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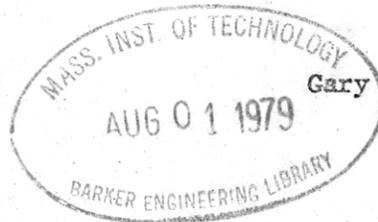


DEPARTMENT OF THE NAVY

A PRELIMINARY INVESTIGATION TO STUDY THE EFFECT OF  
FLAT SPOILERS ON THE AERODYNAMIC CHARACTERISTICS  
OF WINGS AT ANGLES OF ATTACK FROM 0° TO 90°

by

Gary W. Brasseur



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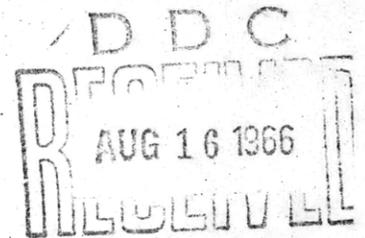
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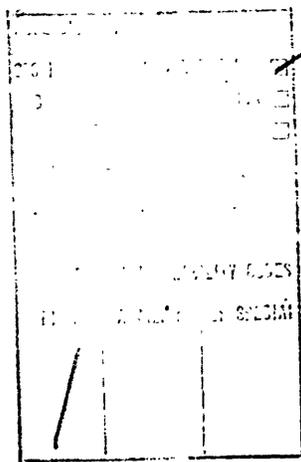
AERODYNAMICS LABORATORY  
RESEARCH AND DEVELOPMENT REPORT



April 1966

Report 2214

A PRELIMINARY INVESTIGATION TO STUDY THE EFFECT OF  
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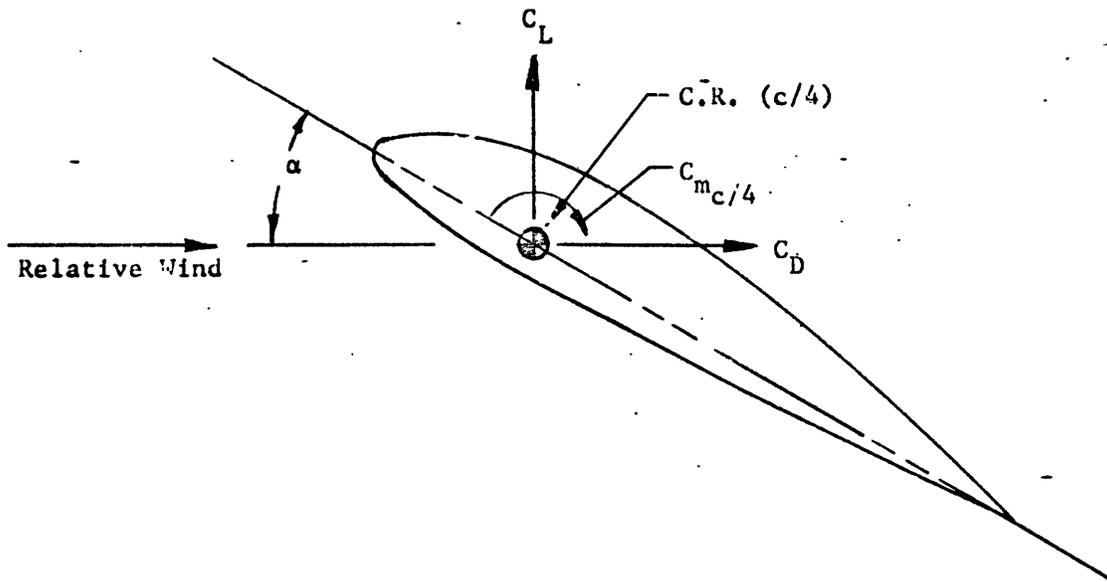
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NOTATION

Positive directions of axes, forces, moment  
and angular displacement are shown by arrows



## SYMBOLS

$c$	chord in inches
$C_D$	drag coefficient (drag/qS)
$C_D^i$	drag coefficient (uncorrected)
$C_L$	lift coefficient (lift/qS)
$C_{m_{c/4}}$	pitching moment coefficient about the wing quarter chord (pitching moment/qSc)
$L$	lift force in pounds
$D$	drag force in pounds
$M$	pitching moment about wing quarter chord in inch-pounds
$q$	free-stream dynamic pressure in pounds per square foot
$R$	Reynolds number, based upon wing chord
$S$	wing area in square feet
$X_{c.p.}$	center of pressure location in percent chord
$\alpha$	angle of attack in degrees
$\alpha'$	angle of attack (uncorrected)

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## SUMMARY

Flat spoilers were tested on a semispan wing as a possible leading-edge, upper-surface device for controlling flow separation on wings rotated through  $90^\circ$  for application to tilt-wing V/STOL aircraft. Model tests indicated that a spoiler height of 0.10 wing chord at the 0.15 wing chord location was capable of partially controlling flow separation.

## INTRODUCTION

A preliminary investigation of flat spoilers was conducted to consider their use as a leading-edge device capable of controlling flow separation on wings rotated through  $90^\circ$ . An acceptable spoiler would minimize or eliminate lift curve slope discontinuities induced by flow separation through approximately  $45^\circ$  effective angle of attack. In achieving the desired flow control, a spoiler should not introduce an adverse pitching moment during the transition phase.

For the case of a powered tilt-wing V/STOL aircraft, if high thrust coefficients are maintained throughout the intermediate transition angles, the free-stream flow should be sufficiently deflected through the propeller plane to keep the effective angle of attack of the wing below  $45^\circ$ . Therefore, a device which can control separation through this angle could improve or eliminate the severe buffeting associated with partial or total separation in this region.

This study was conducted prior to the testing of an open-ocean V/STOL canard seaplane to investigate the particular problem of flow separation on tilting wings during transition from cruising flight to hovering.

## MODEL AND TEST PROCEDURE

The test was conducted in the 15- by 20-inch DTMB Model Wind Tunnel using a wall balance with three-component readout (Reference 1). The test was conducted at a constant dynamic pressure of 30 pounds per square foot and Reynolds number of 336,000, based on a four-inch wing chord.

The model used for the test was an NACA 4415 airfoil section with an eleven-inch semispan and four-inch chord (Figure 1). The full-span aluminum spoilers were mounted perpendicular to the wing surface. Two

gated spoiler configurations, with spacing of three-percent and six-percent of the chord, were tested at four heights and two chordwise locations (Figure 2).

Figure 3 shows photographs of the wall-mounted wing with spoilers. Figure 4 is a tuft photograph of the wing without spoilers, illustrating an early root stall.

### RESULTS

Test results are presented in Figures 5 through 9. The nondimensional coefficients of lift and drag are plotted versus angle of attack in Figures 5 and 6, respectively. The drag polar for all configurations tested is given in Figure 7 and the  $C_{m_{c/4}}$  versus  $C_L$  is shown in Figure 8. The center-of-pressure travel as a function of angle of attack has been computed and is presented in Figure 9 along with the pitching moment data.

### DISCUSSION

Test results show that the six-percent (0.06c) spoiler, at the fifteen-percent (0.15c) chordwise location, had the more nearly linear response through a wing incidence angle of approximately  $45^\circ$  (Figure 5). Spoiler effectiveness appears to be a function of height, with the ten-percent chord height controlling separation through the largest usable range of angle of attack (Figure 5). The lift curve of the six-percent spoiler configuration is slightly more linear because of the more complete mixing of the flow behind the wider spaced spoiler. Figure 8 shows that the slope of  $dC_{m_{c/4}}/dC_L$  was more negative for the wing with spoilers than for the plain wing through the initial  $\alpha$ . Figure 9, showing pitching moment and center-of-pressure travel, indicates that both were affected by the presence of spoilers, but only for angles of less than  $30^\circ$ . For angles greater than  $30^\circ$ , the pitching moment and center-of-pressure location, with spoilers, essentially coincided with the data of the plain airfoil. For angles less than  $30^\circ$ , test results indicated that the pitching moment was less negative and the center of pressure was further from the leading edge with the spoiler in the rearward location.

The lift curve slope,  $dC_L/d\alpha$ , was decreased by approximately sixty percent and seventy percent with the spoiler in the rearward (0.15c) and

forward (0.05c) chordwise locations, respectively (Figure 5). The results indicated that the decrease in lift curve slope was essentially independent of spoiler height or configuration.

The incremental change in drag with the introduction of spoilers appears to be dependent upon angle of attack, spoiler height, location, and configuration (Figure 6). At low angles of attack, with the maximum height spoiler in the rearward location (0.15c), the drag was significantly greater than the drag for the wing alone. At high angles of attack (above  $50^\circ$ ), the effect of spoilers on drag was negligible.

#### CONCLUDING REMARKS

From this preliminary investigation, it was concluded that a flat spoiler is capable of partially controlling separation on a tilting V/STOL wing, with perhaps a significant contribution to the longitudinal stability during transition. The investigation also indicates that flat spoilers warrant further study in tilt-wing V/STOL separation problems.

Aerodynamics Laboratory  
David Taylor Model Basin  
Washington, D. C.  
March 1966

#### REFERENCE

1. Patterson, Raymond T. Balance Number 69 (1-inch Wall Balance); Description, Instructions, and Corrections. Rev. Wash., May 1956. 28 l. incl. illus. (David Taylor Model Basin. Aero Memo 49)

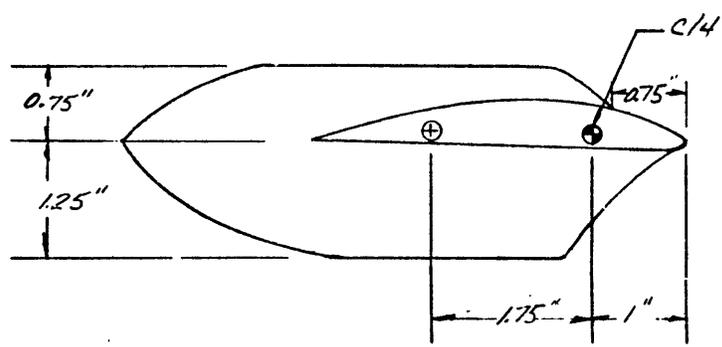
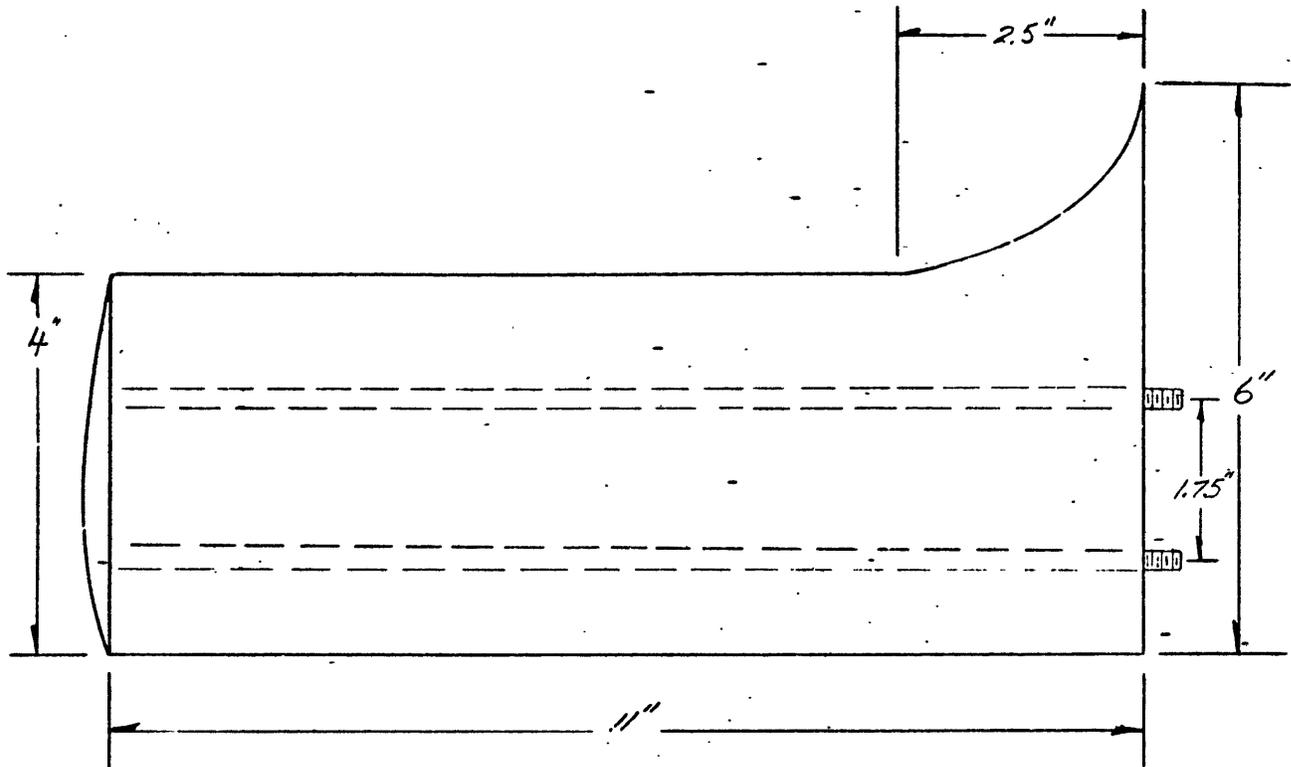
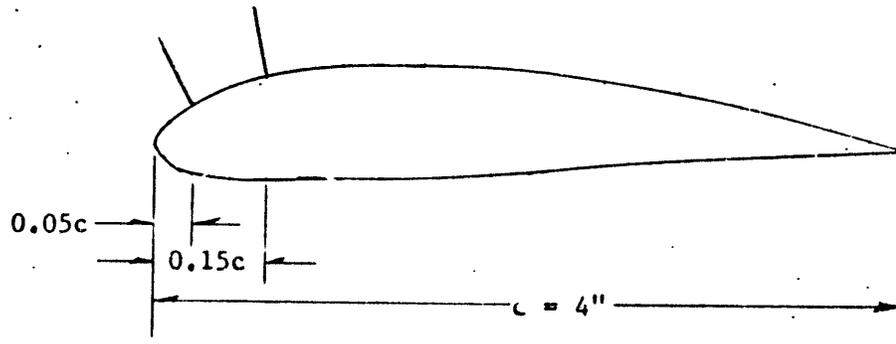
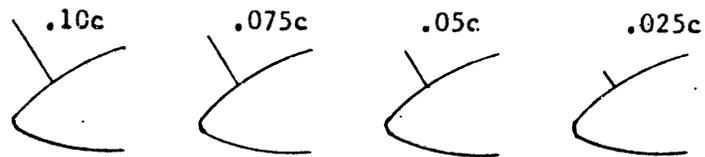


