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EFFECTS OF VARIOUS AFTERBODIES ON THE AERODYNAMIC CHARACTERISTICS OF A GENERAL MISSILE CONFIGURATION

M. L. Homan

ARO, Inc.

March 1969

PROPULSION WIND TUNNEL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

NOTICES

EFFECTS OF VARIOUS AFTERBODIES ON THE AERODYNAMIC CHARACTERISTICS OF A GENERAL MISSILE CONFIGURATION

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ARO, Inc.

FOREWORD

The work reported herein was done at the request of the Army Missile Command (AMC), Redstone Arsenal, Alabama, under Program Area 921C.

The results of the test were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Stystems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract F40600-69-C-0001. The test was conducted from October 30 through December 18, 1968, under ARO Project No. PA1943, and the manuscript was submitted for publication on February 6, 1969.

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This technical report has been reviewed and is approved.

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ABSTRACT

A test was conducted in the Aerodynamic Wind Tunnel, Transonic (1T), to determine the effects of various afterbodies on the aerodynamic characteristics of a generalized missile. Two similar models were tested with various afterbodies consisting of flared, cylindrical, finned cylindrical, and finned flared afterbodies. A primary model was used to evaluate the static longitudinal stability of the complete model, and a similar model with a metric afterbody was used to evaluate the contribution of the afterbody to the static longitudinal stability of the model. Tests were conducted at free-stream Mach numbers from 0.7 to 1.5 for an angle-of-attack range from -4 to 6 deg.

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NOMENCLATURE

C_m	Pitching-moment coefficient about the nose, $M_m/q_\infty SD$
C_N	Normal-force coefficient, $F_N/q_\infty S$
D	Diameter of model, 9.17×10^{-2} ft
F_N	Normal force, positive up, lb
M_m	Pitching moment about the nose, positive nose up, ft/lb
M_∞	Free-stream Mach number
q_∞	Free-stream dynamic pressure, psfa
Re	Reynolds number, per foot
S	Cross-sectional area of basic model (reference area), 6.604×10^{-3} ft^2
α	Model angle of attack, positive nose up, deg

CONFIGURATION NOTATION

A	Cylindrical afterbody (see Fig. 5)
A_{xx}	Flared afterbody (see Fig. 5)
B	Forebody
C_x	Canard (see Fig. 3a)
F_x	Fin (see Fig. 3b)
(x)	Denotes configuration variable

SECTION I
INTRODUCTION

This report presents the results of wind tunnel tests which were made to determine the overall static stability of missiles with various afterbodies and to determine the contribution of the afterbody configurations to this stability. Force data were obtained on two similar models: one model was constructed so that only a small portion of its afterbody was attached to an internal strain-gage balance to measure afterbody forces and moments, and the other model had an internal strain-gage balance to measure total model forces and moments. Tests were made over the Mach range of 0.7 to 1.5 for an angle-of-attack range of -4 to 6 deg.

SECTION II
APPARATUS

2.1 WIND TUNNEL

The Aerodynamic Wind Tunnel, Transonic (1T), is an open-circuit, continuous flow wind tunnel capable of operation over a Mach number range from 0.50 to 1.50. The test section is 12 in. square and 37.5 in. long and has four perforated walls.

A detailed description of the tunnel, its equipment, and calibration may be found in Refs. 1 and 2. Details of the test section wall configuration and location of the model in the tunnel are shown in Fig. 1. Typical model installations in the tunnel are shown in Fig. 2.

2.2 TEST ARTICLE

Two similar models were tested and will be referred to hereafter as primary and floated-afterbody models. The primary model was instrumented to measure overall or complete model forces and moments. The floated-afterbody model was instrumented to measure only the forces and moments on the afterbody in the presence of the forebody. Interchangeable canards and fins were provided so that rapid configuration changes could be made. Details of the canards and fins are presented in Fig. 3. A 0.20-in. band of No. 80 transition grit was located 1.00 in. aft of the model nose throughout the test.

2.2.1 Primary Model

The primary model consisted of an ogive-cylinder forebody and a flared or cylindrical afterbody. The model was 13.20 in. in length. The primary model was attached to a six-component balance which measured the total model forces and moments. Interchangeable flared and cylindrical afterbodies were provided to which fins could be attached. Primary model and flared- and cylindrical-afterbody details are presented in Figs. 4 and 5.

2.2.2 Floated-Afterbody Model

The floated-afterbody model consisted of an ogive-cylinder model that was 13.20 in. in length with a base diameter of 1.10 in. The fuselage section of the model consisted of two parts: the ogive-cylinder forebody to which the canards were attached and a cylindrical afterbody to which the fins were attached. The afterbody was connected to a six-component, internal strain-gage balance which measured forces and moments on the afterbody and fins.

Floated-afterbody model details are presented in Fig. 6.

Schematics of various configurations tested are shown in Fig. 7.

2.3 INSTRUMENTATION

An internally-mounted, six-component, strain-gage balance was used to measure either model or afterbody forces and moments. Outputs from the balance were digitized and code punched on paper tape for off-line data reduction by a Raytheon 520 computer.

SECTION III
TEST DESCRIPTION

3.1 PROCEDURE

Data were obtained while holding Mach number constant and varying angle of attack. The tunnel stagnation pressure ranged from 2750 to 2900 psf, and the total temperature varied from 160 to 220°F. The Reynolds number variation is presented in Fig. 8.

3.2 DATA REDUCTION

The force and moment data were reduced to coefficient form in the body axis system. Pitching and yawing moments were referenced to the model nose. All force and moment coefficients are based on model diameter and cross-sectional area. Although axial and side forces and yawing moments were measured, they are not pertinent for analysis of the model stability in pitch at zero sideslip and consequently are not presented.

3.3 PRECISION OF MEASUREMENTS

An estimate of the accuracy of measurements is presented in the following table:

Primary Model

	$\pm M_\infty$	$\pm C_m$	$\pm C_N$
M < 1	0.003	0.016	0.010
M > 1	0.008	0.008	0.006

Floated Afterbody Model

	$\pm M_\infty$	$\pm C_m$	$\pm C_N$
M < 1	0.003	0.011	0.005
M > 1	0.008	0.005	0.003

SECTION IV
RESULTS AND DISCUSSION

The results of an experimental investigation to determine the effects of various afterbodies on the static-stability characteristics of missiles in the transonic flow regime are presented in two sections. The first section presents the effects of flared and finned afterbodies on the static-longitudinal stability characteristics of the primary model. The second section presents comparisons of the static-longitudinal stability characteristics of the primary and the floated-afterbody models.

4.1 STATIC-STABILITY CHARACTERISTICS OF THE PRIMARY MODEL

The static longitudinal stability characteristics of the primary model can be interpreted from the slope of the pitching-moment versus normal-force coefficient plots. For the flared-afterbody models, the test results at supersonic Mach numbers only were of interest and are presented.

The static-stability characteristics of the primary model with various flared afterbodies, Fig. 9, show that the addition of the flared afterbody improves the static-longitudinal stability. Varying the afterbody flare angle, for a constant diameter base, produced negligible effect on the static longitudinal stability of the primary model. As shown in Fig. 10, increasing the base diameter of the flared afterbody increases the static longitudinal stability as would be expected.

The effect of the fins and canards on the static stability of the primary model with flared afterbodies was investigated for several afterbody flare angles and base diameters. The trends observed from these tests were similar for all the flared-afterbody configurations tested and, therefore, only the data for the flared-afterbody configuration A_{L1} are presented to show the effect of fins and canards on the longitudinal stability.

As shown in Fig. 11, the addition of fins to the flared afterbody resulted in an increase in the longitudinal stability. Increasing the fin span also resulted in an increase in the longitudinal stability; however, since the fin chord was held constant, the increase in stability resulted primarily from the increase in lift as a result of the larger fin area and increased aspect ratio. As shown in Fig. 12, the addition of canards (see Fig. 4) to the primary model with a flared afterbody resulted in an increase in the longitudinal stability. The center of pressure of the canards is aft of that for the primary model with a flared afterbody. Increasing the canard span also resulted in an increase in the longitudinal stability.

Presented in Fig. 13 are the static longitudinal stability characteristics of the primary model with canards and finned flared afterbody. The addition of canards to the primary model with a finned flared afterbody resulted in a decrease in stability, and increasing the canard span resulted in a further decrease in the stability.

As shown in Fig. 14, increasing the fin span of the primary model with canards and a finned flared afterbody increases the longitudinal stability. Presented in Fig. 15 are the static longitudinal-stability characteristics of build up of the primary model. The trends are as would be expected for the model build up and the contributions of the various components can be determined from the data.

4.2 COMPARISON OF FLOATED-AFTERBODY MODEL AND PRIMARY MODEL

The primary model and the floated-afterbody model were tested from Mach numbers of 0.7 to 1.5 and results for only selected Mach numbers are presented.

Static longitudinal-stability characteristics of the primary model with fins and the finned floated afterbody are presented in Figs. 16 and 17. Increasing the fin span increased the magnitude of the pitching-moment and normal-force coefficient. Increasing the fin span had little or no effect on the center-of-pressure location of the floated afterbody.

Static longitudinal-stability characteristics of the primary model with canards and fins and the finned floated afterbody with canards are presented in Figs. 18 and 19. As shown in Fig. 19, the addition of canards ahead of the finned floated afterbody resulted in negligible changes in the longitudinal stability of the finned floated afterbody. The destabilizing effect of the forebody can readily be seen in Fig. 19 by comparison of primary-model and floated-afterbody data.

SECTION V
CONCLUSIONS

The results of an investigation of the effects of various afterbodies on the aerodynamic characteristics of a general missile configuration at Mach numbers from 0.7 to 1.5 for angles of attack from -4 to 6 deg produced the following conclusions:

1. Flared afterbodies improved the static longitudinal stability of the primary model.
2. Increasing the base diameter of the flared afterbodies increased the static longitudinal stability of the primary model.
3. Increasing the canard span decreased the static longitudinal stability of the finned floated afterbody.

REFERENCES

1. Test Facilities Handbook (7th Edition). "Propulsion Wind Tunnel Facility, Vol. 5." Arnold Engineering Development Center, July 1968.

2. Jackson, F. M. and Sloan, E. H. "Calibration of the AEDC-PWT 1-Foot Transonic Tunnel." AEDC-TR-68-4 (AD827912) February 1968.

