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TECHNICAL MEMORANDUM

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EXPERIMENTAL FLUTTER INVESTIGATION OF SOME SIMPLE MODELS OF A BOOST-GLIDE-VEHICLE WING AT MACH NUMBERS OF 3.0 AND 7.3

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON August 1959

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-37

EXPERIMENTAL FLUTTER INVESTIGATION OF SOME SIMPLE MODELS OF A BOOST-GLIDE-VEHICLE WING AT MACH NUMBERS OF 3.0 AND 7.3*

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SUMMARY

Results of tests at Mach numbers of 3.0 and 7.3 for possible wing flutter of a series of models of a boost-glide-vehicle wing are presented herein. All of the models were tested at conditions which exceeded the proposed nominal design requirements for the full-scale vehicle; namely, dynamic pressure of 1,000 pounds per square foot at the test Mach numbers. None of the models experienced flutter; therefore, large margins of safety from wing flutter are indicated. However, the effects of body freedoms on the flutter characteristics and local types of flutter were not investigated.

INTRODUCTION

Since configurations which are suitable for long-range hypersonic flight are quite unlike those used for flight at lower Mach numbers, there has been an increase in interest in the aeroelastic characteristics of these high-speed plan forms. There is practically no wind-tunnel test data available on this subject; hence, this short experimental study was undertaken.

As a part of the aeroelastic test program of a boost-glide-vehicle feasibility study proposal, exploratory tests were made in the Langley 9- by 18-inch supersonic aeroelasticity tunnel and in the 8-inch Langley hypersonic aeroelasticity tunnel on a series of semispan cantilever-mounted wing models. The models were $\frac{1}{35}$ the size of the full-scale vehicle and were designed to have the same frequency ratios and relative density ratios as the prototype.

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*Title, Unclassified.

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These tests were very elementary in nature, in that several important factors such as body freedoms, camber deflections, control surfaces, and so forth were not simulated. Also, no consideration was given to skin or panel flutter. The purpose in testing these simplified models was to obtain an idea of the general stiffness levels required to prevent flutter of configurations of this type at high Mach numbers.

SYMBOLS

a	speed of sound, ft/sec
b	reference semichord (taken at approximately 3/4 semispan), ft
M	Mach number, V/a
m	total mass, slugs
q	dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft
V	velocity, ft/sec
ρ	density, slugs/cu ft
μ	mass-ratio parameter (See section entitled "Results and Discussion.")
ω_n	natural frequency of nth vibration mode where $n = 1, 2, 3,$ radians/sec
$\frac{b\omega_2}{a}\sqrt{\mu}$	altitude-stiffness parameter

MODEL DESCRIPTION

The models were $\frac{1}{35}$ the size of the full-scale vehicle and were designed to have the same frequency ratios and relative density ratios as the prototype. Four models having progressively lower stiffnesses were constructed. The models are designated 1, 1-A, 3-A, and 9, respectively.

The models were constructed by covering an aluminum-alloy flat plate of the desired plan form with a plastic foam to give the desired airfoil

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section. The flat plates for models 1, 1-A, and 3-A were drilled in order to reduce the overall stiffness of the model and also to provide a rough simulation of the structural members of the full-scale vehicle. An X-ray photograph of a typical drilled model is shown in figure 1. All of the models were equipped with a vertical tip fin which simulated the mass and geometry of the full-scale fin but not the stiffness. The fin was not equipped with a rudder. All of the models were equipped with an elevon. The mass and geometry of the full-scale elevon were simulated, but the stiffness was not. For models 1, 1-A, and 3-A the elevon was made of balsa wood. A drilled aluminum-alloy plate was used to simulate the elevon for model 9. Presented in figure 2 are several photographs of a typical model, and a line drawing giving some details of the model geometry is shown in figure 3. The total mass and the experimentally determined natural frequencies for all of the models are presented in table I.

The first natural still-air vibration mode of the models resembled the conventional bending mode of a cantilever beam; however, the second and third modes were somewhat unusual. The second mode had a nodal line which, essentially, coincided with the elevon hinge line; however, there were appreciable deflections of the wing ahead of the node. The fin rotated in pitch about this nodal line as an axis. The third mode was characterized by a rotary motion of the fin in the roll direction, with the axis or nodal line coinciding with the base of the fin. Again there were appreciable motions of the wing inboard of the fin. The node lines for the second and third natural modes of a typical model are presented in figure 4.

APPARATUS AND PROCEDURE

The tests were conducted in the Langley 9- by 18-inch supersonic aeroelasticity tunnel at a Mach number of 3.0 and in the 8-inch-diameter, $M = 7.3$, nozzle of the Langley hypersonic aeroelasticity tunnel. Both tunnels are of the fixed-nozzle blowdown type exhausting into a vacuum reservoir. The test media used are air and helium, respectively. Some of the characteristics of helium as a flutter-testing medium are discussed in reference 1. In both tunnels the test-section density varied to a controlled maximum. The approximate duration of each test was 8 seconds. The models were cantilever mounted on a reflection plane in the test section. The reflection plane was mounted outside the tunnel boundary layer by means of a faired spacer block. Presented in figure 5 are photographs of a typical model mounted on the reflection planes used for the two tunnels. A wooden fairing was used to simulate the fuselage. For the tests at $M = 7.3$, all of the models were tested at 0° angle of attack. For the test at $M = 3.0$ for model 9, which was the only model tested at this Mach number, the angle of attack was 1.5°.