Figure 1 - Principal Dimensions of NACA 4415 Half-Span Model  
With Root Fairing

Airfoil Section Showing Spoiler Locations



Spoiler Heights (at 0.05c Location)



Spoiler Configurations

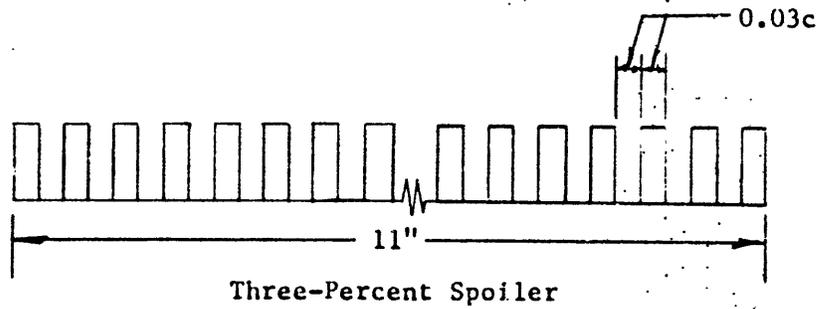
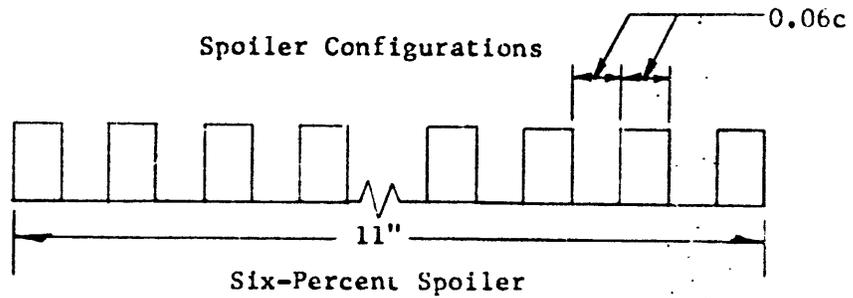
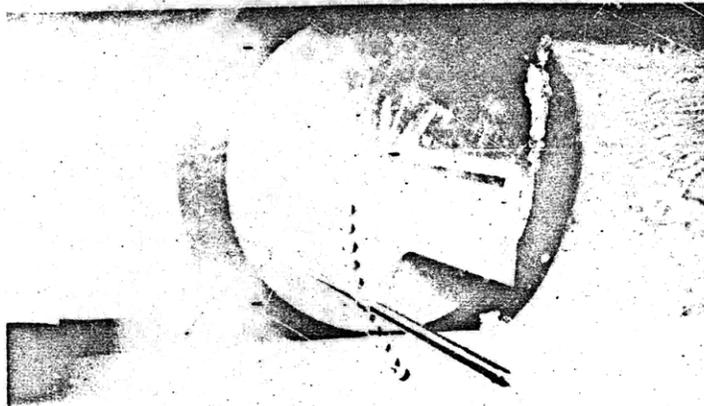


Figure 2 - Sketches of NACA 4415 Wing and Spoilers



(a)  $\alpha = 90^\circ$



(b)  $\alpha = 20^\circ$

Figure 3 - Views of Wall-Mounted Wing With  
Three-Percent Spoiler at the Fifteen  
Percent Chord Position

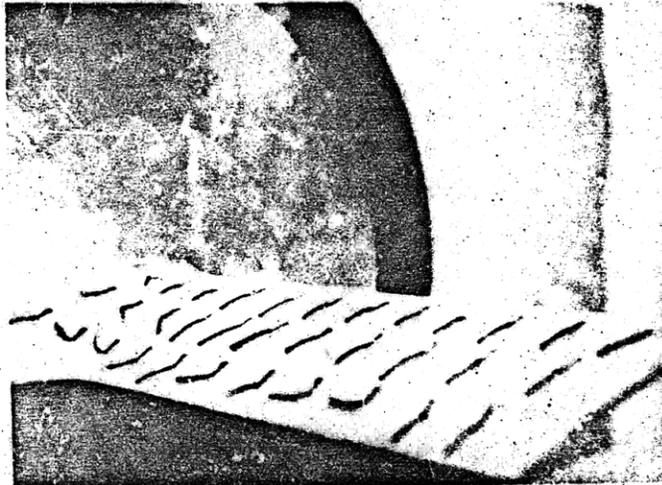


Figure 4 - Tuft Photograph of Wing Without  
Spoilers,  $\alpha = 10^\circ$   
(Note partial stall at wing root.)

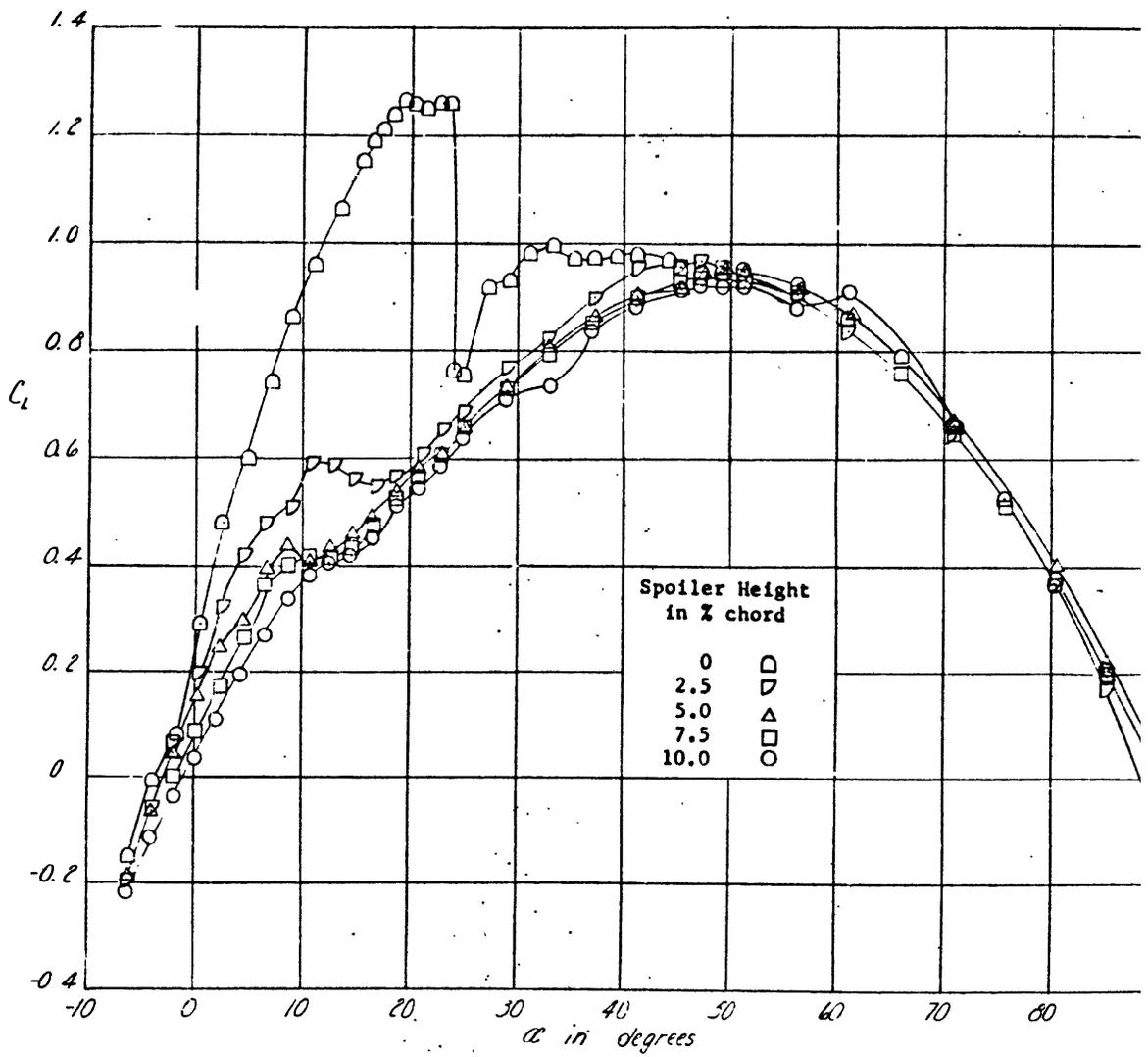


Figure 5 - Lift Coefficient Versus Angle of Attack for the Spoiler Configurations Tested  
 (a) Six-Percent Spoiler (0.06c) Located Five Percent (0.05c) From the Leading Edge

