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LOW-SPEED AERODYNAMIC CHARACTERISTICS OF A FUSELAGE MODEL WITH VARIOUS ARRANGEMENTS OF ELONGATED LIFT JETS

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16. Abstract

Data were obtained for a round jet located on the center line of the bottom of a fuselage and for elongated slots separated spanwise by distances of 0.8 and 1.2 of the fuselage width. The effect of yawing the slots, inclining the jets laterally, and combining slot yaw with jet inclination was determined. Data were obtained in and out of ground effect through a range of effective velocity ratios and through a range of sideslip angles.

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SUMMARY

An investigation was made in the 5.18-meter test section of the Langley 300-MPH 7- by 10-foot tunnel to obtain the aerodynamic characteristics of a fuselage model with various arrangements of elongated slots in the fuselage bottom to provide vertical lift. Lateral and longitudinal data were obtained in and out of ground effect for configurations that would show the effects of lateral separation of the slots, positive and negative yawing of the slots, lateral inclination of the jets, and combinations of slot yaw and jet inclination.

Elongated slots, separated spanwise by distances of 0.8 and 1.2 of the fuselage width, showed less lift loss and smaller positive pitching moments in or out of ground effect than a single centrally located circular jet. Model sideslip usually produced an increase in lift and more negative pitching moments for all configurations. Increased lateral spacing between the slots reduced the lift loss due to interference and increased the incremental lateral force and moments due to sideslip. A combination of small angles of outward yaw of the slots and outward inclination of the jets gave less lift loss and generally smaller pitching moments than configurations without the angular deflections.

INTRODUCTION

Research is continuing toward the development of jet-powered airplanes capable of vertical or short take-off and landing (V/STOL). Such airplanes at very low speeds get negligible lift from the wing and must be supported by direct lift from jets. This lift may be obtained by deflecting the jet efflux of cruise engines with vanes and flaps (refs. 1 and 2) or by using lift engines set vertically in wing pods or in the fuselage (refs. 3 and 4). These reference reports show that lift losses occur when a jet model is hovering near the ground and that jet-induced lift losses and nose-up pitching moments occur at transition speeds. These lift losses and moment changes result from interference effects between the model, jets, and free stream. These interference effects as well as the ground effects vary with the velocity ratio, location and geometric arrangement of the jets, and the surface area adjacent to the jet exit. Jets elongated in the streamwise direction have shown less adverse effects of interference than multiple circular jets (ref. 4).

The purpose of this investigation was to extend the knowledge of the effect of elongated downward-ejecting jets on the aerodynamic characteristics of a fuselage in which they are installed. Data were obtained in and out of ground effect to determine the effects of lateral spacing of the jets, yawing the slots, inclining the jets laterally, and combining slot yaw with lateral inclination of the jets. Longitudinal data were obtained through a range of effective velocity ratios and lateral data were obtained through a range of sideslip angles for different effective velocity ratios.

SYMBOLS

The force and moment data are referred to the stability-axis system with the origin at the moment center shown in figure 1. The units of measurement used in this report are given in the International System of Units (SI). (See ref. 5.) The measurements were made in the U.S. Customary Units.

b — model span, cm

C_D — drag coefficient, $D/q_\infty S$

C_L — lift coefficient, $L/q_\infty S$

C_m — pitching-moment coefficient, $M_Y/q_\infty S l$

C_l — rolling-moment coefficient, $M_X/q_\infty S b$

C_n — yawing-moment coefficient, $M_Z/q_\infty S b$

C_Y — side-force coefficient, $F_Y/q_\infty S$

D — drag, including any jet forces, N

d_e — effective diameter (diameter of a circle equivalent in area to total jet-exit area of a given configuration), cm

F_Y — side force, N

h — height of model moment center above ground plane, cm

L — lift, N

L_∞ static lift ($V_\infty = 0$) out of ground effect, N

l model length, cm

M_X rolling moment, cm-N

M_Y pitching moment, cm-N

M_Z yawing moment, cm-N

q_∞ free-stream dynamic pressure, N/m^2

S model planform area, m^2

V_e effective velocity ratio, $\sqrt{\frac{\text{Free-stream dynamic pressure}}{\text{Jet-exit dynamic pressure}}}$

V_∞ free-stream velocity, m/sec

y distance between jet-exit centers, cm

α model angle of attack, deg

β model angle of sideslip, deg

ϕ lateral inclination of jet, deg

ψ angle between longitudinal center line of slot exit and model plane of symmetry (positive for forward end of slot yawed outward), deg

MODEL AND APPARATUS

The model (fig. 1), which was almost square in cross section, represented the fuselage of an airplane. The outer surface was made of fiber glass and the internal parts, with the exception of the nozzle blocks, were made of steel to withstand the high pressures. The nozzles were molded from a fiber-glass—resin compound.

Details of a typical nozzle installation are shown in figure 2. In order to get sufficient volume of air to operate the nozzle, it was necessary to bring the air into the model under high pressure. The incoming air line located inside the sting branched into three parts in the high-pressure fuselage chamber. In order to get good flow distribution in the nozzle exits, the air was directed through a row of holes in the top side of the air tubes against the roof of the fuselage high-pressure chamber and then through a layer of screen wire over a perforated plate which separated the high-pressure chamber from the nozzle plenum chamber. The eight interchangeable nozzle configurations are shown in figure 3. The total nozzle-exit area was 45.61 cm^2 and the effective diameter was 7.62 cm for each nozzle configuration.

The model was attached to a six-component strain-gage balance on the end of the mounting sting over a movable ground plane in the 5.18-meter test section of the Langley 300-MPH 7- by 10-foot tunnel. The moving ground plane was a fabric belt between two rollers driven by an electric motor. Details of the ground belt showing a typical model installation are given in reference 6.

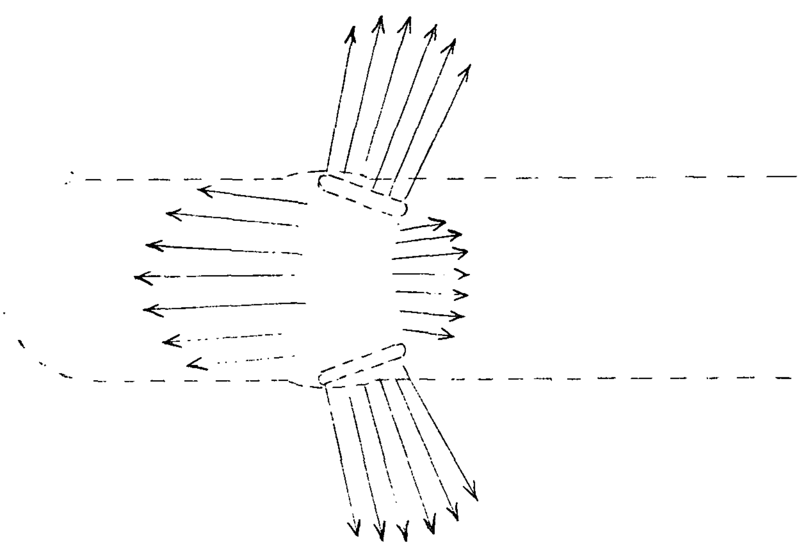
PRELIMINARY PROCEDURES

Before tunnel testing began, considerable preliminary checking for uniformity of nozzle-exit flows was carried out. A total-head pressure tube attached to a Bourdon tube gage was used to measure the incremental pressures at several stations in the nozzle exits for high and moderate incoming line and nozzle plenum pressures to be used in tunnel testing. Uniform flow at the nozzle exits was obtained by throttling the flow in the middle branch of the three branches of the air line in the fuselage high-pressure chamber and by trying screens of different mesh over the perforated plate.

A range of nominal nozzle-exit dynamic pressures corresponding to a range of nozzle plenum pressures was established to cover the effective-velocity-ratio range in the tunnel. The same nozzle plenum pressures were used in the tunnel tests, and the jet dynamic pressure was determined from the Mach number based on the ratio of the nozzle plenum pressure to the free-stream static pressure. While the nozzle plenum pressures to be used in the tunnel tests were being determined, the forces and moments on the model were measured for each nozzle plenum pressure, and the measured static lift out of ground effect thus obtained was used as a check against out-of-ground-effect lift obtained in the tunnel at zero forward speed. The out-of-ground-effect lift obtained in the tunnel at zero forward speed was used for obtaining the ratios $\left(L/L_\infty,\ M_Y/L_\infty d_e,\ \text{etc.}\right)$ presented in this report.

FLOW PATTERNS ON THE GROUND PLANE

Studies of the horizontal flow of the jet efflux after it impinges against the ground plane were made with the aid of tufts and streamers at zero forward velocity and with the model in a horizontal attitude. The ground-flow pattern becomes important when an airplane gets close enough to the ground to have its forces and moments influenced by the flow after the jet efflux impinges against the ground. No precise measurements were made of the direction and intensity of the flow, but the following observations were made and recorded for each nozzle configuration. At the greater model heights (22 and 16 effective nozzle diameters), the circular jet produced a symmetrical radial ground-flow pattern, and the elongated slots produced flow in all horizontal directions but somewhat more intense in the model longitudinal and lateral directions. At the lower heights, the circular jet continued to produce symmetrical flows, but the elongated slots produced definite asymmetrical radial flow patterns on the ground plane. The unyawed slots (nozzles 2 and 3) at heights of 1 to 3 effective nozzle diameters produced horizontal flow on the ground plane laterally, normal to the longitudinal axes of the jets, with very little flow longitudinally under the model. When the slots were yawed (nozzles 4 and 5), the lateral flow remained normal to the slot longitudinal axis. There was also longitudinal flow with an intensity about equal to that of the lateral flow. The flow was forward when the slots had positive yaw (nozzle 4) and rearward with negative yaw (nozzle 5). The flow pattern of the positive-yaw slots is indicated in the following sketch:



Except for the circular jet, there was very little ground flow along the diagonals between the model lateral and longitudinal axes at heights of 1 to 3 effective nozzle diameters. Also, at these heights, lateral inclination of the jets (nozzles 6, 7, and 8) had little effect on the horizontal flow patterns. Generally, when the model was near the ground, the flow patterns were such that negative pressures were produced on the bottom of the fuselage and on the lower surface of the wings of a model with wings.

RESULTS AND DISCUSSION

Presentation of Results

The data figures (figs. 4 to 17) are listed and described in table I. Figures 4 to 8 present the longitudinal aerodynamic data and figures 9 to 16 present the lateral data. Figure 17 presents the power-off aerodynamic characteristics.

Longitudinal Aerodynamic Characteristics

The longitudinal aerodynamic characteristics of the model with various nozzle configurations are given in figures 4 to 8 for a range of effective velocity ratios and heights of 1, 2, 4, 8, and 28 effective nozzle diameters above the ground plane. At an effective velocity ratio of 0.1, both the tunnel and the jet-exit velocities were a maximum for this investigation. At this effective velocity ratio, the tunnel dynamic pressure and the jet force were about 479 N/m^2 and 420 N, respectively. To obtain effective velocity ratios less than 0.1, the tunnel velocity was reduced, and to obtain ratios greater than 0.1, the jet-exit velocity was reduced. The model was considered out of ground effect at a height of 28 effective nozzle diameters $\left(h/d_e = 28\right)$ above the ground plane, a position near the center of the tunnel. All data except some noted in figures 8 and 17 were obtained at a model angle of attack of 0^o.

The aerodynamic characteristics of the model with jet power off and out of ground effect are shown in figure 17. The data show that at an angle of attack of 0^o the aerodynamic lift is zero out of ground effect. Hence, any variation from unity in the lift ratios presented in this report at 0^o angle of attack out of ground effect is due only to interference between the model and the free stream. Lift ratios less than 1 $\left(L/L_\infty < 1\right)$ obtained under the aforementioned conditions indicate that there is a lift loss due to interference. However, when the model is pitched, yawed, or in ground effect, the aerodynamic forces and moments are not necessarily the same as they are at zero pitch and yaw and out of ground effect. These aerodynamic characteristics must be determined from power-off tests. Since these data were not measured except for the out-of-ground-effect conditions, it is not possible to isolate the aerodynamic interference effects for the in-ground-effect data. However, comparisons between different configurations for given test conditions give a valid indication of relative total interference effects, including ground effect.

Effect of spanwise location of the slots.- The effect of moving the slots outward from the center of the bottom surface of the model is shown in figure 4. The spanwise location of the slots has little effect on the model forces and moments at very low effective velocity ratios (near hovering) when the model is away from the ground plane (figs. 4(a) and 4(b)). At the higher velocity ratios (transition speeds), all three configurations show a reduction in lift compared with the static lift of the jets at zero forward velocity. This reduced lift results from negative pressures on the bottom surface of the model beside and behind the slot exits. These negative pressures on the rear of the model produce the indicated positive increase in pitching moments. Moving the slots outward reduces the affected model area directly behind the jets, thereby reducing the interference effects (lift loss) between the model, jets, and free stream.

As the model gets closer to the ground (figs. 4(c), 4(d), and 4(e)), the lift losses increase for the circular jet configuration but decrease for the other two configurations and even show lift ratios greater than 1 $\left(L/L_{\infty} > 1\right)$ for some combinations of height and velocity ratio. When two jets have a spanwise space between them, some of the jet air after striking the ground plane is forced back up against the lower surface of the model in the manner of an "inverted fountain," with a resulting increase in lift. The magnitude of the increase varies with effective velocity ratio, model height above the ground plane, and spacing between the jets; in general, however, slots with lateral spacing between them show less lift loss and smaller positive pitching moments in or out of ground effect than a single centrally located circular lift jet. Other forces and moments on the model were not greatly affected by varying the spanwise location of the jets.

Effect of yawing the slots.- Yawing the slots either outward or inward at the forward end generally results in a reduction in lift and an increase in positive pitching moments, in or out of ground effect, compared with the unyawed slots (fig. 5). Evidently the yawed slot causes more interference between the jet and free stream. Yawing the slots outward (nozzle 4) is less detrimental than inward yaw (nozzle 5) of the slot forward end. One benefit from yawing might be that it gives some direction to the horizontal flow in ground effect. The tendency of some of the horizontal flow to be perpendicular to the longitudinal axis of the slot was mentioned in the section entitled "Flow Patterns on the Ground Plane."

Effect of jet inclination.- The effect of inclining the jet 20° away from the plane of symmetry is shown in figure 6. Out of ground effect (fig. 6(a)), there is some lift improvement and a more negative pitching moment as a result of less interference between the free stream and the outward spreading jets. Close to the ground plane (fig. 6(e)) the lift ratios with jets inclined ($\phi = 20^{\circ}$) are larger near hovering conditions but are smaller at the higher velocity ratios than the lift ratios for the model with jets vertical. However, any indicated benefit from inclining the jet would be partly nullified by the 6-percent loss in lift resulting from the inclination of the thrust axis.

Effect of slot yaw and jet inclination.- A nozzle configuration with a combination of outward yaw of the forward end of the slot and an outward inclination of the jet, each of 10°, gave less lift loss and generally smaller pitching moments in or out of ground effect than the configuration without slot yaw and jet inclination or the configuration with a combination of inward slot yaw and outward jet inclination. The slots having 20° of yaw without inclination (fig. 5) showed adverse effects on the lift ratios and the jets with 20° of inclination without yaw (fig. 6) showed improvement in lift only out of ground effect, compared with the nozzle without slot yaw or jet inclination; but the nozzle having a combination of outward slot yaw and outward jet inclination at smaller angles (10°) gave considerably improved lift ratios (fig. 7). However, the nozzle with inward slot yaw and outward jet inclination gave smaller lift ratios than the nozzle without slot yaw and jet inclination (fig. 7). Yaw affects the results more than inclination, if they are considered separately, since yaw causes more interference with the free stream.

Other forces and moments on the models, with the exception of the drag and pitching-moment ratios, did not show significant differences between configurations. Since it was more difficult to duplicate the thrust for each model than it was to hold a constant tunnel dynamic pressure, some of the differences in drag ratios between configurations probably resulted from the variations in the nondimensionalizing lift factor of the various configurations. Also the rapid rise in the drag ratios resulted mainly from the reduction in thrust (lift) to obtain the higher velocity ratios.

Effect of angle of attack.- The effect of angle of attack on one configuration is shown in figure 8. The flat bottom of the fuselage acted as a very low aspect-ratio wing and produced an increase in the lift ratio. The increase was greater in ground effect, probably the result of some ram effect between model and ground at the higher velocity ratios. Some of the increase in drag ratio resulted from the drag component of the thrust vector.

Characteristics in Sideslip

The aerodynamic characteristics of the configurations through a range of sideslip angles in $\left(h/d_e = 1\right)$ and out $\left(h/d_e = 28\right)$ of ground effect are givèn in figures 9 to 16 for several effective velocity ratios. The configurations are grouped according to the presentation of the longitudinal data so that any effects of jet spanwise location, jet inclination, and slot yaw may also be noted.

With very few exceptions, sideslipping the model produced an increase in the lift ratios and more negative pitching-moment ratios. Sideslipping the model reduced the interference lift losses, especially on the rear part of the model, since the rear of the model was displaced from the interference region of the jet and free stream. However, reduced interference would not account for lift ratios greater than 1 $\left(L/L_\infty > 1\right)$. A possible explanation for such ratios is that the yawed model acts as a highly swept wing with the jets near the leading and trailing edges producing higher velocities over the upper surface in the manner of a jet-flapped wing. It is noted that the slots were more effective in increasing the lift ratios in sideslip than the centerally located circular jet (figs. 9 and 10). The effects of sideslip on the side-force, yawing-moment, and rolling-moment ratios were as expected with the moment center near the front and at the lower surface of a rather large fuselage. Negative sideslip always produced positive increments of side force and rolling moments and negative increments of yawing moment. These increments increased as the spanwise distance between the slots increased (figs. 9 and 10). The increments due to sideslip for the configurations with the slots yawed (figs. 11 and 12) were about the same except at a velocity ratio of 0.30 (fig. 11(c)) where the increments were much smaller in lift and pitch for the slots yawed inward. Jet inclination (figs. 13 and 14) and combinations of small angles of slot yaw and jet inclination (figs. 15 and 16) had little effect on the variations of force and moment ratios with angle of sideslip, although the absolute magnitudes of the forces and moments were different.

SUMMARY OF RESULTS

An investigation was made at low forward velocities to obtain the aerodynamic characteristics of a fuselage model with various arrangements of elongated slots in the fuselage bottom to provide vertical lift. Data were obtained for configurations that would show the effects of lateral separation of the slots, positive and negative yaw of the slots, lateral inclination of the jets, and combinations of slot yaw and jet inclination. Data were obtained in and out of ground effect at 0° angle of attack through a range of ratios of free-stream velocity to jet-exit velocity, and through a range of sideslip angles at constant effective velocity ratios. Some of the results are as follows:

1. Slots with lateral spacing between them showed less lift loss and smaller positive pitching moments in or out of ground effect than a single centrally located circular jet.

2. Model sideslip usually produced an increase in lift ratios and more negative pitching moments for all configurations.

3. Increased spacing between the slots reduced the lift loss due to interference and increased the incremental lateral force and moments due to sideslip.

4. Slot yaw either outward or inward at the forward end generally resulted in a reduction in lift and an increase in positive pitching moment, in or out of ground effect, compared with no slot yaw.

5. Inclining the jets outward from the plane of symmetry gave some improvement in lift and a more negative pitching moment out of ground effect than was realized without jet inclination.

6. A combination of 10° outward yaw of the slots and 10° outward inclination of the jets gave less lift loss and generally smaller positive pitching moments, in or out of ground effect, than configurations without angular deflections. The combination had little effect on the lateral force and moment increments due to sideslip.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., May 21, 1973.

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TABLE I.- INDEX TO FIGURES FOR BASIC AERODYNAMIC DATA

Figure	Data description	Nozzle	V_e	h/d_e
Longitudinal data				
4	Effect of spanwise location of slots	1, 2, 3	Range	Range
5	Effect of slot yaw	4, 2, 5	Range	Range
6	Effect of jet inclination	2, 6	Range	Range
7	Effect of slot yaw and jet inclination	7, 2, 8	Range	Range
8	Effect of angle of attack	3	Range	28, 2
Lateral data				
9	Effect of spanwise location of slots	1, 2, 3	0.10, 0.20, 0.30	28
10	Effect of spanwise location of slots	1, 2, 3	0.10, 0.20, 0.40	1
11	Effect of slot yaw	4, 2, 5	0.10, 0.20, 0.30	28
12	Effect of slot yaw	4, 2, 5	0.10, 0.20, 0.30	1
13	Effect of jet inclination	2, 6	0.10, 0.20, 0.30	28
14	Effect of jet inclination	2,6	0.10, 0.20	1
15	Effect of slot yaw and jet inclination	7, 2, 8	0.10, 0.20, 0.30	28
16	Effect of slot yaw and jet inclination	7, 2, 8	0.10, 0.20, 0.30	1
17	Power-off aerodynamic characteristics	1	-------------	28

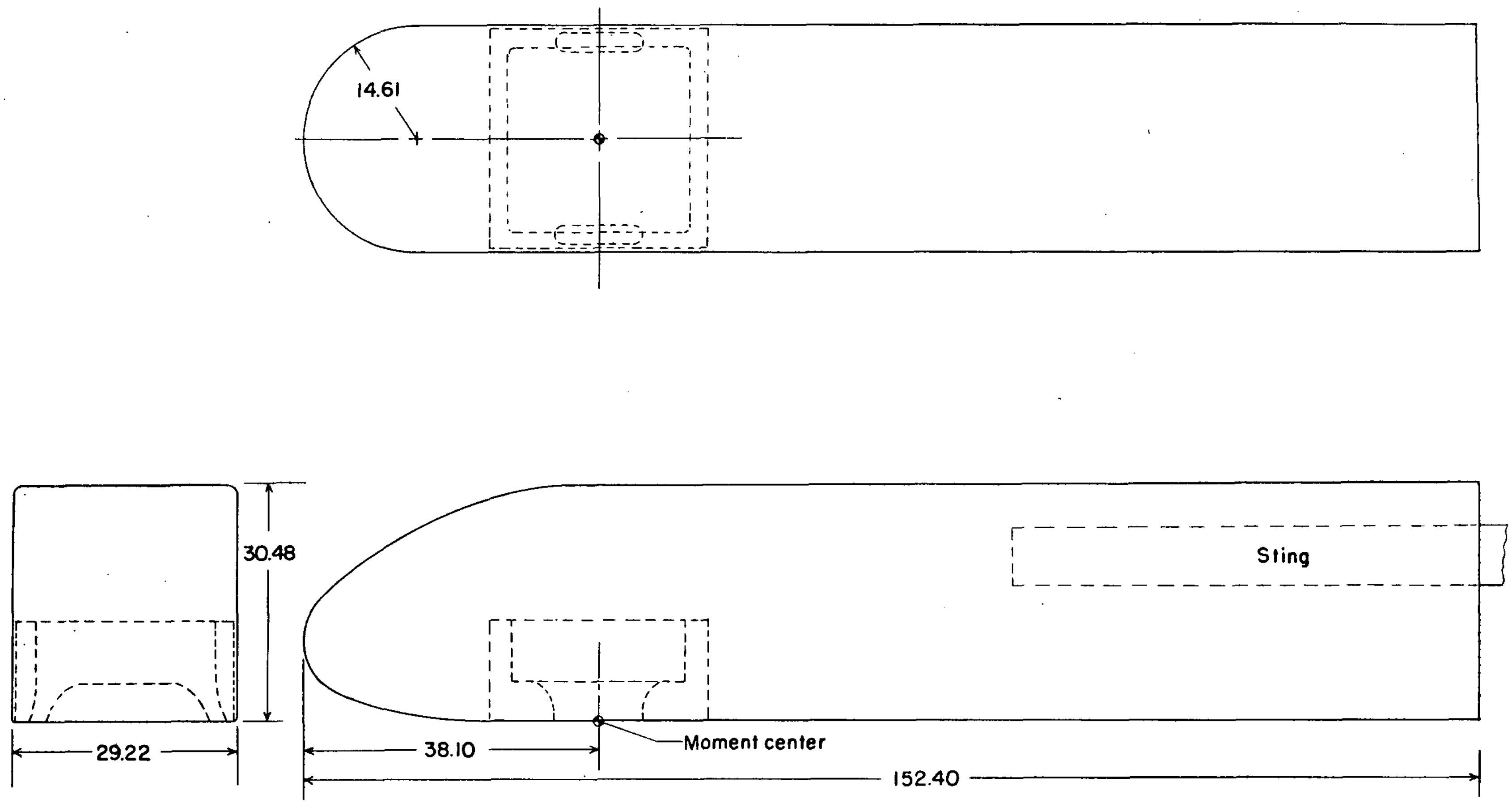


Figure 1.- Three-view drawing of model showing removable nozzle block. Dimensions are in centimeters.

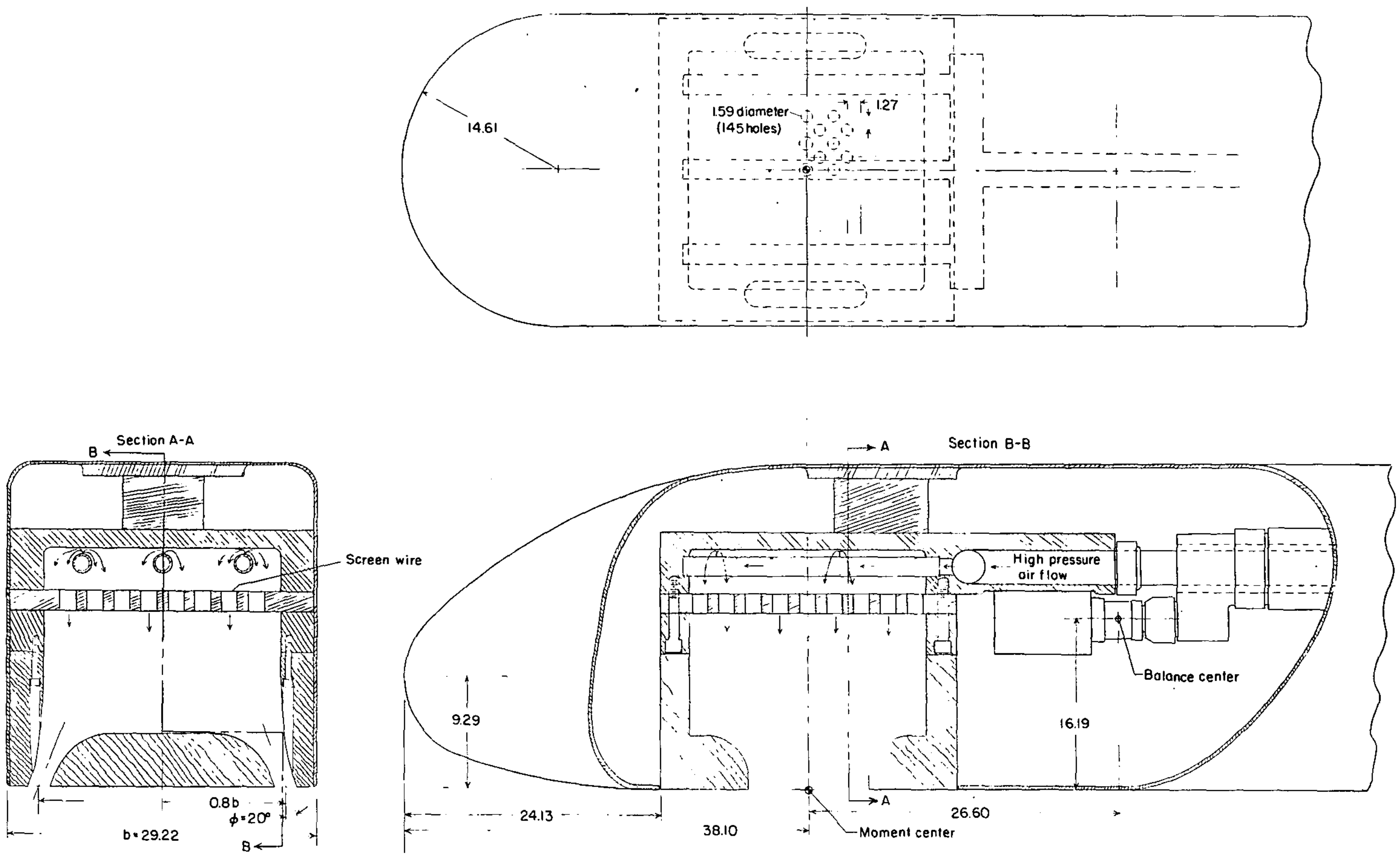


Figure 2.- Sketch showing balance, air-line system, and details of a typical nozzle installation. Dimensions are in centimeters.

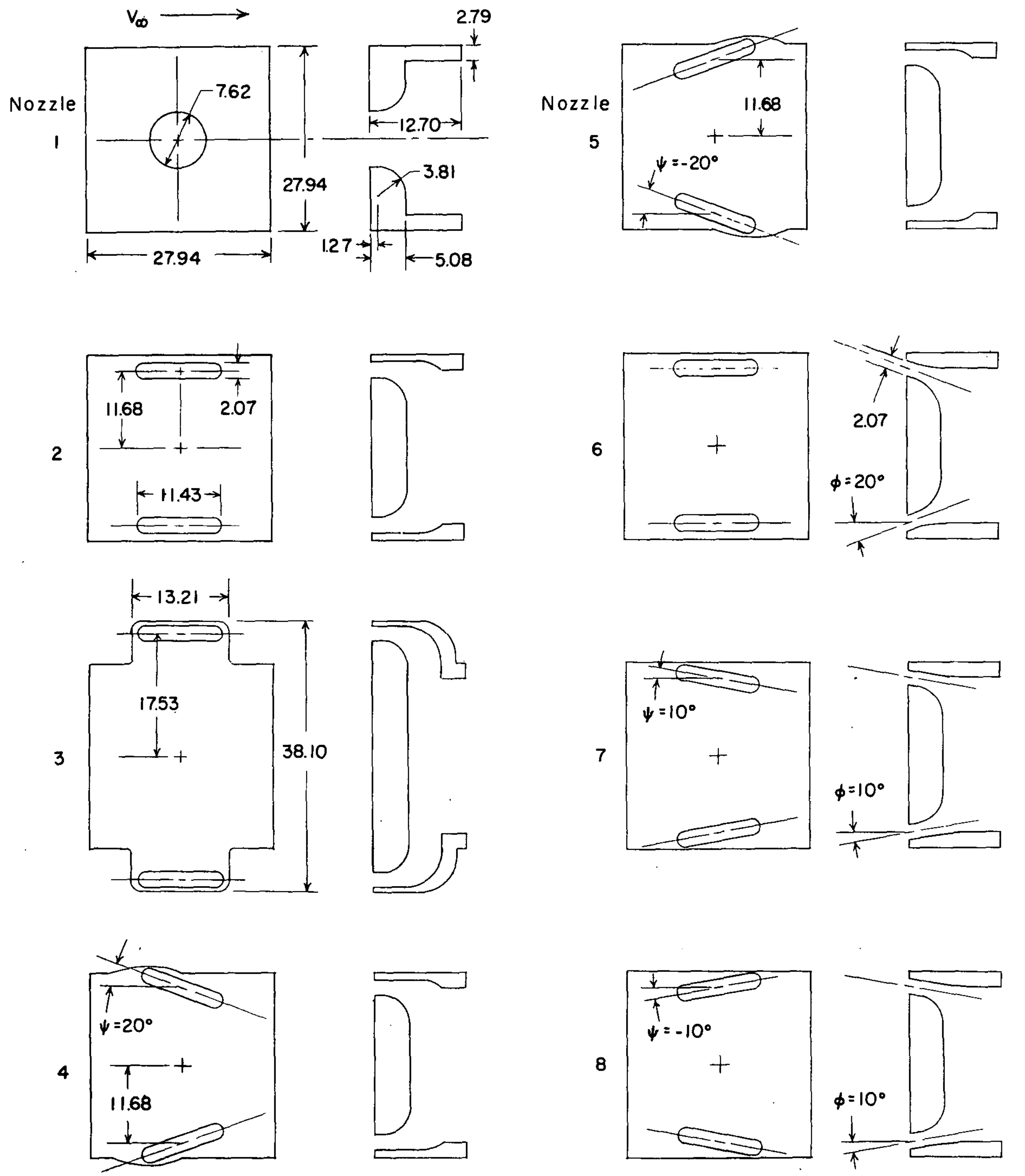
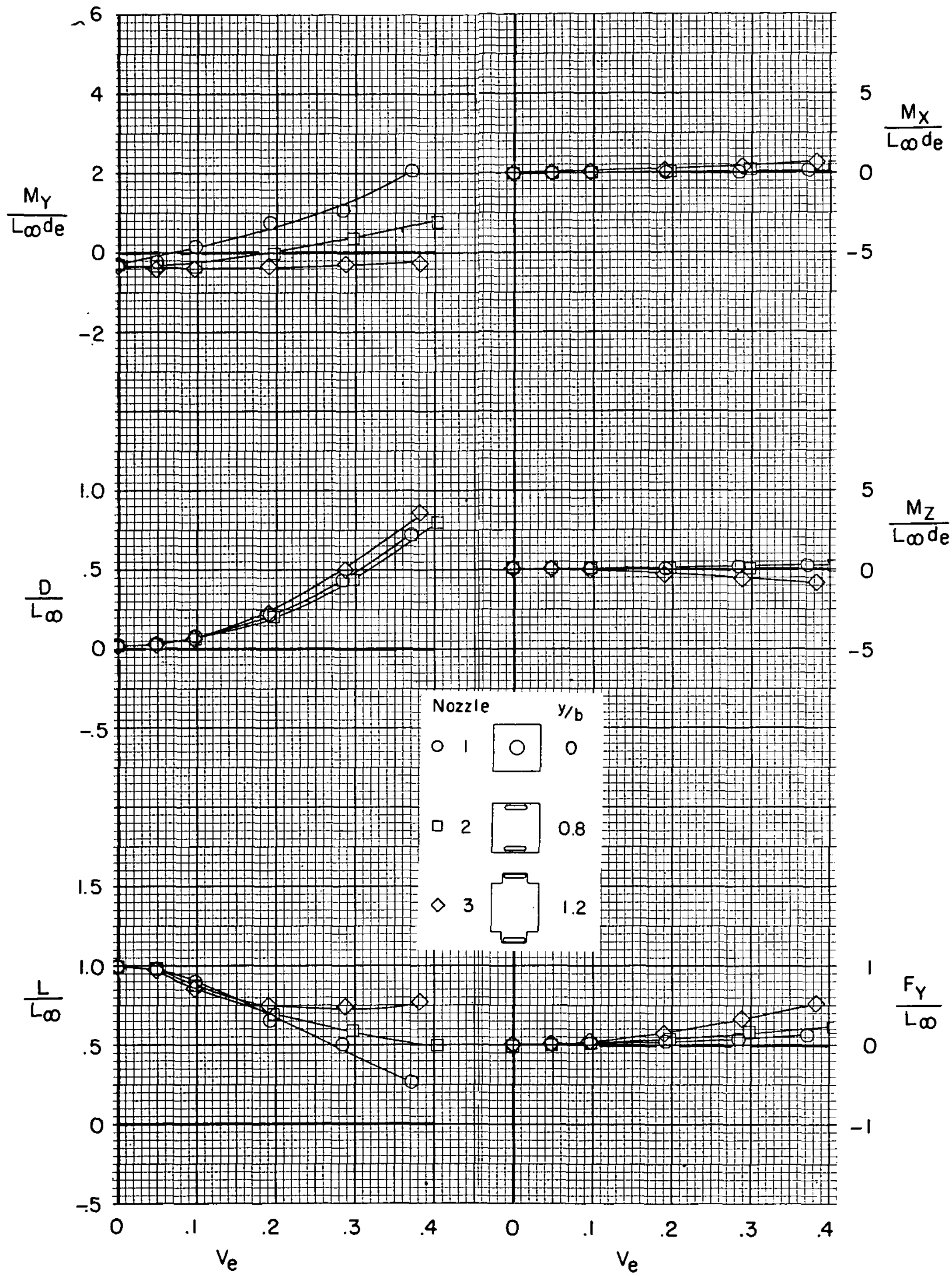
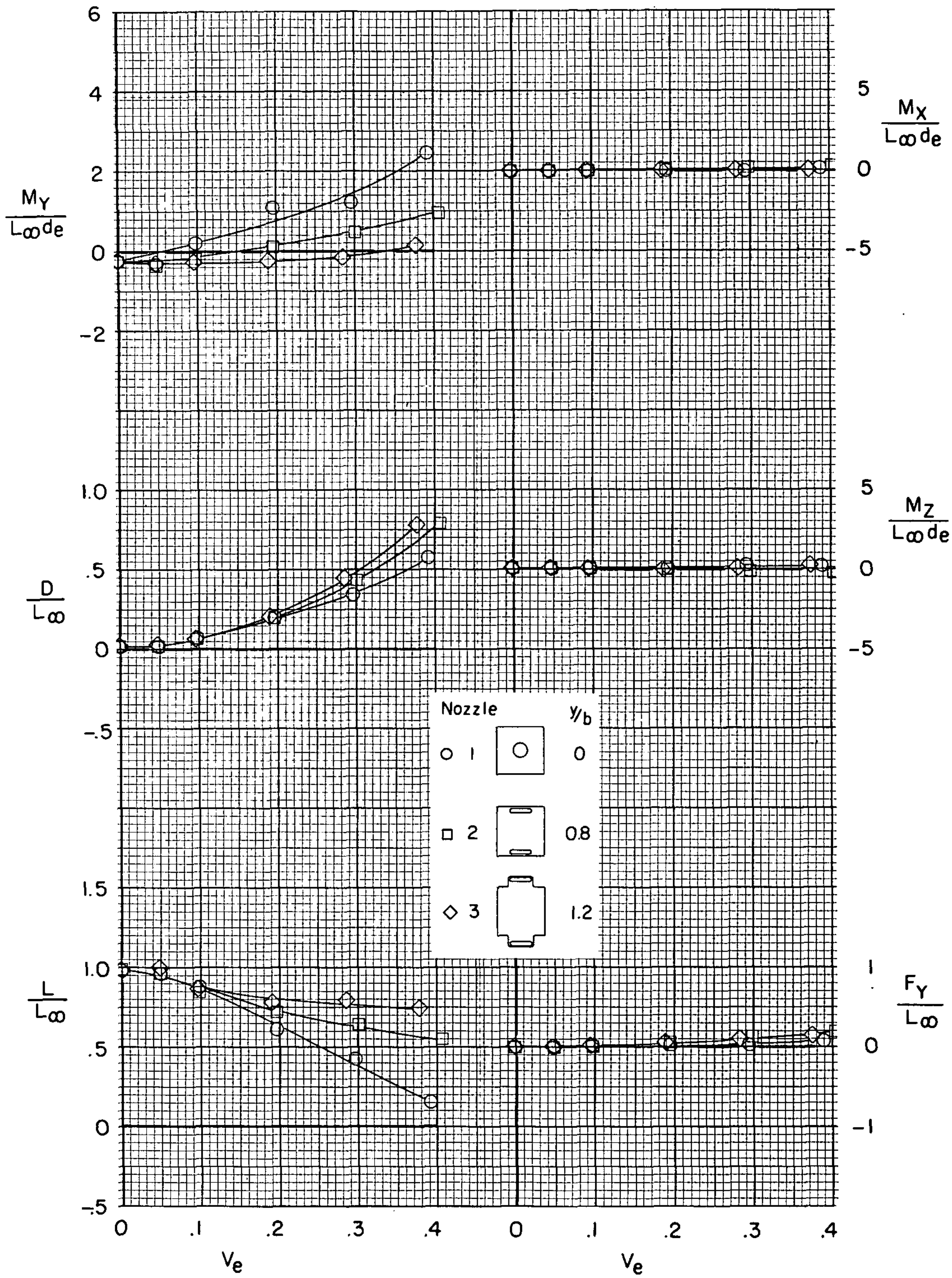


Figure 3.- Bottom views and lateral sections of nozzle configurations investigated. Dimensions are in centimeters.



