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STABILITY AND CONTROL CHARACTERISTICS OF A LARGE-SCALE DEFLECTED SLIPSTREAM STOL MODEL WITH A WING OF 5.7 ASPECT RATIO

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16. Abstract

A wind-tunnel investigation was conducted to determine the stability and control characteristics of a large-scale model representative of a propeller-driven STOL transport. Longitudinal and lateral-directional characteristics were obtained for a four-engine configuration having a wing of 5.7 aspect ratio fully immersed in the propeller slipstream Configuration variables included an aileron, a spoiler, a slot-lip aileron, a spanwise variation of propeller thrust, and two vertical heights of the horizontal tail.

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NOTATION

b wing span, m (ft); or propeller blade width, cm (in.)

c wing chord parallel to fuselage center line, m (ft)

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

C_D drag coefficient including thrust, $\frac{\text{measured drag}}{qS}$

C_L lift coefficient including thrust, $\frac{\text{measured lift}}{qS}$

c_{L_d} propeller blade section design lift coefficient

C_l rolling-moment coefficient, $\frac{\text{rolling moment}}{qSb}$

C_m pitching-moment coefficient, $\frac{\text{pitching moment}}{qS\bar{c}}$

C_n yawing-moment coefficient, $\frac{\text{yawing moment}}{qSb}$

C_y side-force coefficient, $\frac{\text{side force}}{qS}$

D propeller diameter, m (ft)

i_t tail incidence, deg

J propeller advance ratio, $\frac{V}{nD}$

L lift including thrust component, n (lb)

M.A.C. mean aerodynamic chord

n propeller rotational velocity, rps

q_∞ free-stream dynamic pressure, n/sq m (lb/sq ft)

R Reynolds number, $\rho\,\frac{V\bar{c}}{\mu}$

r propeller blade radius, m (ft)

S wing area, sq m (sq ft)

T	total thrust of all four propellers, n (lb)
T_c'	thrust coefficient, $\frac{T}{qS}$
t	blade thickness, cm (in.)
$\dot{V}_\infty$	free-stream velocity, m/sec (fps)
x	chordwise dimension from leading edge
y	lateral distance spanwise from fuselage center line, m (ft), or vertical dimension perpendicular to chord
α	angle of attack of fuselage reference line, deg
β	propeller blade angle at 0.75 r, deg
$\beta\frac{xx}{xx}$	propeller blade angle at 0.75 r for inboard/outboard propellers, deg
δ_a	aileron deflection, deg (trailing edge down, positive)
δ_e	elevator deflection, deg (trailing edge down, positive)
δ_f	total aft flap deflection relative to local wing chord, deg
$\delta\frac{xx}{xx}$	differential spanwise flap deflection where numerator is for flap extents inboard of midpoint between nacelles and denominator is for flap extents outboard, for example, $\delta_f \frac{100}{60} = \frac{100° \text{ inboard}}{60° \text{ outboard}}$
δ_r	rudder deflection, deg (trailing edge left, positive)
δ_s	spoiler deflection, deg
δ_{sla}	slot-lip aileron deflection, deg
η	wing semispan station, $\left(\frac{2y}{b}\right)$
μ	coefficient of viscosity, Nsec/m^2 (slugs/ft-sec)
ρ	mass density of air, kg/m^3 (slugs/ft^3)
ψ	angle of yaw, deg

Subscripts

l	left wing
t	horizontal tail
u	uncorrected data

STABILITY AND CONTROL CHARACTERISTICS OF A LARGE–SCALE DEFLECTED SLIPSTREAM STOL MODEL WITH A WING OF 5.7 ASPECT RATIO

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SUMMARY

A wind-tunnel investigation was conducted to determine the stability and control characteristics of a large-scale model representative of a propeller-driven STOL transport. Longitudinal and lateral-directional characteristics were obtained for a four-engine configuration having a wing of 5.7 aspect ratio fully immersed in the propeller slipstream. Configuration variables included an aileron, a spoiler, a slot-lip aileron, a spanwise variation of propeller thrust, and two vertical heights of the horizontal tail.

INTRODUCTION

An advanced propeller driven STOL aircraft has been studied in the Ames 40- by 80-Foot Wind Tunnel. The large scale model used in the program is typical of conventional propeller-driven transport airplanes able to operate in and out of 305 to 610 meter (1000- to 2000-foot) runways. The basic longitudinal aerodynamic characteristics of the model with the horizontal tail off are presented in reference 1. Supplemental wing surface pressure data are tabulated in reference 2. A flight investigation on an airplane similar to this model is reported in reference 3.

Stability and control characteristics are considered in the phase of the wind-tunnel investigation reported here. In this investigation, several lateral control devices (i. e., conventional ailerons, spoilers, and a slot-lip aileron) were tested. Longitudinal control power of the horizontal tail for two vertical heights was also considered. All tests were made with the wing fully immersed in the propeller slipstream, with and without a spanwise variation of propeller thrust.

MODEL AND APPARATUS

Figures 1(a) and (b) are photographs of the model installed in the 40- by 80-foot test section. Figure 2(a) is a three-view drawing of the model. The model was tested with the leading-edge slats installed as shown in figures 1(a) and 2(b).

The airfoil section of the wing was an NACA 63_2–416 modified by fairing the reflex on the aft portion of the lower surface. The wing had a span of 13.21 m (43.34 ft) and an aspect ratio of

5.71. The horizontal tail had an inverted NACA 63A212 airfoil section, a span of 6.3 m (20.65 ft), and an area of 11.79 sq m (126.9 sq ft). Other pertinent details are listed in table 1.

The horizontal tail could be mounted in two positions, as shown in figure 2(a). The low position placed the quarter chord 0.34 m (1.1 ft) above and 7.97 m (26.14 ft) aft of the wing quarter chord. The high position increased this tail length to 8.56 m (28.1 ft) and the vertical height to 2.2 m (7.2 ft) above the wing chord plane.

A cross section of the wing leading-edge slat and trailing-edge triple-slotted flap is shown in figure 2(b). The trailing-edge flap could be deflected 100° with respect to the wing chord line. For flap deflections of 80° or less, the foreflap was set at one-half the total deflection of the aft flap. For a flap deflection of 100° the foreflap was deflected 40°. Coordinates for the wing leading-edge slat and trailing-edge flap are given in reference 1.

Figure 2(c) presents cross-section views of the spoiler (0.1 c; $\eta = 0.57-1.0$) and slot-lip aileron (0.2 c; $\eta = 0.385-1.0$). Angles of deflection of these controls are referenced to the wing-chord plane. Additional details of the slot-lip aileron are given in reference 4. The aileron was the aft flap segment outboard of the midpoint ($\eta = 0.61-1.0$) between the nacelles.

The geometric characteristics of the three-bladed model propellers are presented in figure 3. The direction of propeller rotation is indicated on figure 2(a). The solid aluminum model propellers had a diameter of 2.84 m (9.3 ft) and an activity factor of 121 per blade. Each propeller was shaft mounted on a gear box and driven by an electric motor. The four motors were connected in parallel from a variable frequency power supply and were not individually controllable.

TEST AND PROCEDURE

Force tests were made at free-stream velocities of 16 to 25 m/sec (31 to 49 knots) (Reynolds number 2.6 to 4.1 million based on the wing M.A.C. of 2.38 m (7.8 ft)). For each run, the angle of attack of the model was varied while the tunnel dynamic pressure, propeller speed, and propeller blade angle were held fixed.

The data presented include the direct propeller forces as well as the aerodynamic forces. The propeller thrust calibration (fig. 4) was determined from wind-tunnel tests with the model at the angle of attack for zero lift, clean wing, and flaps up. Propeller thrust is defined as the sum of the measured thrust (propellers on) and the measured drag of the model with propellers removed. For runs with propellers at equal thrust, the inboard and outboard propellers were set at a blade angle of 16° measured at the three-quarter-radius station. To obtain differential thrust, the blade angles for both inboard propellers were left at 16° while the outboard propeller blade angles were set at 0°. For the same propeller speeds, assuming inboard thrust to be independent of outboard thrust, the two inboard propellers were expected to produce high positive thrust and the two outboard propellers, slightly negative thrust. To simulate one engine out, the right outboard propeller was removed and the same tunnel test settings (i.e., RPM, q, and blade angle) used as if four propellers were in operation.

Pitching-moment coefficients were computed about a moment center at 0.25 $\bar{c}$.

CORRECTIONS

The following corrections were made to account for the wind-tunnel-wall interference effects:

$$\alpha = \alpha_u + 0.652C_{L_u}$$

$$C_D = C_{D_u} + 0.01138C_{L_u}^2$$

$$C_m = C_{m_u} - 0.0399C_{L_u}\text{(tail on)}$$

where the subscript u stands for uncorrected for tunnel wall effects.

A small drag tare correction ($\Delta C_D \approx 0.02$) was applied to account for the drag of the portions of the mounting struts exposed to the wind-tunnel air flow.

RESULTS

The basic force data are presented in figures 5 to 18. An index to the figures is given in table 2.

The first portion of data is for the model with the horizontal tail off. The longitudinal characteristics are presented in figures 5(a) to (c). These data are for the clean wing, with four propellers, two propellers, and for propellers off.

The second portion of the data is for the model with the horizontal tail in the low position (figs. 6 through 13). Figure 6 presents the basic longitudinal characteristics for a flap setting of 60° inboard and 40° outboard. The effect of tail incidence with 80° of flap deflection can be found in figure 7. Aerodynamic characteristics of the low tail configuration are presented in figure 8 for "one engine out" with 80° of flap deflection. Lateral-directional control characteristics at 0° yaw and 80° of flap deflection, using an aileron, a spoiler, and a slot-lip aileron of two spanwise extents are presented in figures 9 to 13.

The third portion of data is for the model with the horizontal tail in the high position (figs. 14 to 18). Figure 14 contains the basic longitudinal characteristics with flaps deflected 40° for uniform and differential propeller thrust. The effect of the slot-lip aileron is shown in figures 17 and 18 where longitudinal and lateral characteristics are presented with the model at 10° of yaw.

DISCUSSION

The longitudinal, lateral, and directional control characteristics are summarized in figures 19, 20, and 21.

Longitudinal Control

The static margins for the two tail heights and three angles of tail incidence (figs. 19(a) and (b)) indicate that the model may be untrimmable at the highest thrust coefficient, 2.5, with the tail size used. In addition, static instability occurs for $i_t = -10°$ at the highest power setting. The instability is caused by the tail being operated beyond stall in a region of high induced downwash. This is clearly indicated by the tail pitching moments plotted in figures 19(a) and (b). Note the reduction in C_m with increasing power at $i_t = -10°$ for both tail locations. The results indicate the problem is more severe in the low tail position because of the higher downwash angle. The data in figure 19(a) also indicate that at $\alpha_u = 0°$ deflecting the elevator -20° will trim the model.

Lateral and Directional Stability and Control

The yawing-moment data of figure 16(b) indicate that, with the 80° flap, increasing thrust coefficient changed directional stability from stable to unstable. Similarly, the rolling moment data show a shift from positive to negative dihedral effect but to a lesser degree. For the lower flap deflection or the 100/60 flap, however, this shift did not occur (fig. 16(a)). The cause of this is not understood, but this factor alone could dictate the selection of the 100/60 flap for an aircraft, even though the 80° flap is more efficient and would permit higher descent angles.

Figure 20(a) shows the incremental yawing moment and rolling moment attributable to a 0.1 chord spoiler used for roll control. The spoiler produced adverse yawing moment except at high deflections or low values of T_c'. Maximum amounts of rolling-moment coefficient for the spoiler were about 0.1, 0.2, and 0.3 for T_c' of 0, 1, and 2.5, respectively. Figure 20(b) presents the corresponding data for the left aileron. For any incremental change in rolling moment due to aileron deflection there is a corresponding adverse yawing moment. Figure 20(c) presents the corresponding data for two spanwise extents of slot-lip aileron with a flap having 80° deflection. Using the shorter span slot-lip aileron produced a small amount of adverse yaw (very similar to the characteristics of the spoiler). When the spanwise length of slot-lip aileron was increased, the magnitude of incremental rolling moment was increased and the yawing moment became favorable. The data for the 100/60 flap setting (fig. 16(c)) show that more favorable yawing moment could be obtained by increasing the slot-lip aileron chord from 10 to 20 percent.

With one propeller off, simulating the loss of a propeller or propeller control, both rolling and yawing moments were high (fig. 8(b)). Although control data were not obtained with one propeller off, the data for the slot-lip aileron shown with the differential thrust mode ($\beta = 16/0$) indicate the amount of control power available with no augmentation from the outboard propellers. The 0.1 c slot-lip aileron can produce a Δc_l of -0.3 (fig. 13) which appears to be sufficient for roll trim with one engine out (fig. 8(b)).

Figures 21(a) and (b) present the directional control data for the 40° and 80° flap deflections for 0° and 12° angle of attack with the horizontal tail in the high position. Figure 21(c) presents corresponding data for the low tail position taken at 0° and 12° angle of attack for a flap setting of 100/60. The data show that moving the tail from the high to low position and increasing flap deflection reduces directional control from ±0.07 ($C_{n_{\delta_r}} = 0.0031$) to ±0.05 yawing-moment coefficient ($C_{n_{\delta_r}}$ = 0.0021) for ±25° rudder deflection at a thrust coefficient of 1.0. This loss in control power for the low tail position was probably caused either by a reduction in end-plate effect or by tail stall, as discussed in the section on longitudinal control. The separated flow area could have been larger in the low position than in the high position because of the increased downwash and the more forward tail position.

With the loss of one outboard propeller, or engine, such large yawing moments (fig. 8(b)) are produced that at low speed, rudder control power is not nearly enough to trim the aircraft. The sideslip required to trim the aircraft in this condition is excessive. If such an aircraft is to be certificated, this condition may be the most critical and difficult to satisfy.

CONCLUDING REMARKS

Lateral control of an aircraft that employs highly deflected flaps for low-speed landing and takeoff poses a severe problem at low airspeeds (i.e., less than 31 m/sec (60 knots)). Neither a conventional aileron nor a plain spoiler (at moderate angles of deflection) was capable of producing roll control without serious adverse yaw. A 0.2 slot-lip aileron was an effective roll control device when installed on a wing fully immersed in the propeller slipstream.

Large downwash angles are induced in the vicinity of the horizontal tail by the propeller slipstream. The downwash was greatest for a low tail position and caused longitudinal instability to develop as thrust was increased. Both horizontal tail and rudder were more effective when the horizontal tail was mounted in the high position.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., 94035, June 28, 1971

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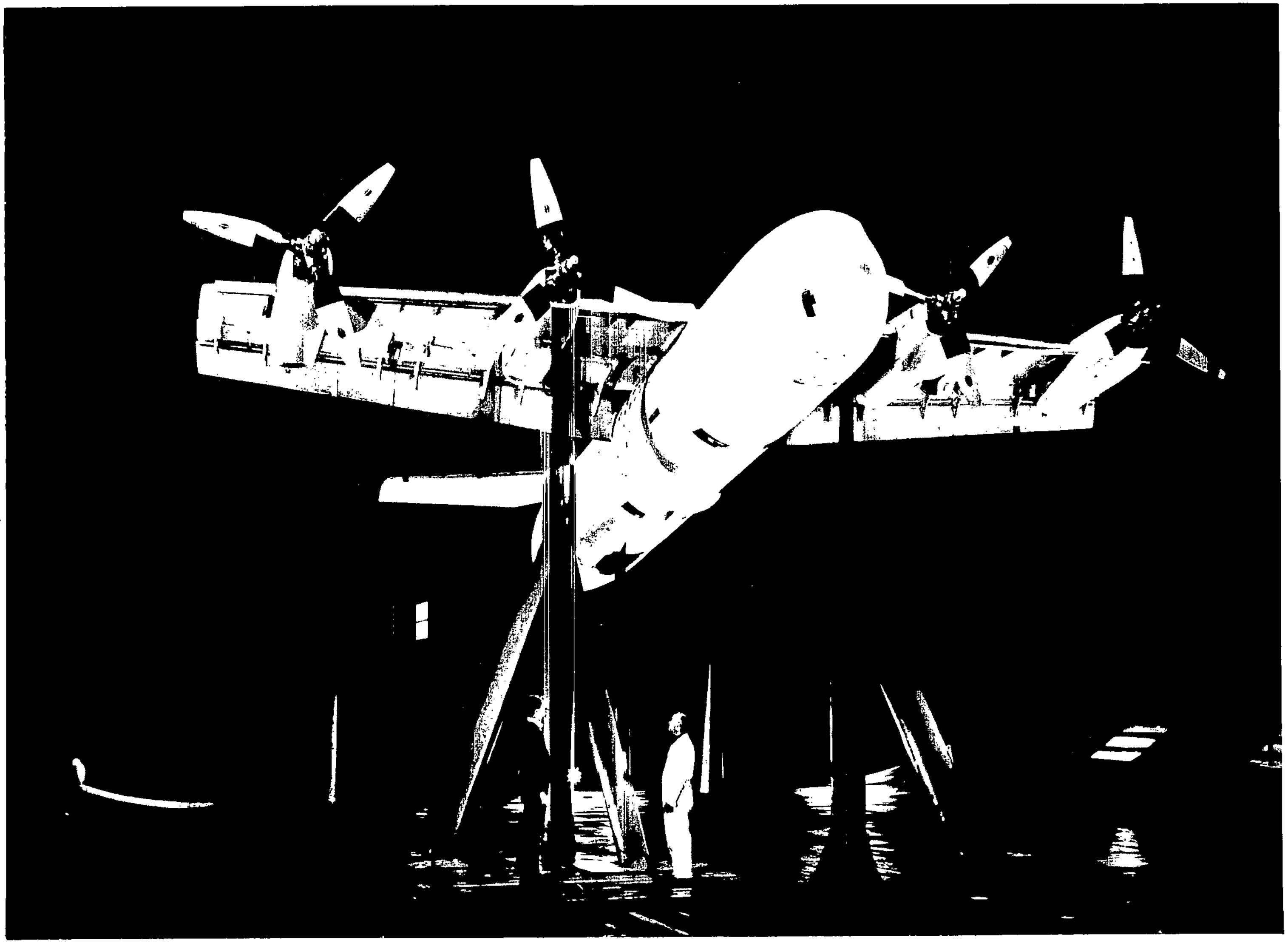
TABLE 1.– MODEL GEOMETRY

Dimension	Wing	Horizontal tail	Vertical tail
Area, sq m (sq ft)	30.6(329)	11.79(126.9)	8.08(86.9)
Span, m (ft)	13.21(43.34)	6.3(20.65)	3.42(11.22)
Mean aerodynamic chord, m (ft)	2.38(7.8)	1.91(6.26)	2.52(8.26)
Aspect ratio	5.71	3.36	1.45
Taper ratio	0.554	0.612	0.389
Twist, deg	0	0	0
Dihedral, deg	0	0	0
NACA airfoil section	63_2–416	Inverted 63A212	63A013
Sweep of leading edge, deg	2.88	15.98	31.33
Sweep of trailing edge, deg	-8.57	0	0
Root chord, m (ft)	2.98(9.77)	2.32(7.62)	3.40(11.17)
Tip chord, m (ft)	1.65(5.41)	1.42(4.66)	1.32(4.34)

TABLE 2.– FIGURE INDEX

Figure		Tail position	Incidence i_t, deg	δ_f, deg	ψ, deg	Blade angle, β	Data
5(a)	Slats off (fig. 5 only)	Off		0	0	16	Longitudinal
(b)	2 props (2&3)					16	
(c)	Props off						
				40			
				60/40			
				80			
				100/60			
6(a)		Low	0	60/40		16	
(b)				60/40		16/0	
7(a)			0	80		16	
(b)			-10				
(c)			+10				
8(a)	One engine out		0				
(b)							Lateral-directional
9	δ_{a_l} = -25°						
10(a)	δ_s = 30°						
(b)	60°						
11(a)	(0.1c), δ_{sla} = 0° η = 0.6–1.0						
(b)	60°						
12(a)	(0.1c), δ_{sla} = 10° η = 0.385–1.0						
(b)	20°						
(c)	40°						
(d)	60°						
13(a)	δ_{sla} = 0° η = 0.385–1.0					16/0	
(b)	10° (0.1c)						
(c)	20°						
(d)	40°						
(e)	60°						
14(a)		High		40		16	Longitudinal
(b)						16/0	
15(a)				80		16	
(b)			-10				
(c)			+10				
16(a)			0	40			Yaw data
(b)				80			
(c)	δ_{sla} = 60° (0.2c)			100/60			
17				100/60			Longitudinal
18(a)	δ_{sla} = 0°				10		Longitudinal
(b)	0°						Lateral-directional
(c)	60° (0.2c)						Longitudinal
(d)							Lateral-directional
(e)	+ δ_{a_l} = -25°						Longitudinal
(f)							Lateral-directional



(a) Front view.

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Figure 1.- Model with short-span wing in Ames 40– by 80–Foot Wind Tunnel.

(b) Rear view.

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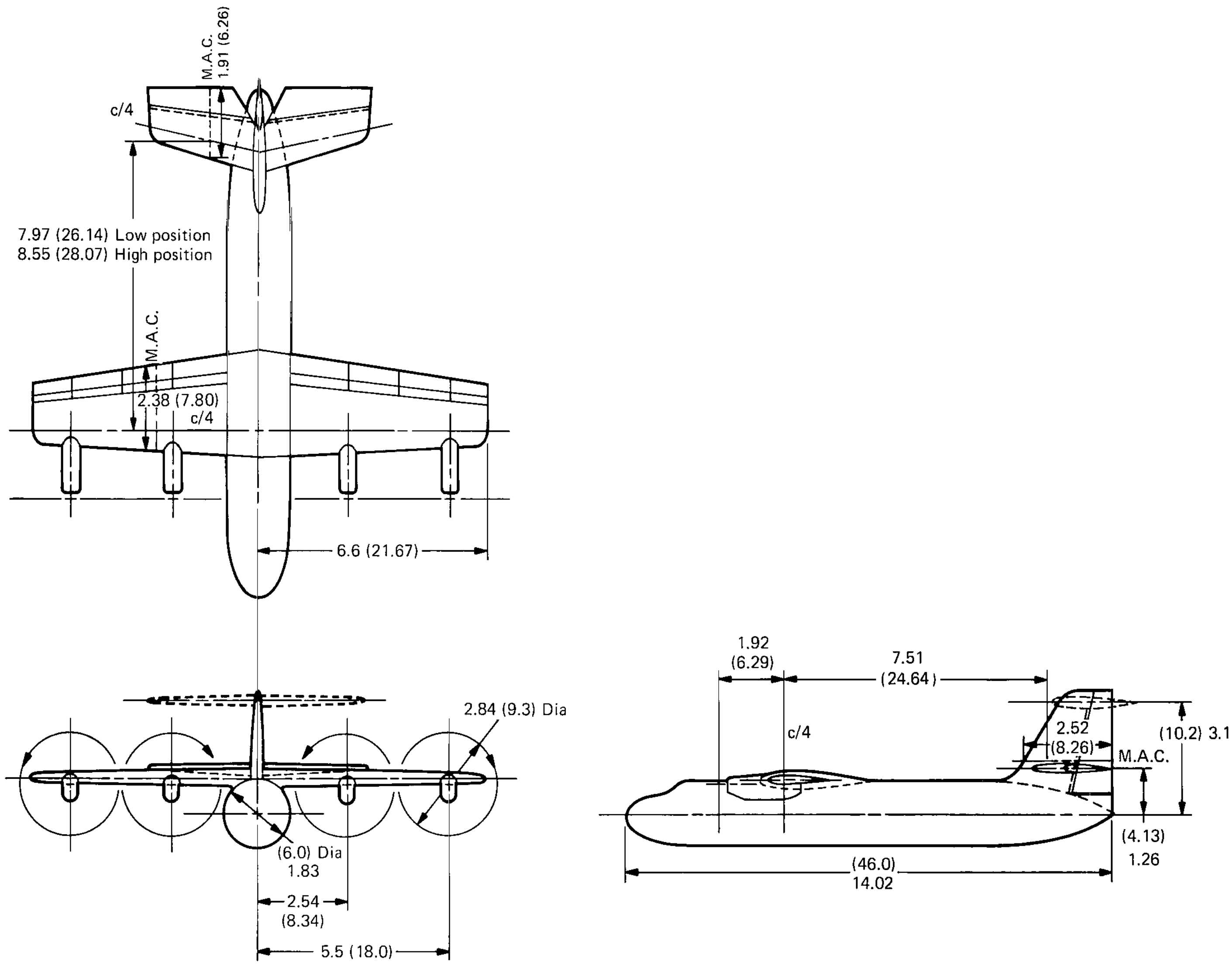
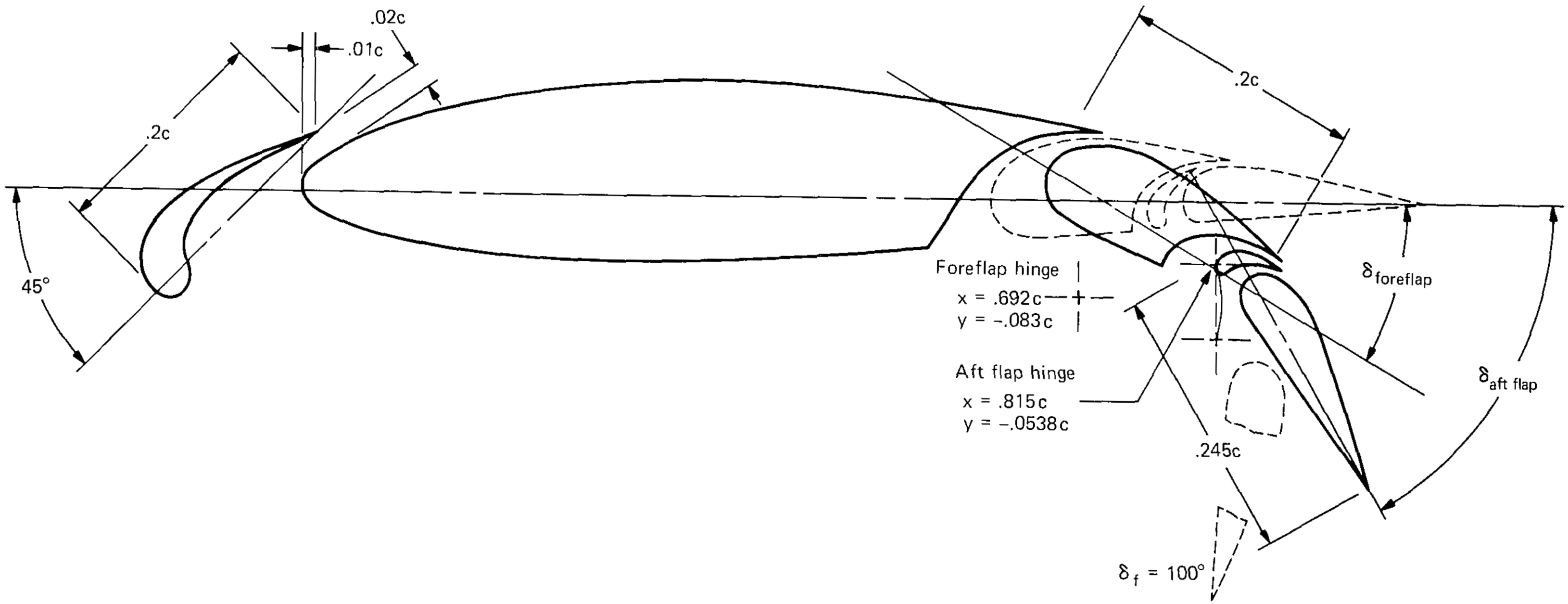
Figure 1.- Concluded.



