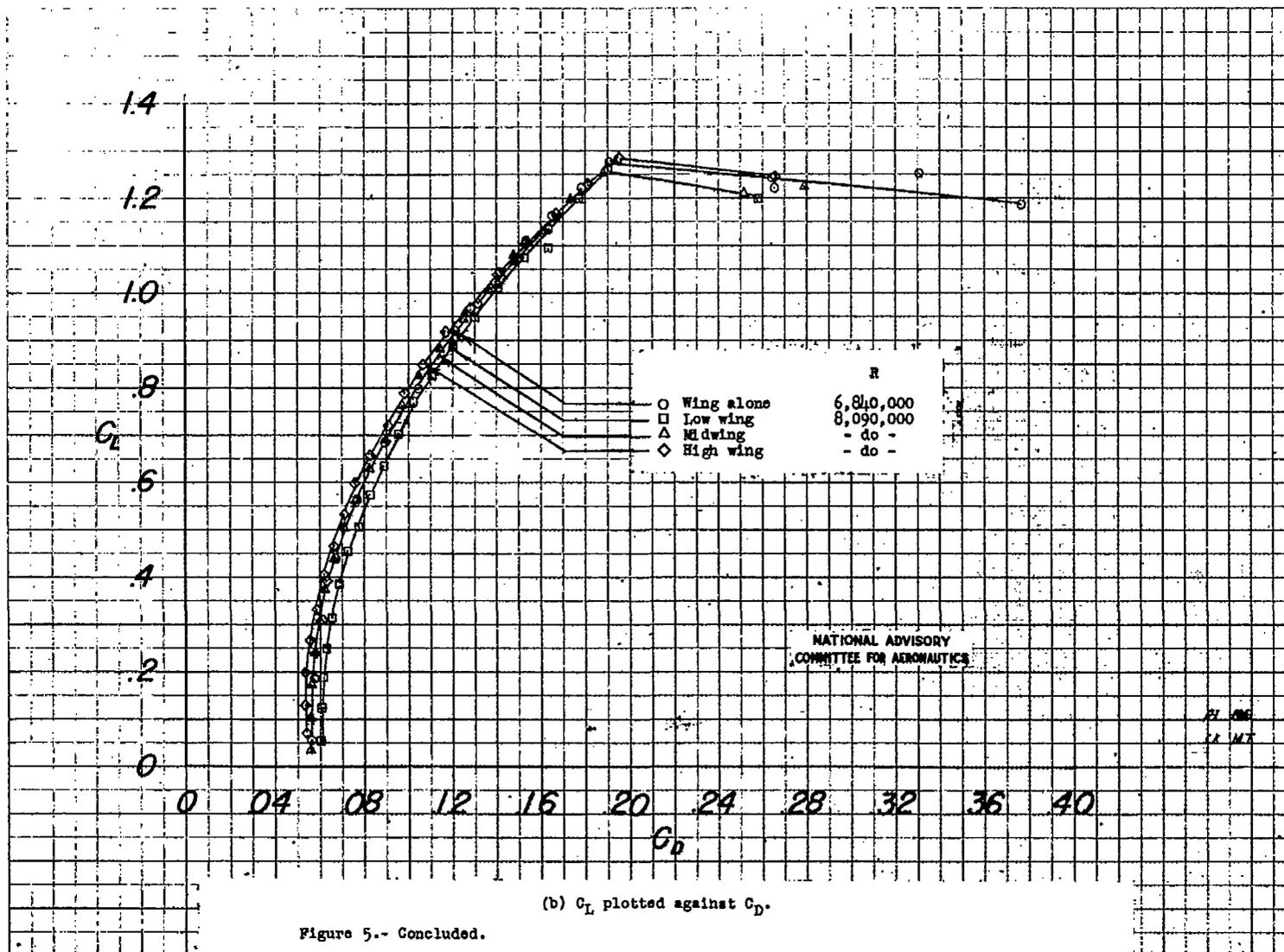


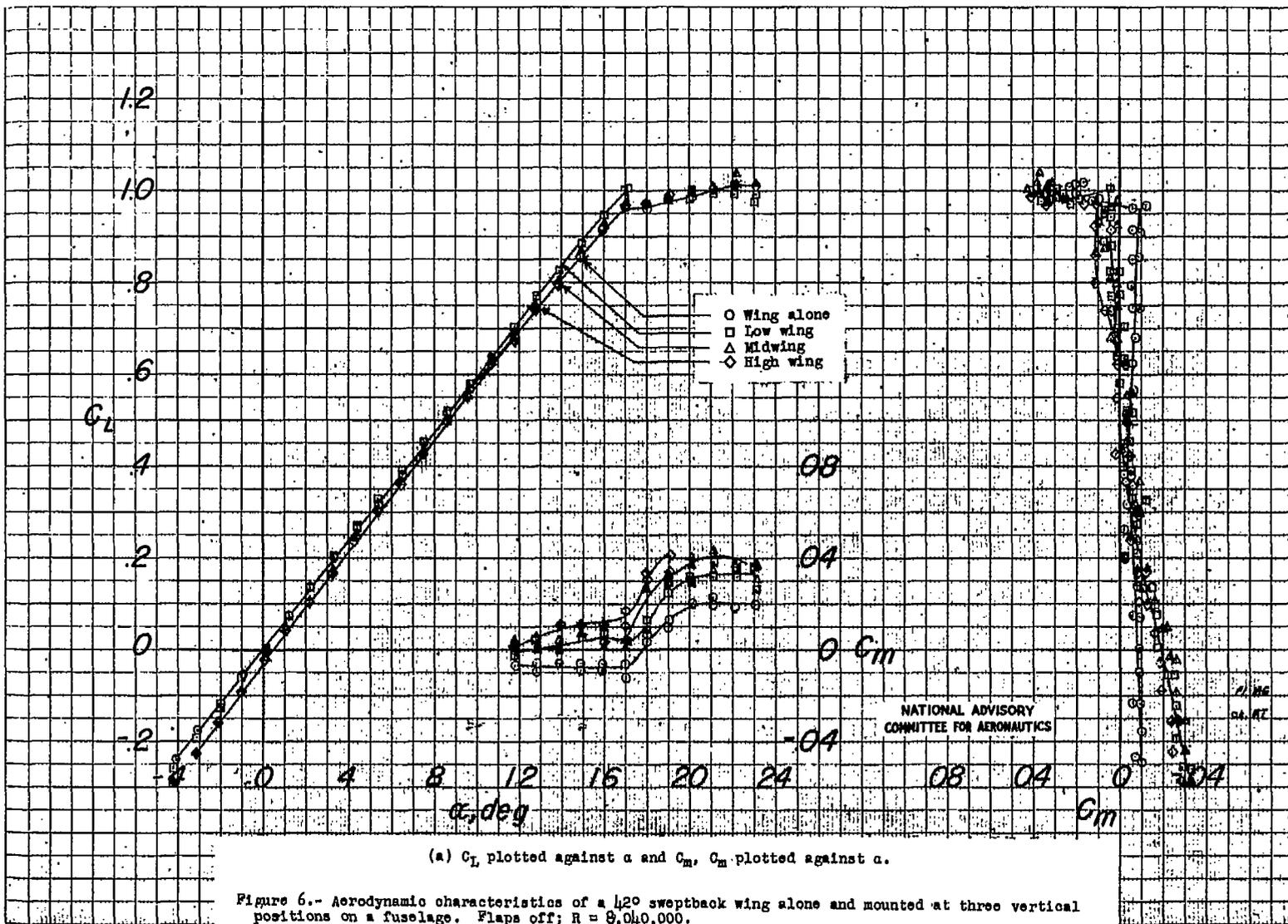


(b) C_L plotted against C_D .

