NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1306

AERODYNAMIC CHARACTERISTICS OF THREE PLANING-TAIL FLYING-BOAT HULLS

By Campbell C. Yates and John M. Riebe

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

An investigation was made to determine the aerodynamic characteristics of three planing-tail flying-boat hulls which differed only in the amount of step fairing. The hulls were derived by altering the step and afterbody of a conventional flying-boat hull having a transverse step.

The investigation indicated that the planing-tail hull with a large pointed step had about the same minimum drag coefficient, 0.0065, as the previously tested conventional hull of the same over-all length-beam ratio. The hulls with step fairing, which are thought to be hydrodynamically acceptable, had up to 18 percent less minimum drag coefficient than the conventional hull or planing-tail hull with a large pointed step. The angle of attack for minimum drag was generally in the angle-of-attack range from 3° to 5°. Longitudinal instability and lateral instability were similar for all planing-tail hulls tested and were about the same as for the conventional hull.

INTRODUCTION

In view of the requirements for increased range and increased speed in future flying-boat designs, an investigation of the aerodynamic characteristics of flying-boat hulls as affected by hull dimensions and hull shape is being conducted at the Langley Memorial Aeronautical Laboratory. The results of one phase of this investigation, the effect of length-beam ratio, are presented in reference 1.

References 2 and 3 present numerous hydrodynamic advantages and disadvantages of the planing-tail hull. Sufficient information, however, was not available to permit an analysis of the aerodynamic qualities of this type of hull. In order to provide such information, the present investigation was made to determine the aerodynamic characteristics of three planing-tail hulls which differed only in the amount of step fairing.

All aerodynamic characteristics determined include the effects of interference of the support wing. Throughout the present paper, the term "aerodynamic characteristics" will be used to indicate aerodynamic characteristics which include wing interference.

COEFFICIENTS AND SYMBOLS

The results of the present tests are presented as standard NACA coefficients of forces and moments. Rolling-moment, yawing-moment, and pitching-moment coefficients are given about the location (wing 30-percent-chord point) shown in figure 1.

Except where noted, the wing area, mean aerodynamic chord, and span of a hypothetical flying boat derived from the Boeing XPBB-1 flying boat are used in determining the coefficients and Reynolds number. The data are referred to the stability axes, which are a system of axes having their origin at the center of moments shown in figure 1 and 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 $\left(\frac{\text{Lift}}{qS}\right)$

C_D drag coefficient $\left(\frac{\text{Drag}}{qS}\right)$

C_Y lateral-force coefficient $\left(\frac{Y}{qS}\right)$

C_l rolling-moment coefficient $\left(\frac{L}{qSb}\right)$

C_m pitching-moment coefficient $\left(\frac{M}{qS\bar{c}}\right)$

C_n yawing-moment coefficient $\left(\frac{N}{qSb}\right)$

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 $\left(\frac{\rho V^2}{2}\right)$
S	wing area of $\frac{1}{10}$-scale model hypothetical flying boat (18.264 sq ft)
$\bar{c}$	wing mean aerodynamic chord (M.A.C.) of $\frac{1}{10}$-scale model hypothetical flying boat (1.377 ft)
b	wing span of $\frac{1}{10}$-scale model 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 M.A.C. of $\frac{1}{10}$-scale model hypothetical flying boat

$$C_{m_\alpha} = \frac{\partial C_m}{\partial \alpha}$$

$$C_{n_\psi} = \frac{\partial C_n}{\partial \psi}$$

$$C_{Y_\psi} = \frac{\partial C_Y}{\partial \psi}$$

When a subscript for the partial derivatives is used herein, the subscript indicates the quantity held constant.

MODEL AND APPARATUS

The hulls (models 221A, 221B, and 221C) were designed by the Langley Hydrodynamics Division by altering the step and afterbody of hull 203 of reference 1 from considerations of the results given in references 2 and 3. Dimensions of the hulls are given in figure 1 and in tables I to III; sketches of the step fairings are given as figure 3.

Only one hull was constructed for testing. Transformation from one configuration to another was facilitated through the use of interchangeable blocks as shown in figure 3. The hull and interchangeable blocks were of laminated-mahogany construction and were finished with pigmented varnish.

The volumes, surface areas, and maximum cross-sectional areas for the three hulls are compared in the following table:

Hull	Volume (cu in.)	Surface area (sq in.)	Maximum cross-sectional area (sq in.)	Side area (sq in.)
221A	12,643	4638	182	1765
221B	12,464	4626	182	1742
221C	12,499	4621	182	1749

The hull was attached to a wing which was mounted horizontally as shown in figures 4 and 5. The wing (which was the same as that of reference 1) was set at an incidence of 4° on all models, had a 20-inch chord, and was of the NACA 4321 airfoil section.

TESTS

Test Conditions

The tests were made in the Langley 300 MPH 7- by 10-foot tunnel at dynamic pressures of approximately 25 and 100 pounds per square foot corresponding to airspeeds of 100 and 201 miles per hour, respectively. Reynolds numbers for these airspeeds, based on the mean aerodynamic chord of the hypothetical flying boat, were approximately 1.30×10^6 and 2.50×10^6, respectively. Corresponding Mach numbers were 0.13 and 0.26.

Corrections

Blocking corrections have been applied to the wing-alone data and to the wing-and-hull data. The hull drag has been corrected for horizontal-buoyancy effects caused by a tunnel static-pressure gradient. Angles of attack have been corrected for structural deflections caused by aerodynamic forces.

Test Procedure

The aerodynamic characteristics of the hulls with interference of the support wing were determined by testing the wing alone and the wing-and-hull combinations under similar conditions. The hull aerodynamic coefficients were thus determined by subtraction of wing-alone coefficients from wing-and-hull coefficients.

Tests were made at two Reynolds numbers. The data at the higher Reynolds number was limited to the angle-of-attack range shown because of structural limitations of the support wing.

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

Hull transition for all tests was fixed by a strip of 0.008-inch-diameter carborundum particles 1/2 inch wide and located at approximately 5 percent of the hull length aft of the bow. All tests were made with the mounting setup shown in figures 4 and 5.

RESULTS AND DISCUSSION

The aerodynamic characteristics of the planing-tail hulls in pitch are presented in figure 6; aerodynamic characteristics in yaw are given in figure 7.

Substantial reductions in minimum drag were attained by fairing the step of the planing-tail hull. (See fig. 6.) Longitudinal instability, lateral instability, and the angle-of-attack range for minimum drag (3° to 5°) were generally the same for all hulls tested. (See figs. 6 and 7.)

In order to compare the aerodynamic characteristics of the planing-tail hulls with the aerodynamic characteristics of a conventional hull, the minimum drag and stability parameters of the three hulls are given with those of hull 203 of reference 1 in table IV. The drag data presented are for a Reynolds number of approximately 2,500,000.

Hull 203 was used in the comparison because it has the same over-all length, maximum cross-sectional area, shape of forebody, over-all length-beam ratio, and about the same volume and surface area as the planing-tail hulls of the present investigation.

A comparison of the drag data for the planing-tail hull 221B with that for hull 203 (reference 1) shows the drag characteristics throughout the pitch range to be very similar; the minimum drag coefficient was about 0.0065 for each hull. Substantial decreases in drag coefficient resulted for the hulls with step fairings, although neither fairing eliminated the step discontinuity entirely; the depth of step used was considered the probable minimum which could be allowed without excessive hydrodynamic penalties. The following percentage reductions in drag were obtained based on the drag of hull 221B or the conventional hull: hull 221C (concave fairing), 12 percent; hull 221A (fairing approaching straight-line elements), 18 percent.

Reference 1 indicates that about a 15-percent reduction in drag should result if a step fairing is added to hull 203. From a consideration of this reduction in drag and the similar drag of hulls 221B and 203, it follows that an extension of the sternpost to the end of the hull probably has a small effect on drag. The chief aerodynamic advantage of the planing-tail hull, therefore, appears to be dependent upon the amount of nonretractable step fairing which can be used hydrodynamically as compared with the amount that can be used on a conventional hull.

