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RESEARCH MEMORANDUM

EFFECTS OF THE SPANWISE, CHORDWISE, AND VERTICAL LOCATION OF AN EXTERNAL STORE ON THE AERODYNAMIC CHARACTERISTICS OF A 45° SWEPTBACK TAPERED WING OF ASPECT RATIO 4 AT MACH NUMBERS OF 1.41, 1.62, AND 1.96

By Carl R. Jacobsen

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RESEARCH MEMORANDUM

EFFECTS OF THE SPANWISE, CHORDWISE, AND VERTICAL LOCATION OF AN EXTERNAL STORE ON THE AERODYNAMIC CHARACTERISTICS OF A 45° SWEPTBACK TAPERED WING OF ASPECT RATIO 4 AT MACH NUMBERS OF 1.41, 1.62, AND 1.96

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SUMMARY

An investigation has been made in the Langley 9- by 12-inch supersonic blowdown tunnel to determine the effects of external-store location on the lift, drag, and pitching-moment characteristics of a 45° sweptback wing at Mach numbers of 1.41, 1.62, and 1.96. The spanwise, chordwise, and vertical location of a Douglas Aircraft Company, Inc., store of fineness ratio 8.58 was systematically varied over the outer 60 percent of the wing semispan. A brief investigation of strut sweep angle was also made. The test Reynolds number based on the wing mean aerodynamic chord ranged from 1.3×10^6 to 1.5×10^6.

INTRODUCTION

External stores have been used to advantage in carrying fuel and ordnance on aircraft and a fairly large amount of information is available concerning their aerodynamic influence on wing characteristics at subsonic and transonic speeds (for example, see refs. 1 to 8). It is desirable to know whether stores can still be used advantageously at supersonic speeds, but little information is available since the few experimental investigations to date (refs. 9 to 11) have been quite limited in scope. Consequently, in order to obtain comprehensive experimental information at supersonic speeds, an exploratory program has been initiated in the Langley 9- by 12-inch supersonic blowdown tunnel to study the effects of stores on the aerodynamic characteristics of several wing configurations. The investigations of the effects of one size store on the aerodynamic characteristics of an unswept wing and a delta wing were reported in references 12 and 13, respectively.

This paper contains data obtained for the same external store on a sweptback wing having an aspect ratio of 4, a taper ratio of 0.6, 45° of sweepback at the quarter-chord line, and 6-percent-thick airfoil sections. The store had a fineness ratio of 8.58 and a Douglas Aircraft Company, Inc., store shape. The ratio of the store size to the wing area was such that for a wing area of 600 square feet the store would have sufficient volume to contain about 400 gallons of fuel. The store spanwise, chordwise, and vertical location was systematically varied on the outboard 60 percent of the wing semispan at Mach numbers of 1.41, 1.62, and 1.96 and at wing lift coefficients up to 0.70. A brief investigation of strut sweep angle was also made. The Reynolds number of the investigation based on the wing mean aerodynamic chord ranged from 1.3×10^6 to 1.5×10^6. The data are presented without analysis to expedite publication.

COEFFICIENTS AND SYMBOLS

C_L lift coefficient, Lift/qS

C_D drag coefficient, Drag/qS

C_m pitching-moment coefficient, $\frac{\text{Pitching moment about } 0.25\bar{c}}{qS\bar{c}}$

$\frac{dC_m}{dC_L}$ rate of change of pitching-moment coefficient with lift coefficient

ΔC_m increment in wing pitching-moment coefficient caused by addition of external store

ΔC_D increment in drag coefficient due to addition of external store

q free-stream dynamic pressure

S semispan wing area, 10.8 sq in.

c wing chord

$\bar{c}$ mean aerodynamic chord

b wing span, twice distance from wing root chord to wing tip

d store diameter

l store length

x	chordwise distance from line perpendicular to $\bar{c}$ at quarter-chord station to store 0.4l point
y	spanwise distance from wing root chord to store center line
z	vertical distance from point of maximum thickness on wing lower surface to store center line
α	angle of attack
$\Delta\alpha$	increment in wing angle of attack due to addition of external store
R	Reynolds number based on $\bar{c}$

MODELS

The principal dimensions of the sweptback semispan wing, which had an aspect ratio of 4 and a taper ratio of 0.6, are contained in figure 1. The sections parallel to the air stream were NACA 65A006 airfoil sections. The blunt streamwise wing tip was not faired. The solid wing was fabricated from SAE 4130 heat-treated steel.

External stores having a Douglas Aircraft Company, Inc., (DAC) store shape of fineness ratio 8.58 were tested at 40, 60, 80, and 107 percent of the wing semispan (fig. 2). The store 40-percent-length point was located on, 0.416$\bar{c}$ behind, and 0.833$\bar{c}$ behind the quarter-chord station of the mean aerodynamic chord. The vertical locations of the stores were varied from 0.5 to 1.0 store diameters below the lower surface of the wing. The center lines of all stores were within 1° of being parallel to the body axis. Each store was molded of plastic and was designed to have a gross volume of 414 gallons for a wing area of 600 square feet.

Swept and unswept struts which were pinned and sweated to the wing lower surface were used to attach the stores to the wing at various vertical store locations. The brass struts had NACA 65A airfoil sections. The swept strut which was 7 percent thick and the unswept strut which was 10 percent thick had chords equal to 0.665$\bar{c}$ and 0.470$\bar{c}$, respectively. The locations at which the various struts were used are fully described in figure 2. The leading edge of the struts coincided with the wing leading edge for all but the inboard rear store location $\left(\frac{y}{b/2} = 0.40, \frac{x}{\bar{c}} = 0.416\right)$ in which case the nose of the store was behind the wing leading edge. In an attempt to approximate the condition that existed at the wing leading edge for the other store locations, a thin brass sheet was used to

fair in the space between a line extending from the wing leading edge to the store nose and the strut leading edge. In order to obtain the effects of strut sweep angle, a swept strut was used to position the store at $\frac{z}{d} = 1.0$ $\left(\frac{y}{b/2} = 0.80,\ \frac{x}{c} = 0.416\right)$ to obtain data comparable to that obtained with an unswept strut at the same position. It might be noted that, although these two struts had different chords, they did have the same maximum thickness. Figure 3 contains a photograph of a typical wing-body-store combination.

TUNNEL

The Langley 9- by 12-inch supersonic blowdown tunnel in which the present tests were made uses the compressed air of the Langley 19-foot pressure tunnel. The air enters at an absolute pressure of about $2\frac{1}{3}$ atmospheres and is conditioned to insure condensation-free flow by being passed through a silica gel dryer and then through banks of finned electrical heaters. The criterions for the amount of drying and heating required were obtained from reference 14. Extensive calibration measurements had been made previously with no model in the test section and a summary of these measurements is contained in reference 15. A brief summary of these results is also contained in the following table along with the average dynamic pressures and Reynolds numbers for the present investigation:

Variables \ Average Mach number	1.41	1.62	1.96
Maximum deviation in Mach number	±0.02	±0.01	±0.02
Maximum deviation of ratio of static to stagnation pressure, percent	±2.0	±1.3	±2.2
Maximum deviation in stream angle, deg	±0.25	±0.20	±0.20
Average dynamic pressure for these tests, lb/sq in.	11.9	11.4	10.6
Average Reynolds number, R	1.5×10^6	1.4×10^6	1.3×10^6

The test Reynolds number decreased about 4 percent during the course of each run because of the decreasing pressure of the inlet air.

TEST TECHNIQUE

The semispan-wing model used in this investigation was cantilevered from a strain-gage balance which mounts flush with the tunnel wall and rotates with the model through the angle-of-attack range. A test body was attached to the wing and loads were measured on the wing-body combination. The test body consisted of a half-body-of-revolution and a 0.25-inch shim which was used to raise the half-body-of-revolution off the tunnel wall and thus minimize the effects of the tunnel-wall boundary layer on the flow over its surface (ref. 16). A gap of about 0.010 inch was maintained between the test body and the tunnel wall (see fig. 1) under a no-load condition. The investigation was made at Mach numbers of 1.41, 1.62, and 1.96 and at wing lift coefficients up to 0.70. There was some indication that at a Mach number of 1.41 the data of the present investigation might have been influenced by the reflection of the model bow wave from the tunnel wall at an angle of attack of 12°.

ACCURACY OF DATA

From a general consideration of the balance calibration accuracy and the repeatability of data, the accuracy of the force and moment measurements, in terms of coefficients, are believed to be about as follows:

C_L . . . . . ± 0.005
C_D . . . . . ± 0.001
C_m . . . . . ± 0.002

For lift coefficients above 0.60, errors in drag coefficient in excess of ± 0.001 could well exist. The angle-of-attack measurements are believed to be accurate within $\pm 0.05^{\circ}$, based upon the limitations of the mechanical angle-of-attack system and the calibration charts from which the actual values were obtained.

RESULTS

Lift, pitching-moment, and drag data are presented herein without analysis for the body alone, for the wing-body combination, and for the wing-body-store combinations. Figure 4 presents the variations of lift, pitching-moment, and drag coefficient with angle of attack at Mach numbers of 1.41, 1.62, and 1.96 for the body alone. Figures 5 to 10 present the variations of pitching-moment coefficient and drag coefficient with lift

coefficient and lift coefficient with angle of attack for the wing-body-store combinations at the same three Mach numbers. Because these force and moment data include loads on a somewhat arbitrary test body, the data are not directly applicable to configurations including more conventional body arrangements. It is believed, however, that trends indicated by the data would not be qualitatively affected by use of a different body arrangement. From the data of figures 5 to 10 values of $\frac{dC_m}{dC_L}$ and increments of pitching-moment coefficient and angle of attack at zero lift due to the addition of the store have been obtained and are presented in figure 11. It might be pointed out that positive increments in pitching-moment coefficient at zero lift caused by the store as shown in figure 11 were also obtained in the investigations of references 11, 12, and 13. The variations of the lift-drag ratios of the wing-body-store combinations with lift coefficient for the various store locations have also been obtained and are presented in figure 12 along with the drag increments caused by the addition of the store.

Generally, the data of figure 12 showed that outboard spanwise movement and forward chordwise movement of the store decreased the store drag increment. There was one exception, however, in that forward chordwise movement of the store at the 40-percent spanwise station (from a position where the store nose was behind the wing leading edge to one where it was ahead of the wing leading edge) resulted in a drag increase. The store drag increment for the condition where the store nose was behind the wing leading edge was equal to or slightly greater than the lowest drag increment caused by the store positioned anywhere else on the wing. These trends were about the same as those indicated by the data obtained for the delta wing of reference 13, and the variations of drag with store spanwise location were also about the same as those indicated by the data obtained for the unswept wing of reference 12 (store chordwise location was not one of the variables considered in the investigation of ref. 12).