Figure 4.- Concluded.



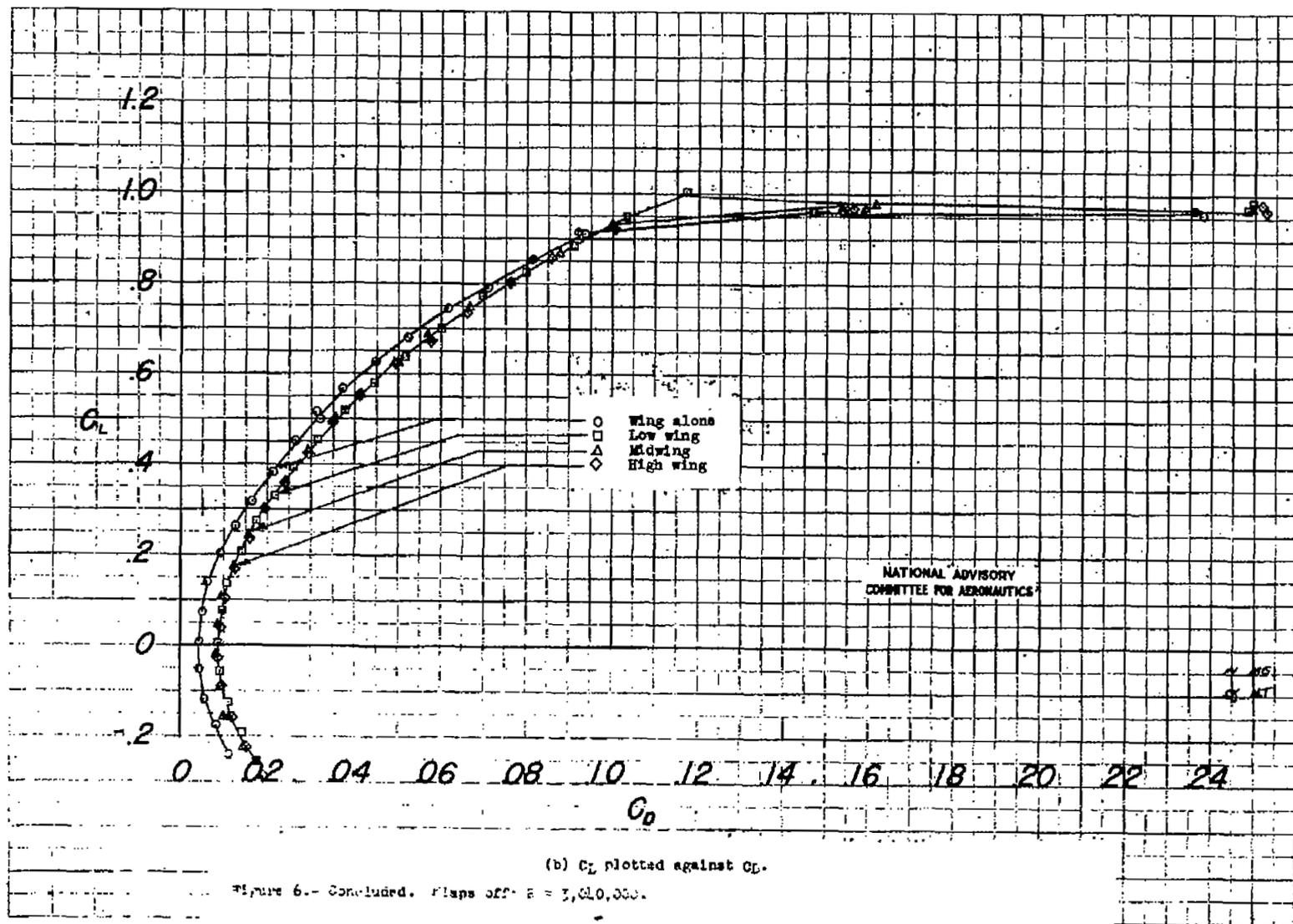


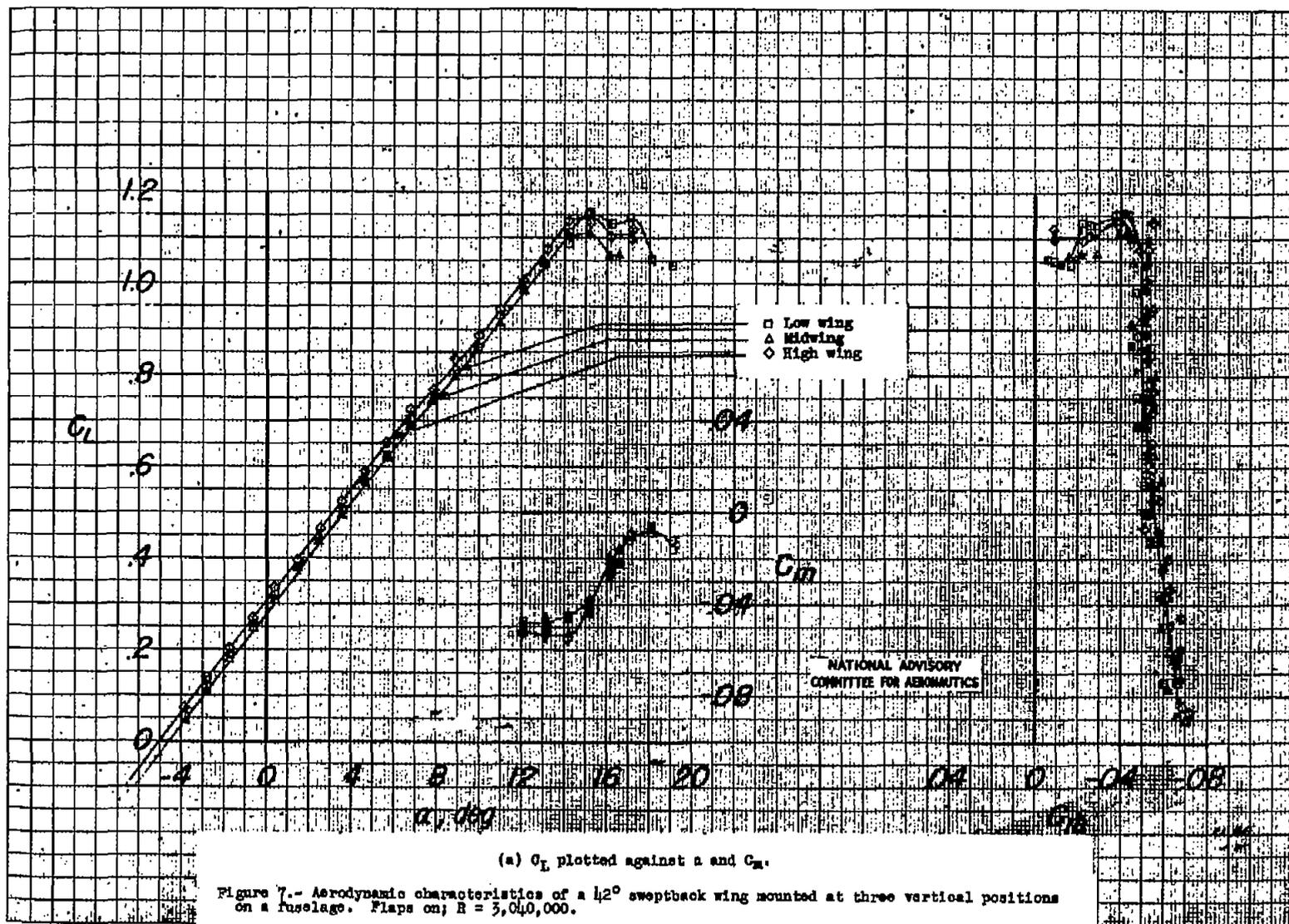


(a) C_L plotted against α and C_m , C_m plotted against α .