Longitudinal instability, measured by C_{m_α}, was the same for the planing-tail hulls as for the conventional hull, and lateral instability was about the same. At an angle of attack of 2°, C_{n_ψ} for the planing-tail hulls was 0.0002 less than for the conventional hull. At an angle of attack of 6° the opposite effect was produced; C_{n_ψ} for the planing-tail hulls was 0.0002 larger.

In order to compare the results of these tests with results of investigations made of other hulls and fuselages the parameters K_f, $\partial C_{n_f}'/\partial\psi'$, and $\partial C_n/\partial\beta$, as derived from references 4, 5, and 6, respectively, are included in table IV. The parameter K_f is a fuselage moment factor, in the form of $\partial C_m/\partial\alpha$, based on hull beam and length, where α is in radians. The yawing-moment coefficient C_{n_f}' in $\partial C_{n_f}'/\partial\psi'$ is based on volume and is given about a reference axis 0.3 hull length from the nose. The parameter $\partial C_n/\partial\beta$ is based on hull side area and length, where the yawing moment is also given about a reference axis 0.3 hull length from the nose and β is given in radians. Instability as given by the parameters $\partial C_{n_f}'/\partial\psi'$ and $\partial C_n/\partial\beta$ generally agreed closely with the hull values given in references 5 and 6.

CONCLUSIONS

The results of tests to determine aerodynamic characteristics of three planing-tail flying-boat hulls, derived by altering the step and afterbody of a conventional hull, indicate the following conclusions:

1. The planing-tail hull with a large pointed step had about the same minimum drag coefficient, 0.0065, as that of a conventional hull; the hull with a concave step fairing and that with a fairing which approaches straight line elements had 12 and 18 percent less minimum drag, respectively.

2. The angle-of-attack range for minimum drag was generally between 3° and 5° for all planing-tail hulls tested.

3. Longitudinal instability and lateral instability were the same for all planing-tail hulls and were about the same as that of the conventional hull.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., March 11, 1947

REFERENCES

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TABLE I

OFFSETS FOR LANGLEY TANK MODEL 221A

[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)	Bottom of hull - heights and half-breadths: Buttocks (in.) 1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	Water line (in.) 1	2	3	4	5	6	7
F.P.	0	10.30	10.30	0	0	11.00	11.00																	
1/2	2.13	5.49	8.30	2.30	2.30	14.29	11.98	10	6.48	7.49	8.14	8.32												
1	4.25	3.76	6.71	3.06	3.06	15.72	12.66	10	4.52	5.30	6.09	6.56	6.77	6.72										
2	8.50	1.83	4.59	3.86	3.86	17.36	13.50	10	2.40	2.96	3.53	4.01	4.38	4.60	4.64									
3	12.75	.80	3.24	4.32	4.32	18.41	14.08	10	1.21	1.64	2.06	2.49	2.85	3.10	3.25	3.28								
4	17.00	.27	2.36	4.61	4.61	19.12	14.52	10	.59	.92	1.25	1.58	1.89	2.14	2.33	2.42	2.38							
5	21.25	.04	1.81	4.79	4.79	19.60	14.81	10	.29	.55	.80	1.04	1.30	1.52	1.70	1.82	1.85							
6	25.50	0	1.51	4.89	4.89	19.88	14.99	5	.19	.40	.59	.78	.98	1.18	1.33	1.46	1.52							
7	29.75	0	1.40	4.92	4.92	19.99	15.07	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40							
8	34.00	0	1.40	4.925	4.925	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40	2.72	4.925	4.925	4.925	4.925	4.925	4.925
9	38.25	0	1.39	4.50	4.925	20.00	15.08			.36		.73		1.09		1.33		2.72	4.72	4.925	4.925	4.925	4.925	4.925
10	42.50	0	1.12	3.14	4.925	20.00	15.08			.36		.73		1.09		1.91		2.72	4.10	4.90	4.925	4.925	4.925	4.925
11	46.75	0	.26	.73	4.925	20.00	15.08			.59		1.32		2.05		2.79		1.57	2.93	4.28	4.925	4.925	4.925	4.925
11 1/4 F.	47.90	0	0	0	4.925	20.00	15.08			.90		1.59		2.29		3.00		1.16	2.57	4.00	4.90	4.925	4.925	4.925
11 1/4 A.	47.90	.10			4.925	20.00	15.08			.90		1.59		2.29		3.00		1.16	2.57	4.00	4.90	4.925	4.925	4.925
12	51.00	.98			4.925	20.00	15.08			1.69		2.32		2.94		3.58		.01	1.48	3.10	4.57	4.925	4.925	4.925
13	55.25	2.11			4.91	20.00	15.09			2.70		3.24		3.79		4.33				1.53	3.39	4.87	4.91	4.91
14	59.50	3.14			4.86	20.00	15.14			3.63		4.11		4.59		5.08					1.74	3.85	4.86	4.86
15	63.75	4.04			4.75	20.00	15.25			4.48		4.90		5.34		5.78						2.21	4.41	4.75
16	68.00	4.86			4.61	20.00	15.39			5.25		5.66		6.07		6.46						.32	2.81	4.61
17	72.25	5.62			4.43	20.00	15.57			6.01		6.39		6.77		7.14							.98	3.61
18	76.50	6.32			4.17	20.00	15.83			6.69		7.06		7.42		7.79								1.82
19	80.75	6.98	8.38		3.87	20.00	16.13																	
20	85.00	7.59	8.86		3.50	20.00	16.50																	
21	89.25	8.20	9.32		3.08	20.00	16.92																	
22	93.50	8.80	9.76		2.61	20.00	17.39																	
23	97.75	9.41	10.20		2.15	20.00	17.85																	
24	102.00	10.03	10.64		1.69	20.00	18.31																	
25	106.25	10.64	11.08		1.22	20.00	18.78																	
26	110.50	11.25	11.52		.76	20.00	19.24																	
27	114.75	11.85	11.96		.31	20.00	19.69																	
A.P.	116.65	12.12	12.16		.10	20.00	19.90																	

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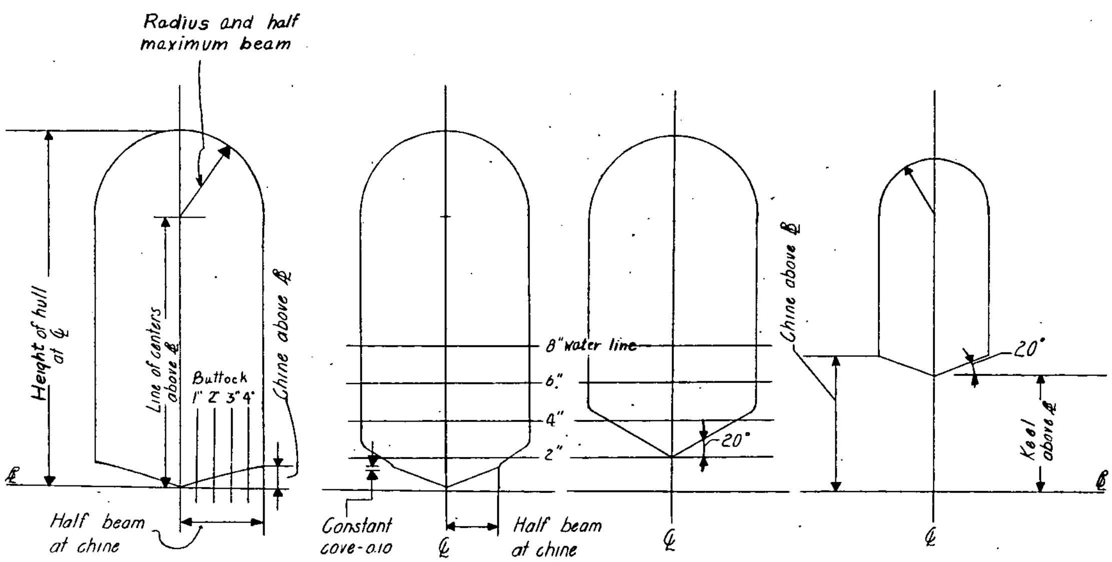

F.P. to station 8 Station 8 to step Step to station 19 Station 19 to A.P.

