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# NACA

# RESEARCH MEMORANDUM

for the

U. S. Air Force

## AERODYNAMIC CHARACTERISTICS OF A 0.04956-SCALE MODEL OF THE CONVAIR F-102B AIRPLANE AT MACH NUMBERS OF 1.41, 1.61, AND 2.01

COORD. NO. AF-231

By Cornelius Driver and Ross B. Robinson

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Langley Field, Va.



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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# AERODYNAMIC CHARACTERISTICS OF A 0.04956-SCALE MODEL OF THE CONVAIR F-102B AIRPLANE AT MACH NUMBERS OF 1.41, 1.61, AND 2.01

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## SUMMARY

An investigation has been made in the Langley 4- by 4-foot supersonic pressure tunnel to determine the aerodynamic characteristics of a 0.04956-scale model of the Convair F-102B airplane at Mach numbers of 1.41, 1.61, and 2.01. Tests were made of the model equipped with a delta wing with 15-percent conical camber and a leading-edge sweep of 57°. Four basic body modifications and two afterbody configurations were evaluated. In addition, limited tests were made on a canard trimmer device and a revised vertical tail.

The results indicated that all four basic body modifications had slightly lower values of minimum drag than the Convair F-102A configuration equipped with the same 15-percent cambered wing. The body modifications caused essentially no change in the static stability and lift-curve-slope values obtained for the F-102A.

The results for the cambered afterbody configuration indicated a large positive shift in the value of the pitching-moment coefficient at zero lift. Since the static stability was unchanged, higher values of trim lift coefficient were obtained for a given elevon deflection.

A swept vertical tail having a larger area than the original delta plan form increased the value of directional stability from 0.00094 to 0.0013 at $M = 1.61$ and at low angles of attack.

Except for a small increase in minimum drag, the effects of airflow through the inlets on the aerodynamic characteristics were negligible.

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## INTRODUCTION

At the request of the Air Force, the National Advisory Committee for Aeronautics has conducted an investigation of the aerodynamic characteristics of the Convair F-102B airplane in the Langley 4- by 4-foot supersonic pressure tunnel at $M = 1.41$, 1.61, and 2.01.

Tests of various arrangements of the F-102 configuration that have been previously tested in the 4-foot supersonic pressure tunnel are as follows: the original XF-102 (ref. 1), the YF-102 with various extended afterbodies (ref. 2), the revised YF-102 having extended and contoured afterbodies and a 6.4-percent conical cambered wing (ref. 3), and the F-102A having, in addition to the improvements of the YF-102, an extended nose, a modified canopy, and extended afterbody fillets (ref. 4).

The F-102B configuration, for which results are presented herein, is a new design. The delta wing has 15-percent conical camber and a leading-edge sweep of 57° instead of the 6.4-percent conical camber and 60.1° sweep of the basic F-102A configuration. The F-102B has a new body cross-sectional shape; the inlets are moved rearward to the leading edge of the wing, and the body contour is revised to improve the longitudinal area distribution of the airplane. Several other body shapes were evaluated, including two configurations with reflexed afterbodies. In addition, a revised vertical tail and a canard-type trimmer were tested. It should be pointed out that the F-102A configuration used for comparison purposes in this text was equipped with the same 57° delta, 15-percent cambered wing as the F-102B configurations. Most of the tests were made with the air inlets faired closed; however, one configuration was tested at each Mach number with inlets open and with inlets completely removed.

## SYMBOLS

The results are presented as standard NACA forces and moments. The data are referred to the stability-axis system (fig. 1) with the reference center of moments located at 25 percent of the wing mean geometric chord.

The symbols are defined as follows:

$C_L$ lift coefficient, $-Z/qS$

$C_X$ longitudinal-force coefficient, $X/qS$ (-drag at $\beta = 0^\circ$)

$C_Y$ lateral-force coefficient, $Y/qS$

| | |
|---|---|
| $C_n$ | yawing-moment coefficient, $N/qSb$ |
| $C_l$ | rolling-moment coefficient, $L'/qSb$ |
| $C_m$ | pitching-moment coefficient, $M'/qS\bar{c}$ |
| X | force along X-axis |
| Y | force along Y-axis |
| Z | force along Z-axis |
| L' | moment about X-axis |
| M' | moment about Y-axis |
| N | moment about Z-axis |
| L | lift (-Z) |
| D | drag (-X) at $\beta = 0^{\circ}$ |
| q | free-stream dynamic pressure |
| S | wing area including body intercept, 1.732 sq ft |
| b | wing span, 24.758 in. |
| $\bar{c}$ | wing mean geometric chord, 13.43 in. |
| M | Mach number |
| $\alpha$ | angle of attack, deg |
| $\beta$ | angle of sideslip, deg |
| $\delta_e$ | elevon deflection, deg |
| $C_{m_0}$ | pitching-moment coefficient at $C_L = 0$ |
| $C_{L_\alpha}$ | lift-curve slope $\frac{\partial C_L}{\partial \alpha}$ at $C_L = 0$ |
| L/D | lift-drag ratio |

$\frac{\partial C_m}{\partial C_L}$ variation of pitching-moment coefficient with lift coefficient at $C_m = 0$ (static-longitudinal-stability parameter)

$C_{n_\beta}$ variation of yawing-moment coefficient with sideslip $\frac{\partial C_n}{\partial \beta}$ at $\beta = 0^\circ$ (static-directional-stability derivative)

$C_{m_\delta}$ longitudinal control parameter, incremental pitching-moment coefficient due to elevon deflection

Subscripts:

max maximum

min minimum

## MODEL AND APPARATUS

A three-view drawing of the 0.04956-scale models of the Convair F-102A (modified) and F-102B configurations, indicating the various body modifications, is shown in figure 2. The longitudinal area distributions (perpendicular sections) are shown in figure 3. Photographs of the F-102B model are shown in figure 4. The geometric characteristics of the model are presented in table I.

All of the models tested, including the F-102A configuration, had a basic 57° delta wing with 15-percent conical camber and with reflexed tips that varied linearly from 5° reflex outboard of the elevon to 9° reflex at the wing tip. The 15-percent conical camber was designed to provide a design lift coefficient of 0.21 at $M = 1.0$. The F-102A model used in the present investigation is the configuration described in reference 3 as the F-102A with the 15-percent conical camber wing. All tests were made with wing fences installed as shown in figure 2.

Four basic F-102B fuselage configurations were tested. Body 1 had the same nose shape, canopy, and afterbody indentation as the F-102A but the inlets were moved rearward to the leading edge of the wing, the vertical tail was moved back slightly, and the body was shortened. Body 2 was the basic version of the F-102B and had a new cross-sectional shape, an improved longitudinal area distribution (fig. 3), and had the inlets and afterbody designed for use with the Wright J67 engine. Body 2A was similar to body 2 but the air inlets were removed. Body 3 had an alternate area distribution with an indentation for the canopy. Body 3A was similar to body 3 but had an alternate afterbody shape to allow for the

Pratt & Whitney J75 engine. (See fig. 2(b).) Body 4 had a cambered afterbody shape (fig. 2(d)) to shift $C_{m_0}$ to a more positive value. Body 4A was similar to body 4 but had less camber at the rear of the fuselage. For the majority of the tests the inlets were closed by means of faired plugs.

A comparison of the revised vertical tail and the basic vertical tail is presented in figure 5. Details of the canard-type trimmer investigated are shown in figure 6. To facilitate rapid model changes, the bodies were constructed of fiber glass and attached to a steel core. Because of the structural limitations of the fiber glass, it was impossible to attach the canards and the modified tail in a manner to allow testing over a full range of canard deflections and sideslip angles. Also, the small diameter of the afterbodies prevented the use of a bent sting with a larger diameter for sideslip tests at angle of attack.

The models were supplied by the Air Force contractor and the internal balance and readout equipment were supplied by the NACA. Forces and moments were measured by means of a six-component internal strain-gage balance and indicating system.

## TESTS AND CORRECTIONS

### Test Conditions

The tests were made at Mach numbers of 1.41, 1.61, and 2.01 for which the Reynolds numbers (based on $\bar{c}$) were $3.41 \times 10^6$, $3.26 \times 10^6$, and $2.82 \times 10^6$, respectively. The stagnation dewpoint was maintained at -25° F or less to prevent any significant condensation effects in the test section.

Pitch tests were made through an angle-of-attack range from about -2° to about 13°. Sideslip tests were made through a sideslip angle range from about -4° to 8°. Sideslip tests were made at $\alpha \approx 1.6^\circ$ and $\alpha \approx 5.6^\circ$.

### Corrections and Accuracy

The angles of attack and sideslip have been corrected for the deflections of the sting and balance due to the aerodynamic loads. The base pressure was measured and the longitudinal-force coefficient was adjusted to correspond to a base pressure equal to free-stream static pressure.

The estimated errors in the individual quantities are as follows:

| | |
|---|---|
| $C_L$ | $\pm 0.006$ |
| $C_X$ | $\pm 0.0010$ |
| $C_m$ | $\pm 0.002$ |
| $C_l$ | $\pm 0.0004$ |
| $C_n$ | $\pm 0.0002$ |
| $C_Y$ | $\pm 0.0004$ |
| $\alpha$, $\beta$, $\delta_e$, deg | $\pm 0.1$ |

## DISCUSSION AND RESULTS

### Longitudinal Characteristics

Effect of body modifications on the drag characteristics.- There were no measurable differences in minimum drag coefficient between F-102B bodies 1, 2, and 3 (fig. 7). However, the drag level at $M = 1.41$ was about 10 percent lower for the F-102B than for the F-102A configuration. The addition of body camber (body 4) increased the value of $C_{D_{min}}$ to about the level of that for the F-102A configuration. At lift coefficients above 0.25 there were no measurable drag differences between any of the F-102B bodies tested.

The value of $C_{D_{min}}$ remained essentially constant through the Mach number range investigated. However, the drag differences between the various configurations decrease with increasing Mach number (fig. 7).

At $M = 1.41$, the spread in untrimmed $(L/D)_{max}$ is small with ranges of $(L/D)_{max}$ from about 6.1 for the F-102A to 6.4 for the F-102B (body 2). (See fig. 8.) The $(L/D)_{max}$ of the cambered body lies between these two values. At higher Mach numbers the value of $(L/D)_{max}$ for all configurations decreases and the differences between configurations diminishes. At $M = 2.01$, $(L/D)_{max}$ is about 5.0 and is essentially constant for all the configurations tested, including the F-102A.

Stability and control characteristics.- The effects of elevon deflection on the longitudinal aerodynamic characteristics for bodies 2, 1, and 4 are presented in figures 9, 10, and 11, respectively.

There was little change in the static-stability parameter $\partial C_m/\partial C_L$ or in the lift-curve slope $C_{L_\alpha}$ between the various configurations tested (fig. 12). The most pronounced effect was the large positive increase in $C_{m_0}$ which resulted from use of the cambered body (body 4) which at $M = 1.41$ increased in $C_{L_{trim}}$ from 0.021 to 0.087 for $\delta_e = 0^\circ$ (fig. 13). A series of elevon deflections at $M = 1.61$ (fig. 9) indicate that the control parameter $C_{m_\delta}$ is essentially linear at a constant lift coefficient over the deflection range investigated.

The longitudinal characteristics summarized in figure 12 indicate that the addition of camber to the body resulted in a positive shift in the trim lift coefficient equivalent to an elevon deflection of $-5^\circ$. This shift in $C_{m_0}$ resulted in an increase in the trim lift coefficient for a constant elevon deflection (fig. 13) with a resultant increase in the maximum trim lift coefficient available and in trim $(L/D)_{max}$. Both of these effects are in a direction to improve the maneuverability and altitude performance. The trim $(L/D)_{max}$ obtained for body 2 at $M = 1.61$ is about 3.9 (fig. 13) as compared with the untrimmed value of 5.7 (fig. 8).

Effect of the canard trimmer.- A fixed canard-type trimmer (mounted on body 1, fig. 6) was tested to determine its effectiveness as a destabilizing device. The canard trimmer reduced the static-stability parameter $\frac{\partial C_m}{\partial C_L}$ from a value of -0.180 to -0.145 (fig. 14). This reduction in stability should reduce the elevon deflection required for trim and consequently lower the trim drag. Further investigation of the effects of canard deflection on the trim drag and the effect of the canard wake on the inlet flow characteristics should be made to complete an analysis of the overall effectiveness of the canards.

Effects of the inlets open, faired closed, and removed.- While most of the tests were made with the air inlets faired closed (fig. 4) several runs were made at each Mach number with the air inlets open and with the air inlets entirely removed (body 2A) to determine the effects on the external aerodynamic characteristics of modifications to the inlet. For the inlets-open configuration a pressure-survey rake was installed at the inlet exit and the longitudinal force was corrected for the effects of internal flow. The data of figure 15 indicate a slightly lower value of minimum longitudinal-force coefficient with the air inlets faired closed. Still lower values of drag were obtained, of course, with the inlets removed. A comparison of the results with inlets on and inlets removed indicates that the addition of the inlets provides an increase in lift and pitching moment.

## Lateral Characteristics

Effect of the canard trimmer.- Tests of the configuration with the original vertical tail and with the canard trimmer on at $\alpha = 5.7^\circ$ and $M = 2.01$ (fig. 16) indicate essentially neutral directional stability. This configuration was not tested in sideslip at $\alpha = 5.7^\circ$ with the canard trimmer removed. However, it is not likely that the installation of the canard trimmer had any appreciable effect on the sideslip characteristics, since tests of the F-102A configuration at the same angle of attack and Mach number (ref. 4) indicated similar characteristics without the canard. However, the effect of the canard wake on $C_{n_\beta}$ at higher angles of attack should be determined before an accurate estimate of the canard effectiveness can be determined.

Effects of the inlets open and faired closed.- Fairing the inlets closed produced no significant change in the aerodynamic characteristics in sideslip (fig. 17).

Effect of the modified vertical tail.- Limited tests were made at low angles of attack of the sideslip characteristics of two vertical-tail configurations using body 1 (F-102B). These tests indicate that for the configuration with the original vertical tail, $C_{n_\beta}$ varies from about 0.00094 at $M = 1.61$ (fig. 18) to about 0.00037 at $M = 2.01$ (fig. 17). The addition of the modified vertical tail increased $C_{n_\beta}$ at $M = 1.61$ to about 0.00130. Since no sideslip tests were made at angles of attack higher than $5.7^\circ$, it should be pointed out that there may be significant decreases in $C_{n_\beta}$ at the higher angles of attack (ref. 4).

## CONCLUSIONS

The results of an investigation of various modifications of a model of the Convair F-102B airplane at Mach numbers of 1.41, 1.61, and 2.01 have indicated the following conclusions:

1. All the body modifications with the exception of the ones having reflexed afterbodies resulted in slightly lower values of minimum drag than those for the F-102A configuration.

2. Results for the reflexed body configuration indicated a large positive increment in pitching-moment coefficient at constant lift with a resultant decrease in the elevon deflection required for trim.

3. Addition of a horizontal canard decreased the static-stability parameter from -0.180 to -0.145 at a Mach number of 2.01 without significantly affecting the directional stability.

4. A swept vertical tail having a larger area than the original delta plan form increased the value of directional stability from 0.00094 to 0.0013 at a Mach number of 1.61.

5. The effects on the external aerodynamic characteristics of fairing the air inlets closed were negligible except for a small decrease in minimum drag.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 7, 1956.

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2. Hilton, John H., Jr., and Palazzo, Edward B.: Wind-Tunnel Investigation of a Modified 1/20-Scale Model of the Convair MX-1554 Airplane at Mach Numbers of 1.41 and 2.01. NACA RM SL53G30, U. S. Air Force, 1953.

3. Spearman, M. Leroy, and Hughes, William C.: Aerodynamic Characteristics at a Mach Number of 1.41 of a Model of the Convair F-102 Airplane Equipped With an Extended Contoured Afterbody, Cambered Wing Leading Edge, and Reflexed Wing-Tip Trailing Edge. NACA RM SL54J26, U. S. Air Force, 1954.

4. Spearman, M. Leroy, and Driver, Cornelius: Aerodynamic Characteristics of a 0.04956-Scale Model of the Convair F-102A Airplane at Mach Numbers of 1.41, 1.61, and 2.01. NACA RM SL55I22, U. S. Air Force, 1955.

TABLE I

GEOMETRIC CHARACTERISTICS OF THE F-102B WING AND VERTICAL TAIL

| Wing: | |
|---|---|
| Area (including body intercept), sq ft | 1.732 |
| Span, in. | 24.76 |
| Mean geometric chord, in. | 13.43 |
| Aspect ratio | 2.46 |
| Taper ratio | 0 |
| Airfoil section | NACA 0004-63(modified) |
| Angle of incidence, deg | 0 |
| Dihedral angle, deg | 0 |
| Sweep of leading edge, deg | 57 |
| Sweep of trailing edge, deg | -5 |
| Leading-edge camber, percent | 15.0 |

| Vertical tails: | Original | Revised |
|---|---|---|
| Area (exposed), sq in. | 23.45 | 30.15 |
| Span (exposed), in. | 5.00 | 5.15 |
| Aspect ratio (exposed) | 1.07 | 0.88 |
| Taper ratio (exposed) | 0 | 0.25 |
| Airfoil section | NACA 0004-65 (modified) | Modified hexagon |
| Sweep of leading edge, deg | 60 | 60 |
| Sweep of trailing edge, deg | -5 | 20 |

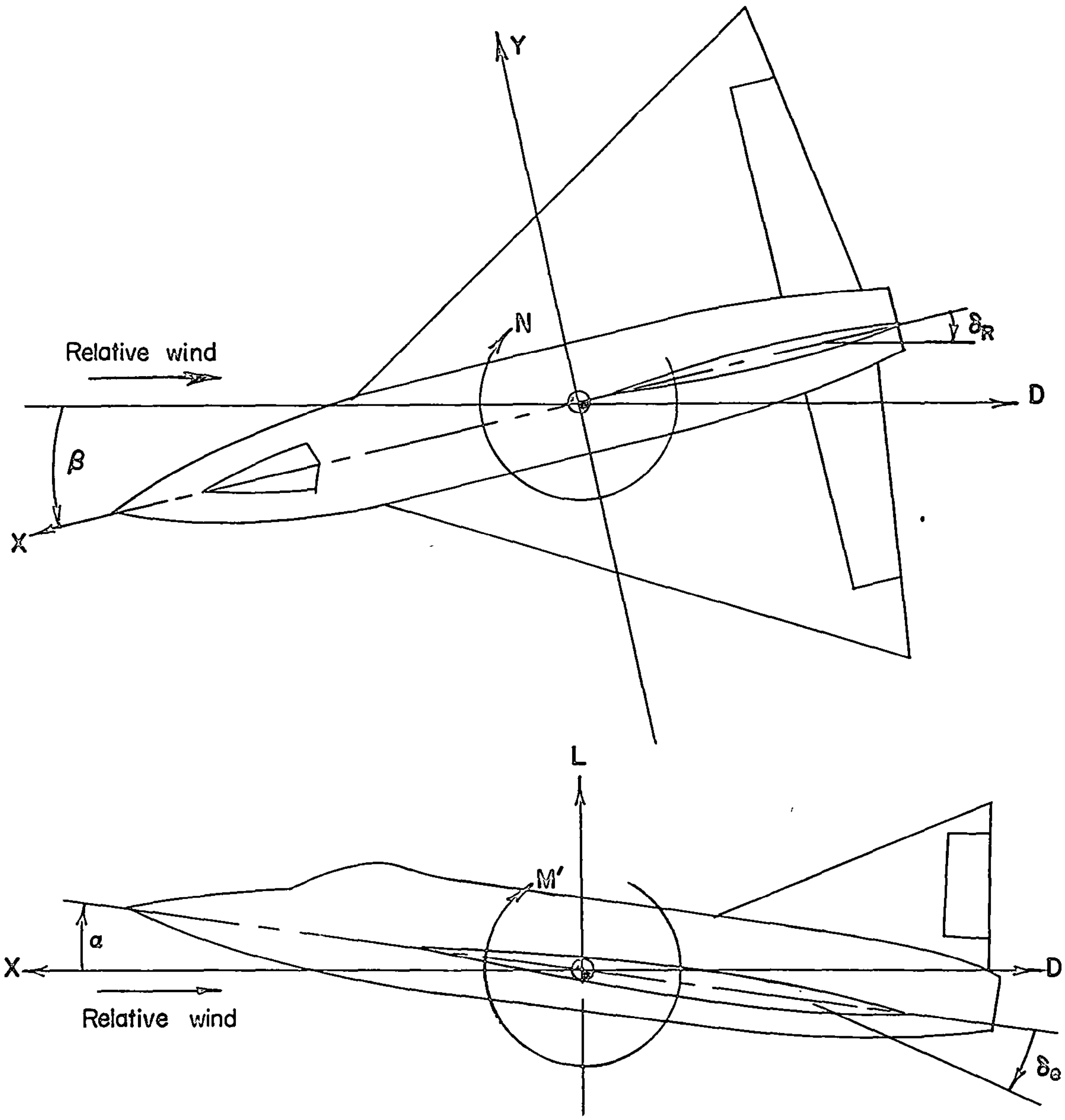


Figure 1.- System of stability axes. Arrows indicate positive direction of forces and moments.