Figure 6.- Aerodynamic characteristics of a 42° sweptback wing alone and mounted at three vertical positions on a fuselage. Flaps off; $R = 9,040,000$.

3,04





(a) C_L plotted against α and C_m .

Figure 7.- Aerodynamic characteristics of a 42° sweptback wing mounted at three vertical positions on a fuselage. Flaps on; $R = 3,040,000$.

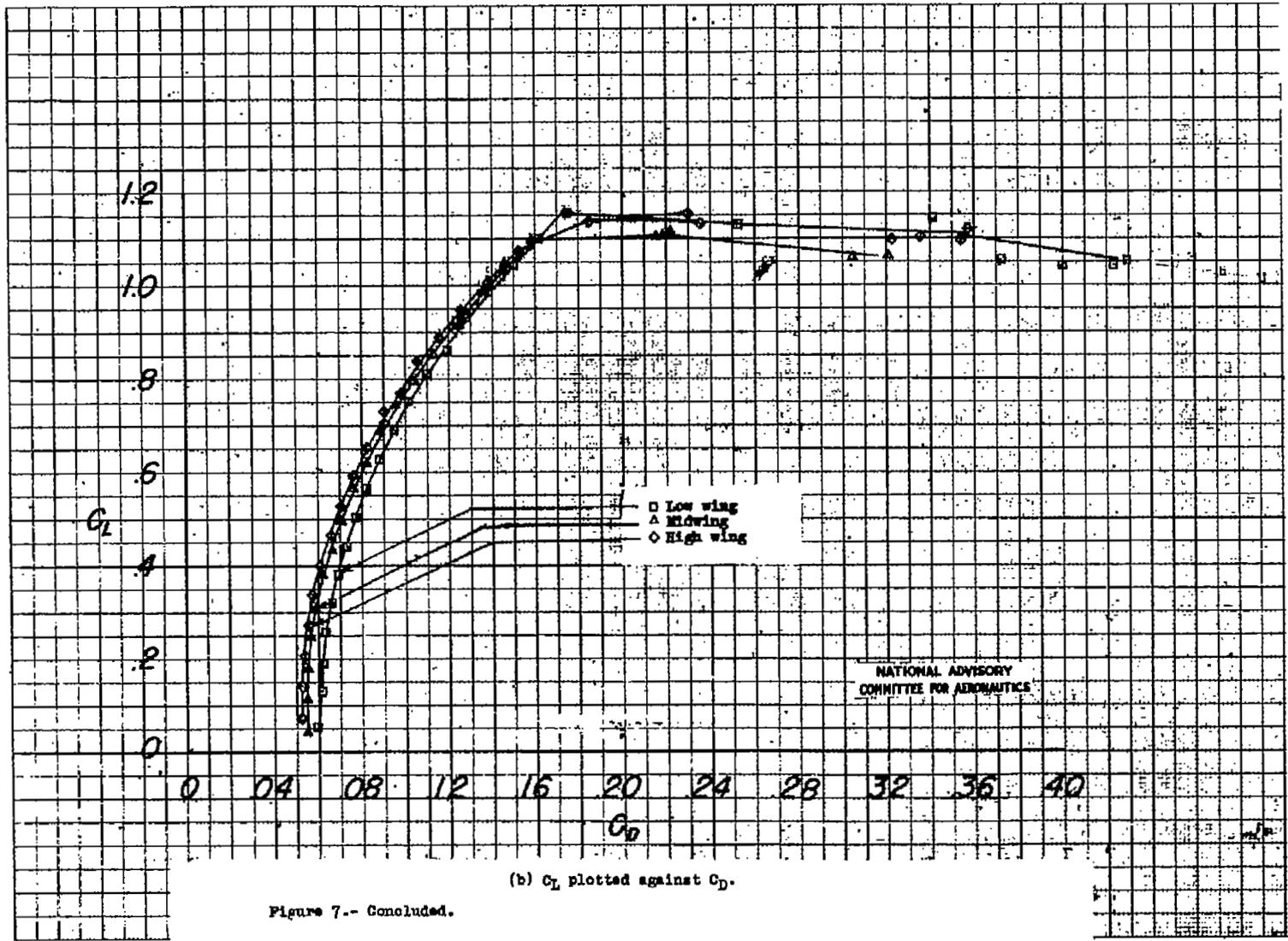


Figure 7.- Concluded.

(b) C_L plotted against C_D .

