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RESEARCH MEMORANDUM

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AERODYNAMIC CHARACTERISTICS OF THREE DEEP-STEP PLANING-TAIL FLYING-BOAT HULLS

By

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AERODYNAMIC CHARACTERISTICS OF THREE DEEP-STEP PLANING-TAIL FLYING-BOAT HULLS

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SUMMARY

An investigation was made to determine the aerodynamic characteristics in the presence of a wing of three deep-step planing-tail flying-boat hulls which differed only in the amount of step fairing. The hulls were derived by increasing the unfaired-step depth of a planing-tail hull of a previous aerodynamic investigation to a depth of about 92 percent of the hull beam. For the purpose of comparison, tests were also made of a transverse-step hull with an extended afterbody.

The investigation indicated that the transverse-step hull with extended afterbody had about the same minimum drag coefficient, 0.0066, as a conventional hull and an angle-of-attack range for minimum drag of 3° to 5°. The hull with a deep unfaired step had a minimum drag coefficient of 0.0057, which was 14 percent less than the transverse-step hull with extended afterbody; the hulls with step fairing had up to 44 percent less minimum drag coefficient than the transverse-step hull. Longitudinal and lateral instability varied little with step fairing and was about the same as for a conventional hull.

INTRODUCTION

In view of the requirements for increased range and speed in flying-boat designs, an investigation of the aerodynamic characteristics of flying-boat hulls as affected by hull dimensions and hull shape has been conducted at the Langley Laboratory of the NACA. The results of one phase of the investigation, presented in reference 1, have indicated that substantial drag reductions can be obtained on planing-tail flying-boat hulls if proper step fairings are incorporated on the hull. In the present investigation, exploratory tests were made to determine whether further drag reductions might be obtained on this type of hull by deepening the step and, therefore, reducing the skin area.

Unpublished data from tests in Langley tank no. 2 have indicated that the three deep-step hulls of the present investigation would have satisfactory hydrodynamic characteristics.

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For the purpose of comparison, tests were also made of a transverse-step hull with extended afterbody.

As in the previous aerodynamic investigation of planing-tail hulls (reference 1) all hull aerodynamic characteristics determined include the effect of interference of the support wing.

COEFFICIENTS AND SYMBOLS

The results of the 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 used in determining the coefficients and Reynolds numbers are those of a hypothetical flying boat described in reference 2. The data are referred to the stability axes, which are a system of axes having their origin at the center of moments shown in figures 1 and 2 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 3.

The coefficients and symbols are defined as follows:

C_L lift coefficient (Lift/qS)

C_D drag coefficient (Drag/qS)

C_{D_v} drag coefficient based on volume v of hull $\left(\text{Drag}/qv^{2/3}\right)$

C_{D_A} drag coefficient based on maximum cross-sectional area A of hull (Drag/qA)

C_{D_W} drag coefficient based on surface area W of hull (Drag/qW)

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 $(\rho V^2/2)$

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

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

b wing span of $\frac{1}{10}$-scale model of 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 $\frac{1}{10}$-scale model of hypothetical flying boat

$\partial C_m/\partial \alpha$ rate of change of pitching-moment coefficient with angle of attack

$\partial C_n/\partial \psi$ rate of change of yawing-moment coefficient with angle of yaw

$\partial C_Y/\partial \psi$ rate of change of lateral-force coefficient with angle of yaw

Subscript:

min minimum

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MODEL AND APPARATUS

The deep-step hull lines of Langley tank models 221E, 221G, and 221F were drawn by the Langley Hydrodynamics Division by increasing the step of hull 221B of reference 1 from a depth which was 23 percent of the hull beam to a depth 92 percent of the hull beam and by maintaining the same height at the sternpost. The transverse-step hull with extended afterbody (Langley tank model 203 with extended afterbody) was the same as Langley tank model 203 of reference 2 with the exception of sternpost location and afterbody angle of keel. Dimensions of the hulls are given in figures 1 and 2 and tables I to IV; sketches of the deep-step fairings are given in figure 4.

The test model was the same one used in the investigation of reference 1; transformation from one hull to another was facilitated by cutting the underpart of the model and replacing interchangeable blocks corresponding to each step-fairing condition. The hull and interchangeable blocks were of laminated-mahogany construction and were finished with pigmented varnish.

The volumes, surface areas, maximum cross-sectional areas, and side areas for the 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.)
203 extended	13,338	4857	182	1845
221E	10,354	4164	182	1512
221G	10,904	4217	182	1568
221F	11,502	4314	182	1636

The hull was attached to a wing which was mounted horizontally as shown in figure 5. The wing (which was the same as that of reference 1) was set at an angle of incidence of 4° on all models, had a 20-inch chord, and was of 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, 100, and 170 pounds per square foot corresponding to airspeeds of 100, 201, and 274 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, 2.50×10^6, and 3.10×10^6, respectively. Corresponding Mach numbers were 0.13, 0.26, and 0.348.

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 three Reynolds numbers. The data at the higher Reynolds numbers were 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 support setup shown in figure 5.

RESULTS AND DISCUSSION

The aerodynamic characteristics of the deep-step planing-tail hulls in pitch are presented in figure 6; aerodynamic characteristics in yaw are given in figure 7. The aerodynamic characteristics of Langley tank model 203 with extended afterbody in pitch and yaw are presented in figures 8 and 9, respectively.

Langley tank model 203 with extended afterbody had a minimum drag coefficient of 0.0066, which is about the same as for a conventional hull of the same over-all length-beam ratio (reference 2); the angle-of-attack range for minimum drag extended from 3° to 5°.

The hull with the unfaired deep step, model 221E, had a minimum drag coefficient of 0.0057 which was 14 percent less than the hull with extended afterbody or a conventional hull. Comparison of the drag results of hull 221E with those of hull 221B of reference 1 indicates that increasing the step from a depth 23 percent of the hull beam to 92 percent of the hull beam resulted in a drag coefficient reduction of 12 percent. The hull with the fairing which had elements approaching straight lines, model 221F, had a minimum drag coefficient of 0.0037; according to unpublished data a streamlined body having approximately the same length and volume and the same wing interference had about 25 percent less minimum drag. The importance of proper step-fairing design in reducing aerodynamic drag on deep-step planing-tail hulls is shown by the larger value of drag coefficient, 0.0045, for hull 221G with the concave step fairing. The drag coefficient for this hull configuration was about 32 percent less than the hull with extended afterbody, whereas hull 221F with the fuller fairing was about 44 percent less.

Tuft studies of the step part of the hulls (fig. 10) indicate that the lower drag for the hulls with step fairing results from the elimination of separation which occurs on the sides of the unfaired deep-step hull.

Minimum drag coefficients based on (volume)$^{2/3}$ $\left(C_{D_V}\right)_{min}$, on maximum cross-sectional area $\left(C_{D_A}\right)_{min}$, and on surface area $\left(C_{D_W}\right)_{min}$ are presented in table V along with minimum drag coefficients based on hypothetical wing area. These data indicate that hull 221F had the least drag for a unit volume and for unit surface areas.

It should be noted when comparing the results of this paper with the results of hulls tested alone that subtraction of wing-alone data from wing-and-hull data, the method used to determine the hull-and-wing interference data in this paper, results in a lower minimum drag coefficient because of negative wing interference drag. This characteristic results because an appreciable part of the support wing was enclosed by the hull and shielded from the air stream. Unless this favorable interference effect is considered when comparisons are made with other hull-drag or fuselage-drag data, the drag coefficients tabulated herein, especially $\left(C_{D_W}\right)_{min}$, may seem abnormally low.

As with the planing-tail hulls of a previous investigation (reference 1), the angle-of-attack range for minimum drag occurred from about 3° to 5°.

Longitudinal and lateral instability, as shown by the parameters $\partial C_m/\partial\alpha$ and $\partial C_n/\partial\psi$ (table V), varied little with step fairing and was about the same as for a conventional hull or for a hull with extended afterbody.

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 3, 4, and 5, respectively, are also included in table V. 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 $\partial C_n/\partial\beta$ agreed closely with values given in references 4 and 5.

CONCLUSIONS

The results of tests to determine the aerodynamic characteristics of three deep-step planing-tail flying-boat hulls which differed only in the amount of step fairing and, for purpose of comparison, of a transverse-step hull with an extended afterbody indicated the following conclusions:

1. The transverse-step hull with extended afterbody had about the same minimum drag coefficient, 0.0066, as a conventional hull.