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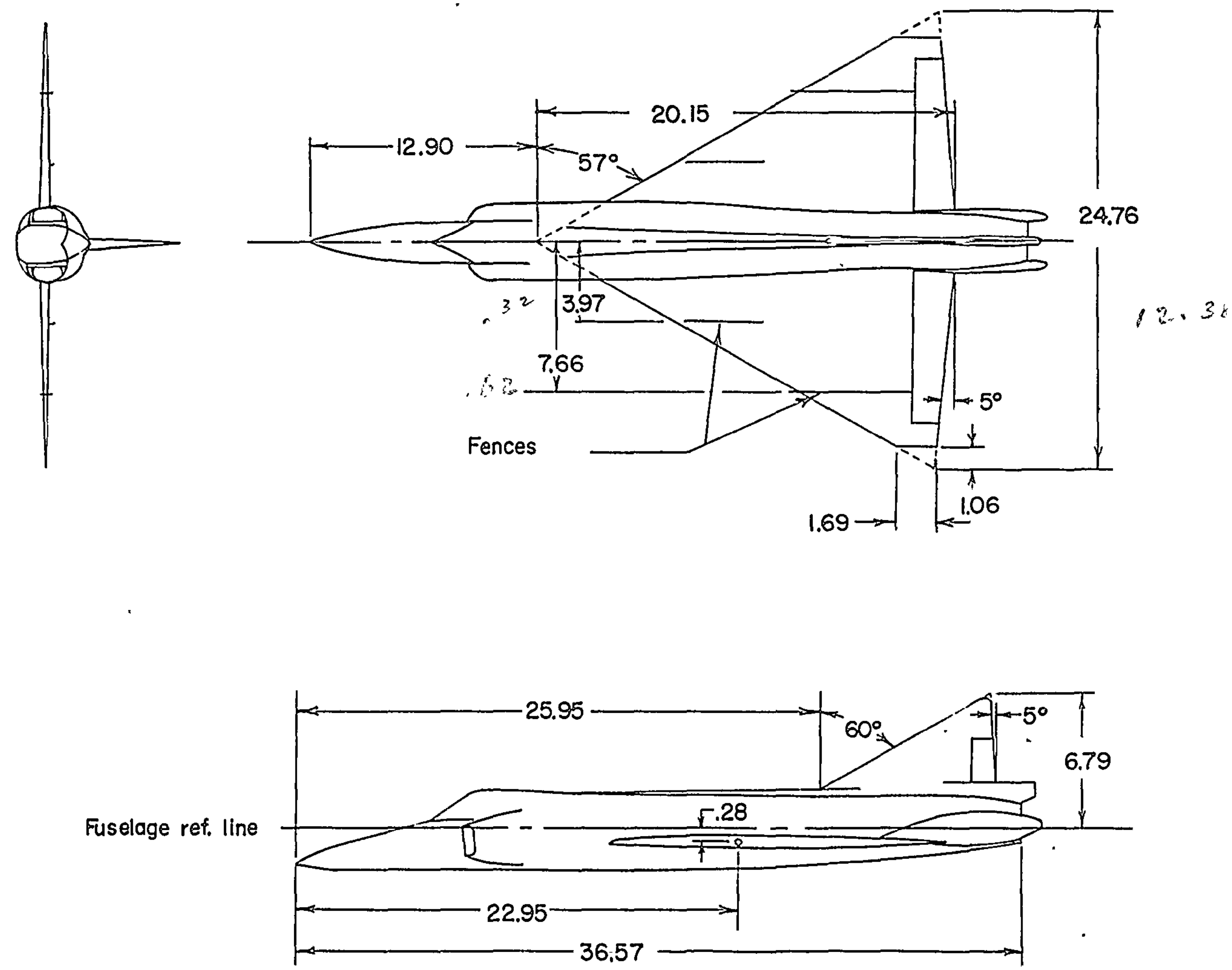


(a) F-102A with 57°, 15-percent cambered wing.

Figure 2.- Sketches of models. All dimensions in inches except as noted.

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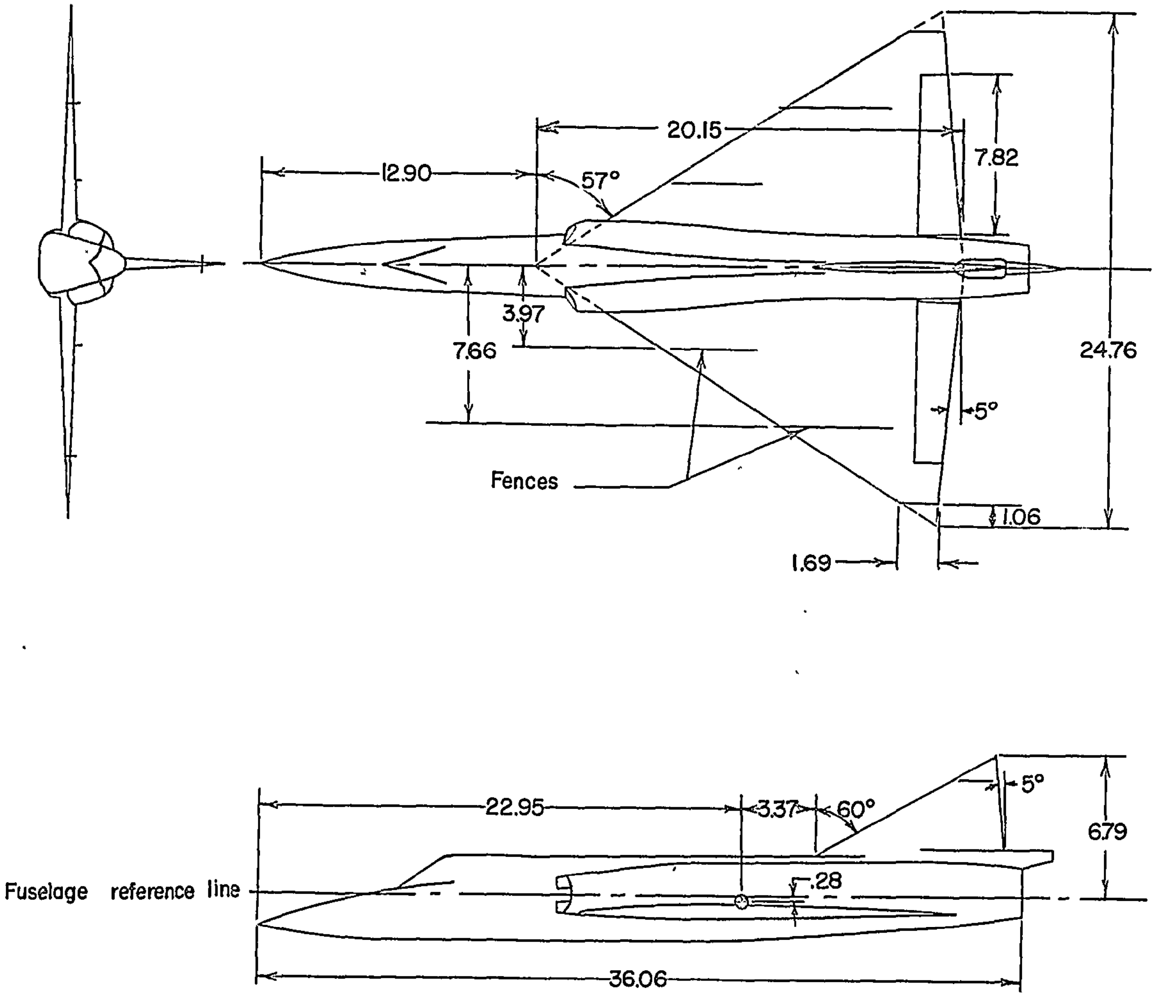


(b) F-102B, body 1.

Figure 2.- Continued.

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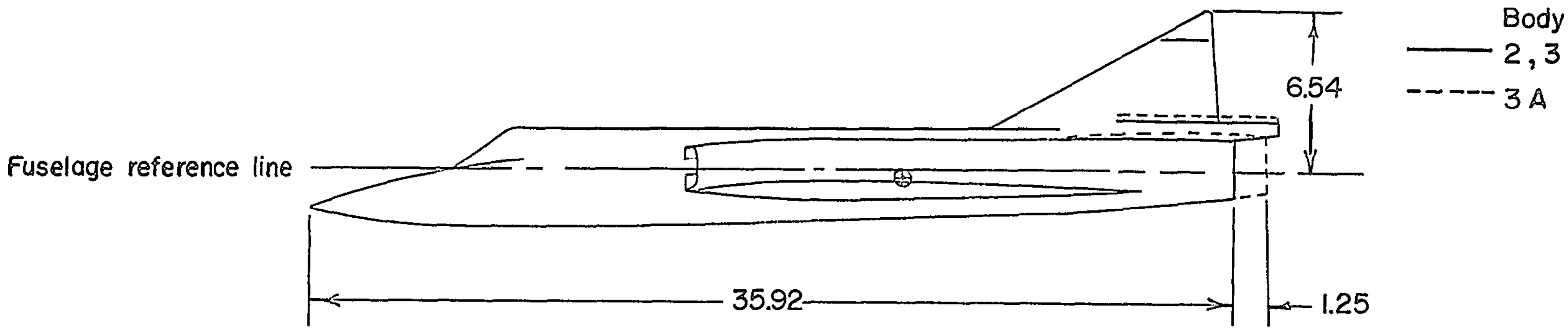
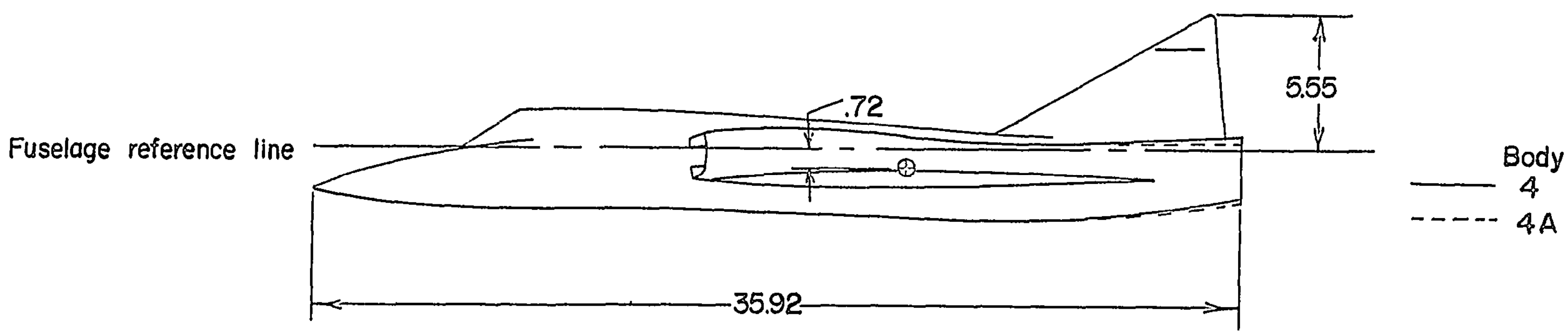



(c) F-102B, bodies 2, 3, and 3A.




(d) F-102B, bodies 4 and 4A.

Figure 2.- Concluded. Dimensions for body 1 apply except as shown.

[redacted]

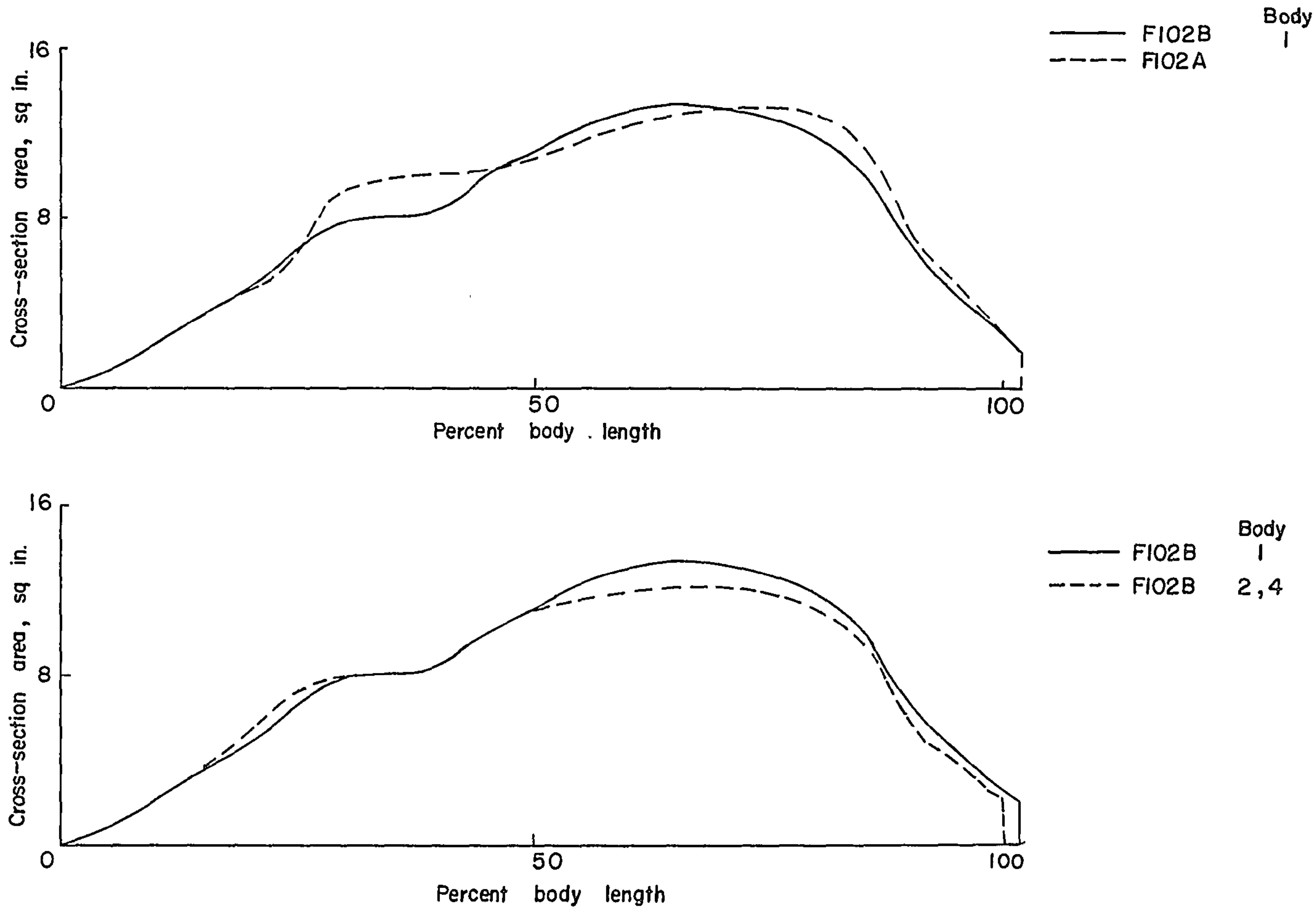



Figure 3.- Longitudinal area distributions (perpendicular sections) at M = 1.0. Percent body lengths based on F-102B, body 2. All areas are for open inlets with internal airflow area subtracted except for body 2A.

