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RESEARCH MEMORANDUM

AERODYNAMIC CHARACTERISTICS OF A FLYING-BOAT HULL HAVING A LENGTH-BEAM RATIO OF 15 AND A WARPED FOREBODY

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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AERODYNAMIC CHARACTERISTICS OF A FLYING-BOAT HULL HAVING A LENGTH-BEAM RATIO OF 15 AND A WARPED FOREBODY

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SUMMARY

An investigation was made in the Langley 300 MPH 7- by 10-foot tunnel to determine the change in aerodynamic characteristics that would result from the substitution of a warped forebody for the conventional-type forebody of a high-length-beam-ratio flying-boat hull. The effect of removing the rear forebody chine flare was also determined.

The minimum drag coefficient of the warped forebody hull, including the interference of a support wing, was 0.0052 and occurred at approximately 2° angle of attack. This value of drag coefficient was slightly greater than the value found for the basic hull. The minimum drag coefficient remained essentially constant with and without the rear forebody chine flare on the hull. The longitudinal and directional stability of the hulls generally remained constant with configuration changes.

INTRODUCTION

Because of the requirements for increased range and speed in flying boats, an investigation of the aerodynamic characteristics of flying-boat hulls as affected by hull dimensions and hull shape is being conducted at the Langley Aeronautical Laboratory. The results of two phases of this investigation, presented in references 1 and 2, have indicated possible ways of reducing hull drag without causing large changes in aerodynamic stability and hydrodynamic performance.

An unpublished investigation to determine the hydrodynamic advantages of forebody warp (progressive increase in dead rise from step to bow) on the length-beam-ratio-15 hull of reference 1 indicated that the stable range of trim was increased, the bow spray characteristics were improved, and the maximum vertical and angular accelerations were reduced.

The present investigation was conducted in order to determine the change in aerodynamic characteristics resulting from the substitution of the warped forebody for the conventional forebody of the length-beam-ratio-15 hull. The effect of removing the chine flare on the rear of the warped forebody was also determined.

COEFFICIENTS AND SYMBOLS

The results of the tests are presented as standard NACA coefficients of forces and moments. The wing area, mean aerodynamic chord, and span of a hypothetical flying boat assumed in reference 1 were used in determining the coefficients and Reynolds number. The data are referred to the stability axes, which constitute a system of axes having their origin at the center of moments shown in figure 1 in which the Z-axis is in the plane of symmetry and perpendicular to the relative wind, the X-axis is in the plane of symmetry and perpendicular to the Z-axis, and the Y-axis is perpendicular to the plane of symmetry. The positive directions of the stability axes are shown in figure 2.

The coefficients and symbols are defined as follows:

C_L lift coefficient (Lift/qS)

C_D drag coefficient (Drag/qS)

C_Y lateral-force coefficient (Y/qS)

C_l rolling-moment coefficient (L/qSb)

C_m pitching-moment coefficient ($M/qS\bar{c}$)

C_n yawing-moment coefficient (N/qSb)

Lift = -Z

Drag = -X when $\psi = 0$

X force along X-axis, pounds

Y force along Y-axis, pounds

Z force along Z-axis, pounds

L rolling moment, foot-pounds

M pitching moment, foot-pounds

N yawing moment, foot-pounds

q free-stream dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

S wing area of a $\frac{1}{10}$-scale model of a hypothetical flying boat (18.264 sq ft)

$\bar{c}$ wing mean aerodynamic chord (M.A.C.) of a $\frac{1}{10}$-scale model of a hypothetical flying boat (1.377 ft)

b	wing span of a $\frac{1}{10}$-scale model of a hypothetical flying boat (13.971 ft)
V	air velocity, feet per second
ρ	mass density of air, slugs per cubic foot
α	angle of attack of hull base line, degrees
ψ	angle of yaw, degrees
R	Reynolds number, based on wing mean aerodynamic chord of a $\frac{1}{10}$-scale model of a hypothetical flying boat
$C_{D_{min}}$	minimum drag coefficient

MODEL AND APPARATUS

The hull used in the present tests was designed by the Langley Hydrodynamics Division and is the same model that was used in the investigation described in reference 1.

The various modifications of the hull, as shown in figure 1, were made possible by the use of interchangeable blocks. The offsets for the warped forebody hull, with and without chine flare, are presented in table I. The offsets for the basic hull are given in reference 1.

The hull and interchangeable blocks were constructed of laminated mahogany and were finished with pigmented varnish. A photograph of the basic hull and the two modified configurations is shown in figure 3. The hulls were attached to a wing which was mounted horizontally in the tunnel as shown in figure 4. The wing, which was the same wing used in the investigation described in reference 1, was set at an angle of incidence of 4° on the model, had a 20-inch chord, a 94.2-inch span, and was of the NACA 4321 section.