APPENDIX
ILLUSTRATIONS

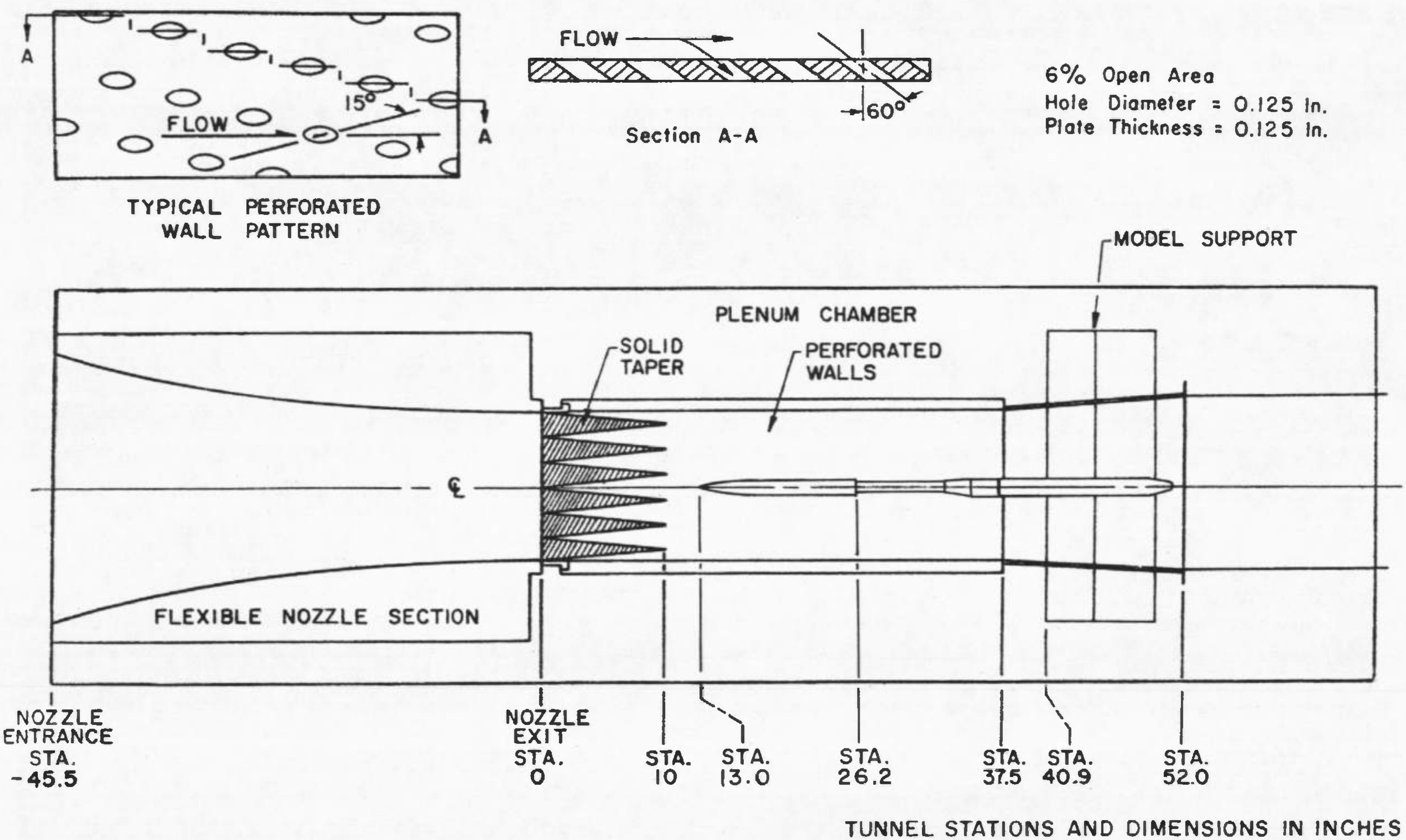
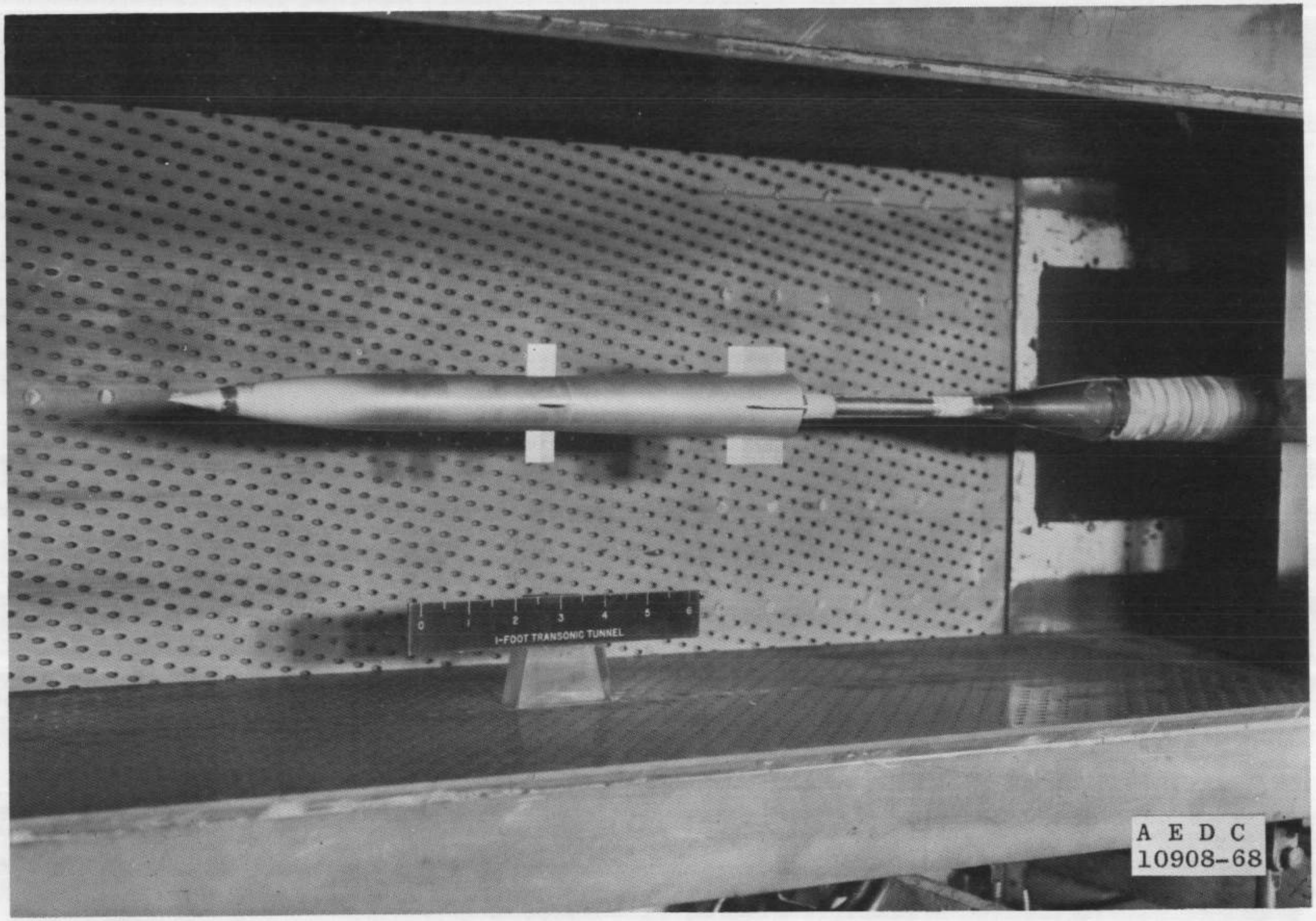
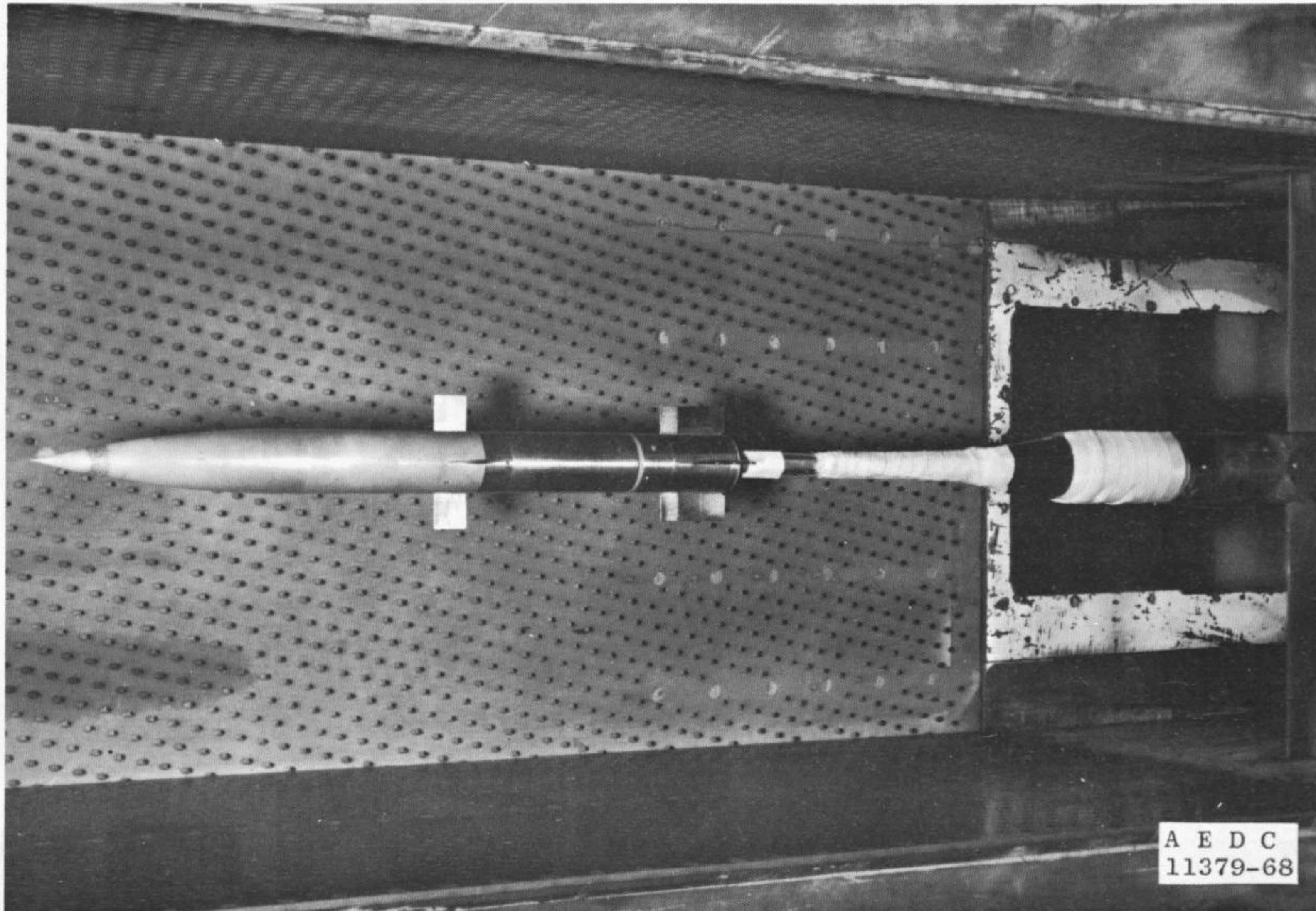