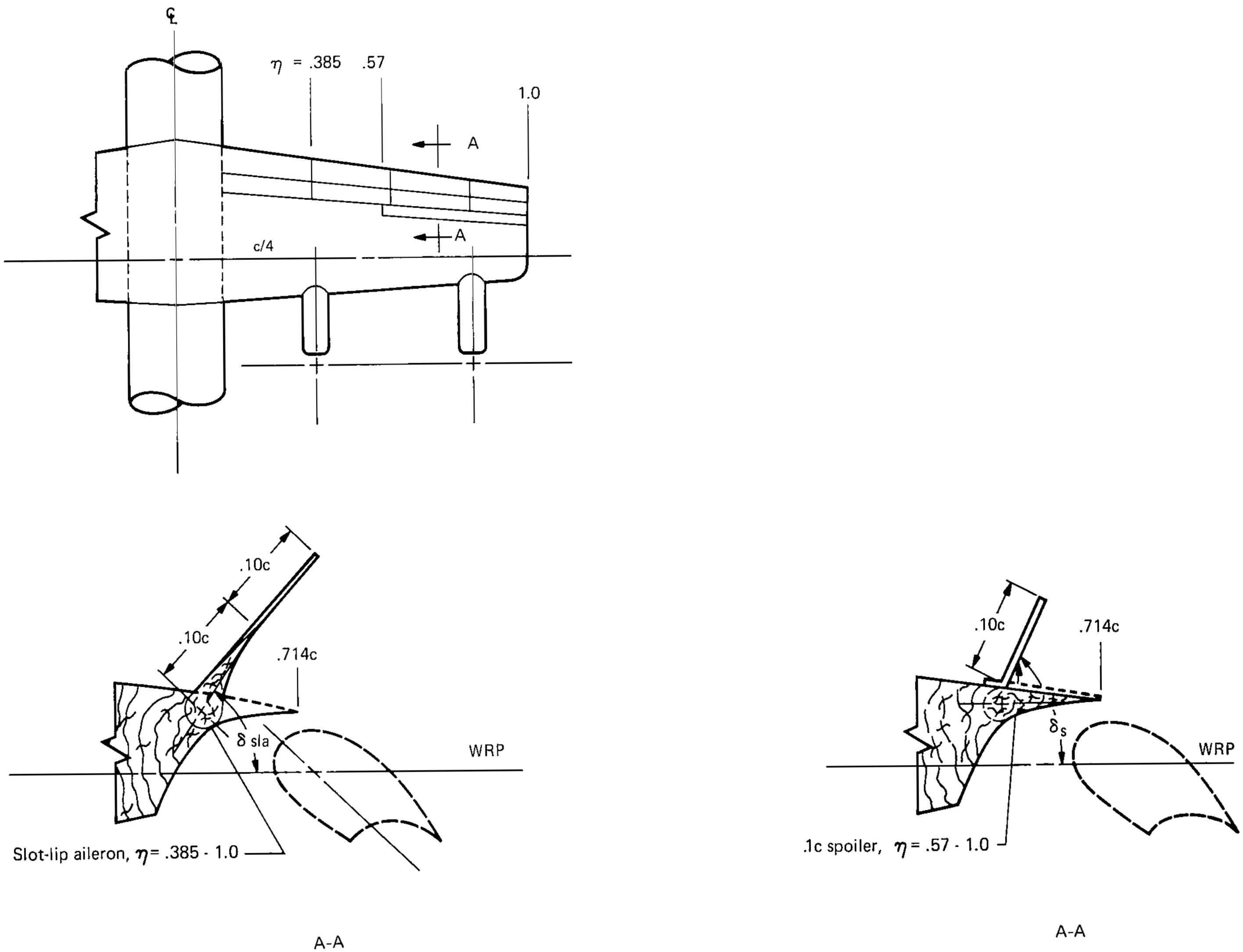
(a) Three-view drawing; dimensions, m (ft).

Figure 2.- Model geometry.



(b) Geometry of 0.2c slat and triple slotted flap.

Figure 2.- Continued.



(c) Spoiler and slot-lip aileron details.

Figure 2.- Concluded.

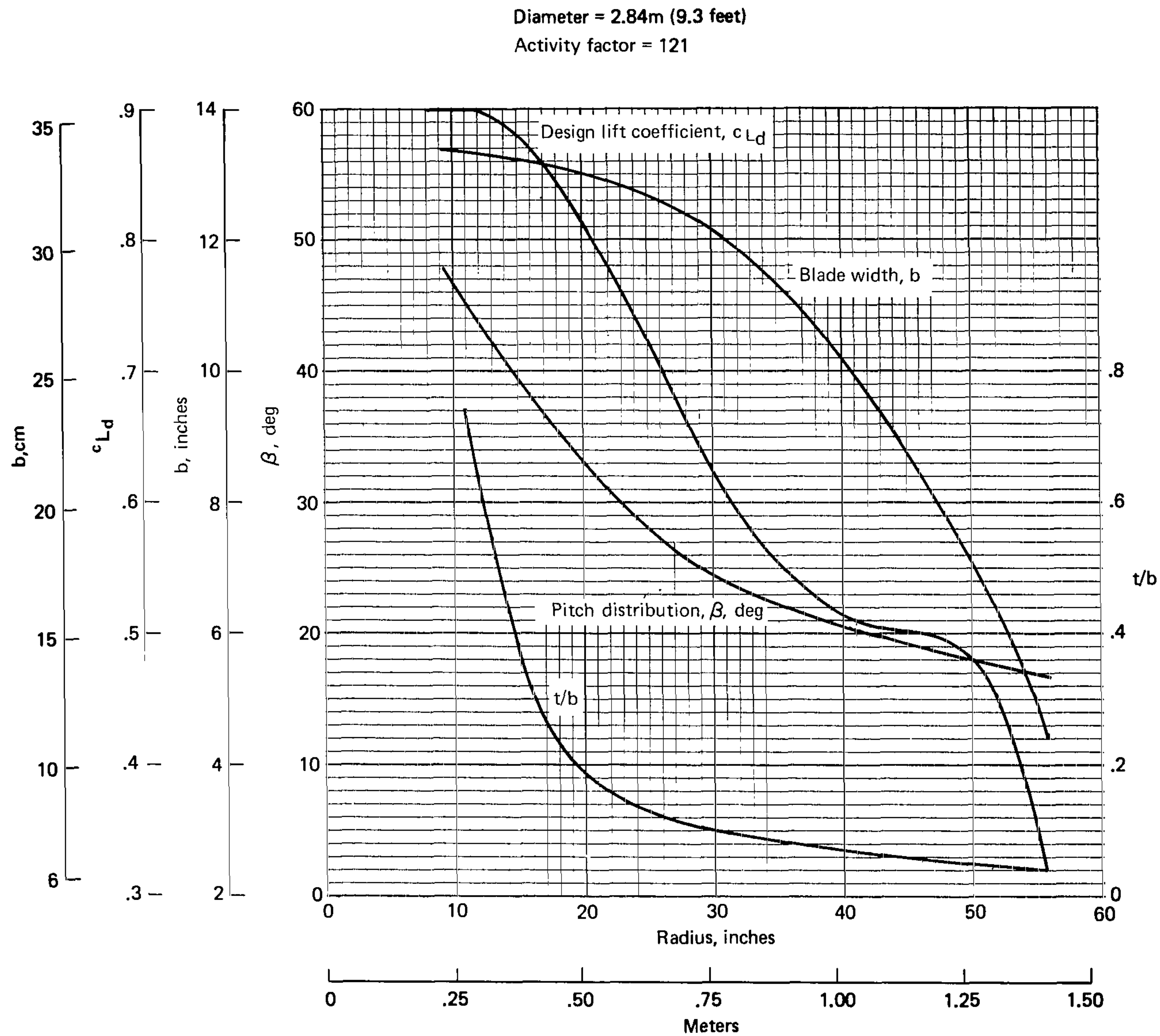


Figure 3.- Blade characteristics for three-blade propeller.

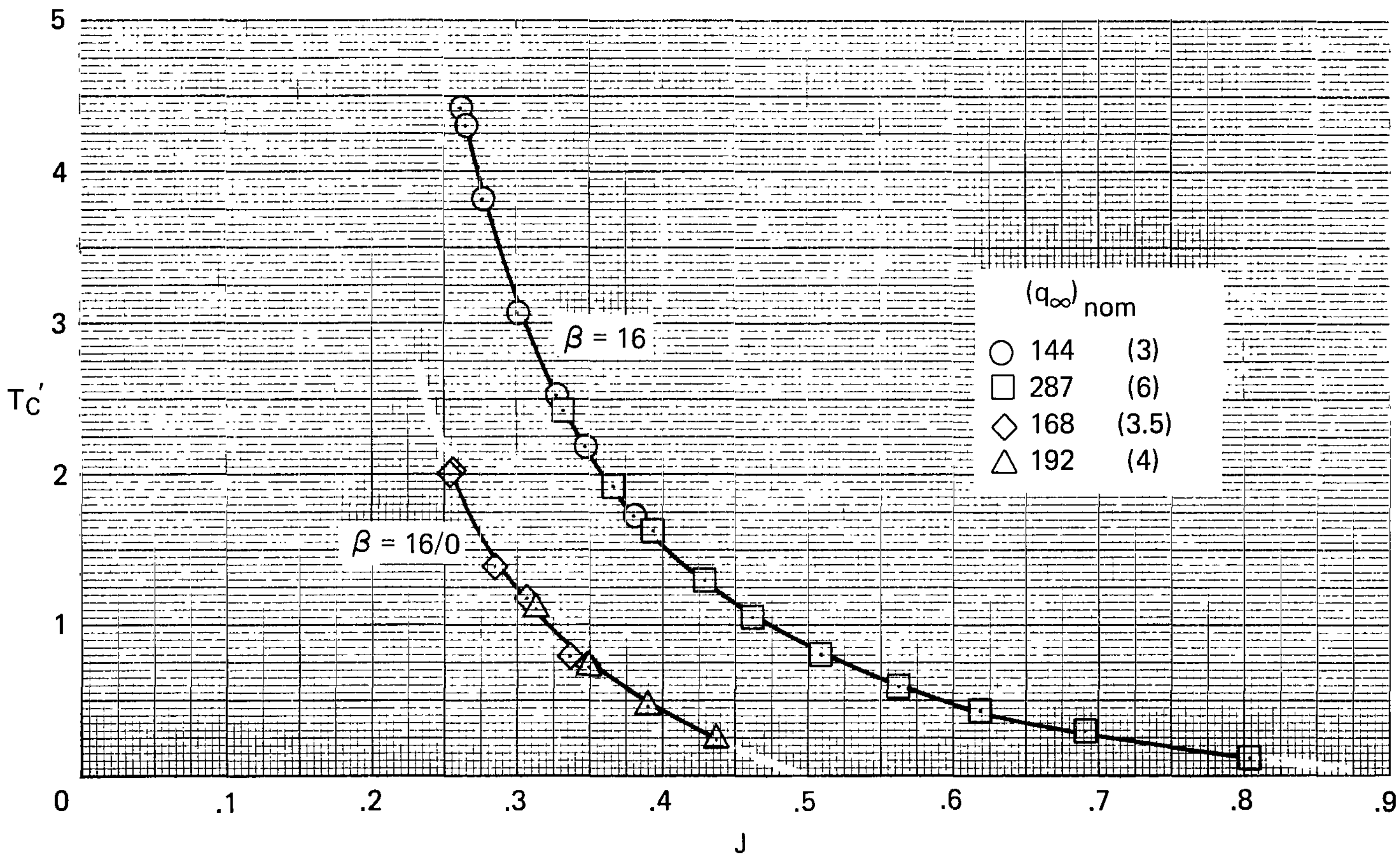
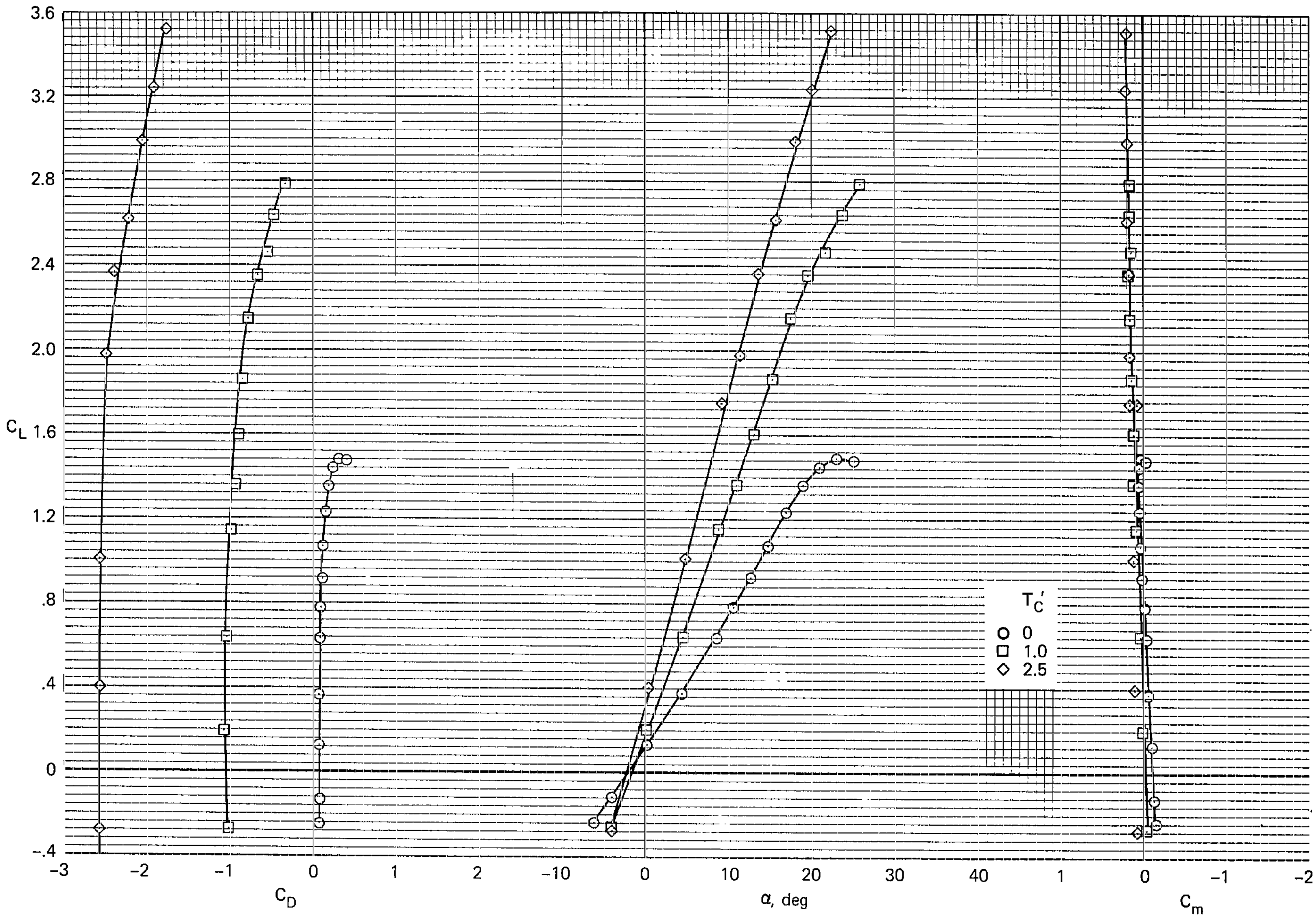
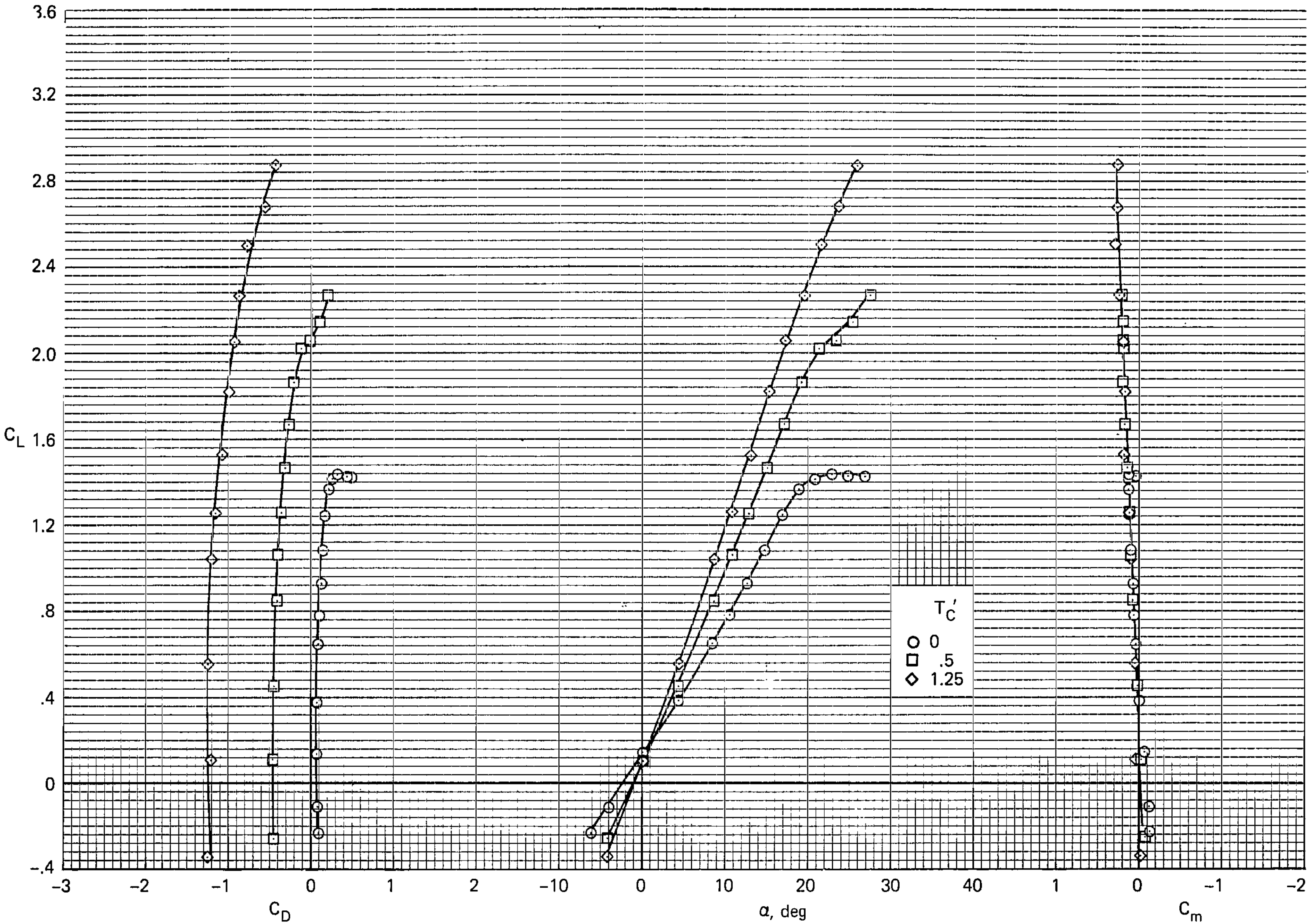


Figure 4.- Variation of thrust coefficient with propeller advance ratio, standard day.



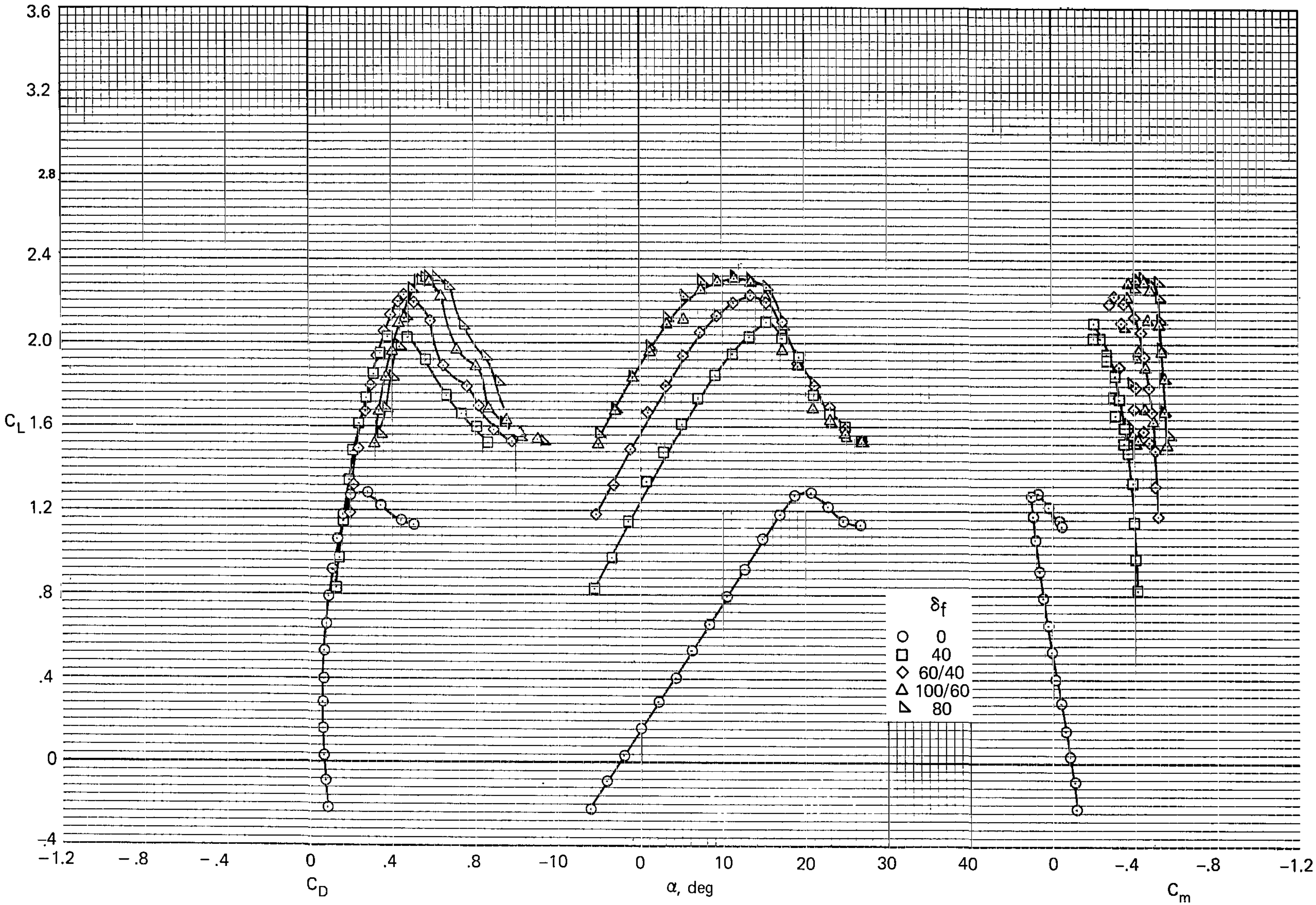
(a) $\delta_f = 0°$, four propellers on.

Figure 5.- Basic longitudinal characteristics; slats off, tail off.



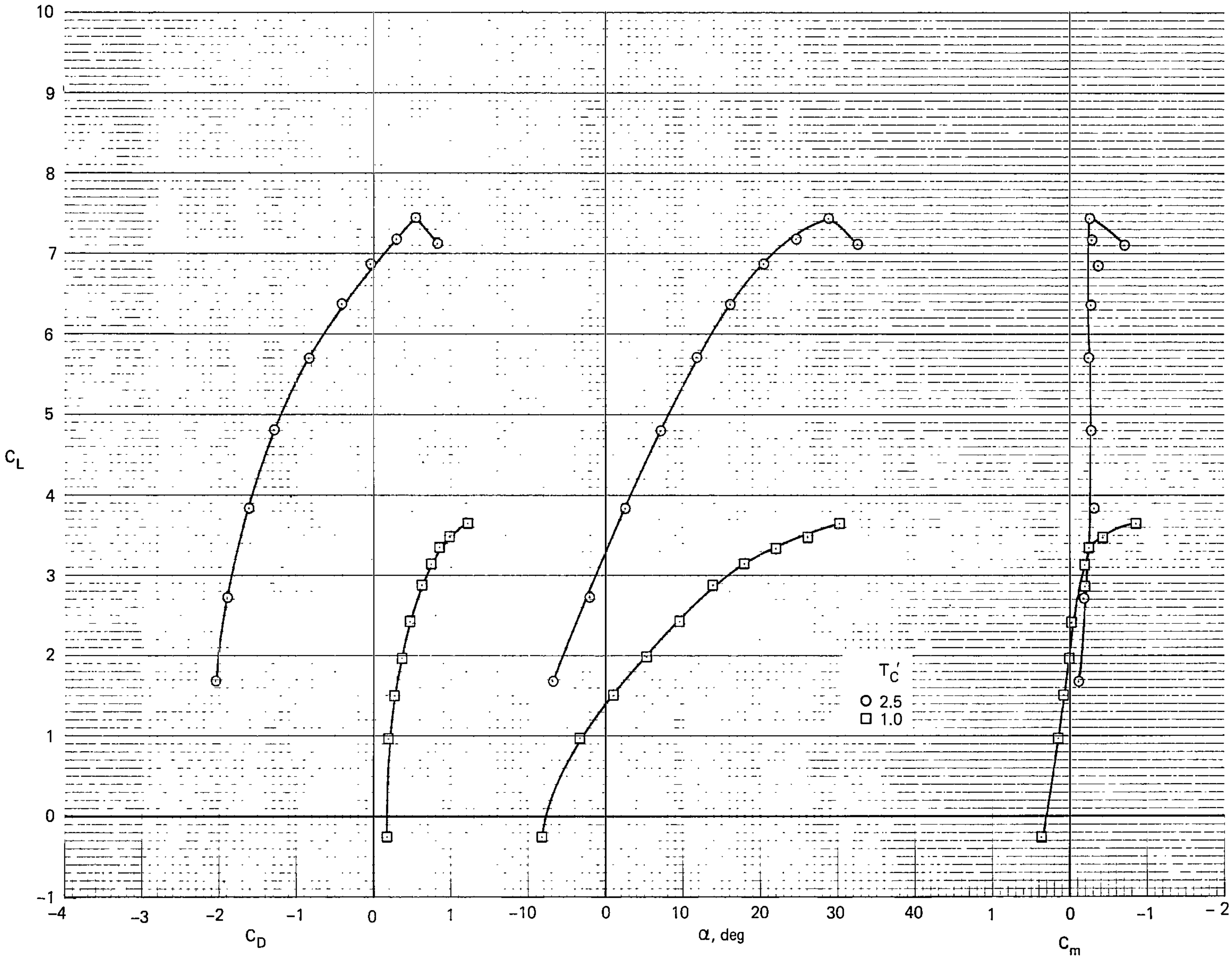
(b) $\delta_f = 0°$, two propellers on.

