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EFFECT OF SPEED BRAKES ON THE SUPERSONIC AERODYNAMIC CHARACTERISTICS OF A VARIABLE-SWEEP TACTICAL FIGHTER MODEL AT MACH NUMBERS FROM 1.60 TO 2.50

by Celia S. Richardson

Langley Research Center
Langley Station, Hampton, Va.

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SUMMARY

An investigation has been made in the Langley Unitary Plan wind tunnel to determine the effect of various speed-brake configurations on the aerodynamic characteristics of a current multimission tactical fighter model. The speed-brake configurations, which included ungapped and gapped brakes with variations in area, location, planform, and deflection angle, were tested at Mach numbers from 1.60 to 2.50 for a wing-leading-edge sweep angle of 72.5°. Tests were made through an angle-of-attack range from about -4° to 28° and at angles of sideslip from about -6° to 11°. The test Reynolds number was 3.0×10^6 per foot $(9.84 \times 10^6$ per meter).

The results indicated the drag values of a gapped and an ungapped brake configuration were about the same; even though the gapped speed brakes were somewhat smaller than the ungapped brakes.

The ungapped speed brakes generally increased the directional stability of the model. The gapped speed brakes generally reduced the directional stability of the model particularly at the higher test Mach numbers.

INTRODUCTION

The National Aeronautics and Space Administration is currently conducting wind-tunnel studies directed toward the development of a multimission, variable-sweep wing, tactical fighter aircraft for use by the military services. References 1 to 15 present some of the results of these studies.

The purpose of the current investigation is to determine the effectiveness of various speed-brake configurations and the effects of these brakes on the static stability and performance of the aircraft.

This report presents data for the wing-leading-edge sweep angle of 72.5° and shows the effects of variations in area, deflection angle, and location of the speed-brake configurations. The tests were performed at angles of attack from about -4° to 28° and at angles of sideslip from about -6° to 11°. The test Mach numbers ranged from 1.60 to 2.50, and the test Reynolds number was 3.0×10^{6} per foot (9.84×10^{6} per meter).

SYMBOLS

The results of this investigation are presented as force and moment coefficients, with the longitudinal characteristics referred to the stability-axis system and the lateral parameters referred to the body-axis system. The present data obtained for a wing-leading-edge sweepback of 72.5° are based on the wing geometry in a 16° sweepback position (see table I) in order to have them compatible with data from references 1 to 15.

b	wing span, inches (meters)
$\bar{c}$	wing mean aerodynamic chord, inches (meters)
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
$C_{D,b}$	duct-exit-plug base-drag coefficient, $\frac{\text{Duct-exit-plug base drag}}{qS}$
$C_{D,c}$	fuselage-chamber-drag coefficient, $\frac{\text{Chamber drag}}{qS}$
$C_{D,i}$	internal-drag coefficient for primary and secondary ducts, $\frac{\text{Internal drag}}{qS}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_{l_β}	effective-dihedral parameter, $\frac{\partial C_l}{\partial \beta}$, per degree
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS\bar{c}}$
$C_{m,o}$	pitching-moment coefficient at $C_L = 0$
C_{n_β}	directional-stability parameter, $\frac{\partial C_n}{\partial \beta}$, per degree
C_{Y_β}	side-force parameter, $\frac{\partial C_Y}{\partial \beta}$, per degree

L/D	lift-drag ratio
M	free-stream Mach number
p_t	stagnation pressure, pounds/inch^2 (newtons/meter^2)
q	free-stream dynamic pressure, pounds/foot^2 (newtons/meter^2)
r	radius of curvature, inches (meters)
S	wing area, feet^2 (meters^2)
T_t	stagnation temperature, degrees Fahrenheit (degrees Kelvin)
α	angle of attack of wing (wing reference chord at 1° incidence to water line), degrees
β	angle of sideslip of model center line, degrees
$\delta_{S.B.}$	speed-brake deflection angle referenced to model, degrees
Λ	wing-leading-edge sweep angle, degrees

Abbreviations:

B.L.	buttock line
H.L.	hinge line
S.B.	speed brake
Sta	fuselage station
W.L.	water line

APPARATUS AND TESTS

Tunnel

Tests were conducted in the low Mach number test section of the Langley Unitary Plan wind tunnel. This tunnel is a variable-pressure, continuous-flow tunnel having a test section approximately 4 feet square and 7 feet long (1.22 meters square and 2.13 meters long). The nozzle leading to the test section is of the asymmetric sliding-block type which permits a continuous variation in test-section Mach number from about 1.5 to 2.9.

Model

Details of the 1/24-scale model are shown in figure 1. Dimensional details are listed in table I. The model was a high-wing configuration with the wing at 1° incidence with respect to water lines and had a wing-glove fairing into the fuselage.

TABLE I.- GEOMETRIC CHARACTERISTICS OF MODEL

[All quantities are model scale and are based on $\Lambda = 16^{\circ}$]

Wing area, S	0.911 ft^2	(0.085 m^2)
Wing span, b	31.500 in.	(80.010 cm)
Wing mean aerodynamic chord, $\bar{c}$	4.521 in.	(11.483 cm)
Fuselage chamber area	0.012531 ft^2	(11.64 cm^2)
Duct-inlet area (one side)	0.012945 ft^2	(12.03 cm^2)
Duct-exit area (one side)	0.014142 ft^2	(13.15 cm^2)
Duct-exit-plug base area	0.016433 ft^2	(15.27 cm^2)
Duct-exit angle with respect to wing reference line		$-4^{\circ}32'$

The speed brakes investigated were of two types, gapped and ungapped, and were positioned on the under side of the fuselage. The details of the speed brakes are shown in figure 2. The D_{8e} and D_{8f} speed brakes (fig. 2(a)) represent 25 percent and 40 percent increases in planform area to the D_8 speed brake while maintaining the basic shape of the D_8. The D_{11} speed brake (fig. 2(b)) has a 1-inch (2.54-cm) gap at the hinge line, and the D_{11}^{a} is the D_{11} configuration mounted 4.437 inches (11.27 cm) aft of the D_{11} location. The D_{13} is a T-shaped gapped configuration having about the same area as D_{11} and is located 4.696 inches (11.93 cm) aft of the D_{11} location.

In order to relate this report with references 1 to 15, the following table of model component designations is provided:

Component	Designation
Body	B_{42}
Wing glove	G_{17}
Wing	W_{29}
Horizontal tail	H_{13}
Vertical tail	V_{38}
Inlet spike	I_{43}
Nozzle	N_{32}
Ventral fin (twin)	V_{29}
Dorsal fairing	X_{25}
Ungapped speed brakes	D_8, D_{8e}, D_{8f}
Gapped speed brakes	D_{11}, D_{11}^{a}, D_{13}

Note: For the present report, the basic configuration is $B_{42}G_{17}H_{13}I_{43}N_{32}V_{29}V_{38}W_{29}X_{25}$.

Test Conditions

The following table presents the conditions at which the tests were performed:

M	T_t		p_t		Reynolds number	
	°F	°K	lb/in^2 abs	kN/m^2	per foot	per meter
1.60	150	338	11.89	81.98	3.0×10^6	9.8×10^6
2.16	150	338	14.87	102.52	3.0	9.8
2.50	150	338	17.61	121.42	3.0	9.8

The dewpoint, measured at stagnation pressure, was maintained below -30° F (239° K) for all tests in order to assure negligible condensation effects.

All configurations incorporated 1/16-inch-wide (0.159-cm-wide) transition strips composed of No. 80 carborundum grit (nominal diameter of 0.008 in. (0.20 mm)) embedded in acrylic plastic. These strips were located 1/2 inch (1.27 cm) rearward (streamwise) on the wing, wing glove, horizontal and vertical tails, and ventral fins. In addition, a 1/16-inch-wide (0.159-cm-wide) transition band was placed 1 inch (2.54 cm) rearward around the model nose.

Measurements

Aerodynamic forces and moments were measured by means of a six-component electrical strain-gage balance housed within the model. The balance in turn was rigidly fastened to a sting-support system. Fuselage chamber pressures and duct-exit-plug base pressures were measured by means of single static orifices located in the balance cavity and at the duct-exit-plug base, respectively.

Corrections

Angles of attack and sideslip have been corrected for both tunnel-flow angularities and deflection of sting and balance caused by aerodynamic loads. The drag data have been adjusted to a condition of free-stream static pressure acting over the fuselage and duct-exit-plug bases. In addition, the drag data have been adjusted to zero momentum and pressure losses at the duct exits. Typical values of these corrections are presented in figure 3.

PRESENTATION OF RESULTS

The results of this investigation are presented in the following figures:

RESULTS AND DISCUSSION

Longitudinal Characteristics

The aerodynamic characteristics in pitch for the various speed-brake configurations are presented in figures 4 and 5.

In comparison with the basic model (speed brakes retracted) all of the D_8-type speed-brake configurations caused large increases in minimum drag and corresponding decreases in $(L/D)_{max}$ (fig. 4). The addition of the basic speed brake D_8, at a deflection angle of 50°, more than doubled the minimum drag of the basic model at all Mach numbers. Increases in the area or deflection angle of the speed brake produced an expected increase in minimum drag over the minimum drag values obtained with the D_8 brake configuration at $\delta_{S.B.} = 50^{\circ}$. For example, the configuration with the D_{8f} speed brake, which is the D_8 with 40 percent additional area, caused a 25 percent increase in minimum drag over that obtained for a similar deflection of the D_8 brake. At a deflection angle of 77°, the D_{8f} configuration produced minimum drag approximately $3\frac{1}{2}$ times greater than that for the basic model.

Deflection of the ungapped speed brakes generally caused an increase in $C_{m,o}$ for the aircraft throughout the test Mach number range.

Deflecting the speed brakes caused a slight decrease in the lift-curve slope over that for the basic model. Increasing the area of the speed brakes, or increasing the deflection angle, caused a further decrease in the lift-curve slope. The linearity of the lift and pitching-moment curves was not materially affected by the addition of speed brakes to the model.

The results in figure 5 indicate that the D_{11}, D_{11}^{a}, and D_{13} speed brakes, at each of the deflection angles, produce effects on the aerodynamic characteristics in pitch of the model that are generally similar to those obtained with the D_8-type speed brakes.

The D_{11} speed brake, deflected 77°, provided the largest increase in minimum drag and gave about the same minimum drag values as that obtained with the D_{8f} brake deflected 77°. Moving the D_{11} aft 4.437 inches (11.27 cm), which is the D_{11}^{a} configuration, yields drag results comparable to those for the D_{11} speed brake.

The T-shaped D_{13} brake, which has an area comparable to the D_{11} and is located 0.259 inch (0.66 cm) further aft than the D_{11}^{a}, had slightly less drag than the D_{11}^{a} at all three Mach numbers.

At the two higher Mach numbers, the D_{11}^{a} and the D_{13} brakes reduced the $C_{m,o}$ of the basic model. At all Mach numbers, the D_{11} produced slight increases in the basic model $C_{m,o}$ values.

The D_{8f} and the D_{11} speed brakes are located at approximately the same position on the fuselage and are the most effective brakes for increasing the minimum drag of the basic model throughout the test Mach number range. The drag values of the D_{8f} configuration and the D_{11} configuration are about the same; however, the D_{11} speed brake is somewhat smaller than the D_{8f} and thus indicates increased braking effectiveness for the gapped brakes.

Lateral Characteristics

The lateral aerodynamic characteristics of the model with the various speed-brake configurations are presented in figures 6 and 7.

All the D_8 series of speed-brake configurations were directionally stable and, with the exception of the D_8 brake deflected 50°, produced an increase in the directional stability at the higher angles of attack over that for the basic model. The D_8 configuration at the 50° deflection angle had less directional stability than the basic model at all test Mach numbers and was only marginally stable at $M = 2.50$.

Each of the D_8-type speed-brake configurations resulted in a positive effective dihedral for the model. At $M = 1.60$, above angles of attack of 6°, all the ungapped speed brakes slightly reduced the positive effective dihedral of the basic model. At the higher Mach numbers, throughout the angle-of-attack range, the positive effective dihedral was increased over that for the basic model.

The data in figure 7 show that with the exception of the D_{11} configuration at $M = 1.60$ and a deflection angle of 77°, these speed-brake configurations generally have an adverse effect on the directional stability of the model.

All the gapped speed-brake configurations, except the D_{11} at the higher angles of attack at $M = 1.60$, resulted in an increase in positive effective dihedral.

In comparison, the D_8-type speed brakes generally increase the directional stability of the model; whereas, the D_{11}- or D_{13}-type speed brakes generally reduced the directional stability of the model, particularly at the higher test Mach numbers.

