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AEDC-TR-67-61

AERODYNAMIC CHARACTERISTICS OF PROPOSED SNAP-29 FUEL BLOCK CONFIGURATIONS AT MACH NUMBER 8

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ARO, Inc.

April 1967

VON KÁRMÁN GAS DYNAMICS FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
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AP - AEDC
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FOREWORD

The work reported herein was done at the request of the Atomic Energy Commission for the Martin Company, Baltimore Division, under Program Area 921D, AEC Activity Number 04-30-13-01.2.

The test results presented herein were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The tests were conducted from January 9 to 13, 1967, under ARO Project No. VB1746, and the manuscript was submitted for publication on March 13, 1967.

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This technical report has been reviewed and is approved.

James N. McCready
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ABSTRACT

Selected static-stability test results of five proposed SNAP-29 fuel block configurations are presented. Test configuration changes were made by varying the edge shape of the basic flat plate fuel block. Tests of 0.25- and 0.50-scale models were conducted at a nominal Mach number of 8, Reynolds number based on model length of 0.6×10^6, and angles of attack from 0 to 90 deg. Results of model support interference studies employing oil flow, pressure distribution, and image-type force data techniques are presented.

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NOMENCLATURE

C_A	Axial-force coefficient, axial force/$q_\infty S$
C_D	Drag coefficient, $C_A \cos \alpha + C_N \sin \alpha$
C_L	Lift coefficient, $C_N \cos \alpha - C_A \sin \alpha$
C_ℓ	Rolling-moment coefficient, rolling moment/$q_\infty S\ell$
C_m	Pitching-moment coefficient, pitching moment/$q_\infty S\ell$
C_N	Normal-force coefficient, normal force/$q_\infty S$
C_n	Yawing-moment coefficient, yawing moment/$q_\infty S\ell$
C_Y	Side-force coefficient, side force/$q_\infty S$
ℓ	Model reference length (see Fig. 1a), in.
L/D	Lift-to-drag ratio
M	Mach number
p	Pressure, psia
q	Dynamic pressure, psi
Re	Unit Reynolds number, ft^{-1}
S	Model reference area (see Fig. 1a), $in.^2$
T	Temperature, °R
x	Distance from model leading edge (see Fig. 1d), in.
α	Angle of attack, deg
γ	Model rotation angle (see Figs. 1b and 1c), deg

SUBSCRIPTS

o	Tunnel stilling chamber conditions
∞	Free-stream conditions

SECTION I
INTRODUCTION

Safety requirements dictate that the fuel block of the SNAP-29 nuclear generator remain intact during re-entry into the atmosphere and that an accurate prediction of its impact footprint be made. A trajectory analysis to determine if these requirements can be met requires the aerodynamic characteristics of the fuel block as inputs. The objective of the present test was to obtain the static-stability and axial-force characteristics of several fuel block configurations at Mach number 8.

The tests were conducted in the 50-in. hypersonic tunnel (Gas Dynamic Wind Tunnel, Hypersonic (B)) of the von Kármán Gas Dynamics Facility (VKF), AEDC. Testing was accomplished at unit Reynolds numbers of 0.42×10^6 and 0.84×10^6 per foot on 0.50- and 0.25-scale fuel block models, respectively. The angle-of-attack range investigated was from 0 to 90 deg at model rotation angles from 0 to 90 deg.

SECTION II
APPARATUS

2.1 MODELS AND SUPPORT

A total of eight models of five configurations (Fig. 1a) were supplied by the Martin Company. These consisted of five 0.50-scale force models, each with a different edge shape, two 0.25-scale force models, and a 0.25-scale pressure model. All models were made of 17-4 PH stainless steel.

The 0.50-scale force models were attached to balance attachment S_1 (Fig. 1b) which enclosed a sting-mounted balance. The models were rotated relative to the balance attachment to provide various model rotation angles while maintaining a fixed balance orientation. A balance attachment image S_1' was provided for addition to the model lower surface during support interference studies. Bent stings of +12 and -12 deg were used with these models giving an angle-of-attack range of -20 to 35 deg.

The 0.25-scale force models were fastened to the balance by means of balance attachments S_2 and S_3 (Fig. 1c), the balance being enclosed by a sting-mounted windshield. These models were rotated relative to the balance attachments in a manner similar to the 0.050-scale models.

Balance attachments S_2 and S_3 were used in conjunction with a straight sting giving model angles of attack from 30 to 60 deg with S_2 and 60 to 90 deg with S_3.

The pressure model lee surface was instrumented with 55 orifices (Fig. 1d). Simulated balance attachments were provided for use in a study of support interference on model surface pressure distribution. The model was mounted on a bent sting and was pivoted to provide total prebend angles of 10, 30, 50, and 80 deg giving an angle-of-attack range from 0 to 90 deg. Another pivot was provided to give model rotation angles of 0 and 15 deg.

2.2 WIND TUNNEL

Tunnel B is a continuous, closed-circuit, variable density wind tunnel with an axisymmetric contoured nozzle and a 50-in.-diam test section. The tunnel operates at a nominal Mach number of 6 or 8 at stagnation pressures from 20 to 280 and from 50 to 900 psia, respectively, at stagnation temperatures up to 1350°R. The model may be injected into the tunnel for a test run and then retracted for model cooling or model changes without interrupting the tunnel flow. A description of the tunnel may be found in Ref. 1.

2.3 INSTRUMENTATION

2.3.1 Force

Model forces and moments were measured with a six-component, moment-type, strain-gage balance supplied and calibrated by VKF. Before the test, combined balance static loadings were applied, simulating the model loading range anticipated during the test. The uncertainties listed below correspond to the differences between the applied loads and the values calculated by the final data reduction balance equations.

Balance Component	Design Load	Maximum Static Loads	Uncertainties
Normal force, lb	±200	±100	±0.5
Pitching moment, in.-lb	±680	±150	±3.3
Side force, lb	±200	±50	±0.3
Yawing moment, in.-lb	±680	±75	±1.9
Rolling-moment, in.-lb	±100	±50	±1.9
Axial force, lb	±50	+130	±0.5

2.3.2 Pressure

Model surface pressures were measured with 15-psid transducers referenced to a near vacuum. From repeat calibrations, the estimated measurement precision was ±0.003 psi or ±0.5 percent, whichever was greater.

2.3.3 Flow Visualization

Model flow field schlieren photographs were obtained for all test conditions during the force tests. Figure 2 shows typical examples of these photographs.

Photographs of the surface flow patterns for selected conditions were obtained by spraying the pressure model with Zyglo Penetrant® and illuminating it with ultraviolet light during exposure to tunnel flow. A complete description of this technique is given in Ref. 2 and representative results are shown in Fig. 3.

SECTION III
PROCEDURE

3.1 TEST CONDITIONS

A summary of test conditions is given below:

M_∞	$Re_\infty \times 10^{-6}$ ft^{-1}	p_O, psia	T_O, °R	p_∞, psia	q_∞, psi
7.87	0.42	70	1170	0.008	0.35
7.91	0.84	160	1225	0.018	0.76

3.2 TEST PROCEDURE

The 0.50-scale models were tested at the low unit Reynolds number and the 0.25-scale models at the high unit Reynolds number thereby providing a constant Reynolds number based on model size. Because of model size, the 0.50-scale model tests were limited to a maximum angle of attack of 35 deg to prevent tunnel blocking. The 0.25-scale force models were tested at angles of attack from 30 to 90 deg, and the pressure model was tested at angles of attack from 0 to 90 deg. A complete summary of the test schedule is presented in Table I.

TABLE I
TEST SUMMARY

Force Tests

Configuration	Balance Attachment	γ, deg						
		0	15	30	45	60	75	90
E_1	S_1, S_2, S_3	A, B, C*, D*	A, B, C*	A, B, C*, D*	A, B, C*, D	A, B, C*, D	A, B, C*, D	A, B, C*, D
E_1	S_1S_1'	A	A	A	A	A	A	A
E_2	S_1, S_2, S_3	A, B, C*, D	A, B, C	A, B, C*, D	A, B, C, D	A, B, C*, D	A, B, C, D	A, B, C, D
E_2	S_1S_1'	A						
E_3	S_1	A, B			A, B			
E_3	S_1S_1'	A						
E_4	S_1	A, B			A, B			
E_4	S_1S_1'	A						
E_5	S_1	A, B			A, B			
E_5	S_1S_1'	A			A			

A - α = -20 to +10 deg, $Re_\infty = 0.42 \times 10^6$, ft^{-1}, 0.50-scale models
B - α = 5 to 35 deg,
C - α = 30 to 60 deg, $Re_\infty = 0.84 \times 10^6$, ft^{-1}, 0.25-scale models
D - α = 60 to 90 deg,

*Also tested at $Re_\infty = 0.42 \times 10^6$, ft^{-1}

Pressure Tests

Configuration	Balance Attachment	α, deg												
		0	5	10	15	20	25	30	40	50	60	70	80	90
E_1		E*	E	E	E*	E	E	E*	E	E*	E	F	F	F
E_1	S_1	E*	E	E	E*	E	E	E*						
E_1	S_2					E	E	E*	E	E*	E			
E_1	S_3											F	F	F

E - γ = 0 and 15 deg
F - γ = 0 only

*Oil Flow Photographs Taken (Only at γ = 0 with S_1 Balance Attachment)

SECTION IV
RESULTS AND DISCUSSION

Experimental determination of the aerodynamic characteristics of a flat plate configuration with an externally mounted balance presented the problem of assessing support interference. Three techniques were used in the present tests to obtain qualitative and quantitative support interference data. These consisted of model lee-side oil flow photographs and pressure distributions and an image technique of obtaining force data.