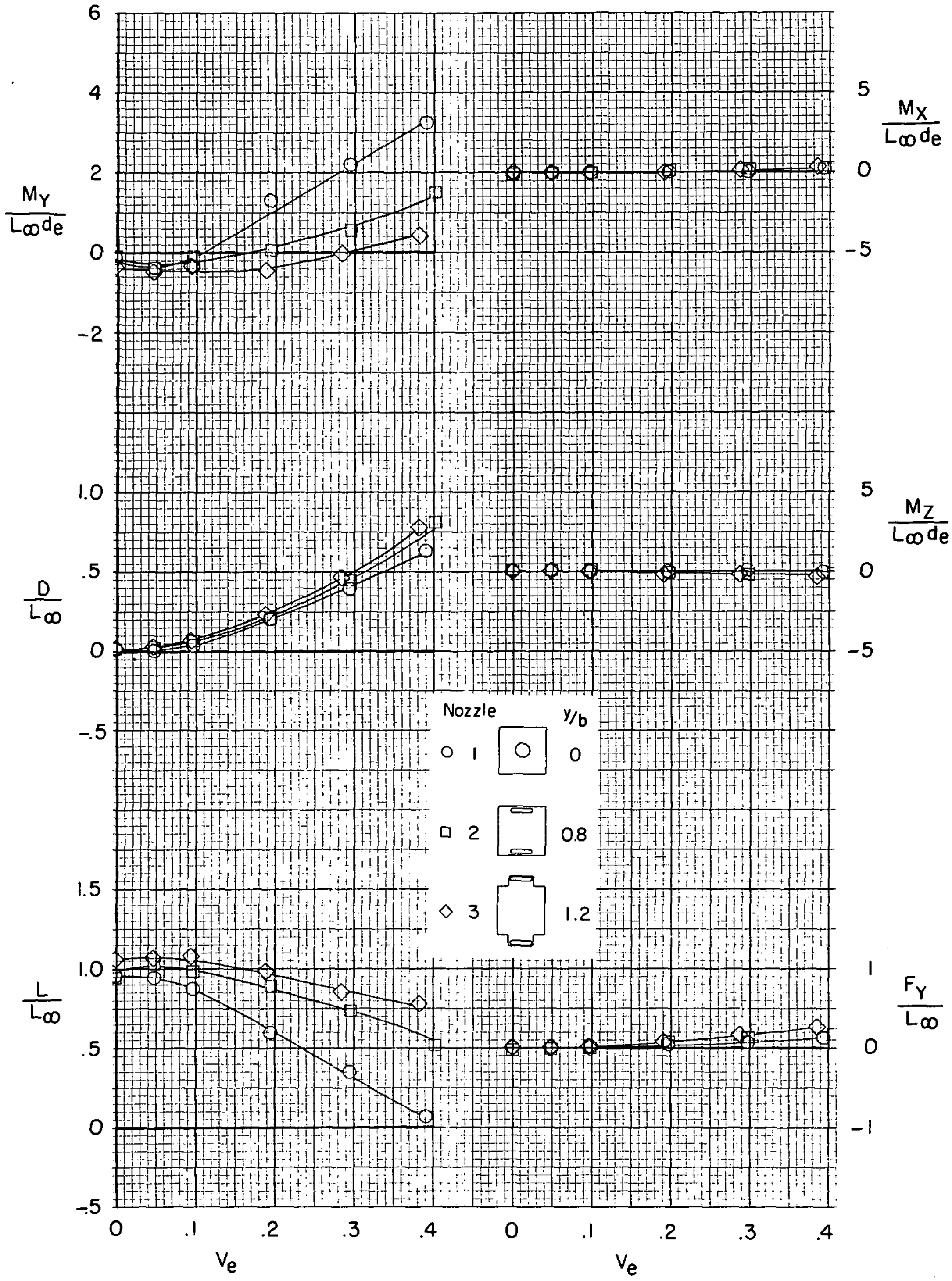
(a) $h/d_e = 28$.

Figure 4.- Effect of spanwise location of the slots on the longitudinal aerodynamic characteristics of the model at various heights above the ground plane. $\psi = 0^o$; $\phi = 0^o$.



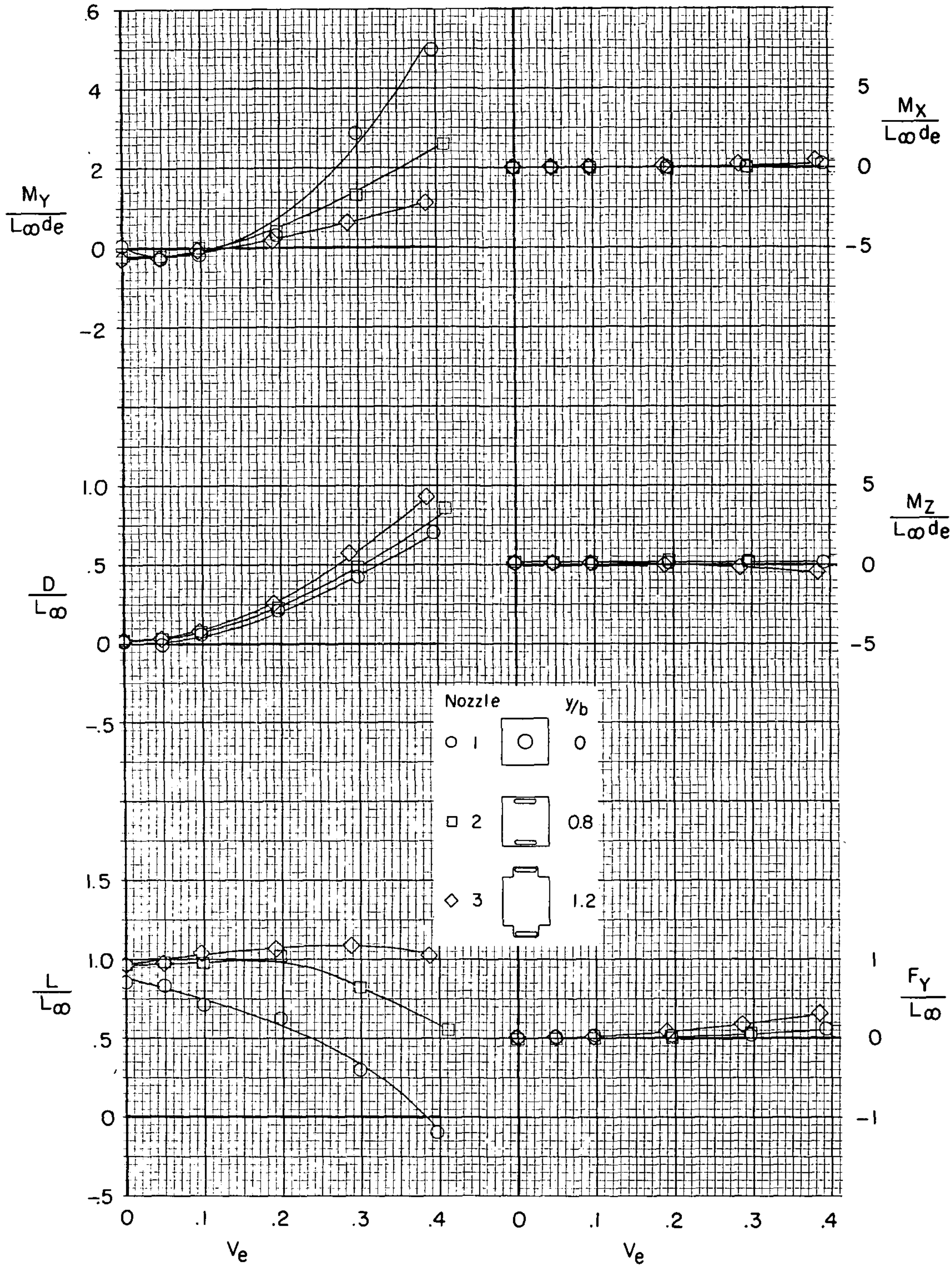
(b) $h/d_e = 8$.

Figure 4.- Continued.



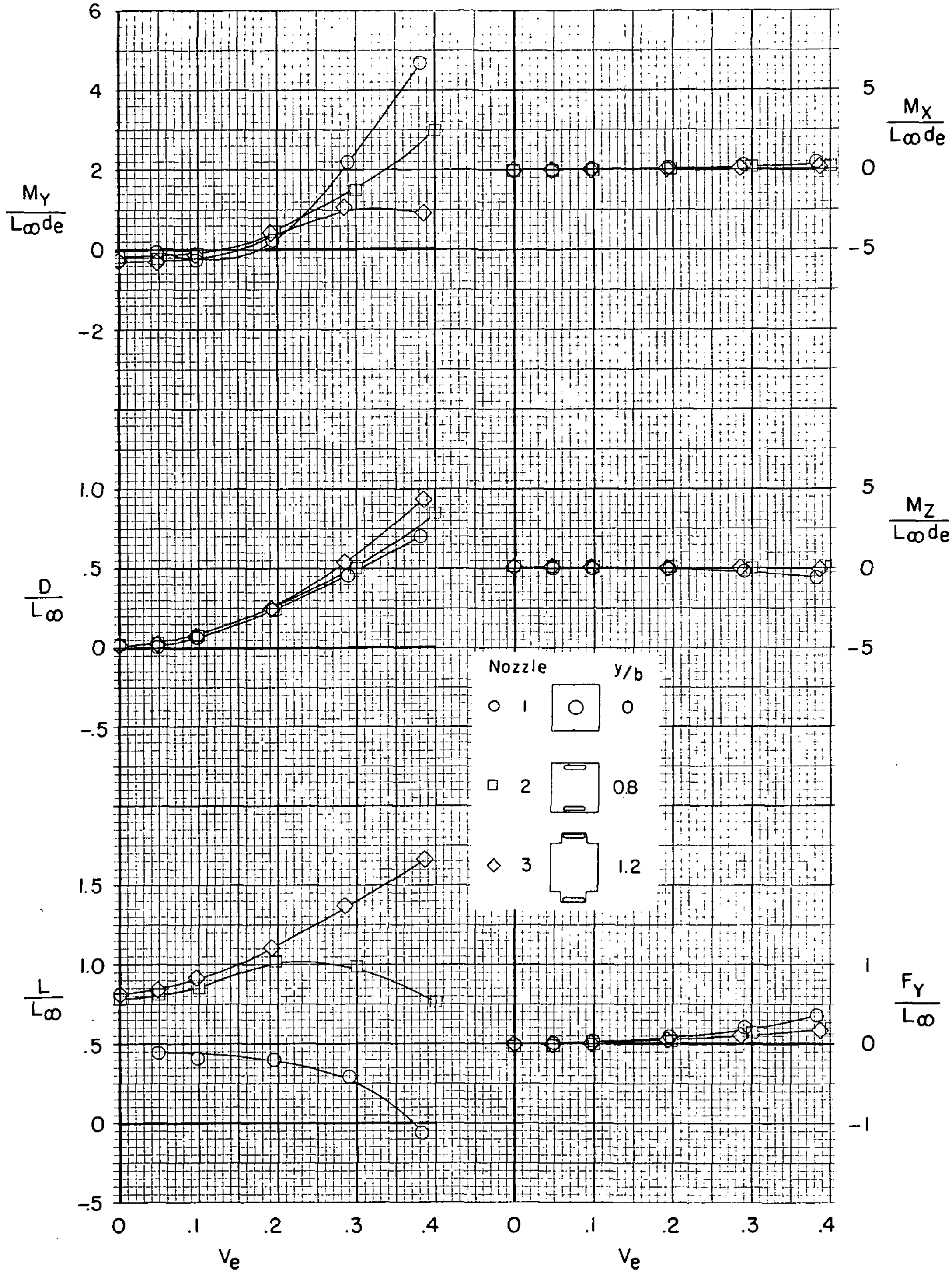
(c) $h/d_e = 4$.

Figure 4.- Continued.



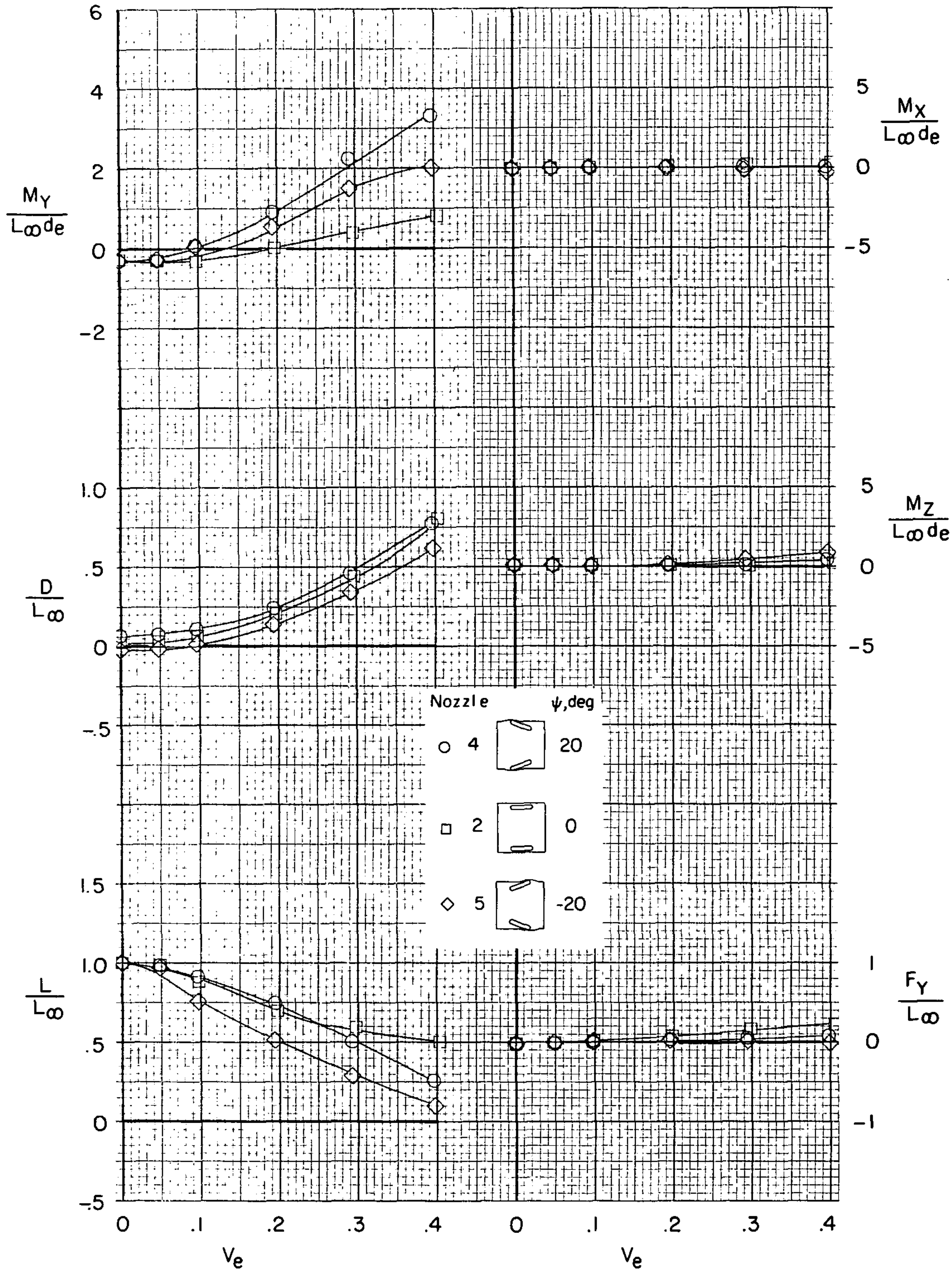
(d) $h/d_e = 2$.

Figure 4.- Continued.



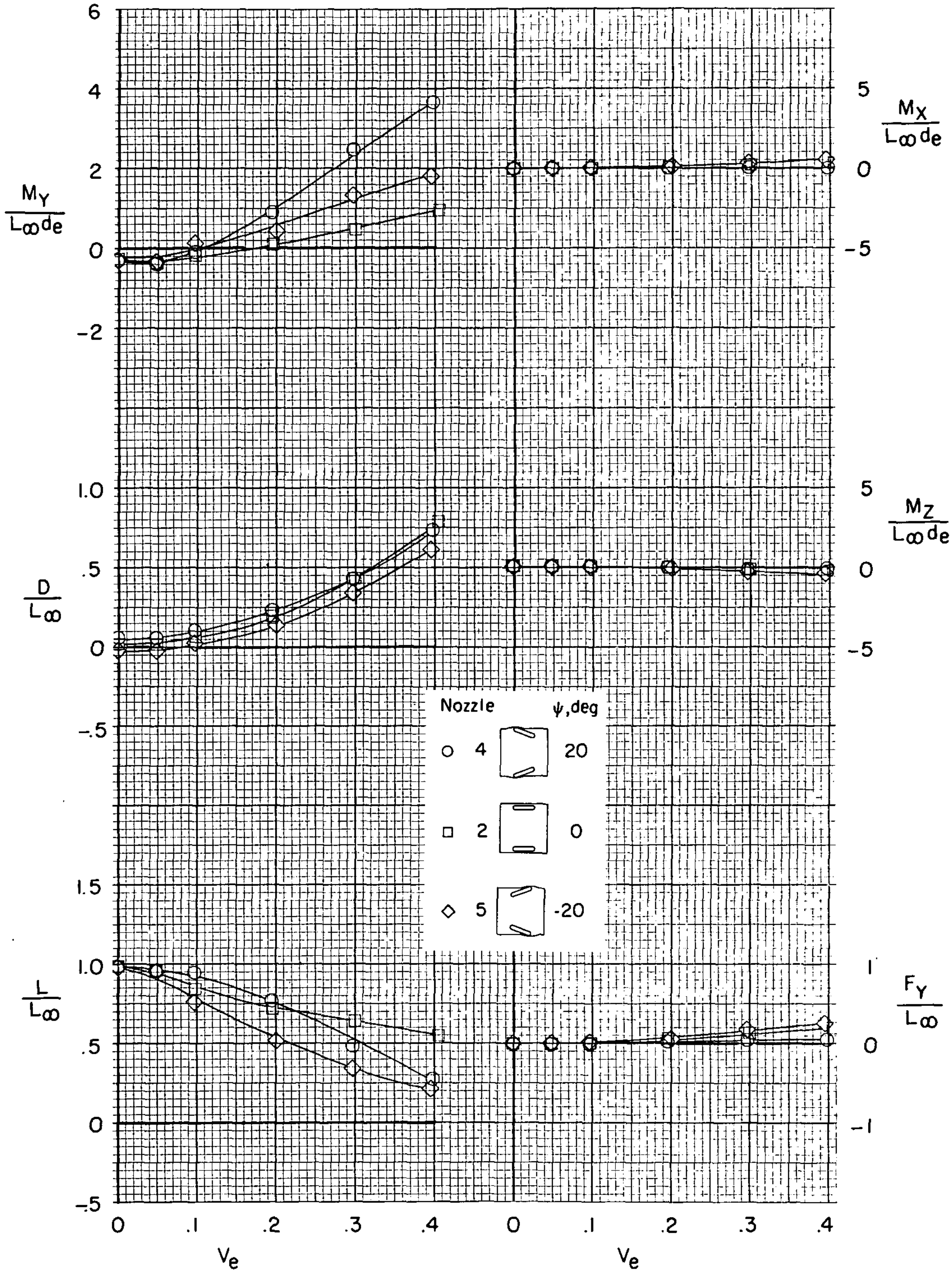
(e) $h/d_e = 1.$

Figure 4.- Concluded.



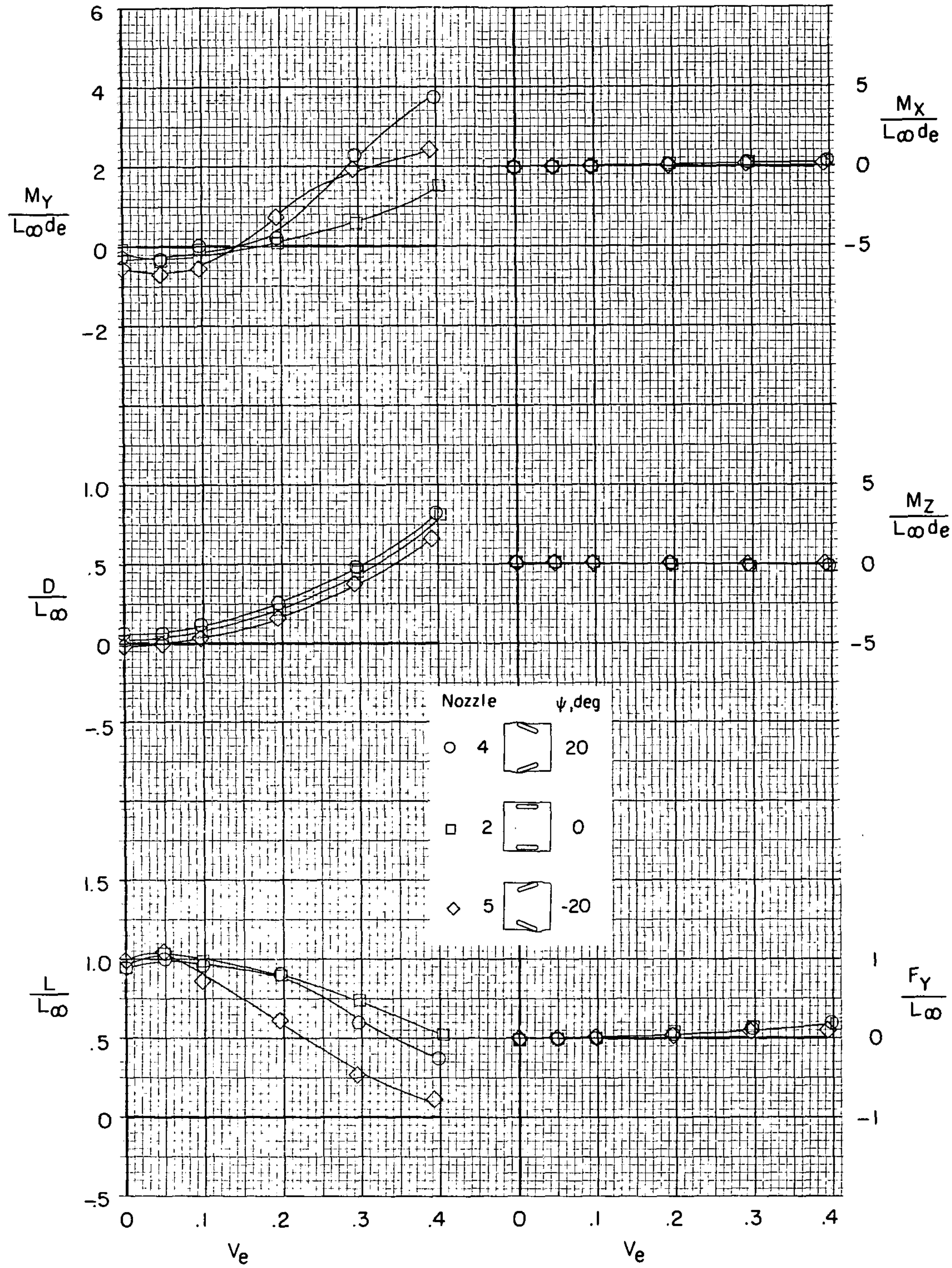
(a) $h/d_e = 28$.

Figure 5.- Effect of slot yaw on the longitudinal aerodynamic characteristics of the model at various heights above the ground plane. $\phi = 0^o$; $y/b = 0.8$.



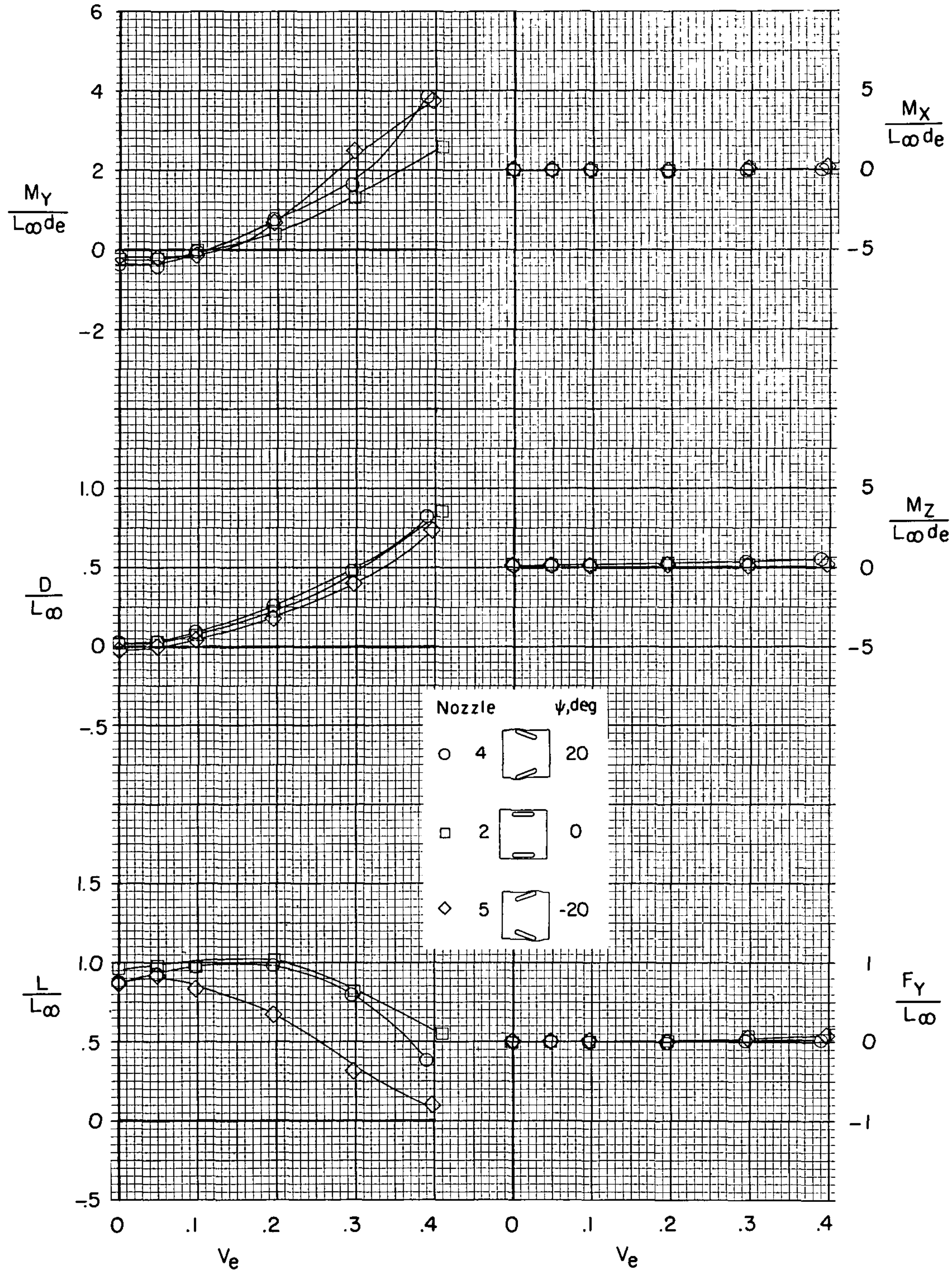
(b) $h/d_e = 8$.

Figure 5.- Continued.



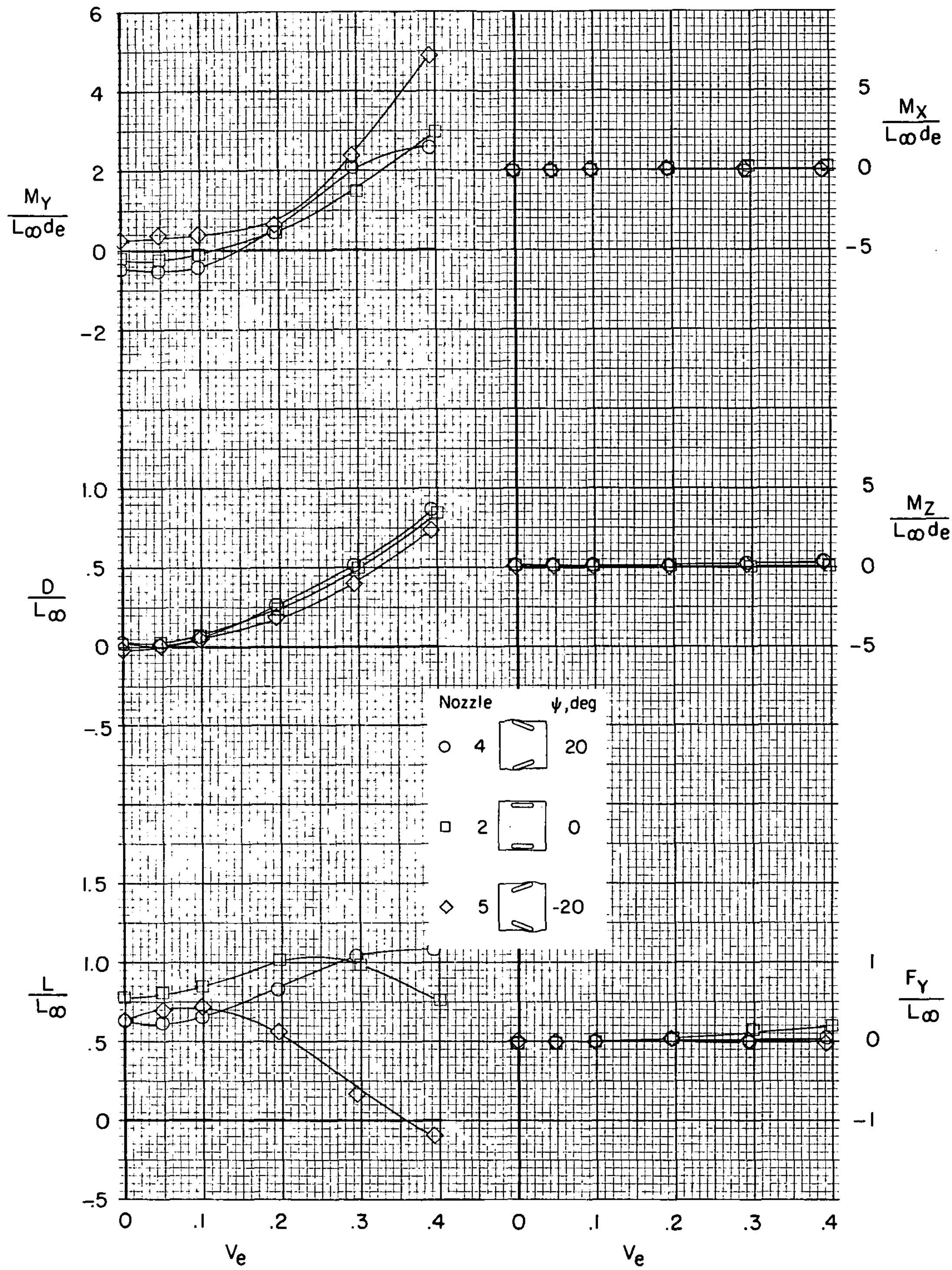
(c) $h/d_e = 4$.

Figure 5.- Continued.



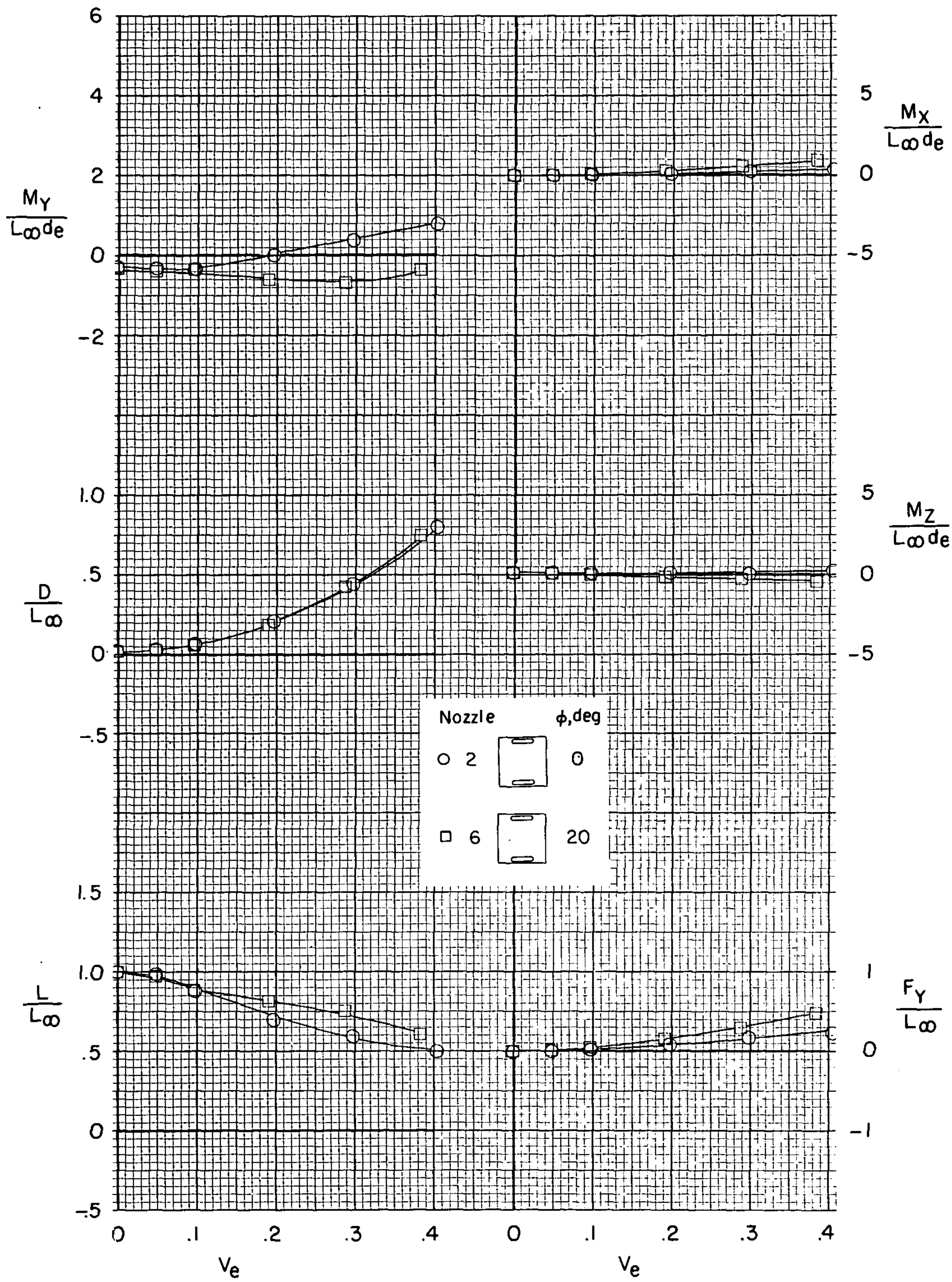
(d) $h/d_e = 2$.

Figure 5.- Continued.