Figure 5.- Continued.



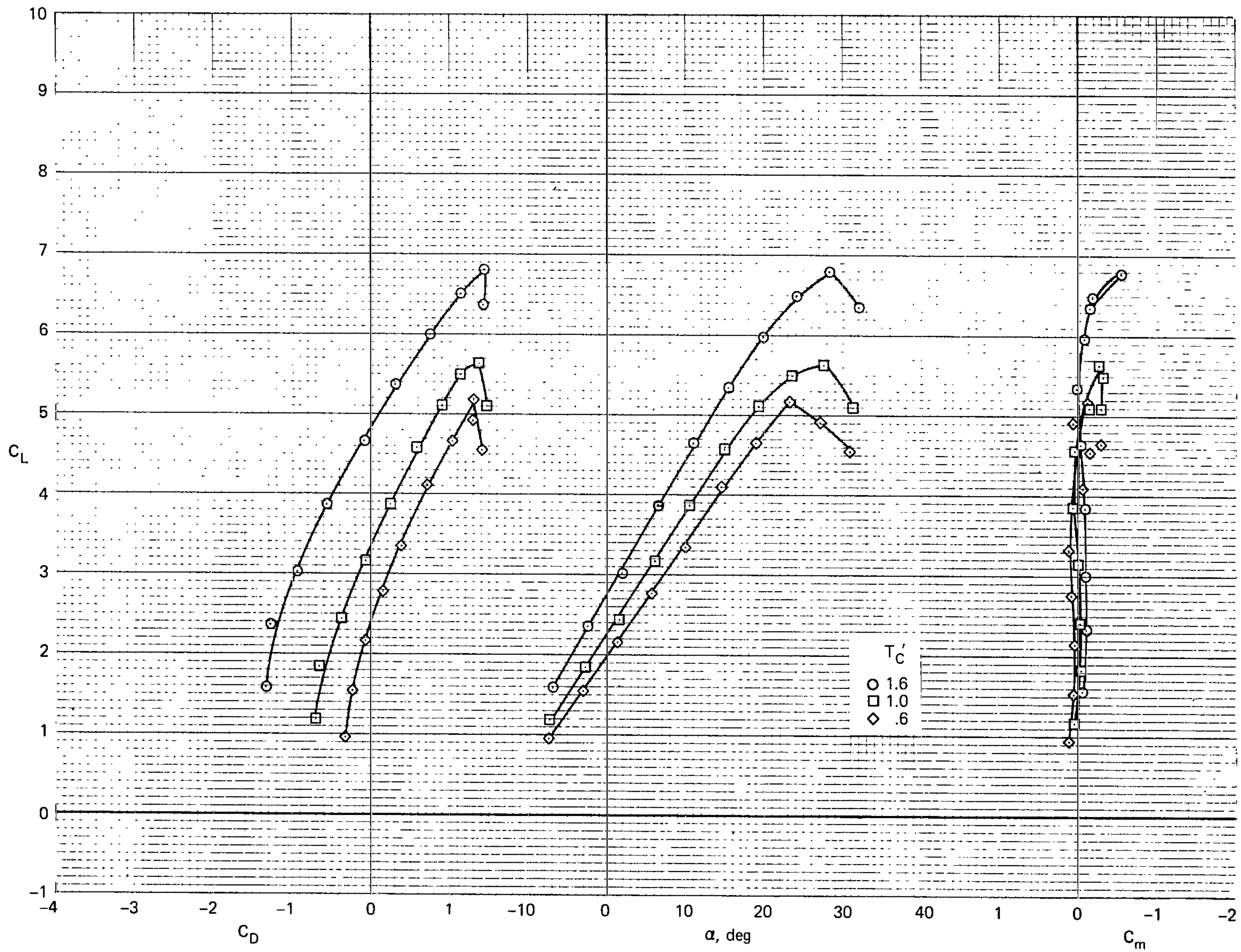
(c) Propellers off.

Figure 5.- Concluded.



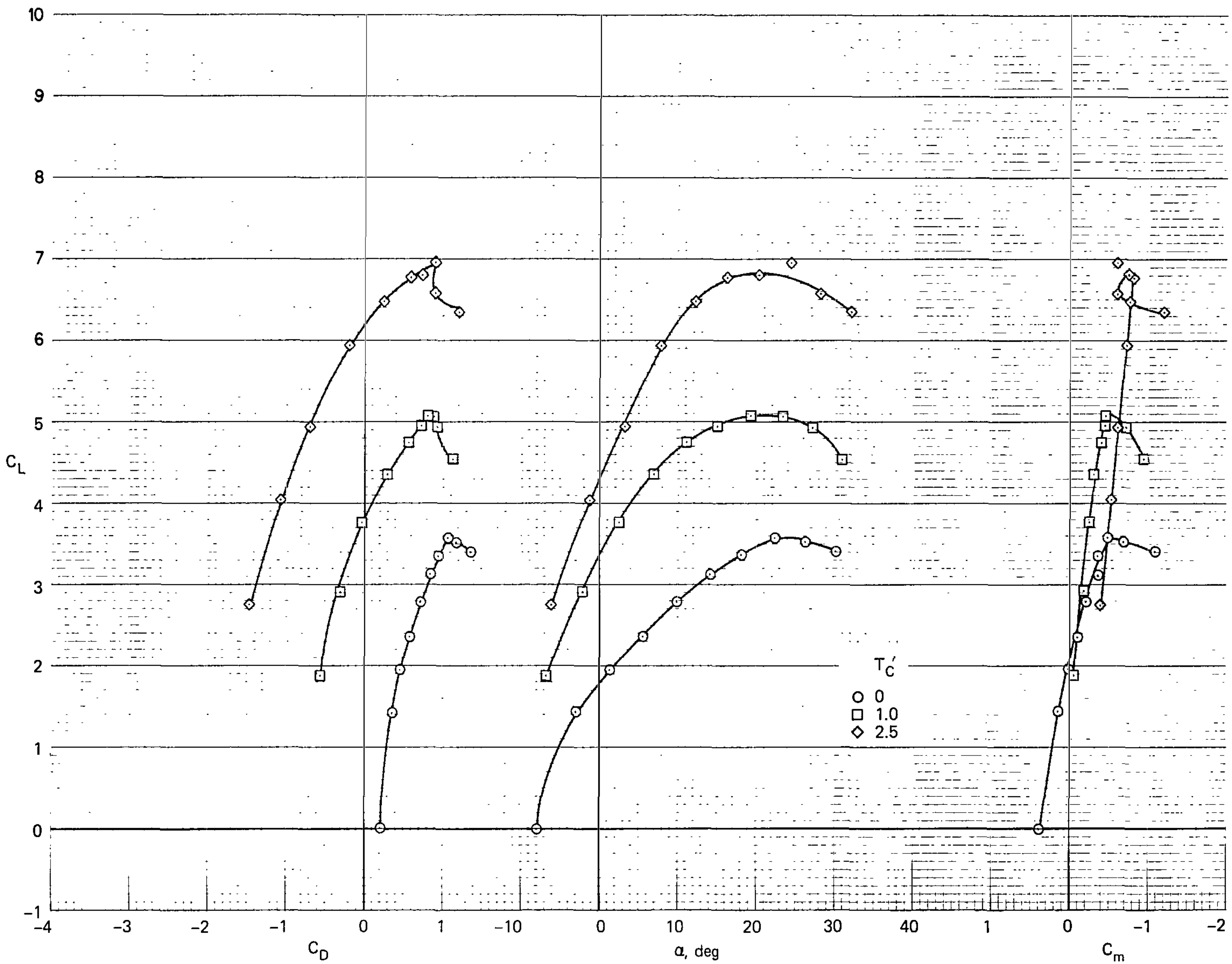
(a) $\beta = 16°$

Figure 6.- Effect of constant and differential propeller thrust on the longitudinal characteristics of the model; $\delta_f = 60/40°$, low tail.



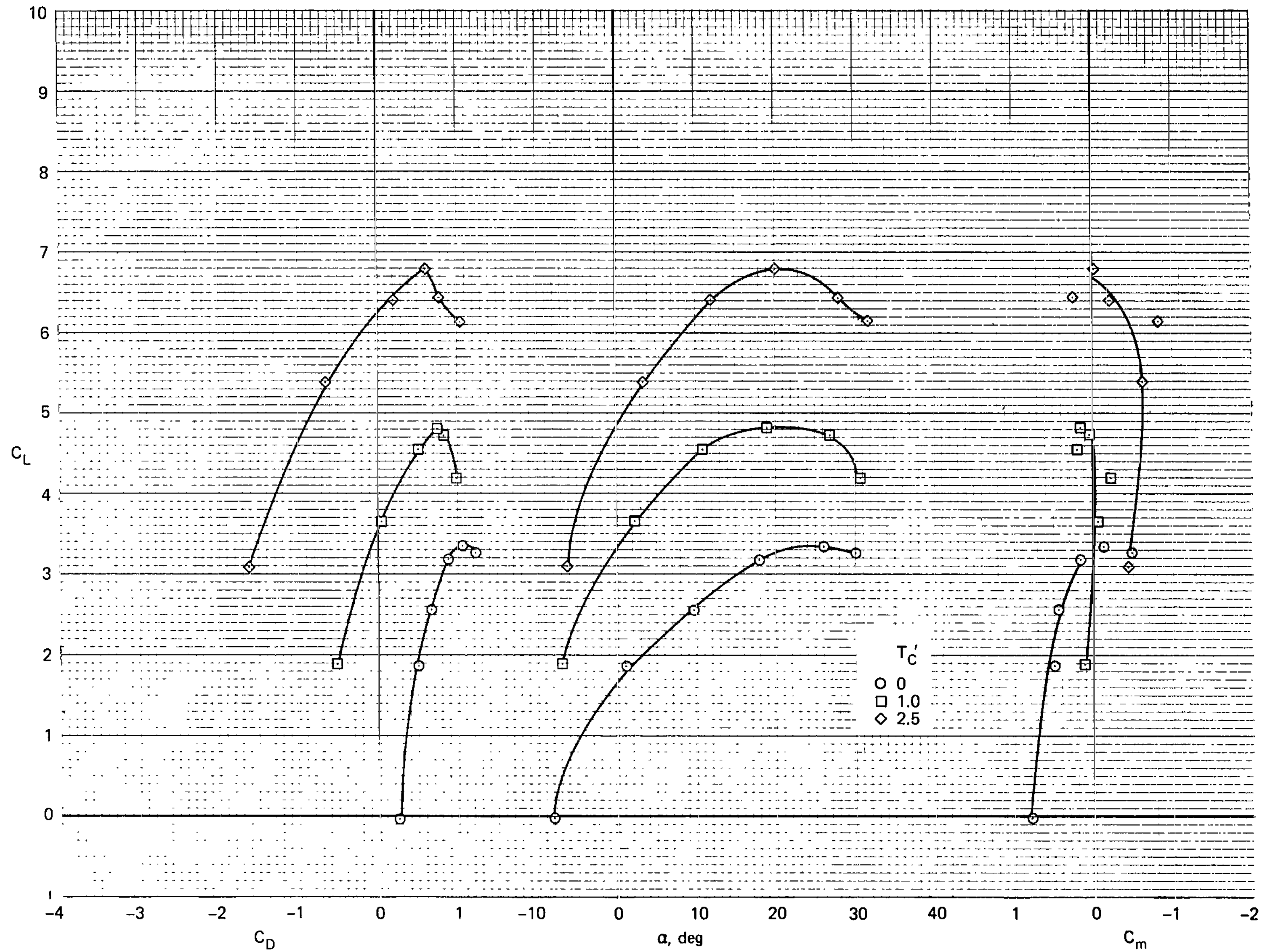
(b) $\beta = 16/0°$

Figure 6.- Concluded.



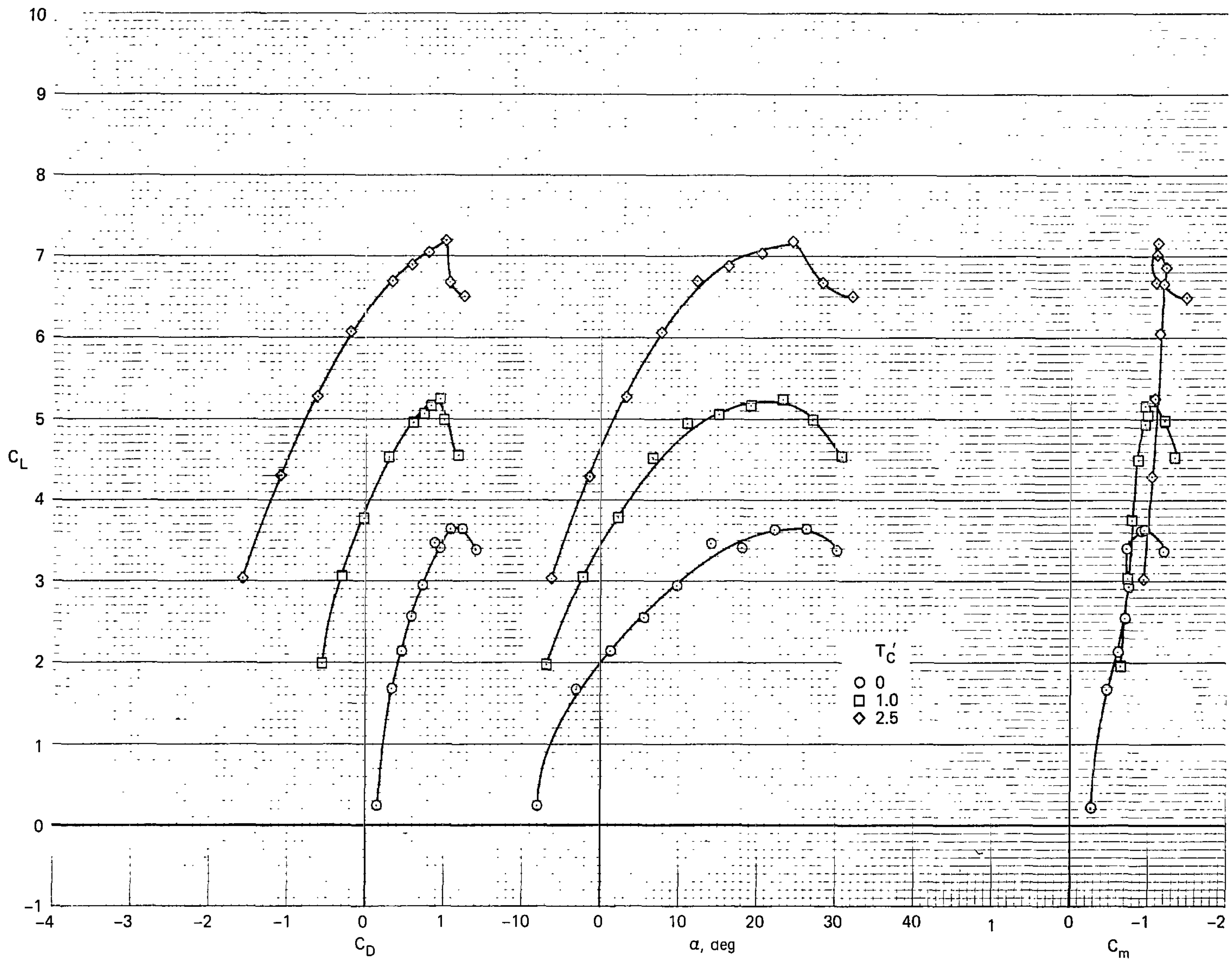
(a) $i_t = 0°$

Figure 7.- Effect of tail incidence on the longitudinal characteristics of the model with the tail in the low position; $\delta_f = 80°$.



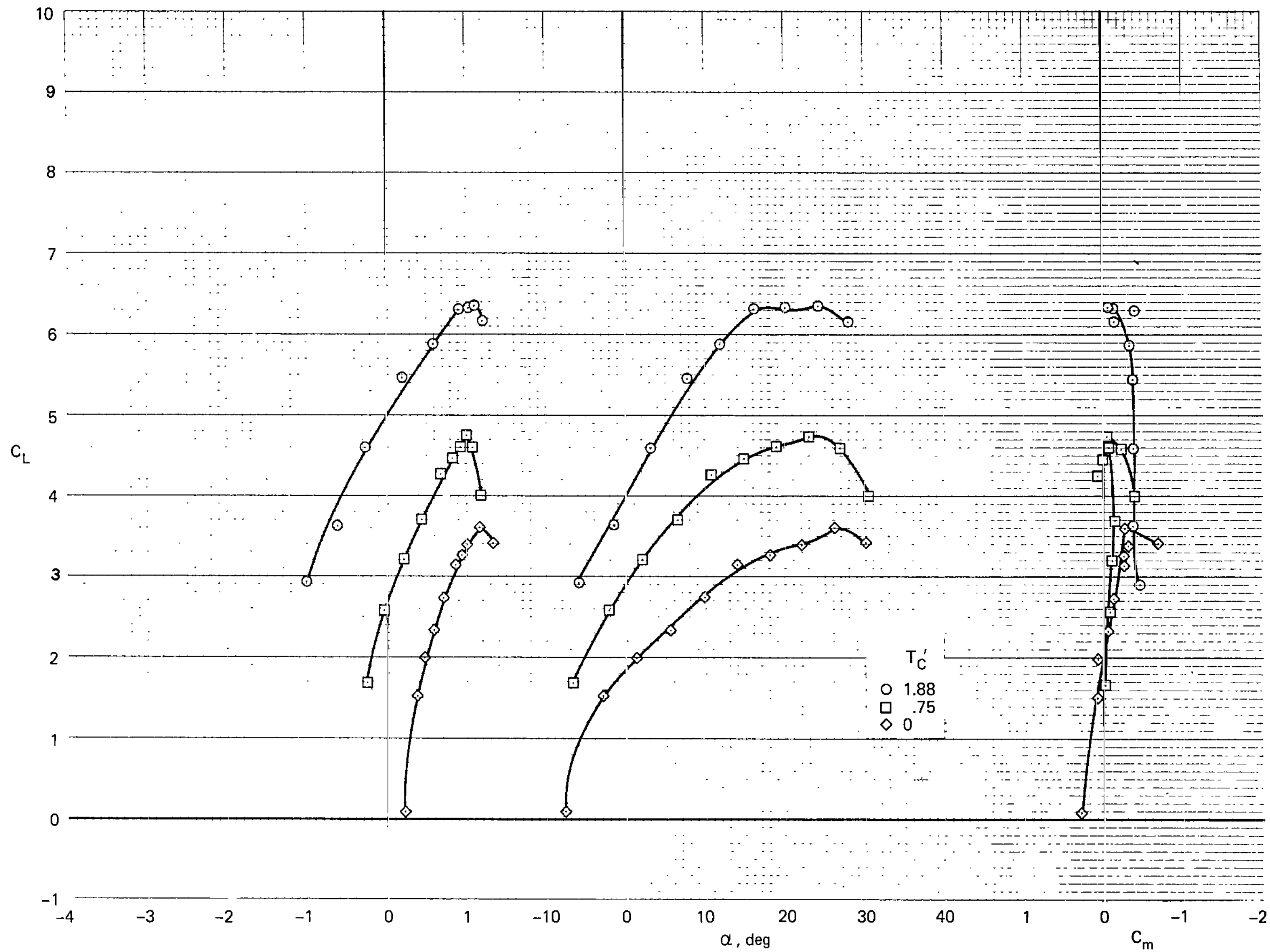
(b) $i_t = -10°$

Figure 7.- Continued.



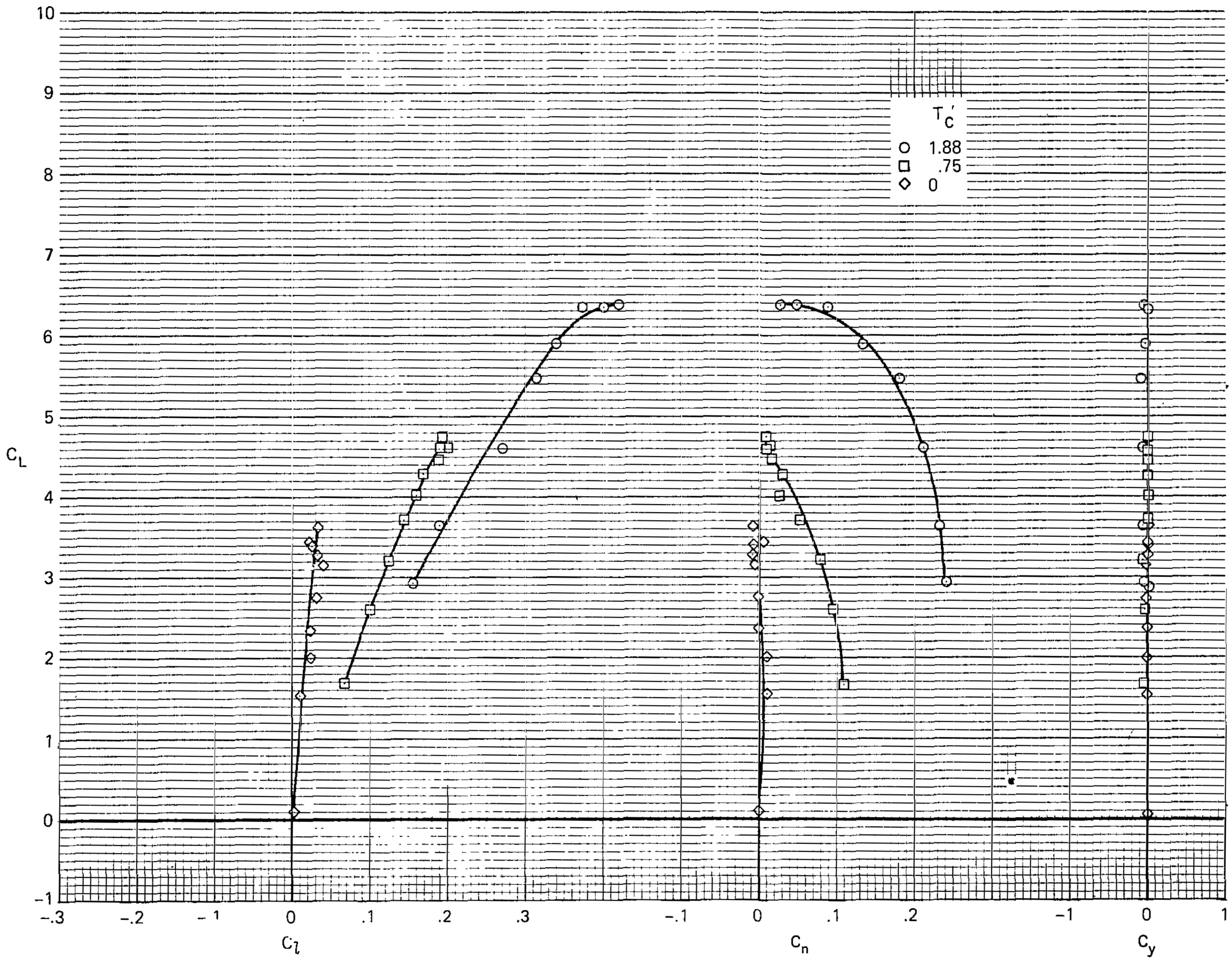
(c) $i_t = 10°$

Figure 7.- Concluded.



(a) Longitudinal.

Figure 8.- Effect of one propeller off on the aerodynamic characteristics of the model with low tail; $\delta_f = 80°$, $\psi = 0°$.



(b) Lateral-directional.

Figure 8.- Concluded.

