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TECHNICAL MEMORANDUM

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STABILITY AND CONTROL CHARACTERISTICS AT A MACH NUMBER OF 2.01 OF A VARIABLE-WING-SWEEP CONFIGURATION WITH OUTBOARD WING PANELS SWEPT BACK 75°

By M. Leroy Spearman and Gerald V. Foster

Langley Research Center
Langley Field, Va.

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STABILITY AND CONTROL CHARACTERISTICS AT A MACH NUMBER OF 2.01 OF A VARIABLE-WING-SWEEP CONFIGURATION WITH OUTBOARD WING PANELS SWEPT BACK 75°*

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By M. Leroy Spearman and Gerald V. Foster

SUMMARY

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An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.01 to determine the stability and control characteristics of a variable-wing-sweep configuration with the outboard wing panels swept back 75°.

The results indicated a reasonably linear variation of pitching moment with lift coefficient, so that the static margin could be reduced to about 5 percent in the low lift range before neutral stability would occur at higher lifts. The maximum lift-drag ratio for the untrimmed complete configuration was 6.1.

Results for the complete configuration indicated positive directional stability up to an angle of attack of about 11° and positive dihedral effect throughout the angle-of-attack range investigated.

INTRODUCTION

An airplane combining the characteristics of low-speed efficiency and supersonic "dash" or supersonic cruise ability would be useful in many operations. For example, in the defense of a naval task force, such an airplane may be required to operate from an aircraft carrier and to loiter for long lengths of time and yet be capable of accelerating to supersonic speeds for the purpose of acquiring a target at some distance from the task force.

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Generally speaking the configuration requirements for efficient low-speed flight are not compatible with those for supersonic flight. Thus to accomplish such a split mission it becomes necessary to either compromise the performance of the airplane or to provide a means of varying the airplane configuration in flight.

A promising means of varying a configuration in flight is through the use of variable wing sweep such as that demonstrated by the Bell X-5 research airplane program of the NASA. With this arrangement an airplane may be flown efficiently at low speeds with a low wing-sweep angle and at supersonic speeds with a high wing-sweep angle. In the case of the X-5 airplane, the configuration was altered by sweeping and translating the entire wing panel. An alternate method of varying the sweep without translation of the entire wing would be to rotate only the outer wing panels with the inner wing panels being fixed at a high sweep angle. L632

A research model incorporating a variable-sweep feature of the outboard wing panels is presently being investigated in several installations at the Langley Research Center. The inboard portion of the wing was fixed with a leading-edge sweep angle of 60°, whereas the leading-edge sweep angle of the outer wing panels could be varied from 12.5° to 75°. For this range of sweep angles the wing aspect ratio varies from about 6.3 to about 1.9. The complete model is equipped with a rearward horizontal and vertical tail. The NASA program for this model includes tests at subsonic speeds, transonic speeds, and supersonic speeds (Mach number range M from 0.25 to 2.01) with various wing-sweep angles used in the subsonic speed range, but only the maximum sweep angle of 75° used in the transonic and supersonic speed ranges.

Results are presented herein of the investigation made in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.01 to determine the longitudinal and lateral stability and control characteristics of the configuration with the wing outboard panels swept back 75°.

SYMBOLS

Force and moment coefficients are referred to the body-axis system except the lift and drag coefficients which are referred to the wind-axis system. The moment reference point is on the body center line at a station 66.1 percent of the body length.

The coefficients and symbols are defined as follows:

A	aspect ratio
b	wing span, 22.68 in.

c	local chord, in.
$\bar{c}$	wing mean geometric chord, 13.64 in.
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_l	rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$
C_{l_β}	effective-dihedral parameter, $\Delta C_l/\Delta\beta$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS\bar{c}}$
C_n	yawing-moment coefficient, $\frac{\text{Yawing moment}}{qSb}$
C_{n_β}	directional-stability parameter, $\Delta C_n/\Delta\beta$
C_Y	side-force coefficient, $\frac{\text{Side force}}{qS}$
C_{Y_β}	side-force parameter, $\Delta C_Y/\Delta\beta$
h	altitude
L/D	lift-drag ratio, C_L/C_D
M	free-stream Mach number
q	free-stream dynamic pressure
S	wing area including fuselage intercept, 1.916 sq ft
t	thickness

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W	weight
α	angle of attack, deg
β	angle of sideslip, deg
δ_h	horizontal tail control deflection, deg

COMPONENTS OF CONFIGURATION

For identification herein, the component parts of the configurations used in the tests are designated by letters, as indicated in the following table:

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Component	Designation
Body	B
Horizontal tail	H
Vertical tail	V
Wing	W

MODELS AND APPARATUS

Details of the model are shown in figure 1. The forward 40 percent of the body was composed of straight-line conical elements that faired into an afterbody of constant cross-sectional area and shape. The afterbody was composed of a flat top and bottom surface with hemispherical sides. The wing was mounted on the body center line with zero dihedral and incidence. The sweep angle of the wing leading edge was 60° out to about 65.4 percent of the semispan, at which point the sweep angle increased to 75°. The trailing-edge sweep angle was constant at 42.5°. The wing was composed of NACA 63_6A004.5 sections normal to the leading edge. The horizontal and vertical tails were identical in plan form and had constant 1/8-inch-thick sections. The horizontal tail was mounted on the body center line with a dihedral angle of -15°. The complete configuration was equipped with movable horizontal tail panels to provide a means of control.

The model was mounted in the tunnel on a remotely controlled rotary sting, and force measurements were made through the use of a six-component internal strain-gage balance.

TESTS, CORRECTIONS, AND ACCURACY

The test conditions are as follows:

Mach number	2.01
Stagnation temperature, °F	100
Stagnation pressure, lb/sq in.	10
Reynolds number based on $\bar{c}$	2.86×10^6

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The stagnation dewpoint was maintained sufficiently low (-25° F or less) to assure that no condensation effects were encountered in the test section.

Tests were made through an angle-of-attack range of about 0° to 17° at sideslip angles of 0° and 4° and through a sideslip range from 0° to 16° at an angle of attack of 0°. Three configurations were tested: the wing-body configuration (WB); the wing and body with only the vertical tail (WBV); and the wing and body with both the vertical and horizontal tails (WBVH).

The angles of attack and sideslip were corrected for the deflection of the balance and sting under load. The base pressure was measured, and the drag force was adjusted to a base pressure equal to free-stream static pressure.