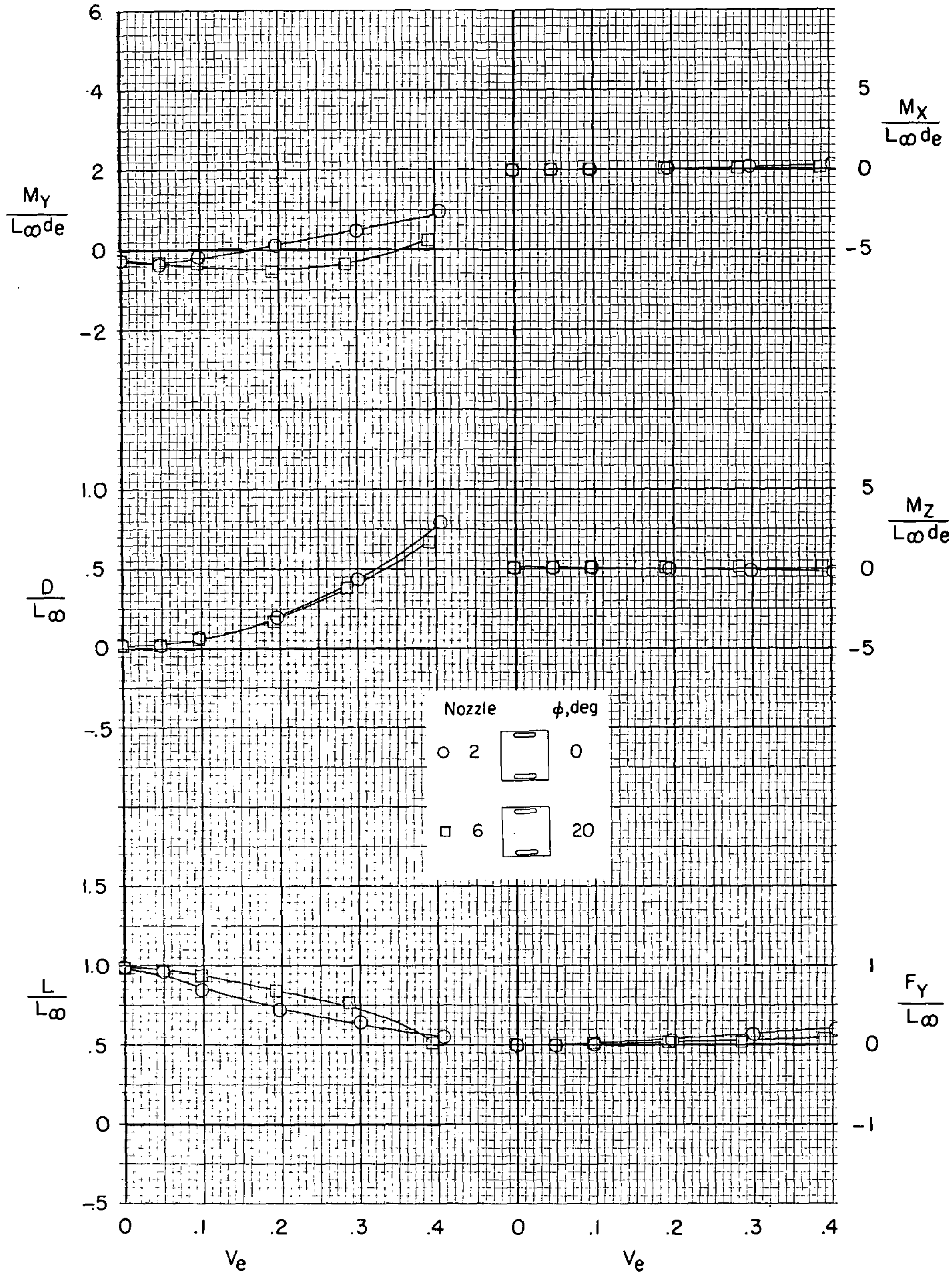
(e) $h/d_e = 1$.

Figure 5.- Concluded.



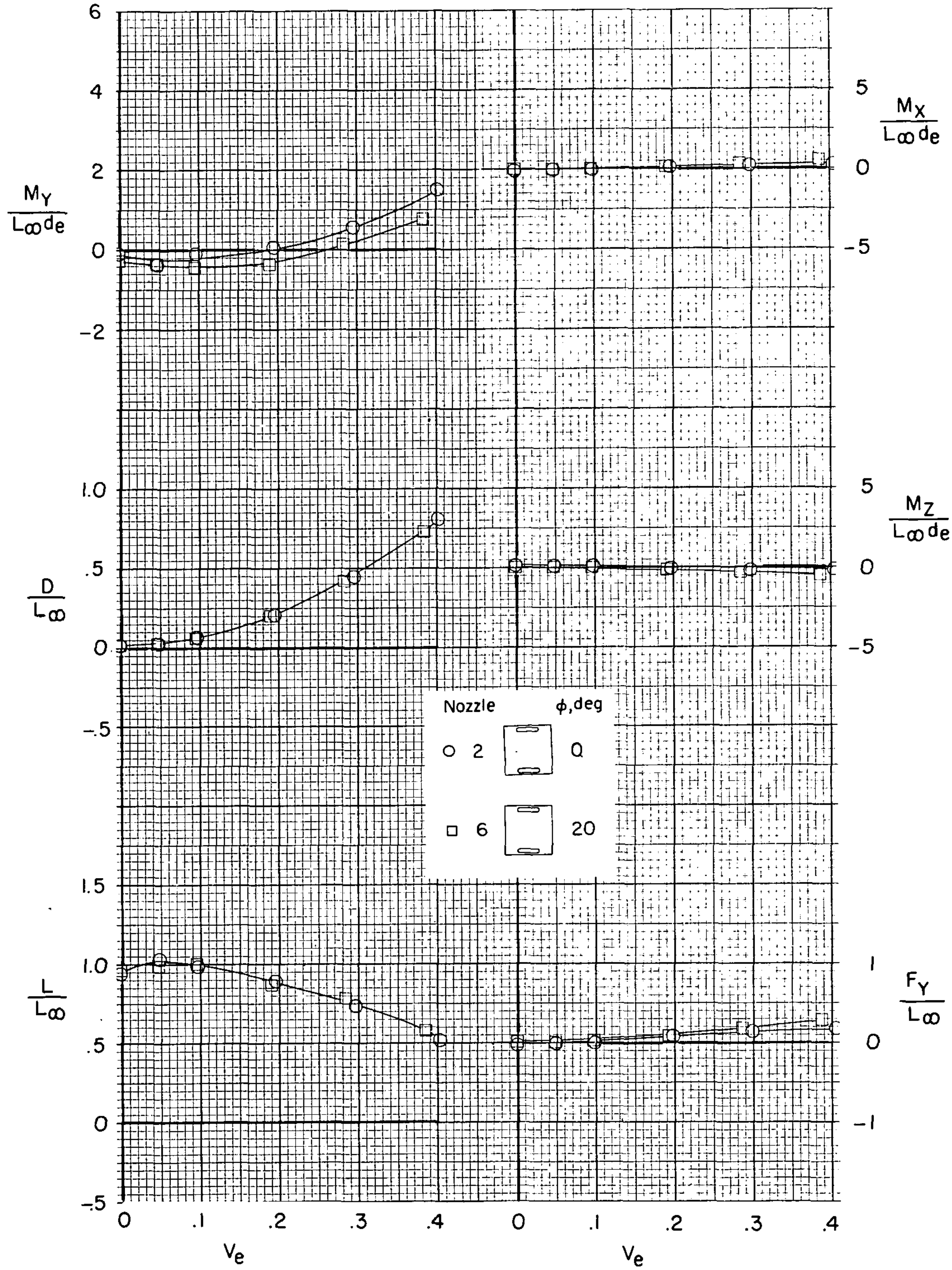
(a) $h/d_e = 28$.

Figure 6.- Effect of jet inclination on the longitudinal aerodynamic characteristics of the model at various heights above the ground plane. $\psi = 0^\circ$; $y/b = 0.8$.



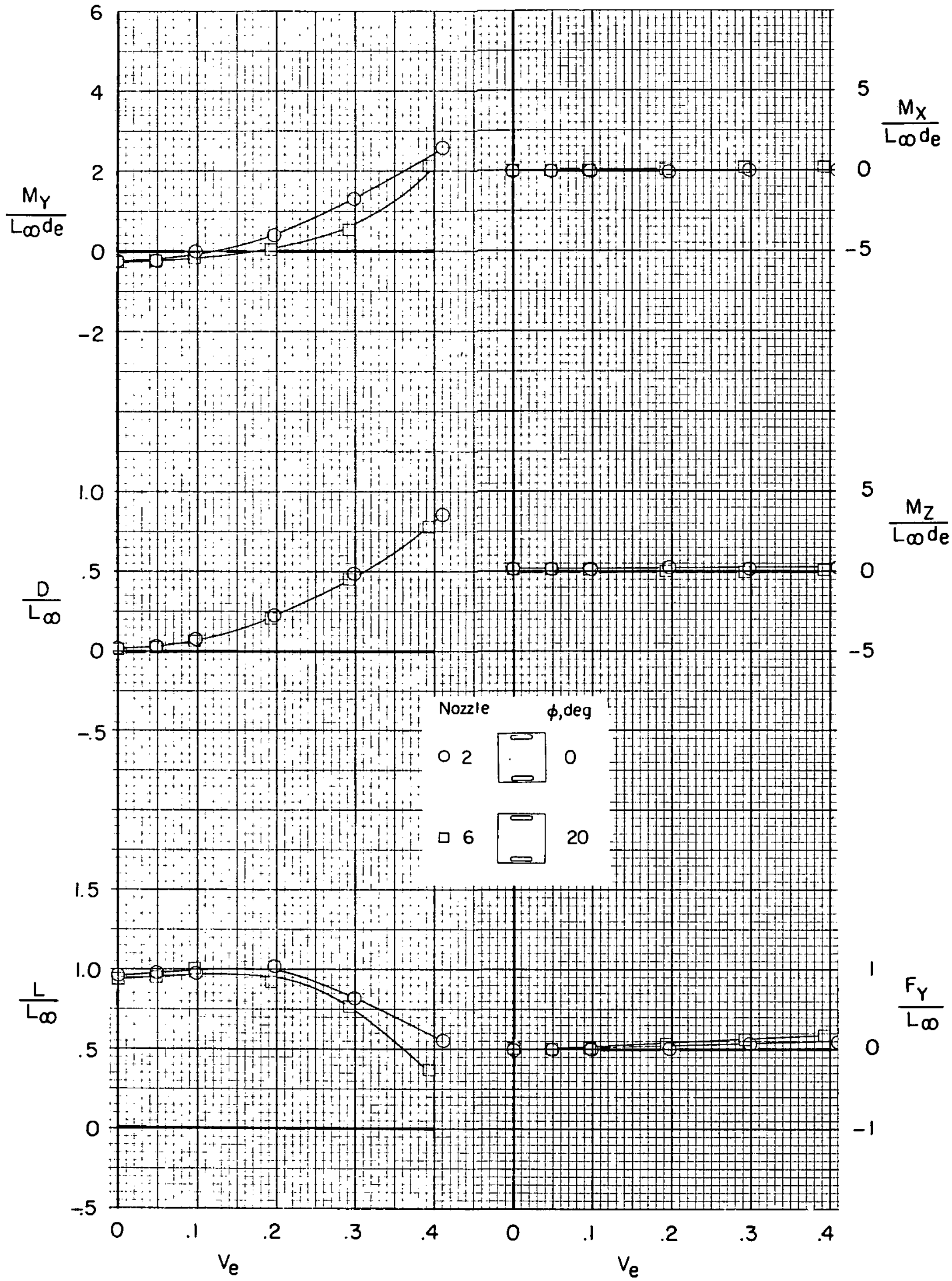
(b) $h/d_e = 8$.

Figure 6.- Continued.



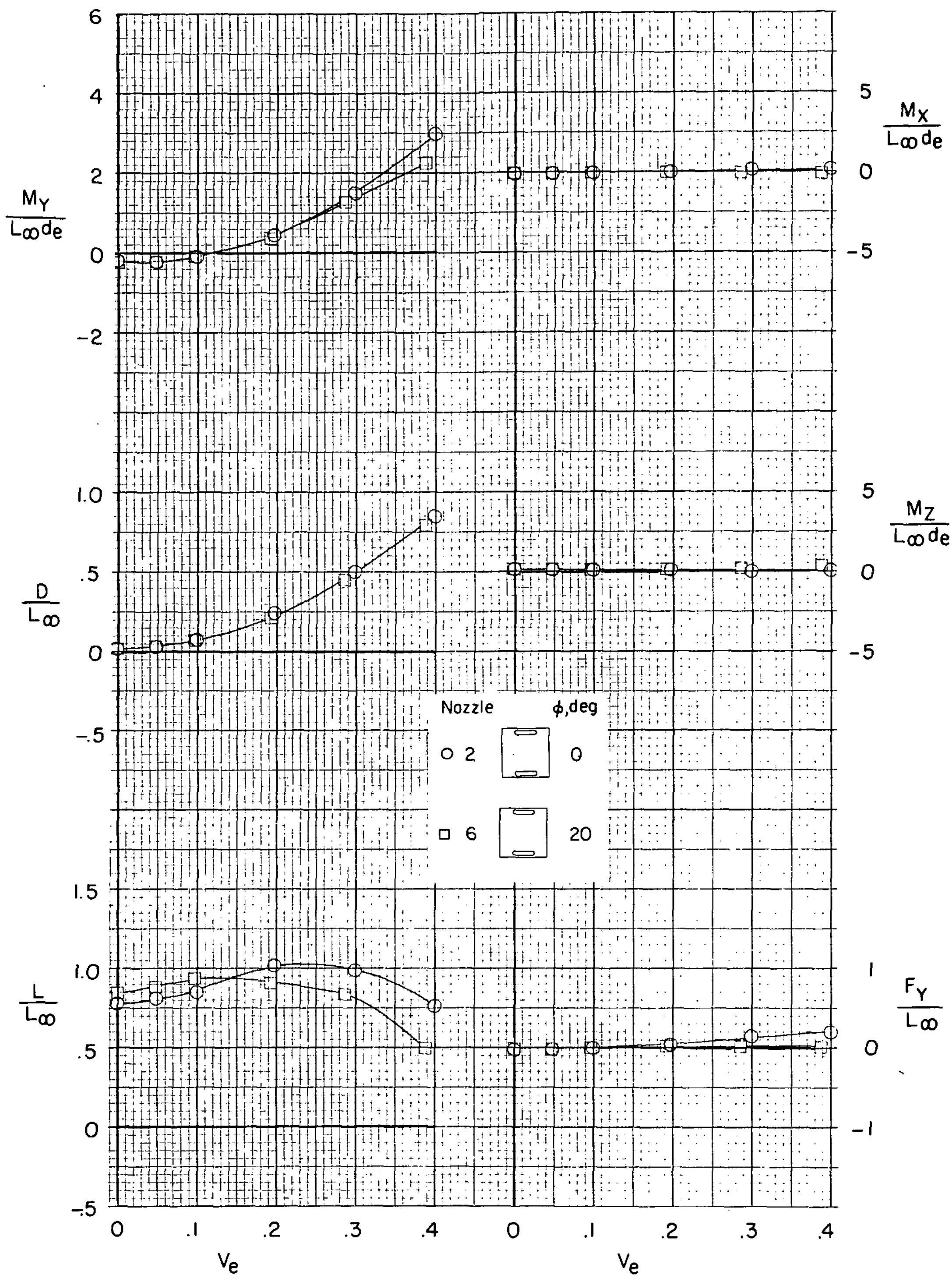
(c) $h/d_e = 4$.

Figure 6.- Continued.



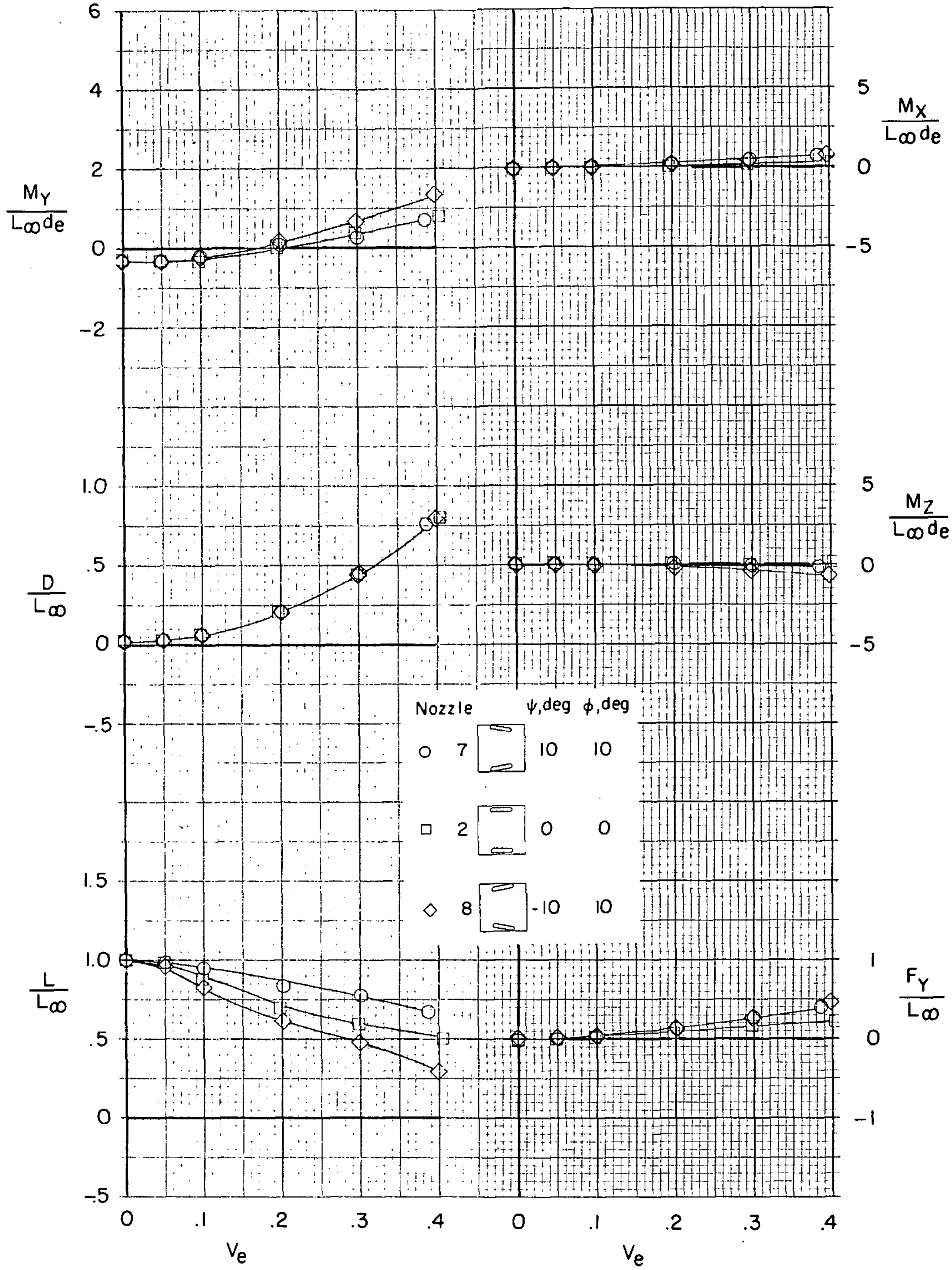
(d) $h/d_e = 2.$

Figure 6.- Continued.



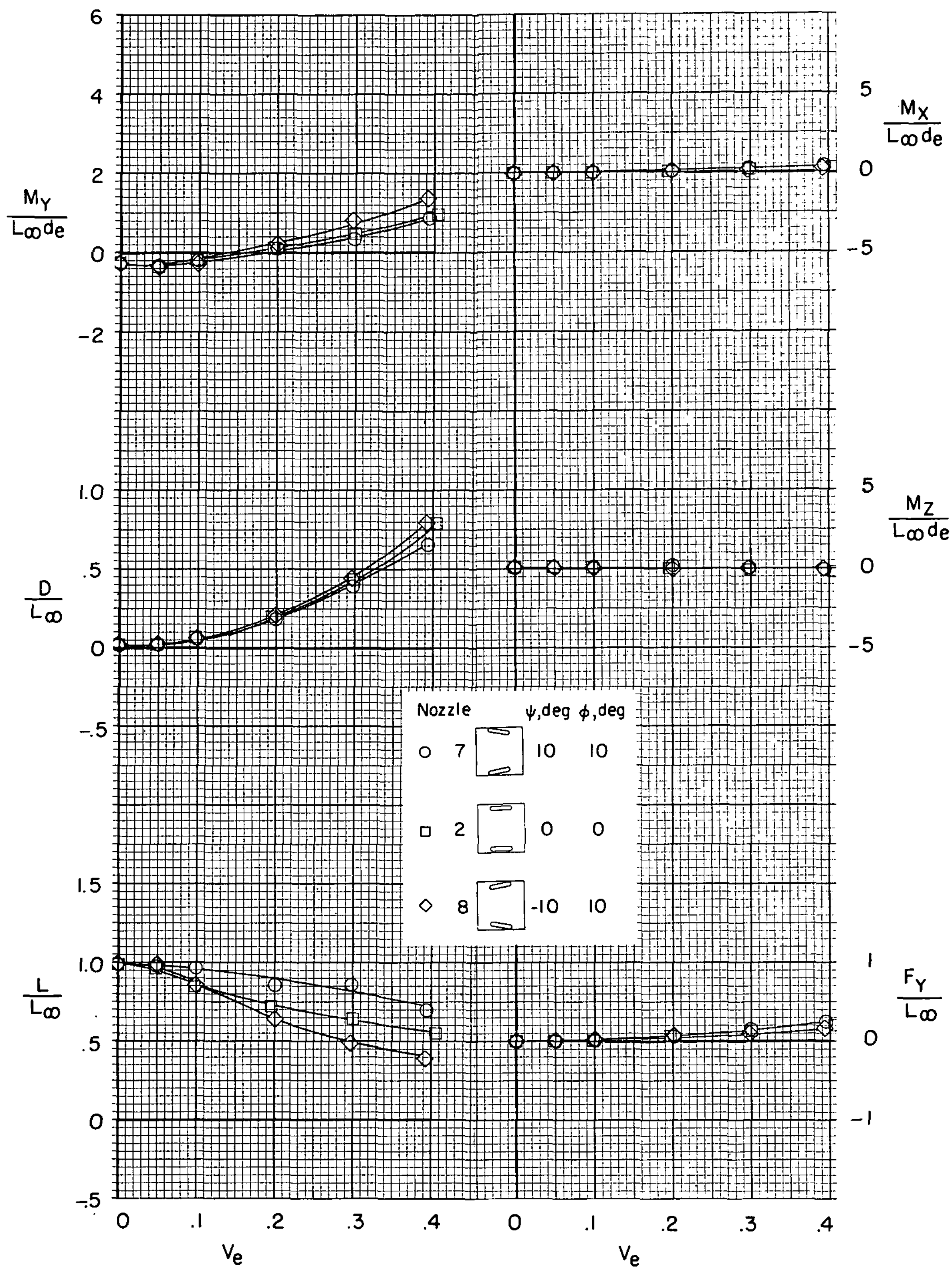
(e) $h/d_e = 1$.

Figure 6.- Concluded.



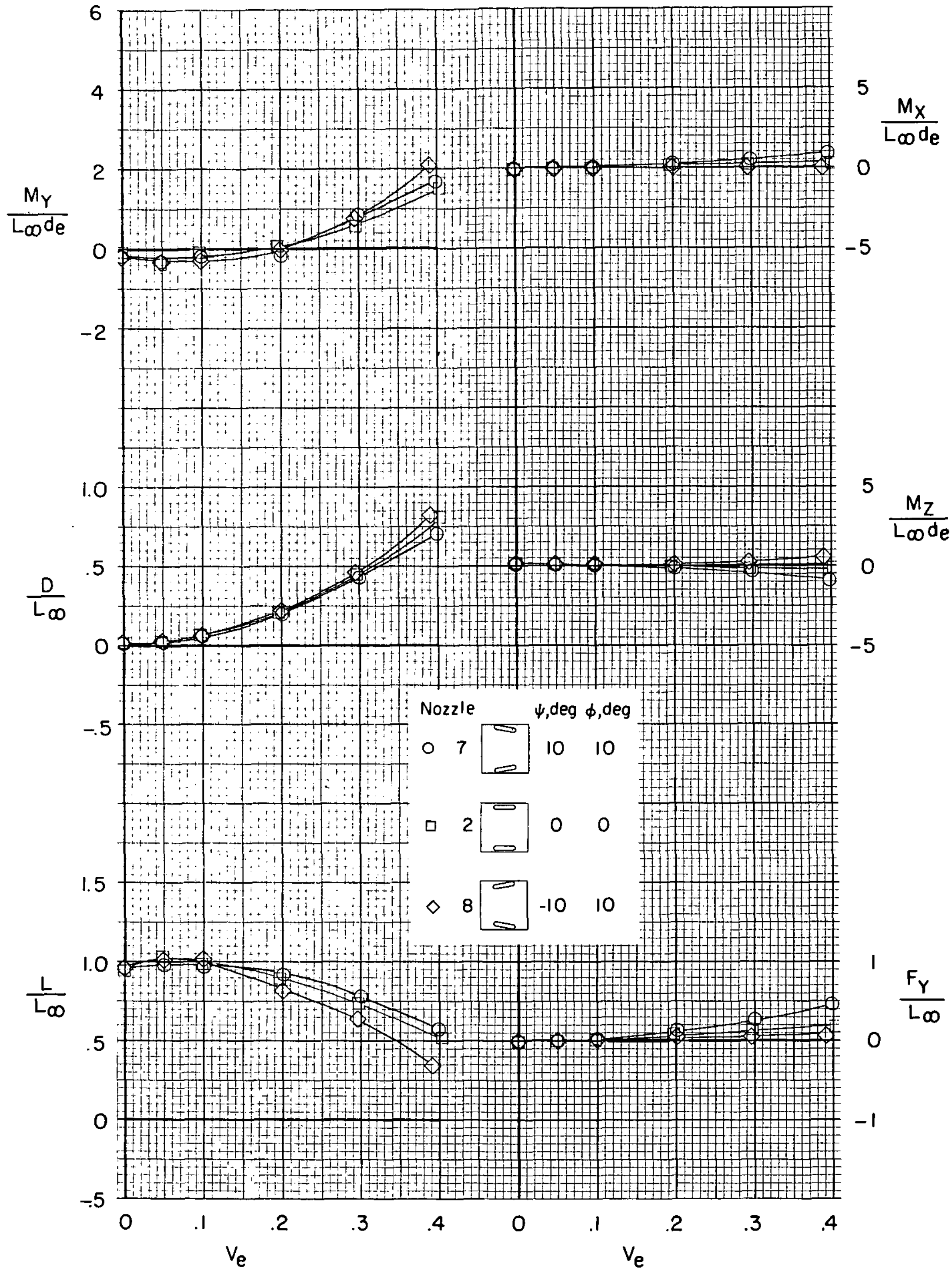
(a) $h/d_e = 28$.

Figure 7.- Effect of combination of slot yaw and jet inclination on the longitudinal aerodynamic characteristics of the model at various heights above the ground plane. $y/b = 0.8$.



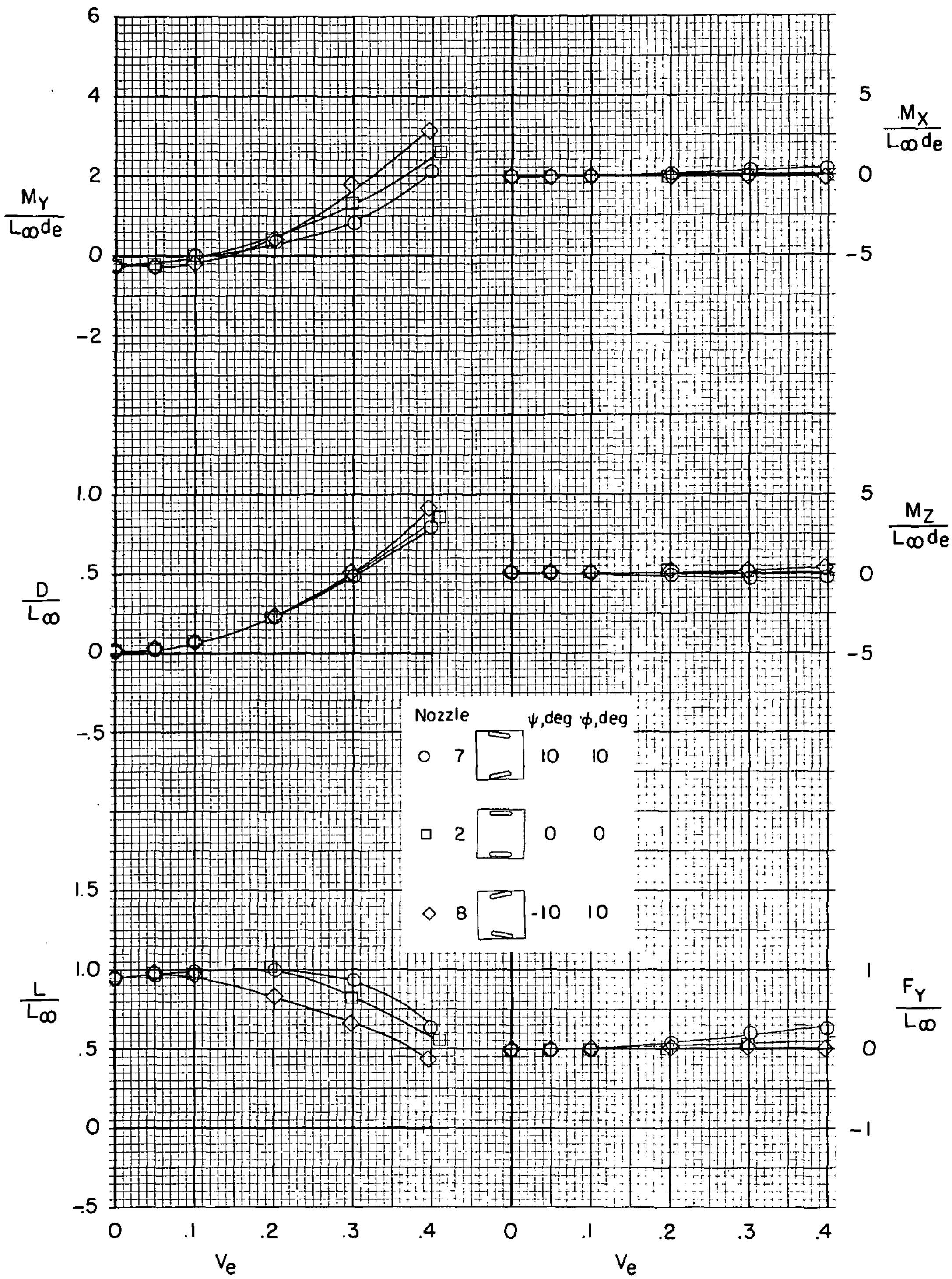
(b) $h/d_e = 8$.

Figure 7.- Continued.



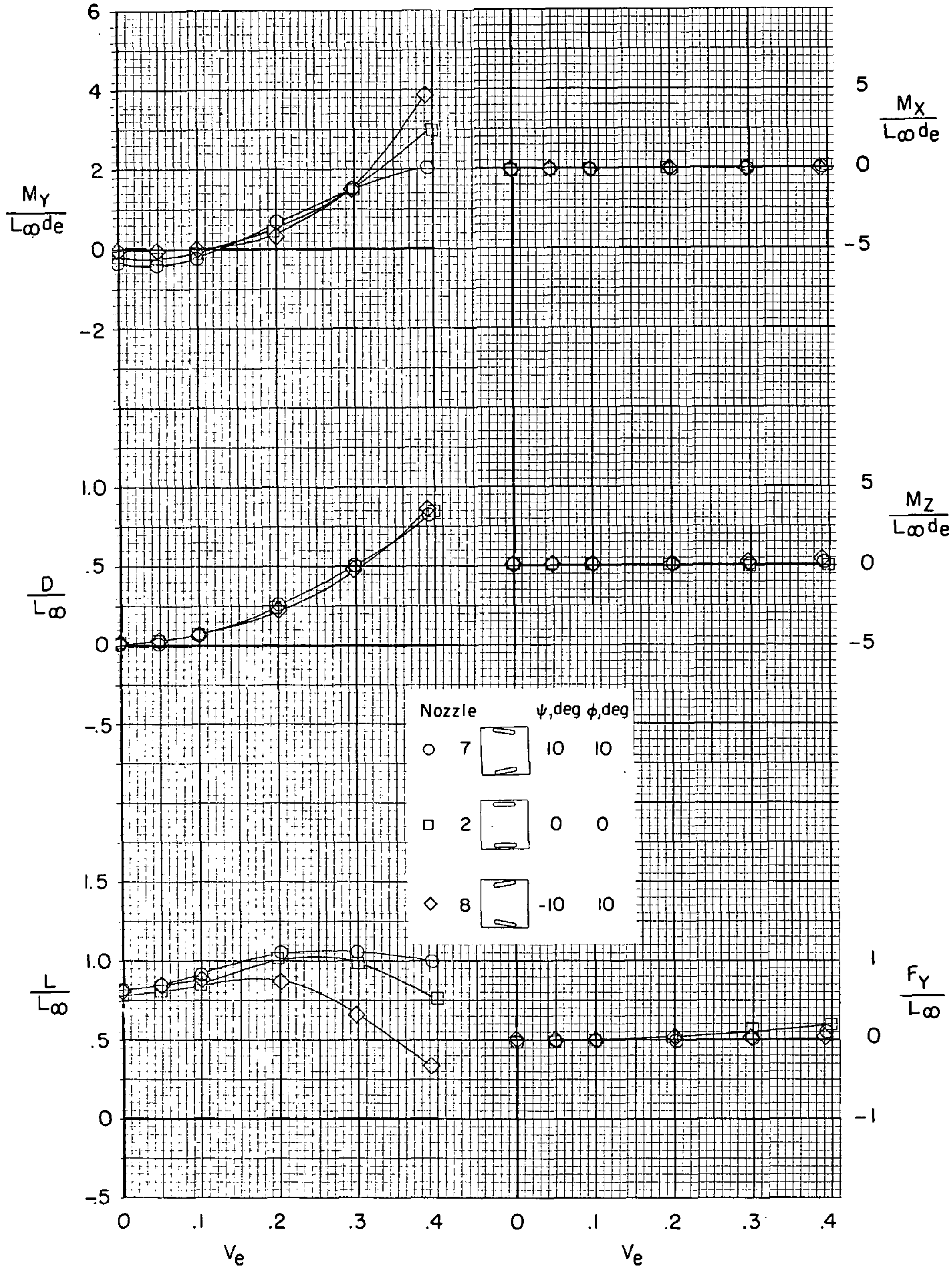
(c) $h/d_e = 4$.

Figure 7.- Continued.



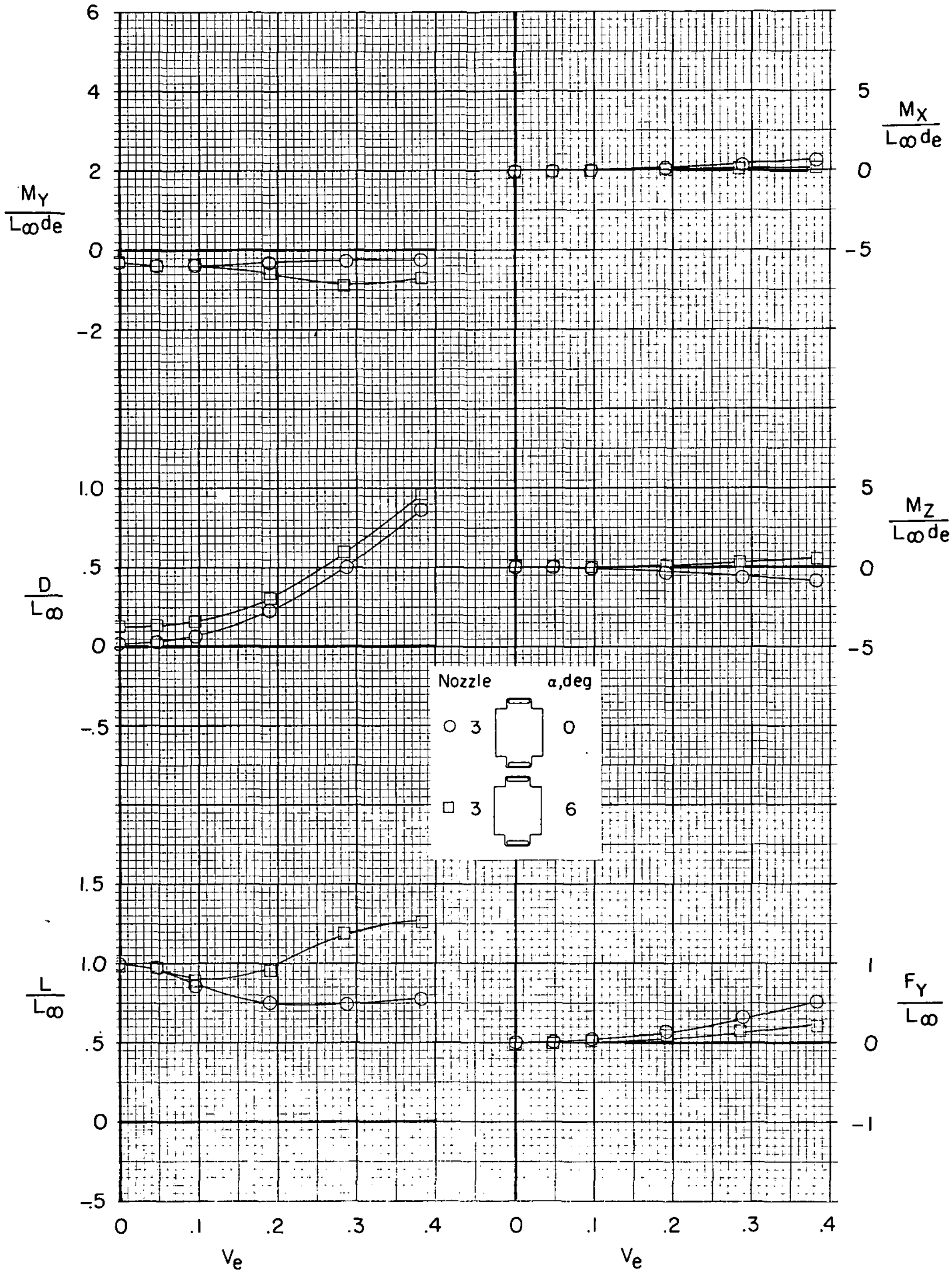
(d) $h/d_e = 2.$

Figure 7.- Continued.