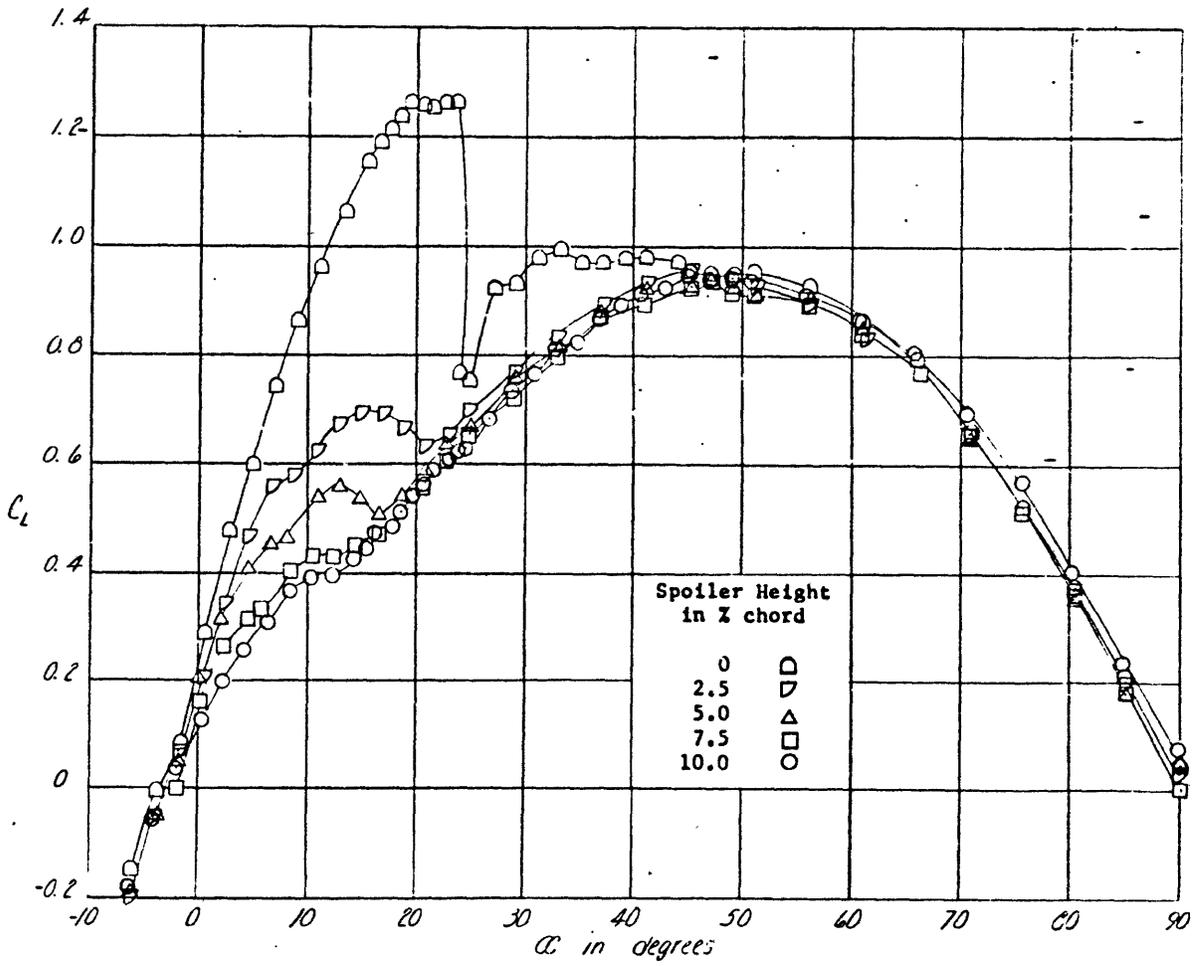


Figure 5 (Continued)  
 (b) Three-Percent Spoiler (0.03c) Located Five Percent (0.05c)  
 From the Leading Edge

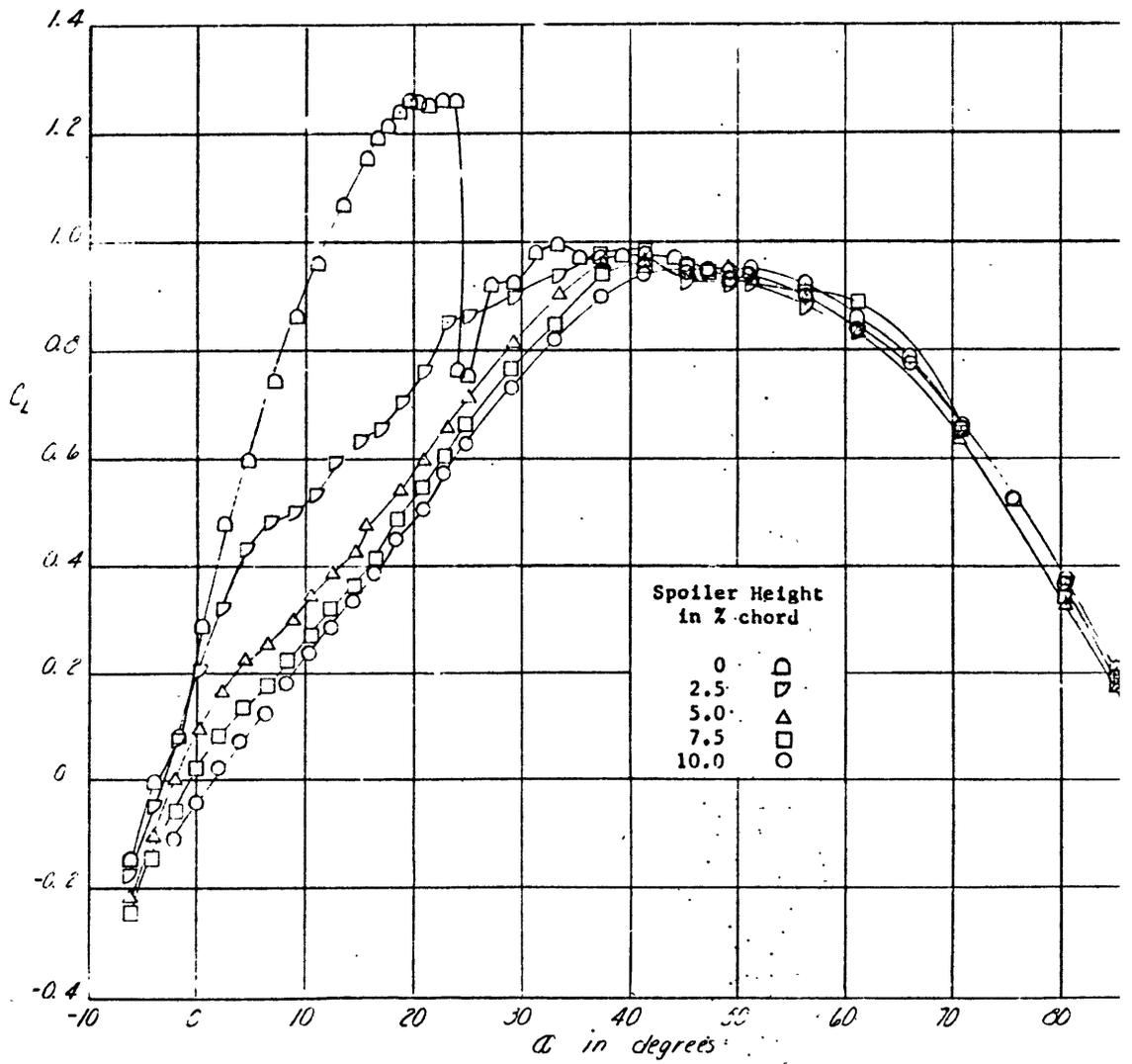


Figure 5 (Continued)

(c) Six-Percent Spoiler (0.06c) Located Fifteen Percent (0.15c) From the Leading Edge

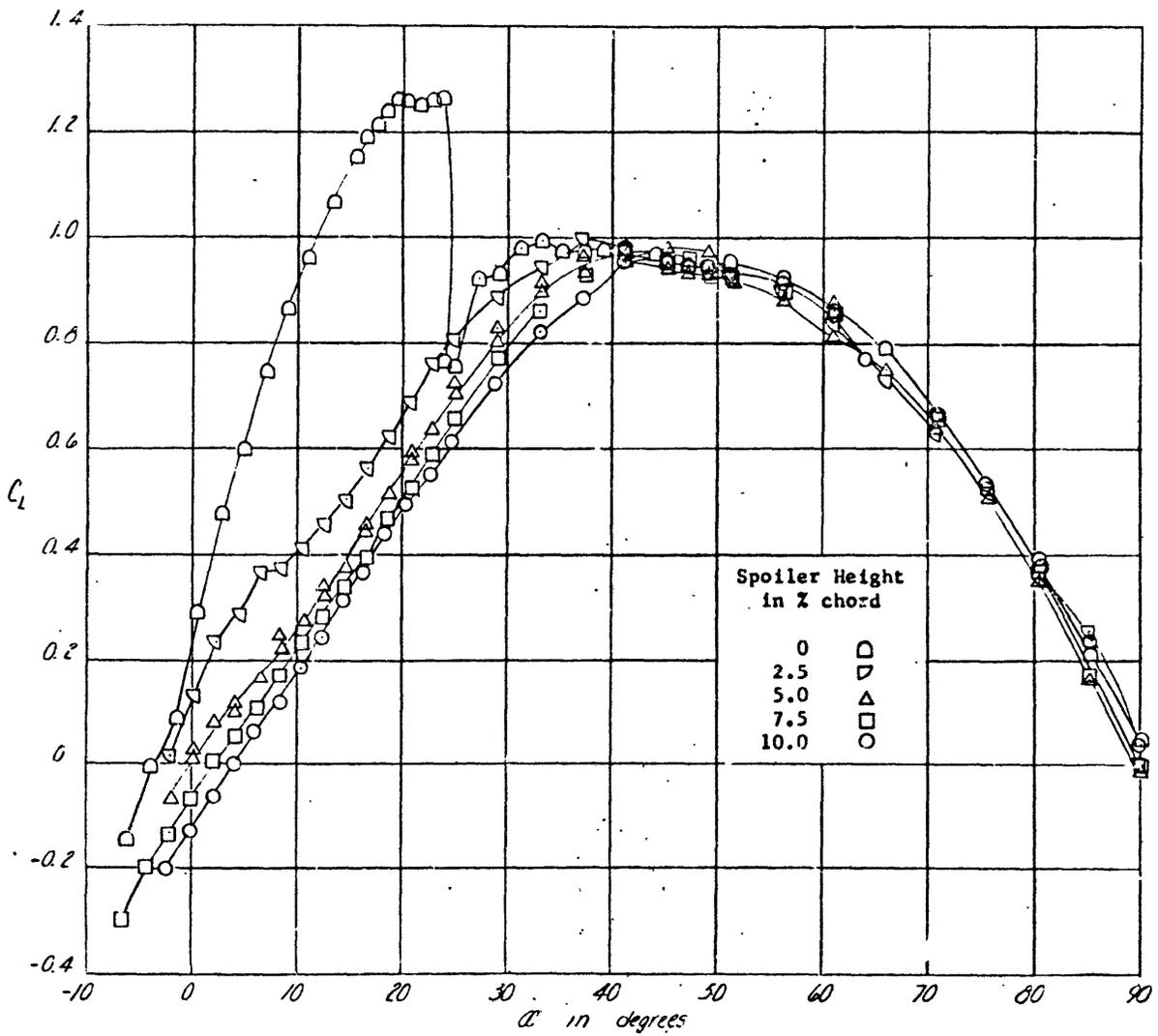


Figure 5 (Concluded)  
 (d) Three-Percent Spoiler (0.03c) Located Fifteen Percent (0.15c)  
 From the Leading Edge