Fig. 1 Location of Model in Test Section

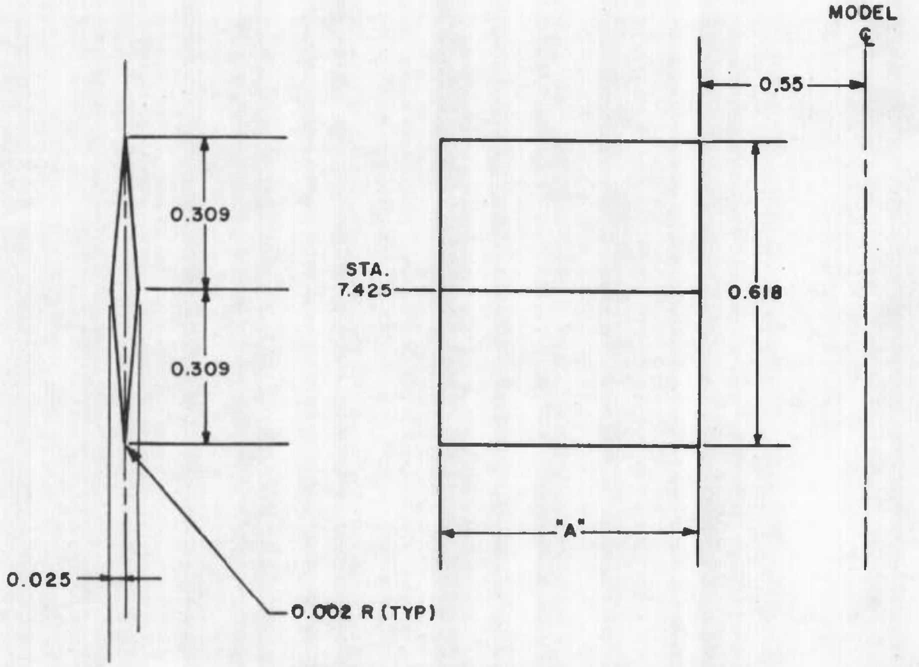


a. Primary Model

Fig. 2 Photograph of Model Installed in Test Section



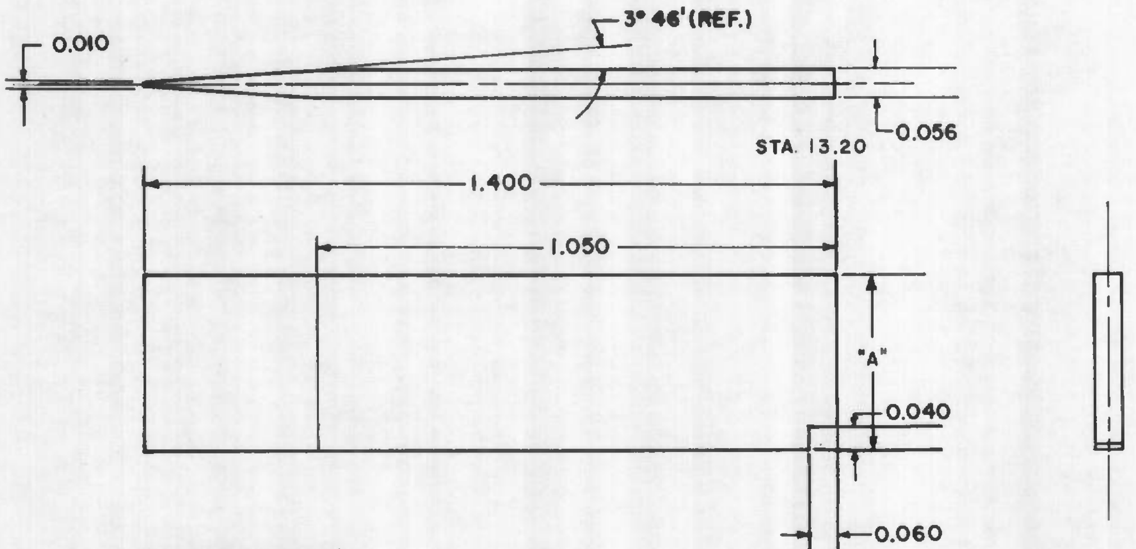
b. Floated-Afterbody Model
Fig. 2 Concluded



CONFIG.	"A"
C_1	0.512
C_2	0.718

NOTE: MODEL STATION AND DIMENSIONS ARE IN INCHES

a. Canard



CONFIG.	"A"
F_1	0.350
F_2	0.525

NOTE: MODEL STATION AND DIMENSIONS ARE IN INCHES

b. Fin

Fig. 3 Canard and Fin Details

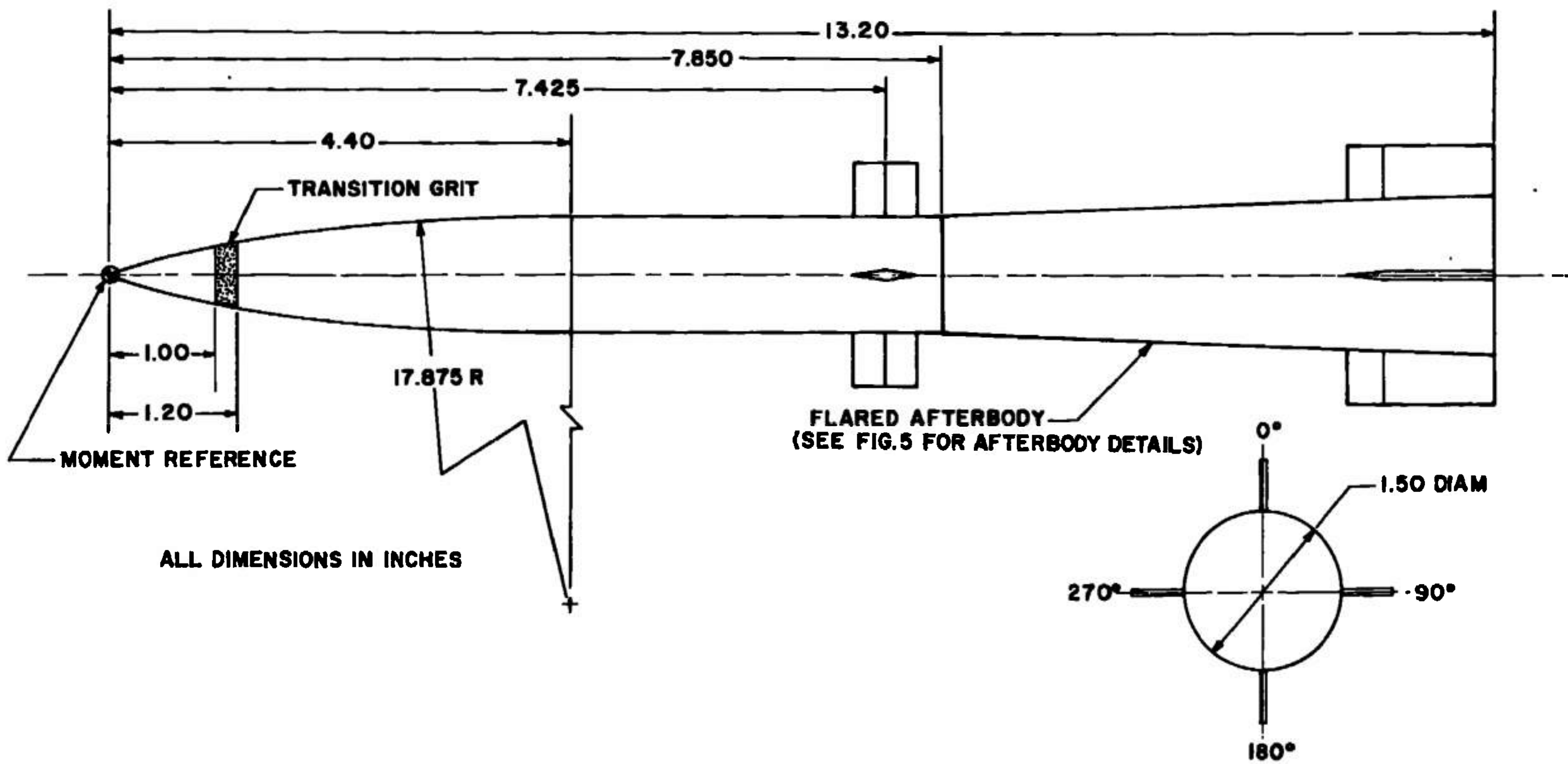
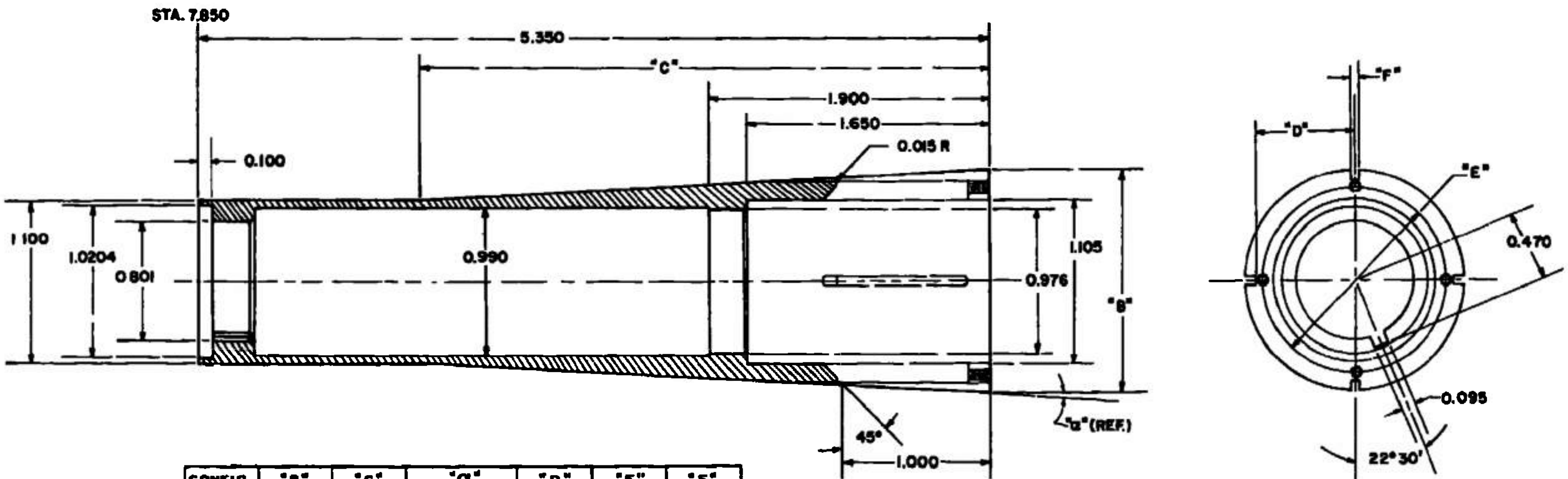