2. The planing-tail hull with a deep unfaired step had a minimum drag coefficient of 0.0057, about 14 percent less than a transverse-step hull; the hulls with step fairing had up to 44 percent less minimum drag coefficient than a transverse-step hull.

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

4. Longitudinal and lateral instability was the same for all planing-tail hulls and was about the same as for the transverse-step hull.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronatics
Langley Field, Va., October 6, 1947

REFERENCES

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

2. 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.

3. Gilruth, R. R., and White, M. D.: Analysis and Prediction of Longitudinal Stability of Airplanes. NACA Rep. No. 711, 1941.

4. Pass, H. R.: Analysis of Wind-Tunnel Data on Directional Stability and Control. NACA TN No. 775, 1940.

5. Imlay, Frederick H.: The Estimation of the Rate of Change of Yawing Moment with Sideslip. NACA TN No. 636, 1938.

[redacted] TABLE I

OFFSETS FOR LANGLEY TANK MODEL 221E

[All dimensions are in inches]

Station	Distance to F.P.	Keel above B.L.	Cove above B.L.	Upper chine above B.L.	Lower chine above B.L.	Lower chine half beam	Radius and half maximum beam	Height of hull at C.L.	Line of centers above B.L.	Angle of chine flare (deg)	Bottom of hull: 1/2 in. Butt	1 in. Butt	1 1/2 in. Butt	2 in. Butt	2 1/2 in. Butt	3 in. Butt	3 1/2 in. Butt	4 in. Butt	4 1/2 in. Butt
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		4.52	5.30	6.09	6.56	6.77	6.72	4.64		
2	8.50	1.83			4.59	3.86	3.86	17.36	13.50		2.40	2.96	3.53	4.01	4.38	4.60	3.25	3.28	
3	12.75	.80			3.24	4.32	4.32	18.41	14.08		1.21	1.64	2.06	2.49	2.85	3.10	2.33	2.42	2.38
4	17.00	.27			2.36	4.61	4.61	19.12	14.52		.59	.92	1.25	1.58	1.89	2.14	1.70	1.82	1.85
5	21.25	.04			1.81	4.79	4.79	19.60	14.81		.29	.55	.80	1.04	1.30	1.52	1.33	1.46	1.52
6	25.50	0			1.51	4.89	4.89	19.88	14.99	5	.19	.40	.59	.78	.98	1.18	1.23	1.33	1.40
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	10.29	10.29	1.40	4.925	4.925	20.00	15.08	0	.18	.36	.55	.73	.92	1.09		1.33	
9	38.25	0	10.32	10.47	1.39	4.50						.36		.73		1.09			
10	42.50	0	10.01	10.66	1.12	3.14						.36		.73		1.09			
11	46.75	0	9.33	10.85	.26	.73													
11 1/4 F	47.90	0	9.08	10.87	0	0													
11 1/4 A	47.90	9.08	9.08	10.87															
12	51.00	9.25		11.01															
13	55.25	9.40		11.19			4.91		15.09										
14	59.50	9.59		11.36			4.86		15.14										
15	63.75	9.78		11.51			4.75		15.25										
16	68.00	9.97		11.65			4.61		15.39										
17	72.25	10.16		11.77			4.43		15.57										
18	76.50	10.34		11.86			4.17		15.83										
19	80.75	10.53		11.94			3.87		16.13										
20	85.00	10.72		11.99			3.50		16.50										
21	89.25	10.91		12.03			3.08		16.92										
22	93.50	11.09		12.04			2.61		17.39										
23	97.75	11.28		12.06			2.15		17.85										
24	102.00	11.47		12.08			1.69		18.31										
25	106.25	11.66		12.10			1.22		18.78										
26	110.50	11.85		12.12			.76		19.24										
27	114.75	12.02		12.12			.31		19.69										
A.P.	116.65	12.12		12.12			.10		19.90										

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OFFSETS OF LANGLEY TANK MODEL 221G

[All dimensions are in inches]

[redacted]

Station	Distance to F.P.	Keel above B.L.	Cove above B.L.	Upper chine above B.L.	Lower chine above B.L.	Lower chine half beam	Radius and half maximum beam	Height of hull at C.L.	Line of centers above B.L.	Angle of chine flare (deg)	Bottom of hull - Heights and half breadths															
											1 in. Butt	2 in. Butt	3 in. Butt	4 in. Butt	1 in. W.L.	2 in. W.L.	3 in. W.L.	4 in. W.L.	5 in. W.L.	6 in. W.L	7 in. W.L.	8 in. W.L.	9 in. W.L.	10 in. W.L.	11 in. W.L.
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	7.49	8.32													
1	4.25	3.76			6.71	3.06	3.06	15.72	12.66	10	5.30	6.56	6.72												
2	8.50	1.83			4.59	3.86	3.86	17.36	13.50	10	2.96	4.01	4.60												
3	12.75	.80			3.24	4.32	4.32	18.41	14.08	10	1.64	2.49	3.10	3.28											
4	17.00	.27			2.36	4.61	4.61	19.12	14.52	10	.92	1.58	2.14	2.42											
5	21.25	.04			1.81	4.79	4.79	19.60	14.81	10	.55	1.04	1.52	1.82											
6	25.50	0			1.51	4.89	4.89	19.88	14.99	5	.40	.78	1.18	1.46											
7	29.75	0			1.40	4.92	4.92	19.99	15.07	0	.36	.73	1.09	1.33											
8	34.00	0	1.50		1.40	4.925	4.925	20.00	15.08	0	.36	.73	1.09	1.33											
9	38.25	0	1.49		1.39	4.50					.36	.73	1.09	1.33		4.55	4.62	4.70	4.76	4.82	4.89				
10	42.50	0	1.22		1.12	3.14					.36	.73	1.09	4.69		3.35	3.60	3.83	4.08	4.31	4.55	4.75	4.88		
11	46.75	0	.36		.26	.73					1.07	3.34	5.55	7.80	.95	1.40	1.85	2.30	2.75	3.20	3.65	4.10	4.50	4.82	
11 1/4 F	47.90	0	.10		0	0					2.43	4.40	6.35	8.31	.34	.79	1.28	1.79	2.30	2.82	3.33	3.89	4.33	4.73	
11 1/4 A	47.90	0									2.43	4.40	6.35	8.31											
12	51.00	3.63									5.15	6.55	7.96	9.36				.24	.91	1.60	2.32	3.05	3.74	4.42	
13	55.25	6.40					4.91		15.09		7.36	8.35	9.31	10.23							.62	1.65	2.68	3.75	4.75
14	59.50	8.07					4.86		15.14		8.79	9.42	10.07	10.74									1.40	2.88	4.40
15	63.75	9.10					4.75		15.25		9.59	10.10	10.62	11.11										1.82	3.83
16	68.00	9.73					4.61		15.39		10.13	10.55	10.97	11.38										.72	3.10
17	72.25	10.08					4.43		15.57		10.48	10.85	11.24	11.61											2.45
18	76.50	10.34		11.86			4.17		15.83		10.69	11.07	11.45	11.83											1.88
19	80.75	10.53		11.94			3.87		16.13		10.90	11.26	11.63												1.36
20	85.00	10.72		11.99			3.50		16.50		11.08	11.45	11.81												.82
21	89.25	10.91		12.03			3.08		16.92		11.27	11.65	12.02												.25
22	93.50	11.09		12.04			2.61		17.39																
23	97.75	11.28		12.06			2.15		17.85																
24	102.00	11.47		12.08			1.69		18.31																
25	106.25	11.66		12.10			1.22		18.78																
26	110.50	11.85		12.12			.76		19.24																
27	114.75	12.02		12.12			.31		19.69																
A.P.	116.65	12.12		12.12			.10		19.90																

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TABLE III

OFFSETS FOR LANGLEY TANK MODEL 221F

[All dimensions are in inches] [redacted]

