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TECHNICAL NOTE

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EFFECT OF LENGTH-BEAM RATIO ON AERODYNAMIC CHARACTERISTICS OF FLYING-BOAT HULLS WITHOUT WING INTERFERENCE

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SUMMARY

An investigation was made to determine the effect of increasing the length-beam ratio from 6 to 15 on the aerodynamic characteristics of flying-boat hulls without wing interference. A comparison was made with results obtained previously for hulls with wing interference reported in NACA TN No. 1305.

An increase in the length-beam ratio decreased the minimum drag coefficient and slightly increased the longitudinal stability in a manner similar to that indicated for hulls with wing interference. As expected, the hull-alone drag coefficients were consistently higher than the hull drag coefficients with wing interference.

INTRODUCTION

The investigation at the Langley Laboratory of aerodynamic characteristics of flying-boat hulls as affected by hull dimensions and hull shape (references 1 and 2) has included the interference effects of a 21-percent-thick wing. Since new high-speed water-based airplanes will probably use extremely thin wings of low aspect ratio and/or large amounts of sweep, it was desirable to obtain the aerodynamic characteristics of the aforementioned hulls without wing interference. The results obtained for the hull without wing interference could be more easily compared with either theoretical or experimental results for other hull and fuselage shapes. The results obtained with wing interference will differ from the values obtained for the hull or fuselage alone because the wing, in addition to adding interference drag, also effectively reduces the drag coefficient because of the part of the wing submerged in the body (reference 3).

This paper presents the results of an investigation made to determine the effect of length-beam ratio on the aerodynamic characteristics of flying-boat hulls without wing interference. These results are compared with previous results for hulls with wing interference. The hulls have approximately the same hydrodynamic performance with respect to spray and resistance characteristics, regardless of length-beam ratio.

COEFFICIENTS AND SYMBOLS

The results of the tests are presented as standard NACA coefficients of forces and moments. Pitching moments are given about the locations shown in figure 1 which are the same as those used in reference 1. Therefore, a direct comparison of the longitudinal stability can be made with the hulls with wing interference. The coefficients and Reynolds number are based on the wing area and the mean aerodynamic chord of a hypothetical flying boat described in reference 1. The data are referred to the stability axes, which are a system of axes having the 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 forces, moments, and angles are shown in figure 2.

The coefficients and symbols are defined as follows:

C_L	lift coefficient ($Lift/qS$ where $Lift = -Z$)
C_D	drag coefficient ($Drag/qS$ where $Drag = -X$ when $\psi = 0^{\circ}$)
C_m	pitching-moment coefficient ($M/qS\bar{c}$)
M	pitching moment, foot-pounds
L'	rolling moment, foot-pounds
N	yawing moment, foot-pounds
X	force along X-axis, pounds
Y	force along Y-axis, pounds
Z	force along Z-axis, pounds
q	free-stream dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$
S	wing area of $\frac{1}{10}$-scale model of hypothetical flying boat (18.264 sq ft)
$\bar{c}$	wing mean aerodynamic chord (M.A.C.) of $\frac{1}{10}$-scale model of hypothetical flying boat (1.377 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
C_{D_W}	drag coefficient, based on surface area W of hull (Drag/qW)
$C_{m_\alpha} = \frac{\partial C_m}{\partial \alpha}$	
L/b	length-beam ratio, where L is distance from forward perpendicular (F.P.) to sternpost and b is maximum beam (fig. 1)

Subscript:

min	minimum

APPARATUS AND TESTS

The models used in this investigation were the same hulls that were used in the investigation reported in reference 1. Dimensions of the models are given in figure 1, and the offsets are given in tables I to IV of reference 1. The models were altered for testing alone by covering the wing gap with a thin sheet of aluminum. The volumes, surface areas, maximum cross-sectional areas, and side areas of the hulls are compared in the following table:

Langley tank model	L/b	Volume (cu in.)	Surface area (sq in.)	Maximum cross-sectional area (sq in.)	Side area (sq in.)
213	6	14,831	4540	226	1639
203	9	12,916	4581	182	1752
214	12	11,528	4654	150	1870
224	15	10,653	4760	130	1985

The models were mounted on a single support strut for testing, as shown in figure 3.