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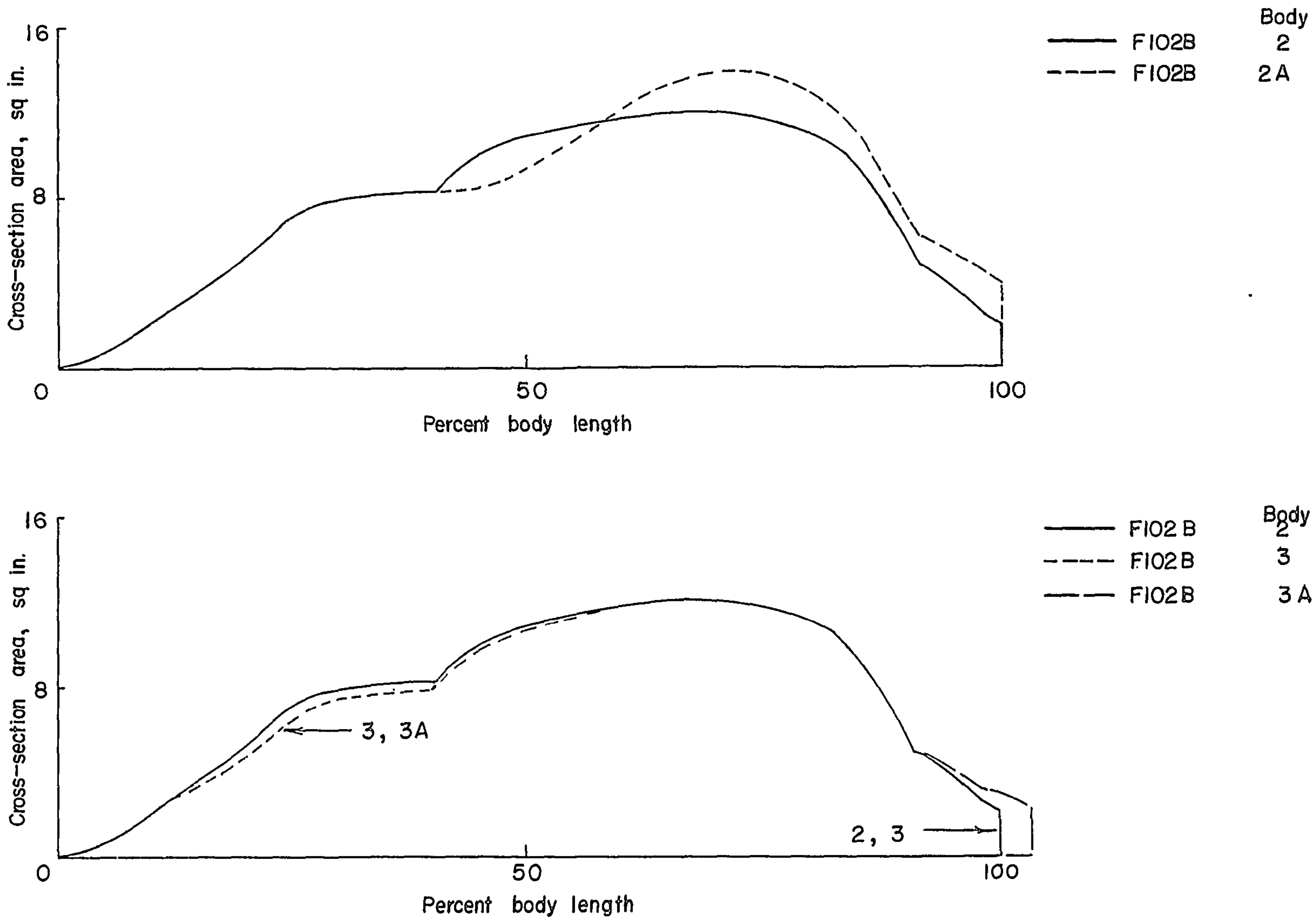
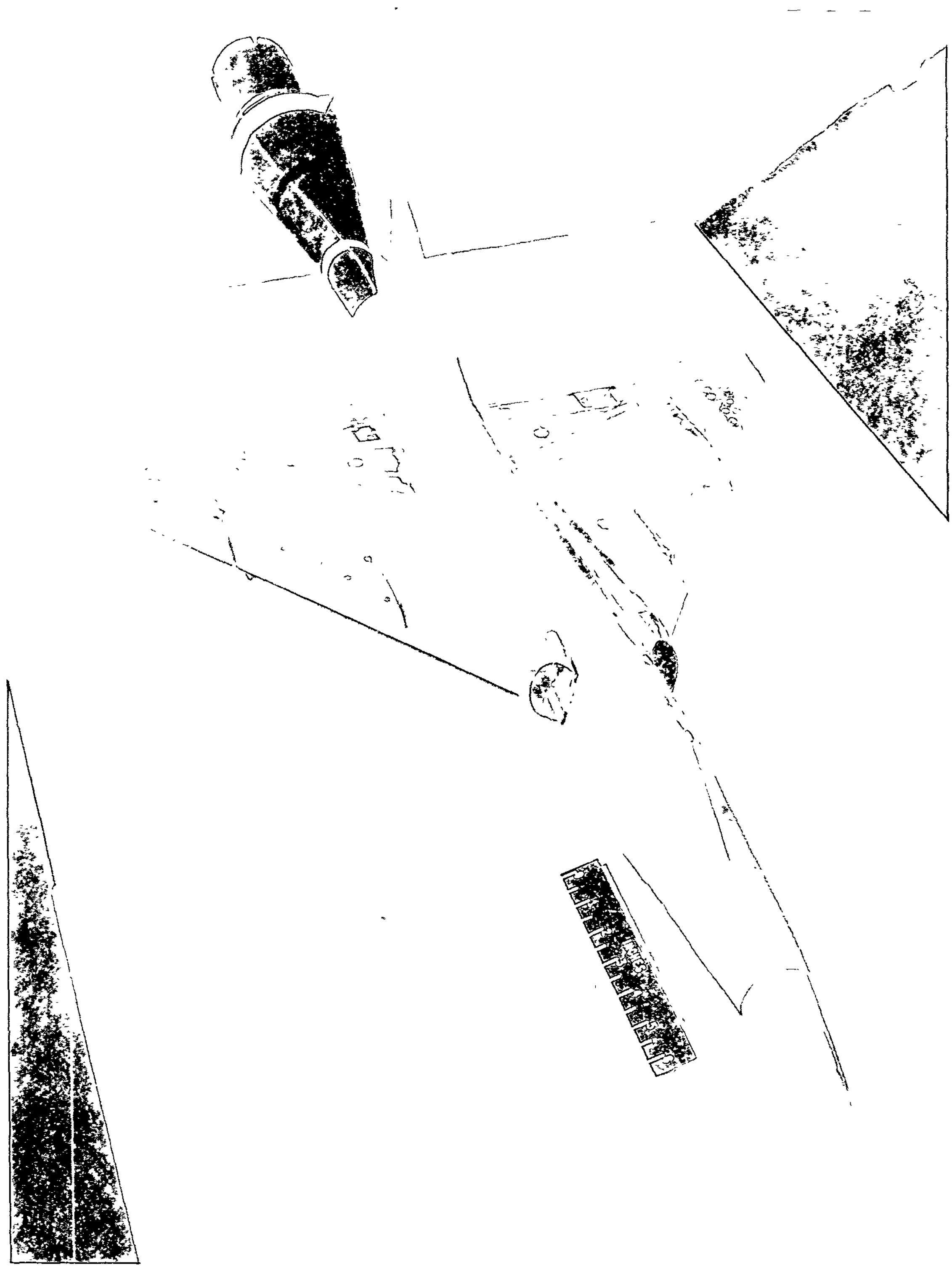



Figure 3.- Concluded.



(a) Air inlets open. L-87820

Figure 4.- Photograph of the Convair F-102B model.

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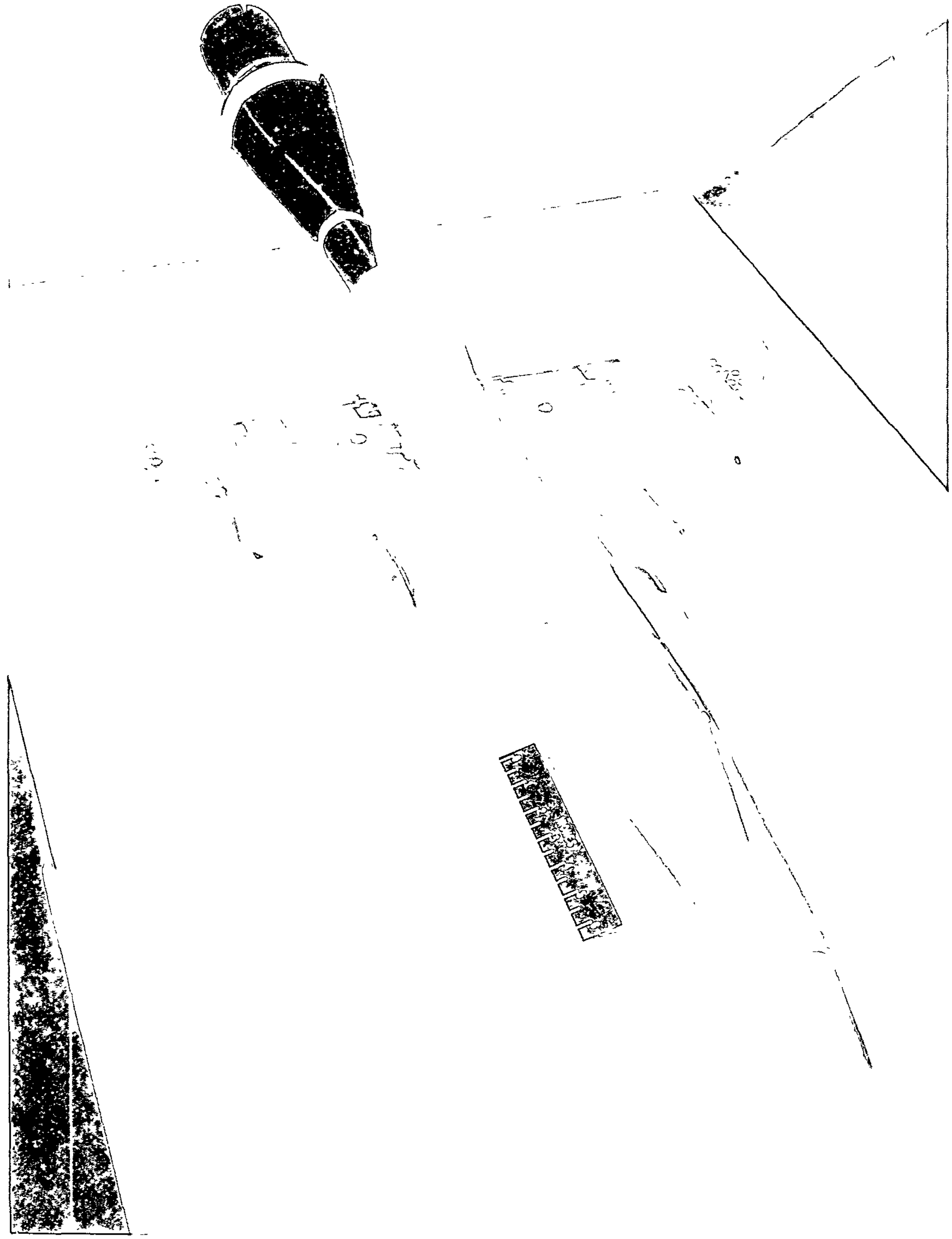

(b) Air inlets faired closed. L-87821

Figure 4.- Concluded.

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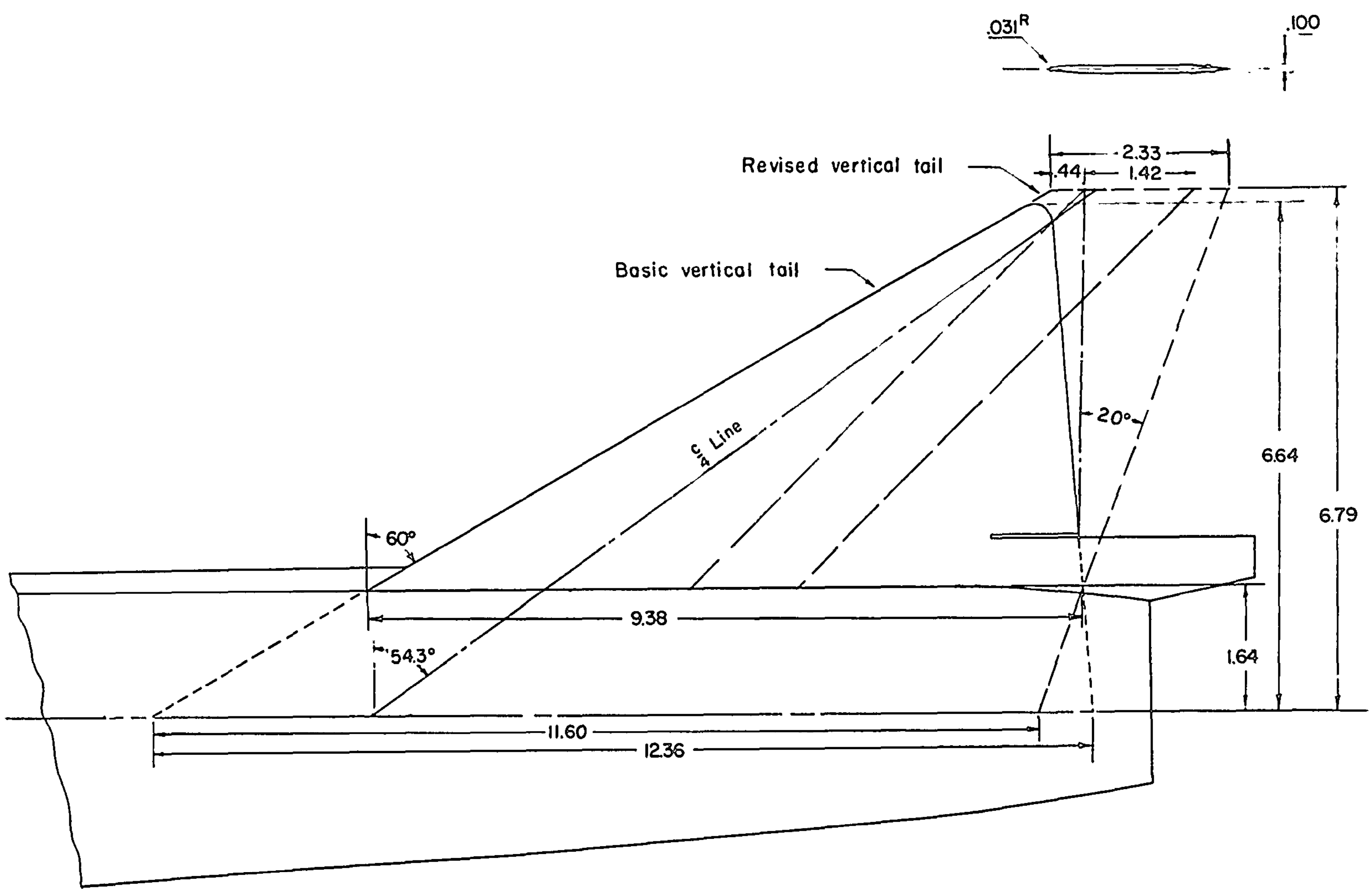



Figure 5.- Details of revised vertical tail.