The volumes, surface areas, and maximum cross-sectional areas of the three hull configurations are given in table II.

TESTS

Test Conditions

The tests were made in the Langley 300 MPH 7- by 10-foot tunnel at dynamic pressures ranging from 25 to 103 pounds per square foot, which correspond to air speeds ranging from 104 to 212 miles per hour. Reynolds numbers, based on the wing mean aerodynamic chord of the hypothetical flying boat, ranged from about 1.2×10^6 to 2.5×10^6. Corresponding Mach numbers ranged from 0.13 to 0.27.

Corrections

Blocking corrections have been applied to the data. The hull drag has been corrected for horizontal-buoyancy effects caused by a tunnel static-pressure gradient. A correction was also applied to the angle of attack because of the structural deflections caused by aerodynamic forces.

Test Procedure

The aerodynamic characteristics of the hull, including the interference effects of the support wing, were determined by testing the wing alone and by testing the wing and hull combination under identical conditions. The hull aerodynamic coefficients were then determined by subtraction of coefficients for the wing alone from the coefficients of the complete configuration.

To obtain a direct comparison between the warped-forebody configurations and the basic hull design, tests were also performed on the basic hull.

Hull transition for all the tests was fixed by a strip of 0.008-inch-diameter carborundum particles $\frac{1}{2}$ inch wide and located approximately 5 percent of the hull length aft of the bow (fig. 3).

The wing transition was fixed at the leading edge by means of roughness strips of carborundum particles of approximately 0.008-inch diameter, thereby reducing possible errors resulting from transition shift on the wing. The particles were applied for a length of 8 percent of the airfoil chord measured along the airfoil contour from the leading edge on both upper and lower surfaces.

RESULTS AND DISCUSSION

The variation of hull aerodynamic characteristics with angle of attack is shown in figure 5; the variation of hull aerodynamic characteristics with angle of yaw is presented in figure 6. For convenience, the minimum drag coefficients $C_{D_{min}}$ for a Reynolds number of about 2.5×10^6 and the longitudinal-stability and lateral-stability parameters for the various configurations are presented in table III.

The data in figure 5 indicate that for a Reynolds number of approximately 2.5×10^6 the warped-forebody hull had a minimum drag coefficient of 0.0052 with wing-interference effects included, which was a slight increase over the basic hull design.

The results of a previous investigation (reference 1) showed only a small effect of Reynolds number on the drag and longitudinal stability of the hulls tested. The Reynolds number range investigated in reference 1 was from 1.25×10^6 to 3.40×10^6. Because of the similarity, it is believed that there would also have been little or no influence of Reynolds number on the current investigation.

Removing the chine flare, as shown in figures 1 and 3, resulted in no noticeable change in the minimum drag coefficient when compared to the warped forebody configuration mentioned above.

The angle-of-attack range for minimum drag was little affected by the configuration changes, and the angle of attack for the minimum coefficient of drag occurred at approximately 2° for all three configurations.

The longitudinal stability and directional stability of the hulls generally remained constant with configuration changes. The values of C_{m_α} and C_{n_ψ} for the altered hulls (table III) were about 0.0034 and 0.0013, respectively.

CONCLUSIONS

The results of tests in the Langley 300 MPH 7- by 10-foot tunnel to determine the change in aerodynamic characteristics that would result from the substitution of a warped forebody for the conventional forebody of a high-length-beam-ratio flying-boat hull and the effect of the rear forebody chine flare removal indicate the following conclusions:

1. Including the interference of the support wing, the warped forebody hull had a minimum drag coefficient of 0.0052 which was slightly greater than the value found for the basic hull.

2. The minimum drag coefficient was not noticeably changed by removing the rear forebody chine flare.

3. The angle of attack for minimum drag was little affected by the configuration changes and occurred at about 2°.

4. The longitudinal stability and directional stability of the hulls generally remained constant with configuration changes.

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REFERENCES

1. Yates, Campbell C., and Riebe, John M.: Effect of Length-Beam Ratio on the Aerodynamic Characteristics of Flying-Boat Hulls. NACA TN No. 1305, 1947.

2. Yates, Campbell C., and Riebe, John M.: Aerodynamic Characteristics of Three Planing-Tail Flying-Boat Hulls. NACA TN No. 1306, 1947.