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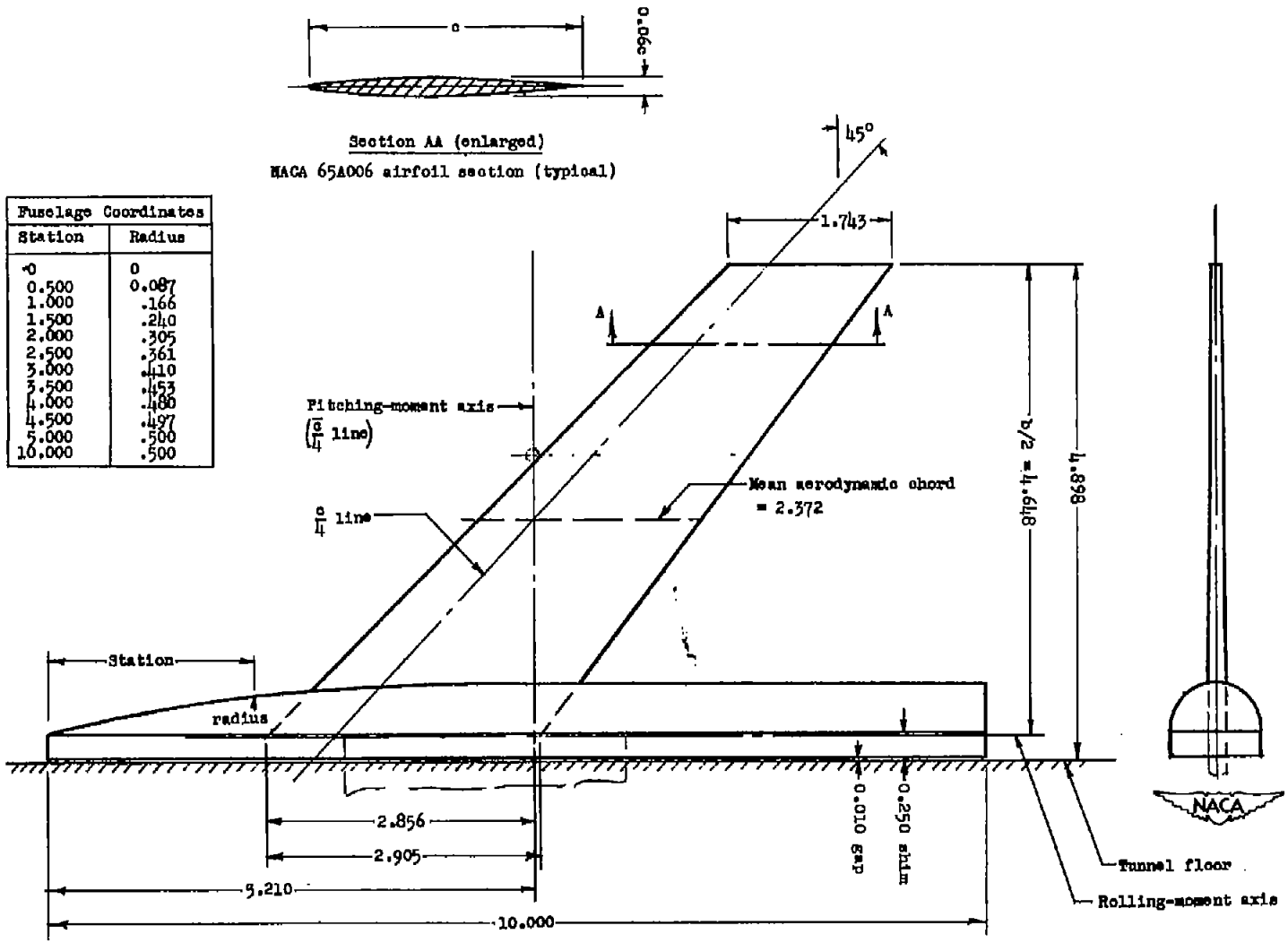
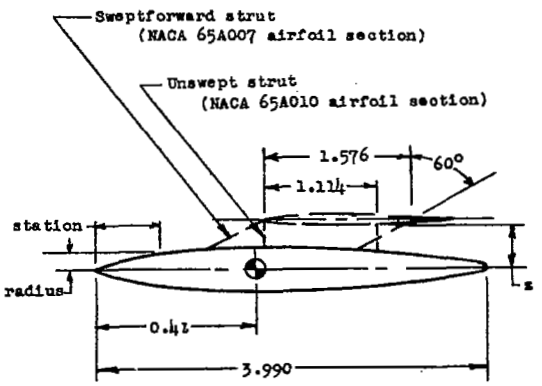


Fuselage Coordinates	
Station	Radius
0	0
0.500	0.087
1.000	.166
1.500	.240
2.000	.305
2.500	.361
3.000	.410
3.500	.453
4.000	.480
4.500	.497
5.000	.500
10.000	.500

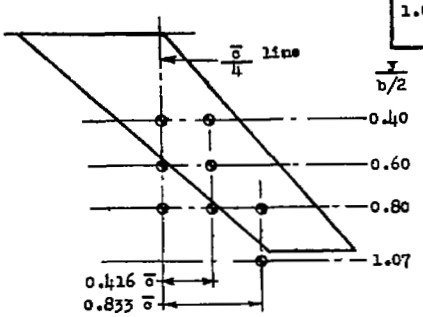
Figure 1.- Details of 45° sweptback semispan wing of aspect ratio 4. All dimensions are in inches.



DAC store (typical)

Fineness ratio = 8.58

DAC Store Coordinates	
station	radius
0	0
0.076	0.036
.188	.080
.299	.116
.411	.140
.519	.160
.630	.176
.742	.188
.966	.211
1.185	.227
1.408	.233
1.983	.233
2.206	.229
2.426	.219
2.645	.203
2.875	.184
3.204	.148
3.423	.120
3.647	.088
3.910	.048
3.990	0
T.E.R.	.022



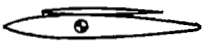
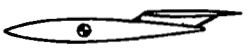
$\frac{y}{b/2}$	$\frac{x}{\bar{c}}$	$\frac{z}{d}$	wing-strut-store configuration
0.40	0	0.5	
	0	1.0	
	0.416	0.5	
0.60	0	0.5	
	0	1.0	
	0.416	0.5	
0.80	0	0.5	
	0	1.0	
	0.416	0.5	
	0.416	1.0	
	0.416	1.0	
	0.833	0.5	
1.07	0.833	0	

Figure 2.- Details of Douglas Aircraft Company, Inc., store and various locations at which the store was tested. All dimensions are in inches.

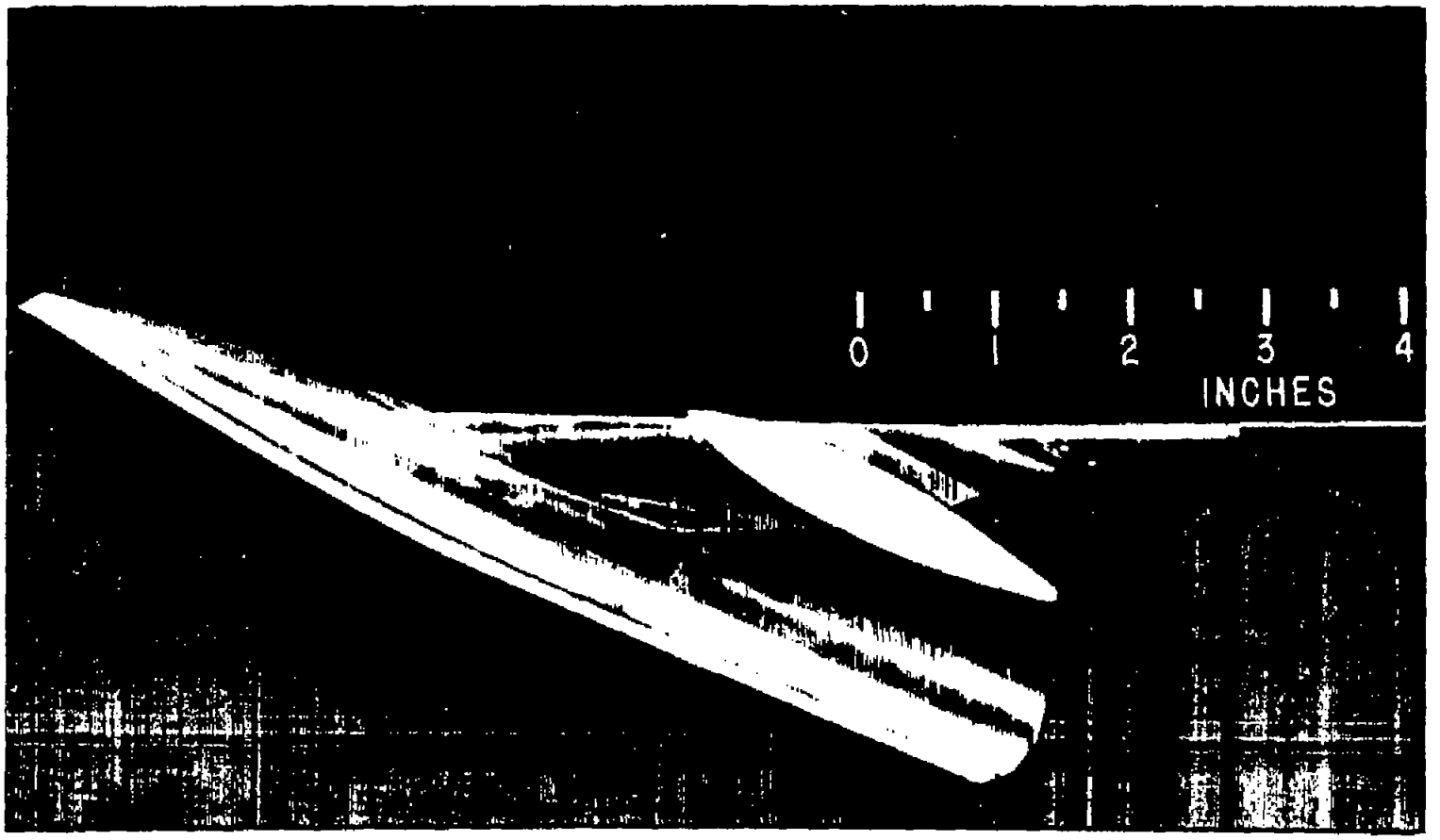


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Figure 3.- Photograph of DAC store mounted on swept strut attached to sweptback wing.