Fig. 4 Primary Model Details



CONFIG.	"B" DIAM	"C"	"α"	"D"	"E" DIAM	"F"
A	1.100	5.350	0°	—	—	—
A_{S1}	1.264	2.200	2° 8' 36"	—	—	—
A_{M1}	1.264	3.850	1° 13' 22"	—	—	—
A_{L1}	1.264	5.350	0° 52' 46"	0.610	1.139	0.0562
A_{S3}	1.500	2.200	5° 11' 40"	—	—	—
A_{M3}	1.500	3.850	2° 58' 24"	—	—	—
A_{L3}	1.500	5.350	2° 8' 36"	0.698	1.313	0.0562

NOTE: MODEL STATION AND ALL DIMENSIONS ARE IN INCHES

Fig. 5 Flared-Afterbody Details

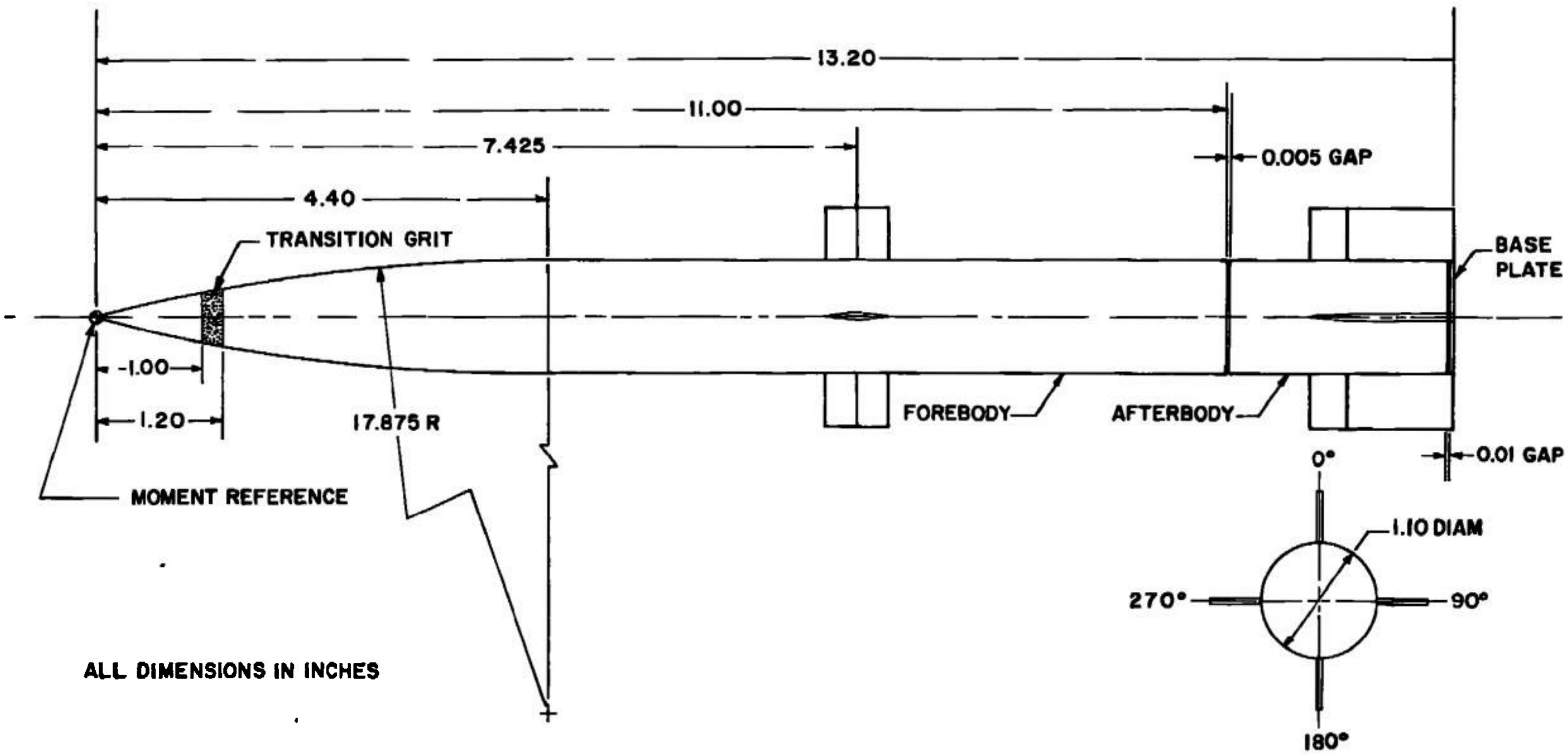


Fig. 6 Floated-Afterbody Model Details

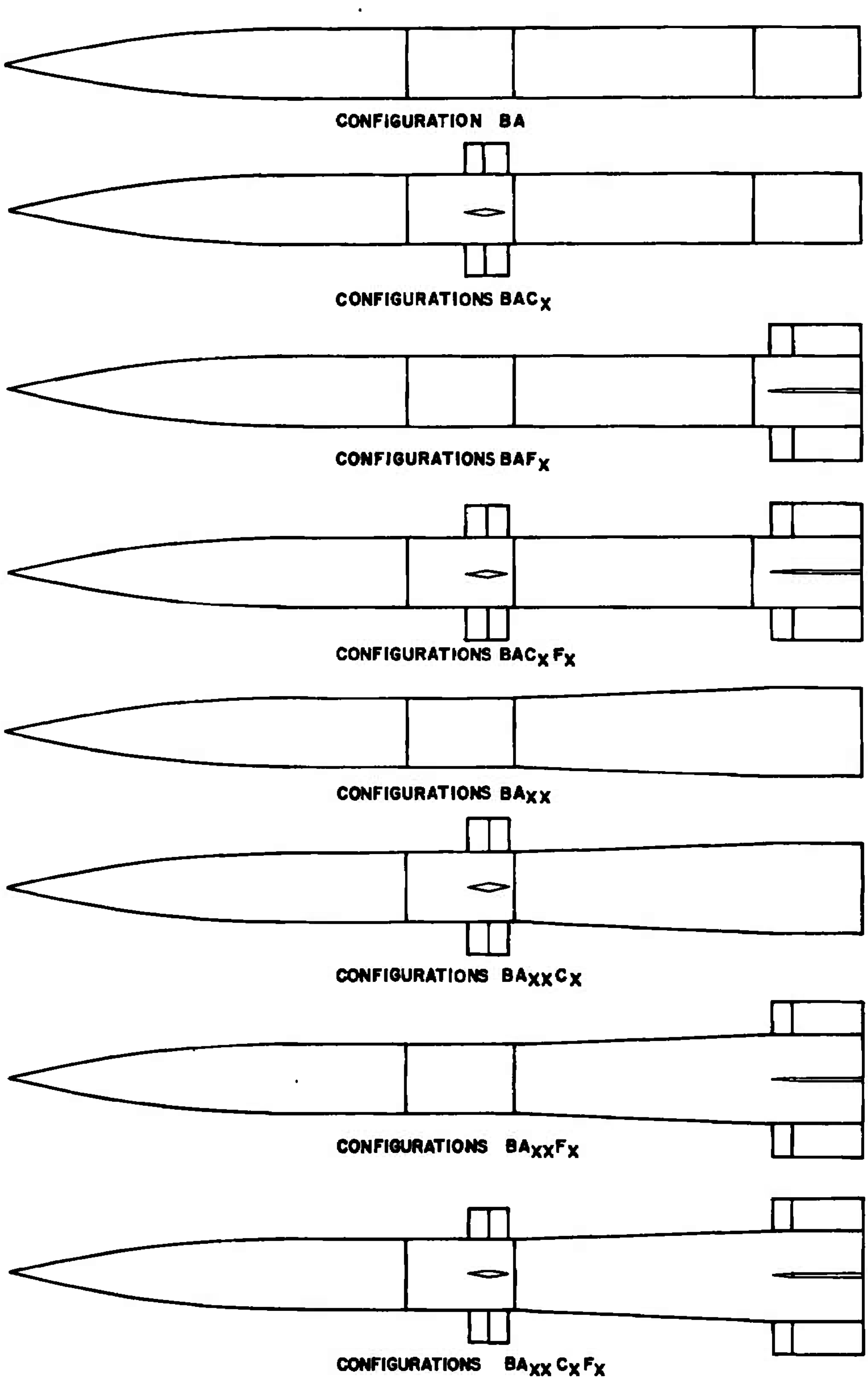


Fig. 7 Schematic of Various Configurations Tested