Examples of the oil flow photographs and pressure distributions are shown in Fig. 3. Diminishing influence of balance attachment S_1 on axial surface pressure distribution as angle of attack was increased from 0 to 15 deg was noted. A corresponding forward movement of flow separation from the model surface was indicated by the oil flow photographs. Balance attachments S_1 and S_2 produced negligible interference at 30-deg angle of attack (lower portion of Fig. 3), and similar results were obtained at higher angles of attack.

A quantitative evaluation of support interference effects on the force and moment coefficients was made by the image technique which is commonly used in low speed wind tunnel testing. Each 0.50-scale model was tested through a negative angle-of-attack range with and without balance attachment image S_1' (Fig. 1b) attached to the model. Typical results of these tests are shown in Fig. 4. An interference correction can be made by subtracting the difference in the coefficients at negative angle of attack from the corresponding coefficients obtained without the image at a positive angle of attack. As can be seen, this correction was small and limited to angles of attack less than 6 deg and was therefore neglected.

Longitudinal stability and axial-force coefficients for the five 0.50-scale configurations are shown in Fig. 5. Edge shape had a pronounced effect on C_m and trim angle. Stable trim points in the $10 < \alpha < 20$-deg range were obtained for all configurations except E_1. Axial-force coefficient increased with leading edge bluntness as expected.

Longitudinal stability and axial-force coefficients for Configurations E_1 and E_2 for α = 0 to 90 deg are shown in Fig. 6. The sharp increase in C_m and corresponding decrease in C_A near α = 45 deg may be attributed to shock detachment, i. e., the transition from a supersonic to a subsonic flow field in the region between the bow shock and the body. A similar phenomenon has been noted in the testing of blunt delta wings (Refs. 3 and 4).

Lift and drag coefficients and lift to drag ratio for Configurations E_1 and E_2 are shown in Fig. 7. Newtonian predictions for Configuration E_1 were obtained using the procedure illustrated in Ref. 5 and a Newtonian constant of 2. The agreement was fair except for C_D at high angles of attack and L/D at low angles of attack.

Configuration E_2 longitudinal stability and axial-force coefficients for model rotation angles from 0 to 45 deg are shown in Fig. 8. The change in effective model geometry resulting from model rotation reduced trim angle and axial-force coefficients. (Note that the axis system remained fixed as the model was rotated.) Rotation angles from 45 to 90 deg produced data essentially symmetric with the γ = 0 to 45-deg data and hence are not shown.

Lateral stability and rolling-moment coefficients for Configuration E_2 are shown in Fig. 9. The slight nonsymmetry about γ = 45 deg of the side force and rolling-moment data is attributed to the rectangular (rather than square) shape of the model.

REFERENCES

1. Test Facilities Handbook (6th Edition). "von Kármán Gas Dynamics Facility, Vol. 4." Arnold Engineering Development Center, November 1966.

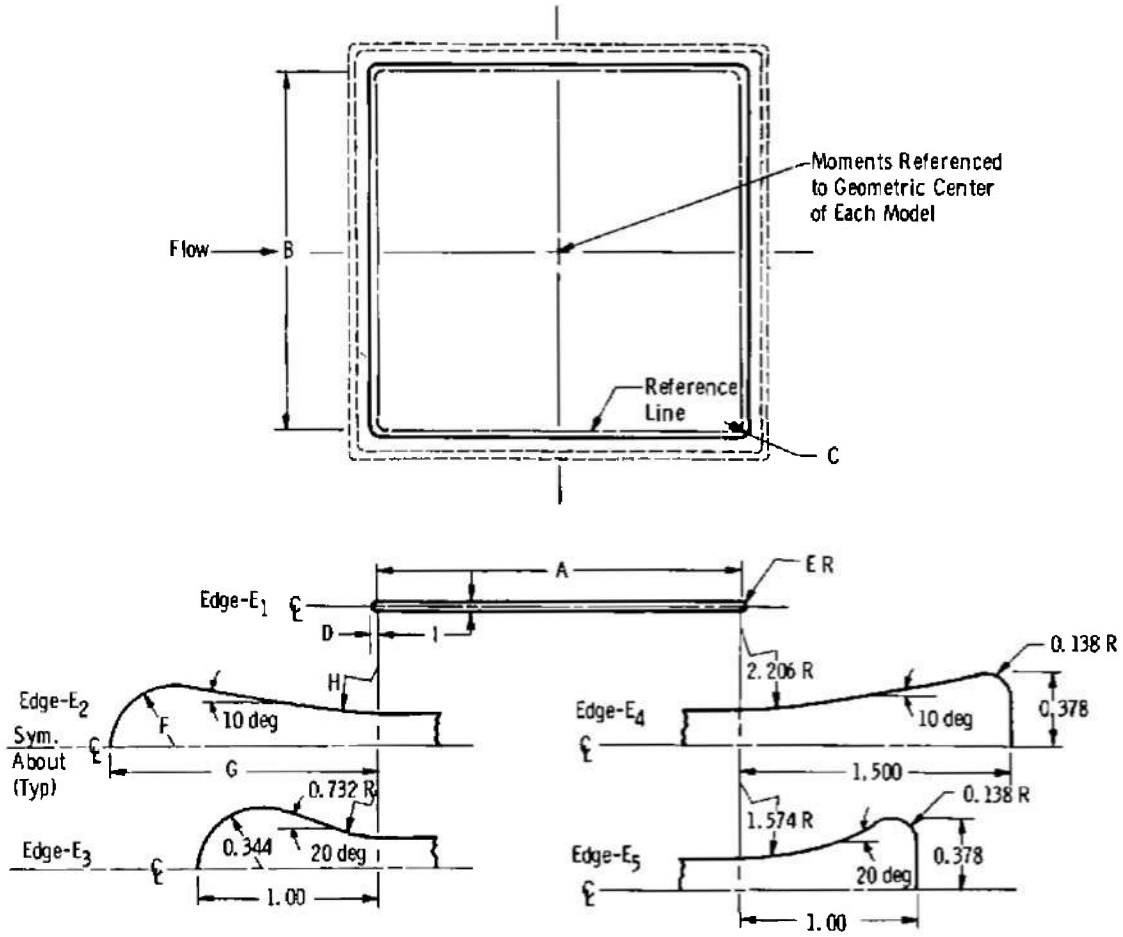
2. Rhudy, R. W. "Flow Visualization Techniques for Use in Hypersonic Wind Tunnels." AEDC-TDR-64-108 (AD448116), October 1964.

3. Bernot, Peter T. "Pressure Distributions on Blunt Delta Wings at Angles of Attack Up to 90° and Mach Number of 6.85." NASA-TN-D-1954, July 1963.

4. Neal, Luther, Jr. and Fetterman, David E. "Control Surface Interaction Effects on Delta-Wing Windward Pressures at a Mach Number of 6.83 at High Angles of Attack." NASA-TN-D-2332, June 1964.

5. Clark, E. L. and Trimmer, L. L. "Equations and Charts for the Evaluation of the Hypersonic Characteristics of Lifting Configurations by Newtonian Theory." AEDC-TDR-64-25 (AD431848), March 1964.