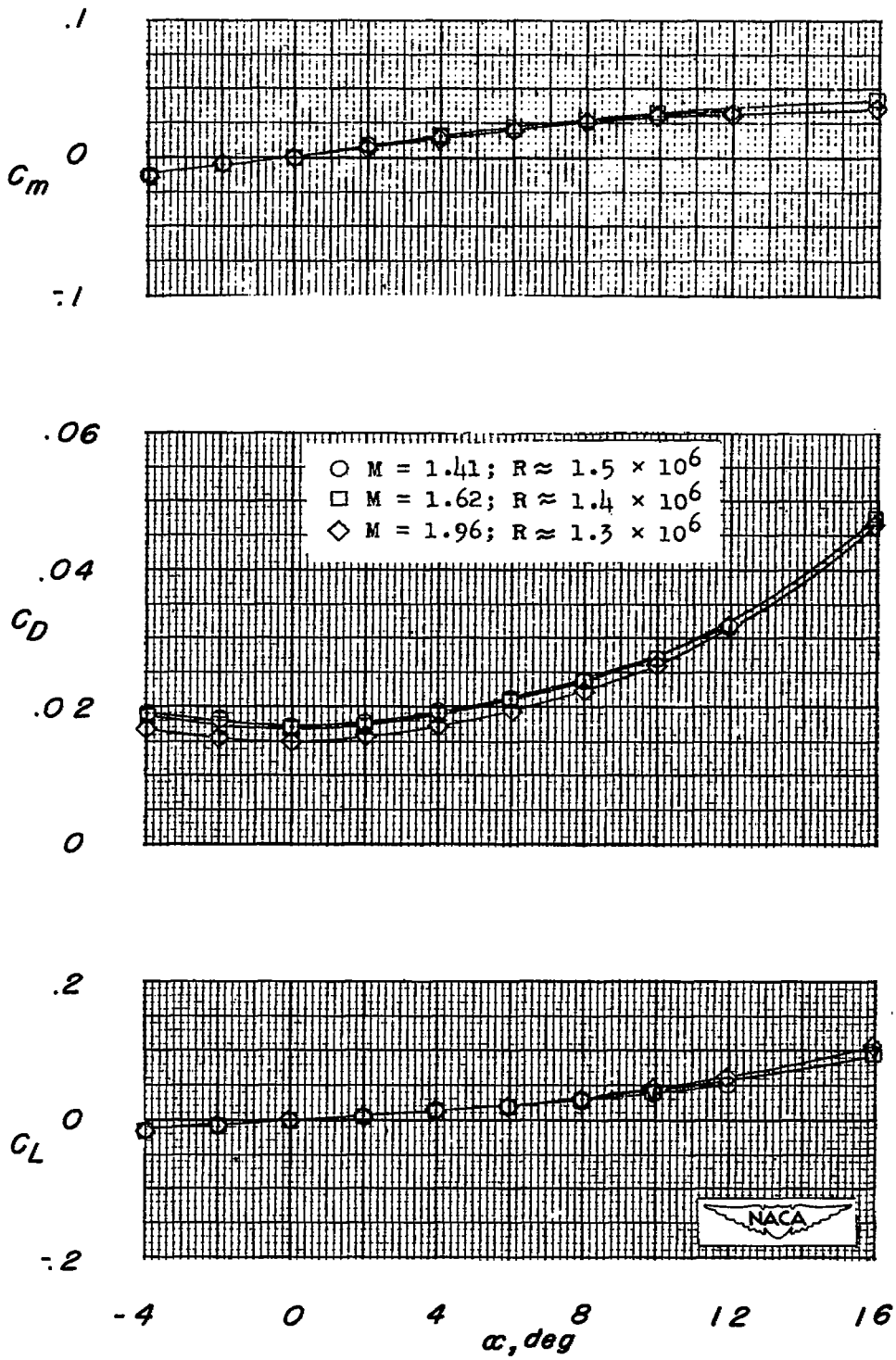
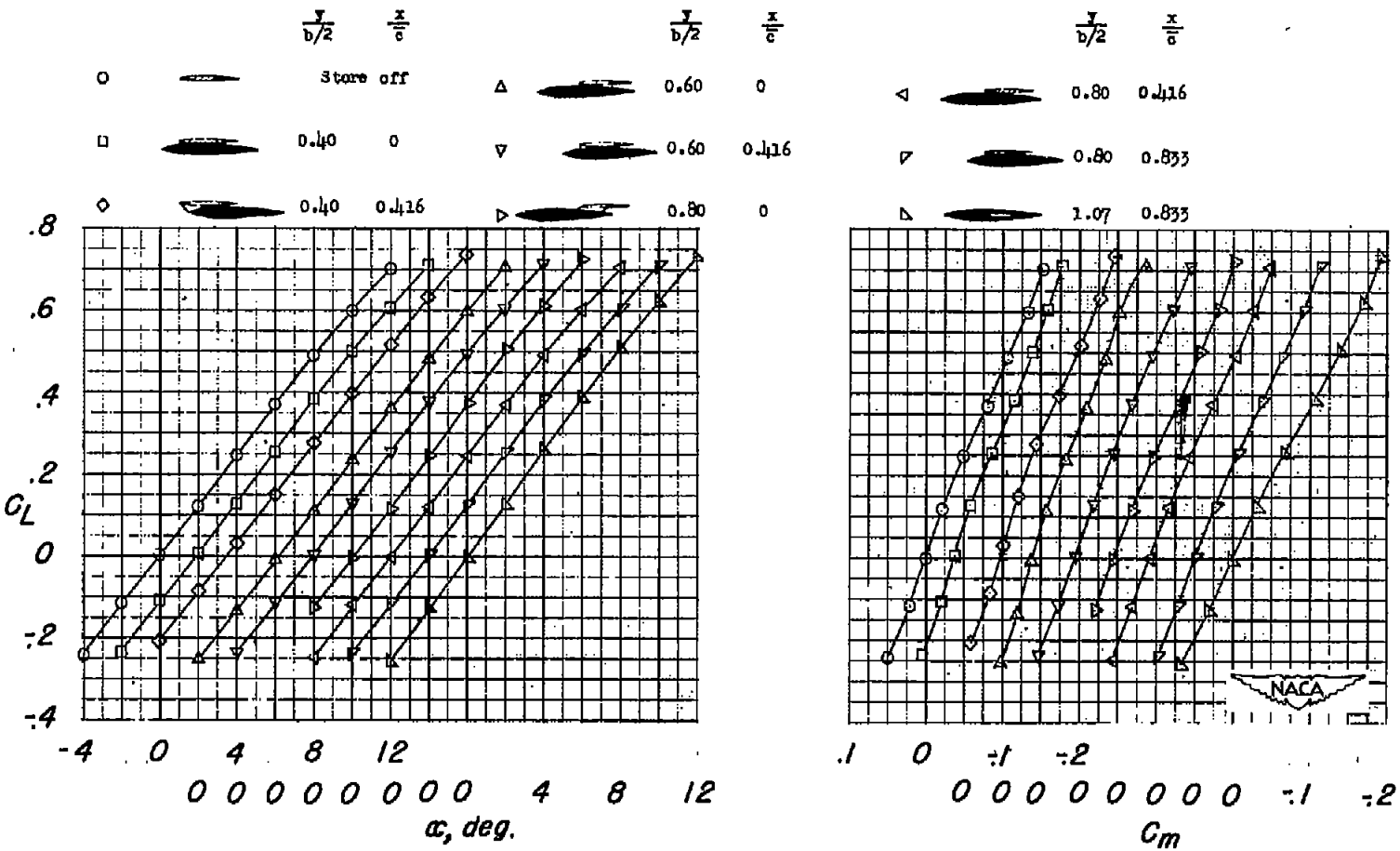
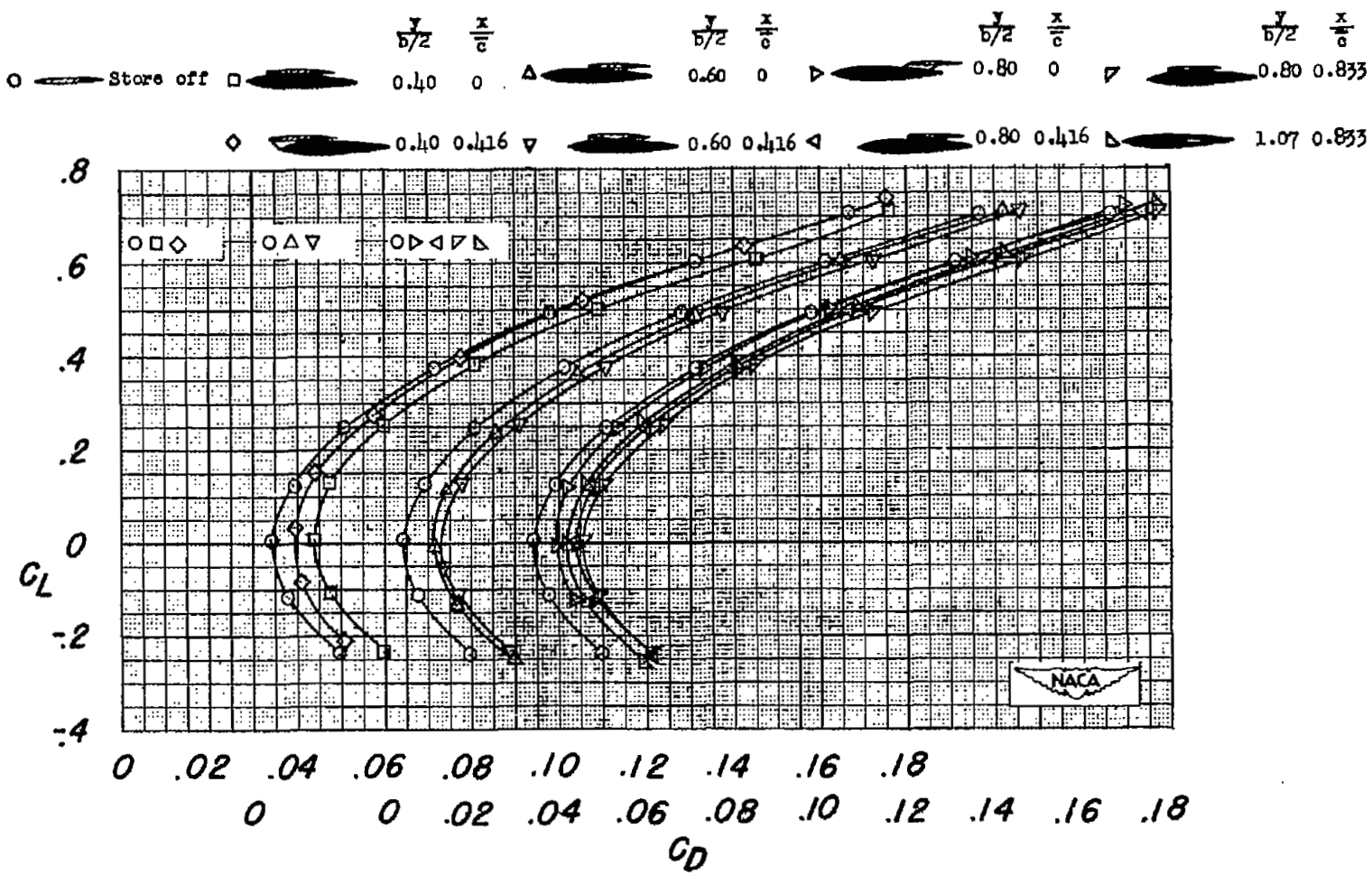


Figure 4.- Aerodynamic characteristics of the half-body.



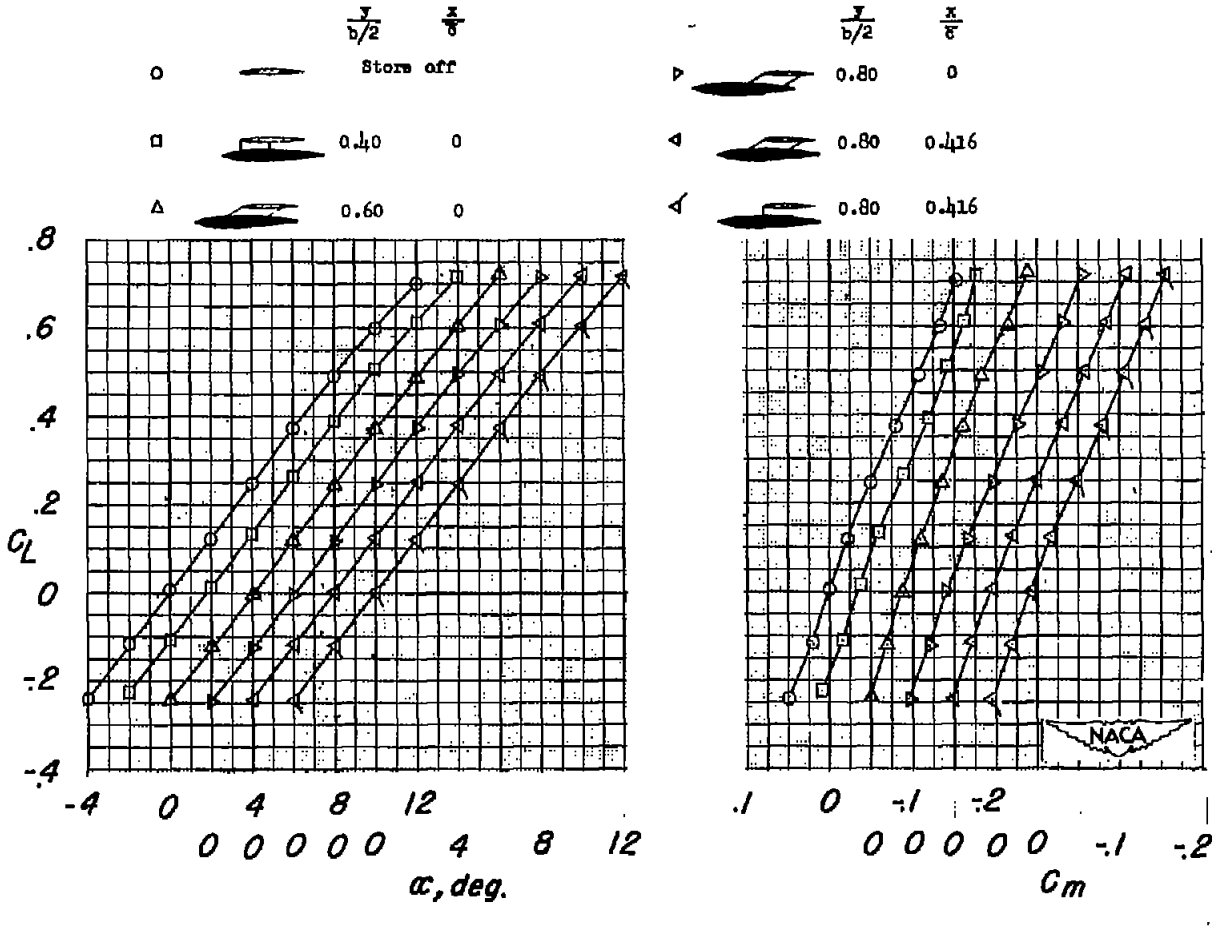
(a) C_L against C_m and α.

Figure 5.- Aerodynamic characteristics of the semispan model with DAC store at various spanwise and chordwise locations. $M = 1.41$; $R \approx 1.5 \times 10^6$; $\frac{z}{d} = 0$ and 0.5.