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RESULTS AND DISCUSSION

A summary of the test results is given in table II. Shown in this table are Mach number, speed of sound, test-section density, dynamic pressure, mass-ratio parameter, and altitude-stiffness parameter. Also included are brief explanatory remarks for each test. No flutter was obtained on the configurations tested. Presented in figure 6 is a comparison, in the form of a plot of the altitude-stiffness parameter $\frac{b\omega_2}{a}\sqrt{\mu}$ against Mach number, of the experimental no-flutter points with the proposed nominal design requirements for the full-scale vehicle; namely, dynamic pressure of 1,000 pounds per square foot at the test Mach numbers. The altitude-stiffness parameter depends upon the physical properties of the wing, and the value of this parameter increases as either altitude or stiffness increases. The mass-ratio parameter μ is defined as the mass of the wing divided by the mass of some representative volume of fluid surrounding the wing. In this case, the volume used was that of a conical frustum having base diameters approximately equal to the model root and tip chords, respectively, and having a height equal to the model span. For the models tested, this volume was 0.03487 cubic foot. As is seen from figure 6, the model tests indicate that a large margin of safety appears to exist with respect to wing flutter for the nominal full-scale vehicle.

CONCLUDING REMARKS

Results of flutter tests made at Mach numbers of 3.0 and 7.3 on a series of models of a boost-glide-vehicle wing are reported herein. All of the models were tested at conditions which exceeded the proposed nominal design requirement for the full-scale vehicle; namely, dynamic pressure of 1,000 pounds per square foot at the test Mach numbers. None of the models experienced flutter; therefore, a large margin of safety from cantilever wing flutter is indicated. It is to be noted that body freedoms were not simulated nor were certain factors important for local types of flutter, such as camber deflections, control surfaces, and skin thicknesses.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., April 29, 1959.

REFERENCE

1. Morgan, Homer G., and Miller, Robert W.: Flutter Tests of Some Simple Models at a Mach Number of 7.2 in Helium Flow. NASA MEMO 4-8-59L, 1959.

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TABLE I.- MODEL PHYSICAL PROPERTIES

Model designation	ω_1	ω_2	ω_3	m	Remarks
1	1,250	3,675	5,655	0.00342	
1-A	1,005	3,141	5,150	.00342	
3-A	861.0	2,576	4,630	.00349	
9	310.0	1,064	2,061	.00192	Before test at M = 7.3
9	226.7	795.5	1,534	.00192	Before test at M = 3.0

TABLE II.- MODEL TEST RESULTS

Model designation	M	a	ρ	q	μ	$\frac{b\omega_2}{a}\sqrt{\mu}$	Remarks
1	7.3	774	0.0002652	4,230	370.0	15.40	No flutter
1-A	7.3	763	.0002615	4,055	375.2	13.45	No flutter
3-A	7.3	761	.0002750	4,230	364.1	10.88	No flutter
9	7.3	755	.0002786	4,230	197.5	3.34	No flutter
9	3.0	703	.00098	2,180	56.20	1.43	No flutter (model tested at angle of attack of 1.5°, model destroyed in stopping shock)