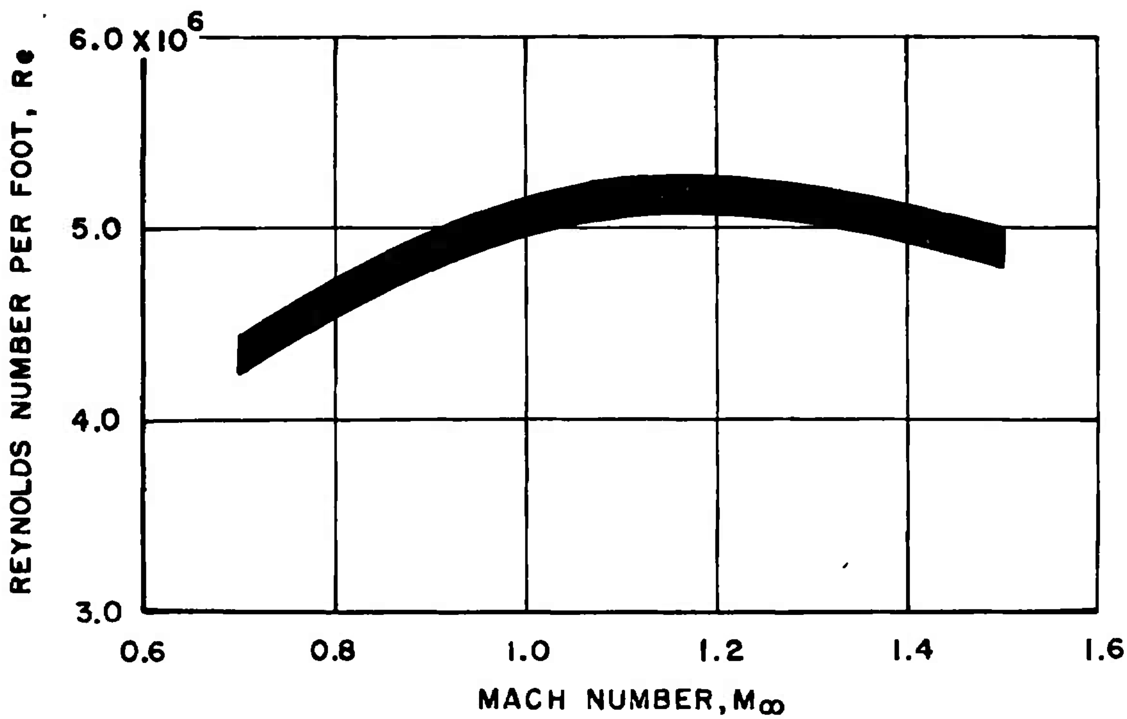


Fig. 8 Variation of Test Reynolds Number with Mach Number

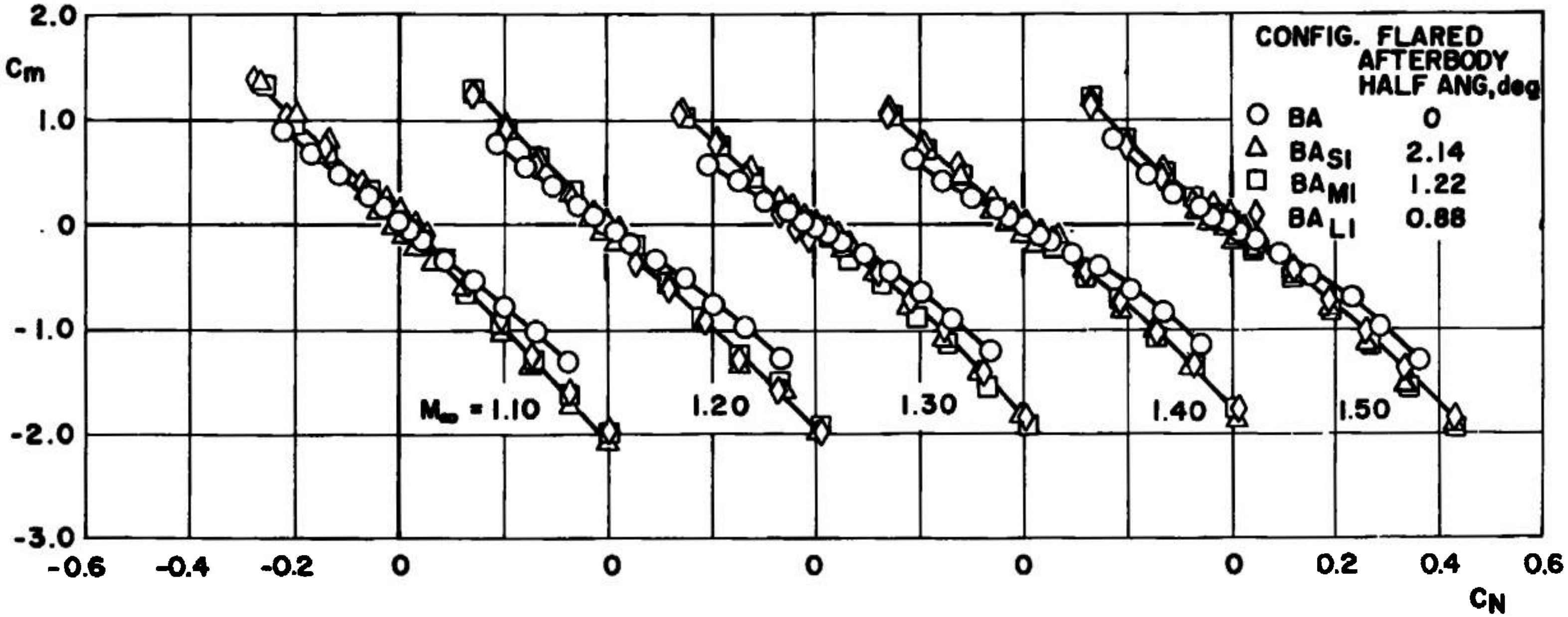


Fig. 9 Static Longitudinal Stability Characteristics of the Primary Model with Flared Afterbody; Constant Base Diameter

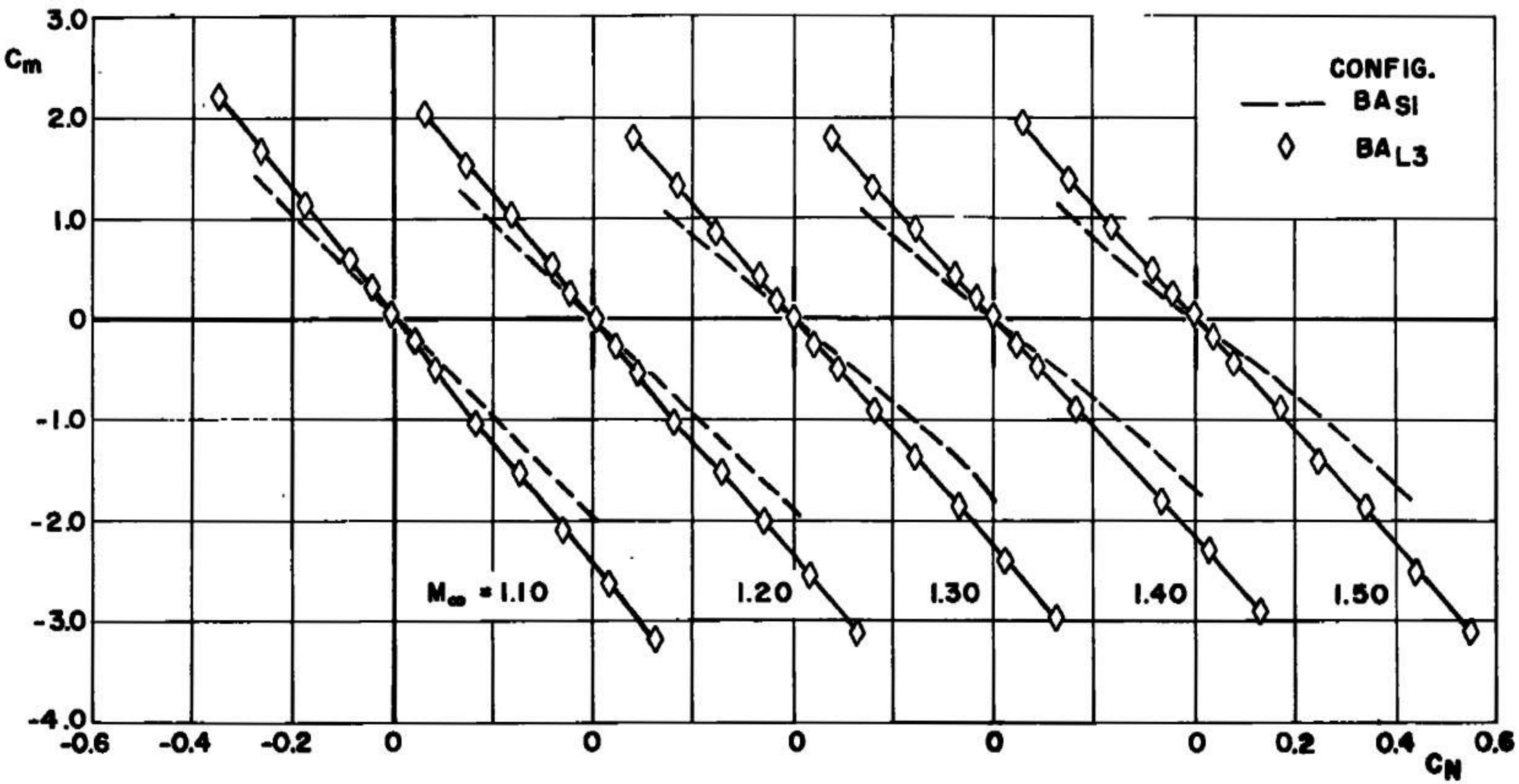


Fig. 10 Static Longitudinal Stability Characteristics of the Primary Model with Flared Afterbody; Variable Base Diameter

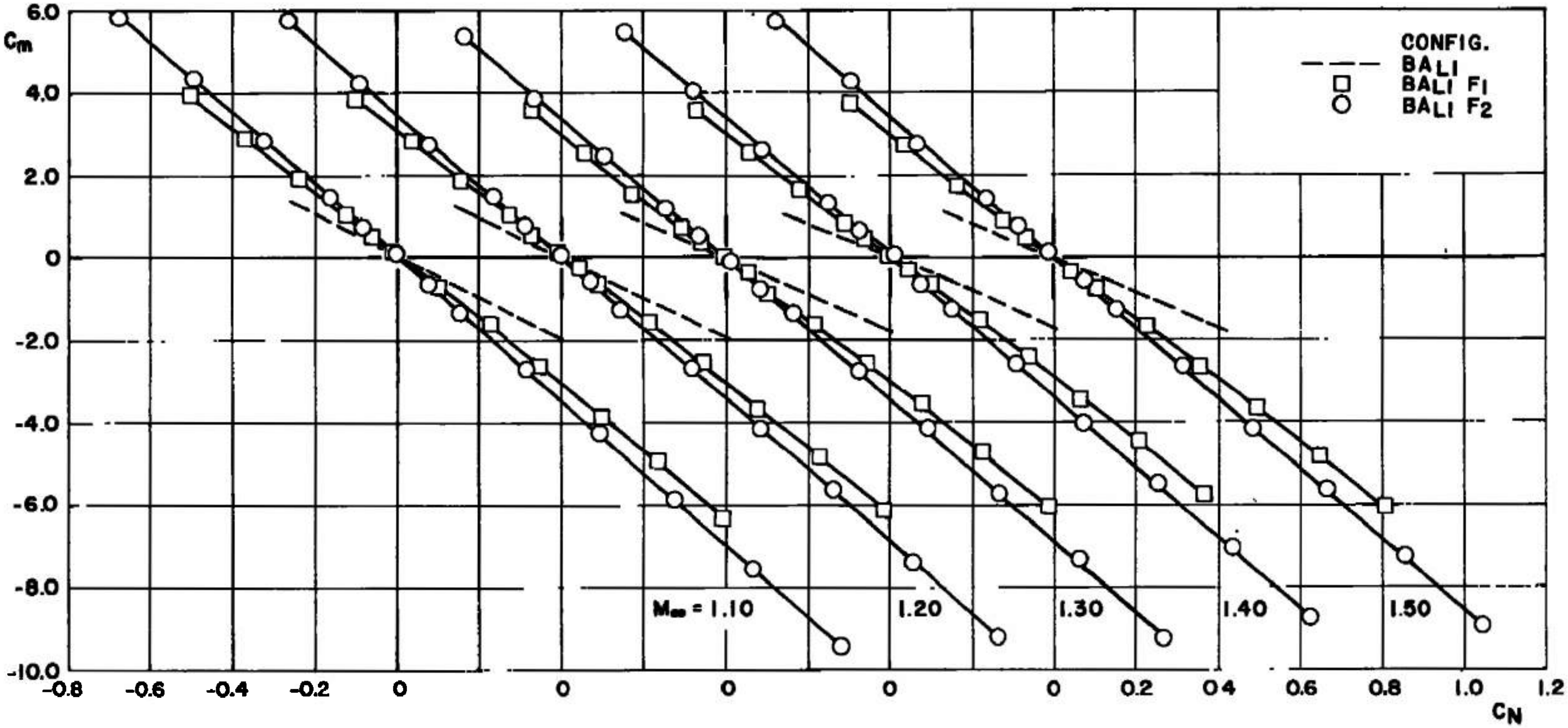


Fig. 11 Static Longitudinal Stability Characteristics of the Primary Model with Fins on a Flared Afterbody