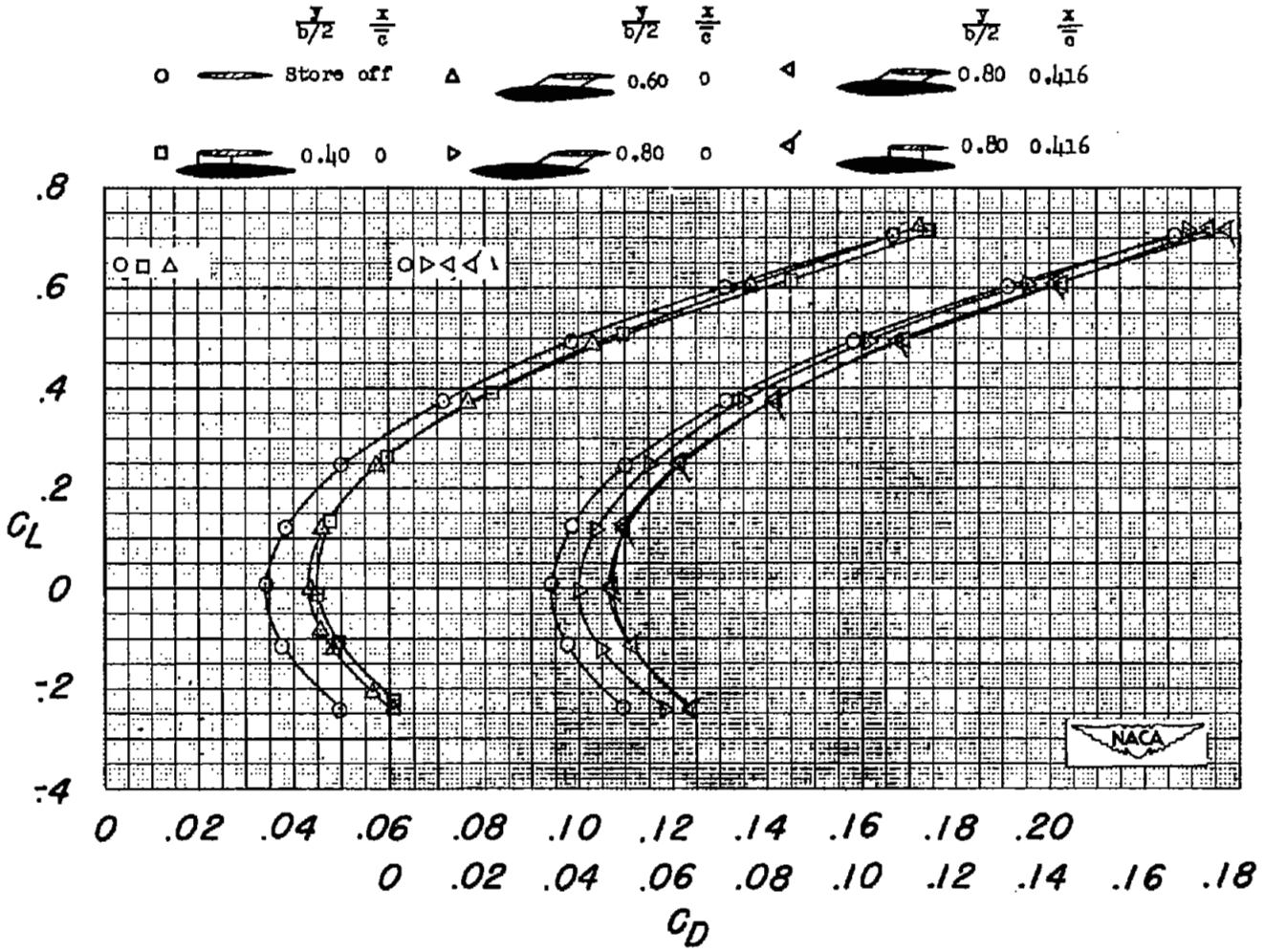
(b) C_L against C_D.

Figure 5.- Concluded.



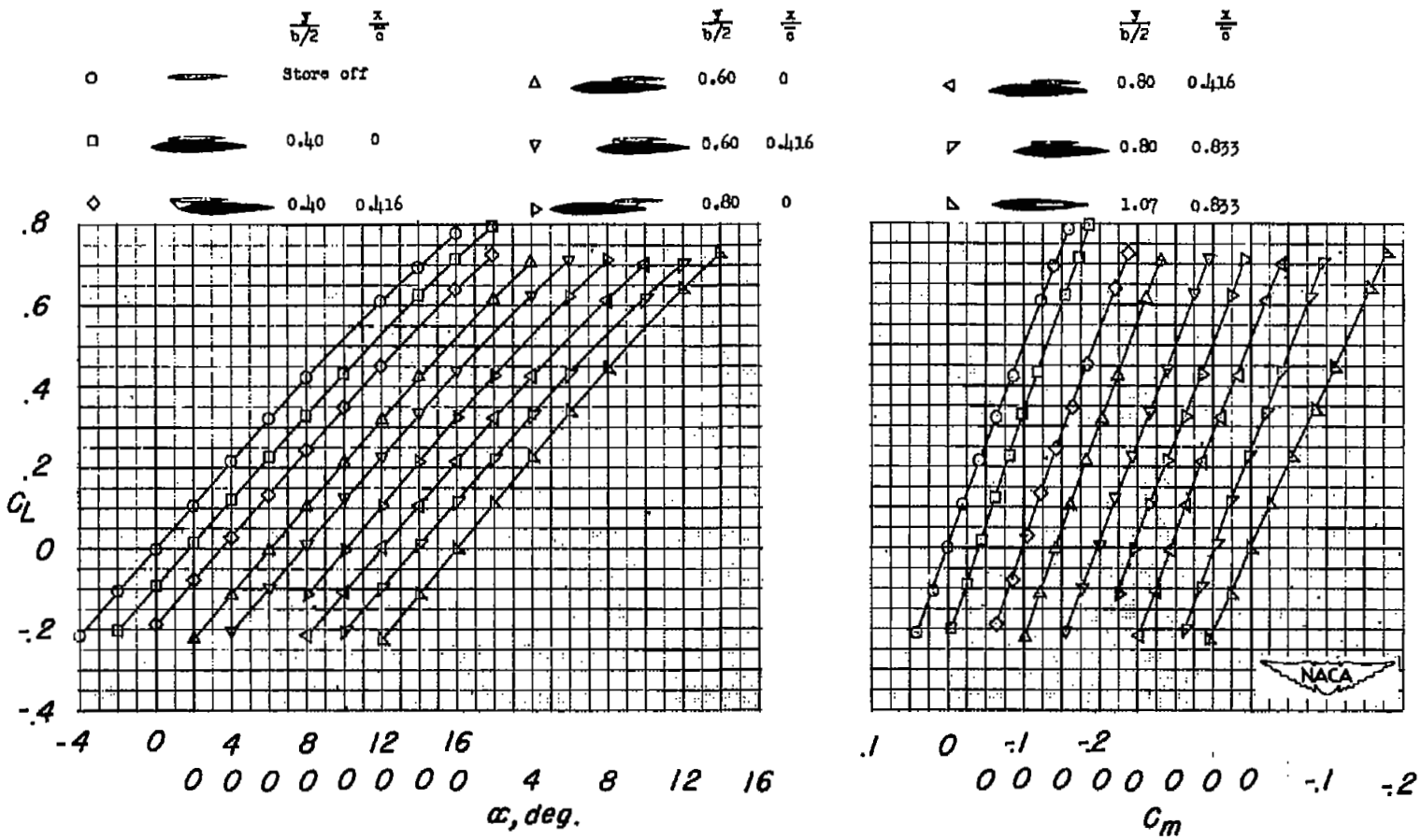
(a) C_L against C_m and α.

Figure 6.- Aerodynamic characteristics of the semispan model with DAC store at various spanwise and chordwise locations mounted on an unswept or swept strut. $M = 1.41$; $R \approx 1.5 \times 10^6$; $\frac{z}{d} = 1.0$.



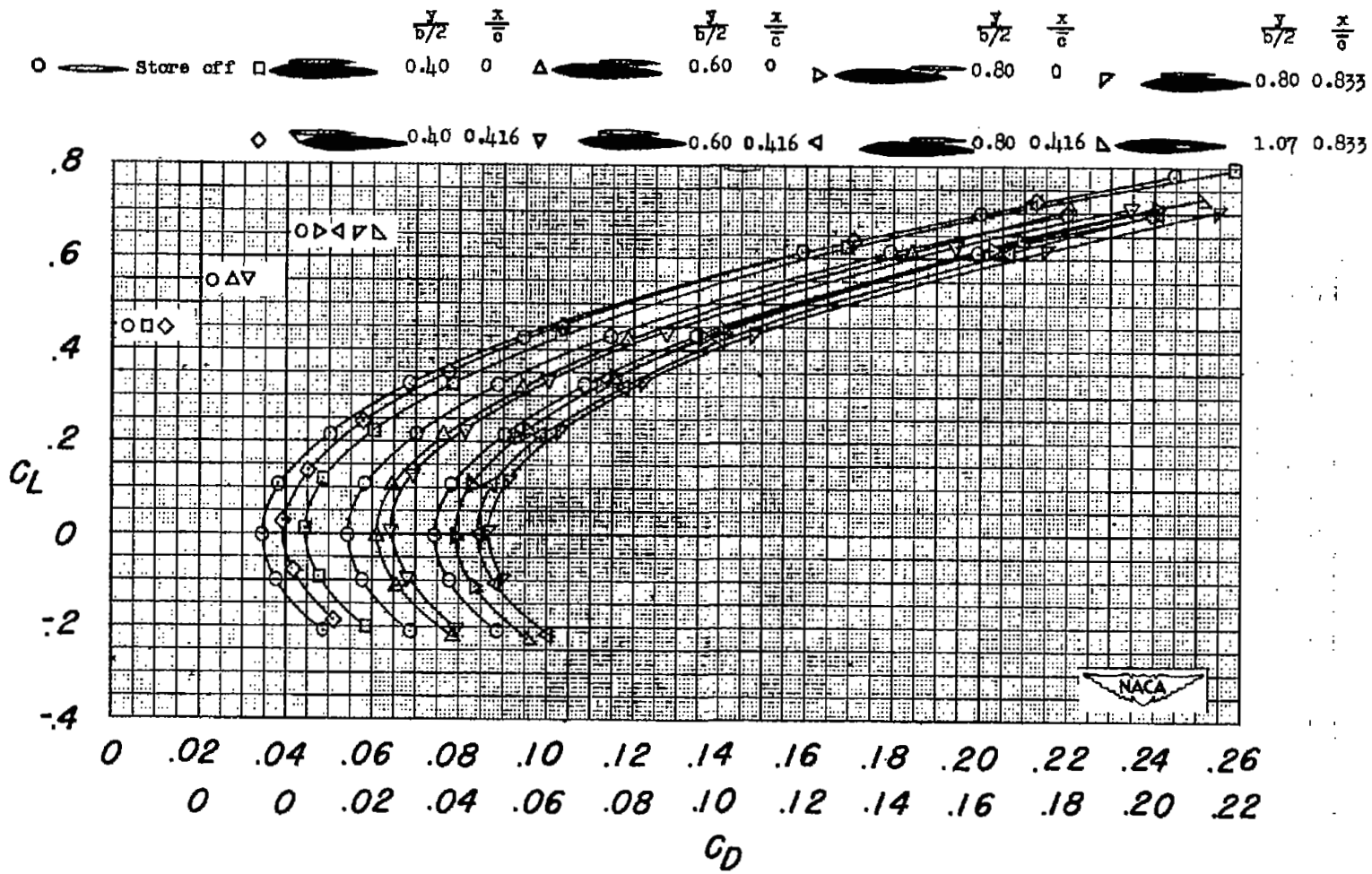
(b) C_L against C_D.

Figure 6.- Concluded.



