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TECHNICAL MEMORANDUM

X-624

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EFFECTS OF BOOSTER TRANSITION SECTION AND RUDDER DEFLECTION ON THE LOW-ANGLE-OF-ATTACK STATIC STABILITY OF A WINGED REENTRY VEHICLE AT MACH NUMBERS OF 10.8 AND 17.8 IN HELIUM

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON [redacted] January 1962

NASA TM X-624

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-624

EFFECTS OF BOOSTER TRANSITION SECTION AND RUDDER DEFLECTION ON THE LOW-ANGLE-OF-ATTACK STATIC STABILITY OF A WINGED REENTRY VEHICLE AT MACH NUMBERS OF 10.8 AND 17.8 IN HELIUM*

By Charles L. Ladson

SUMMARY

An investigation has been carried out to obtain aerodynamic stability and control data on a model of a winged reentry vehicle at Mach numbers of 10.8 and 17.8 in helium. The effects of a booster transition section on the static stability were obtained at angles of attack from -5° to 15° and at angles of sideslip from -5° to 10° at an angle of attack of 0°. Directional control data were also obtained at an angle of attack of 0° for sideslip angles from -5° to 10°. No detailed analysis of the data has been made.

INTRODUCTION

For some time, an extensive investigation has been in progress at the Langley 11-inch hypersonic tunnel to determine the hypersonic aerodynamic characteristics of winged reentry vehicles. Numerous general and specific configurations have been tested, and the results of these investigations have been presented in references 1 to 15. This type of vehicle is intended to operate at an angle of attack α between that for maximum lift-drag ratio ($\alpha \approx 15^\circ$) and that for maximum lift coefficient ($\alpha \approx 60^\circ$). However, it is also desirable for the vehicle to be statically stable and controllable at very low angles of attack, inasmuch as this region may be entered during low-lift maneuvers or in an emergency condition.

The purpose of this investigation was to determine the effects of a booster transition section on the low-angle-of-attack static stability

*Title, Unclassified.

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characteristics and to determine the directional-control characteristics due to deflecting one rudder outward. Longitudinal data were obtained at angles of attack from -5° to 15°, whereas the directional and lateral data were obtained at angles of sideslip from -5° to 10° at an angle of attack of 0°. Data were obtained at Mach numbers of 10.8 and 17.8 with helium as the test medium.

Although helium was used as the test medium for this investigation, references 14 and 16 indicate that at these Mach numbers the trends of the data with angle of attack in air are duplicated by using helium. The magnitude of the coefficients may be different by several percent, however, since the ratios of specific heats for air and helium are not the same. (See ref. 17.)

SYMBOLS

All longitudinal data are presented for the stability-axis system, whereas the directional and lateral data are presented for the body-axis system.

b span, in.

$\bar{c}$ mean aerodynamic chord, in.

C_D drag coefficient, $\frac{\text{Drag}}{qS}$

C_l rolling-moment coefficient about body center line, $\frac{\text{Rolling moment}}{qSb}$

C_L lift coefficient, $\frac{\text{Lift}}{qS}$

C_m pitching-moment coefficient about moment center at $0.43\bar{c}$, $\frac{\text{Pitching moment}}{qS\bar{c}}$

C_n yawing-moment coefficient about moment center at $0.43\bar{c}$, $\frac{\text{Yawing moment}}{qSb}$

C_N normal-force coefficient, $\frac{\text{Normal force}}{qS}$

[redacted]

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

l body length, in.

L/D lift-drag ratio

M Mach number

q dynamic pressure, lb/sq in.

S reference area, sq in.

α angle of attack (referenced to wing lower surface), deg

β angle of sideslip, deg

δ_r deflection angle of left rudder, deg

MODELS AND DESIGNATIONS

A three-view drawing showing the dimensions of the model tested is presented in figure 1, and photographs of the model are shown in figure 2. The various component parts of the model are designated by letter symbols and numerical subscripts to conform with usage of the vehicle contractor and are identified as follows:

B_2 body

W_2 wing

E_3 elevons

C_1 elevon actuator fairings (see fig. 1)

V_1 vertical tails on

V_0 vertical tails off

S_1 long booster transition section (fig. 1)

S_2 short booster transition section (fig. 1)

[redacted]

[redacted]

The model was constructed of aluminum and had a flat wing lower surface with a nose incidence angle of 4° to provide stability at high angles of attack. (See ref. 1.) The basic model incorporated vertical tails at the wing tips to provide directional stability. The configurations tested included models with the vertical tails removed (model $W_2B_2E_3V_0C_1$) and with two booster transition sections added (models $W_2B_2E_3V_1C_1S_1$ and $W_2B_2E_3V_1C_1S_2$). The transition-section dimensions are indicated in figure 1.

All coefficients presented are based on total projected planform area, span, and mean aerodynamic chord of the basic model $W_2B_2E_3V_1C_1$. The moment center is located at $0.43\bar{c}$ ($0.677l$ behind nose) and $0.1055b$ above the wing lower surface. (See fig. 1.) The reference areas and lengths are as follows:

$$S = 12.64 \text{ square inches}$$

$$b = 3.79 \text{ inches}$$

$$\bar{c} = 4.04 \text{ inches}$$

$$l = 5.539 \text{ inches}$$

APPARATUS, TESTS, AND PROCEDURES

The data presented were obtained in the Langley 11-inch hypersonic tunnel with an internal 6-component strain-gage balance at Mach numbers of 10.8 and 17.8 in helium. At a Mach number of 10.8 the stagnation pressure was 300 pounds per square inch, the stagnation temperature was about 500° R, and the corresponding Reynolds number was 0.33×10^6 per inch. At a Mach number of 17.8, the stagnation pressure was 1,000 pounds per square inch, the stagnation temperature was 500° R, and the Reynolds number was 0.45×10^6 per inch. A description and calibration of the nozzles used to provide these Mach numbers is contained in appendix A of reference 4 and in reference 18. No corrections have been made to the Mach numbers for real-gas effects. Reference 19 indicates that these real-gas effects would increase the Mach number by 0.17 for the $M = 17.8$ nozzle but would be negligible for the $M = 10.8$ nozzle.

The angles of attack and sideslip of the model were measured optically by use of a light beam reflected from a prism in the model onto a calibrated scale. This method gives the true angle of the model including the deflection of both the balance and sting under load. Longitudinal data were obtained at angles of attack from -5° to 15°, whereas the directional and lateral data were obtained at sideslip angles from -5° to 10° at an angle of attack of 0°.

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RESULTS AND DISCUSSION

Typical schlieren photographs of the flow past the models are presented in figure 3. Longitudinal-performance data are shown in figures 4 to 6, and the stability data are presented in figure 7. Directional and lateral characteristics of all configurations at both Mach numbers 10.8 and 17.8 are presented in figures 8 to 10 for an angle of attack of 0°. Although no detailed analysis of the data is made, some of the more important results are mentioned in the following discussion.

From figures 4 and 7(a) it can be seen that adding the vertical tails to the model produced a negative incremental lift, a positive drag, a positive or nose-up increment in pitching moment, and an increase in longitudinal stability. In references 8 and 14 these same trends were noted on similar models tested at a Mach number of 9.6 in air.

As may be noted from figure 5, adding the booster transition sections S_1 and S_2 also created a negative increment in lift coefficient at angles of attack below about 5°. Although a positive incremental lift would be expected from the geometry of the configuration, flow separation probably occurred ahead of the flare and resulted in the negative incremental lift. Figure 7(b) indicates that adding the booster transition section resulted in the rotation of the pitching-moment curves about $C_N \approx 0$ and increased the longitudinal stability of the vehicle. Increasing the Mach number from 10.8 to 17.8, as shown in figures 6 and 7(c), had little effect on the longitudinal characteristics except for a reduction in the lift-curve slope.

Figures 8 and 9 show that at $\alpha = 0^{\circ}$ the configurations with vertical tails and booster transition section had nonlinear rolling-moment and yawing-moment variations with sideslip angle. These nonlinear characteristics are probably a result of interaction between the nose flow field and the vertical tails and are similar to those observed in reference 14. Adding the booster transition section to the basic body had little effect on the lateral stability parameter $\partial C_l/\partial\beta$ but increased the directional stability parameter $\partial C_n/\partial\beta$.