Station	Distance to F.P.	Keel above base line	Cove above base line	Upper chine above base line	Lower chine above base line	Lower chine half beam	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	3	4	1	2	3	4	5	6	7	8	9	10	11
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	7.49	8.32													
1	4.25	3.76			6.71	3.06	3.06	15.72	12.66	10	5.30	6.56	6.72												
2	8.50	1.83			4.59	3.86	3.86	17.36	13.50	10	2.96	4.01	4.60												
3	12.75	.80			3.24	4.32	4.32	18.41	14.08	10	1.64	2.49	3.10	3.28											
4	17.00	.27			2.36	4.61	4.61	19.12	14.52	10	.92	1.58	2.14	2.42											
5	21.25	.04			1.81	4.79	4.79	19.60	14.81	10	.55	1.04	1.52	1.82											
6	25.50	0			1.51	4.89	4.89	19.88	14.99	5	.40	.78	1.18	1.46											
7	29.75	0			1.40	4.92	4.92	19.99	15.07	0	.36	.73	1.09	1.33											
8	34.00	0	1.50		1.40	4.93	4.93	20.00	15.08	0	.36	.73	1.09	1.33											
9	38.25	0	1.49		1.39	4.50	4.93	20.00	15.08		.36	.73	1.09	1.33		4.59	4.74	4.87							
10	42.50	0	1.22		1.12	3.14	4.93	20.00	15.08		.36	.73	1.09	2.70		3.61	4.11	4.46	4.75	4.89					
11	46.75	0	.36		.26	.73	4.93	20.00	15.08		.66	1.80	3.03	4.62	1.32	2.17	2.99	3.64	4.17	4.56	4.80	4.90			
11 1/4 F	47.90	0	.10		0	0	4.93	20.00	15.08		1.16	2.29	3.52	5.10	.86	1.75	2.60	3.33	3.95	4.41	4.72	4.86			
11 1/4 A	47.90	.10					4.93	20.00	15.08		1.16	2.29	3.52	5.10	.86	1.75	2.60	3.33	3.95	4.41	4.72	4.86			
12	51.00	1.42					4.93	20.00	15.08		2.45	3.54	4.75	6.27		.57	1.51	2.40	3.17	3.85	4.35	4.67	4.86		
13	55.25	3.15					4.91	20.00	15.09		4.14	5.20	6.32	7.75				.85	1.82	2.74	3.50	4.13	4.56	4.85	4.90
14	59.50	4.77					4.86	20.00	15.14		5.67	6.65	7.67	8.95					.25	1.32	2.34	3.27	4.02	4.57	4.85
15	63.75	6.26					4.75	20.00	15.25		7.07	7.91	8.84	9.93							.87	2.11	3.15	4.05	4.68
16	68.00	7.58					4.61	20.00	15.39		8.29	9.05	9.84	10.71								.60	1.95	3.18	4.27
17	72.25	8.71					4.43	20.00	15.57		9.33	9.97	10.62	11.29									.47	2.05	3.57
18	76.50	9.62		11.86			4.17	20.00	15.83		10.12	10.66	11.17	11.71										.74	2.70
19	80.75	10.29		11.94			3.87	20.00	16.13		10.70	11.13	11.54												1.74
20	85.00	10.71		11.99			3.50	20.00	16.50		11.08	11.45	11.81												.76
21	89.25	10.91		12.03			3.08	20.00	16.92																
22	93.50	11.09		12.04			2.61	20.00	17.39																
23	97.75	11.28		12.06			2.15	20.00	17.85																
24	102.00	11.47		12.08			1.69	20.00	18.31																
25	106.25	11.66		12.10			1.22	20.00	18.78																
26	110.50	11.85		12.12			.76	20.00	19.24																
27	114.75	12.02		12.12			.31	20.00	19.69																
A.P.	116.65	12.12		12.12			.10	20.00	19.90																

[redacted]

NACA

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TABLE IV

OFFSETS FOR NACA HULL MODEL 203 WITH EXTENDED AFTERBODY

[All dimensions are in inches]

[redacted]

Station	Distance to F.P.	Keel above base line	Chine above base line	Radius and half beam at chine	Height of hull at center line	Line of centers above base line	Angle of chine flare (deg)	Forebody bottom, heights above base line - buttocks								
								1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2
F.P.	0	10.30	10.30	0	11.00	11.00										
1/2	2.13	5.49	8.30	2.30	14.29	11.98	10	6.48	7.49	8.14	8.32					
1	4.25	3.76	6.71	3.06	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	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	18.41	14.09	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	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	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	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	19.99	15.07	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40
8	34.00	0	1.40	4.93	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40
9	38.25	0	1.40	4.93	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40
10	42.50	0	1.40	4.93	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40
11	46.75	0	1.40	4.93	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40
12 F	51.04	0	1.40	4.93	20.00	15.08	0	.18	.36	.55	.73	.92	1.09	1.23	1.33	1.40
12 A	51.04	1.16	2.95	4.93	20.00	15.08										
13	55.25	1.78	3.57	4.91	20.00	15.09										
14	59.50	2.41	4.18	4.86	20.00	15.14										
15	63.75	3.04	4.77	4.75	20.00	15.25										
16	68.00	3.66	5.34	4.61	20.00	15.39										
17	72.25	4.29	5.90	4.43	20.00	15.57										
18	76.50	4.92	6.44	4.17	20.00	15.83										
19	80.75	5.55	6.96	3.87	20.00	16.13										
20	85.00	6.17	7.44	3.50	20.00	16.50										
21	89.25	6.80	7.92	3.08	20.00	16.92										
22	93.50	7.43	8.38	2.61	20.00	17.39										
23	97.75	8.06	8.84	2.15	20.00	17.85										
24	102.00	8.69	9.31	1.69	20.00	18.31										
25	106.25	9.31	9.75	1.22	20.00	18.78										
26	110.50	9.94	10.22	.76	20.00	19.24										
27	114.75	10.57	10.68	.31	20.00	19.69										
A.P.	116.65	10.85	10.89	.10	20.00	19.90										

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TABLE V

DRAG COEFFICIENTS AND STABILITY PARAMETERS FOR LANGLEY TANK

MODELS 221E, 221G, 221F, AND 203 WITH EXTENDED AFTERBODY

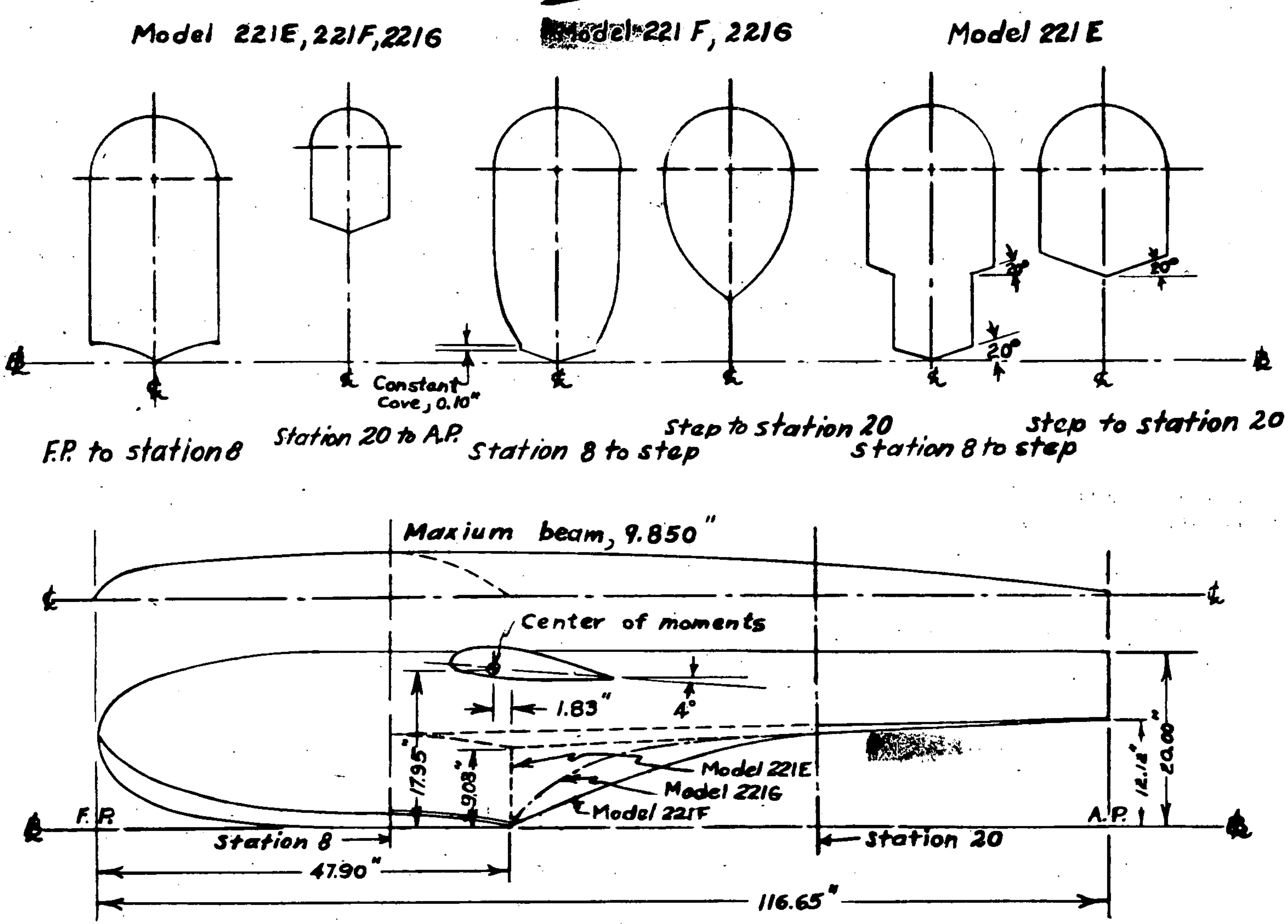
[The drag coefficients are given for a Reynolds number of approximately 2.5×10^6]