APPENDIX
ILLUSTRATIONS

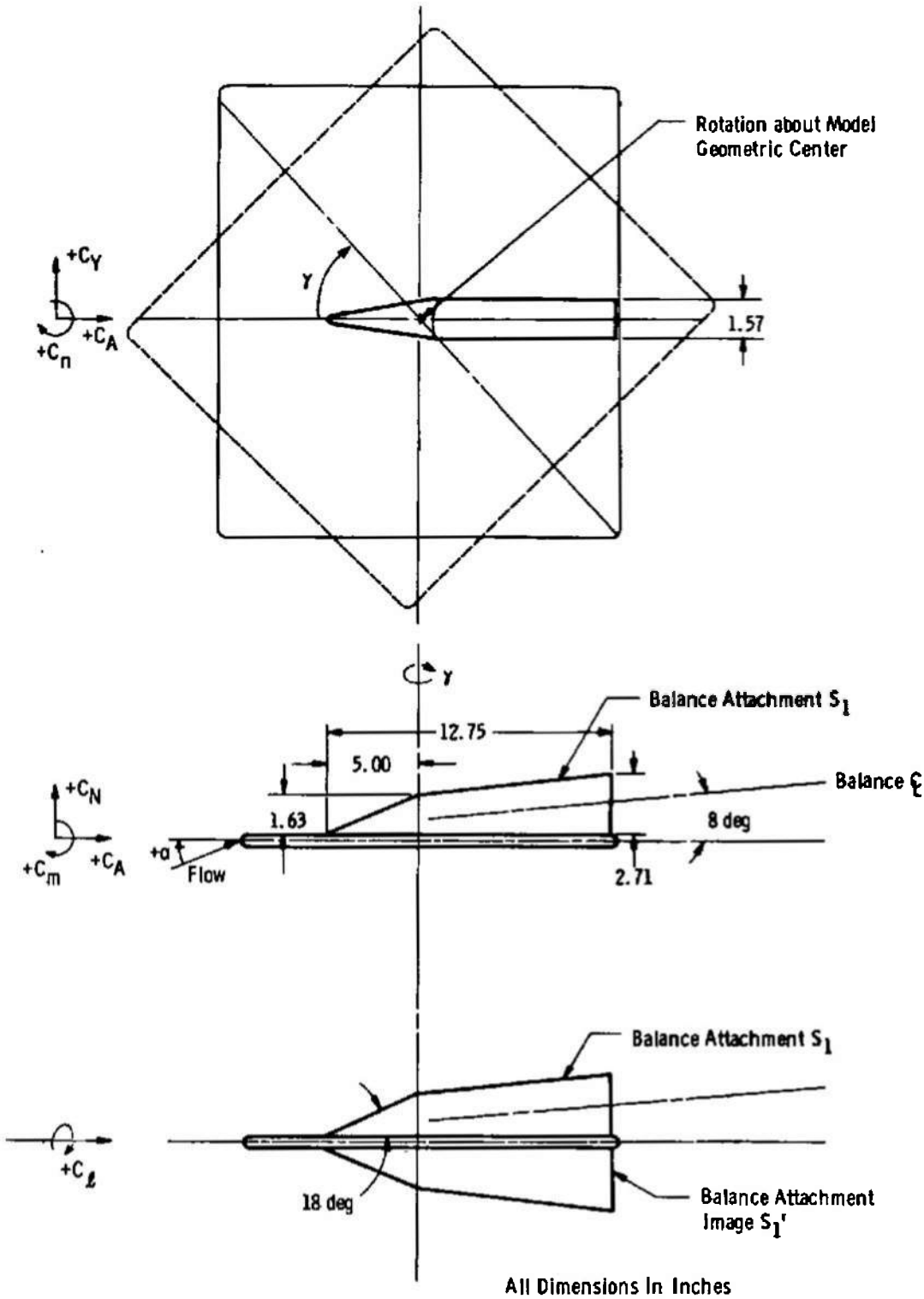


Configuration Dimension	E_1, 0.25	E_1, 0.50	E_2, 0.25	E_2, 0.50	E_3, 0.50	E_4, 0.50	E_5, 0.50
A	7.875	15.750	7.875	15.750	15.750	15.750	15.750
B	8.688	17.276	8.688	17.276	17.276	17.276	17.276
C	0.250	0.500	0.750	1.500	1.000	1.500	1.000
D	0.125	0.250					
E	0.087	0.174					
F			0.172	0.344			
G			0.750	1.500			
H			0.934	1.868			
I	0.174	0.348	0.174	0.348	0.348	0.348	0.348
S (Area)	72.22	288.9	95.04	380.2	342.2	380.2	342.2
ℓ	8.125	16.25	9.375	18.75	17.75	18.75	17.75