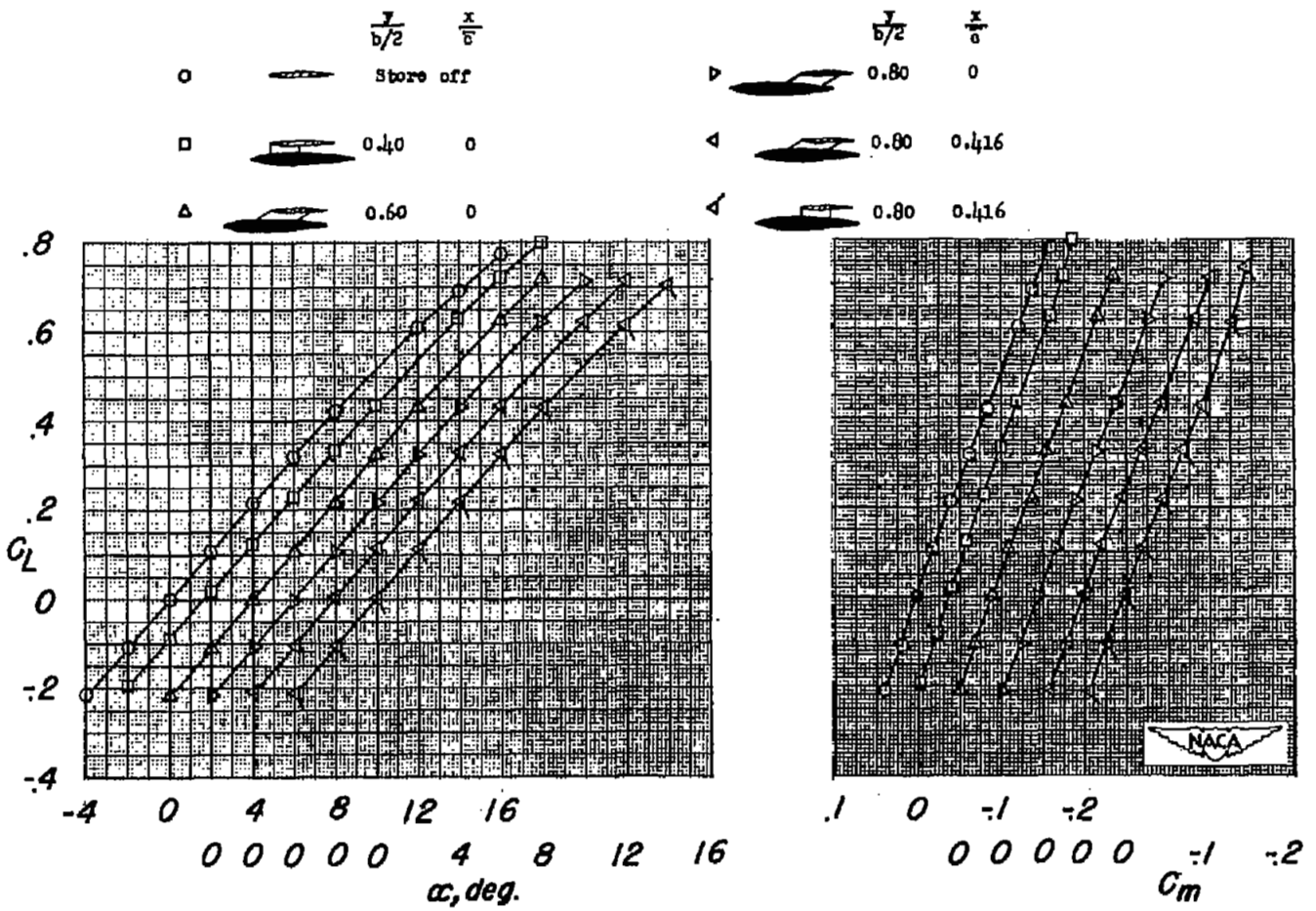
(a) C_L against C_m and α.

Figure 7.- Aerodynamic characteristics of the semispan model with DAC store at various spanwise and chordwise locations. $M = 1.62$; $R \approx 1.4 \times 10^6$; $\frac{z}{d} = 0$ and 0.5.



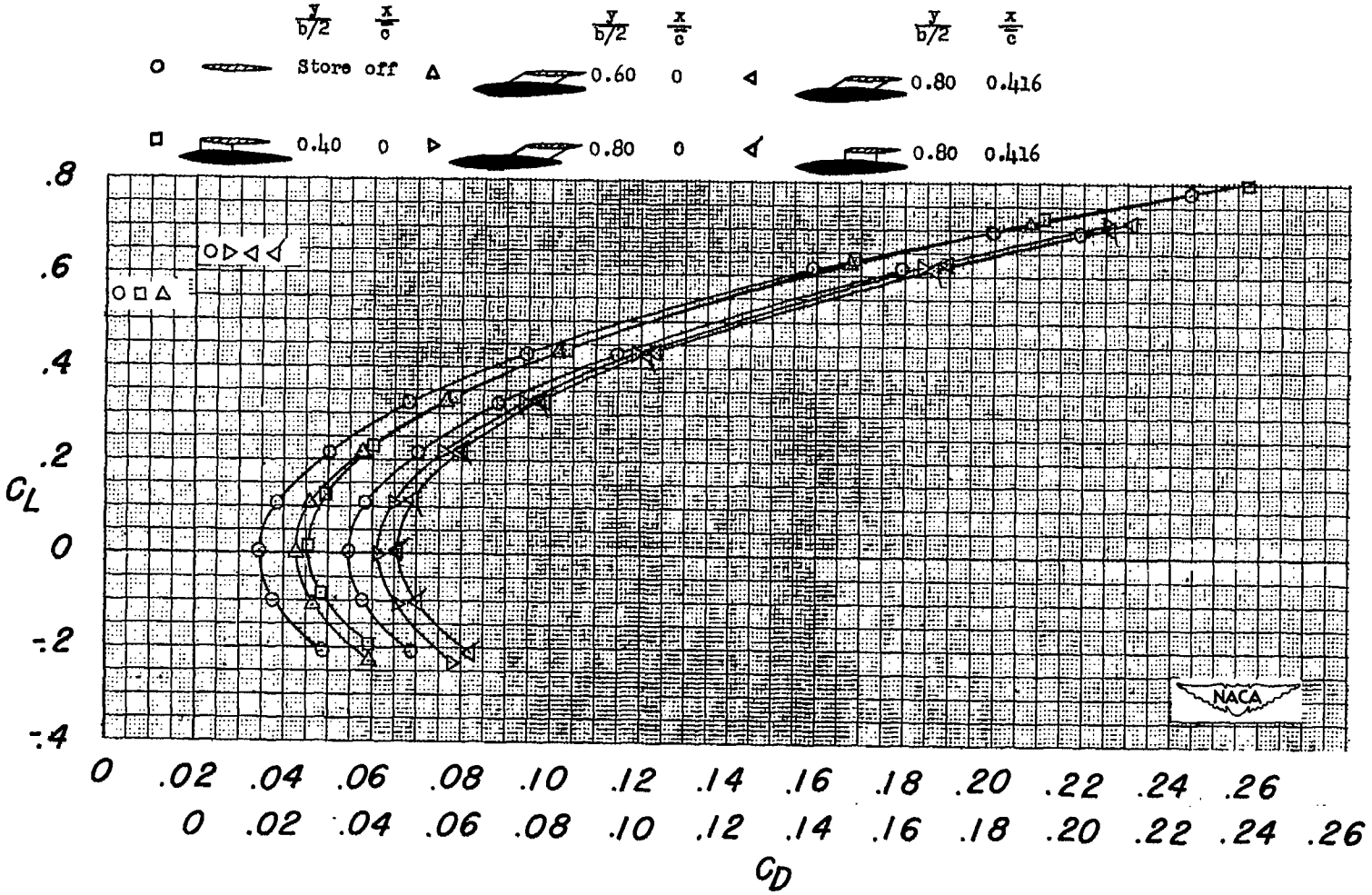
(b) C_L against C_D.

Figure 7.- Concluded.



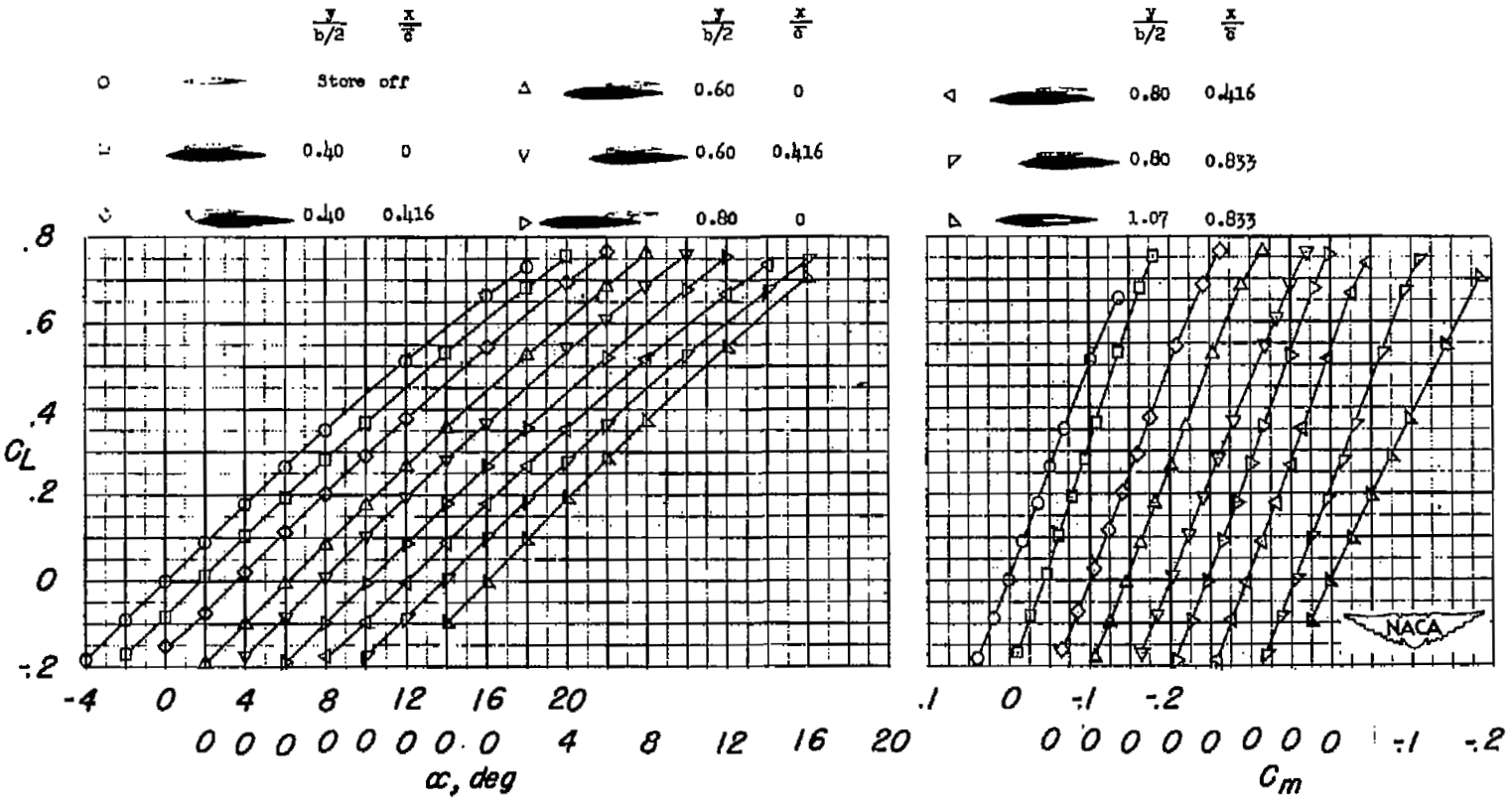
(a) C_L against C_m and α.

Figure 8.- Aerodynamic characteristics of the semispan model with DAC store at various spanwise and chordwise locations mounted on an unswept or swept strut. $M = 1.62$; $R \approx 1.4 \times 10^6$; $\frac{z}{d} = 1.0$.



