[redacted]

Copy

NASA TM X-116

NASA TM X-116

N65-28449
(ACCESSION NUMBER)

45
(PAGES)

(NASA CR OR TMX OR AD NUMBER)

1
(THRU)

(CODE)

01
(CATEGORY)

FACILITY FORM 602

TECHNICAL MEMORANDUM

X-116

DECLASSIFIED BY AUTHORITY OF NASA
CLASSFICATION CHANGE NOTICES NO. 12
DATED 5-20-65 ITEM NO. 3

EFFECT OF FOREBODY STRAKES ON THE AERODYNAMIC CHARACTERISTICS IN PITCH AND SIDESLIP OF A HYPERSONIC AIRPLANE CONFIGURATION AT MACH NUMBERS OF 1.41, 2.01, AND 6.86

By Cornelius Driver

Langley Research Center
Langley Field, Va.

GPO PRICE $ ________

OTS PRICE(S) $ ________

Hard copy (HC) 2.00

Microfiche (MF) .50

...CLASSIFIED: EFFECTIVE 11-29-65
...THORITY F.G. DROBKA (ATSS-A)
... dated 5-13-65; AFSDO 5439

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON September 1959

[redacted]

DECLASSIFIED

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-116

EFFECT OF FOREBODY STRAKES ON THE AERODYNAMIC CHARACTERISTICS IN PITCH AND SIDESLIP OF A HYPERSONIC AIRPLANE CONFIGURATION AT MACH NUMBERS OF 1.41, 2.01, AND 6.86*

By Cornelius Driver

SUMMARY

28449

An investigation has been made to determine the effect of forebody strakes on the aerodynamic characteristics in pitch and sideslip of a hypersonic airplane configuration. The investigation was conducted in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.41 and 2.01 and in the Langley 11-inch hypersonic tunnel at a Mach number of 6.86. Three strake configurations were investigated through an angle-of-attack range from -4° to 28° at various sideslip angles from 0° to 21°.

The results indicated that the short, small-span strake, which had been found suitable from a directional-stability standpoint for the low-speed landing condition, had only a negligible effect on the longitudinal stability at all supersonic speeds. The presence of the strakes at Mach numbers of 1.41 and 2.01, although resulting in some increase in the level of directional stability in the higher angle-of-attack range, did not increase the angle of attack at which neutral stability occurred. In addition, the strakes provided an increase in positive dihedral effect at Mach numbers of 1.41 and 2.01. The strakes had no measurable effect on the sideslip derivatives at a Mach number of 6.86.

Author

INTRODUCTION

The use of forebody strakes to improve the directional-stability level at angle of attack of various generalized airplane configurations has been reported in references 1, 2, and 3. Reference 3, in particular,

*Title, Unclassified.

presents details of the effects of strakes at supersonic speeds. Recent tests at low speeds (unpublished) of the present hypersonic airplane configuration have shown the desirability of using forebody strakes as a means of increasing the subsonic directional-stability level at angles of attack corresponding to the landing condition.

The present tests were made to evaluate the strake characteristics at supersonic and hypersonic speeds and to develop a strake configuration which would be satisfactory throughout the aircraft speed range.

SYMBOLS

The results are presented as force and moment coefficients with lift, drag, and pitching-moment coefficients referred to the stability-axis system and rolling-moment, yawing-moment, and side-force coefficients referred to the body-axis system. The reference center of moments was located on the body center line at 20 percent of the wing mean aerodynamic chord.

C_L	lift coefficient, Lift/qS
C_D	drag coefficient, Drag/qS
C_m	pitching-moment coefficient, Pitching moment/$qS\bar{c}$
C_l	rolling-moment coefficient, Rolling moment/qSb
C_n	yawing-moment coefficient, Yawing moment/qSb
C_Y	side-force coefficient, Side force/qS
q	free-stream dynamic pressure, lb/sq ft
S	wing area, sq ft
b	wing span, in.
$\bar{c}$	wing mean aerodynamic chord, in.
M	Mach number
x	longitudinal distance measured from wing leading edge
y	vertical distance measured from plane of symmetry of wing

L/D	lift-drag ratio
α	angle of attack, deg
β	angle of sideslip, deg
C_{n_β}	directional-stability parameter, $\partial C_n/\partial\beta$
C_{l_β}	effective-dihedral parameter, $\partial C_l/\partial\beta$
C_{Y_β}	side-force parameter, $\partial C_Y/\partial\beta$

MODELS

A three-view drawing of the complete model is presented in figure 1 and geometric characteristics are given in table I. The model is of conventional tail-rearward design, having an ogival nose and a cylindrical fuselage with side fairings. The cylindrical portion of the model is slightly boattailed at the base. The model has a trapezoidal wing with 25.64° sweep of the quarter-chord line. The horizontal tail is swept 45° at the quarter-chord line and has 15° of negative dihedral. Both the wing and the horizontal tail have modified NACA 66(006)-005 airfoil sections; the ordinates are presented in table II. The model is provided with nearly symmetrical upper and lower vertical tail surfaces having 5° semi-angle wedge airfoil sections.

Details of the three strake configurations tested on the model are shown in figure 2. On the long-strake configuration the strakes extended rearward from body station 0.36 to the fairings along the sides of the fuselage (body station 2.64). On the short-strake configuration the strakes were attached at the same body station but extended rearward only about half the distance of the long strake (body station 1.11). The short, small-span strake had the same length as the short strake but had only one-half the exposed span. The short, small-span strake configuration was determined from unpublished low-speed tests to be the minimum strake that would provide a substantial increment in the directional-stability level at low speeds without an adverse effect on the longitudinal stability.

TESTS AND APPARATUS

The tests at $M = 1.41$ and 2.01 were made in the Langley 4- by 4-foot supersonic pressure tunnel. This tunnel is a closed throat, single-return, variable-density type and is further described in reference 4.

The tests at $M = 6.86$ were made in the Langley 11-inch hypersonic tunnel described in reference 5. This tunnel is an intermittent-flow type employing a single-step, two-dimensional, Invar nozzle. Running periods of about 80 seconds are possible. The stagnation temperature was maintained at about 675° F to prevent air liquefaction in the test section. The Reynolds numbers of the tests (based on the wing mean aerodynamic chord of 2.465 inches) were as follows:

Mach number	Reynolds number
1.41	710,000
2.01	456,000
6.86	640,000

Forces and moments were measured through the use of a six-component internal strain-gage balance system. For the tests at Mach numbers of 1.41 and 2.01, the model was mounted on a remote-controlled rotary sting which allowed testing at combined angles of attack and sideslip. The angles of attack and sideslip were corrected for deflection under load. For the tests at a Mach number of 6.86, the model was mounted on an offset sting and the sideslip-derivative data were obtained at a constant sideslip angle through the angle-of-attack range. The angles of attack were determined by using a lens prism imbedded in the model surface to reflect and focus a spot from a light source on a previously calibrated screen. By using this method the true angles of attack were obtained directly.

DISCUSSION

Characteristics in Pitch

The effect of the strakes on the aerodynamic characteristics in pitch of the model at Mach numbers of 1.41, 2.01, and 6.86 is presented in figure 3. The presence of the strakes caused no significant effect on lift or drag at any of the Mach numbers of the tests. The strakes caused little or no effect on the longitudinal stability at low lift coefficients, but at higher lift coefficients a tendency toward reduced stability was indicated that increased as the strake size increased. Even for the largest strake, however, the reduction in stability was of little consequence because of the initially high stability level. The short, small-span strake, which low-speed tests (unpublished) indicated would provide adequate values of C_{n_β} at angles of attack corresponding to the landing condition, had a negligible effect on the pitching moment at supersonic speeds.

Characteristics in Sideslip

The effect of the strakes on the aerodynamic characteristics in sideslip of the model with the upper vertical tail on or off at Mach numbers of 1.41 and 2.01 is presented in figures 4 to 7. The effect of the strakes on sideslip derivatives for small sideslip angles is summarized in figures 8(a), 8(b), and 8(c) for Mach numbers of 1.41, 2.01, and 6.86, respectively. The presence of the strakes at Mach numbers of 1.41 and 2.01 resulted in some increase in the directional-stability level in the angle-of-attack range above $\alpha = 8^\circ$ to 12° (fig. 8) but provided no increase in the angle of attack at which the directional stability became zero. The strake effectiveness appeared to decrease with an increase in Mach number (1.41 to 2.01). A similar result for a 42° swept-wing configuration has been reported in reference 6 for Mach numbers from 1.60 to 2.50. At Mach numbers of 1.41 and 2.01, the strakes provided an increase in the effective-dihedral parameter $\left(-C_{l_\beta}\right)$ at high angles of attack, apparently because of the localized strake lift and the wake effect on the leeward wing panel. The effect on the lateral derivatives in sideslip is in proportion to the strake size, with the short, small-span strake, which had been found suitable for the low-speed landing condition, providing the smallest effect at the low supersonic speeds (fig. 8(b)).

No basic data for the tests at $M = 6.86$ are shown since the data were obtained through the angle-of-attack range at sideslip angles of 0° and 4°. The presence of the strakes on the configuration, with the upper vertical tail either on or off, had no measurable effect on the sideslip derivatives at $M = 6.86$.

CONCLUDING REMARKS

The results of an investigation of various forebody strake configurations on a model of a hypersonic airplane at Mach numbers of 1.41, 2.01, and 6.86 indicated that the short, small-span strake, which had been found suitable from a directional stability standpoint at angles of attack corresponding to the landing condition, would have only a negligible effect on the longitudinal stability at supersonic speeds. The presence of the strakes at Mach numbers of 1.41 and 2.01, although resulting in some increase in the level of directional stability in the higher angle-of-attack range, did not increase the angle of attack at which neutral stability occurred. In addition, the strakes provided an increase in positive dihedral effect at Mach numbers of 1.41 and 2.01. The strakes had no measurable effect on the sideslip derivatives at a Mach number of 6.86.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., June 2, 1959.

REFERENCES

1. Paulson, John W., and Boisseau, Peter C.: Low-Speed Investigation of the Effect of Small Canard Surfaces on the Directional Stability of a Sweptback-Wing Fighter-Airplane Model. NACA RM L56F19a, 1956.

2. Sleeman, William C., Jr.: Investigation at High Subsonic Speeds of the Effects of Various Horizontal Fuselage Forebody Fins on the Directional and Longitudinal Stability of a Complete Model Having a 45° Sweptback Wing. NACA RM L56J25, 1957.

3. Driver, Cornelius: Wind-Tunnel Investigation at a Mach Number of 2.01 of Forebody Strakes for Improving Directional Stability of Supersonic Aircraft. NACA RM L58C11, 1958.

4. Robinson, Ross B., and Driver, Cornelius: Aerodynamic Characteristics at Supersonic Speeds of a Series of Wing-Body Combinations Having Cambered Wings With an Aspect Ratio of 3.5 and a Taper Ratio of 0.2 - Effects of Sweep Angle and Thickness Ratio on the Aerodynamic Characteristics in Pitch at $M = 1.60$. NACA RM L51K16a, 1952.

5. McLellan, Charles H., Williams, Thomas W., and Beckwith, Ivan E.: Investigation of the Flow Through a Single-Stage Two-Dimensional Nozzle in the Langley 11-Inch Hypersonic Tunnel. NACA TN 2223, 1950.

6. Church, James D.: Effects of Components and Various Modifications on the Drag and the Static Stability and Control Characteristics of a 42° Swept-Wing Fighter-Airplane Model at Mach Numbers of 1.60 to 2.50. NACA RM L57K01, 1957. (Reprinted 1959.)

TABLE I.- GEOMETRIC CHARACTERISTICS OF MODEL

Wing:	
Area, total, sq in.	11.520
Area, exposed sq in.	6.050
Span, in.	5.366
Aspect ratio	2.500
Root chord, in.	3.578
Root chord, exposed, in.	2.640
Tip chord, in.	0.716
Mean aerodynamic chord, in.	2.465
Sweepback angles, deg -	
Leading edge	36.75
25-percent-chord line	25.64
Trailing edge	-17.74
Taper ratio	0.200
Dihedral angle, deg	0.00
Incidence angle, deg	0.00
Airfoil section, parallel to fuselage center line	Modified NACA 66(006)-005
Horizontal tail:	
Area, total, sq in.	6.643
Area, exposed, sq in.	2.300
Span, in.	4.339
Aspect ratio	2.833
Taper ratio	0.206
Root chord, exposed, in	1.685
Tip chord, in.	0.505
Mean aerodynamic chord, in.	1.201
Sweepback angles, deg -	
Leading edge	50.58
25-percent-chord line	45.00
Trailing edge	19.28
Dihedral, deg	-15.00
Airfoil section, parallel to fuselage center line	Modified NACA 66(006)-005
Upper vertical tail:	
Area, exposed, sq in.	2.356
Span, in.	1.099
Aspect ratio	0.516
Taper ratio	0.741
Root chord, in.	2.450
Tip chord, in.	1.815
Mean aerodynamic chord, in.	2.148
Sweepback angles, deg -	
Leading edge	30.00
25-percent-chord line	23.41
Trailing edge	0.00
Airfoil section, parallel to fuselage center line	10° full wedge
Leading-edge radius, in.	0.010
Area, stabilizer, sq in.	1.420
Root chord, stabilizer, in.	2.248
Mean aerodynamic chord, in.	2.039
Lower vertical tail:	
Area, sq in.	1.982
Span, in.	0.920
Aspect ratio	0.429
Taper ratio	0.783
Root chord, in.	2.450
Tip chord, in.	1.919
Mean aerodynamic chord, in.	2.200
Sweepback angles, deg -	
Leading edge	30.00
25-percent-chord line	23.41
Trailing edge	0.00
Airfoil section, parallel to fuselage center line	10° full wedge
Leading-edge radius, in.	0.100
Area, stabilizer, sq in.	1.149
Root chord, stabilizer, in.	2.248
Mean aerodynamic chord, stabilizer, in.	2.093
Fuselage:	
Length, in.	11.760
Maximum diameter, in.	1.12
Maximum width, including side fairings	1.76
Fineness ratio	10.50
Base diameter	0.960

TABLE II.- AIRFOIL SECTION ORDINATES

[Modified NACA 66(006)-005]

(a) Wing

x, percent chord	y, percent chord	
	Root	Tip
0	0	0
1.25	.358	1.048
2.5	.533	1.123
5.0	.854	1.263
7.5	1.137	1.395
10	1.382	1.523
15	1.759	1.769
20	2.001	2.001
25	2.182	2.182
30	2.318	2.318
35	2.416	2.416
40	2.476	2.476
45	2.500	2.500
50	2.487	2.487
55	2.437	2.437
60	2.346	2.346
65	2.176	2.176
67	2.085	2.085
100	.500	.500

L. E. radius: 0.008-inch constant, tangent to leading edge.

Basic airfoil modified for linear taper between root and tip forward of 17-percent-chord line and modified to straight side rearward of 67-percent-chord line to 1-percent-thick trailing edge.

(b) Horizontal tail

x, percent chord	y, percent chord	
	Root	Tip
0	0	0
.1	.269	.348
.25	.408	.538
.5	.531	.728
.75	.590	.846
1.25	.650	.969
2.50	.791	1.052
5.00	1.048	1.206
7.5	1.270	1.353
10	1.460	1.495
15	1.766	1.768
20	2.001	2.001
25	2.182	2.182
30	2.318	2.318
35	2.416	2.416
40	2.476	2.476
45	2.500	2.500
50	2.487	2.487
55	2.437	2.437
60	2.346	2.346
75	1.653	1.653
90	.961	.961
100	.500	.500

L. E. radius: 0.005-inch constant, tangent to leading edge.

Basic airfoil modified for linear taper between root and tip forward of 5-percent-chord line at root and 15-percent-chord line at tip.

[redacted]

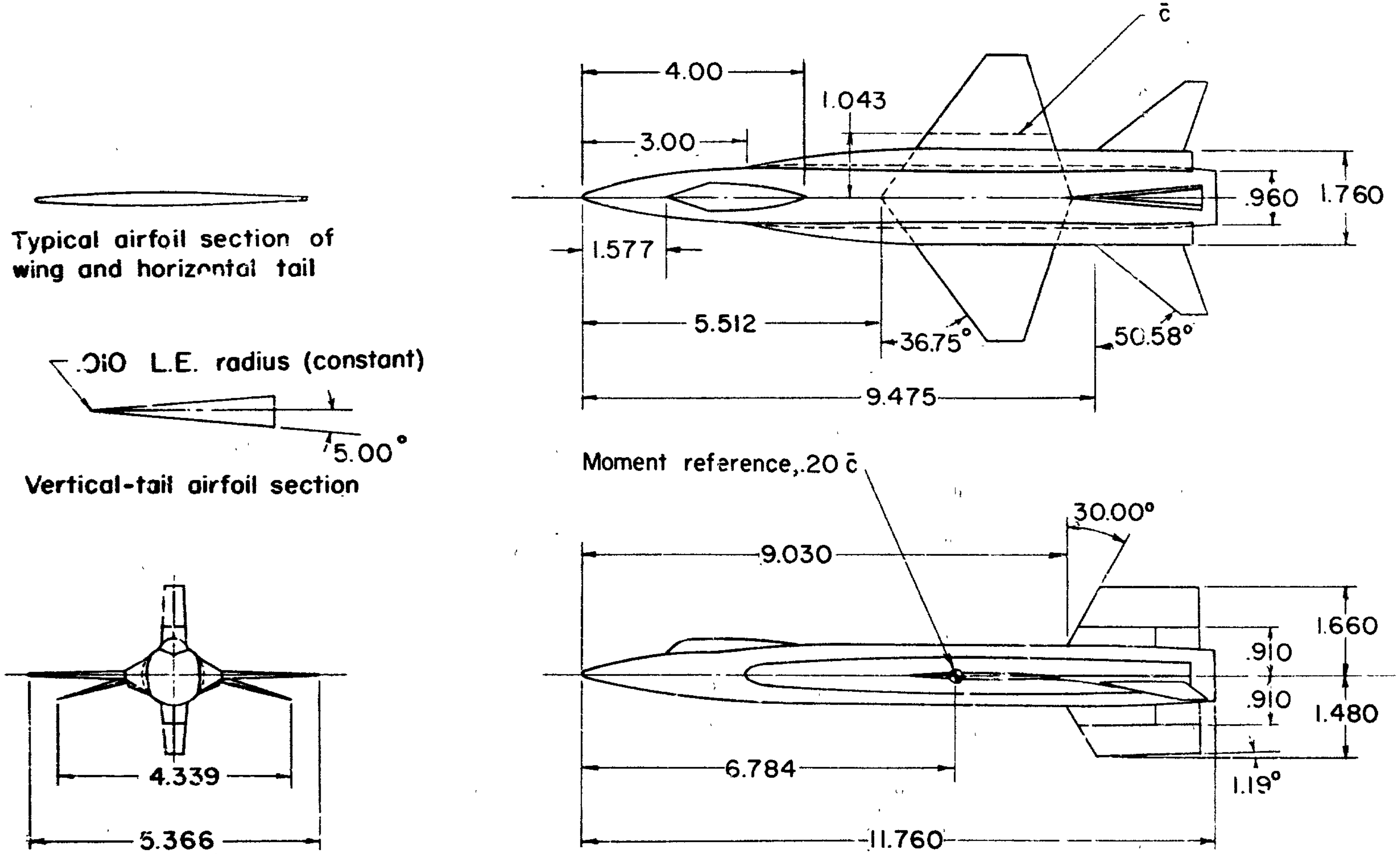


Figure 1.- Details of the model. (All dimensions are in inches.)