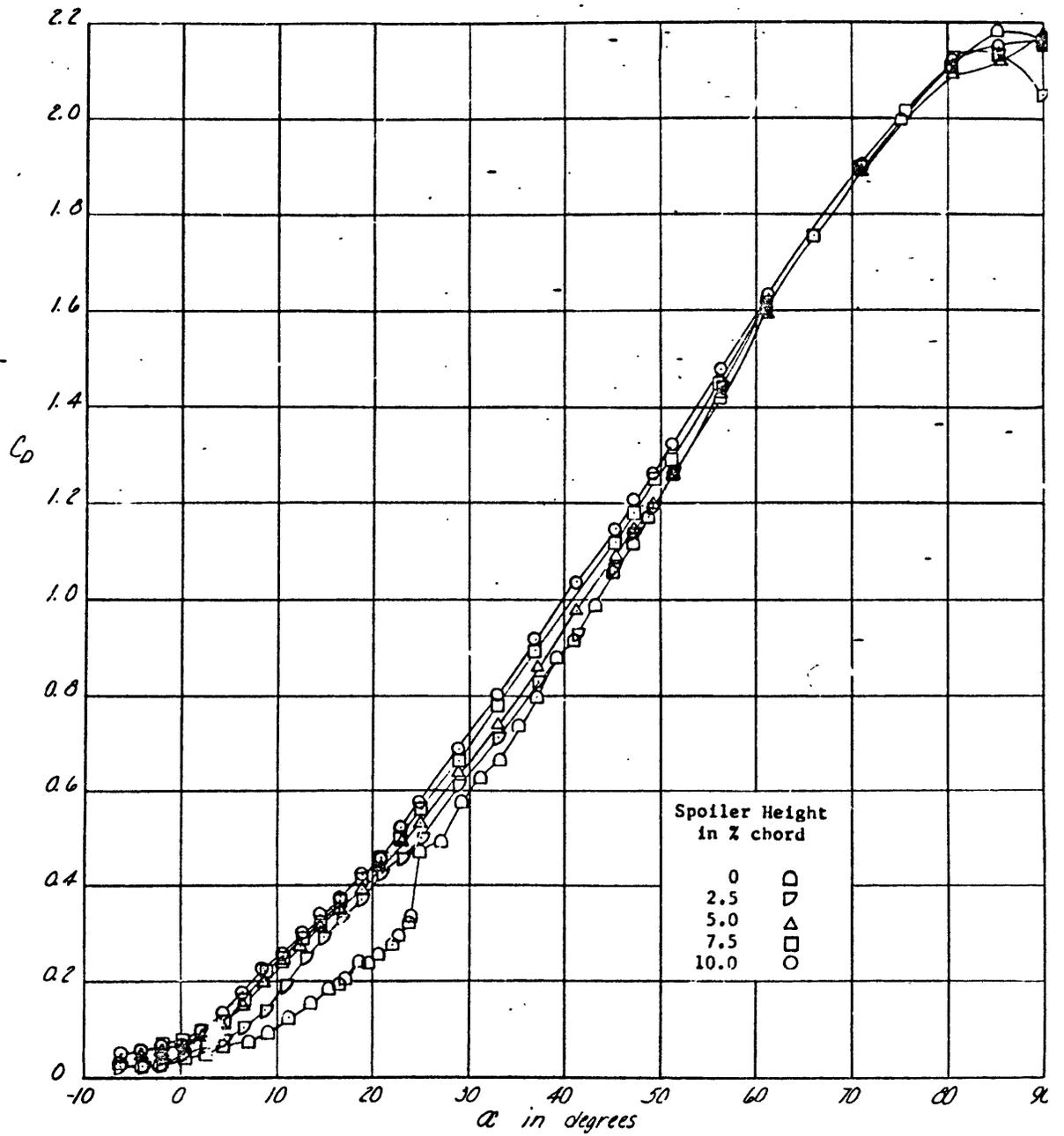


Figure 6 - Drag Coefficient Versus Angle of Attack for the Spoiler Configurations Tested  
 (a) Six-Percent Spoiler (0.06c) Located Five Percent (0.05c)  
 From the Leading Edge

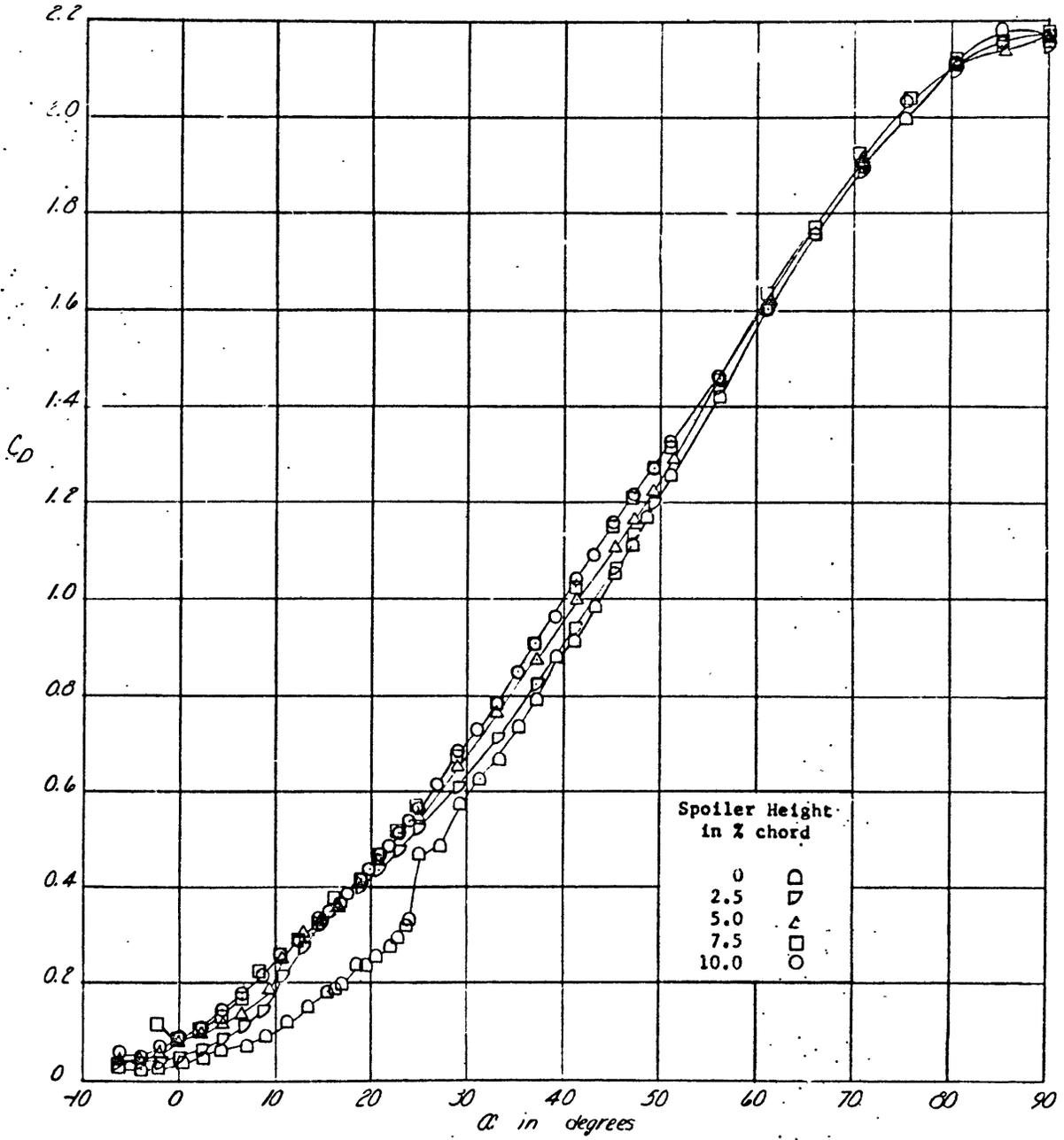


Figure 6 (Continued)  
 (b) Three-Percent Spoiler (0,06c) Located Five Percent (0,05c)  
 From the Leading Edge

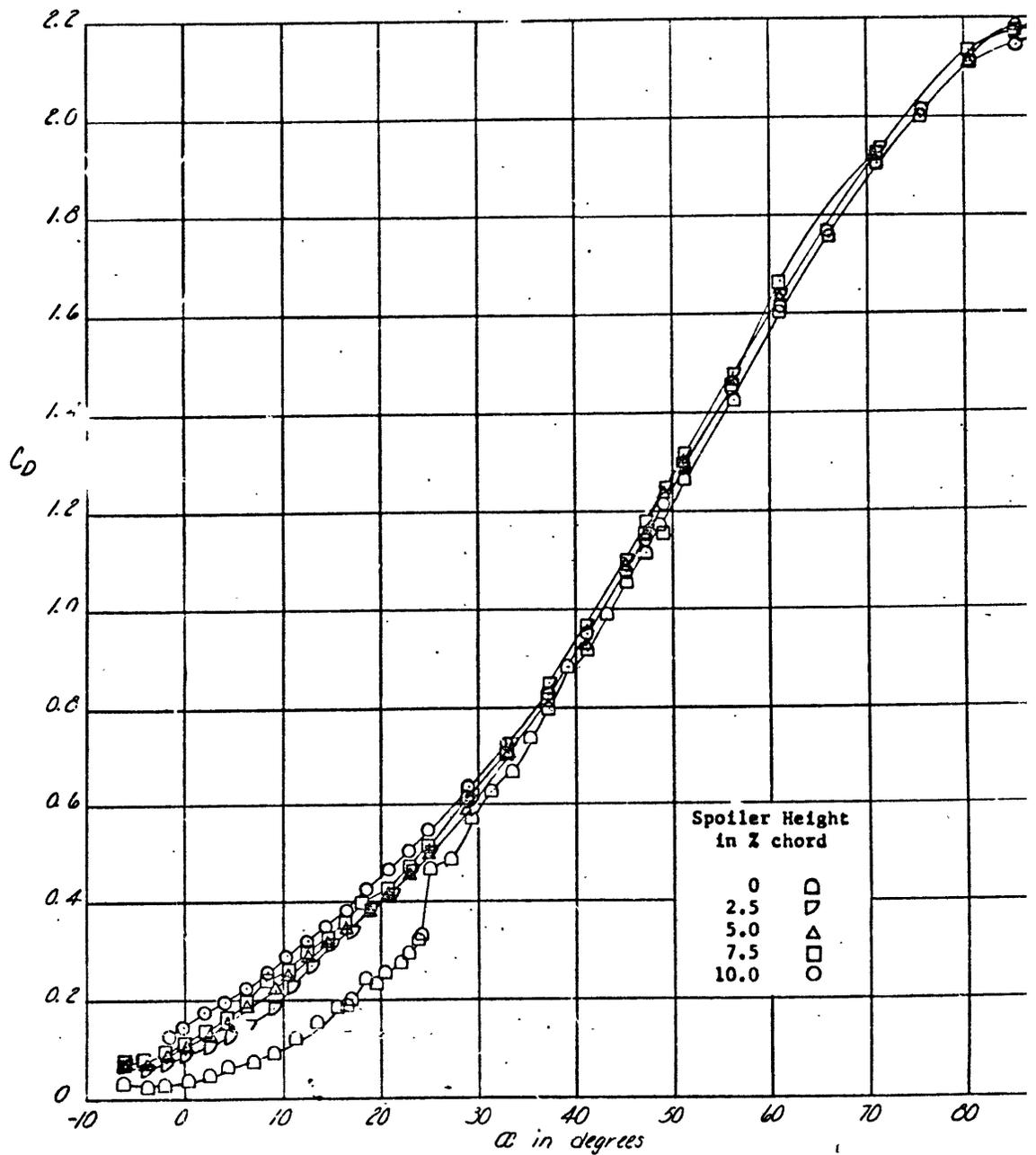


Figure 6 (Continued)

(c) Six-Percent Spoiler (0.06c) Located Fifteen Percent (0.15c)  
From the Leading Edge

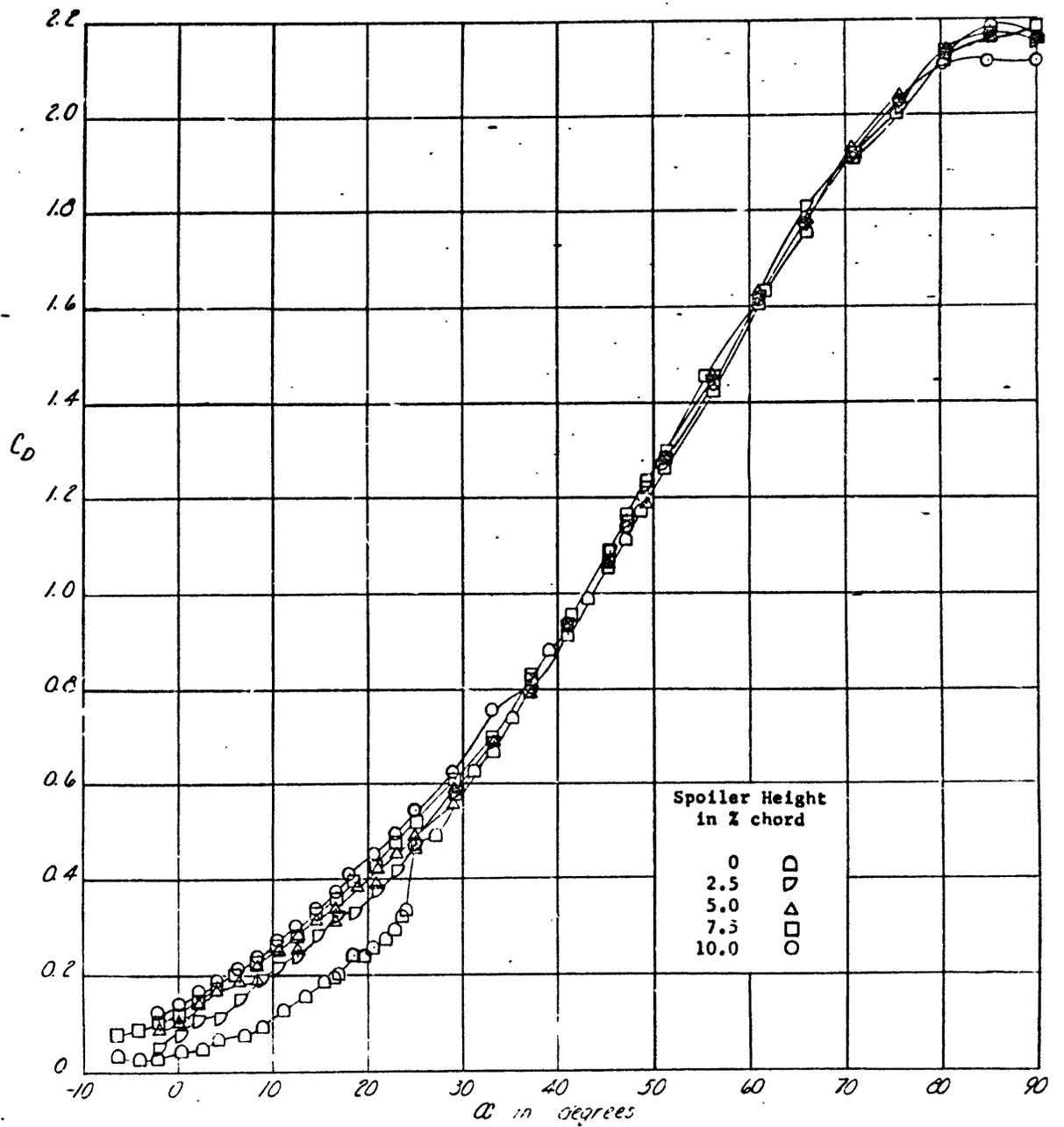


Figure 6 (Concluded)