The estimated accuracy of the individual measured quantities is as follows:

C_L	±0.0024
C_D	0.0007
C_m	0.0007
C_l	0.0001
C_n	0.0001
C_Y	0.0006
α, deg	±0.1
β, deg	±0.1
δ_h, deg	±0.1

PRESENTATION OF RESULTS

The results of the investigation and the figures in which they will be found are indicated in the following table:

	Figure
Aerodynamic characteristics in pitch for various combinations of components	2
Effect of horizontal tail deflection on the aerodynamic characteristics in pitch for the complete configuration . . .	3
Trimmed longitudinal characteristics for various stability levels	4
Variation of the lift required with wing loading and altitude and the lift available with $\delta_h = -10^\circ$ for various stability levels	5
Aerodynamic characteristics in sideslip for various combinations of components at $\alpha = 0^\circ$	6
Variation of sideslip derivatives with angle of attack for various combinations of components	7
Roll control characteristics with differentially deflected horizontal tail	8

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DISCUSSION

The variation of pitching moment with lift for the complete model (WBVH) is shown in figures 2 and 3 to be reasonably linear for a configuration having such a highly swept wing. Although the pitching-moment curves indicate a tendency toward reduced stability at higher lifts, the tendency is lessened for the configuration with the horizontal tail, apparently as a result of an effective upwash induced at the tail by the body. It was determined that the static margin for the complete configuration could be reduced to as low as 5 percent in the low lift range before neutral stability would occur at higher lifts (above $C_L \approx 0.3$).

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A reasonably high value of maximum L/D (7.4) was obtained with the wing-body combination (fig. 2(b)), primarily because of the low minimum drag that results from the use of a high fineness ratio of the forebody and from the thin wing sections. The addition of both tails, however, causes a decrease in maximum L/D to about 6.15 for the configuration with $\delta_h = 0^\circ$. The trimmed longitudinal-stability characteristics (fig. 4) indicate the usual decrease in maximum L/D as the stability level (negative $\partial C_m/\partial C_L$) is increased with the maximum trimmed value of L/D being about 5.3 for $\frac{\partial C_m}{\partial C_L} = -0.25$.

Some operational capabilities at $M = 2.01$ for an airplane similar to the test configuration can be determined through the use of figure 5, wherein the lift required for level flight as a function of wing loading and altitude is shown, together with the lift available at various stability levels for the maximum tail deflection investigated ($\delta_h = -10^\circ$). For a given stability level, the area below the curve of lift available indicates the combinations of wing loading and altitude obtainable in level flight. In addition, for given values of wing loading, altitude, and stability level, the maximum normal acceleration available for maneuvering may be determined by comparing the lift available with the lift required.

It is interesting to note that the lift coefficient required for maximum L/D ($C_L \approx 0.2$) entails flight at altitudes generally in excess of about 60,000 feet for wing loadings W/S up to about 90 pounds per square foot. For supersonic cruise at lower altitudes or wing loadings, lower lift coefficients are required and values of L/D less than maximum must be accepted.

The results for the complete configuration in figure 7 indicate positive directional stability up to about $\alpha = 11^\circ$, above which directional instability occurs. The deterioration of directional stability with increasing angle of attack is a consequence of an increase in instability of the wing-body combination and a loss in vertical tail effectiveness. Both of these effects may be caused by the sidewash induced by the wing-body juncture and could probably be offset to some extent through the use of forebody strakes. (See ref. 1.) The complete configuration has a positive dihedral effect (negative C_{l_β}) throughout the angle-of-attack range (fig. 7).

Limited tests were made to determine the roll control characteristics of the configuration with a differentially deflected horizontal tail. The results (fig. 8) indicate a positive roll effectiveness and a favorable yaw.

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CONCLUDING REMARKS

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.01 to determine the stability and control characteristics of a variable-wing-sweep configuration with the outboard wing panels swept back 75°.

The results indicated a reasonably linear variation of pitching moment with lift coefficient such that the static margin could be reduced to about 5 percent in the low lift range before neutral stability would occur at higher lifts. The maximum untrimmed lift-drag ratio for the complete configuration was 6.1.

Results for the complete configuration indicated positive directional stability up to an angle of attack of about 11° and positive dihedral effect throughout the angle-of-attack range investigated.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., May 29, 1959.

REFERENCE

1. Spearman, M. Leroy: Some Factors Affecting the Static Longitudinal and Directional Stability Characteristics of Supersonic Aircraft Configurations. NACA RM L57E24a, 1957.