TABLE II

OFFSETS FOR LANGLEY TANK MODEL 221B

[All dimensions are in inches]

Station	Distance to F.P.	Keel above base line	Cove 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)	Bottom of hull – heights and half breadths															
										Buttocks (in.)									Water line (in.)						
										1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	1	2	3	4	5	6	7
F.P.	0	10.30		10.30	0	0	11.00	11.00																	
1/2	2.13	5.49		8.30	2.30	2.30	14.29	11.98	10	6.48	7.49	8.14	8.32												
1	4.25	3.76		6.71	3.06	3.06	15.72	12.66	10	4.52	5.30	6.09	6.56	6.77	6.72										
2	8.50	1.83		4.59	3.86	3.86	17.36	13.50	10	2.40	2.96	3.53	4.01	4.38	4.60	4.64									
3	12.75	.80		3.24	4.32	4.32	18.41	14.08	10	1.21	1.64	2.06	2.49	2.85	3.10	3.25	3.28								
4	17.00	.27		2.36	4.61	4.61	19.12	14.52	10	.59	.92	1.25	1.58	1.89	2.14	2.33	2.42	2.38							
5	21.25	.04		1.81	4.79	4.79	19.60	14.81	10	.29	.55	.80	1.04	1.30	1.52	1.70	1.82	1.85							
6	25.50	0		1.51	4.89	4.89	19.88	14.99	5	.19	.40	.59	.78	.98	1.18	1.33	1.46	1.52							
7	29.75	0		1.40	4.92	4.92	19.99	15.07	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40							
8	34.00	0	2.06	2.06	4.925	4.925	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40	2.72	4.925	4.925	4.925	4.925	4.925	4.925
9	38.25	0	2.51	2.67	4.50	4.925	20.00	15.08			.36		.73		1.09		1.33		2.72	4.72	4.925	4.925	4.925	4.925	4.925
10	42.50	0	2.63	3.28	3.14	4.925	20.00	15.08			.36		.73		1.09		1.91		2.72	4.10	4.90	4.925	4.925	4.925	4.925
11	46.75	0	2.36	3.89	.73	4.925	20.00	15.08			.59		1.32		2.05		2.79		1.57	2.93	4.28	4.925	4.925	4.925	4.925
11 1/4 F	47.90	0	2.27	4.06	0	4.925	20.00	15.08			.90		1.59		2.29		3.00		1.16	2.57	4.00	4.90	4.925	4.925	4.925
11 1/4 A	47.90	2.27		4.06		4.925	20.00	15.08			.90		1.59		2.29		3.00		1.16	2.57	4.00	4.90	4.925	4.925	4.925
12	51.00	2.71		4.50		4.925	20.00	15.08			1.69		2.32		2.94		3.58		.01	1.48	3.10	4.57	4.925	4.925	4.925
13	55.25	3.32		5.11		4.91	20.00	15.09			2.70		3.24		3.79		4.33				1.53	3.39	4.87	4.91	4.91
14	59.50	3.93		5.70		4.86	20.00	15.14			3.63		4.11		4.59		5.08					1.74	3.85	4.86	4.86
15	63.75	4.54		6.27		4.75	20.00	15.25			4.48		4.90		5.34		5.78						2.21	4.41	4.75
16	68.00	5.15		6.83		4.61	20.00	15.39			5.25		5.66		6.07		6.46						.32	2.81	4.61
17	72.25	5.76		7.37		4.43	20.00	15.57			6.01		6.39		6.77		7.14							.98	3.61
18	76.50	6.37		7.89		4.17	20.00	15.83			6.69		7.06		7.42		7.79								1.82
19	80.75	6.98		8.38		3.87	20.00	16.13																	
20	85.00	7.59		8.86		3.50	20.00	16.50																	
21	89.25	8.20		9.32		3.08	20.00	16.92																	
22	93.50	8.81		9.76		2.61	20.00	17.39																	
23	97.75	9.42		10.20		2.15	20.00	17.85																	
24	102.00	10.03		10.64		1.69	20.00	18.31																	
25	106.25	10.64		11.08		1.22	20.00	18.78																	
26	110.50	11.25		11.52		.76	20.00	19.24																	
27	114.75	11.85		11.96		.31	20.00	19.69																	
A.P.	116.65	12.12		12.16		.10	20.00	19.90																	

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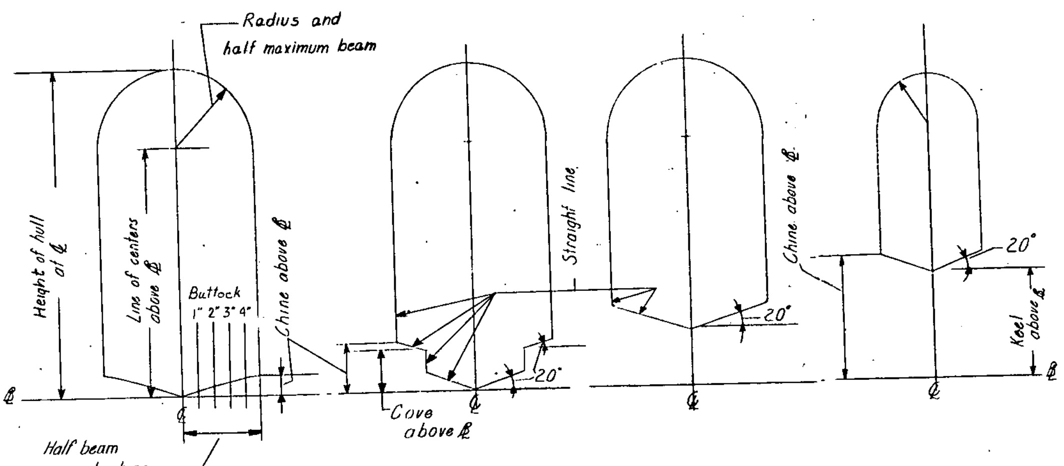

F.P. to station 8 Station 8 to step Step to station 19 Station 19 to A.P.

TABLE III

OFFSETS FOR LANGLEY TANK MODEL 221C

[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)	Bottom of hull – heights and half breadths															
									Buttocks (in.)									Water line (in.)						
									1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	1	2	3	4	5	6	7
F.P.	0	10.30	10.30	0	0	11.00	11.00																	
1/2	2.13	5.49	8.30	2.30	2.30	14.29	11.98	10	6.48	7.49	8.14	8.32												
1	4.25	3.76	6.71	3.06	3.06	15.72	12.66	10	4.52	5.30	6.09	6.56	6.77	6.72										
2	8.50	1.83	4.59	3.86	3.86	17.36	13.50	10	2.40	2.96	3.53	4.01	4.38	4.60	4.64									
3	12.75	.80	3.24	4.32	4.32	18.41	14.08	10	1.21	1.64	2.06	2.49	2.85	3.10	3.25	3.28								
4	17.00	.27	2.36	4.61	4.61	19.12	14.52	10	.59	.92	1.25	1.58	1.89	2.14	2.33	2.42	2.38							
5	21.25	.04	1.81	4.79	4.79	19.60	14.81	10	.29	.55	.80	1.04	1.30	1.52	1.70	1.82	1.85							
6	25.50	0	1.51	4.89	4.89	19.88	14.99	5	.19	.40	.59	.78	.98	1.18	1.33	1.46	1.52							
7	29.75	0	1.40	4.92	4.92	19.99	15.07	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40							
8	34.00	0	1.40	4.925	4.925	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40	2.72	4.925	4.925	4.925	4.925	4.925	4.925
9	38.25	0	1.39	4.50	4.925	20.00	15.08			.36		.73		1.09		1.33		2.72	4.67	4.925	4.925	4.925	4.925	4.925
10	42.50	0	1.12	3.14	4.925	20.00	15.08			.36		.73		1.09		2.45		2.72	3.59	4.58	4.925	4.925	4.925	4.925
11	46.75	0	.26	.73	4.925	20.00	15.08			.91		2.06		2.77		3.33		1.05	1.91	3.40	4.91	4.925	4.925	4.925
11 1/4 F	47.90	0	0	0	4.925	20.00	15.08			1.62		2.43		3.02		3.52		.45	1.40	2.97	4.79	4.925	4.925	4.925
11 1/4 A	47.90	.10			4.925	20.00	15.08			1.62		2.43		3.02		3.52		.45	1.40	2.97	4.79	4.925	4.925	4.925
12	51.00	2.08			4.925	20.00	15.08			2.64		3.13		3.60		4.05				1.71	3.89	4.925	4.925	4.925
13	55.25	3.12			4.91	20.00	15.09			3.52		3.93		4.33		4.71					2.14	4.72	4.91	4.91
14	59.50	3.88			4.86	20.00	15.14			4.25		4.62		4.99		5.36					.29	3.02	4.86	4.86
15	63.75	4.54	6.27	4.75	4.75	20.00	15.25			4.48		4.90		5.34		5.78							4.41	4.75
16	68.00	5.15	6.83	4.61	4.61	20.00	15.39			5.25		5.66		6.07		6.46							2.81	4.61
17	72.25	5.76	7.37	4.43	4.43	20.00	15.57			6.01		6.39		6.77		7.14							.96	3.61
18	76.50	6.37	7.89	4.17	4.17	20.00	15.83			6.69		7.06		7.42		7.79								1.82
19	80.75	6.98	8.38	3.87	3.87	20.00	16.13																	
20	85.00	7.59	8.86		3.50	20.00	16.50																	
22	89.25	8.20	9.32		3.08	20.00	16.92																	
22	93.50	8.80	9.76		2.61	20.00	17.39																	
23	97.75	9.41	10.20		2.15	20.00	17.85																	
24	102.00	10.03	10.64		1.69	20.00	18.31																	
25	106.25	10.64	11.08		1.22	20.00	18.78																	
26	110.50	11.25	11.52		.76	20.00	19.24																	
27	114.75	11.85	11.96		.31	20.00	19.69																	
A.P.	116.65	12.12	12.16		.10	20.00	19.90																	