CONCLUSIONS

An investigation has been conducted to determine the effects of various speed-brake configurations on the aerodynamic characteristics of a current multimission tactical fighter model. Tests at Mach numbers from 1.60 to 2.50 indicate the following conclusions:

1. The drag values for a gapped and an ungapped brake configuration were about the same; even though the gapped speed brakes were somewhat smaller than the ungapped brakes.

2. The ungapped speed brakes generally increased the directional stability of the model; whereas, the gapped-type speed brakes generally reduced the directional stability of the model particularly at the higher test Mach numbers.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., February 6, 1968,
126-13-02-20-23.

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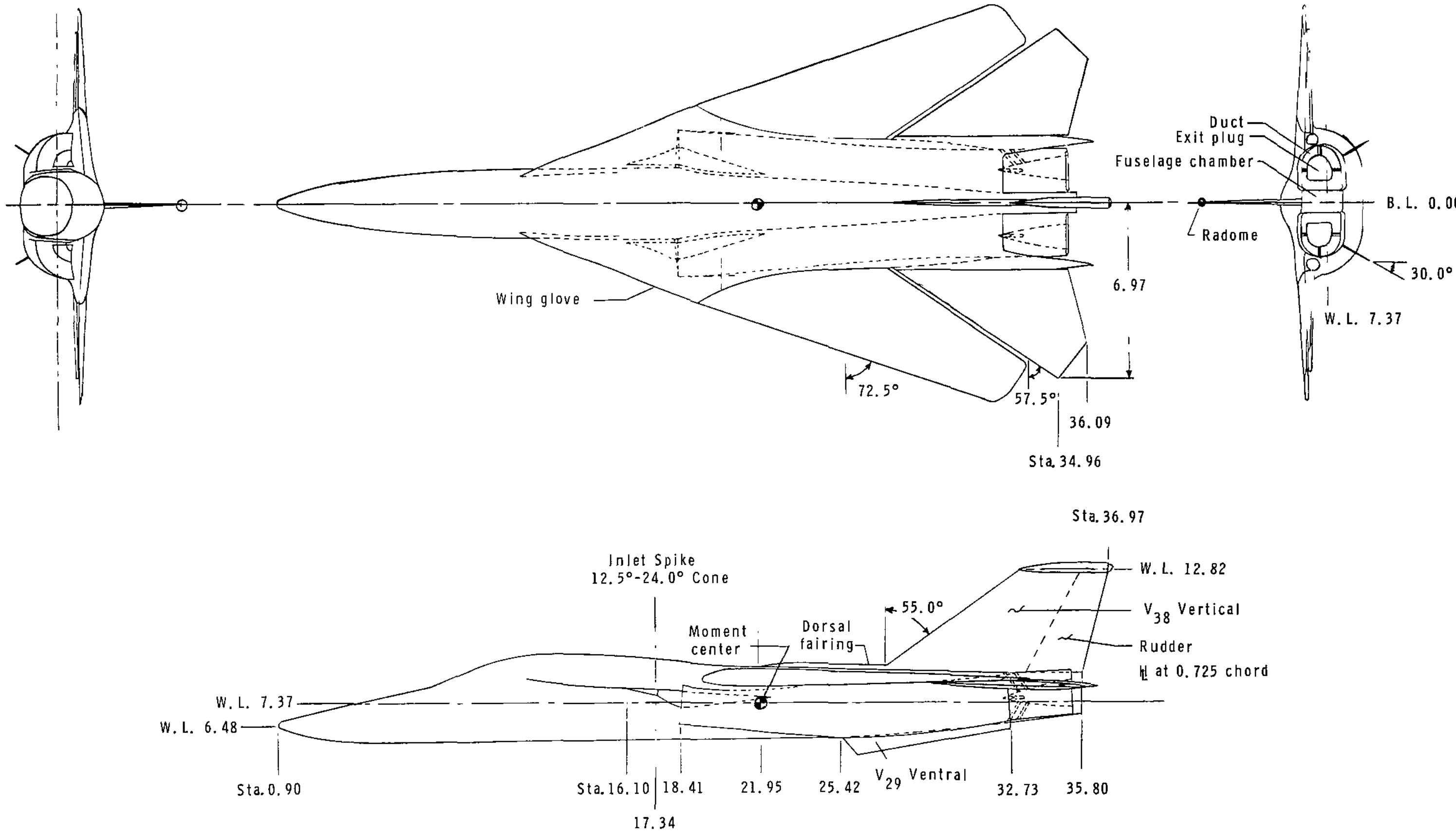
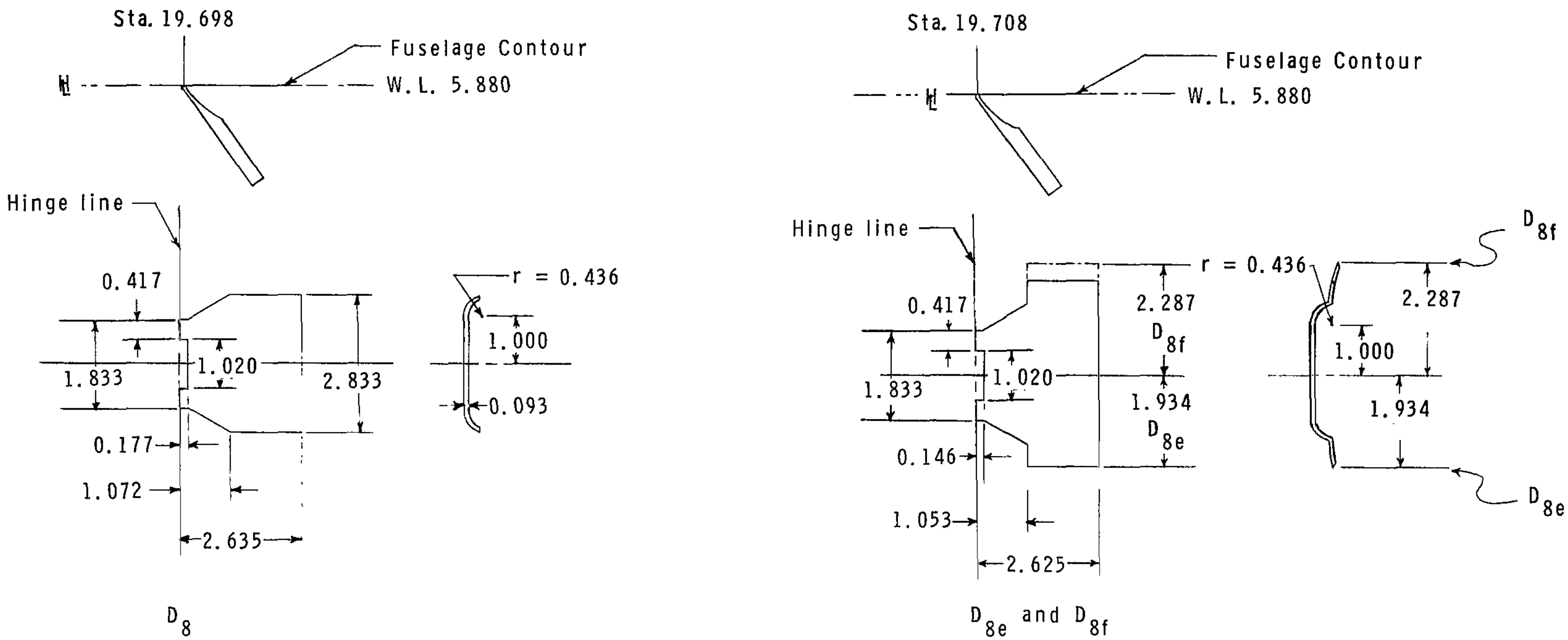
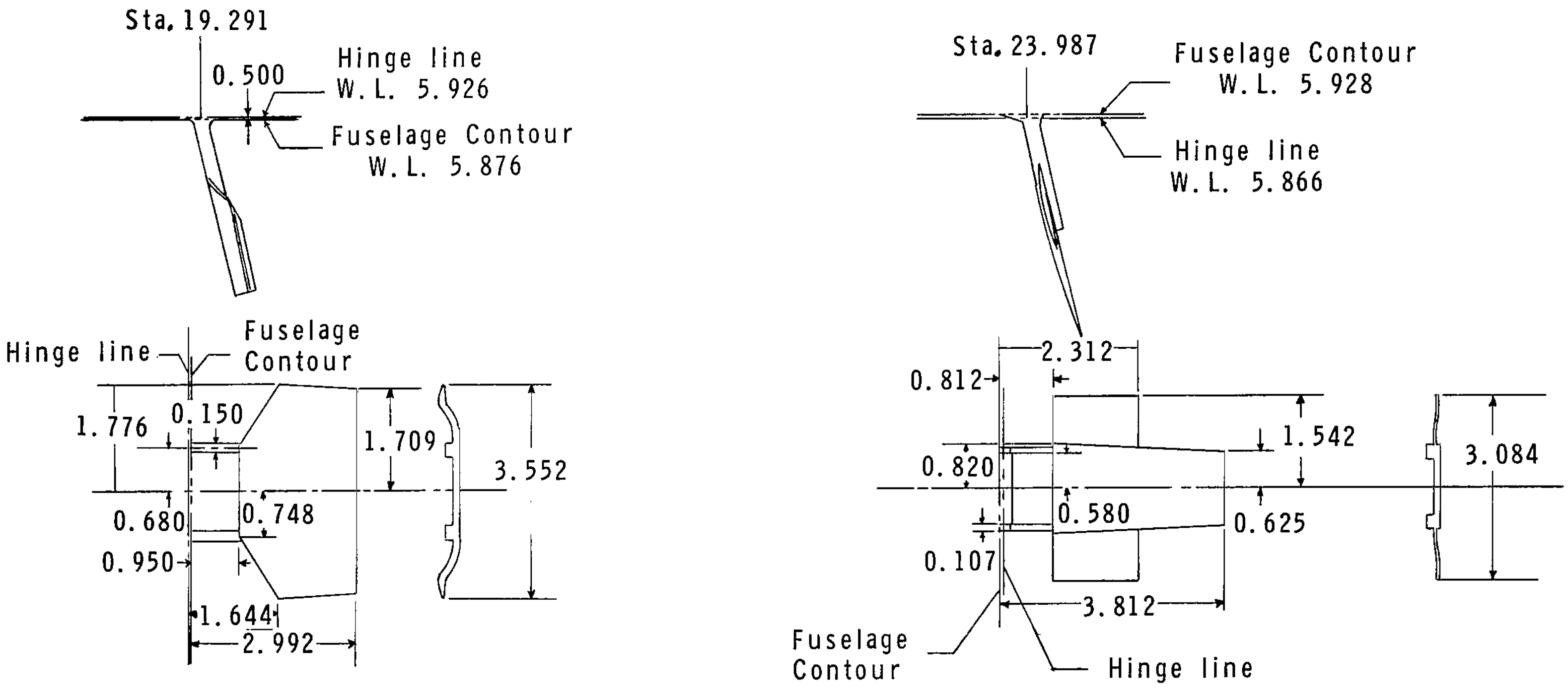


Figure 1.- Model details. (All dimensions are in inches unless otherwise noted; 1 in. = 2.54 cm.)



(a) Ungapped speed brakes.