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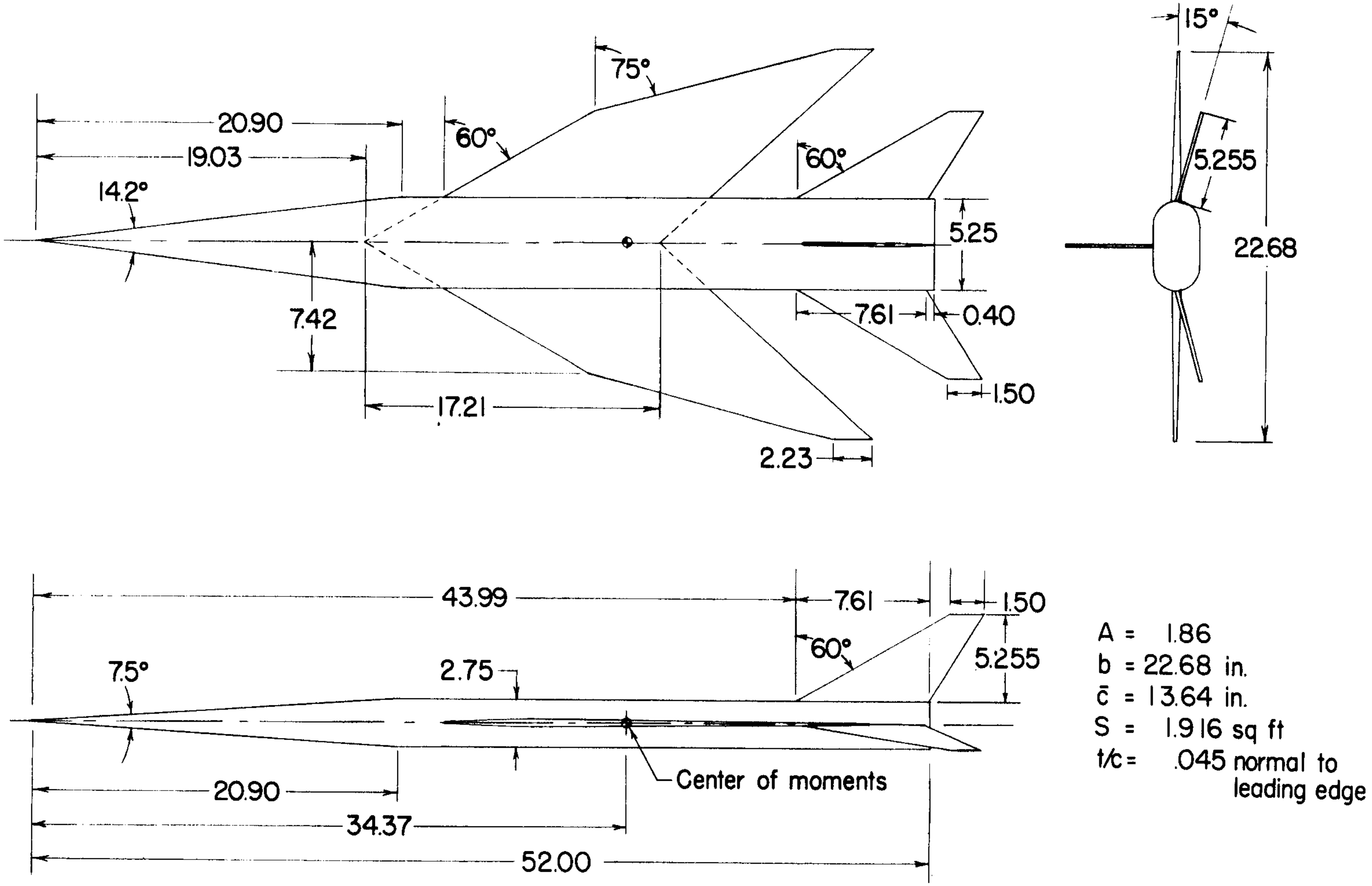

Figure 1.- Details of model. All dimensions in inches unless otherwise noted.

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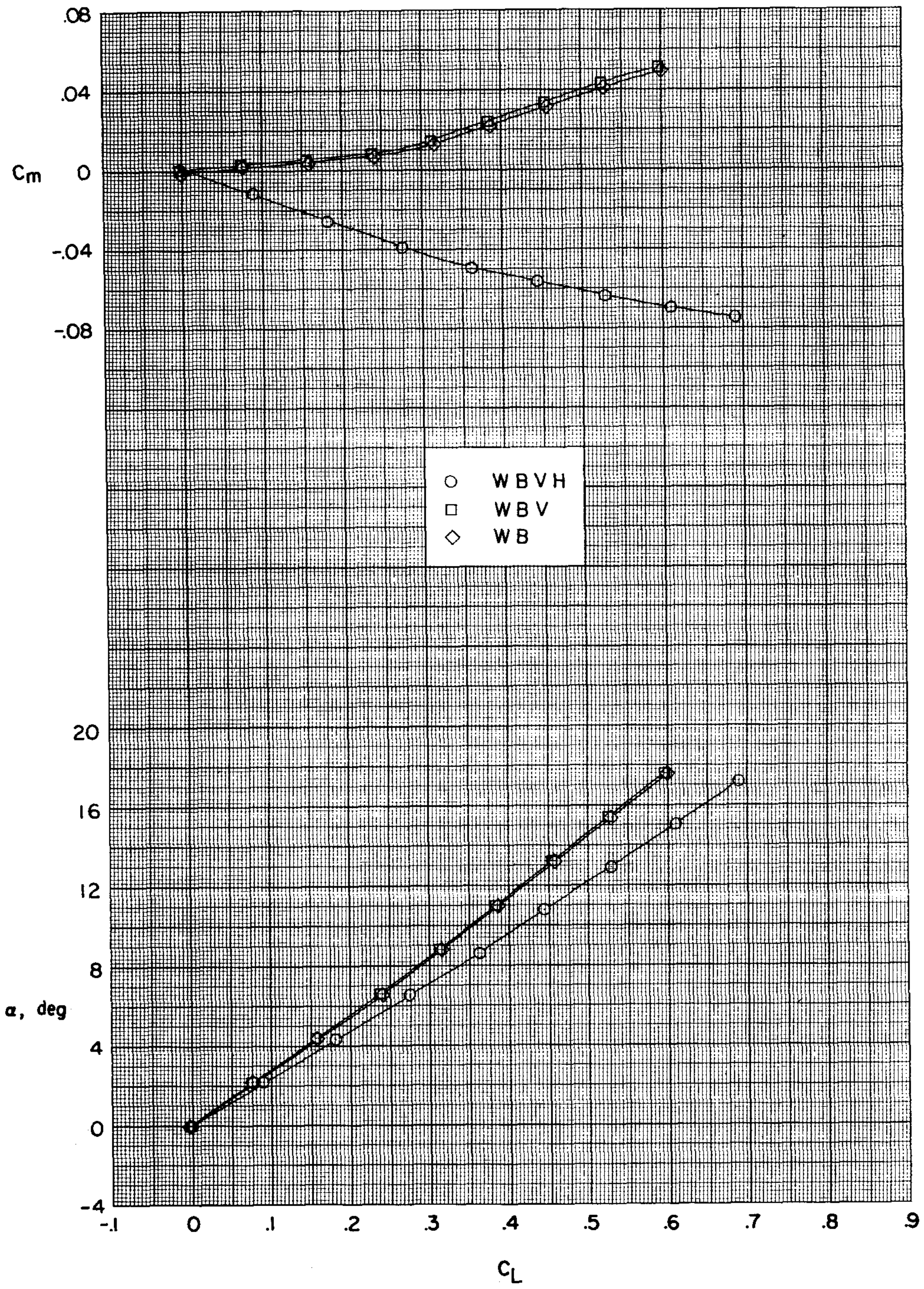

(a) C_m and α against C_L.

Figure 2.- Aerodynamic characteristics in pitch for various combinations of components. M = 2.01.

