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SURFACE EFFECT TAKE-OFF AND LANDING  
SYSTEM (SETOLS) SUBSONIC STATIC STABILITY  
OUT OF GROUND EFFECT

H. Dulany Davidson, Jr., et al

Naval Ship Research and Development Center

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**SURFACE EFFECT TAKE-OFF AND LANDING SYSTEM (SETOLS)  
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by

**H. Dulany Davidson, Jr. and Lawrence A. Frank**

**Sponsored by  
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**AVIATION AND SURFACE EFFECTS DEPARTMENT**

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This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Naval Air Systems Command.

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Evaluation Report AL-97

TABLE OF CONTENTS

	Page
ABSTRACT . . . . .	1
INTRODUCTION . . . . .	1
MODELS . . . . .	1
CORRECTIONS . . . . .	2
WIND TUNNEL CONDITIONS . . . . .	2
DATA ANALYSIS . . . . .	3
REFERENCES . . . . .	4

LIST OF FIGURES

Figure 1 - Three View Drawing of the Basic Configuration of the 10% Scale F-8C Model . . . . .	5
Figure 2 - Three View Drawing of the Basic Configuration of the 10% Scale A-4E Model . . . . .	6
Figure 3 - Air Cushion Landing Gear Designs for F-8 . . . . .	7
Figure 4 - Air Cushion Landing Gears for A-4 . . . . .	10
Figure 5 - Bottom View of Air Cushion Models . . . . .	11
Figure 6 - SANDAIRE Air Cushion Configuration Mounted on the F-8 . . . . .	12
Figure 7 - Bell Air Cushion Configuration Mounted on the F-8 . . . . .	13
Figure 8 - Goodyear Air Cushion Configuration #1 Mounted on the F-8 . . . . .	14
Figure 9 - Goodyear Air Cushion Configuration #2 Mounted on the F-8 . . . . .	15
Figure 10 - Bell Air Cushion Configuration Mounted on the A-4 . . . . .	16
Figure 11 - Boeing Air Cushion Configuration Mounted on the A-4 . . . . .	17
Figure 12 - Effect of SANDAIRE Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics . . . . .	18
Figure 13 - Effect of Bell Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics . . . . .	20
Figure 14 - Effect of Goodyear Model #1 Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics . . . . .	22
Figure 15 - Effect of Goodyear Model #2 Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics . . . . .	24
Figure 16 - Effect of Bell Air Cushion Landing Gear on the A-4 Aerodynamic Characteristics . . . . .	26

#### NOTATION

b	wing span (F-8 - 42.41 in.) (A-4 - 33.0 in.)
$\bar{c}$	mean aerodynamic chord (F-8 - 14.14 in.) (A-4 - 12.96 in.)
$C_D$	drag coefficient; $\frac{\text{drag}}{qS}$
$C_L$	lift coefficient; $\frac{\text{lift}}{qS}$
$C_m$	pitching moment coefficient; $\frac{\text{pitching moment}}{qSc}$
q	tunnel dynamic pressure; lbs/ft <sup>2</sup>
S	wing reference area (F-8 - 3.75 ft <sup>2</sup> ) (A-4 - 2.60 ft <sup>2</sup> )
$\alpha$	angle of attack in degrees

## ABSTRACT

The effect of a deployed air cushion landing gear on the stability of a high performance aircraft was studied at the Naval Ship Research and Development Center's 8 x 10 foot subsonic wind tunnel. Air cushion designs submitted by Bell Aerospace Corporation and Boeing were fitted to a ten percent scale A-4E and air cushions designed by Goodyear (two configurations), San Diego Aircraft Engineering Incorporated (SANDAIRE), and Bell were fitted to a ten percent scale F-8C. The effects of the air cushion landing gear ranged from minor destabilization, to very detrimental destabilization on both aircraft in the landing approach configuration.

## INTRODUCTION

A program is under way at the Naval Ship Research and Development Center (NSRDC) to study the feasibility of an air cushion landing gear on a high performance aircraft. Aircraft carrier interface, static stability, and cushion dynamics are under investigation in a surface effects take-off and landing system (SETOLS) program. This report covers the effects of an air cushion landing gear on the out of ground effect drag and static stability characteristics of the A-4 and F-8 aircraft.

## MODELS

The ten percent models of the A-4 and F-8 were originally capable of simulating only the high speed configurations and had to be modified to simulate the landing configuration (Figures 1 and 2). The F-8 airplane model had interchangeable brackets to deflect the wing leading edge and flaps. Additional brackets were constructed to permit the deflections required for the landing configuration. The wing fuselage attachment was altered to enable the positioning of the wing at a  $7^{\circ}$  angle of incidence for the landing configuration. Because of internal ducting and fibre glass coating, conventional landing gear simulation was not feasible.

The A-4 model did not have moveable leading edges or flaps. Since the airplane employs a split flap, a wooden wedge bonded to the wing

lower surface adequately simulated the flap deflection. The A-4 also did not have a landing gear.

The initial air cushion designs submitted by the contractors (Figures 3 and 4) were made into wood models. All models excepting the Goodyear model #2 had concave bottoms (Figure 5). Photographs of the finished models on the aircraft are shown in Figures 6 through 11.

#### CORRECTIONS

Wind tunnel data from other facilities were used to correct the data to a landing configuration, such that the data could be compared on a valid incremental basis (Ref. 1 - 3). The following increments were added to the data:

1. Landing gear effects added to the A-4 conventional landing configuration.
2. Trailing edge flap effects added to the A-4 Boeing air cushion configuration. (This was done because the wooden wedge used for a flap could not be added when the Boeing gear was attached.)
3. Landing gear effect added to the F-8 conventional landing configuration. No corrections were made for leading edge slats on the A-4 since none of the configurations simulating the A-4 model had slats down.

#### WIND TUNNEL CONDITIONS

A tunnel dynamic pressure of 65 lb/ft<sup>2</sup> was used. The models were run through an angle of attack range of -4 to 18 degrees with side slip angles of 0 and 5 degrees. Horizontal tail deflections of 0 and -5 degrees were set on the F-8 and deflections of -4 and -8 degrees were set on the A-4.

The six component TSB-7 balance used for readout is accurate to 0.5% of the balances maximum rated loads. Based on maximum loads of 1000 lbs normal force, 100 lbs axial force, and 500 lbs side force the following accuracy was calculated for the lift drag and pitching moment coefficients.

F-8	A-4
$C_L \pm .0206$	$\pm .0296$
$C_D \pm .0020$	$\pm .0030$
$C_m \pm .0053$	$\pm .0098$

## DATA ANALYSIS

The air cushion design submitted by SANDAIRE had the largest effect on the longitudinal stability of the F-8. The minimum drag was increased by approximately 50% and the angle of zero lift was increased one degree (Figure 12). The airplane was unstable in pitch about the  $\frac{1}{4}$  chord point of the mean aerodynamic chord but there was sufficient elevator travel for trim.

The Bell design also had a significant effect on the aerodynamic characteristics of the F-8 (Figure 13). The minimum drag was increased approximately 25% and the angle of attack at zero lift was increased  $\frac{1}{2}$  a degree. This configuration was more destabilizing than the SANDAIRE design.

The Goodyear Model #1 for the F-8 increased the minimum drag by about 25%. The lift curve was unaffected but there was a slight decrease in longitudinal stability (Figure 14).

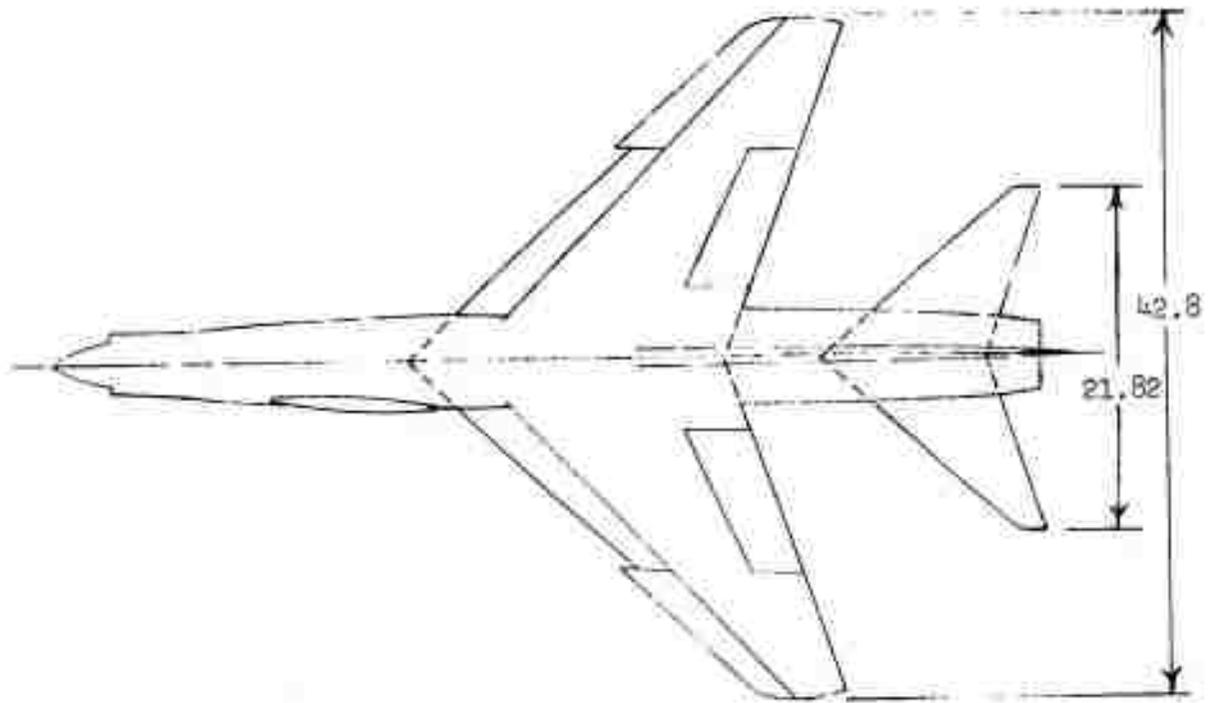
The Goodyear Model #2 design had a small effect on the F-8 aerodynamic characteristics. The minimum drag was decreased slightly and the lift curve was unaffected. There was an insignificant decrease in longitudinal stability (Figure 15).