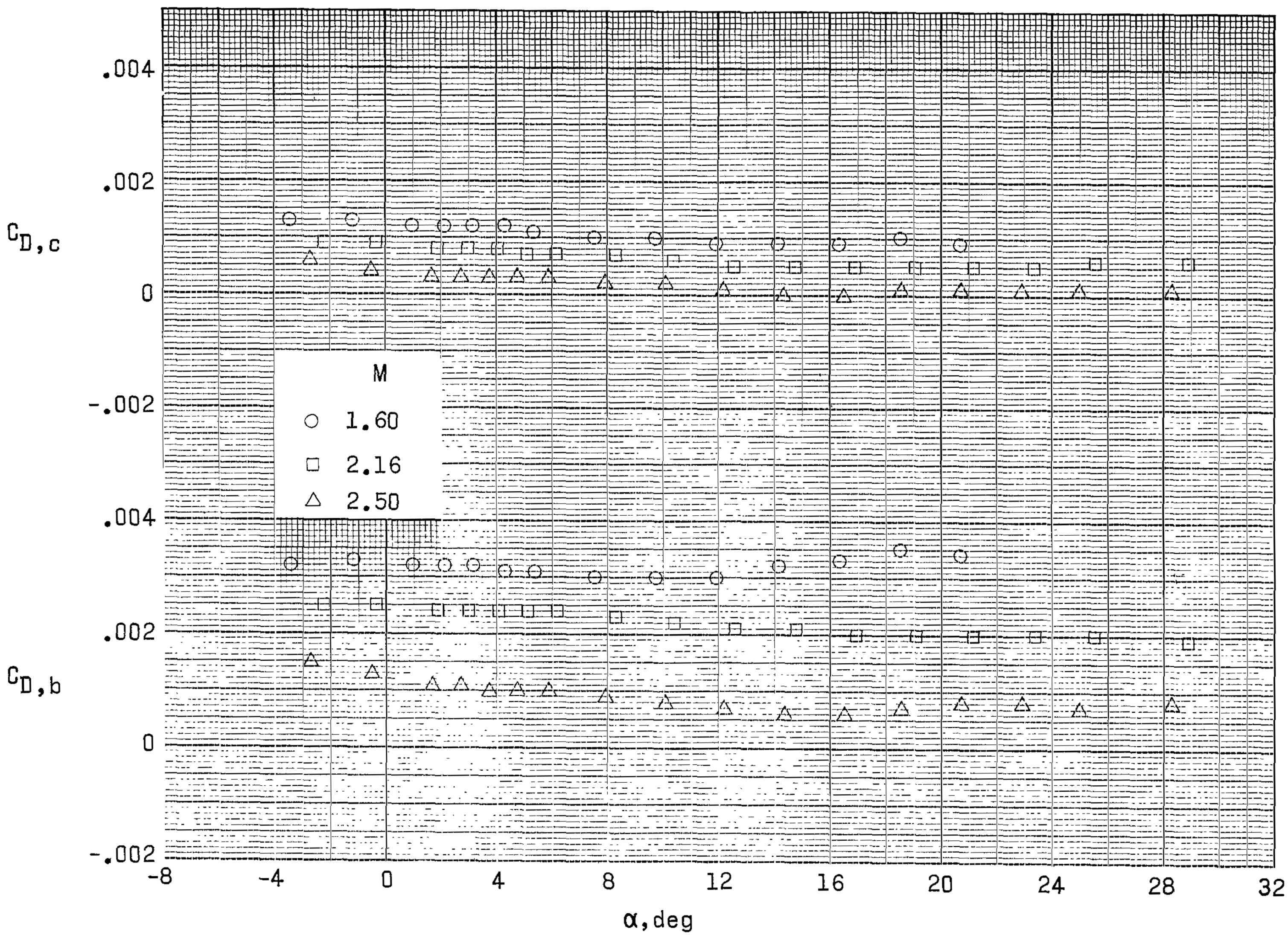
Figure 2.- Speed brake details. (All dimensions are in inches unless otherwise noted; 1 in. = 2.54 cm.)



D_{11} D_{13}

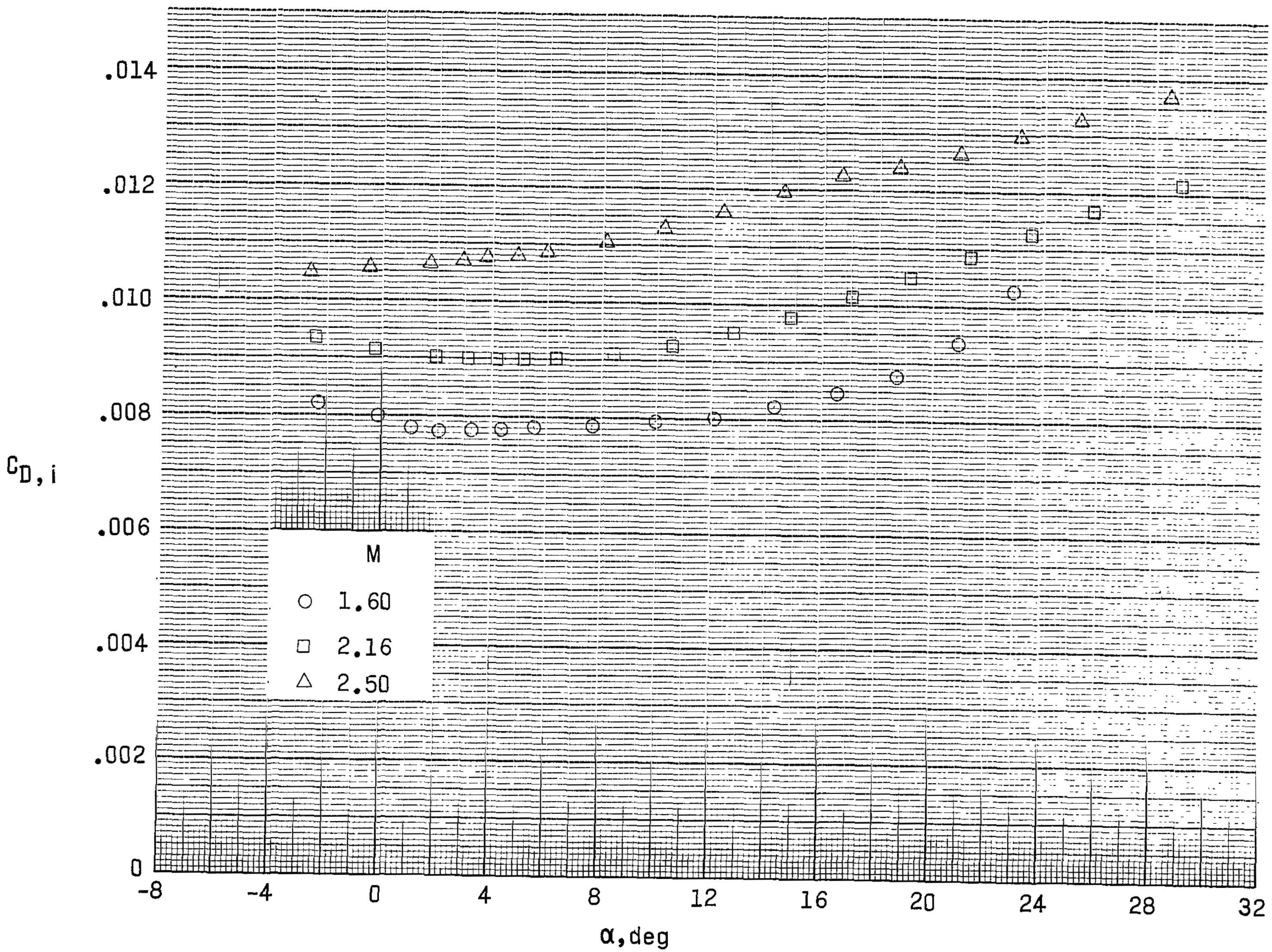
(b) Gapped speed brakes.

Figure 2.- Concluded.



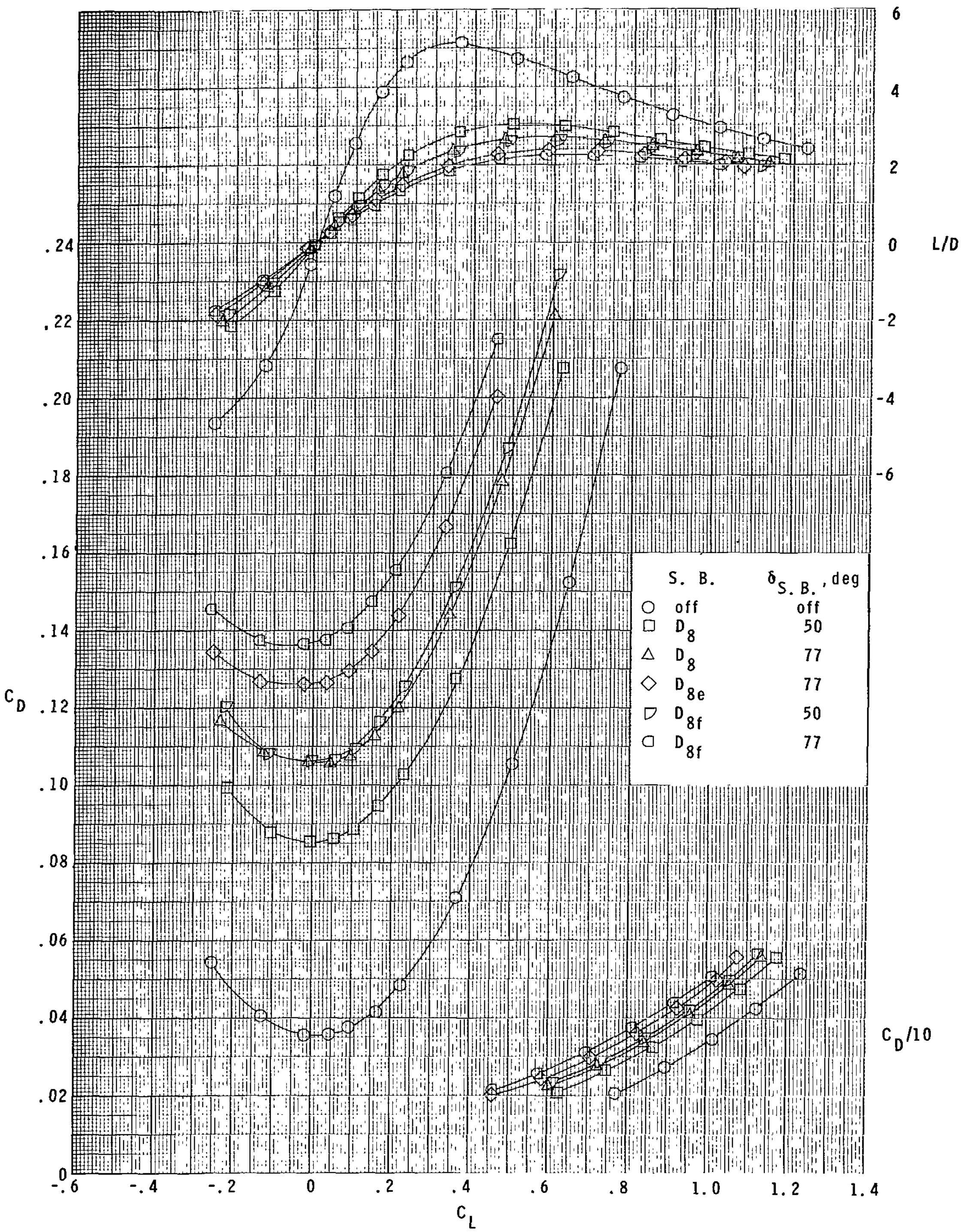
(a) Base- and chamber-drag coefficients.

Figure 3.- Typical values of base-, chamber-, and internal-drag coefficients.



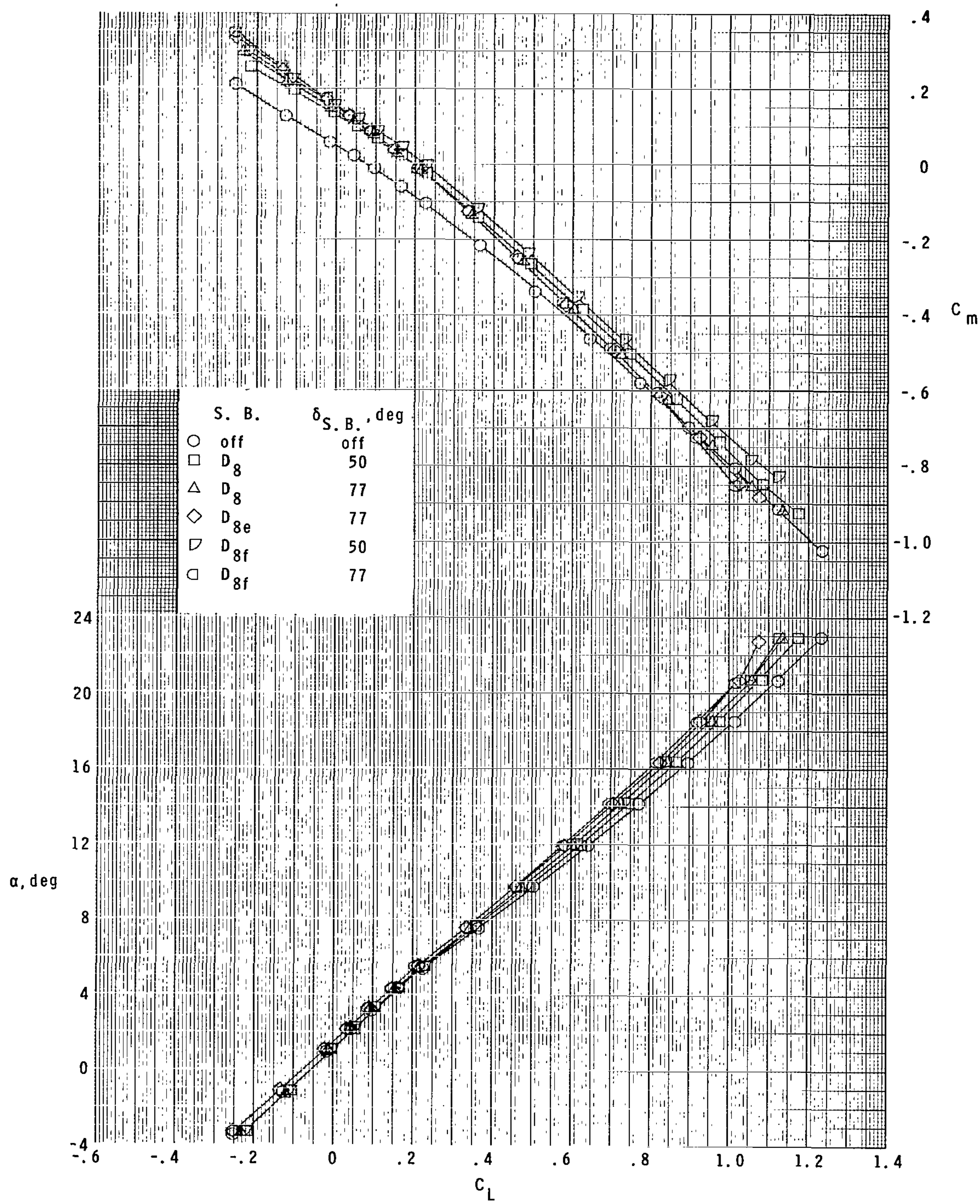
(b) Internal-drag coefficients.