Yaw-control characteristics due to deflecting the left rudder are presented in figure 10. Yaw-control effectiveness drops off rapidly as sideslip angle is increased from 0° to 10°. Deflecting the rudder had little effect on the lateral stability but increased the directional stability.

Figures 8, 9, and 10 indicate that increasing the Mach number from 10.8 to 17.8 had little effect on the trends of directional and lateral stability.

[redacted]

CONCLUSIONS

Data have been presented to show the effects of booster transition sections and of deflections of the left rudder on the low-angle-of-attack static stability of a winged reentry vehicle at Mach numbers of 10.8 and 17.8. The results indicate that:

1. Adding the booster transition sections increased the longitudinal and directional stability of the model but had little effect on the lateral stability.

2. Deflecting the left rudder increased the directional stability but affected the lateral stability only slightly. Yaw-control effectiveness decreased rapidly as sideslip angle increased from 0° to 10°.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Air Force Base, Va., October 20, 1961.

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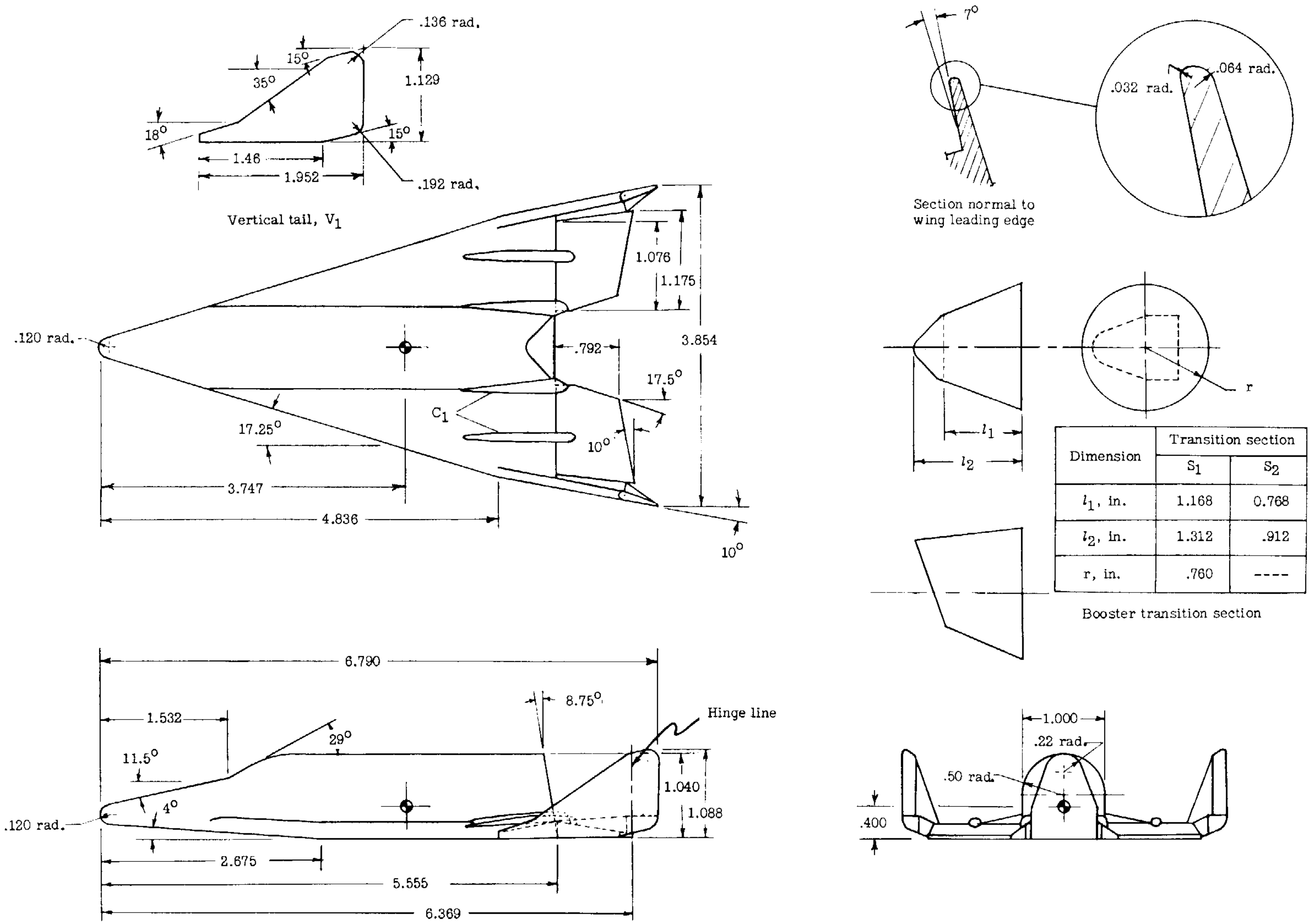

Dimension	Transition section	
	S_1	S_2
l_1, in.	1.168	0.768
l_2, in.	1.312	.912
r, in.	.760	----

Booster transition section

Figure 1.- Model drawings and dimensions. All linear dimensions in inches.

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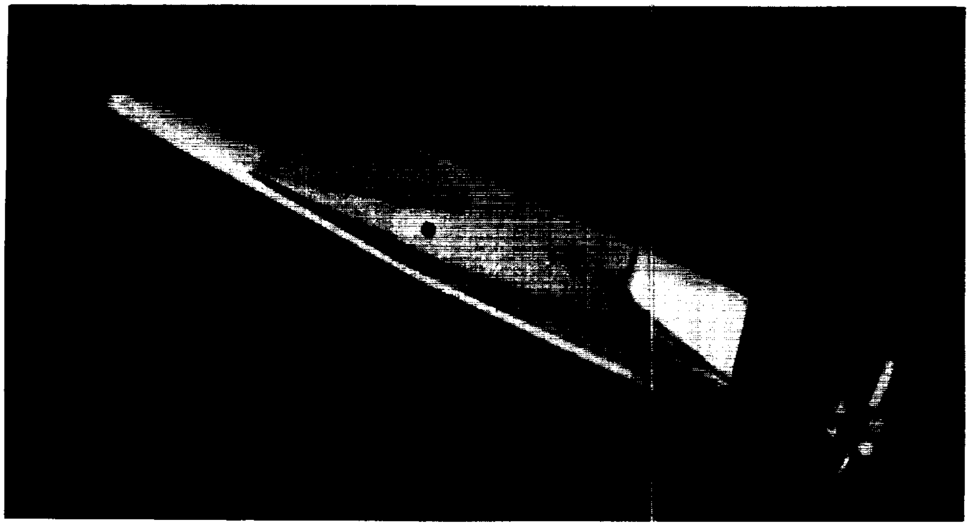