The tests were made in the Langley 300 MPH 7- by 10-foot tunnel at a dynamic pressure of 100 pounds per square foot, which corresponded to an airspeed of about 200 miles per hour. The Reynolds number, based on the mean aerodynamic chord of the wing of the hypothetical flying boat, was about 2.5×10^6. The corresponding Mach number was about 0.22.

The hulls were tested with the transition fixed by a $\frac{1}{2}$-inch-wide strip of 0.008-inch-diameter carborundum particles located approximately 5 percent of the hull length aft of the bow.

CORRECTIONS

Blocking corrections have been applied to the hull data. The drag of the hulls has been corrected for horizontal buoyancy effects caused by a tunnel static-pressure gradient. The effects of the support strut which were determined by using an image system have been subtracted from the data.

RESULTS AND DISCUSSION

The effect of length-beam ratio on the aerodynamic characteristics in pitch of the hulls are presented in figure 4. A comparison of these data with the data obtained in reference 1 for hulls with wing interference indicates that the minimum drag occurs nearer zero angle of attack, 0° to 2°, for the hull alone. This effect might be expected since the support wing used in reference 1 had considerable camber and was set at 4° angle of incidence, which tends to give body minimum drags at positive angles of attack (reference 3). The hull-alone data showed about the same variation of pitching-moment coefficient with angle of attack as was shown for the hulls with wing interference. Smaller values of lift coefficient were obtained for the hull alone than were obtained for the hull with wing interference. An increase in the length-beam ratio decreased the minimum drag coefficient and slightly increased the longitudinal stability. This effect is shown in figure 5 where a comparison is also made of the minimum drag coefficient $C_{D_{min}}$ and the stability parameter $C_{m_{\alpha}}$ for the hulls alone and hulls with wing interference. The minimum drag coefficients for the hulls alone are consistently higher than those for the hulls with wing interference; the longitudinal stability of the hulls is only slightly affected by the wing interference. The relatively large increase in minimum drag was to be expected since the results of reference 4 indicated that the minimum drags of fuselages were lower by an amount approximately equal to the drag on the support wing submerged within the fuselage. The interference effect caused by the interaction of the velocity fields in the fuselage and wing, in general, increases the drag coefficient; however, the increase is small compared to the favorable effect of the submerged wing.

The variation of minimum drag coefficient with length-beam ratio is about the same for the hull alone as for the hull with wing interference as reported in reference 1; that is, minimum drag coefficient decreased when the length-beam ratio was increased from 6 to 15.

This fact would indicate, therefore, that the comparative drag coefficients of other hulls (reference 2), although representing a value lower than the hull-alone value, should indicate the relative merits of the various hulls. The values presented in references 1 and 2 are representative only for a flying boat having a wing very similar to the support wing used in those investigations, and any other wing either thinner, less cambered, or with sweep is expected to give different values of minimum drag coefficient and is also expected to present similar trends with hull modifications. In order to indicate the relative efficiency of the length-beam-ratio series hulls, the minimum drag coefficients based on the wetted area of the hull $C_{D_{W_{min}}}$ have been compared in figure 6 with theoretical values of $C_{D_{W_{min}}}$ for streamline bodies, as given in reference 4. In order to obtain a more nearly comparable value of fineness ratio than is indicated by length-beam ratio, the fineness ratio of the hulls was calculated by using the ratio of the diameter of a circle with an area equal to the frontal area of the hull and the over-all length of the hull (the distance from the fore perpendicular to the aft perpendicular). In this comparison the skin area of the equivalent body is less than that for the actual hull. The comparison in figure 6 shows that a large percentage of the drag of the hull with $\frac{L}{B} = 6$ (fineness ratio, 6.5) was caused by form drag because the theoretical drag was largely skin friction. The form drag becomes a smaller part of the total drag as the fineness ratio increases. The trend of the two curves indicates that some reduction in hull drag coefficient might also be expected for hulls of larger length-beam ratio than presented herein.

CONCLUSIONS

The results of an investigation made to determine the effect of increasing the length-beam ratio on the aerodynamic characteristics of flying-boat hulls without wing interference and a comparison of the results with results previously obtained for hulls with wing interference indicated the following:

1. The minimum drag coefficient decreased when the length-beam ratio was increased from 6 to 15 in a manner similar to that indicated for hulls with wing interference.