Figure 3.- Concluded.



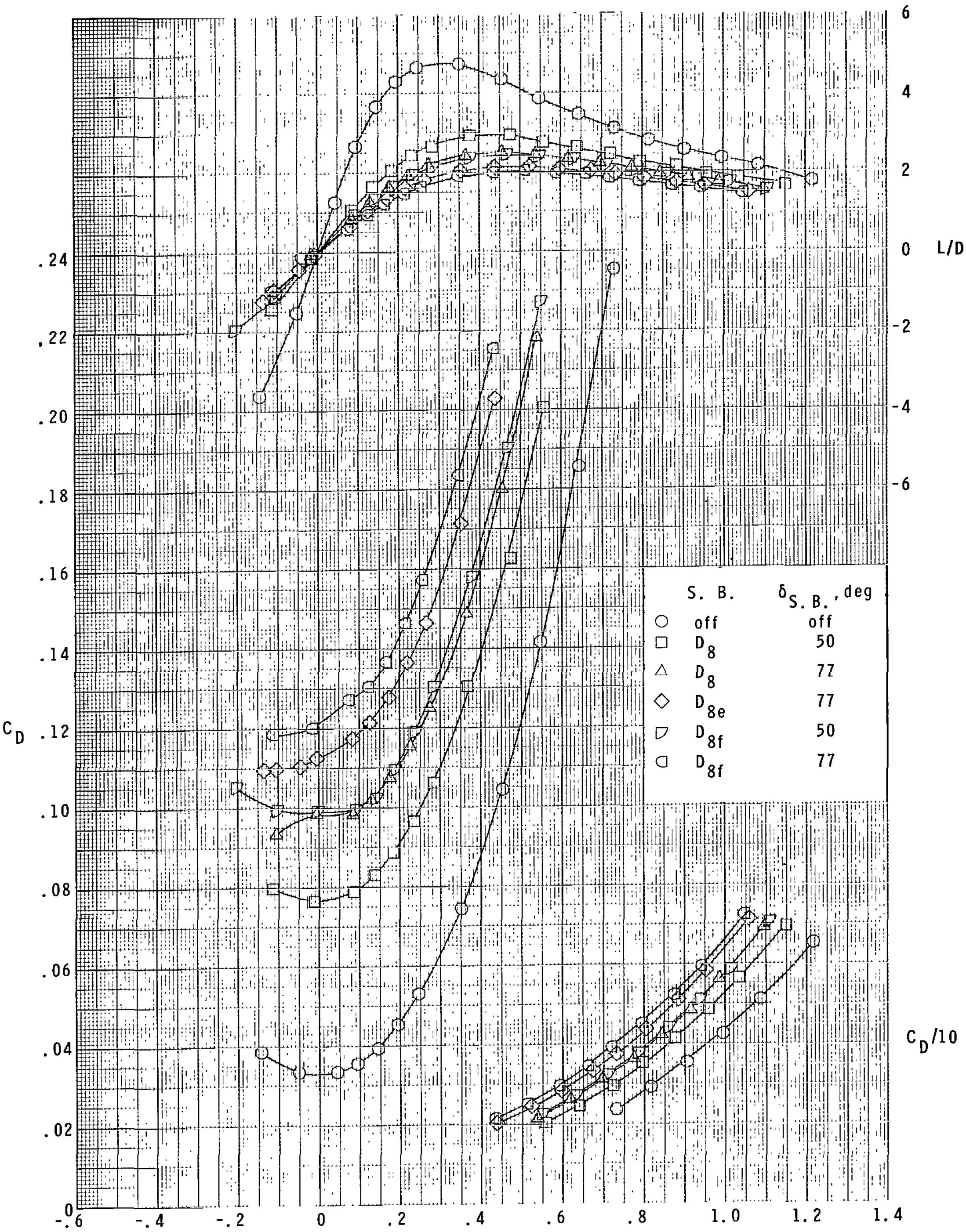
(a) M = 1.60.

Figure 4.- Effect of D_8, D_{8e}, and D_{8f} speed brakes on the aerodynamic characteristics of the model in pitch.



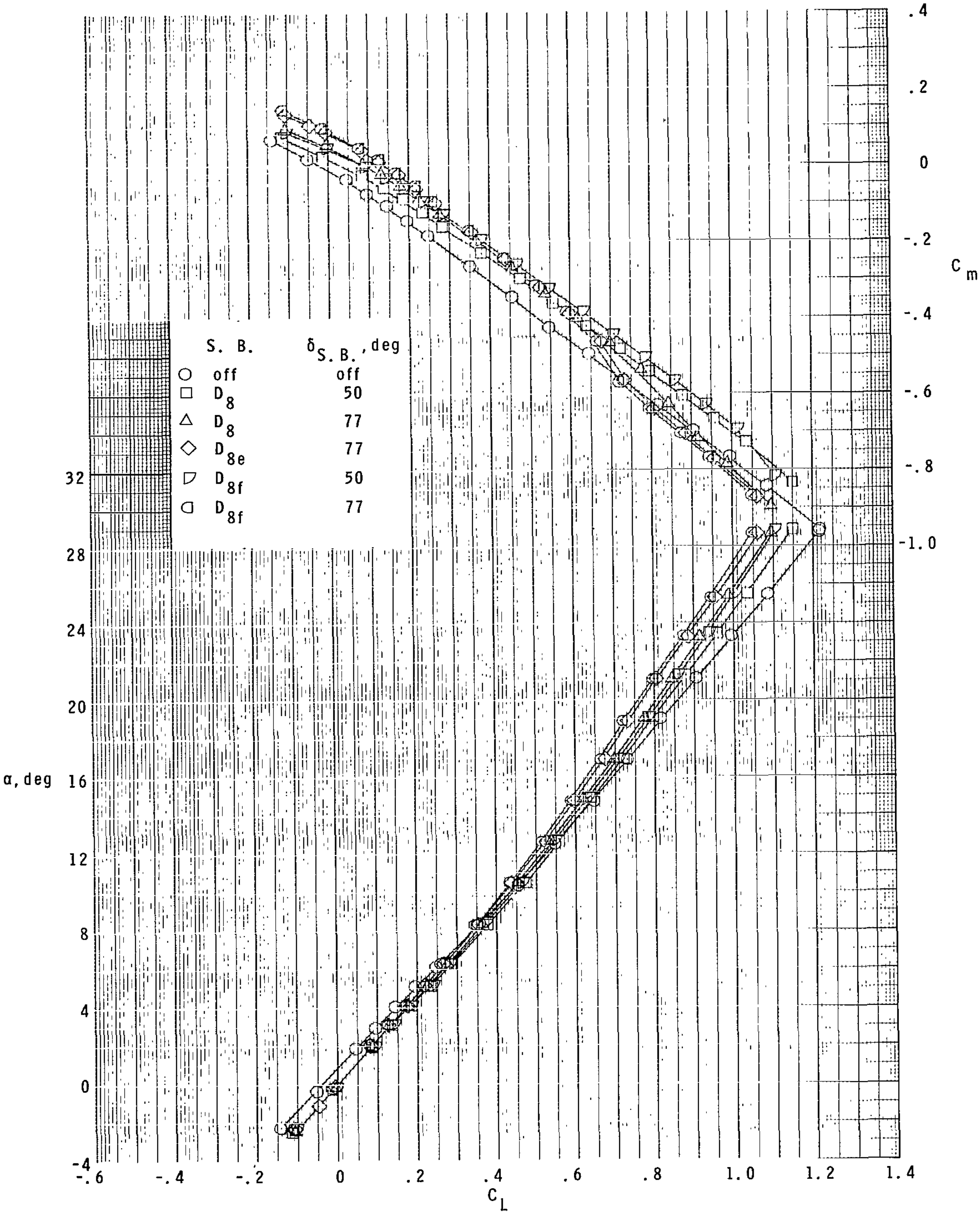
(a) Concluded.

Figure 4.- Continued.



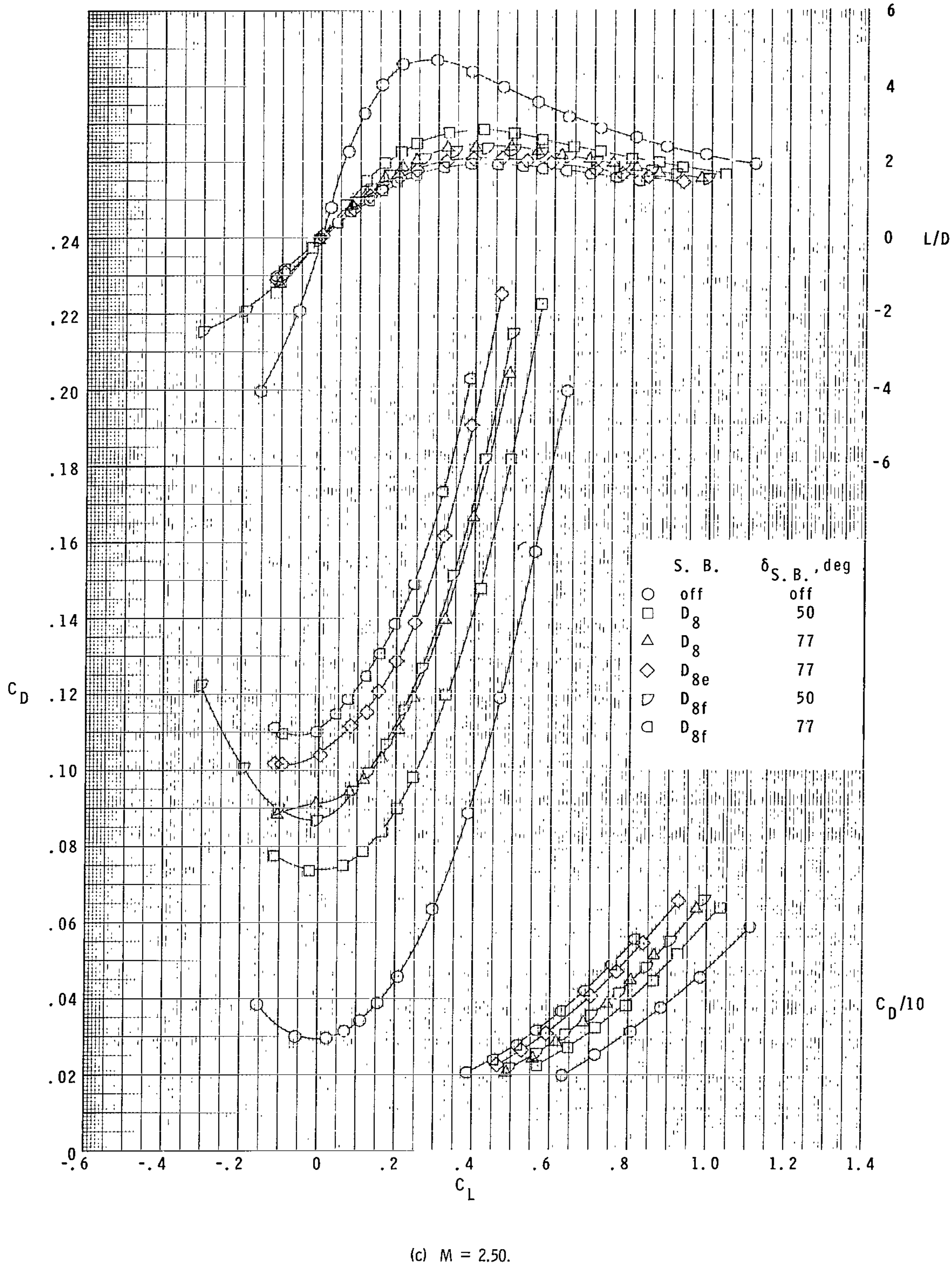
(b) M = 2.16.