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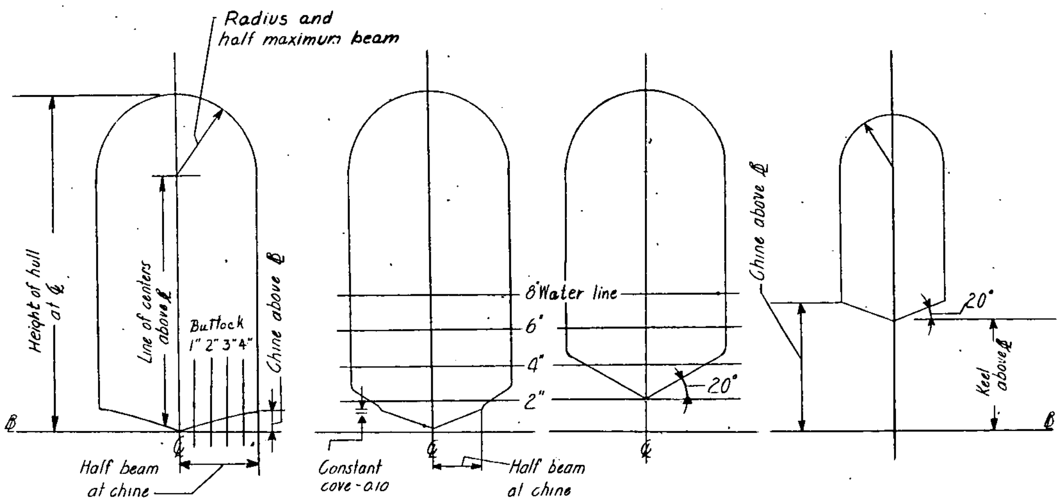

F.P. to station 8 Station 8 to step Step to station 19 Station 19 to A.P.

TABLE IV

MINIMUM DRAG COEFFICIENTS AND STABILITY PARAMETERS FOR LANGLEY TANK MODELS 221A, 221B, 221C, AND 203

Model	$C_{D_{min}}$	$\frac{\partial C_m}{\partial \alpha}$	K_f	$\left(\frac{\partial C_Y}{\partial \psi}\right)_{\alpha=2^\circ}$	$\left(\frac{\partial C_Y}{\partial \psi}\right)_{a=6^\circ}$	$\left(\frac{\partial C_n}{\partial \psi}\right)_{\alpha=2^\circ}$	$\left(\frac{\partial C_n}{\partial \psi}\right)_{\alpha=6^\circ}$	$\left(\frac{\partial C_n}{\partial \beta}\right)_{\alpha=2^\circ}$	$\left(\frac{\partial C_n}{\partial \beta}\right)_{\alpha=6^\circ}$	$\left(\frac{\partial C_{n_f}'}{\partial \psi'}\right)_{\alpha=2^\circ}$	$\left(\frac{\partial C_{n_f}'}{\partial \psi'}\right)_{\alpha=6^\circ}$
221A	0.0054	0.0050	1.10	0.0040	0.0030	0.0010	0.0012	-0.086	-0.115	0.024	0.033
221B	.0065	.0050	1.10	.0040	.0030	.0010	.0012	-.087	-.117	.025	.033
221C	.0058	.0050	1.10	.0040	.0030	.0010	.0012	-.087	-.116	.025	.033
203	.0066	.0050	1.10	.0051	.0050	.0012	.0010	-.100	-.088	.027	.023

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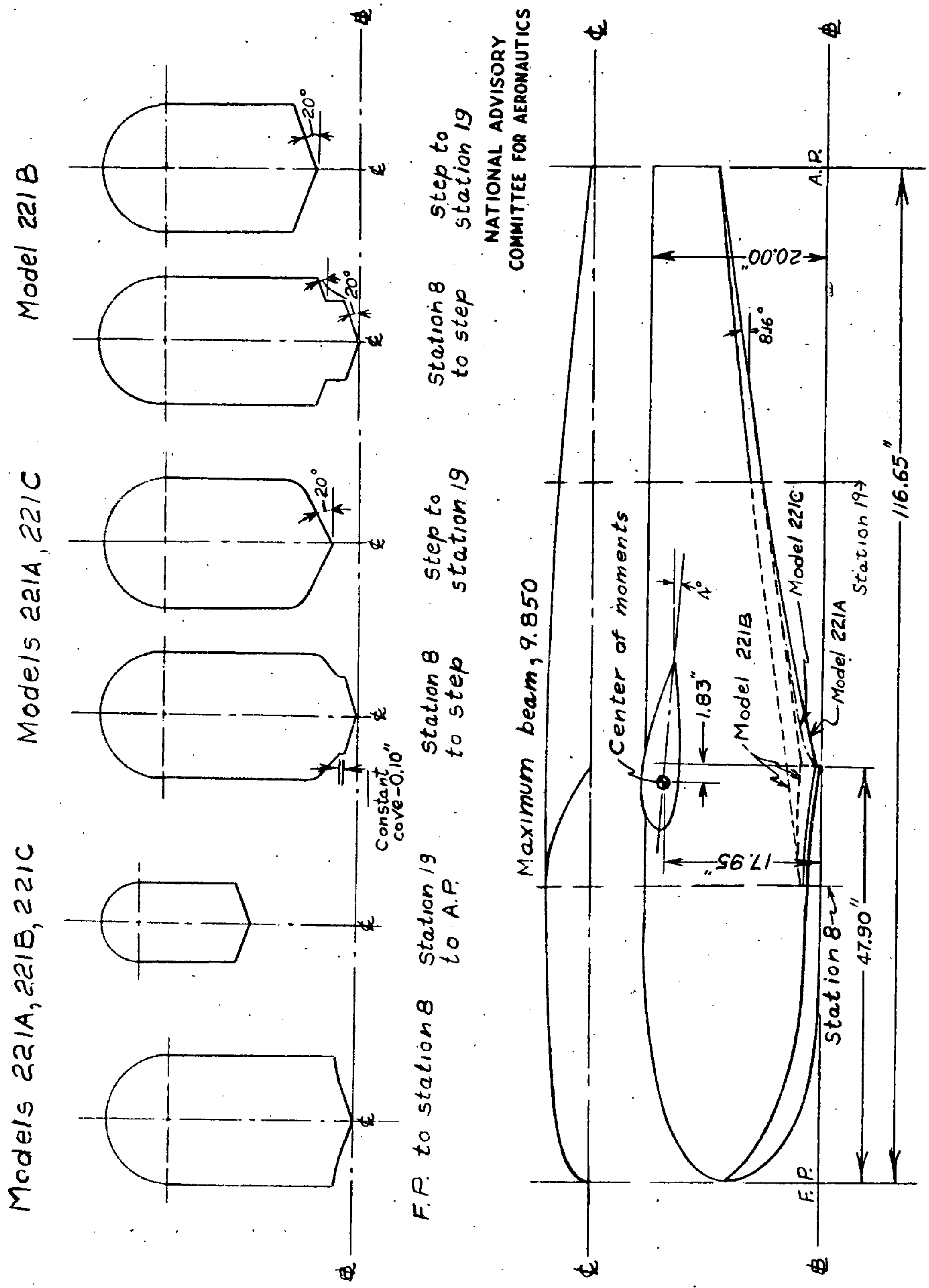

Figure 1.- Lines of Langley tank models 221A, 221B, and 221C.