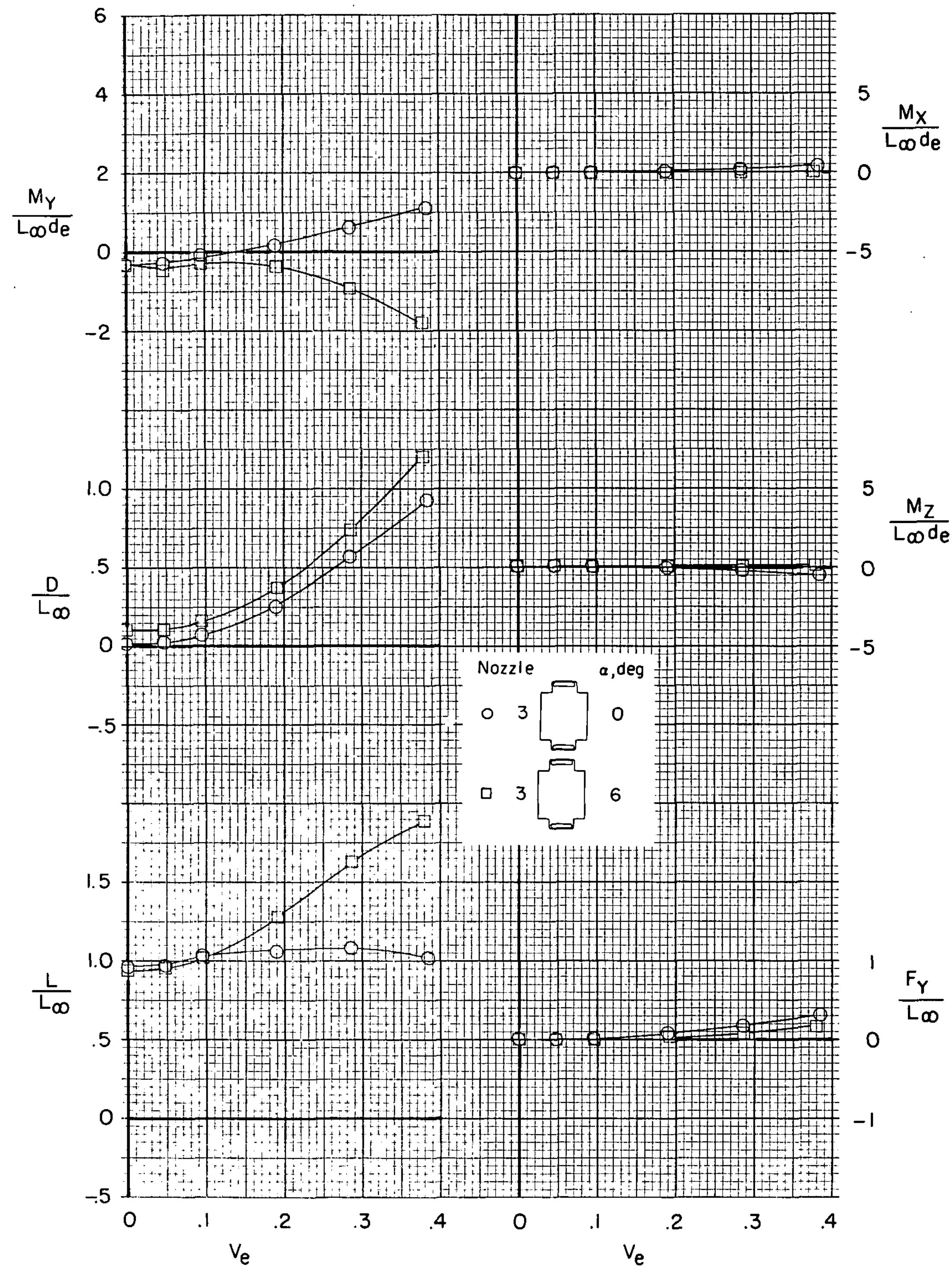
(e) $h/d_e = 1.$

Figure 7.- Concluded.



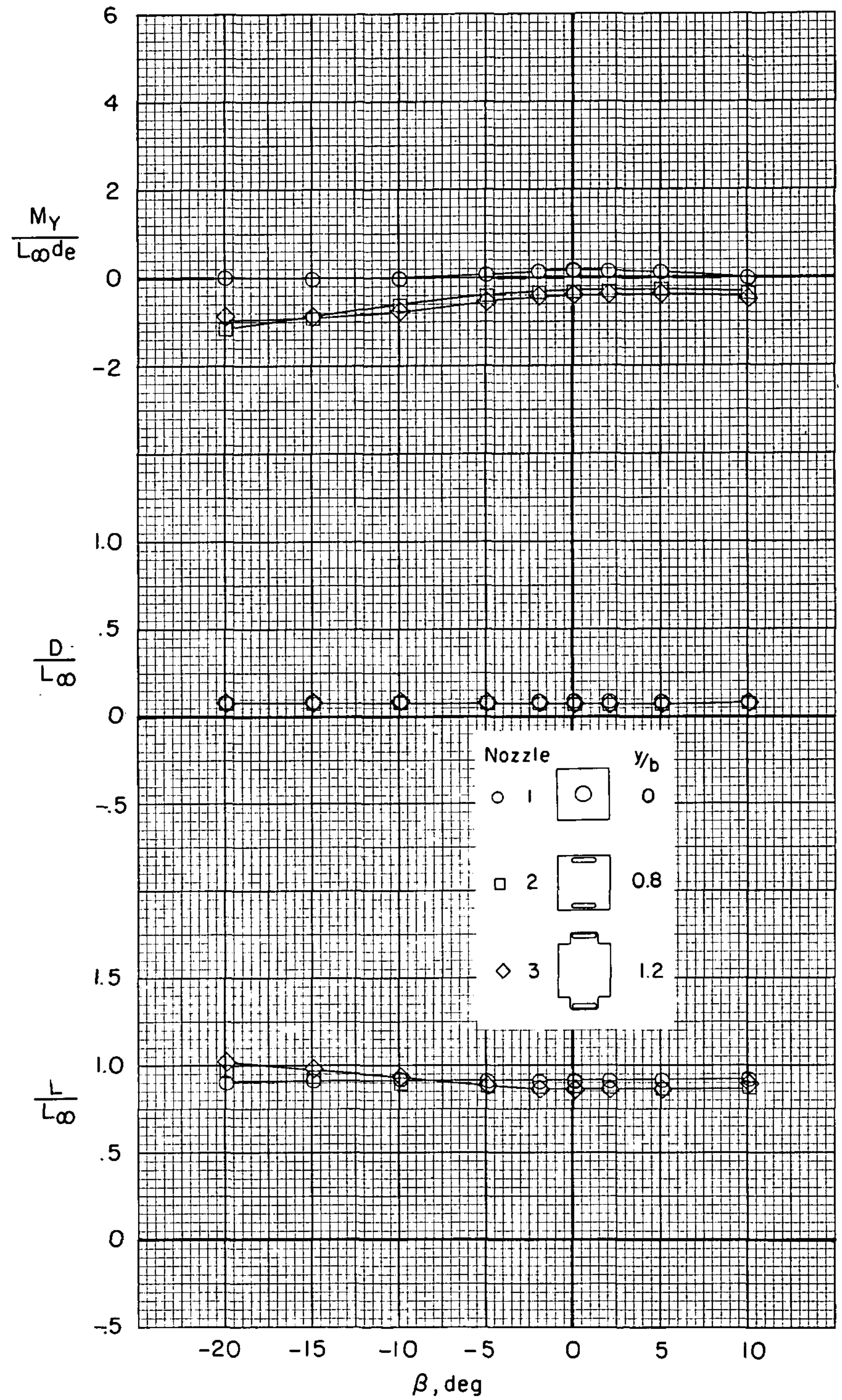
(a) $h/d_e = 28.$

Figure 8.- Effect of angle of attack on the longitudinal aerodynamic characteristics of the model at two heights above the ground plane. $\psi = 0^o$; $\phi = 0^o$; $y/b = 1.2$.



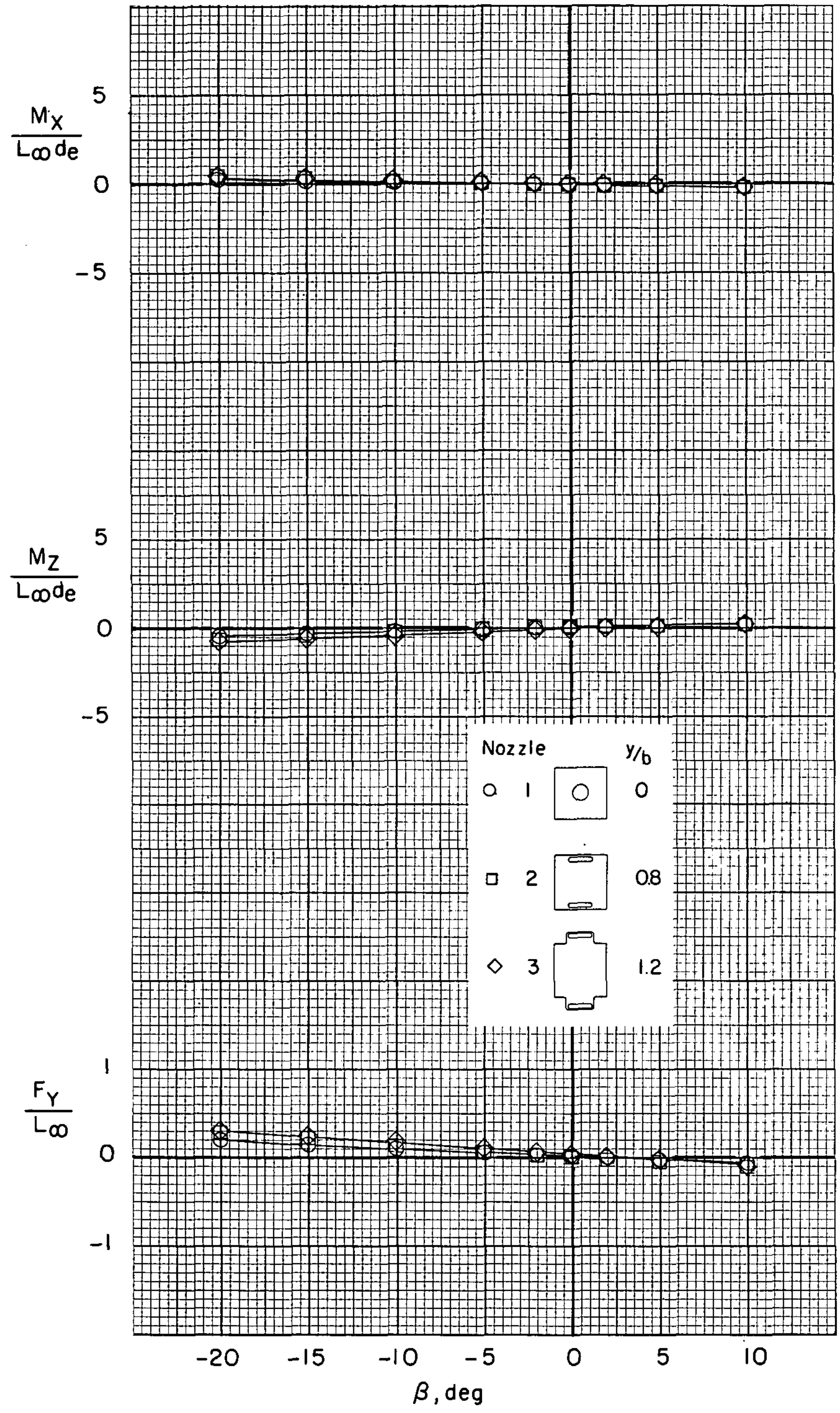
(b) $h/d_e = 2$.

Figure 8.- Concluded.



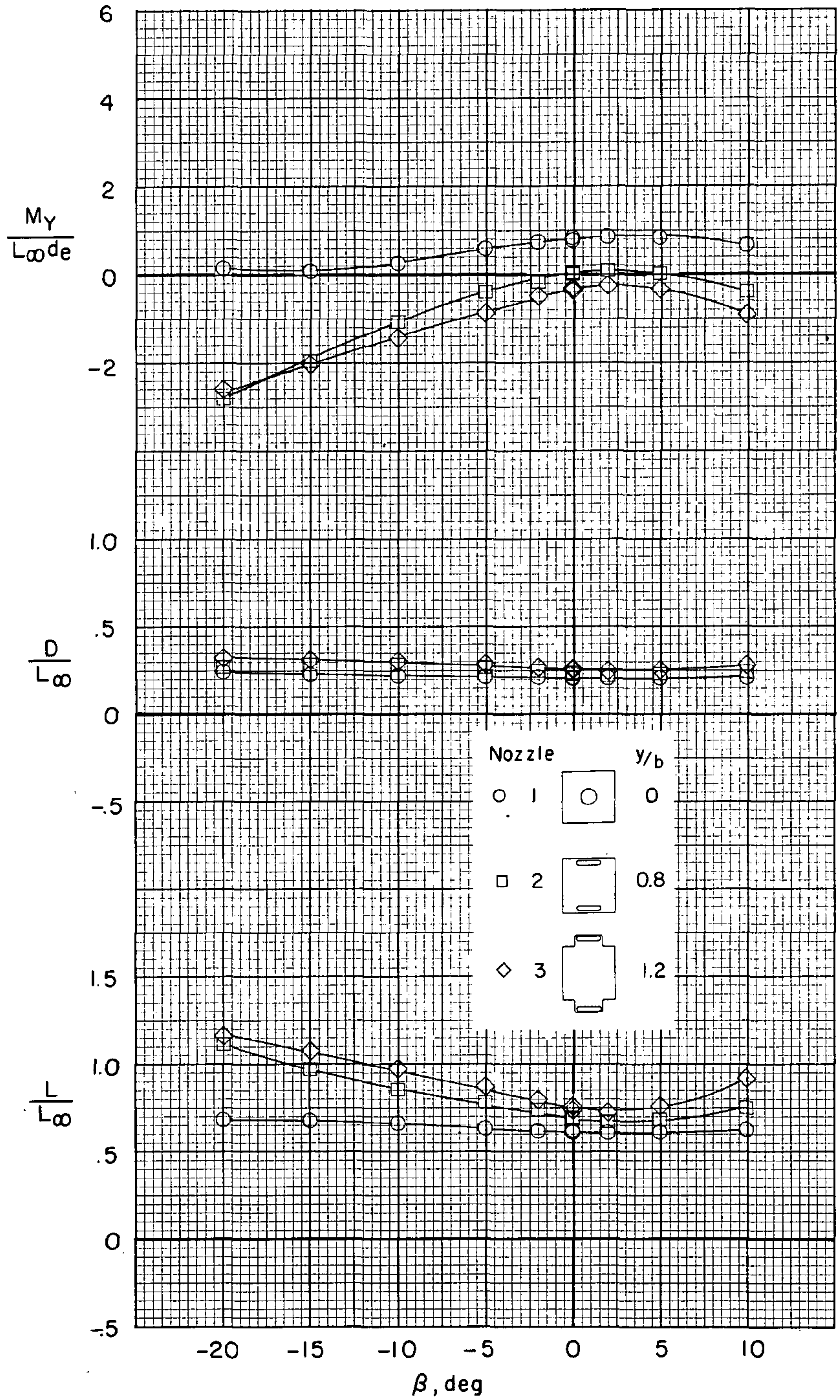
(a) $V_e = 0.10$.

Figure 9.- Effect of spanwise location of the slots on the aerodynamic characteristics of the model in sideslip out of ground effect. $\alpha = 0^{\circ}$; $\psi = 0^{\circ}$; $\phi = 0^{\circ}$; $h/d_e = 28$.



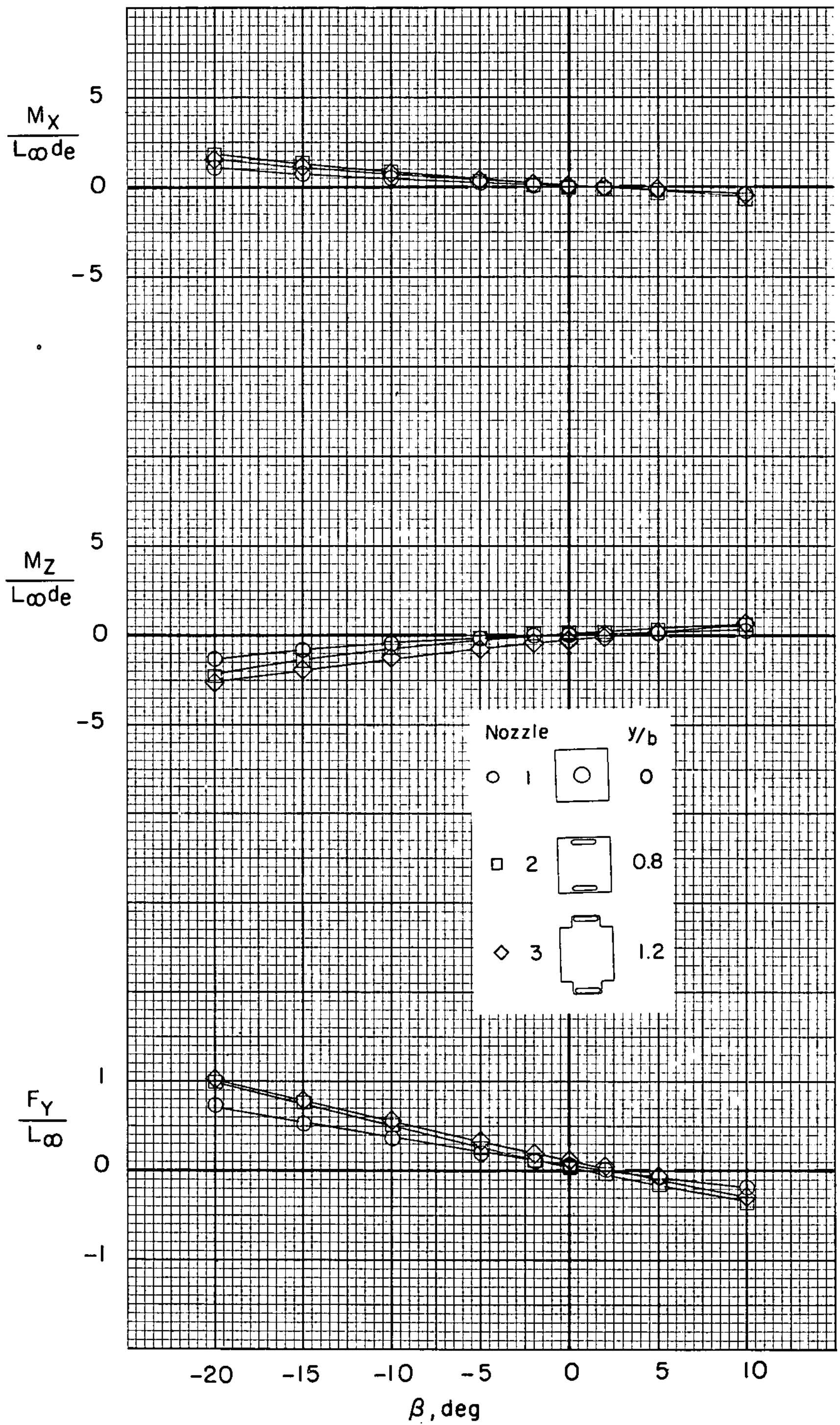
(a) Concluded.

Figure 9.- Continued.



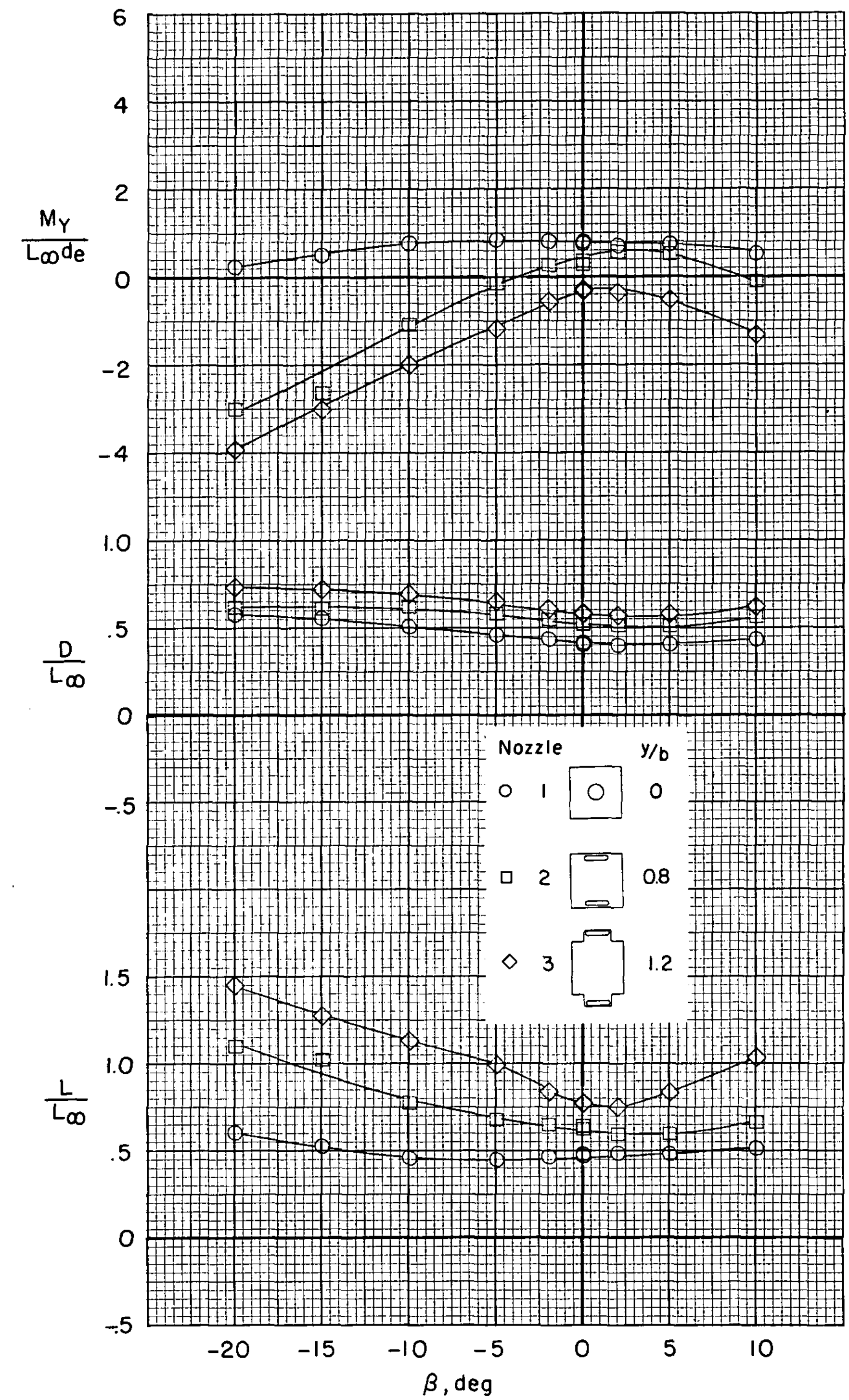
(b) $V_e = 0.20$.

Figure 9.- Continued.



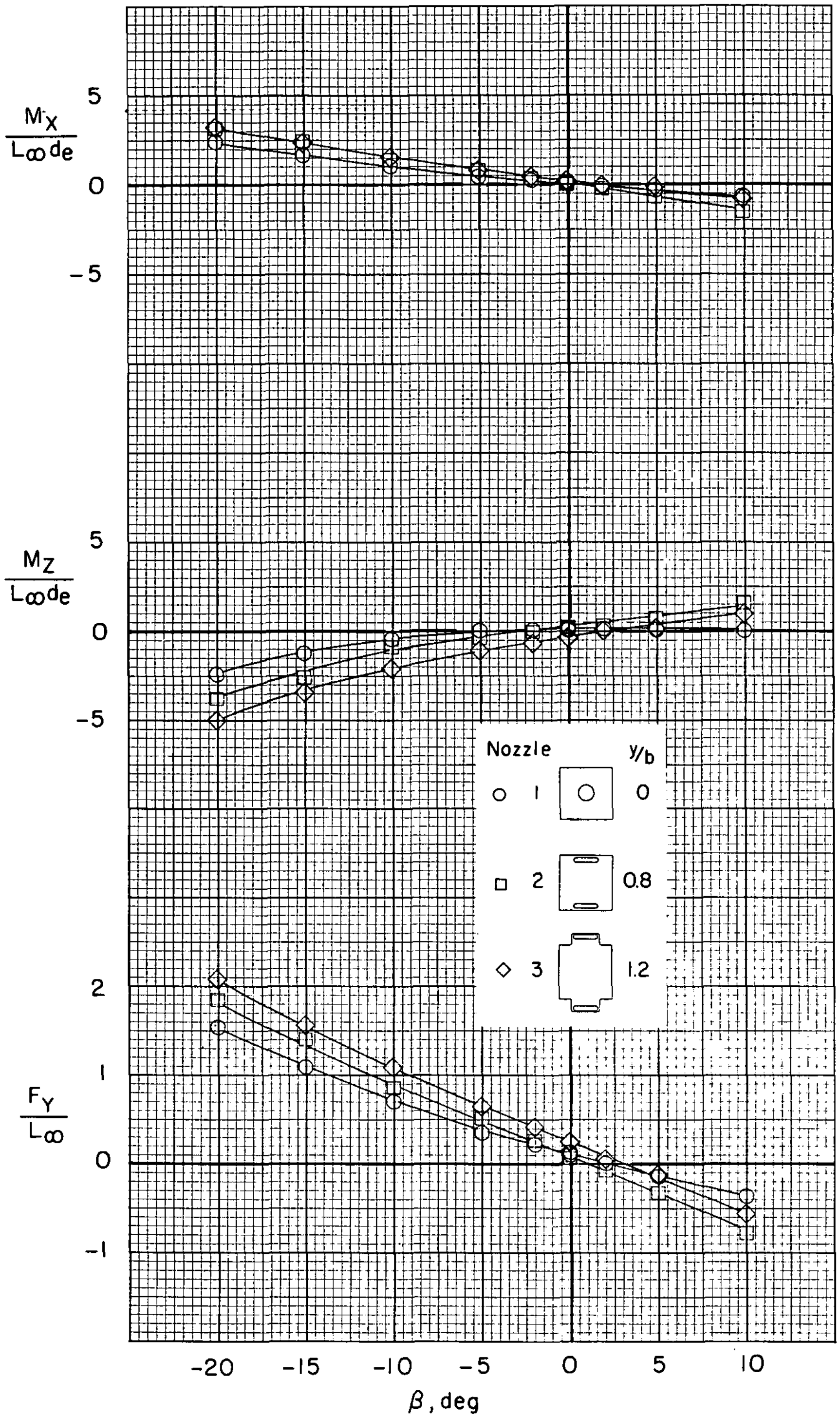
(b) Concluded.

Figure 9.- Continued.



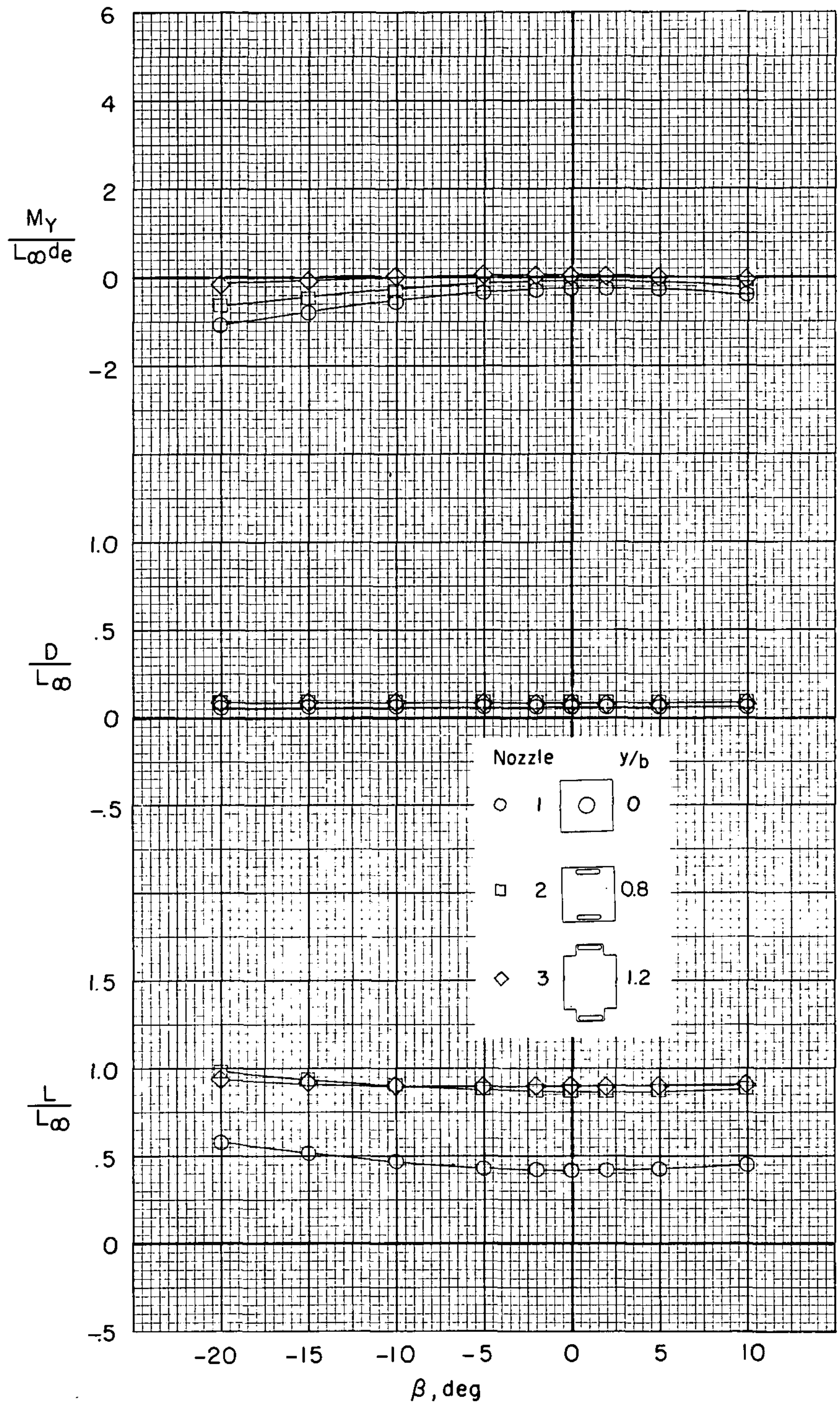
(c) $V_e = 0.30$.

Figure 9.- Continued.



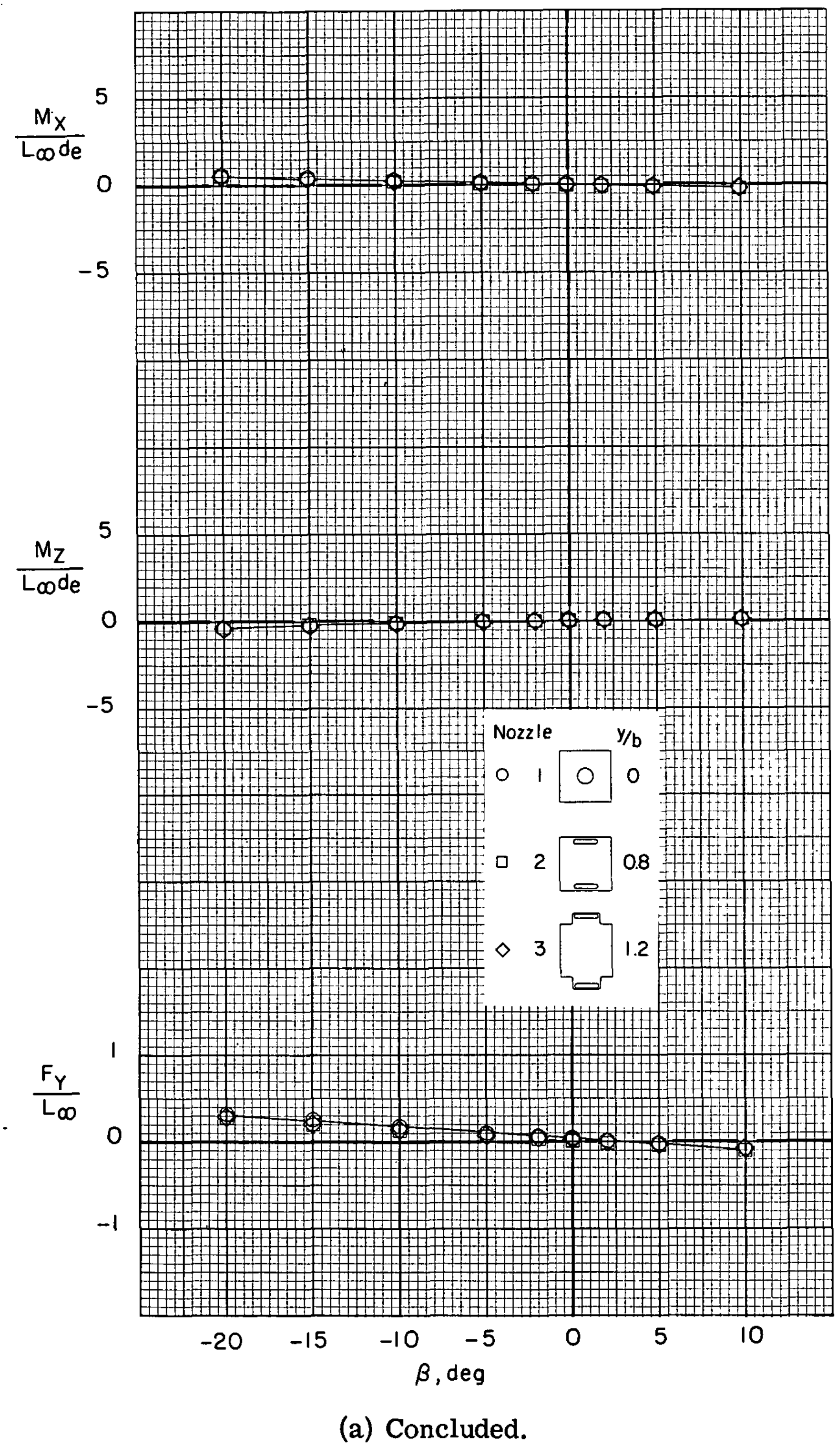
(c) Concluded.

Figure 9.- Concluded.



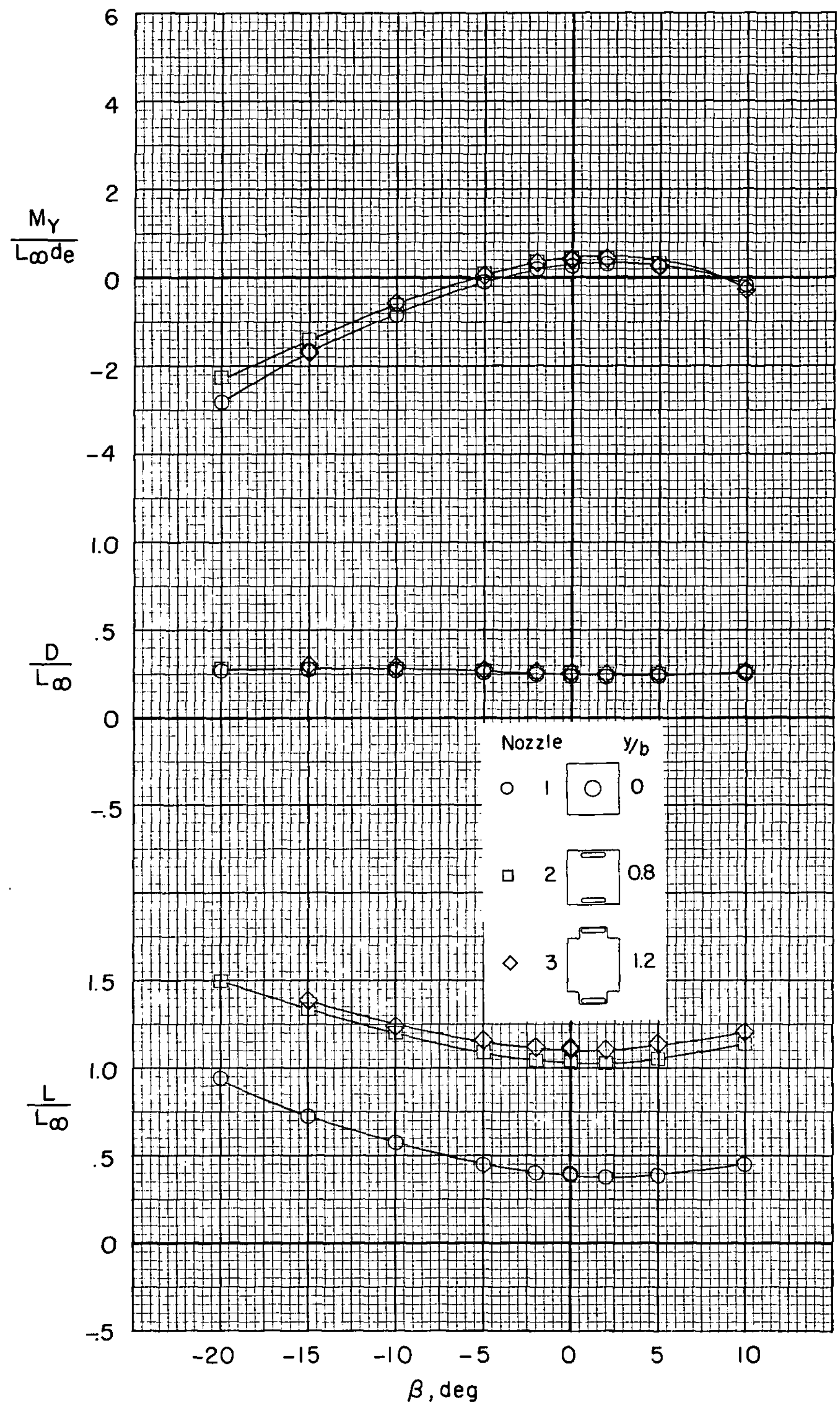
(a) $V_e = 0.10$.