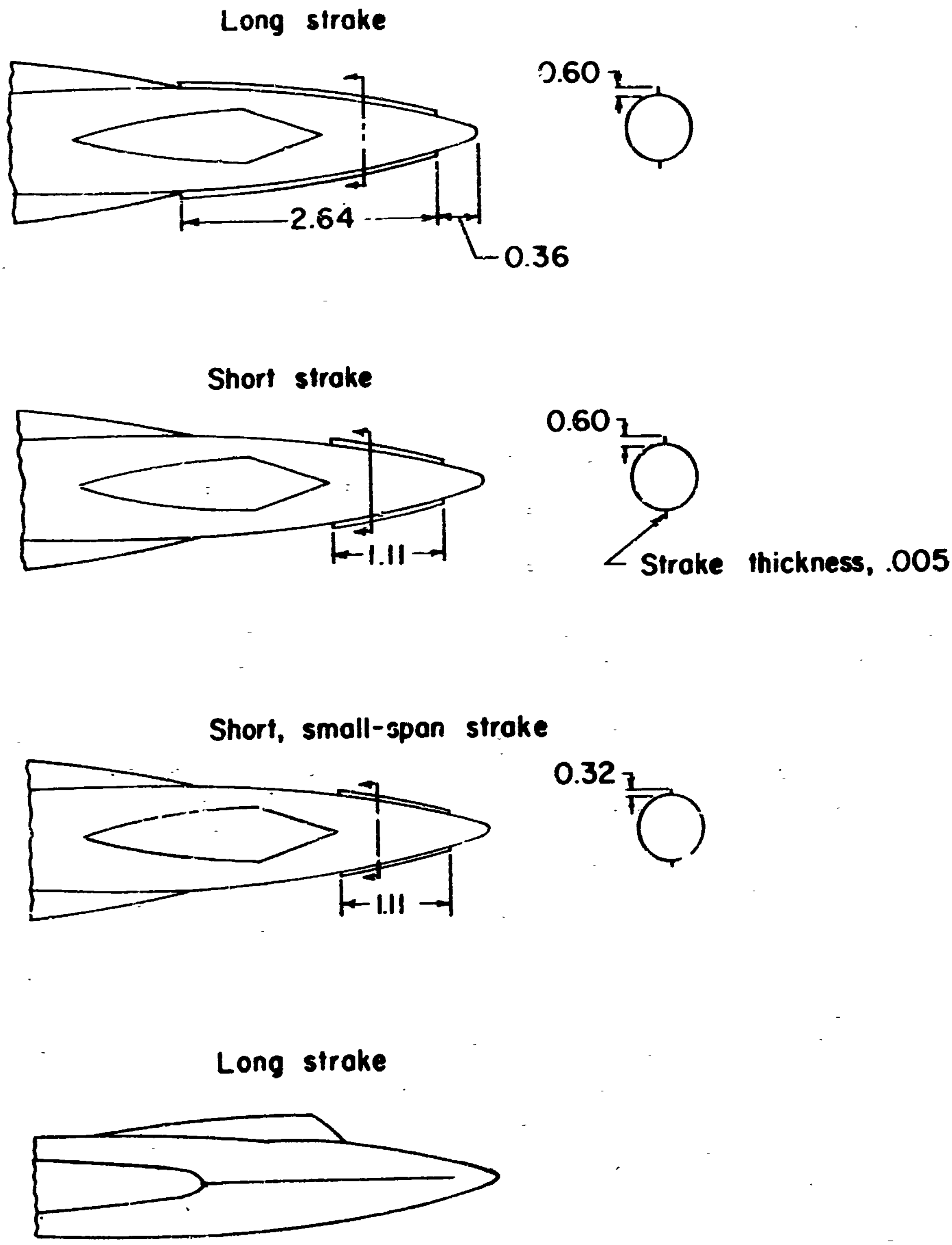
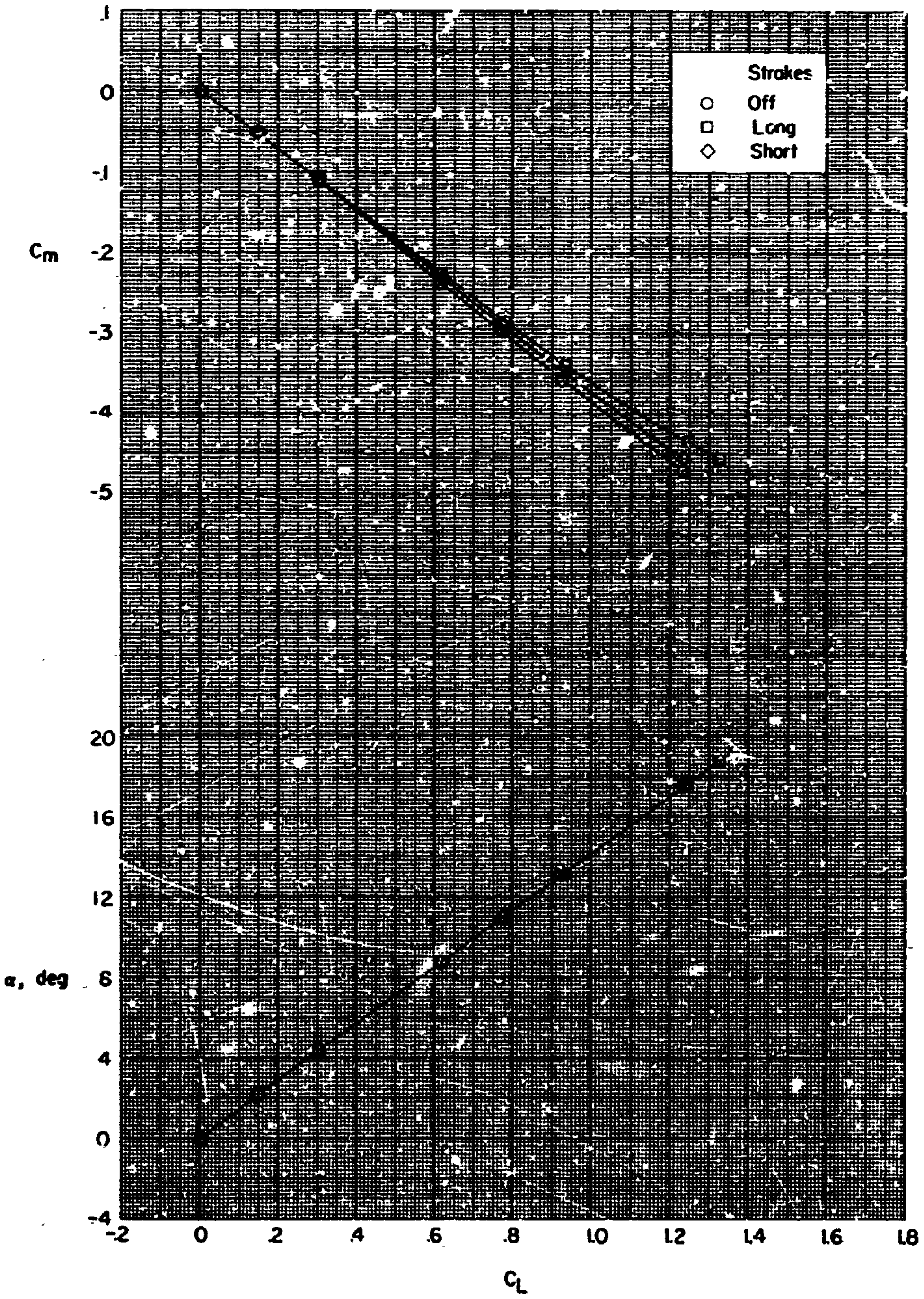
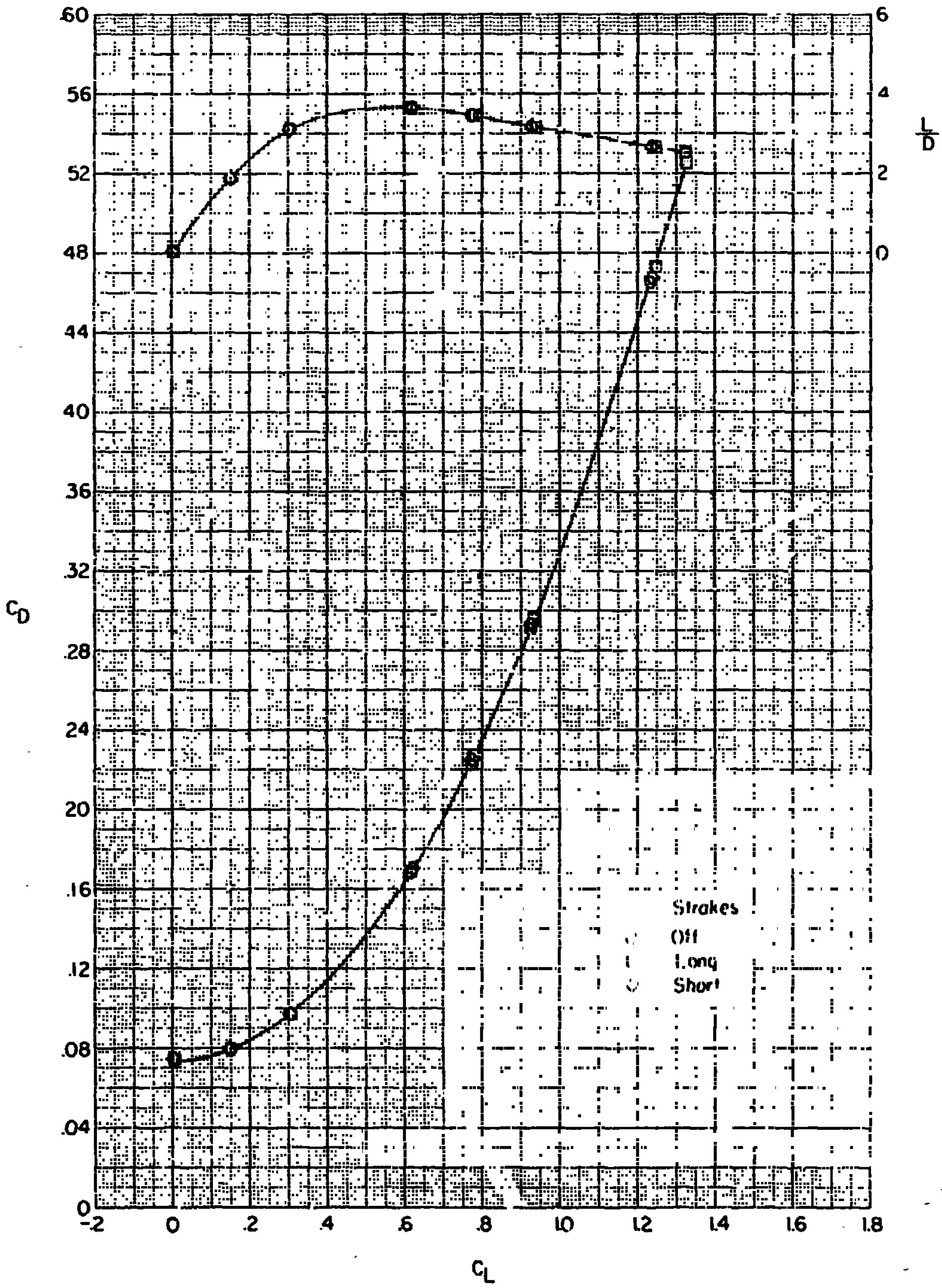


Figure 2.- Strake details. (All dimensions are in inches.)



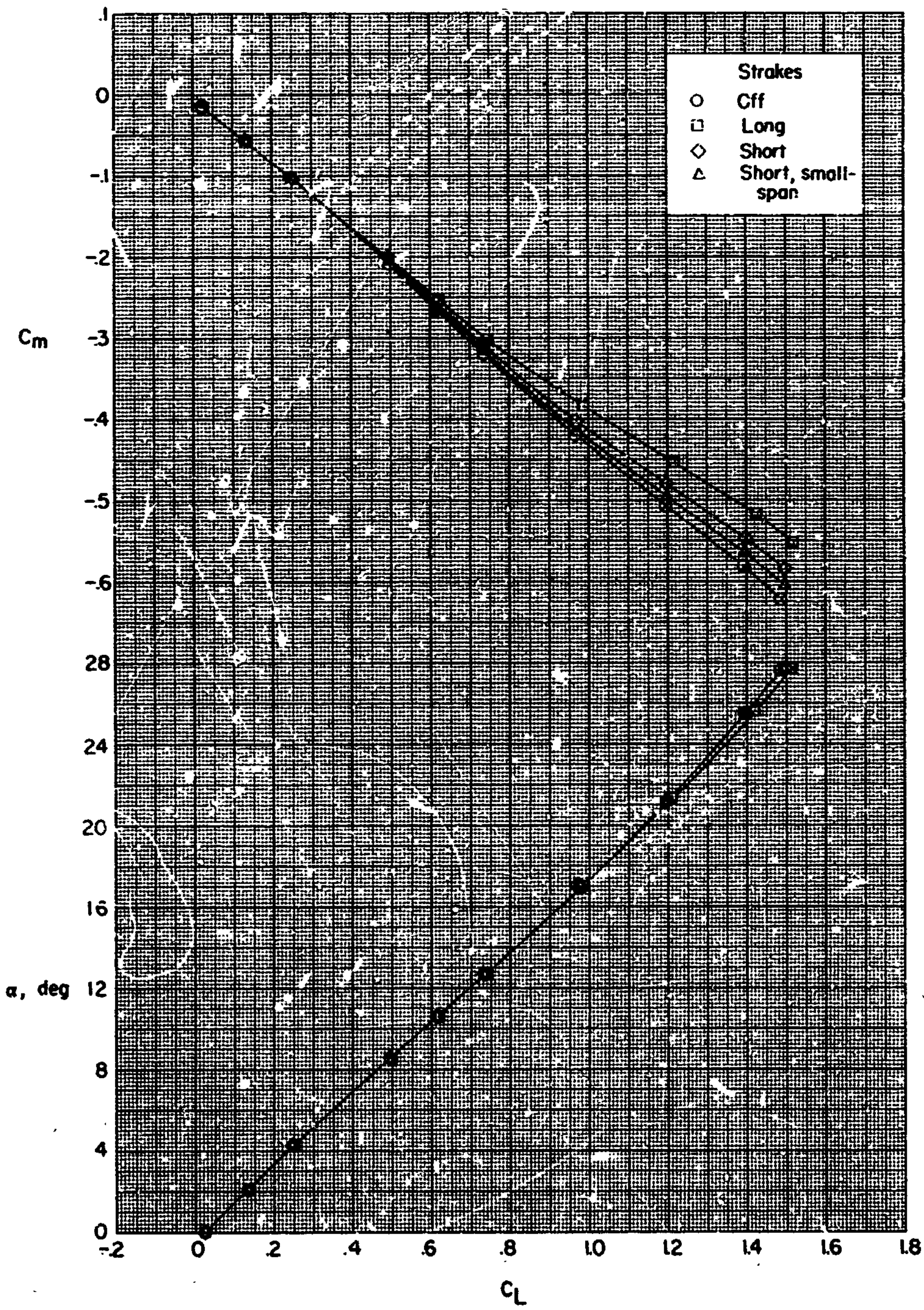
(a) M = 1.41.

Figure 3.- Effect of strakes on aerodynamic characteristics in pitch of complete model.



(a) M = 1.41. Concluded.

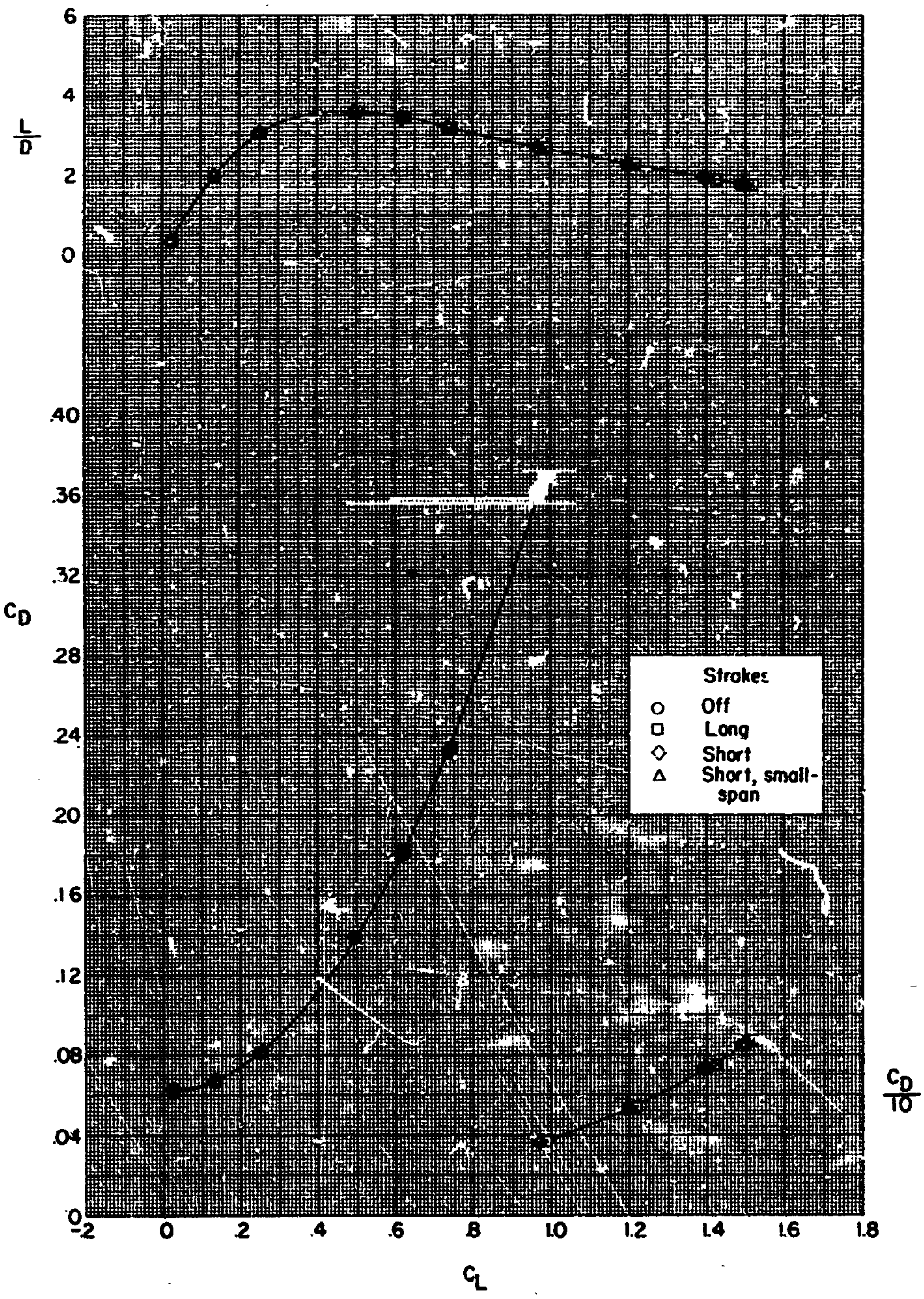
Figure 3.- Continued.



(b) M = 2.01.

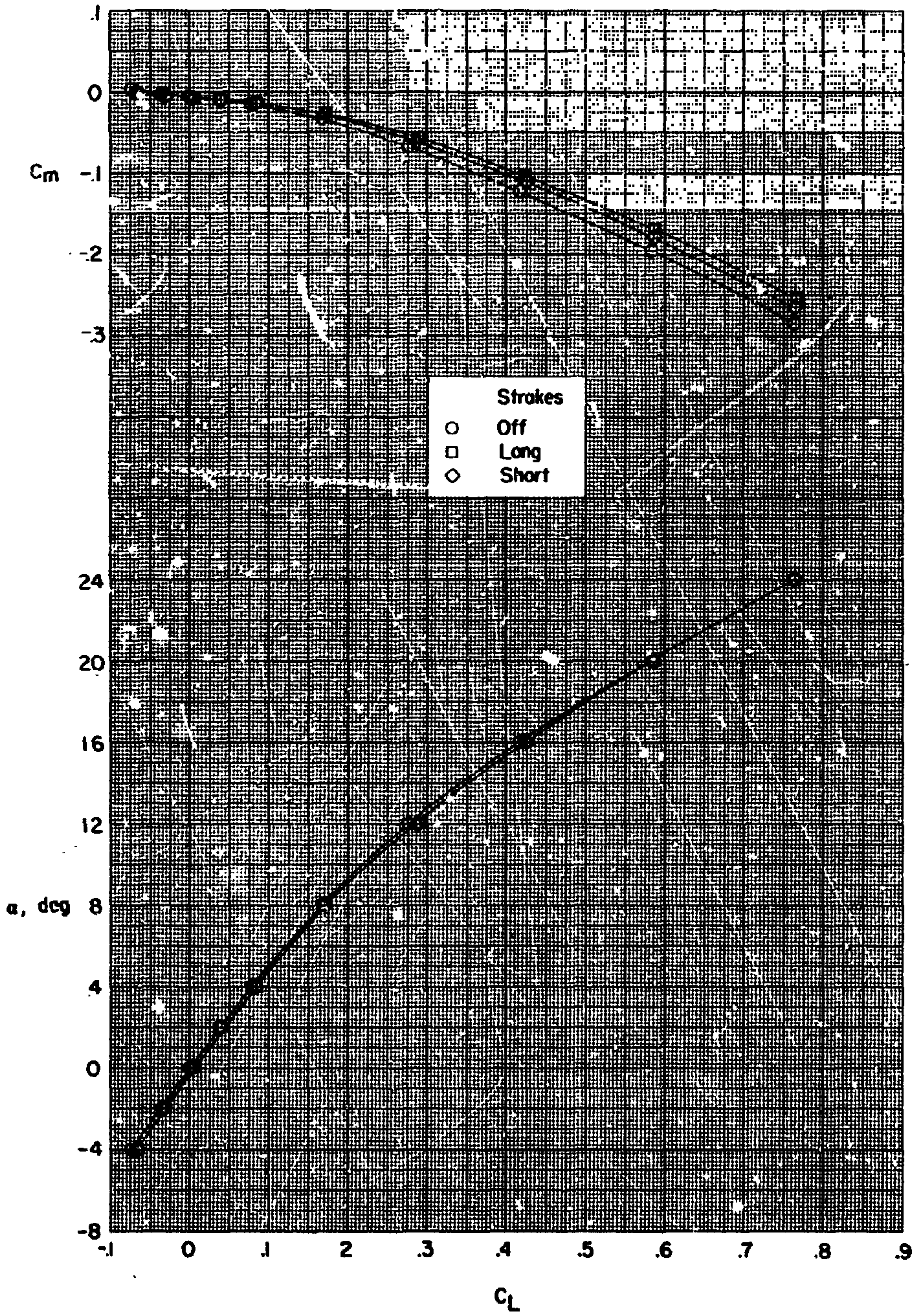
Figure 3.- Continued.