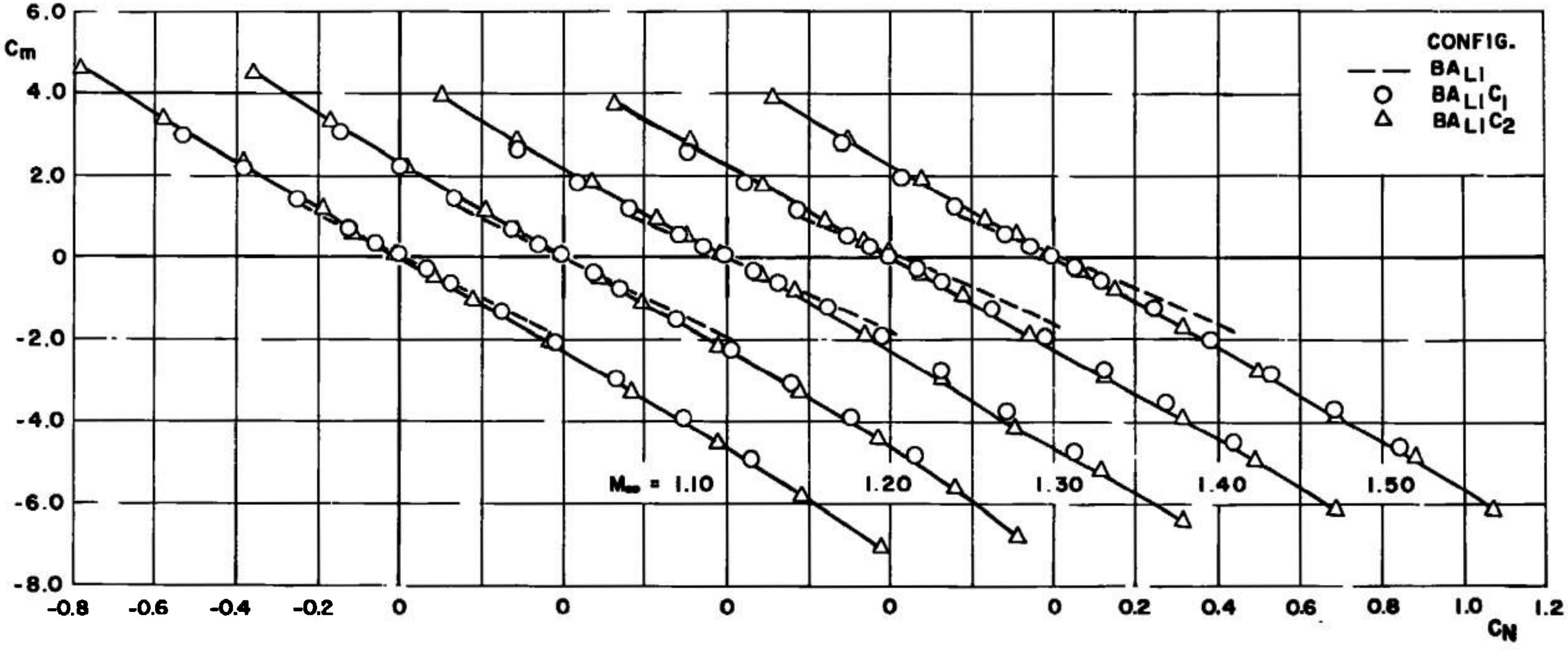


Fig. 12 Static Longitudinal Stability Characteristics of the Primary Model with Canards and a Flared Afterbody

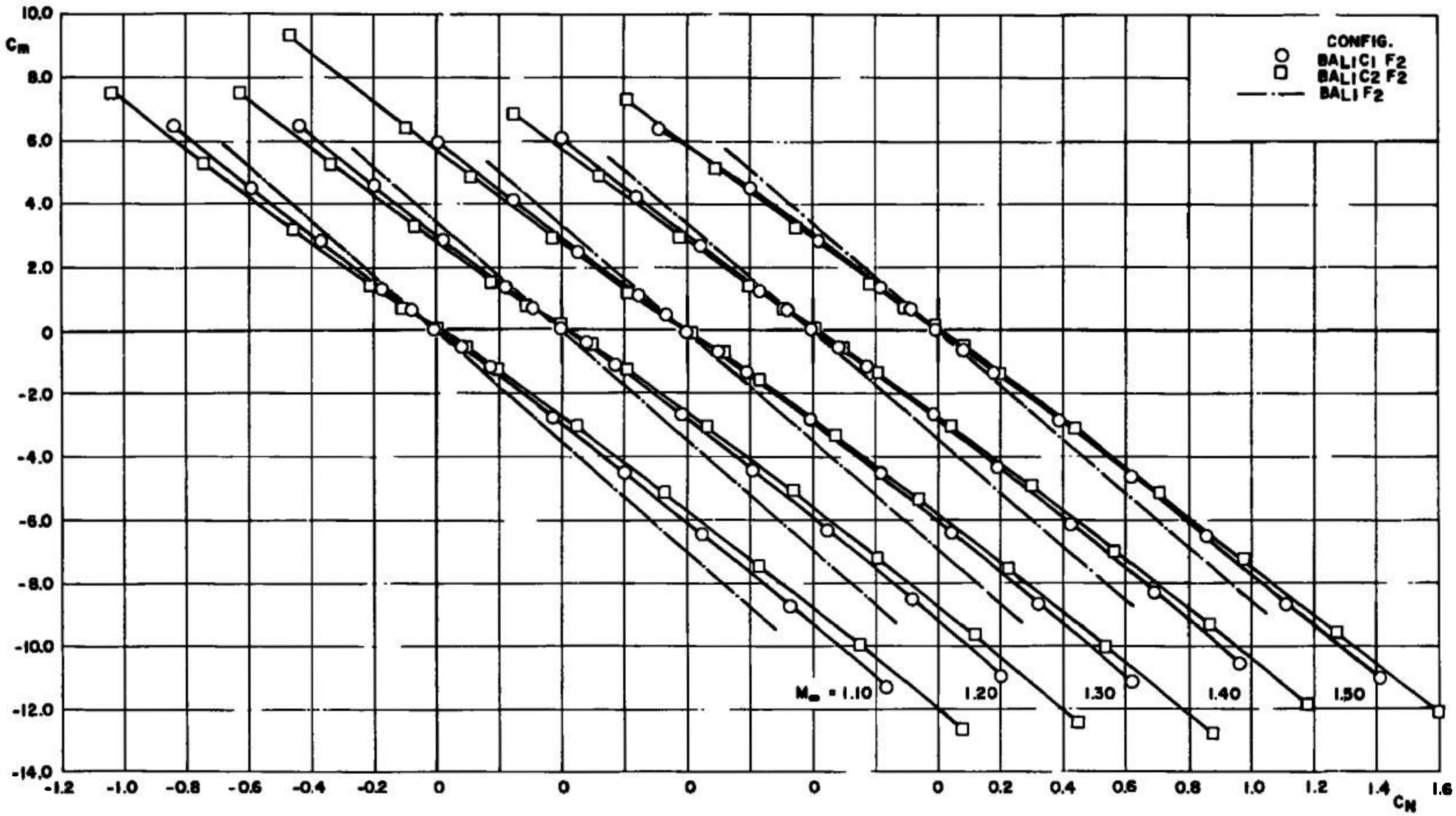


Fig. 13 Static Longitudinal Stability Characteristics of the Primary Model with Canards and Finned Flared Afterbody

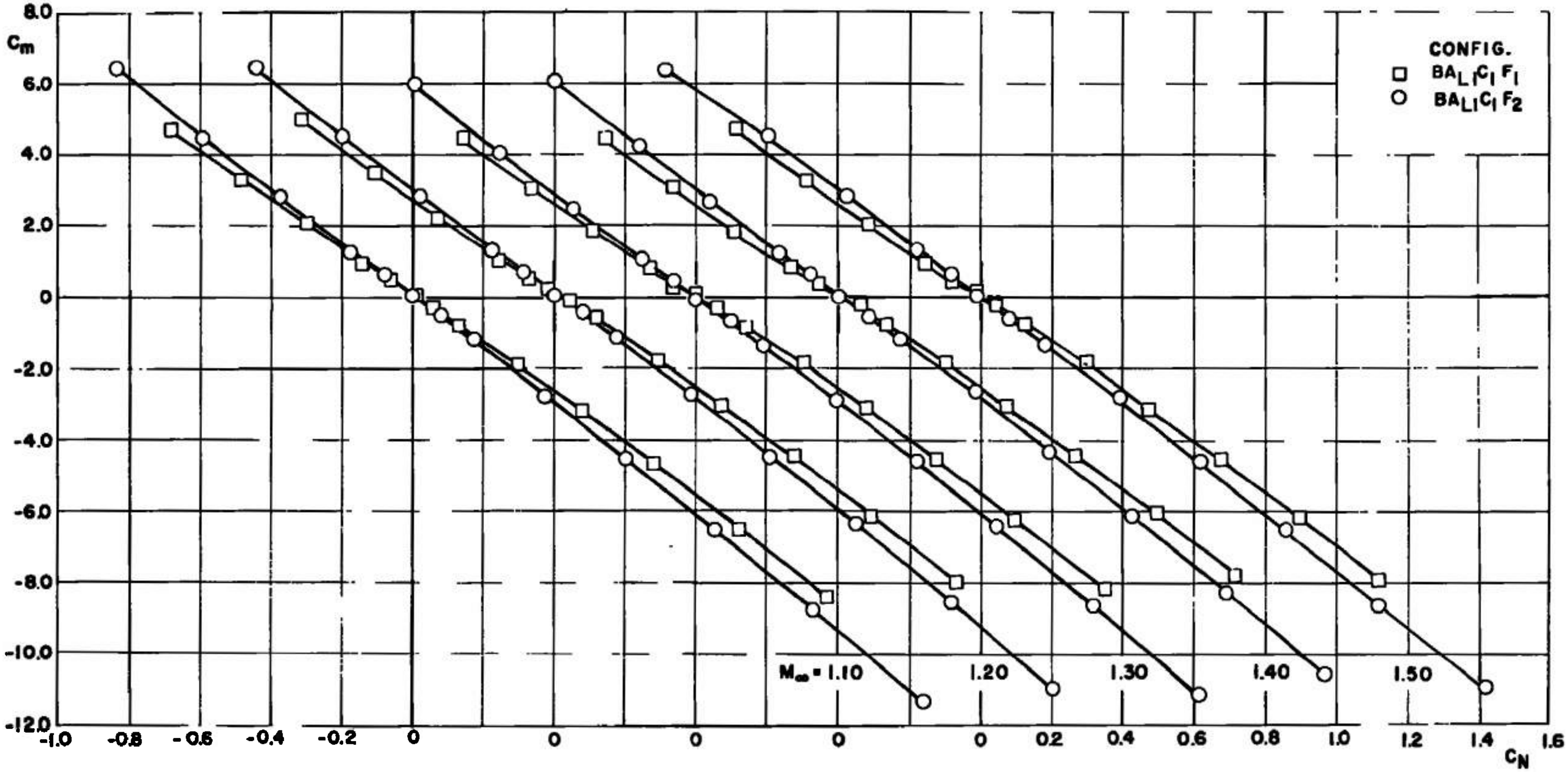


Fig. 14 Static Longitudinal Stability Characteristics of the Primary Model with Canards and Fins on a Flared Afterbody