(d) Three-Percent Spoiler (0.03c) Located Fifteen Percent (0.15c) From the Leading Edge

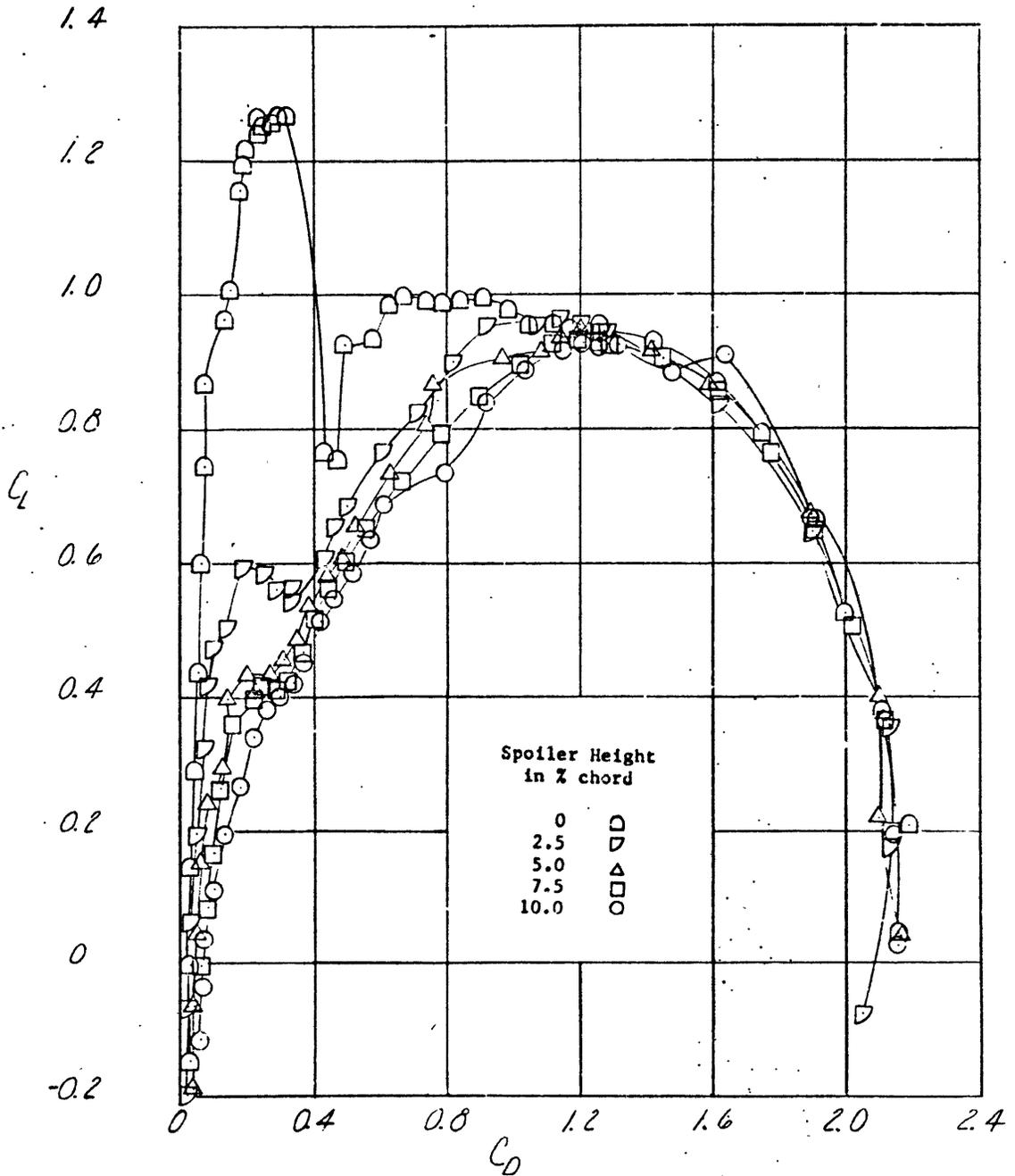


Figure 7 - Drag Polar for the Spoiler Configurations Tested  
 (a) Six-Percent Spoiler (0.06c). Located  
 Five Percent (0.05c) From  
 the Leading Edge

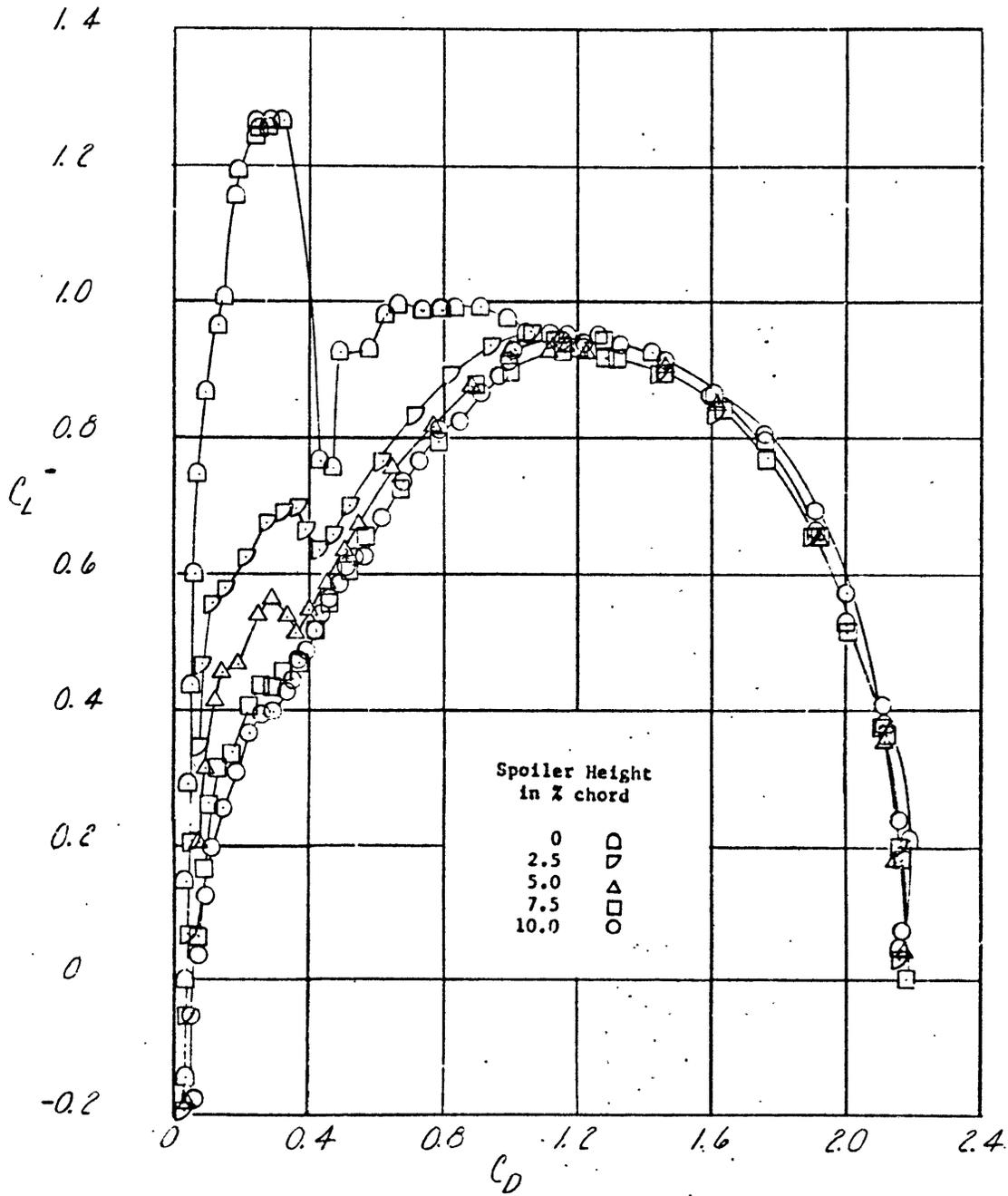


Figure 7 (Continued)

(b) Three-Percent Spoiler (0.03c) Located Five Percent (0.05c)  
From the Leading Edge

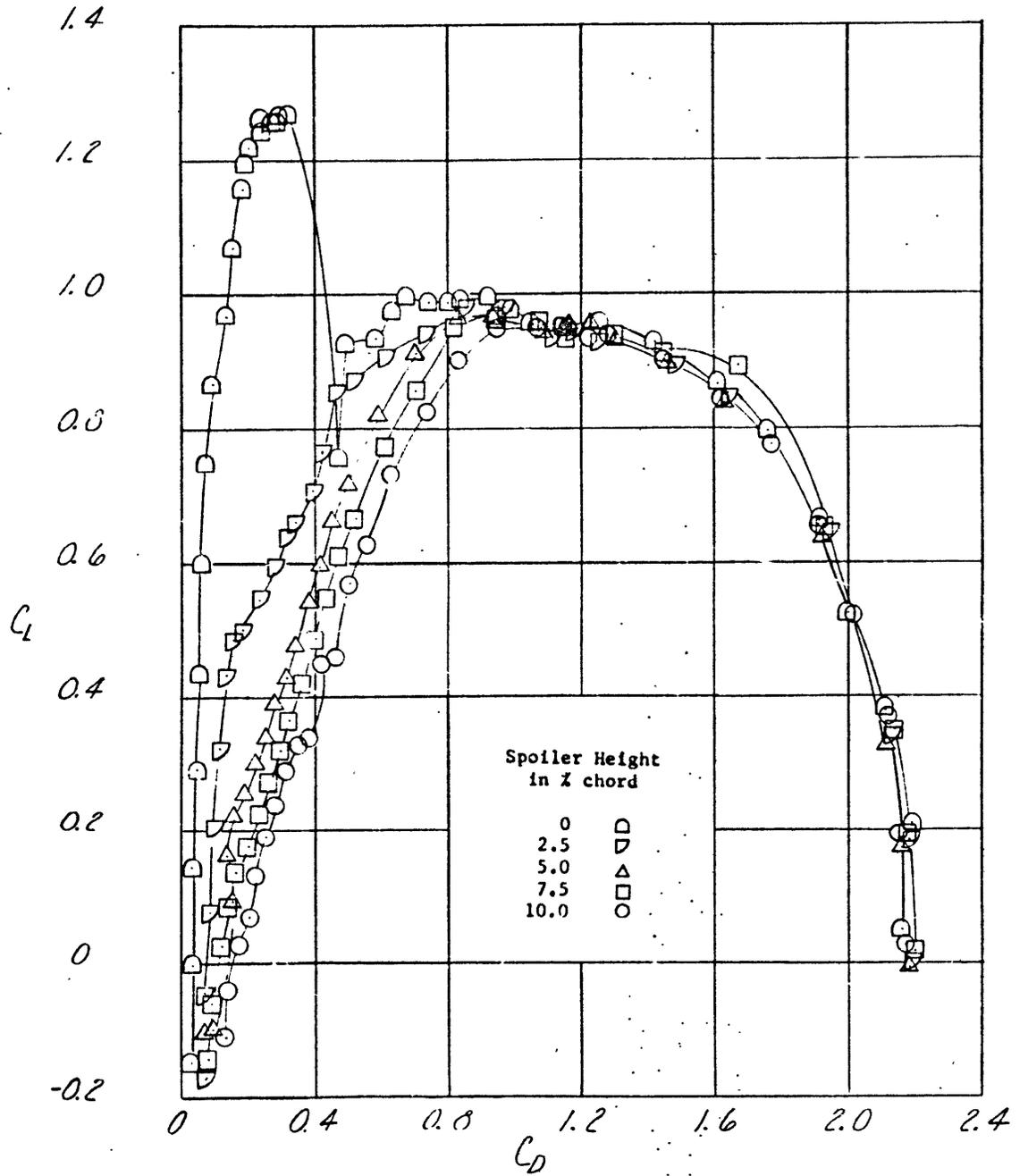


Figure 7 (Continued)