[redacted]



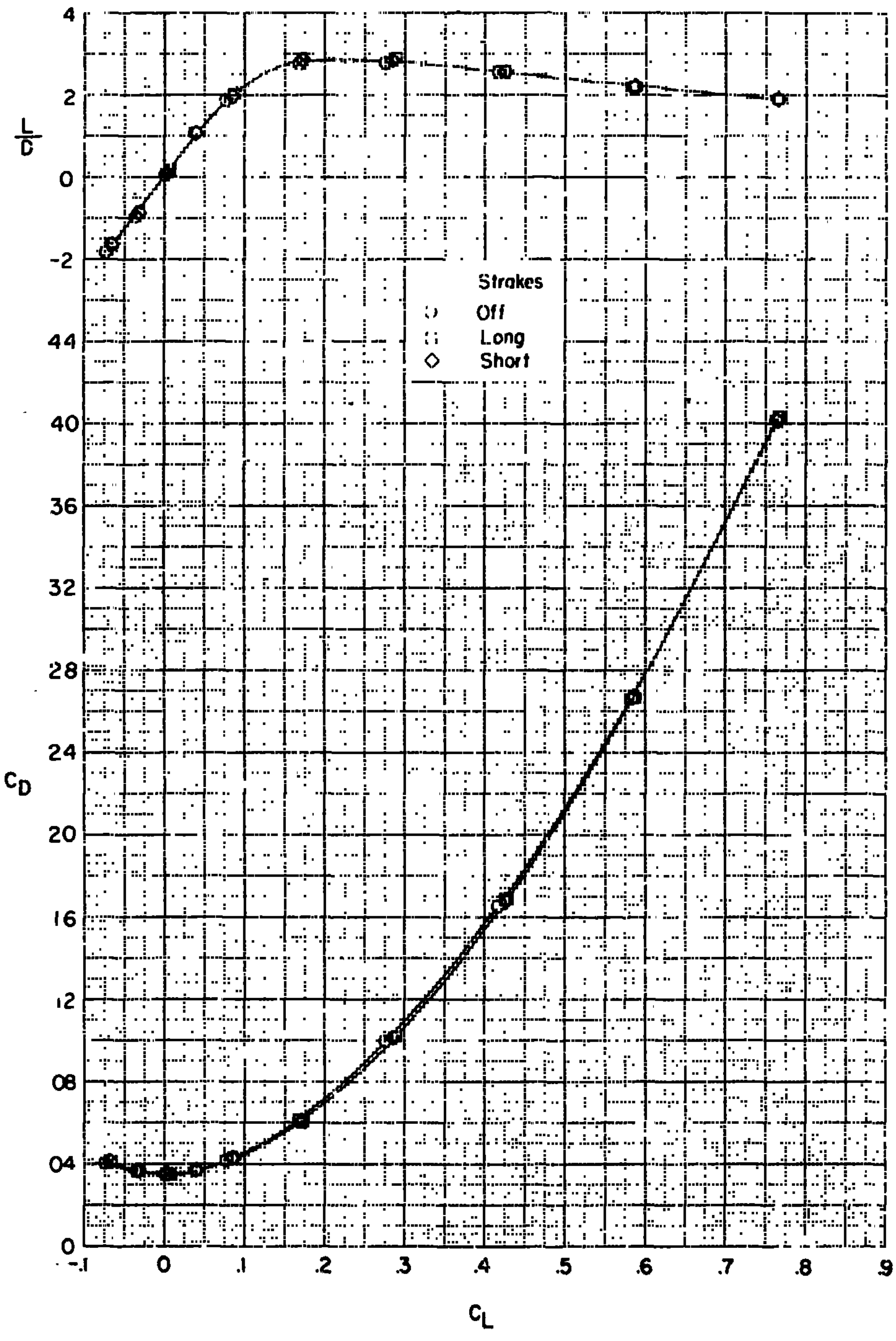
(b) M = 2.01. Concluded.

Figure 3.- Continued.



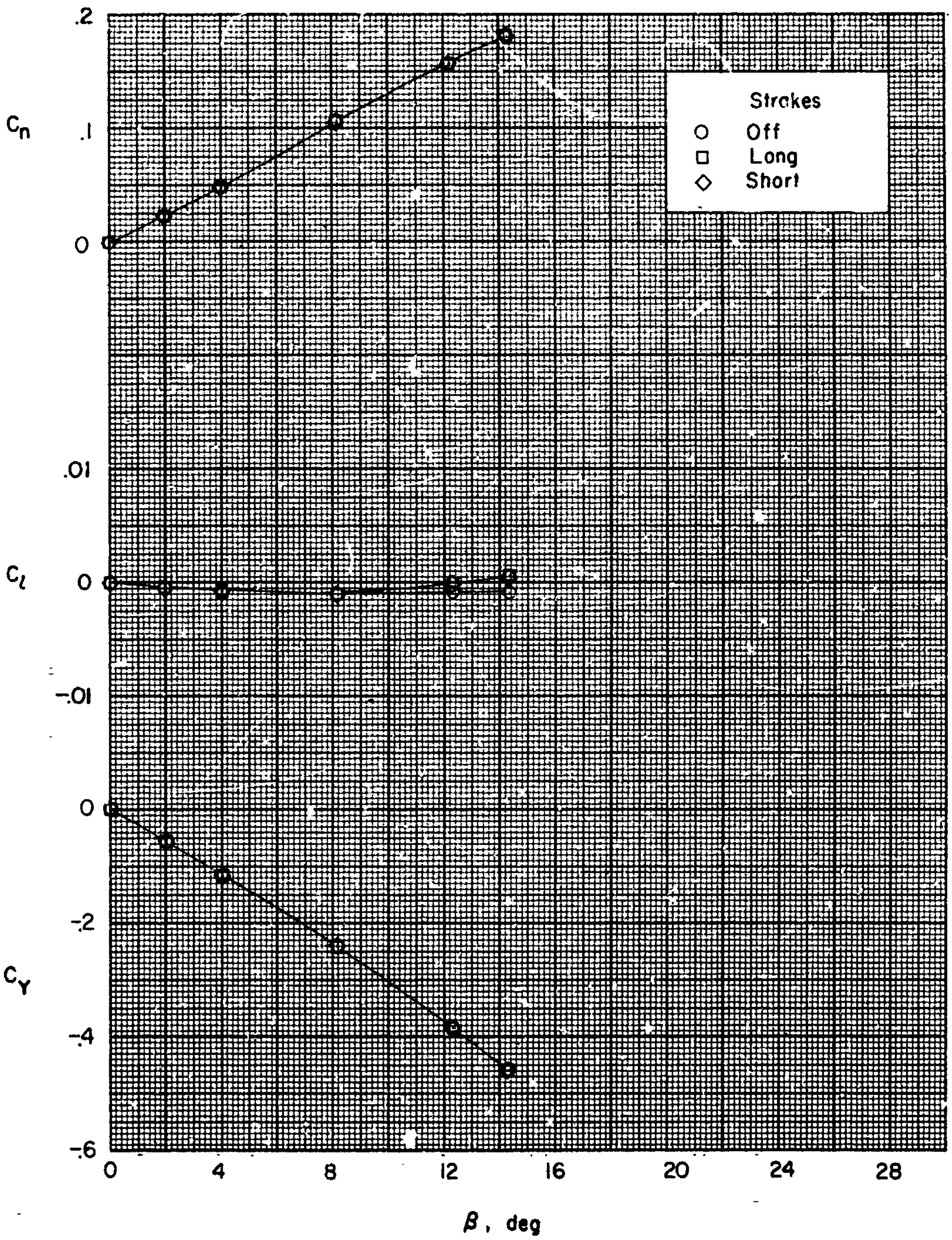
(c) M = 6.86.

Figure 3.- Continued.



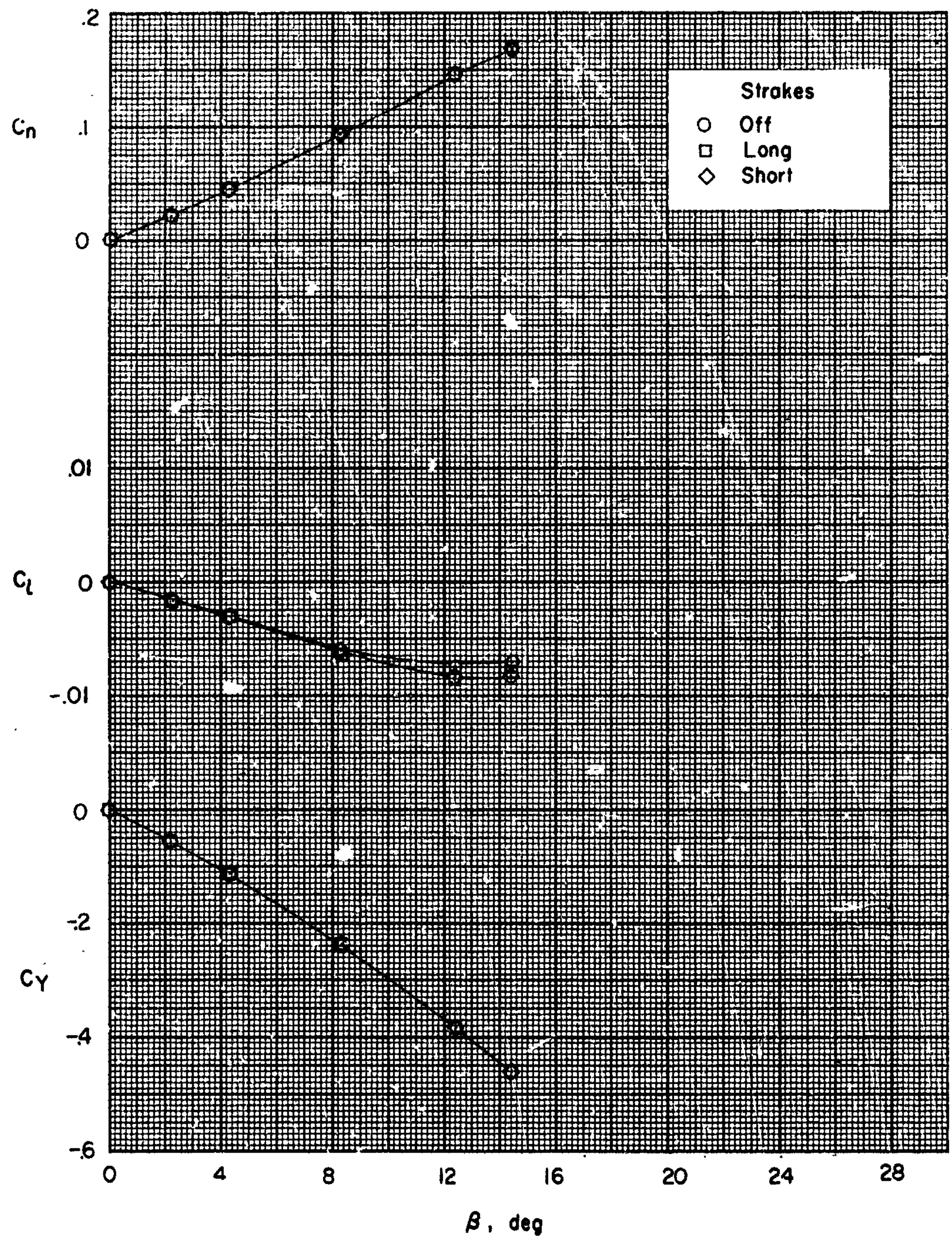
(c) M = 6.86 Concluded.

Figure 3.- Concluded.



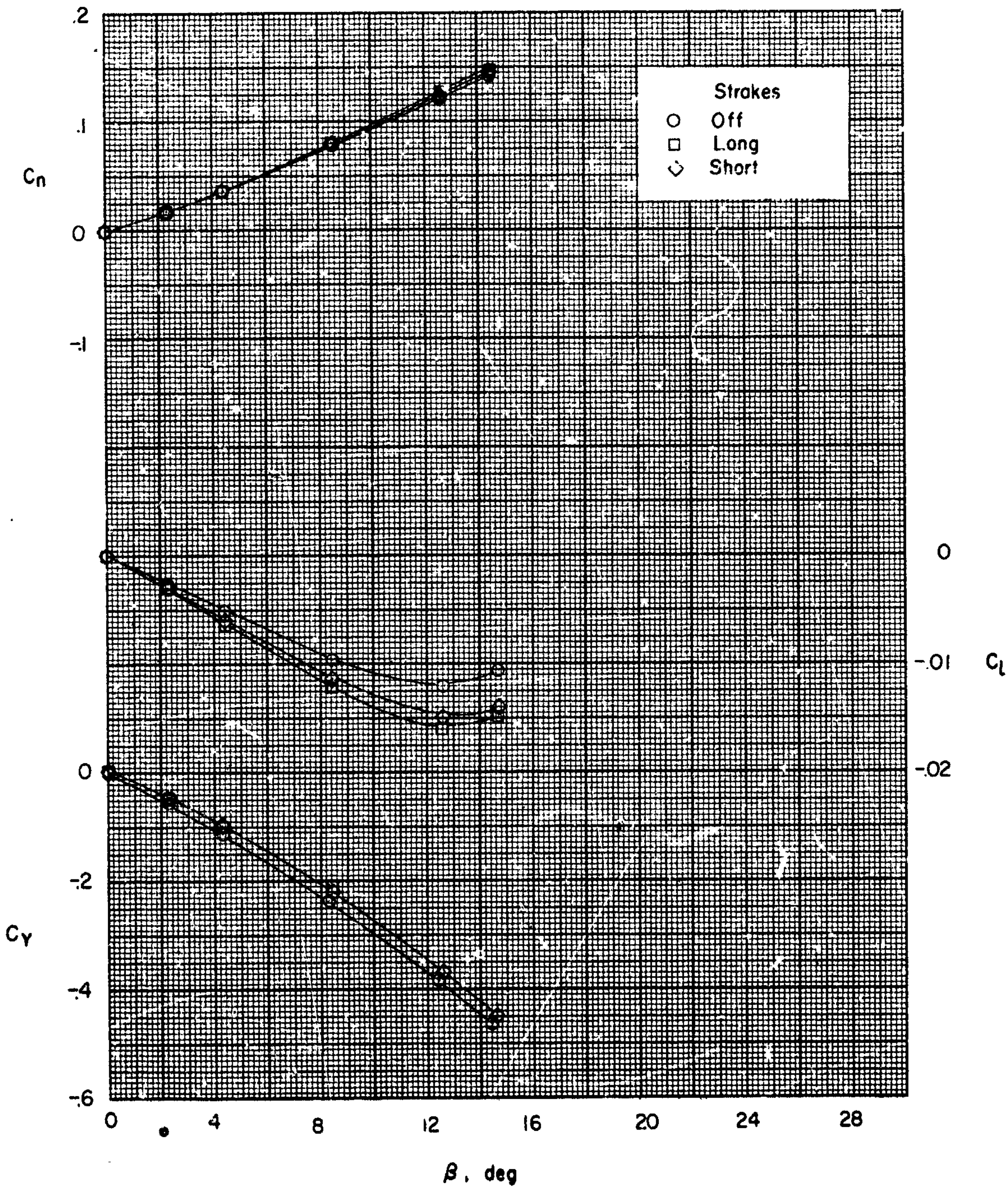
(a) $\alpha \approx 0^{\circ}$.

Figure 4.- Effect of strakes on aerodynamic characteristics in sideslip of complete model. M = 1.41.



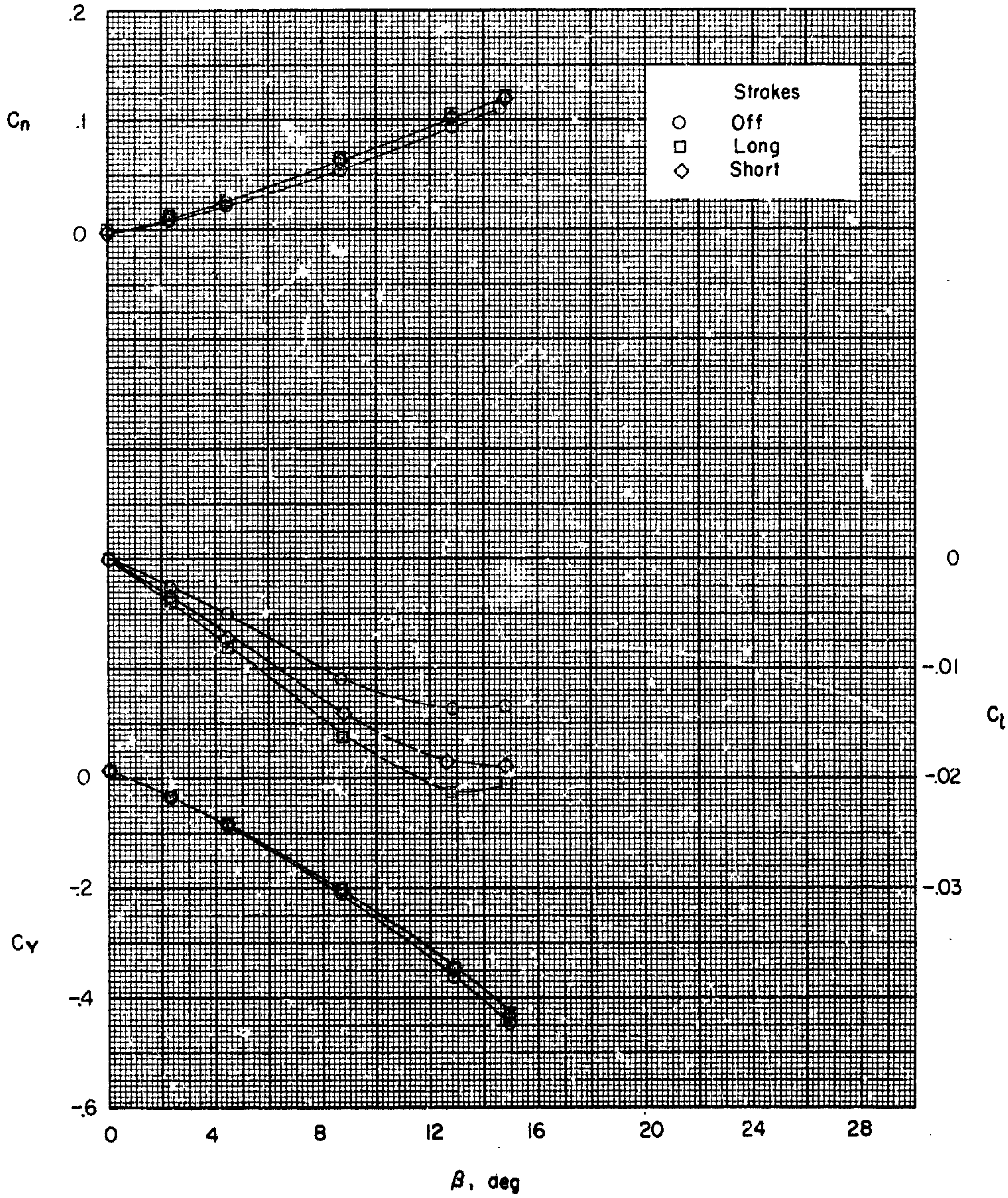
(b) $\alpha \approx 4.3^\circ$.

Figure 4.- Continued.