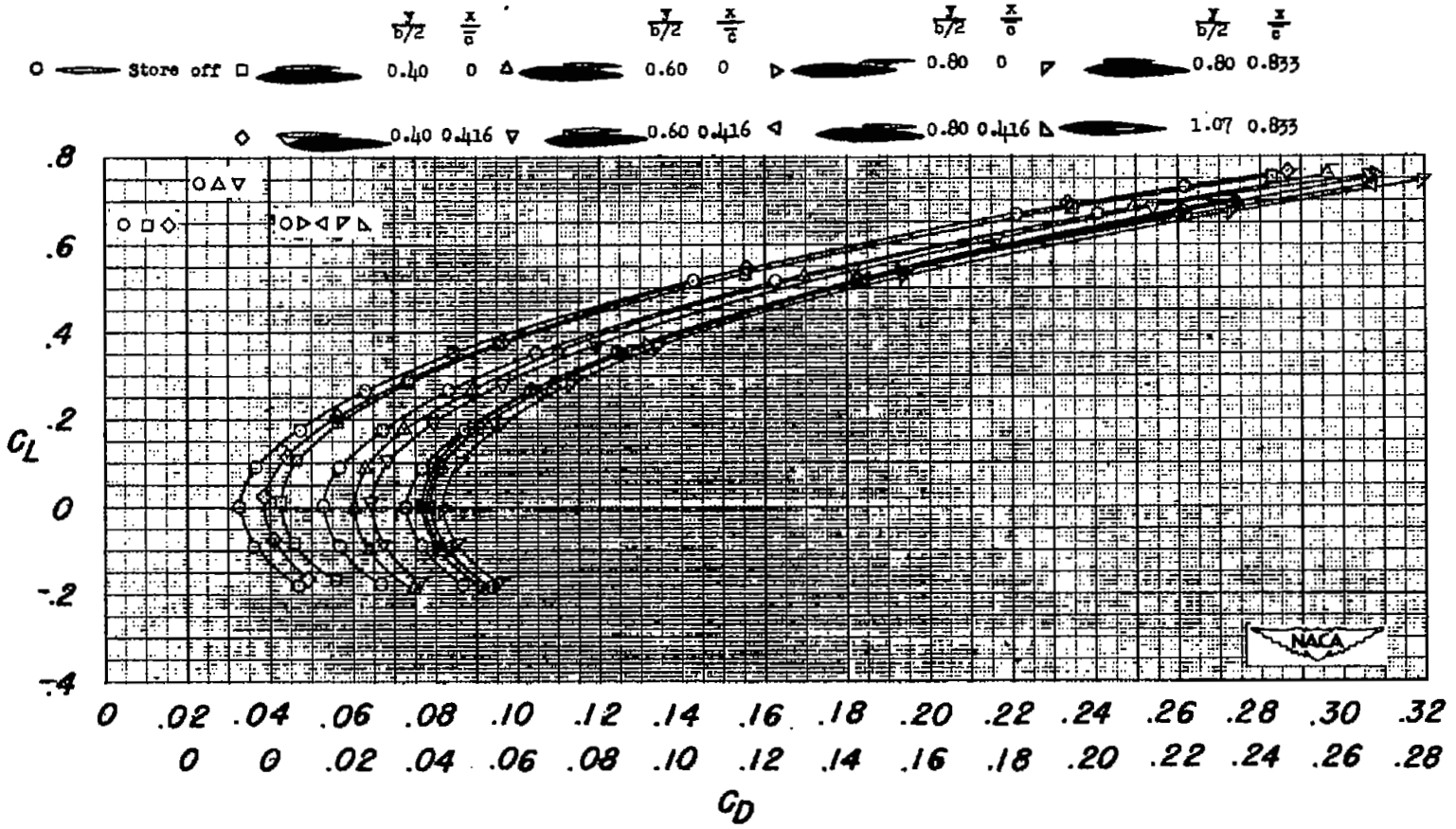
(b) C_L against C_D.

Figure 8.- Concluded.



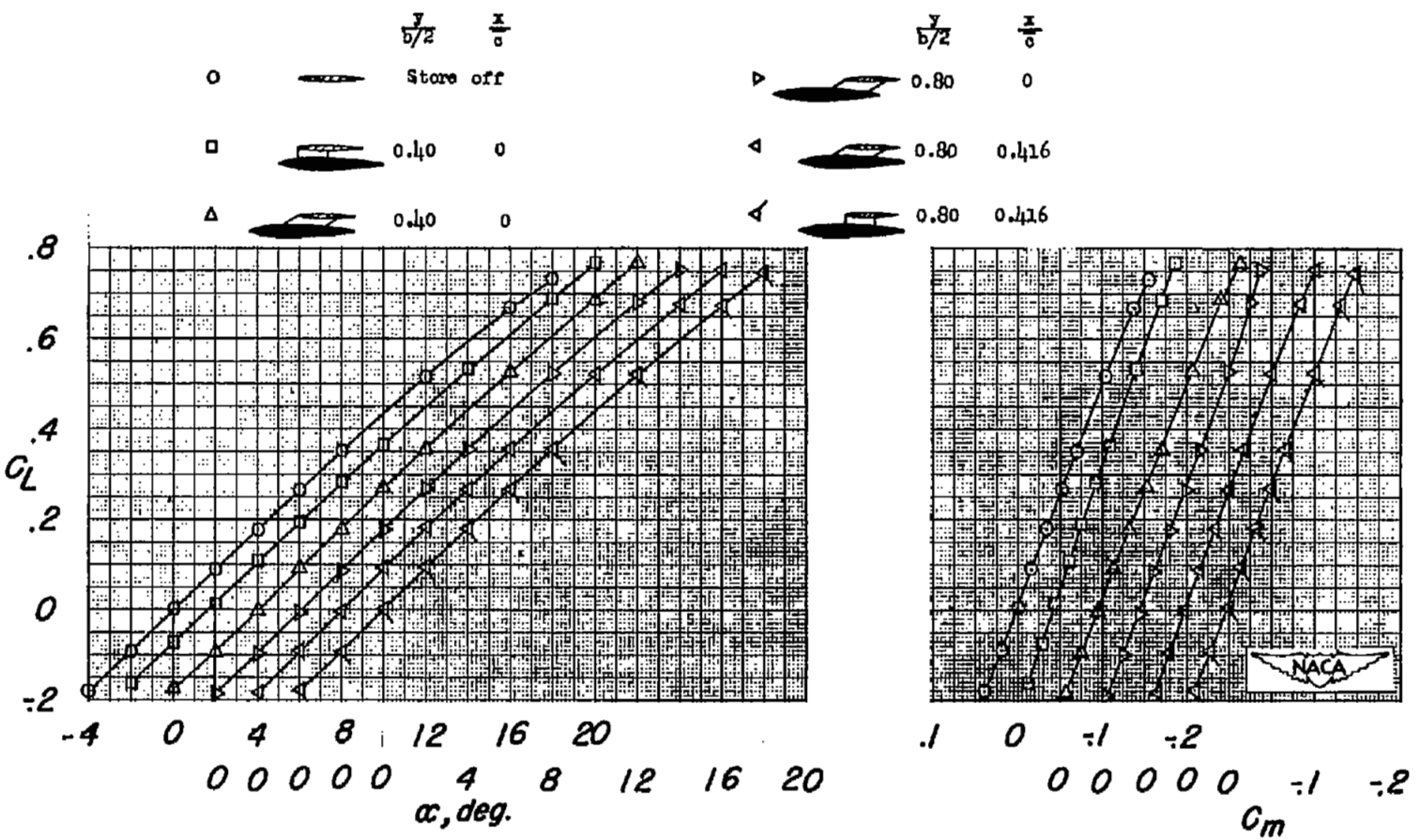
(a) C_L against C_m and α.

Figure 9.- Aerodynamic characteristics of the semispan model with DAC store at various spanwise and chordwise locations. M = 1.96; $R \approx 1.3 \times 10^6$; $\frac{z}{d} = 0$ and 0.5.



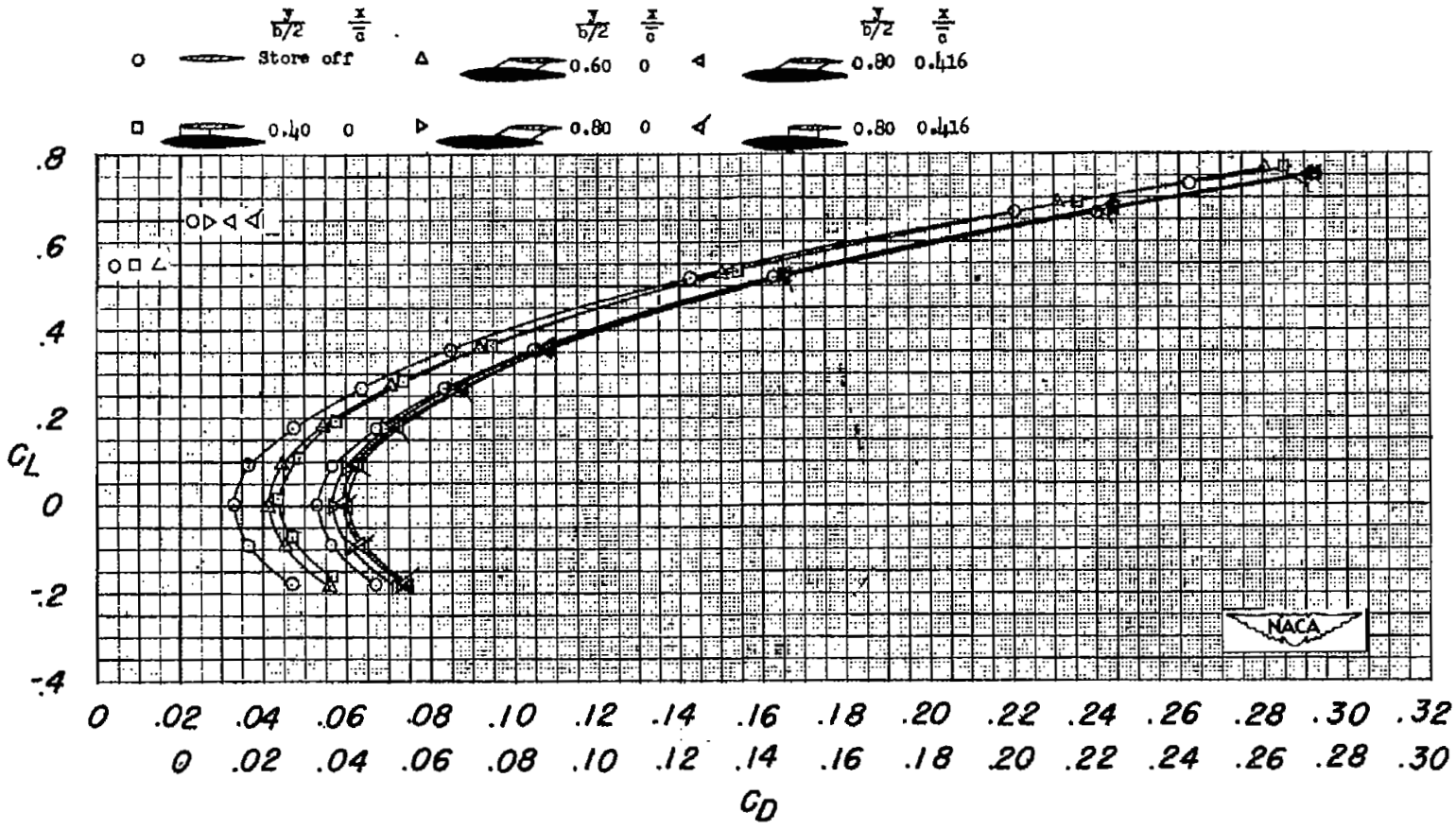
(b) C_L against C_D.

Figure 9.- Concluded.



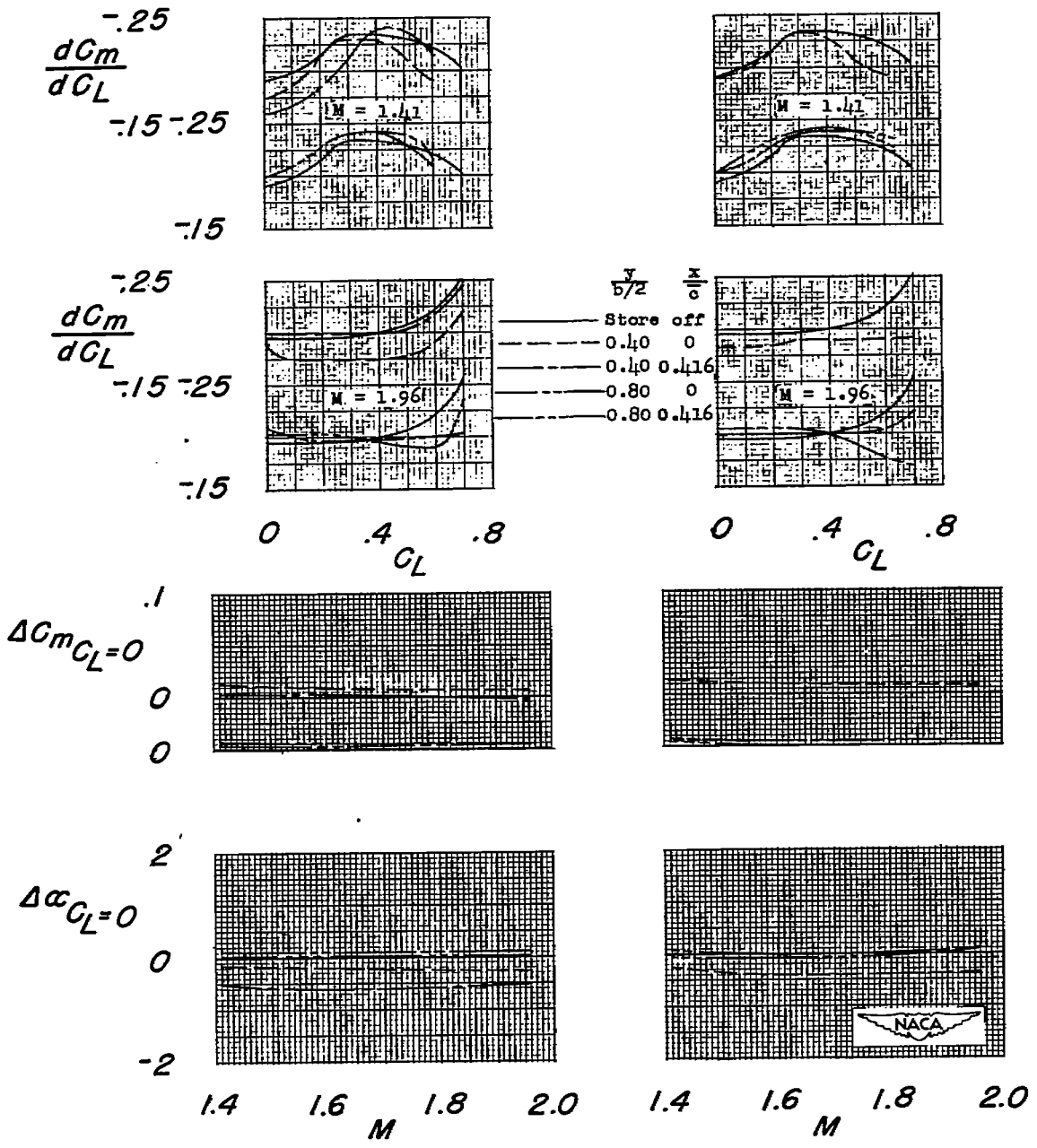
(a) C_L against C_m and α.