The air cushion designed by Bell for the A-4 had significant effects on the airplane aerodynamics (Figure 16). The minimum drag was 10% lower than the conventional landing configuration. The angle of zero lift was increased  $5\frac{1}{2}$  degrees and the maximum lift obtainable was around 5 to 8% less than the conventional landing configuration. Because of the forward location of the bag, it had a strong destabilizing effect on the airplane. The bag blocked the airflow to the flaps, rendering them ineffective. The Bell configuration is neutrally stable at lift coefficients below 0.3, and becomes very unstable above lift coefficients of 0.6. Horizontal tail settings in excess of  $-12^\circ$  are required to trim the airplane.

The wind tunnel results using the Boeing design for the A-4 (not presented) indicated that severe trim changes would be encountered. Results from another investigation using the same model indicated that the method of correcting the data (using incremental flap data from Reference 3) was not valid. Results for this configuration will be presented in a later report.

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1. Cronk, A. E. Low Speed Test of a .15 Scale F-8U-2N Model for Chance Vought Corporation, Texas Engineering Experiment Station, College Station, Texas. December 1962. Project Number LTV - 001 - 014.
2. Ogawa, H. Results of High Speed Tests of an A4D-1 0.10 Scale Model at the NACA LAL 8 - Foot Transonic Wind Tunnel. Douglas Aircraft Co., Inc., El Segundo, Calif. August 1955. Report No. ES 26043
3. Wolhart, W. D. and H. S. Fletcher. Wind-Tunnel Investigation at Low Speed of the Static Lateral and Longitudinal Stability Characteristics of a 1/10 Scale Model of the Douglas A4D-1 Airplane. NACA RM SL54H13



Note: all dimensions in inches except as noted

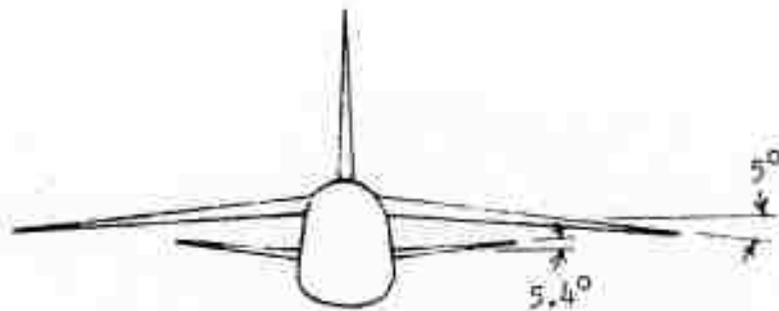
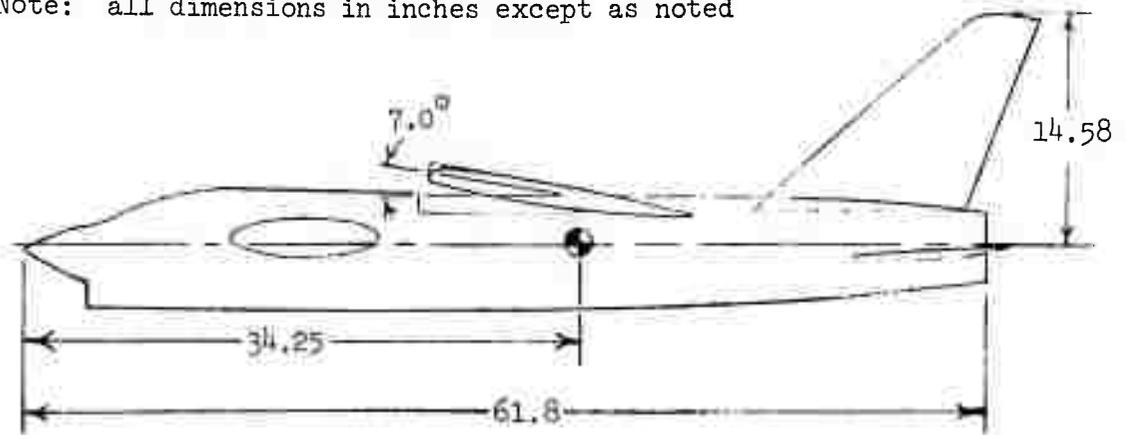
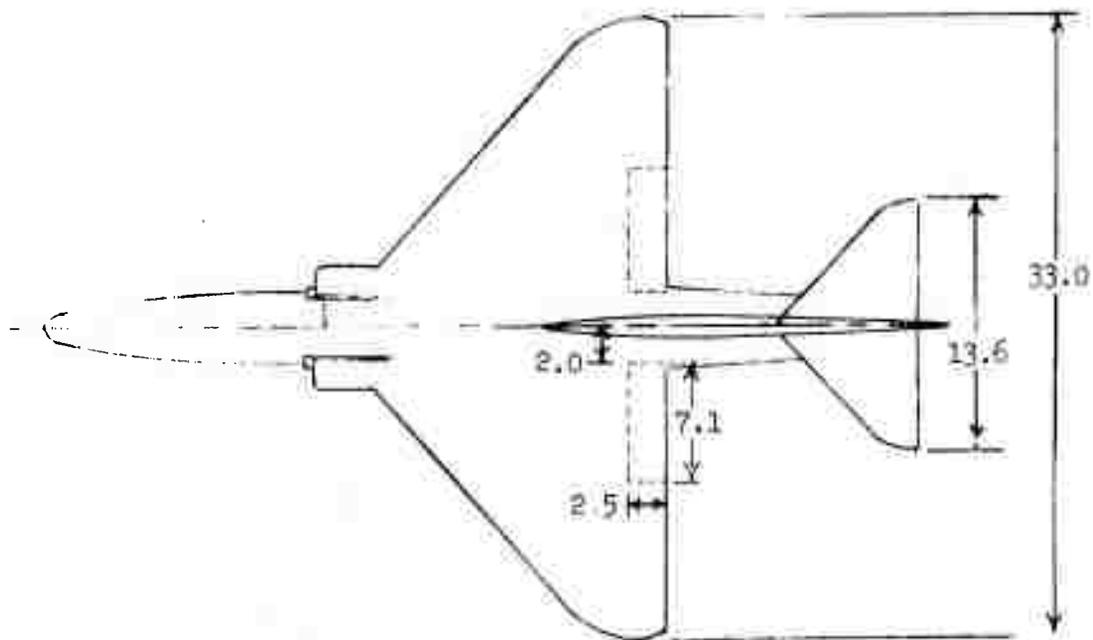


Figure 1 - Three View Drawing of the Basic Configuration of the 10% Scale F-8C Model



Note: all dimensions in inches except as noted

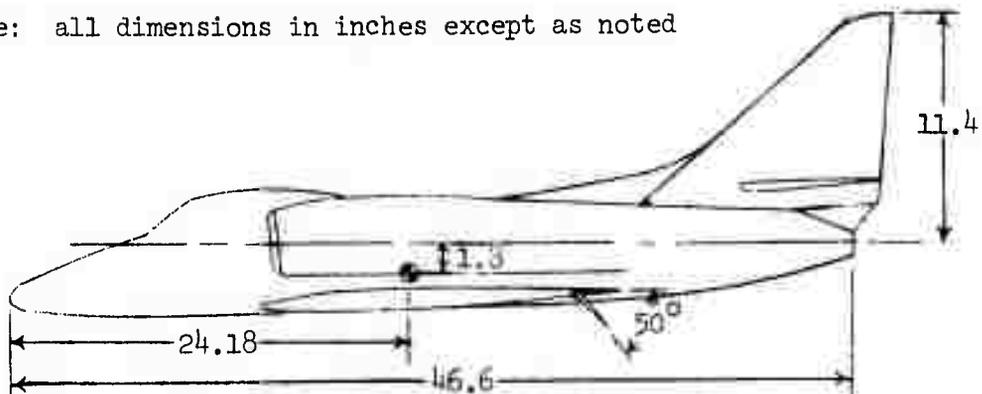
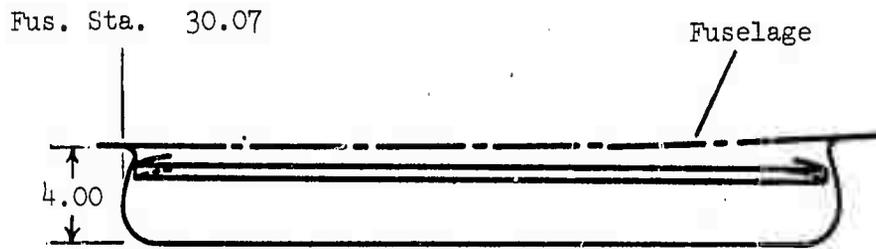
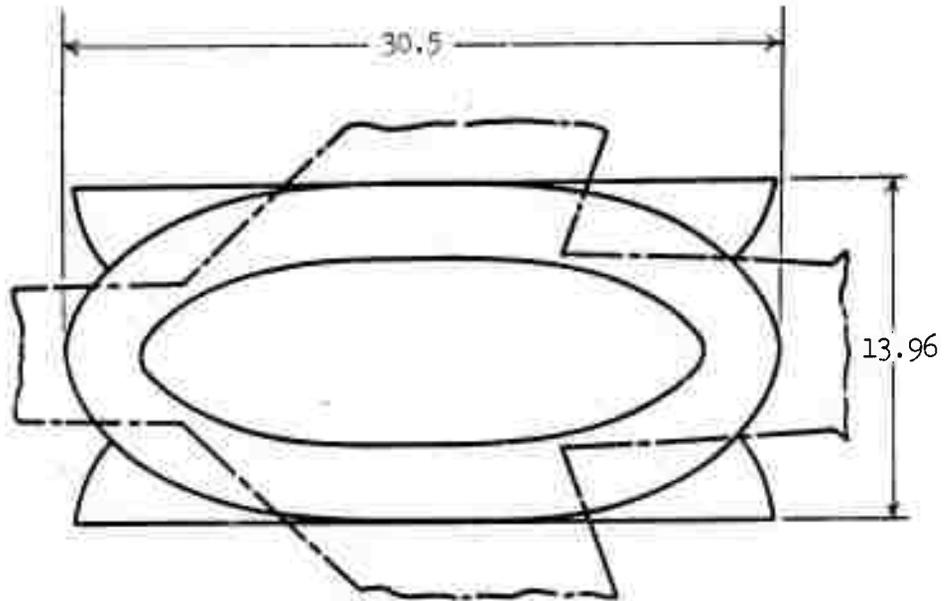