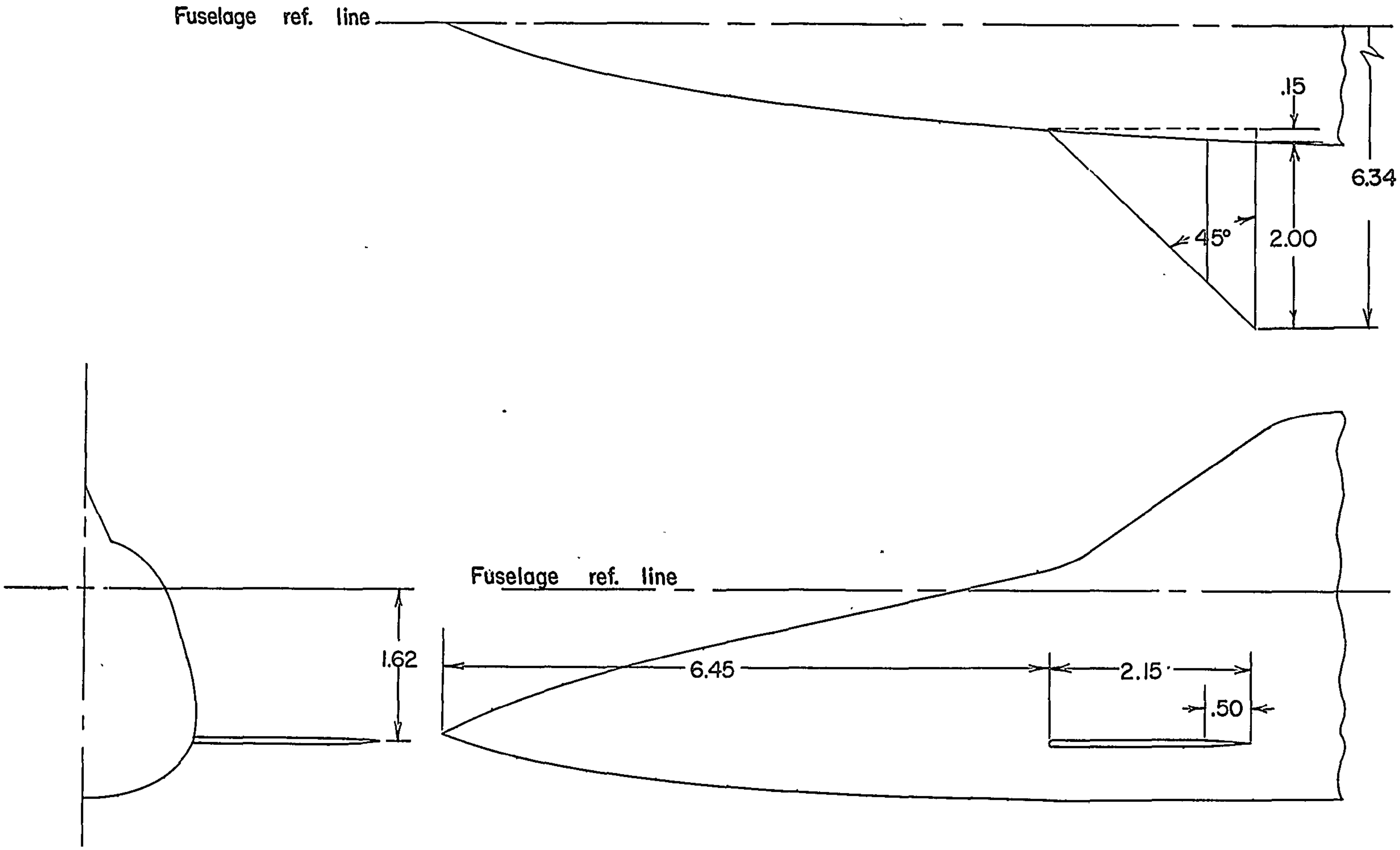
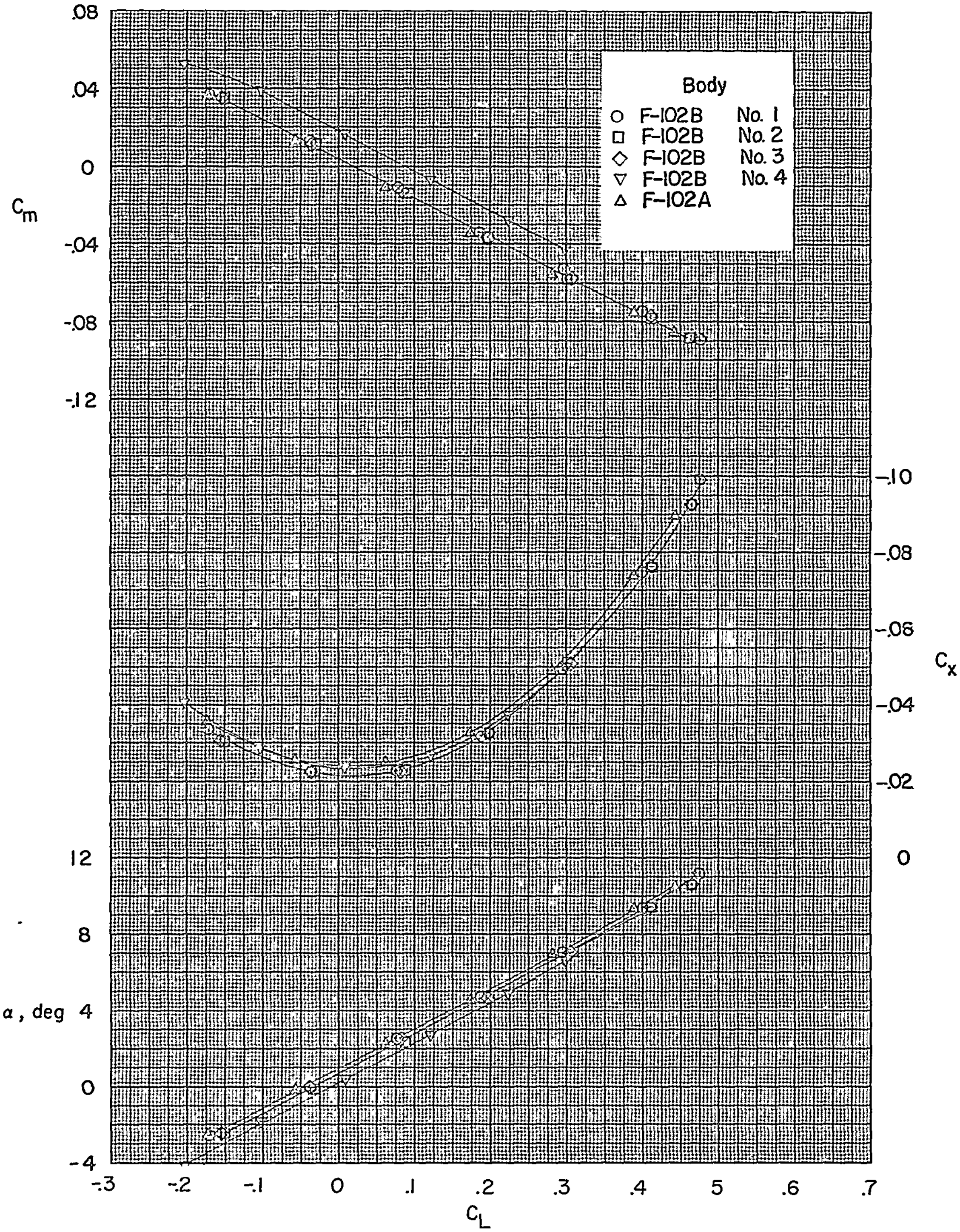
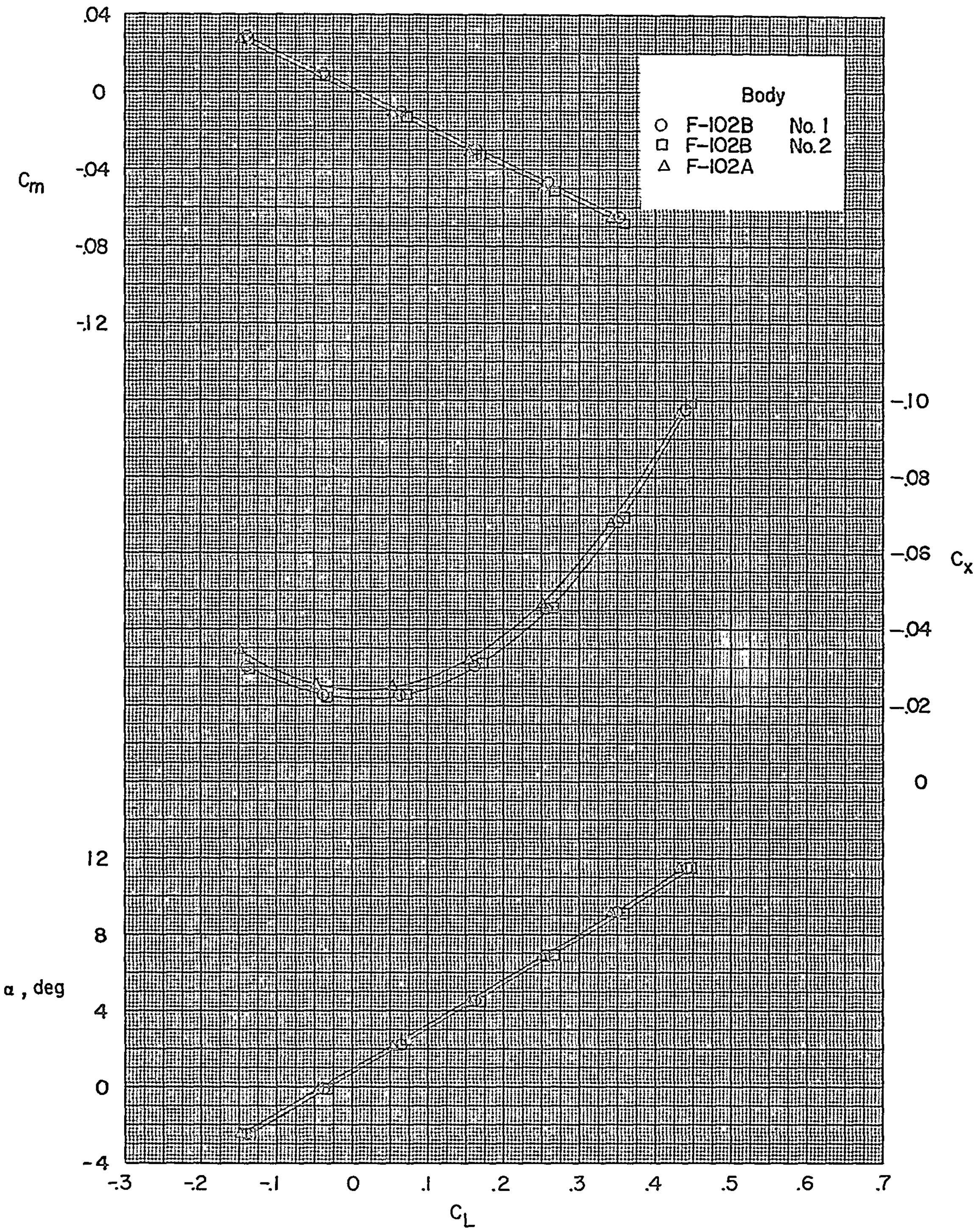



Figure 6.- Details of canard trimmer.



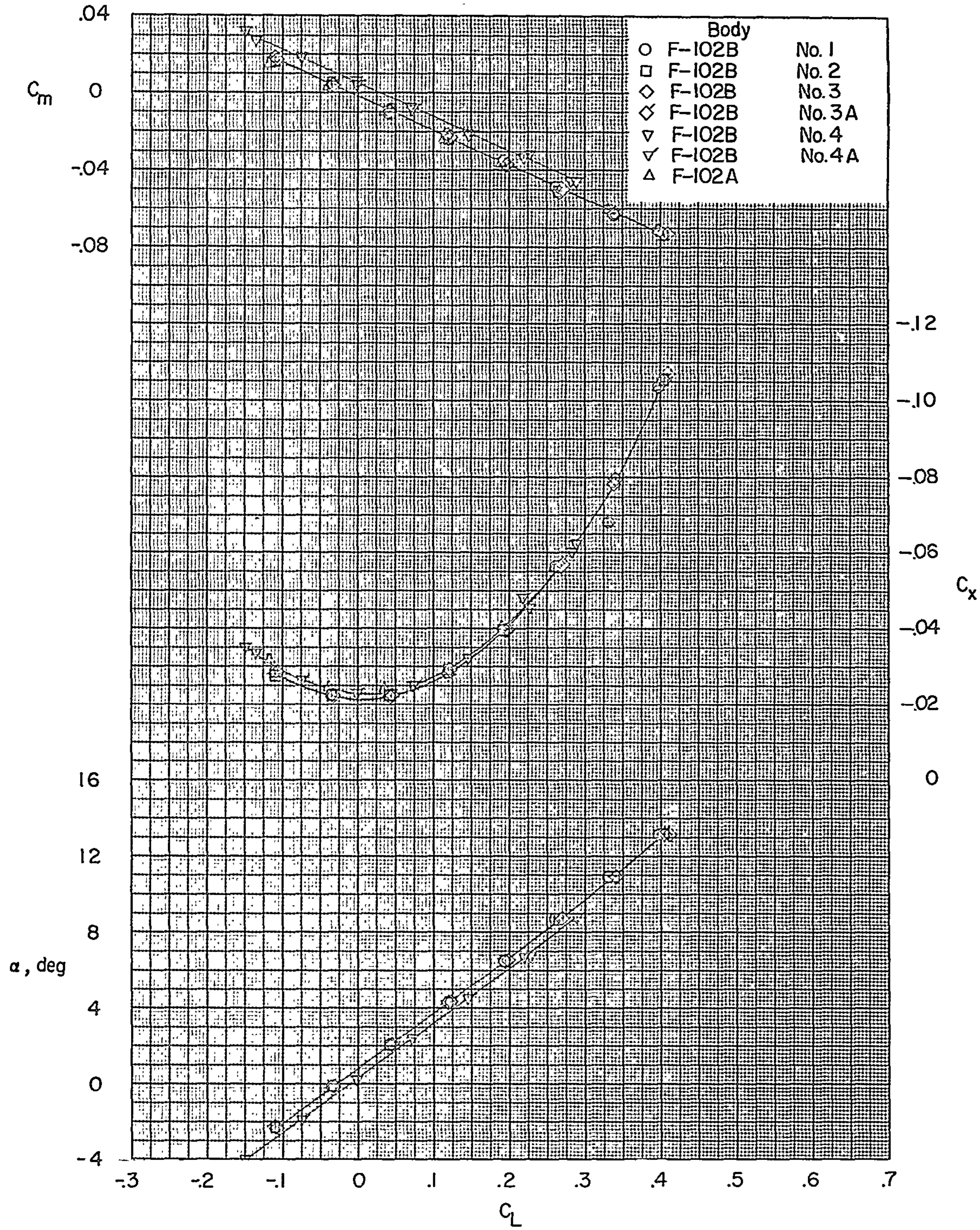

(a) M = 1.41.

Figure 7.- Effects of various fuselage modifications on the longitudinal aerodynamic characteristics. $\delta_e = 0^{\circ}$.



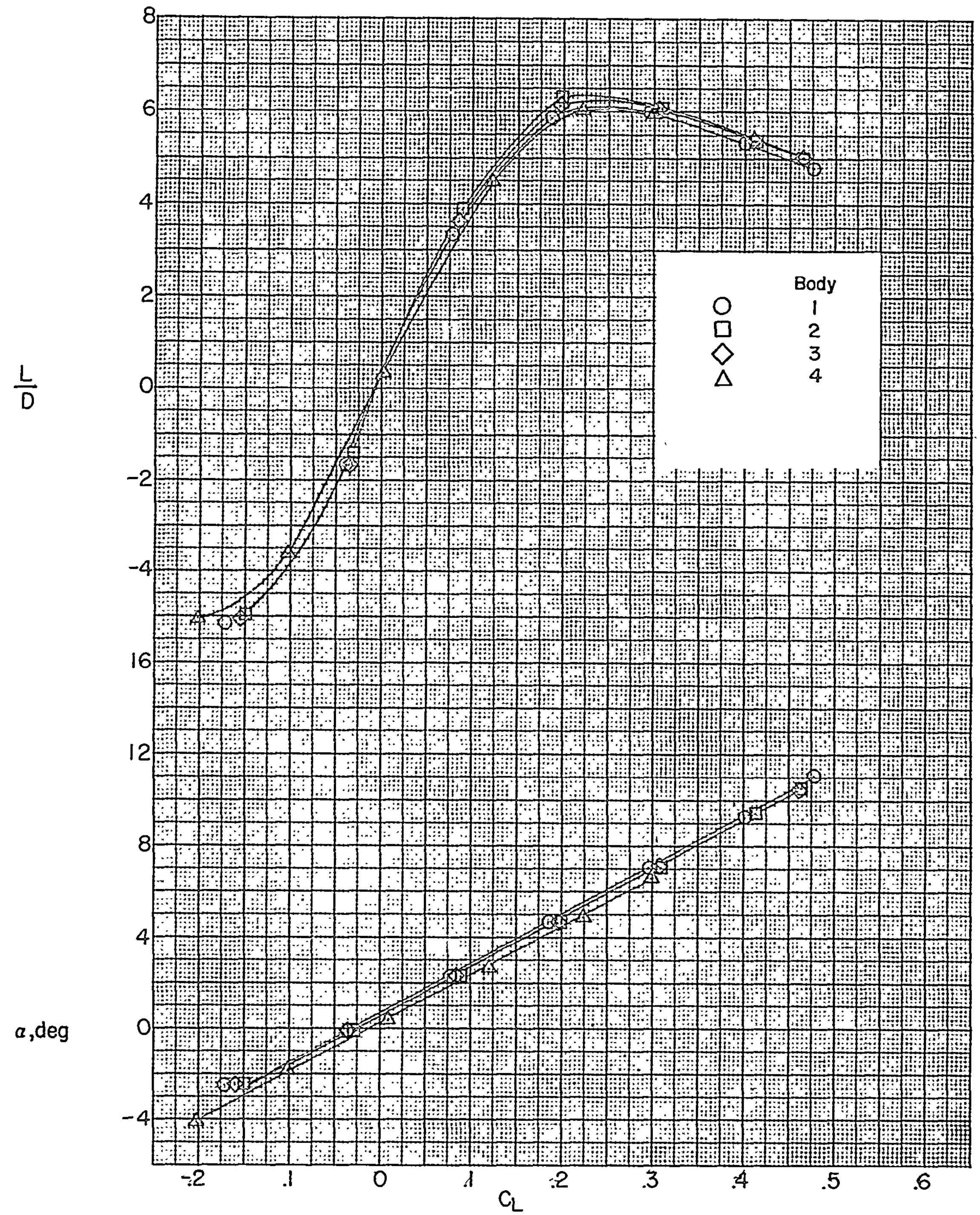

(b) M = 1.61.

Figure 7.- Continued.



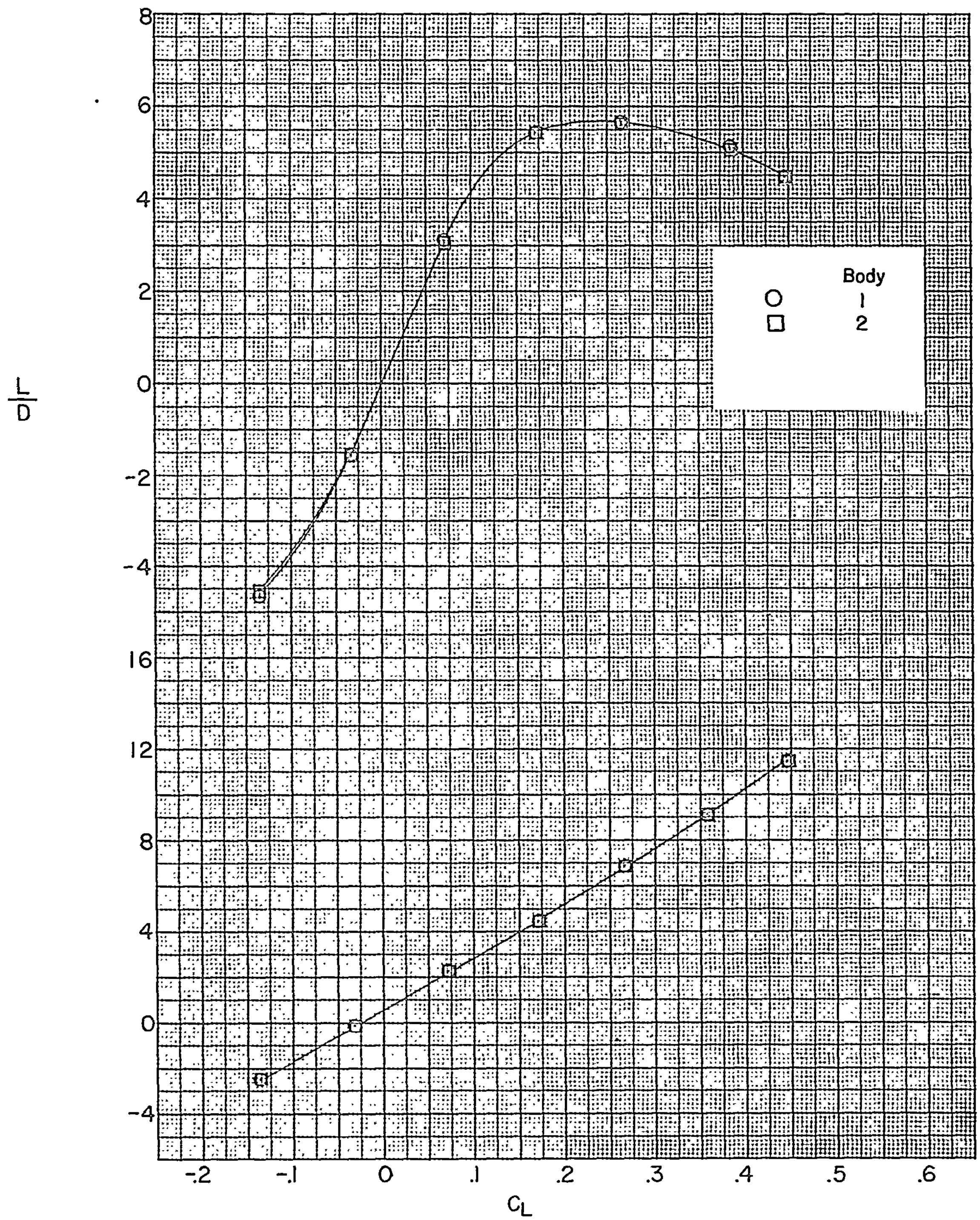

(c) M = 2.01.

Figure 7.- Concluded.