Figure 10.- Aerodynamic characteristics of the semispan model with DAC store at various spanwise and chordwise locations mounted on an unswept or swept strut. $M = 1.96$; $R \approx 1.3 \times 10^6$; $\frac{z}{d} = 1.0$.



(b) C_L against C_D.

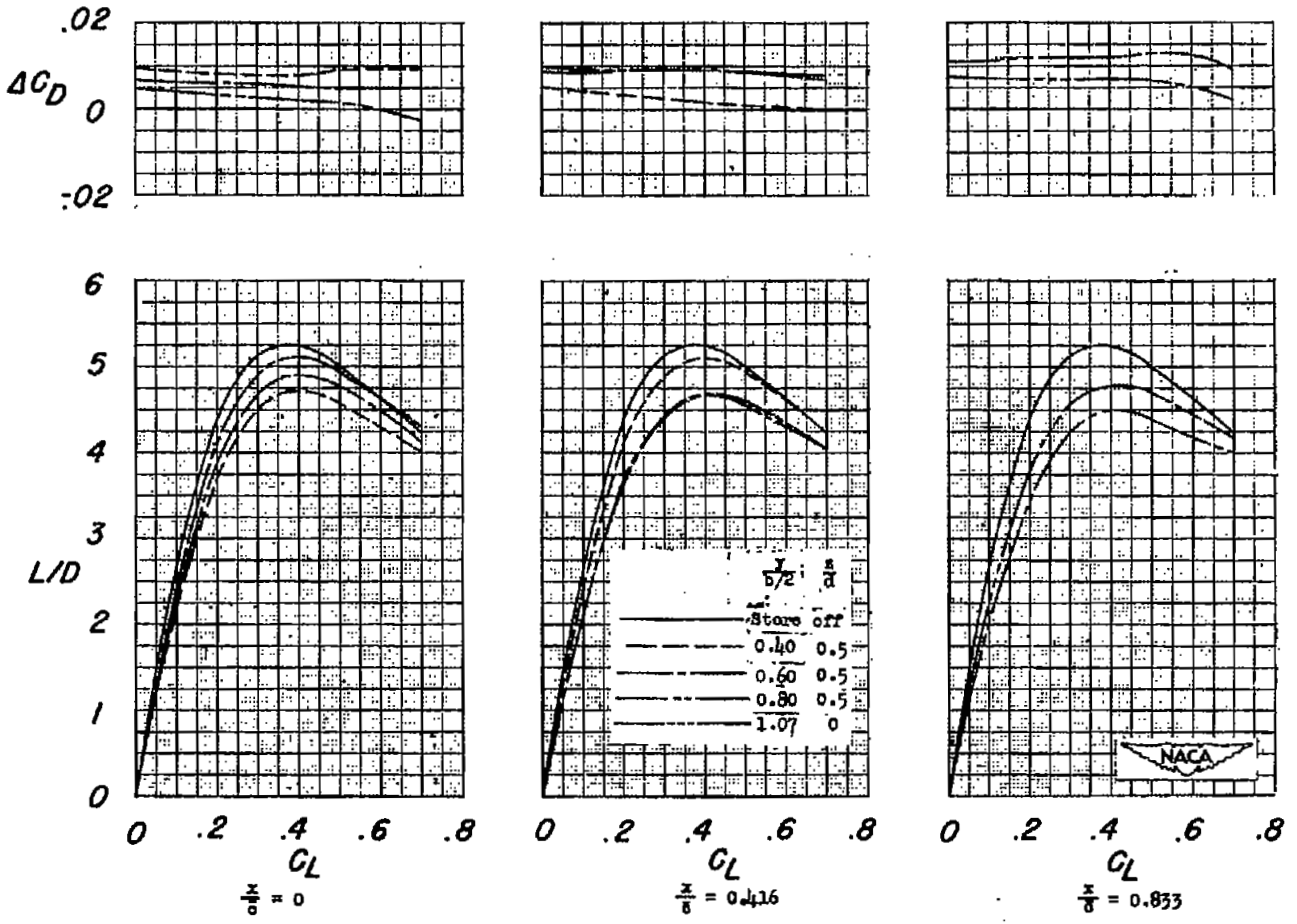
Figure 10.- Concluded.



(a) $\frac{z}{d} = 0.5$.

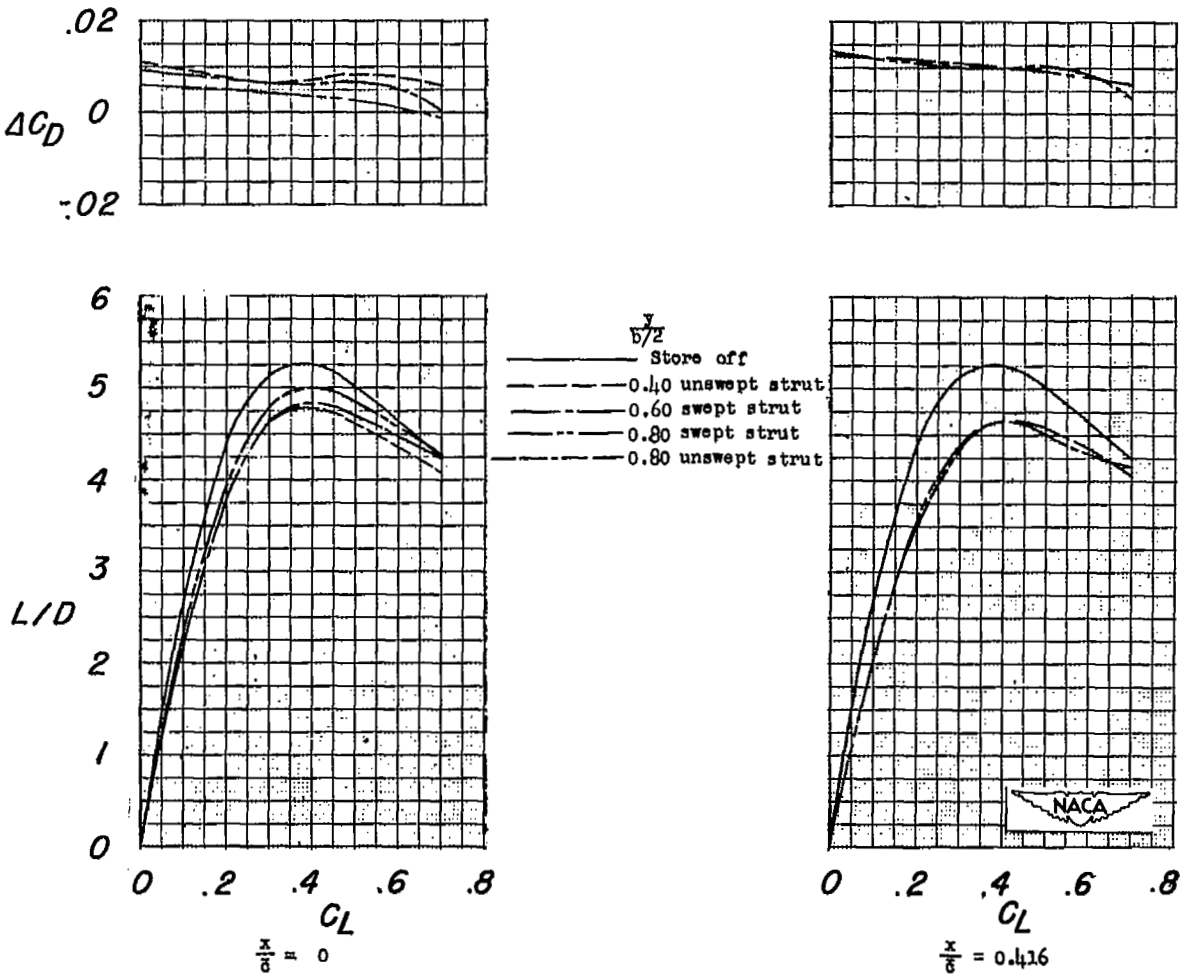
(b) $\frac{z}{d} = 1.0$.

Figure 11.- Effects of DAC store on wing dC_m/dC_L and on ΔC_m and $\Delta\alpha$ at zero lift.



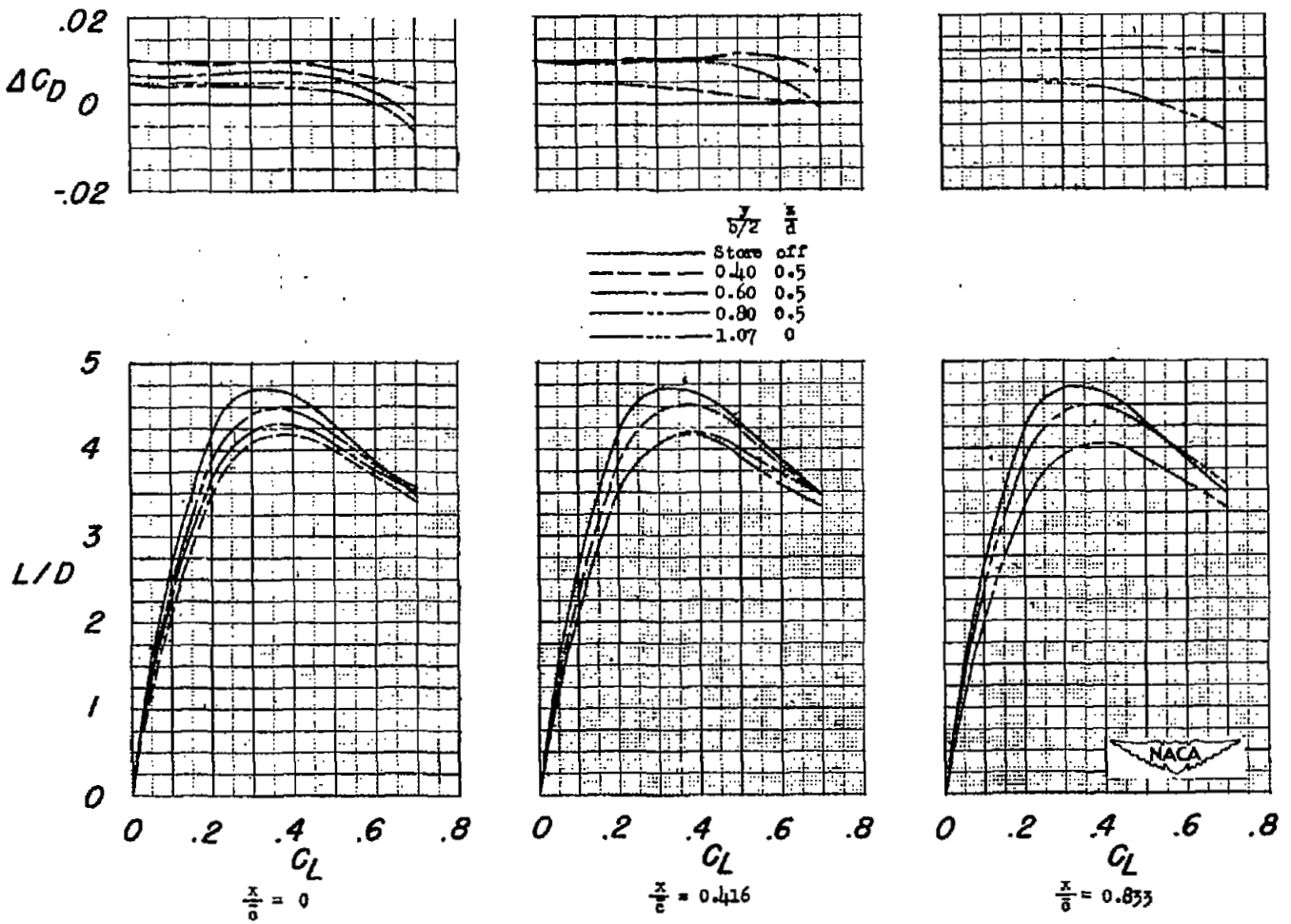
(a) $\frac{z}{d} = 0$ and 0.5; $M = 1.41$; $R \approx 1.5 \times 10^6$.