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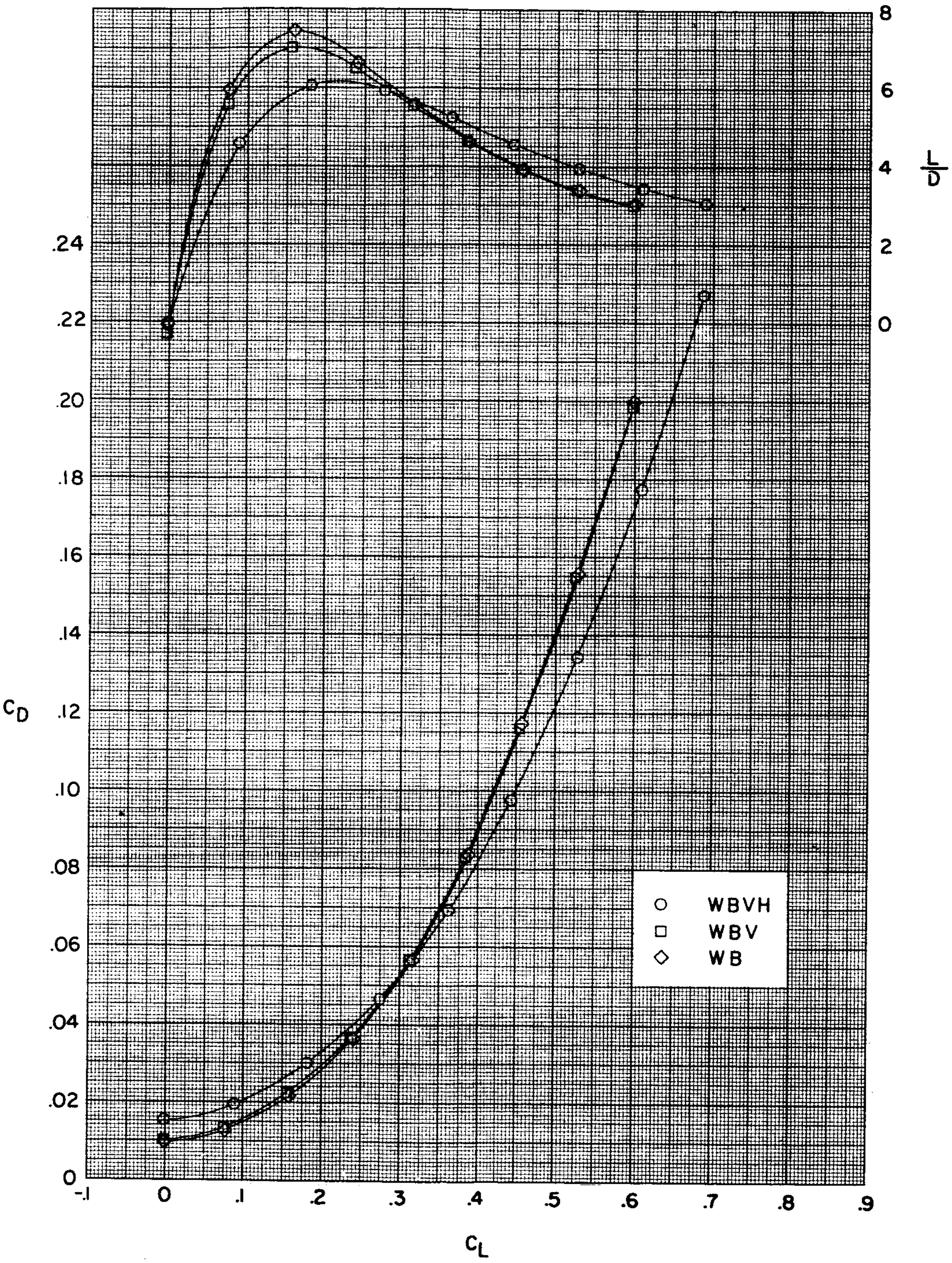

(b) $\frac{L}{D}$ and C_D against C_L.

Figure 2.- Concluded.

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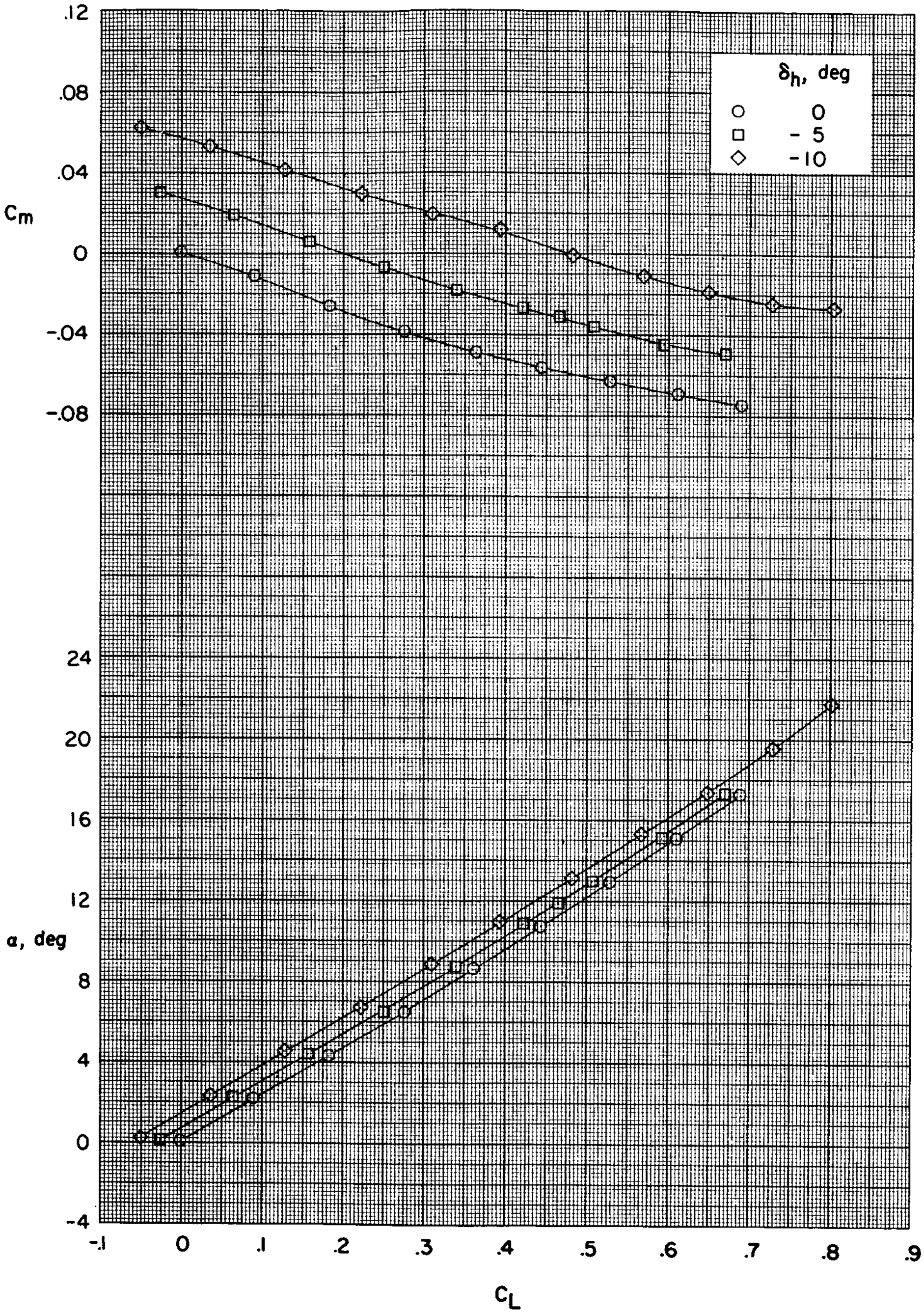