Figure 2 - Three View Drawing of the Basic Configuration of the 10% Scale A-4E Model



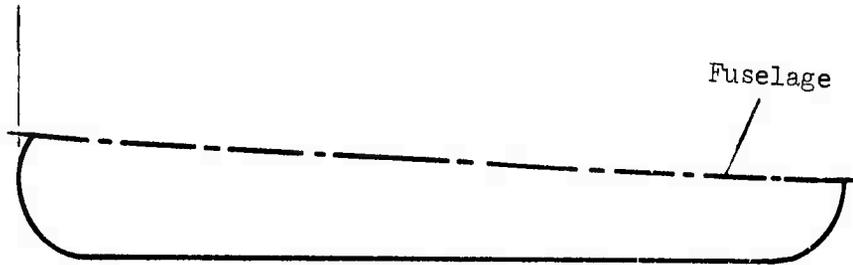
All Dimensions in Inches



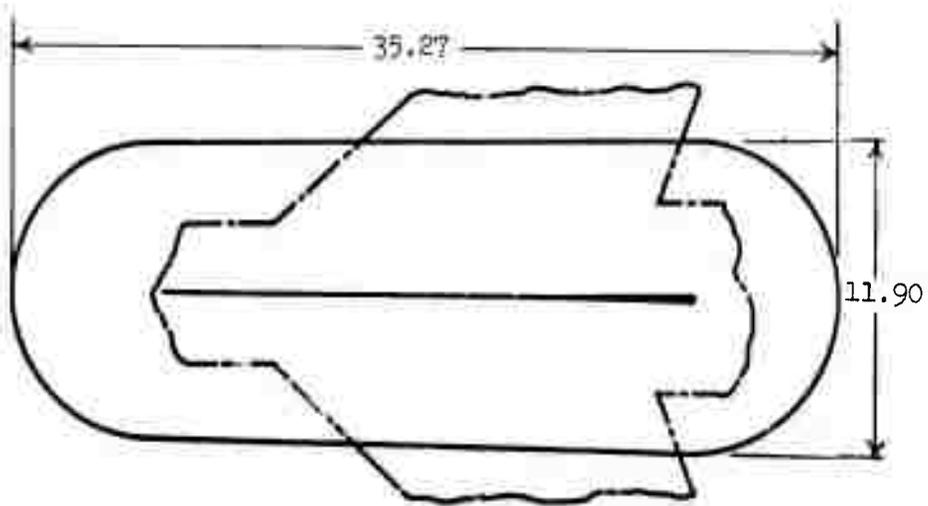
SANDAIRE Configuration

Figure 3 - Air Cushion Landing Gear Designs for F-8

Fus. Sta. 24.55



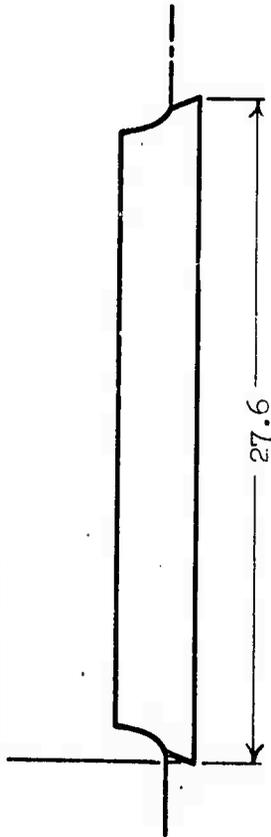
All Dimensions in Inches



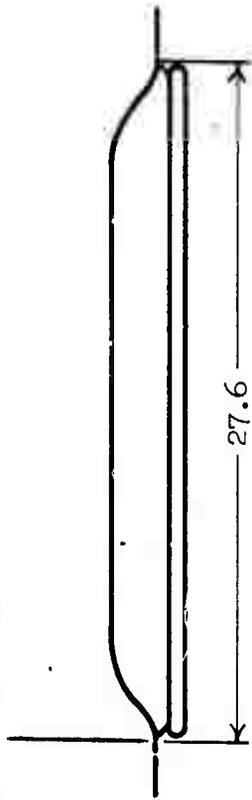
Bell Configuration

Figure 3 (Continued)

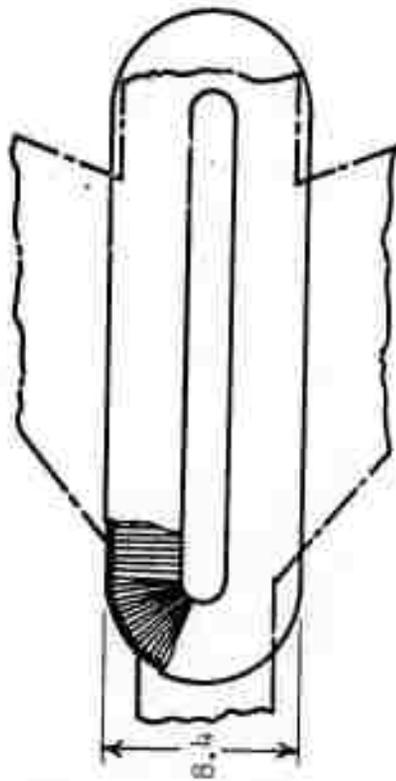
Fus. Sta. 31.5



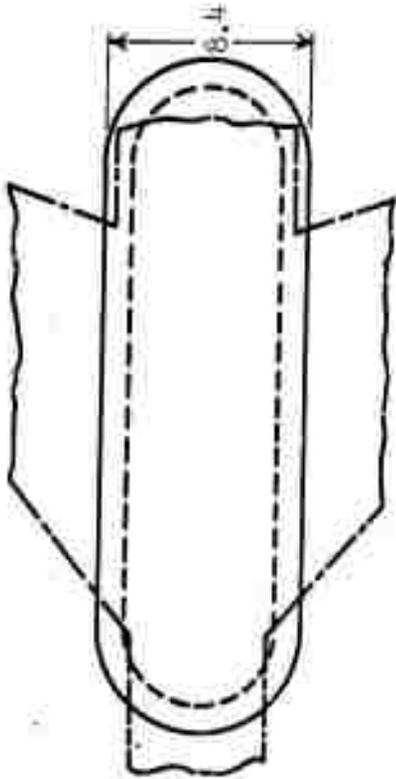
Fus. Sta. 31.5



All Dimensions in Inches



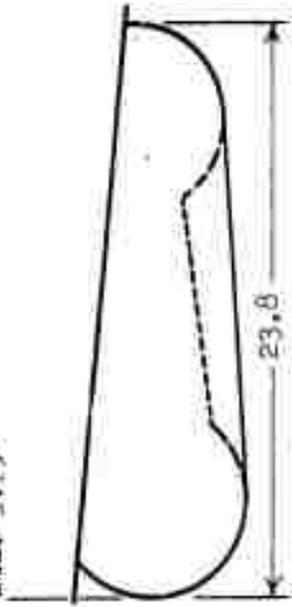
Goodyear #1



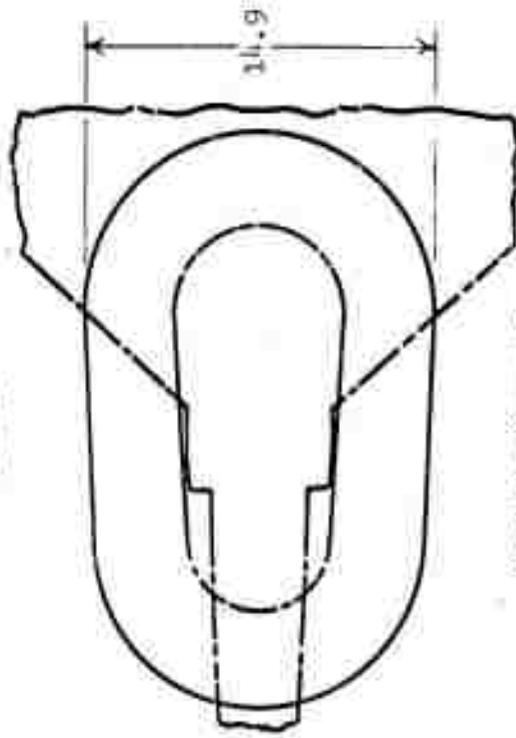
Goodyear #2

Figure 3 (Concluded)