Figure 12.- Variations of store incremental drag coefficient and lift-drag ratio with lift coefficient for various spanwise, chordwise, and vertical locations of the DAC store on the semispan model.



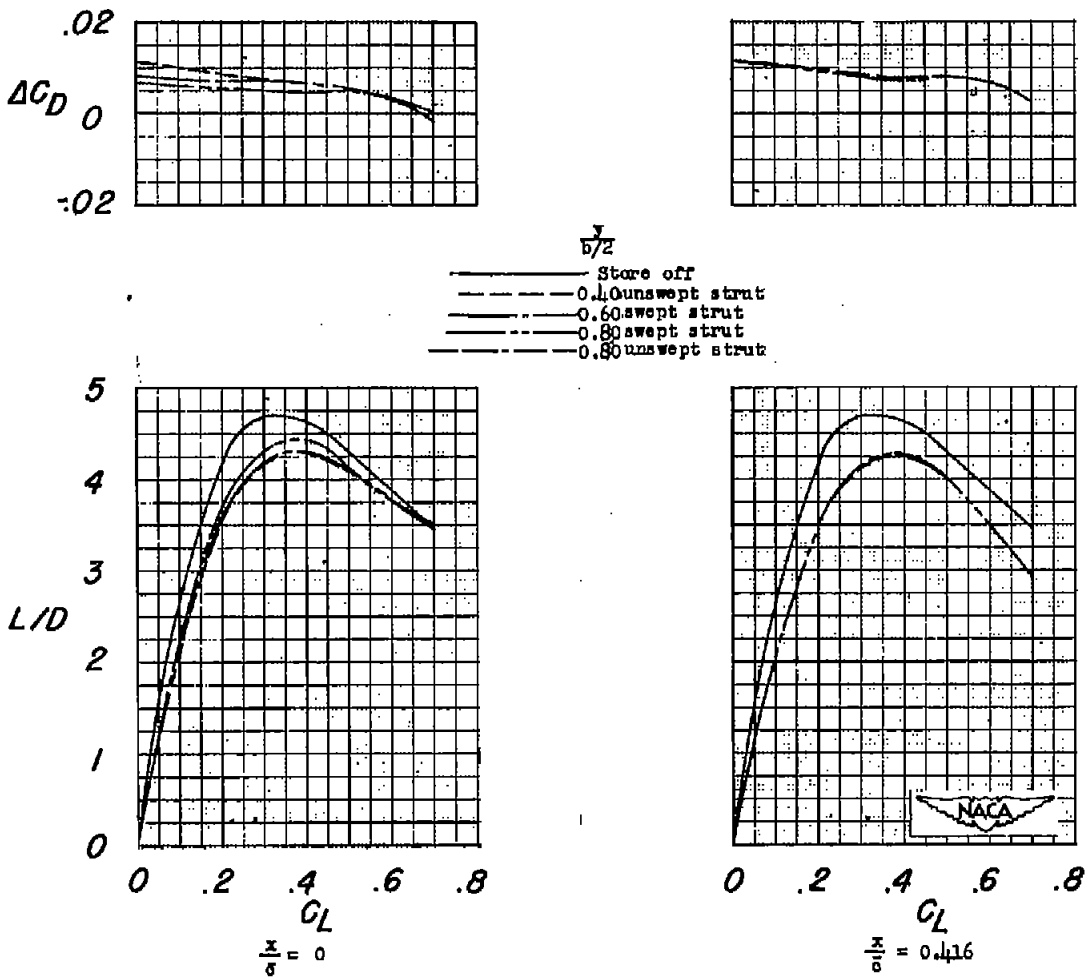
(b) $\frac{z}{d} = 1.0$; $M = 1.41$; $R \approx 1.5 \times 10^6$.

Figure 12.- Continued.



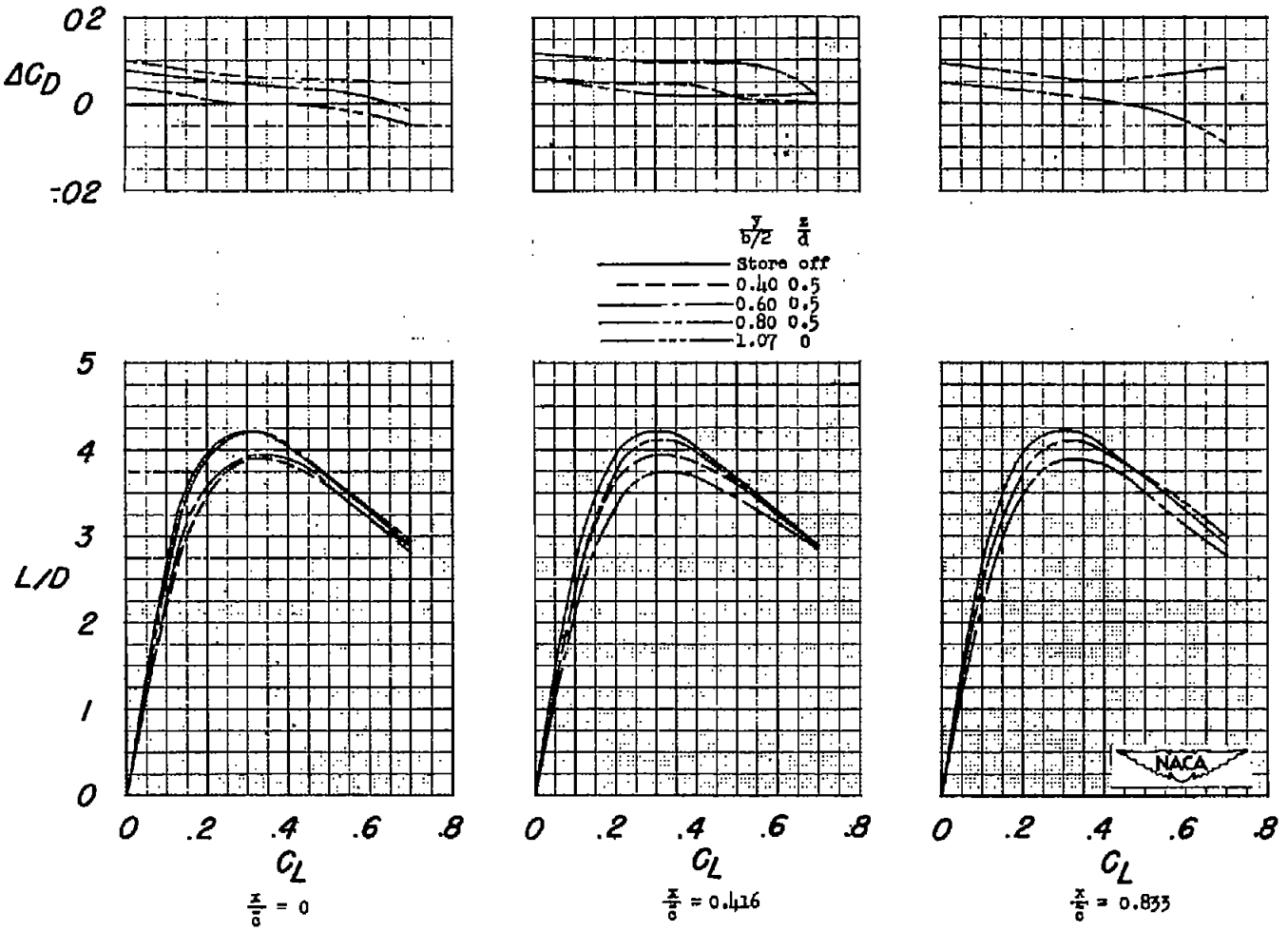
(c) $\frac{z}{d} = 0$ and 0.5; $M = 1.62$; $R \approx 1.4 \times 10^6$.

Figure 12.- Continued.



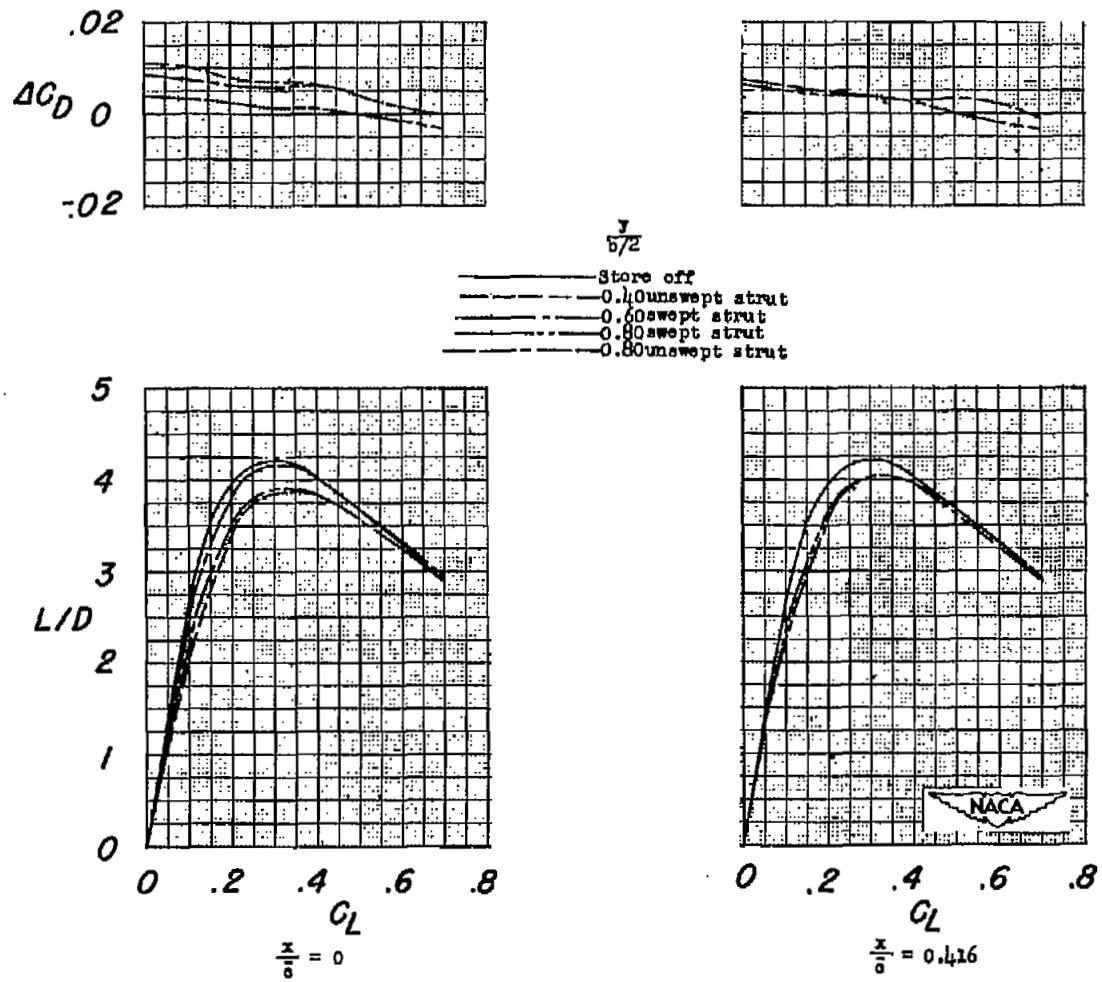
(d) $\frac{z}{d} = 1.0$; $M = 1.62$; $R \approx 1.4 \times 10^6$.

Figure 12.- Continued.



(e) $\frac{z}{d} = 0$ and 0.5; M = 1.96; R $\approx 1.3 \times 10^6$.

Figure 12.- Continued.



(f) $\frac{z}{d} = 1.0$; $M = 1.96$; $R \approx 1.3 \times 10^6$.

Figure 12.- Concluded.

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