(a) C_m and α against C_L.

Figure 3.- Effect of horizontal-tail deflection on the aerodynamic characteristics in pitch for the complete configuration (WBVH). M = 2.01.

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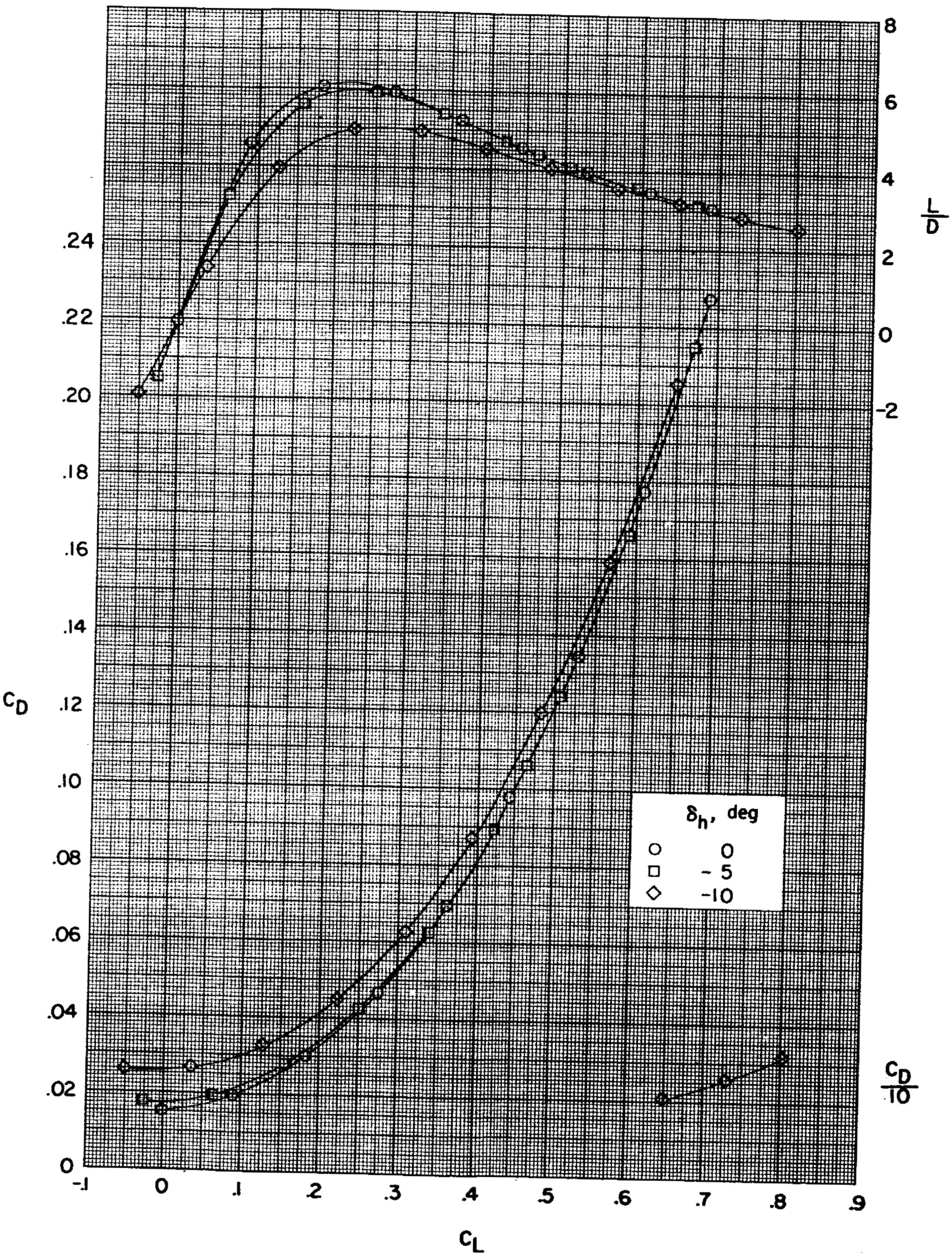

(b) $\frac{L}{D}$ and C_D against C_L.

Figure 3.- Concluded.