Figure 4.- Continued.



(b) Concluded.

Figure 4.- Continued.



(c) M = 2.50.

Figure 4.- Continued.

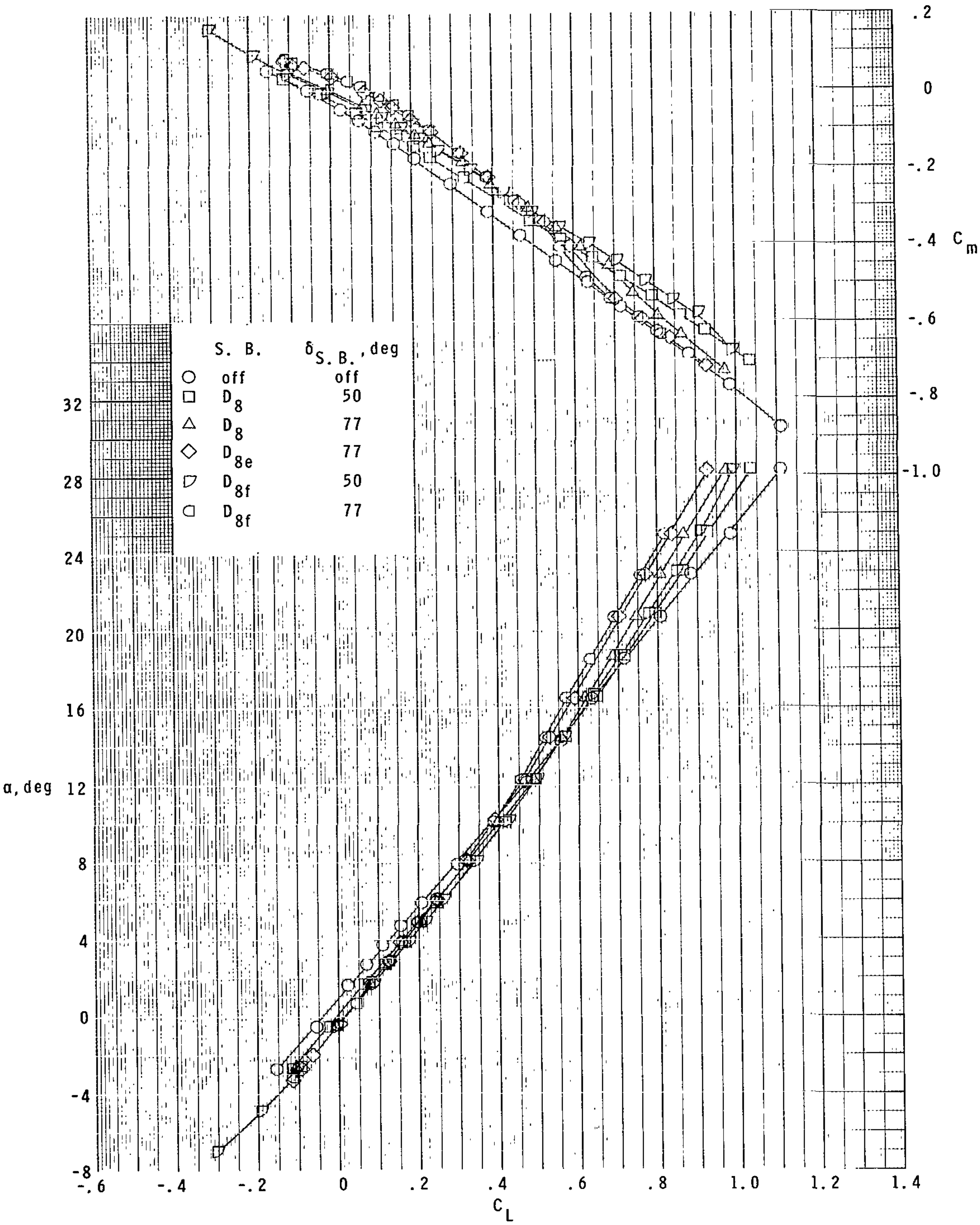


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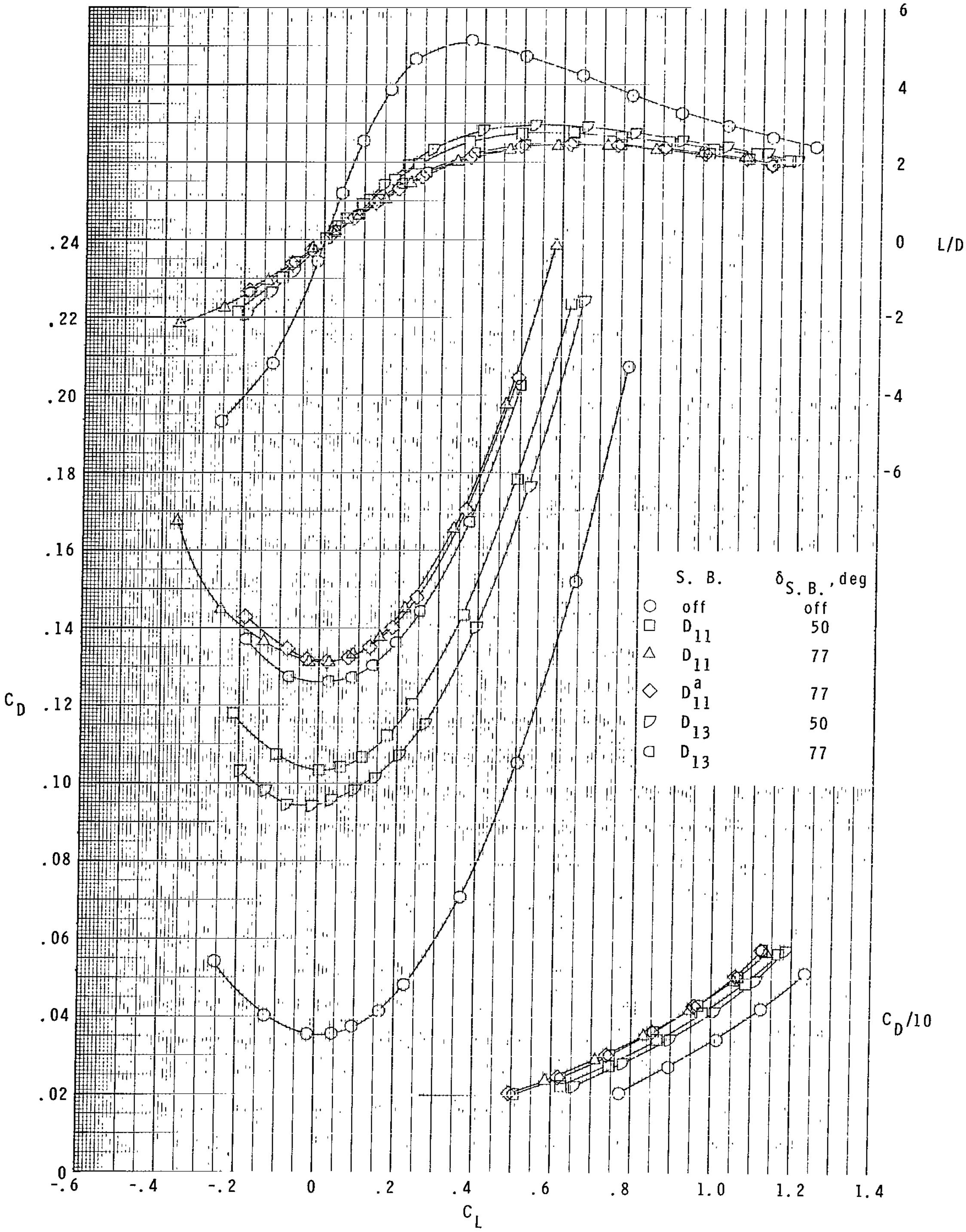
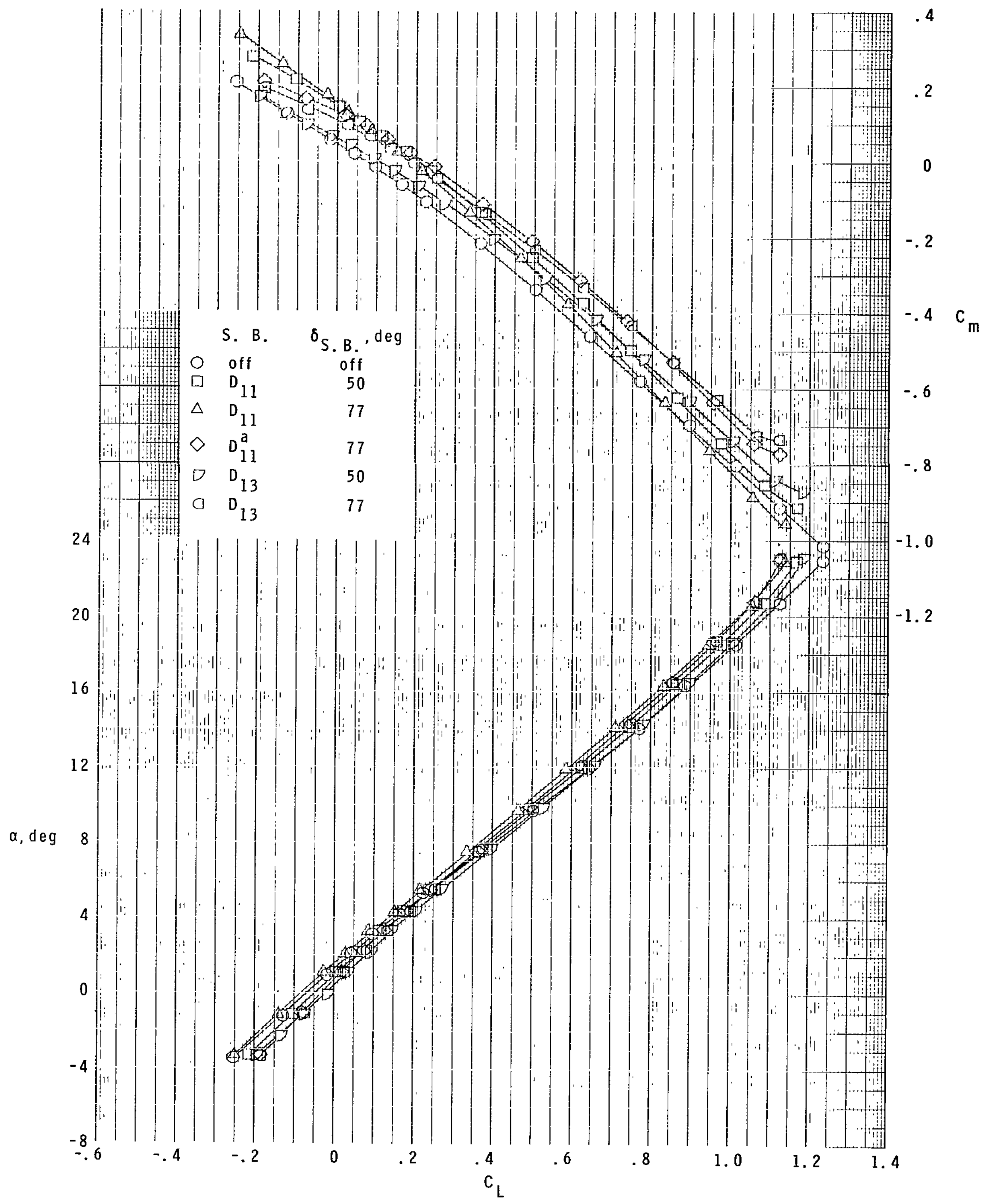
Figure 4.- Concluded.