Fus. Sta. 5.75



ALL Dimensions in Inches



Bell Configuration



Boeing Configuration

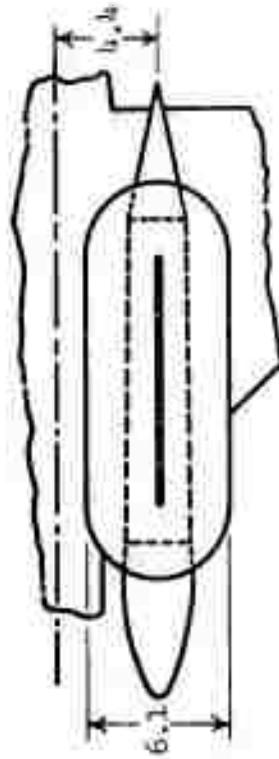


Figure 4 - Air Cushion Landing Gears for A-4

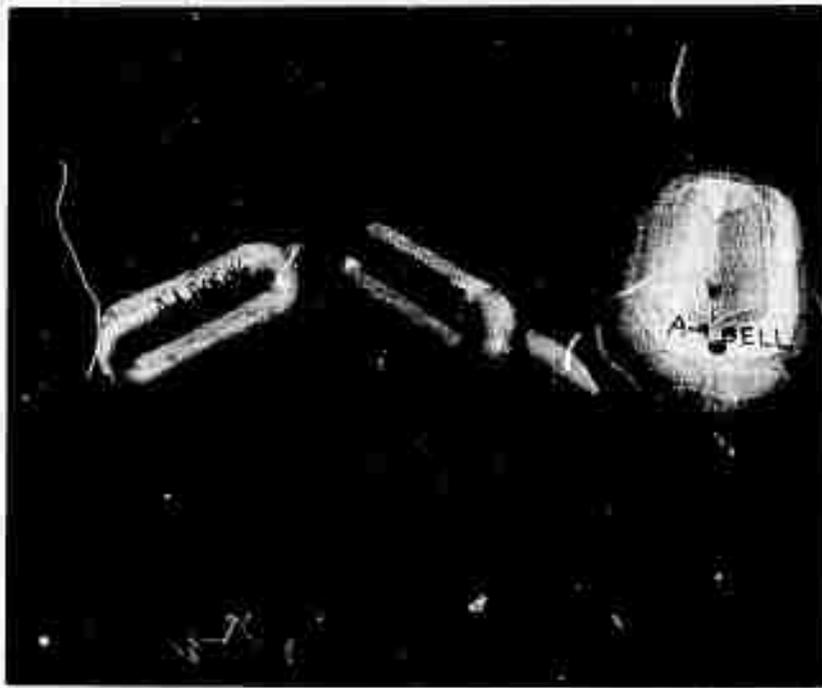


Figure 5 - Bottom View of Air Cushion Models

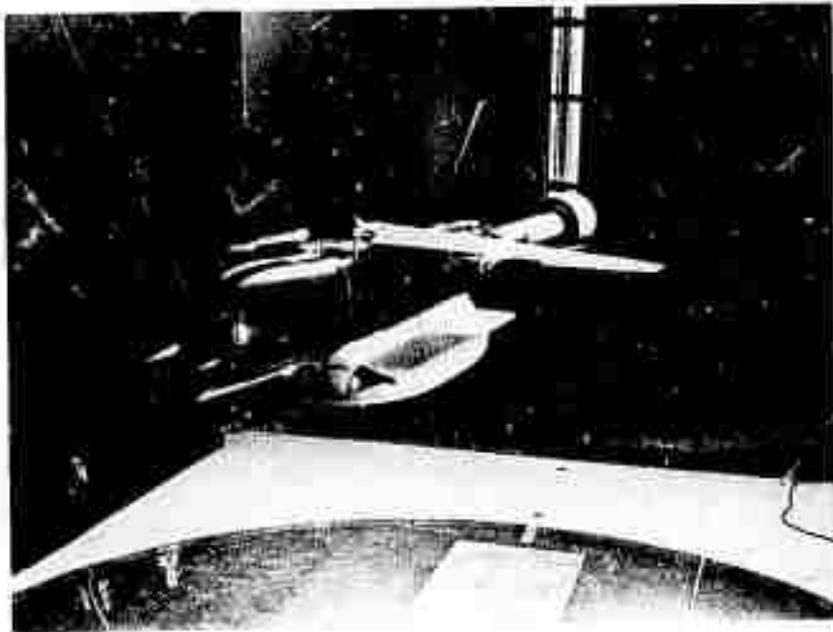


Figure 6 - SANDAIRE Air Cushion Configuration Mounted on the F-8

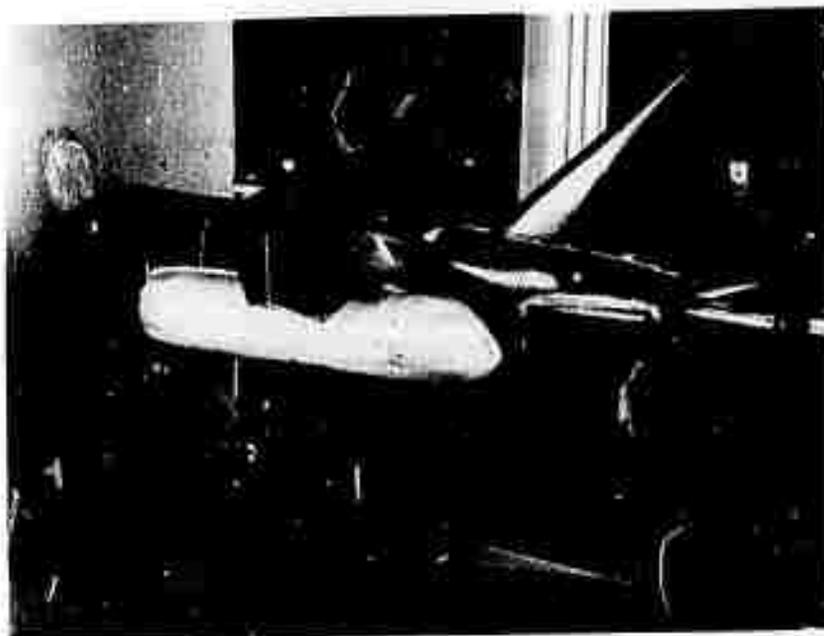
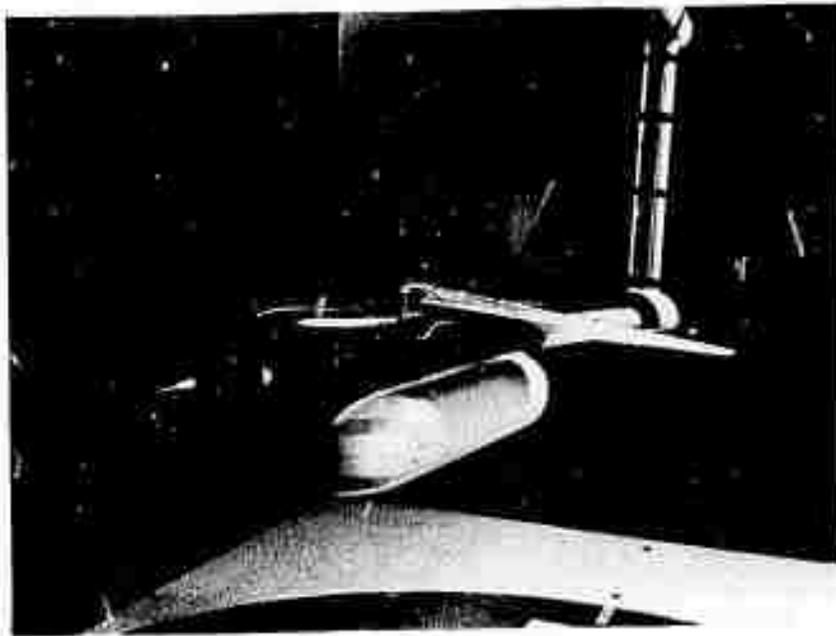