All Dimensions in Inches

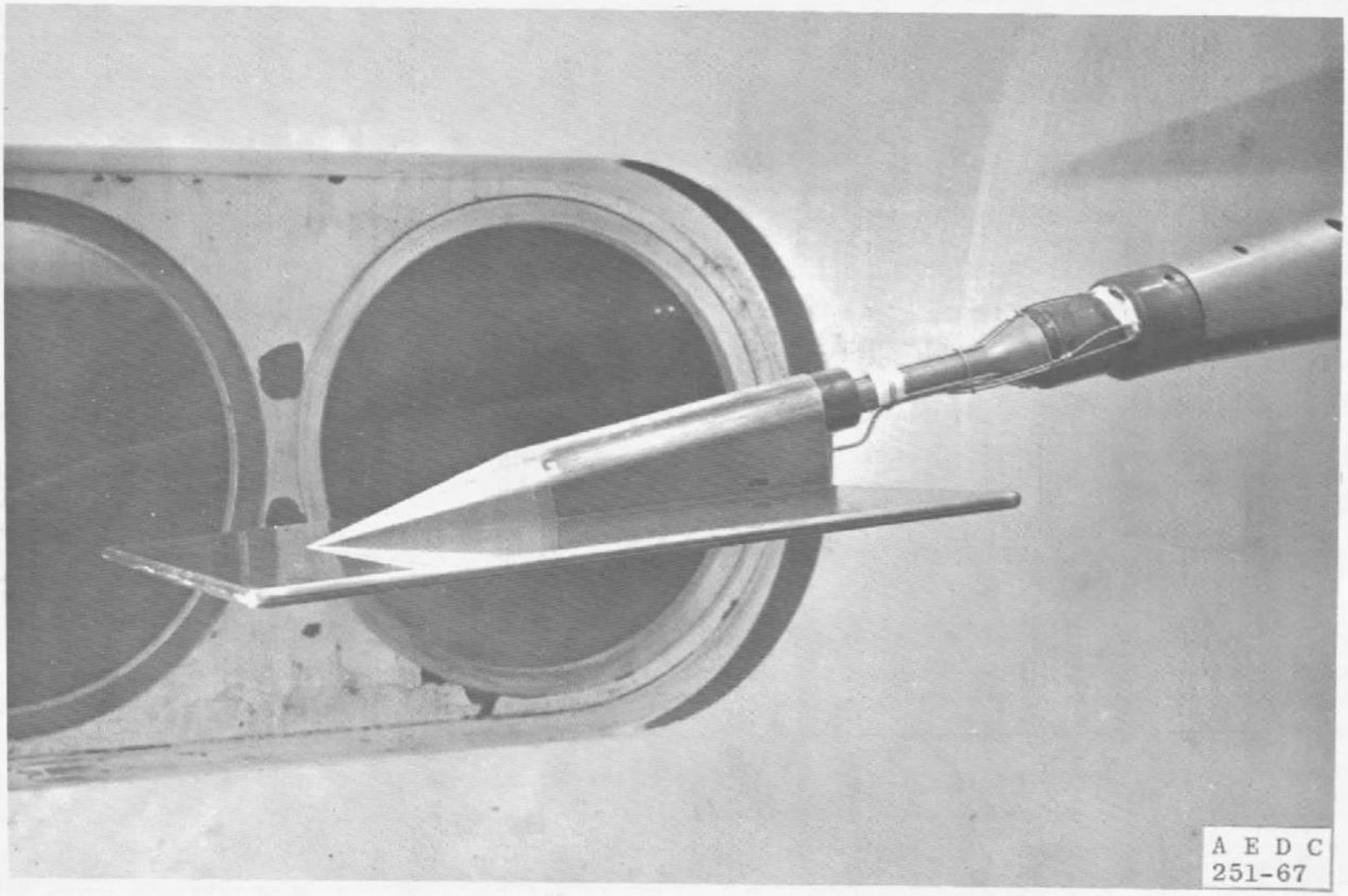
a. Force Models

Fig. 1 Model Details



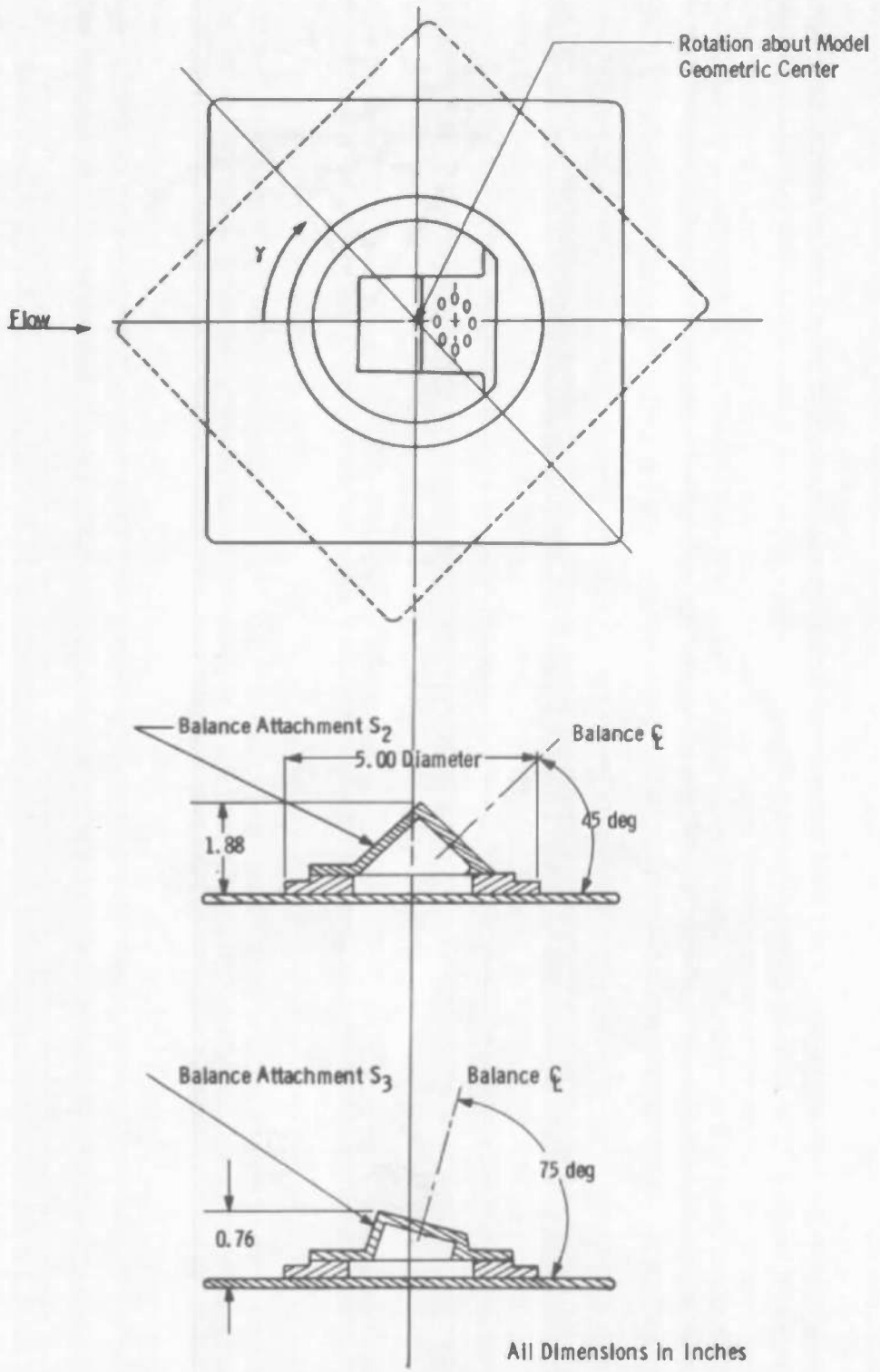
b. Balance Attachment for the 0.50-Scale Force Models

Fig. 1 Continued



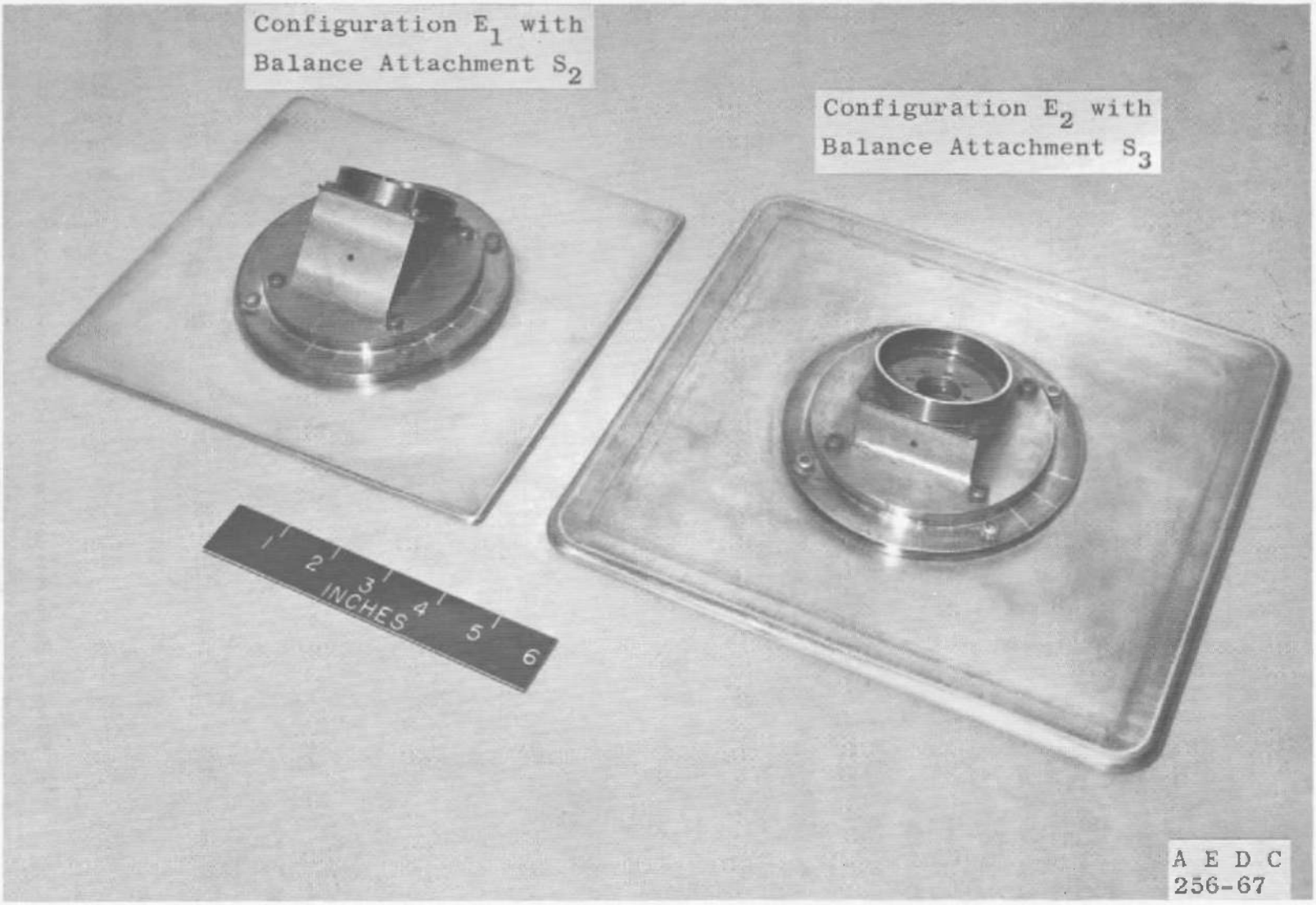
b. Concluded

Fig. 1 Continued



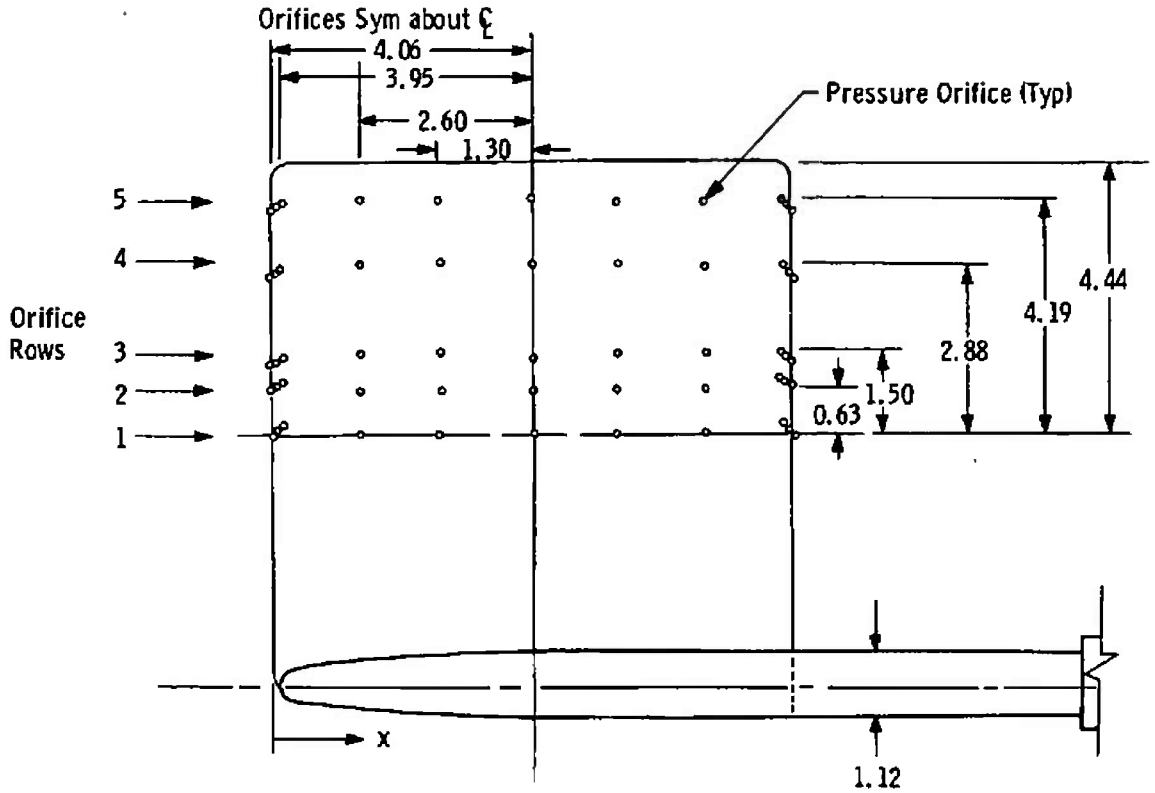
c. Balance Attachments for the 0.25-Scale Force Models

