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HYPERSONIC STATIC STABILITY INVESTIGATION OF A TOMAHAWK 20-PERCENT-SCALE MODEL

Glenn H. Merz
ARO, Inc.

August 1966

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NOTICES

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FOREWORD

The work reported herein was done at the request of NASA, Goddard Space Flight Center, for Fairchild-Hiller Corporation under System 921E.

The results of tests presented 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 test was conducted from May 27 to June 2, 1966, under ARO Project No. VB1686, and the manuscript was submitted for publication on July 14, 1966.

The author wishes to thank L. L. Trimmer, ARO, Inc., for his technical assistance during these tests.

This technical report has been reviewed and is approved.

Donald E. Beitsch	Leonard T. Glaser
Major, USAF	Colonel, USAF
AF Representative, VKF	Director of Test
Directorate of Test	

ABSTRACT

An experimental investigation was conducted to obtain detailed static stability, induced roll and yaw, and roll forcing information on several configurations of a Tomahawk 20-percent-scale model. Tests were conducted at nominal Mach numbers of 6 and 8, free-stream Reynolds numbers of 2.5×10^6 and 5.0×10^6 per foot, angles of attack from -2 to 14 deg, and roll angles from 0 to 90 deg. Selected results are presented to illustrate types and quality of data obtained.

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CONTENTS

ILLUSTRATIONS

TABLE

NOMENCLATURE

C_ℓ	Rolling-moment coefficient, rolling moment/$q_\infty Sd$
C_m	Pitching-moment coefficient, pitching moment*/$q_\infty Sd$
C_N	Normal-force coefficient, normal force*/$q_\infty S$
C_n	Yawing-moment coefficient, yawing moment*/$q_\infty Sd$
C_Y	Side-force coefficient, side force*/$q_\infty S$
ΔC_ℓ	Differential rolling-moment coefficient, $C_{\ell_\alpha} - C_{\ell_{\alpha=0}}$
ΔC_n	Differential yawing-moment coefficient, $C_{n_\alpha} - C_{n_{\alpha=0}}$
ΔC_Y	Differential side-force coefficient, $C_{Y_\alpha} - C_{Y_{\alpha=0}}$
d	Model centerbody diameter, 1.80 in.
M_∞	Free-stream Mach number
P_o	Tunnel stagnation pressure, psia
q_∞	Free-stream dynamic pressure, psia
Re_∞	Free-stream Reynolds number, ft^{-1}
S	Model centerbody cross-sectional area, 2.545 $in.^2$
T_o	Tunnel stagnation temperature, °R
X_{cp}	Center of pressure, $10.539 + C_m/C_N$, diameter from base
α	Angle of attack, deg
ϕ	Roll angle, deg

*Measured in ballistic axis

SECTION I
INTRODUCTION

The purpose of these tests was to obtain detailed static stability, induced roll and yaw, and roll forcing information on a Tomahawk rocket vehicle 20-percent-scale model at Mach 6 and 8. Model centerbody extensions were used to obtain configurations of three different lengths. The medium length model was tested with three nose and three fin configurations. Induced roll and yaw tests were conducted only at Mach 6.

Tests were conducted in the von Kármán Gas Dynamics Facility (VKF) 50-in. hypersonic tunnel (Gas Dynamic Wind Tunnel, Hypersonic (B)) at Mach numbers of 6 and 8, free-stream unit Reynolds numbers of 2.5×10^6 and 5.0×10^6, angles of attack from -2 to 14 deg, and roll angles from 0 to 90 deg.

SECTION II
APPARATUS

2.1 MODELS

Model photographs and details are shown in Figs. 1 and 2. The various configurations consisted of three nose sections, two ogive and one conical; three centerbody extensions; and three sets of flaps, two without cant and one with a 1-deg positive cant.

2.2 WIND TUNNEL

Tunnel B is a 50-in.-diam continuous flow, closed-circuit, variable density wind tunnel equipped with interchangeable Mach 6 and 8 axisymmetric, contoured nozzles. It operates at nominal Mach numbers of 6 and 8 at stagnation pressures from 20 to 280 psia and from 50 to 900 psia, respectively, at temperatures up to 1350°R.

Figure 3 shows the tunnel and its associated equipment. As shown in this figure, the model may be injected into the tunnel for a test run and then retracted from the test section for model changes without interrupting tunnel airflow.

2.3 INSTRUMENTATION

A six-component, moment-type, strain-gage balance was used to measure model forces and moments. Prior to testing, a static calibration was performed using combined loads of the magnitude anticipated during this test. The expected deviations, based on this calibration, are summarized below:

Component	Deviation
Normal Force	±0.15 lb
Pitching Moment	±0.50 in.-lb
Side Force	±0.05 lb
Yawing Moment	±0.15 in.-lb
Rolling Moment	±0.05 in.-lb

The data presented in Section IV were obtained by rolling the model on the balance to obtain ballistic axes data directly; thus, the above-mentioned deviations apply directly to the data.