2. The minimum drag coefficients were consistently higher than those obtained with wing interference.

3. The minimum drag for all hulls tested generally occurred in the angle-of-attack range of about 0° to 2°.

4. The longitudinal stability of the hulls was only slightly affected by the wing interference.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., May 18, 1948

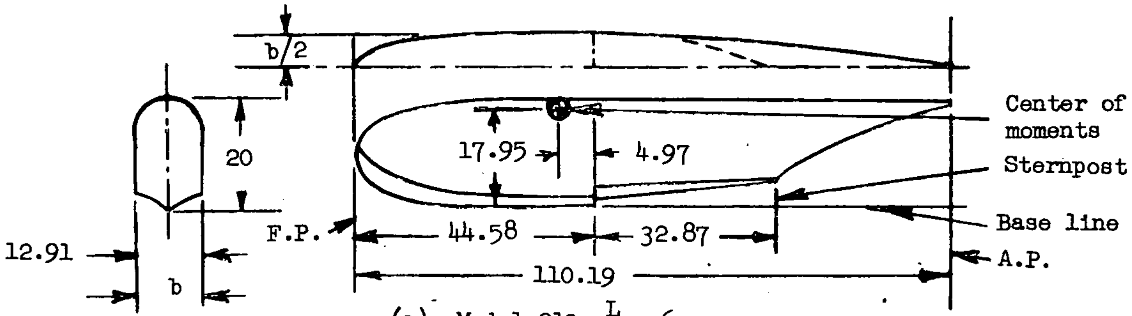
REFERENCES

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.

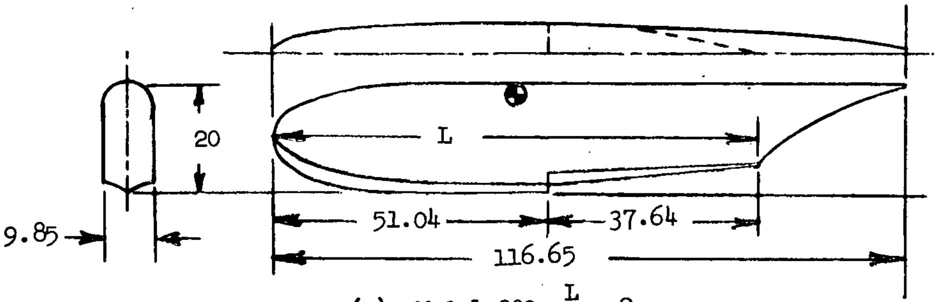
2. Yates, Campbell C., and Riebe, John M.: Aerodynamic Characteristics of Three Planing-Tail Flying-Boat Hulls. NACA TN No. 1306, 1947.

3. Jacobs, Eastman N., and Ward, Kenneth E.: Interference of Wing and Fuselage from Tests of 209 Combinations in the N.A.C.A. Variable-Density Tunnel. NACA Rep. No. 540, 1935.

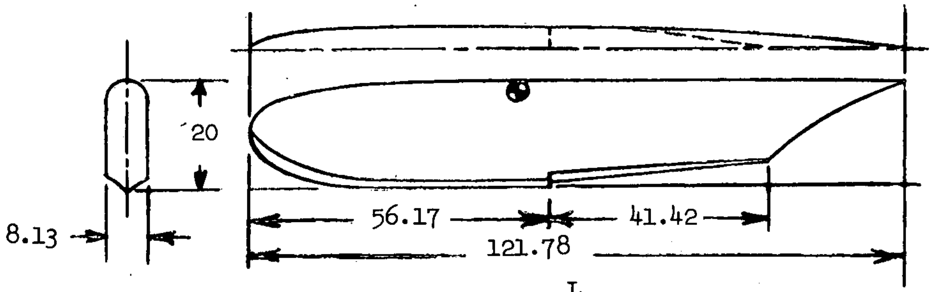
4. Young, A. D.: The Calculation of the Total and Skin Friction Drags of Bodies of Revolution at Zero Incidence. R. & M. No. 1874, British A.R.C., 1939.