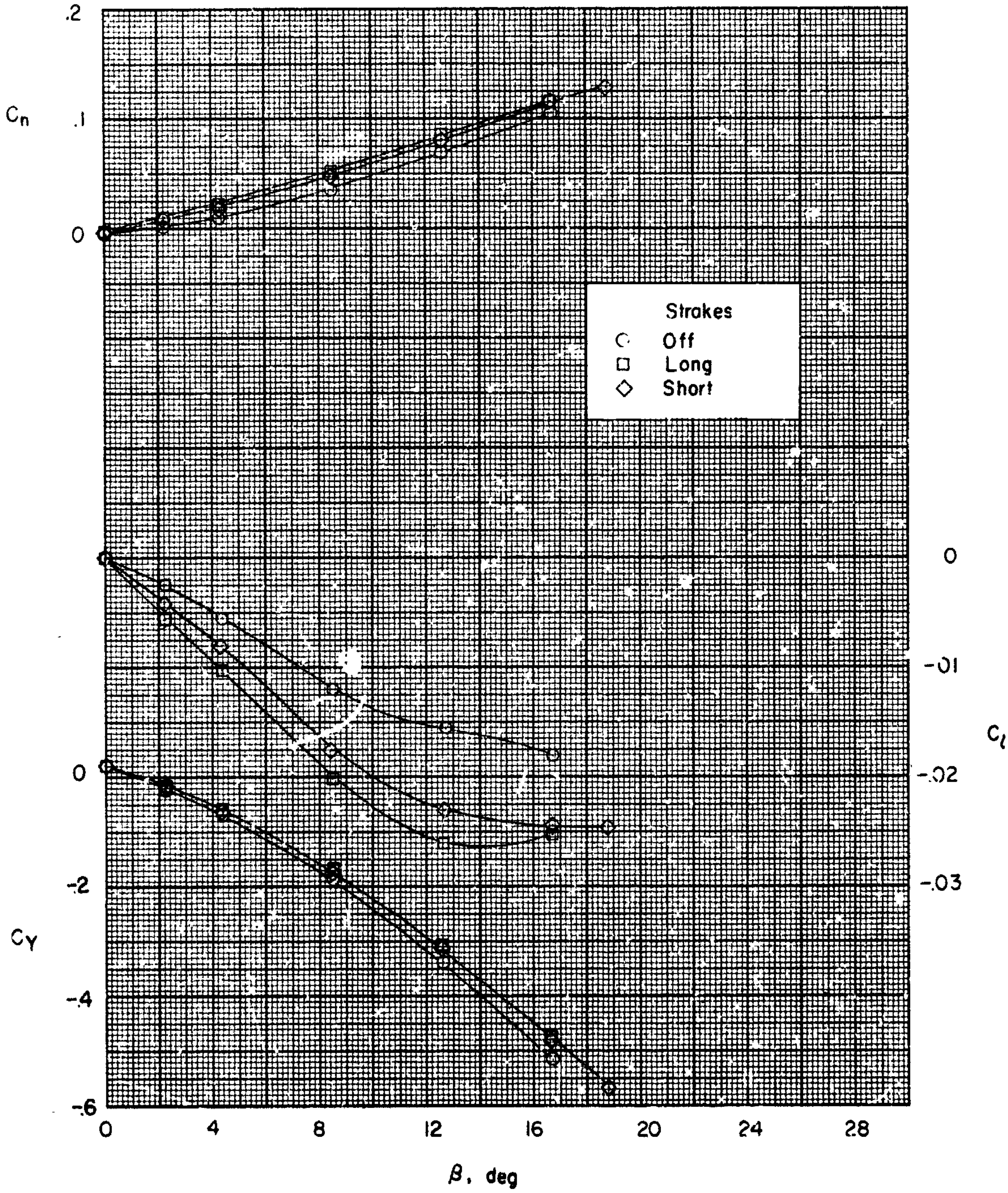
(c) $\alpha \approx 8.7^\circ$.

Figure 4.- Continued.



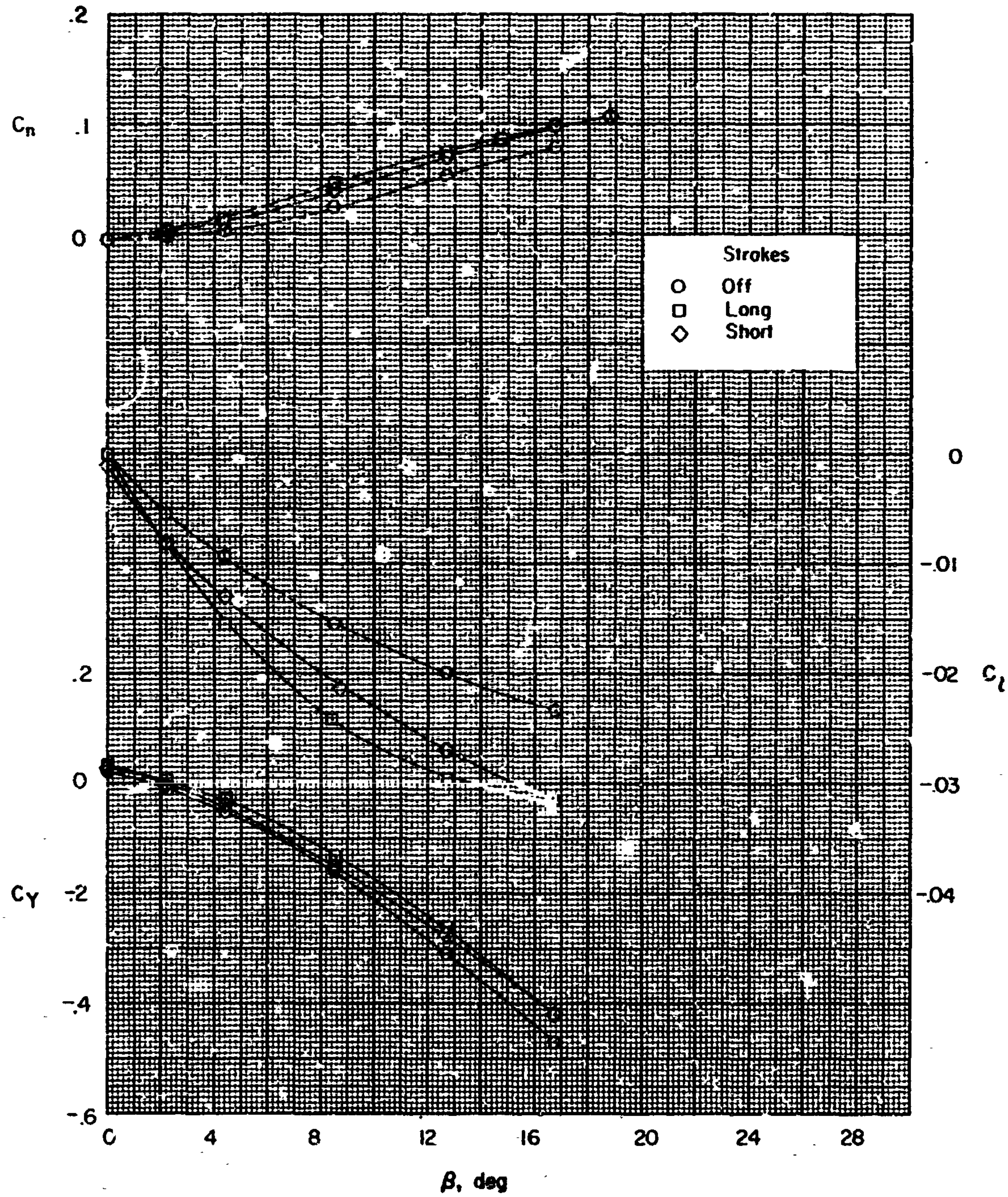
(d) $\alpha \approx 13.1^{\circ}$.

Figure 4.- Continued.



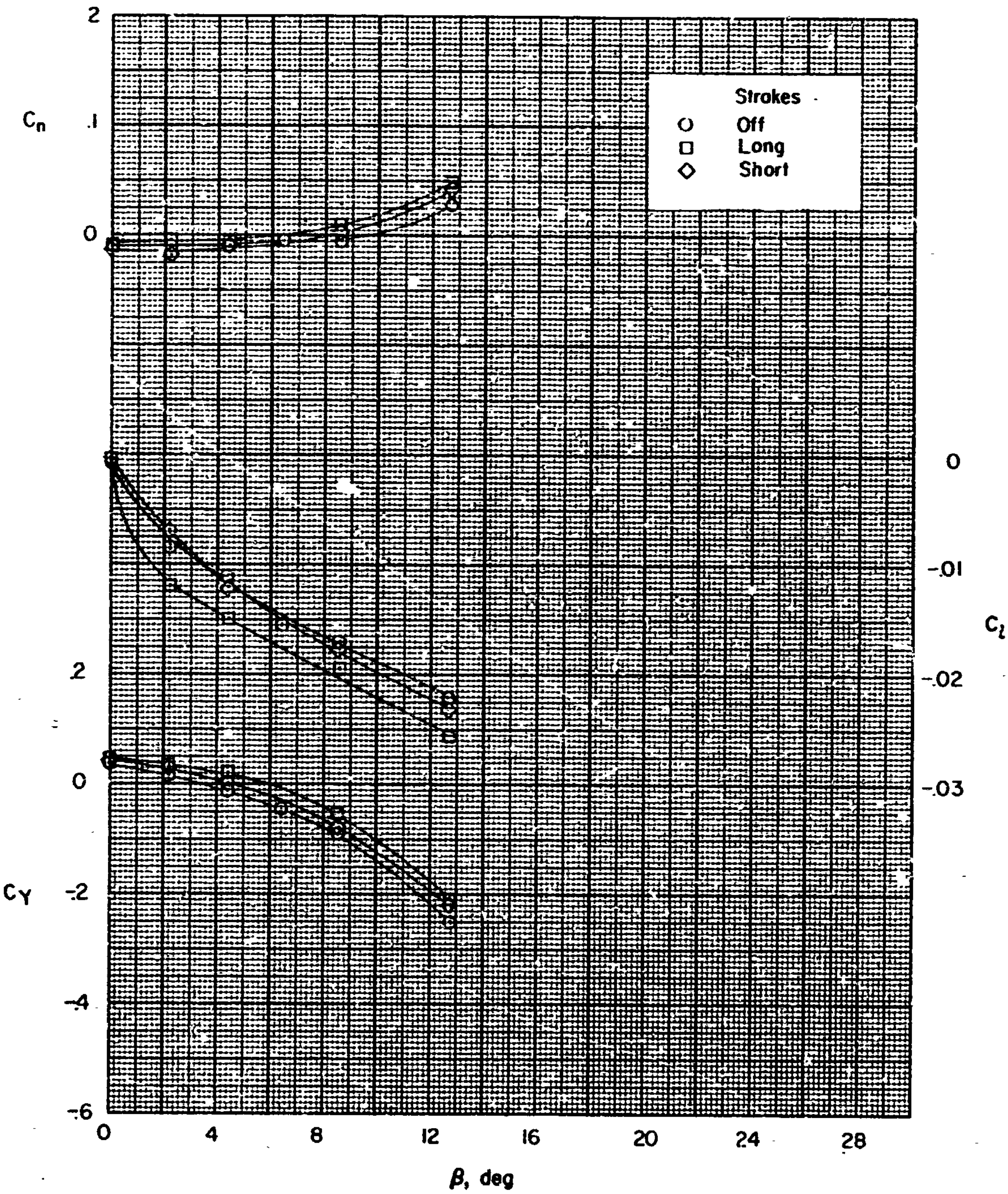
(e) $\alpha \approx 17^{\circ}$.

Figure 4.- Continued.



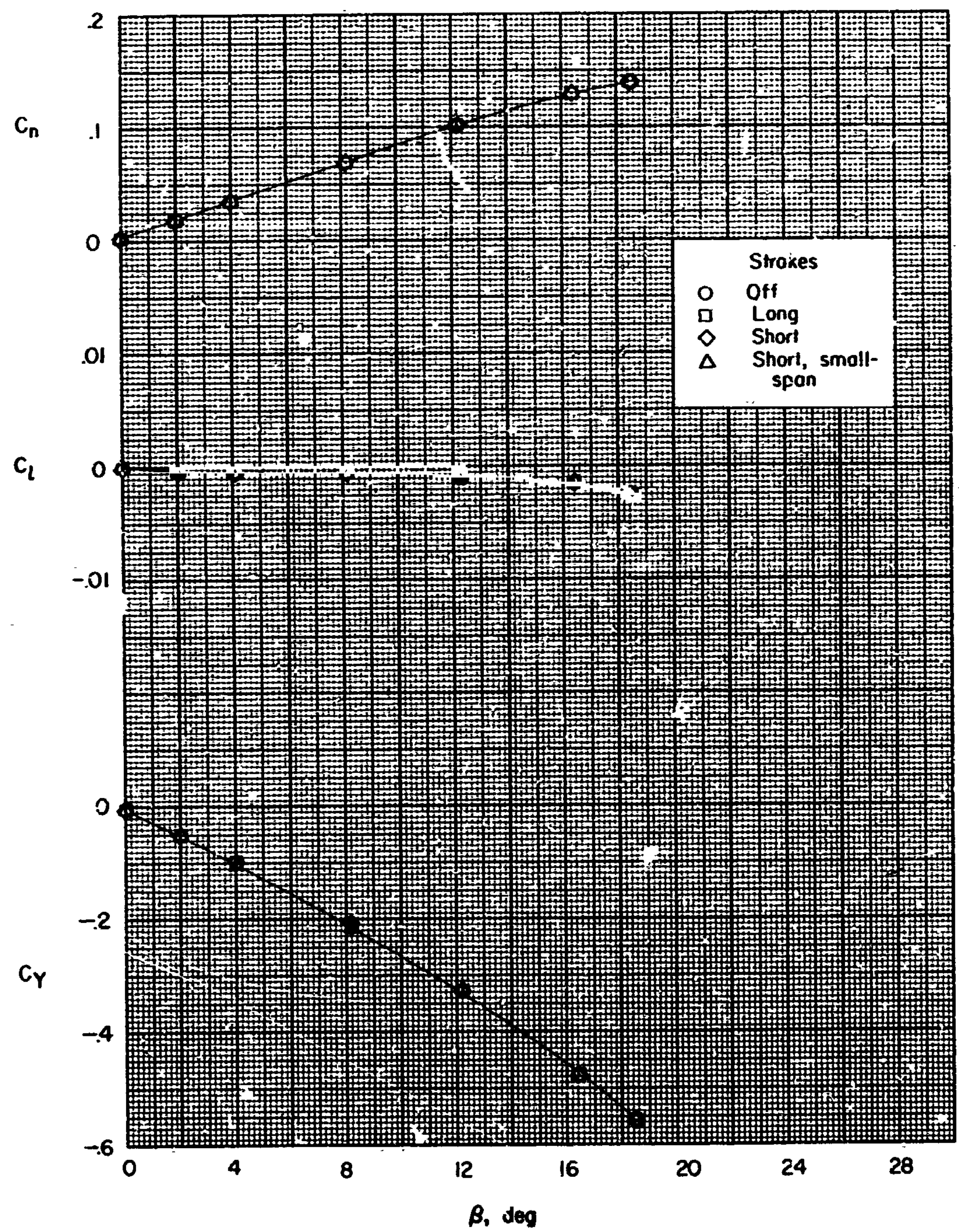
(f) $\alpha \approx 21.3^{\circ}$.

Figure 4.- Continued.



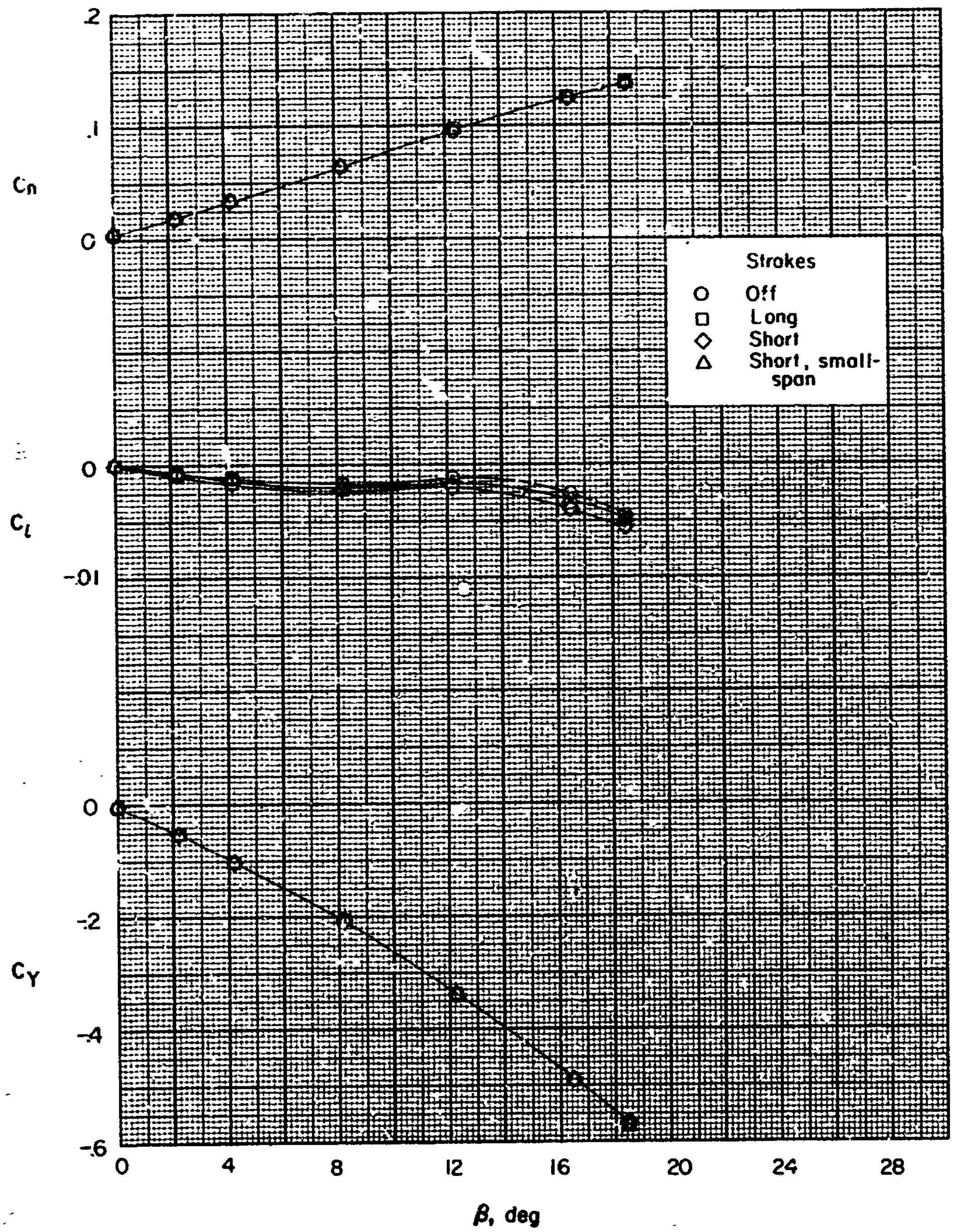
(g) $\alpha \approx 25.6^{\circ}$.

Figure 4.- Concluded.



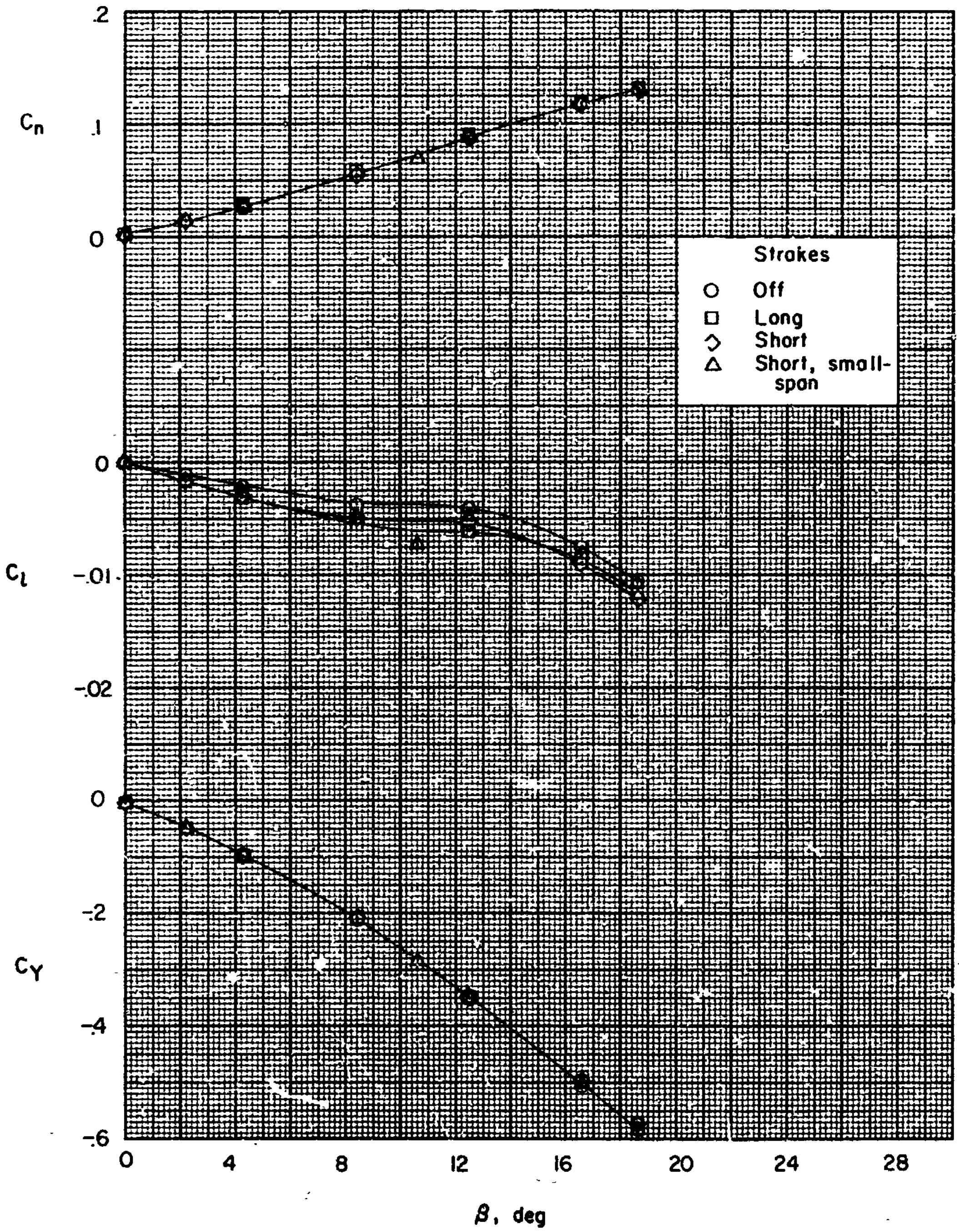
(a) $\alpha \approx 0^{\circ}$.