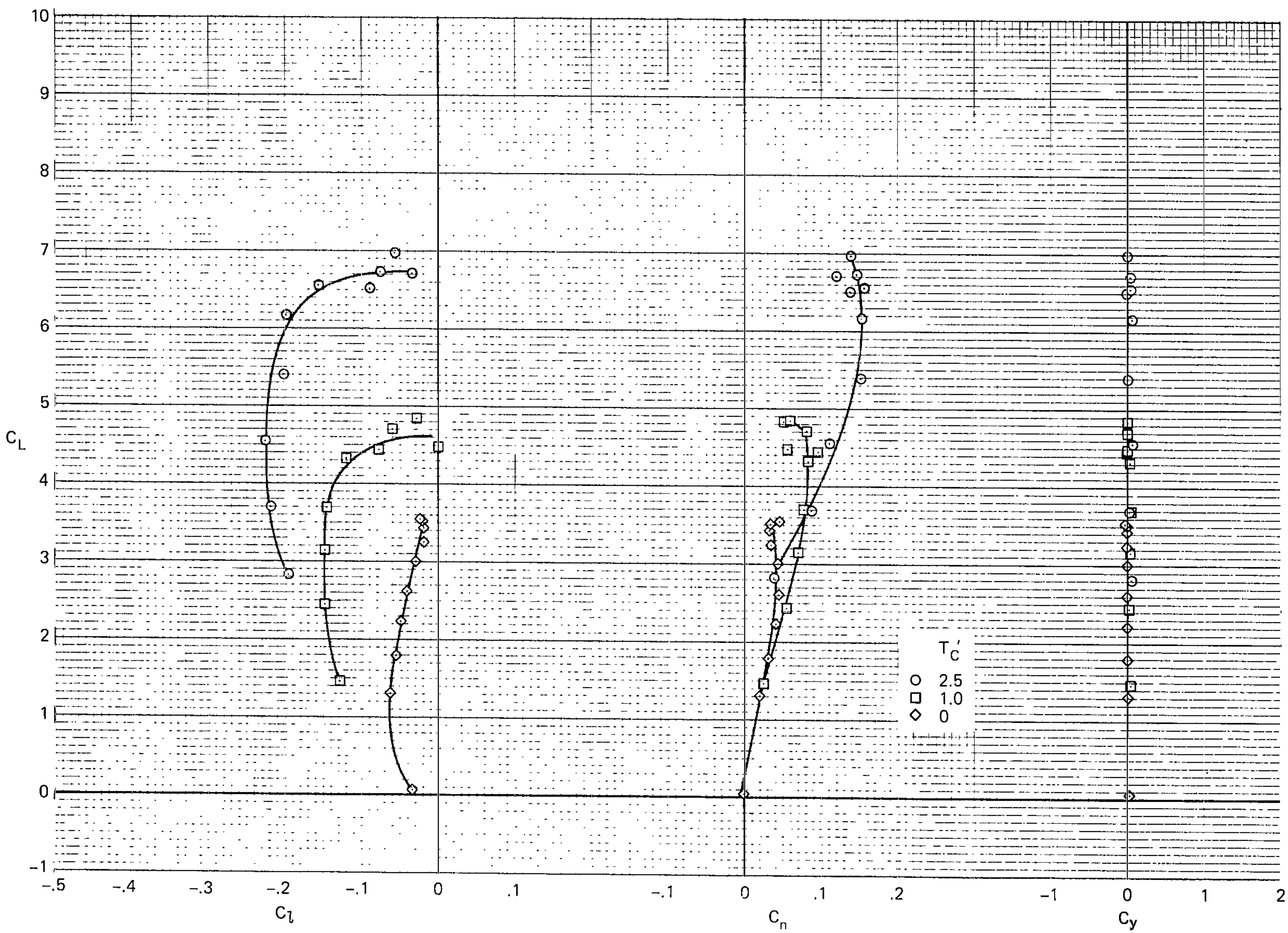
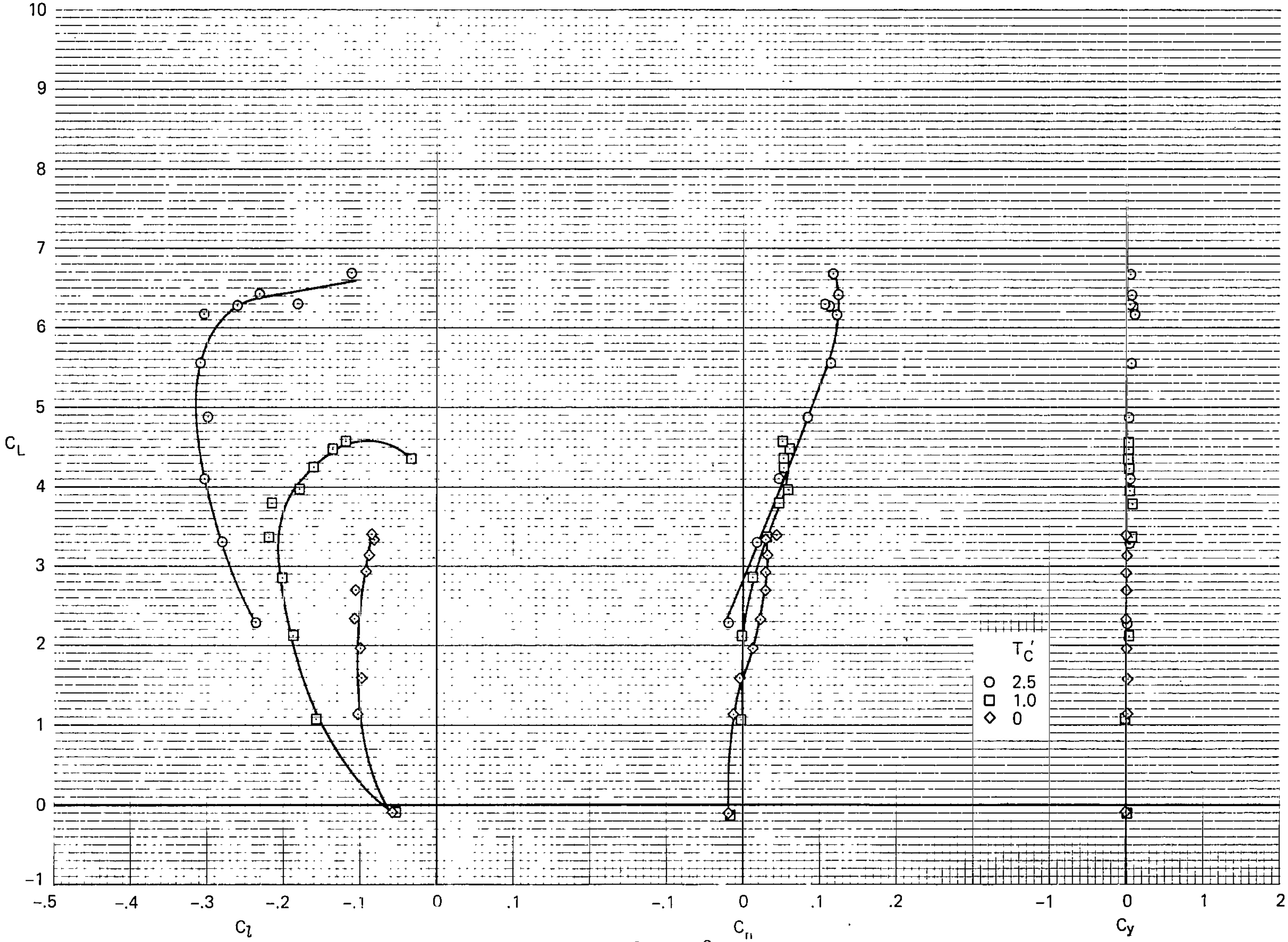
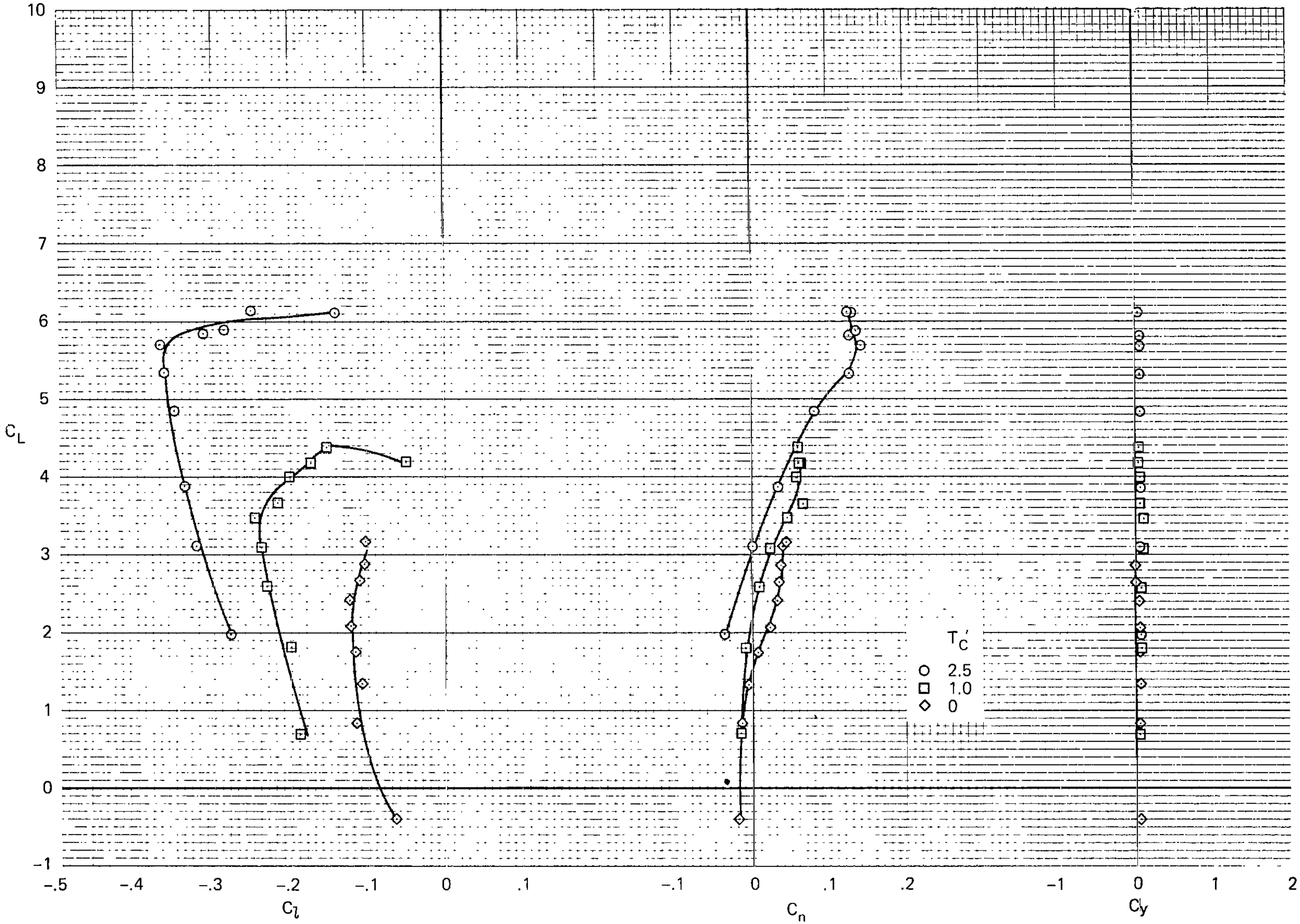


Figure 9.- Effect of aileron deflection on rolling moment, yawing moment, and side force at zero yaw; $\delta_f = 80°$, $\delta_{a_l} = -25°$, low tail.



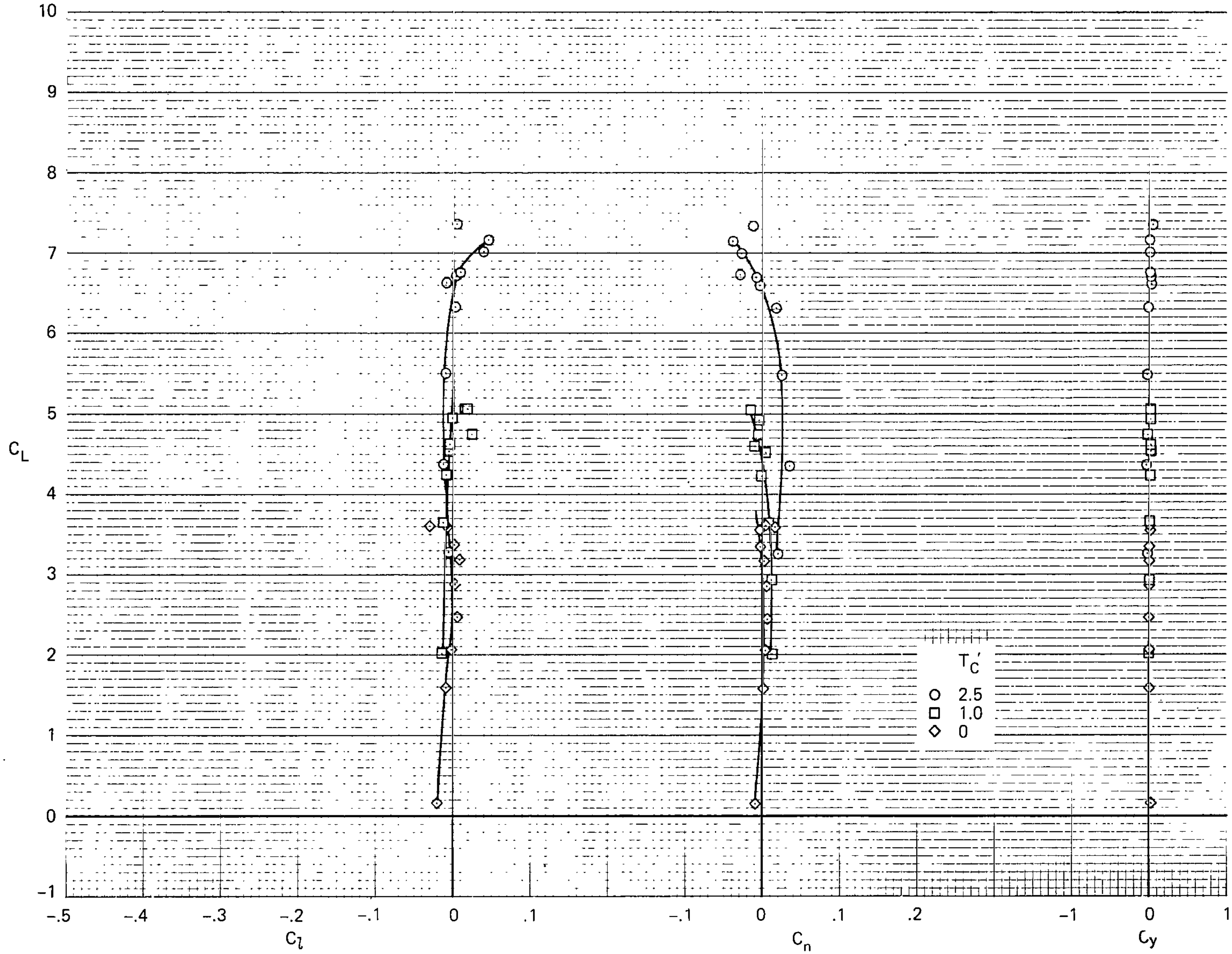
(a) $\delta_s = 30°$

Figure 10.- Effect of plain spoiler on rolling moment, yawing moment, and side force; low tail, $\delta_f = 80°$, $\delta_{i_t} = 0°$, $\psi = 0°$.



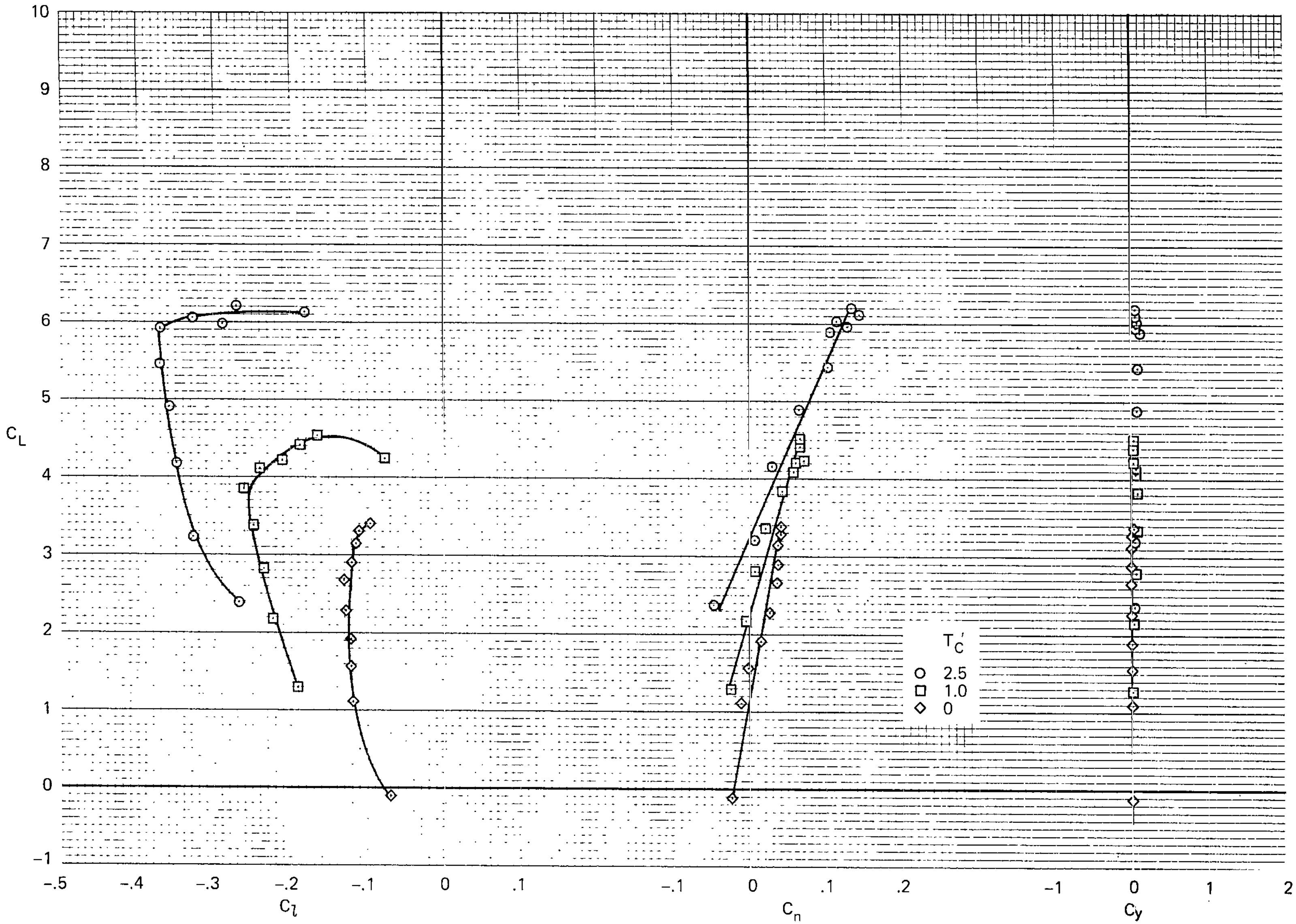
(b) $\delta_S = 60°$

Figure 10.- Concluded.



(a) $\delta_{sla} = 0°$ (η = 0.6 to 1.0).

Figure 11.- Effect of slot-lip aileron on lateral-directional characteristics of model; $\delta_f = 80°$, $\psi = 0°$.



(b) $\delta_{sla} = 60°$ (η = 0.6 to 1.0)

Figure 11.- Concluded.

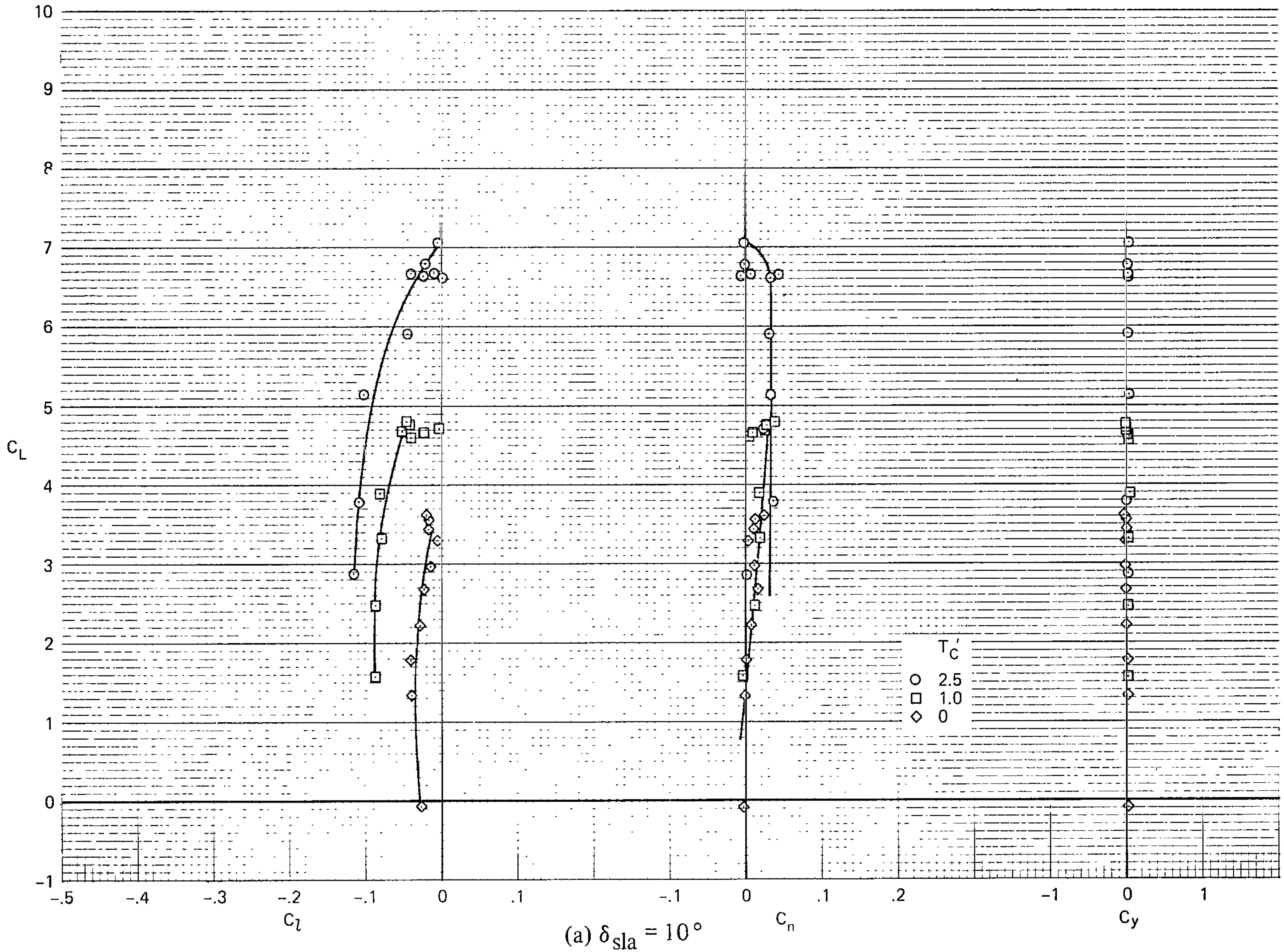
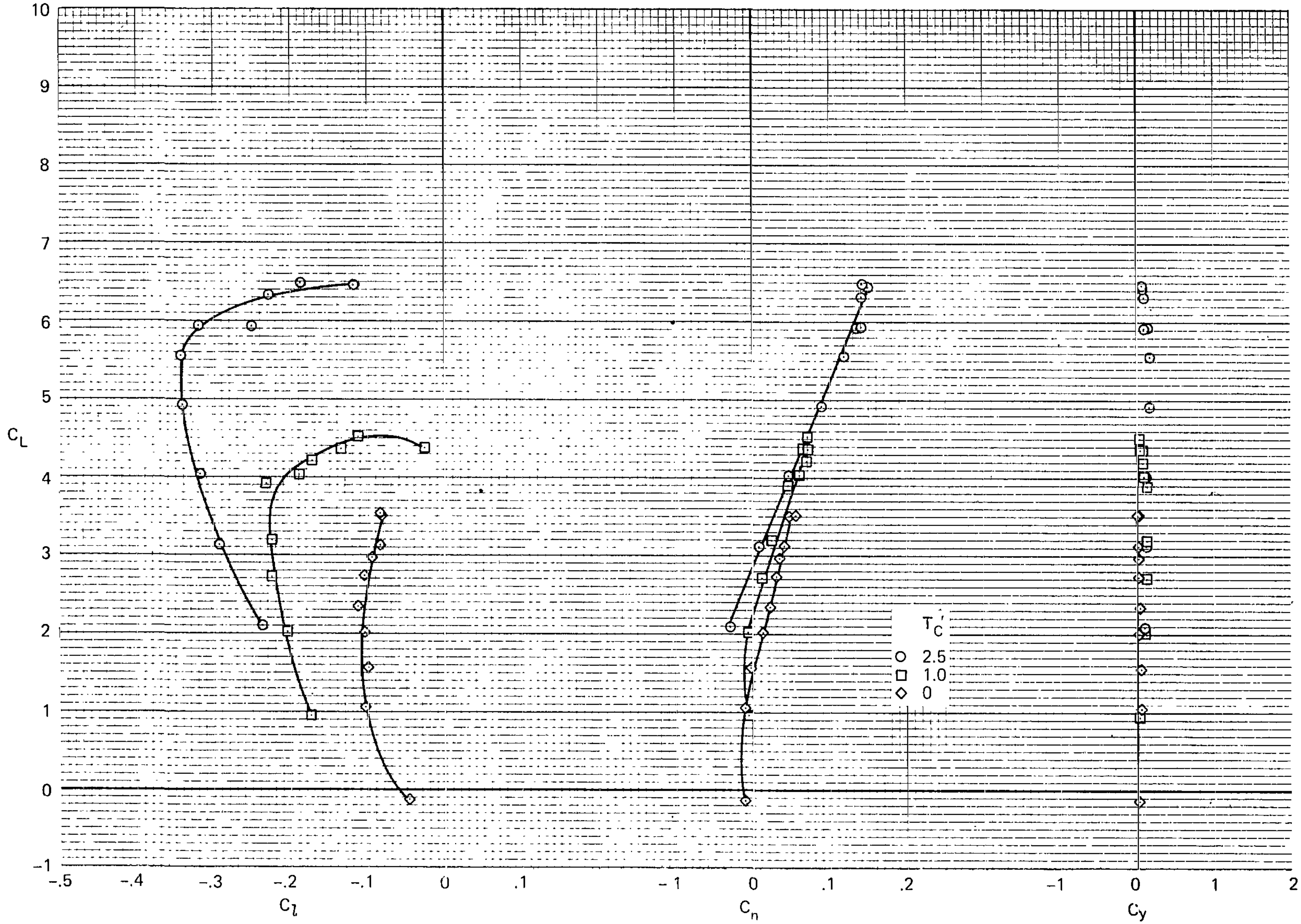
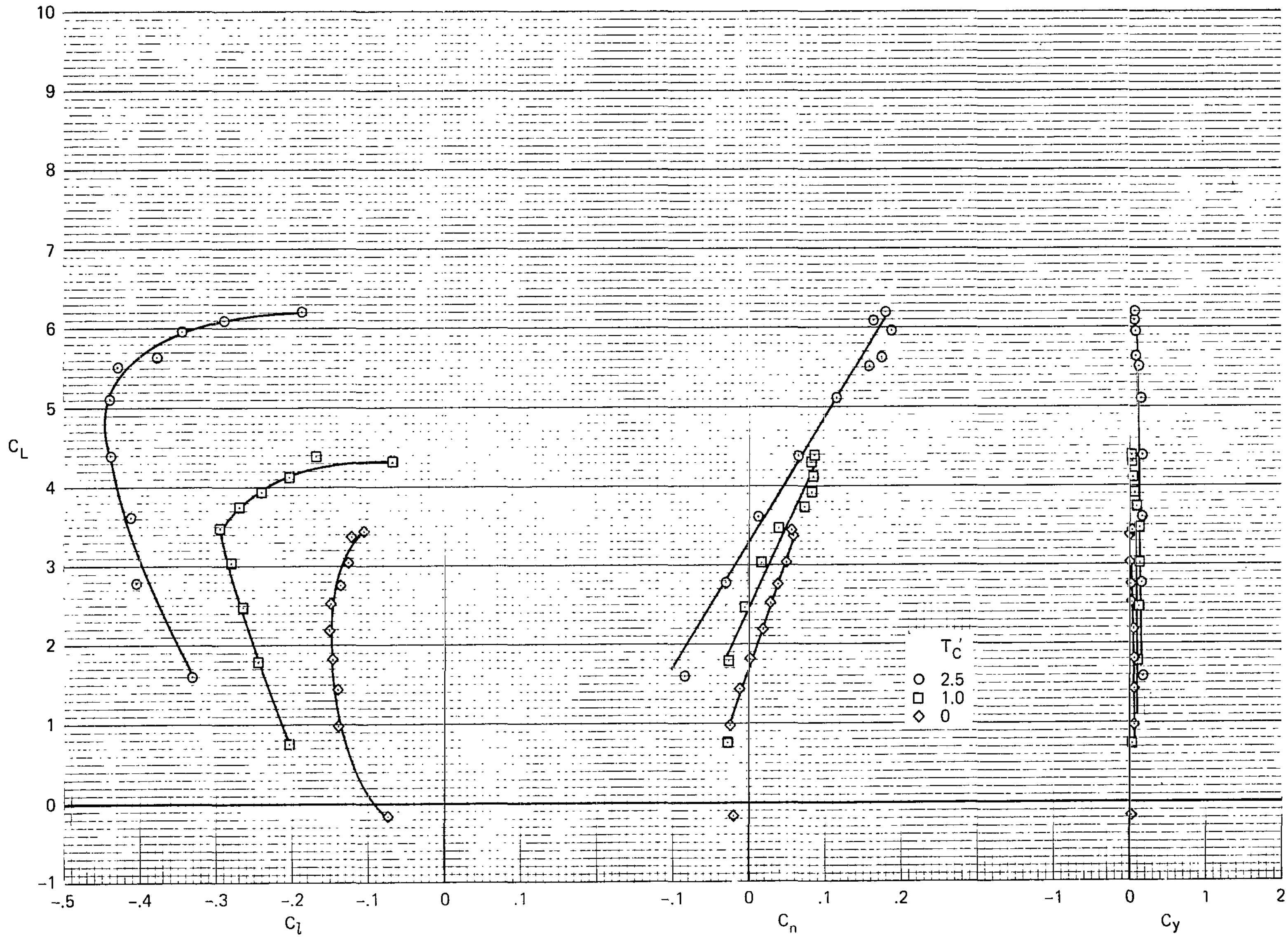


Figure 12.- Effect of 0.1c slot-lip aileron on lateral-directional characteristics of model (spanwise extent of δ_{sla}: $\eta = 0.385$ to 1.0); $\delta_f = 80°$, $\psi = 0°$, $\beta = 16°$.