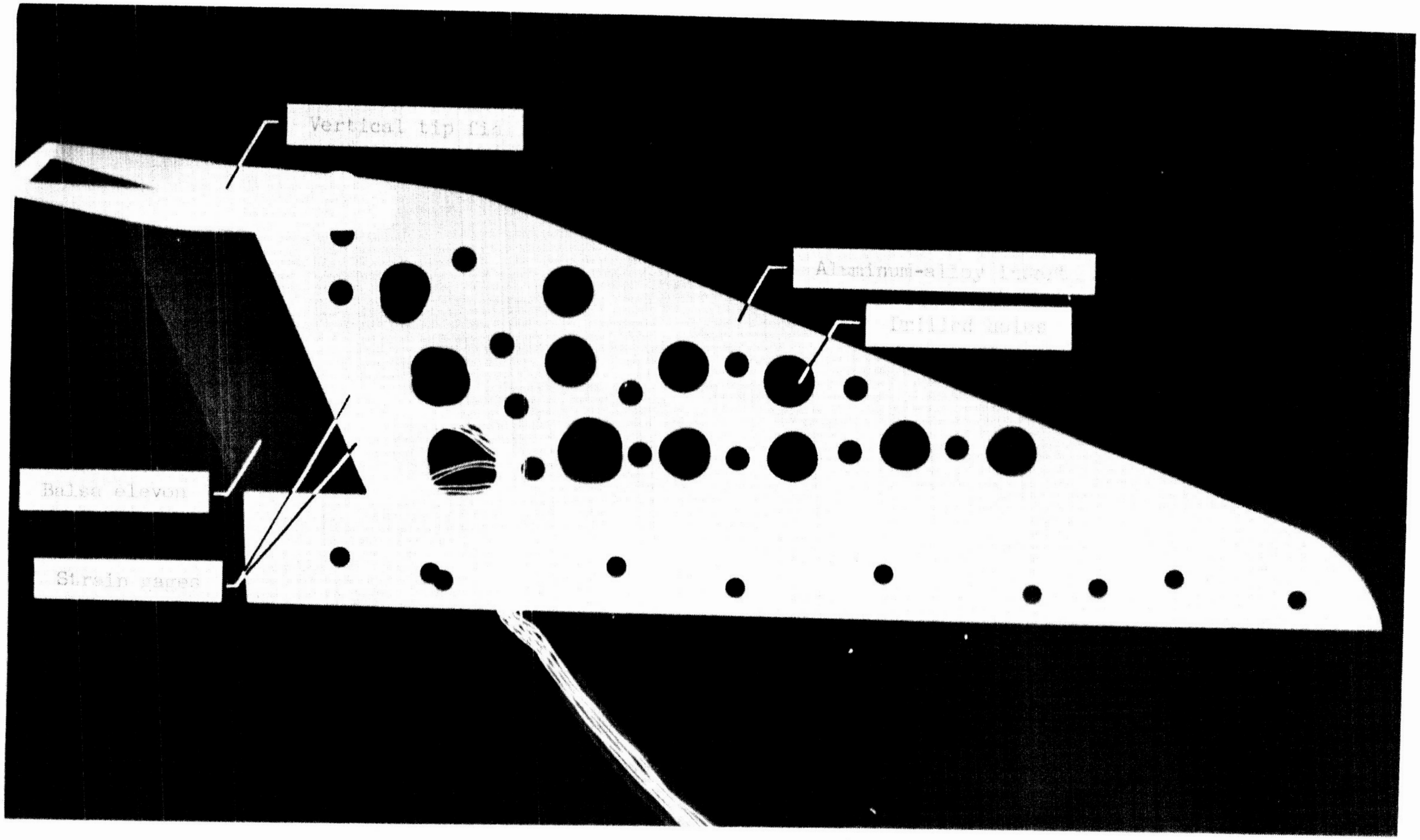
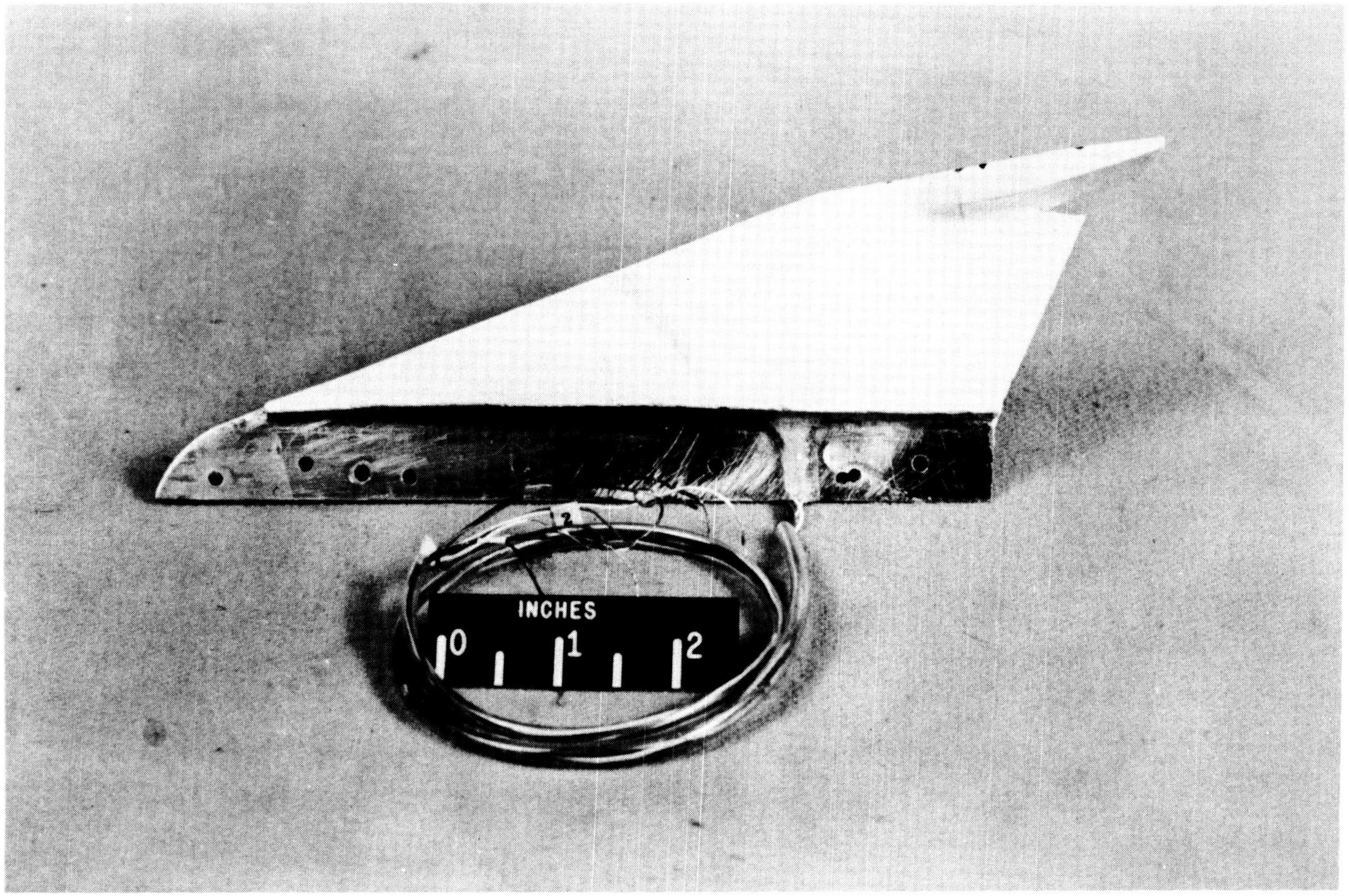