[redacted]

Model	$C_{D_{min}}$	$\left(C_{D_V}\right)_{min}$	$\left(C_{D_A}\right)_{min}$	$\left(C_{D_W}\right)_{min}$	$\frac{\partial C_m}{\partial \alpha}$	K_f	$\left(\frac{\partial C_n}{\partial \psi}\right)_{\alpha=2^\circ}$	$\left(\frac{\partial C_{n_f}{}'}{\partial \psi'}\right)_{\alpha=2^\circ}$	$\left(\frac{\partial C_n}{\partial \beta}\right)_{\alpha=2^\circ}$	$\left(\frac{\partial C_Y}{\partial \psi}\right)_{\alpha=2^\circ}$
221E	0.0057	0.032	0.082	0.0036	0.0050	1.10	0.0010	0.029	-0.098	0.0048
221G	.0045	.024	.065	.0028	.0050	1.10	.0010	.026	-.090	.0050
221F	.0037	.019	.053	.0023	.0050	1.10	.0010	.026	-.090	.0050
203 extended	.0066	.031	.095	.0036	.0050	1.10	.0011	.027	-.098	.0050

[redacted]

[redacted]



[redacted]

Figure 1.- Lines of Langley tank models 221E, 221G, and 221F.

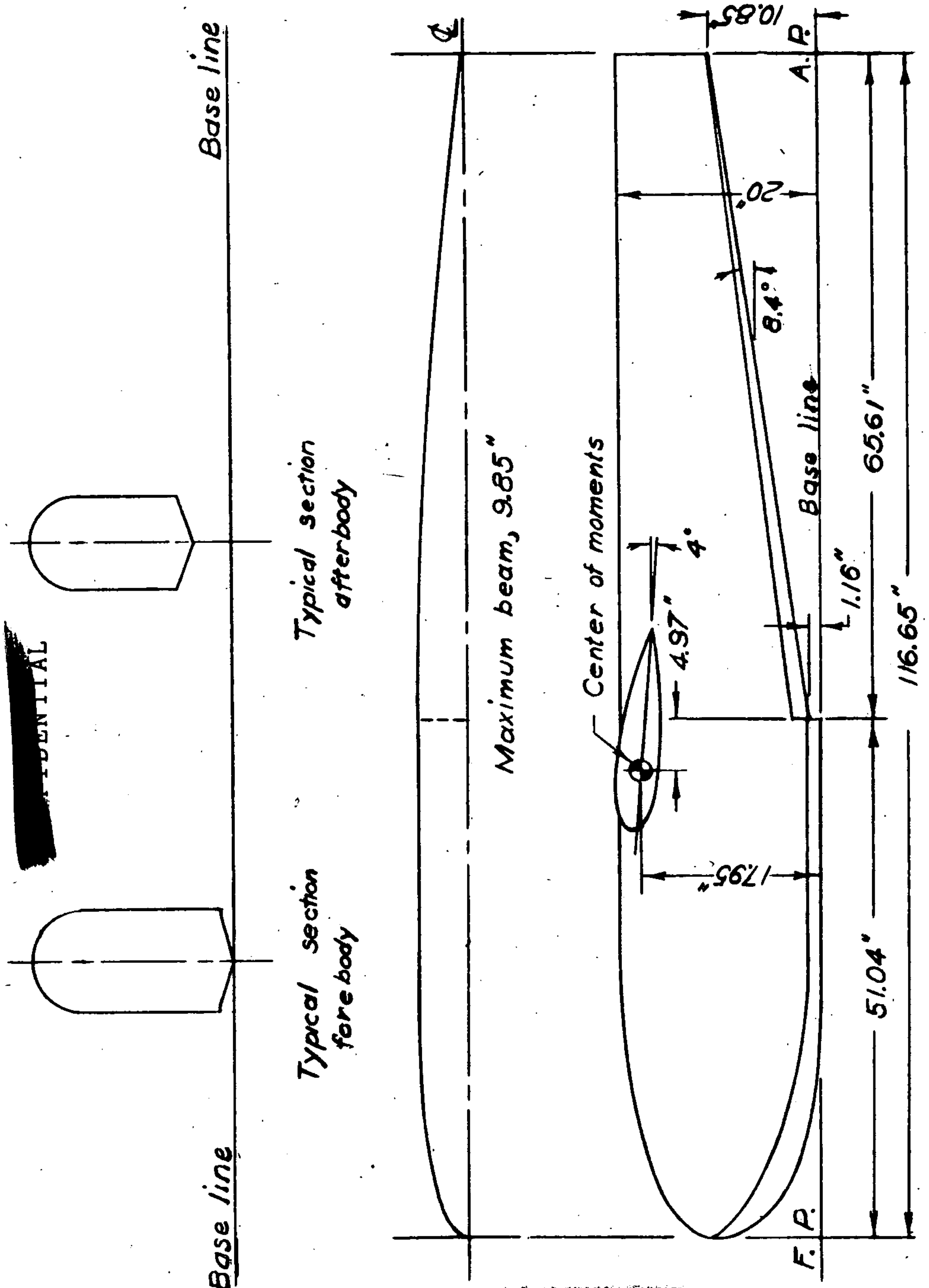


Figure 2.- Lines of Langley tank model 203 with extended afterbody.

[redacted]