SECTION III
TEST CONDITIONS

Conditions used during the tests are summarized as follows:

Configuration	M_∞	P_o, psia	T_o, °R	$Re_\infty \times 10^{-6}$
$N_1E_2B_1F_1$	6.06	280	860	5.0
All	6.03	150	860	2.5
All	7.99	545	1310	2.5

SECTION IV
RESULTS AND DISCUSSION

Selected data at Mach 6, zero roll, $Re_\infty/ft = 2.5 \times 10^6$ are presented in Fig. 4 to illustrate types of data obtained for various length models. As would be expected, the center of pressure moved forward on the model as the length was increased. Typical data for the basic configuration are presented in Fig. 5 to illustrate the effect of Mach number on the stability characteristics.

Figure 6 is a summary of the Mach 6 lateral stability data at various roll angles. Canting the fins 1 deg produced a significant change in the rolling-moment data over the entire angle-of-attack range. However, it did not appreciably alter the side-force and yawing-moment data at the lower angles of attack.

The differential lateral stability characteristics are presented in Fig. 7. These coefficients were computed by subtracting the zero angle-of-attack data from the data obtained at various angles of attack. The canted fins had little effect on the incremental forces and moments produced by changing angle of attack.

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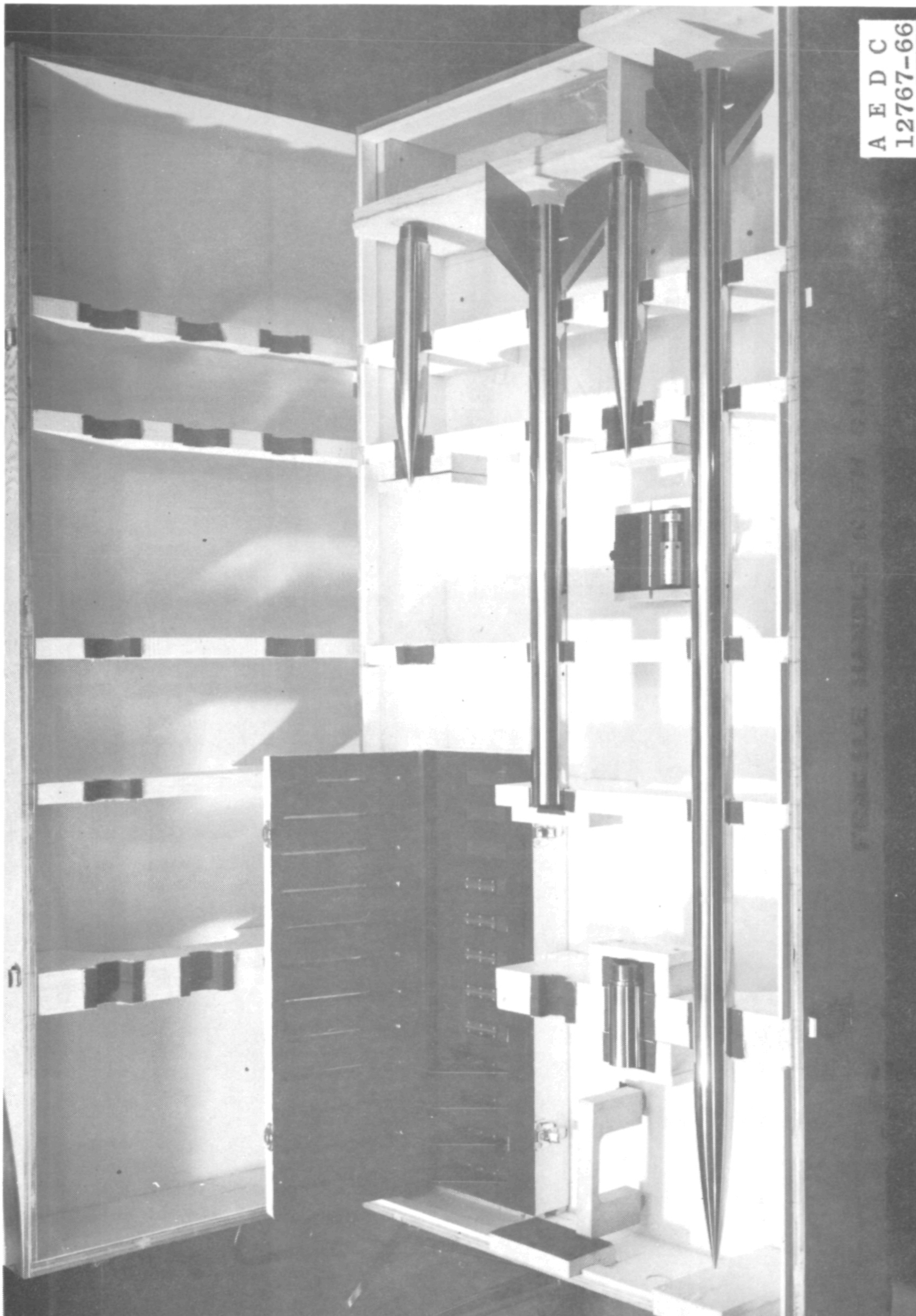
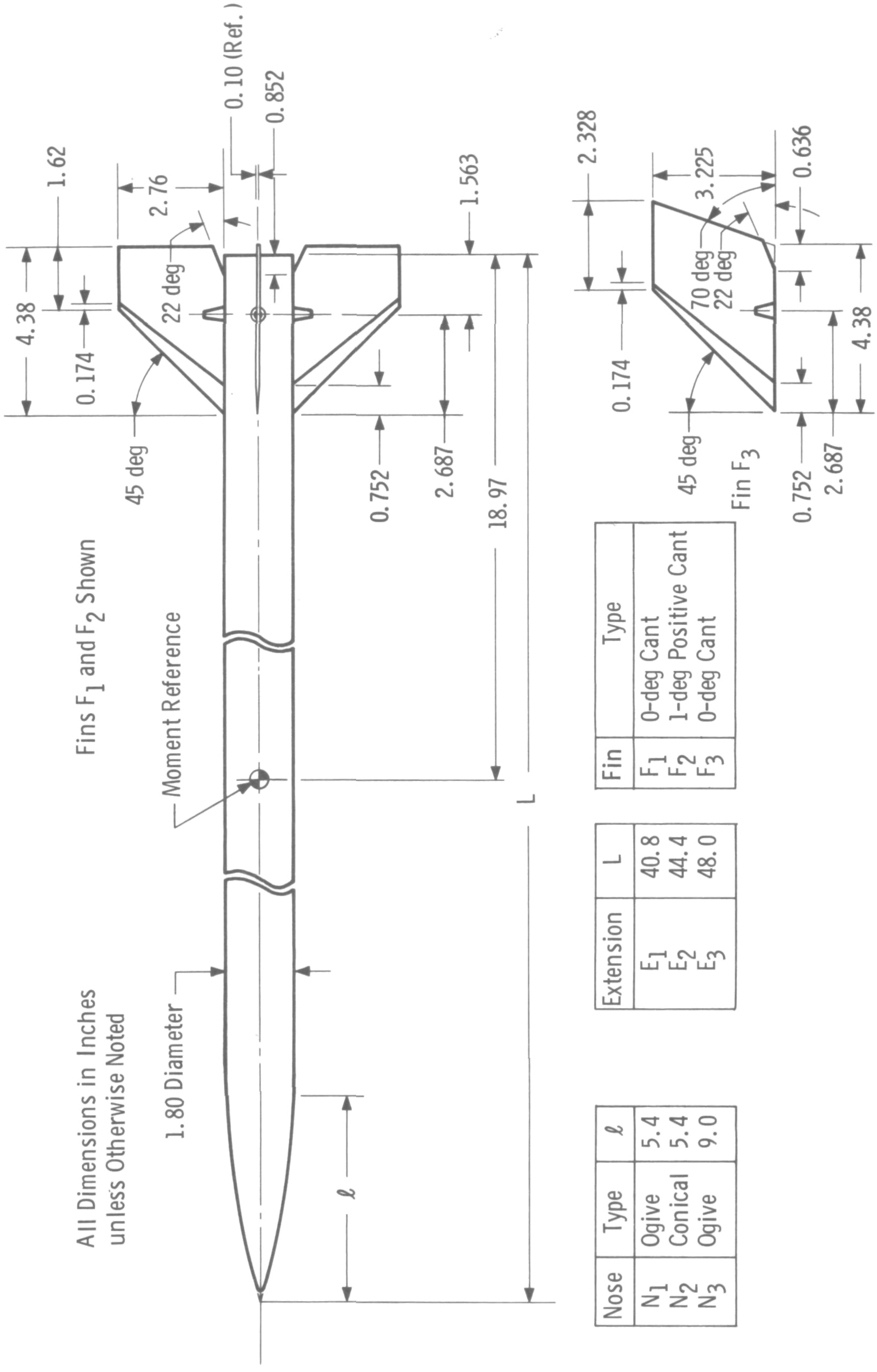