Figure 7 - Bell Air Cushion Configuration Mounted on the F-8

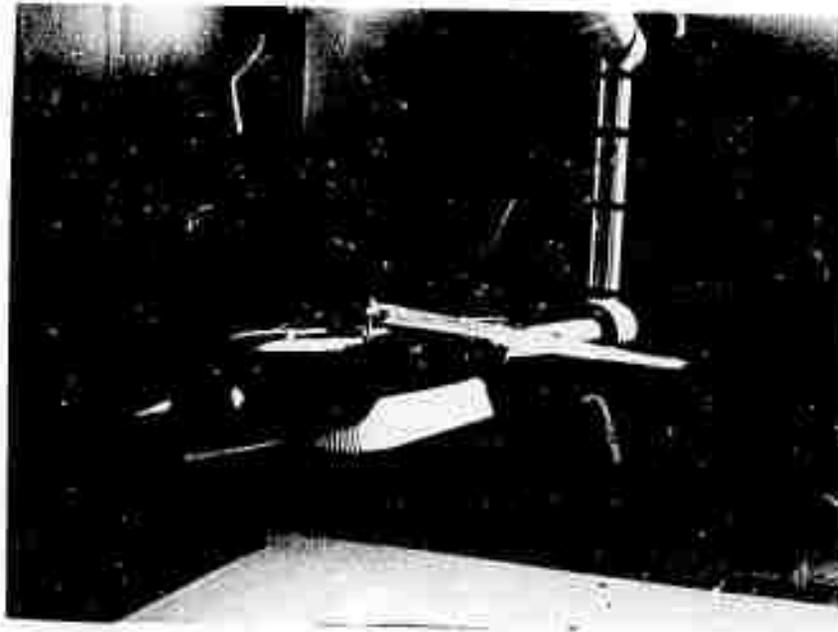


Figure 8 - Goodyear Air Cushion Configuration #1 Mounted on the F-8

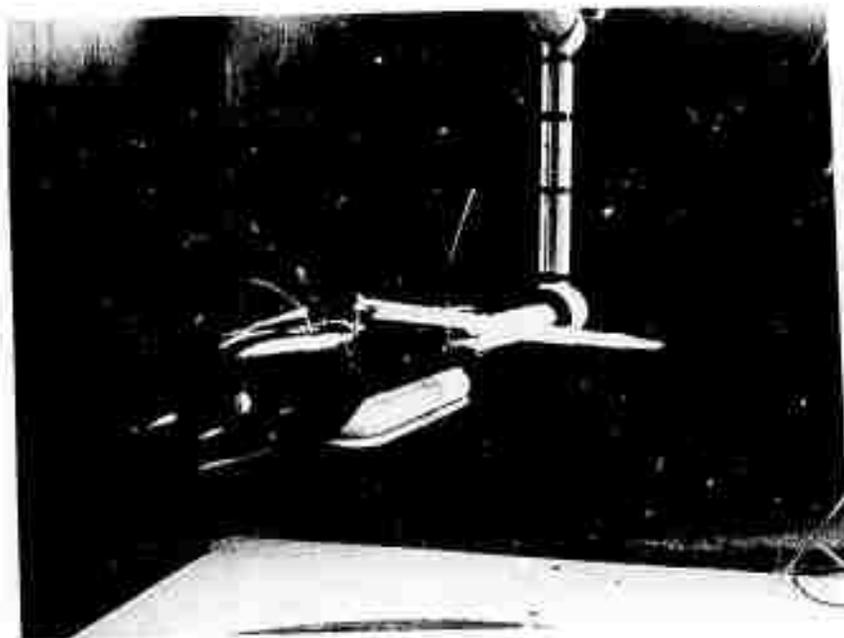


Figure 9 - Goodyear Air Cushion Configuration #2 Mounted on the F-8

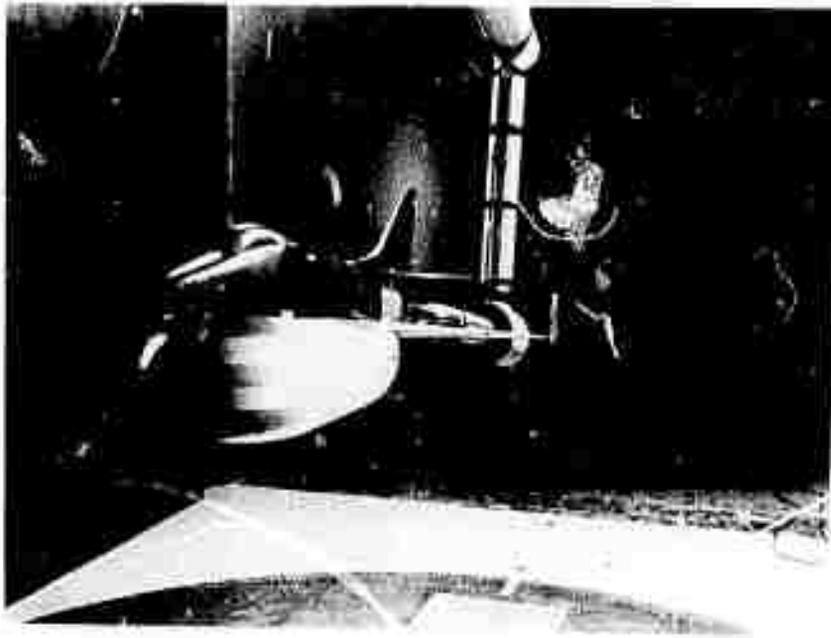


Figure 10 - Bell Air Cushion Configuration Mounted on the A-4

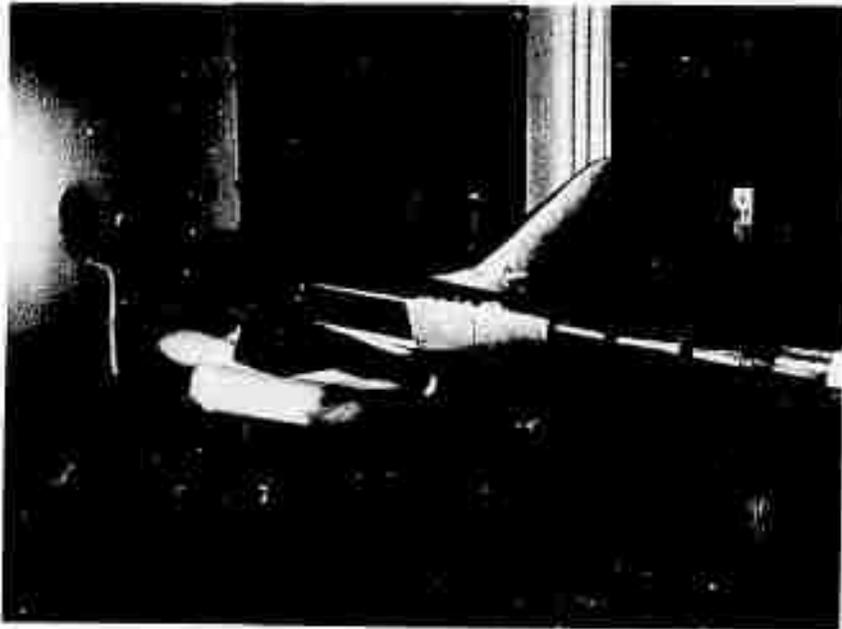


Figure 11 - Boeing Air Cushion Configuration Mounted on the A-4

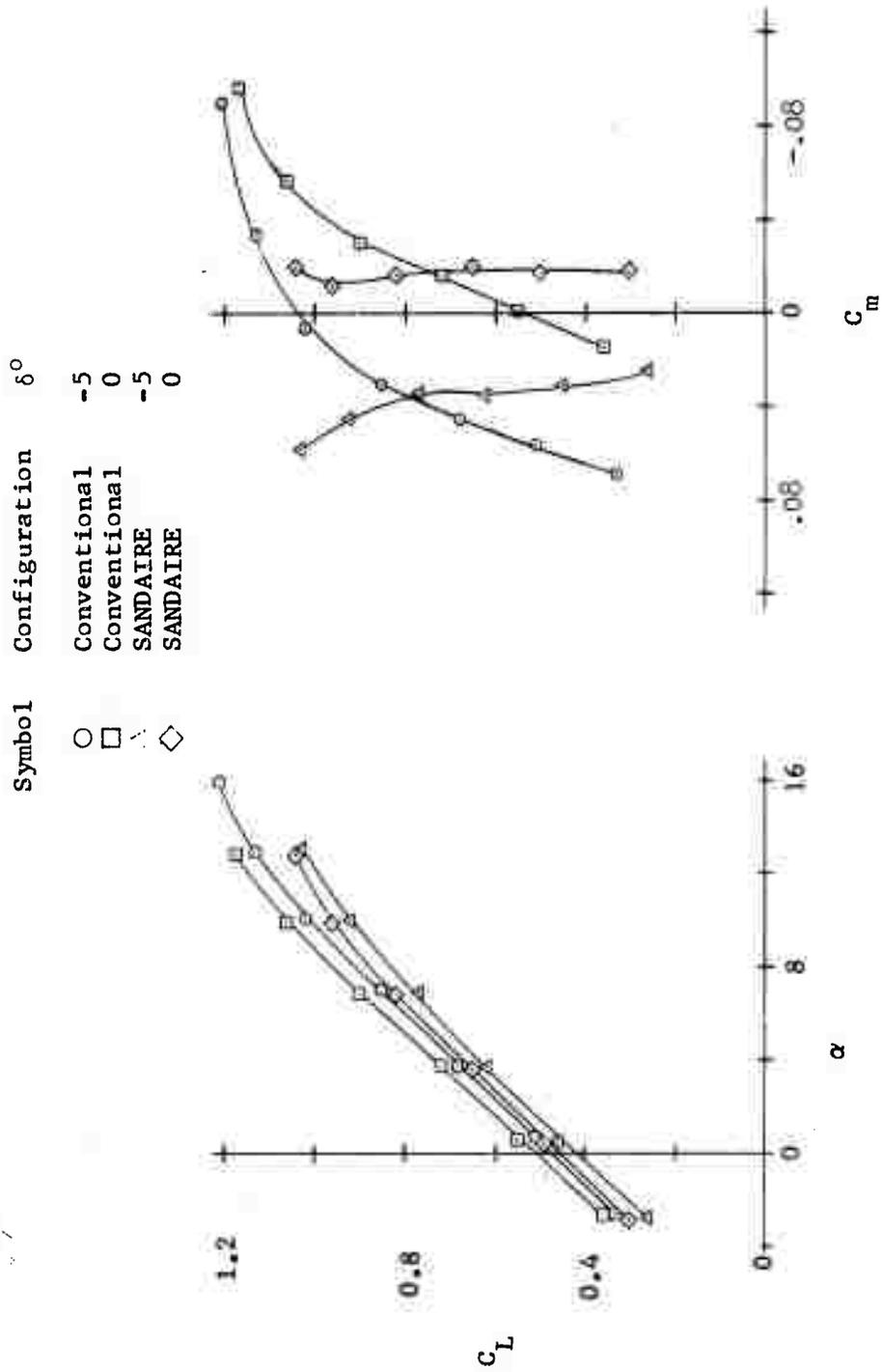


Figure 12 - Effect of SANDAIRE Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics

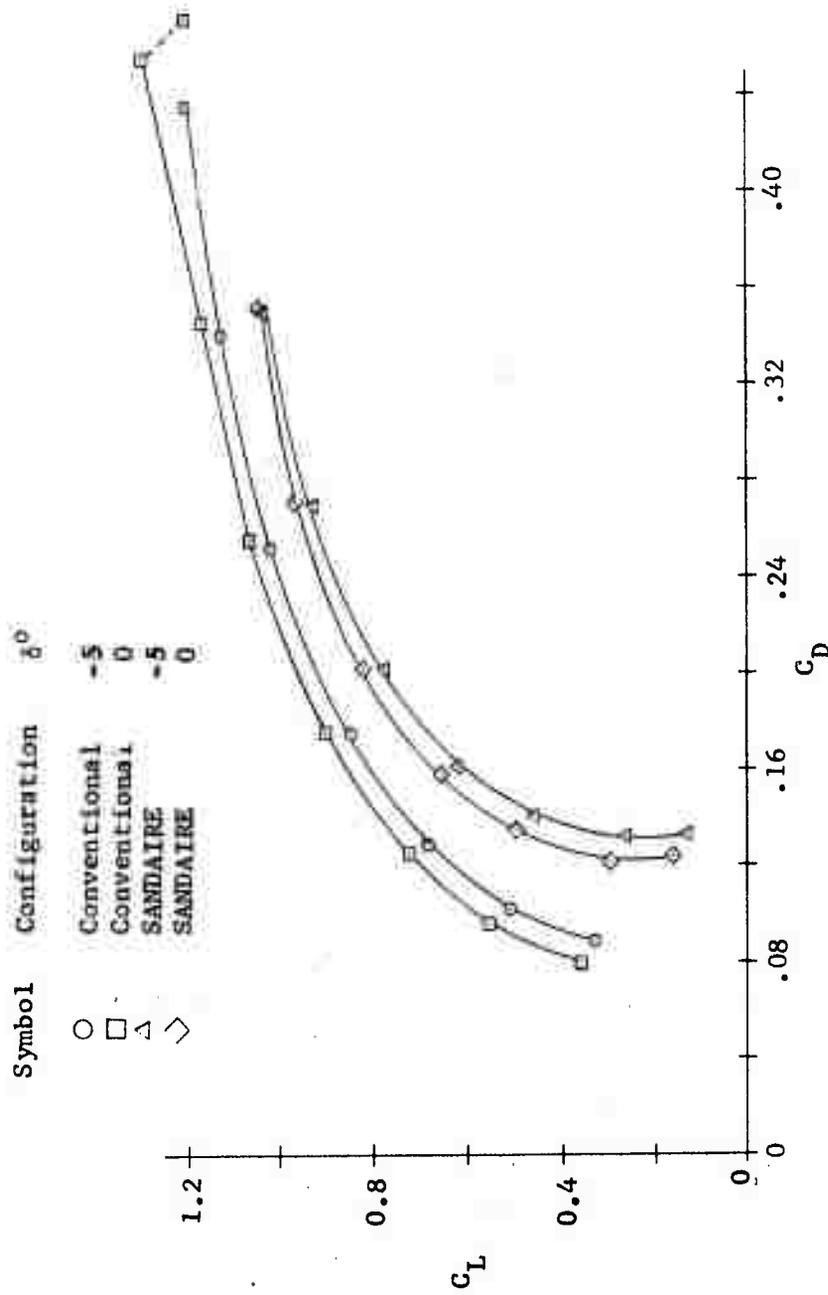


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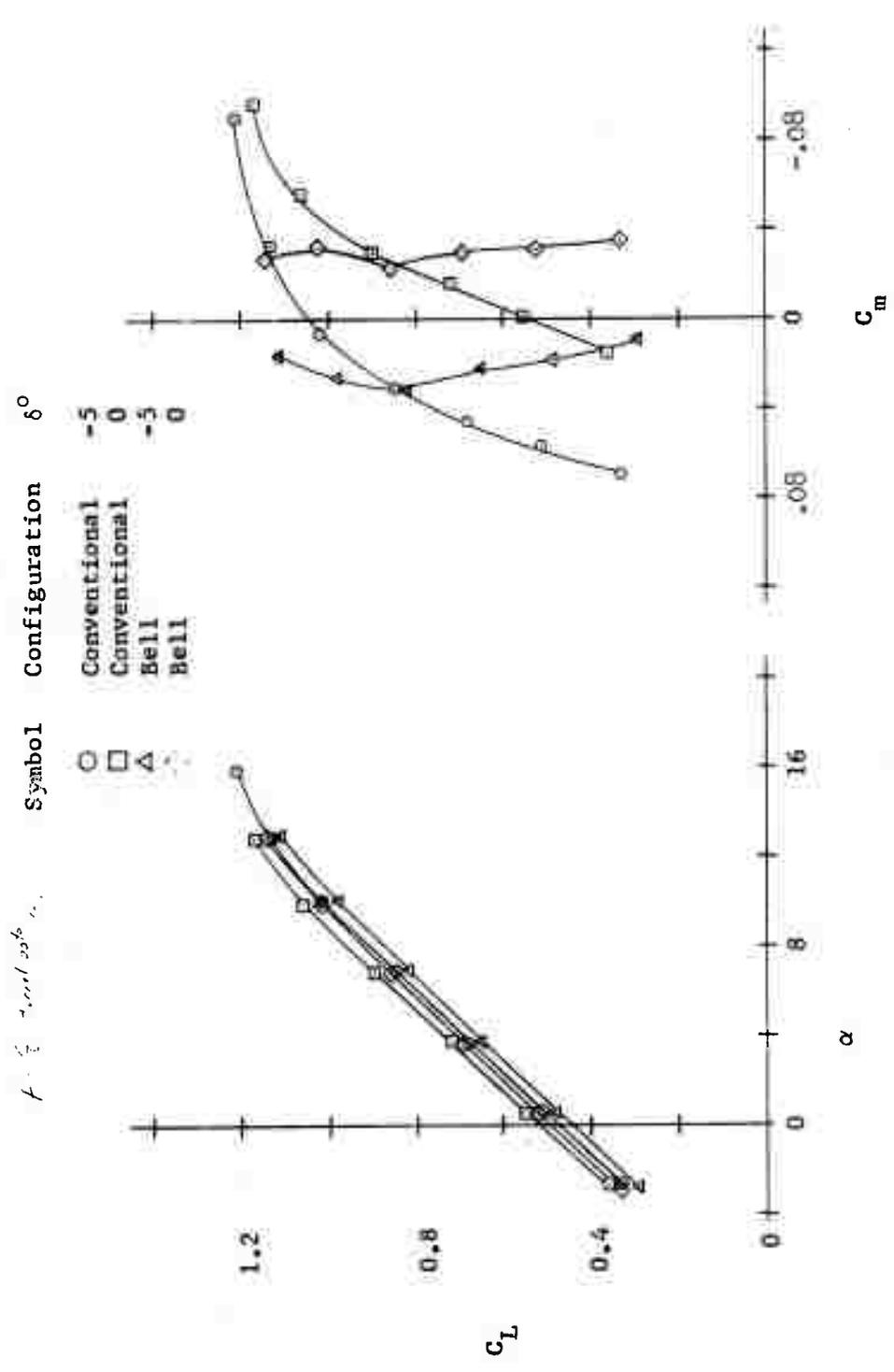


Figure 13 - Effect of Bell Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics

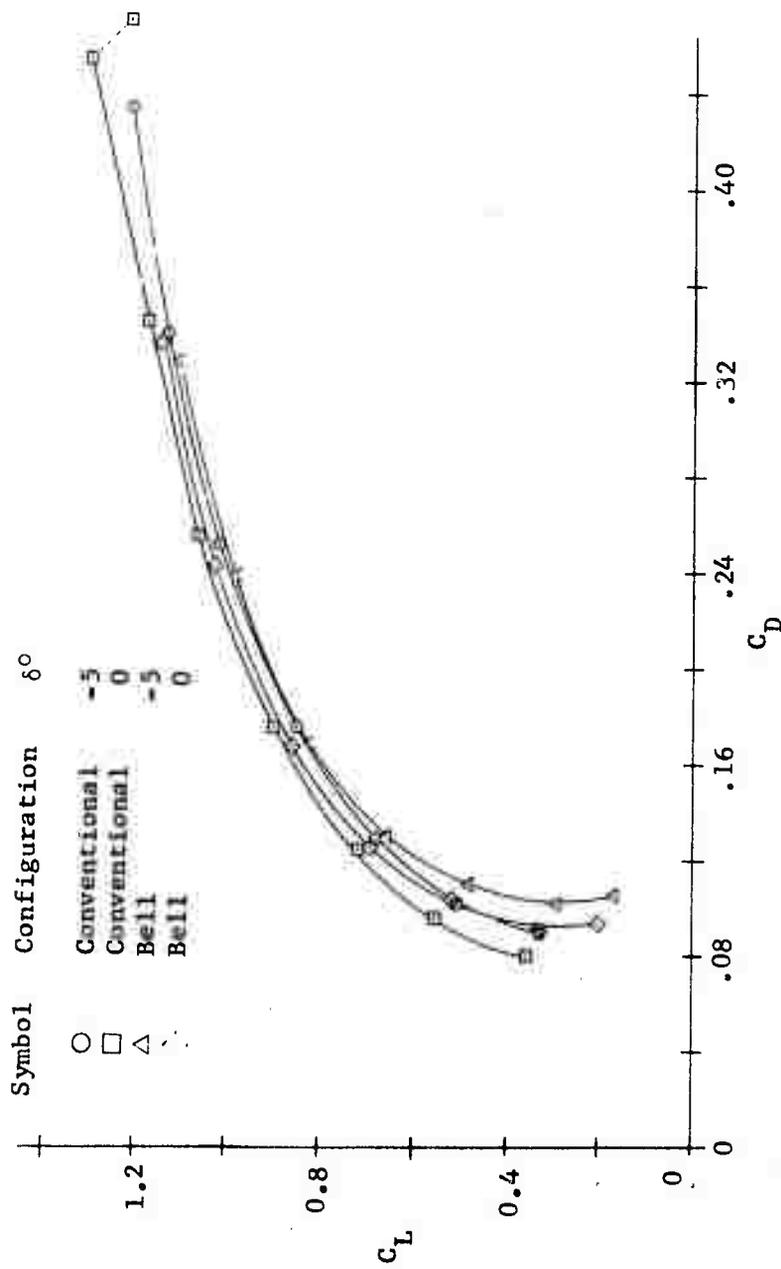


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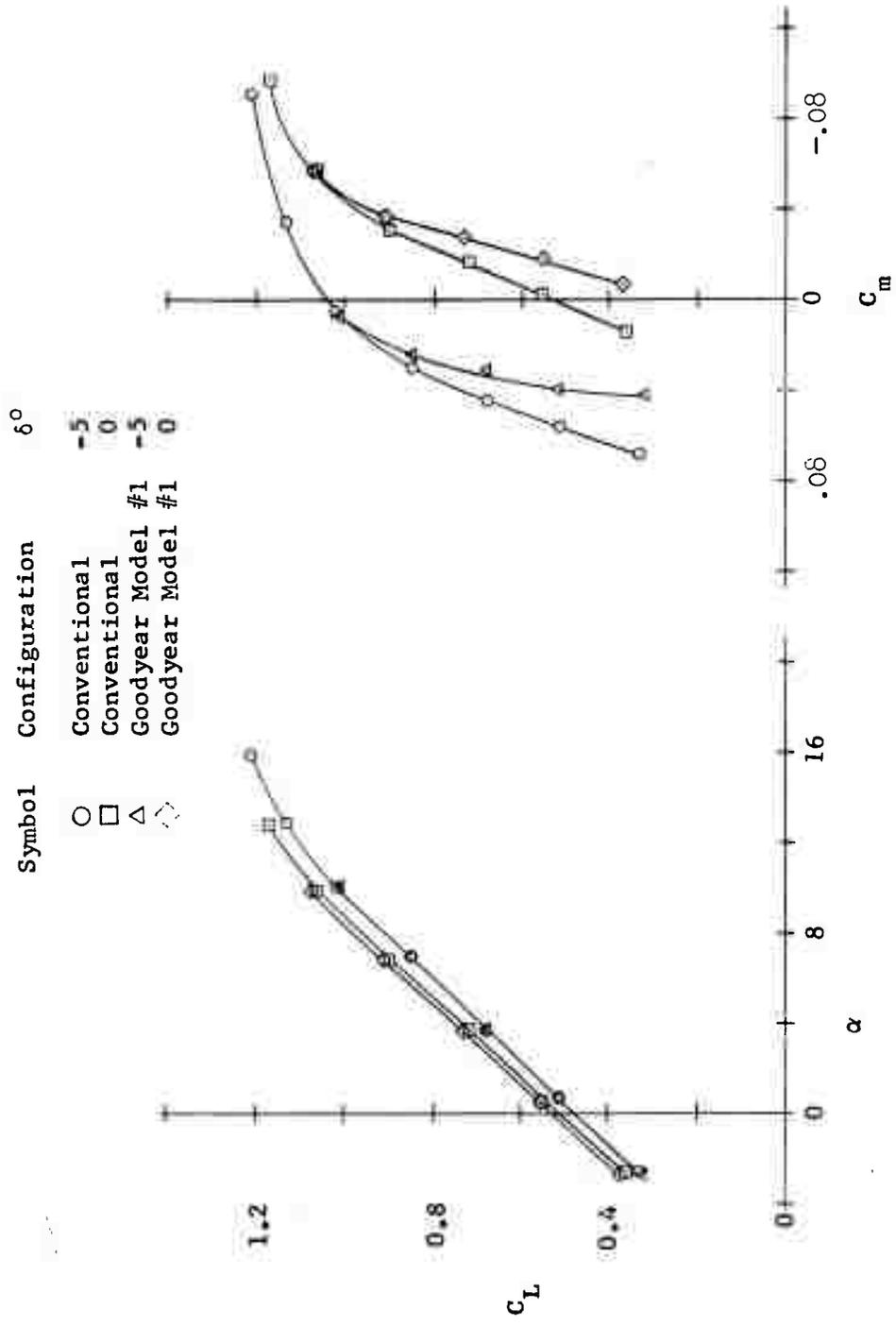