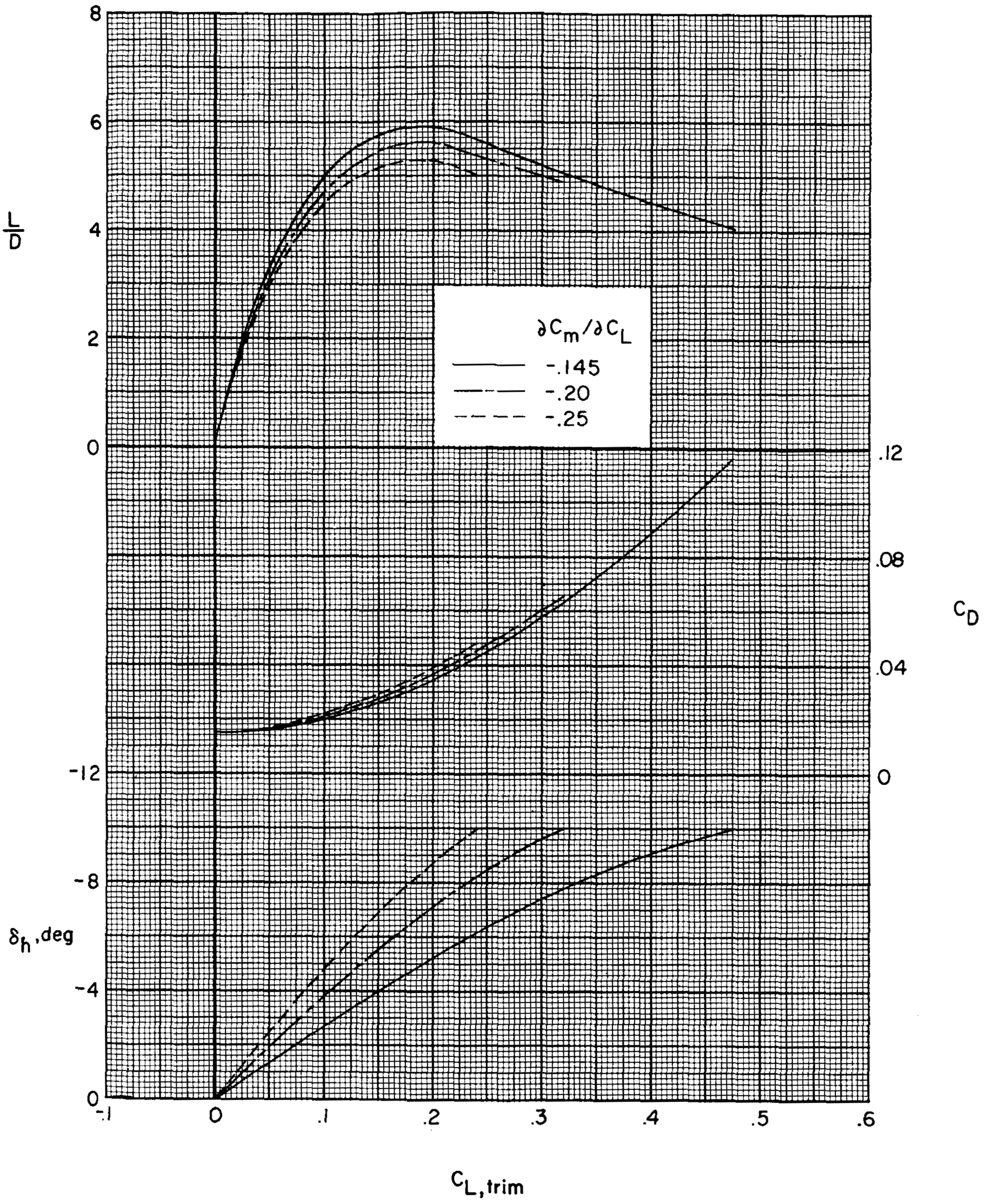

Figure 4.- Trimmed longitudinal-stability characteristics for various stability levels. Complete configuration; M = 2.01.

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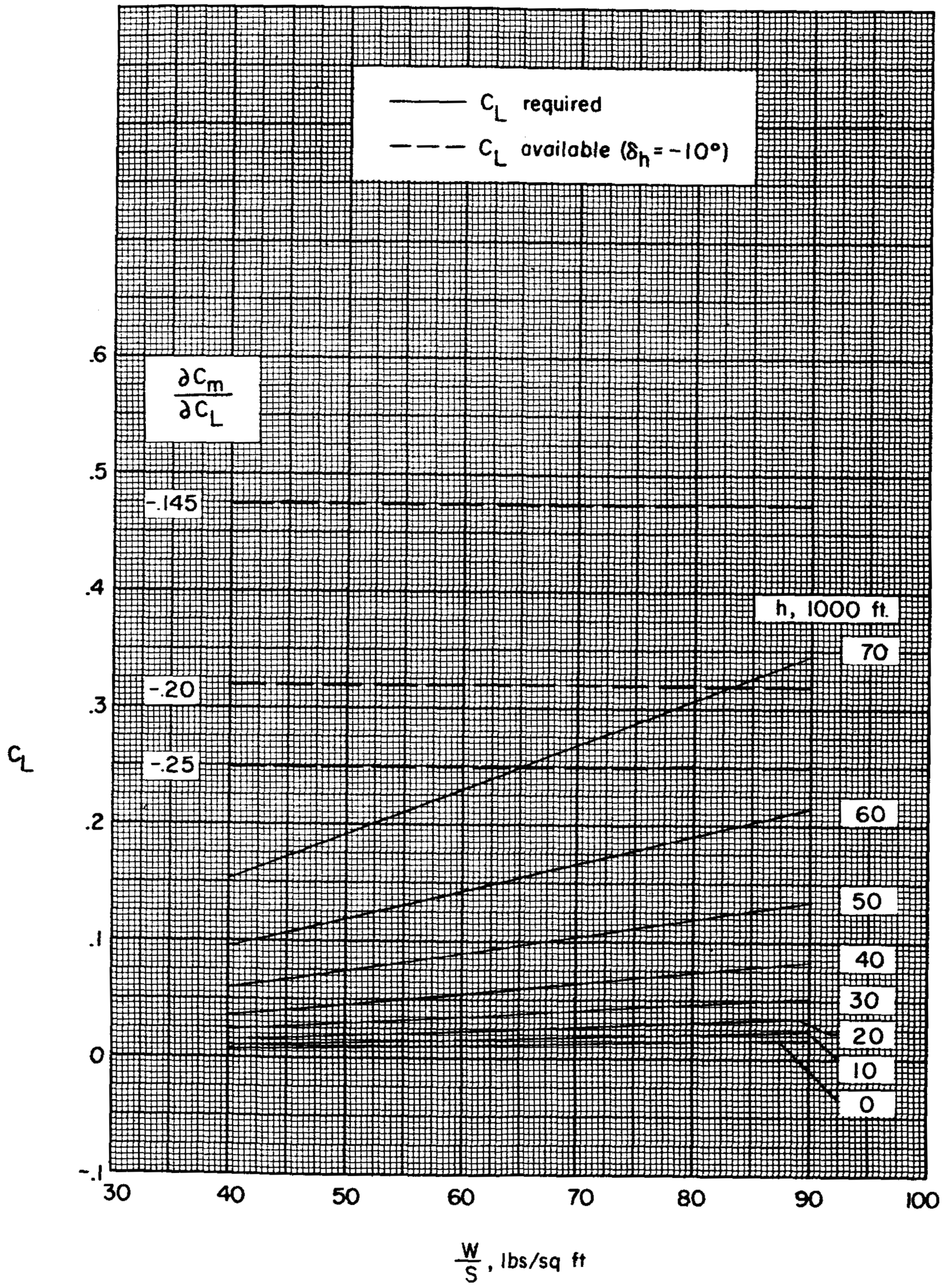

Figure 5.- Variation of the lift required with wing loading and altitude and the lift available with $\delta_h = -10^{\circ}$ for various stability levels. Complete configuration; M = 2.01.