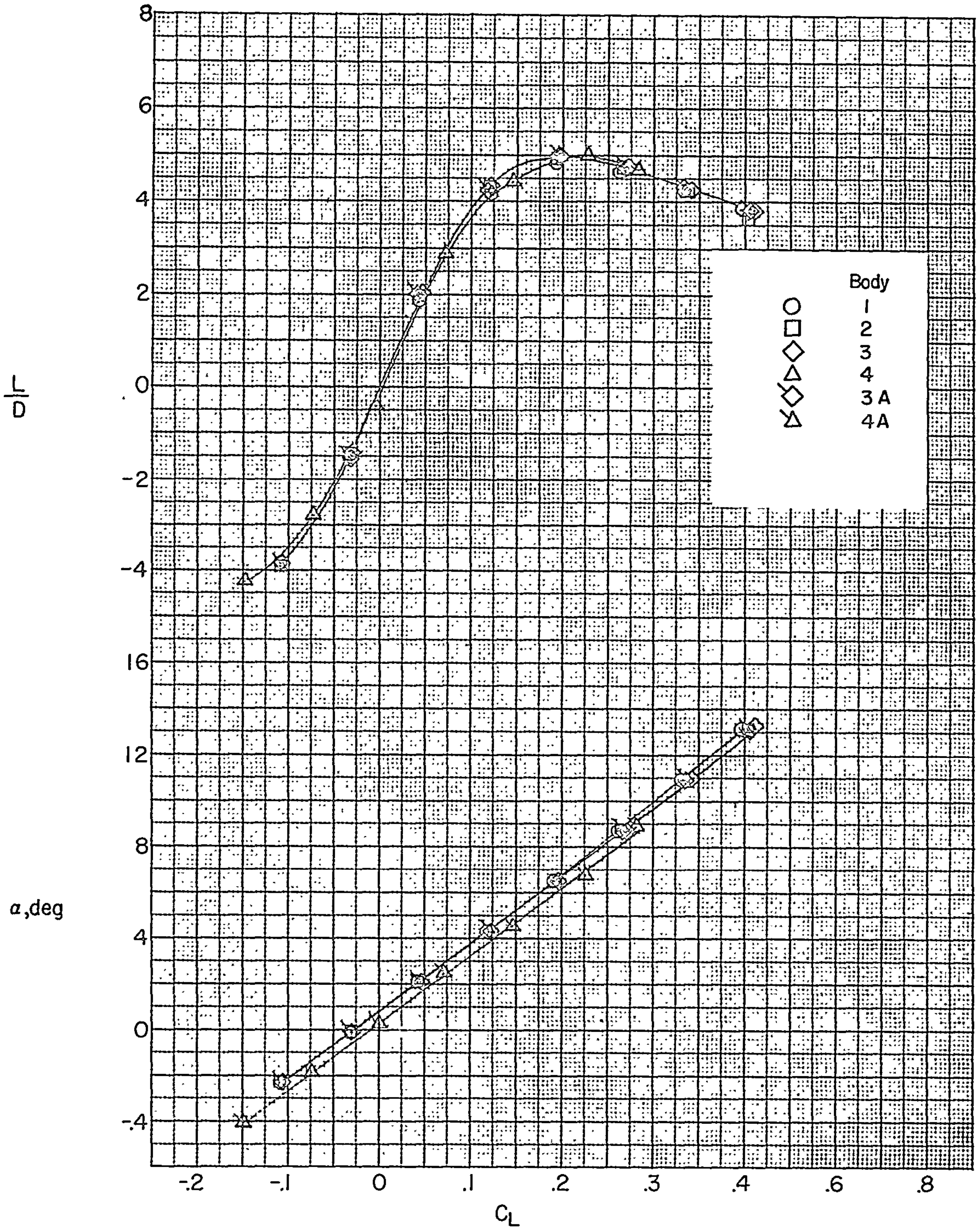

(a) M = 1.41.

Figure 8.- Effect of fuselage modifications on the variation of angle of attack and lift-drag ratio with lift coefficient. $\delta_e = 0^\circ$.



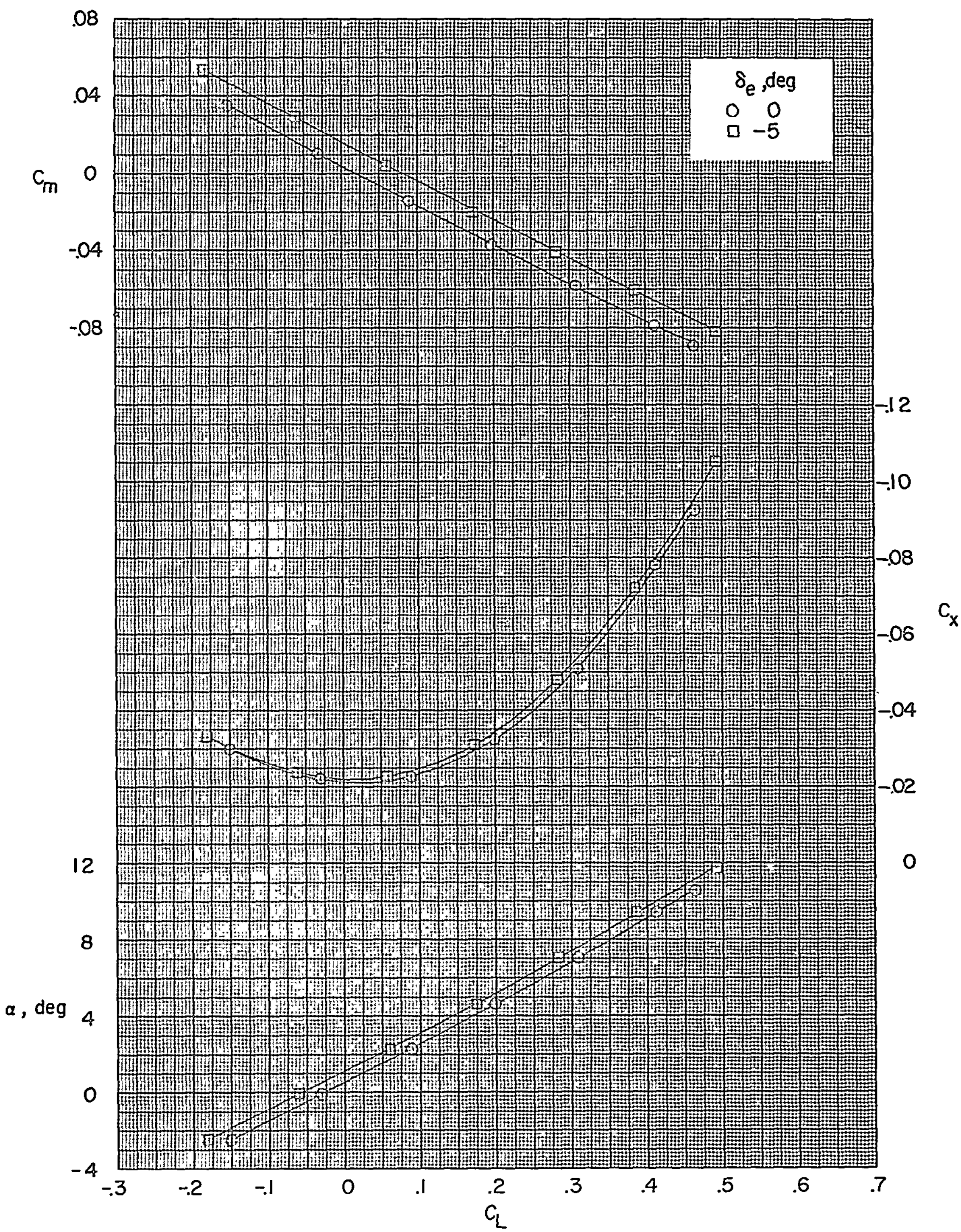

(b) M = 1.61.

Figure 8.- Continued.



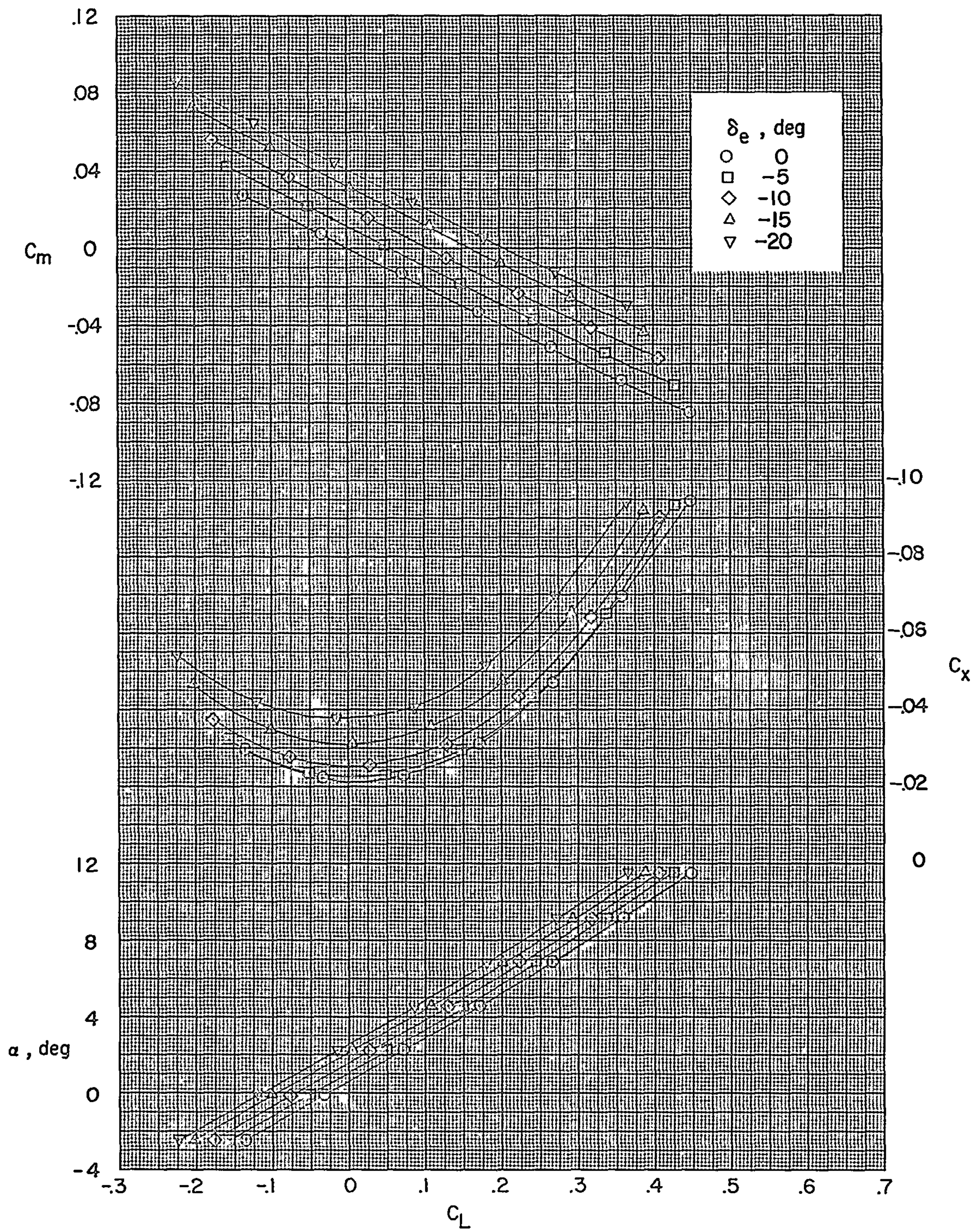

(c) M = 2.01.

Figure 8.- Concluded.



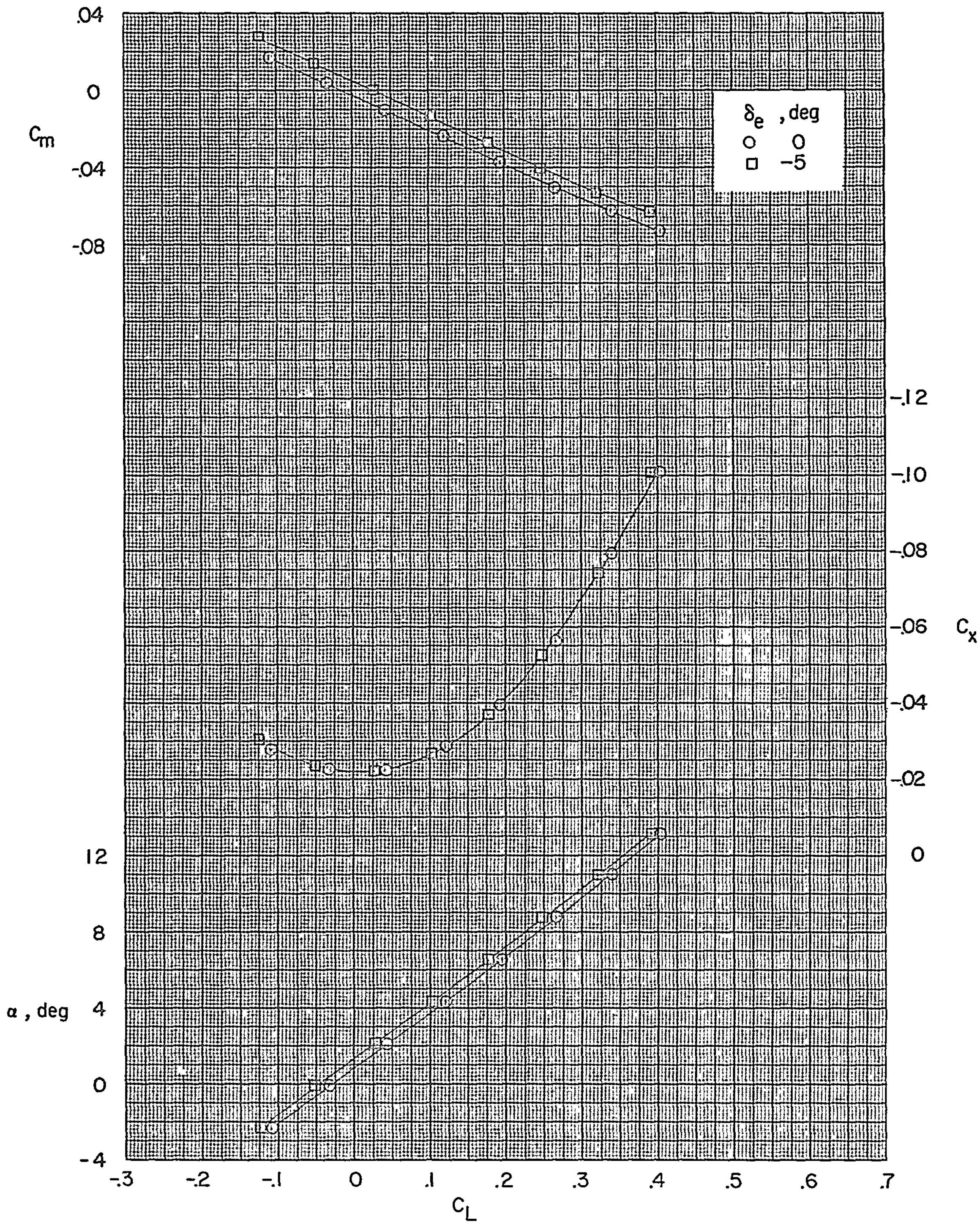

(a) M = 1.41.

Figure 9.- Effects of elevon deflection on the longitudinal aerodynamic characteristics of body 2.




(b) M = 1.61.

Figure 9.- Continued.




(c) M = 2.01.

Figure 9.- Concluded.

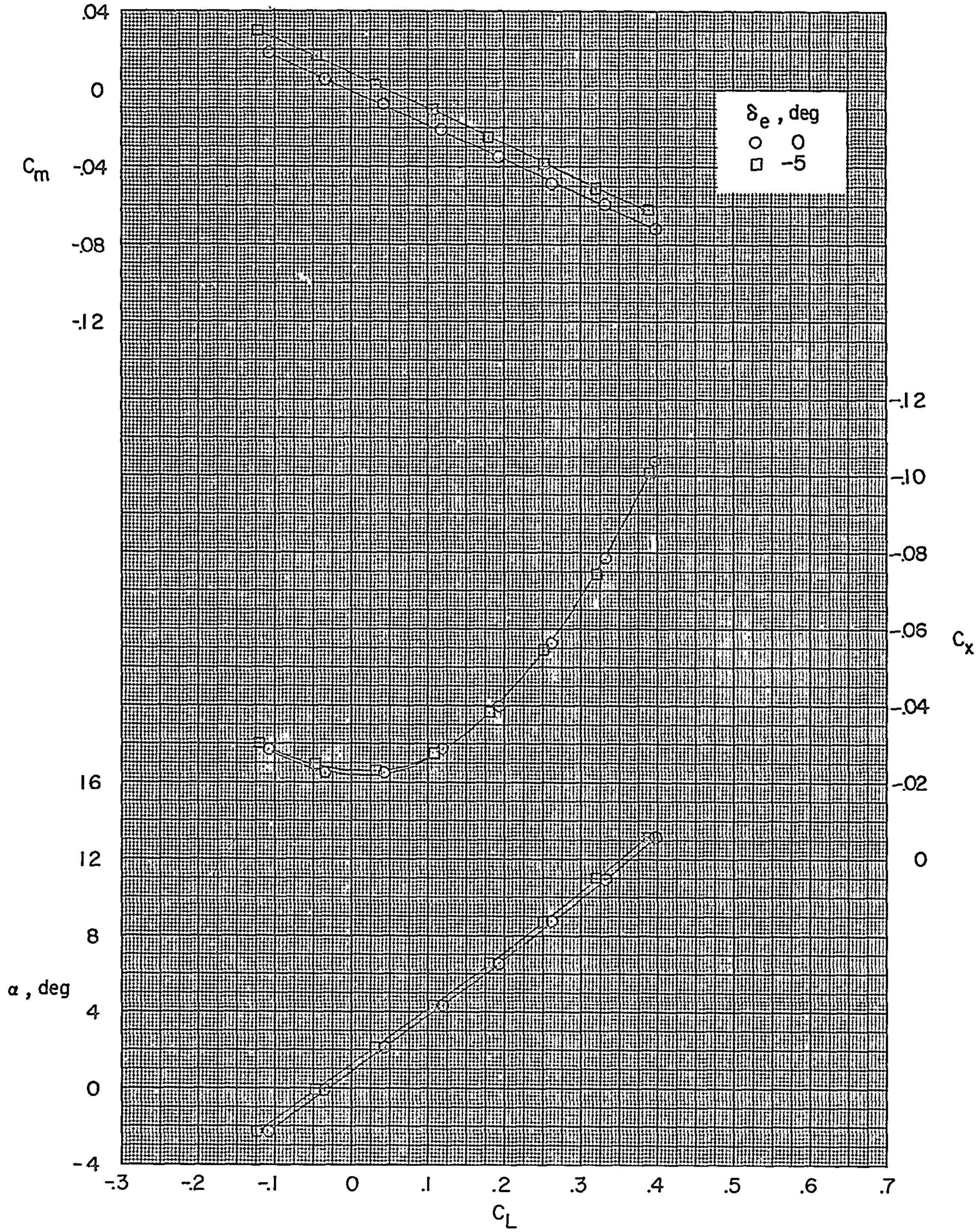



Figure 10.- Effects of elevon deflection on the longitudinal aerodynamic characteristics of body 1. M = 2.01.