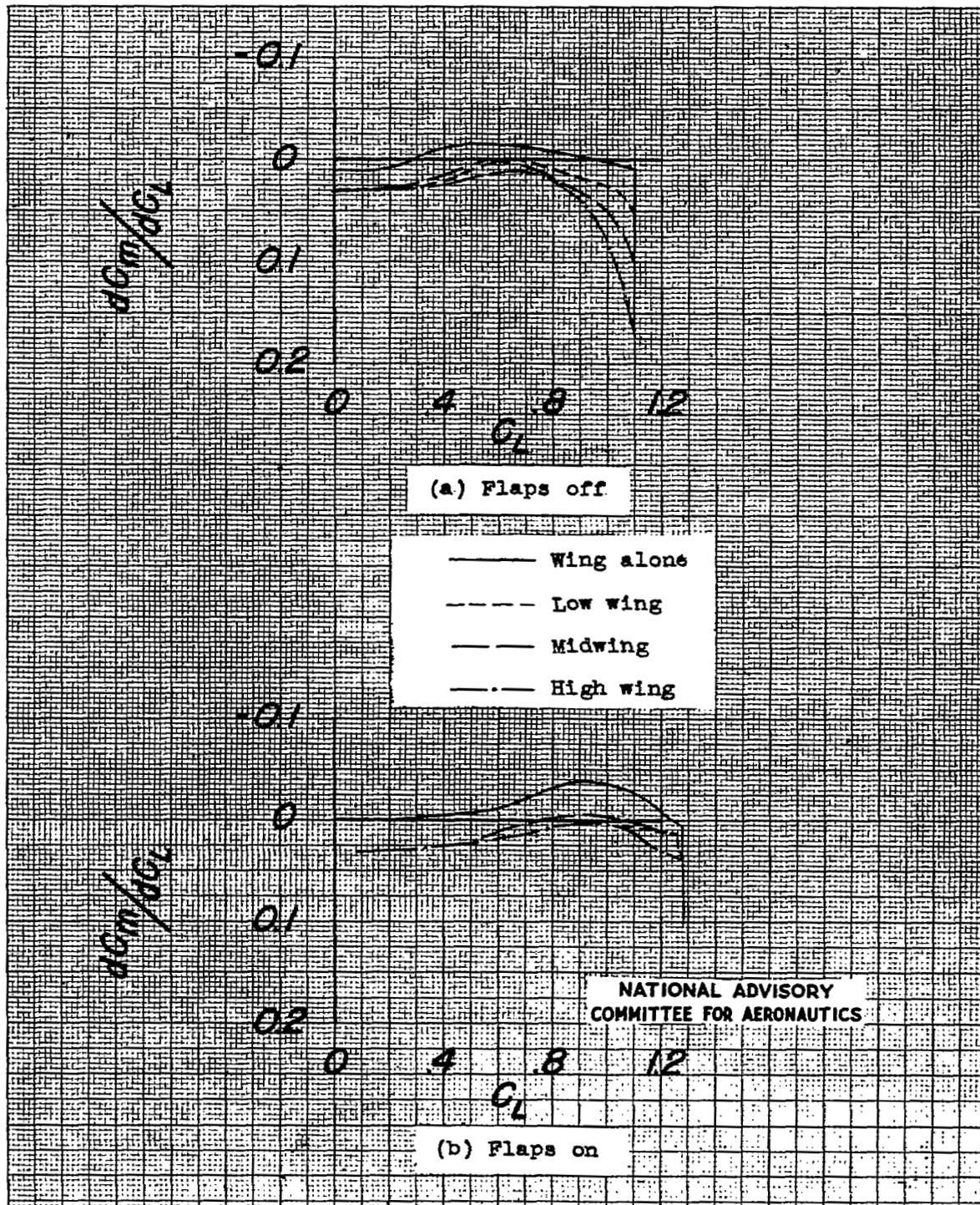
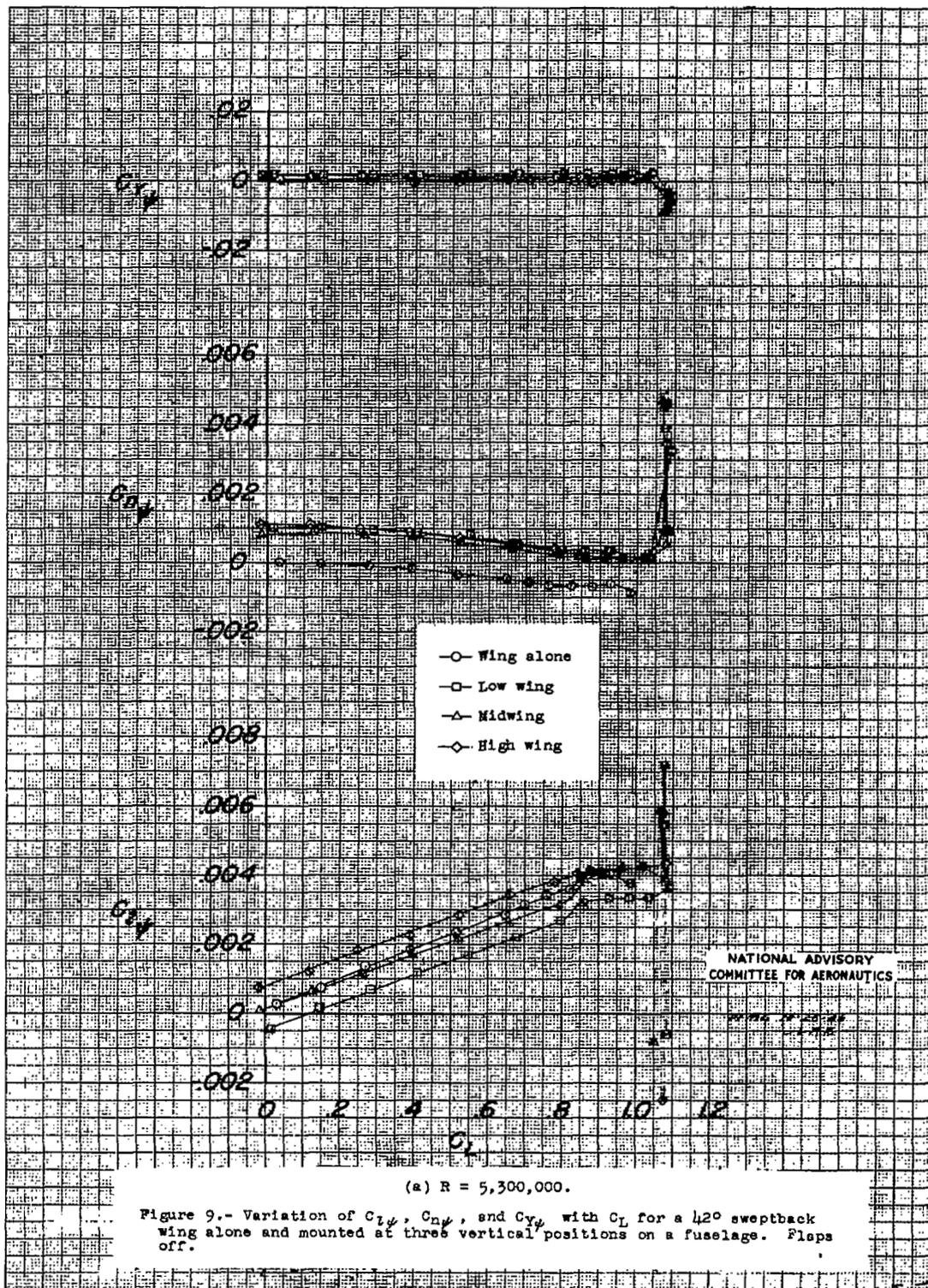
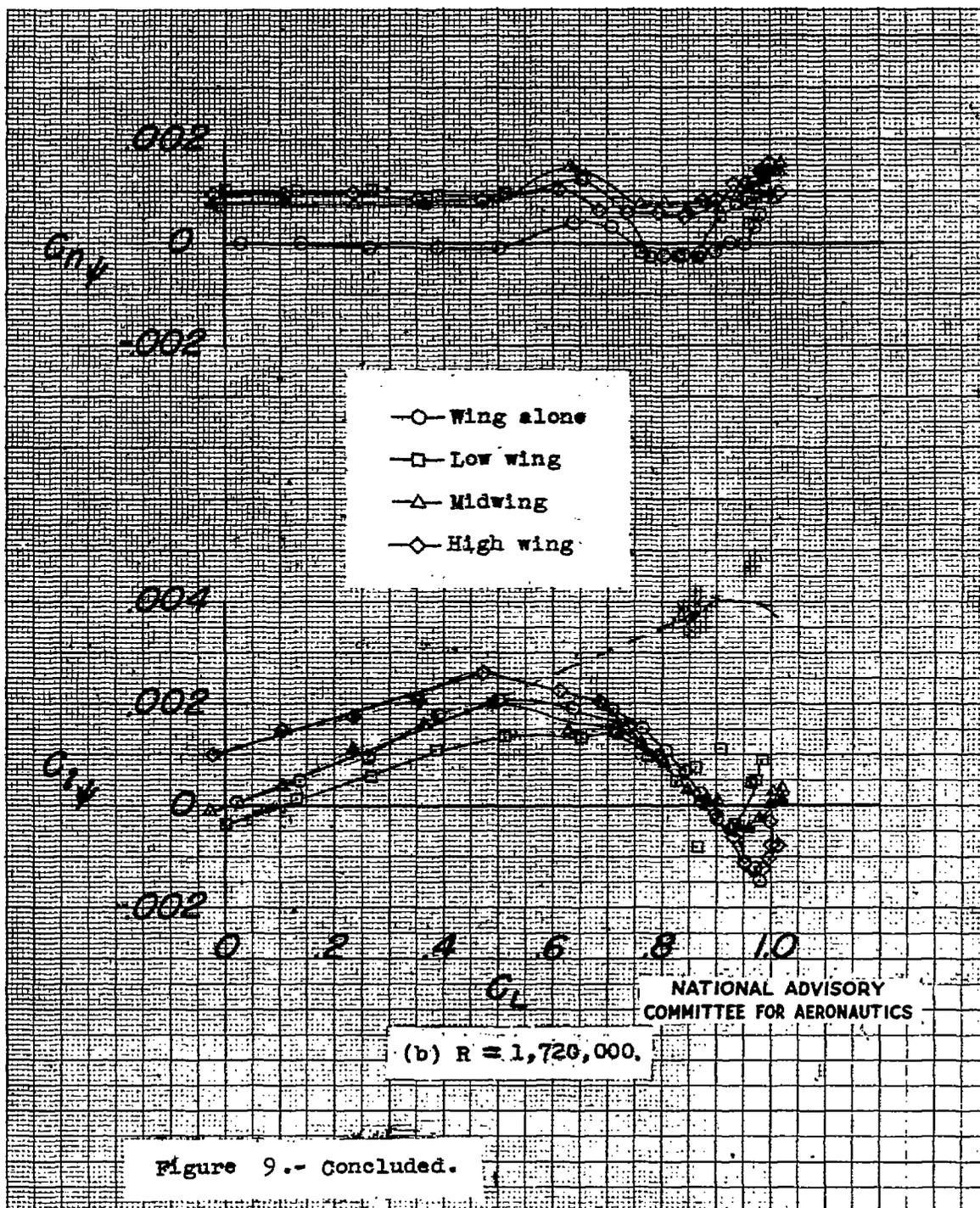