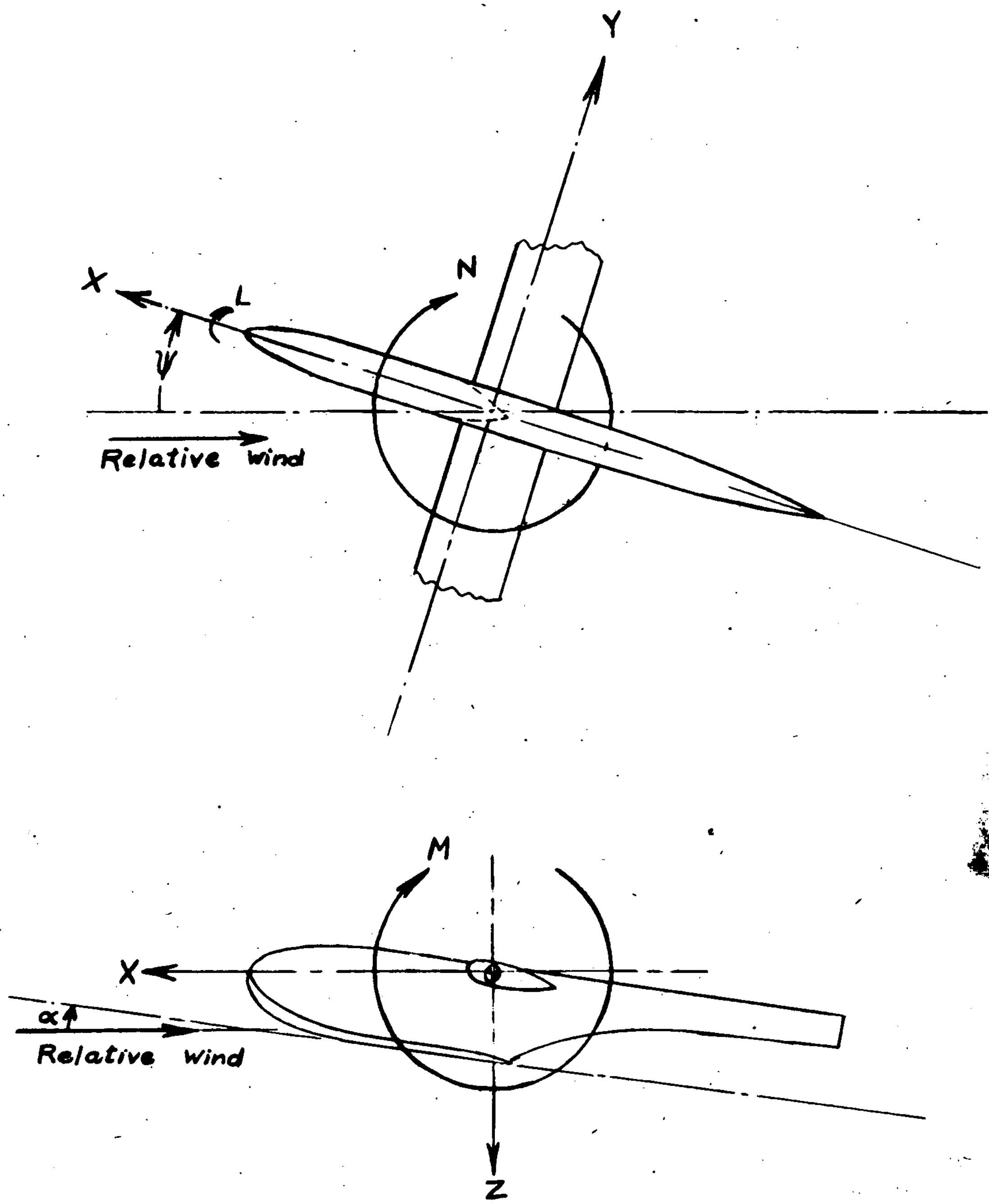


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Figure 3.- System of stability axes. Positive values of forces, moments, and angles are indicated by arrows.

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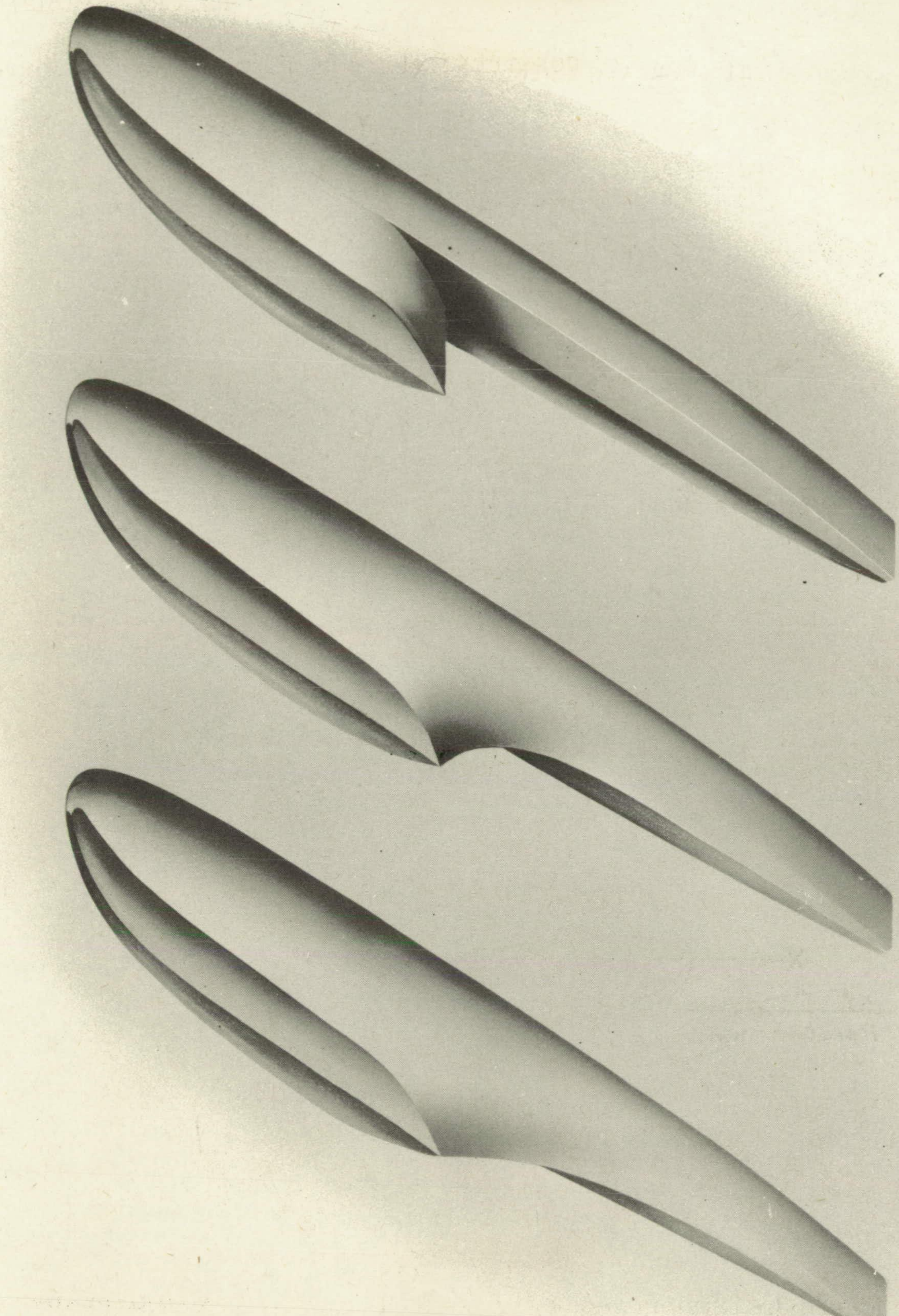

221E

221G

221F

[redacted]

Figure 4.- Langley tank models 221E, 221G, and 221F tested in Langley 300 MPH 7- by 10-foot tunnel.