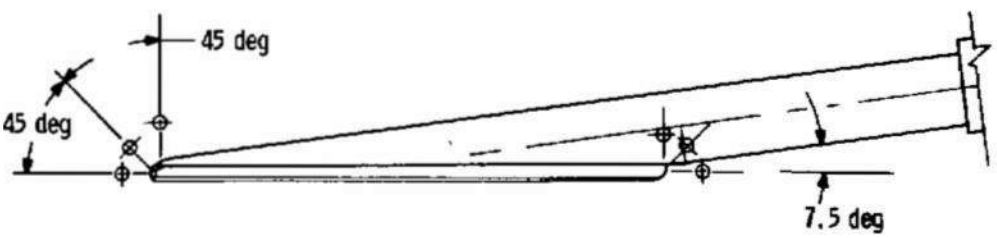
Fig. 1 Continued



c. Concluded

Fig. 1 Continued

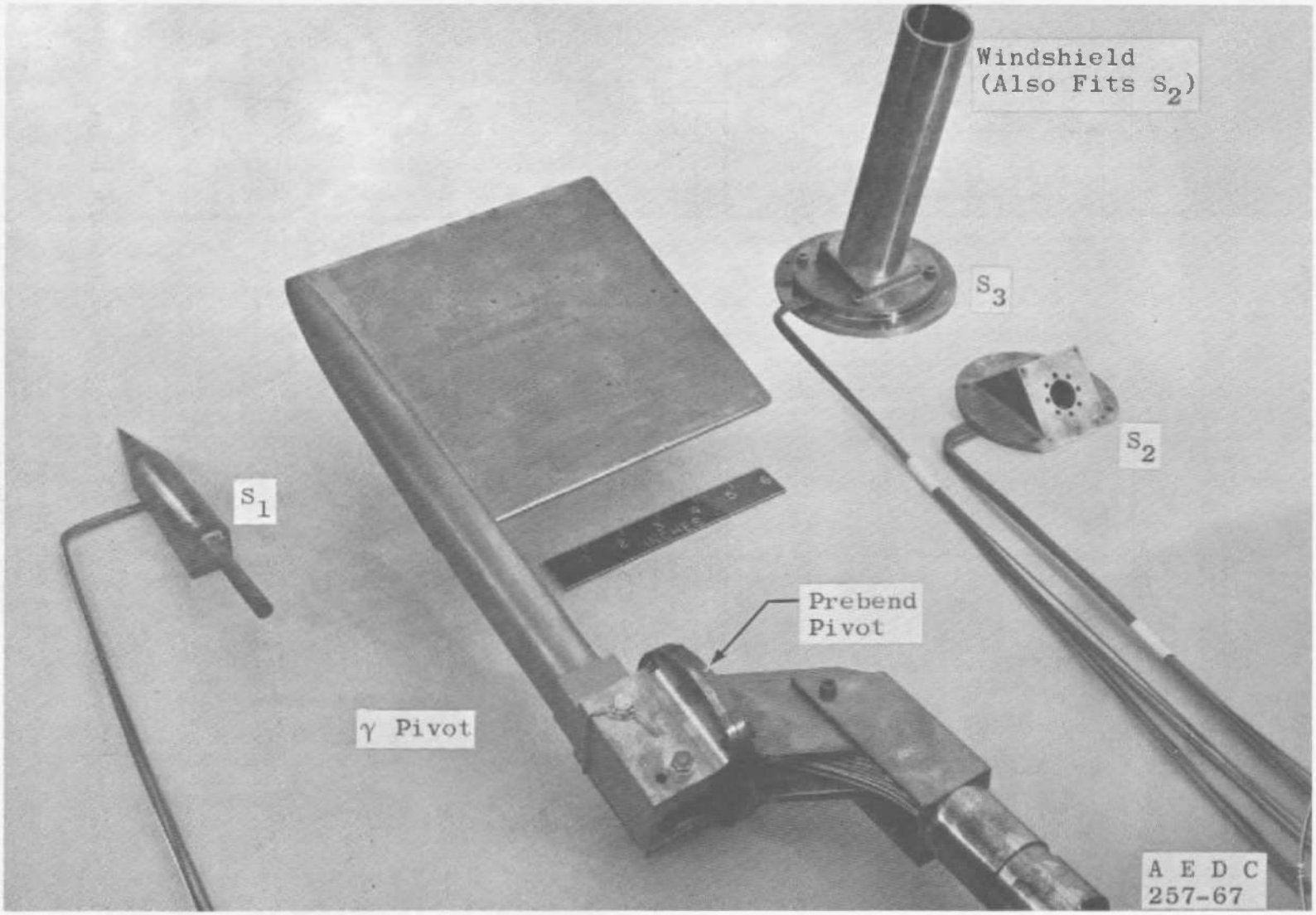




All Dimensions in Inches

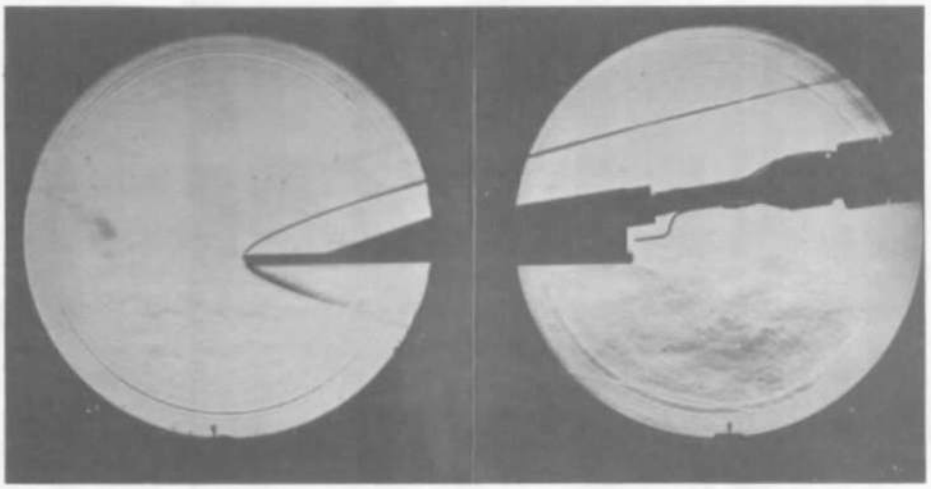
d. 0.25-Scale Pressure Model

Fig. 1 Continued



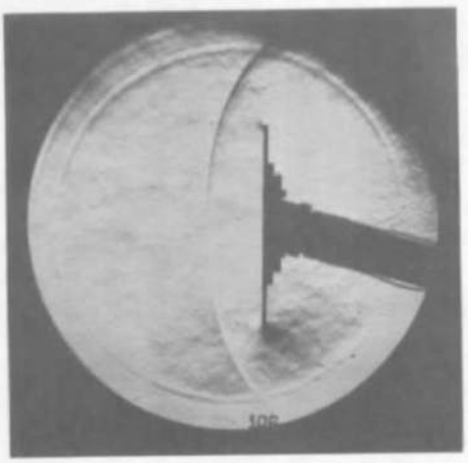
d. Concluded

Fig. 1 Concluded



α = 0, 0.50-Scale Model

α = 43.3 deg, 0.25-Scale Model