Fig. 1 Model Photograph

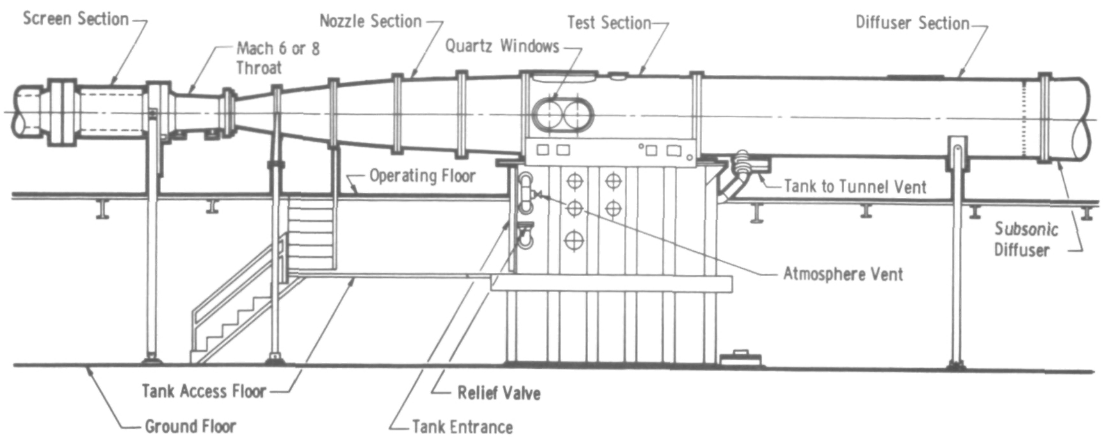


Nose	Type	ℓ
N_1	Ogive	5.4
N_2	Conical	5.4
N_3	Ogive	9.0

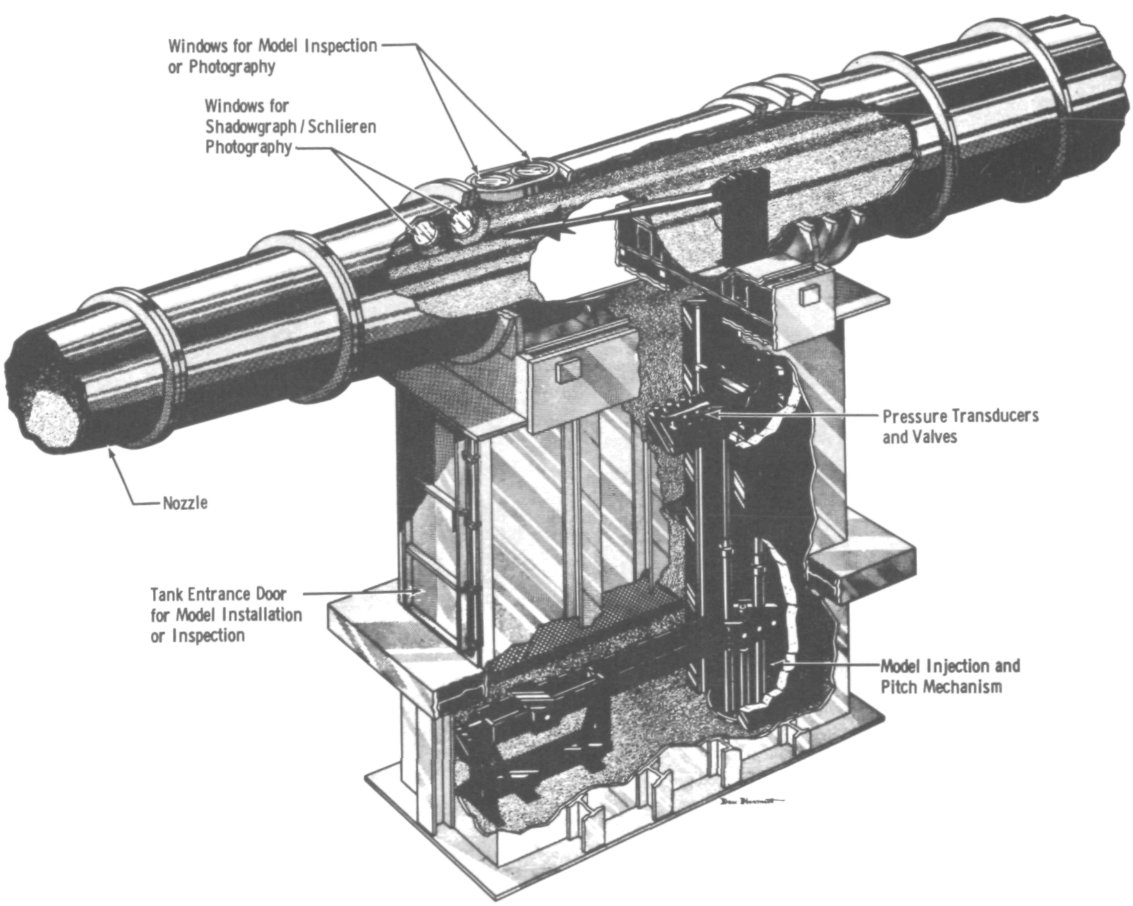
Extension	L
E_1	40.8
E_2	44.4
E_3	48.0

Fin	Type
F_1	0-deg Cant
F_2	1-deg Positive Cant