Figure 10.- Effect of spanwise location of the slots on the aerodynamic characteristics of the model in sideslip in ground effect. $\alpha = 0^o$; $\psi = 0^o$; $\phi = 0^o$; $h/d_e = 1$.



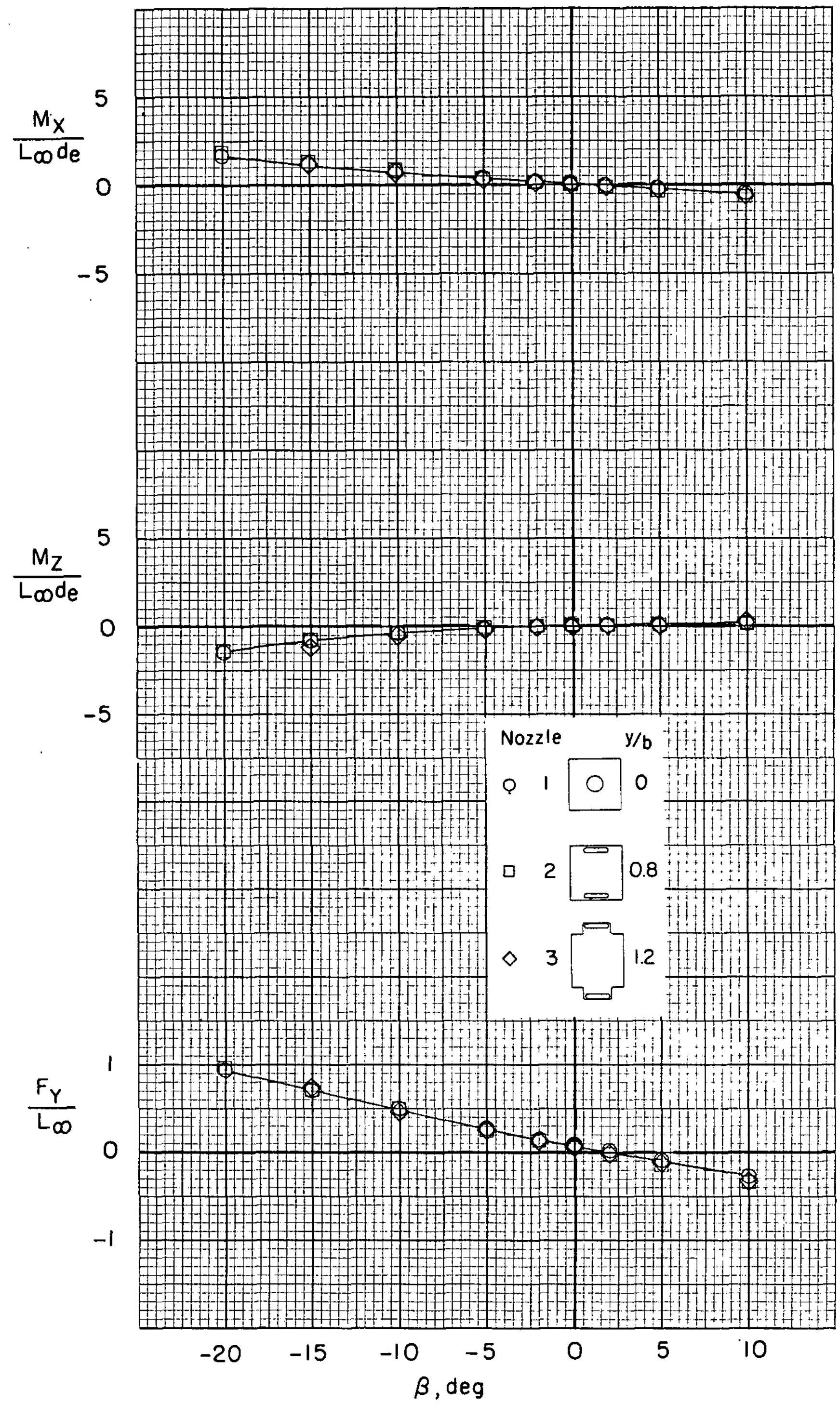
(a) Concluded.

Figure 10.- Continued.



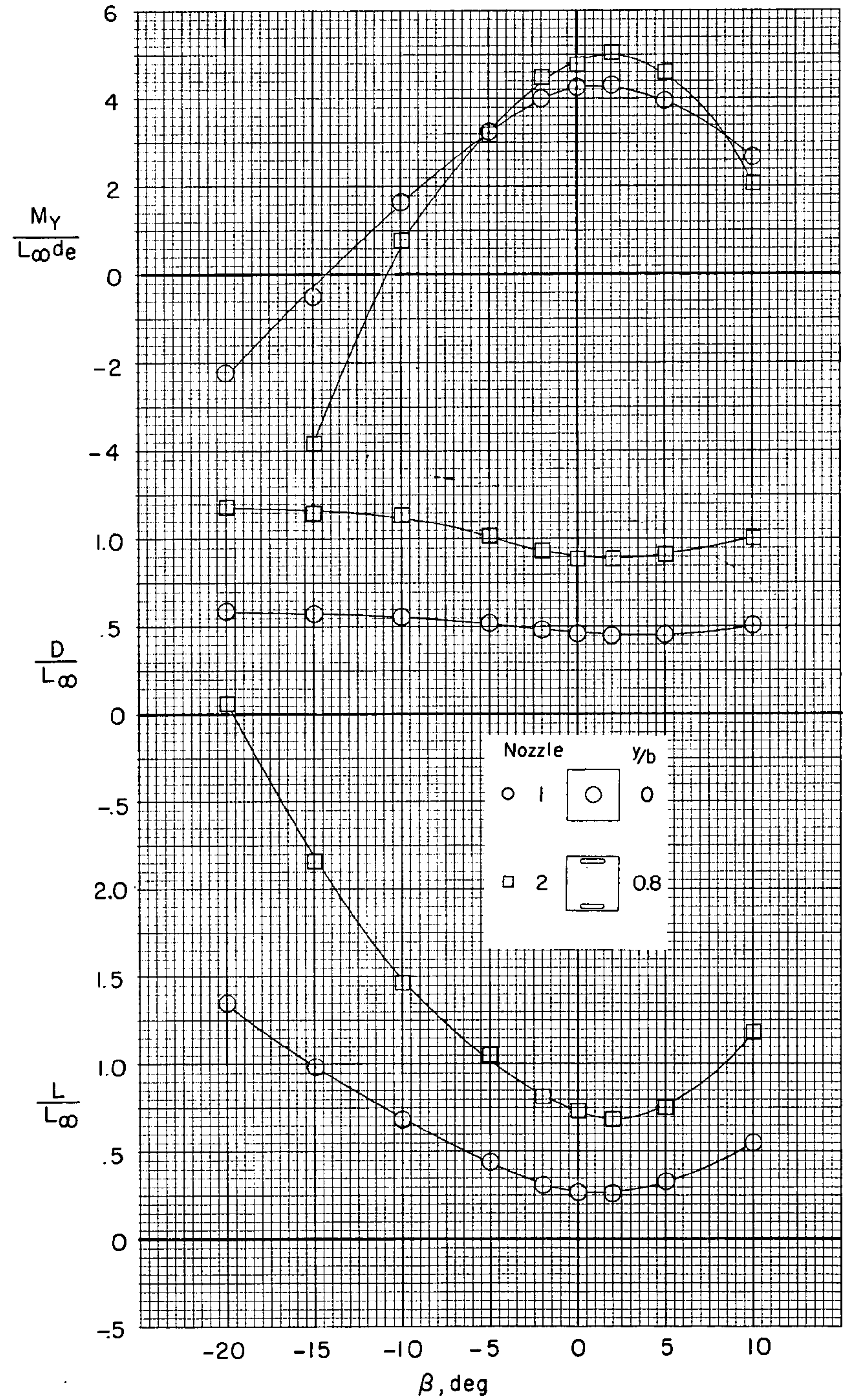
(b) $V_e = 0.20$.

Figure 10.- Continued.



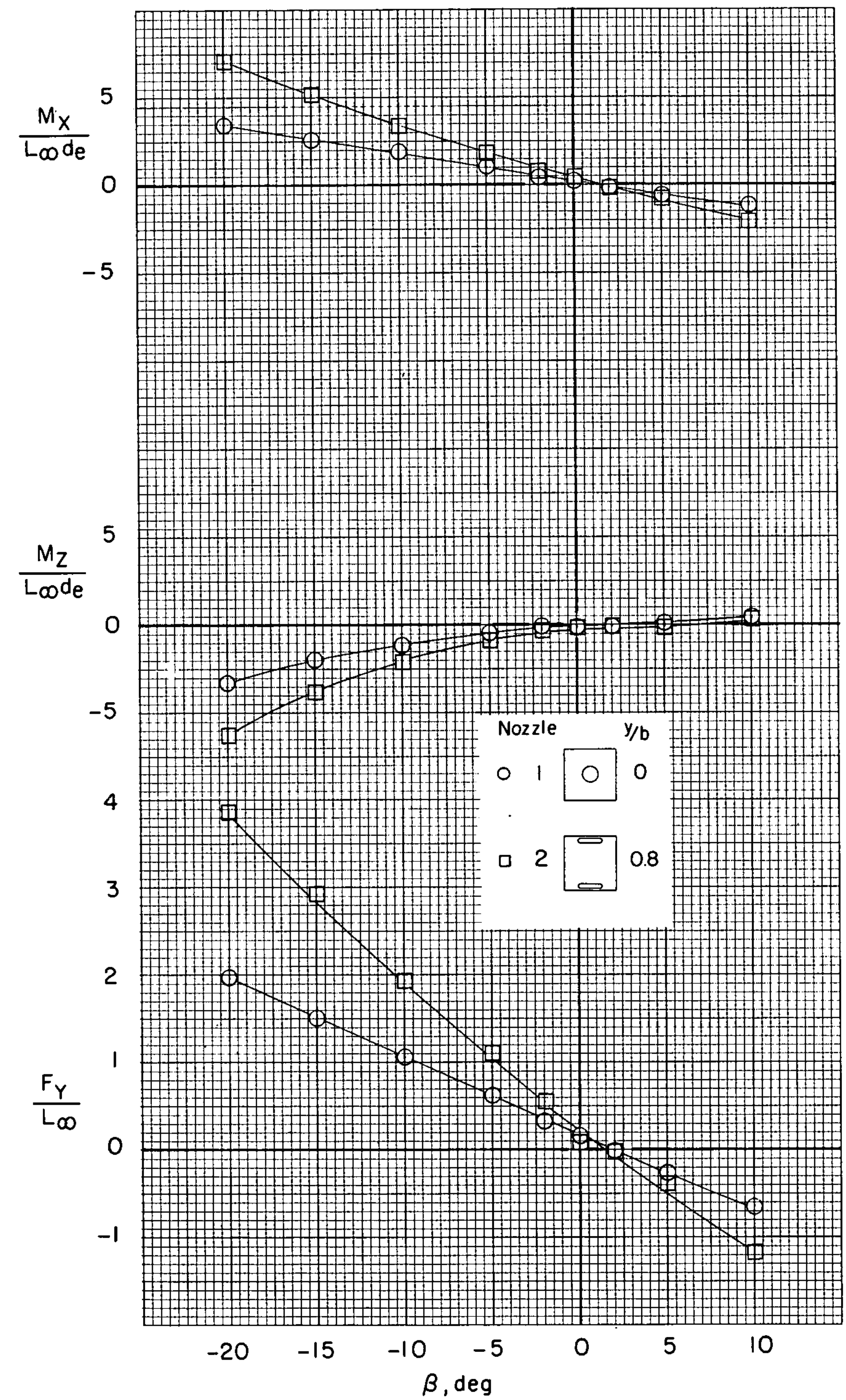
(b) Concluded.

Figure 10.- Continued.



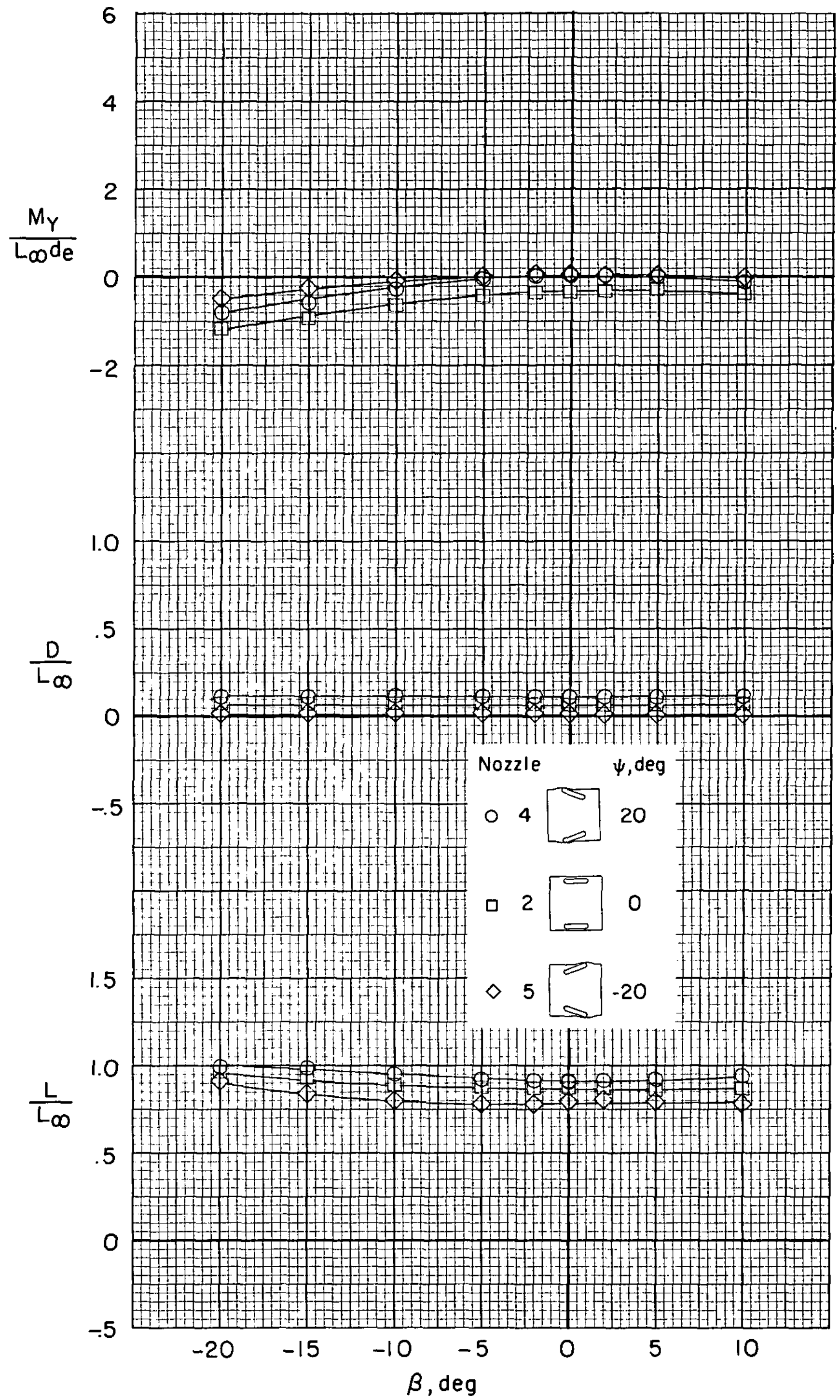
(c) $V_e = 0.40$.

Figure 10.- Continued.



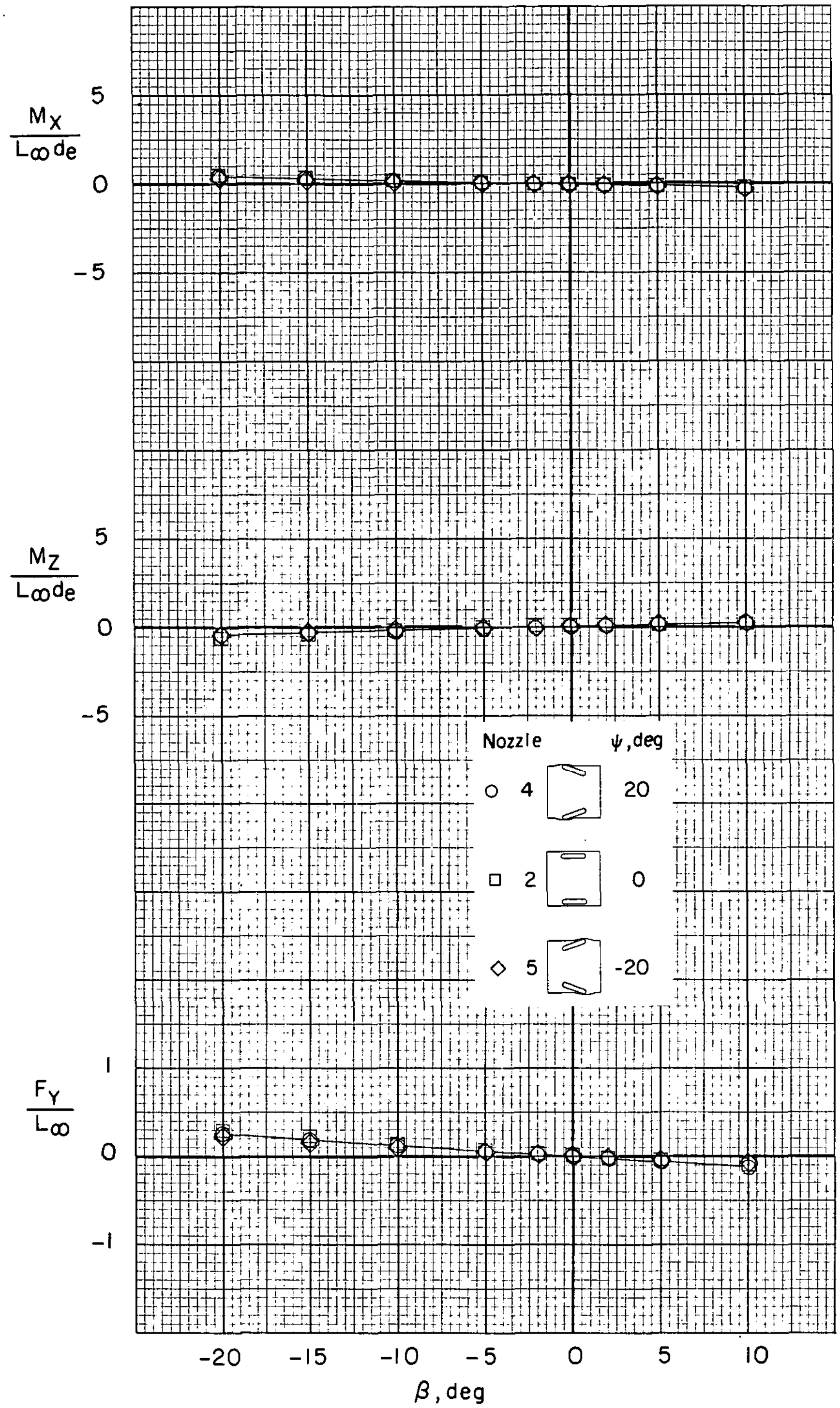
(c) Concluded.

Figure 10.- Concluded.



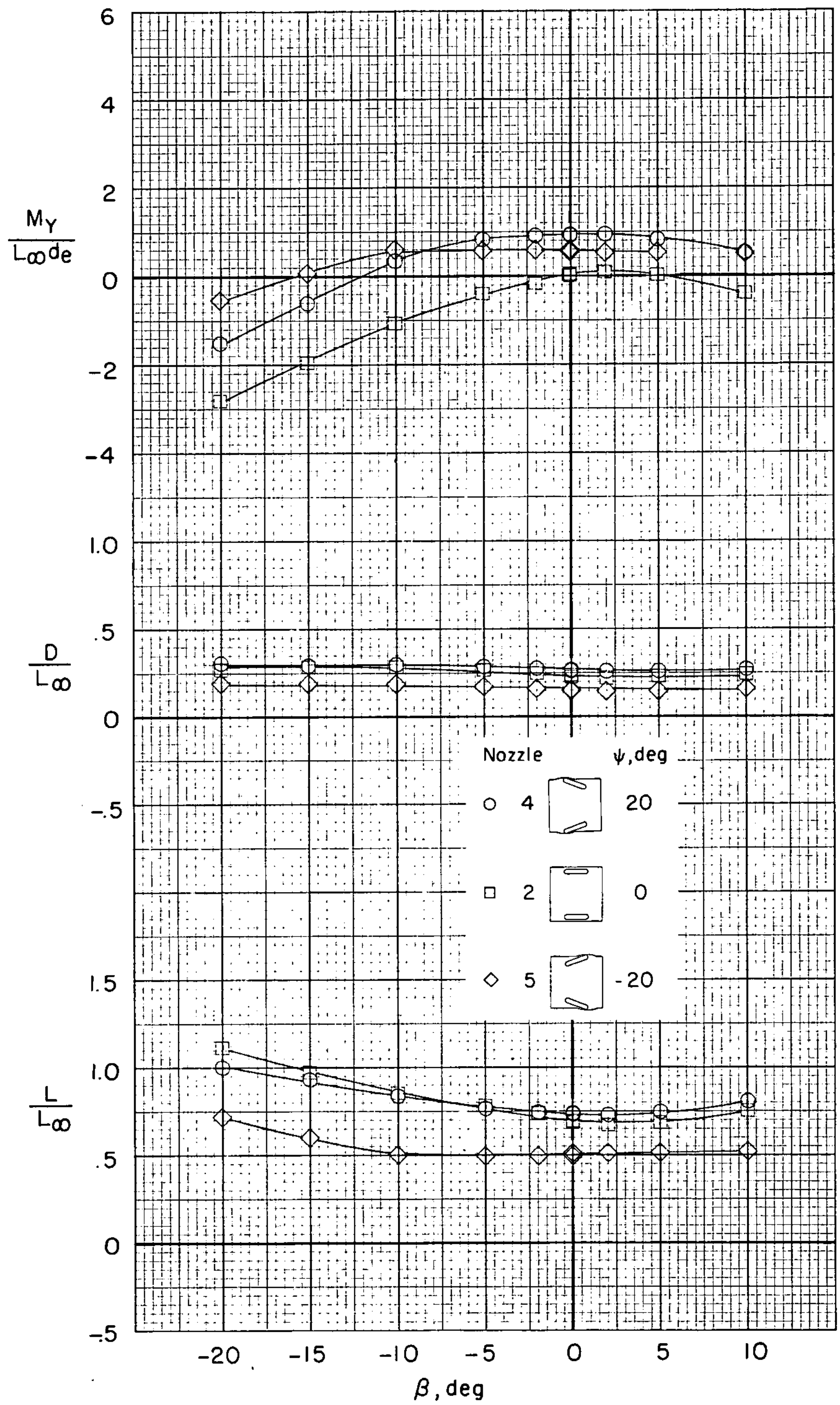
(a) $V_e = 0.10$.

Figure 11.- Effect of slot yaw on the aerodynamic characteristics of the model in sideslip out of ground effect. $\alpha = 0^o$; $\phi = 0^o$; $h/d_e = 28$; $y/b = 0.8$.



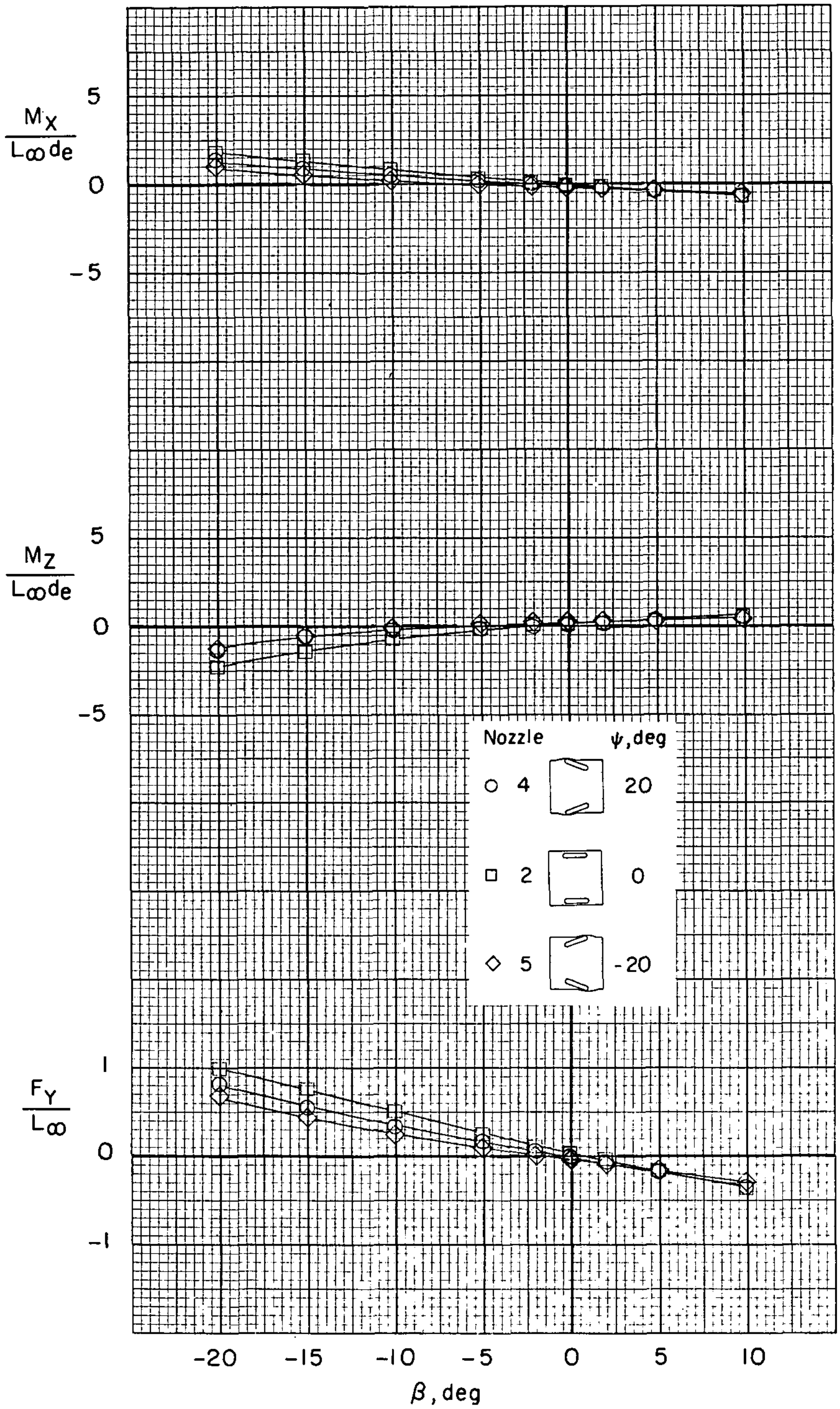
(a) Concluded.

Figure 11.- Continued.



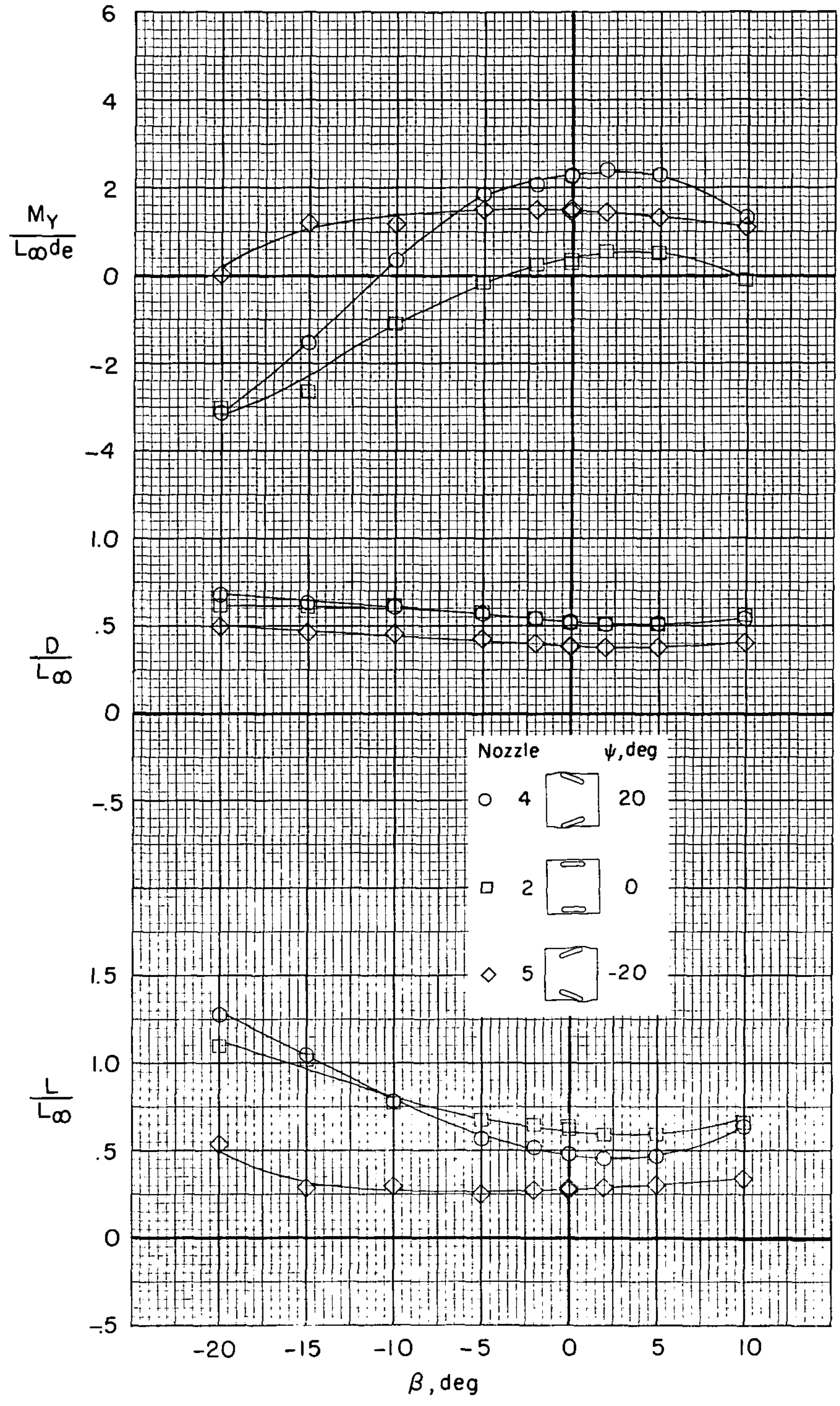
(b) $V_e = 0.20$.

Figure 11.- Continued.



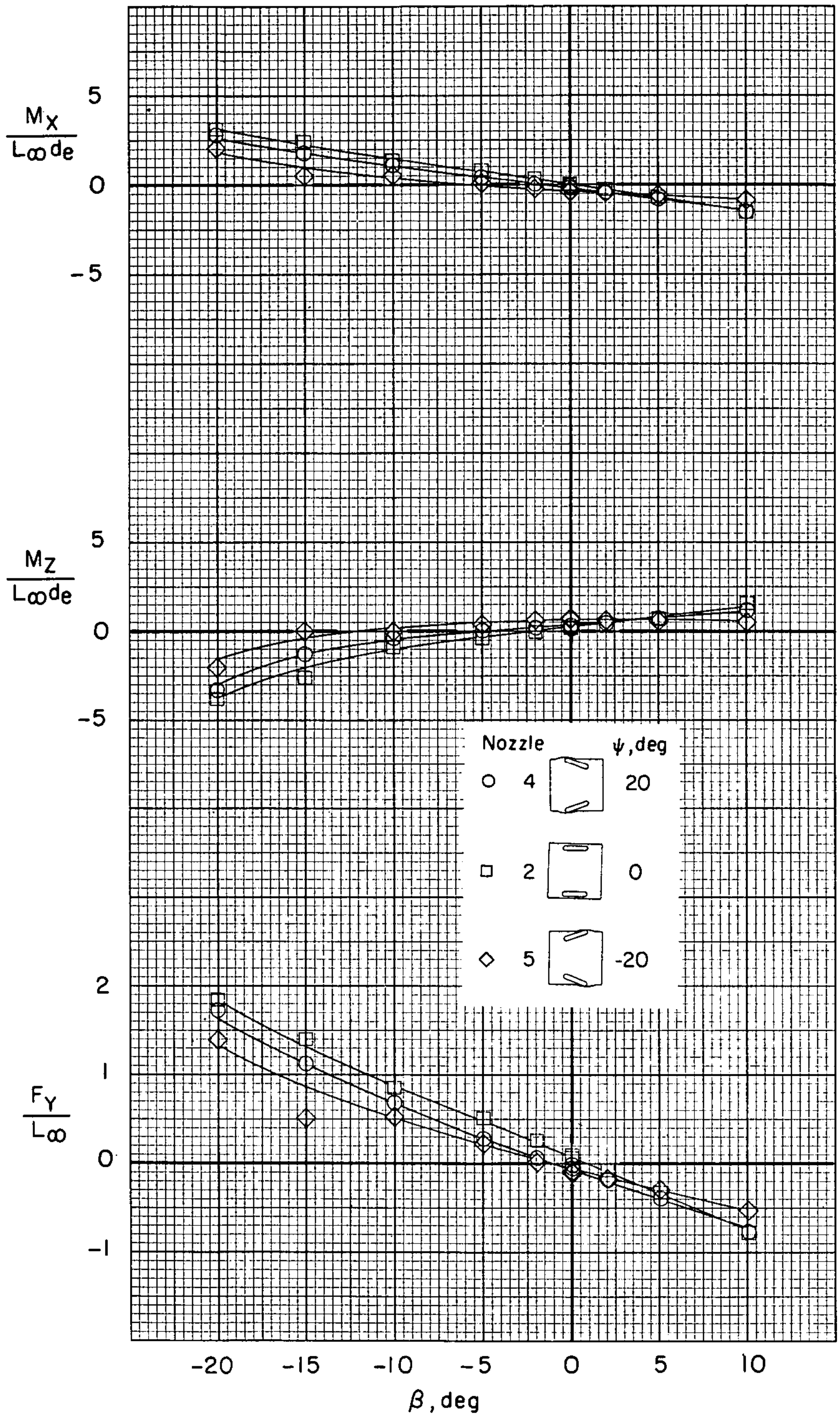
(b) Concluded.

Figure 11.- Continued.