Figure 5.- Effect of strakes on aerodynamic characteristics in sideslip of complete model. M = 2.01.



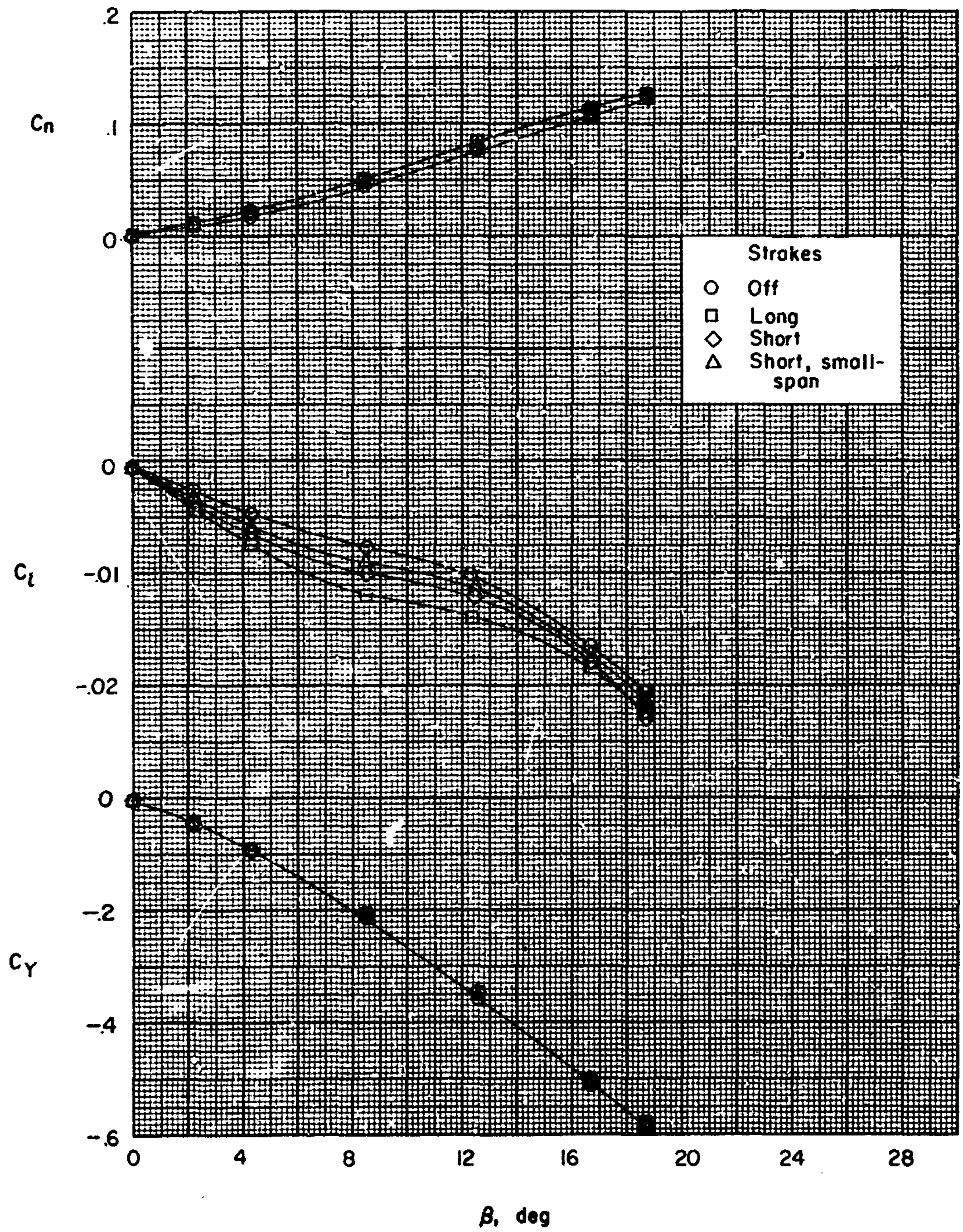
(b) $\alpha \approx 4.3^{\circ}$.

Figure 5.- Continued.



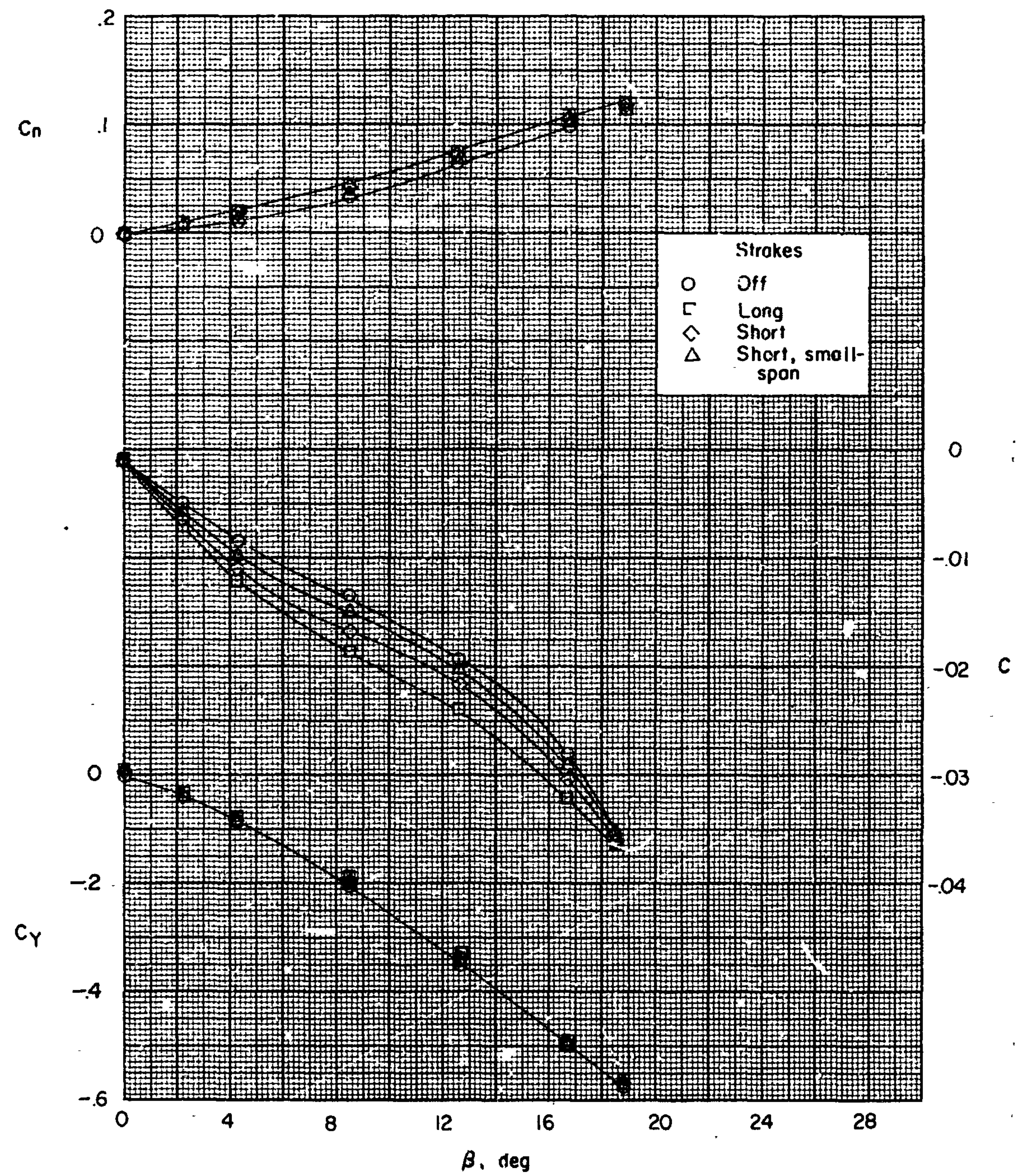
(c) $\alpha \approx 8.4^{\circ}$.

Figure 5.- Continued.



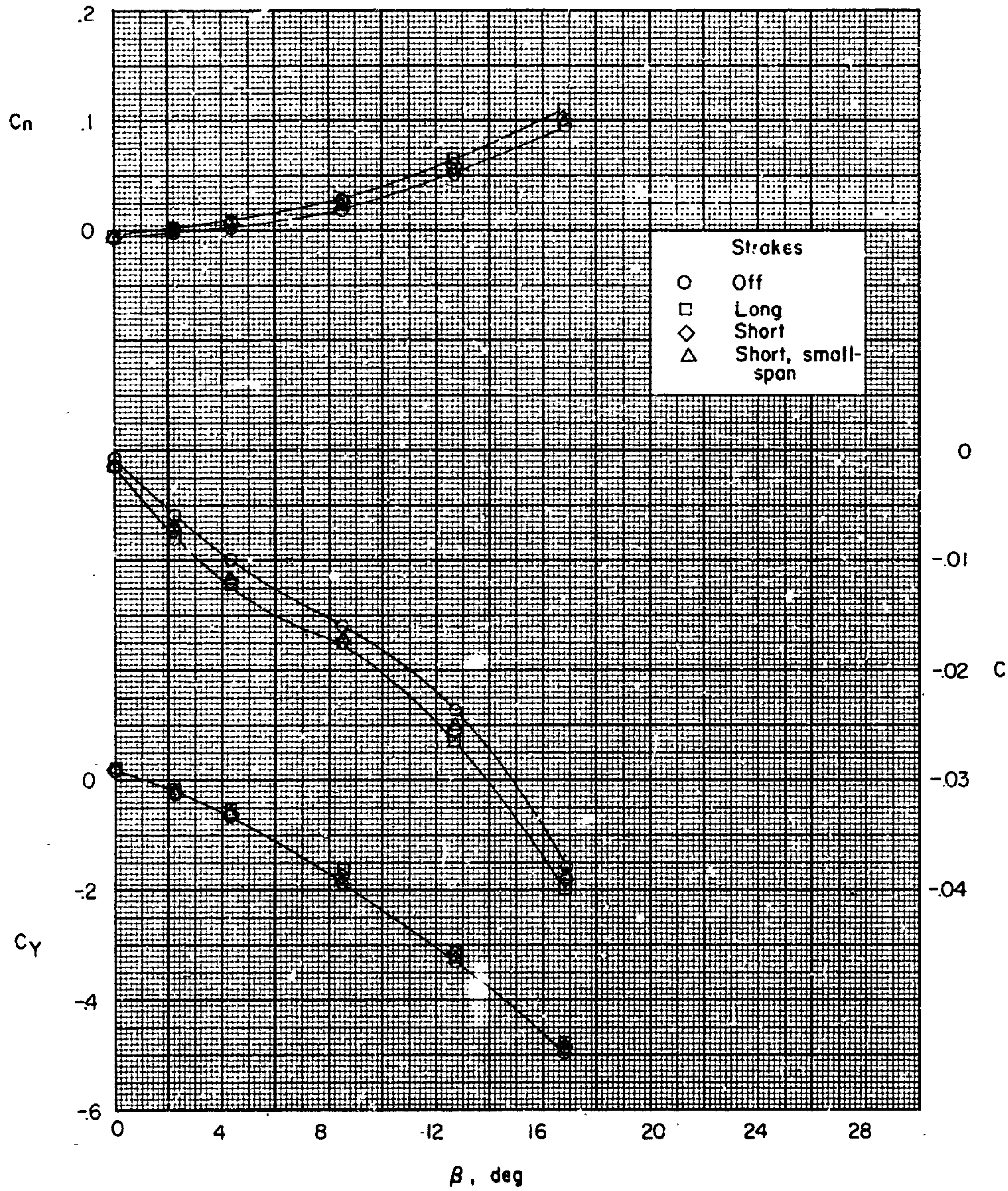
(d) $\alpha \approx 12.7^{\circ}$.

Figure 5.- Continued.



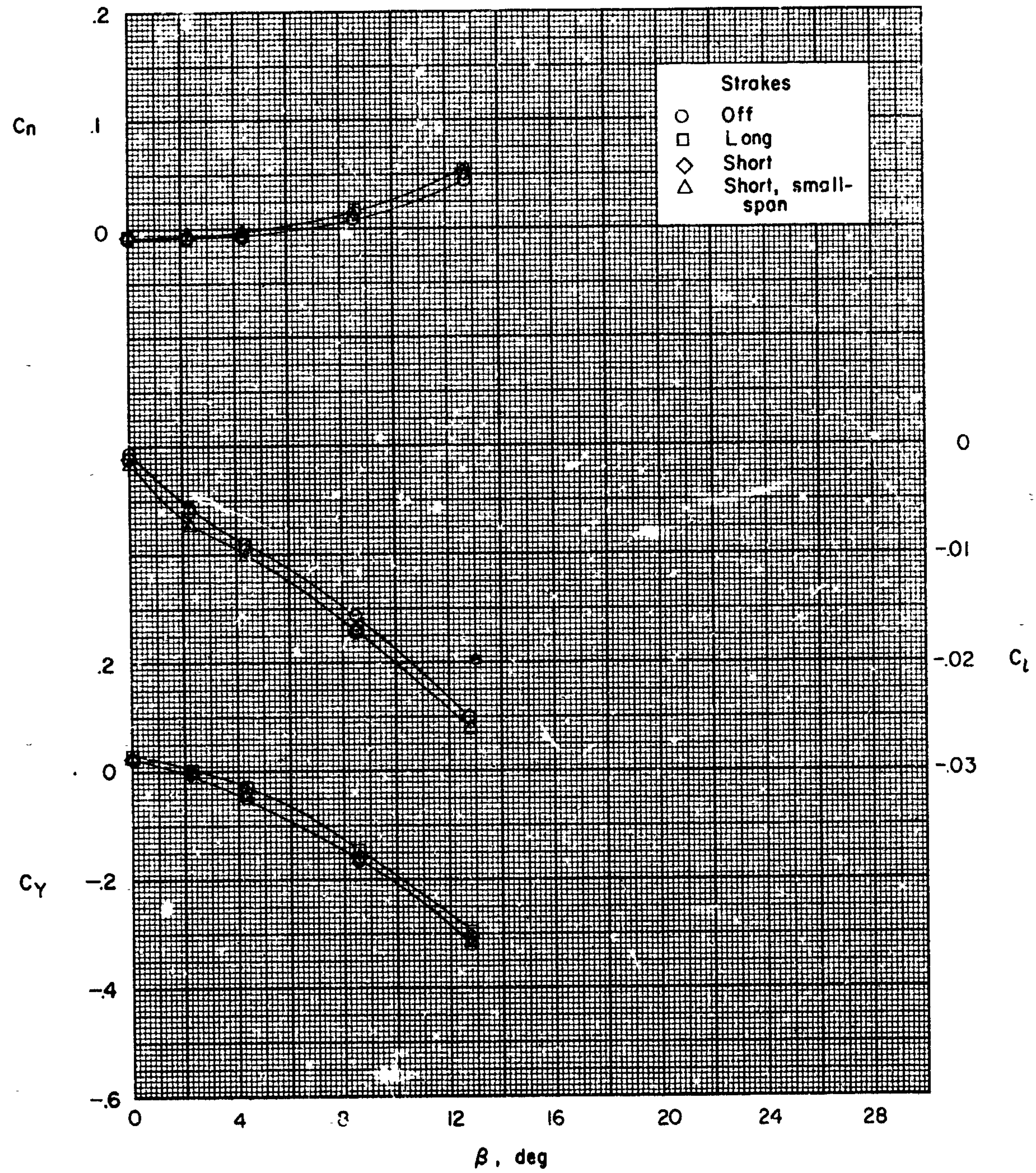
(e) $\alpha \approx 16.9^{\circ}$.

Figure 5.- Continued.



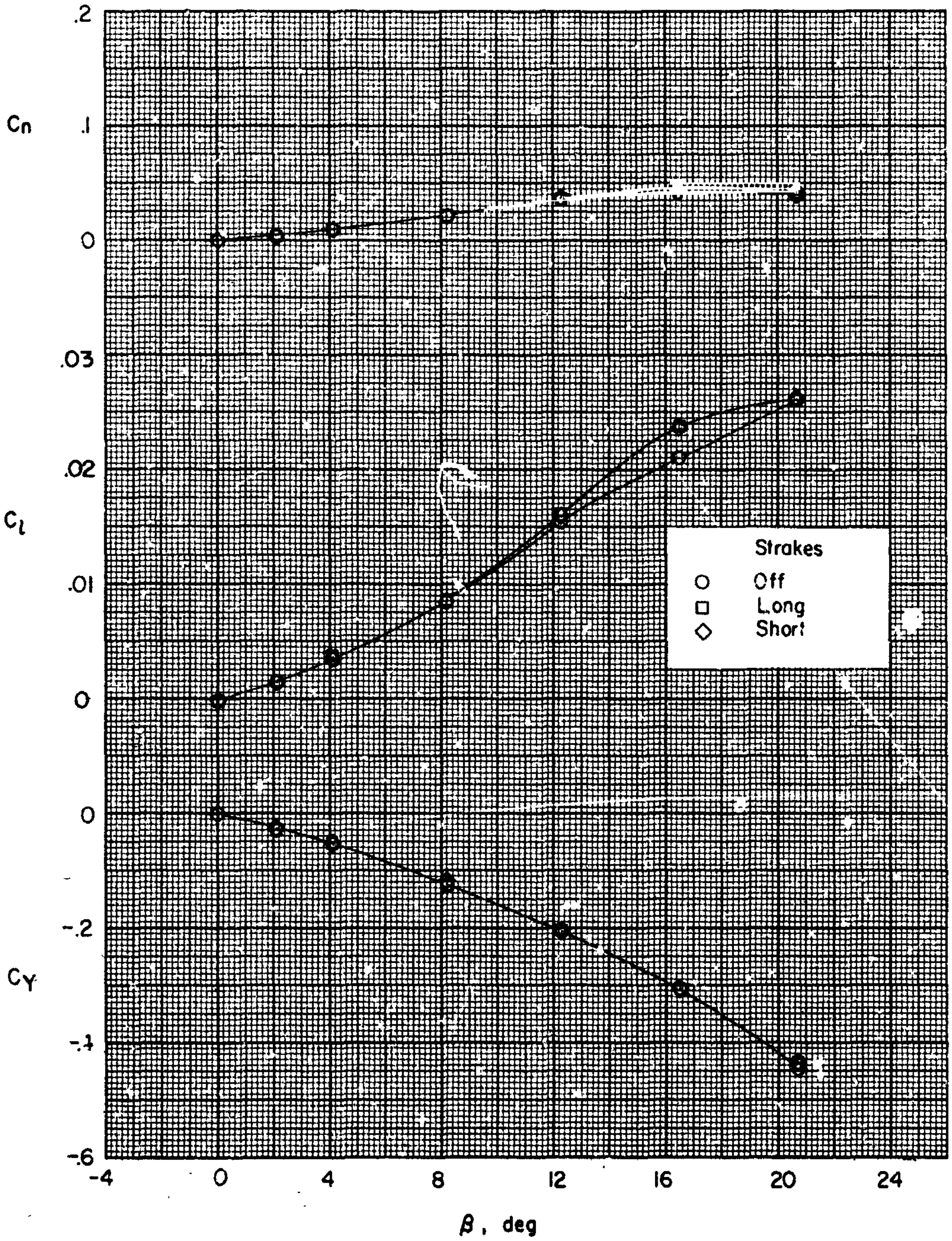
(f) $\alpha \approx 21.2^{\circ}$.