F_3	0-deg Cant

Fig. 2 Model Details



Tunnel Assembly



Tunnel Test Section

Fig. 3 Tunnel B

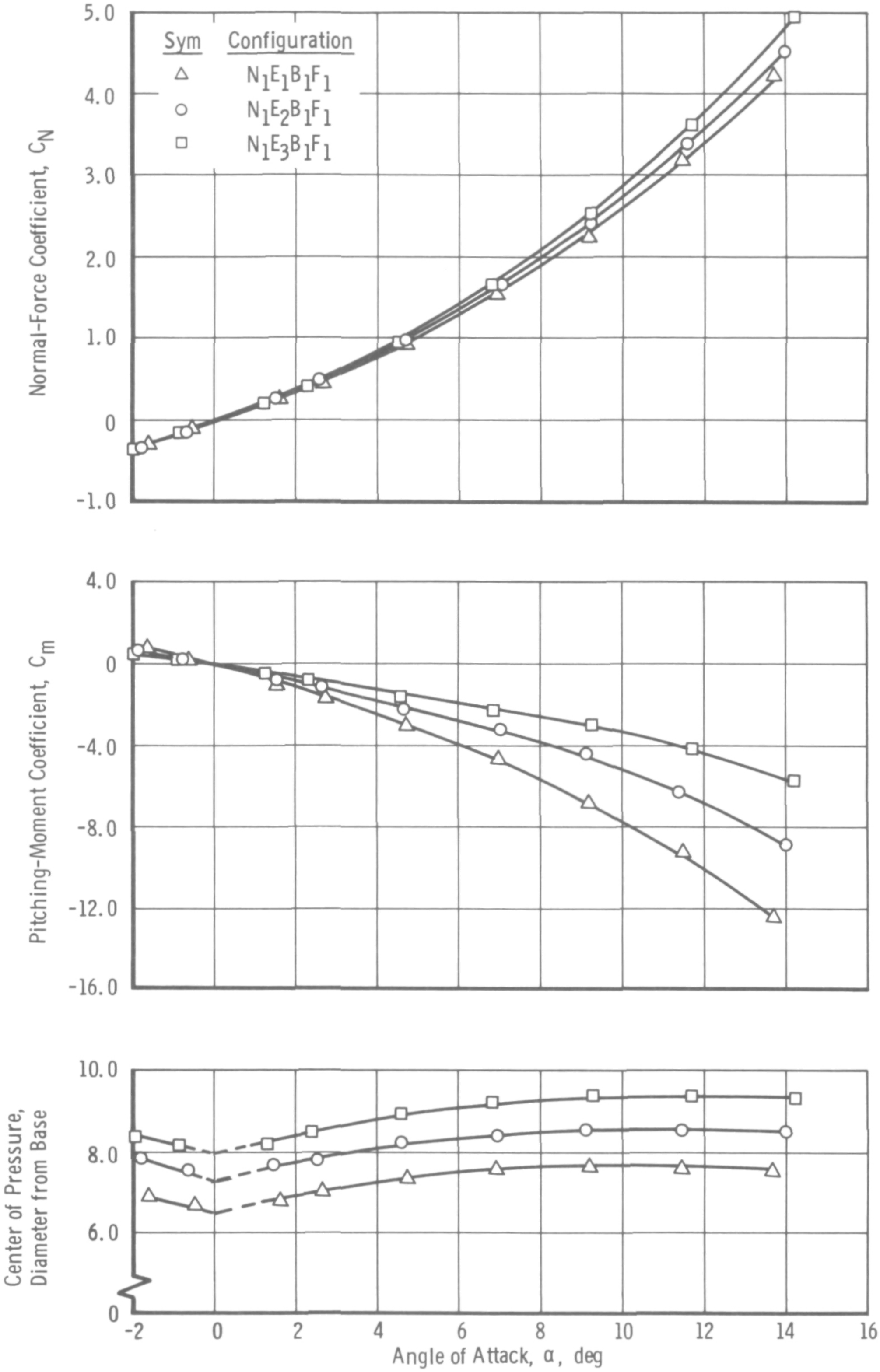


Fig. 4 Effect of Model Length on Longitudinal Stability Characteristics at Mach 6, Zero Roll, Re_∞/ft = 2.5×10^6