TABLE I

OFFSETS FOR LANGLEY TANK MODEL 224 WITH MODIFICATIONS

[All dimensions are in inches]

Station	Distance to F.P.	Keel above base line	Chine above base line		Half-beam at chine	Radius and half maximum beam	Height of hull at center line	Line of centers above base line	Angle of chine flare (deg)	Forebody bottom								
										Heights above base line								
			With flare	Without flare						Buttock 0.36	Buttock 0.71	Buttock 1.07	Buttock 1.42	Buttock 1.78	Buttock 2.13	Buttock 2.49	Buttock 2.85	Buttock 3.20
F.P.	0	10.30	10.30	10.30	0	0	11.00	11.00										
1/2	2.52	5.49	9.34	9.34	1.64	1.64	14.29	12.65	10	7.89	8.81	9.19	9.34					
1	5.04	3.76	8.42	8.42	2.18	2.18	15.72	13.54	10	5.65	7.15	7.88	8.23	8.39	8.43			
2	10.08	1.83	6.82	6.82	2.75	2.75	17.36	14.61	10	3.09	4.31	5.40	6.11	6.53	6.78	6.84		
3	15.12	.80	5.57	5.57	3.07	3.07	18.41	15.34	10	1.72	2.61	3.53	4.34	4.93	5.30	5.50	5.58	
4	20.15	.27	4.60	4.60	3.28	3.28	19.12	15.84	10	.98	1.67	2.39	3.08	3.73	4.15	4.42	4.57	4.61
5	25.19	.04	3.88	3.88	3.41	3.41	19.60	16.19	10	.61	1.17	1.74	2.29	2.86	3.32	3.63	3.82	3.89
6	30.23	0	3.35	3.35	3.48	3.48	19.88	16.40	5	.47	.92	1.39	1.85	2.31	2.71	3.03	3.24	3.34
7	35.27	0	2.91	3.25	3.50	3.50	19.99	16.49	0	.39	.77	1.15	1.53	1.91	2.29	2.58	2.79	2.89
8	40.31	0	2.52	3.25	3.505	3.505	20.00	16.49	0	.33	.67	.99	1.32	1.65	1.97	2.23	2.40	2.50
9	45.34	0	2.14	2.76	3.505	3.505	20.00	16.49	0	.28	.56	.83	1.12	1.39	1.67	1.89	2.04	2.13
10	50.38	0	1.76	2.27	3.505	3.505	20.00	16.49	0	.23	.46	.69	.92	1.14	1.37	1.56	1.69	1.76
11	55.42	0	1.38	1.78	3.505	3.505	20.00	16.49	0	.18	.35	.54	.72	.89	1.07	1.21	1.32	1.38
12F	60.51	0	1.00	1.28	3.505	3.505	20.00	16.49	0	.13	.25	.39	.52	.64	.77	.88	.95	1.00
12A	60.51	1.16	2.43	2.43	3.505	3.505	20.00	16.49										
13	65.50	1.63	2.89	2.89	3.45	3.48	20.00	16.52										
14	70.54	2.11	3.31	3.31	3.31	3.44	20.00	16.56										
15	75.58	2.58	3.71	3.71	3.10	3.35	20.00	16.65										
16	80.61	3.06	4.10	4.10	2.85	3.23	20.00	16.77										
17	85.65	3.54	4.44	4.44	2.48	3.07	20.00	16.93										
18	90.69	4.01	4.75	4.75	2.04	2.84	20.00	17.16										
19	95.73	4.49	5.02	5.02	1.46	2.58	20.00	17.42										
20	100.77	4.97	5.24	5.24	.75	2.29	20.00	17.71										
SP	105.13	5.38	5.38	5.38	0	2.00	20.00	18.00										
21	105.80	6.19				1.96	20.00	18.04										
22	110.84	11.17				1.59	20.00	18.41										
23	115.88	14.63				1.19	20.00	18.81										
24	120.92	17.09				.75	20.00	19.25										
25	125.96	18.84				.29	20.00	19.71										
A.P.	126.12	18.90				.28	20.00	19.72										

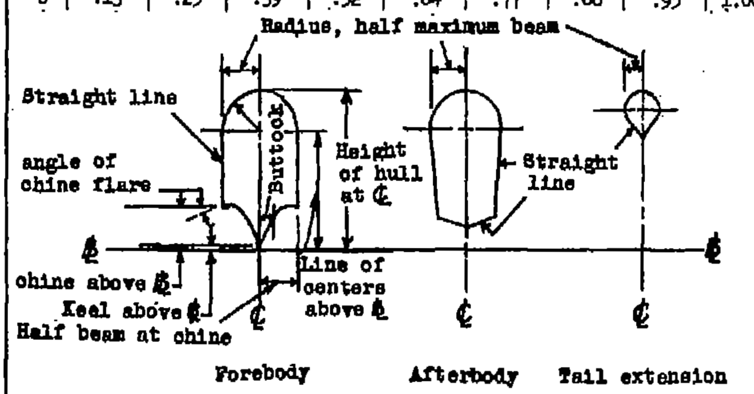

TABLE II

VOLUMES, SURFACE AREAS, SIDE AREAS, AND MAXIMUM CROSS-SECTIONAL AREAS OF LANGLEY TANK MODEL 224 WITH MODIFICATIONS

Configuration	Volume (cu in.)	Surface area (sq in.)	Side area (sq in.)	Maximum cross-sectional area (sq in.)
Basic forebody	10,653	4760	1985	130.8
Warped forebody, with chine flare	10,174	4675	1985	130.8
Warped forebody, without chine flare	10,152	4662	1985	130.4