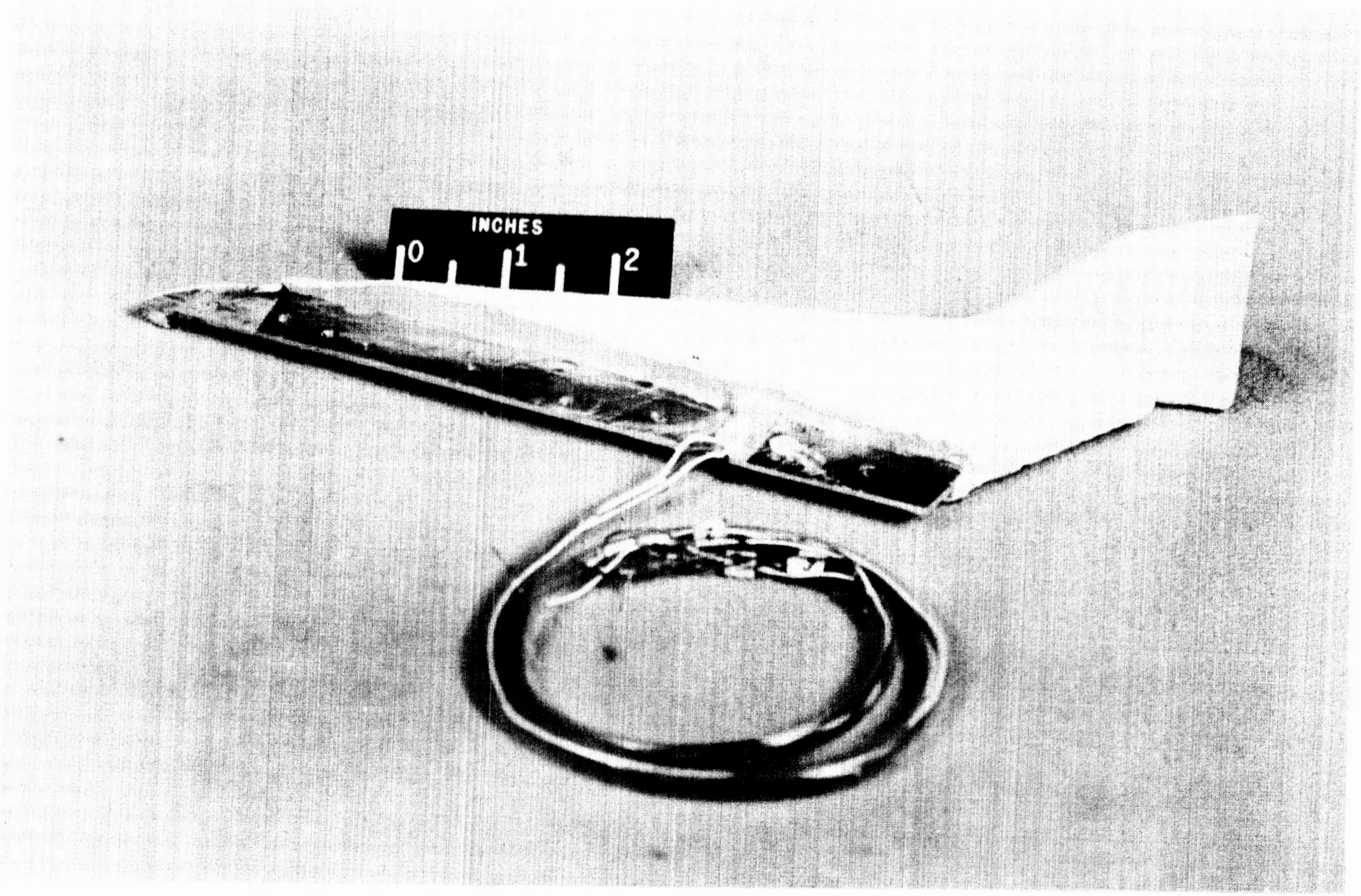