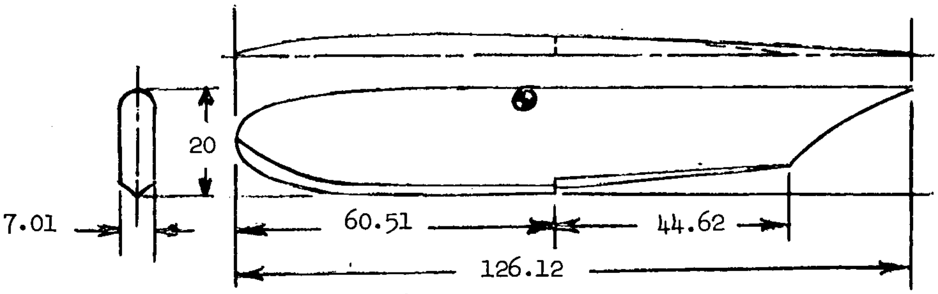
(a) Model 213; $\frac{L}{b} = 6$.



(b) Model 203; $\frac{L}{b} = 9$.



(c) Model 214; $\frac{L}{b} = 12$.



(d) Model 224; $\frac{L}{b} = 15$.

Figure 1.– Lines of Langley tank models. (All dimensions are in inches.)

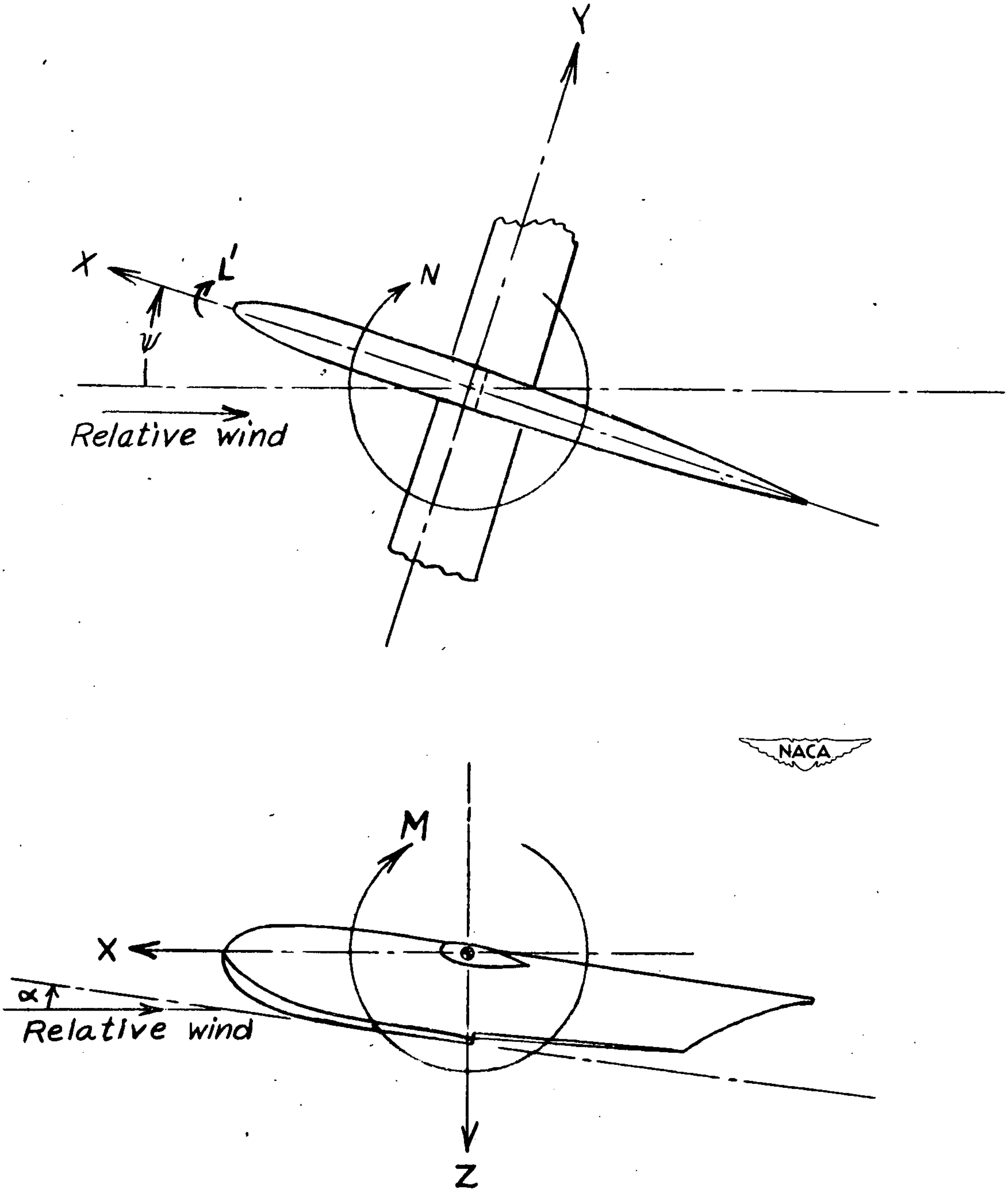


Figure 2.- System of stability axes. Positive directions of forces, moments, and angles are indicated by arrows.

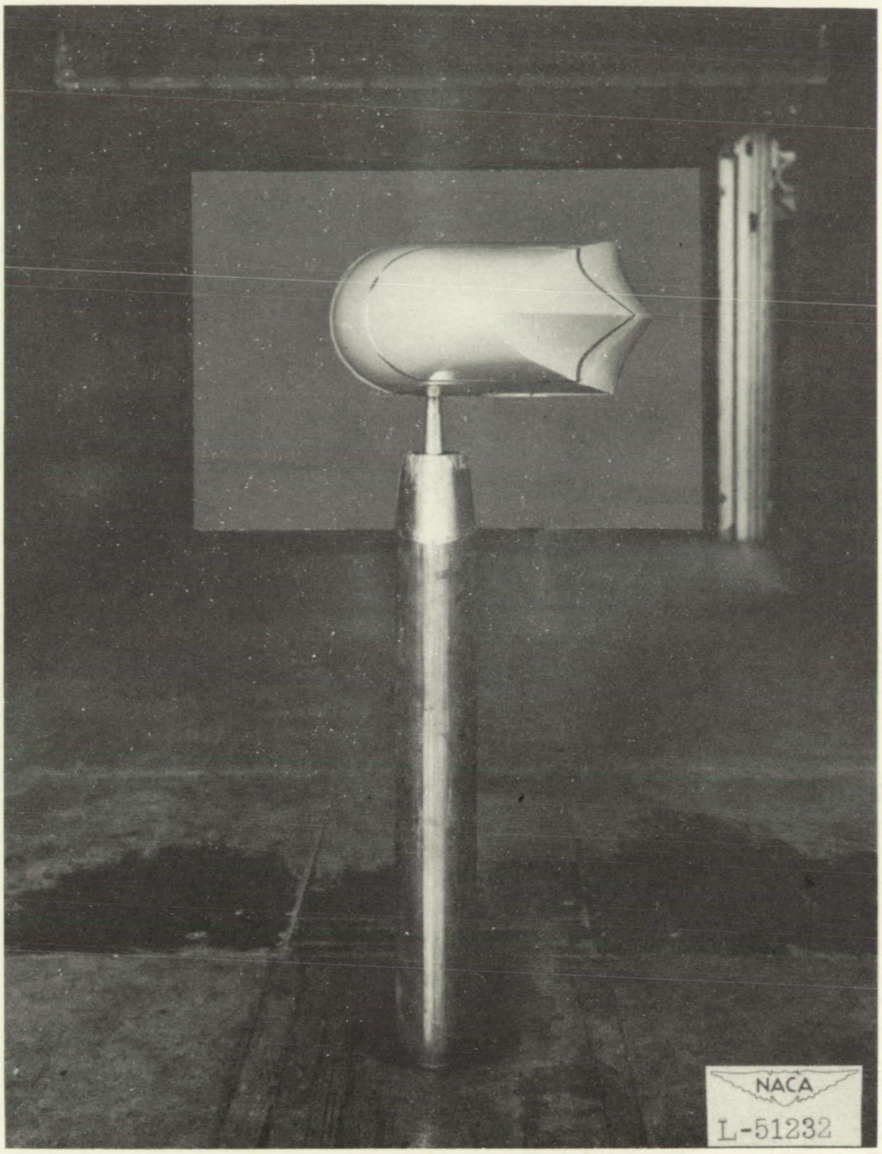


Figure 3.- Hull mounted on single support strut in Langley 300 MPH 7- by 10-foot tunnel.