Figure 5.- Continued.



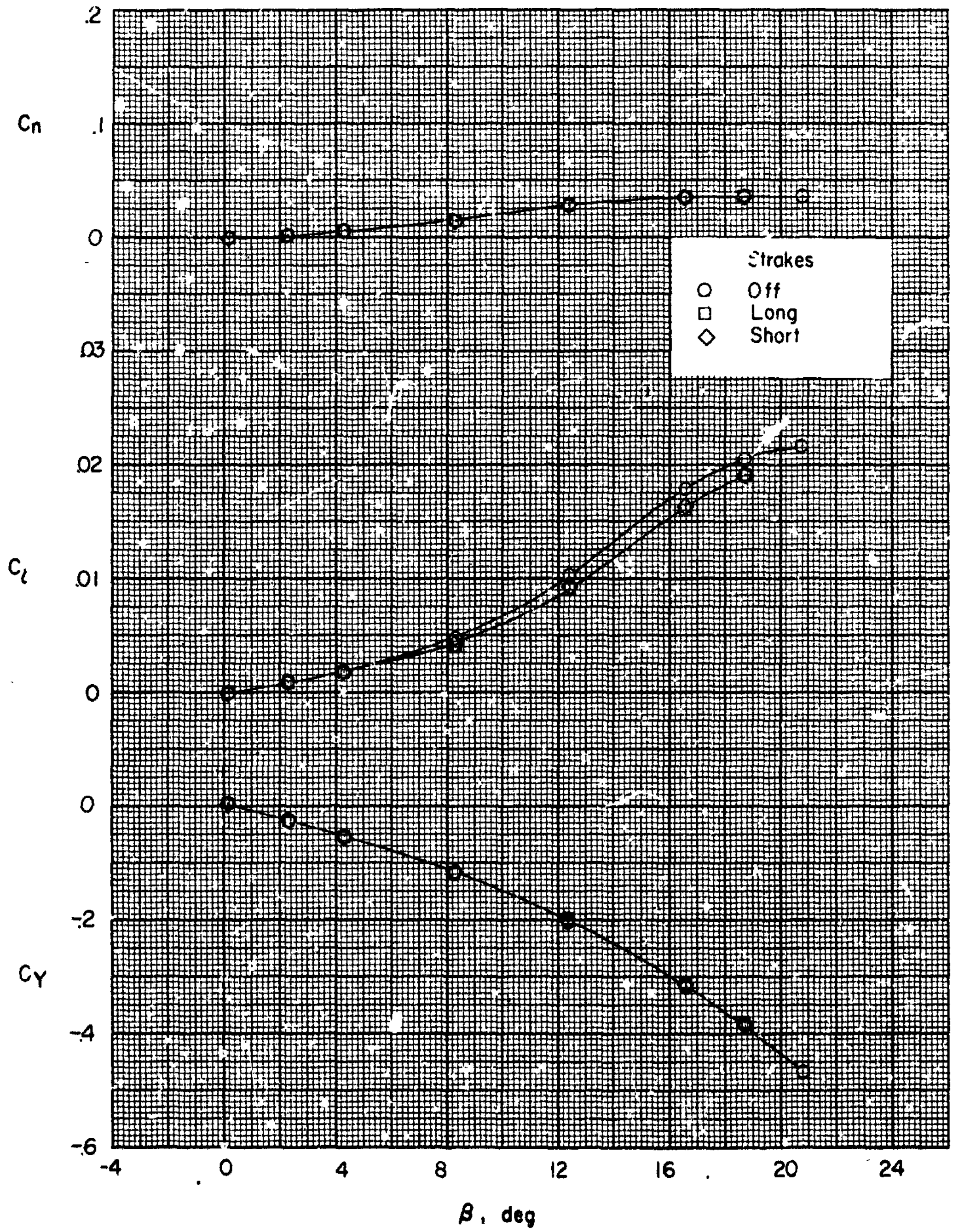
(g) $\alpha \approx 25.5^o$.

Figure 5.- Concluded.



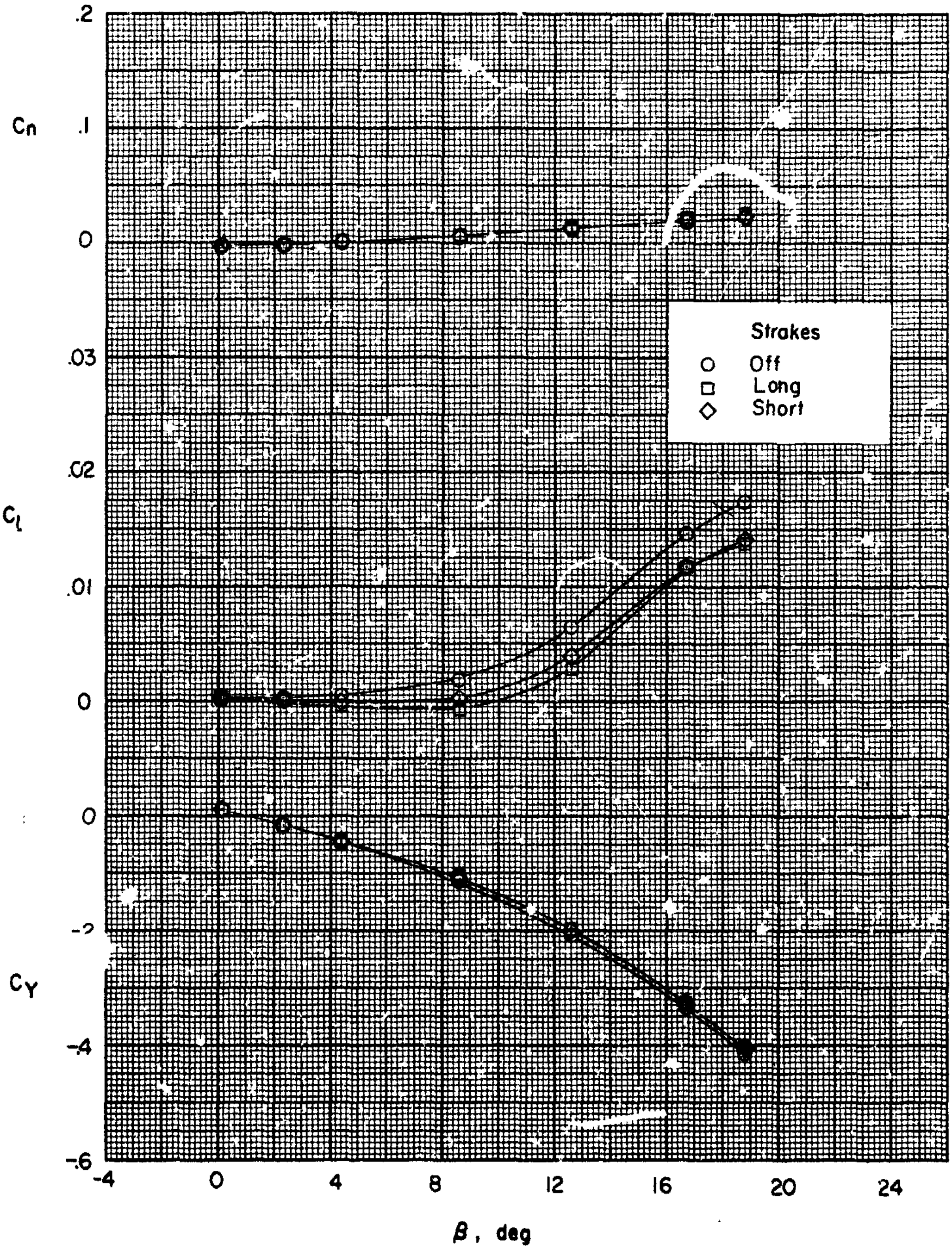
(a) $\alpha \approx 0^{\circ}$.

Figure 6.- Effect of strakes on aerodynamic characteristics in sideslip of model with upper vertical tail off. M = 1.41.



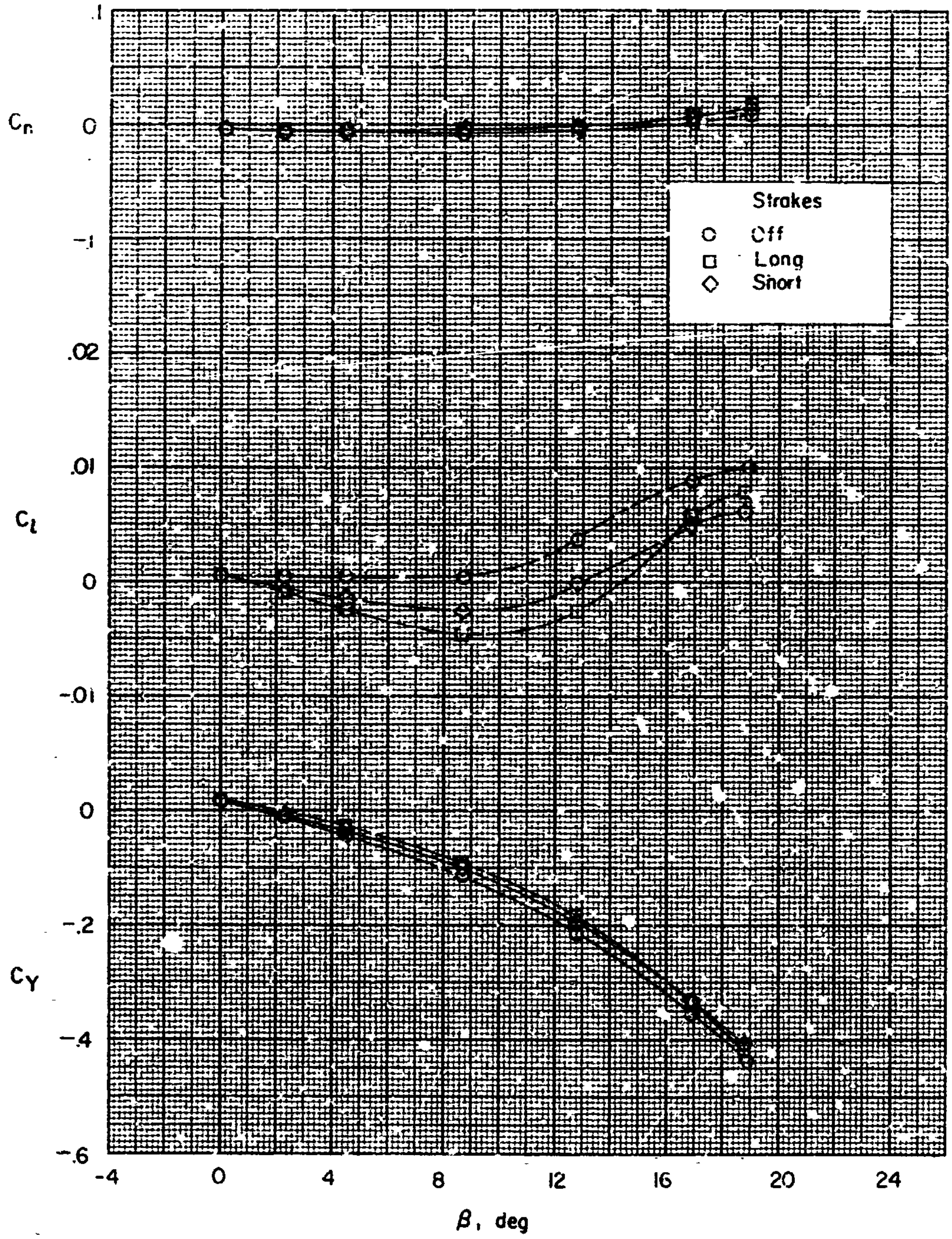
(b) $\alpha \approx 4.3^{\circ}$.

Figure 6.- Continued.



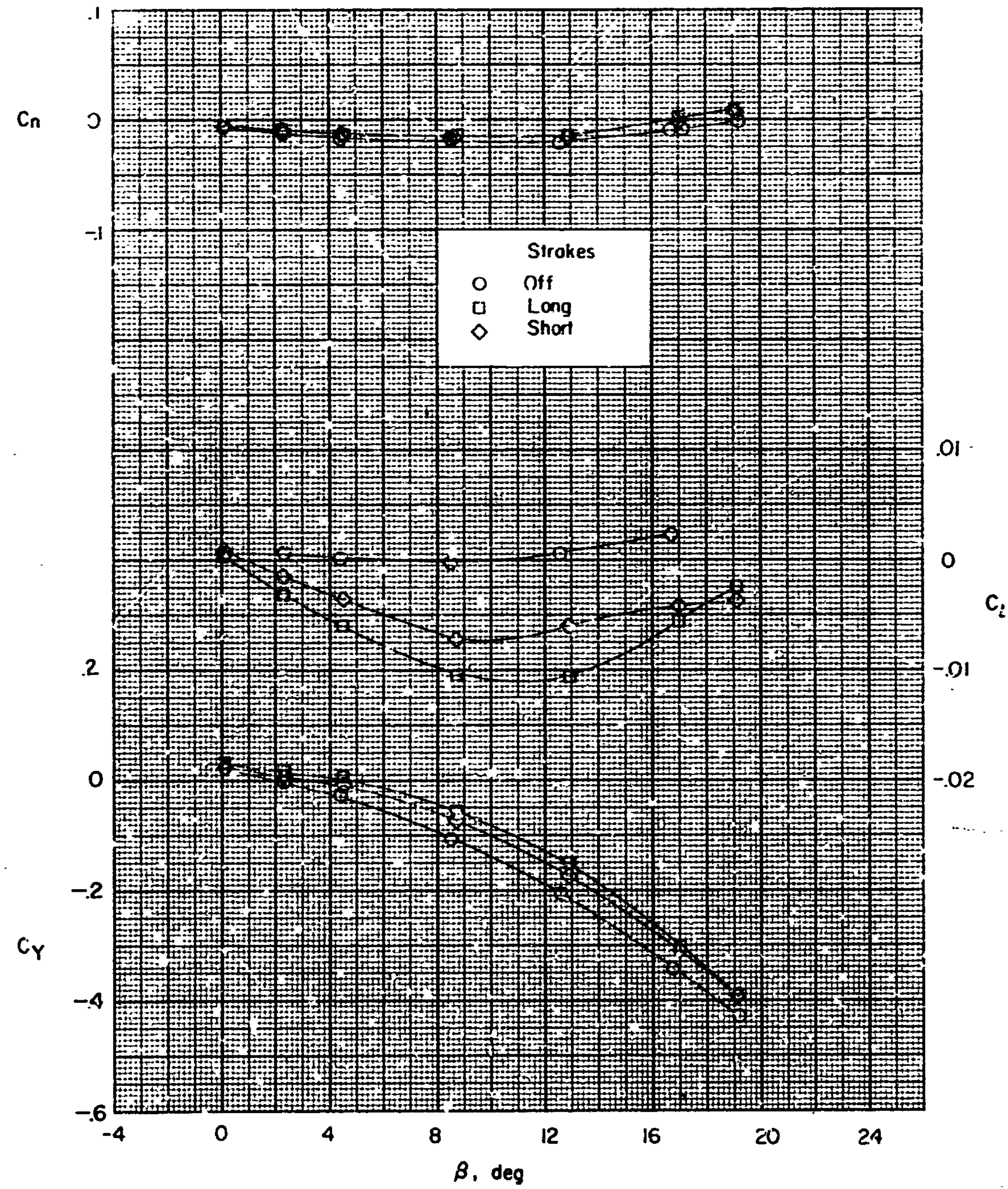
(c) $\alpha \approx 8.7^{\circ}$.

Figure 6.- Continued.



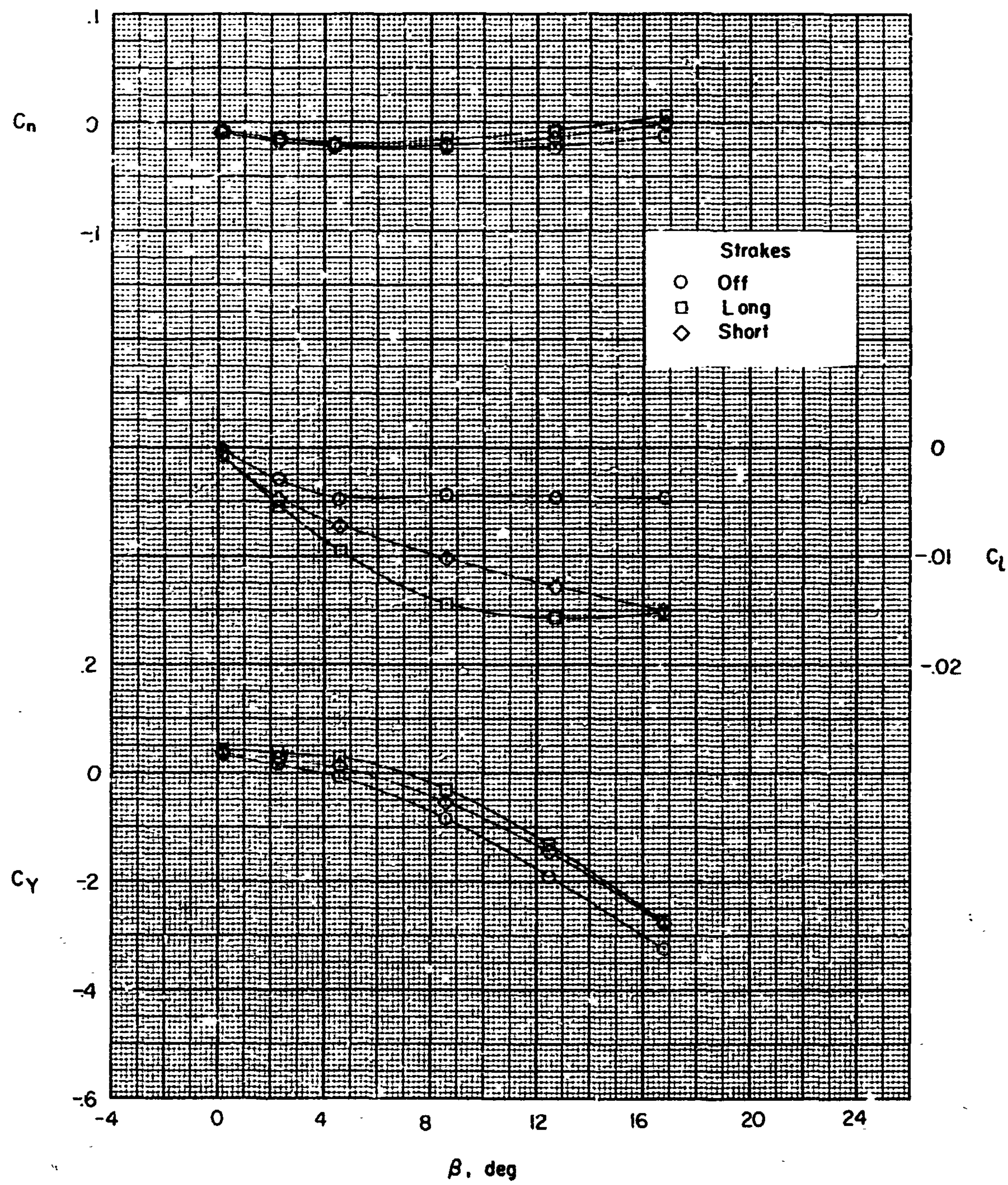
(d) $\alpha \approx 13.1^{\circ}$.

Figure 6.- Continued.