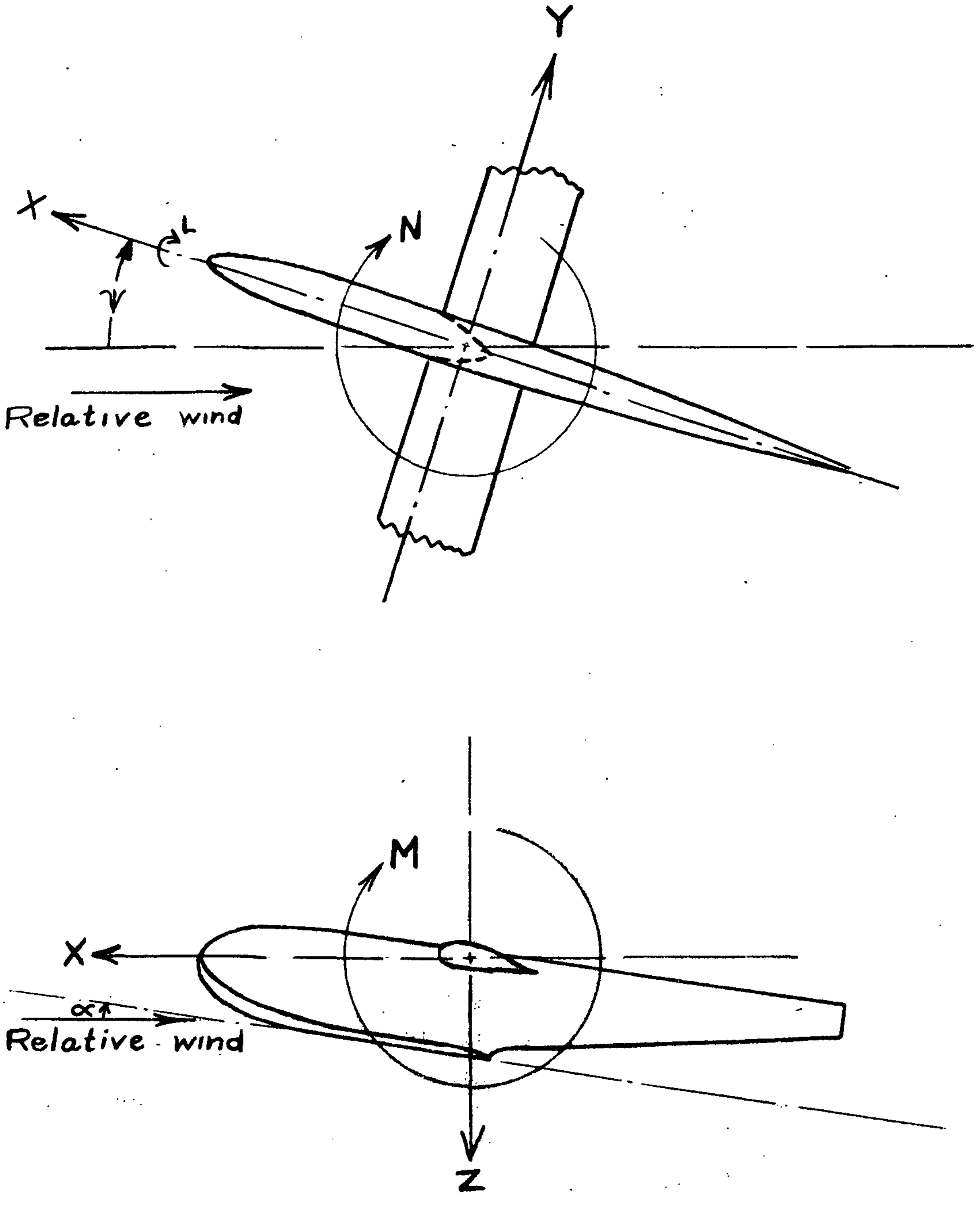

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Figure 2.- System of stability axes. Positive values of forces, moments, and angles are indicated by arrows.

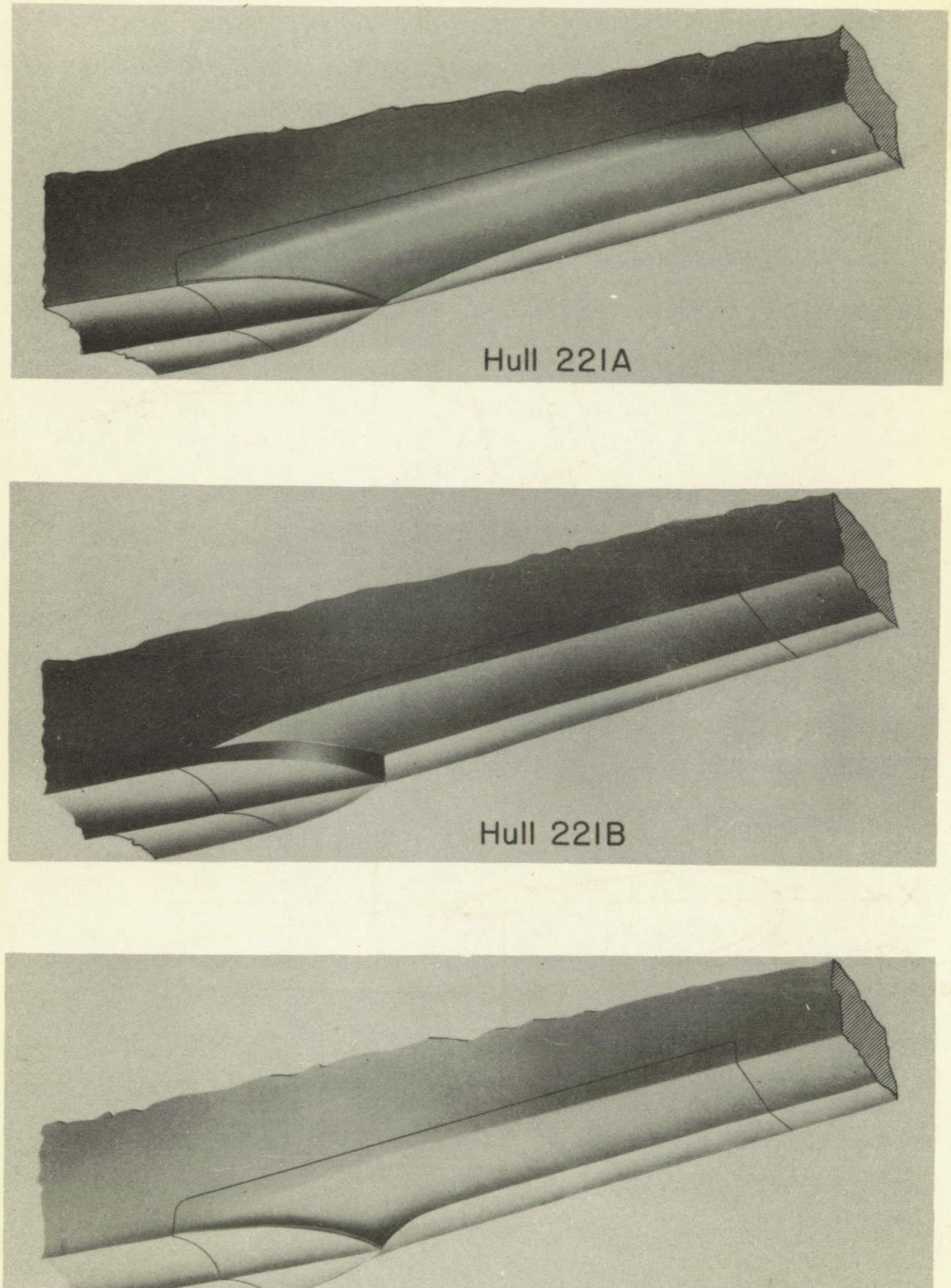

Figure 3.- Step fairings of planing-tail hulls 221A, 221B, and 221C.