TABLE III

DRAG AND STABILITY PARAMETERS OF LANGLEY TANK MODEL 224

WITH MODIFICATIONS

[Drag coefficients are presented for $R \approx 2.5 \times 10^6$]

Configuration	$C_{D_{min}}$	$\frac{\partial C_m}{\partial \alpha}$	$\frac{\partial C_n}{\partial \psi}$ for $\alpha = 2^\circ$	$\frac{\partial C_Y}{\partial \psi}$ for $\alpha = 2^\circ$
Basic forebody	0.0048	0.0036	0.0014	0.0053
Warped forebody, with chine flare	.0052	.0034	.0013	.0053
Warped forebody, without chine flare	.0052	.0034	.0013	.0053

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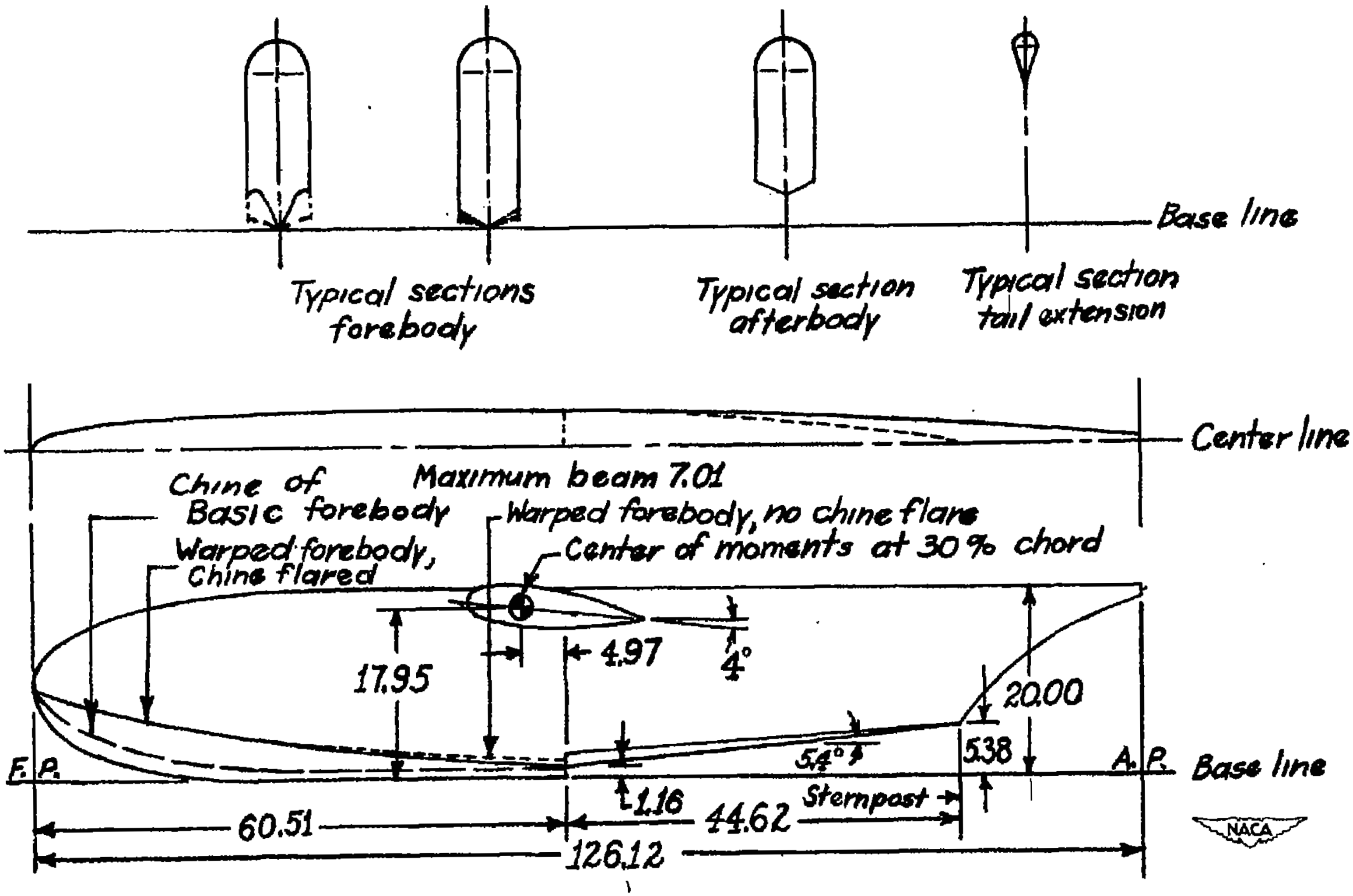


Figure 1.- Lines of Langley tank model 224 with modifications. (All dimensions are in inches.)