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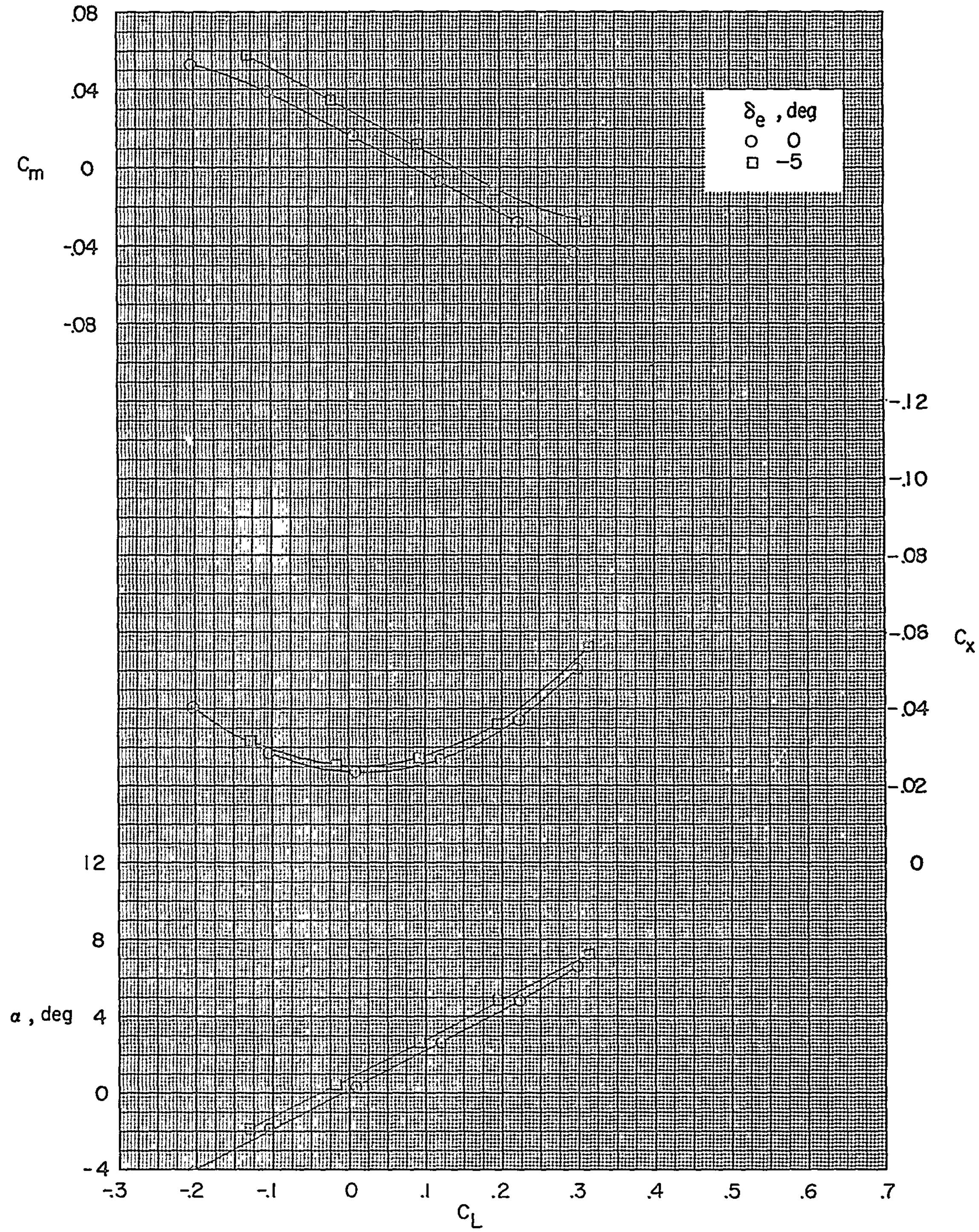
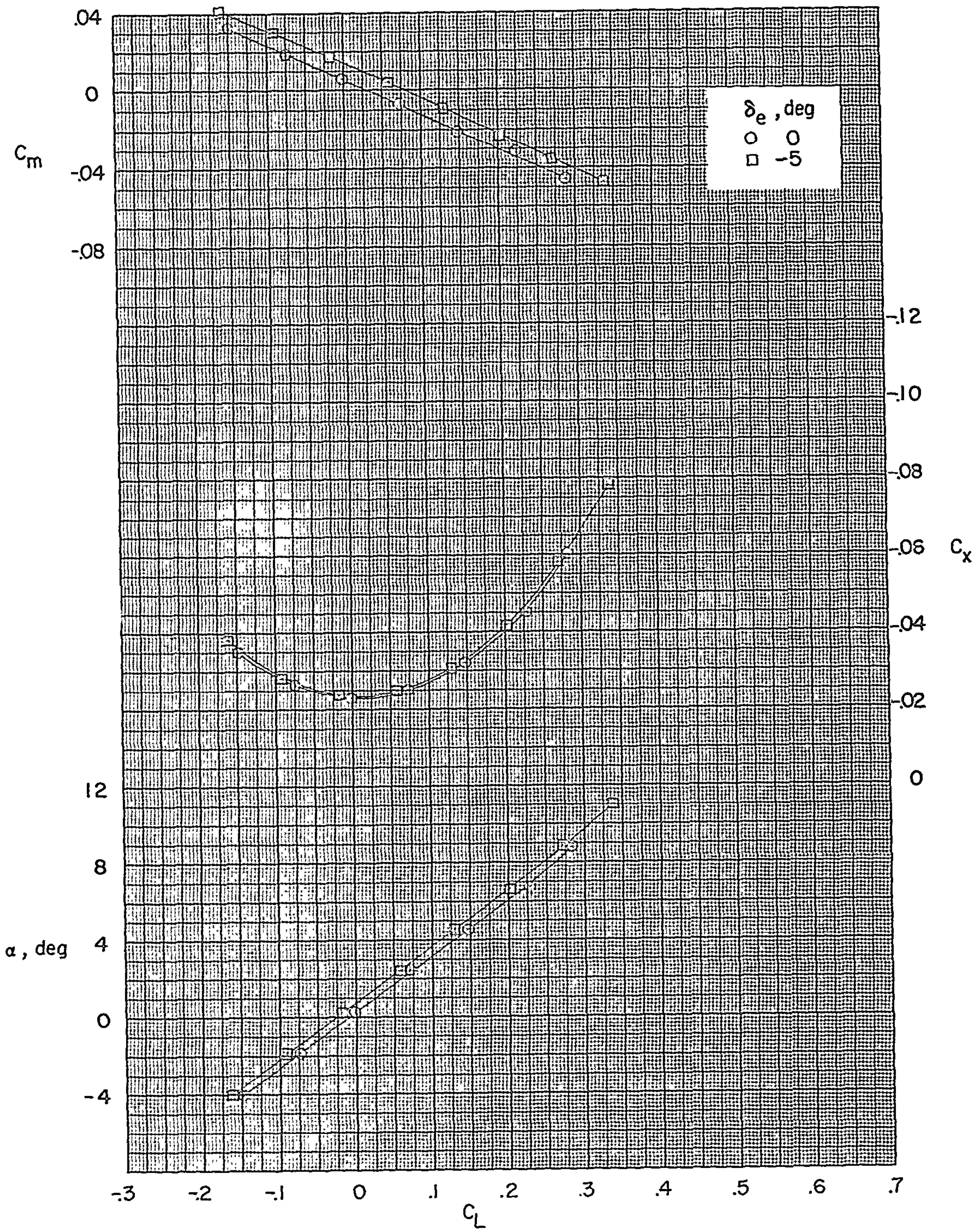



(a) M = 1.41.

Figure 11.- Effects of elevon deflection on the longitudinal aerodynamic characteristics of body 4.

[redacted]




(b) M = 2.01.

Figure 11.- Concluded.

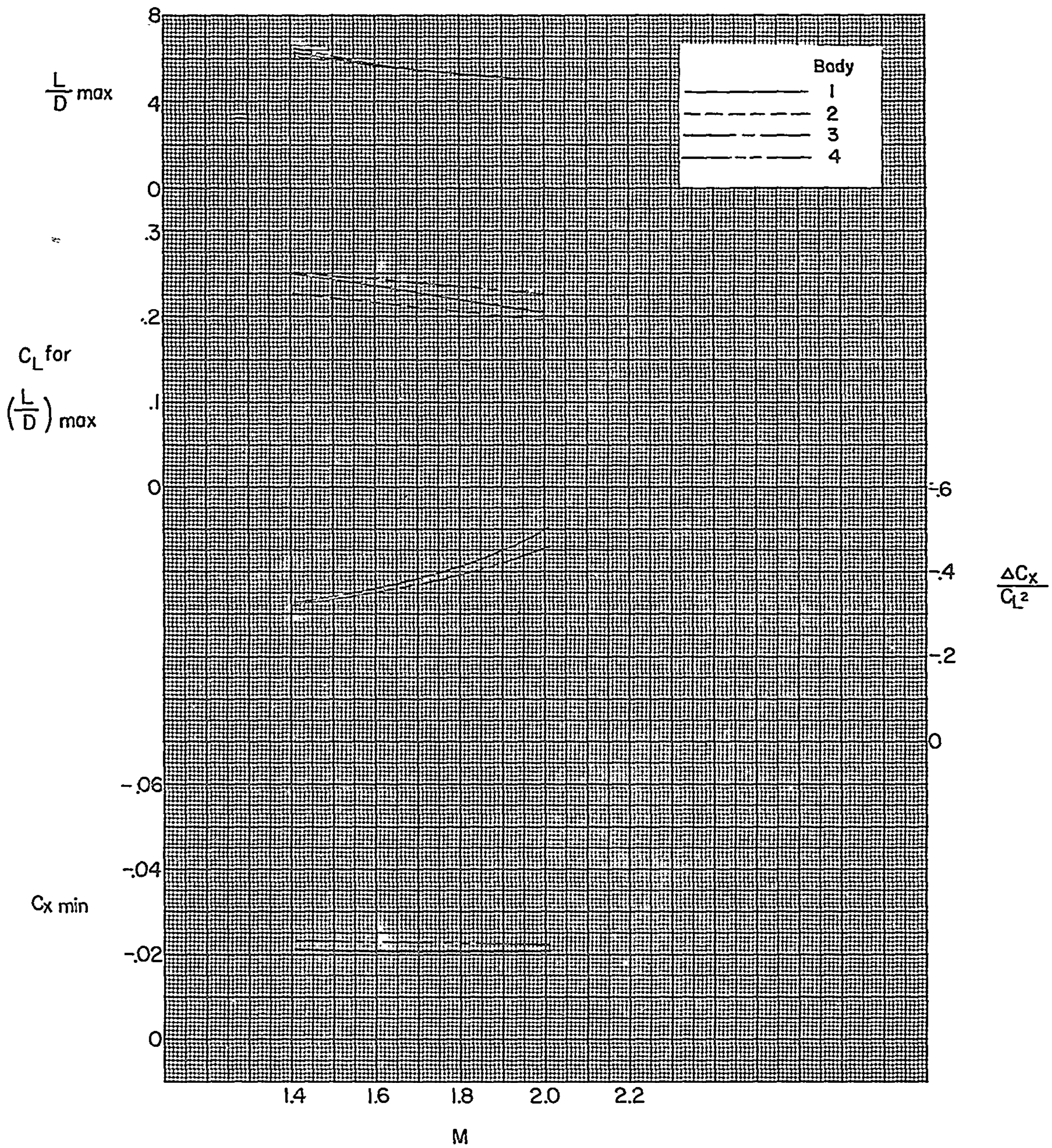



Figure 12.- Variation of the longitudinal characteristics with Mach number. $\delta_e = 0^{\circ}$.

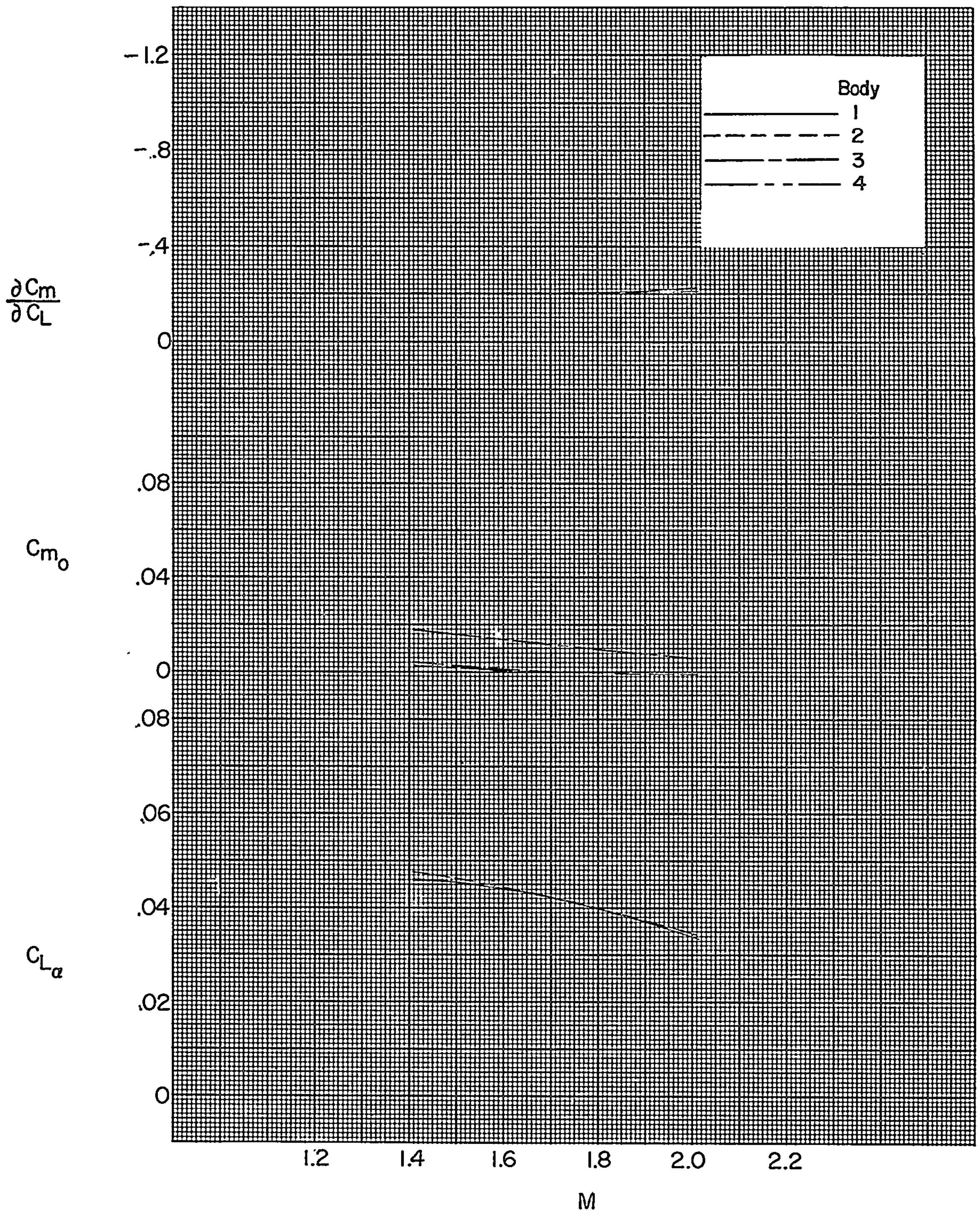
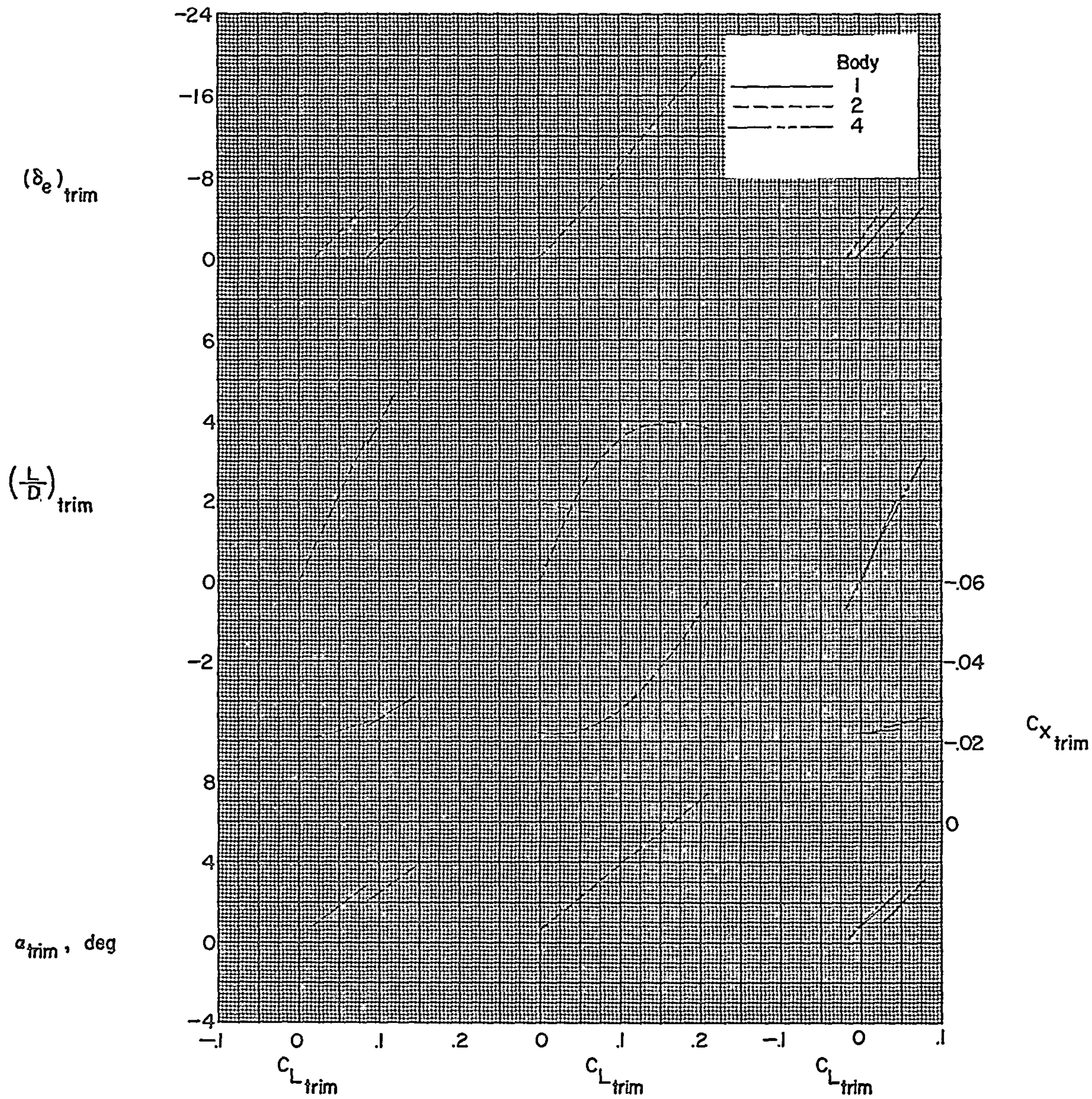



Figure 12.- Concluded.




(a) M = 1.41. (b) M = 1.61. (c) M = 2.01.

Figure 13.- Longitudinal trim characteristics.