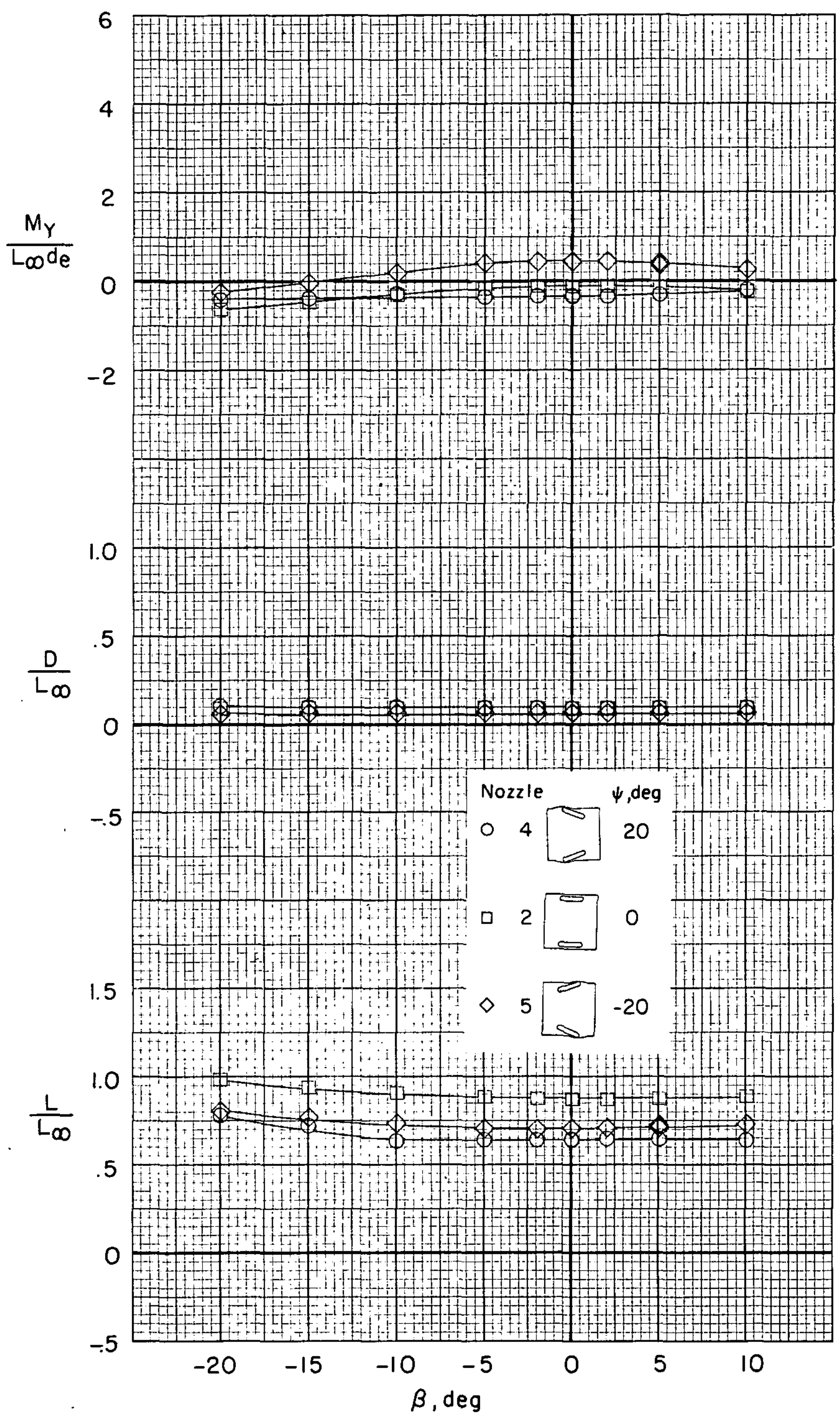
(c) $V_e = 0.30$.

Figure 11.- Continued.



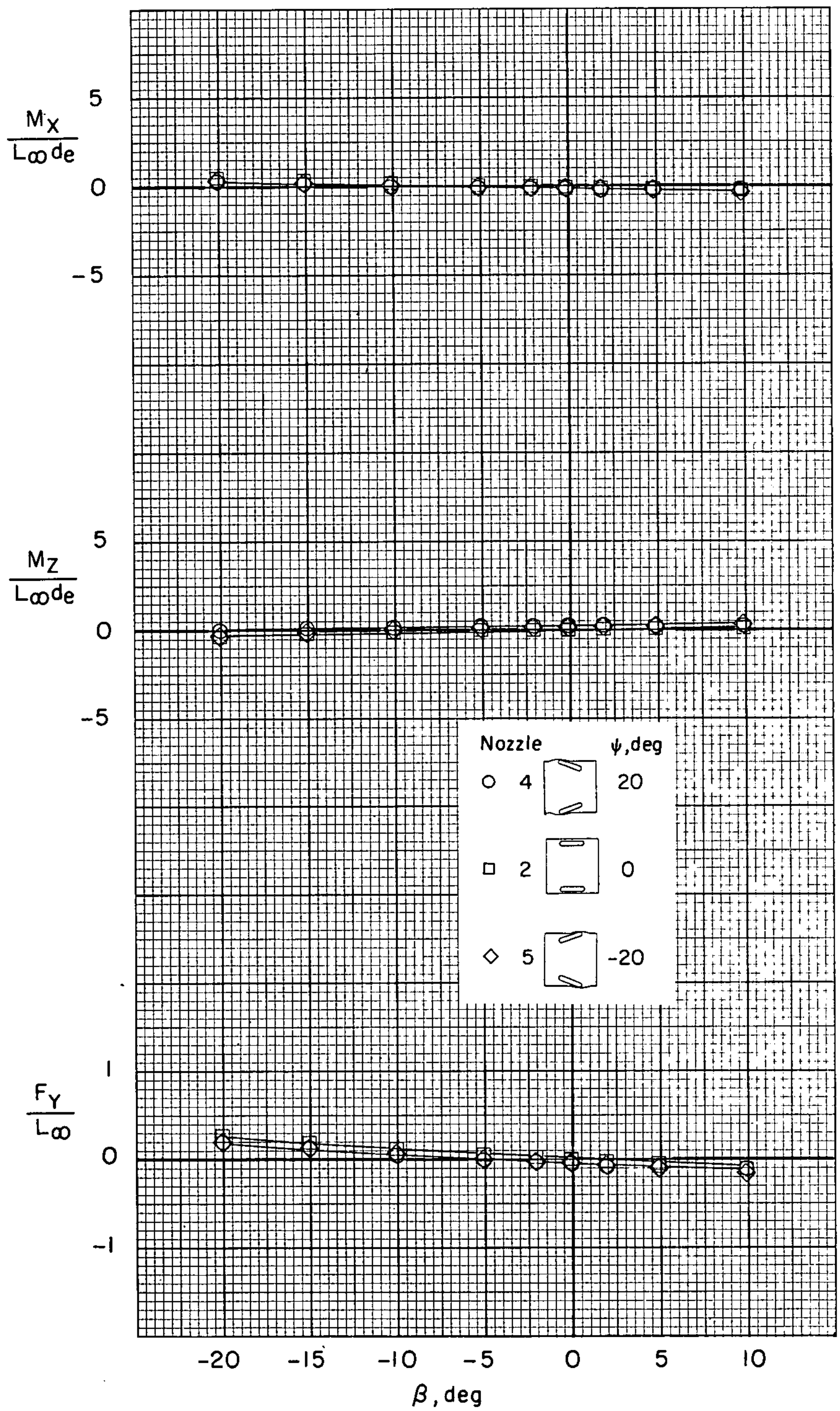
(c) Concluded.

Figure 11.- Concluded.



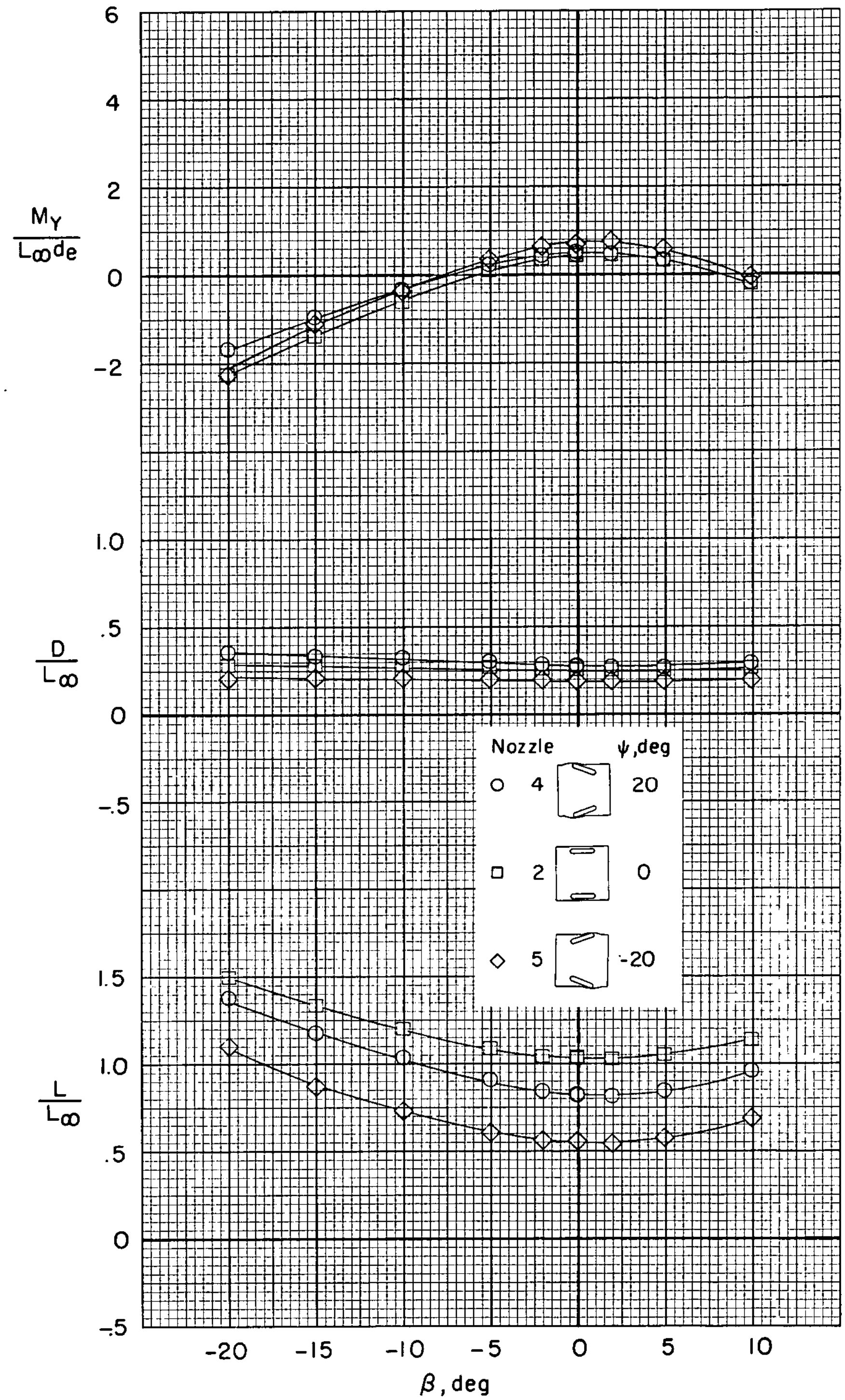
(a) $V_e = 0.10$.

Figure 12.- Effect of slot yaw on the aerodynamic characteristics of the model in sideslip in ground effect. $\alpha = 0^{\circ}$; $\phi = 0^{\circ}$; $h/d_e = 1$; $y/b = 0.8$.



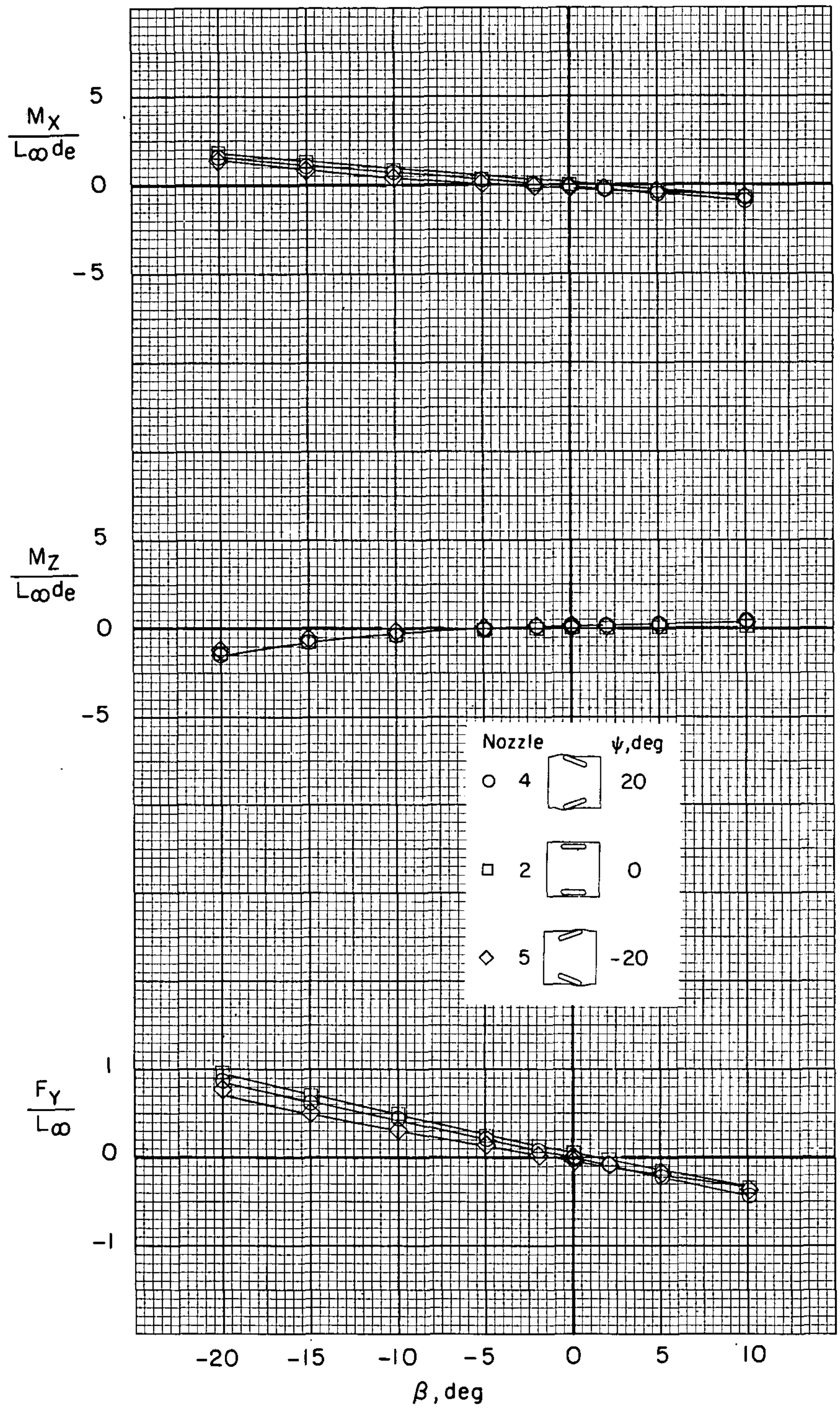
(a) Concluded.

Figure 12.- Continued.



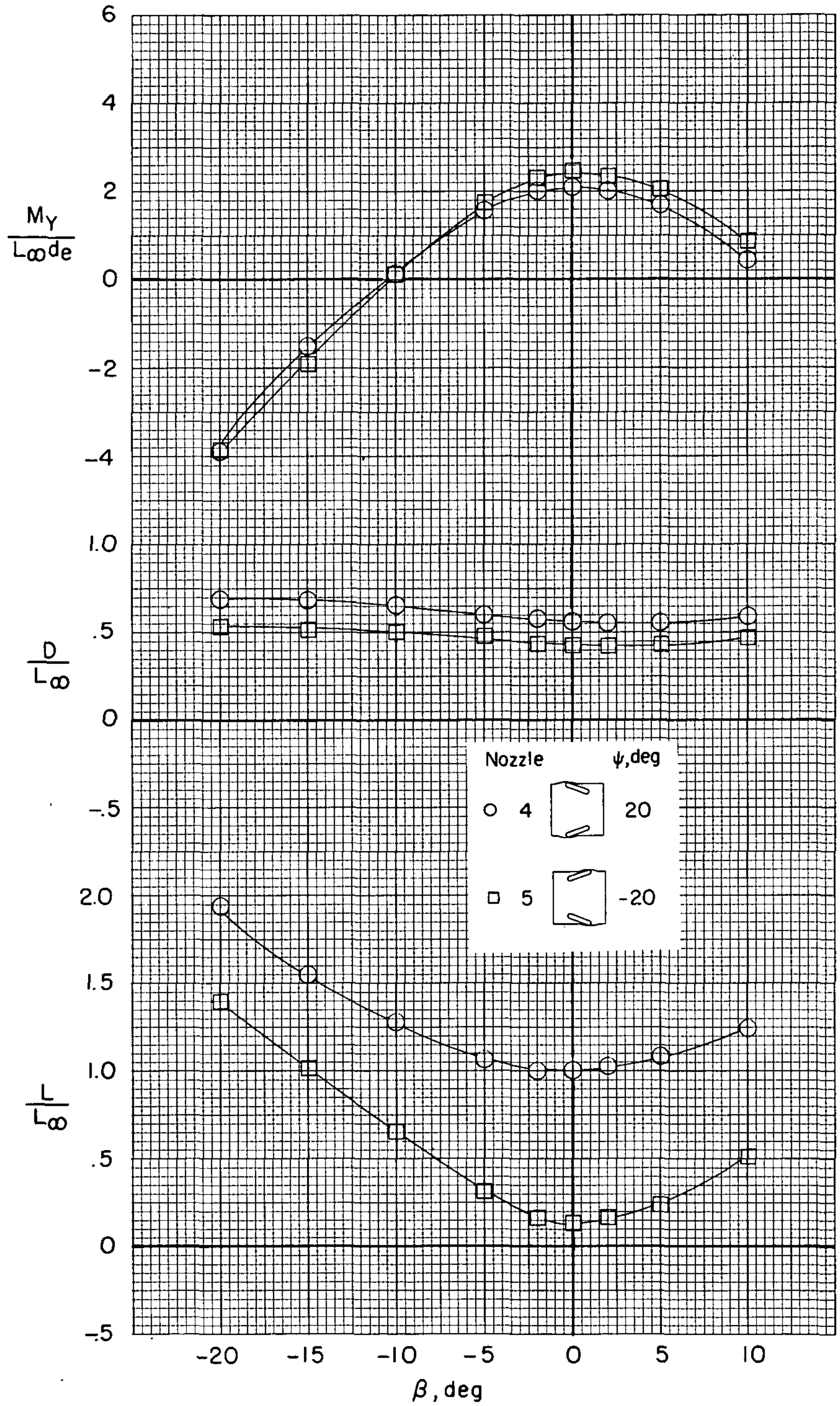
(b) $V_e = 0.20$.

Figure 12.- Continued.



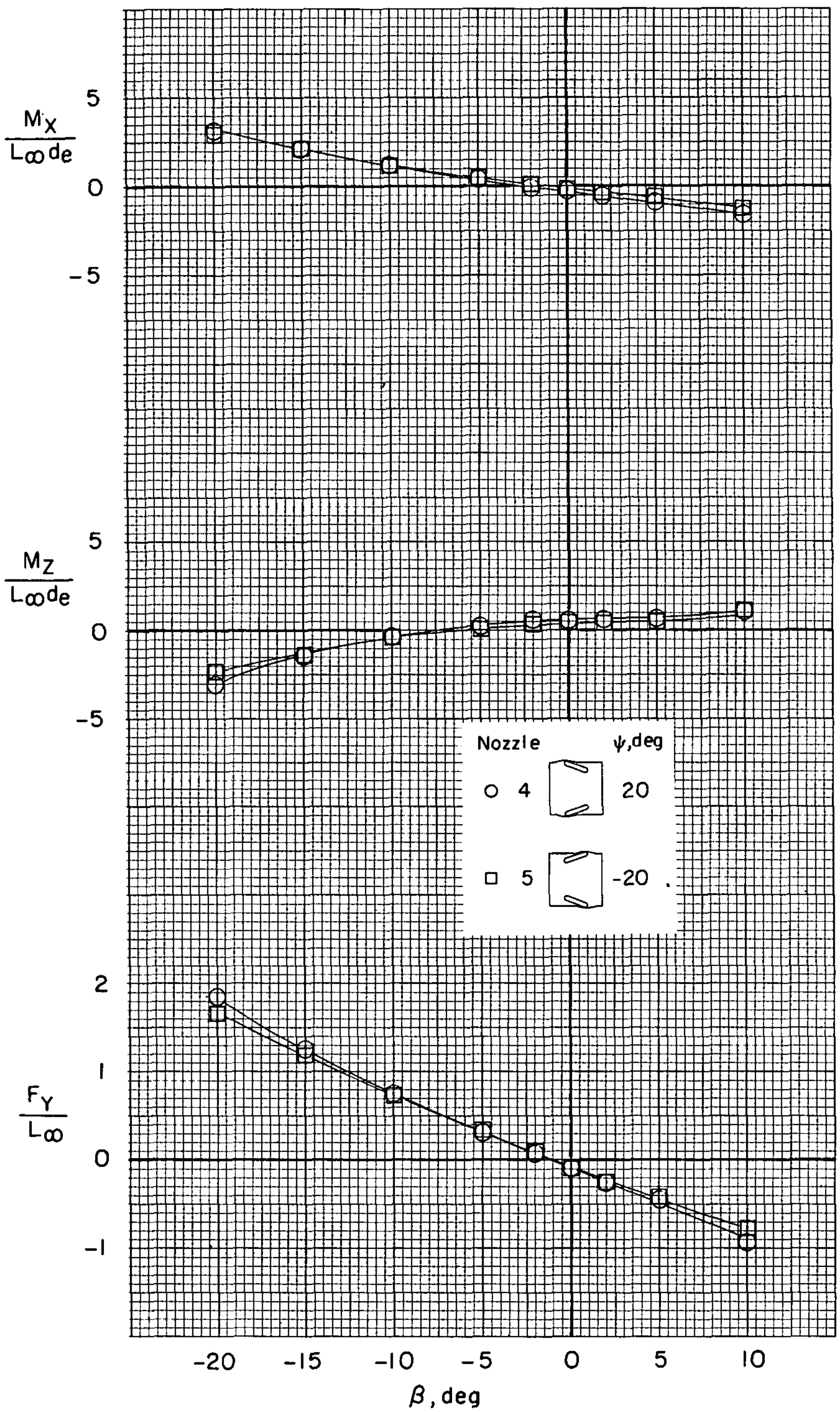
(b) Concluded.

Figure 12.- Continued.



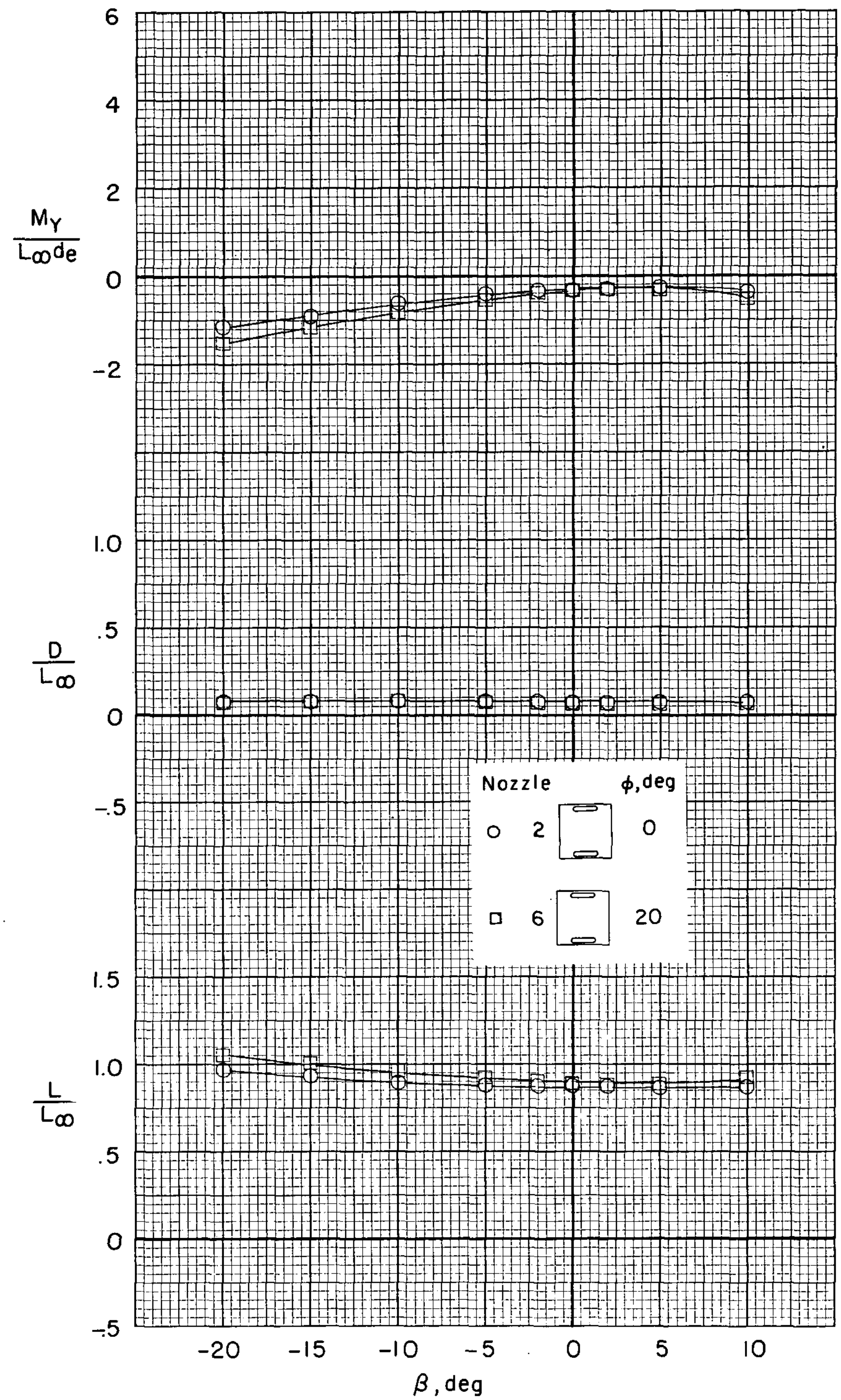
(c) $V_e = 0.30$.

Figure 12.- Continued.



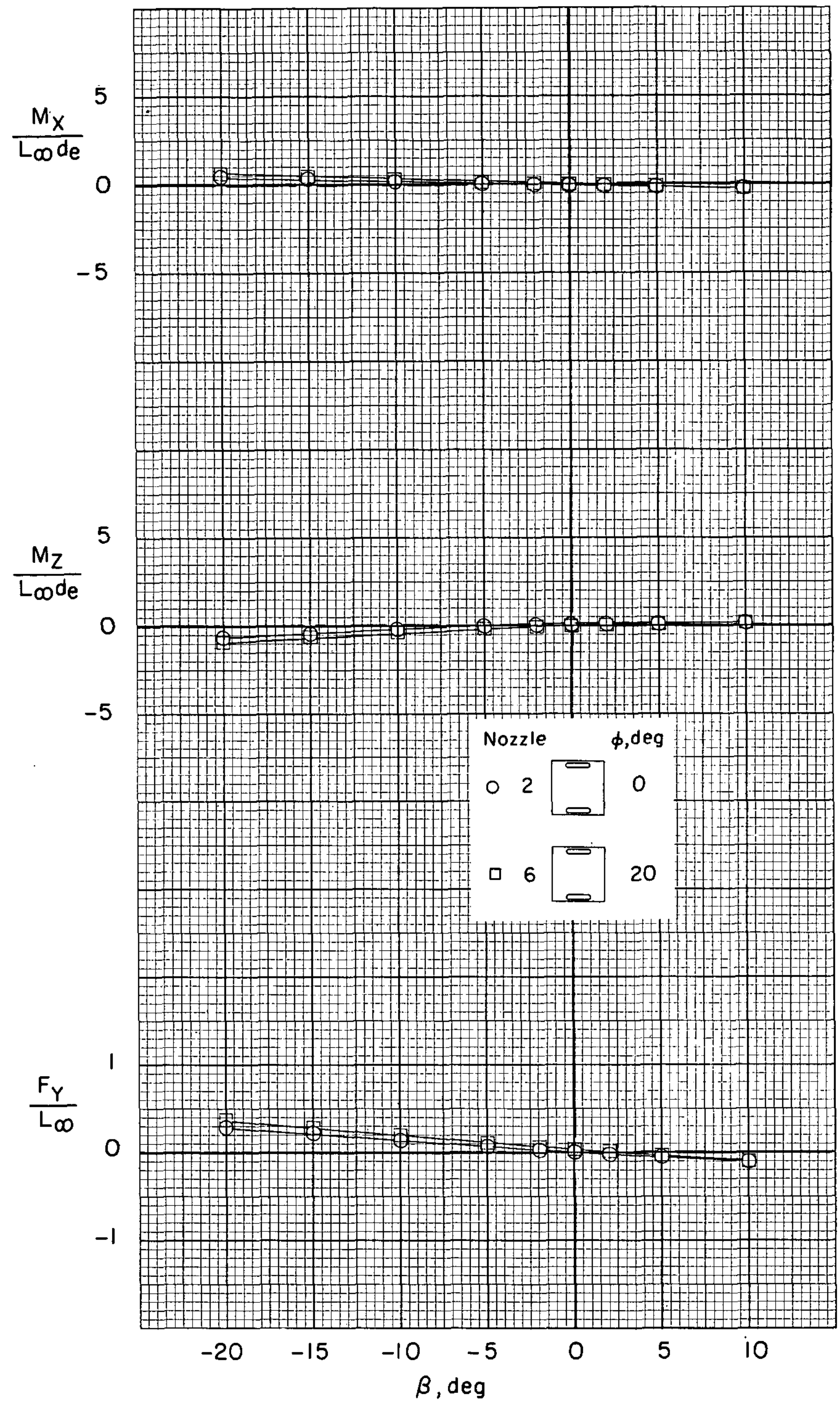
(c) Concluded.

Figure 12.- Concluded.



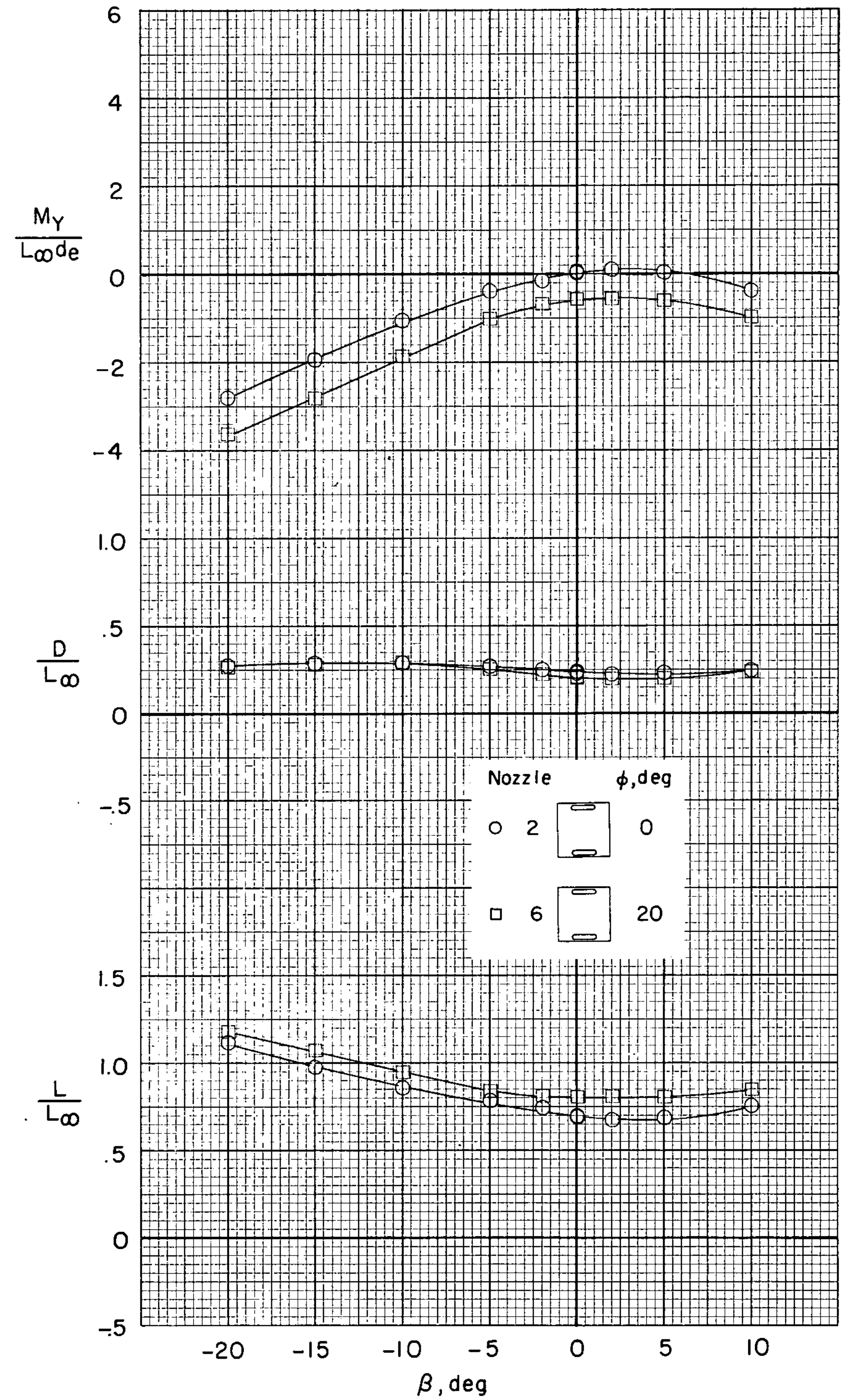
(a) $V_e = 0.10$.

Figure 13.- Effect of jet inclination on the aerodynamic characteristics of the model in sideslip out of ground effect. $\alpha = 0^\circ$; $\psi = 0^\circ$; $h/d_e = 28$; $y/b = 0.8$.



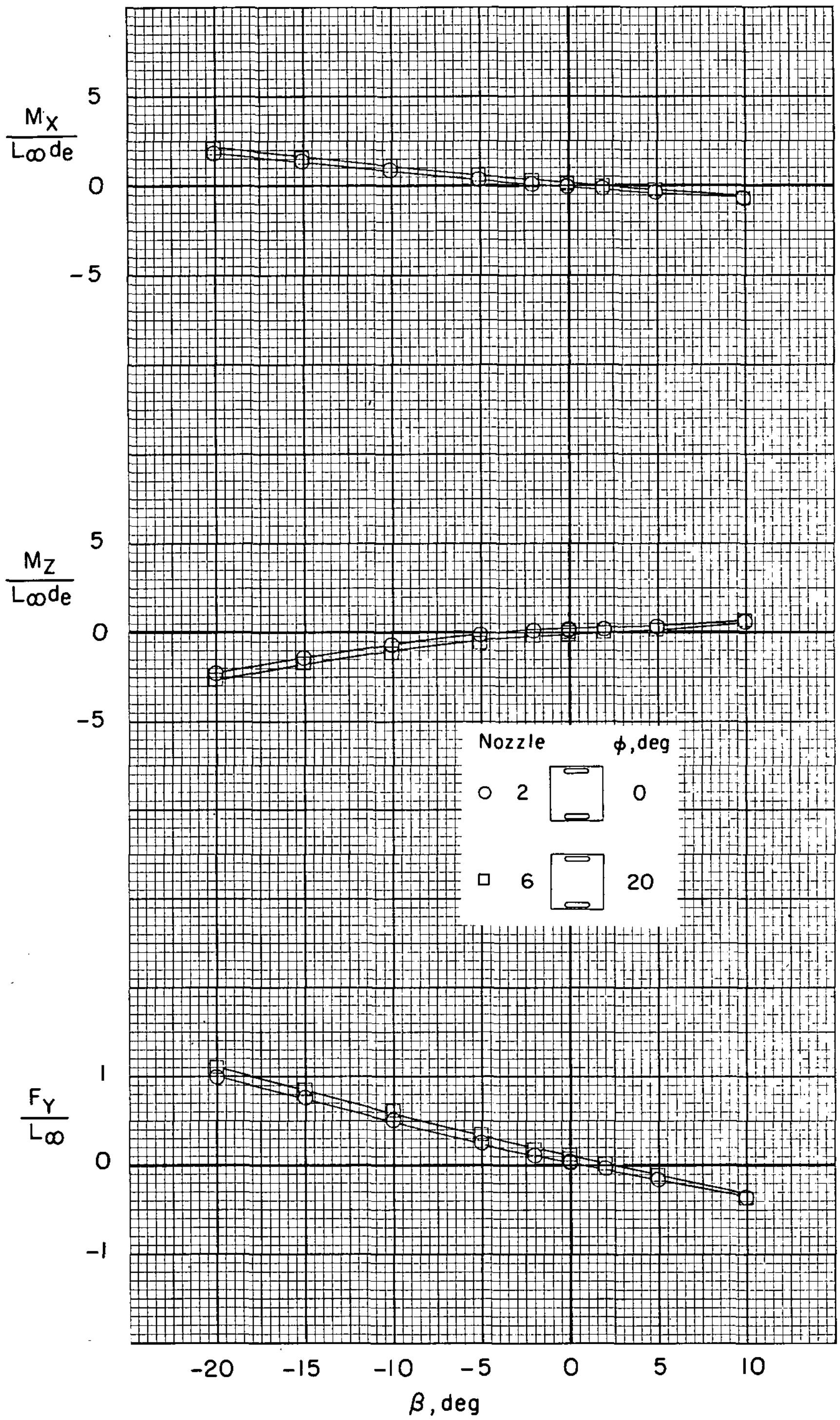
(a) Concluded.

Figure 13.- Continued.