(c) Six-Percent Spoiler (0.06c) Located Fifteen Percent (0.15) From the Leading Edge

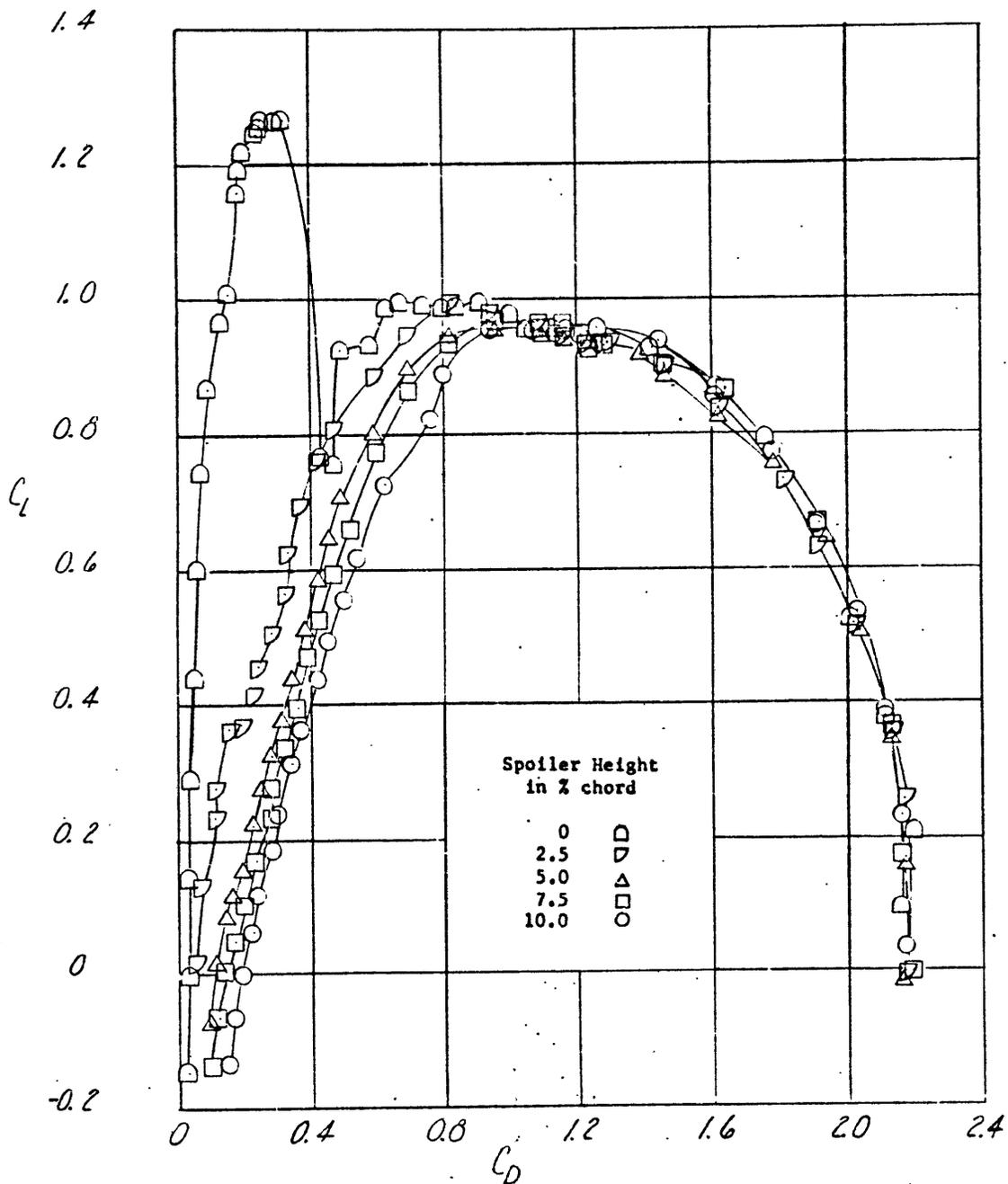


Figure 7 (Concluded)

(d) Three-Percent Spoiler (0.03c) Located Fifteen Percent (0.15c) From the Leading Edge

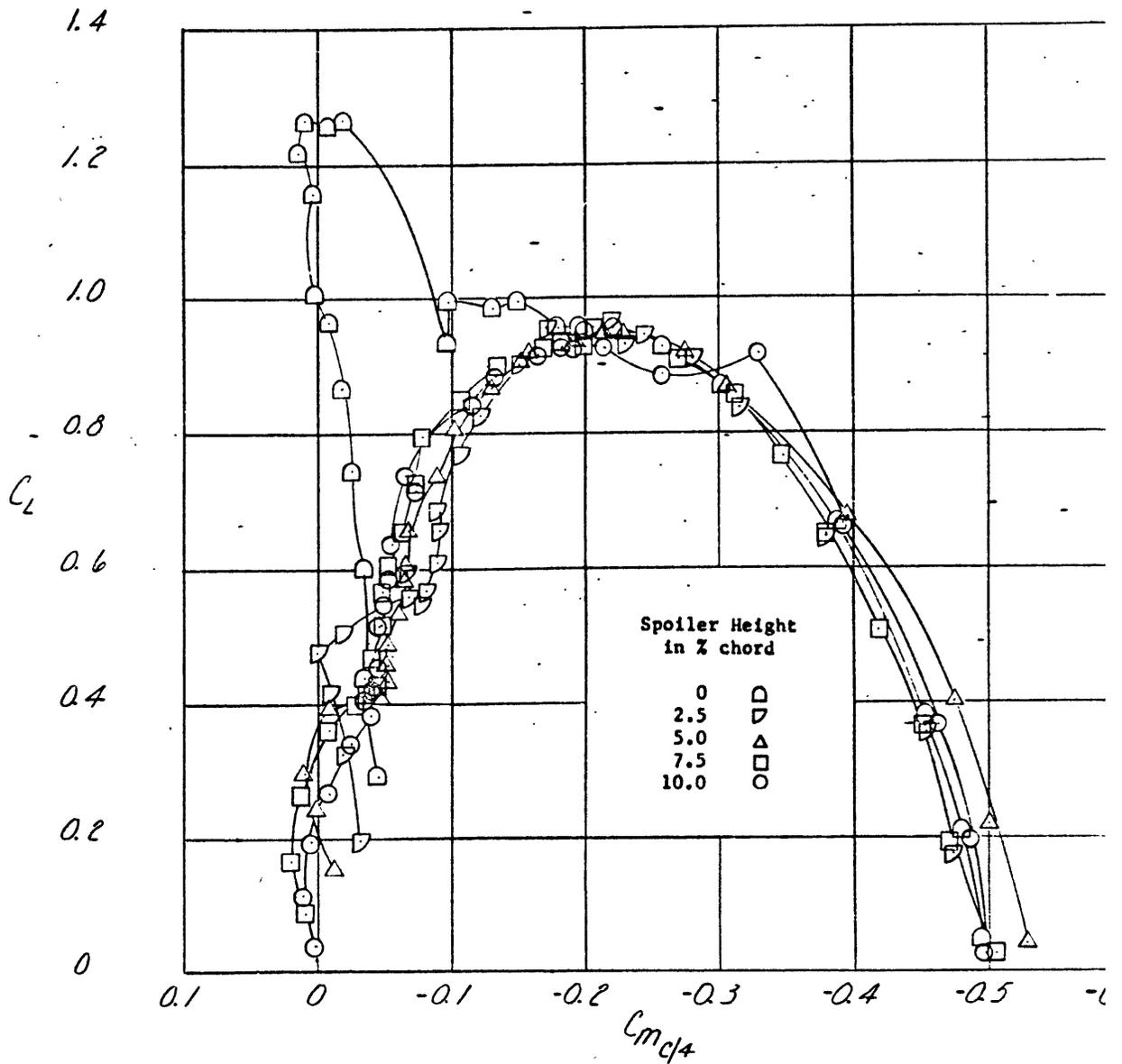


Figure 8 - Lift Coefficient Versus Pitching Moment Coefficient  
for the Spoiler Configurations Tested

(a) Six-Percent Spoiler (0.06c) Located Five Percent (0.05c)  
From the Leading Edge

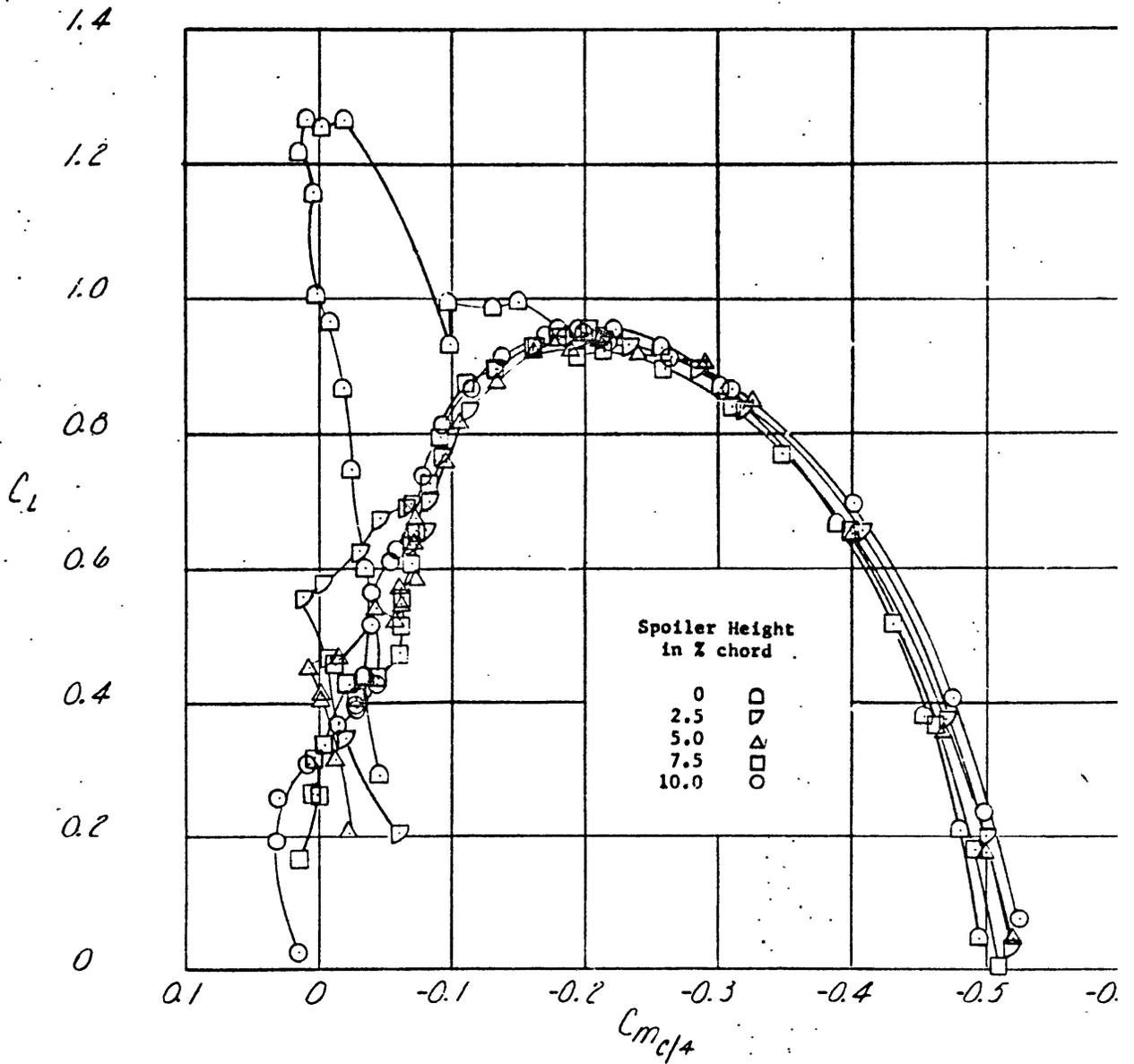


Figure 8 (Continued)  
 (b) Three-Percent Spoiler (0.03c) Located Five Percent (0.05c)  
 From the Leading Edge