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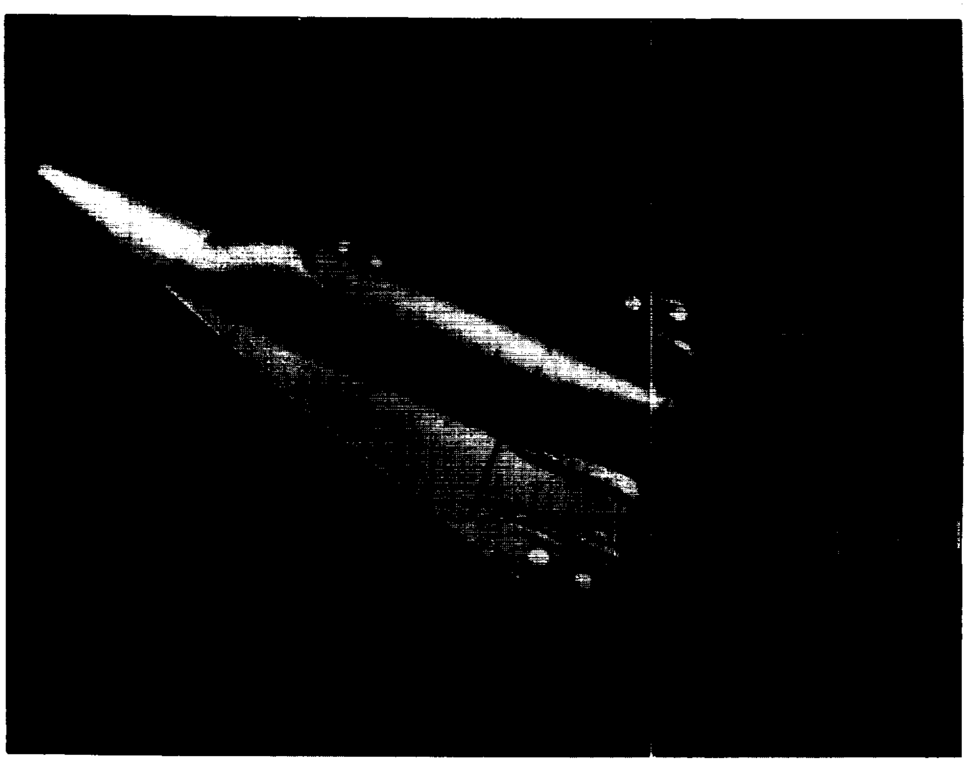
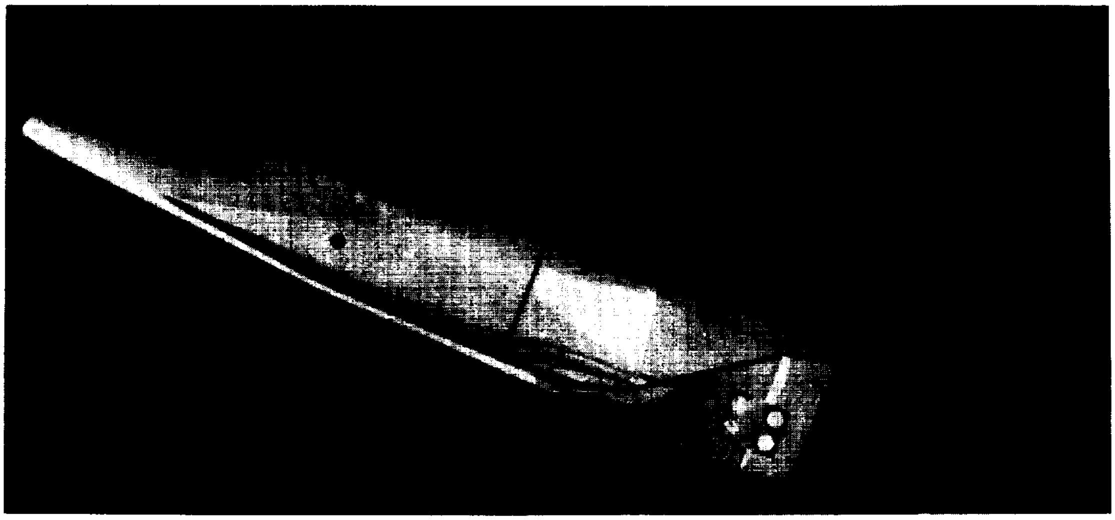


(a) Basic model $\left(W_2B_2E_3V_1C_1\right)$. L-61-1331

Figure 2.- Model photographs.

[redacted]



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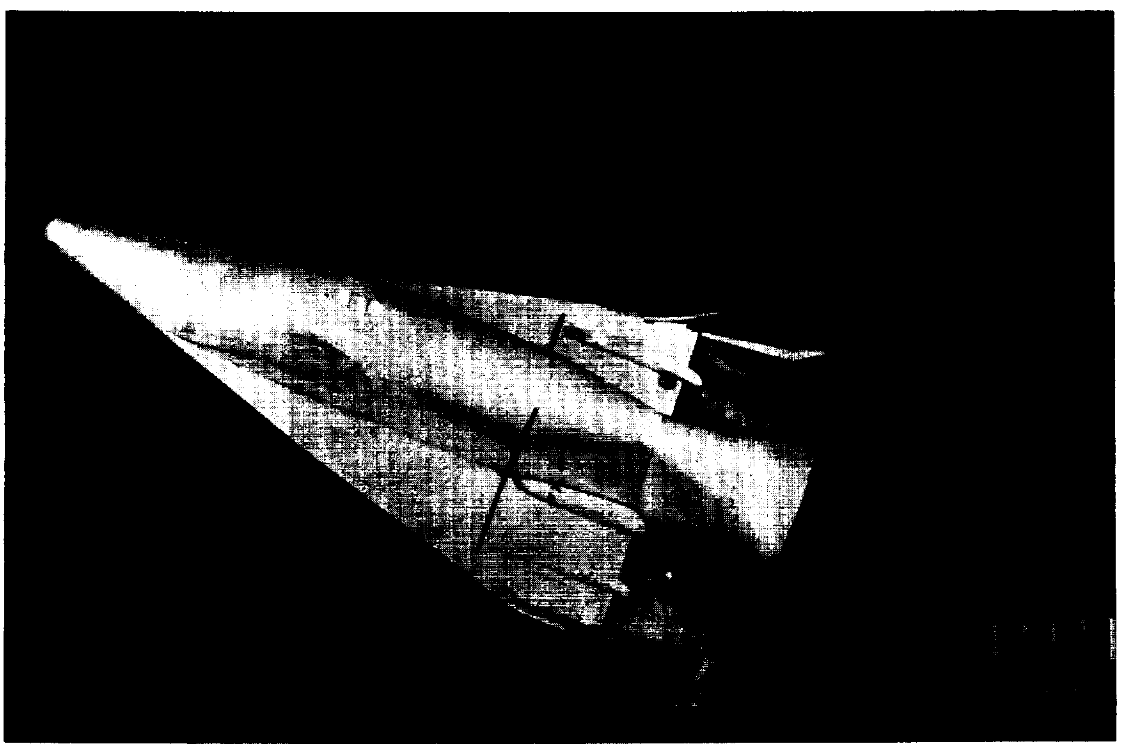

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(b) Model with long booster transition section $\left(W_2B_2E_3V_1C_1S_1\right)$.

Figure 2.- Concluded.

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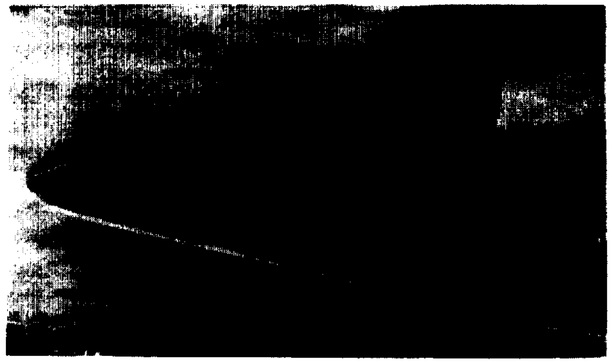
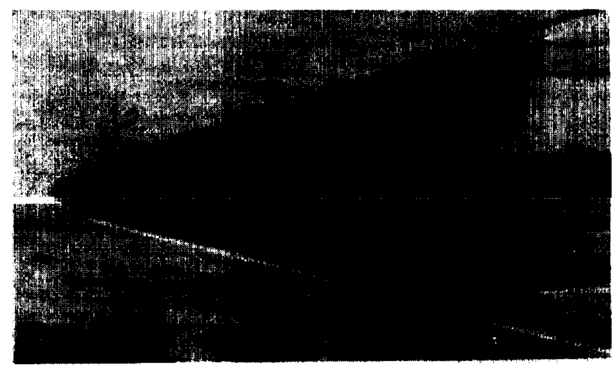


Model without vertical tail $\left(W_2B_2E_3V_0C_1\right)$
$M = 10.8$

Basic model $\left(W_2B_2E_3V_1C_1\right)$
$M = 10.8$

Model without vertical tail $\left(W_2B_2E_3V_0C_1\right)$
$M = 17.8$



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Basic model $\left(W_2B_2E_3V_1C_1\right)$
$M = 17.8$

(a) Planform view. $\alpha = 0^{\circ}$; $\beta = 0^{\circ}$.

Figure 3.- Schlieren flow photographs of model.