Figure 1.- X-ray photograph of typical drilled model. L-59-1949



(a) Plan view. L-59-2012

Figure 2.- Photographs of a typical model.



(b) View showing trailing edge and root chord. L-59-2011

Figure 2.- Continued.

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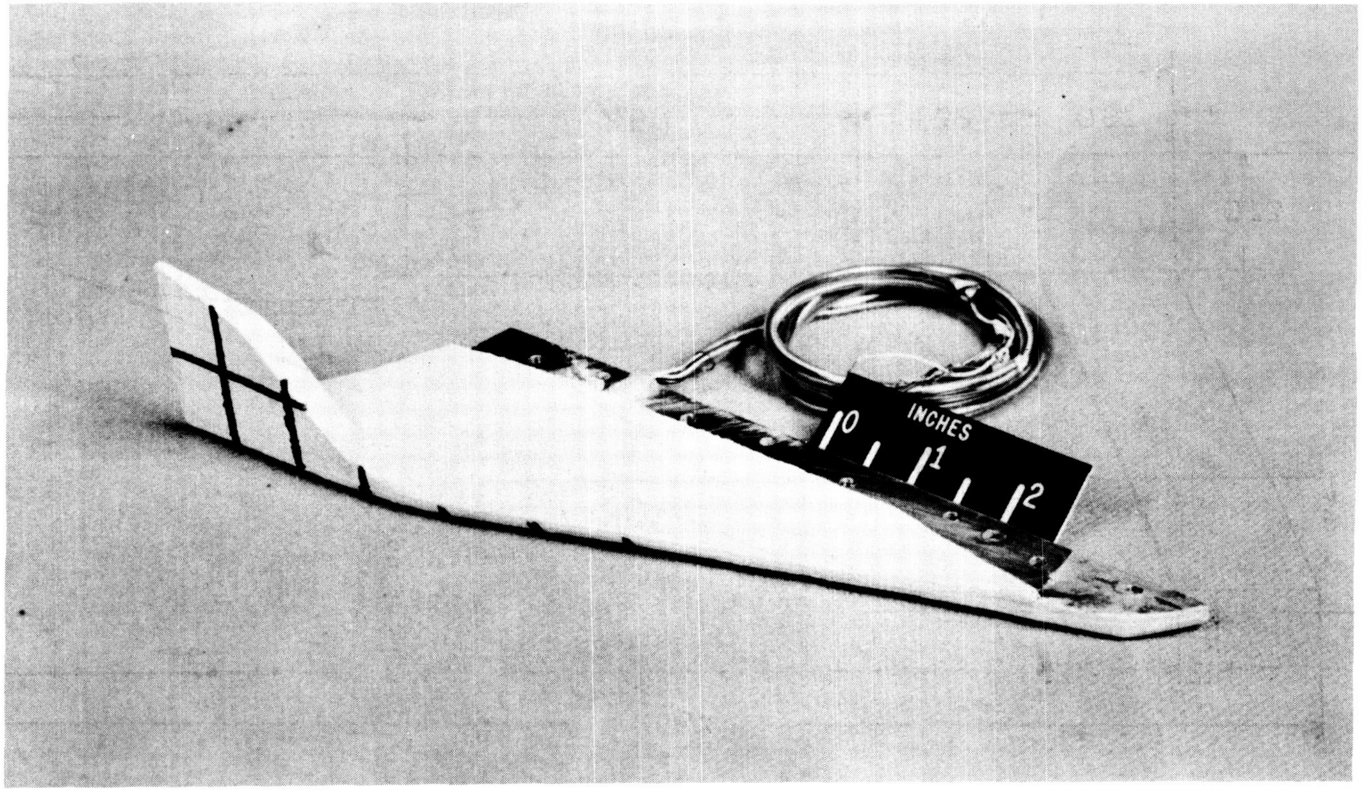

(c) Leading-edge view. L-59-2013

Figure 2.- Concluded.

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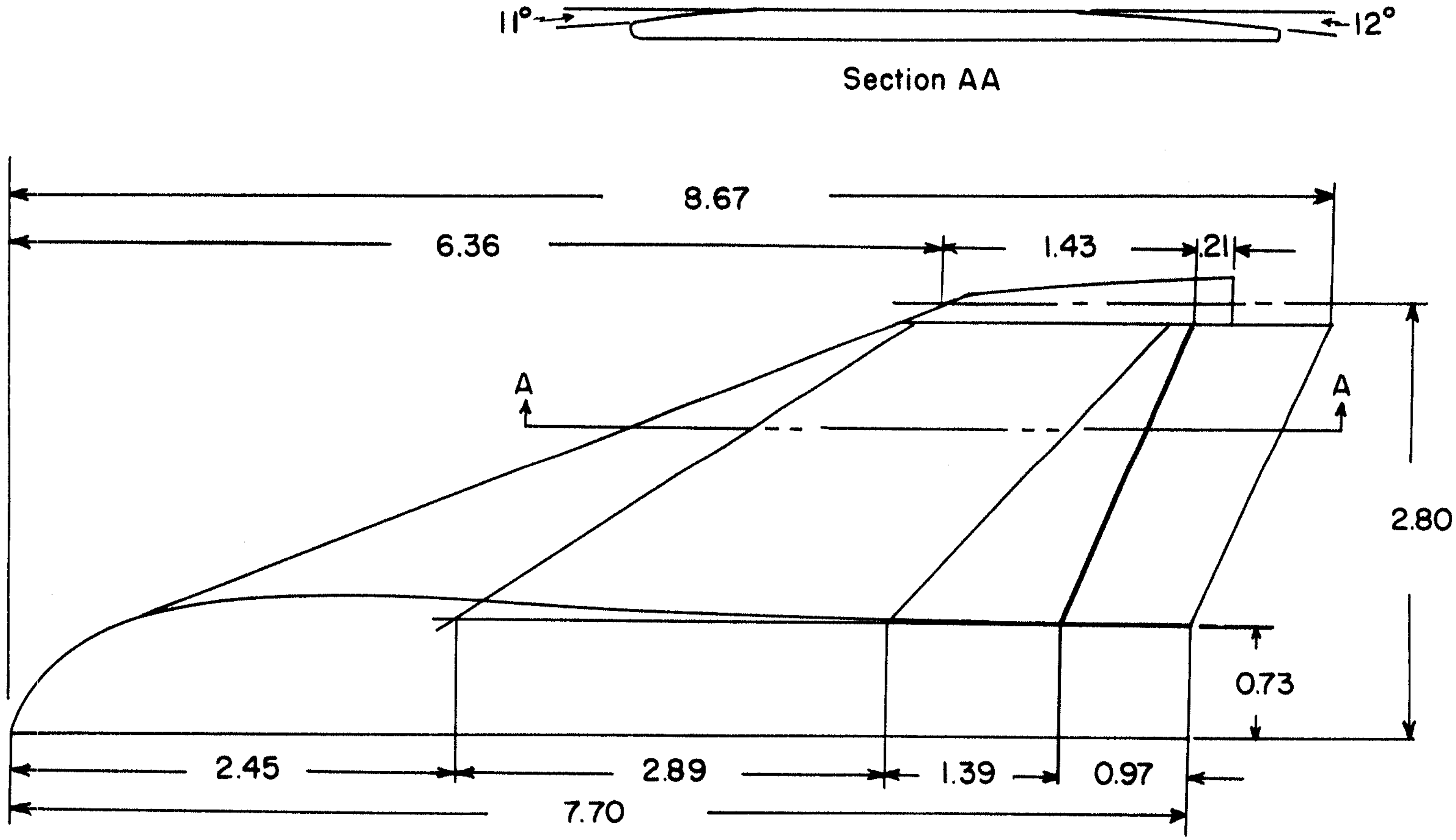