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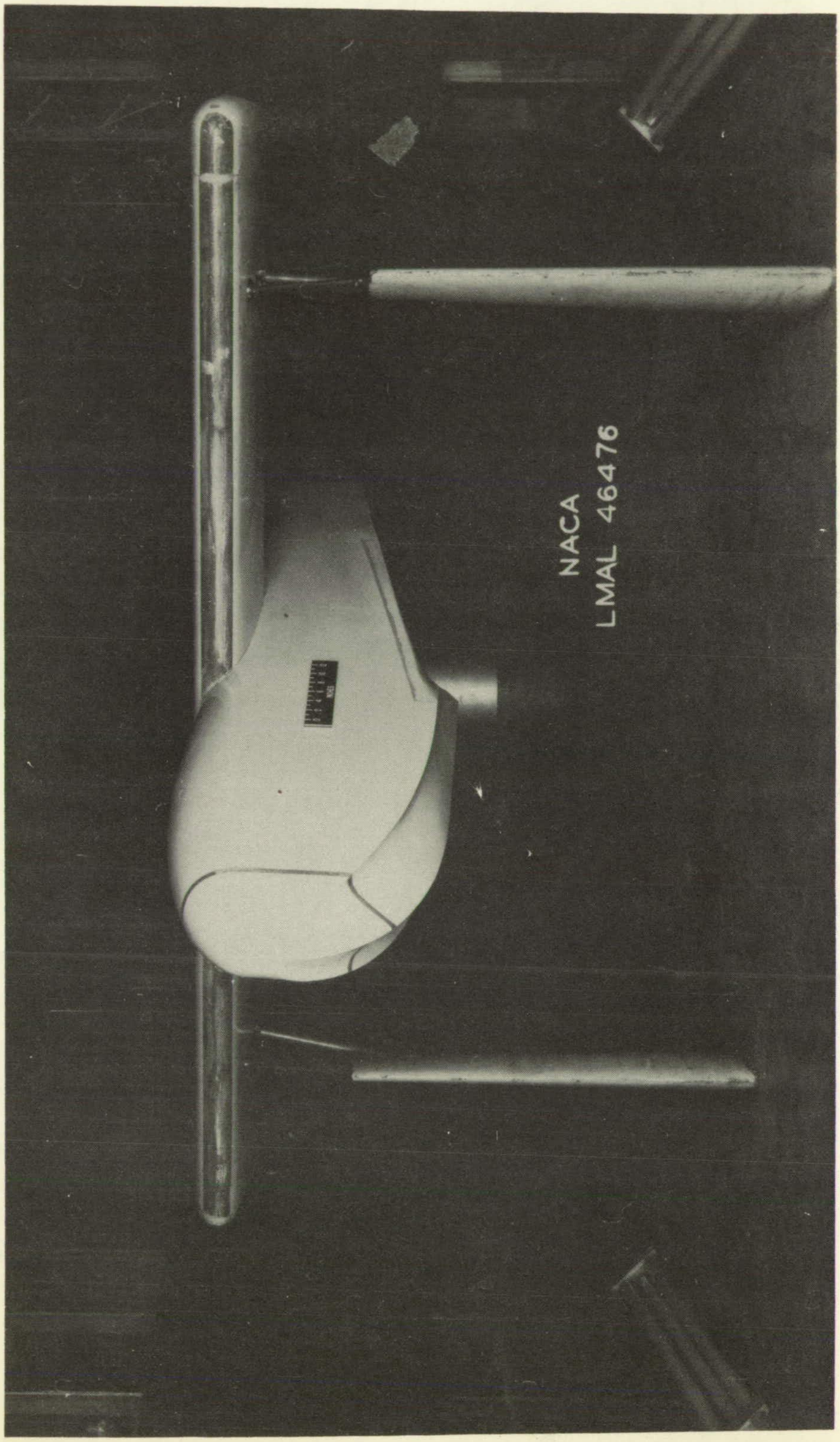


Figure 4.- NACA planing-tail hull model 221C mounted in the Langley 300 MPH 7- by 10-foot tunnel.