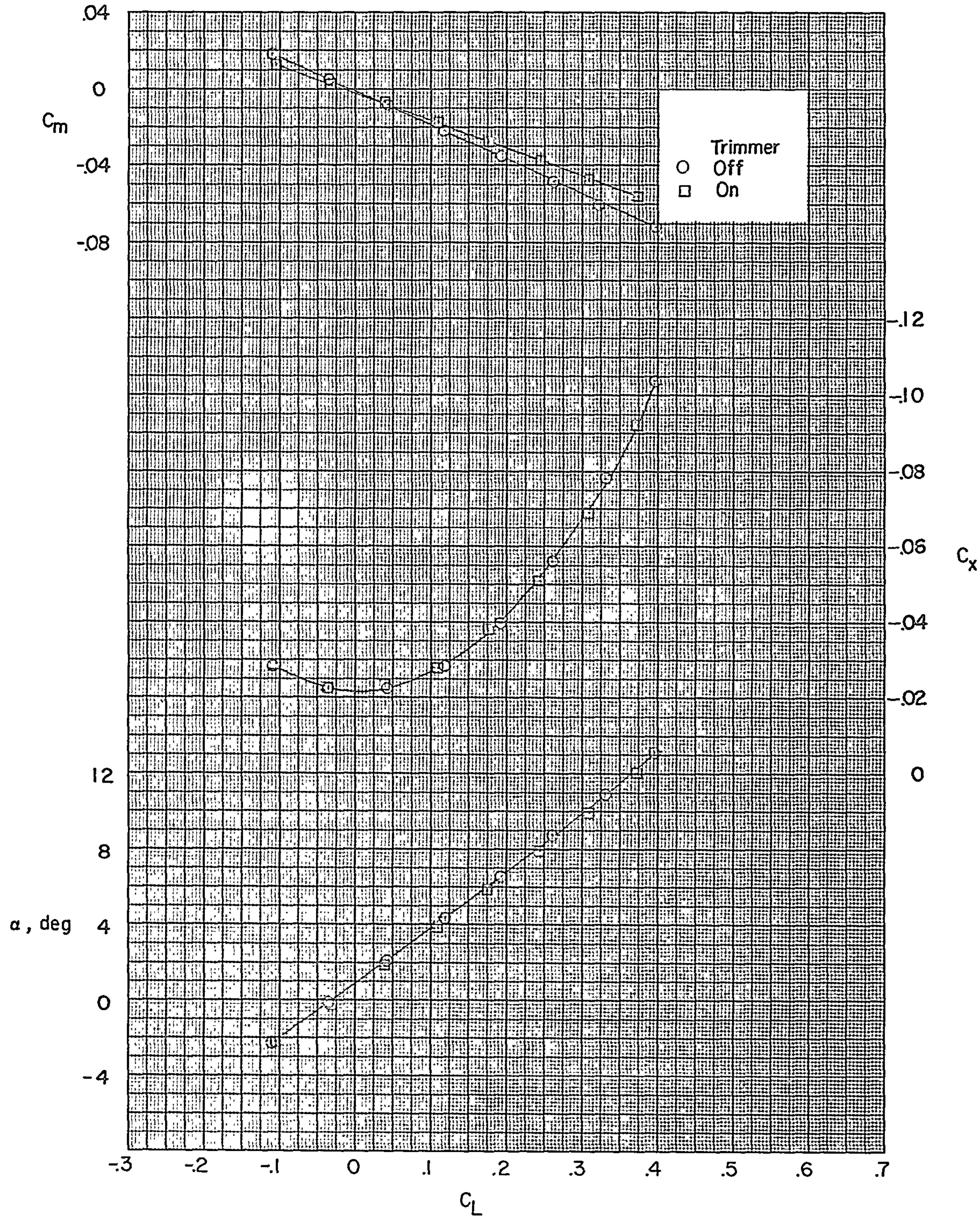
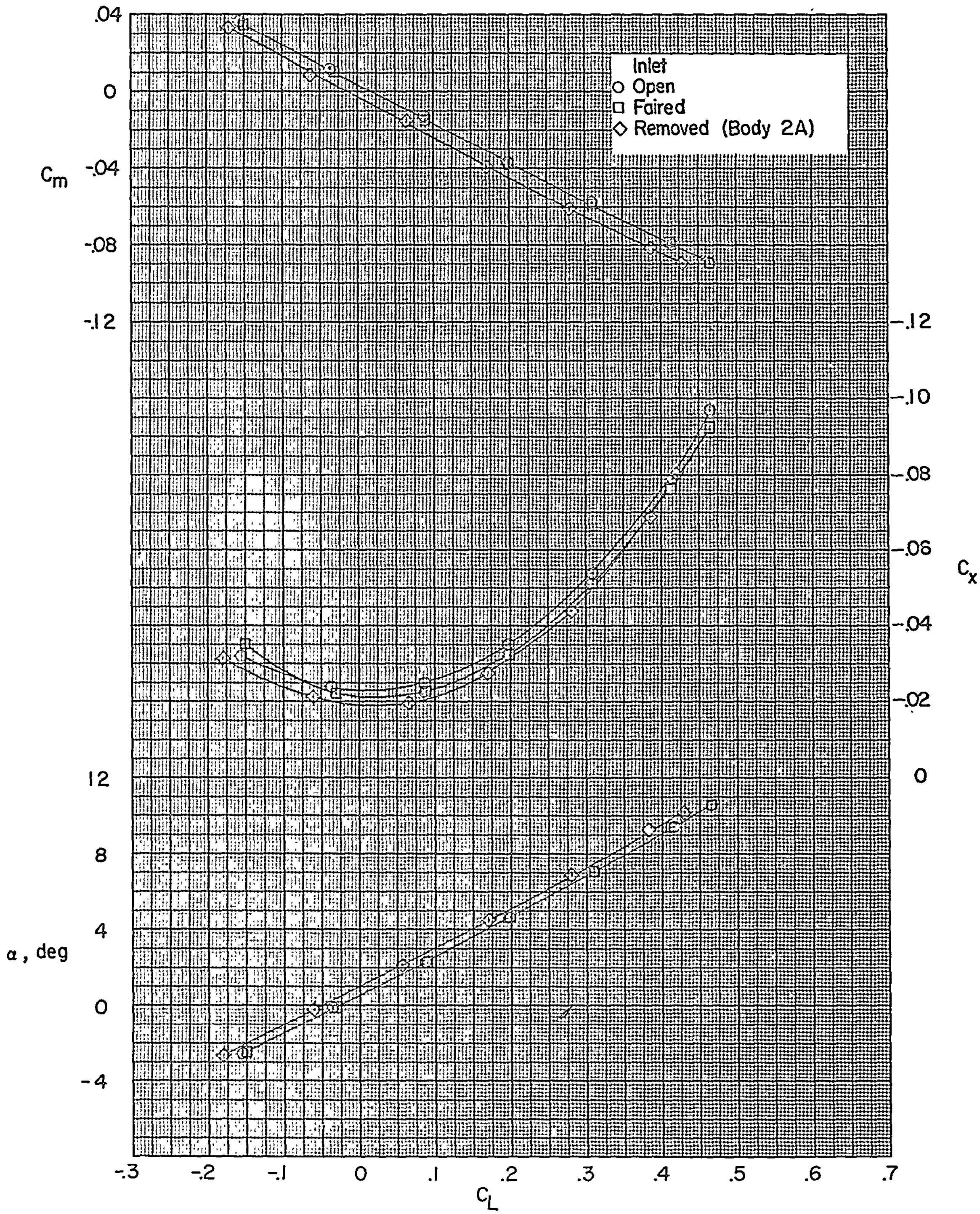
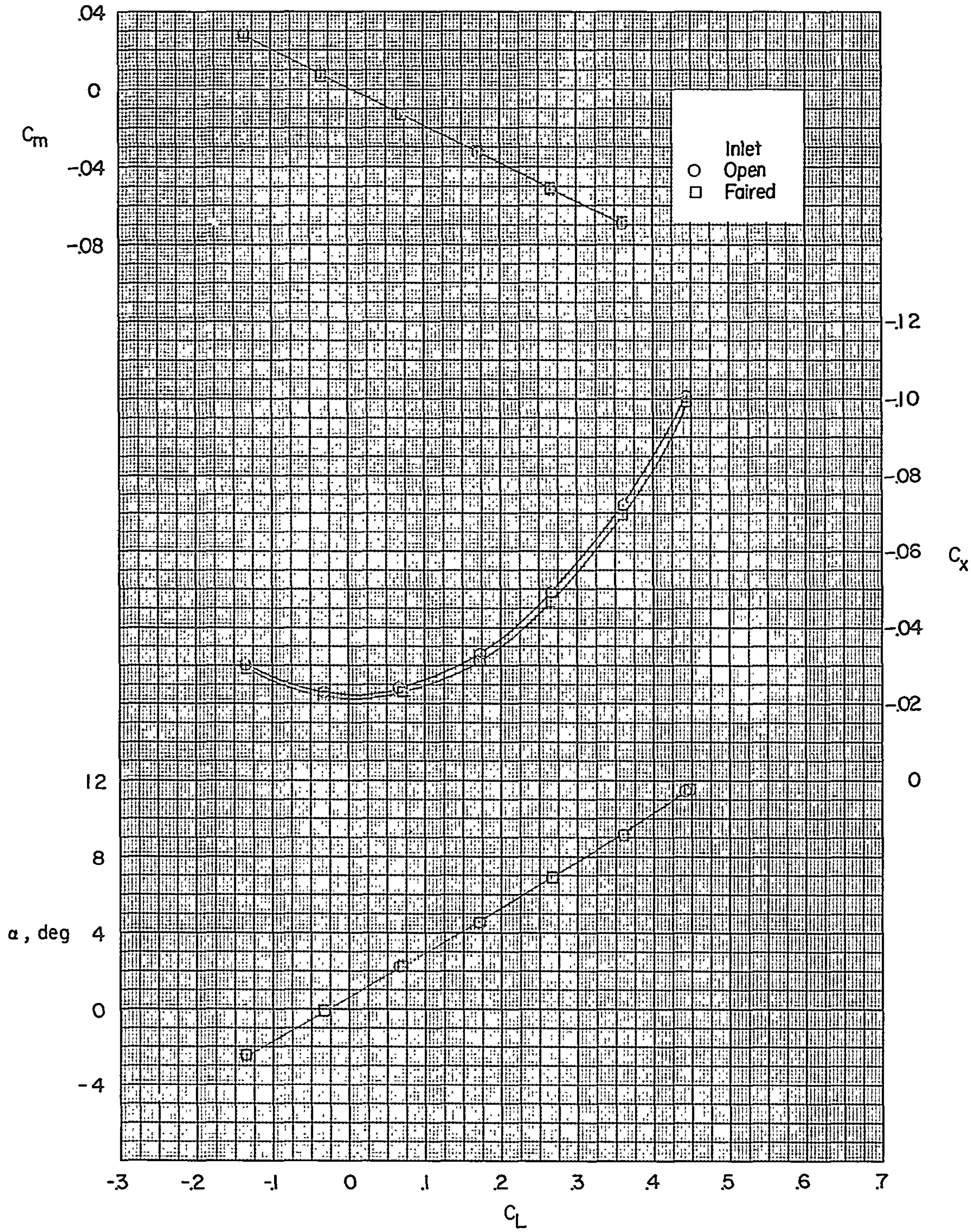



Figure 14.- Effects of a canard-type nose trimmer on the longitudinal aerodynamic characteristics of body 1. M = 2.01.




(a) M = 1.41.

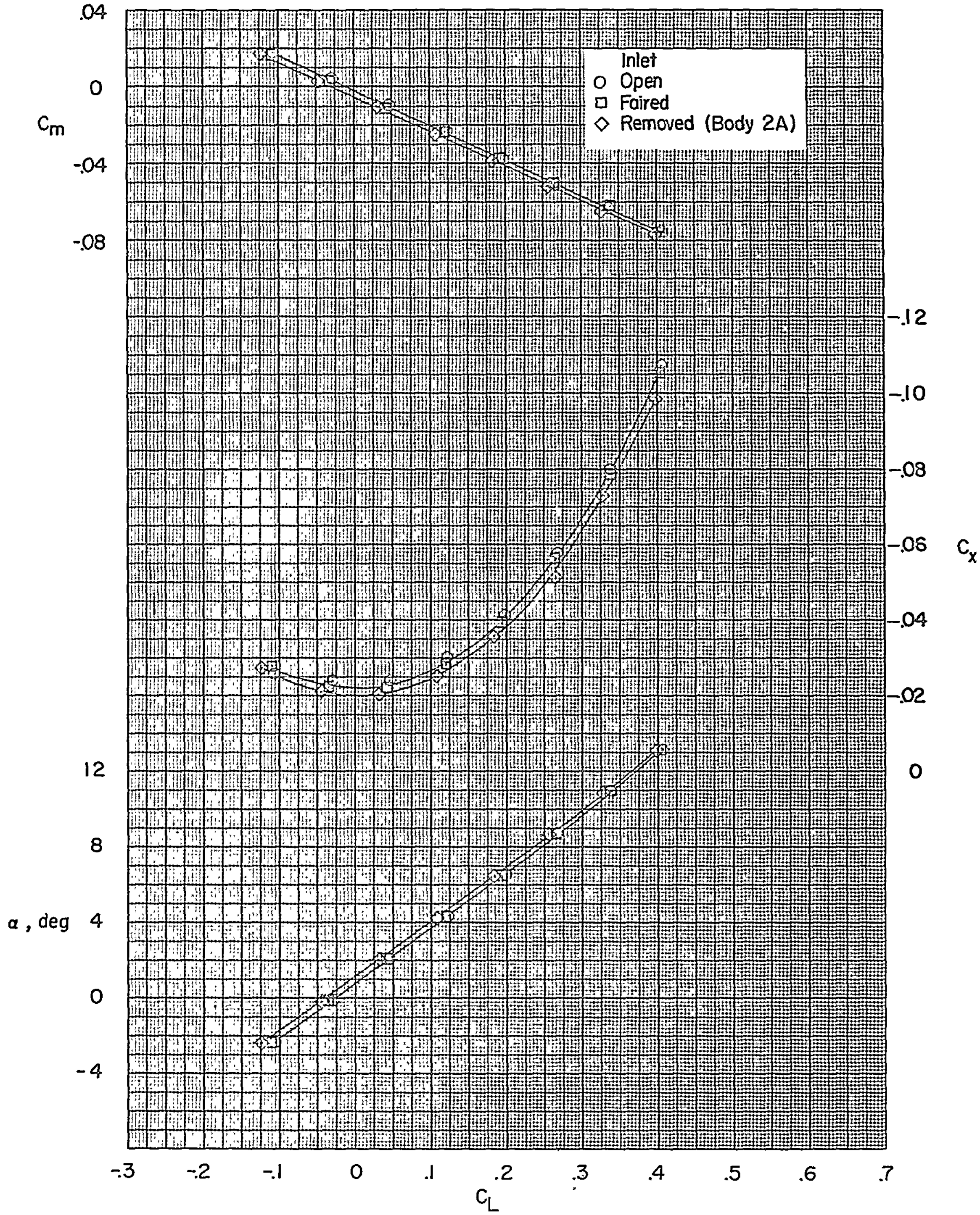
Figure 15.- Effect of inlets on the longitudinal aerodynamic characteristics of body 2. $\delta_e = 0^{\circ}$.




(b) M = 1.61.

Figure 15.- Continued.

[redacted]




(c) M = 2.01.

Figure 15.- Concluded.

[redacted]

[redacted]

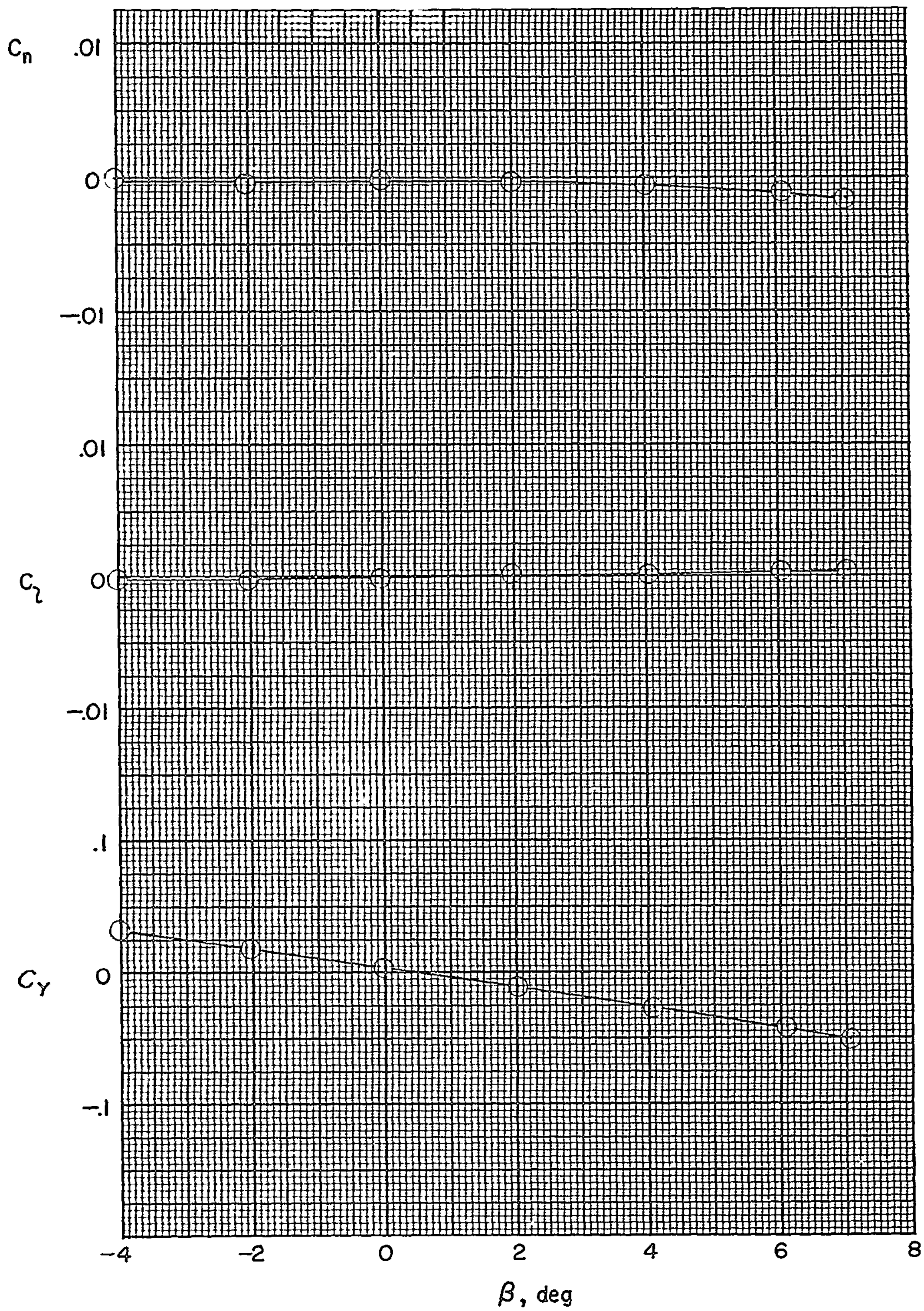



Figure 16.- Aerodynamic characteristics of body 1 in sideslip. Canard-type nose trimmer on; $\delta_e = 0^\circ$; $\alpha = 5.7^\circ$; $M = 2.01$.