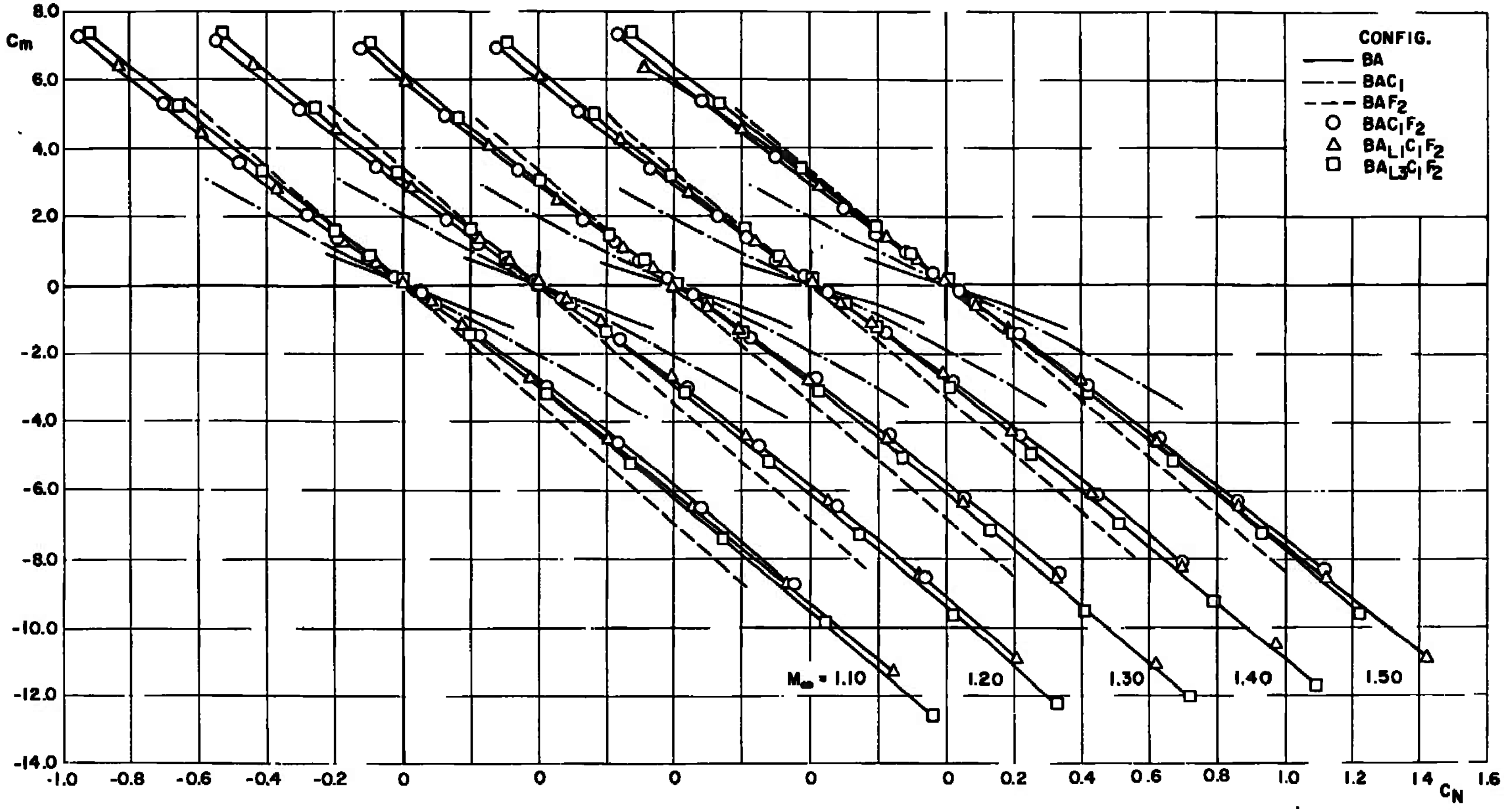


Fig. 15 Static Longitudinal Stability Characteristics of the Primary Composite Model with a Flared Afterbody

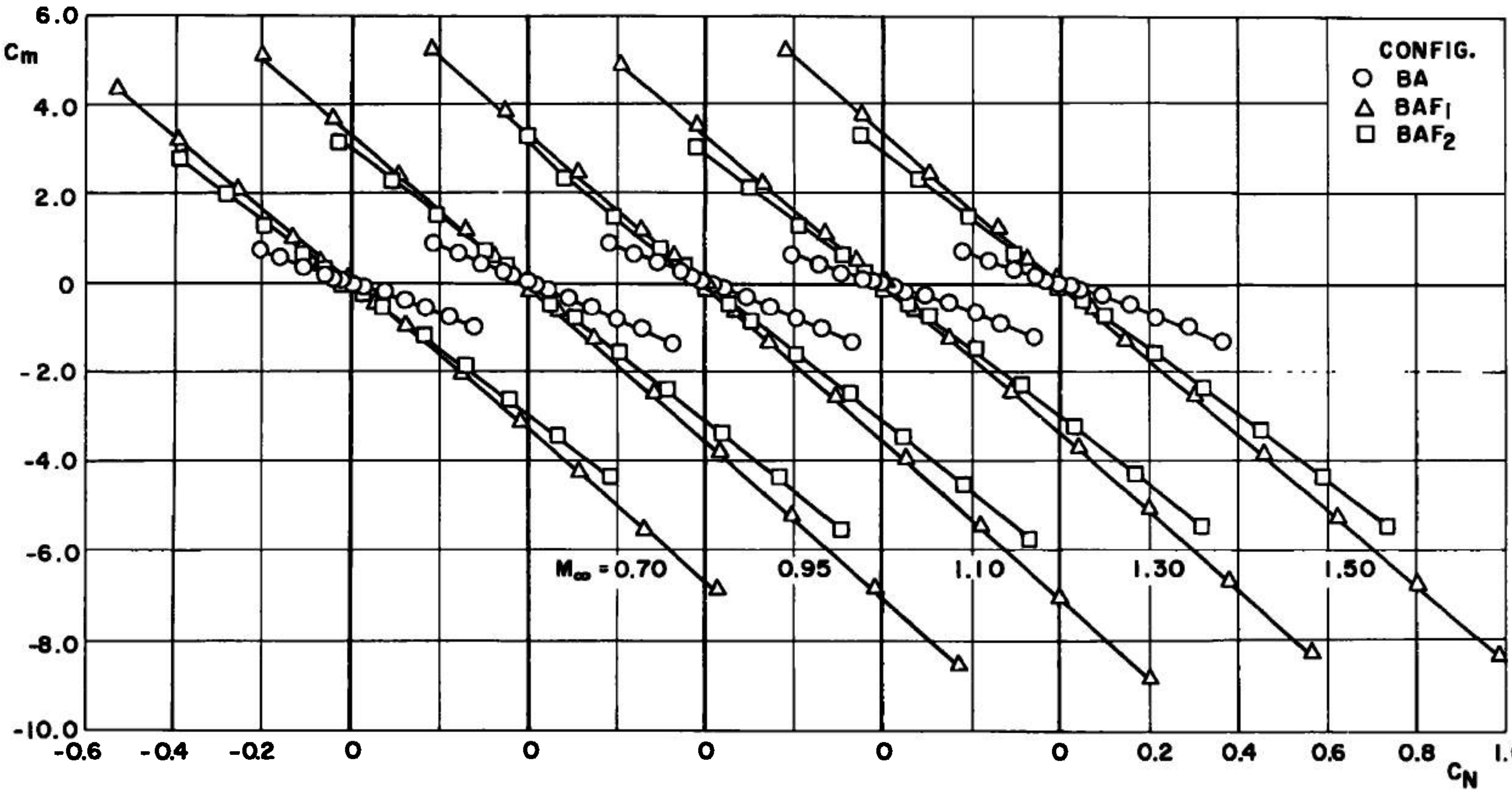


Fig. 16 Static Longitudinal Stability Characteristics of the Primary Model with Fins