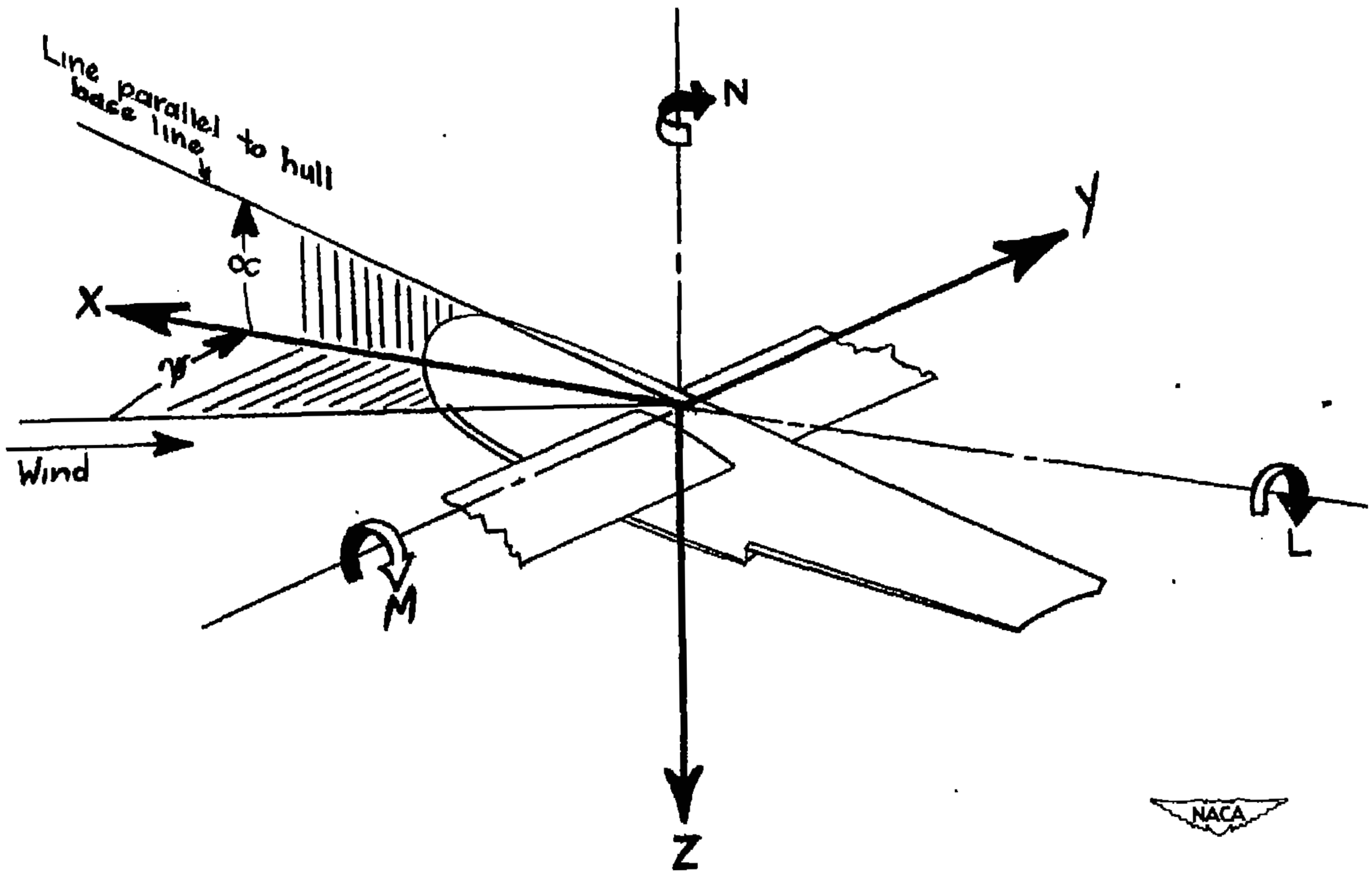
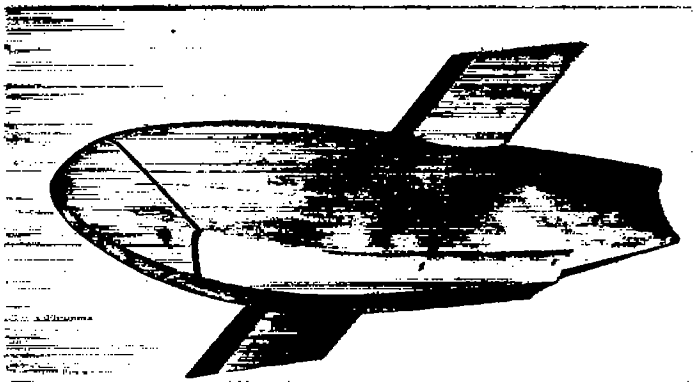
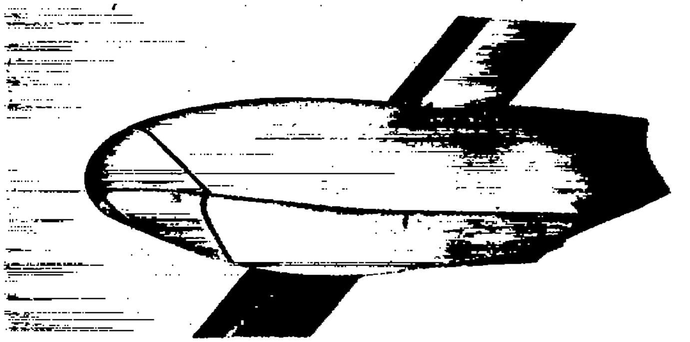