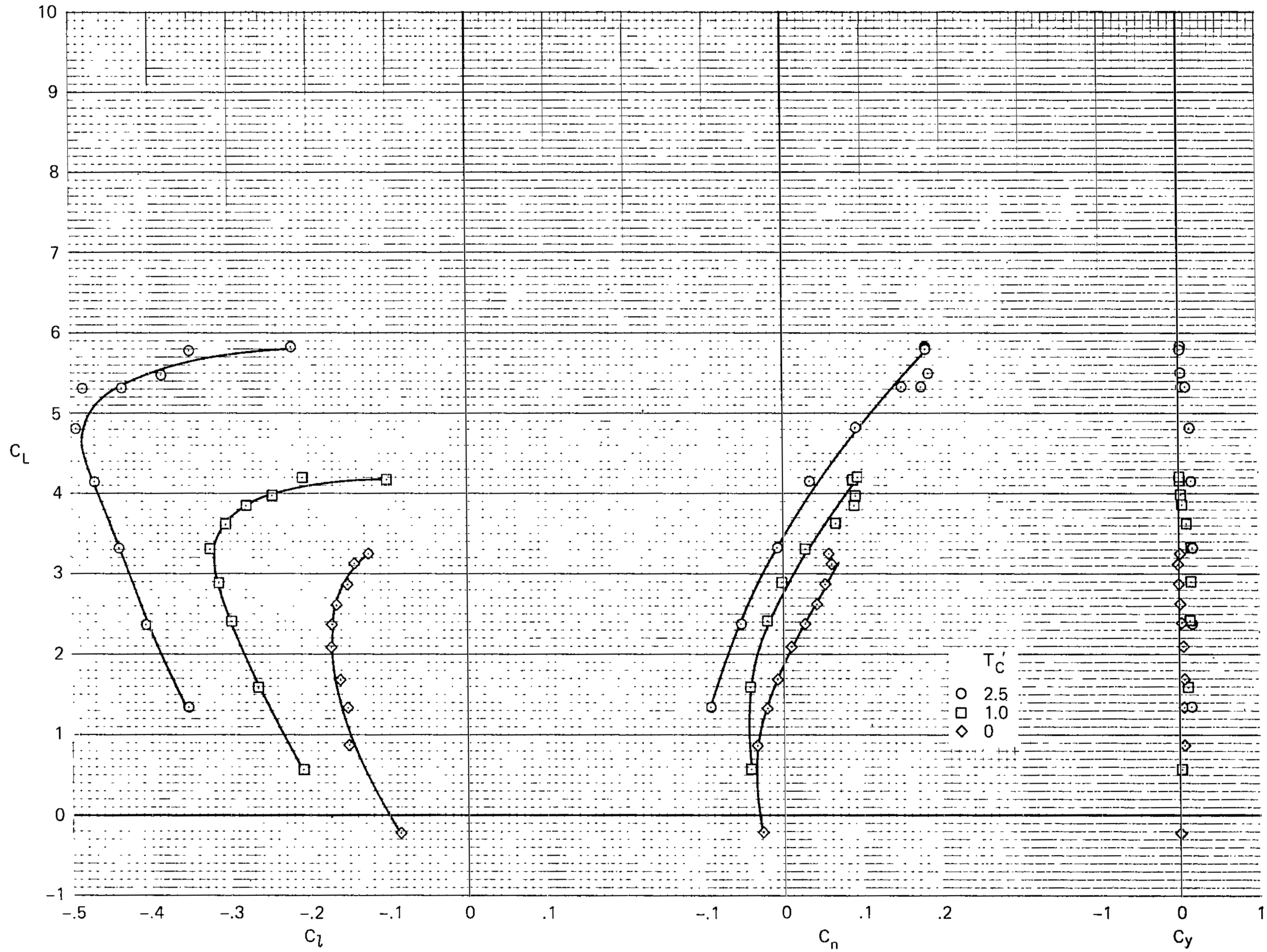
(b) $\delta_{sla} = 20°$

Figure 12.- Continued.



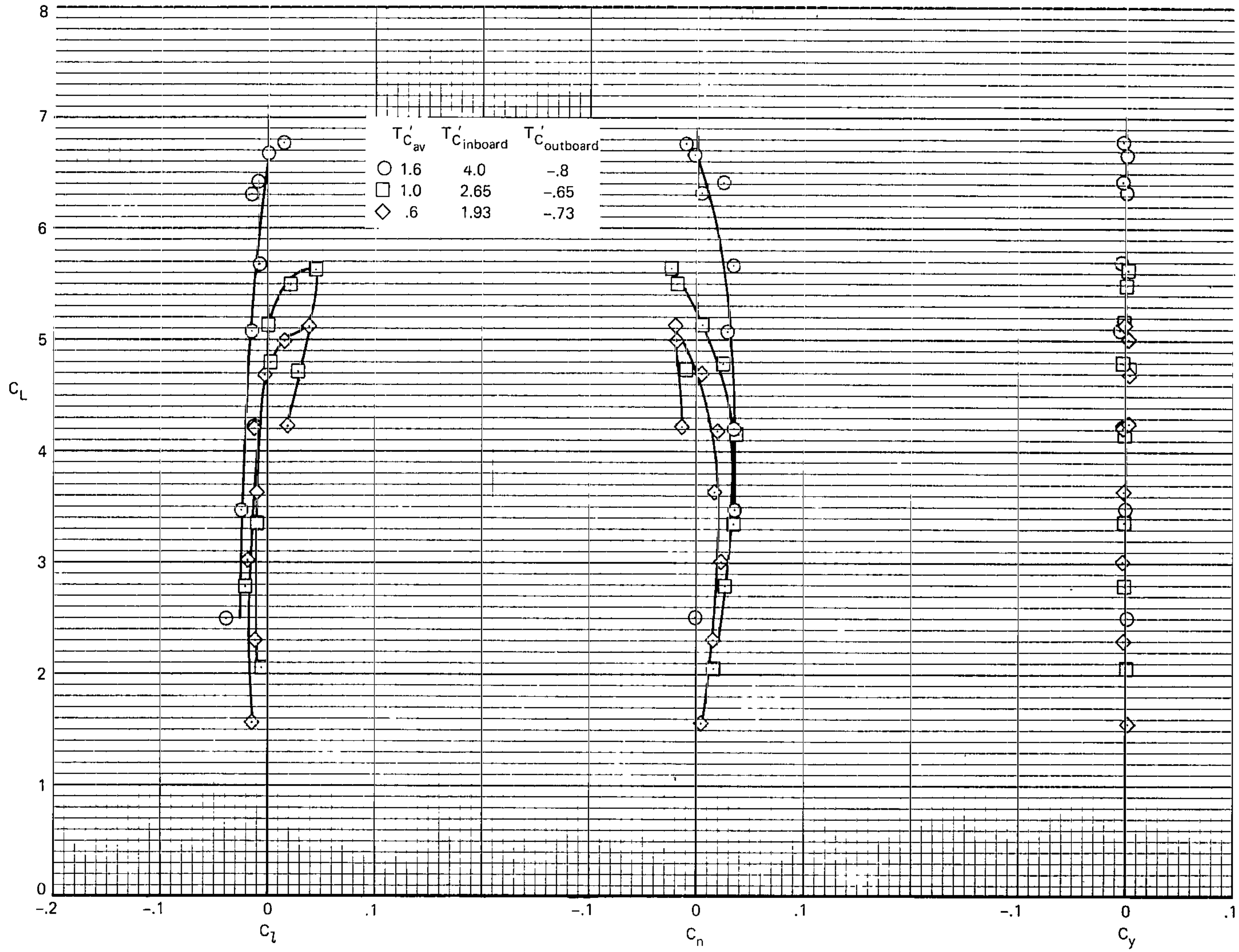
(c) $\delta_{sla} = 40°$

Figure 12. - Continued.



(d) $\delta_{sla} = 60°$

Figure 12.- Concluded.

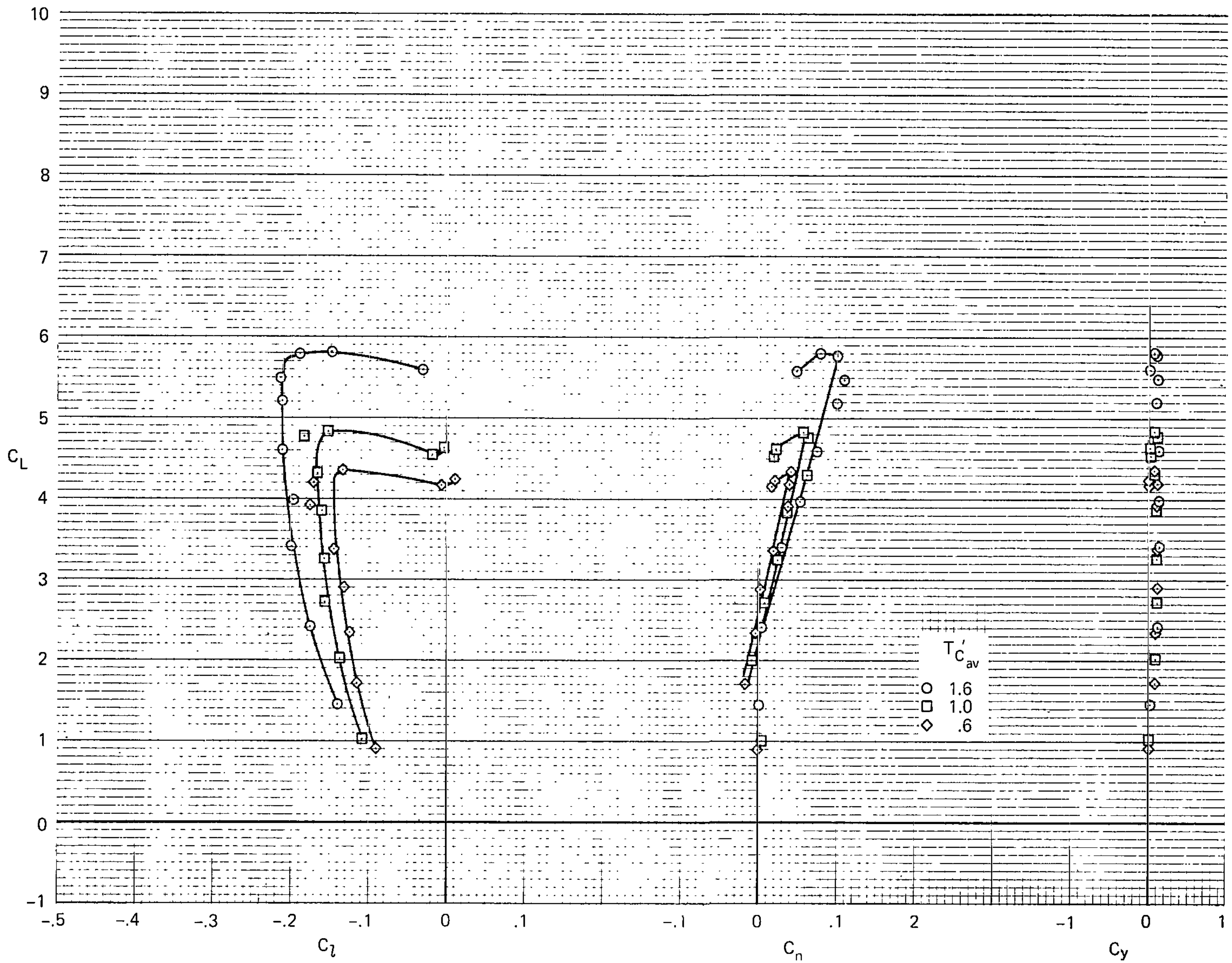


(a) 0.1c $\delta_{sla} = 0°$

Figure 13.- Effect of slot-lip aileron on lateral-directional characteristics with differential spanwise thrust ($\beta = 16/0$); $\delta_f = 80°$, $\eta_{extent} = 0.385$ to 1.0 .

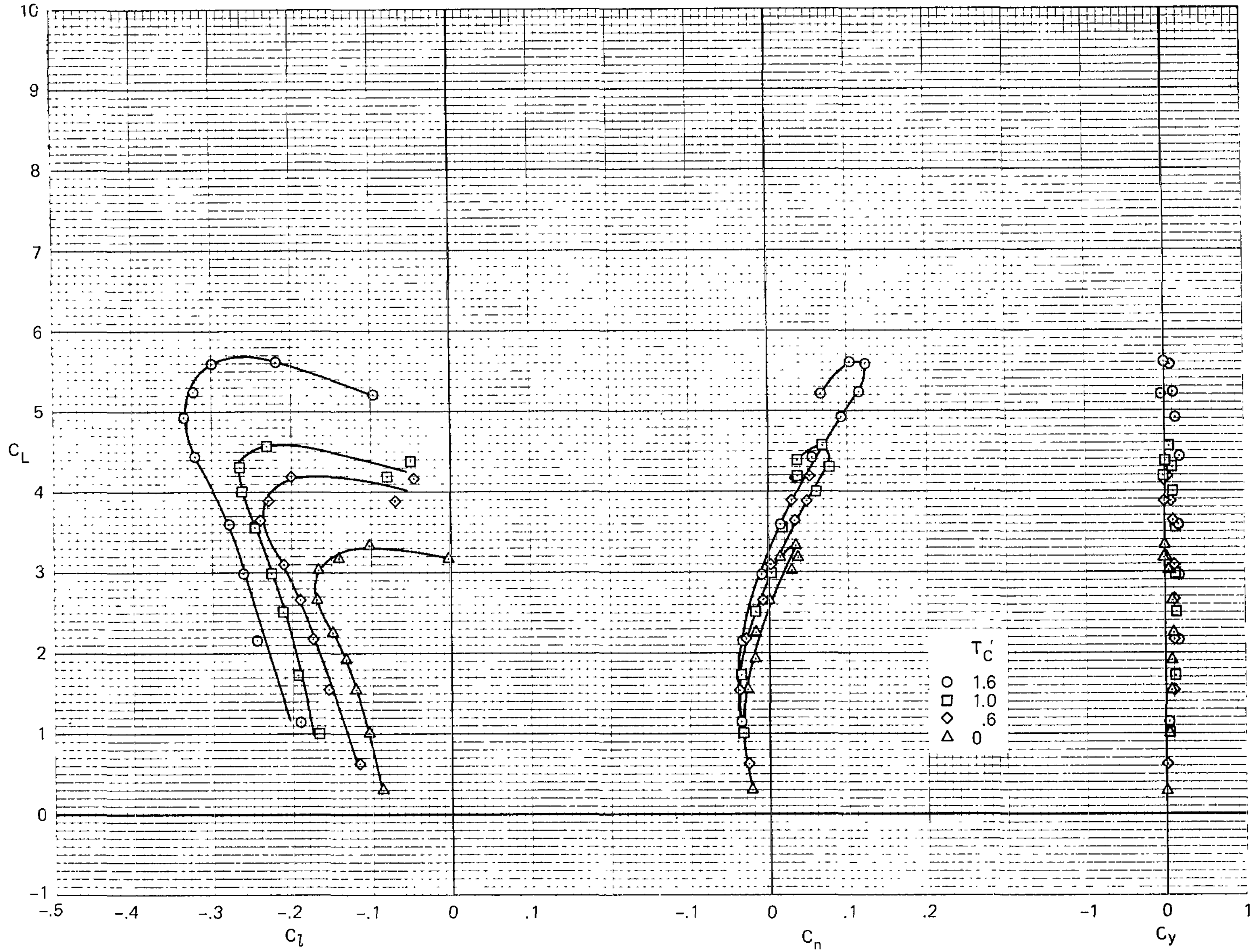
(b) 0.1c $\delta_{sla} = 10°$

Figure 13.- Continued.



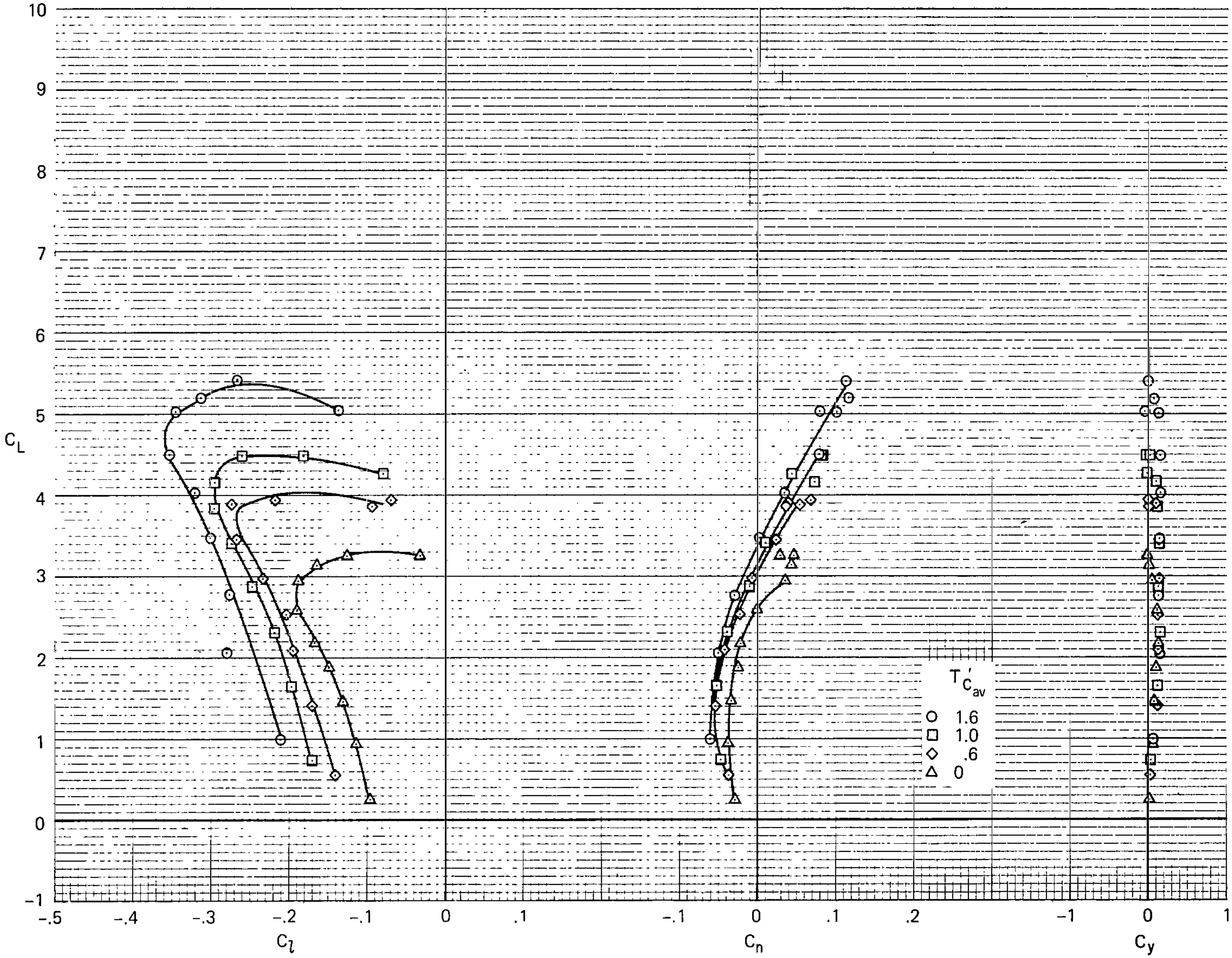
(c) 0.1c δ_{sla} = 20°

Figure 13.- Continued.



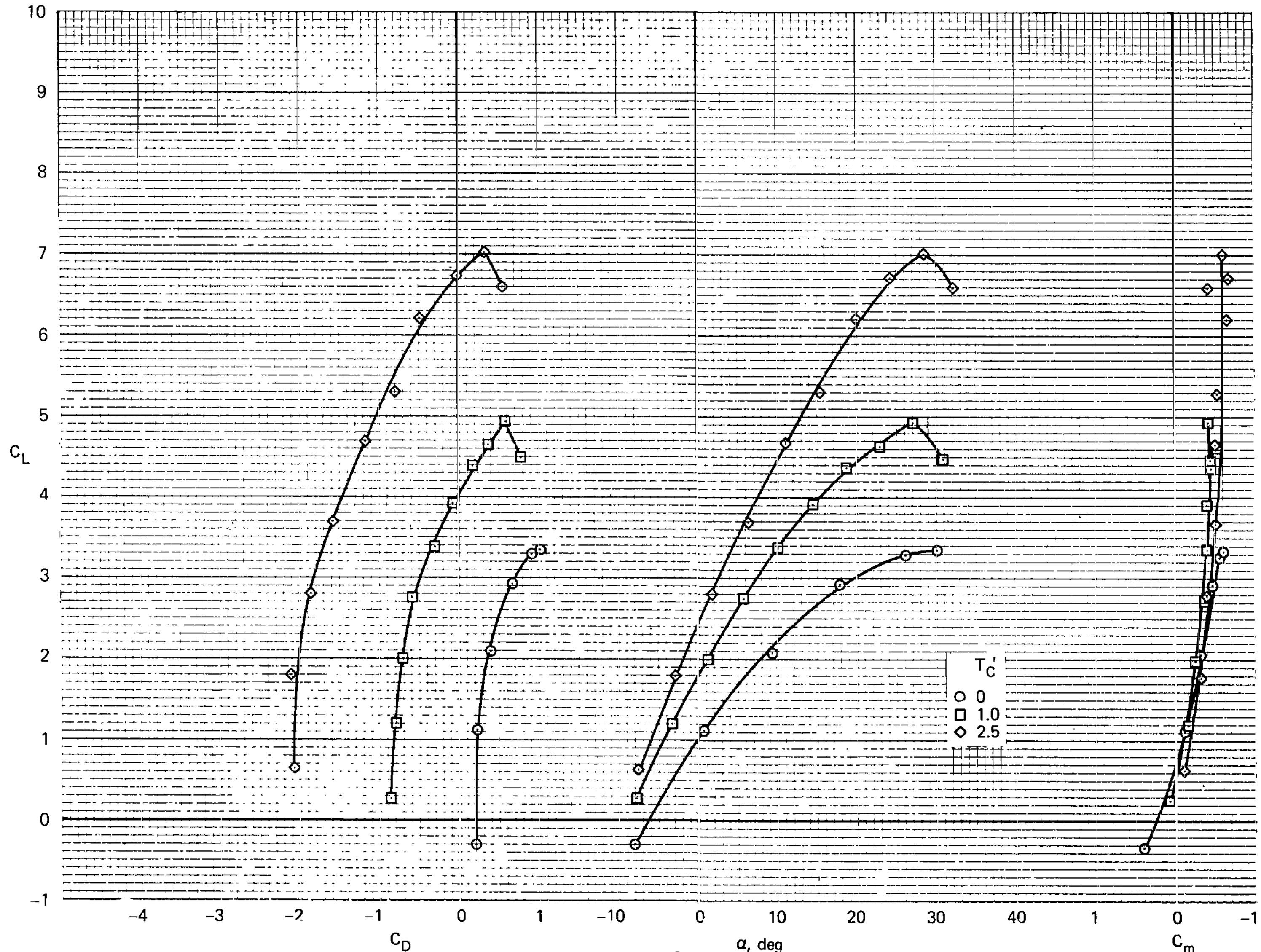
(d) 0.1c $\delta_{sla} = 40°$

Figure 13. - Continued.



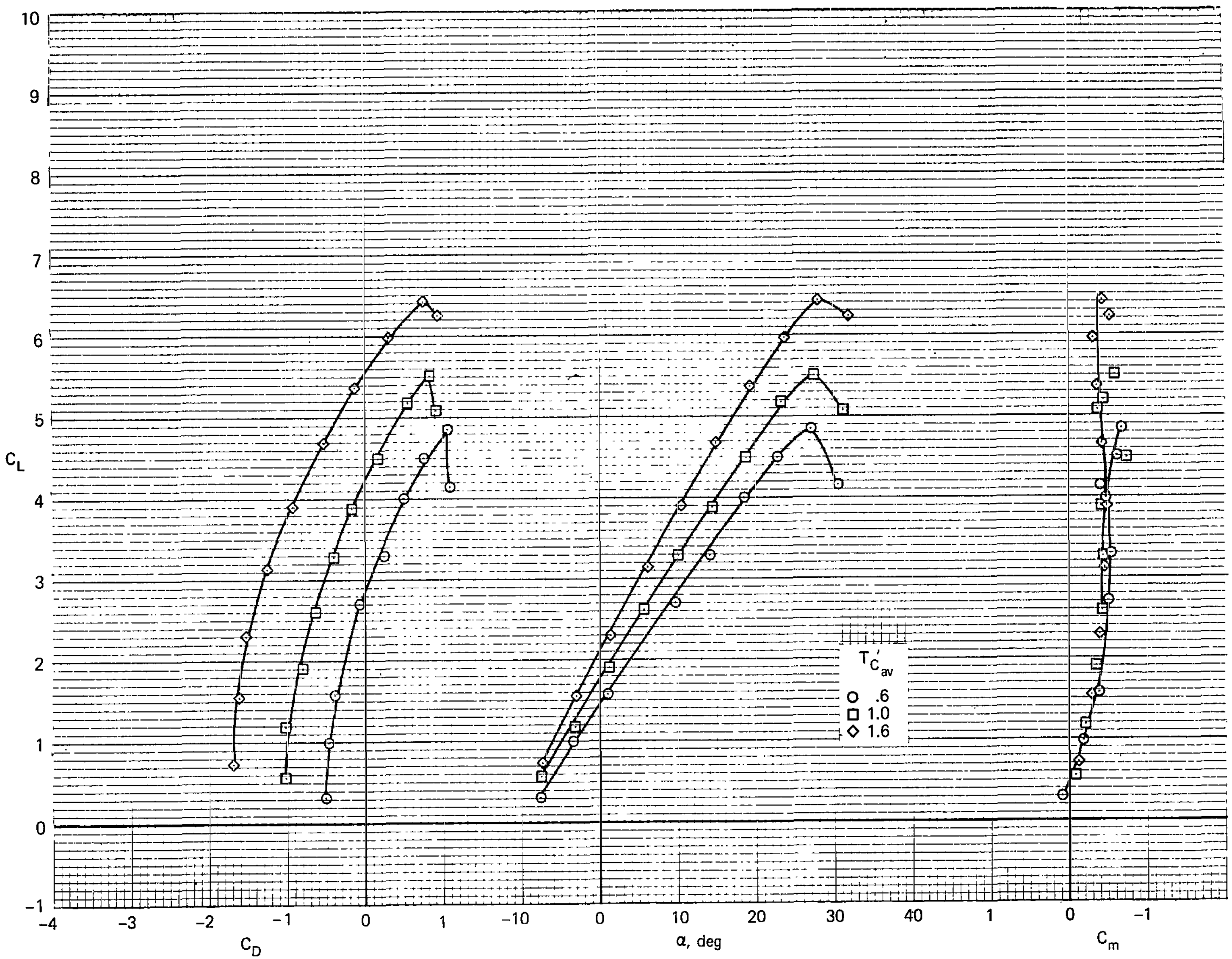
(e) 0.1c $\delta_{sla} = 60°$

Figure 13.- Concluded.