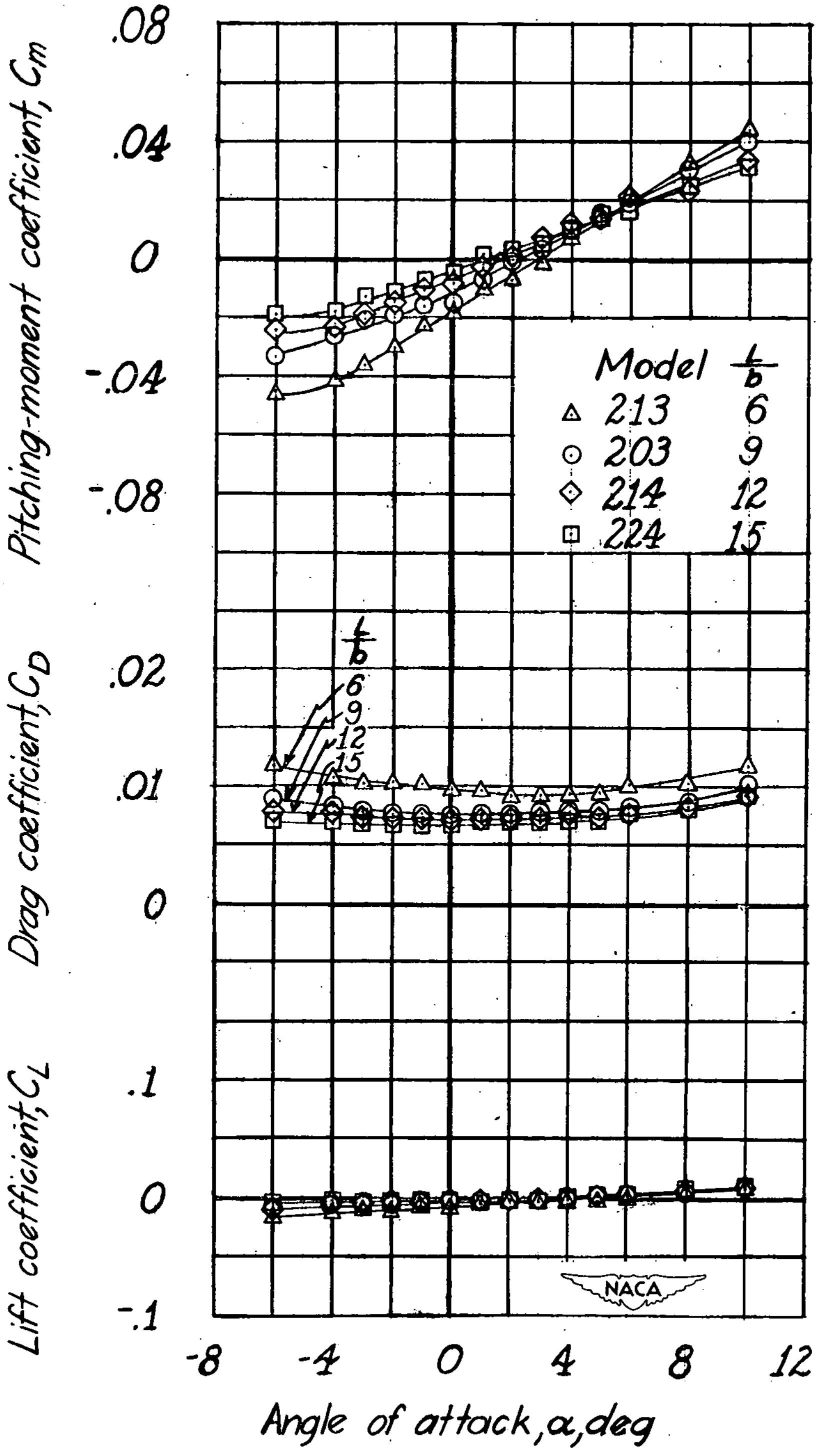


Figure 4.- Effect of length-beam ratio on aerodynamic characteristics in pitch of $\frac{1}{10}$-scale hulls of hypothetical flying boat.