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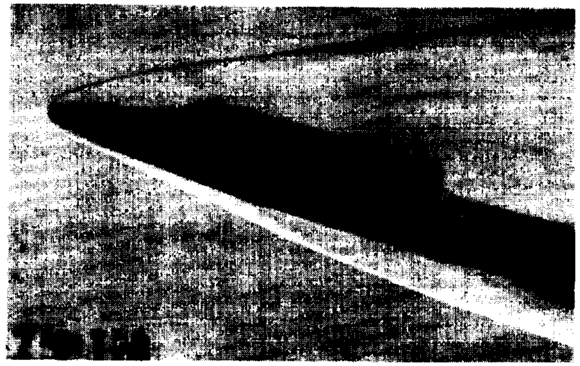
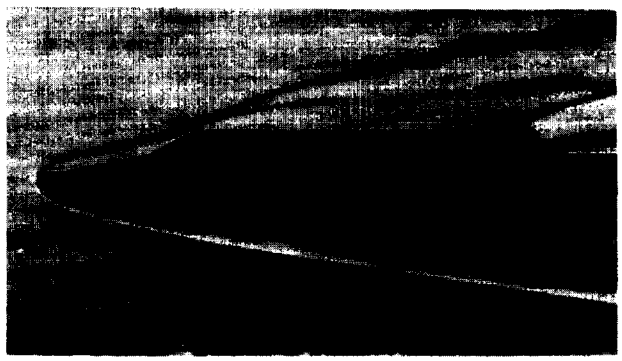


Model without vertical tail $\left(W_2B_2E_3V_0C_1\right)$
$\alpha = 15^\circ$

Basic model $\left(W_2B_2E_3V_1C_1\right)$
$\alpha = 10^\circ$



Model with short booster transition section
$\left(W_2B_2E_3V_1C_1S_2\right)$
$\alpha = 0^\circ$

Model with long booster transition section
$\left(W_2B_2E_3V_1C_1S_1\right)$
$\alpha = 5^\circ$

L-61-5122

(b) Side view. $\beta = 0^\circ$; $M = 17.8$.

Figure 3.- Concluded.

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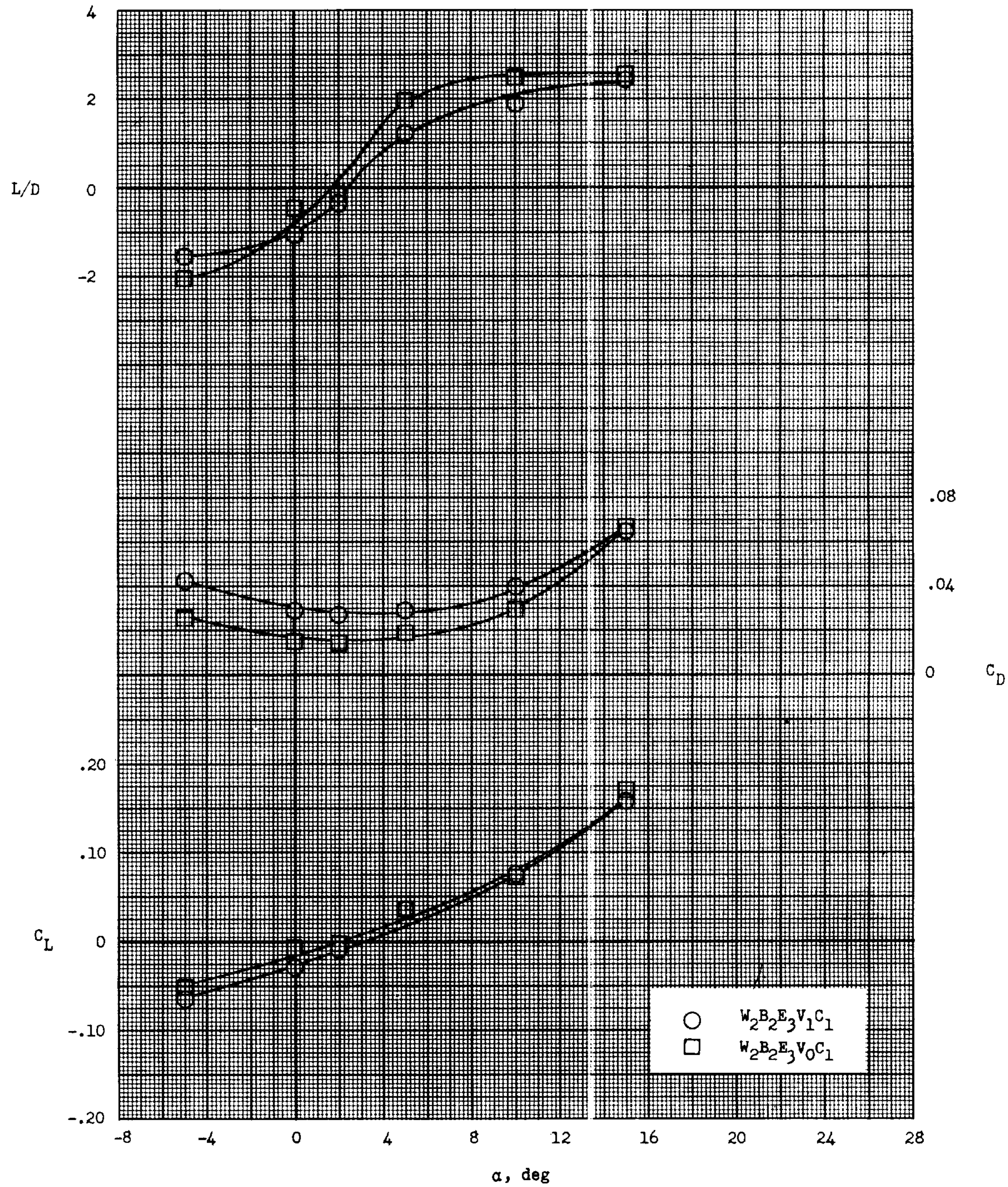

Figure 4.- Effects of vertical tail on longitudinal-performance characteristics at $M = 17.8$ and $\beta = 0^\circ$.

[redacted]

[redacted]

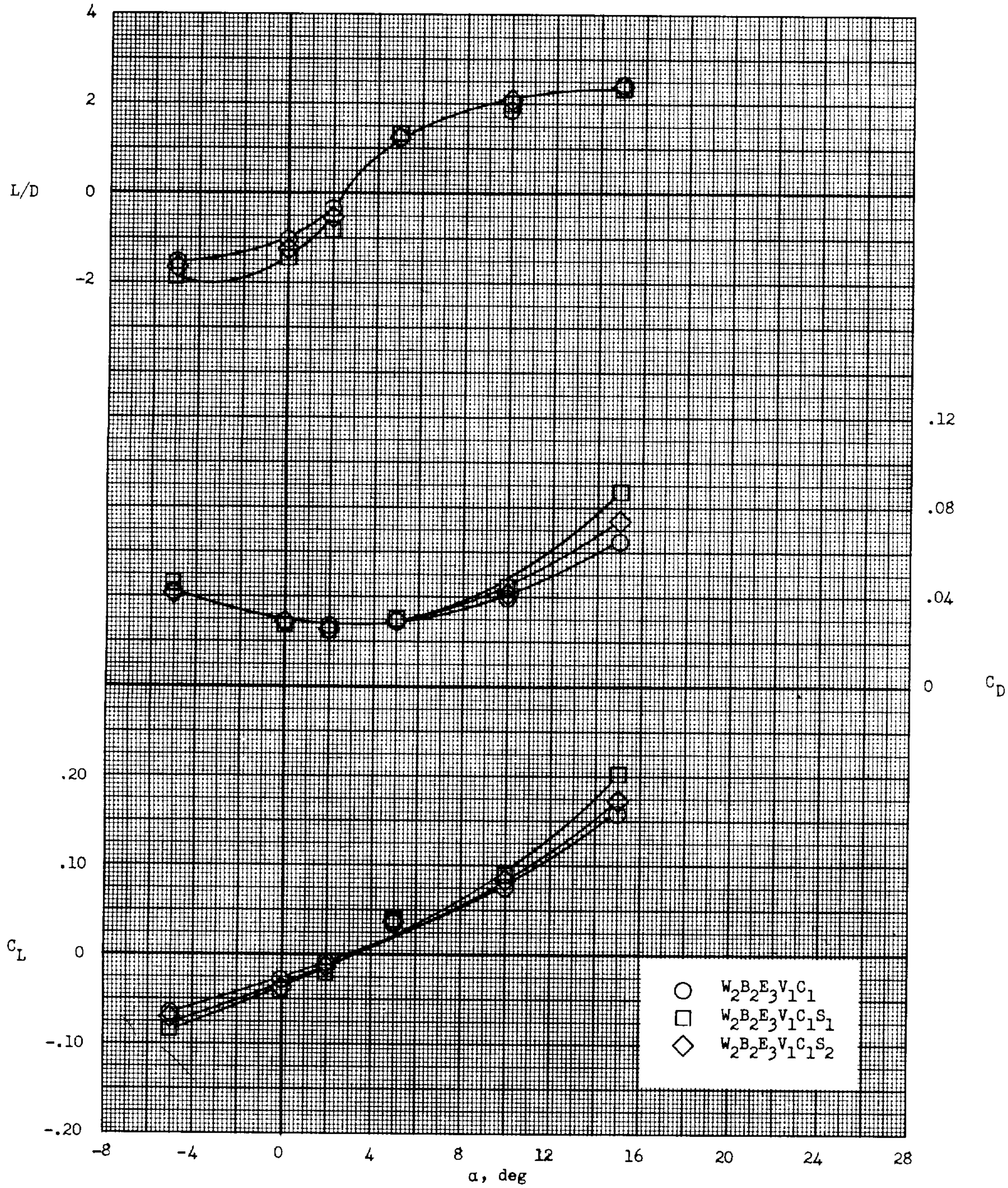

Figure 5.- Effects of booster transition section on longitudinal-performance characteristics at $M = 17.8$ and $\beta = 0^\circ$.