α = 90.1 deg, 0.25-Scale Model

Configuration E_1, γ = 0

Fig. 2 Schlieren Photographs

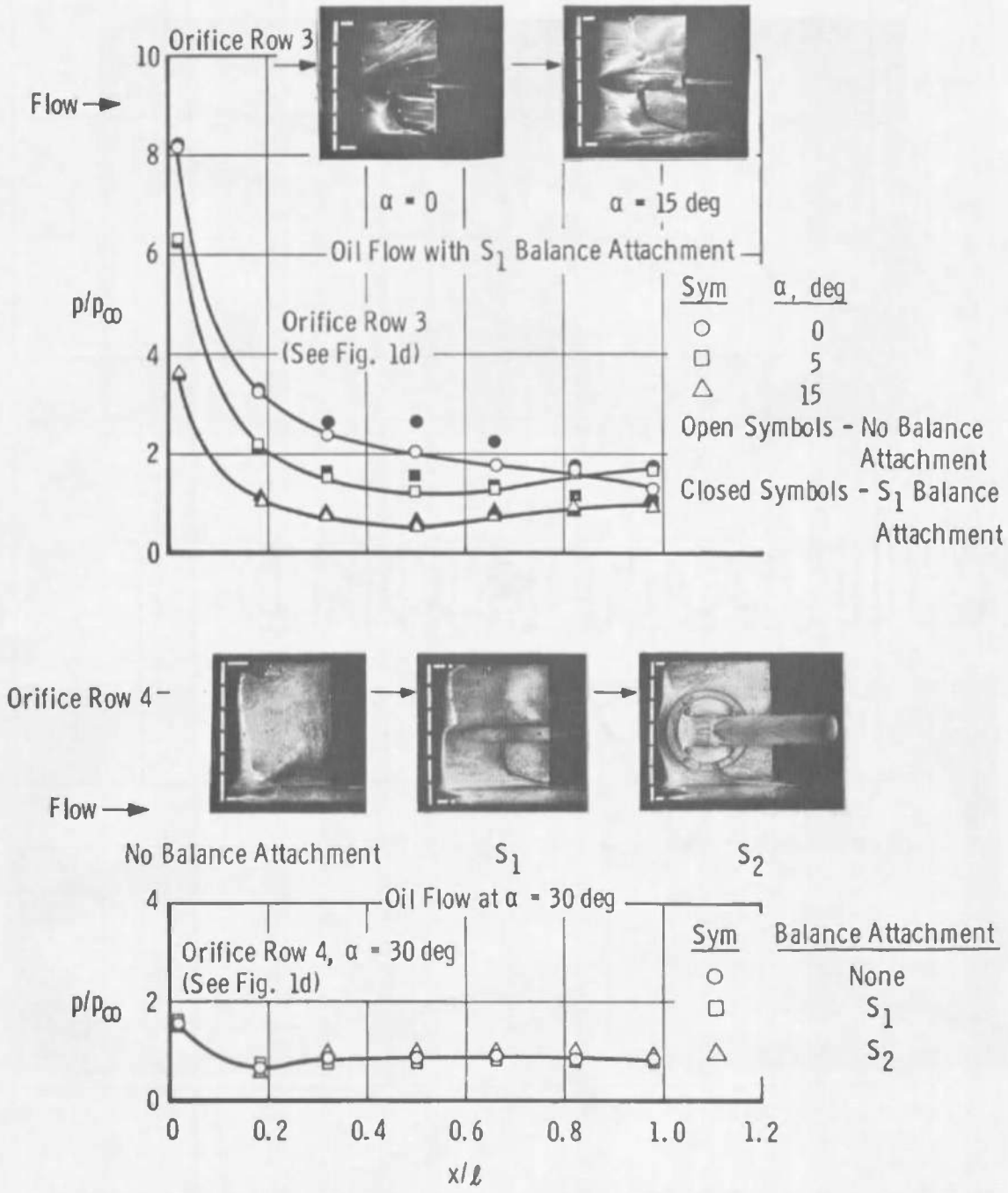


Fig. 3 Axial-Pressure Distributions and Oil Flow Photographs for Configuration E_1, $\gamma = 0$

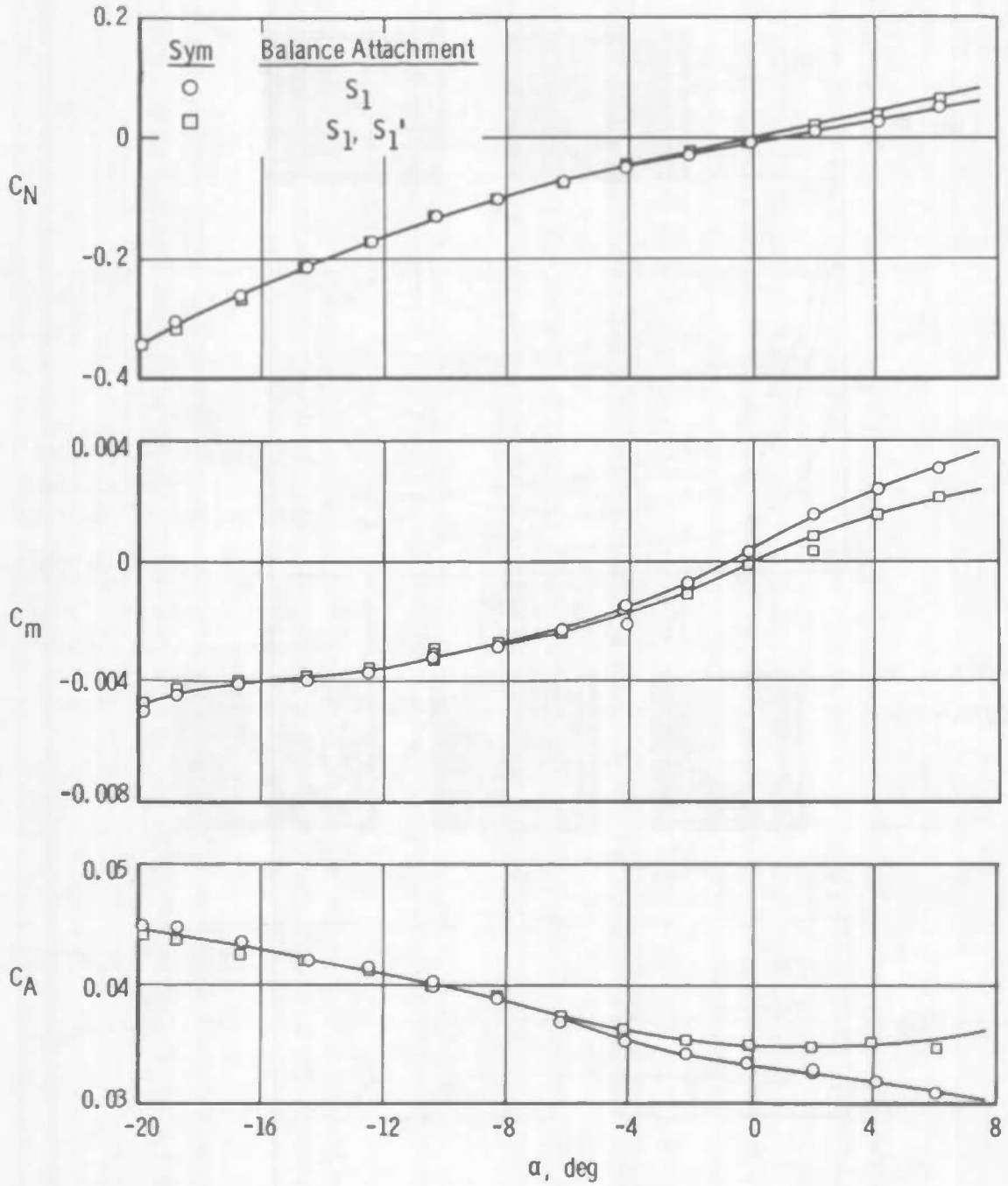


Fig. 4 Effect of Balance Attachment Image, S_1', on the Longitudinal Stability and Axial-Force Coefficients of Configuration E_1, $\gamma = 0$