Figure 3.- Model geometry. Linear dimensions are in inches.

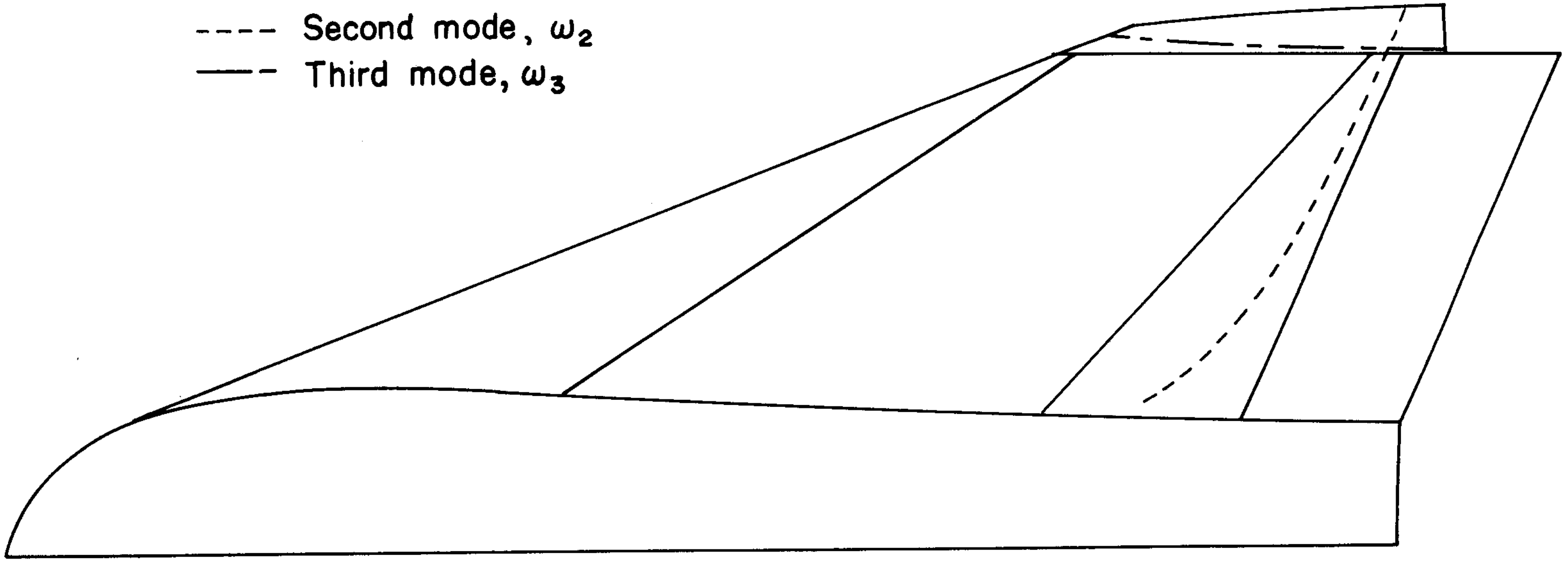

Figure 4.- Node lines for second and third natural modes of a typical model.