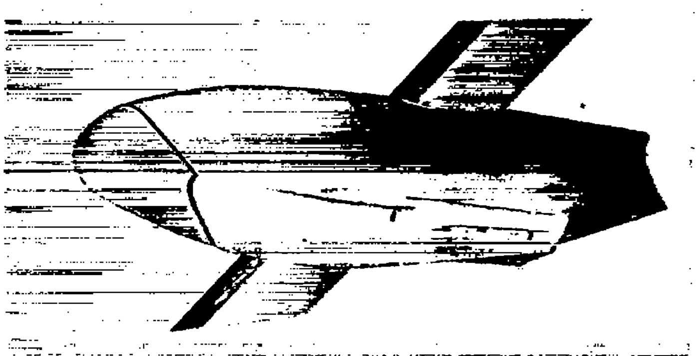
Figure 2.– System of stability axes. Positive values of forces, moments, and angles are indicated by arrows.



Basic forebody



Warped forebody,
with chine flare



Warped forebody,
without chine flare

Figure 3.— Basic and warped forebodies.

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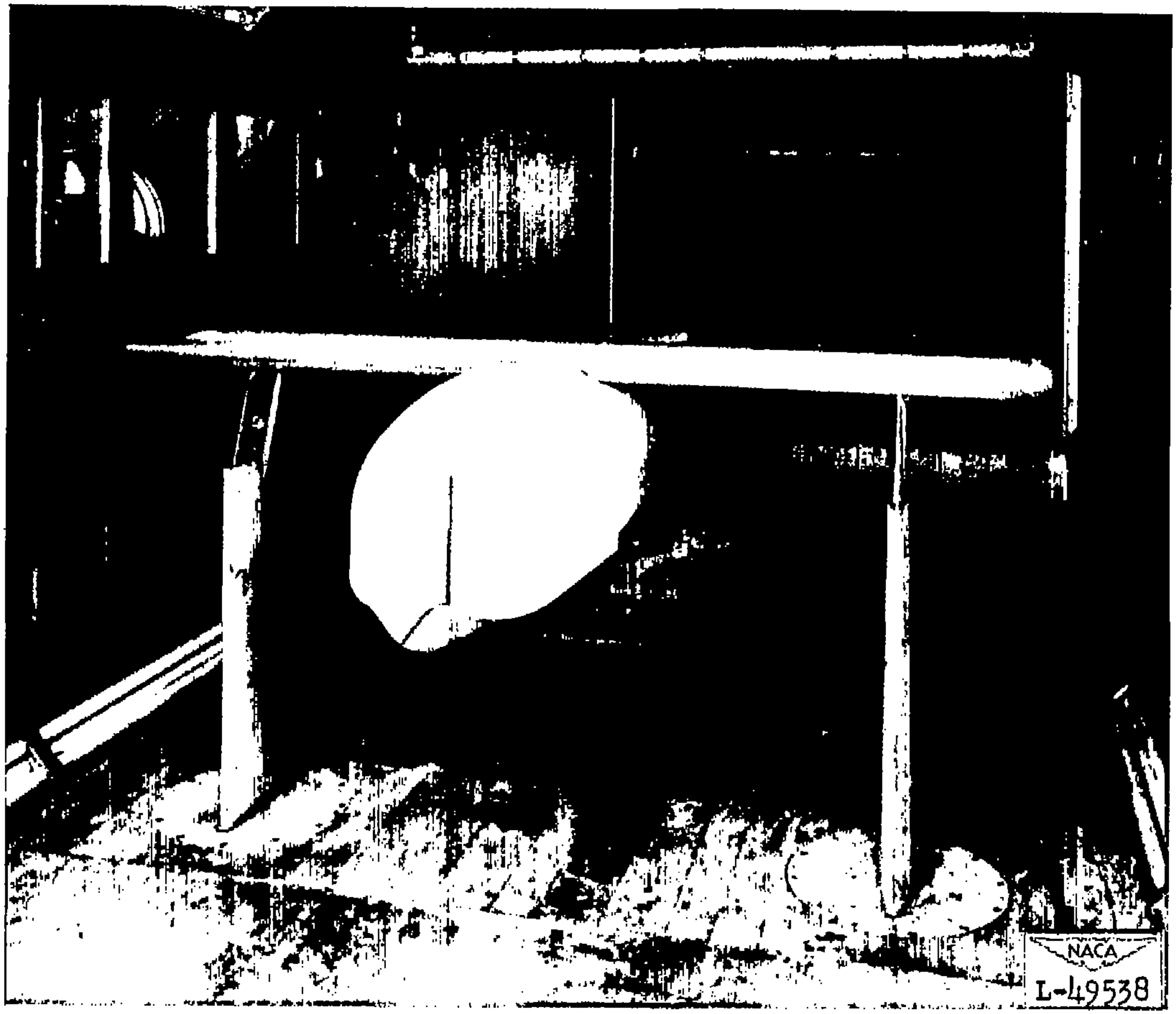