Figure 8.- Variation of dC_m/dC_L with C_L for a 42° sweptback wing alone and mounted at three vertical positions on a fuselage. $R = 8,090,000$.





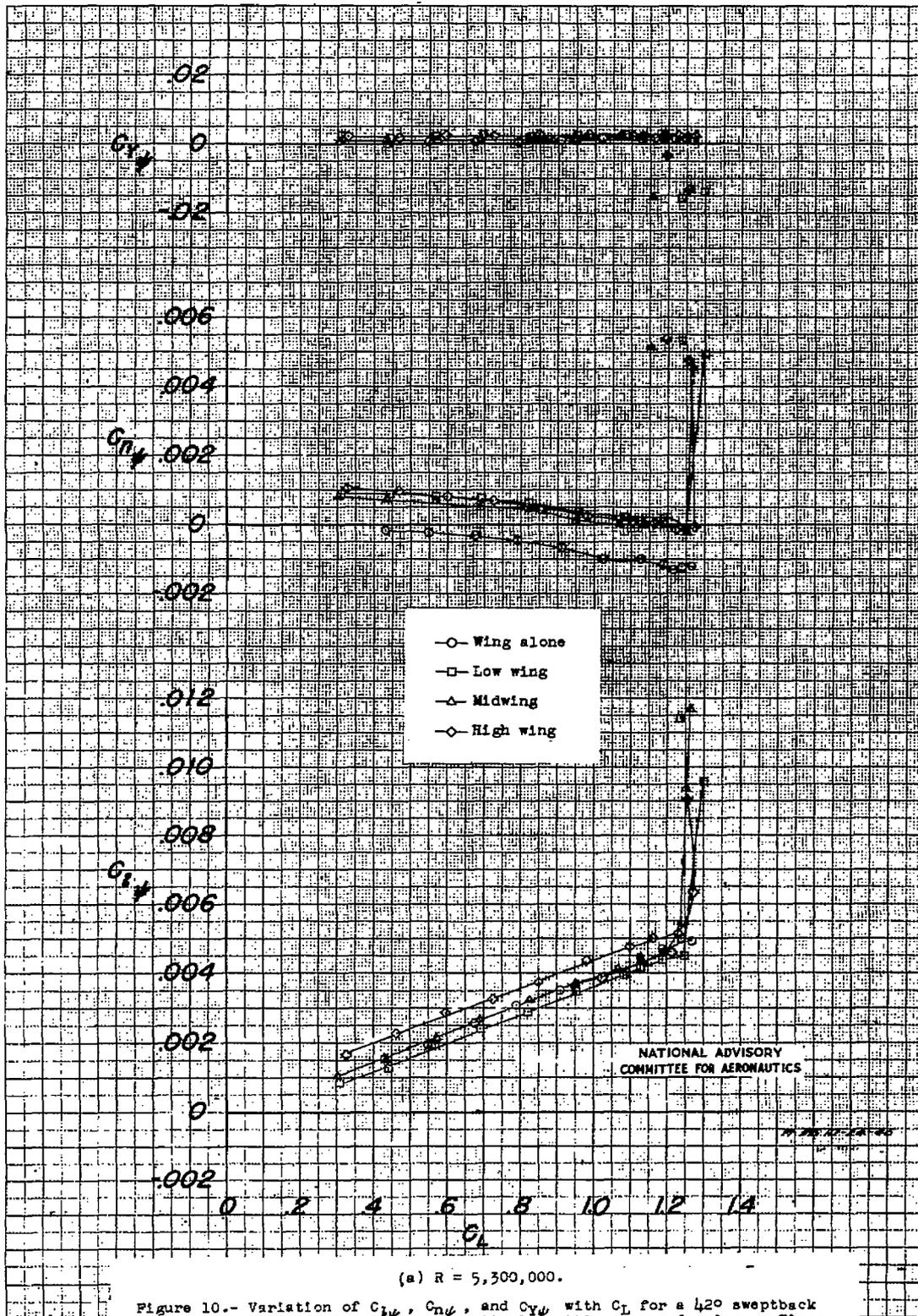
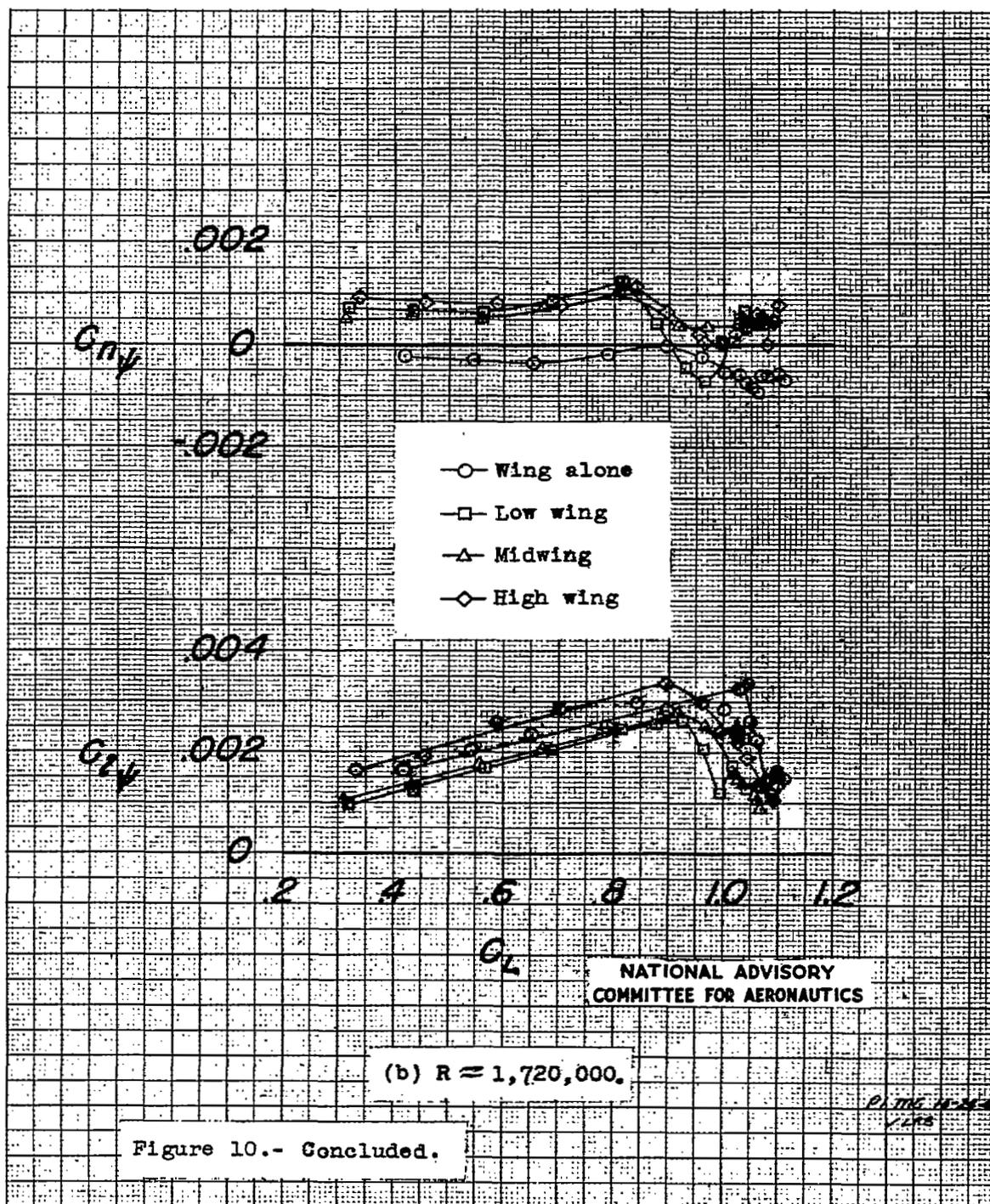
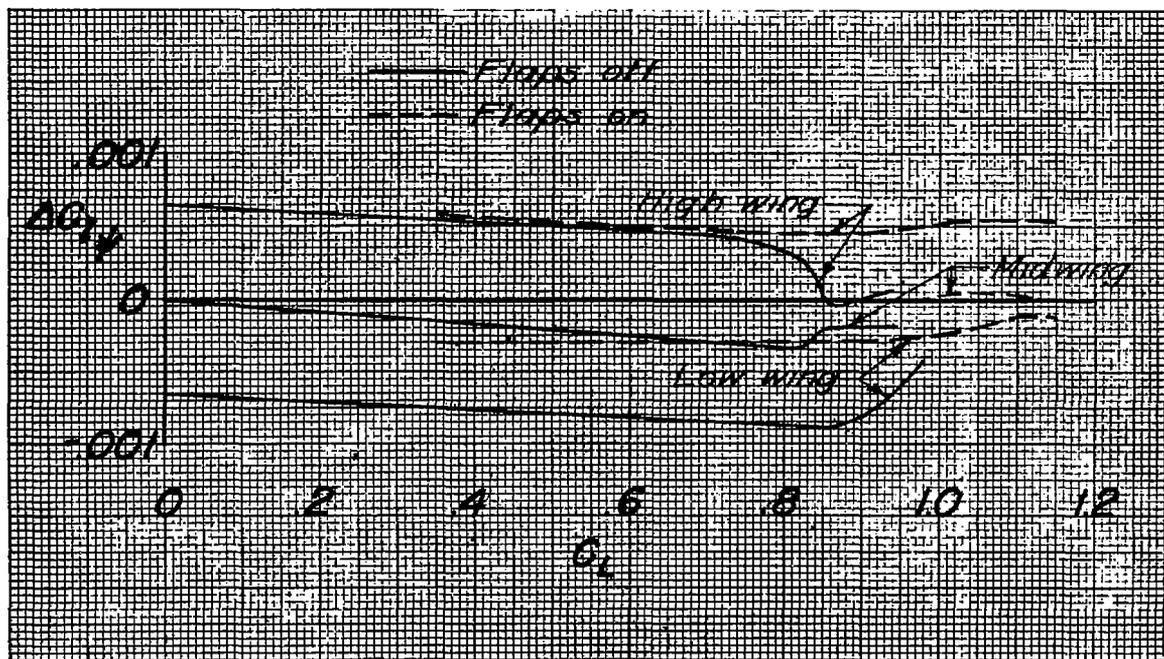
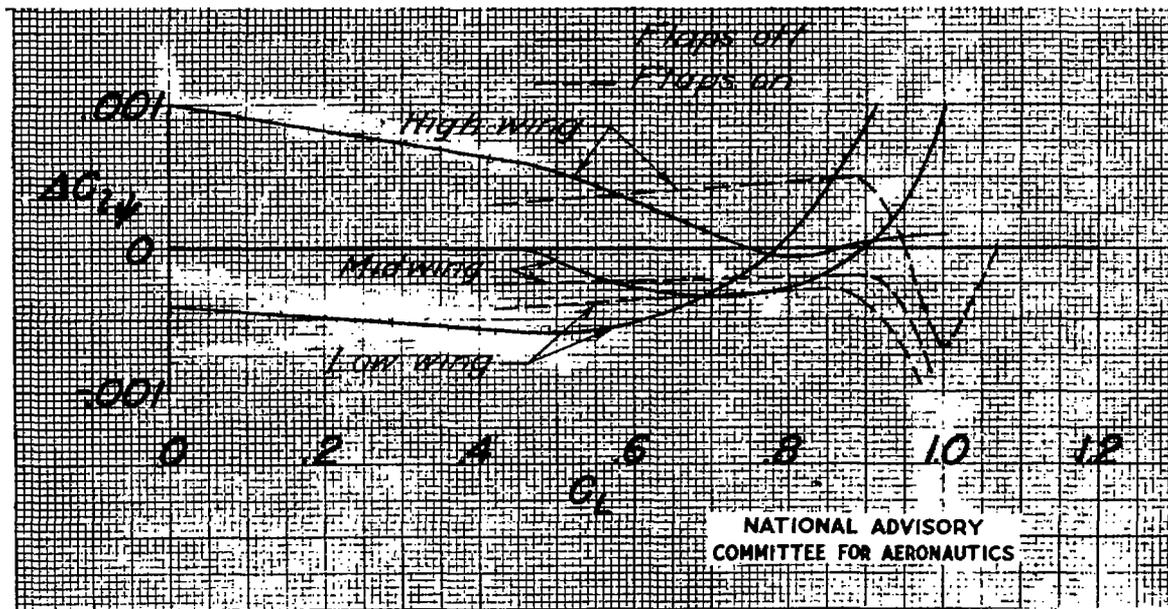