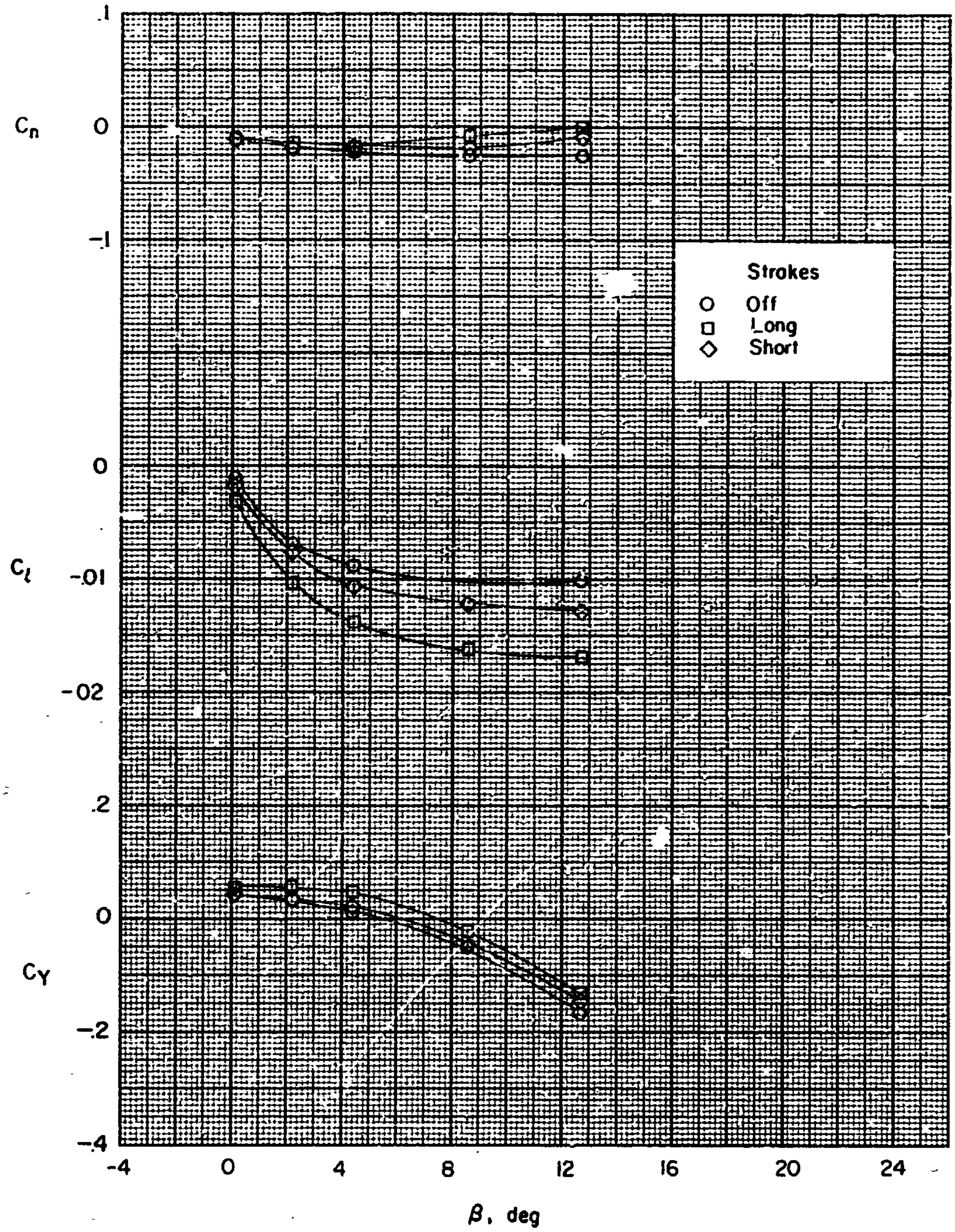
(e) $\alpha \approx 17.5^{o}$.

Figure 6.- Continued.



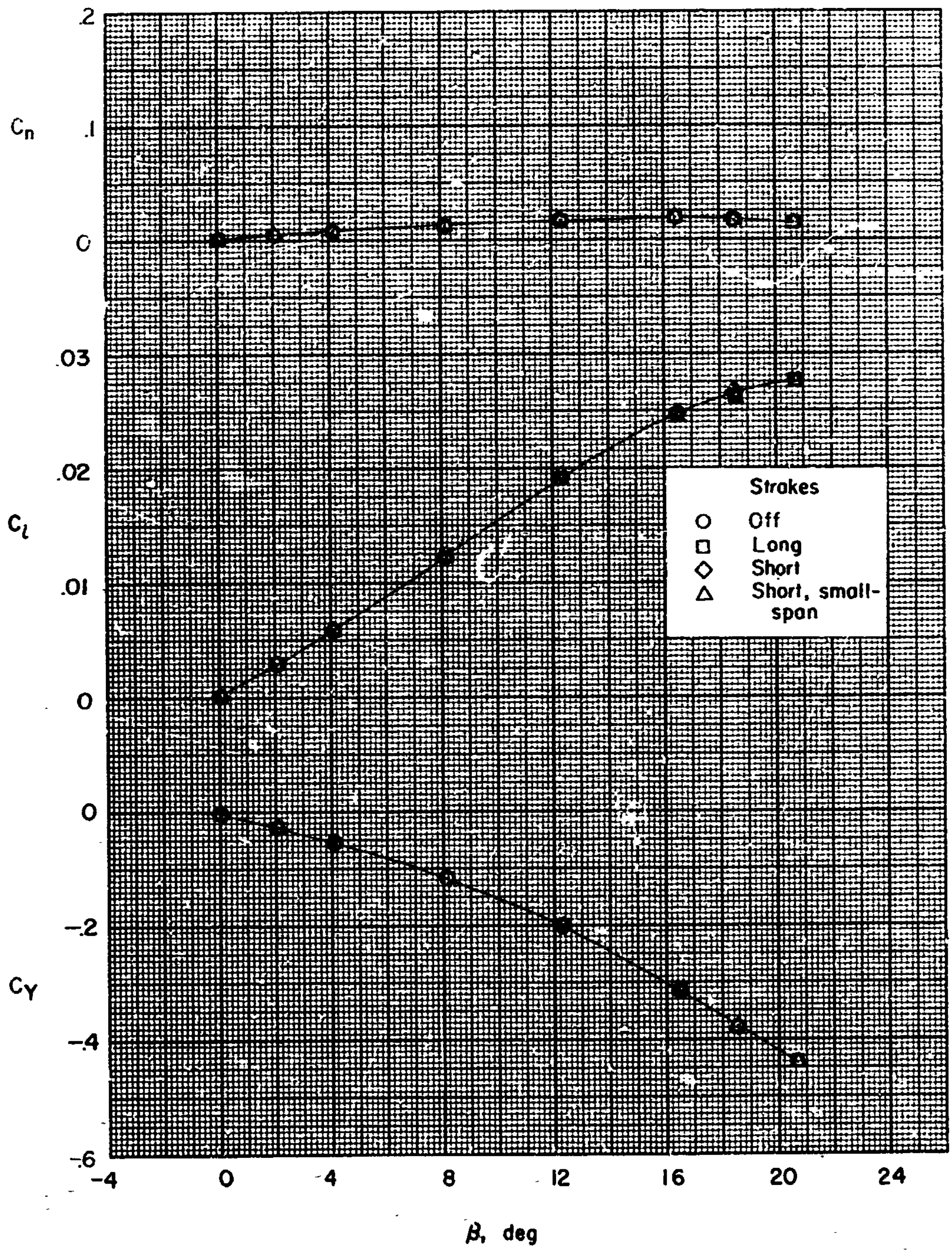
(f) $\alpha \approx 21.3^{\circ}$.

Figure 6.- Continued.



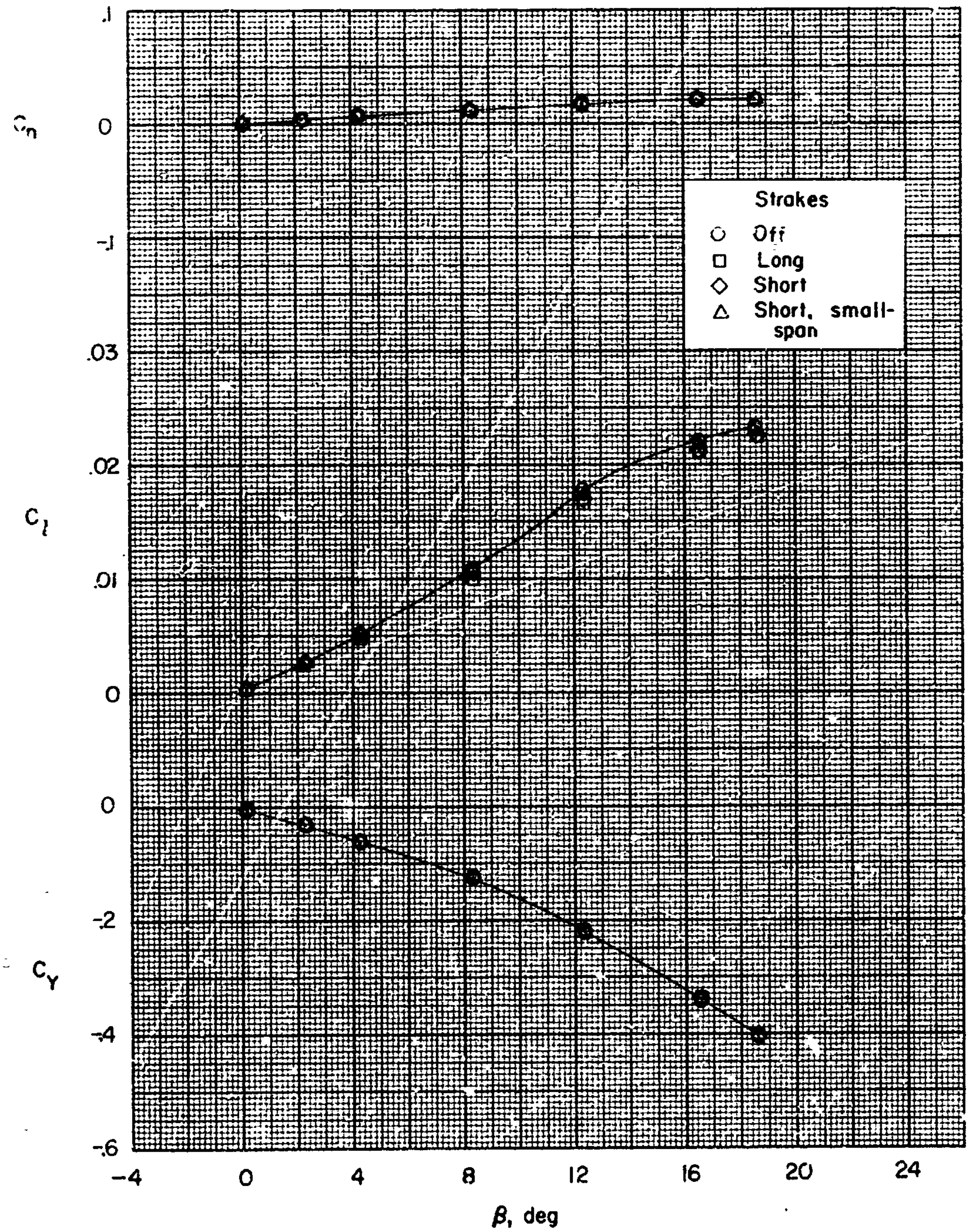
(g) $\alpha \approx 25.5^{\circ}$.

Figure 6.- Concluded.



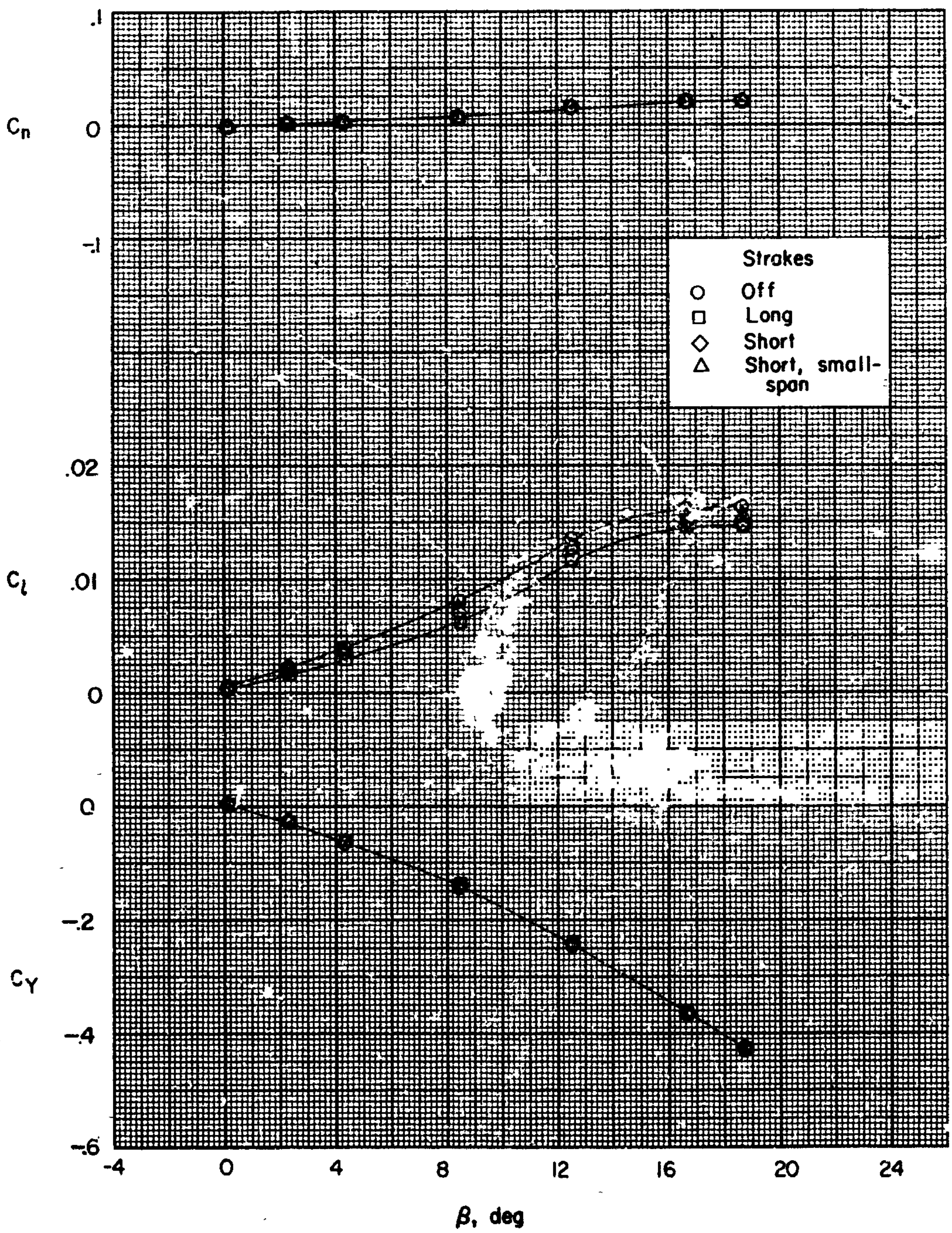
(a) $\alpha \approx 0^{\circ}$.

Figure 7.- Effect of strakes on aerodynamic characteristics in sideslip of model with upper vertical tail off. M = 2.01.



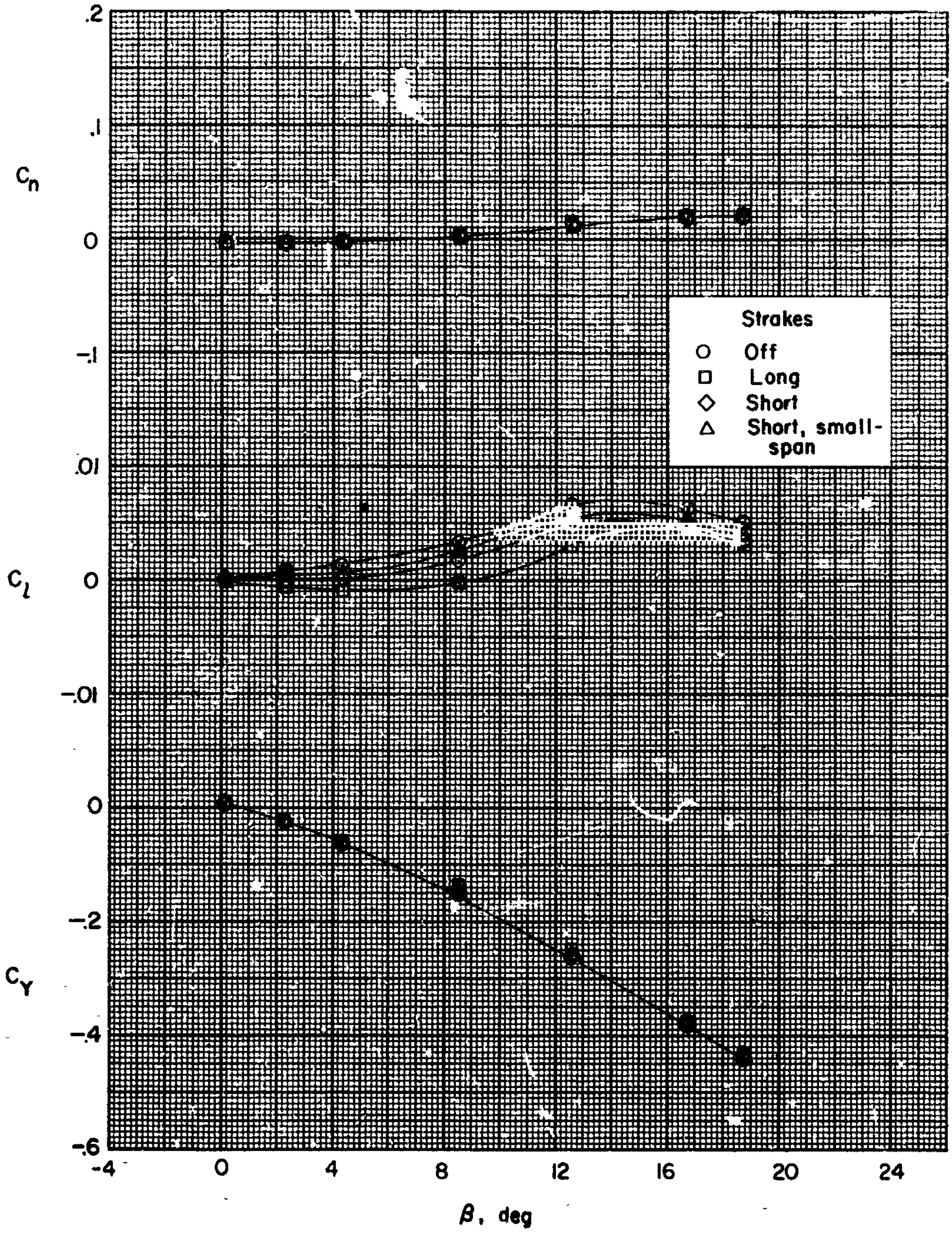
(b) $\alpha \approx 4.3^{\circ}$.

Figure 7.- Continued.



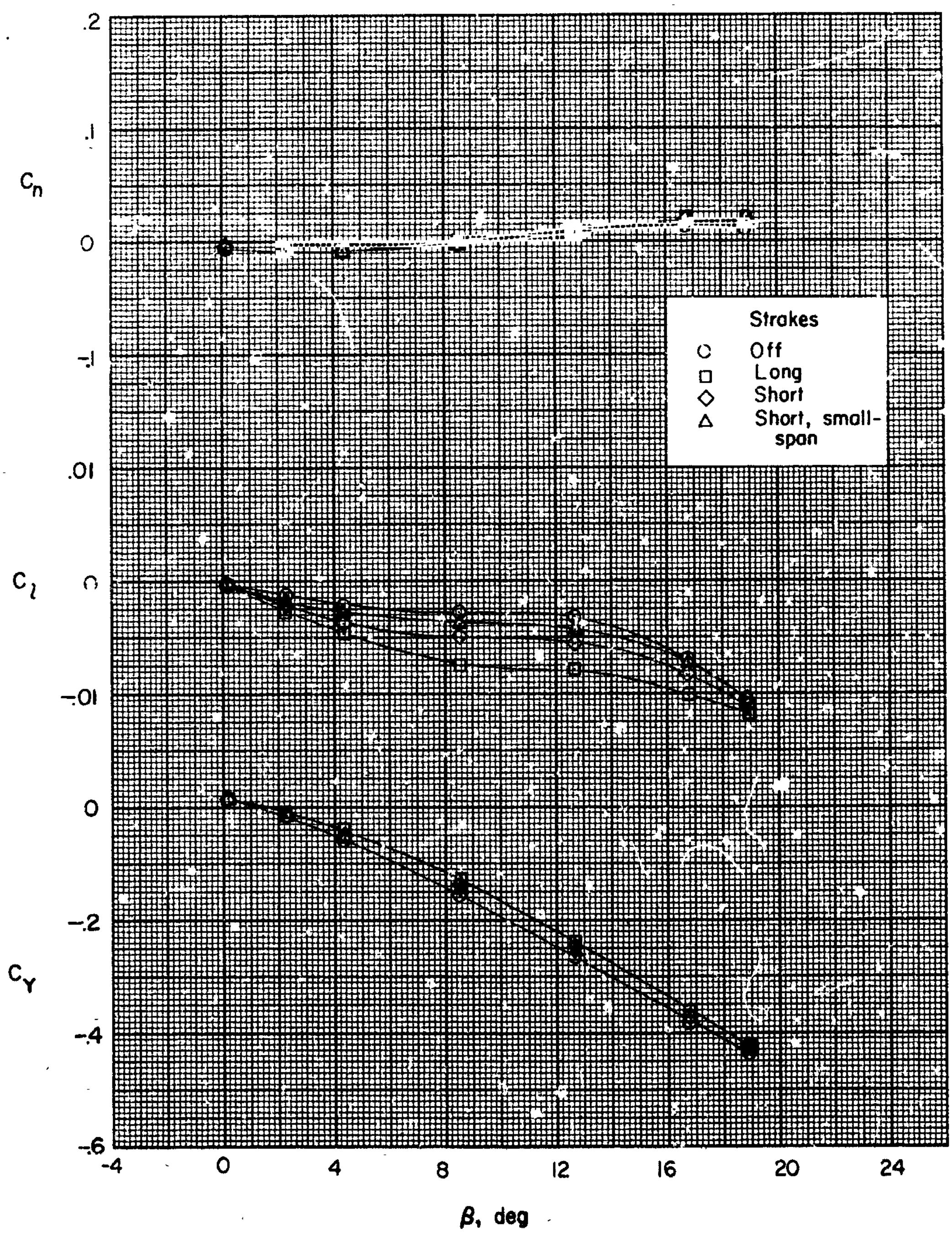
(c) $\alpha \approx 8.4^{\circ}$.