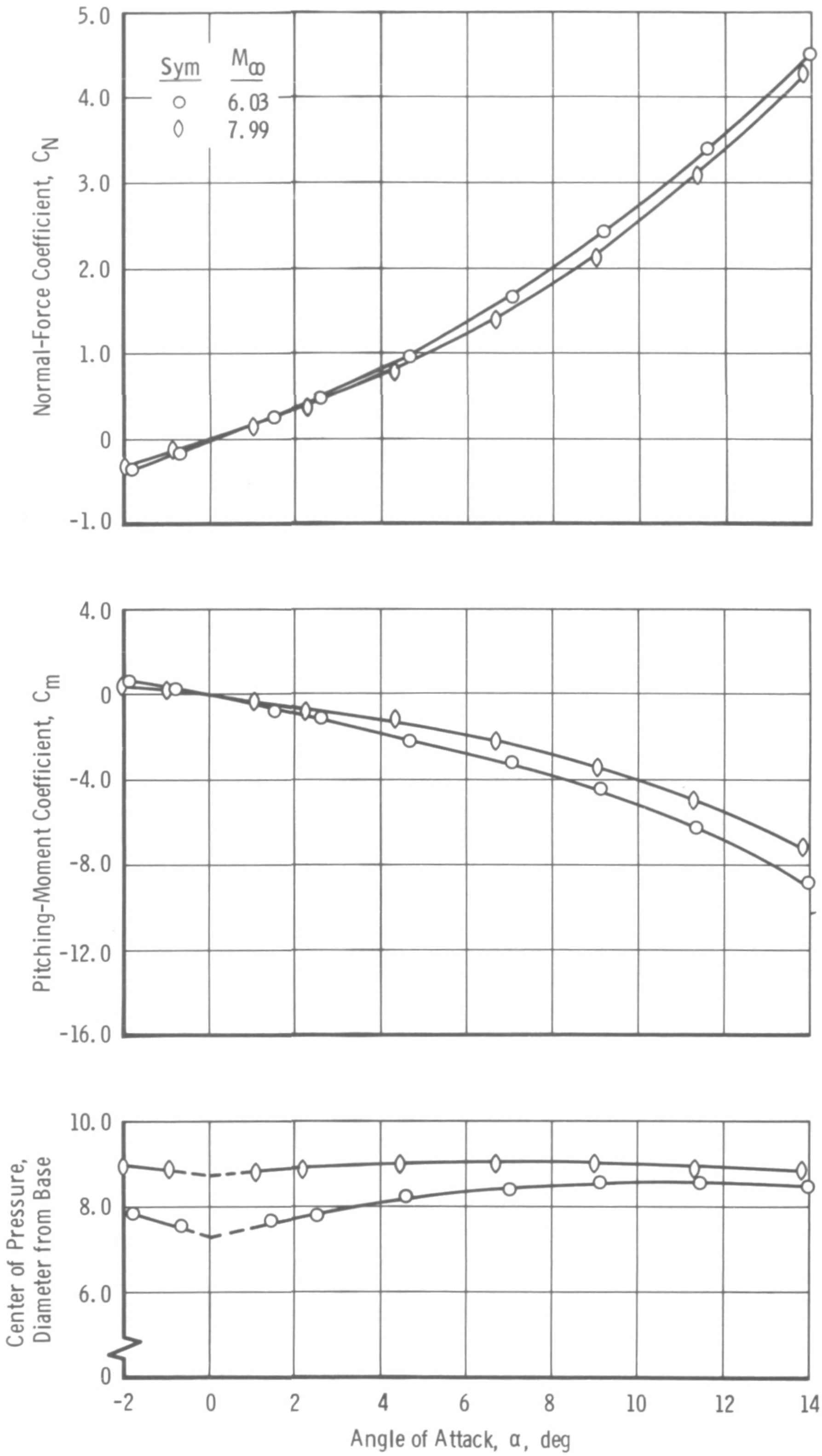


Fig. 5 Effect of Mach Number on Longitudinal Stability Characteristics of Configuration $N_1E_2B_1F_1$, Zero Roll, $Re_\infty/ft = 2.5 \times 10^6$