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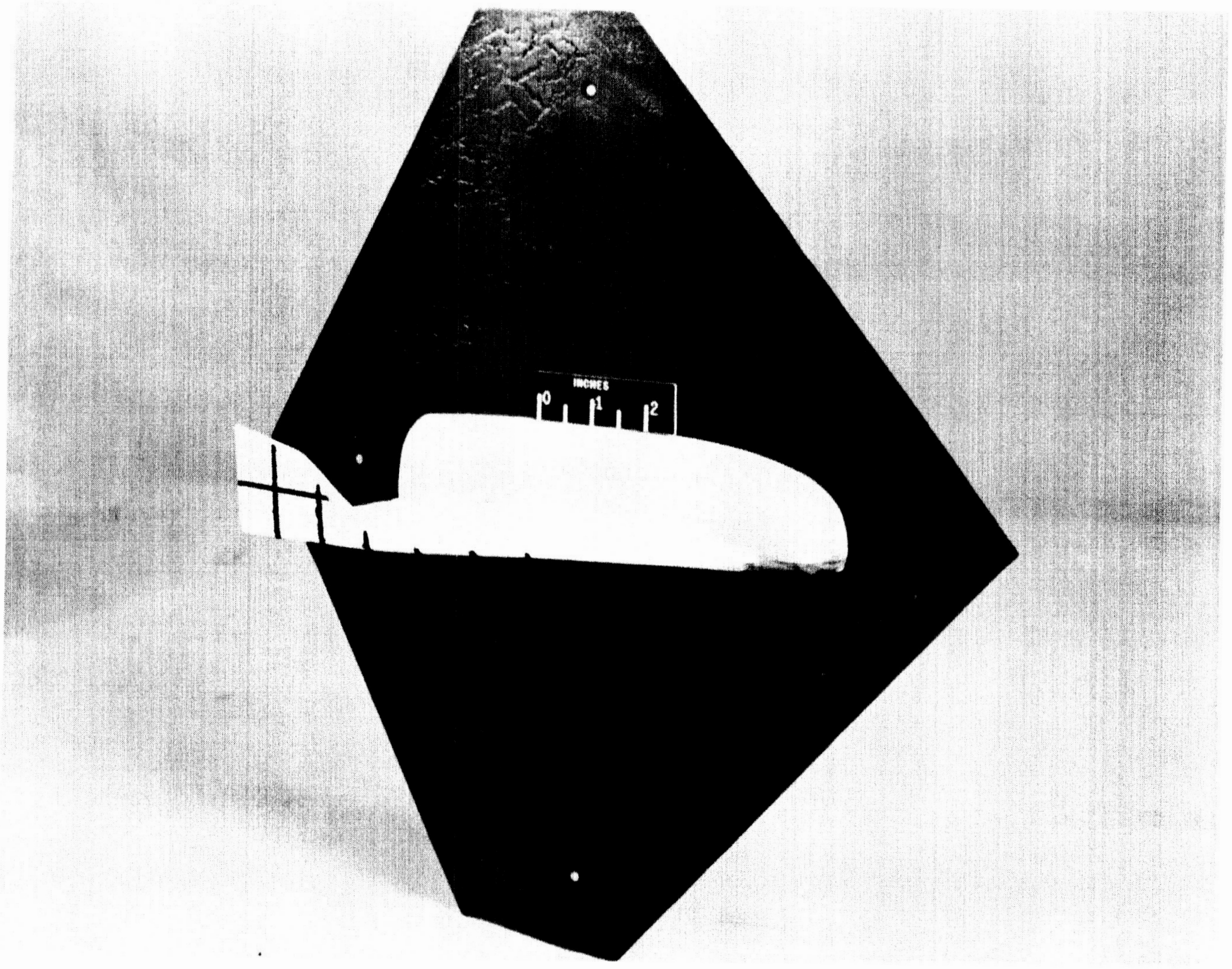

(a) Supersonic test. M = 3.0. L-59-2014

Figure 5.- Photographs of typical model mounted on reflection planes.

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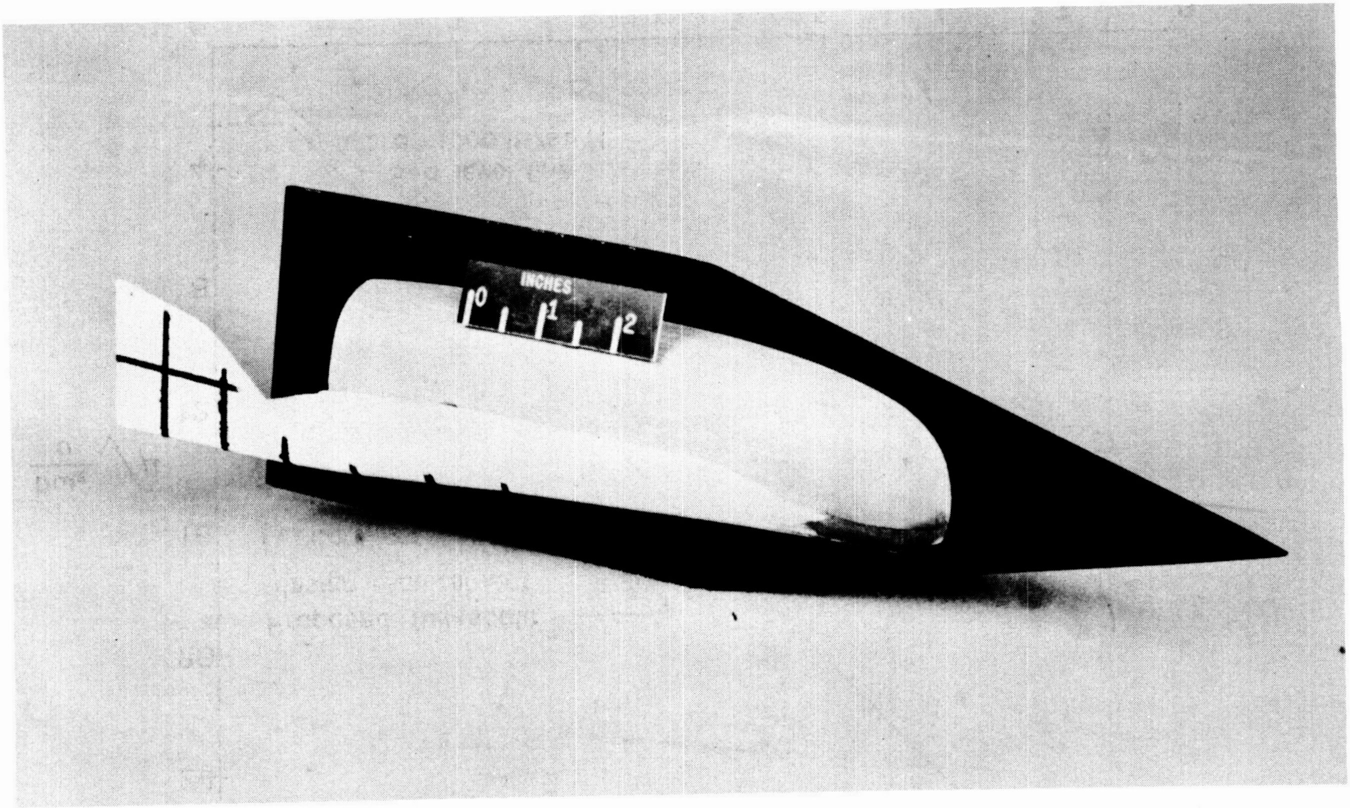