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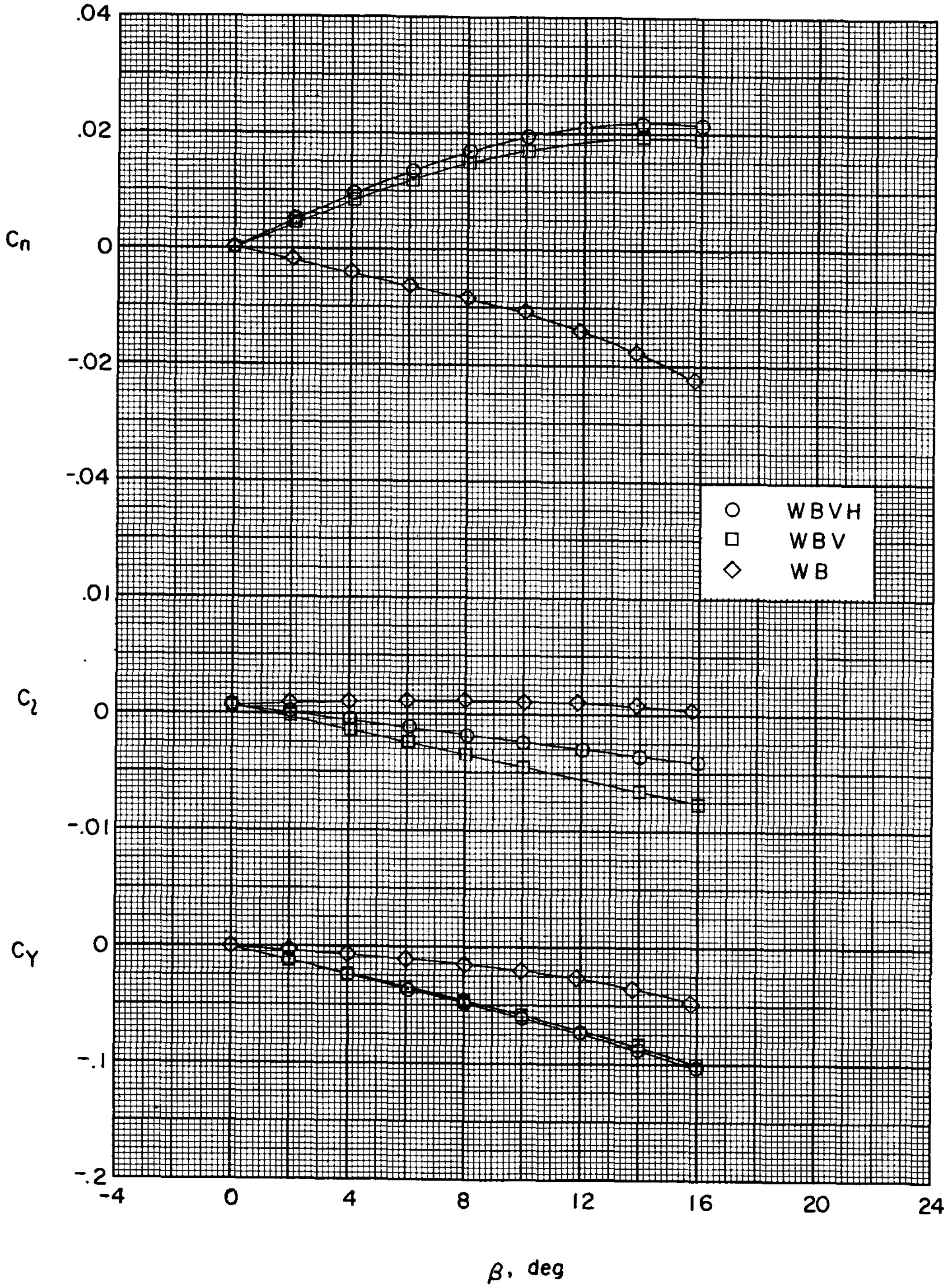

Figure 6.- Aerodynamic characteristics in sideslip for various combinations of components. $M = 2.01$; $\alpha = 0^{\circ}$.