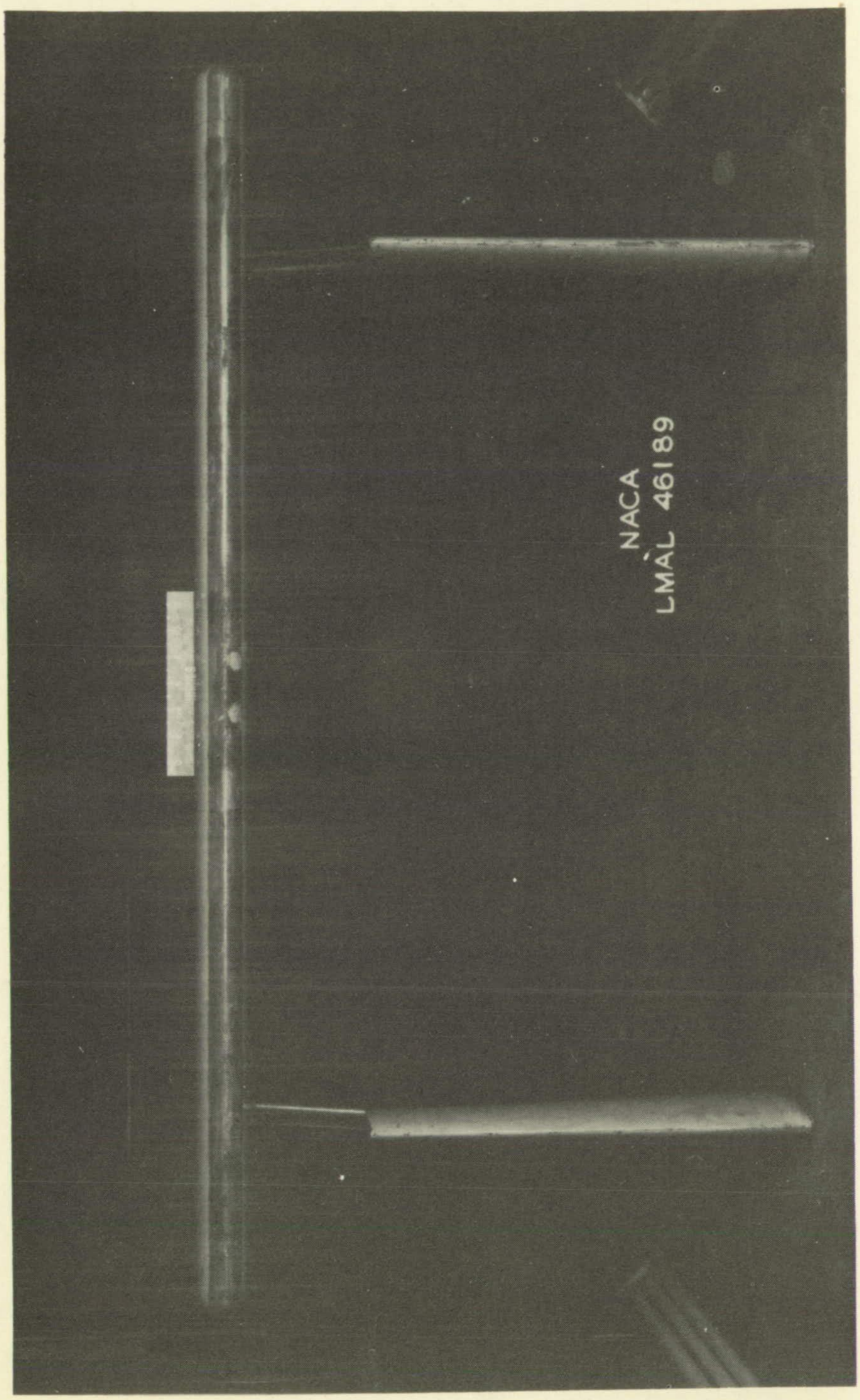
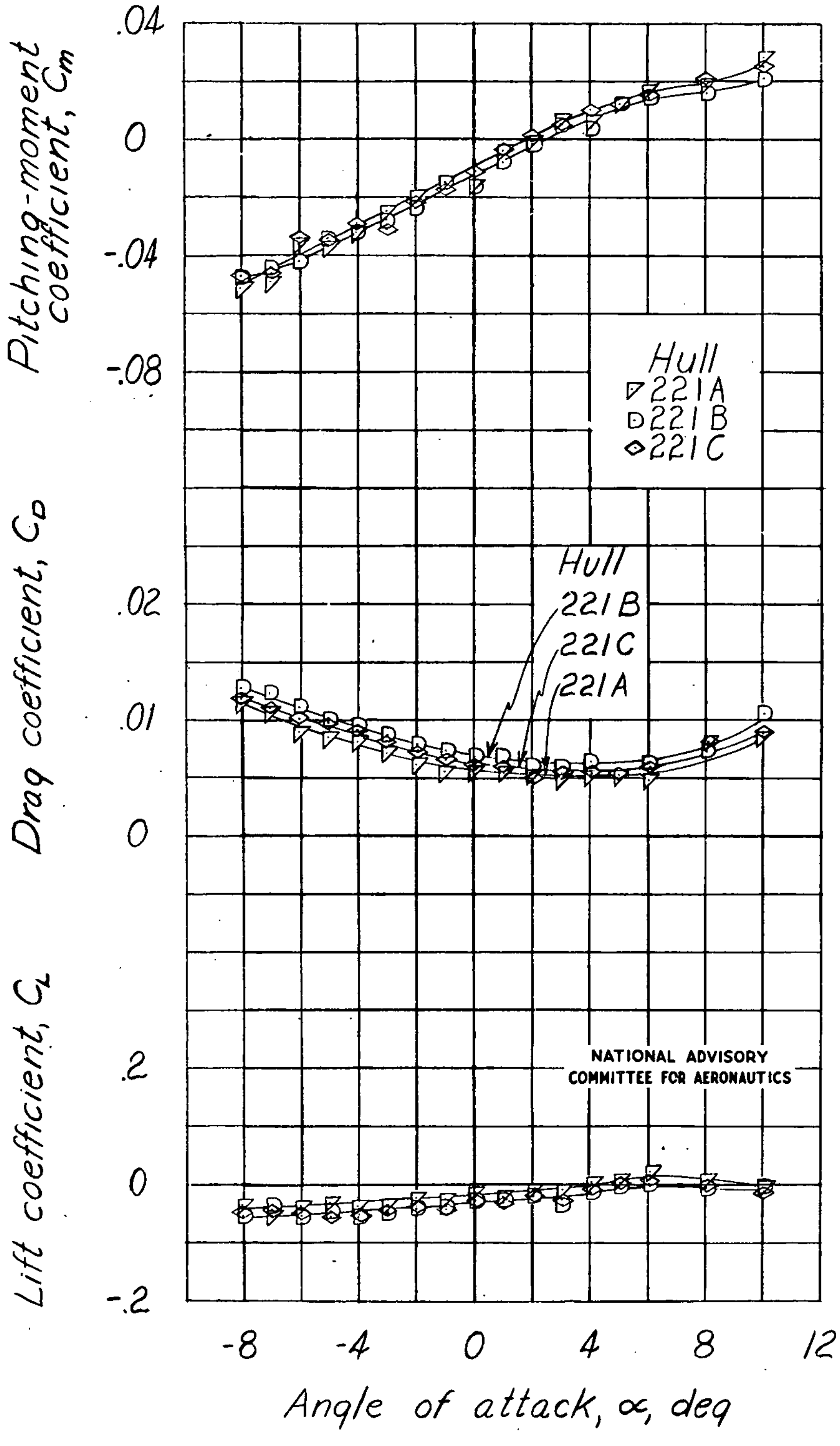
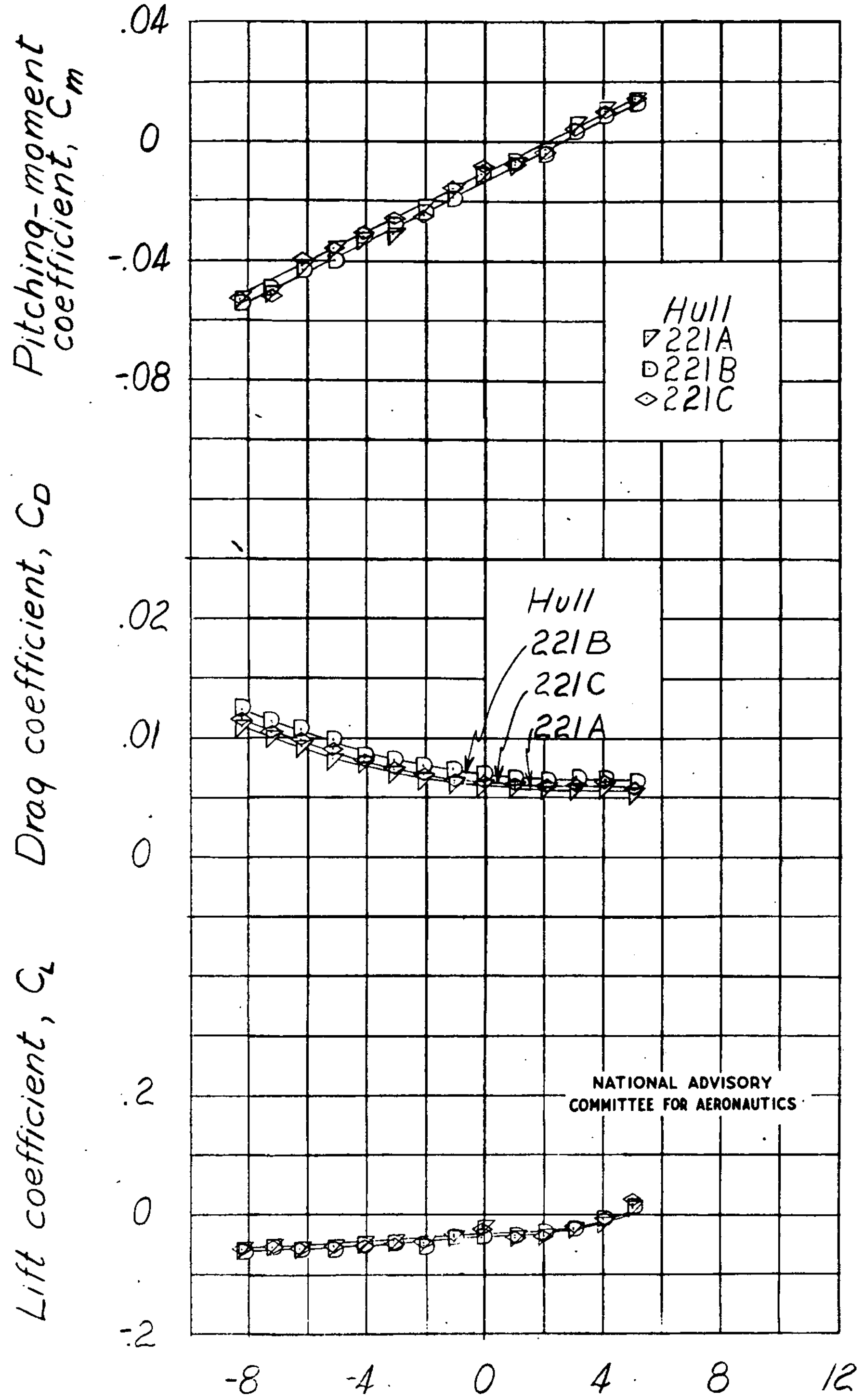


Figure 5.- Wing-alone mounting of the planing-tail-hull investigation in the Langley 300 MPH 7- by 10-foot tunnel.