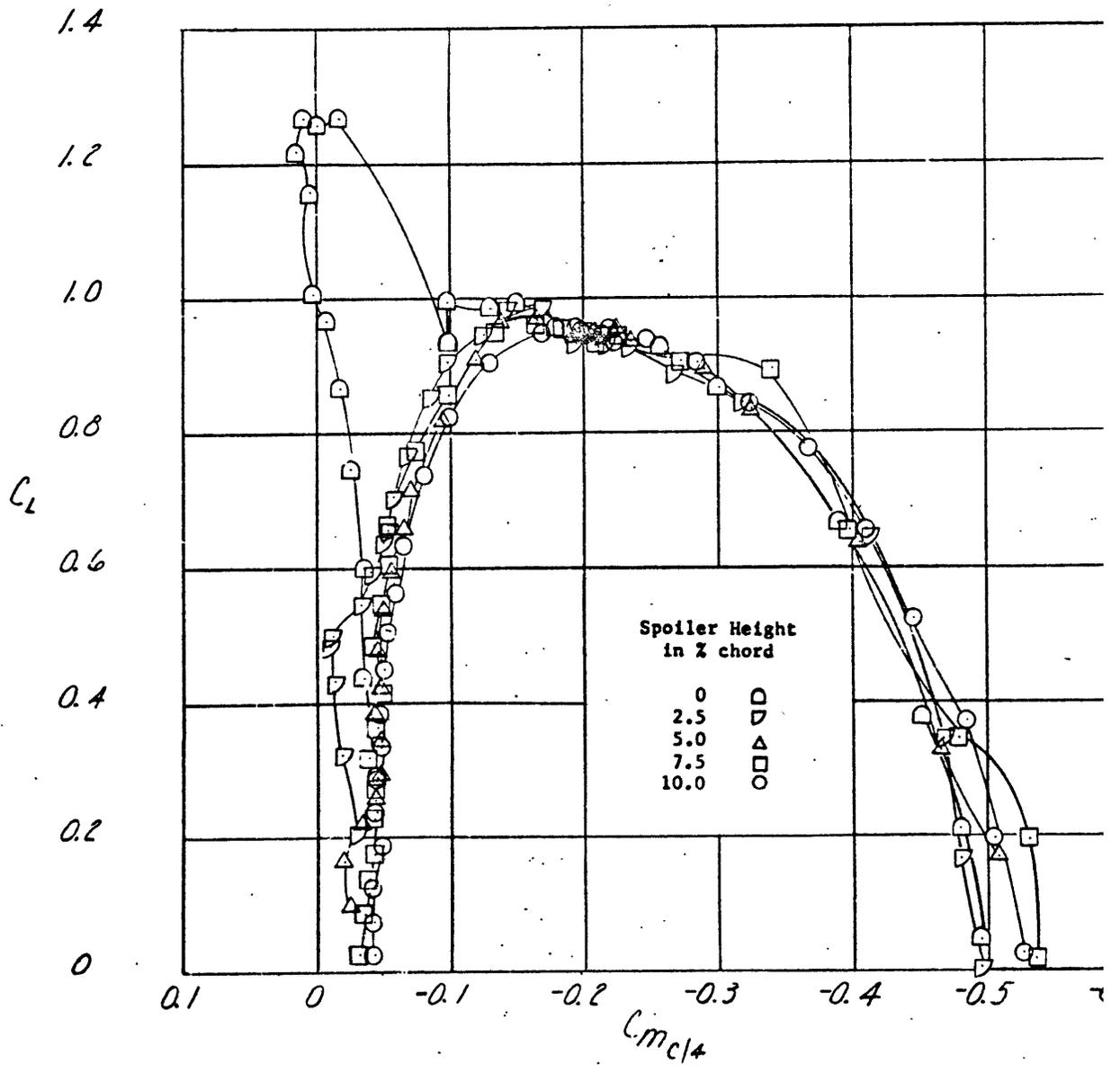


Figure 8 (Continued)

(c) Six-Percent Spoiler (0.06c) Located Fifteen Percent (0.15c)  
From the Leading Edge

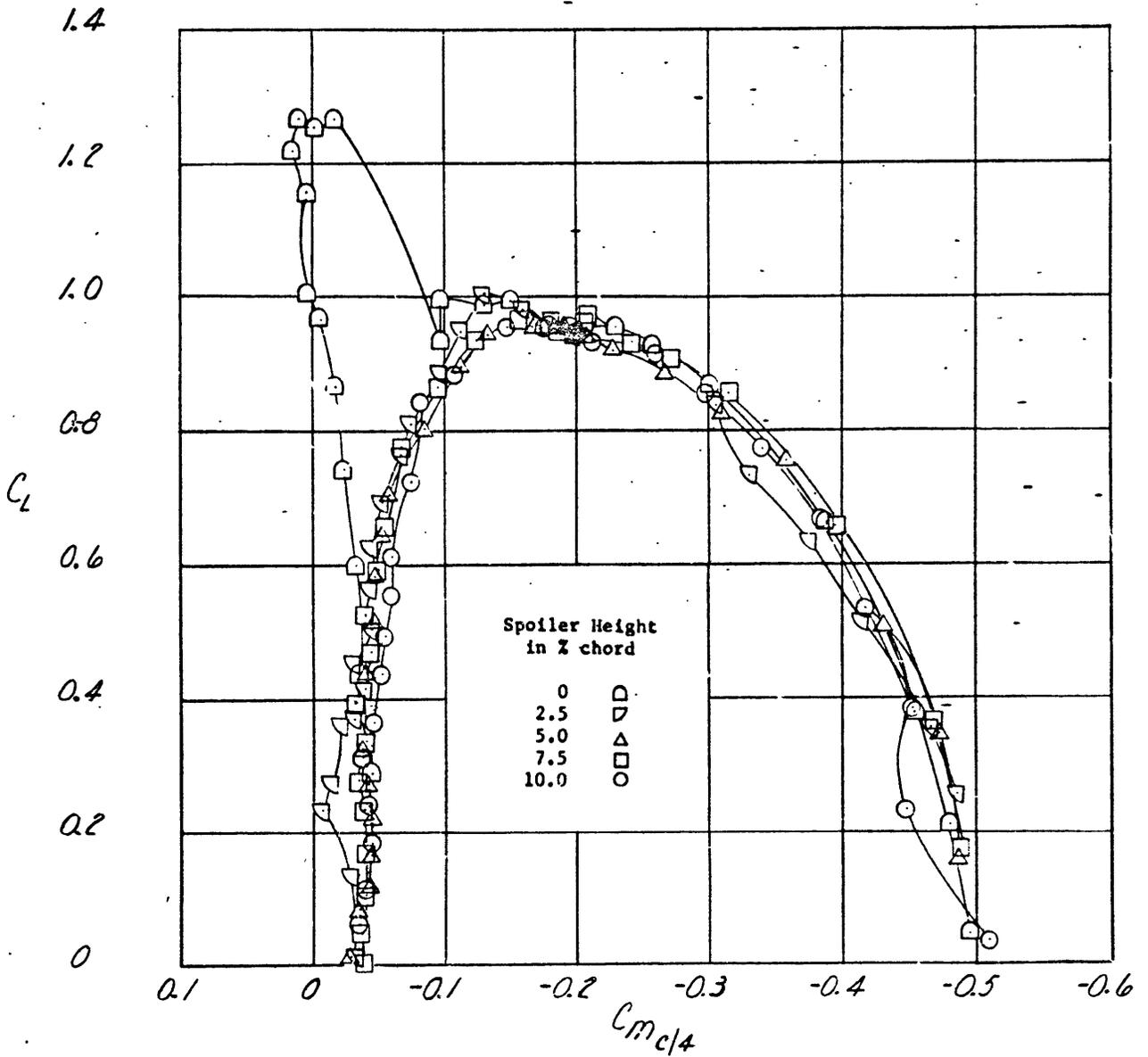


Figure 8 (Concluded)

(d) Three-Percent Spoiler (0.03c) Located Fifteen Percent (0.15c)  
From the Leading Edge

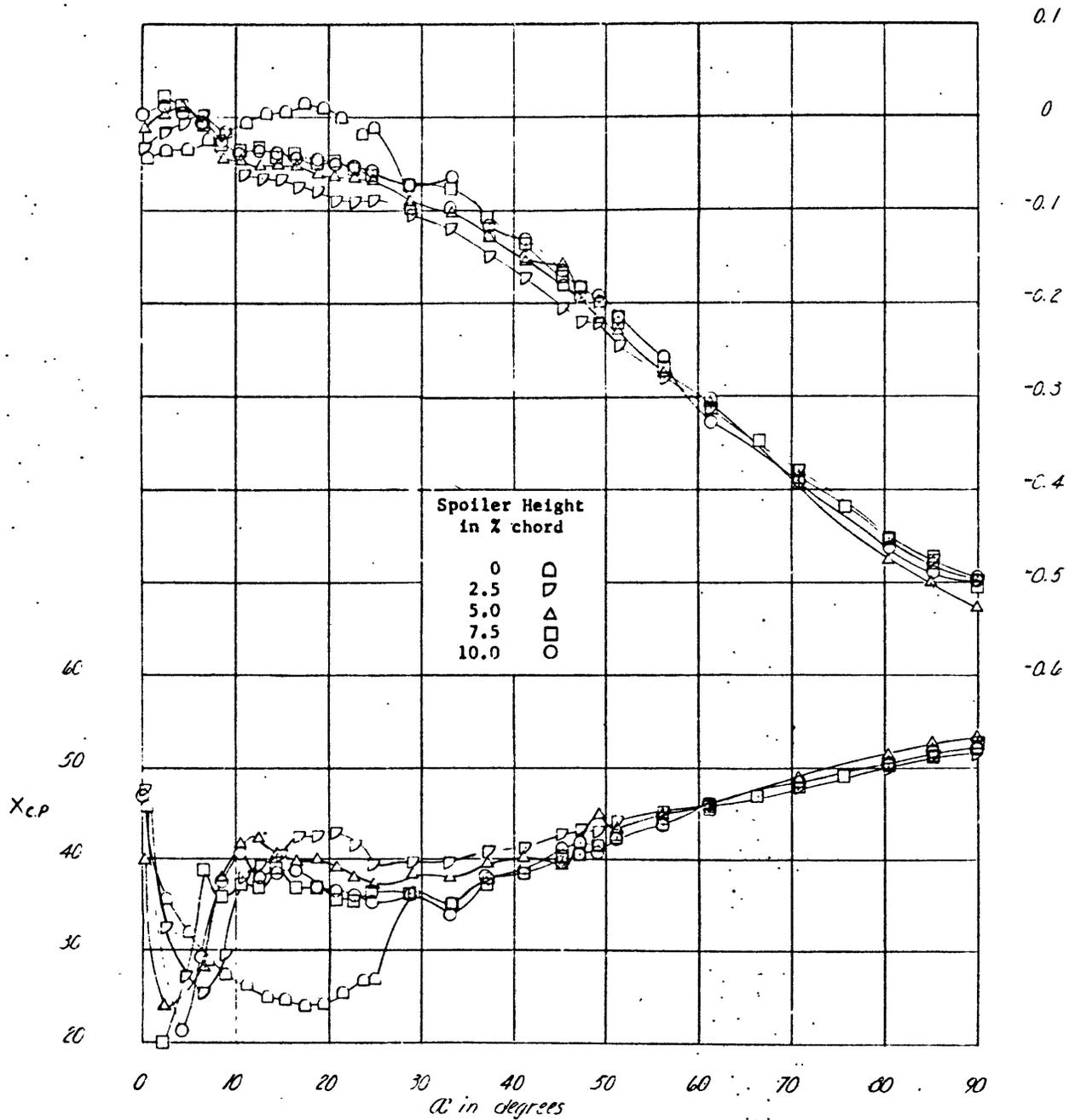


Figure 9 - Center-of-Pressure Travel and Pitching Moment Coefficient Versus Angle of Attack for the Configurations Tested  
 (a) Six-Percent Spoiler (0.06c) Located Five Percent (0.05c) From the Leading Edge