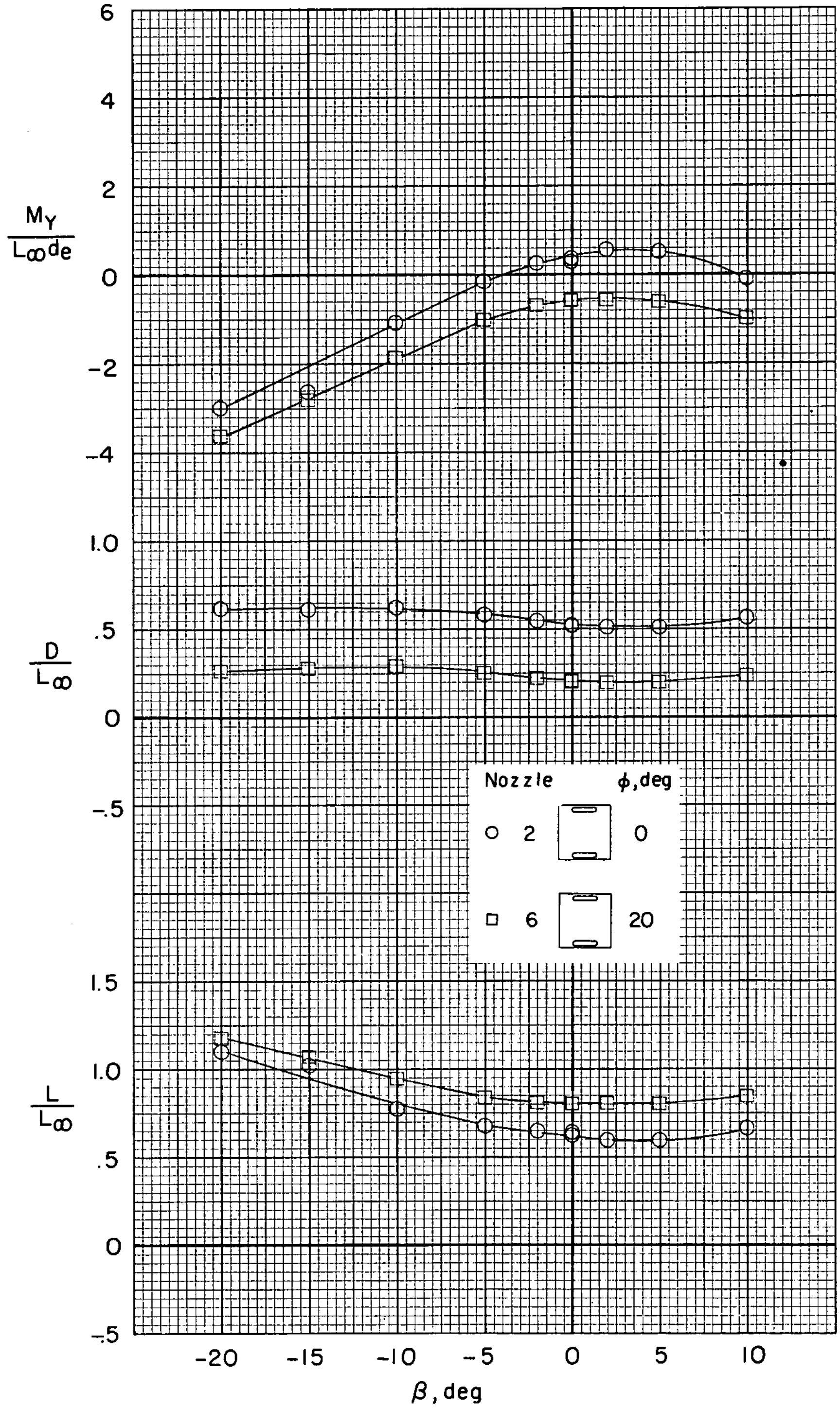
(b) $V_e = 0.20.$

Figure 13.- Continued.



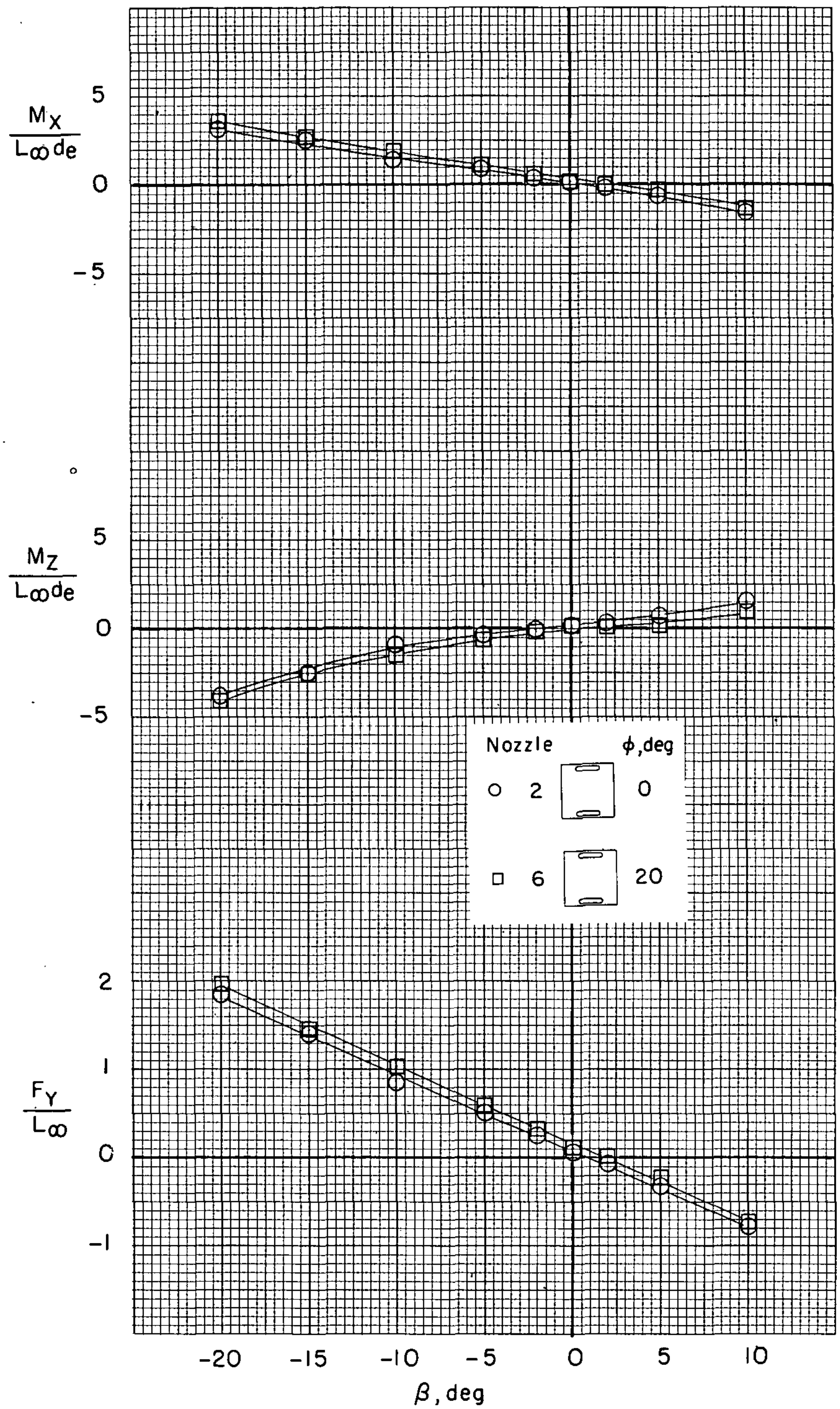
(b) Concluded.

Figure 13.- Continued.



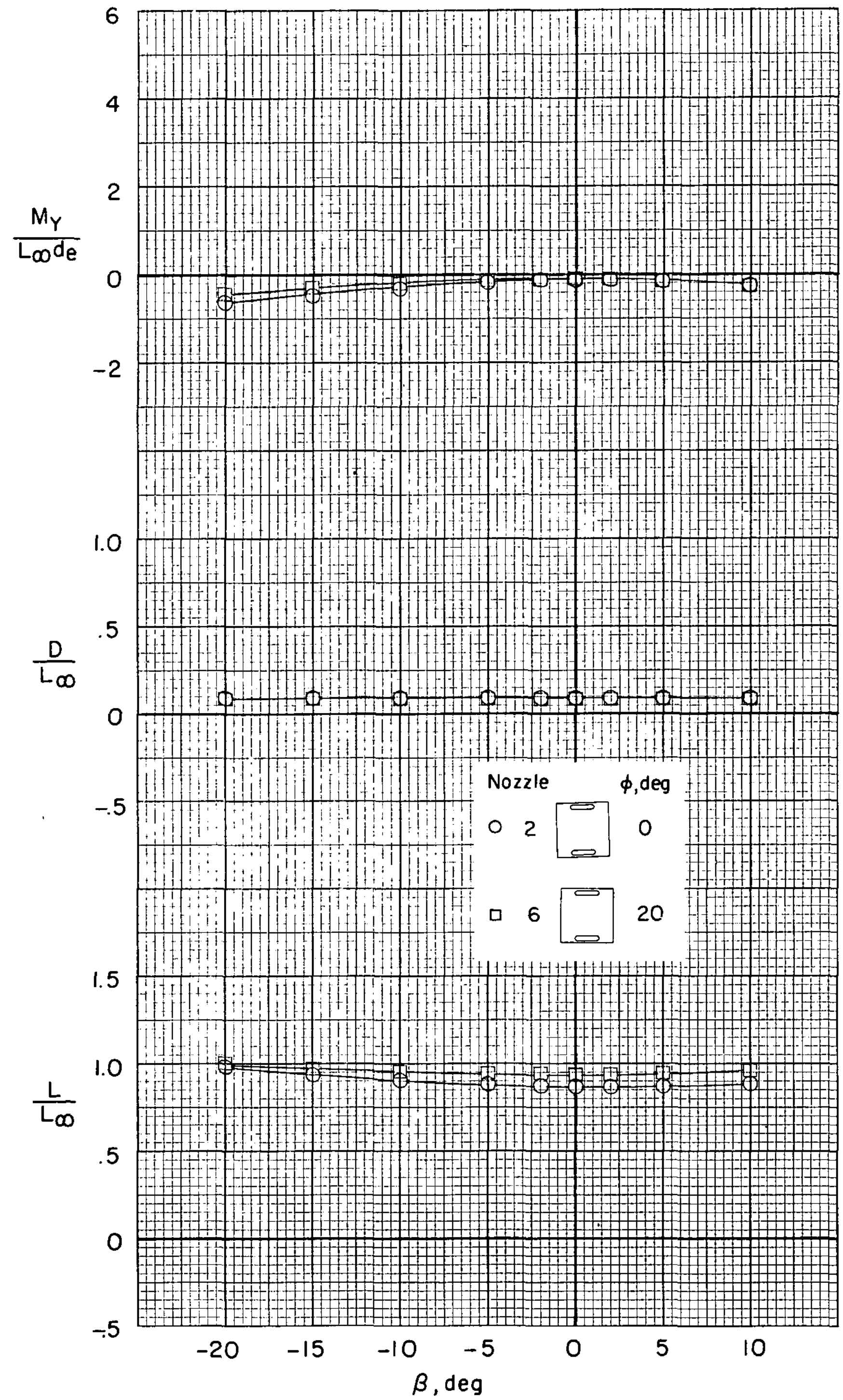
(c) $V_e = 0.30$.

Figure 13.- Continued.



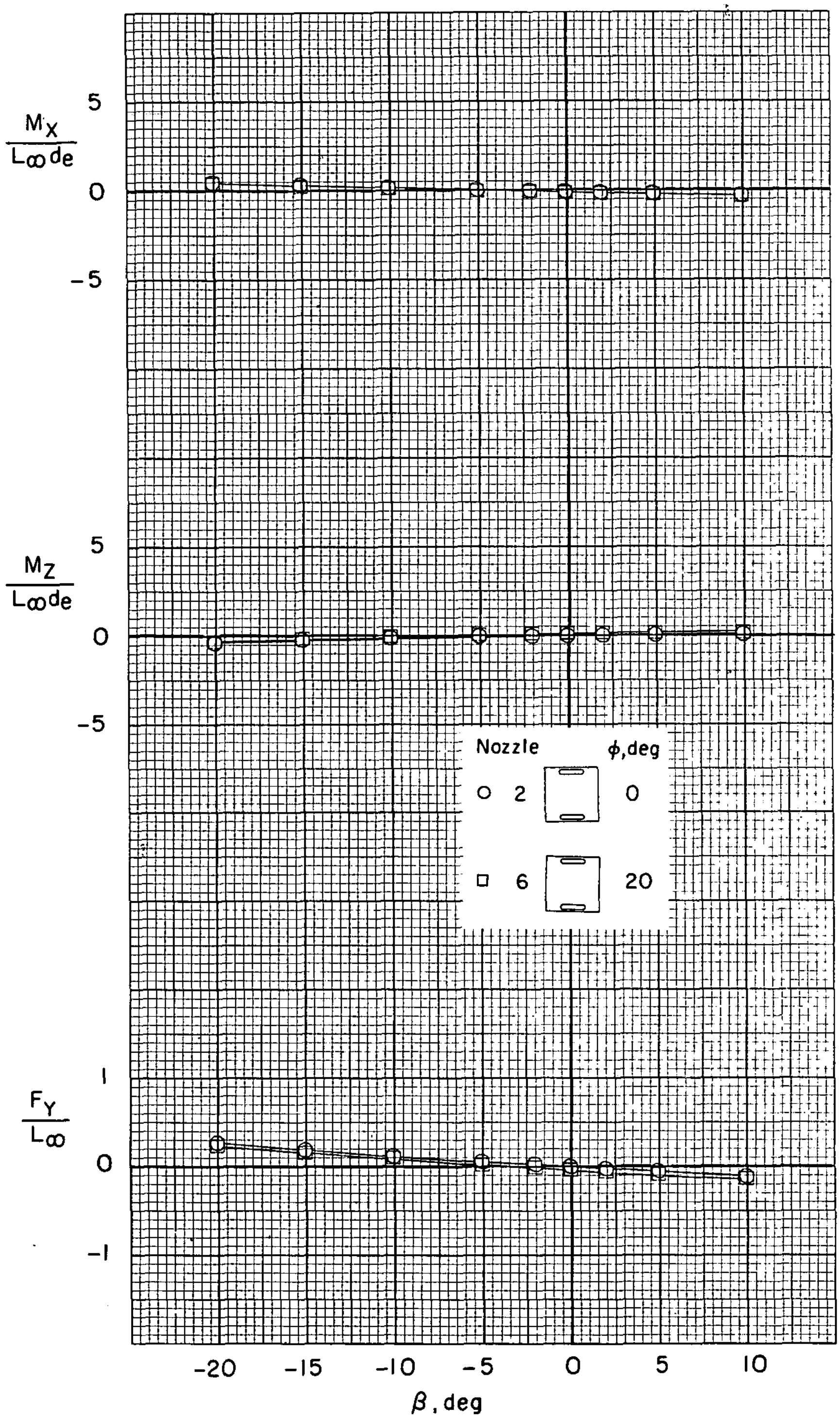
(c) Concluded.

Figure 13.- Concluded.



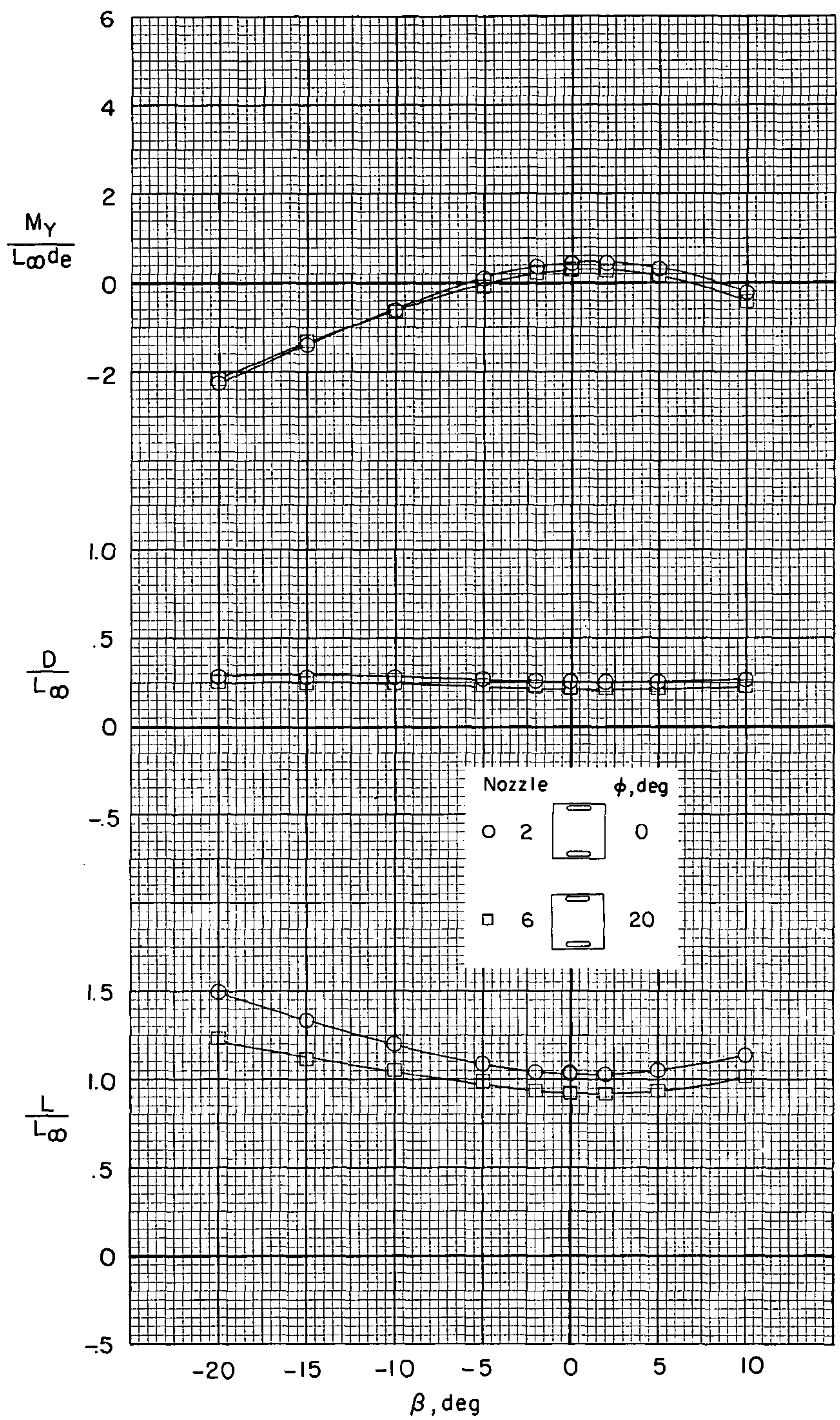
(a) $V_e = 0.10$.

Figure 14.- Effect of jet inclination on the aerodynamic characteristics of the model in sideslip in ground effect. $\alpha = 0^o$; $\psi = 0^o$; $h/d_e = 1$; $y/b = 0.8$.



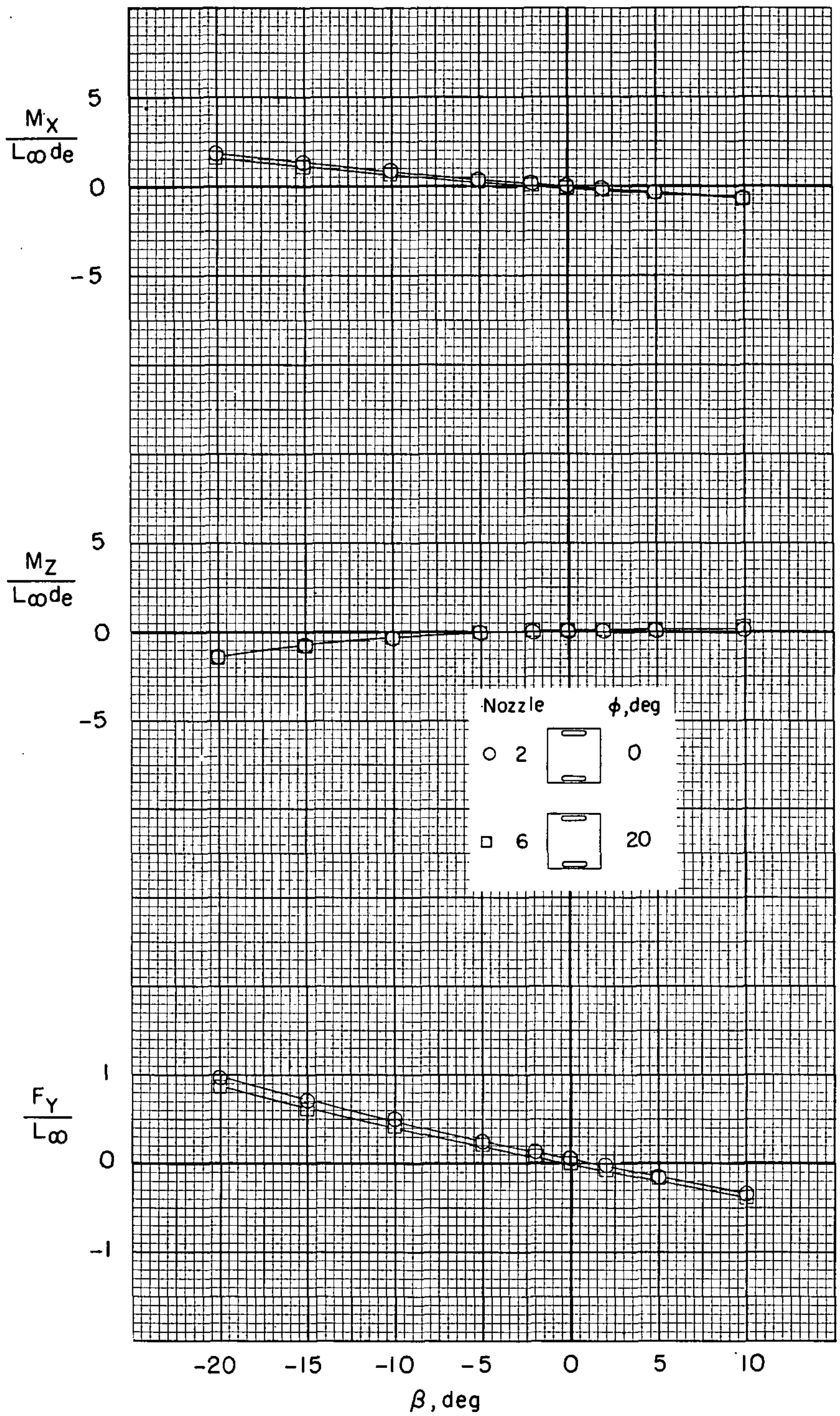
(a) Concluded.

Figure 14.- Continued.



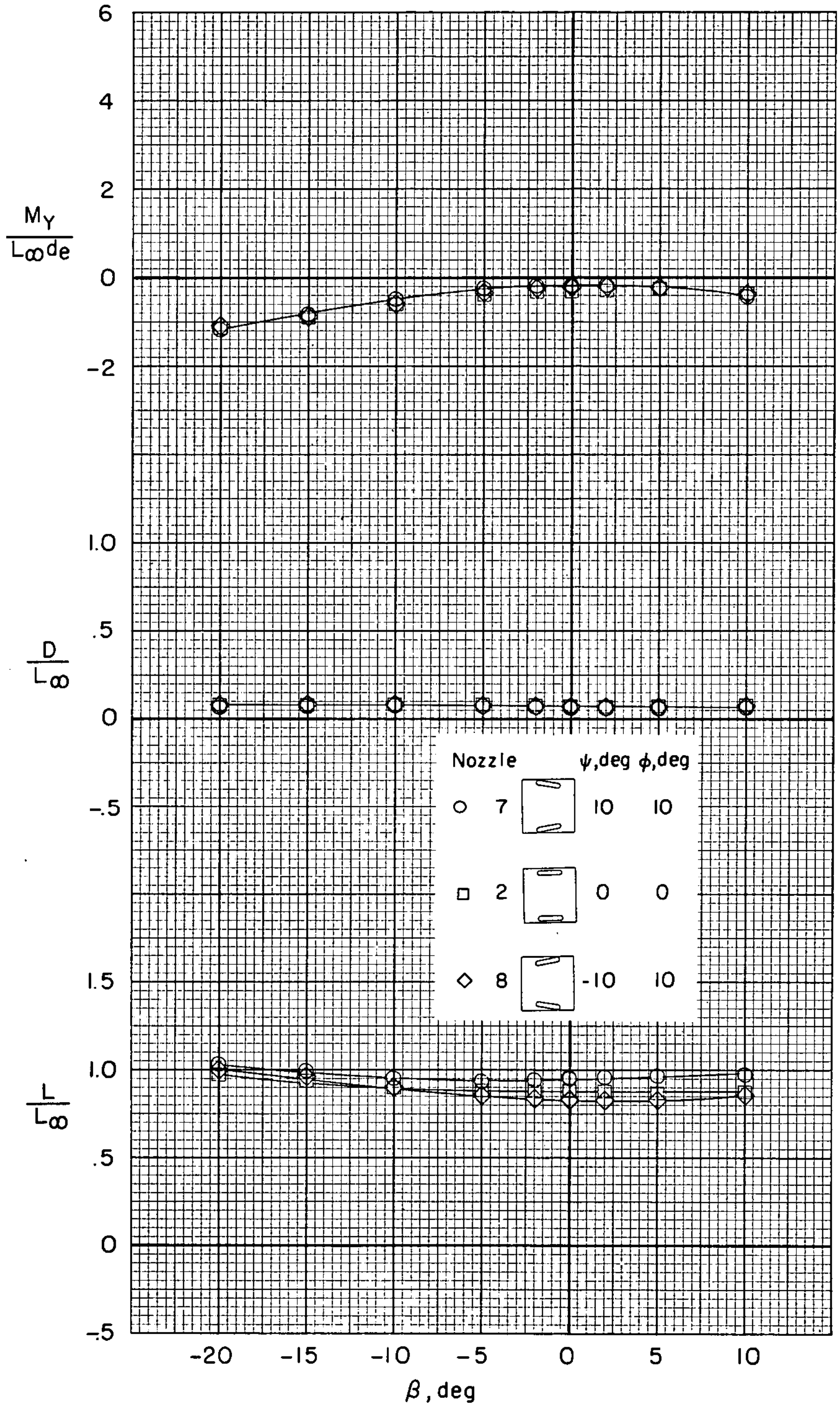
(b) $V_e = 0.20$.

Figure 14.- Continued.



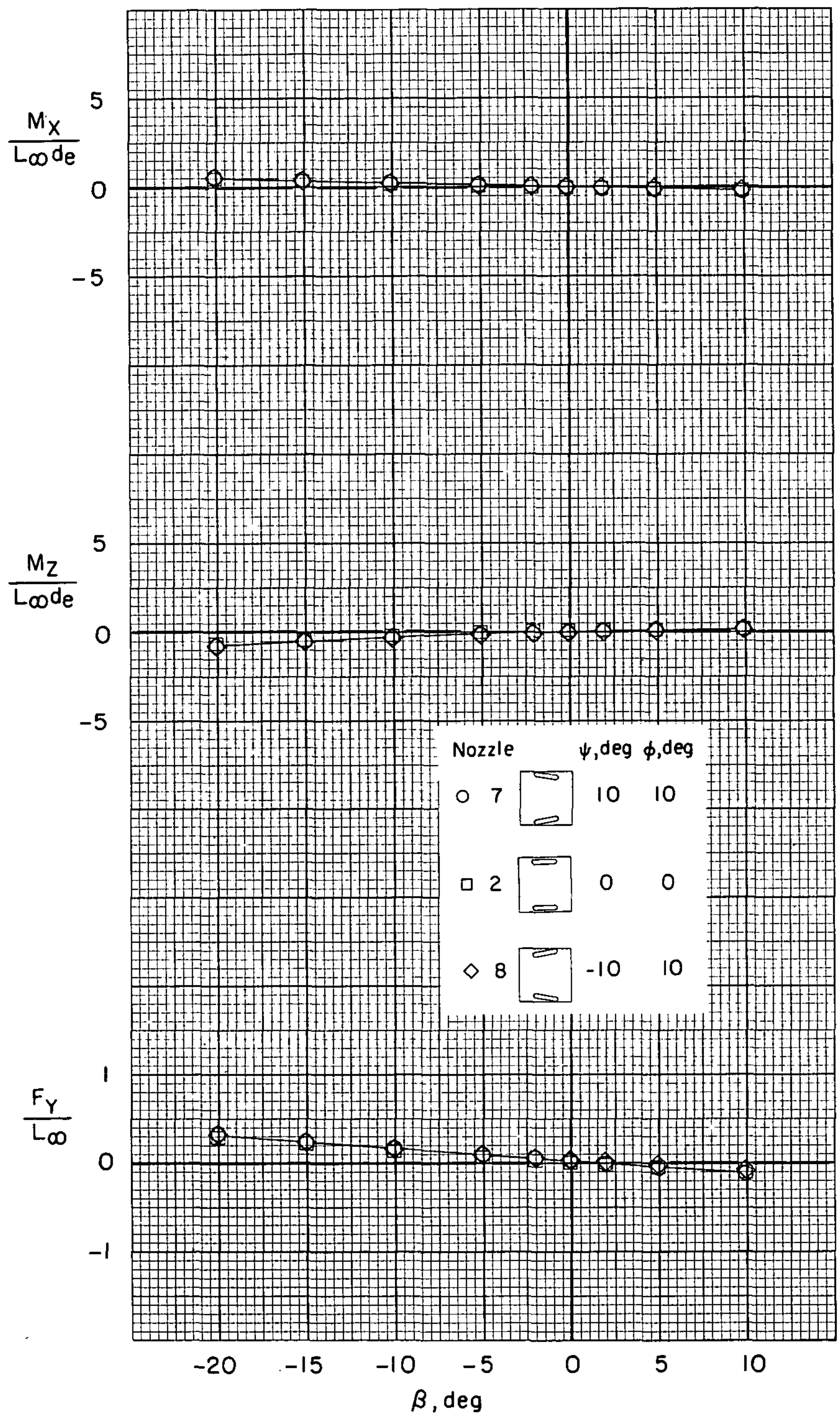
(b) Concluded.

Figure 14.- Concluded.



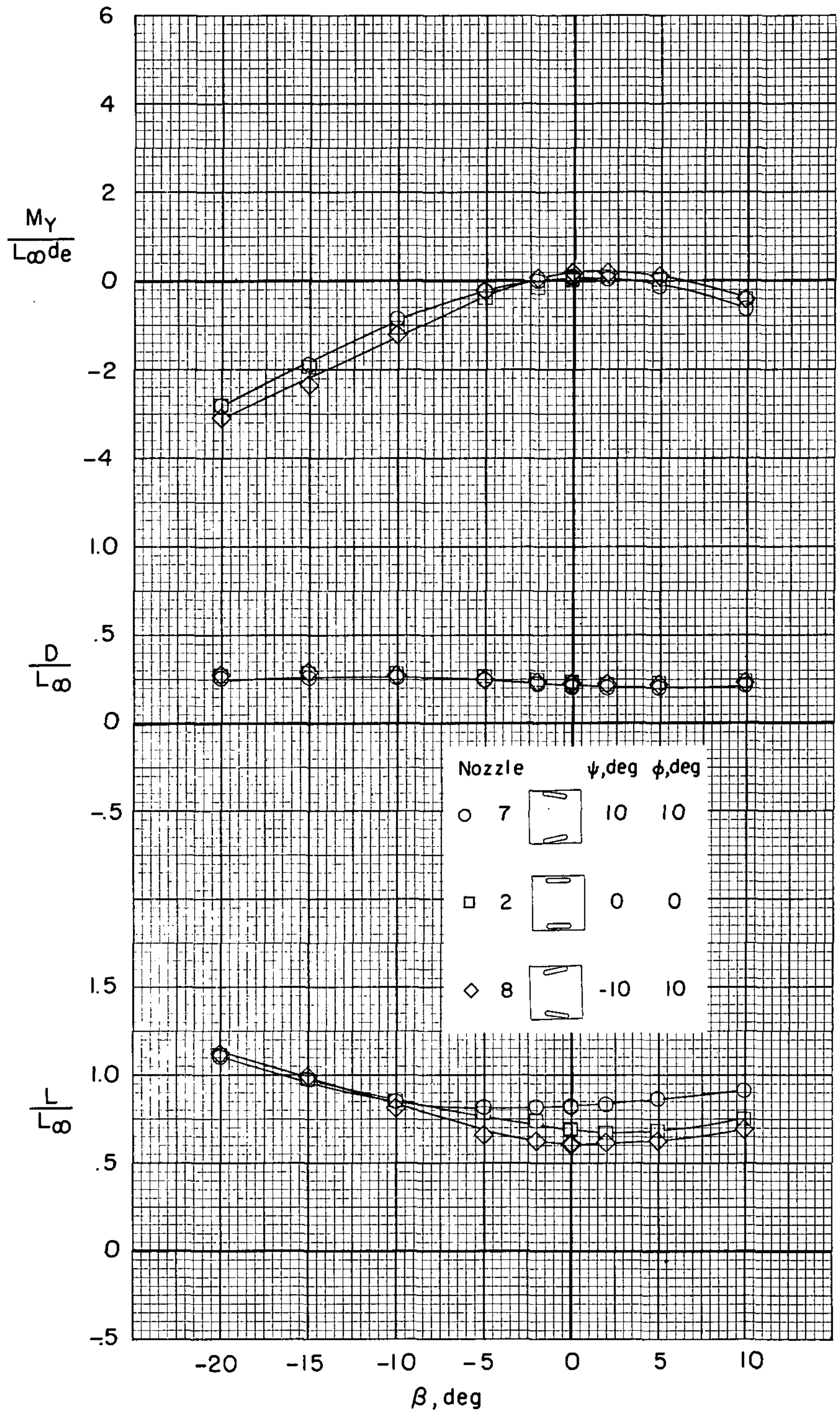
(a) $V_e = 0.10$.

Figure 15.- Effect of combinations of slot yaw and jet inclination on the aerodynamic characteristics of the model in sideslip out of ground effect. $\alpha = 0^{\circ}$; $h/d_e = 28$; $y/b = 0.8$.



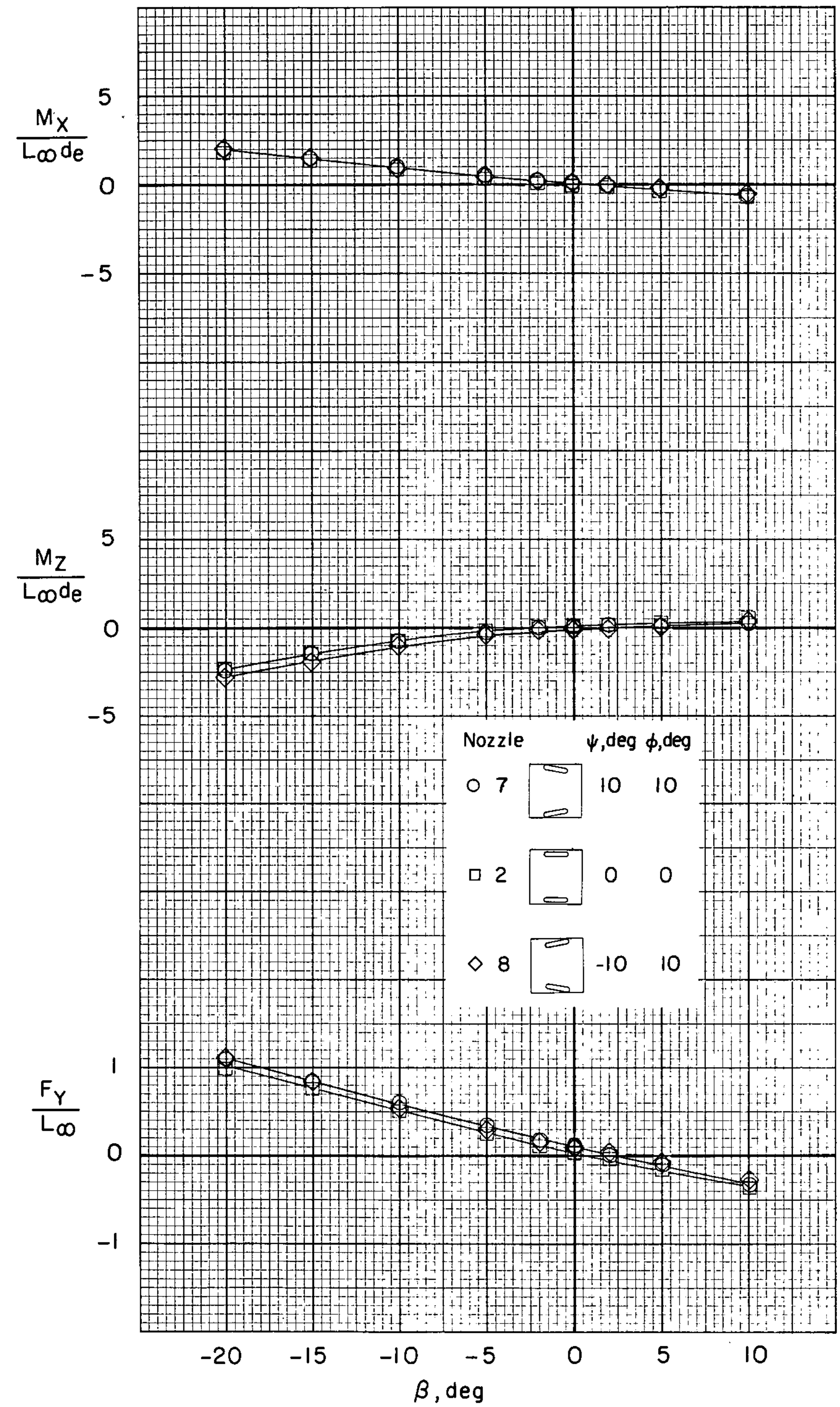
(a) Concluded.

Figure 15.- Continued.