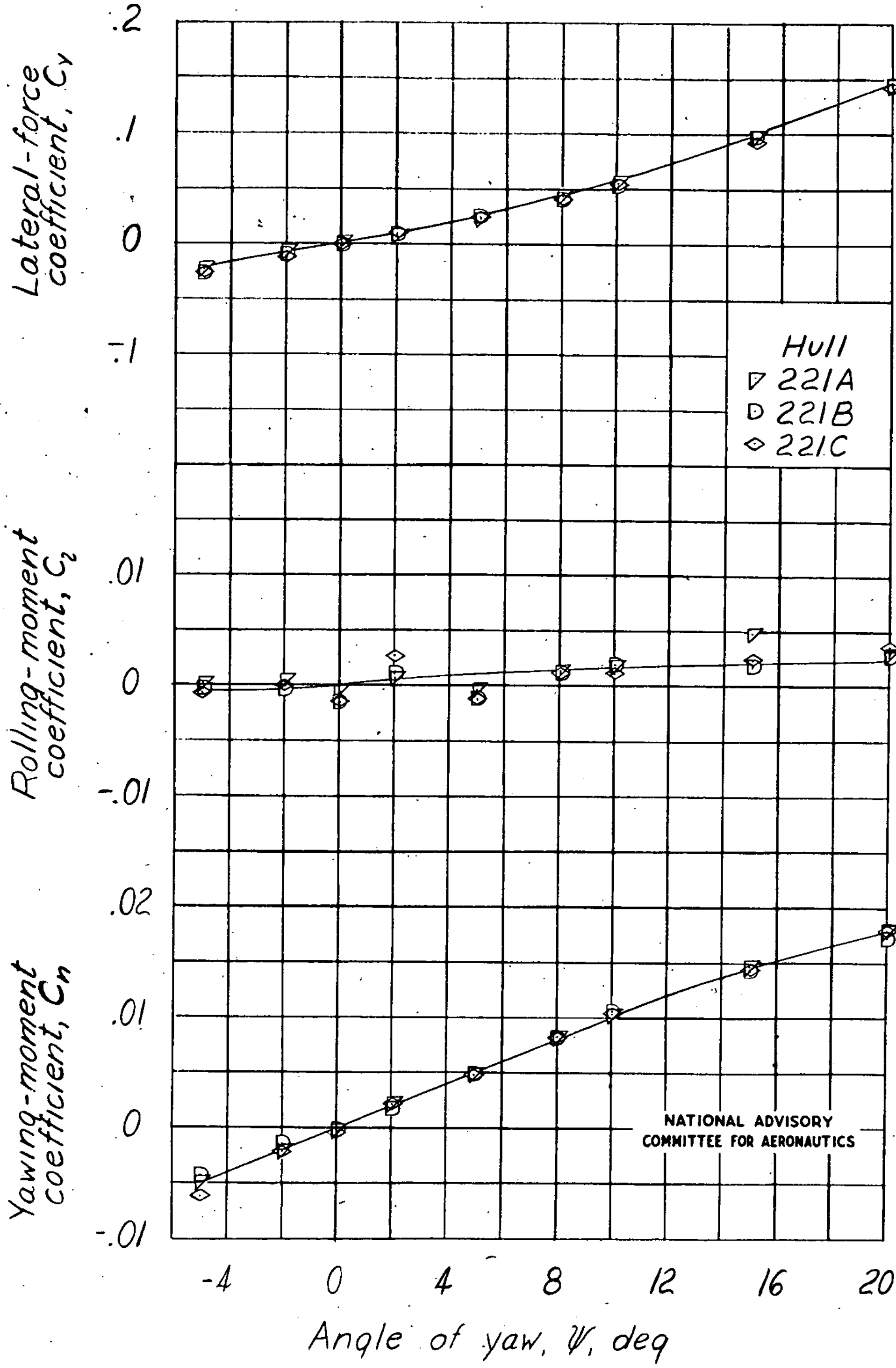
(a) $R = 1,300,000$.

Figure 6.- Aerodynamic characteristics in pitch of NACA planing-tail hull models 221A, 221B, and 221C.



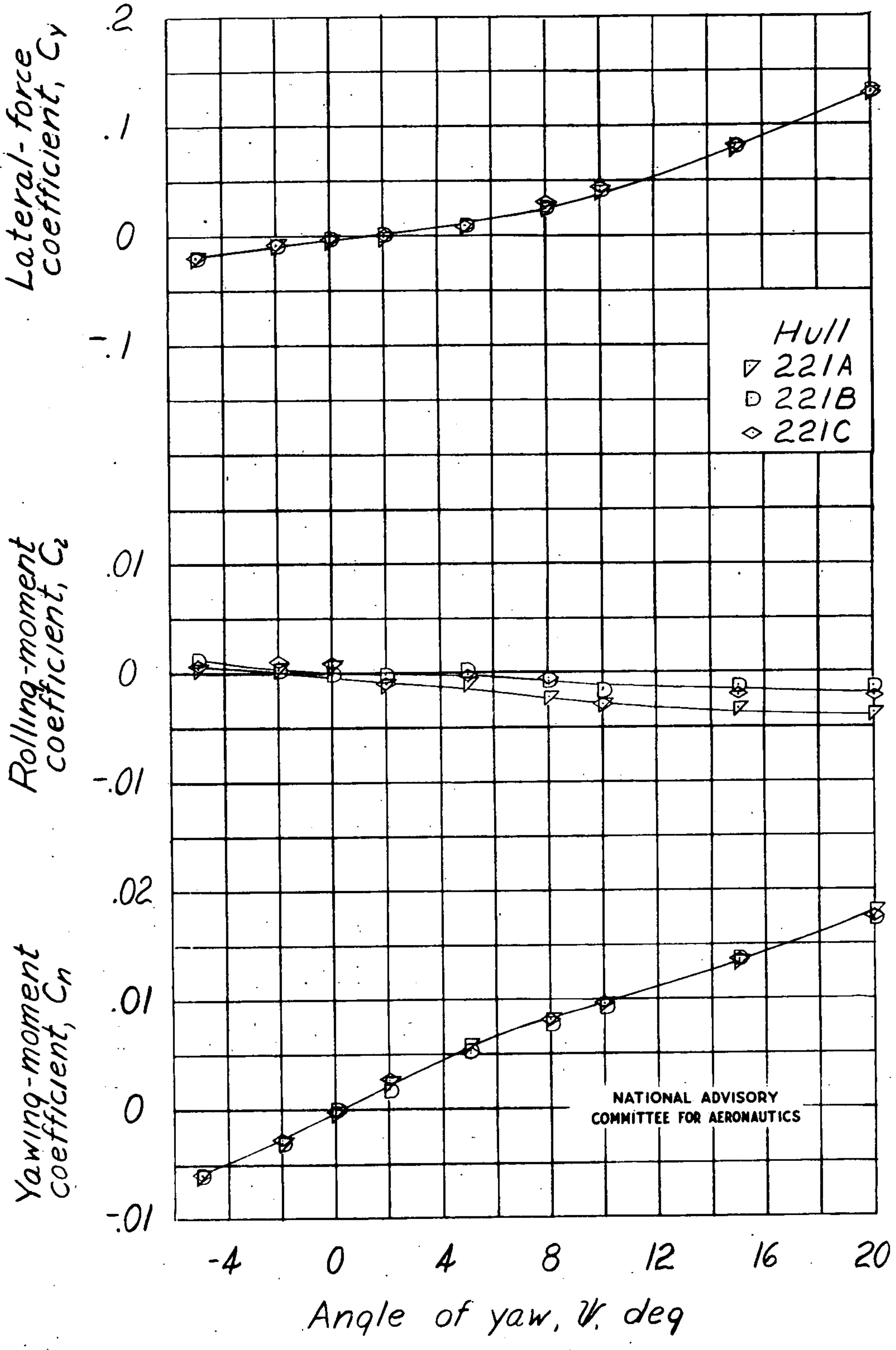
(b) R = 2,500,000.

Figure 6 .- Concluded.



(a) $\alpha = 2$; $R = 1,300,000$.

Figure 7.- Aerodynamic characteristics in yaw of NACA planing-tail hull models 221A, 221B, and 221C.



(b) $\alpha = 6$; $R = 1,300,000$.

Figure 7.- Concluded.