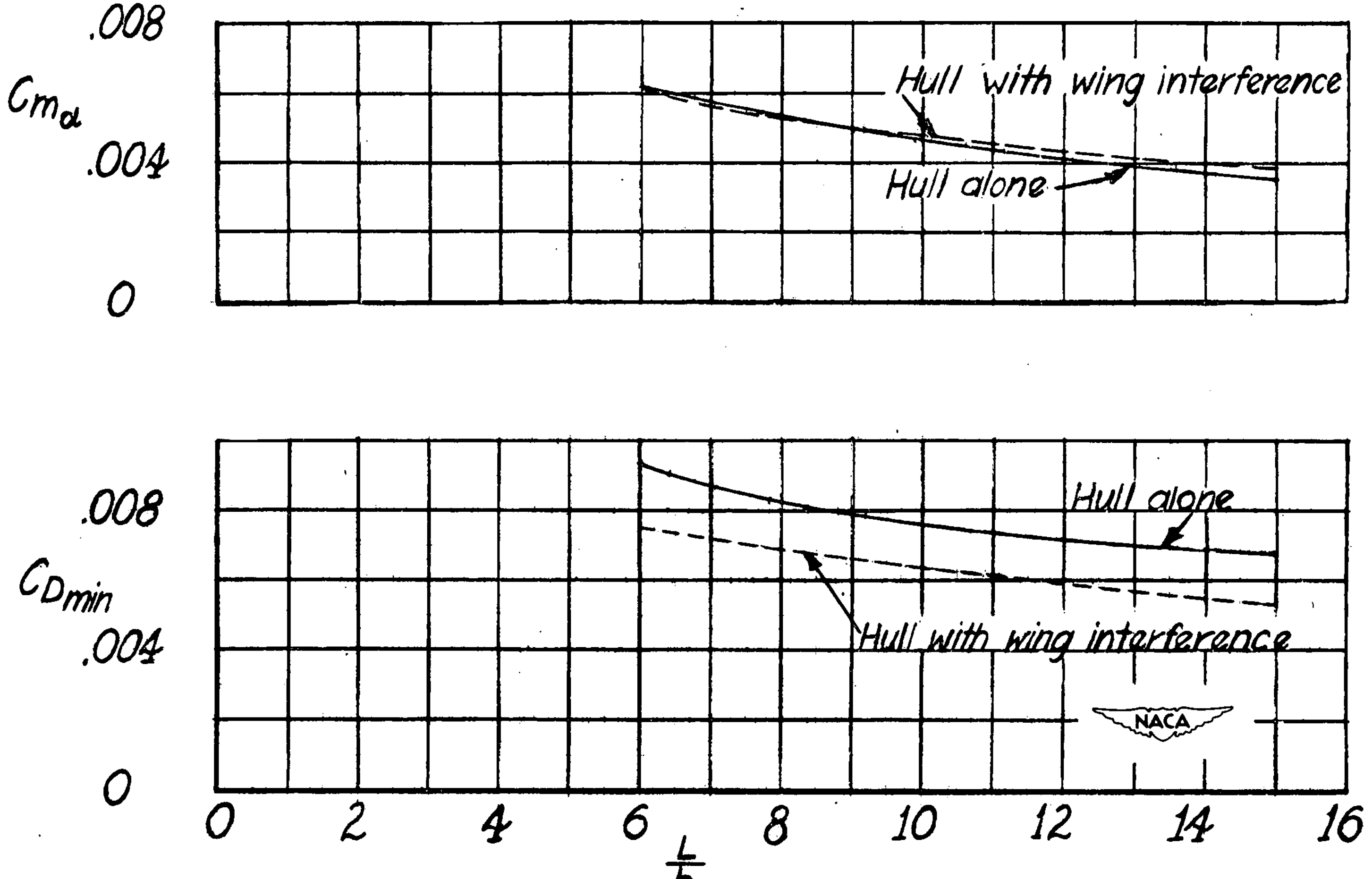


Figure 5.- Effect of length-beam ratio on $C_{D_{min}}$ and parameter C_{m_α} for the $\frac{1}{10}$-scale hulls of a hypothetical flying boat.