Figure 7.- Continued.



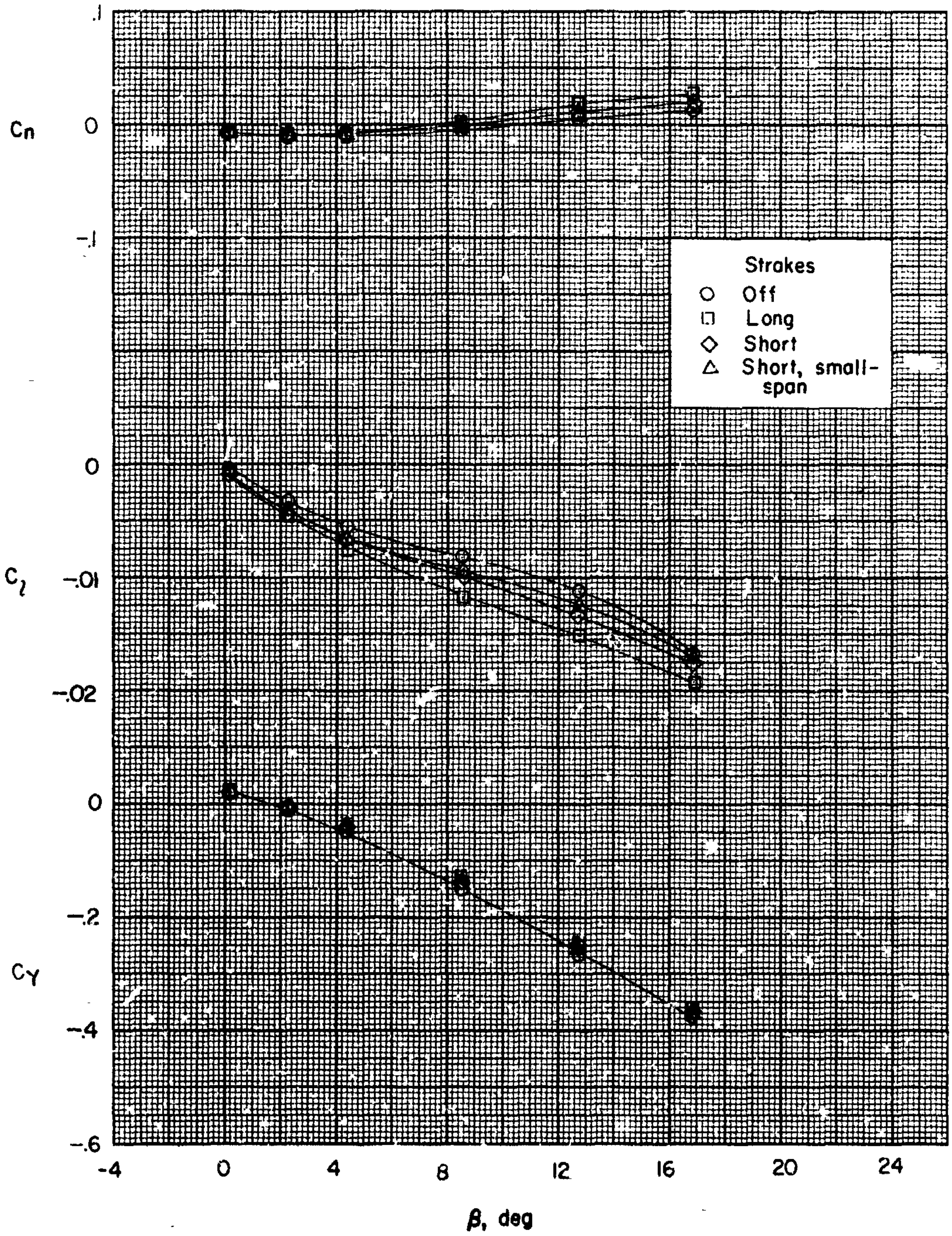
(d) $\alpha \approx 12.7^{\circ}$.

Figure 7.- Continued.



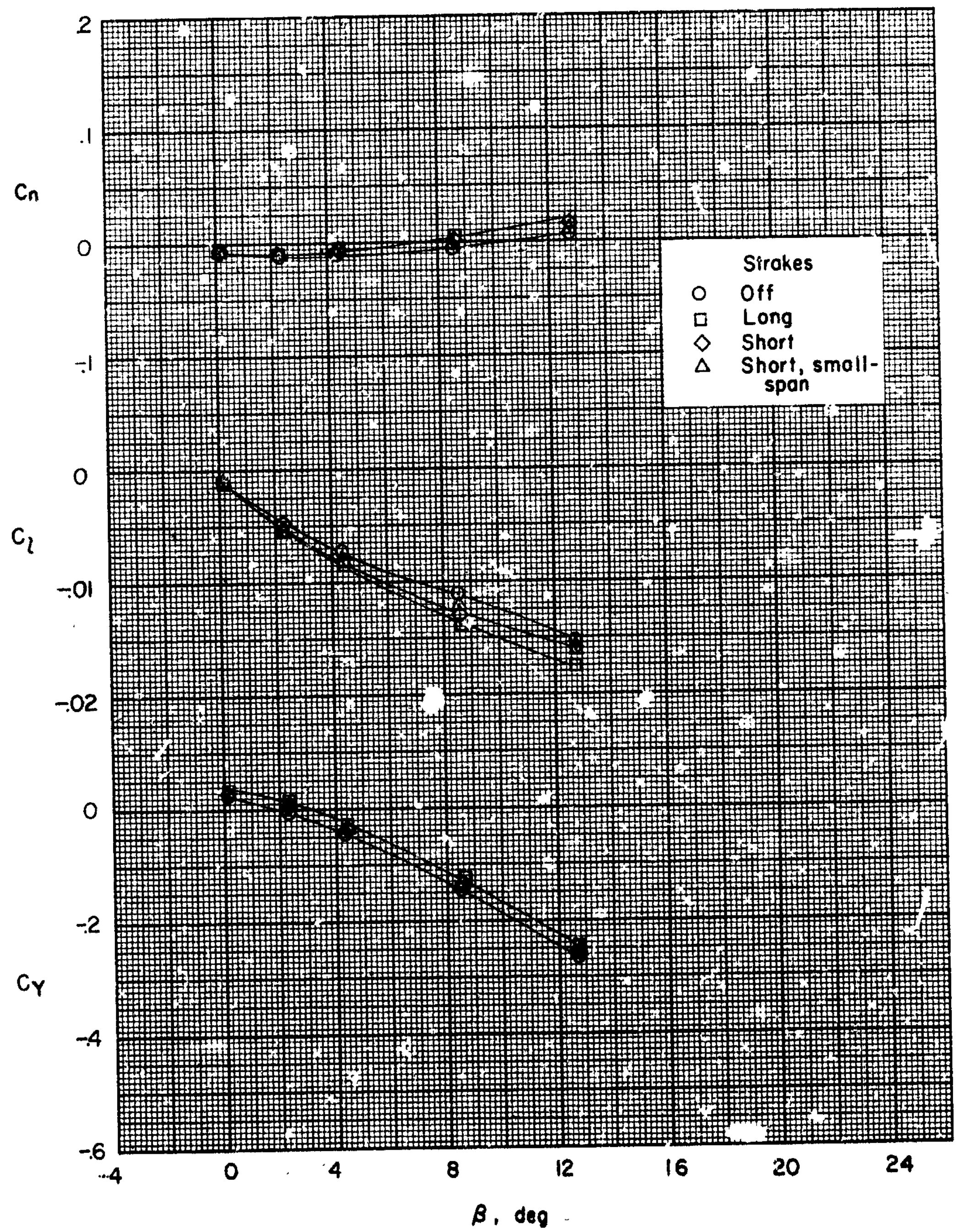
(e) $\alpha \approx 16.9^{\circ}$.

Figure 7.- Continued.



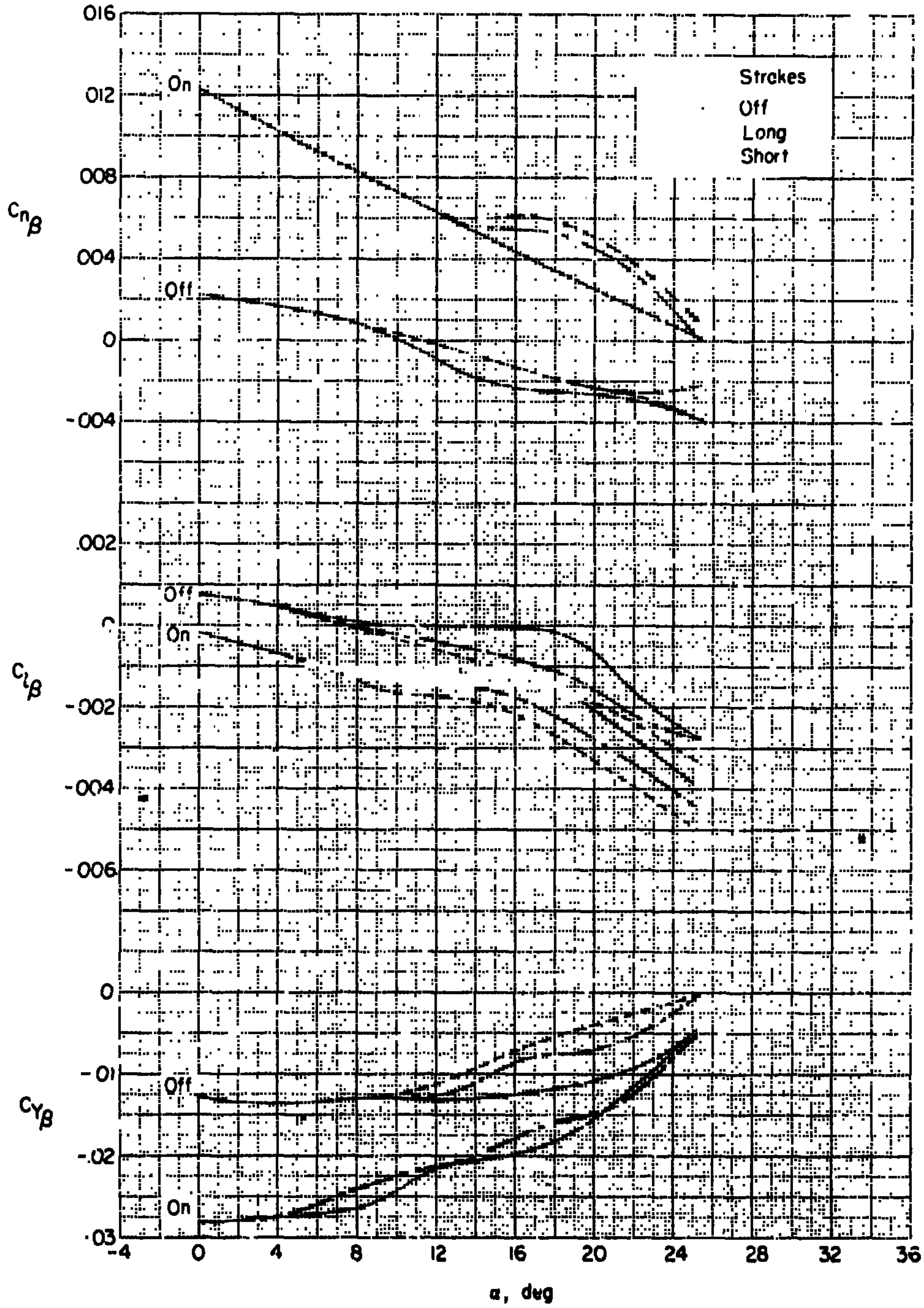
(f) $\alpha \approx 21.2^{\circ}$.

Figure 7.- Continued.



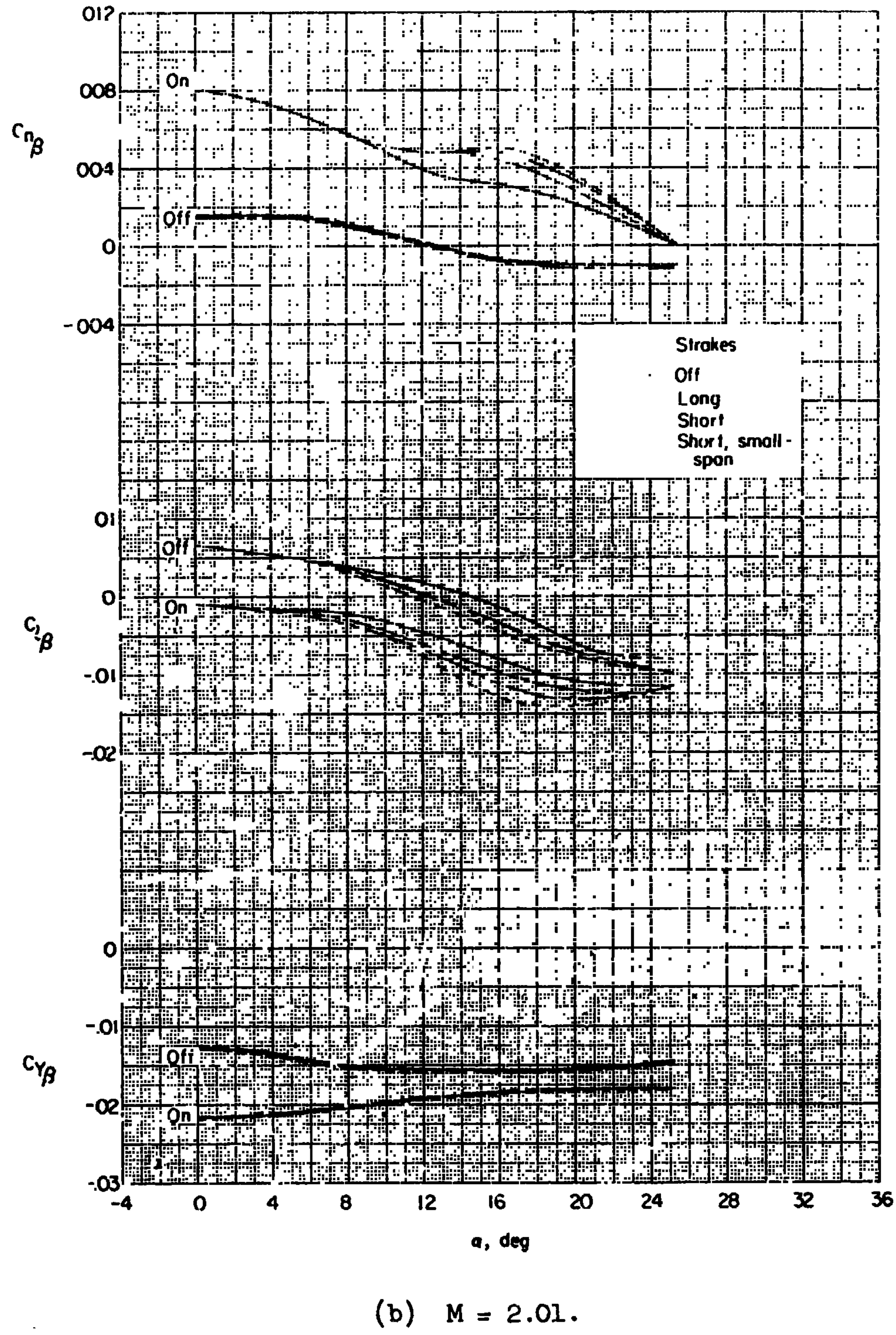
(g) $\alpha \approx 25.5^{\circ}$.

Figure 7.- Concluded.



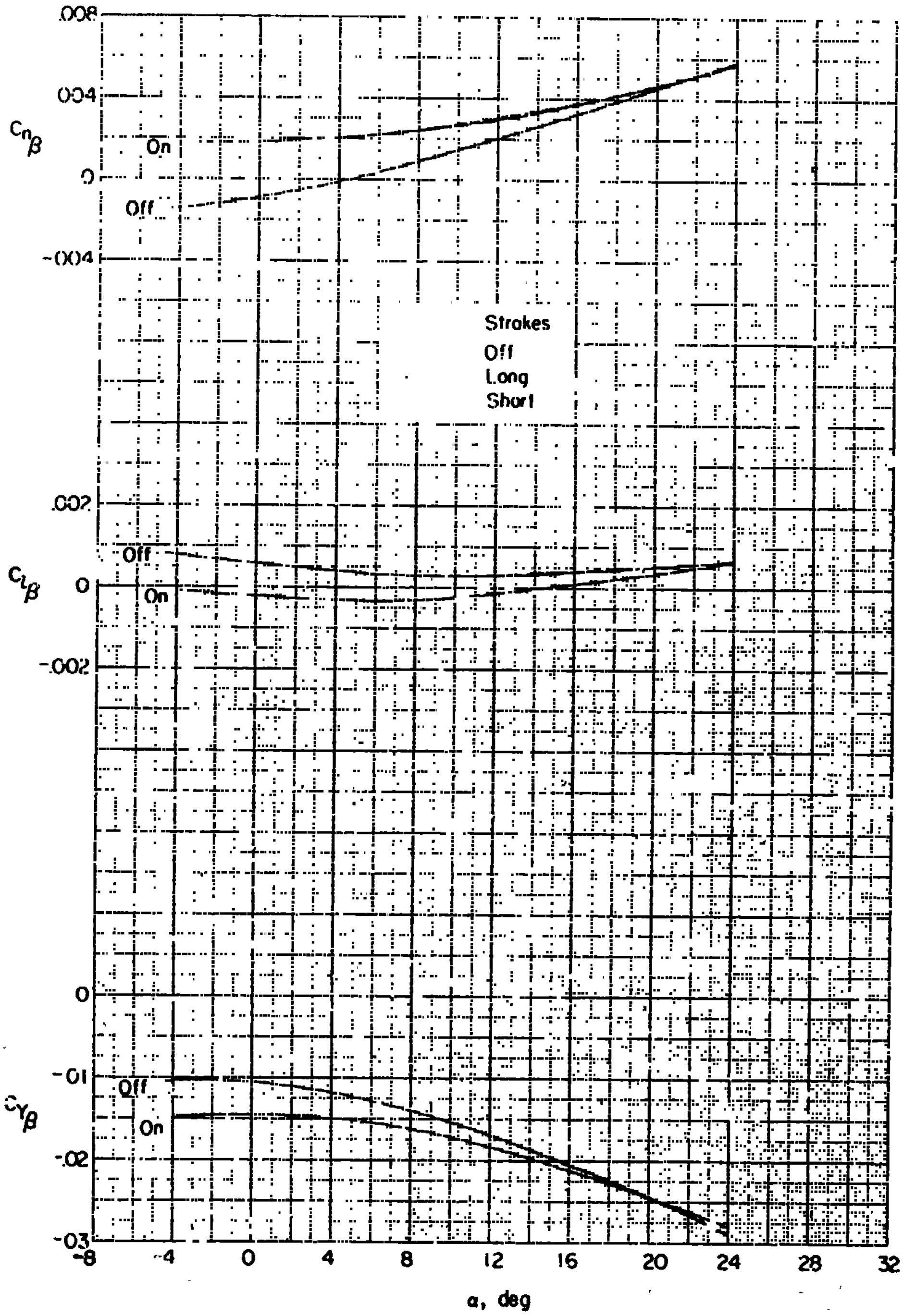
(a) M = 1.41.

Figure 8.- Effect of strakes on sideslip derivatives of model with upper vertical tail on and off.



(b) M = 2.01.

Figure 8.- Continued.



(c) M = 6.86.

Figure 8.- Concluded.