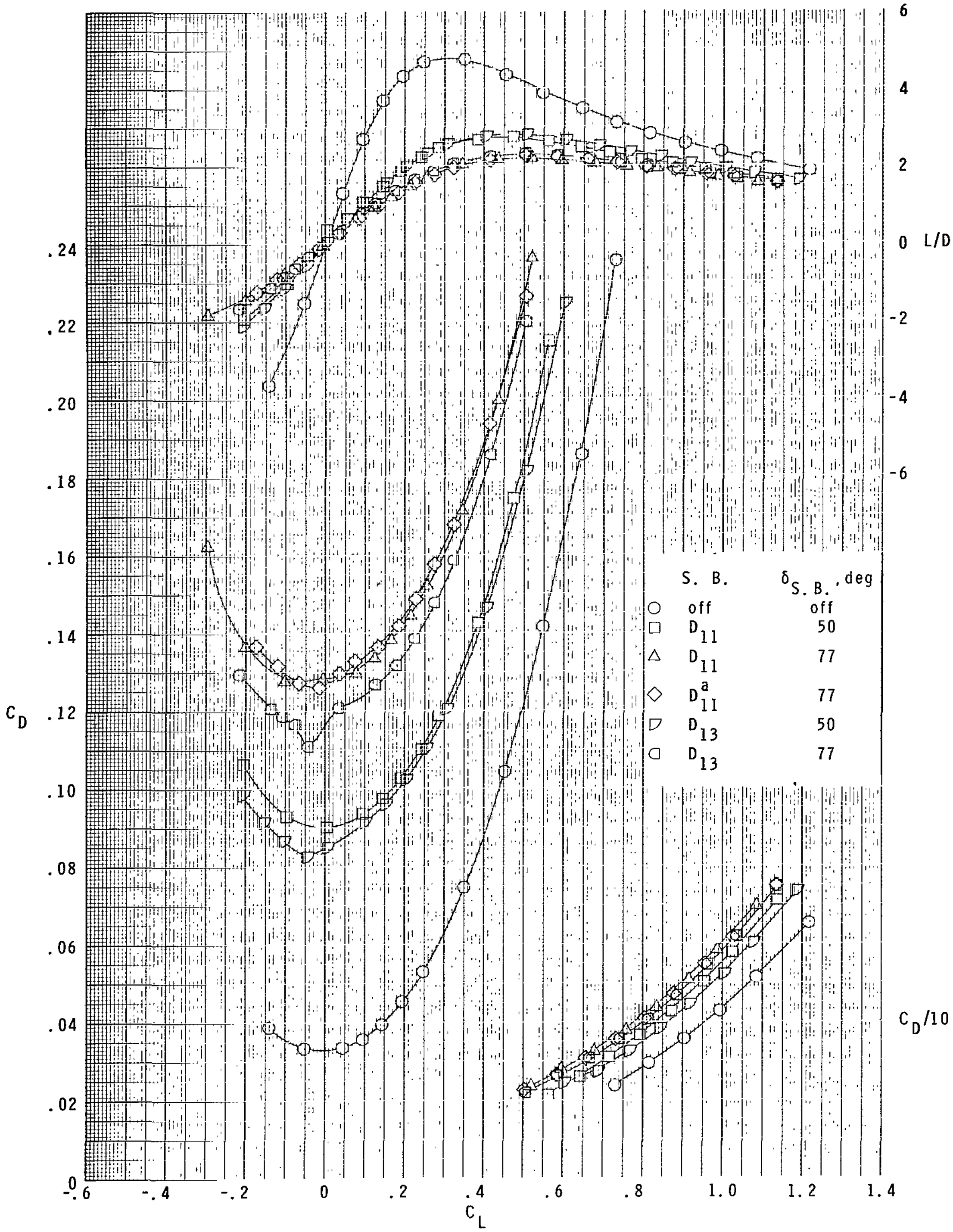
(a) M = 1.60.

Figure 5.- Effect of D_{11}, D_{11}^a, and D_{13} speed brakes on the aerodynamic characteristics of the model in pitch.



(a) Concluded.

Figure 5.- Continued.



(b) M = 2.16.

Figure 5.- Continued.

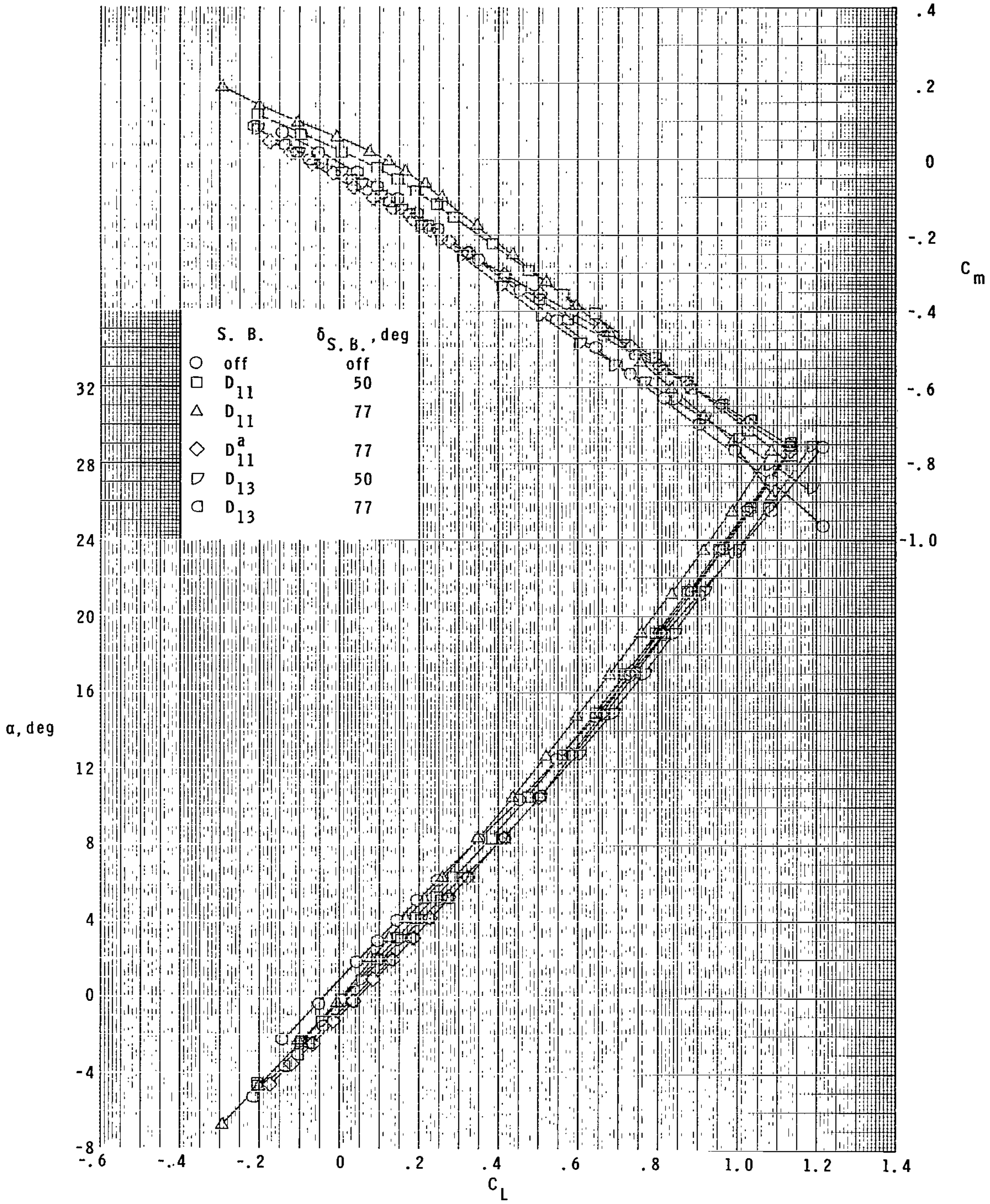


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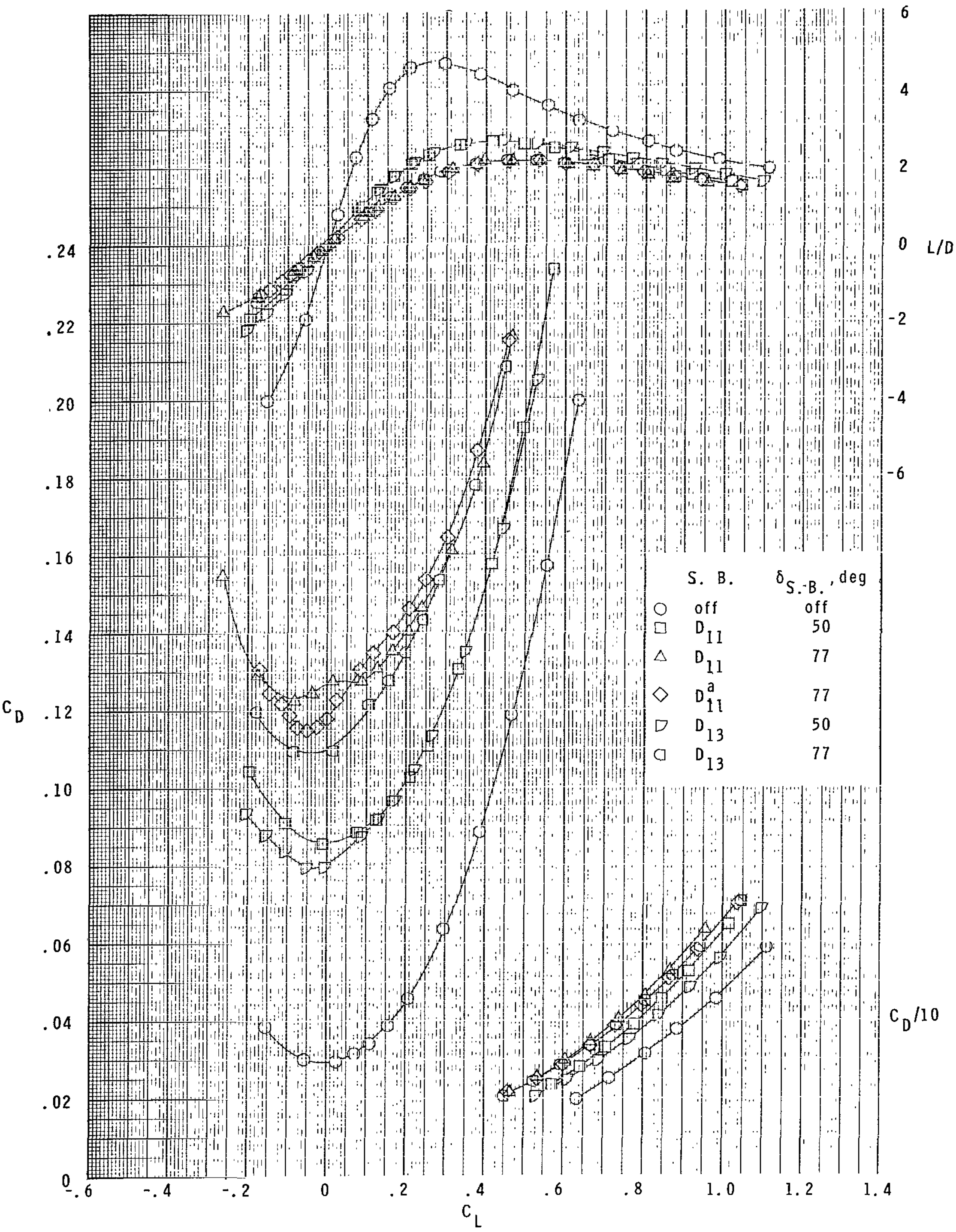
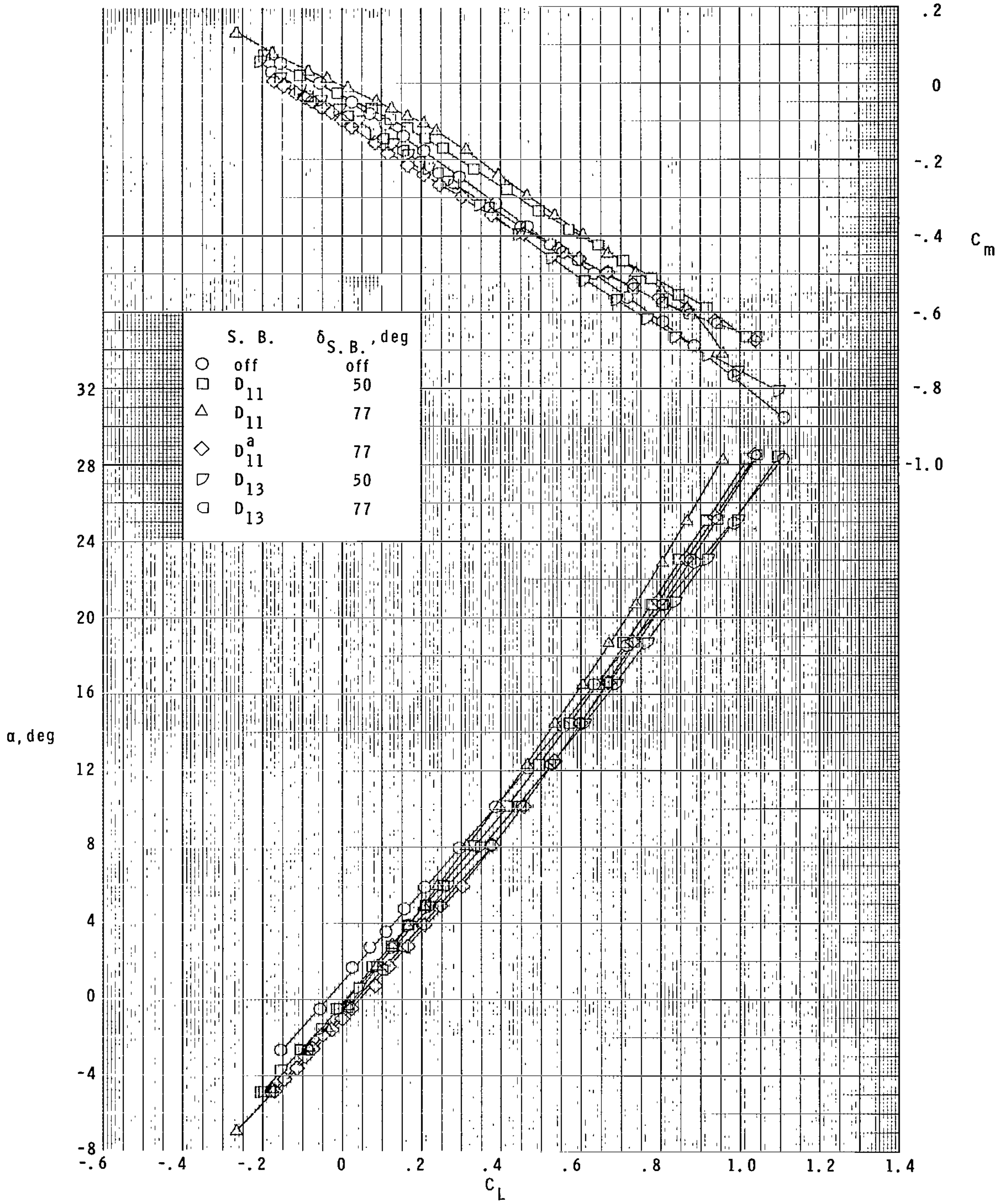
Figure 5.- Continued.