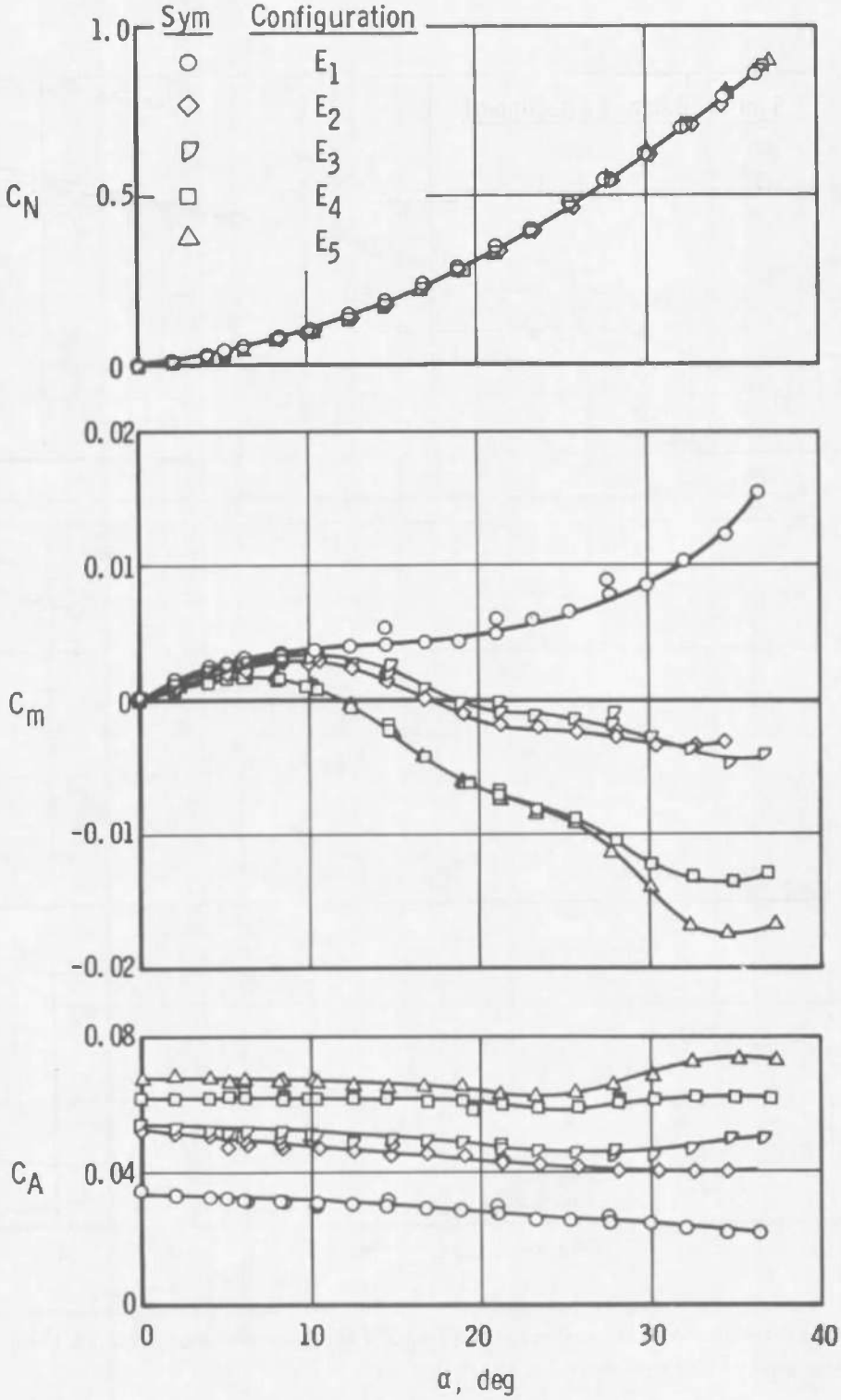


Fig. 5 Effect of Edge Shape on Longitudinal Stability and Axial-Force Coefficients, $\gamma = 0$, $\alpha = 0$ to 35 deg

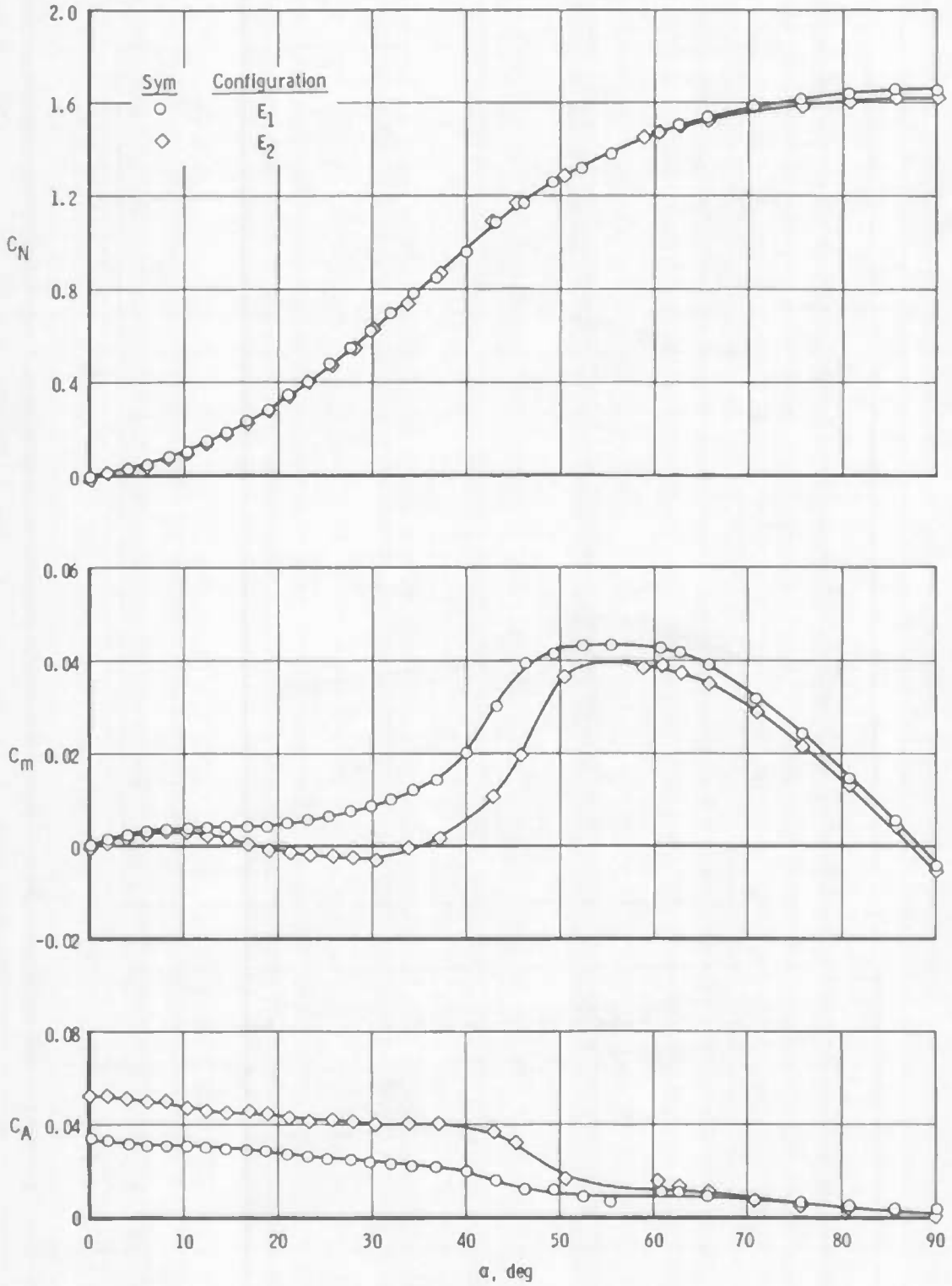


Fig. 6 Langitudinal Stability ond Axial-Farce Coefficients for Configurations E_1 and E_2, $\gamma = 0$, $\alpha = 0$ ta 90 deg

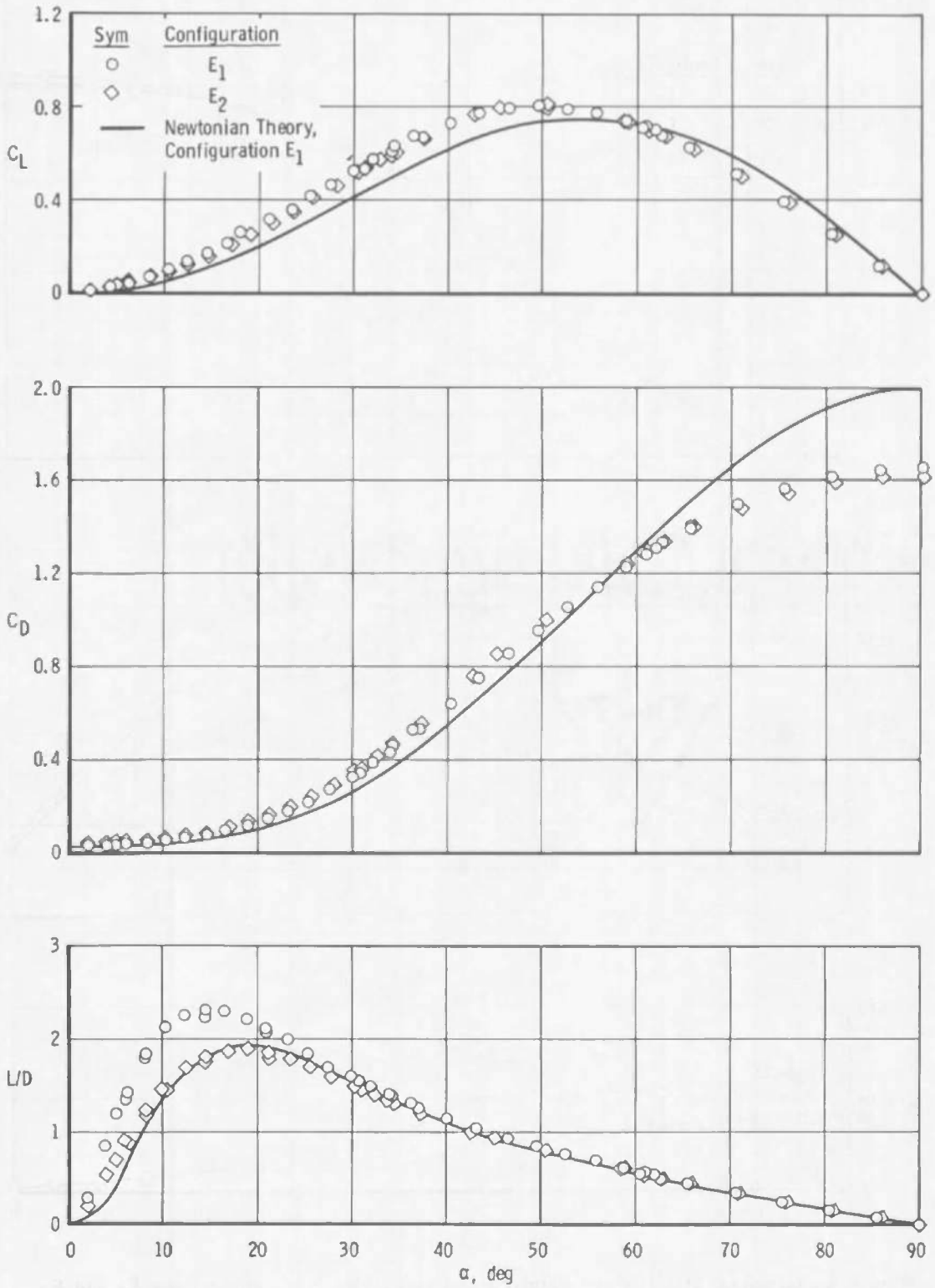


Fig. 7 Lift and Drag Characteristics of Configurations E_1 and E_2, $\gamma = 0$, $\alpha = 0$ to 90 deg