Figure 4.– Support wing and typical hull model mounted in the Langley 300 MPH 7– by 10–foot wind tunnel.

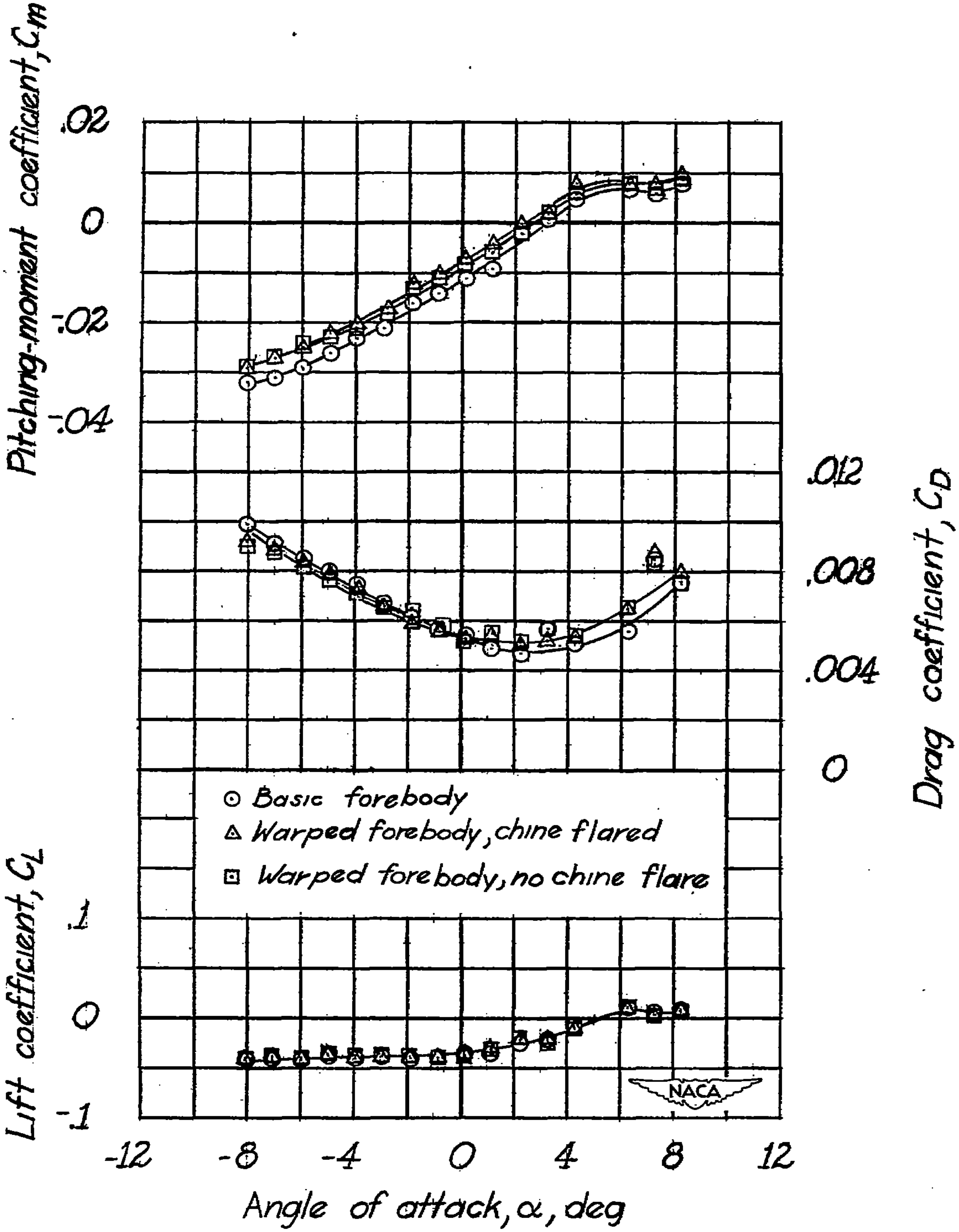

Figure 5.– Aerodynamic characteristics in pitch of Langley