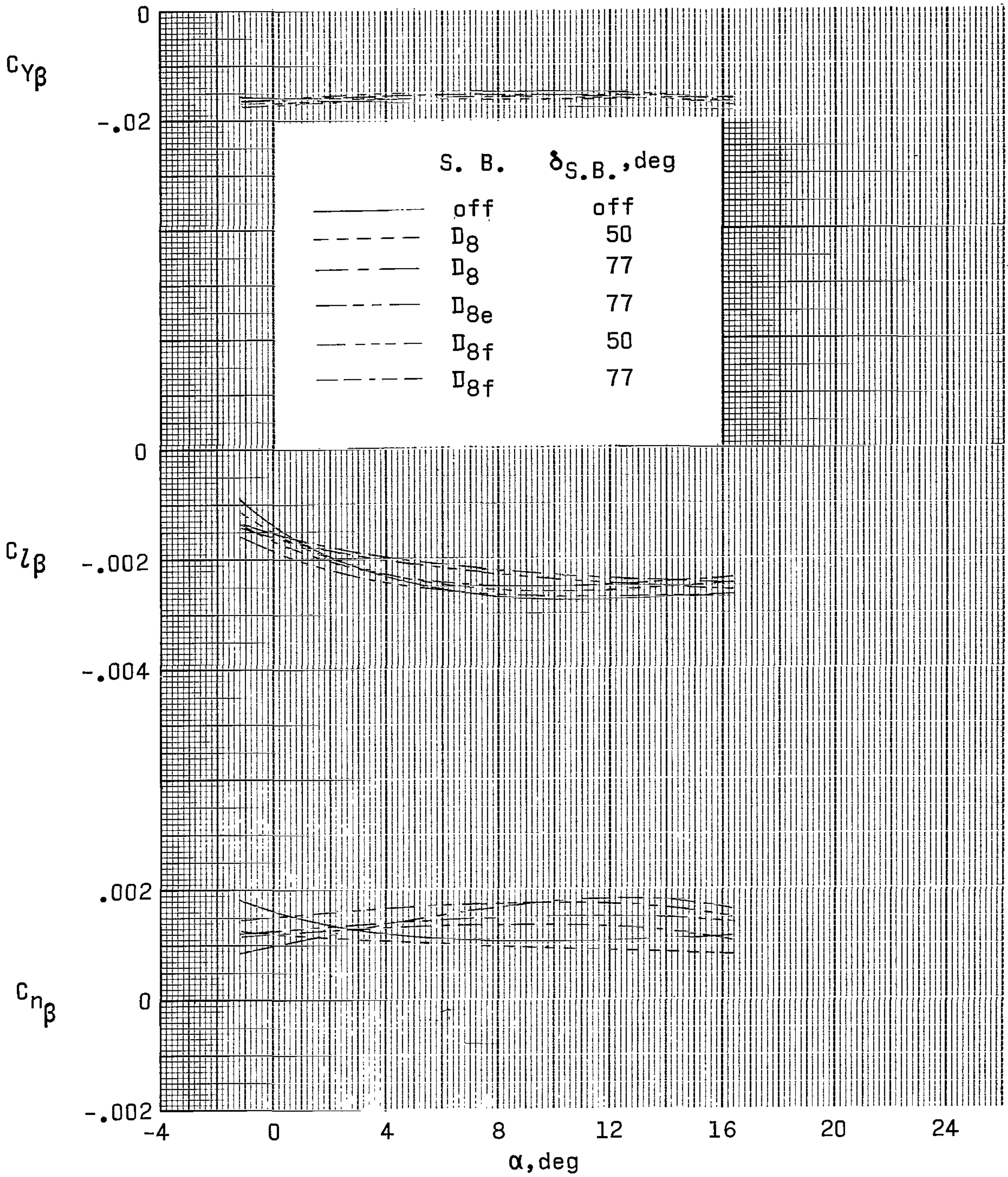
(c) M = 2.50.

Figure 5.- Continued.



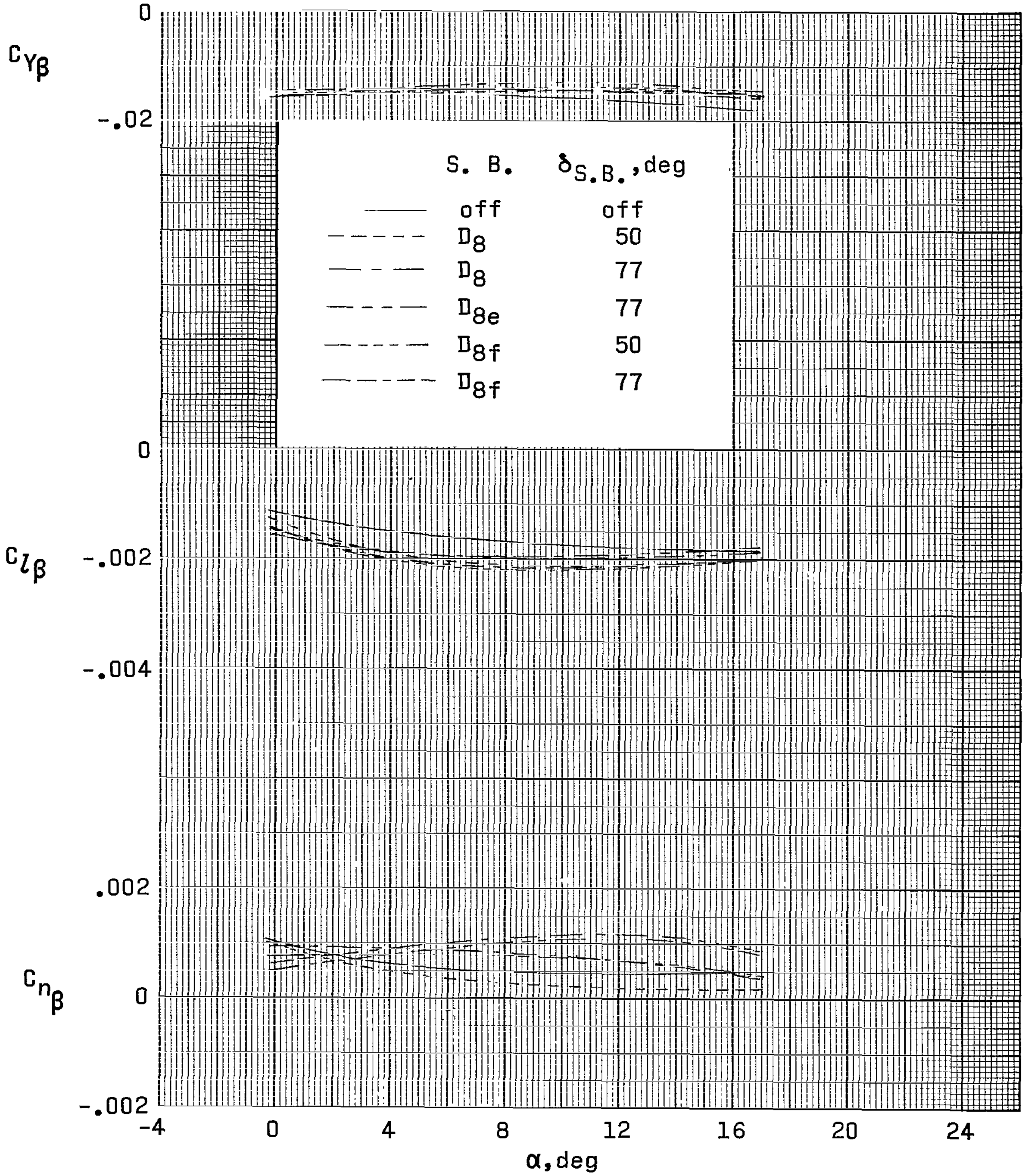
(c) Concluded.

Figure 5.- Concluded.



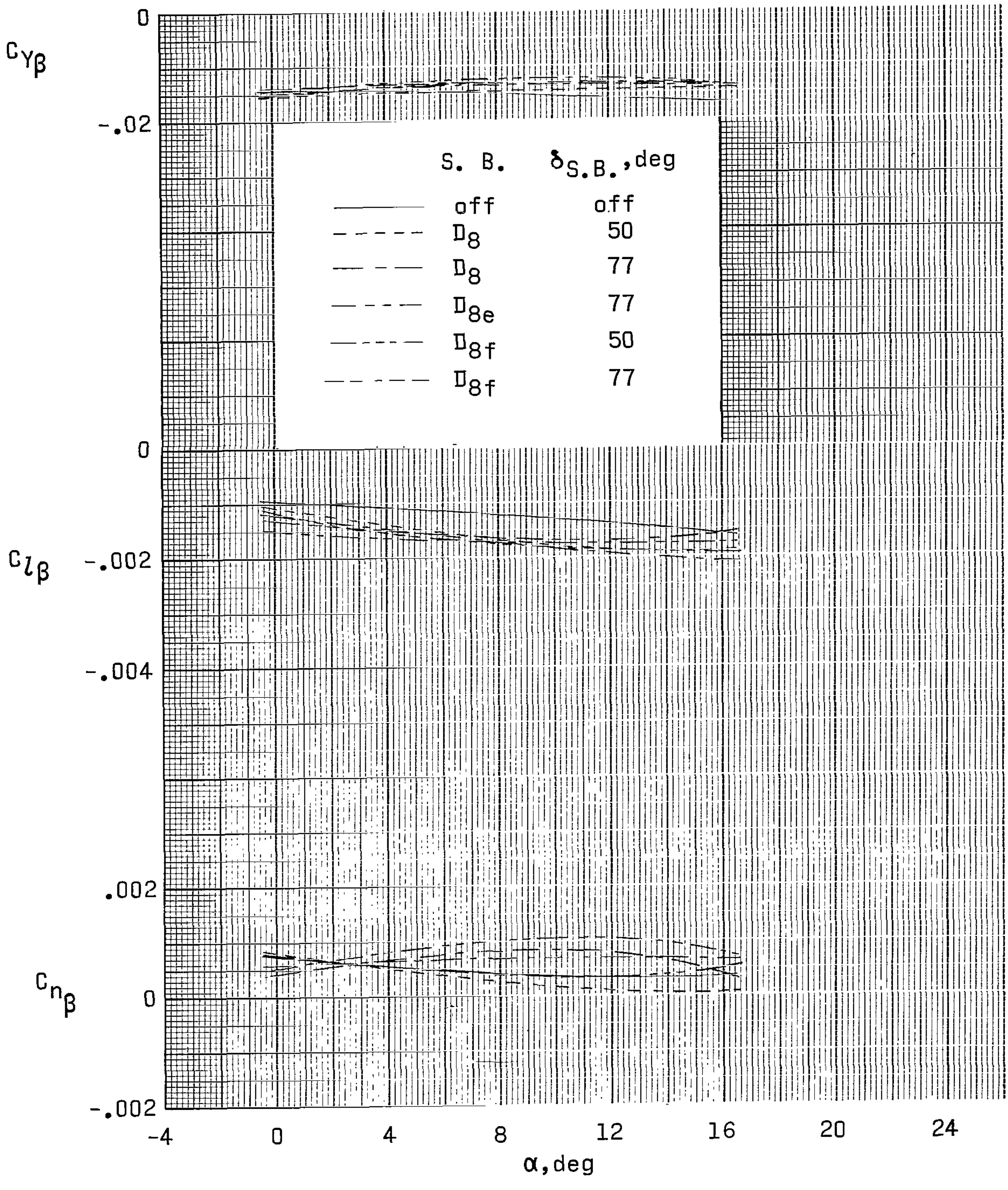
(a) M = 1.60.