Figure 10.-- Variation of $C_{L\beta}$, $C_{N\beta}$, and $C_{Y\beta}$ with C_L for a 42° sweptback wing alone and mounted at three vertical positions on a fuselage. Flaps on.





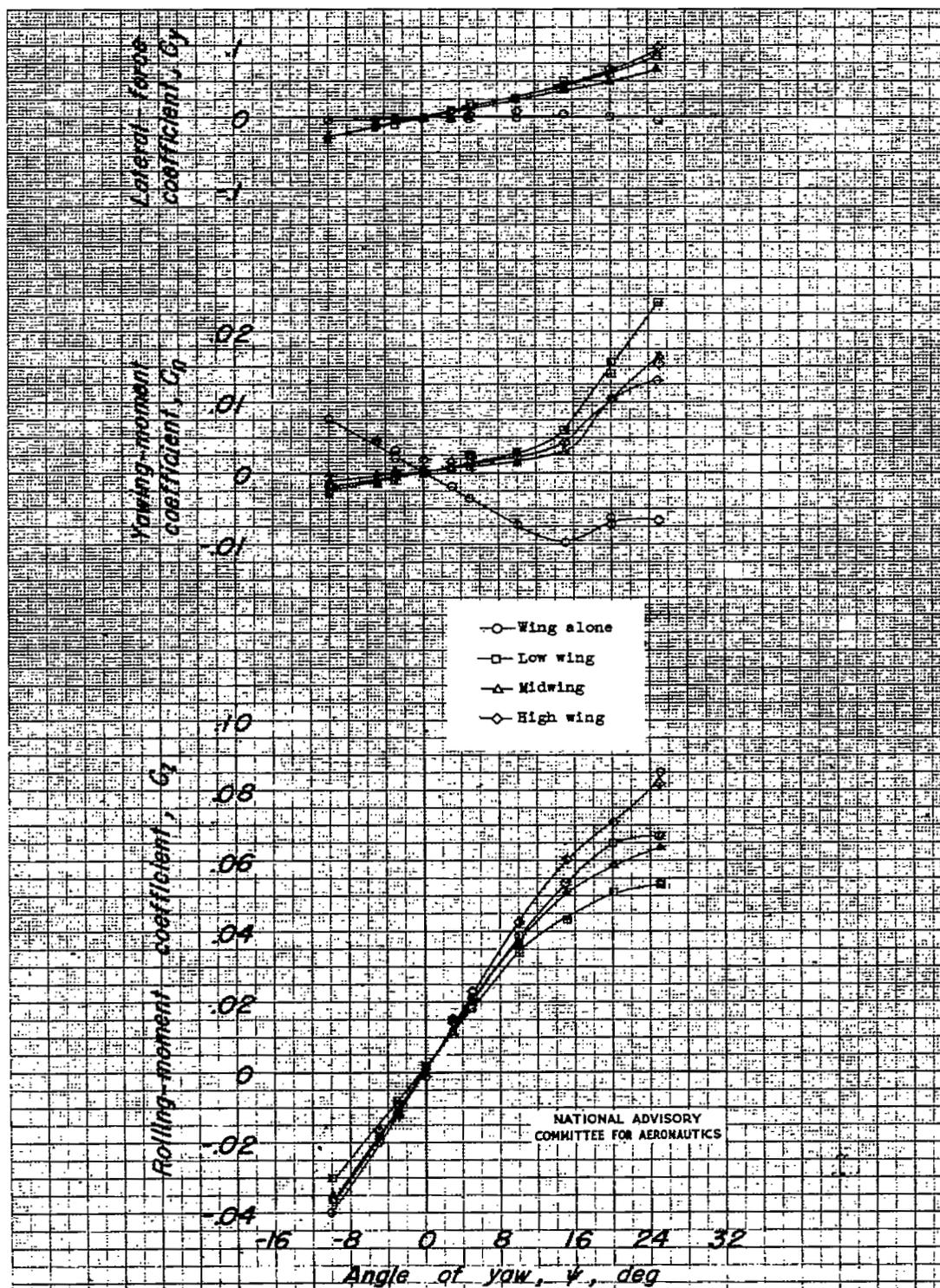
(a) $R = 5,300,000$.



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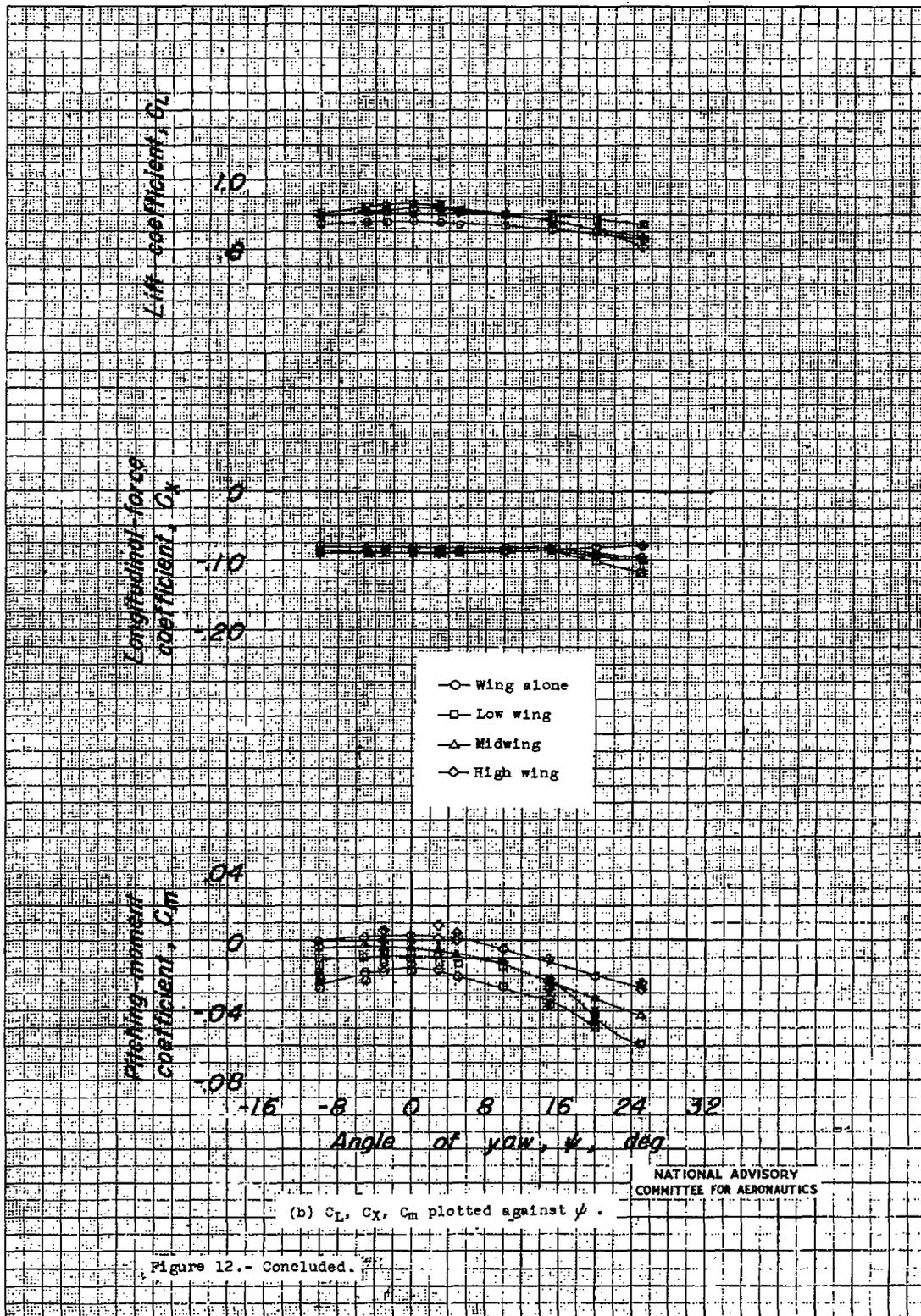
(b) $R = 1,720,000$.