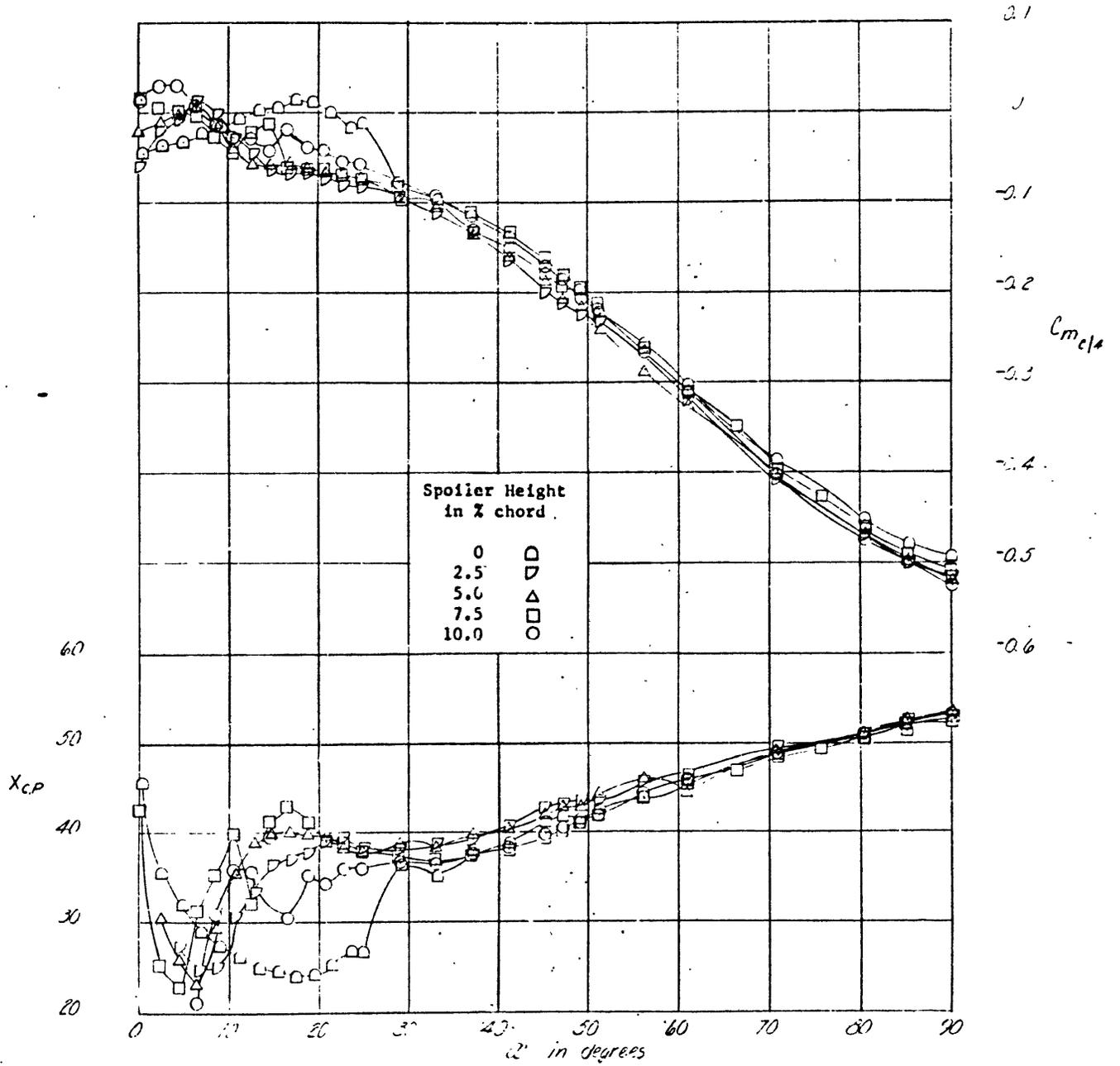


Figure 9 (Continued)  
 (b) Three-Percent Spoiler (0.3c) Located Five Percent (0.05c)  
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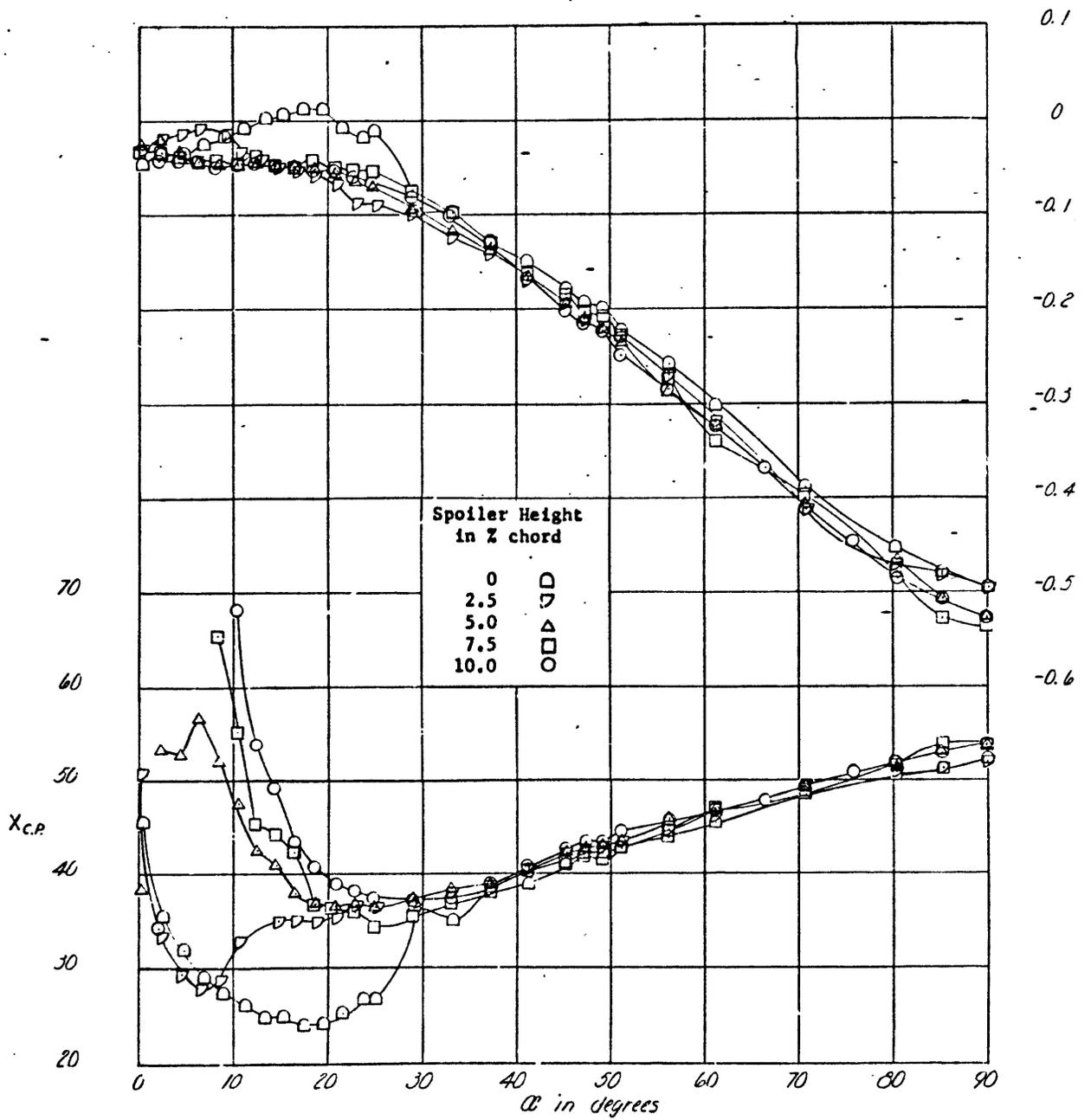


Figure 9 (Continued)  
(c) Six-Percent Spoiler (0.06c) Located Fifteen Percent (0.15c)  
From the Leading Edge

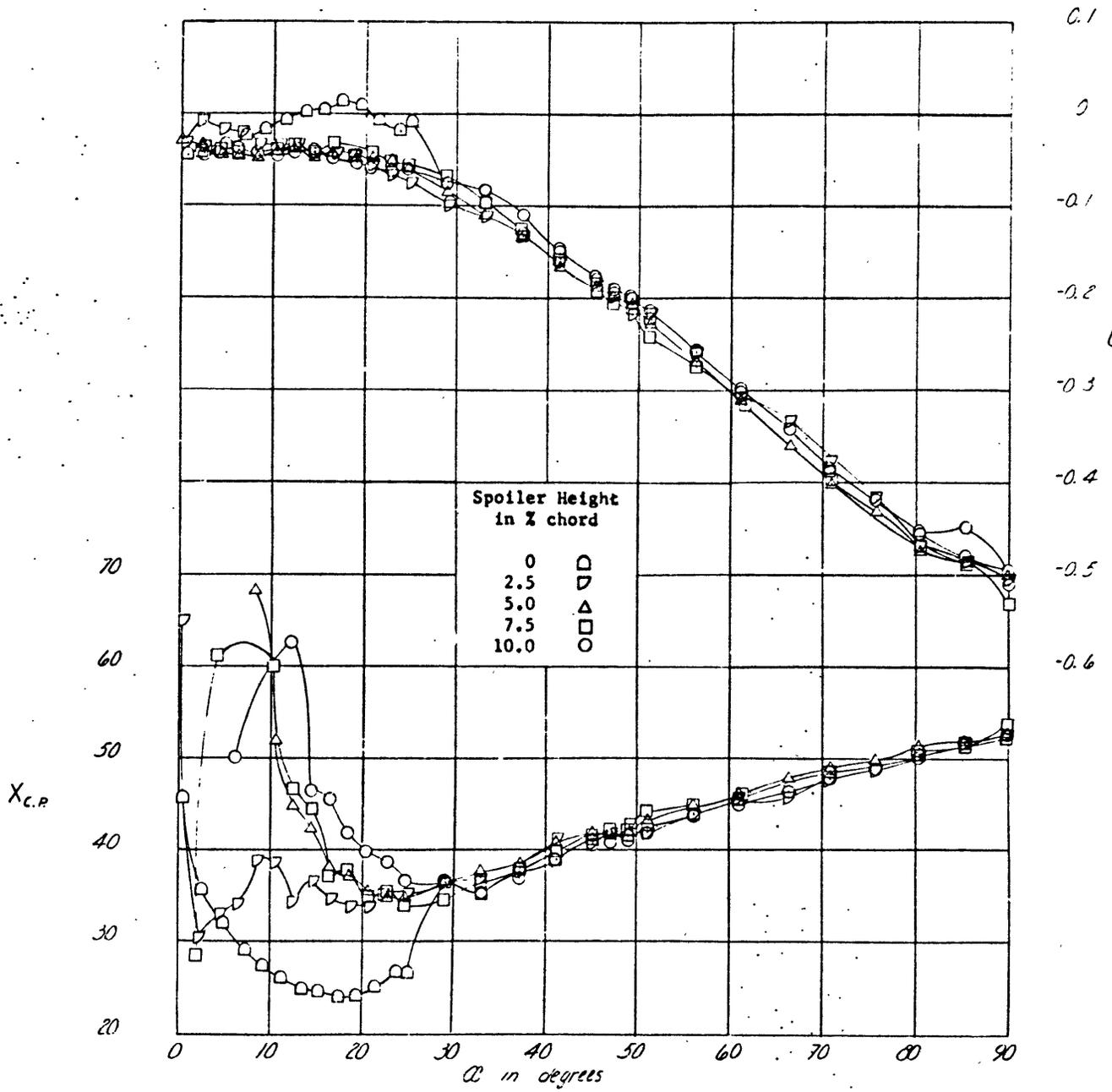


Figure 9 (Concluded)  
 (d) Three-Percent Spoiler (0.03c) Located Fifteen Percent (0.15c) From the Leading Edge

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