Figure 6.- Effect of D_8, D_{8e}, and D_{8f} speed brakes on lateral parameters of the model.



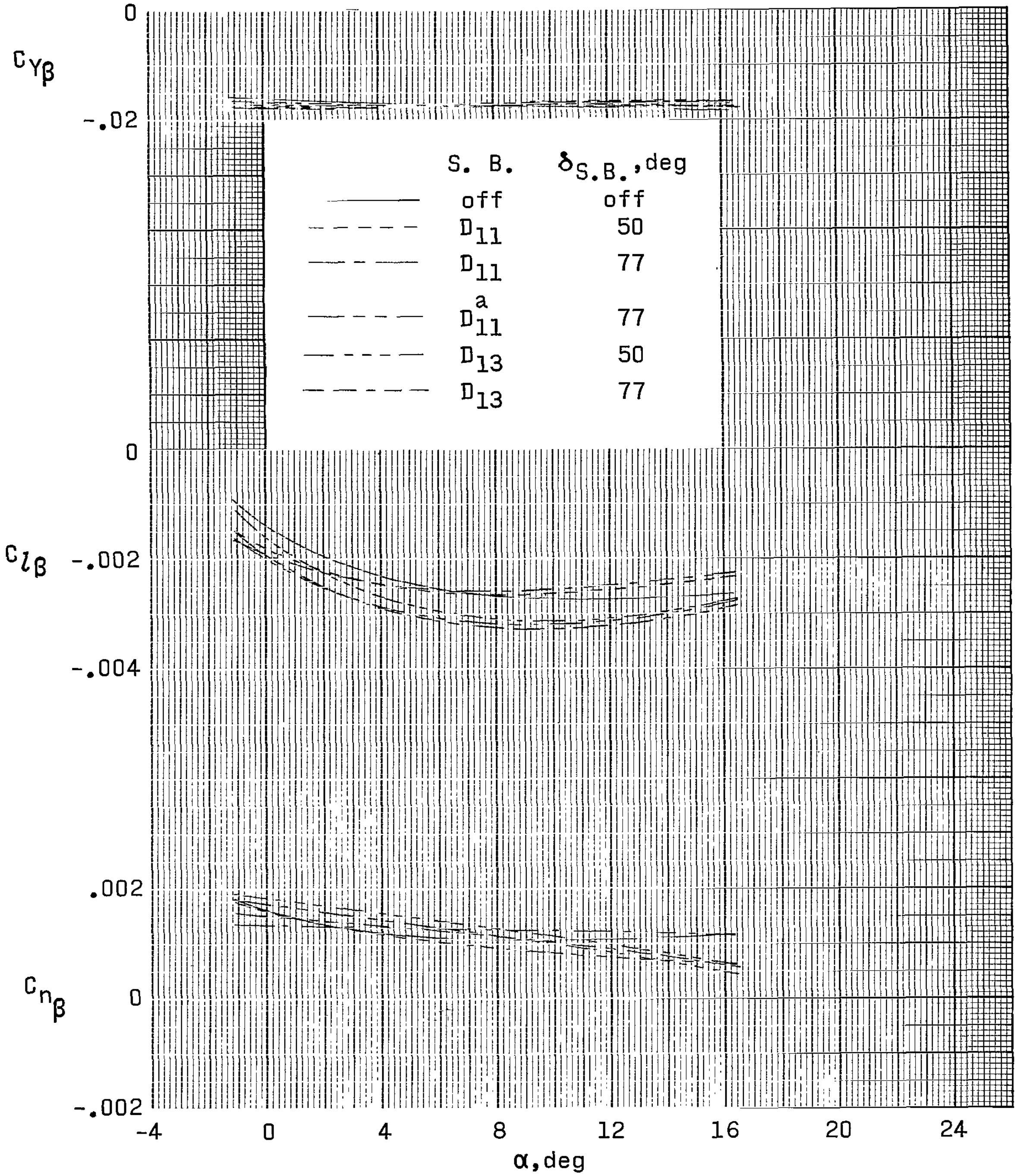
(b) M = 2.16.

Figure 6.- Continued.



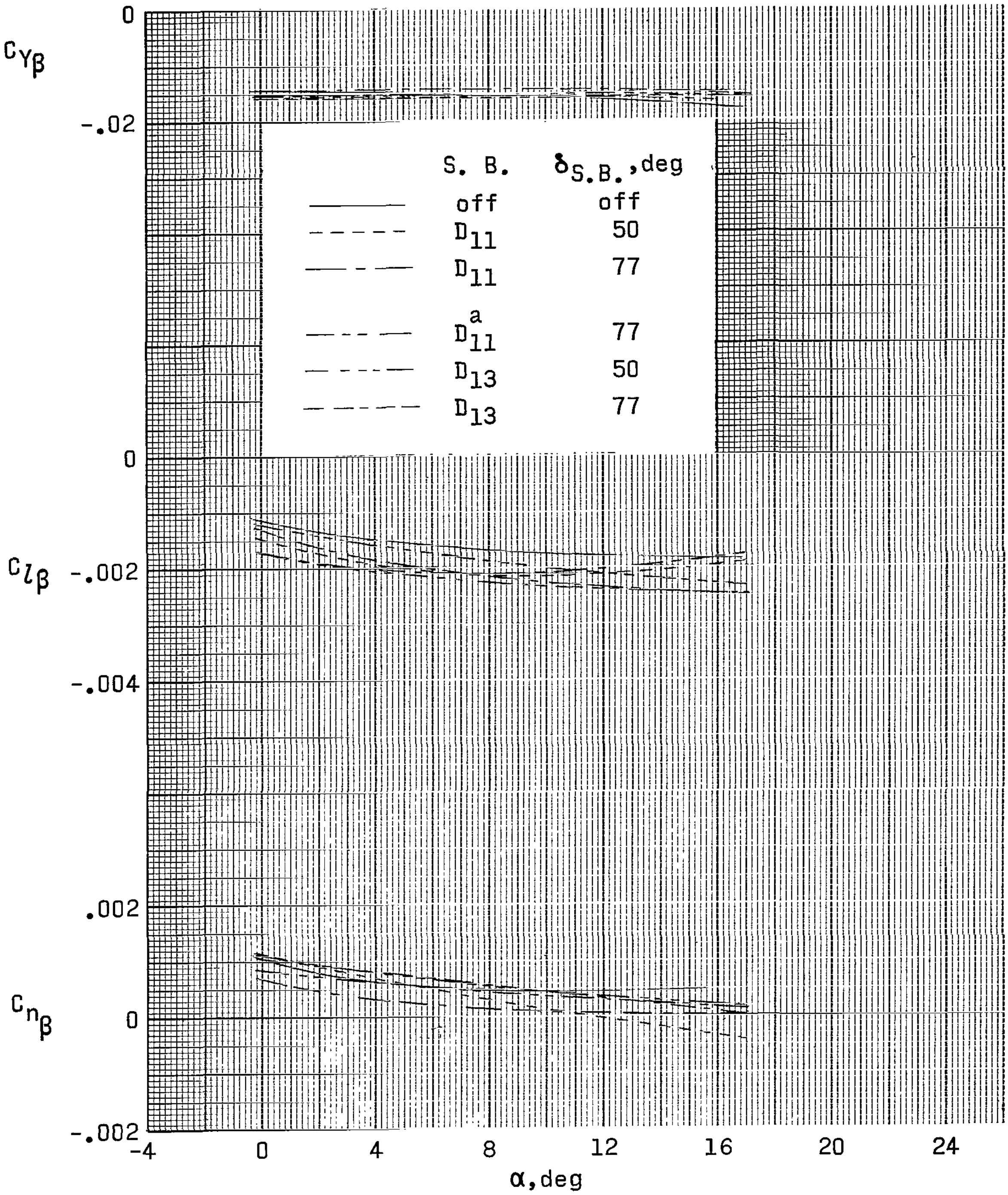
(c) M = 2.50.

Figure 6.- Concluded.



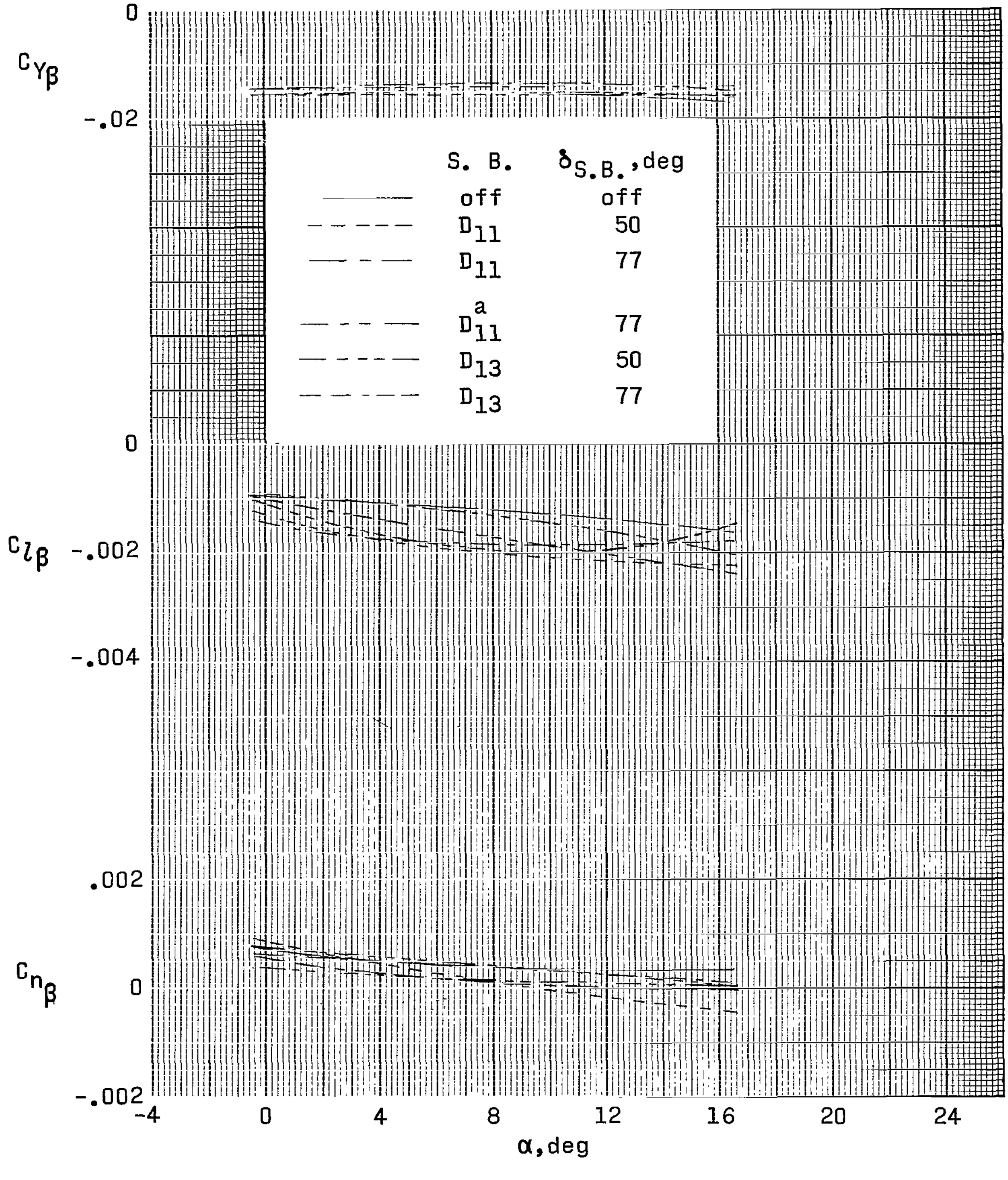
(a) M = 1.60.

Figure 7.- Effect of D_{11}, D_{11}^{a}, and D_{13} speed brakes on lateral parameters of the model.



(b) M = 2.16.

Figure 7.- Continued.



(c) M = 2.50.

Figure 7.- Concluded.

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