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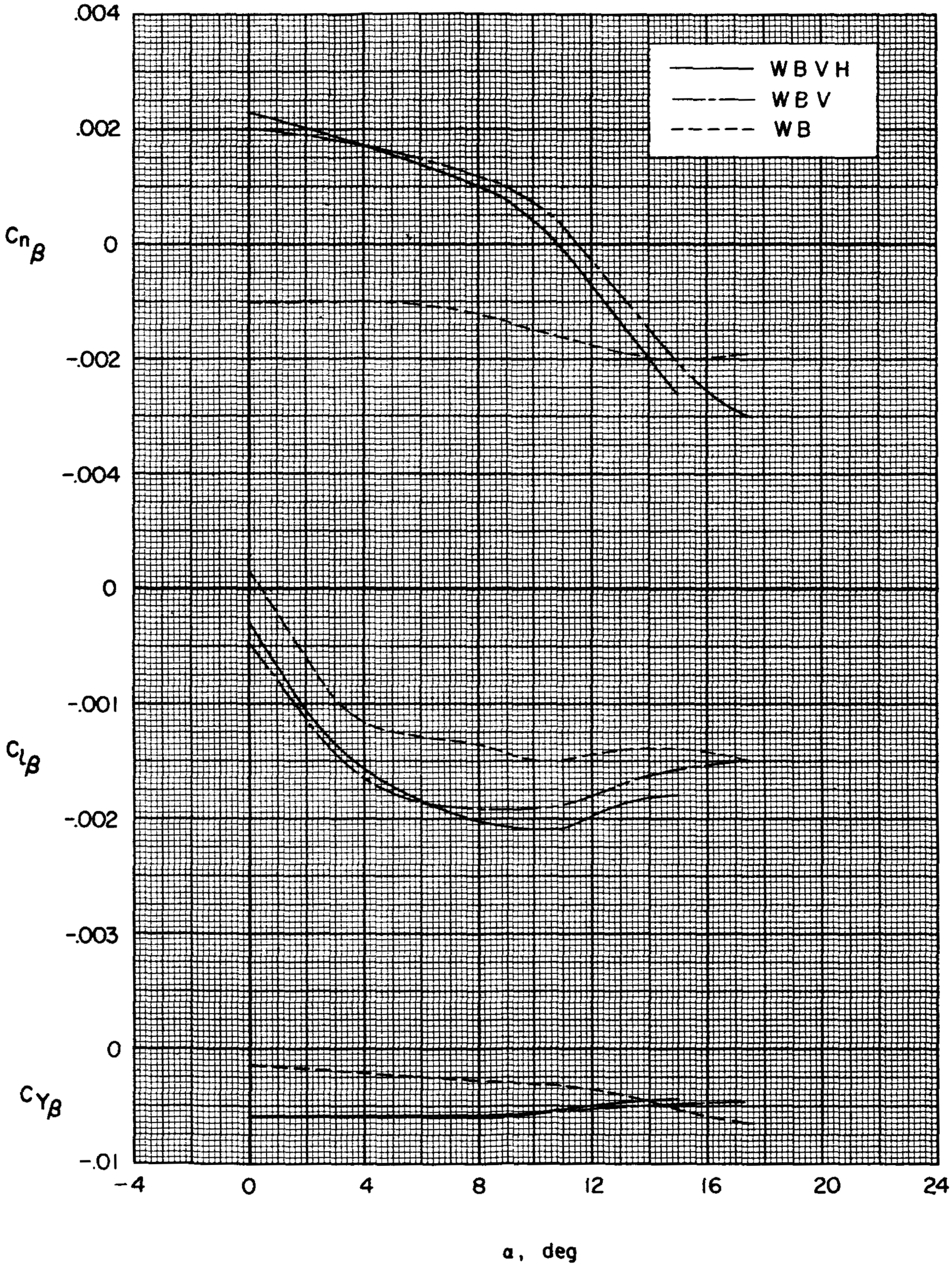

Figure 7.- Variation of sideslip derivatives with angle of attack for various combinations of components. M = 2.01.

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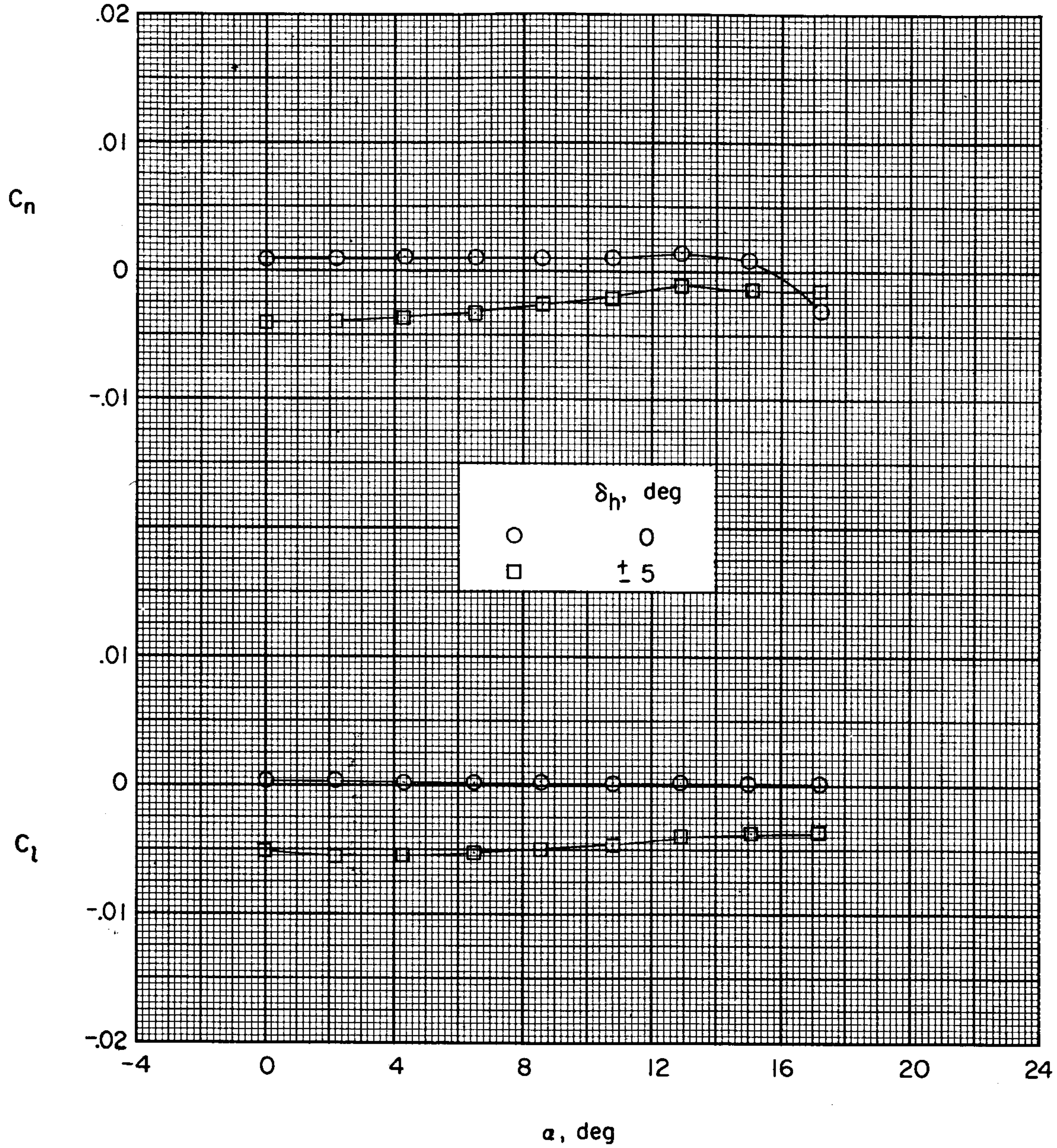

Figure 8.- Roll-control characteristics with differentially deflected horizontal tail. Complete configuration; M = 2.01.

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