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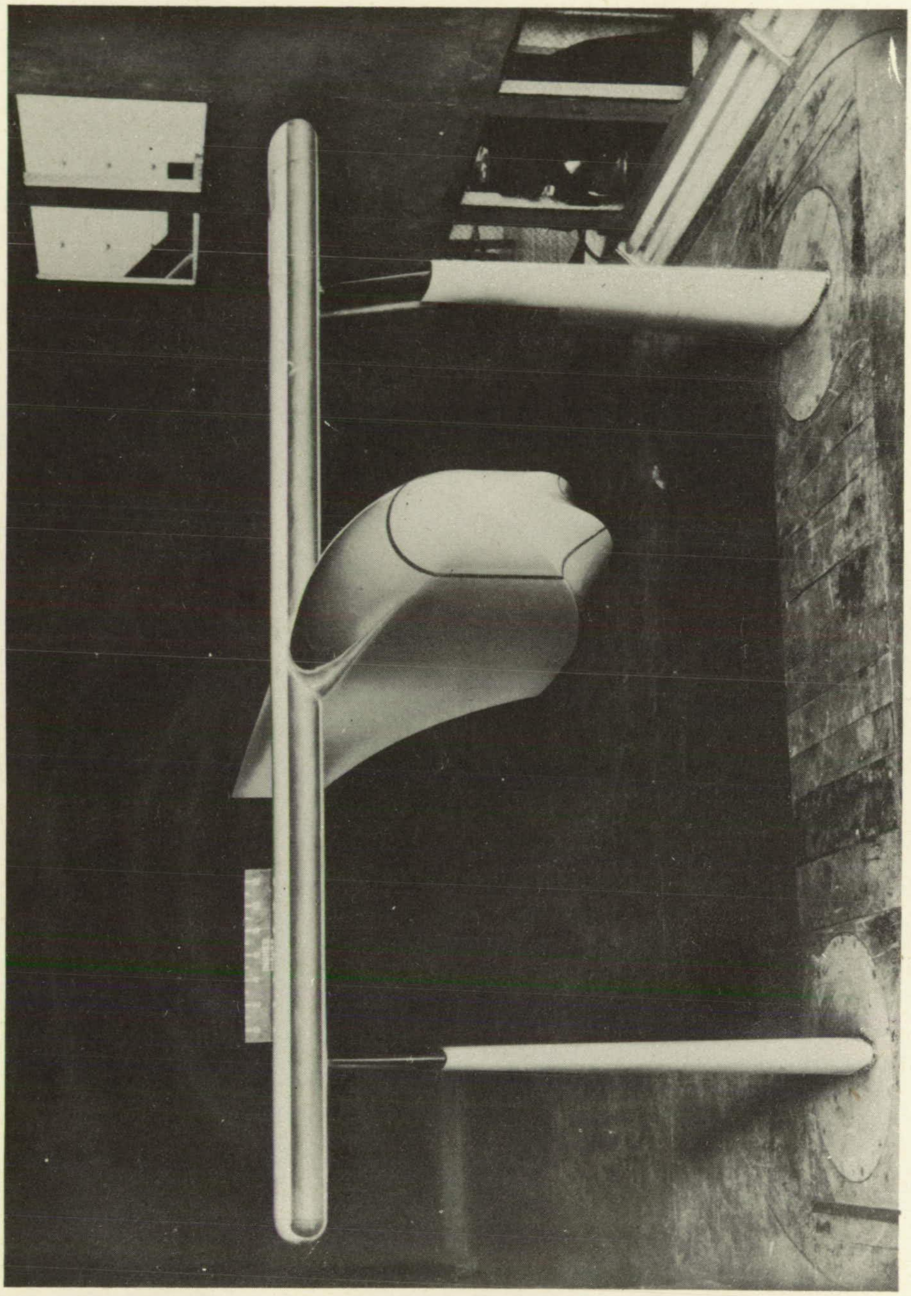
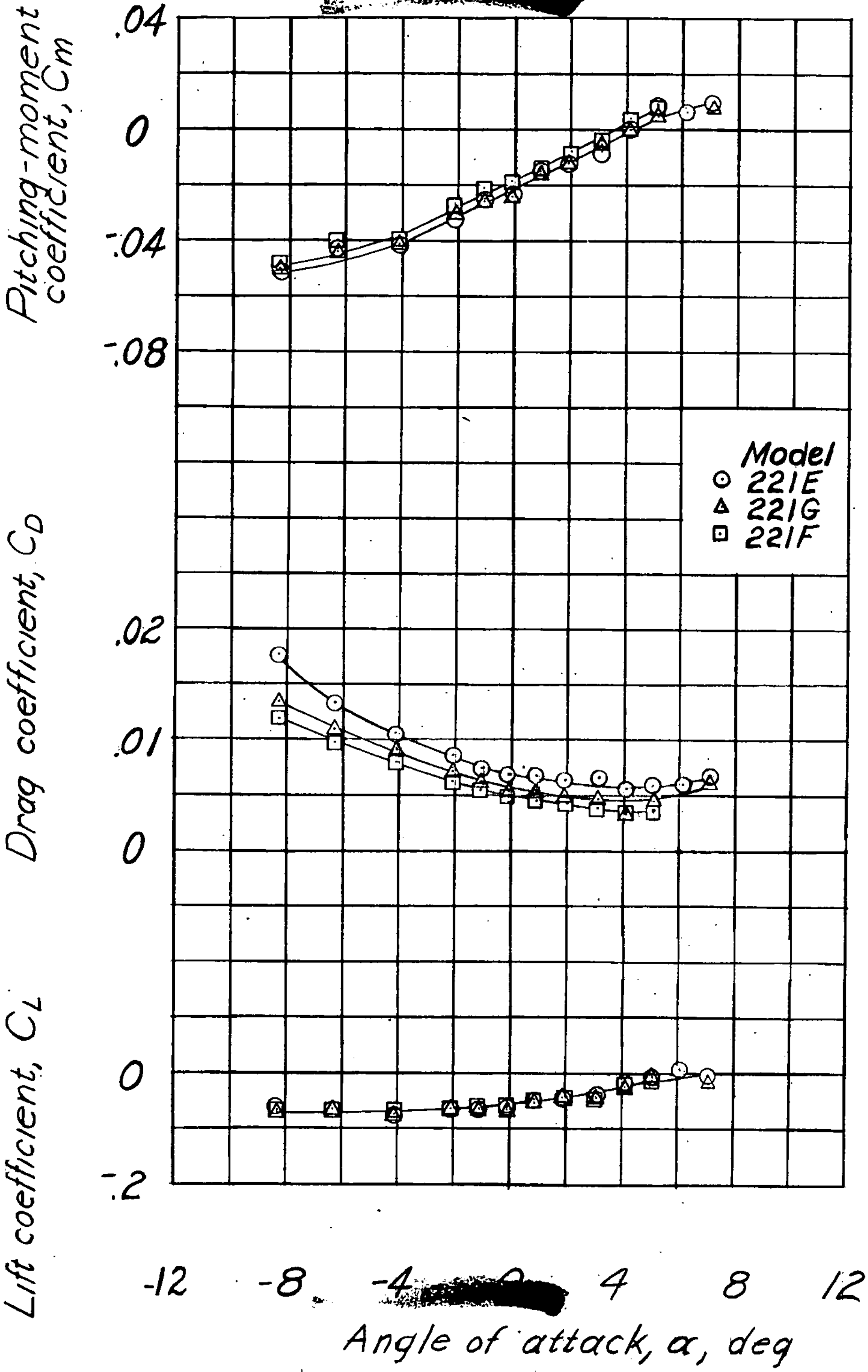


Figure 5.- Langley tank model 221F mounted in Langley 300 MPH 7- by 10-foot tunnel.

[redacted]

[redacted]