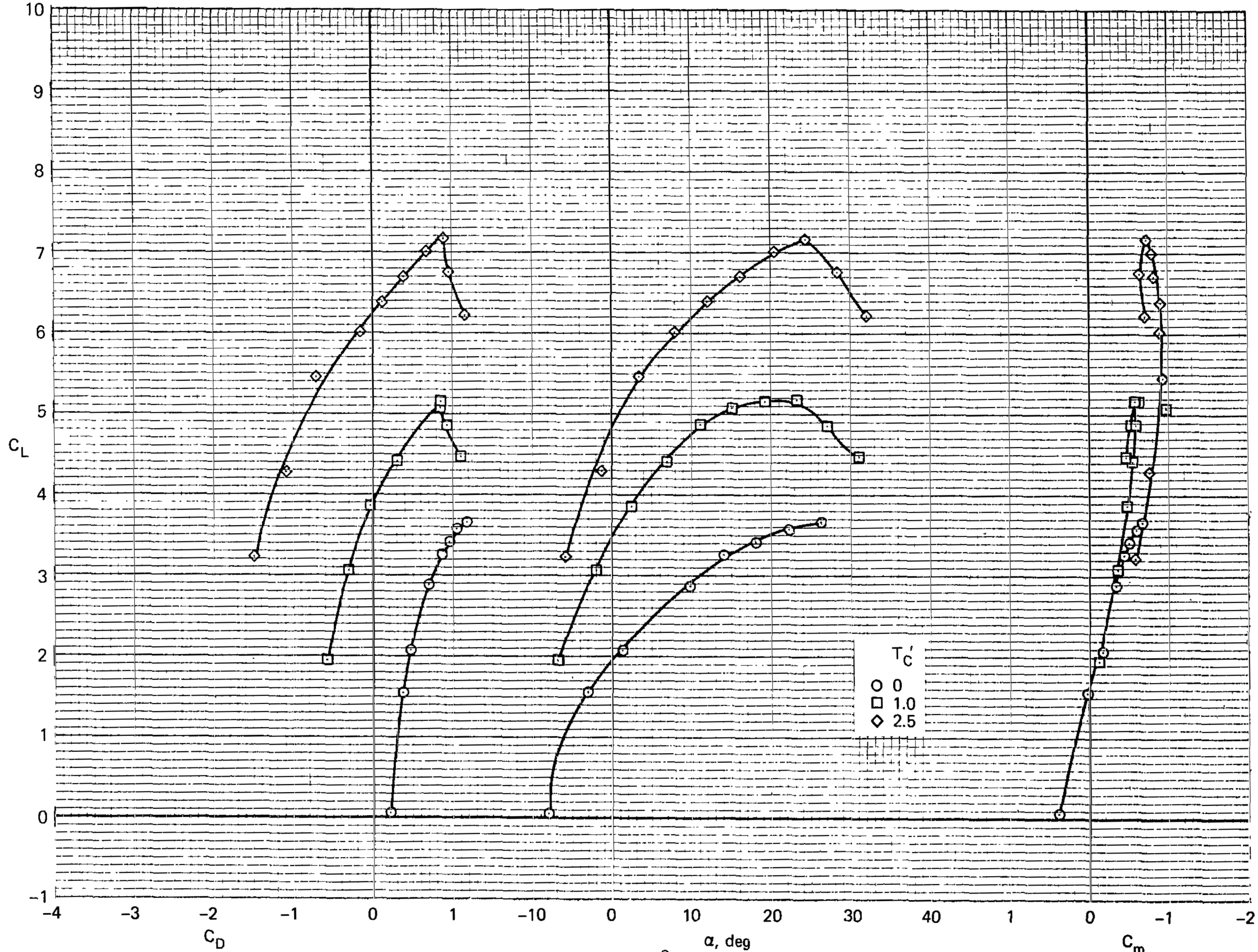
(a) $\beta = 16°$

Figure 14.- Effect of uniform and differential propeller thrust on the longitudinal characteristics of the model; $i_t = 0°$, high tail, $\delta_f = 40°$.



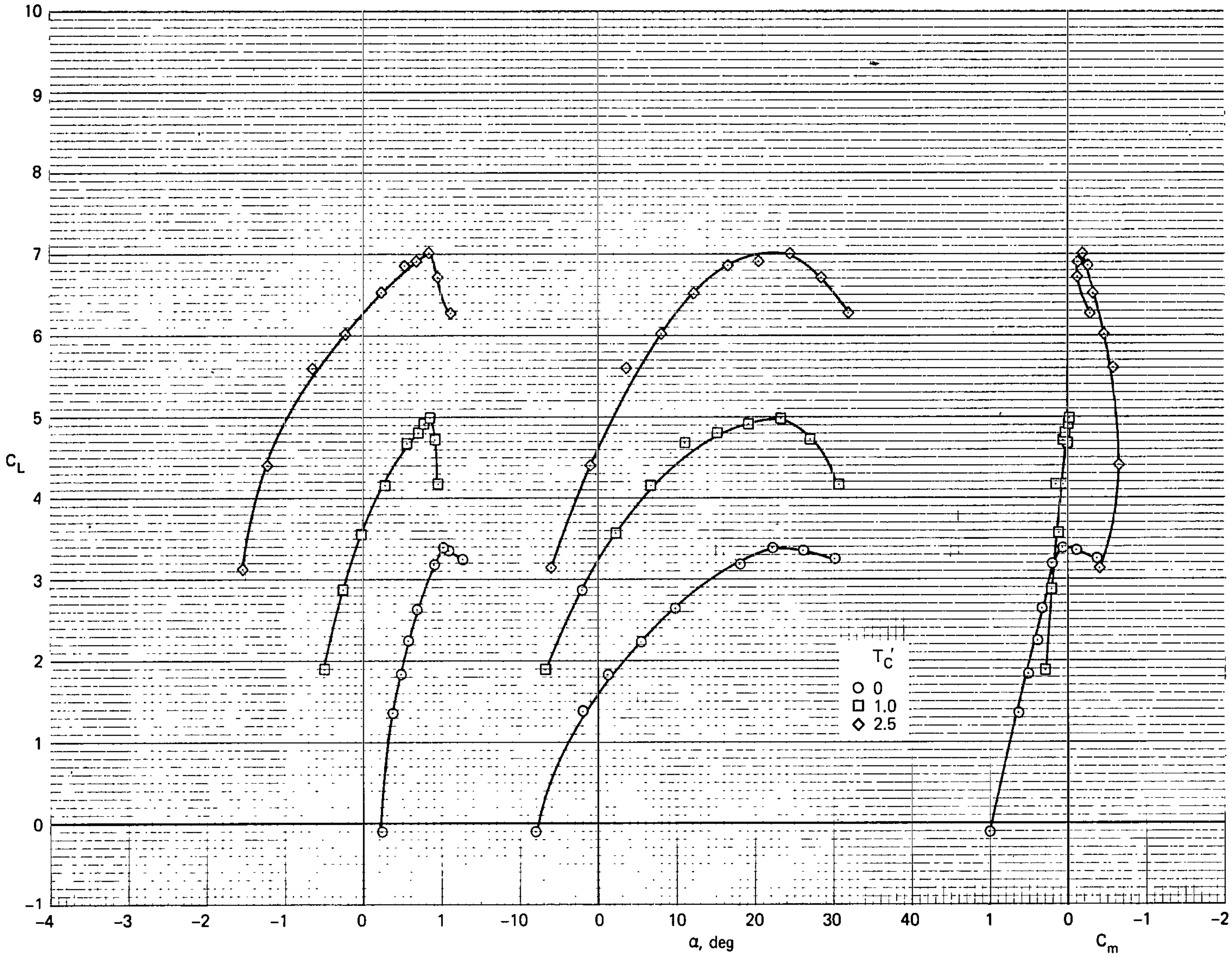
(b) $\beta = 16/0°$

Figure 14.- Concluded.



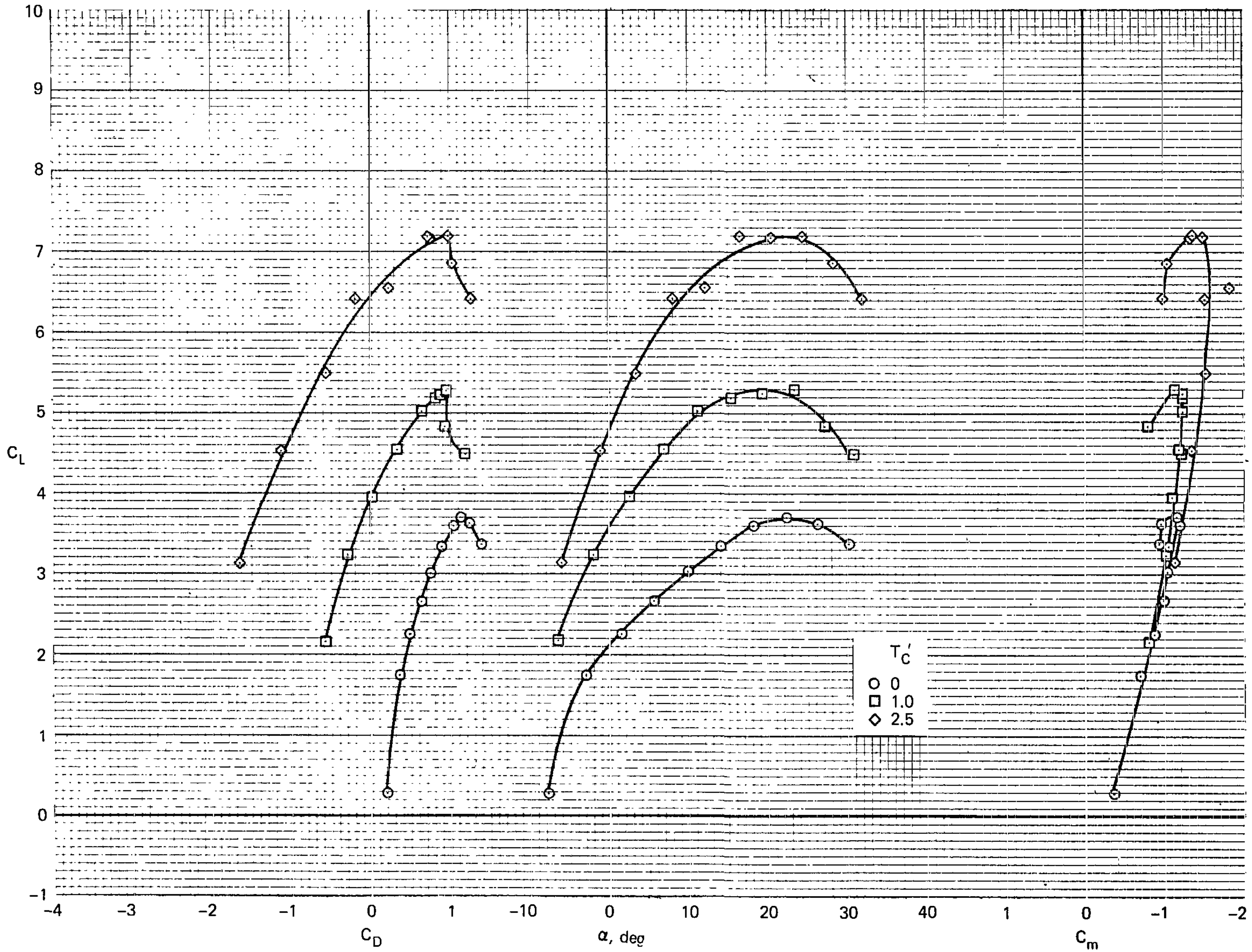
(a) $i_t = 0°$

Figure 15.- Effect of tail incidence on the longitudinal characteristics of the model with the tail mounted in the high position; $\delta_f = 80°$.



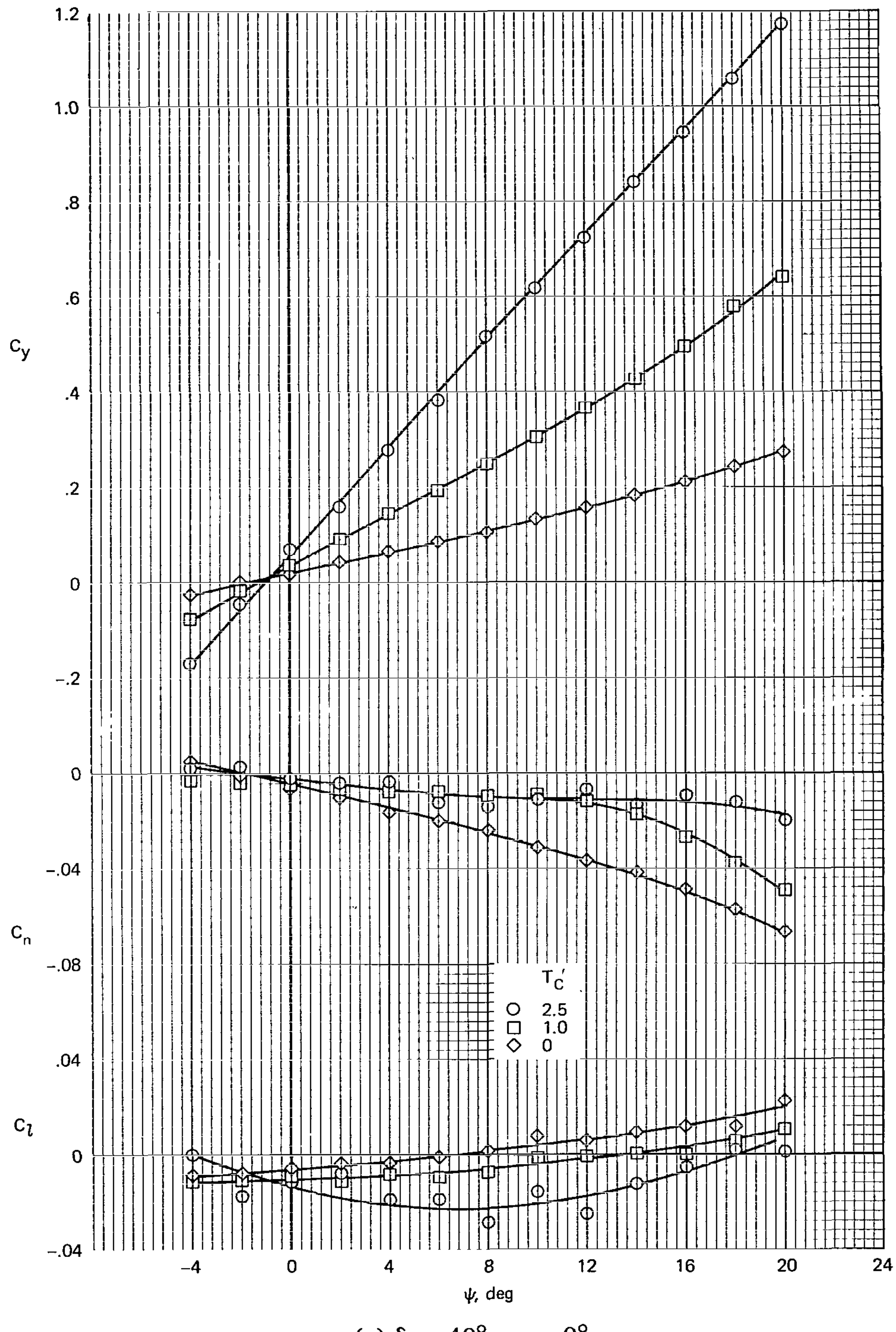
(b) $i_t = -10^\circ$

Figure 15.- Continued.



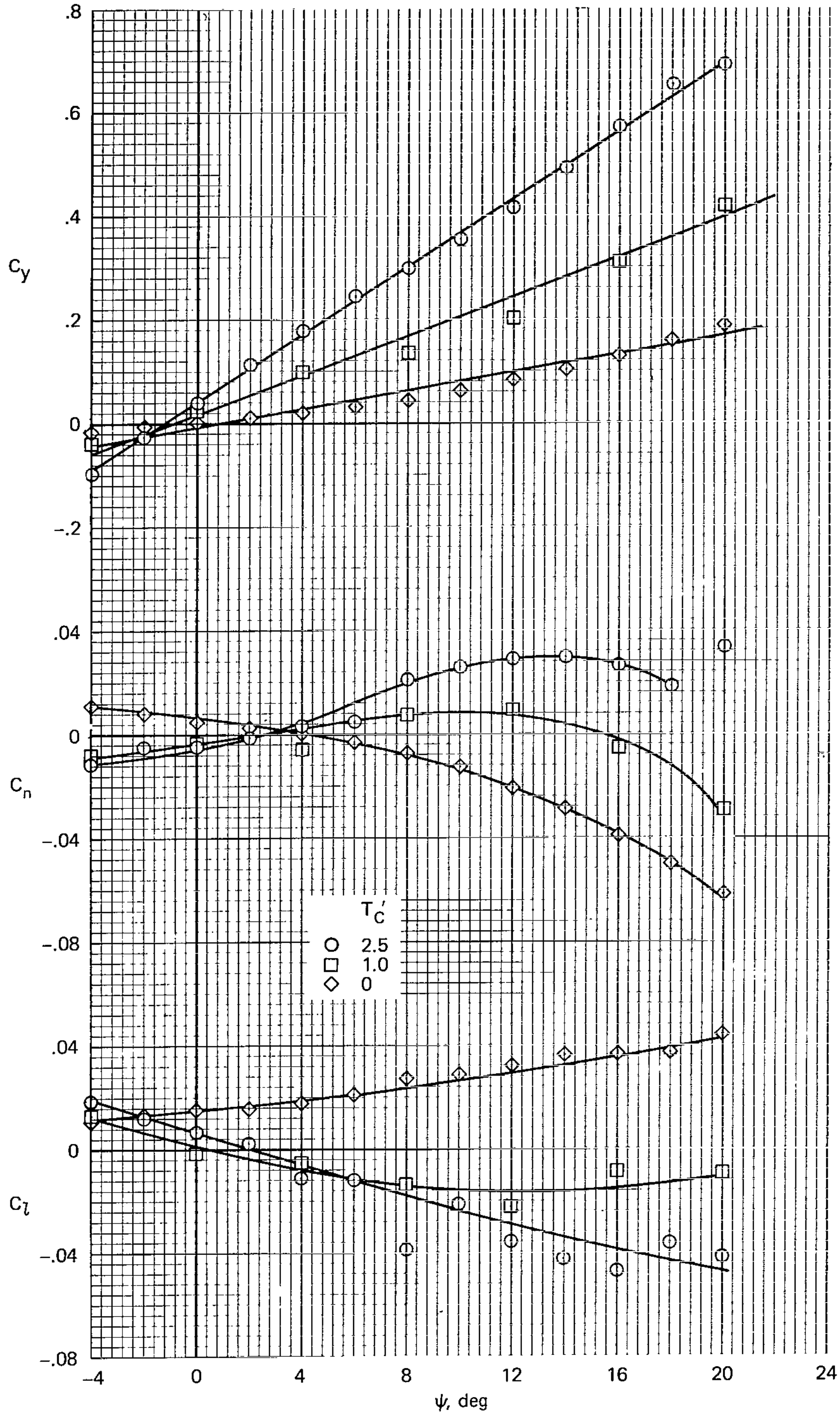
(c) $i_t = 10^\circ$

Figure 15.- Concluded.



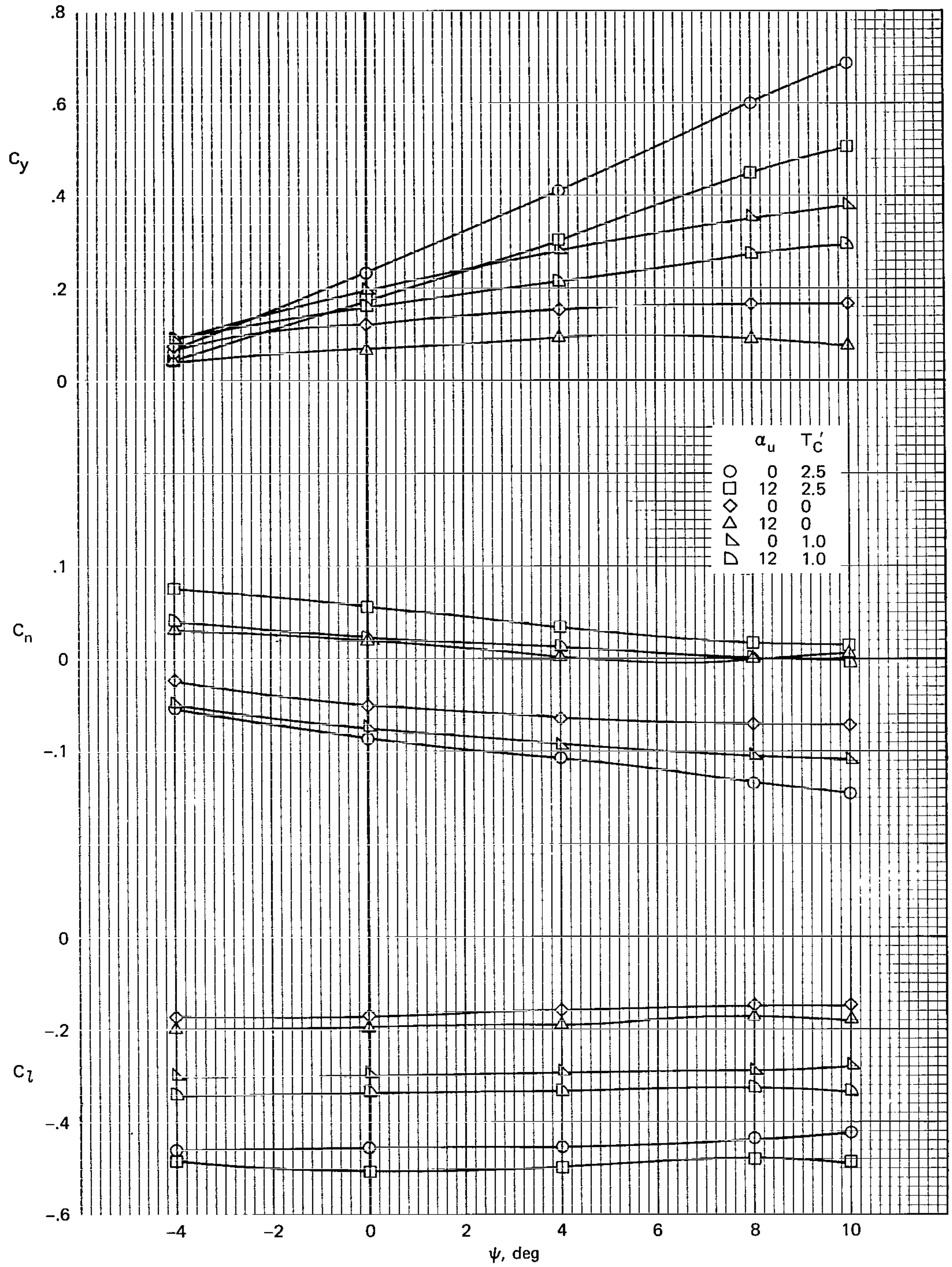
(a) $\delta_f = 40°$, $\alpha_u = 0°$

Figure 16.- Variation of lateral-directional characteristics with angle of yaw of the model for three flap deflections; high tail.



(b) $\delta_f = 80°, \alpha_u = 0°$

Figure 16.- Continued.



(c) $\delta_f = 100/60°$, 0.2c $\delta_{sla} = 60°$

Figure 16.- Concluded.