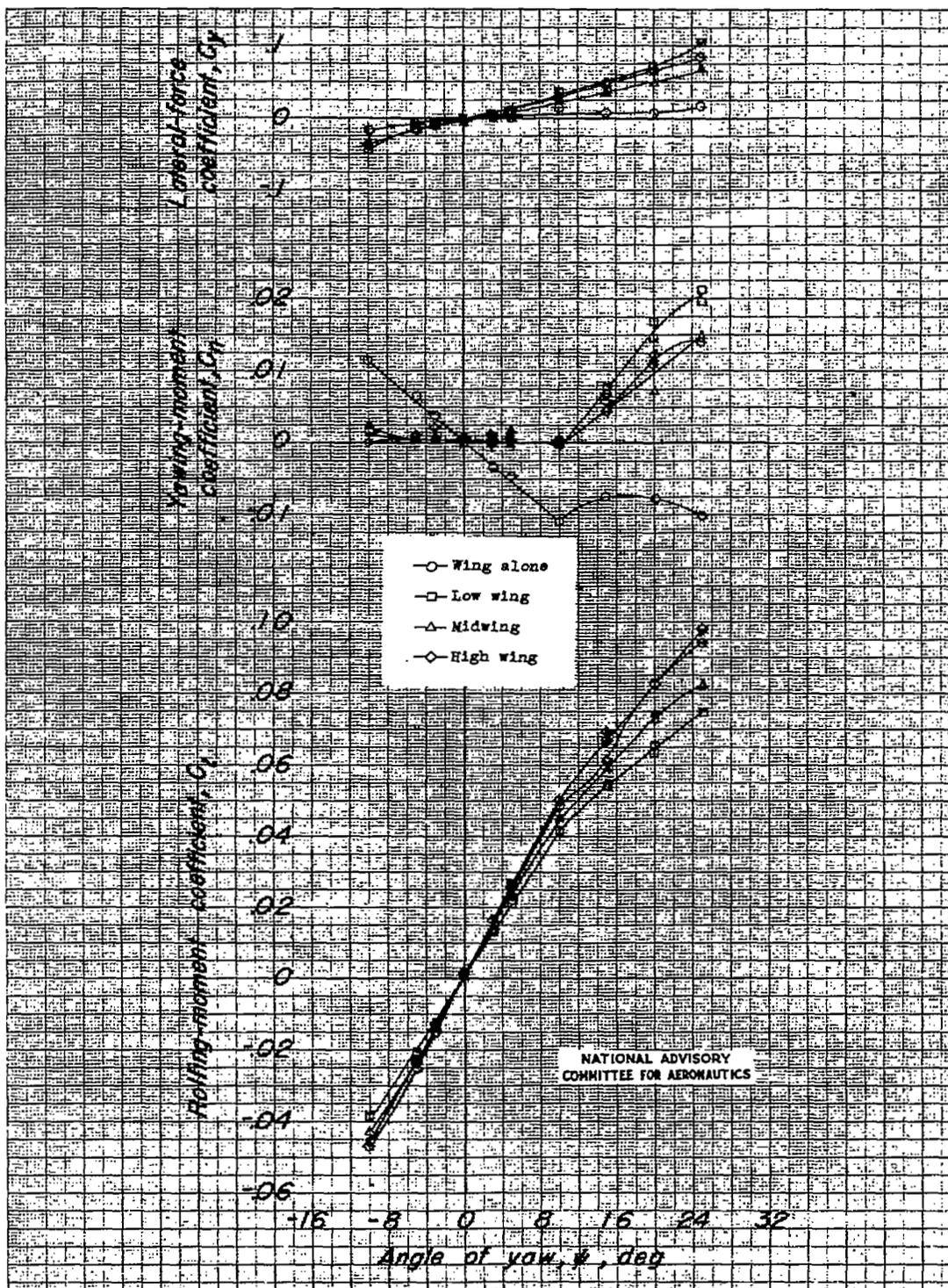
Figure 11.- Effects of a fuselage on C_{iy} of a 42° sweptback wing for three vertical positions of the wing.



(a) C_y , C_n , C_l plotted against ψ .

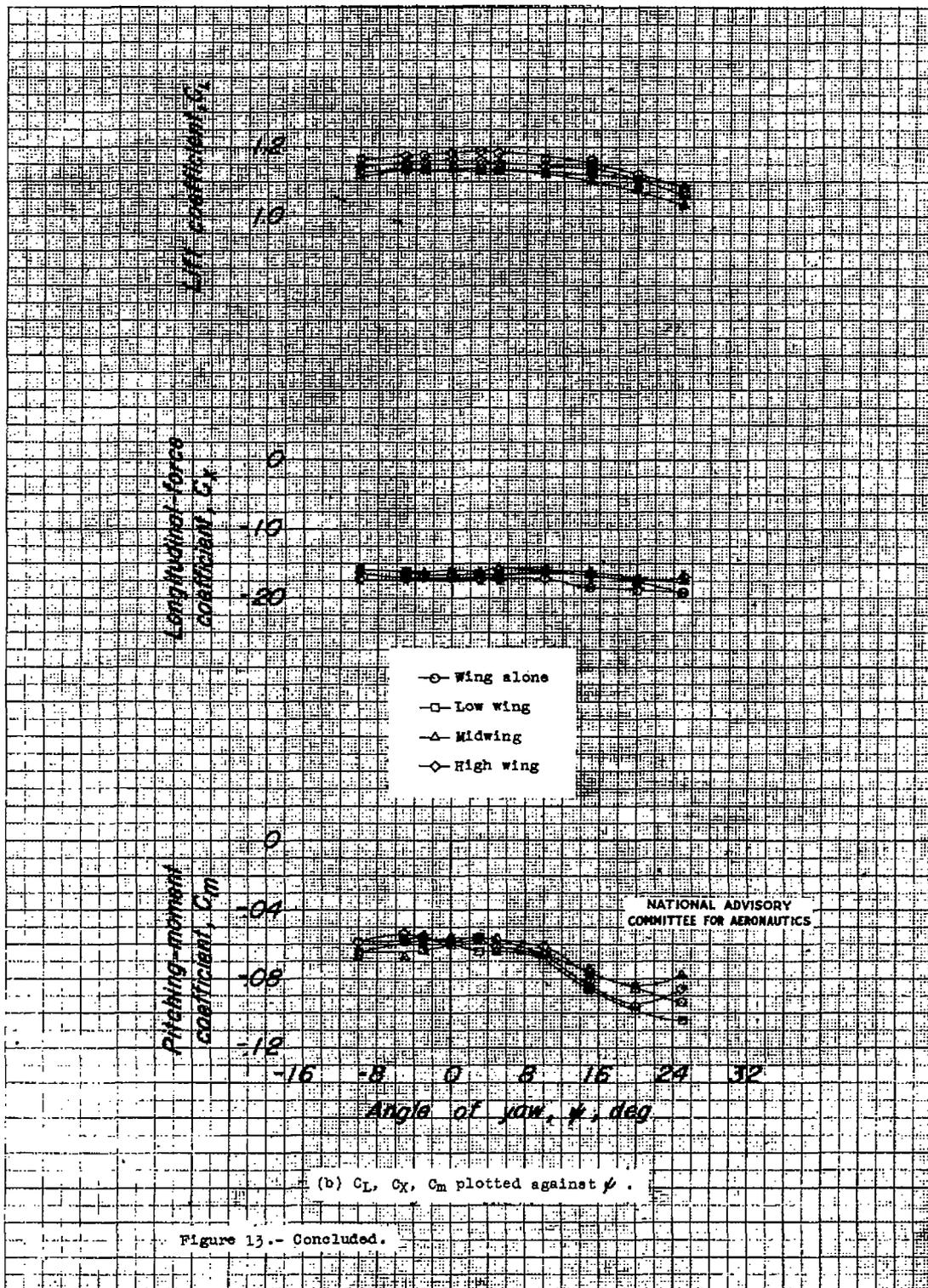
Figure 12.- Aerodynamic characteristics in yaw of a 12° sweptback wing alone and mounted at three vertical positions on a fuselage. Flaps off; $c = 15.3^\circ$; $R = 5,300,000$.





(a) C_y , C_n , C_z plotted against ψ .

Figure 13.- Aerodynamic characteristics in yaw of a 42° sweptback wing alone and mounted at three vertical positions on a fuselage. Flaps on; $\alpha = 14.2^\circ$; $R = 5,300,000$.



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