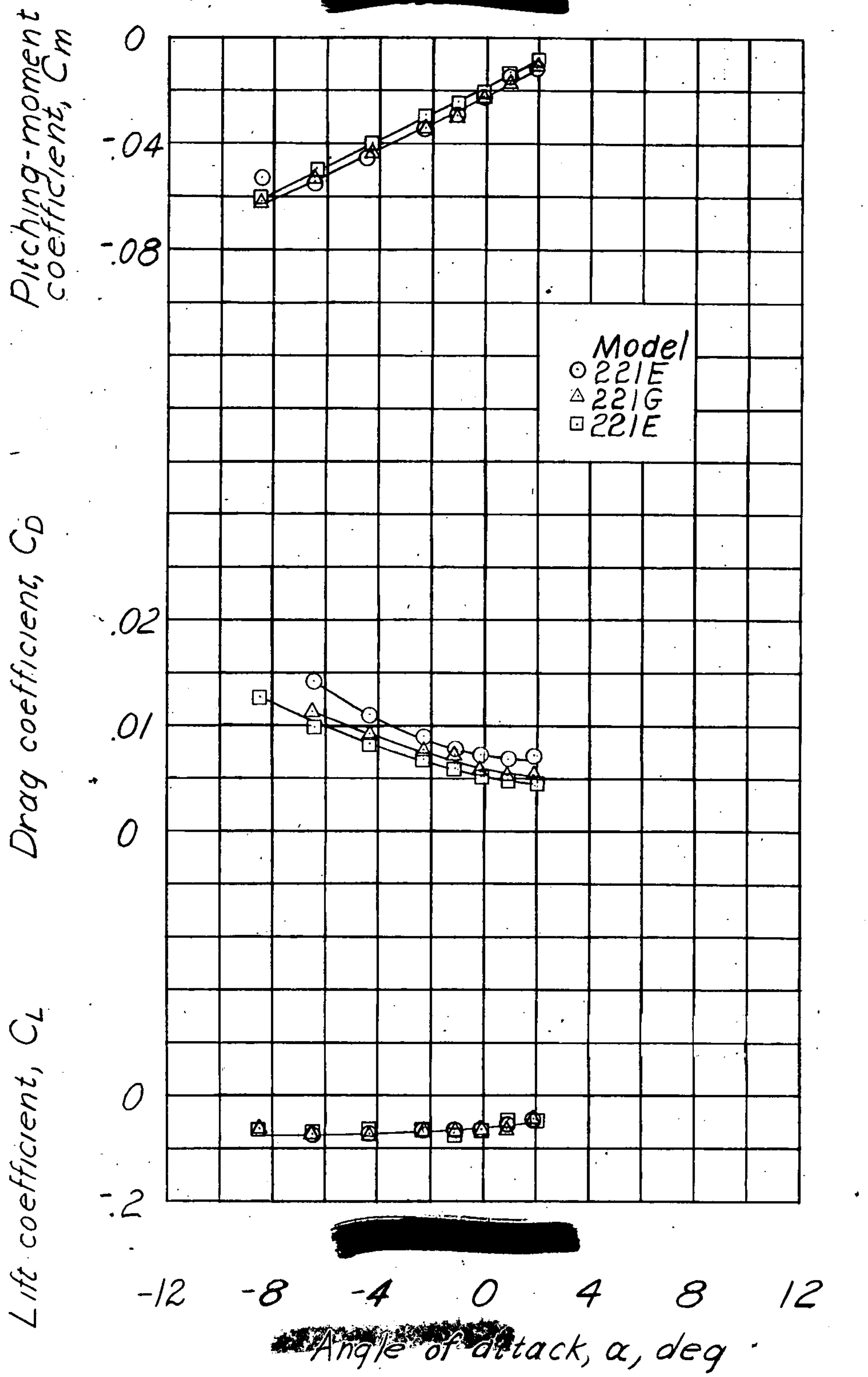


[redacted]

(a) R ≈ 2.5 × 10^6.

Figure 6.- Aerodynamic characteristics in pitch of Langley tank models 221E, 221G, and 221F.

[redacted]



[redacted]

(b) $R \approx 3.1 \times 10^6$.

Figure 6.- Concluded.

[redacted]

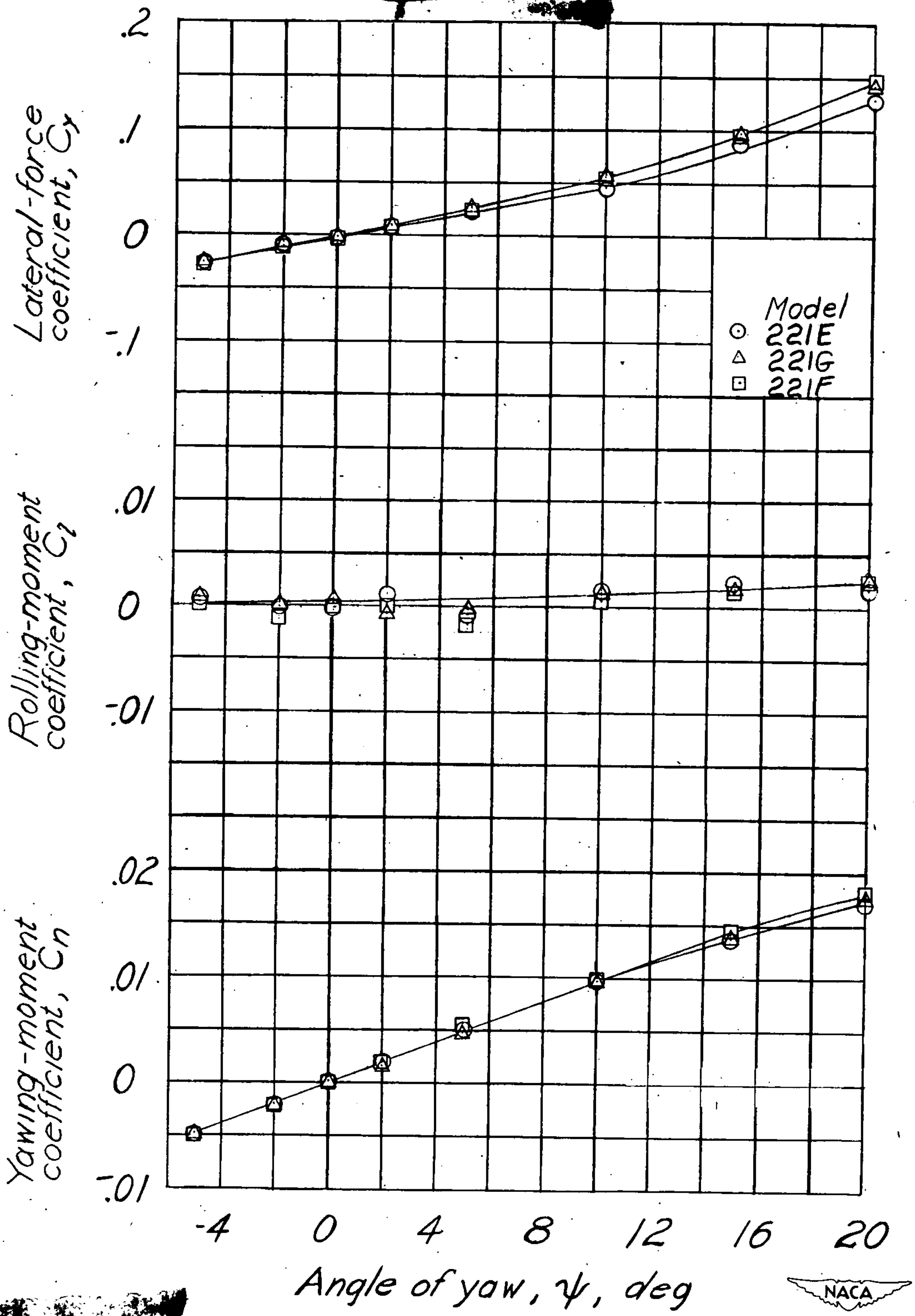


Figure 7.- Aerodynamic characteristics in yaw of Langley tank models 221E, 221G, and 221F. $\alpha = 2^{\circ}$; $R \approx 1.3 \times 10^{6}$.

[redacted]

[redacted]