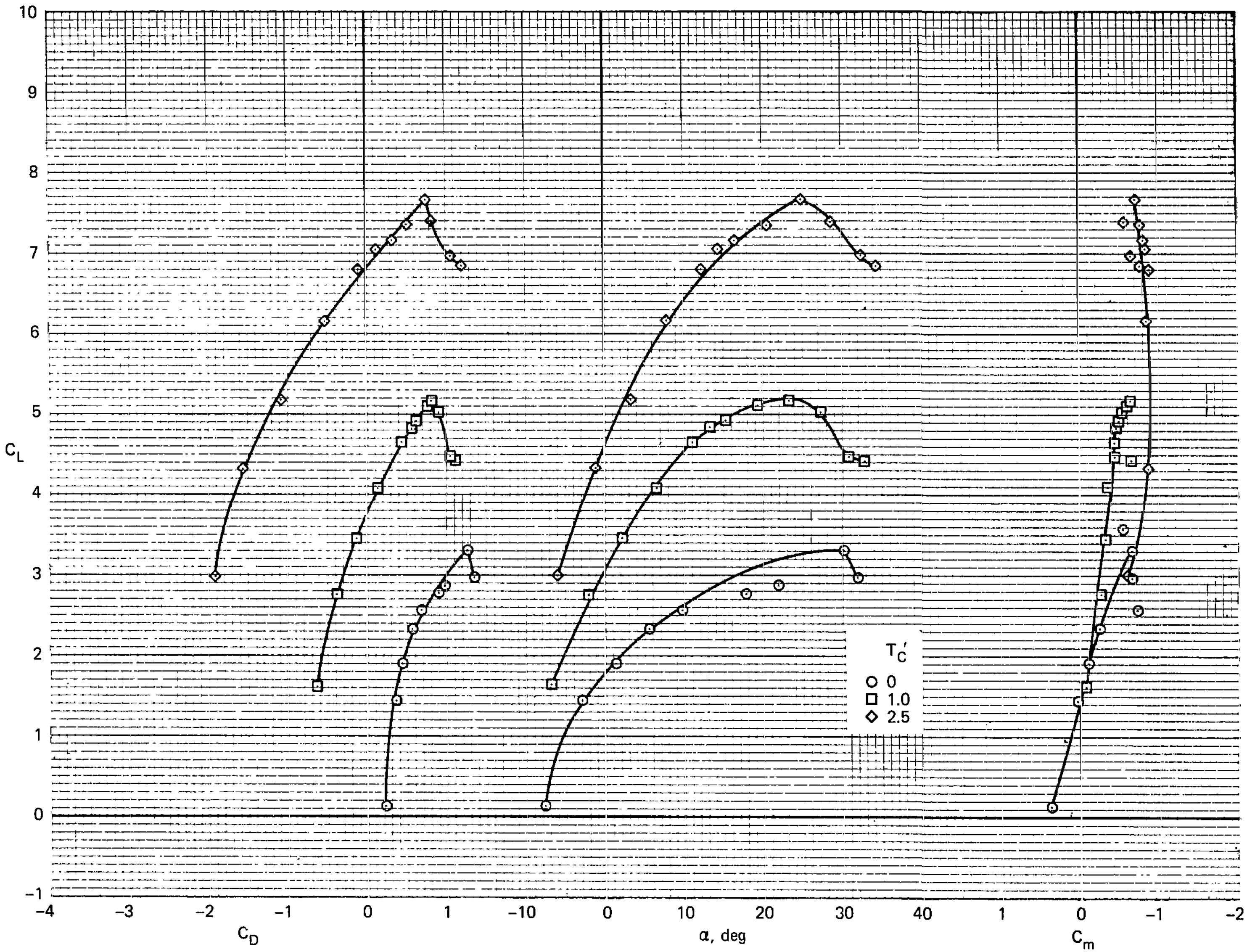
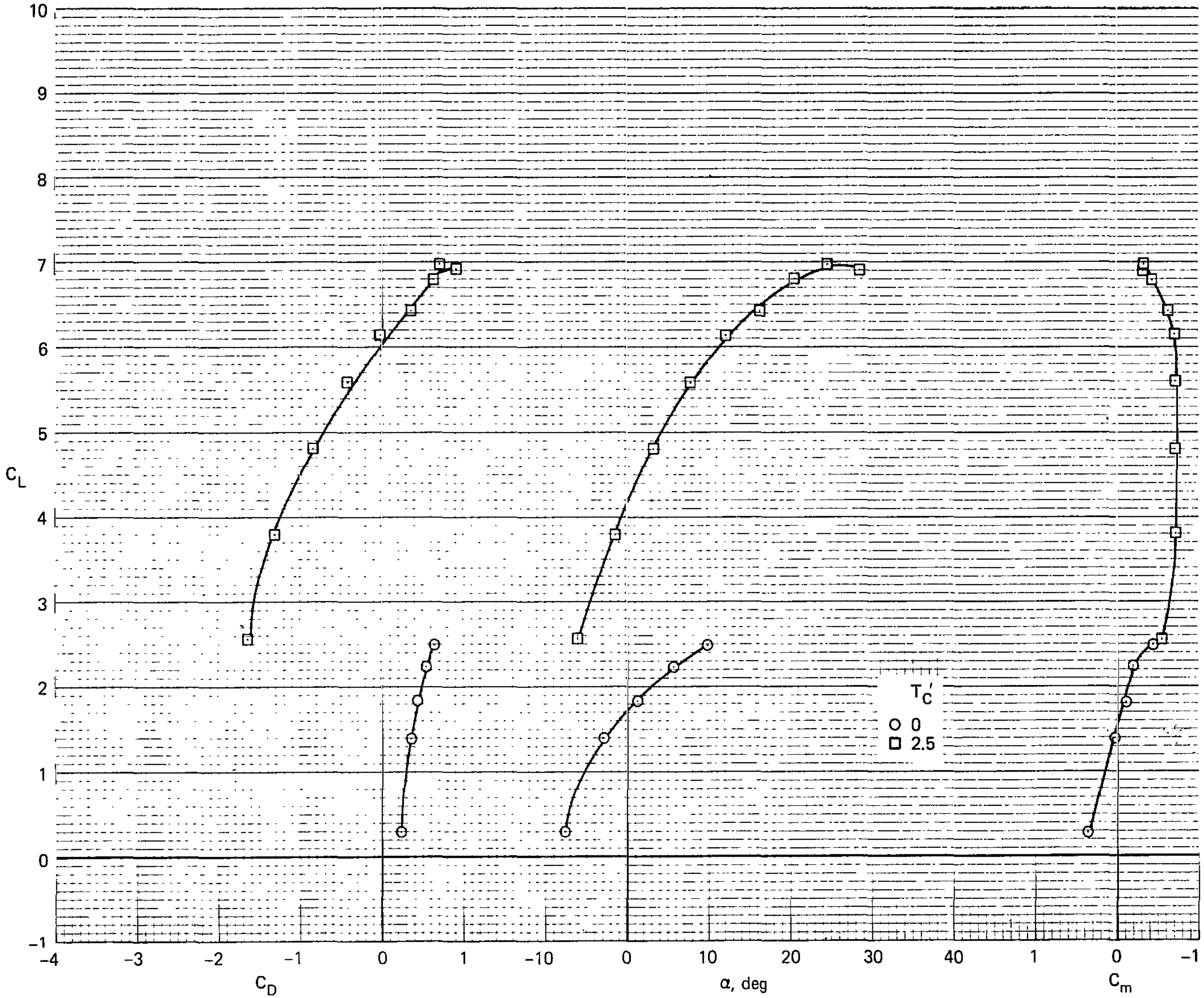
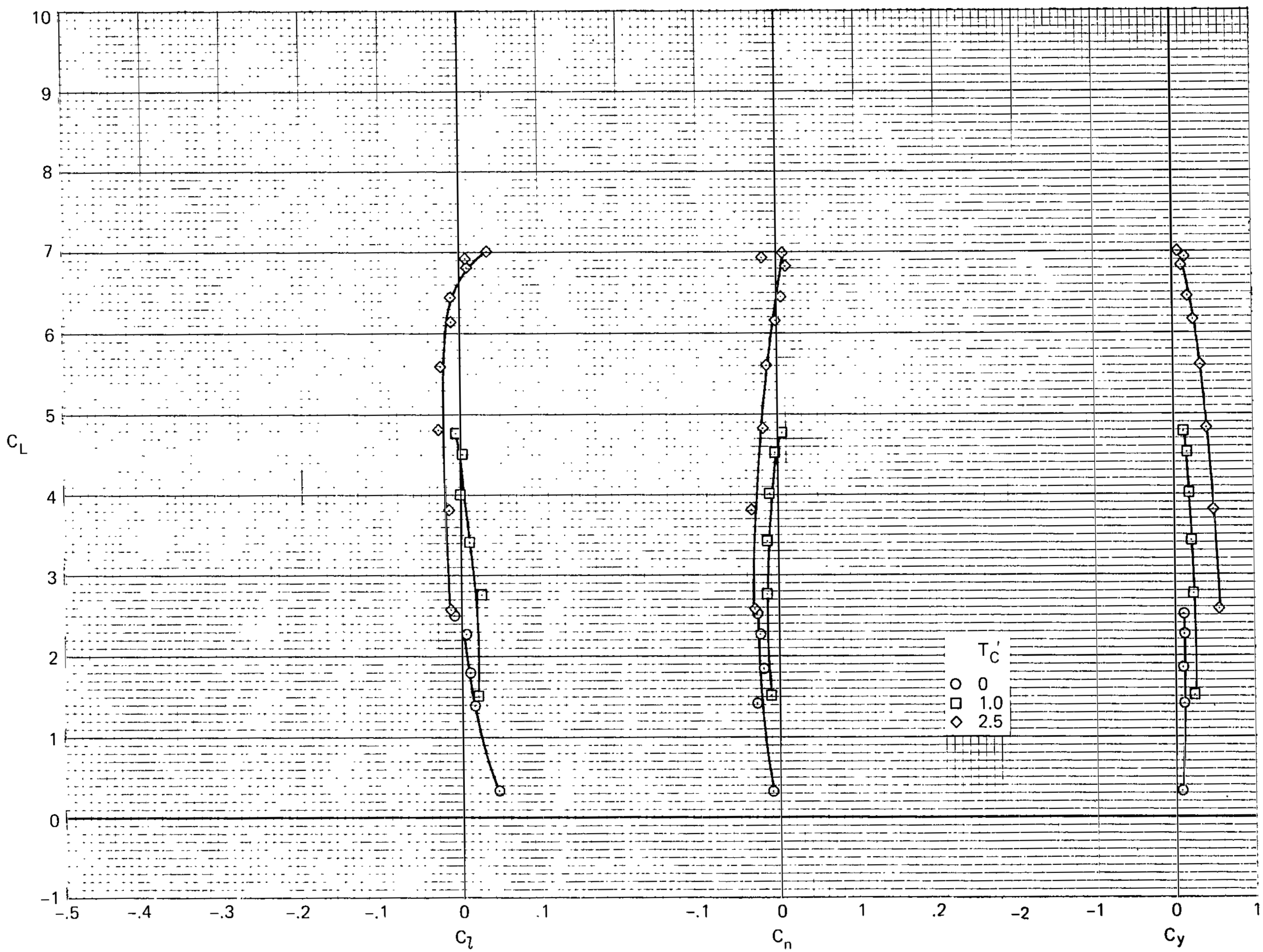


Figure 17.- Effect of thrust on longitudinal characteristics; $\delta_f = 100/60°$, high tail, $\psi = 0°$.



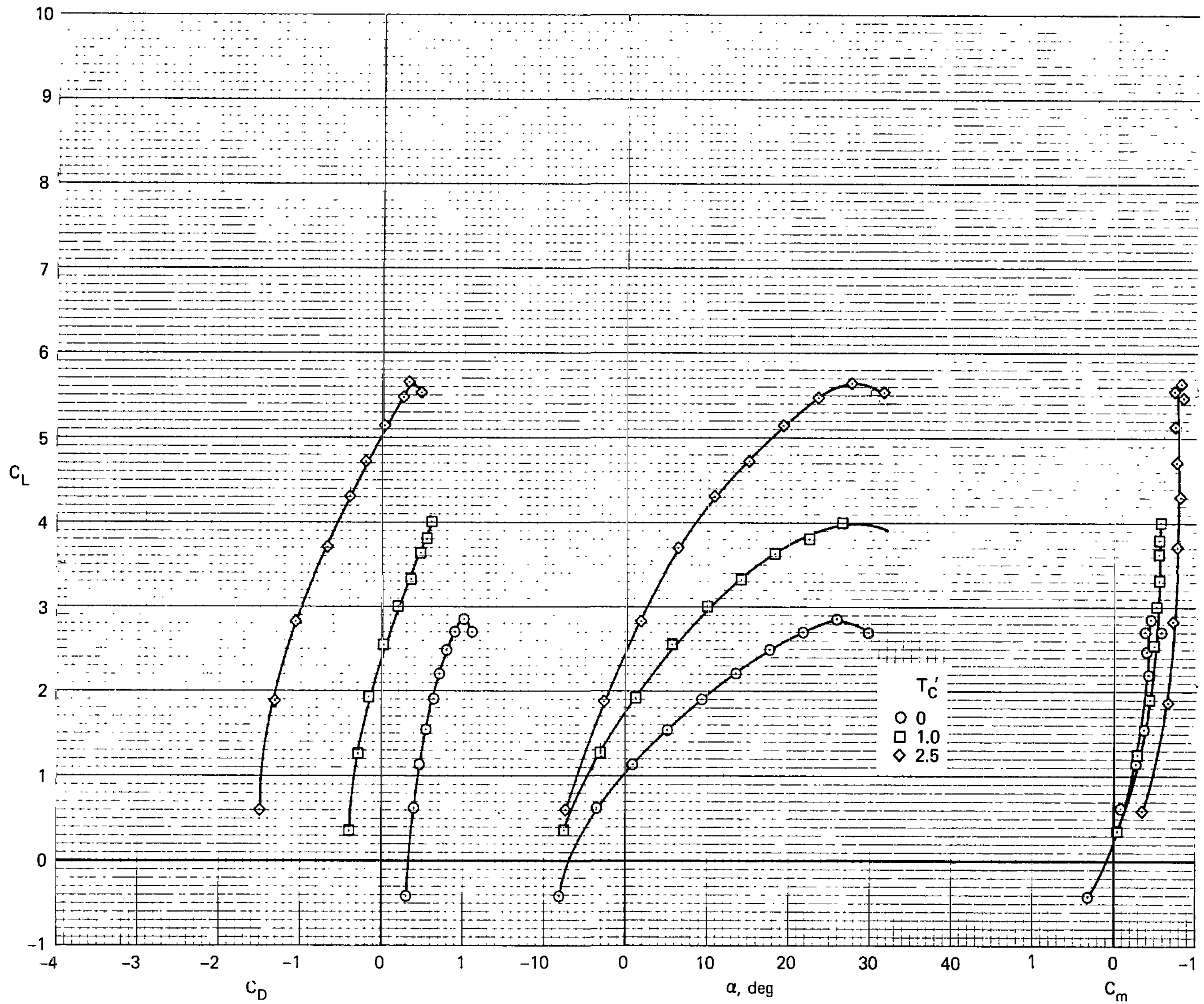
(a) $\delta_{sla} = 0°$

Figure 18.- Effect of slot-lip aileron on longitudinal and lateral-directional characteristics of the model with 10° of yaw ($\psi = 10°$); high tail, $i_t = 0°$, $\delta_f = 100/60°$.



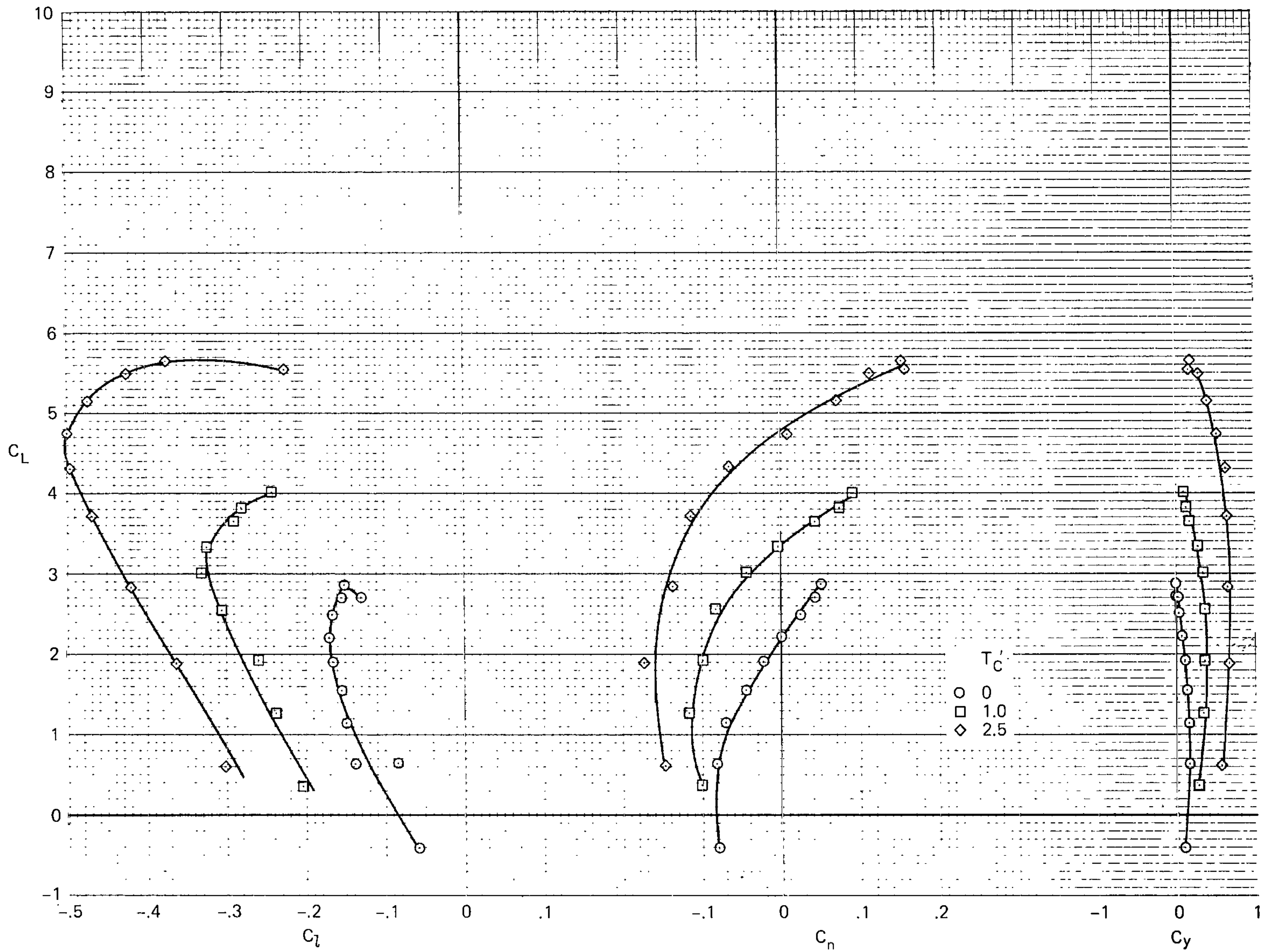
(b) $\delta_{sla} = 0°$

Figure 18.- Continued.



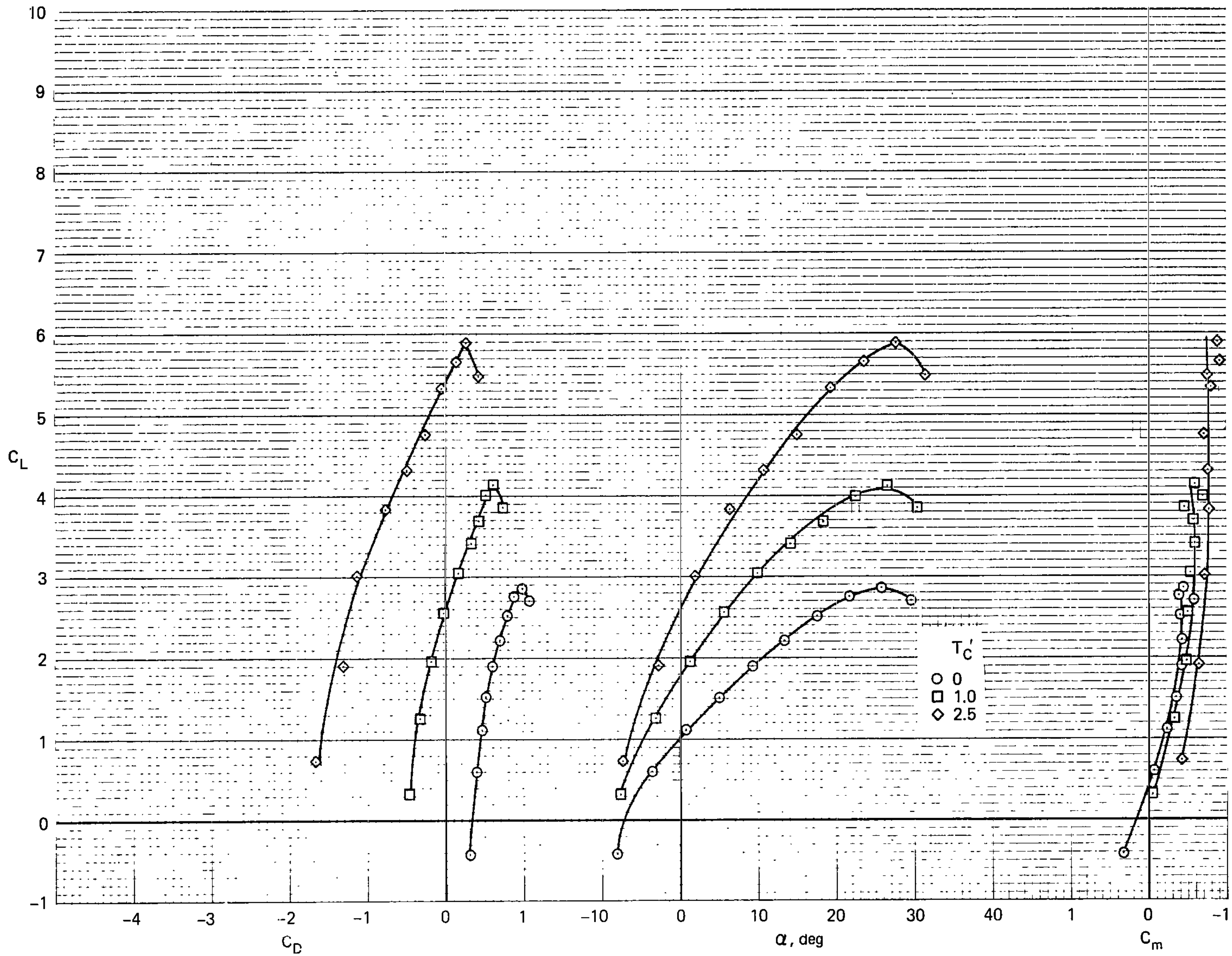
(c) 0.2c δ_{sla} = 60°

Figure 18.- Continued.



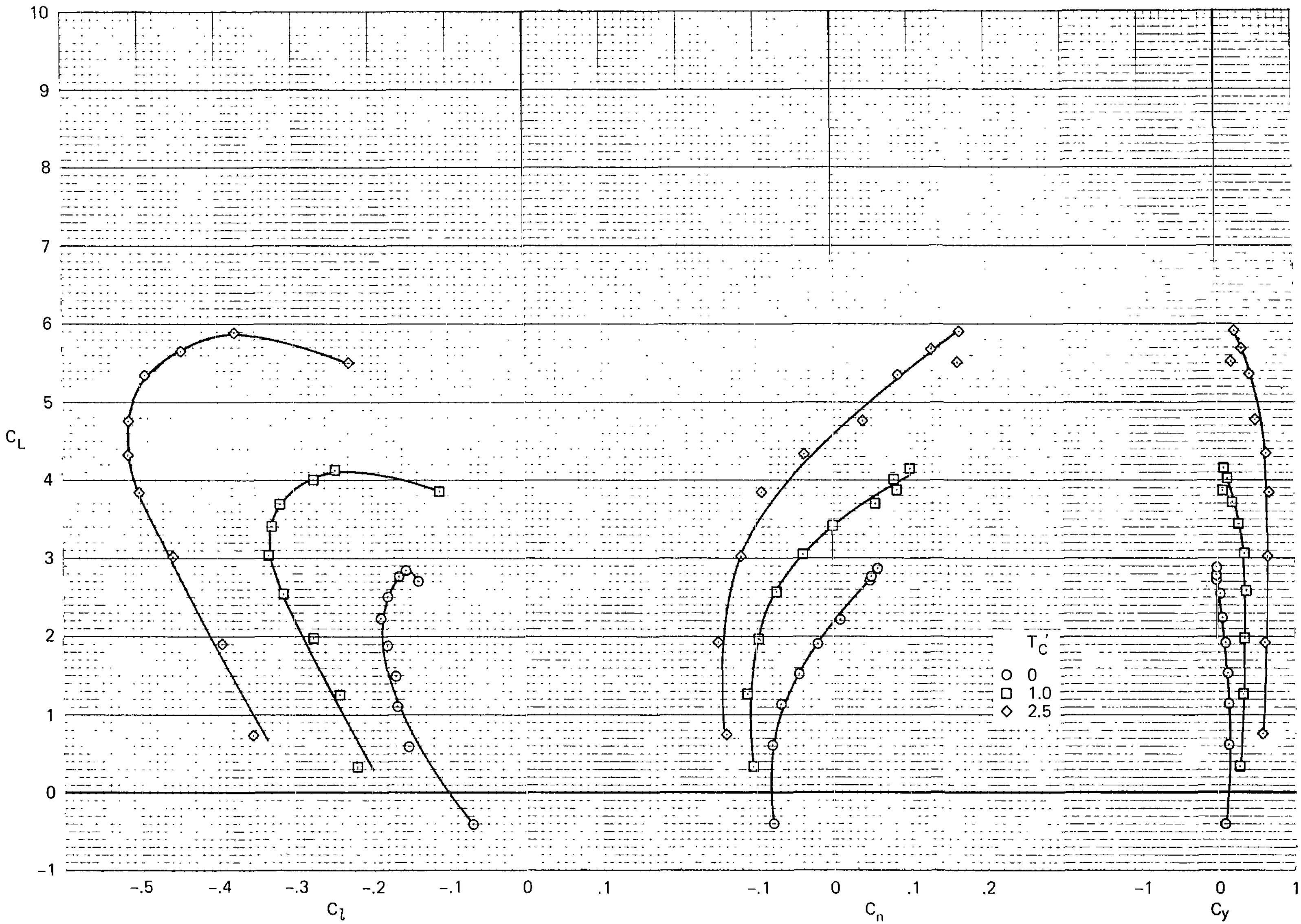
(d) 0.2c $\delta_{sla} = 60°$

Figure 18.- Continued.



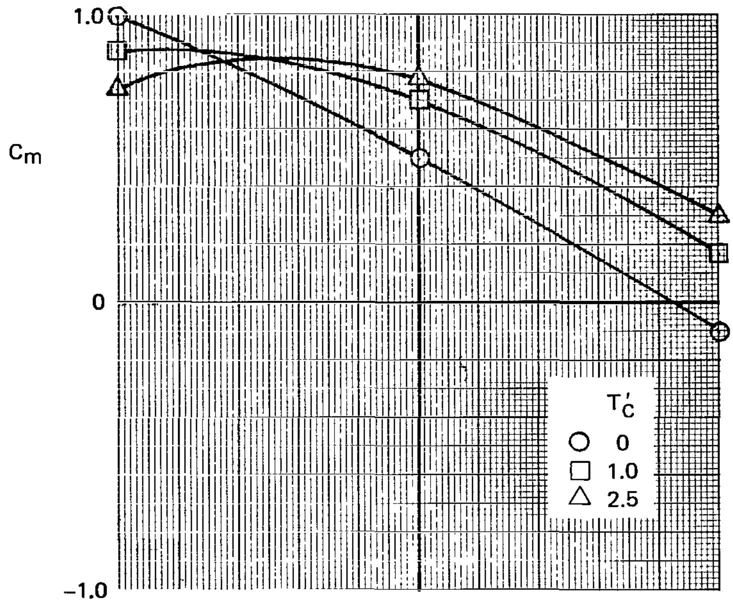
(e) 0.2c $\delta_{sla} = 60°$, $\delta_{a_l} = -25°$

Figure 18.- Continued.