[redacted]

[redacted]

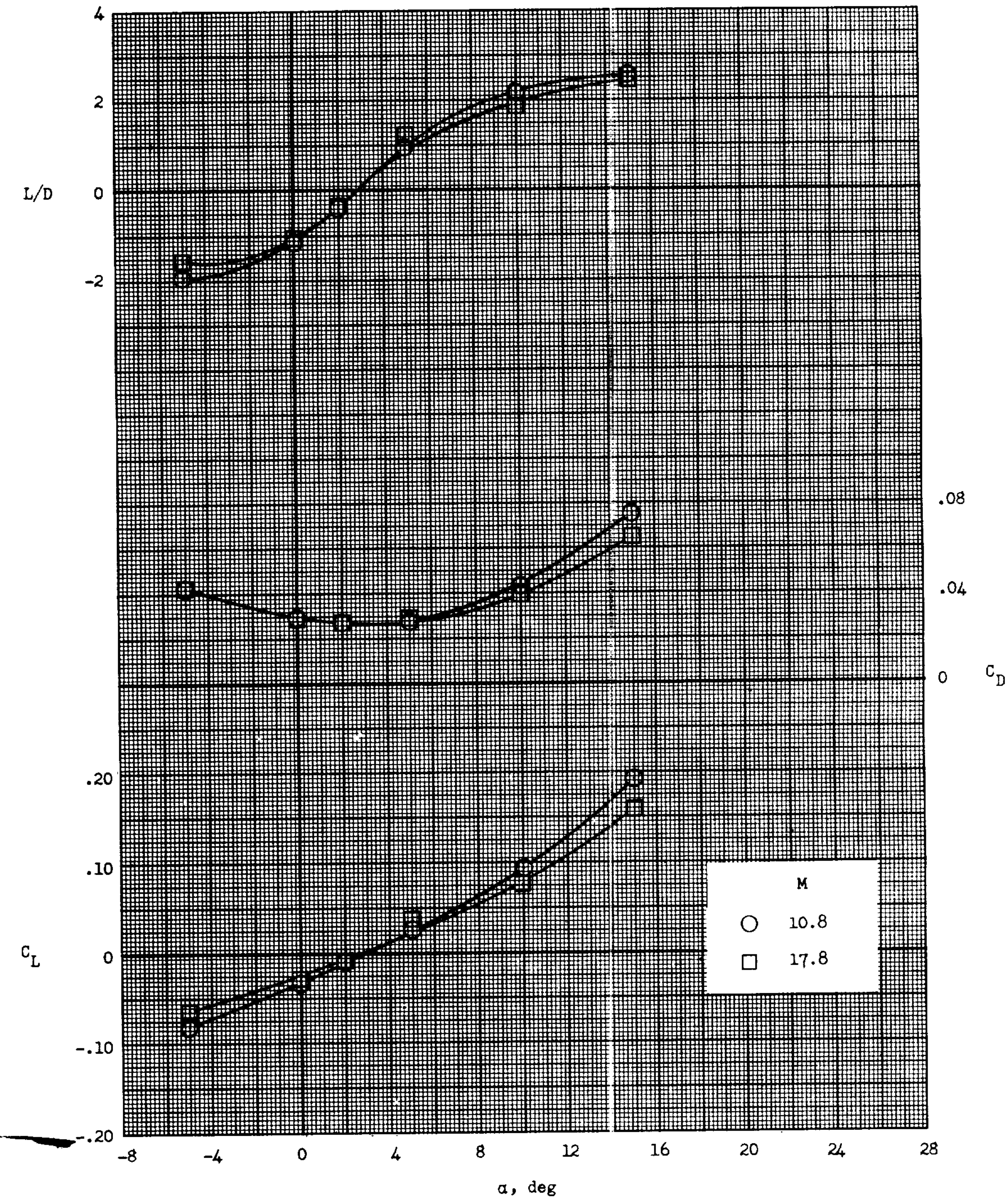

Figure 6.- Effects of Mach number on longitudinal-performance characteristics of basic configuration at $\beta = 0^{\circ}$.

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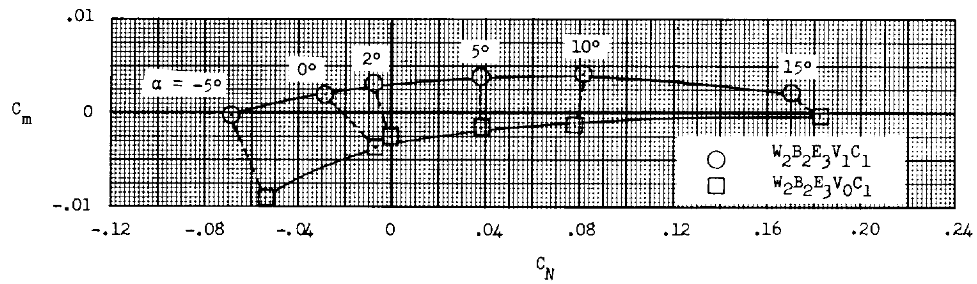
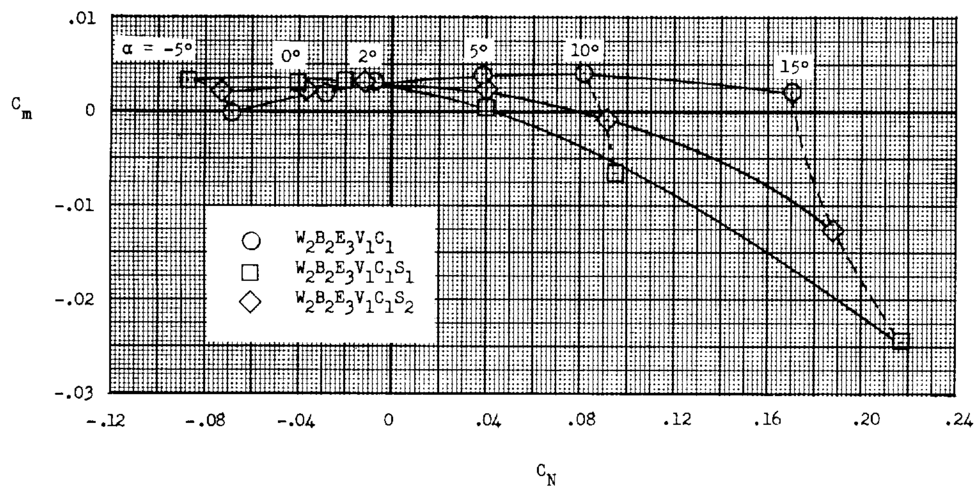
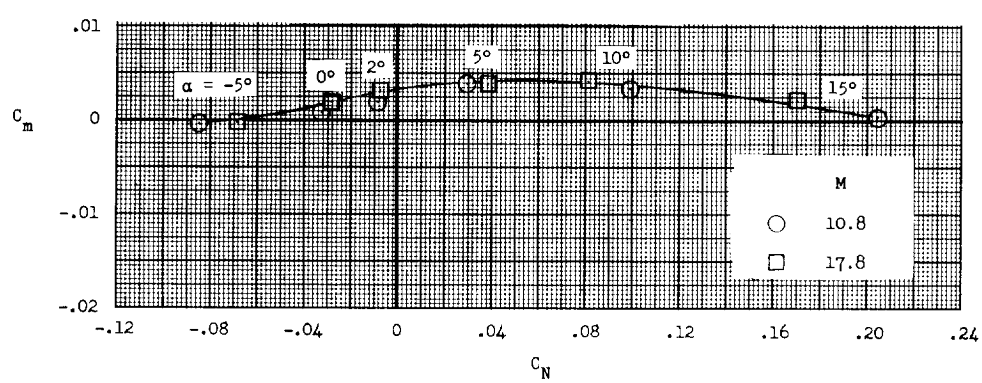
[redacted]



(a) Effects of vertical tail.