Figure 14 - Effect of Goodyear Model #1 Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics

1/10/1

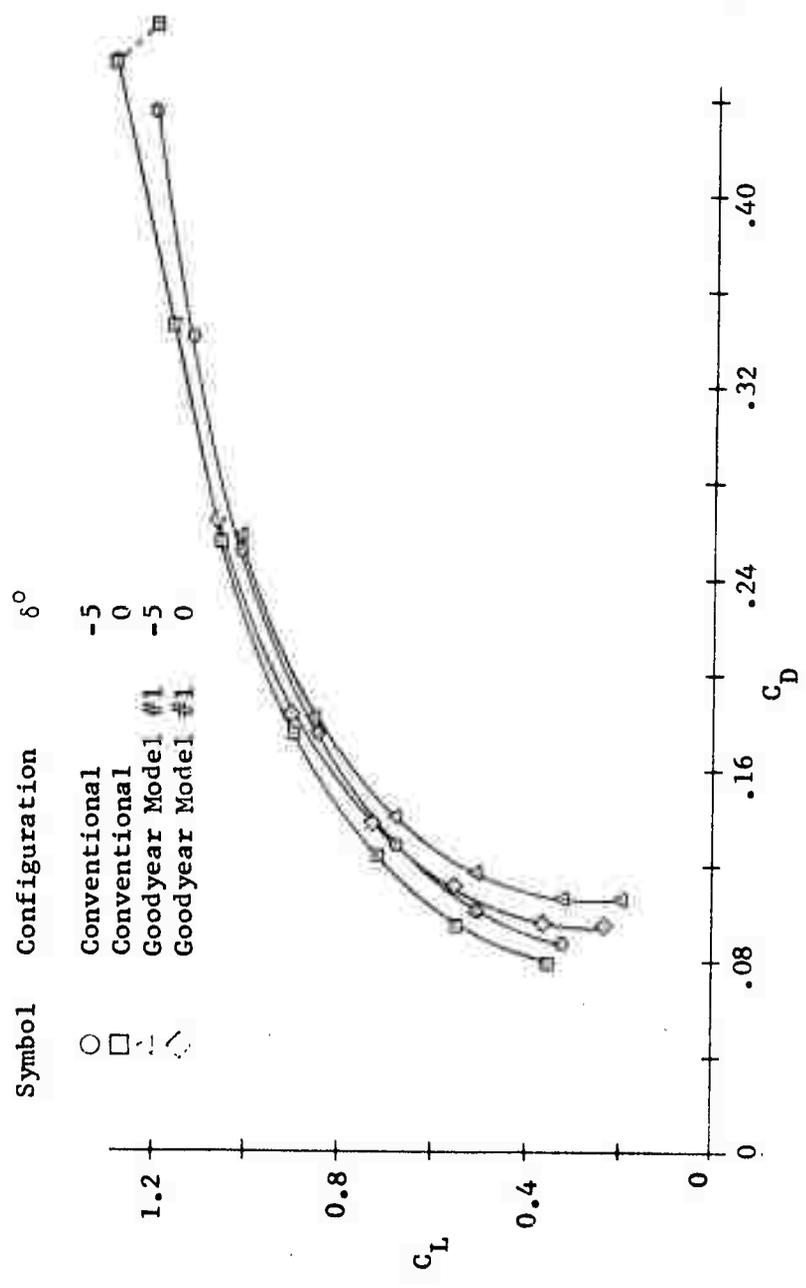


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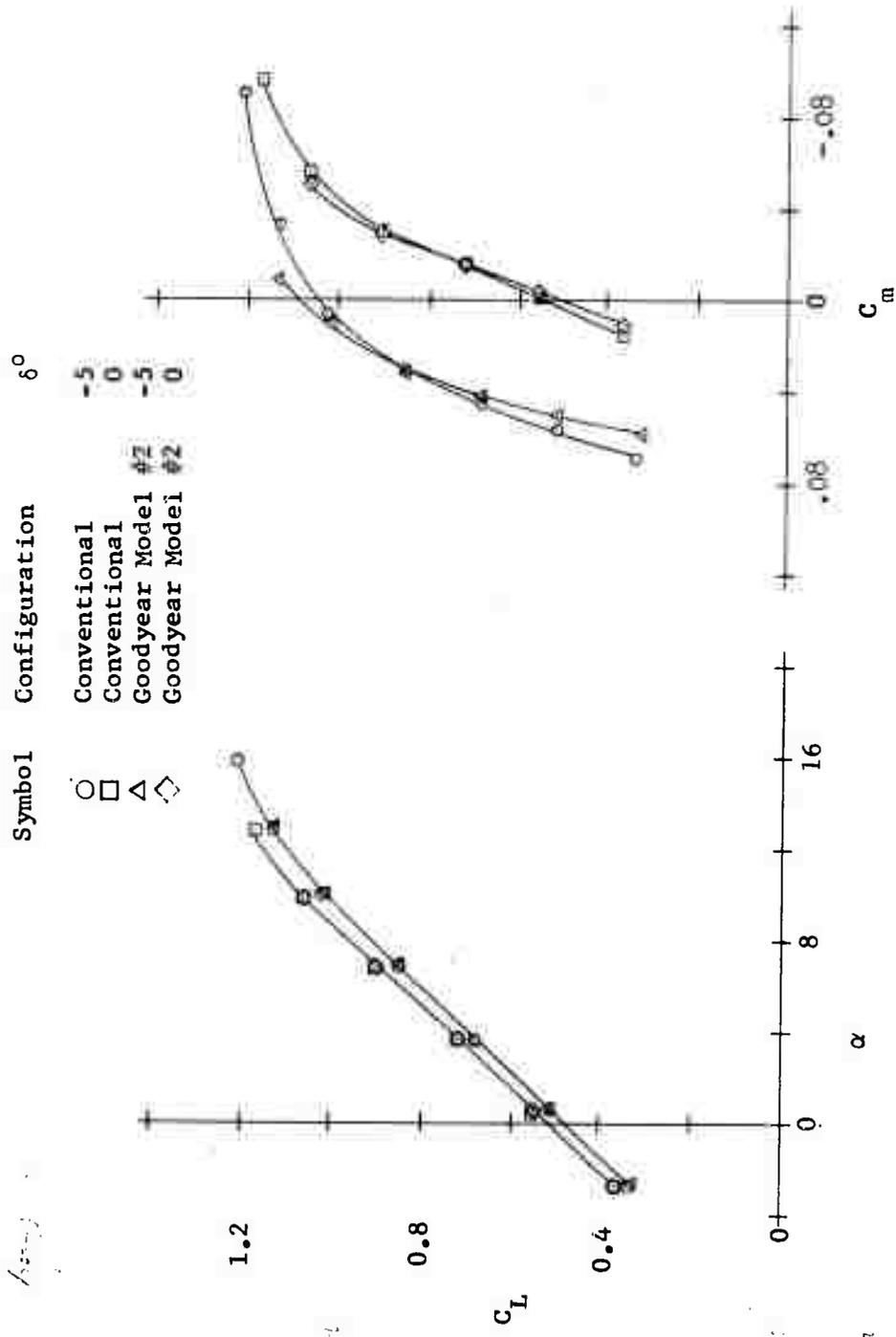


Figure 15 - Effect of Goodyear Model #2 Air Cushion Landing Gear on the F-8 Aerodynamic Characteristics