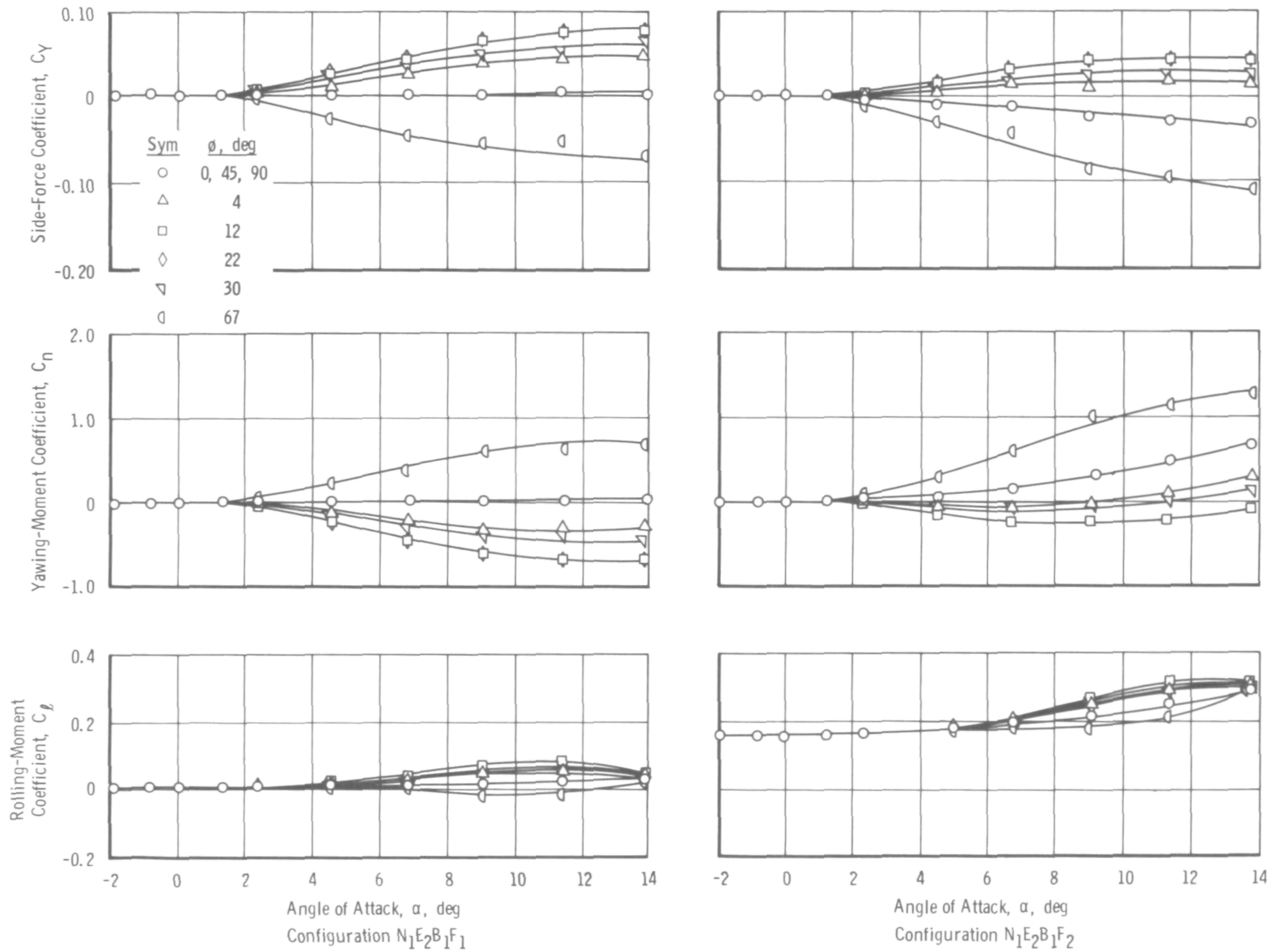


Fig. 6 Effect of Roll Angle on Lateral Stability Characteristics of Configurations $N_1E_2B_1F_1$ and $N_1E_2B_1F_2$ at Mach 6, $Re_\infty/ft = 2.5 \times 10^6$