(b) Effects of booster transition section.



(c) Effects of Mach number on $W_2B_2E_3V_1C_1$.

Figure 7.- Longitudinal-stability characteristics at $\beta = 0^{\circ}$.

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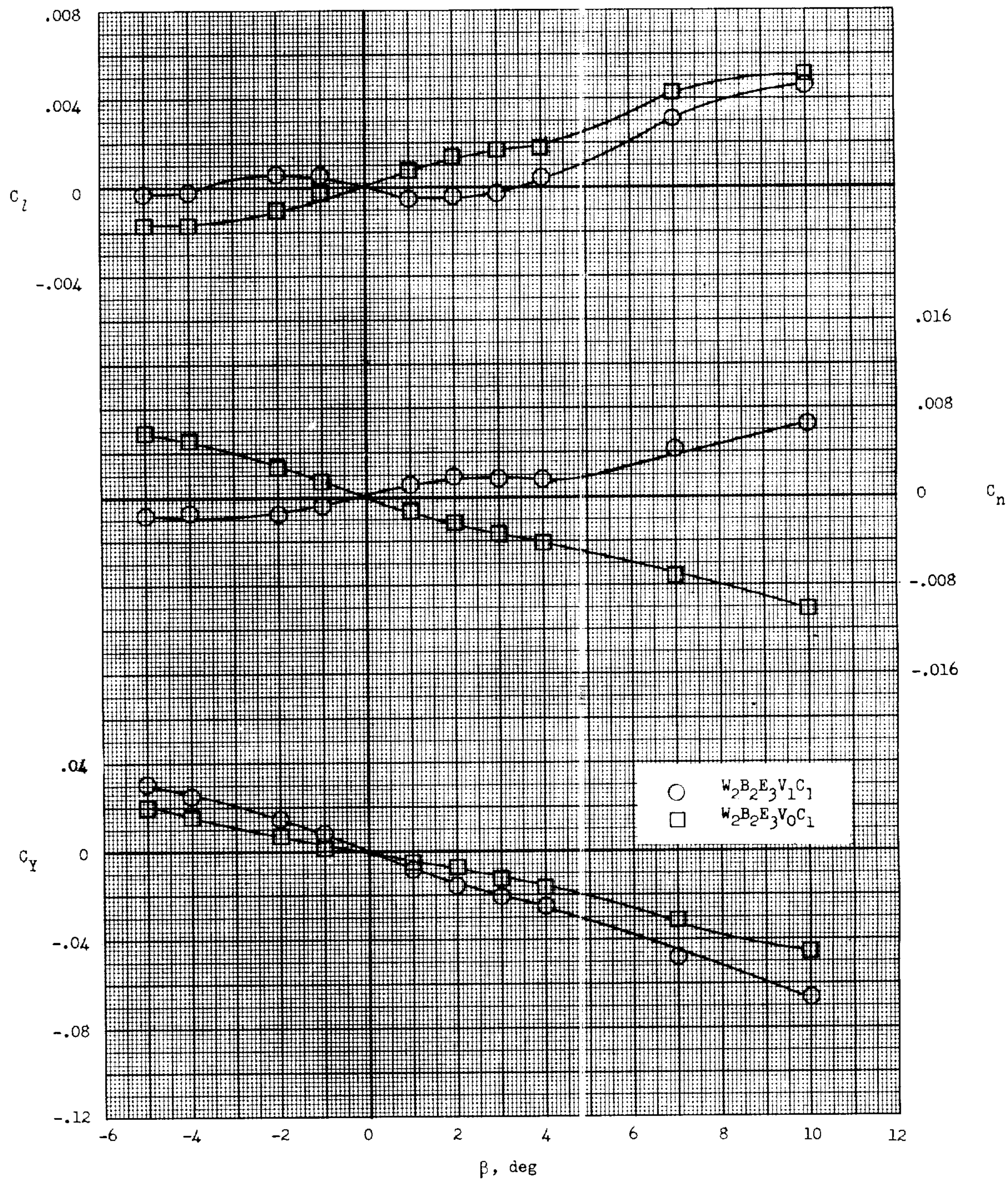
[redacted]

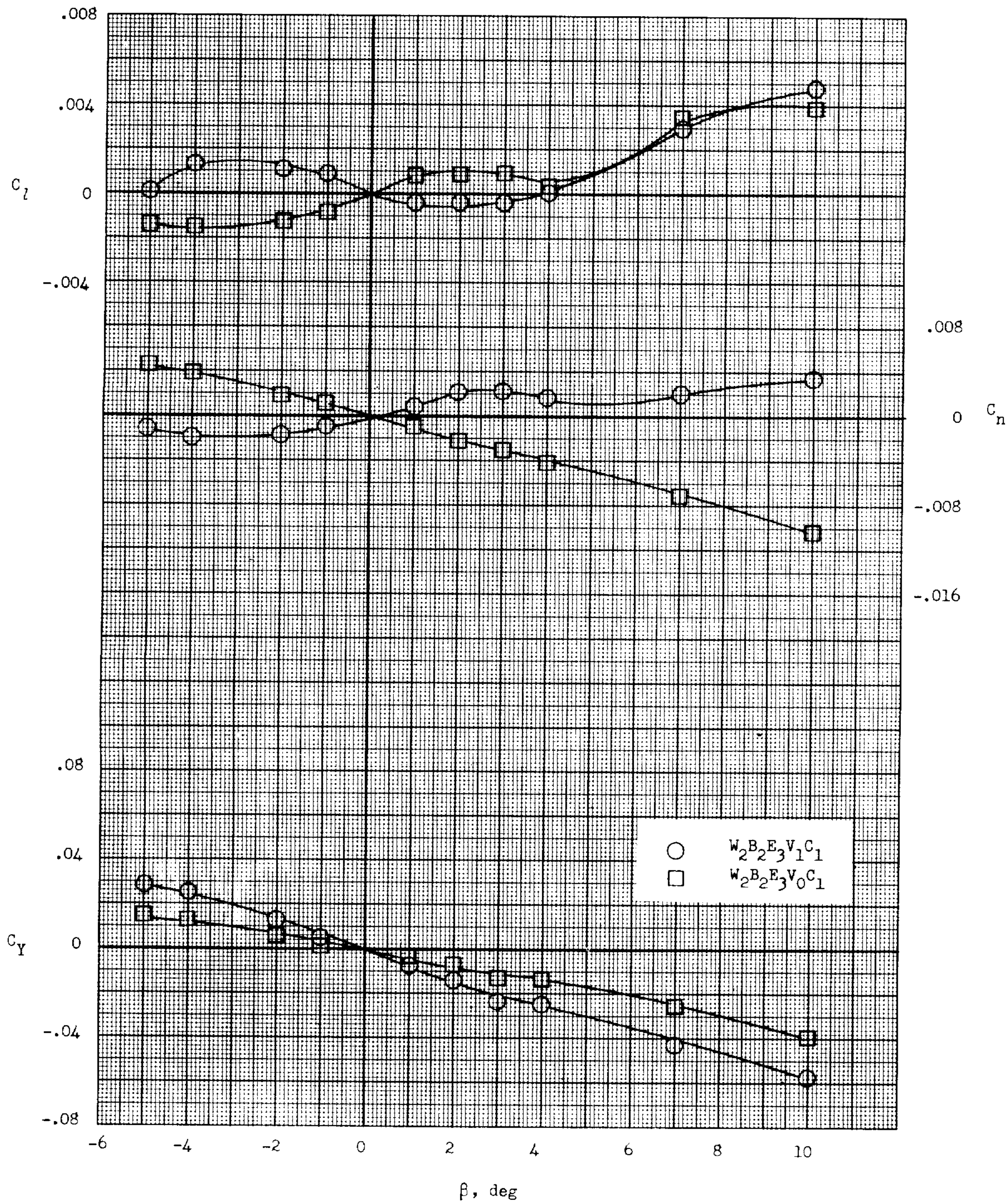


(a) M = 10.8

Figure 8.- Effects of vertical tails on directional and lateral characteristics at $\alpha = 0^{\circ}$.