tank model 224. $R \approx 2.5 \times 10^6$.

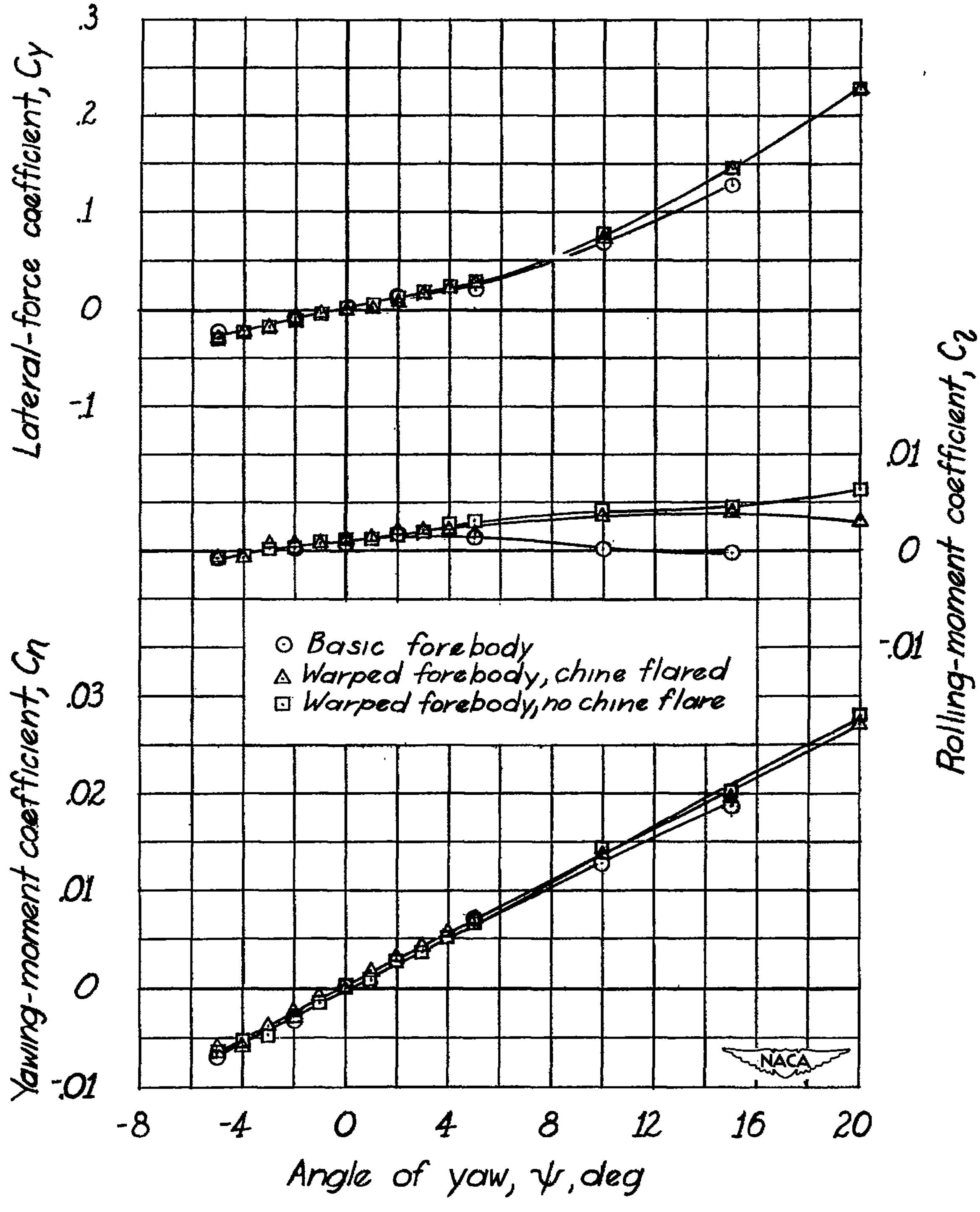

Figure 6.– Aerodynamic characteristics in yaw of Langley tank model 224. $R \approx 1.3 \times 10^6$; $\alpha = 2^\circ$.