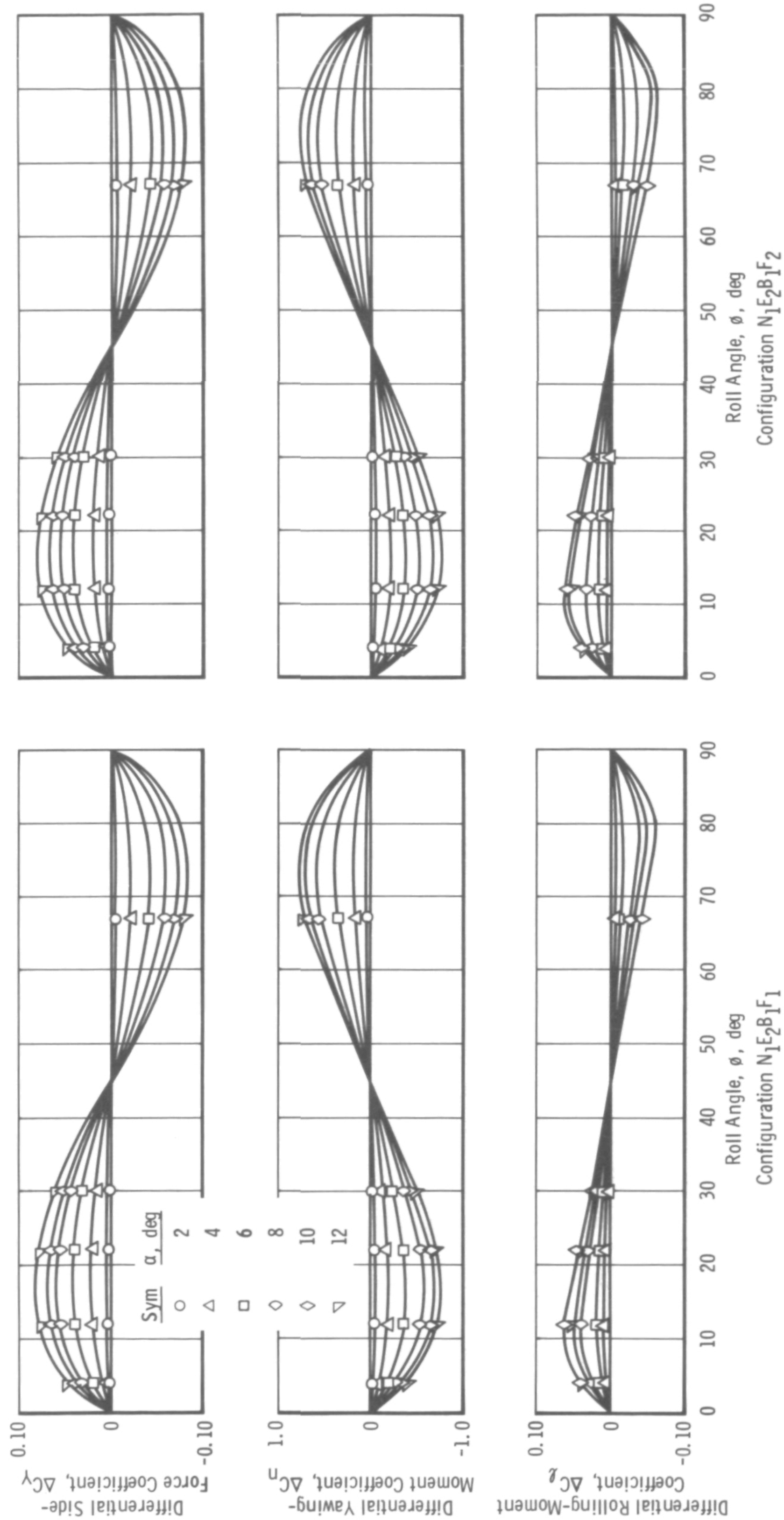


Fig. 7 Effect of Angle of Attack on Lateral Stability Characteristics of Configurations $N_1E_2B_1F_1$ and $N_1E_2B_1F_2$ at Mach 6, $Re_\infty/ft = 2.5 \times 10^6$

TABLE I
TEST SUMMARY

Configuration	M_∞	$Re_\infty \times 10^{-6}$, ft^{-1}	α, deg	ϕ, deg
$N_1E_2B_1F_1$	6.06	5.0	-2 to 14	0 and 12
"	6.03	2.5		0, 4, 12, 22, 30, 45, 67, 90
$N_1E_1B_1F_1$				0
$N_1E_3B_1F_1$				
$N_2E_2B_1F_1$				
$N_3E_2B_1F_1$				0, 4, 12, 22, 30, 45, 67, 90
$N_1E_2B_1F_2$				0
$N_1E_2B_1F_3$				
$N_1E_2B_1$				
$N_1E_1B_1F_1$	7.99			
$N_1E_2B_1F_1$				
$N_1E_3B_1F_1$				
$N_2E_2B_1F_1$				
$N_3E_2B_1F_1$				
$N_1E_2B_1$				

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13. ABSTRACT

An experimental investigation was conducted to obtain detailed static stability, induced roll and yaw, and roll forcing information on several configurations of a Tomahawk 20-percent-scale model. Tests were conducted at nominal Mach numbers of 6 and 8, free-stream Reynolds numbers of 2.5×10^6 and 5.0×10^6 per foot, angles of attack from -2 to 14 deg, and roll angles from 0 to 90 deg. Selected results are presented to illustrate types and quality of data obtained.

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