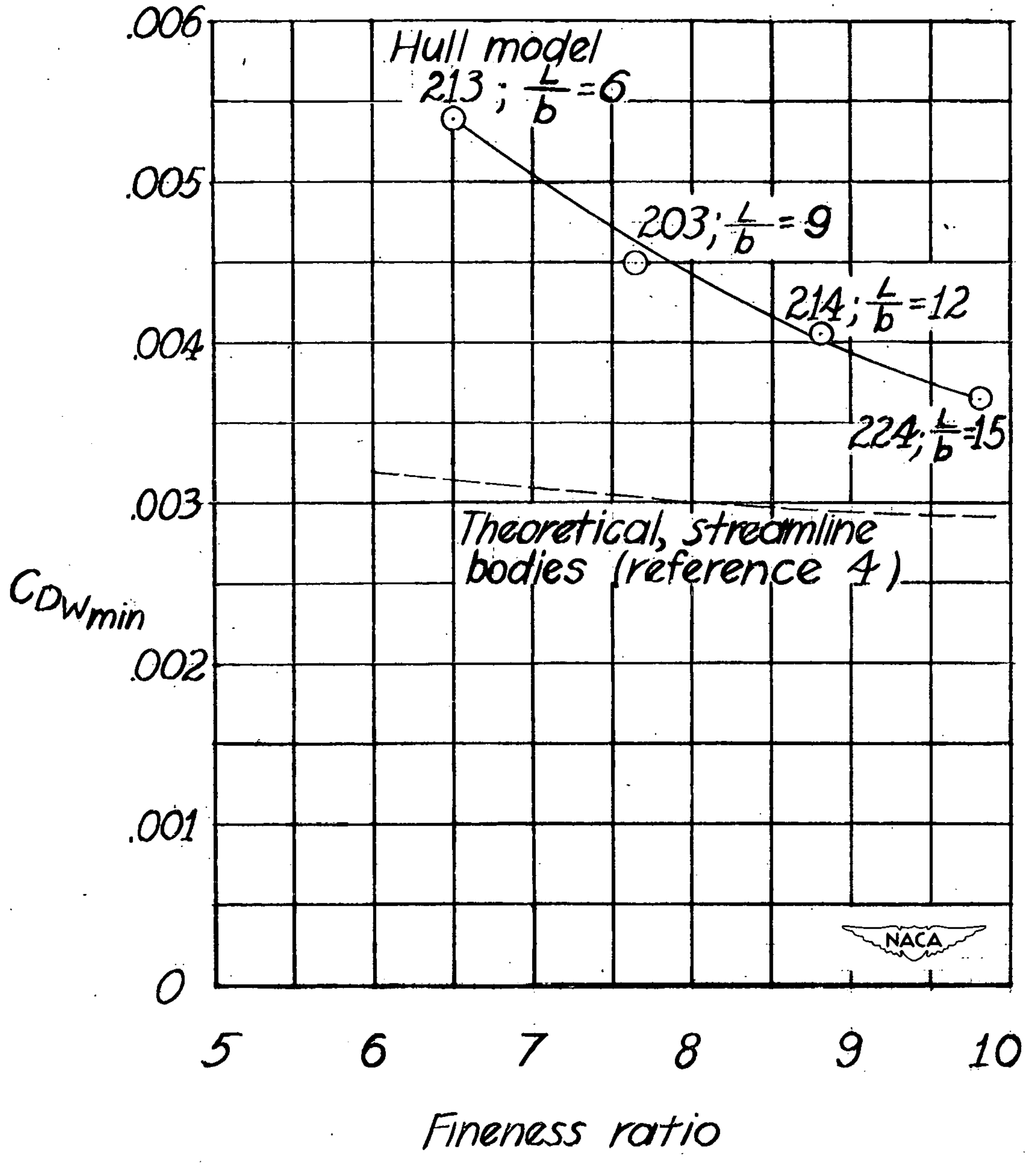


Figure 6 .- Comparison of theoretical drag coefficients of streamline bodies with experimental drag coefficients of flying-boat hulls with length-beam ratios of 6, 9, 12, and 15.

Abstract

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Fineness Ratio – Bodies 1.3.2.1

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Cross Section – Bodies 1.3.2.2

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Hulls – Aerodynamic 1.3.5

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Airplanes –
Components in Combination 1.7.1.1

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