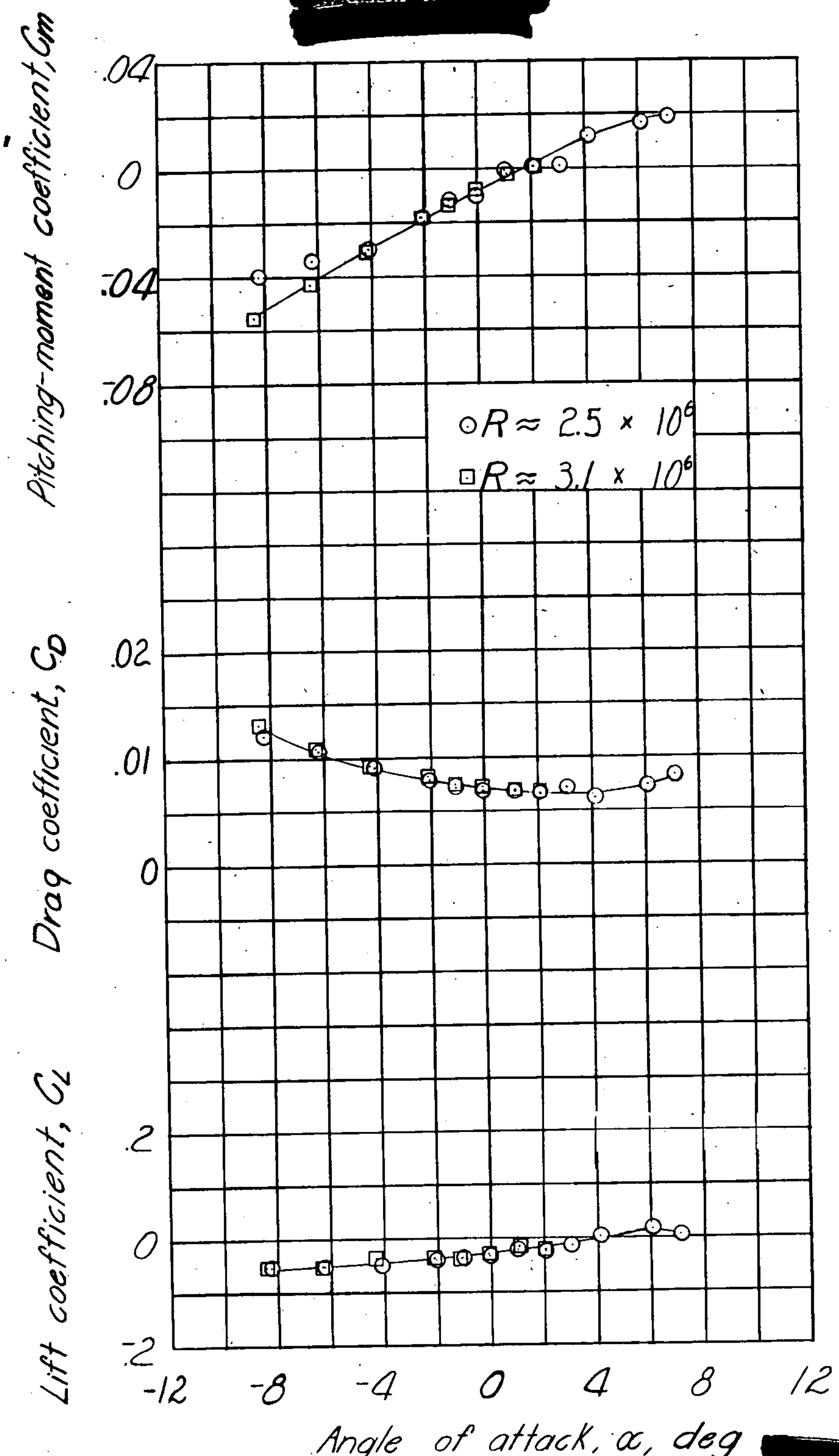


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Figure 8.- Aerodynamic characteristics in pitch of Langley tank model 203 with extended afterbody.

[redacted]

[redacted]

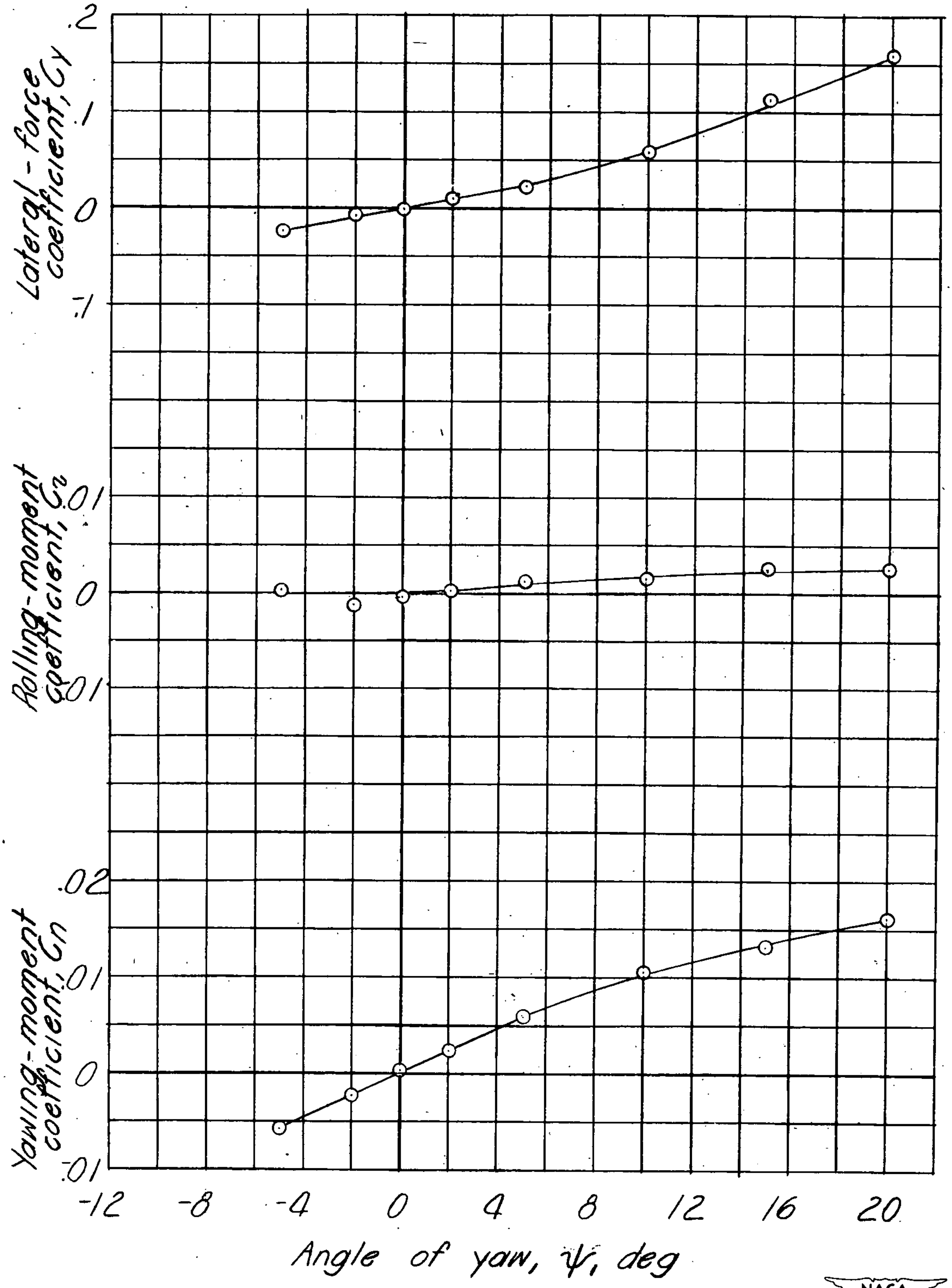

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Figure 9.- Aerodynamic characteristics in yaw of Langley tank model 203 with extended afterbody. $\alpha = 2^{\circ}$; $R \approx 1.3 \times 10^{6}$.

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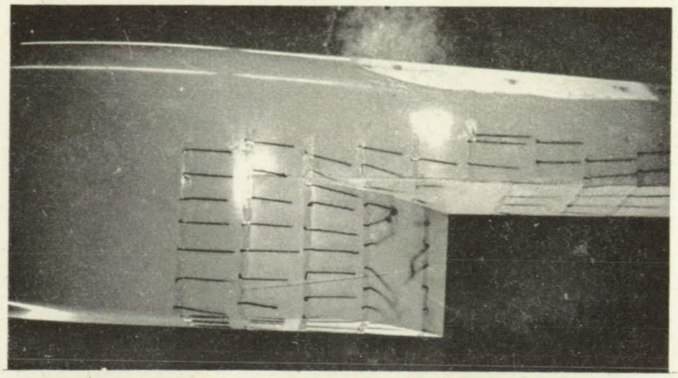
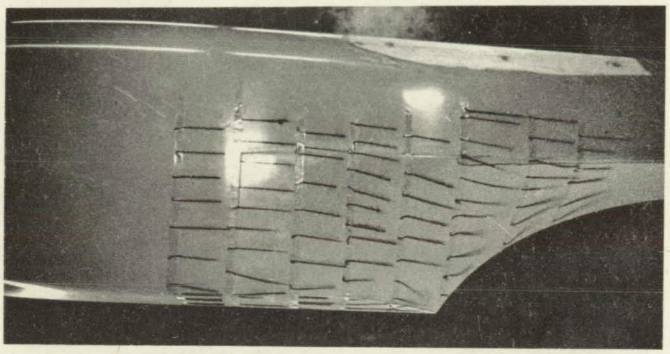
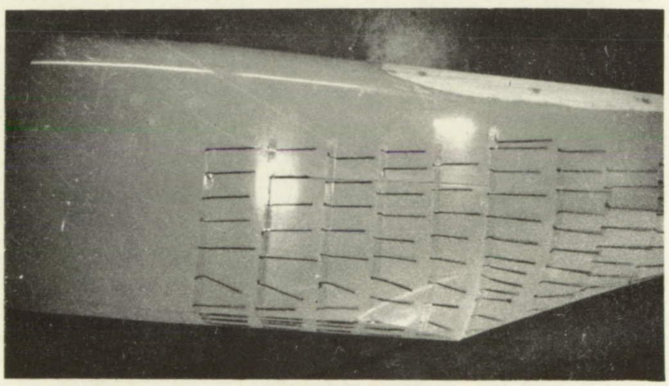


(a) Langley tank model 221E: $\alpha = 2^{\circ}$.



(b) Langley tank model 221G: $\alpha = 2^{\circ}$.



(c) Langley tank model 221F; $\alpha = 4^{\circ}$.

Figure 10.- Tuft studies of Langley tank models 221E, 221G, and 221F. Tests were made with models mounted on single strut support.

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