[redacted]

[redacted]



(b) M = 17.8.

Figure 8.- Concluded.

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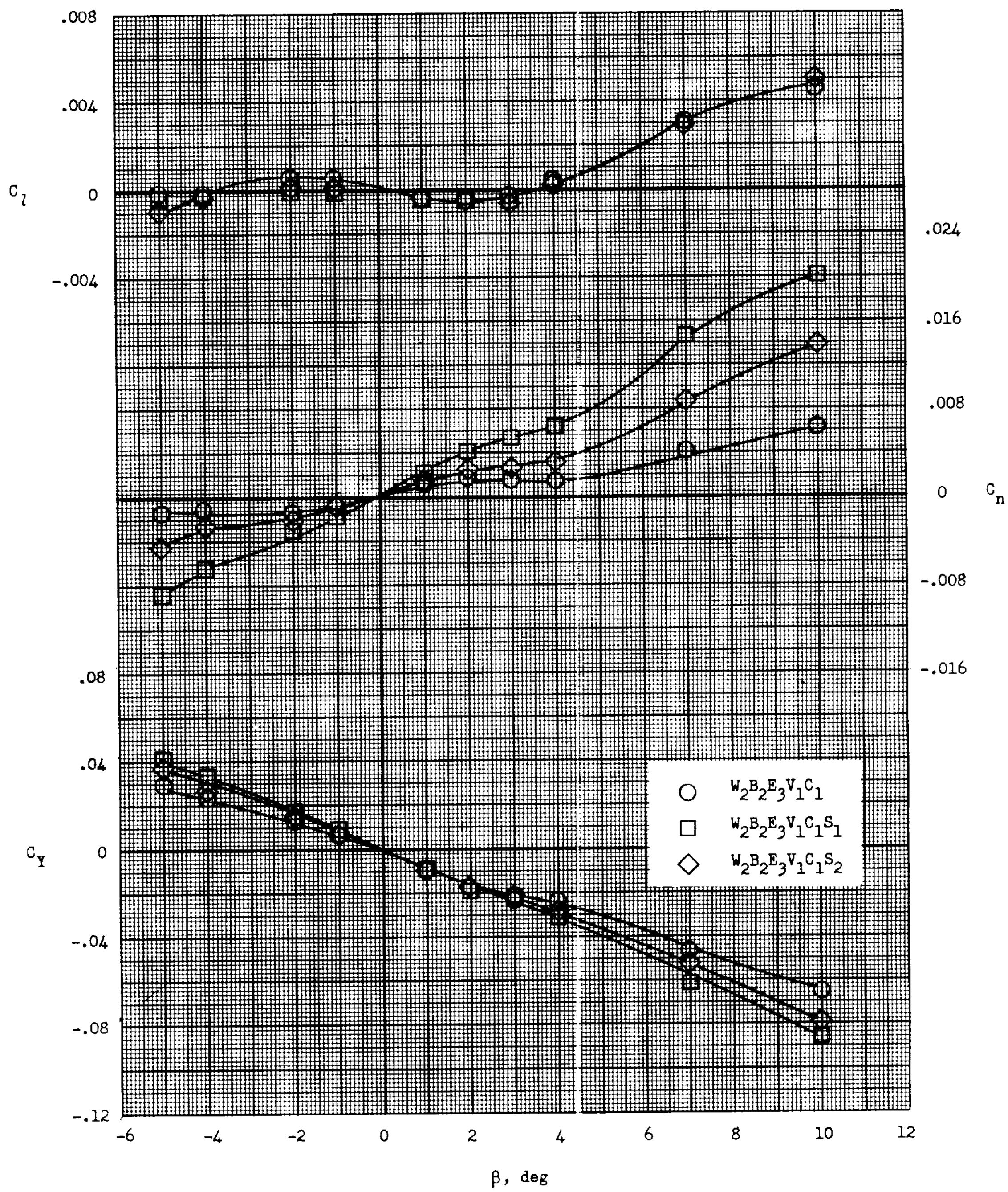

(a) M = 10.3.

Figure 9.- Effects of booster transition section on directional and lateral characteristics at $\alpha = 0^{\circ}$.

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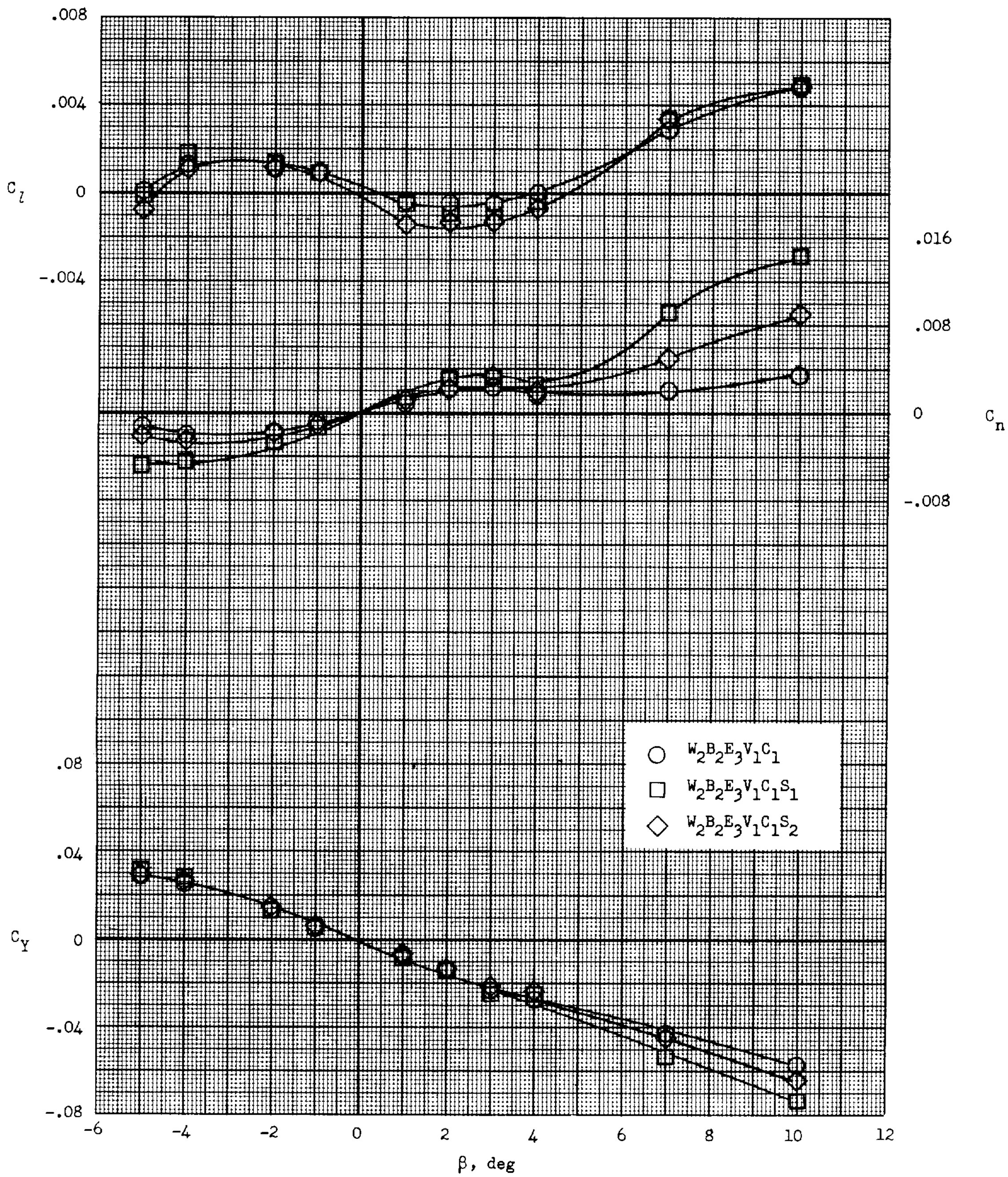

(b) M = 17.8.

Figure 9.- Concluded.