(b) Hypersonic test. M = 7.3. L-59-2015

Figure 5.- Concluded.

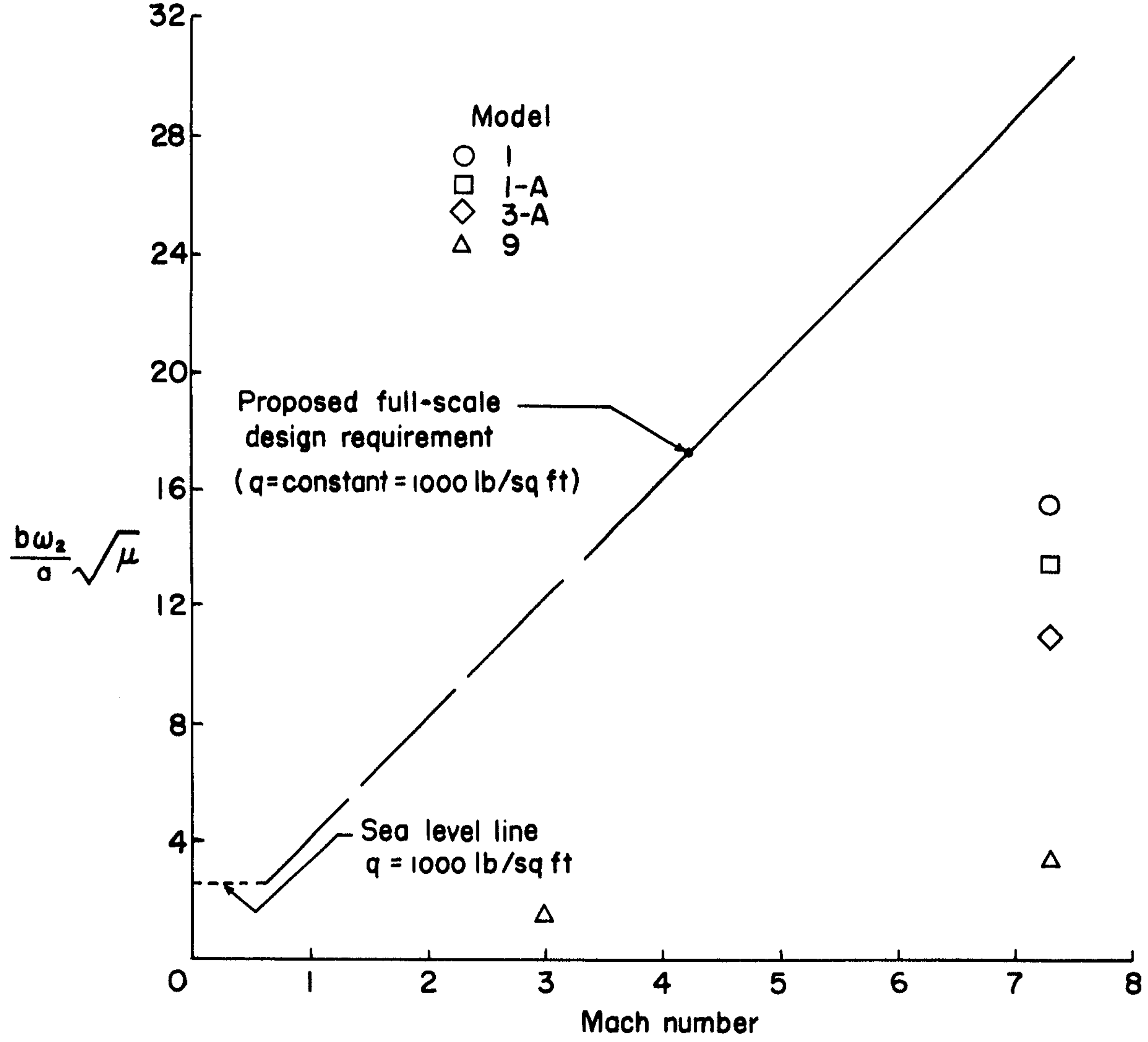

Figure 6.- Comparison of model test results (no-flutter data) with proposed design requirement of full-scale vehicle.

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