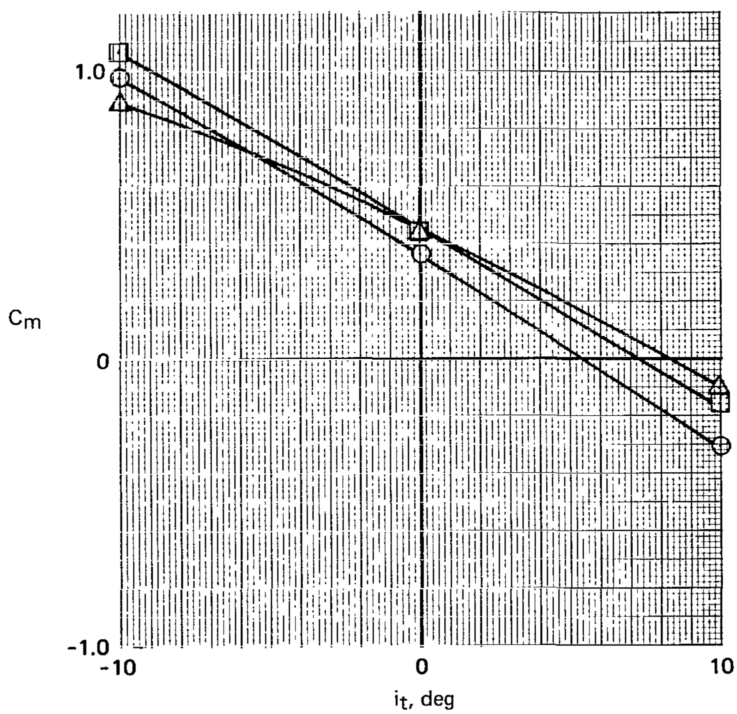


(f) 0.2c $\delta_{sla} = 60°$, $\delta_{a_l} = -25°$.

Figure 18.- Concluded.

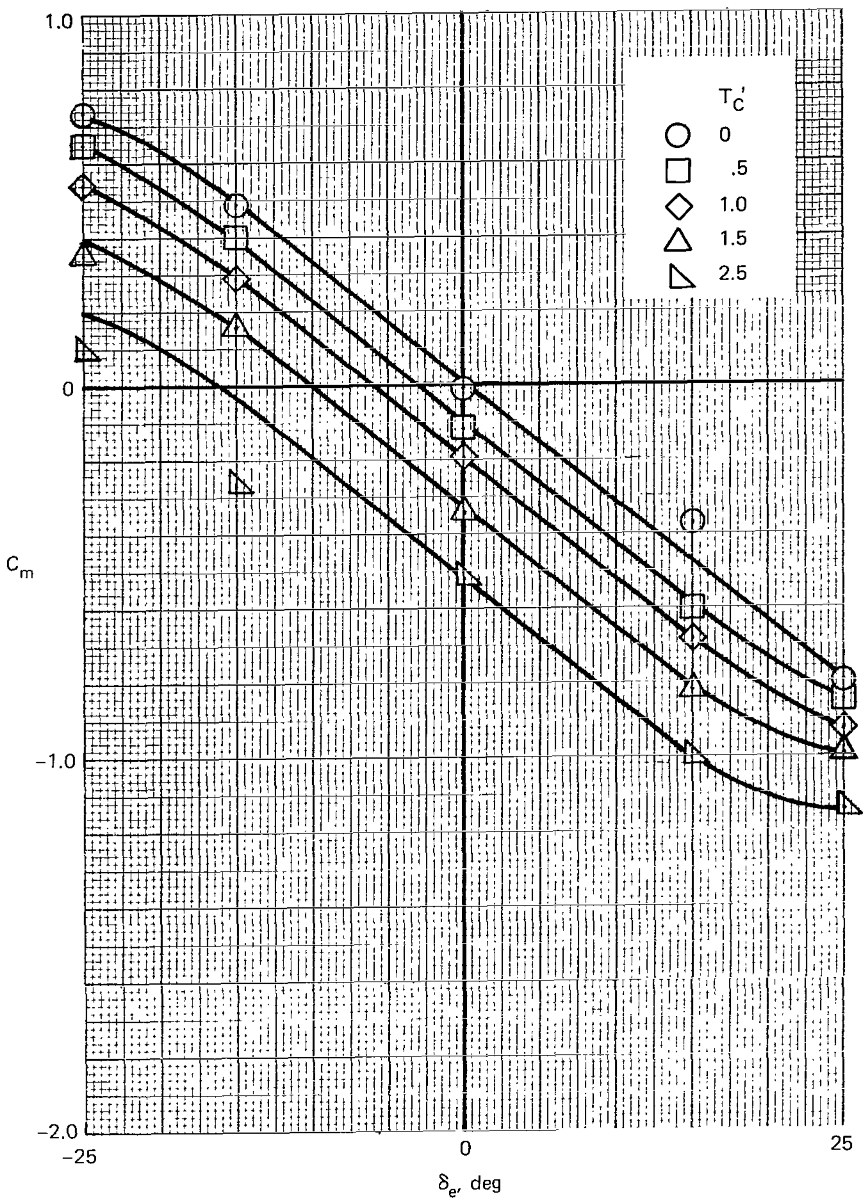


(a) C_m vs. i_t ; low tail.



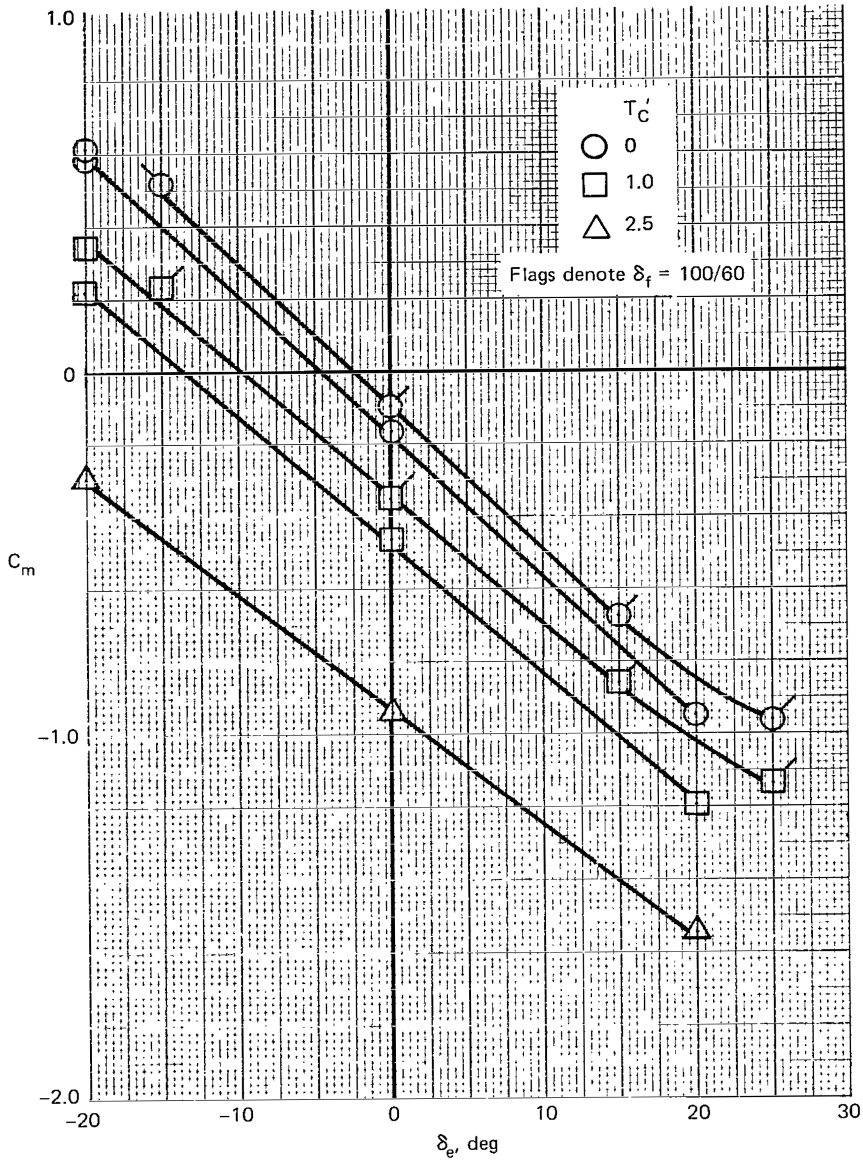
(b) C_m vs. i_t; low tail.

Figure 19.- Variation of pitching moment with tail incidence and elevator deflection; $\alpha_u = 0°$, $\delta_f = 80°$.



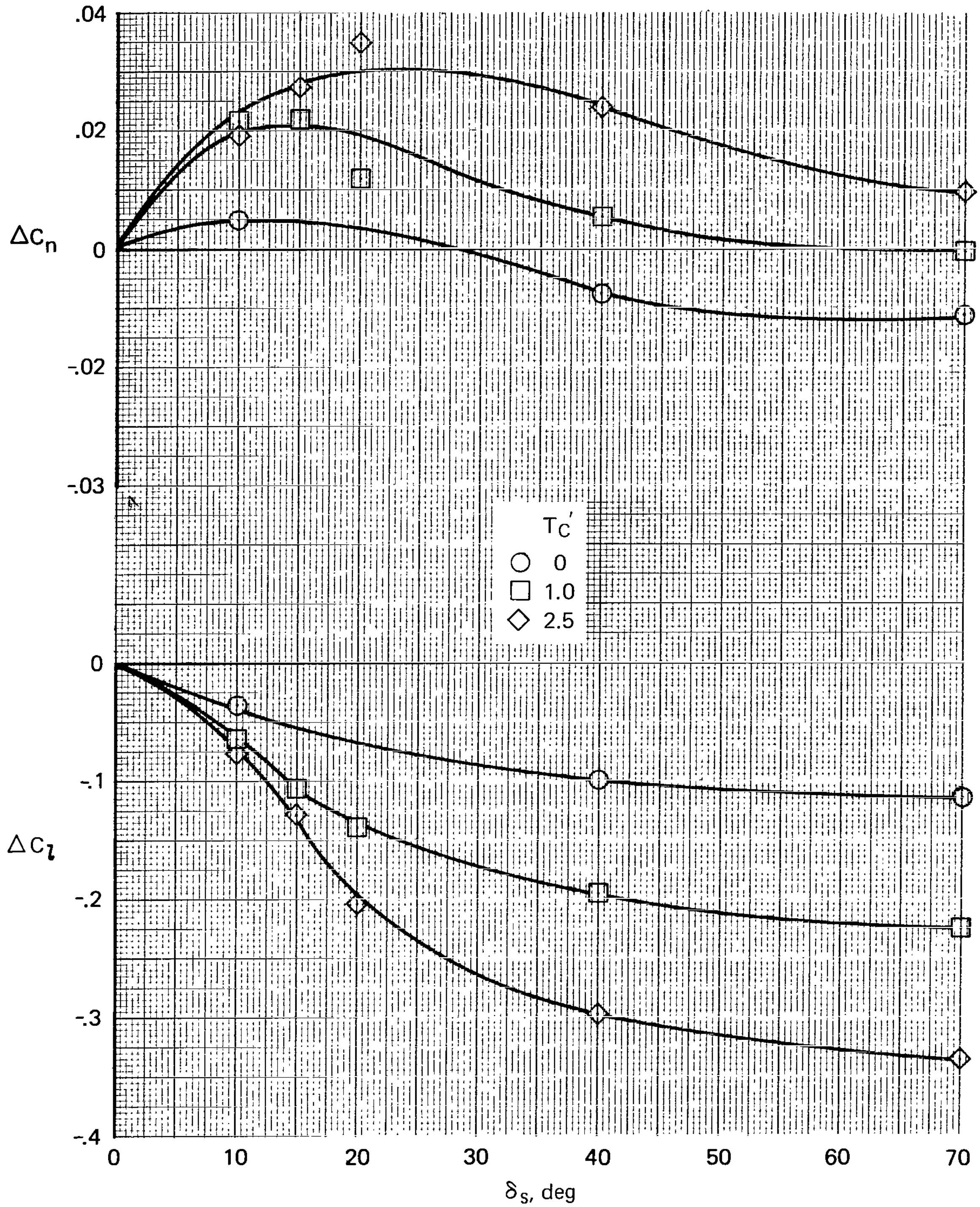
(c) C_m vs. δe; $i_t = 0°$, low tail.

Figure 19.- Continued.



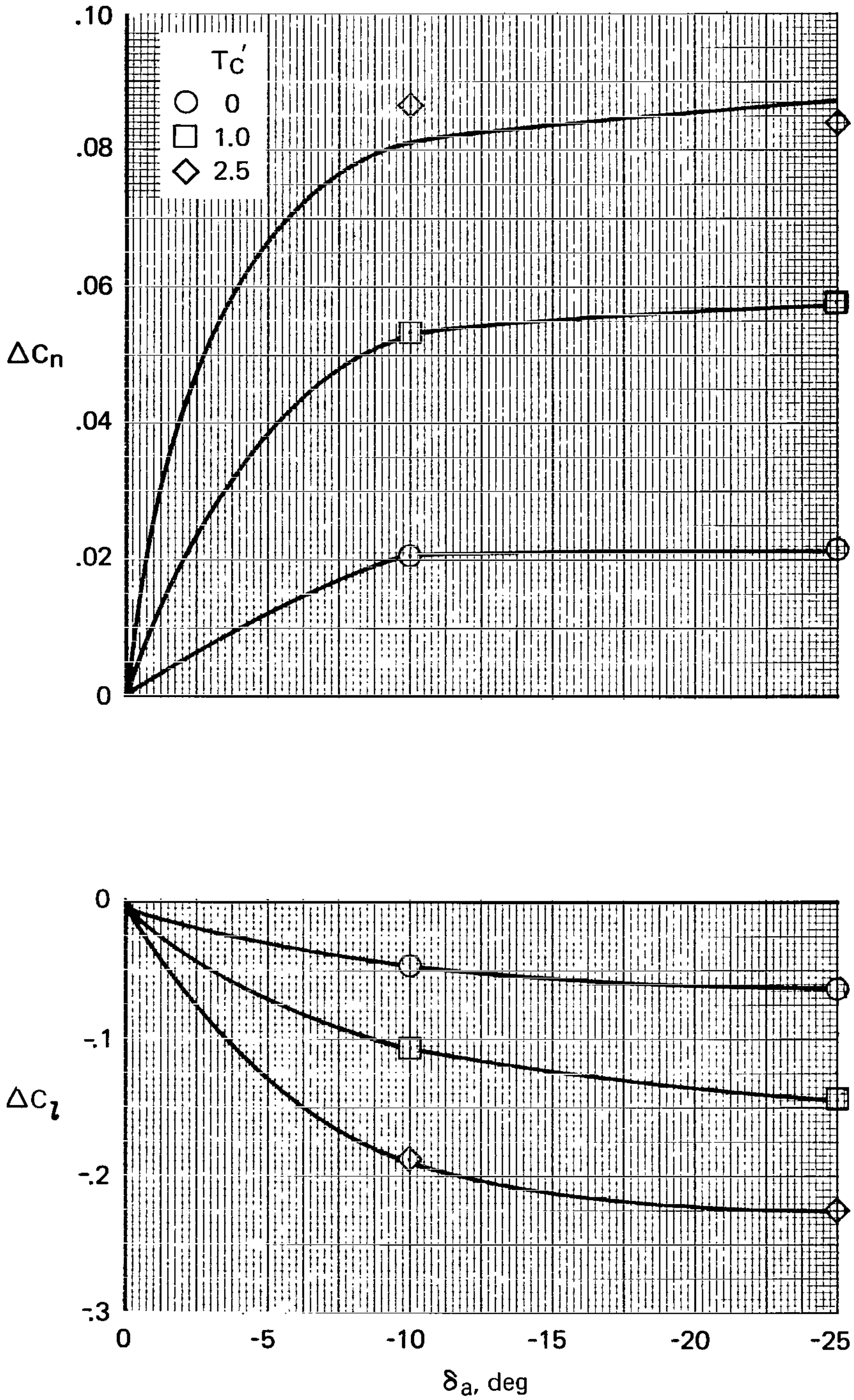
(d) C_m vs. δe; $i_t = 0°$, high tail.

Figure 19.- Concluded.



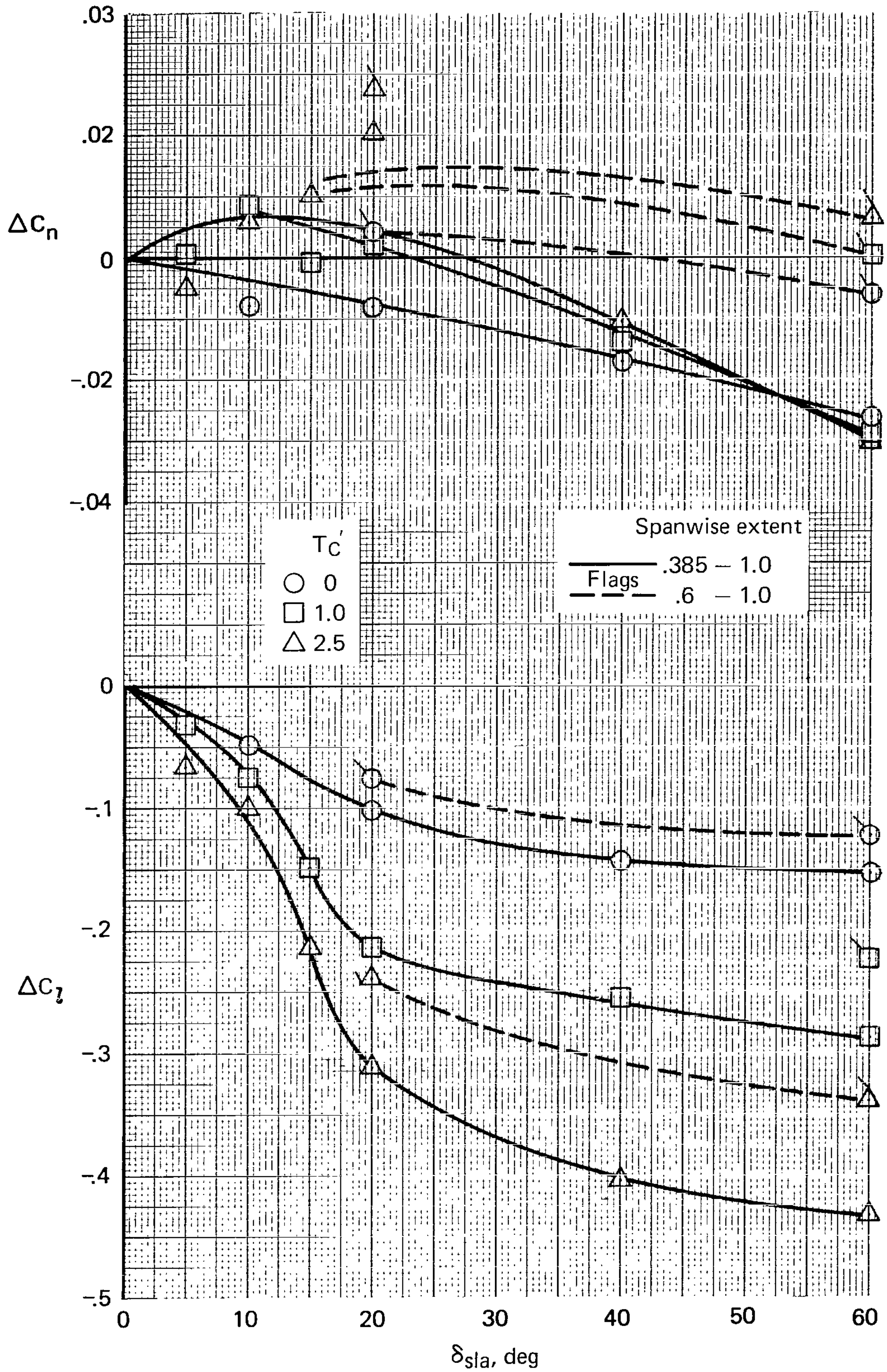
(a) 0.1c spoiler on left wing.

Figure 20.- Incremental yawing-moment and rolling-moment variation with deflection angles of three lateral control devices; $\delta_f = 80°$, $\alpha_u = 0°$.



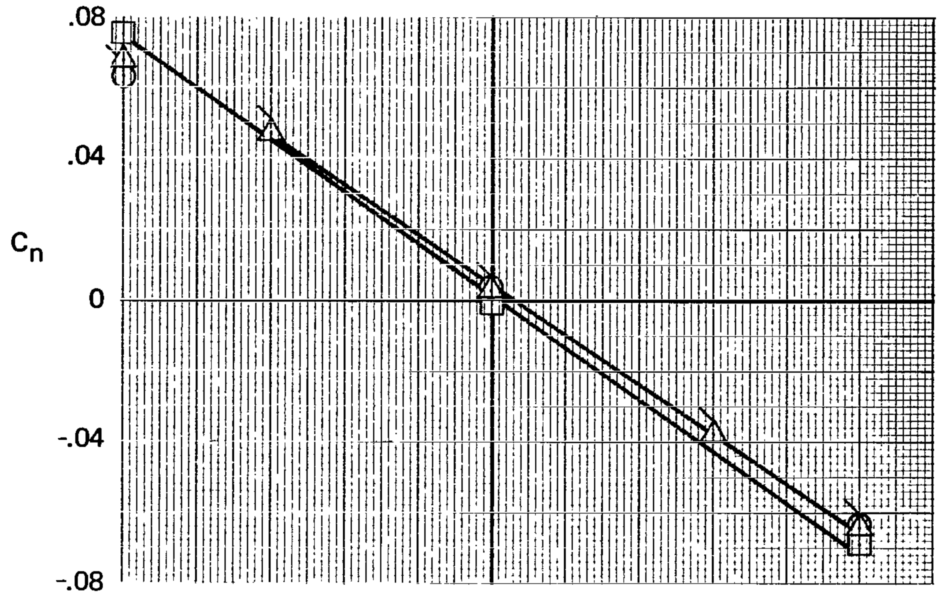
(b) Aileron (left side only).

Figure 20.- Continued.

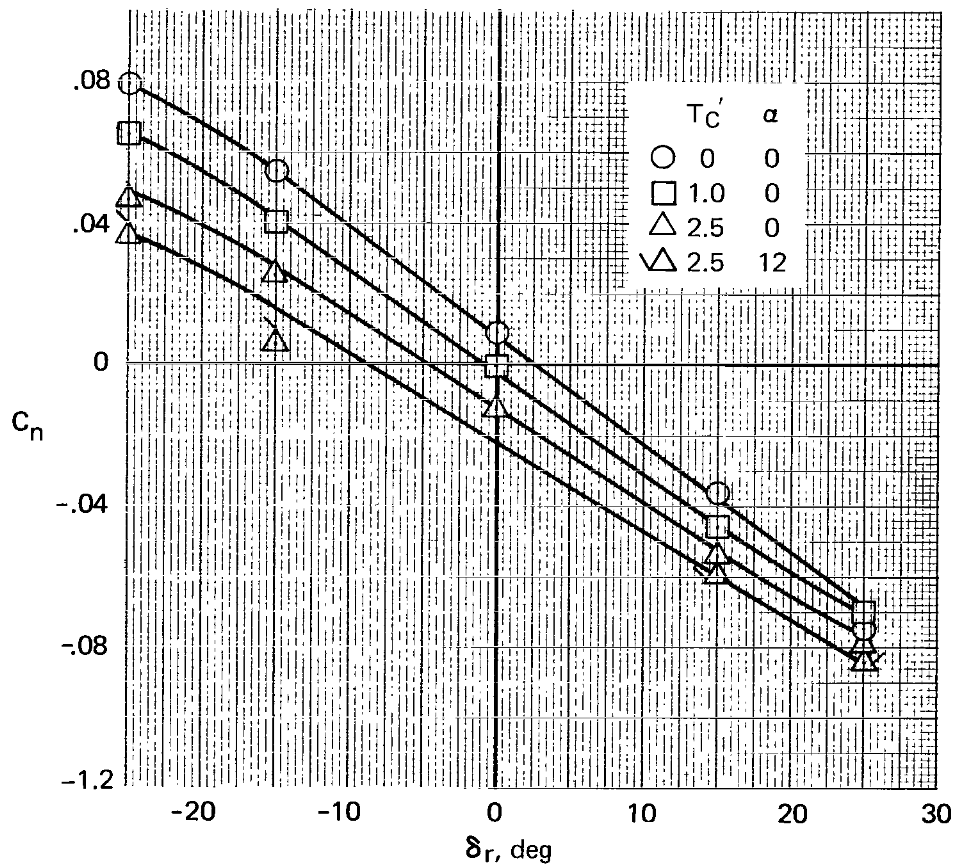


(c) 0.1c slot-lip aileron.

Figure 20.- Concluded.

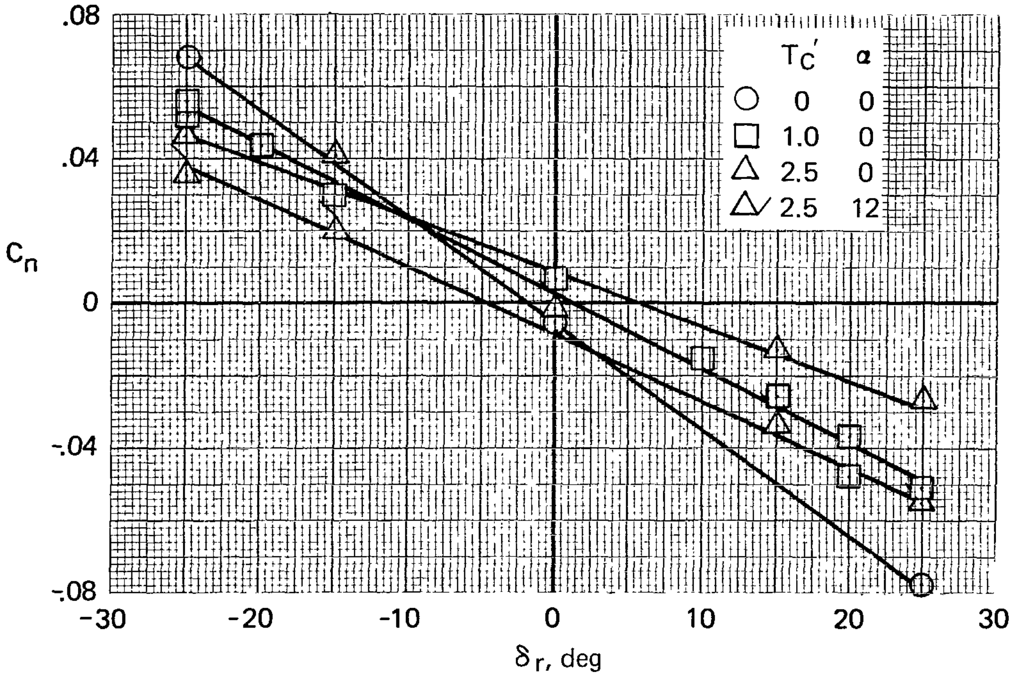


(a) $\delta_f = 40°$, high tail.



(b) $\delta_f = 80°$, high tail.

Figure 21.- Variation of yawing moment with rudder deflection.



(c) $\delta_f = 100/60°$, low tail.

Figure 21.- Concluded.

NASA-Langley, 1971 —— 2 A–3342

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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