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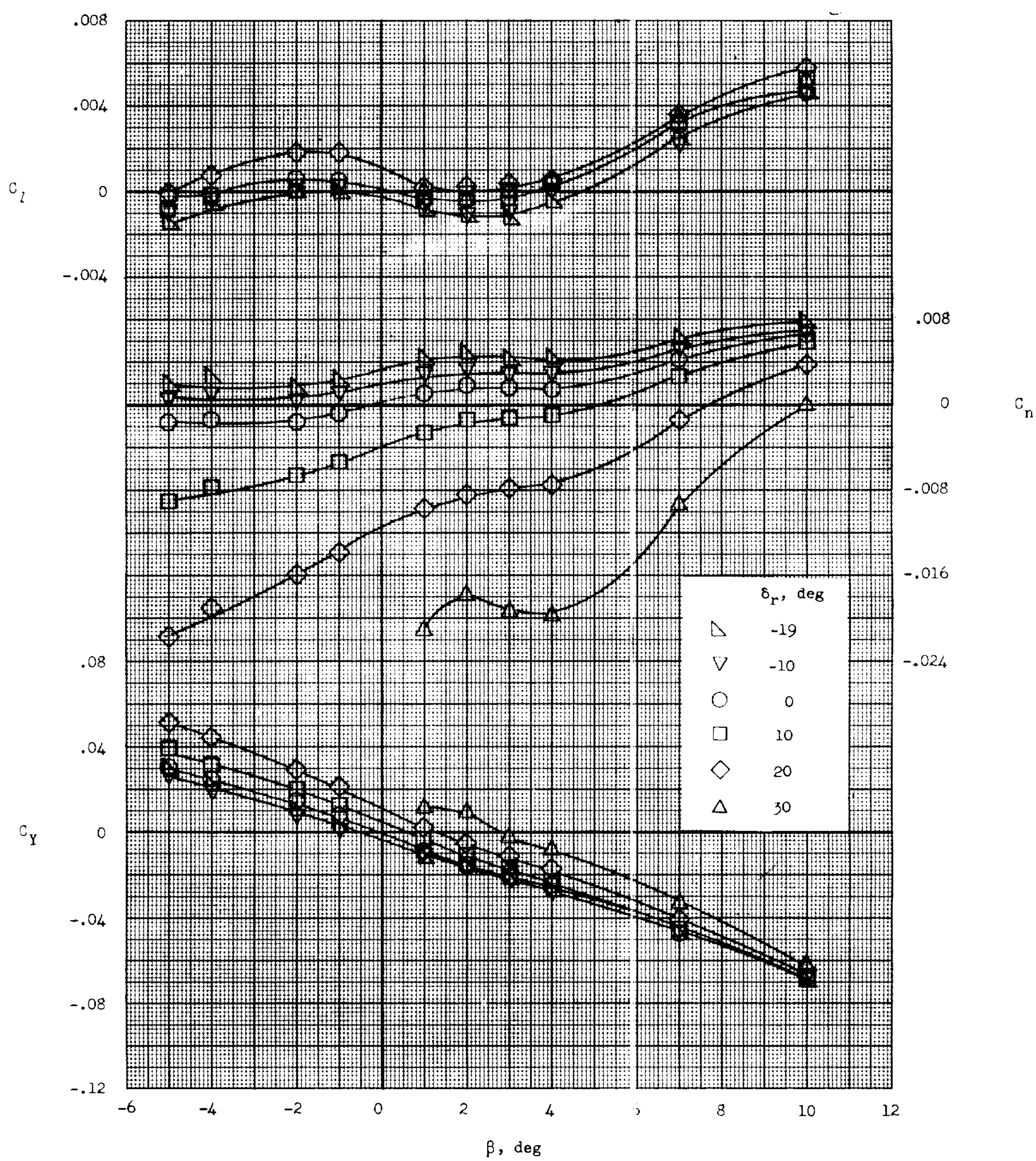

(a) M = 10.8.

Figure 10.- Effects of left rudder deflection on directional and lateral characteristics of the basic model configuration at $\alpha = 0^{\circ}$.

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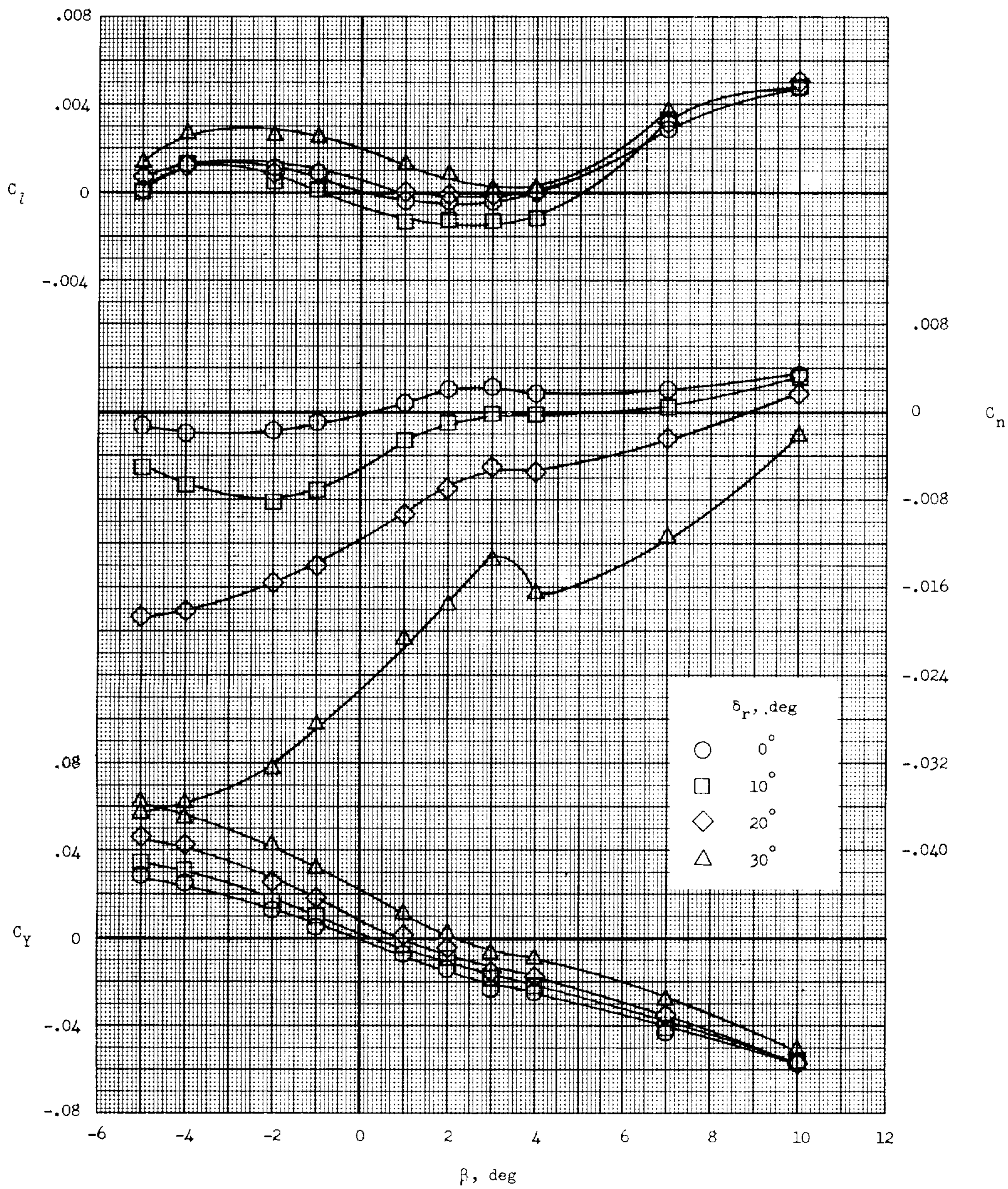

(b) M = 17.8.

Figure 10.- Concluded.

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(NASA TECHNICAL MEMORANDUM X-624) [redacted]

(Title, Unclassified)

The tests were conducted in the Langley 11-inch hypersonic tunnel at Mach numbers of 10.8 and 17.8 with helium as the test medium. Longitudinal stability and performance characteristics are presented at angles of attack from -5° to 15°. Directional-control characteristics are presented only for an angle of attack of 0° for sideslip angles from -5° to 10°. No detailed analysis of the data is presented.

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(Initial NASA distribution:
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2, Aerodynamics, missiles and space vehicles;
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