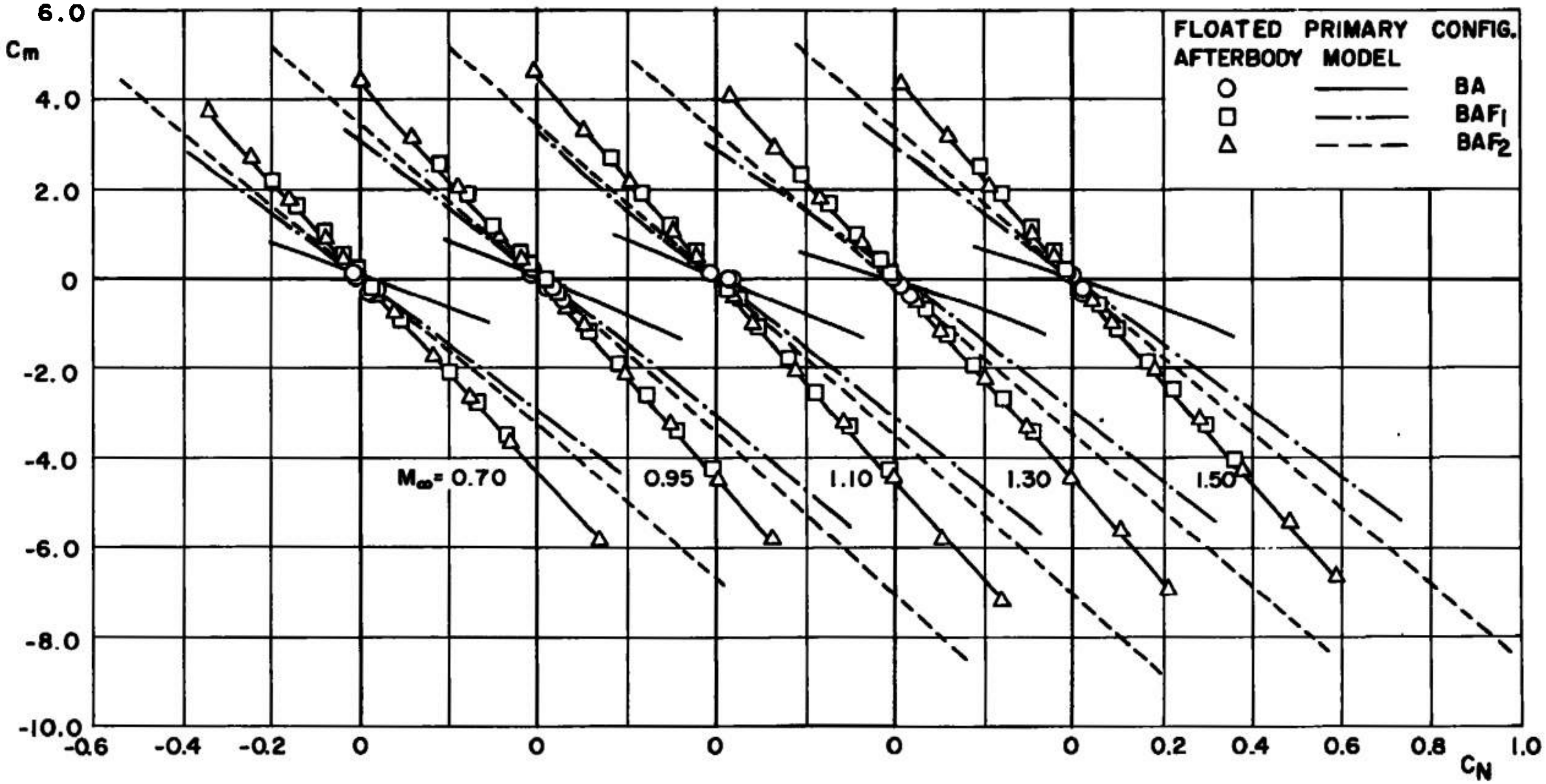


Fig. 17 Static Longitudinal Stability Contribution of the Afterbody with Fins in the Presence of the Forebody

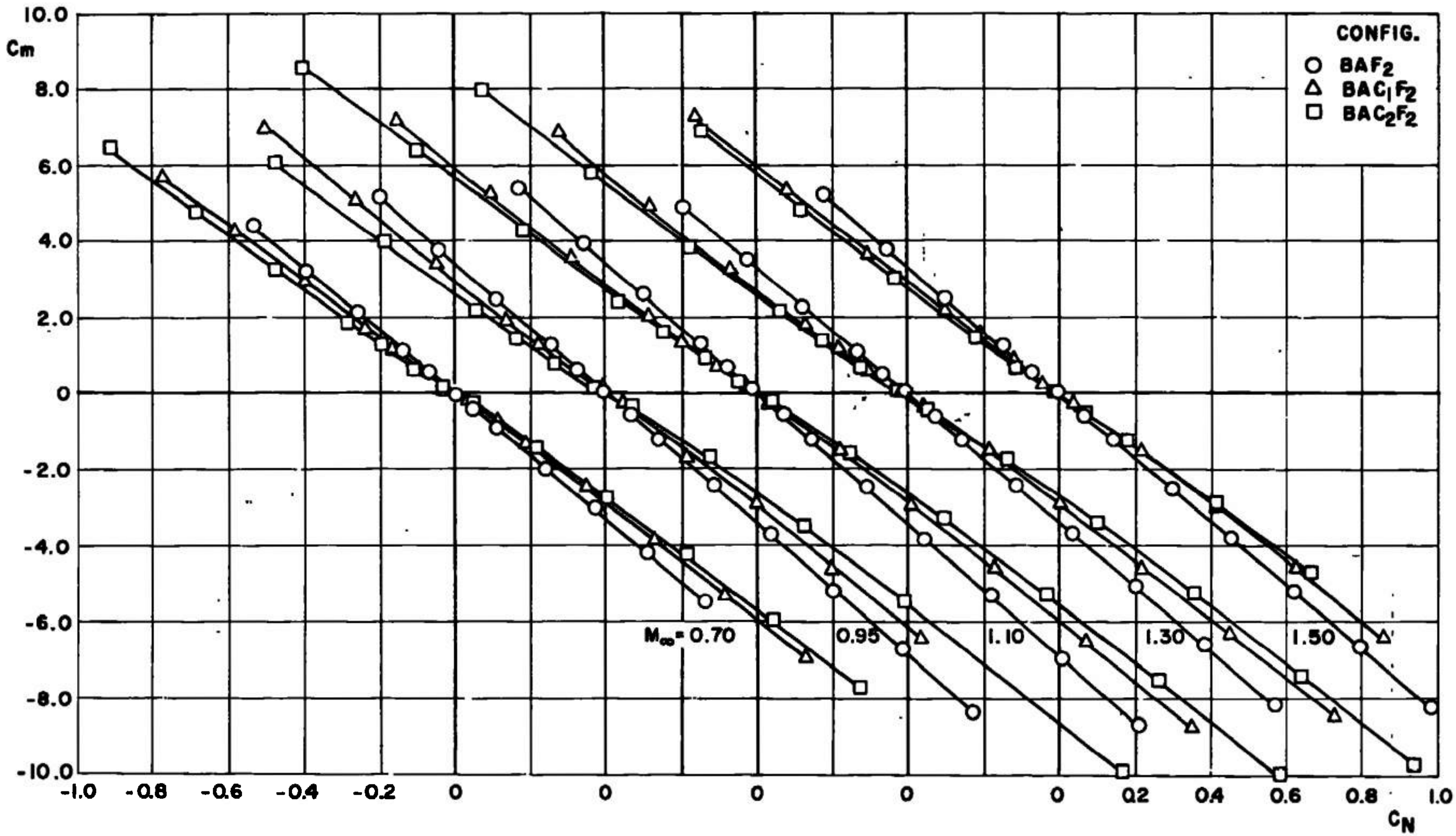


Fig. 18 Static Longitudinal Stability Characteristics of the Primary Model with Canards and Fins

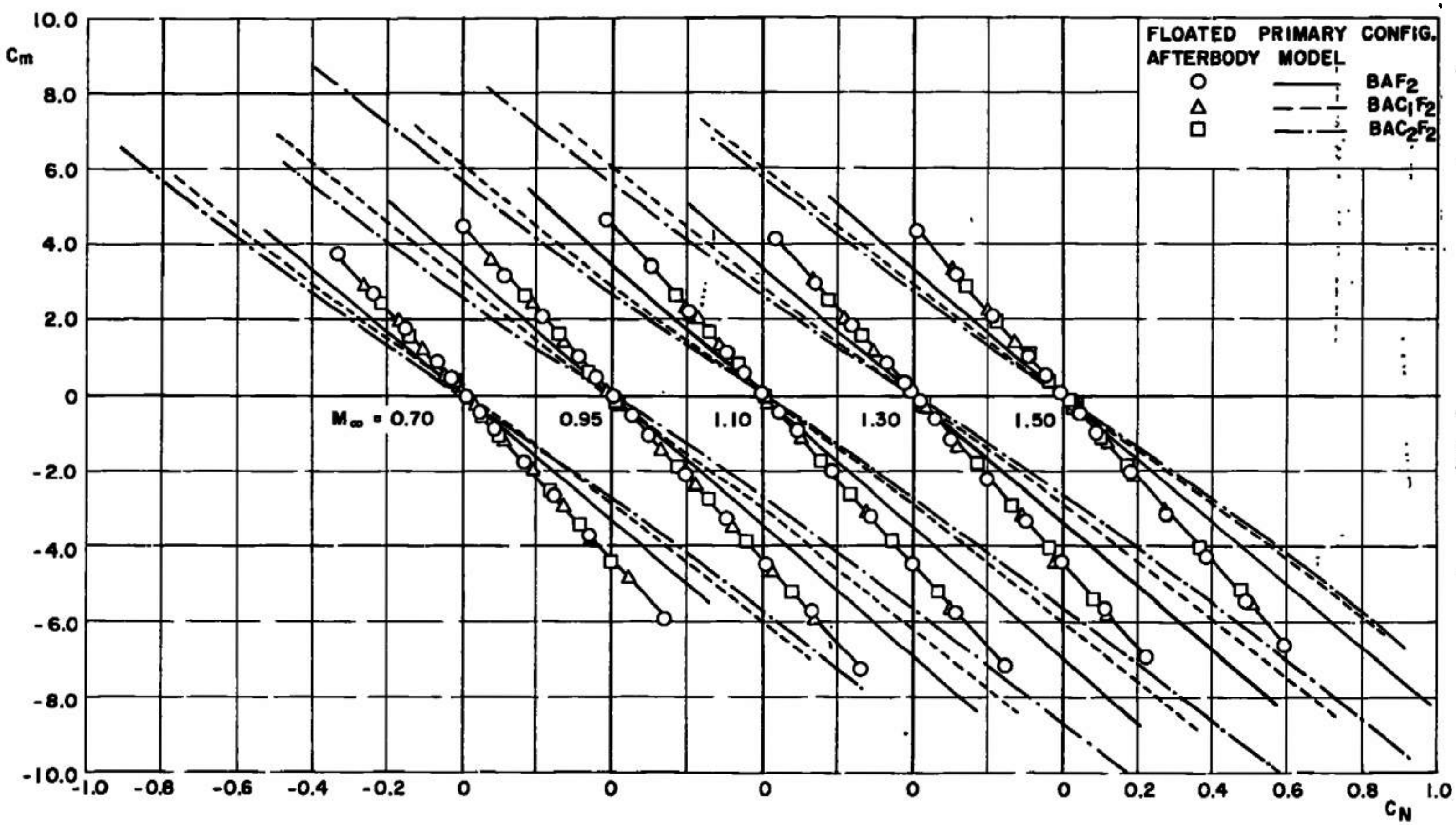


Fig. 19 Static Longitudinal Stability Contribution of the Afterbody with Fins in the Presence of the Forebody with Canards

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13. ABSTRACT
A test was conducted in the Aerodynamic Wind Tunnel, Transonic (1T), to determine the effects of various afterbodies on the aerodynamic characteristics of a generalized missile. Two similar models were tested with various afterbodies consisting of flared, cylindrical, finned cylindrical, and finned flared afterbodies. A primary model was used to evaluate the static longitudinal stability of the complete model, and a similar model with a metric afterbody was used to evaluate the contribution of the afterbody to the static longitudinal stability of the model. Tests were conducted at free-stream Mach numbers from 0.7 to 1.5 for an angle-of-attack range from -4 to 6 deg.

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aerodynamic characteristics						
model tests						
transonic flow						
3. Missiles -- Aerodynamic Characteristics						
1-12						