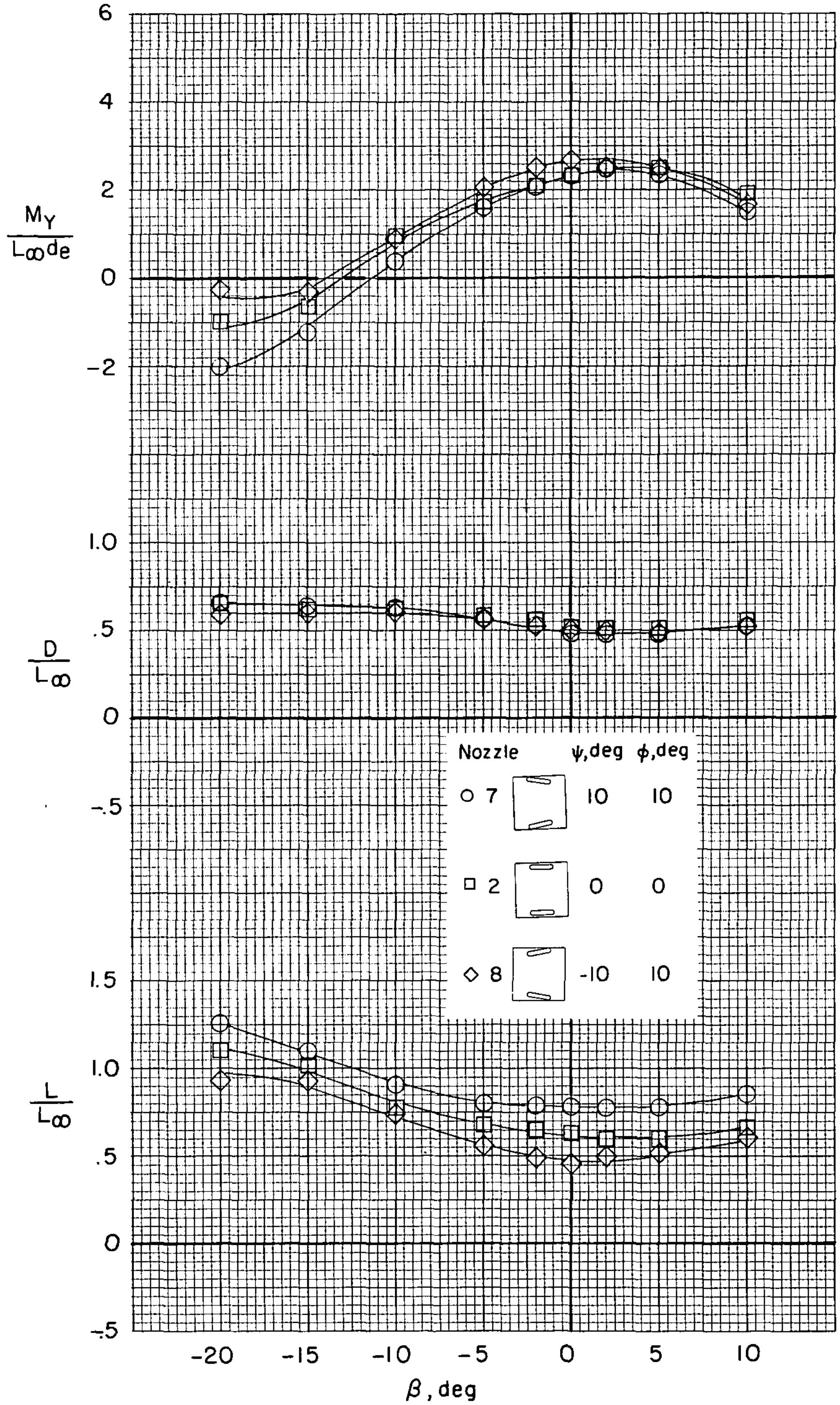
(b) $V_e = 0.20$.

Figure 15.- Continued.



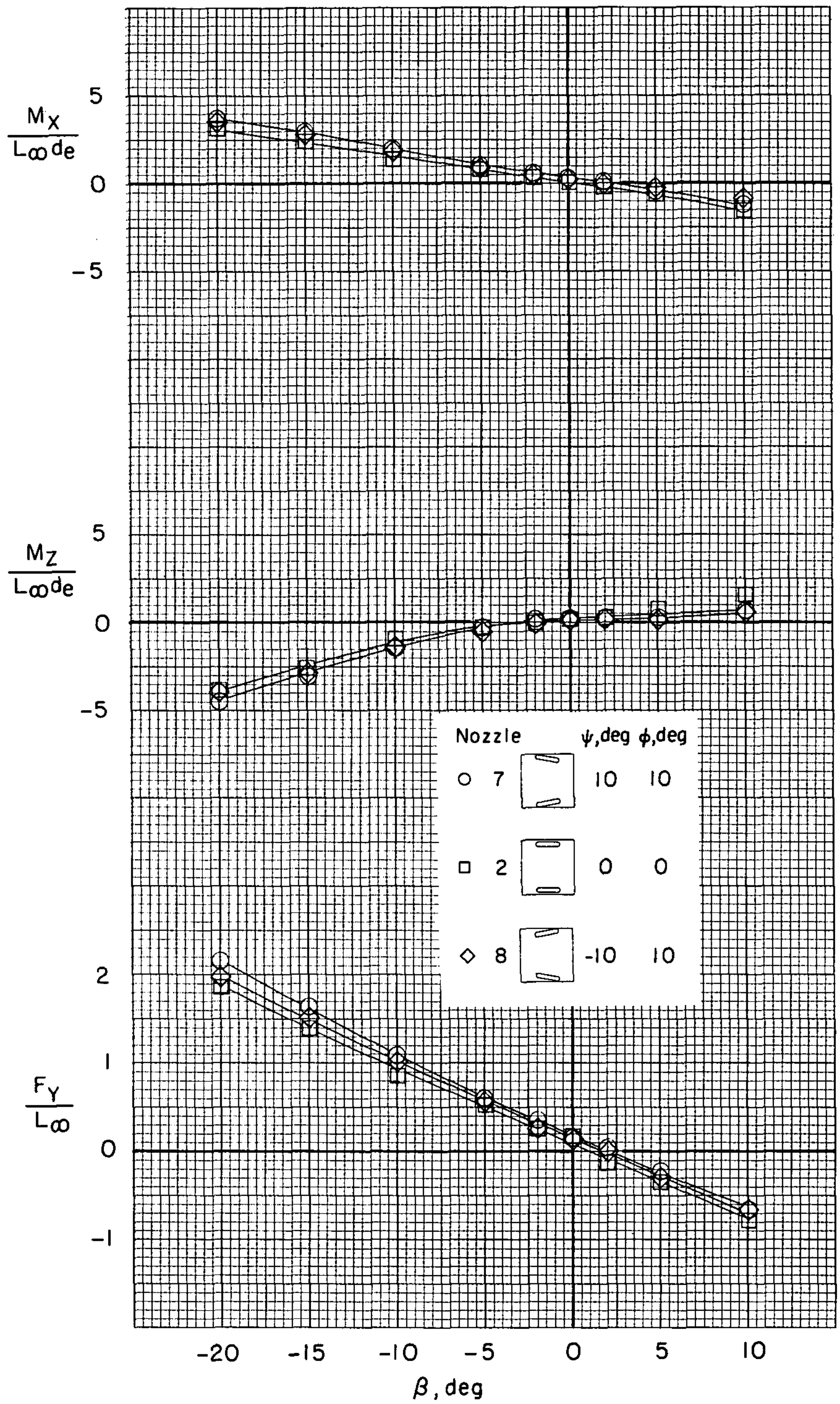
(b) Concluded.

Figure 15.- Continued.



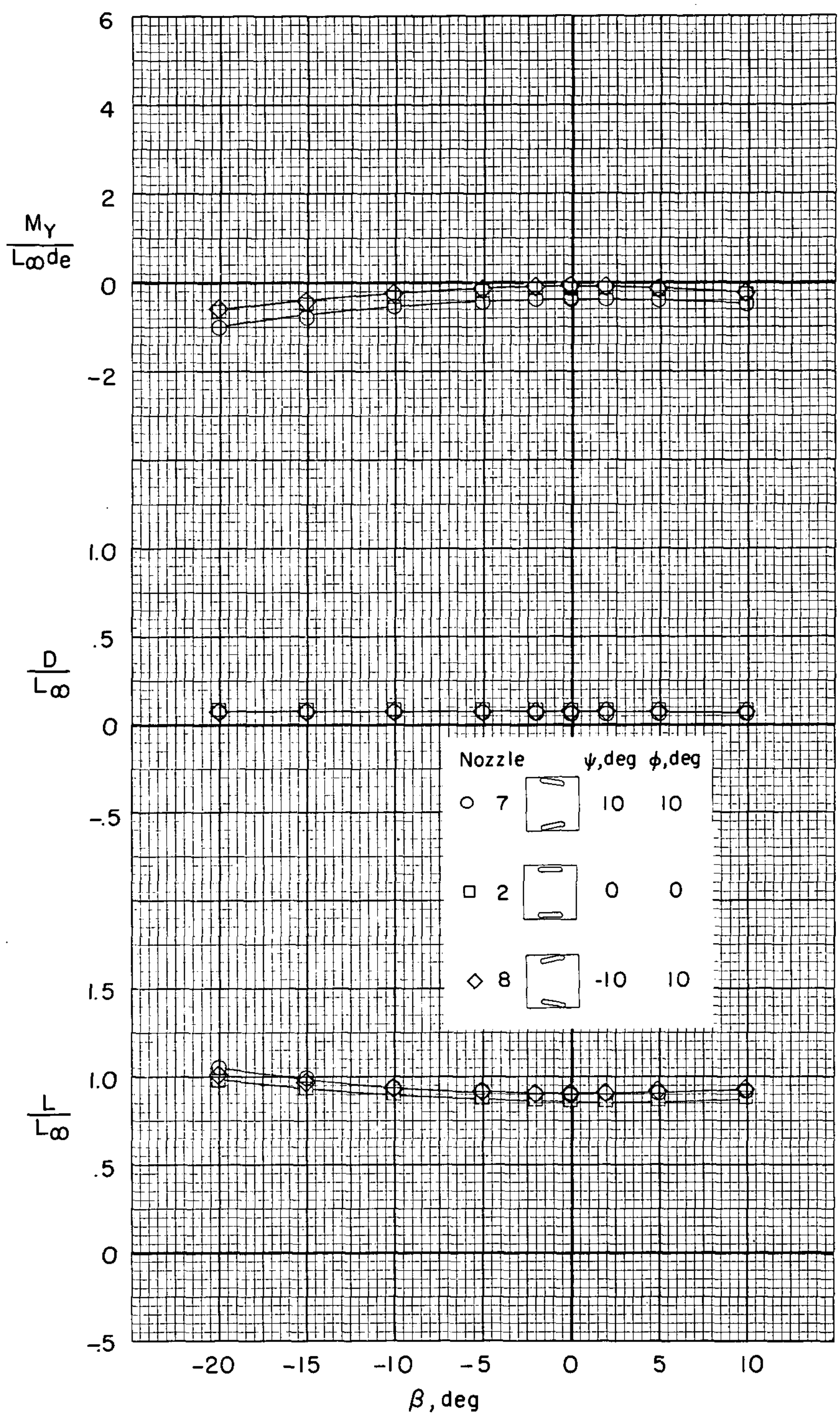
(c) $V_e = 0.30$.

Figure 15.- Continued.



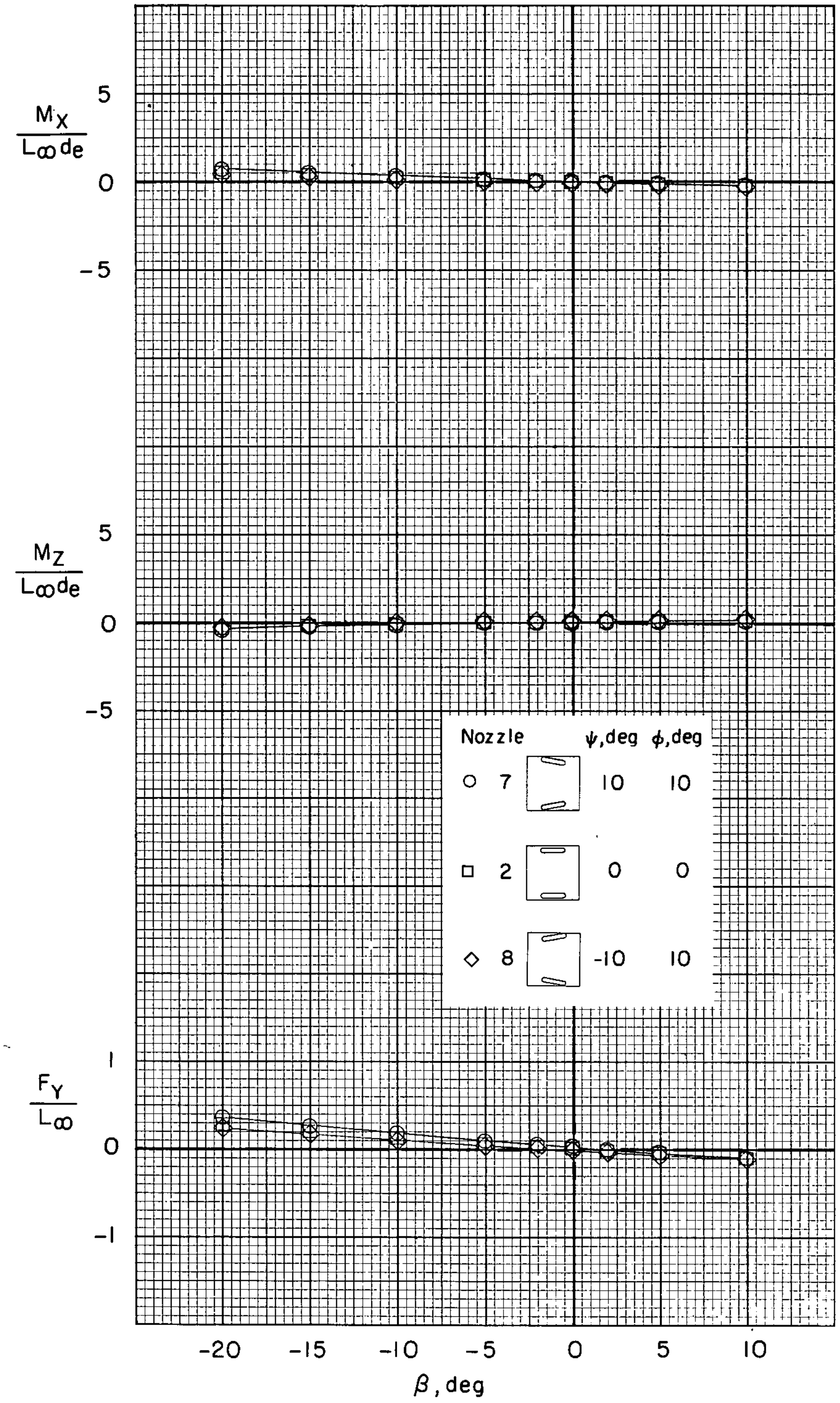
(c) Concluded.

Figure 15.- Concluded.



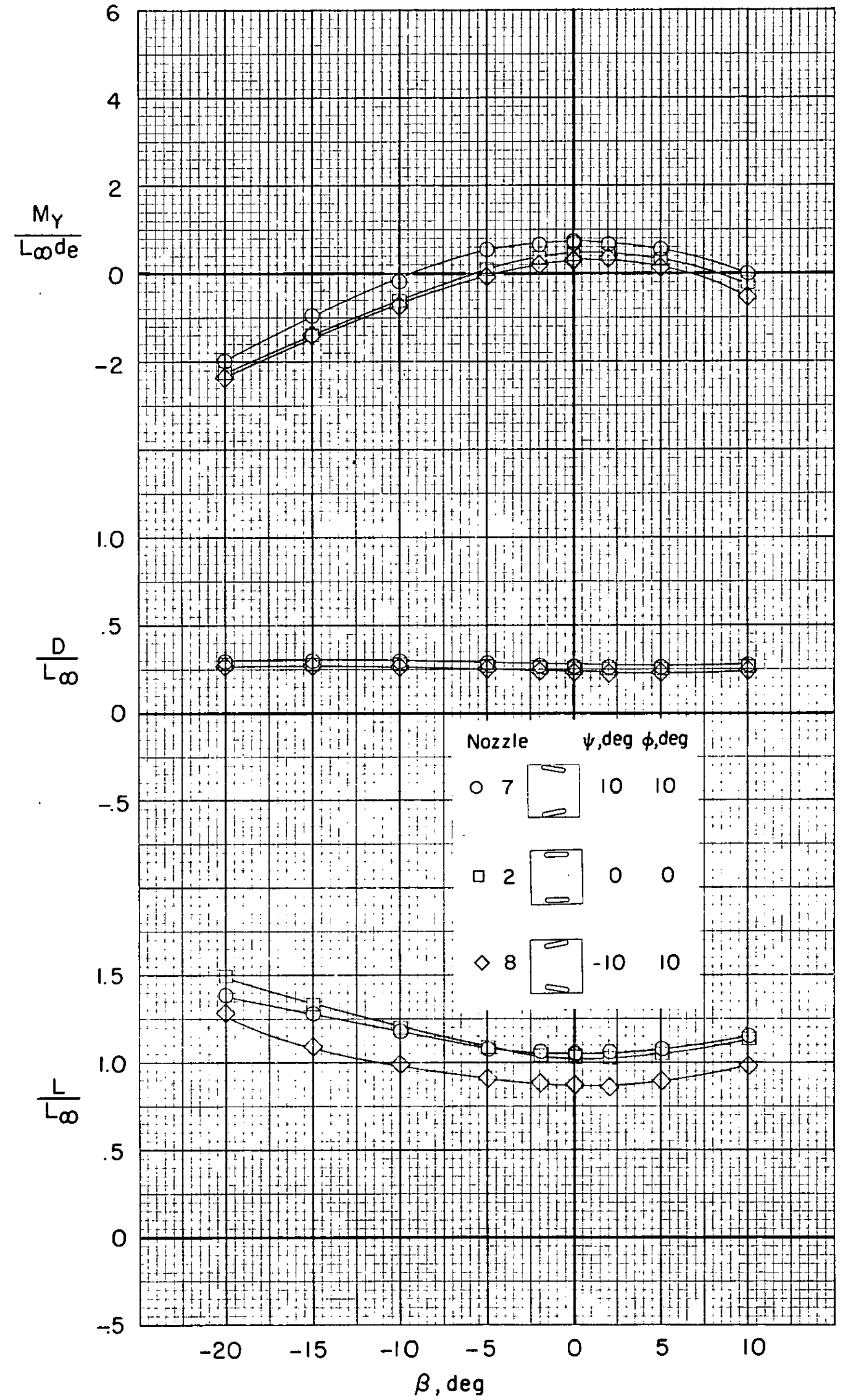
(a) $V_e = 0.10$.

Figure 16.- Effect of combinations of slot yaw and jet inclination on the aerodynamic characteristics of the model in sideslip in ground effect. $\alpha = 0^o$; $h/d_e = 1$; $y/b = 0.8$.



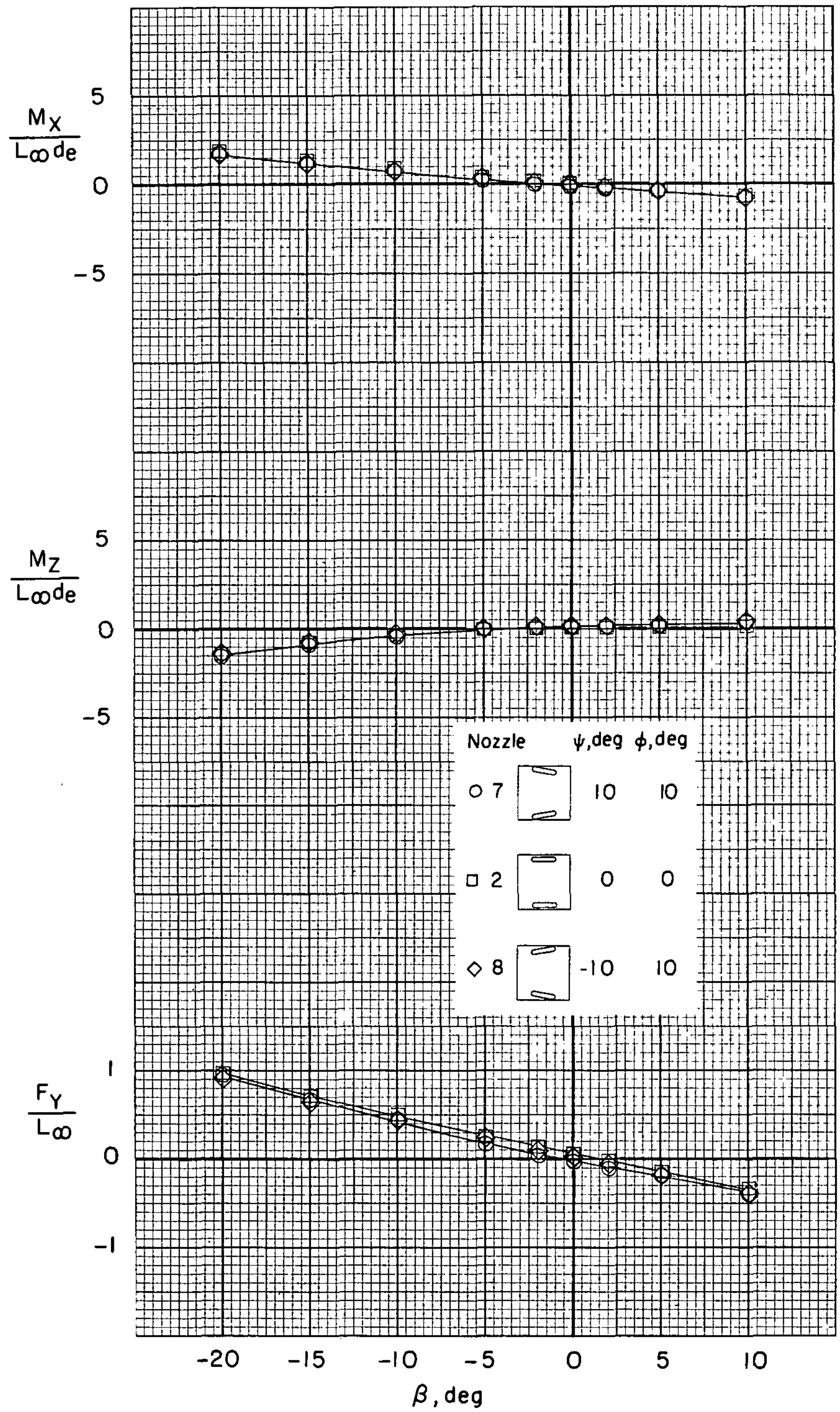
(a) Concluded.

Figure 16.- Continued.



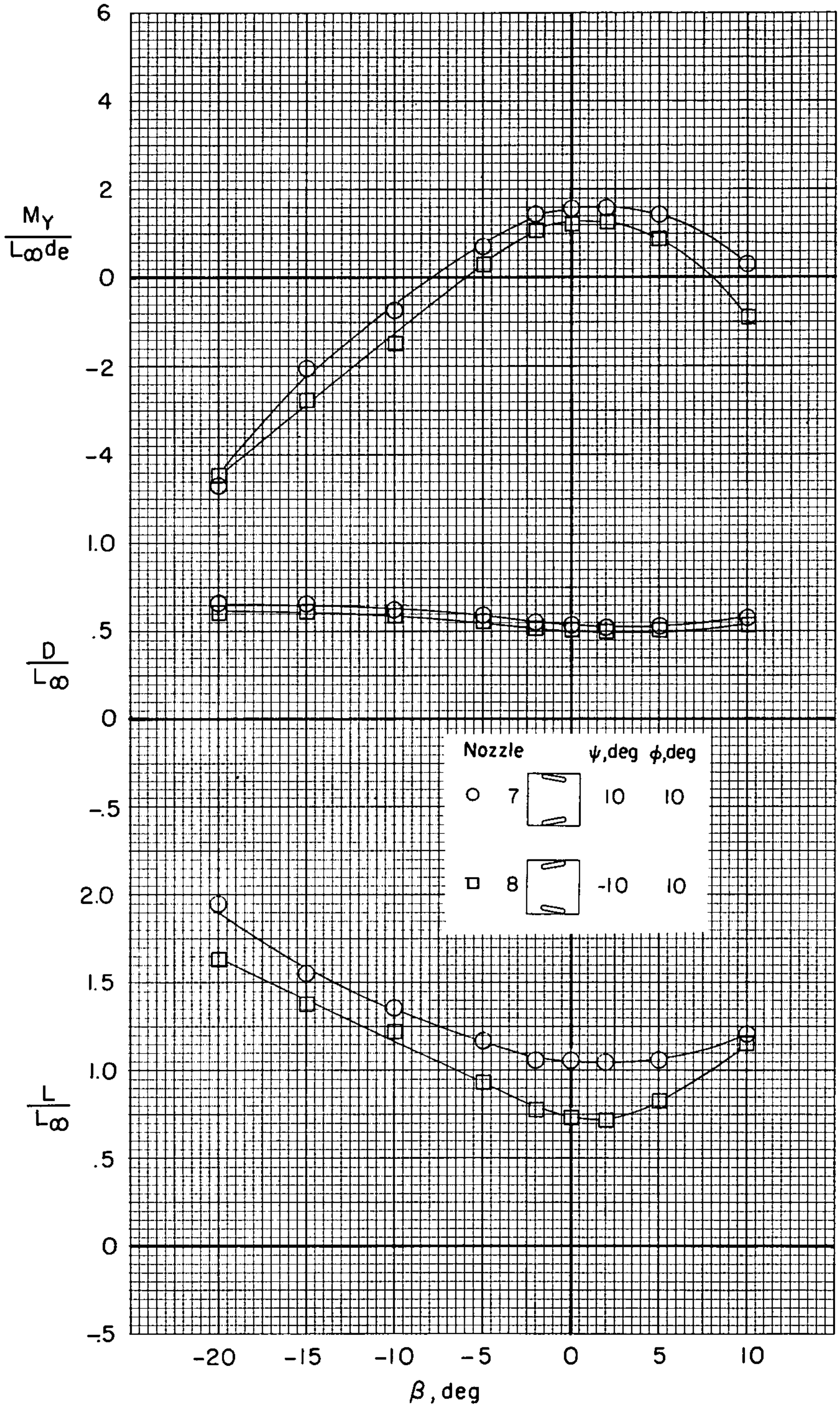
(b) $V_e = 0.20$.

Figure 16.- Continued.



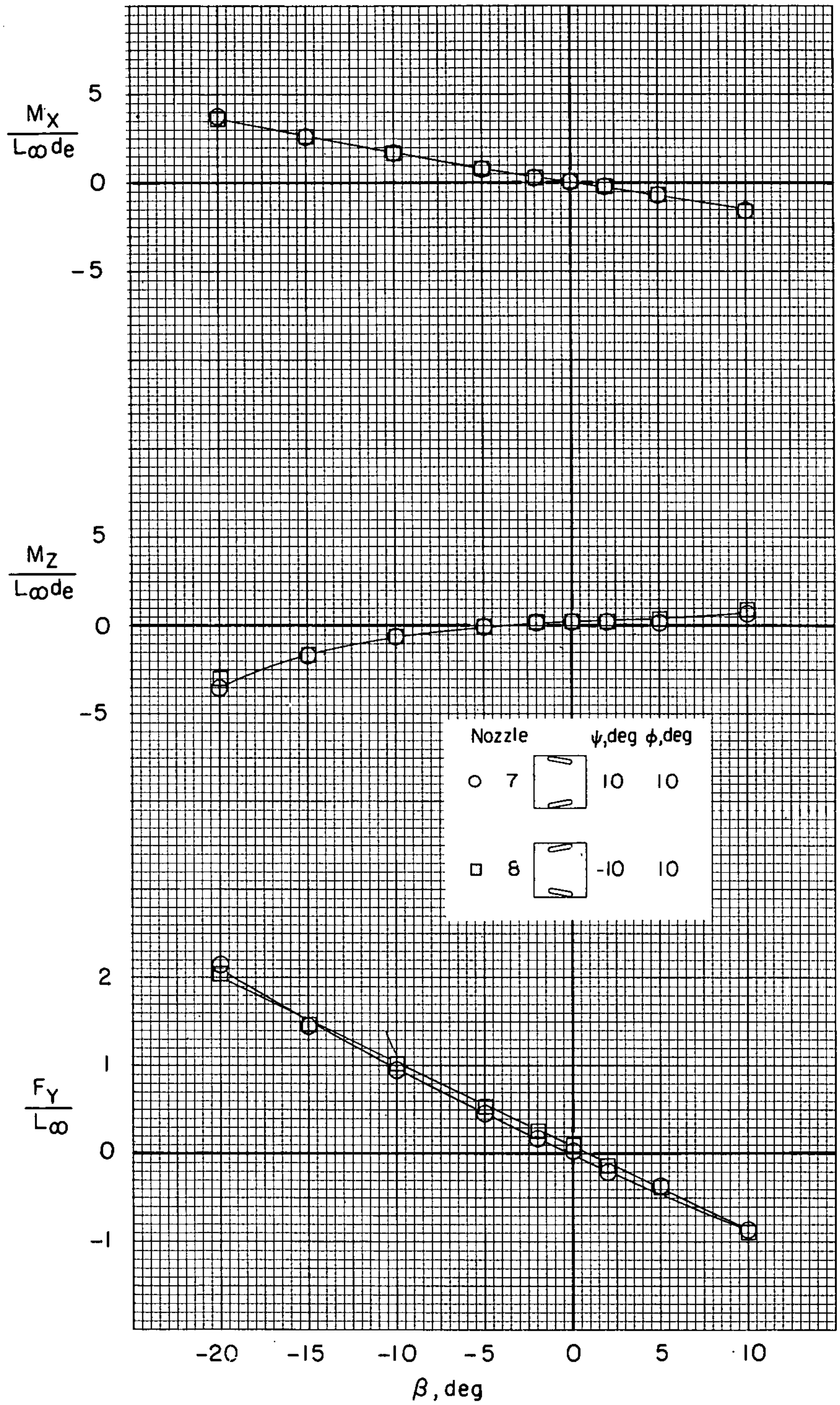
(b) Concluded.

Figure 16.- Continued.



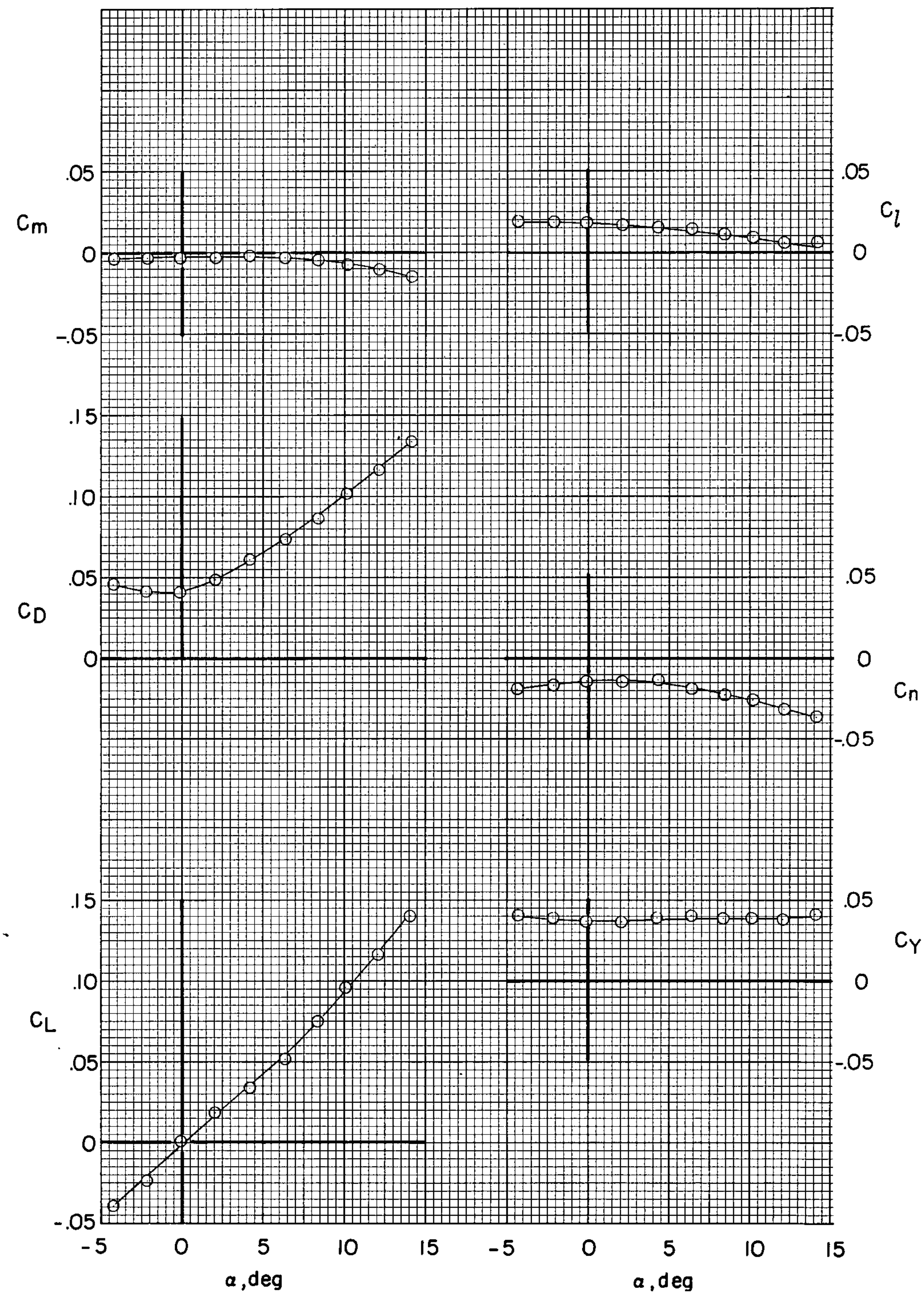
(c) $V_e = 0.30$.

Figure 16.- Continued.



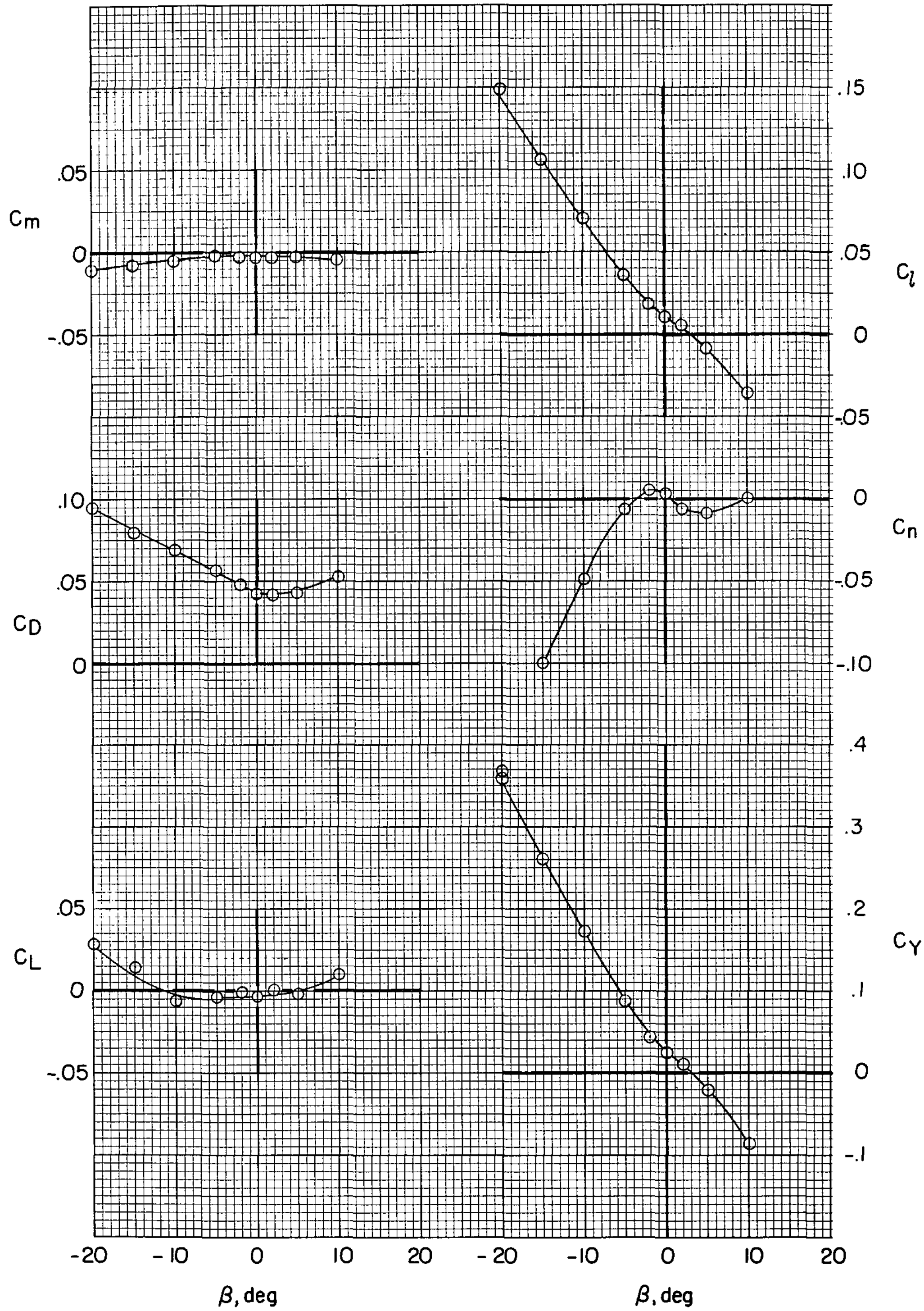
(c) Concluded.

Figure 16.- Concluded.



(a) $\beta = 0^{\circ}$.

Figure 17.- Power-off aerodynamic characteristics of the fuselage-body model. Nozzle 1 with slot exit sealed; out of ground effect $\left(h/d_e = 28\right)$.



(b) $\alpha = 0^{\circ}$.

Figure 17.- Concluded.

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