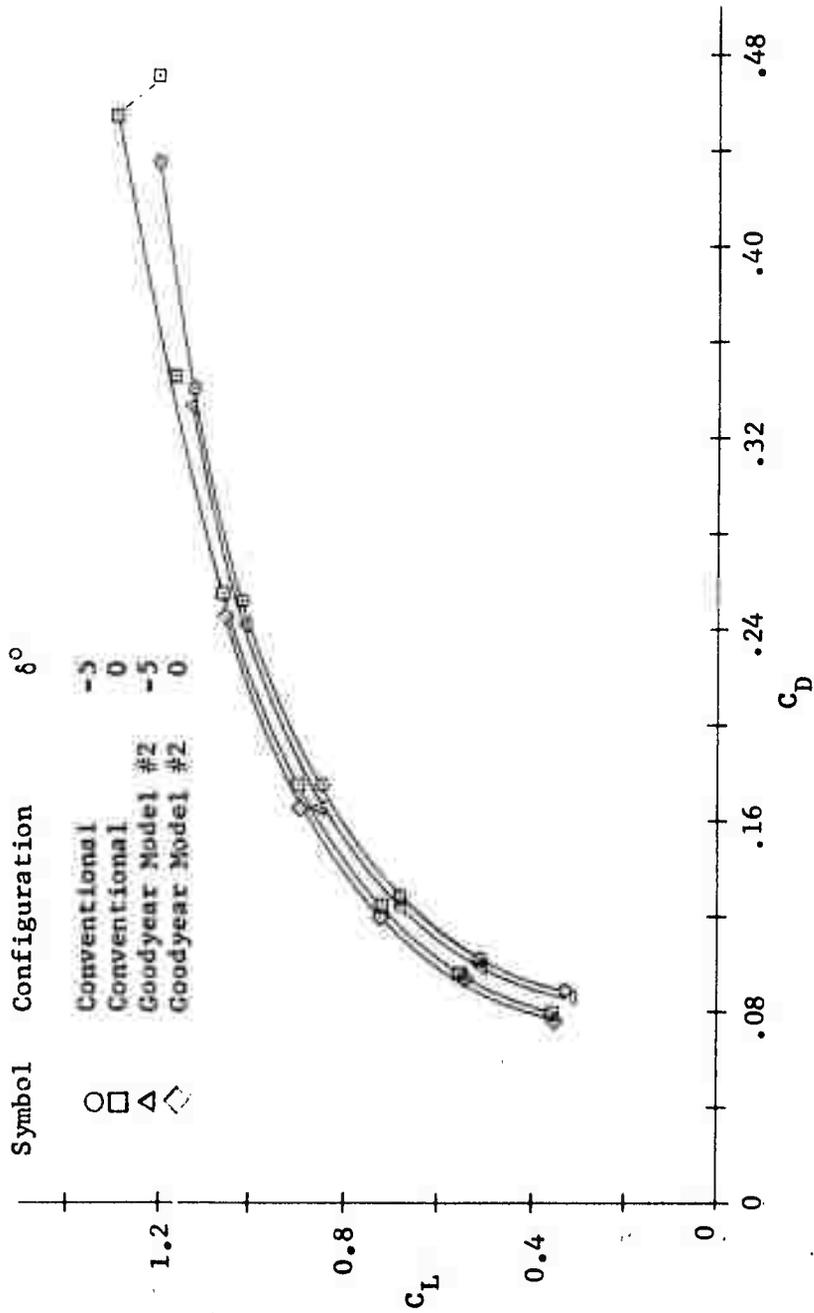


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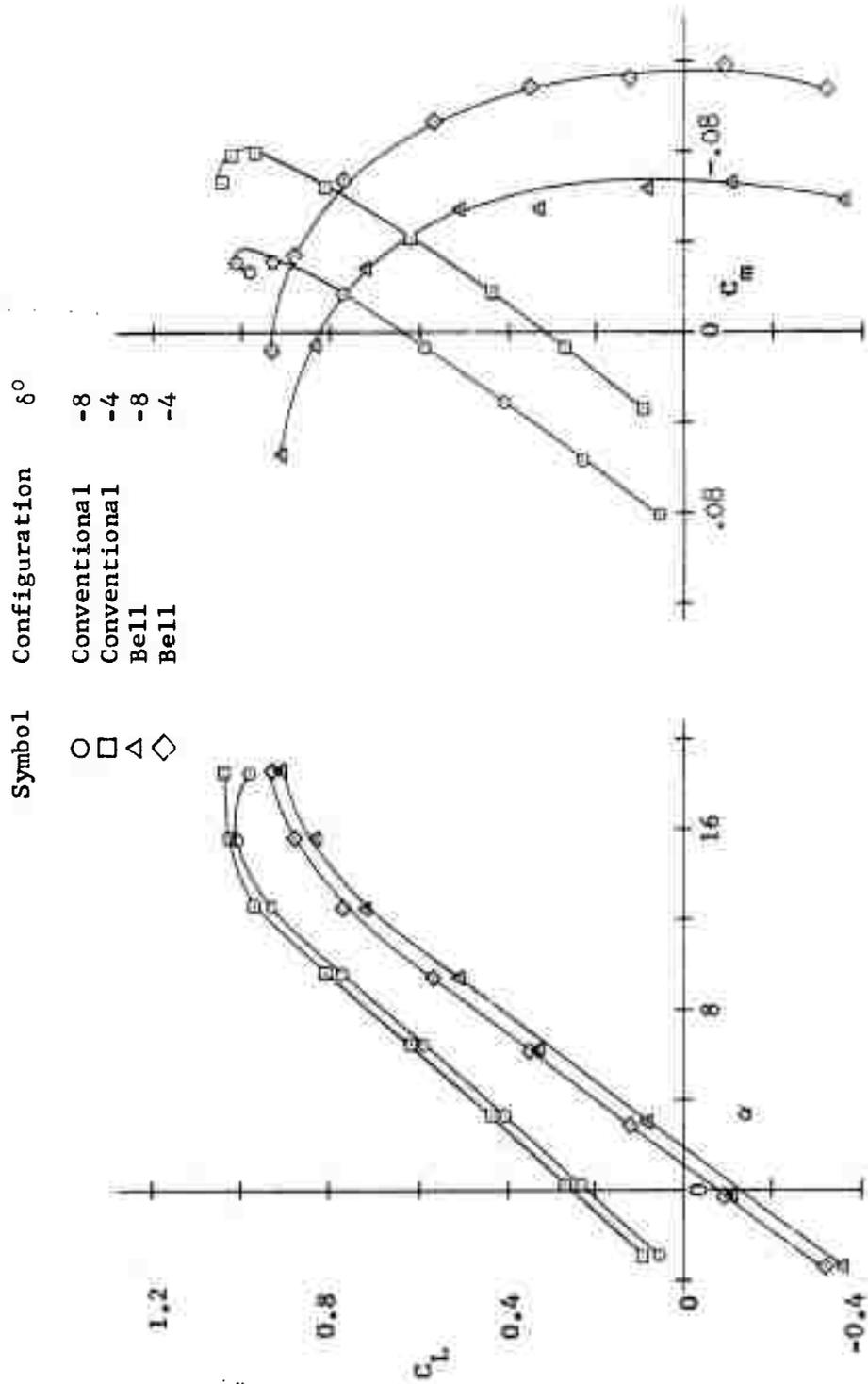


Figure 16 - Effect of Bell Air Cushion Landing Gear on the A-4 Aerodynamic Characteristics

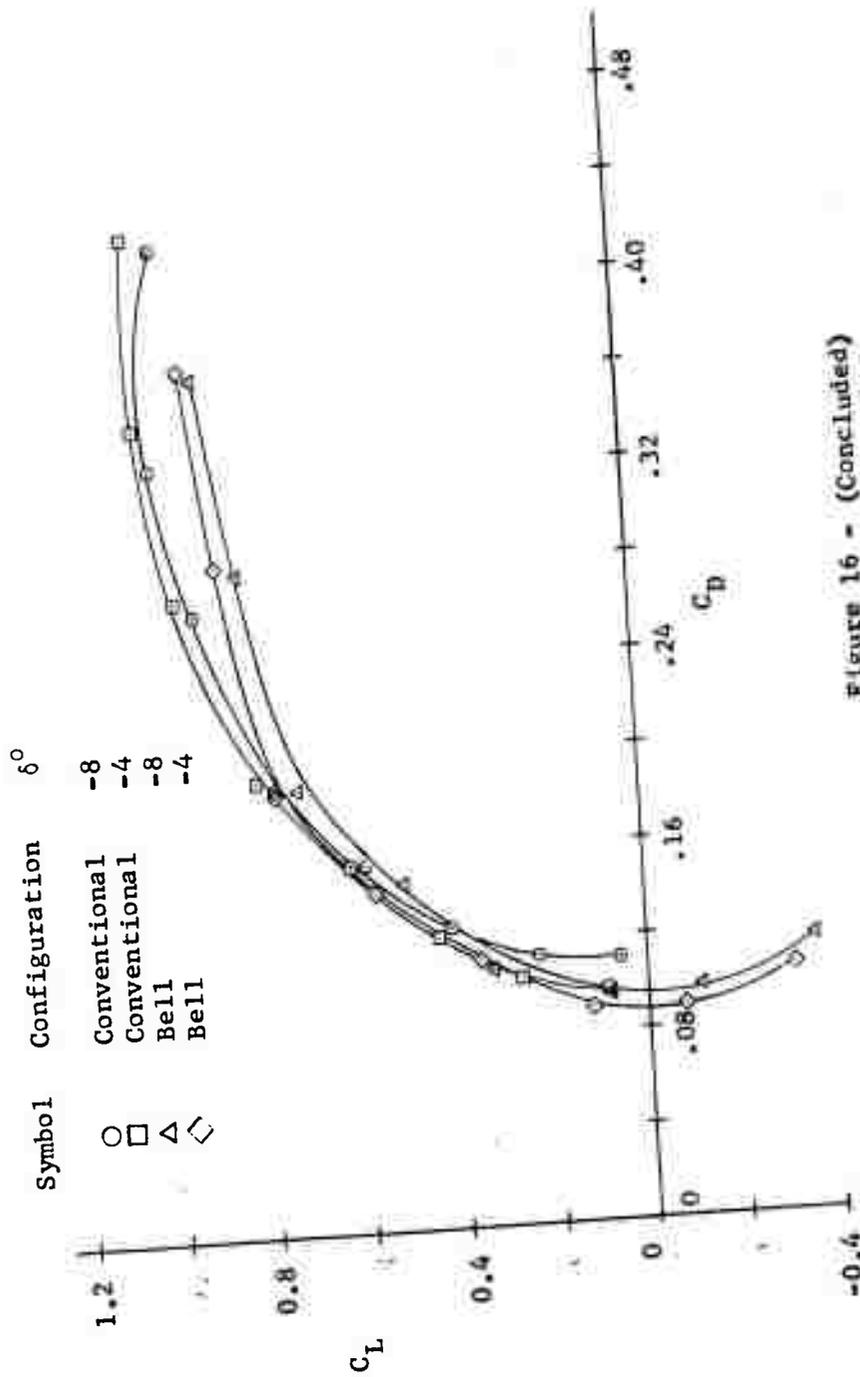


Figure 16 - (Concluded)