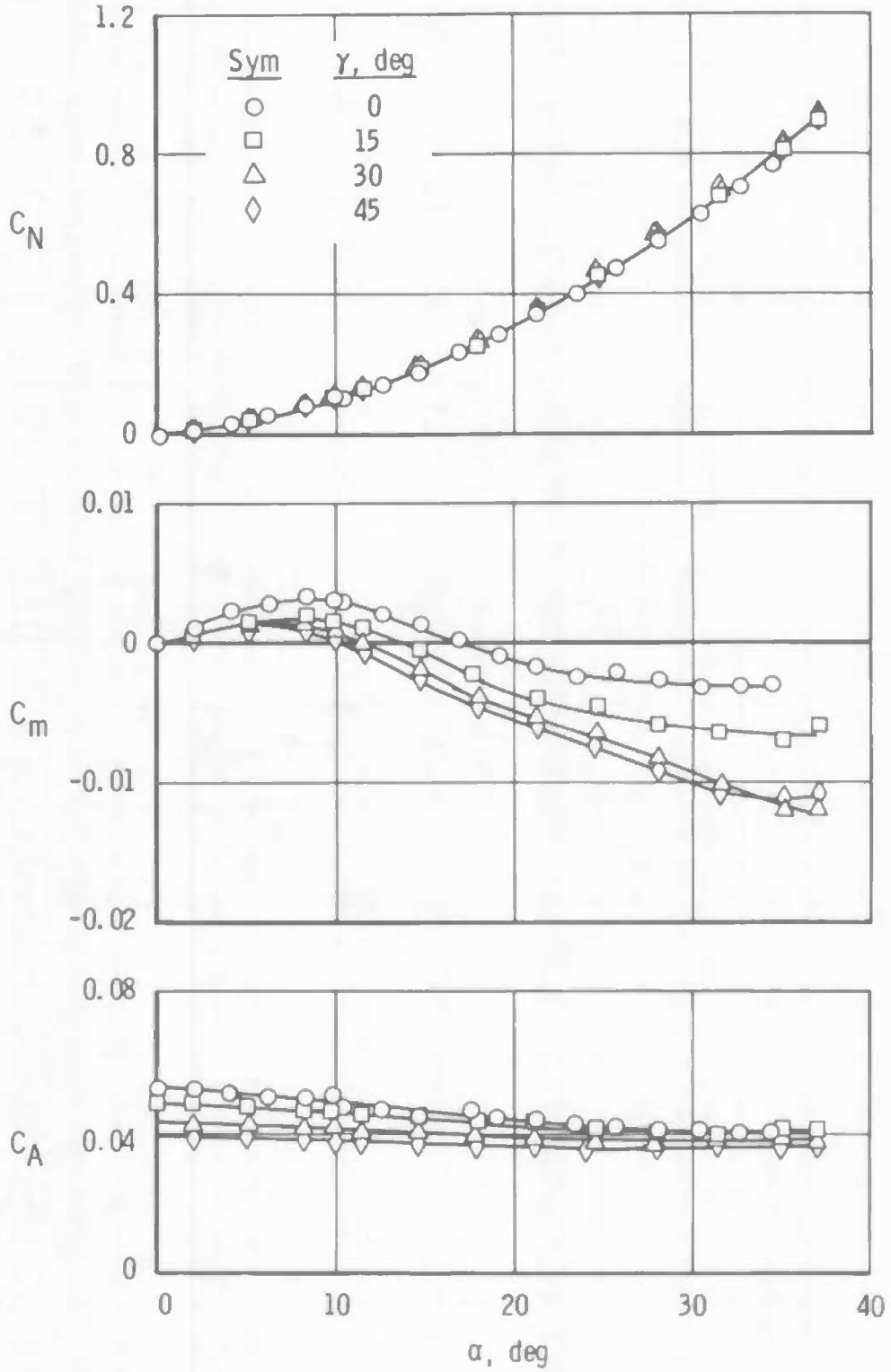


Fig. 8 Effect of Model Rotation on the Longitudinal Stability and Axial-Force Coefficients of Configuration E_2, α = 0 to 35 deg

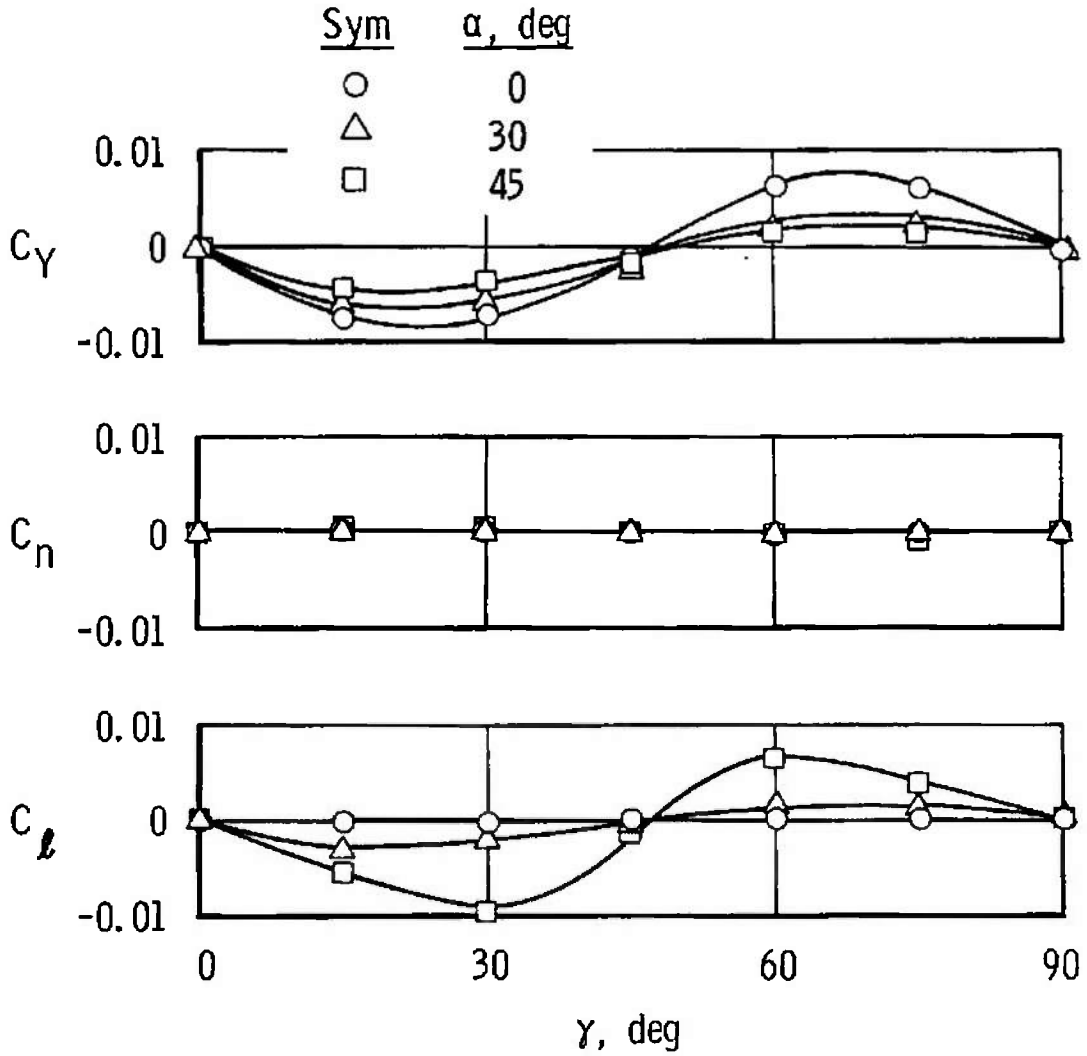


Fig. 9 Lateral Stability and Rolling-Moment Coefficients for Configuration E_2

Security Classification

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1 ORIGINATING ACTIVITY (Corporate author) Arnold Engineering Development Center ARO, Inc., Operating Contractor Arnold Air Force Station, Tennessee	2a REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP N/A

3 REPORT TITLE

AERODYNAMIC CHARACTERISTICS OF PROPOSED SNAP-29 FUEL BLOCK CONFIGURATIONS AT MACH NUMBER 8

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

N/A

5 AUTHOR(S) (Last name, first name, initial)

Burt, R. H. and Martindale, W. R., ARO, Inc.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
April 1967	31	5

8a CONTRACT OR GRANT NO	9a ORIGINATOR'S REPORT NUMBER(S)
AF 40(600)-1200 b PROJECT NO c Program Area 921D d	AEDC-TR-67-61 9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A

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