[redacted]

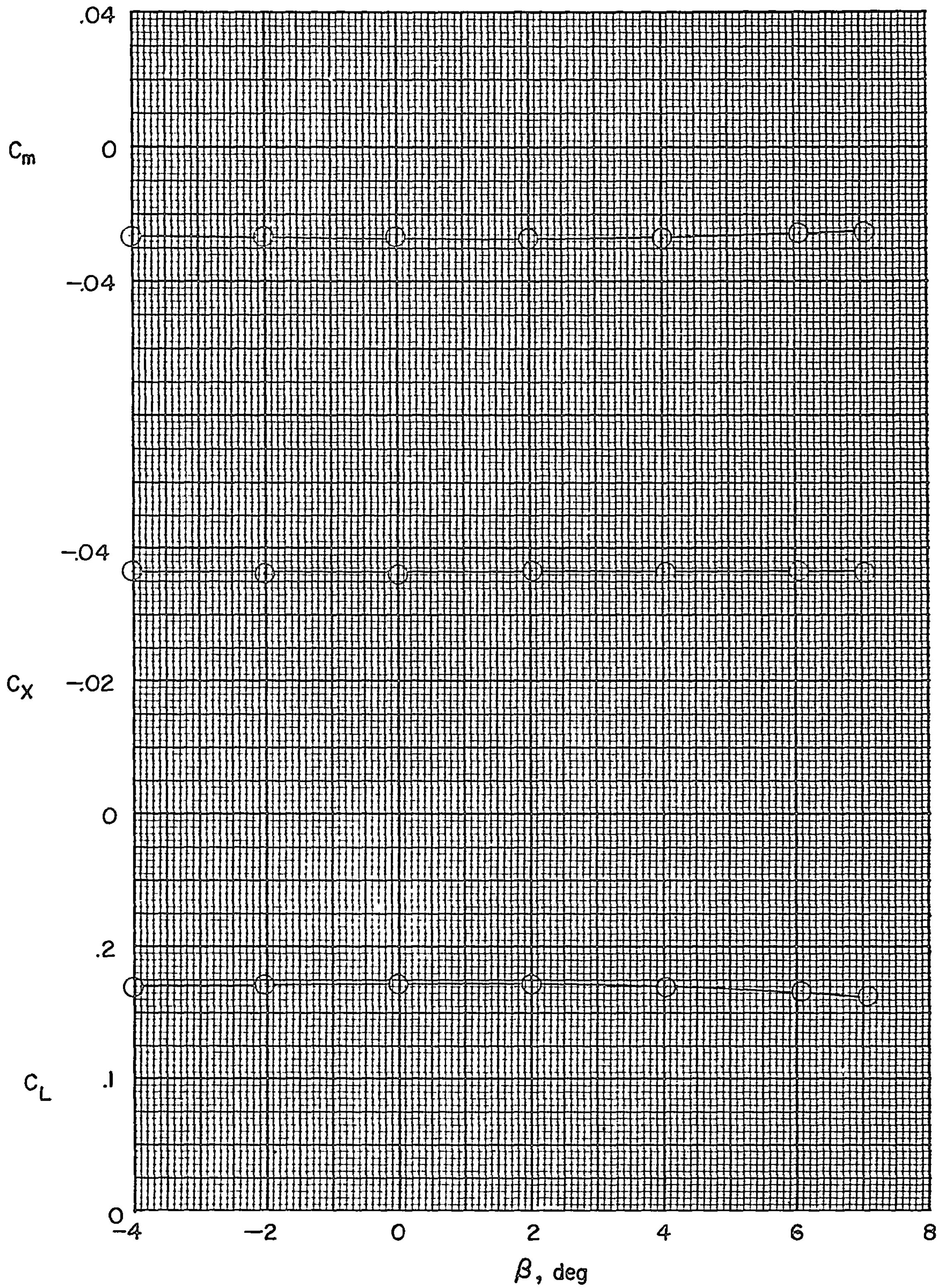



Figure 16.- Concluded.

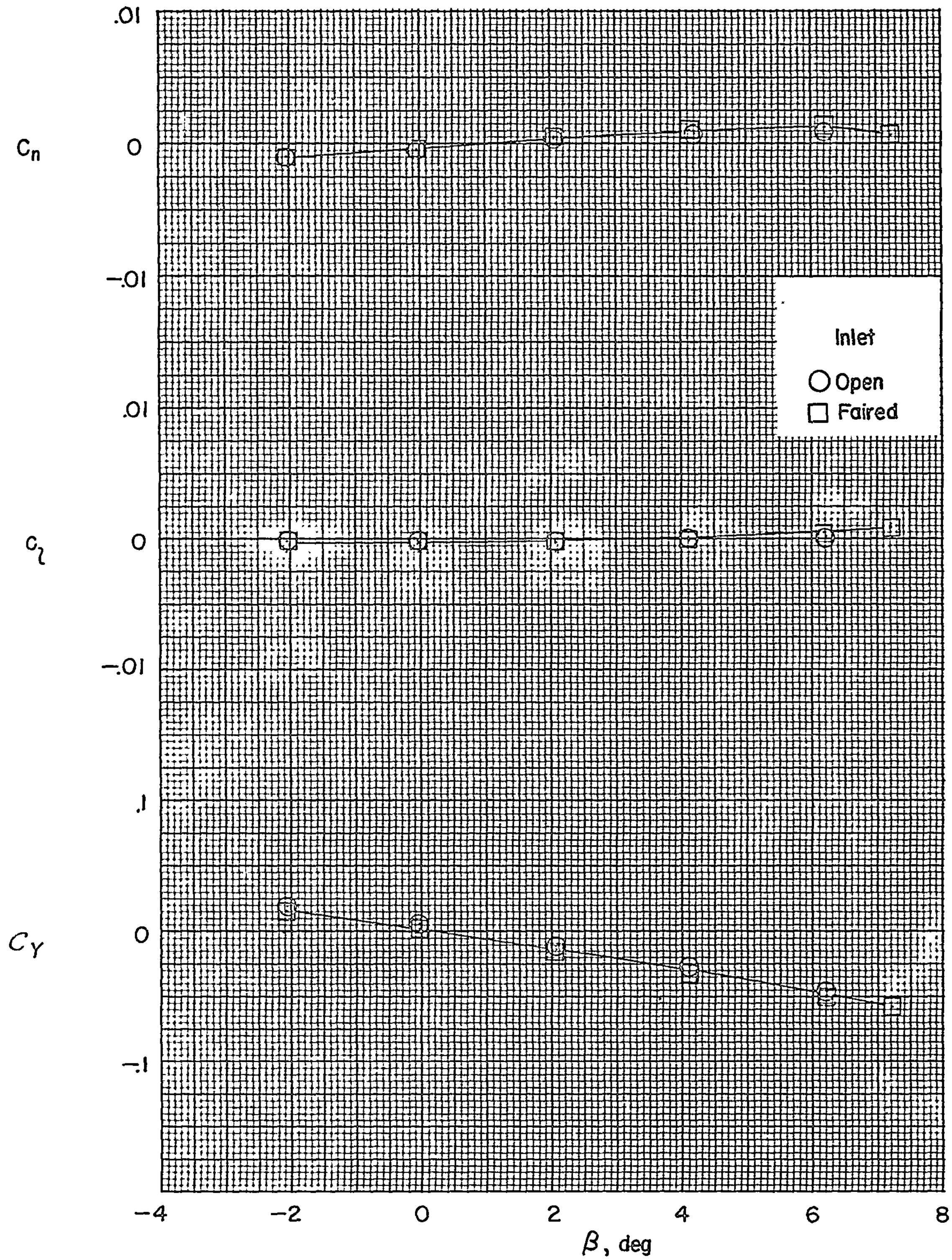



Figure 17.- Effects of open inlets on the aerodynamic characteristics of body 1 in sideslip. $\alpha \approx 1.7^{\circ}$; $M = 2.01$.

[redacted]

[redacted]

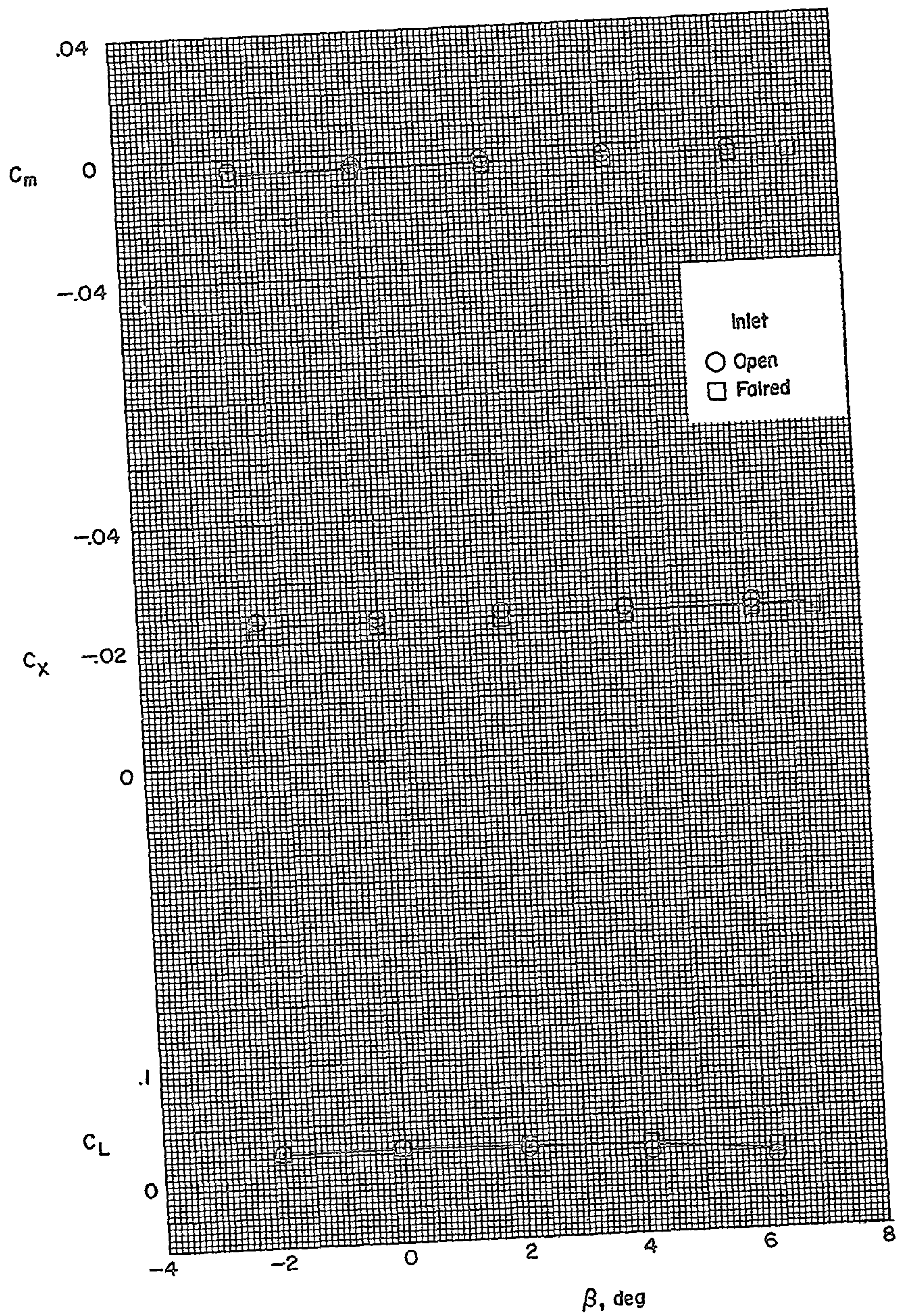



Figure 17.- Concluded.

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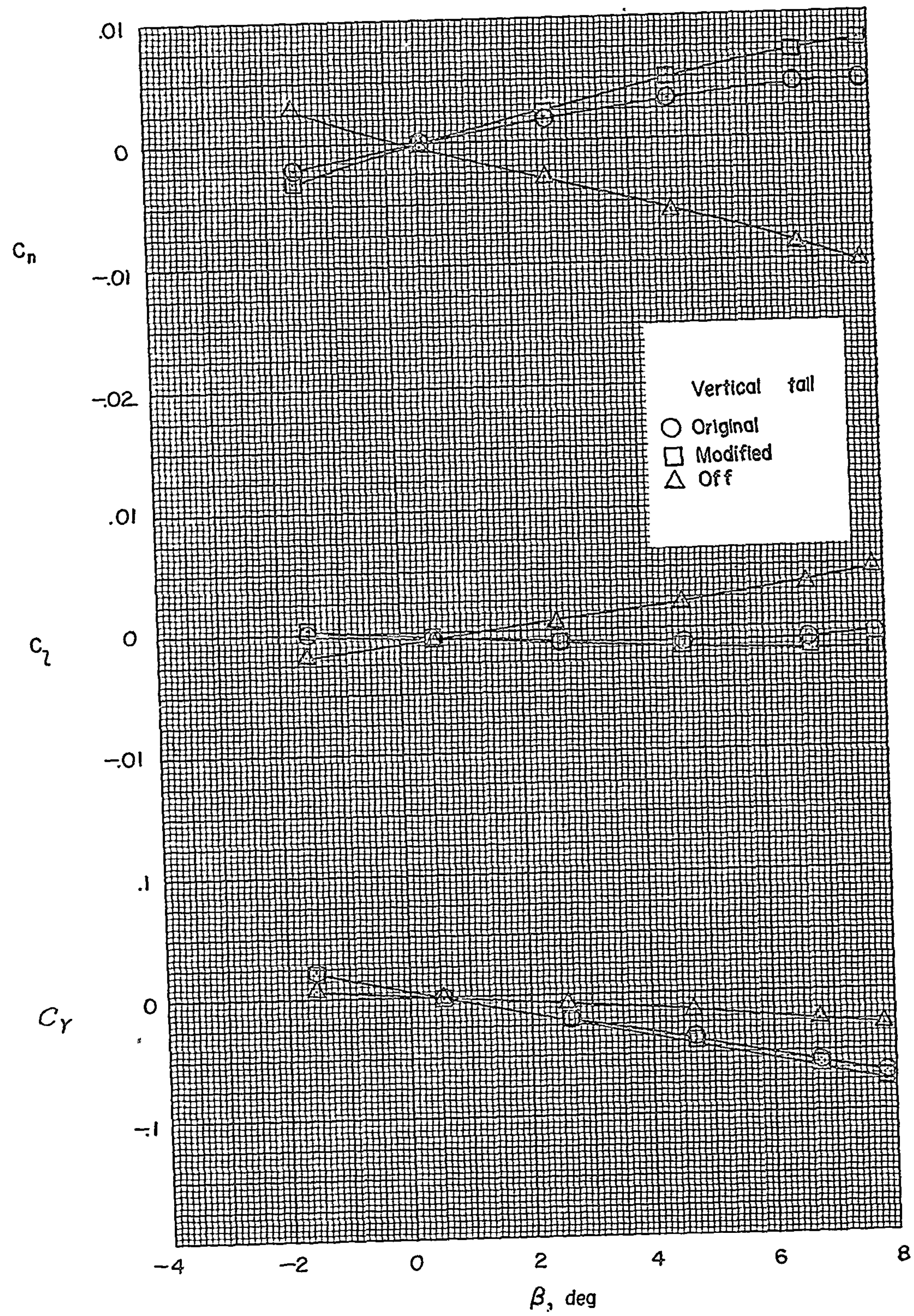


Figure 18.- Effects of vertical-tail modification on aerodynamic characteristics of body 1 in sideslip. $\alpha = 1.6^{\circ}$; $M = 1.61$.

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[redacted]

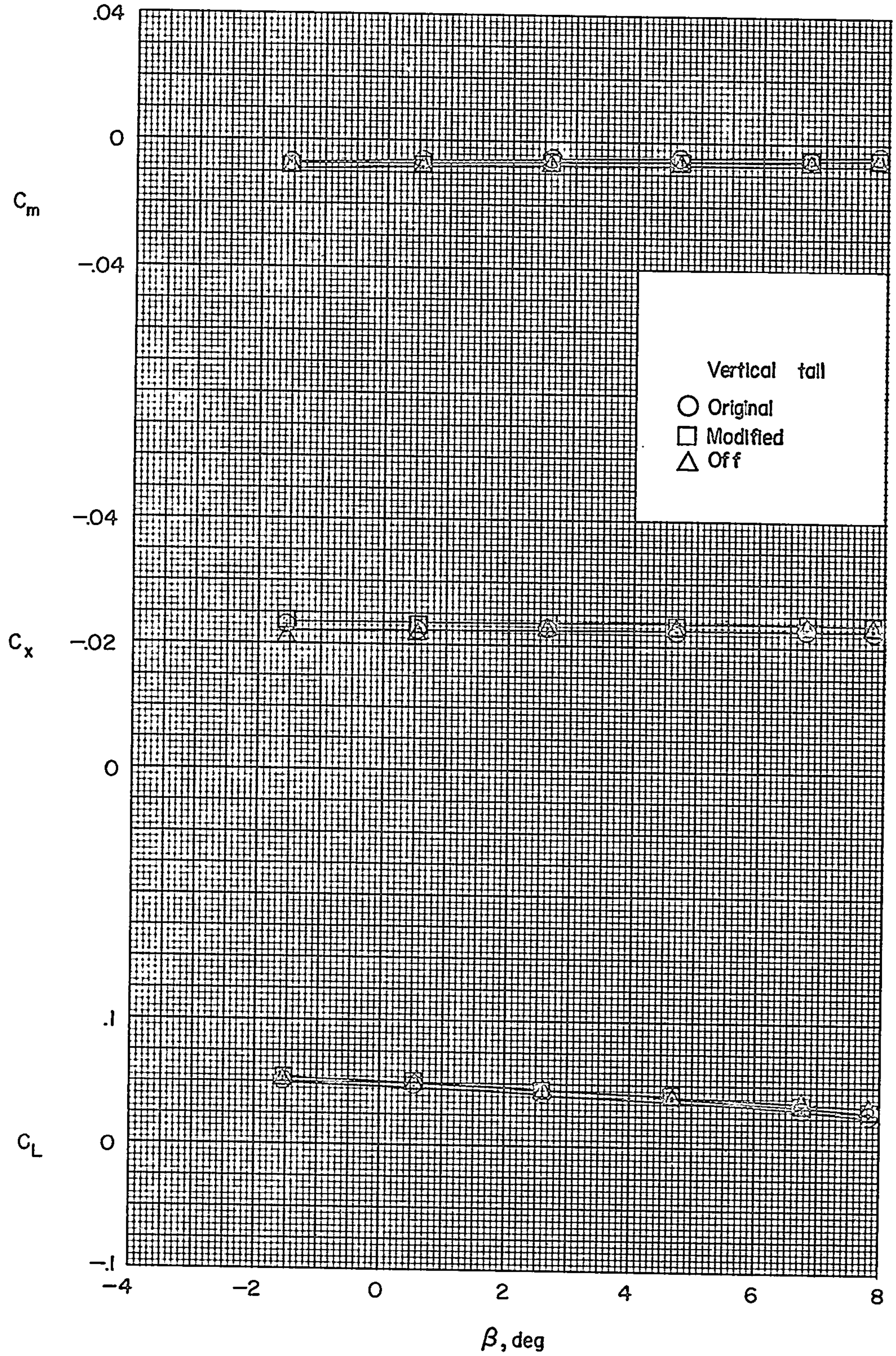


Figure 18.- Concluded.

[redacted]

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ABSTRACT

An investigation has been made in the Langley 4- by 4-foot supersonic pressure tunnel to determine the aerodynamic characteristics of a 0.04956-scale model of the Convair F-102B airplane at Mach numbers of 1.41, 1.61, and 2.01. Tests were made of the model equipped with a delta wing with 15-percent conical camber and a leading-edge sweep of 57°. Four basic body modifications and two afterbody configurations were evaluated. In addition, limited tests were made on a canard trimmer device and a revised vertical tail.