NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM 1227

MOMENTS OF CAMBERED ROUND BODIES

By Günther Kempf

Translation of "Momente von gekrümmten Rundkörpern." Ludwig Prandtl zum 70. Geburtstag, Schriften der Deutschen Akademie der Luftfahrtforschung.

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The rotationally symmetrical form for submarines is frequently abandoned in regard to surface run; for instance the stern with the screw-propeller is pressed down in order to make the water flow more easily toward the screw, or the prow is lifted to keep the deck from being flooded.

For dimensioning the control elements it is important to know the influence of such cambers of the center line of a round body on the longitudinal stability, thus the ratio between the moment coefficients for cambered round bodies and the body of revolution.

This problem caused the investigation of the moments and the position of the force centers in a series of round bodies derived from a torpedo-like body of revolution. The length-width ratio of all bodies is 6:1; all show the same circular cross sections as the body of rotation and consequently, all have the same longitudinal volume distribution (fig. 1). They differ solely by the form of the axis of gravity of their cross sections, that is, the line connecting the centers of the circles, thus their center line.

In case of the body of rotation A this center line is the axis going through the main-bulkhead plane.

For the four round bodies derived from it the center line is for body

B - cambered in front

C - cambered toward the rear

D - cambered in the same sense on both sides

E - cambered in the opposite sense on both sides

The extent of these two-dimensional cambers is determined by the circular cross sections being shifted in each case until they touch a plane parallel to the center axis and tangent to the main bulkhead.

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*"Momente von gekrümmten Rundkörpern." Ludwig Prandtl zum 70. Geburtstag, Schriften der Deutschen Akademie der Luftfahrtforschung, pp. 139-151. (To Ludwig Prandtl upon his 70th birthday, Publications of the German Academy for Aviation Research), Berlin 1945.

Figure 2 represents the five round bodies thus originated. Their length is 80.8 centimeters, their maximum diameter 13.9 centimeters.

The torques about two axes normal to the plane of the cambered center line were measured by moving the body along in the water toward both sides for various angles of attack from 0° to 40°, the center line being immersed below the water surface to a depth of 2.65-times the diameter of the body. At this depth the influence of the surface waves is already sufficiently eliminated. After a sufficient constancy of the moment coefficient at small angles of attack had been determined for speeds of 1 to 2.5 meters per second, the tests were, for reasons of measuring accuracy, performed at a constant speed of 1 meter per second corresponding to a Reynolds number of $Rl = 6.7 \times 10^5$ or $Rd* = 1.16 \times 10^5$.[1]

The measurement was made as follows (fig. 3):

A traction exerted by a weight was applied at a horizontal disc placed on the vertical axis of rotation. The body rotated during the measurement at constant water speed up to the angle corresponding to the prescribed weight moment which was then read off. The measurement was made about two axes of rotation at a distance a from each other. If x is the distance of the point of attack of the force P from the axis of rotation of the moment M_1, there follows from the two moments $M_1 = Px$ and $M_2 = P(x + a)$ for the same position of angles by elimination of P:

$$x = \frac{aM_1}{M_2 - M_1}$$

In the presentation of the results in figures 4, 5, 6, 7, and 8 the moment coefficients $C_m = M/qFl$ are referred to the leading edge of the body, and the force centers are represented in their position with respect to the body. F is the main-bulkhead area, l, the length of the body.

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*Reviewer's note: Rd signifies, according to Forschungsbericht Nr. 1982 by Albring, the Reynolds number referred to the maximum diameter of the body.

[1]According to Albring's investigations in Forschungsbericht Nr. 1982 the results can be transferred to higher Reynolds numbers only from $Rd \sin \alpha = 3 \times 10^5$ onward, that is, in the present case for angles of attack below 22°. This is indicated also by the fluctuations in measurement observed in case of larger angles. For the present purpose the transferability for angles of attack smaller than 22° is sufficient. An investigation for higher Reynolds numbers would have required a considerably more complicated test-apparatus.

It is seen that all five bodies have a considerable unstable region, referred to the leading edge; this extends for instance for the body of rotation up to $\pm 17^{\circ}$ toward both sides whereas it is more or less unilaterally shifted for the other bodies, according to their asymmetry; on the whole, however, it covers about the same angular range from 30° to 35°.

The moment coefficients of the five round bodies are plotted referred to the leading edge in figure 9 and referred to the center of gravity of the body in figure 10.

The essential difference in the stability properties of these round bodies compared to a cylinder of the same profile as it is given, for instance, by the Göttingen profiles 409, 410, and 411, is striking; whereas the latter are stable, referred to their leading edge, the round bodies are, to a great extent, unstable.

Thus arises the problem of what effect fins on the rear part have on the longitudinal stability of the round body. In order to solve this problem, four fins of different size were investigated for the body of revolution as to their stabilizing effect. The form and magnitude of these fins is represented in figure 11. The fins I, II, and IV lie within the circumference of the round body given by the main bulkhead. The magnitude is

for I 1/20 of the horizontal section

for II 1/10 of the horizontal section

for IV 1/6.66 of the horizontal section

Fin III is of the same magnitude as IV, but the area attached to fin II outside of the circumference is in case of IV attached ahead of the fin II within the circumference.

Moreover, for fin II the effect of a "stagnation wedge" attached to its trailing edge was investigated.

The results of these measurements are plotted together in figure 12.

The curves show that the tail fins, in order to ensure sufficient stability, must have a magnitude of at least approximately one-eighth of the horizontal section.

The investigation will be completed by determination of the C_a and C_w values for the five round bodies.

Translated by Mary L. Mahler
National Advisory Committee
for Aeronautics.

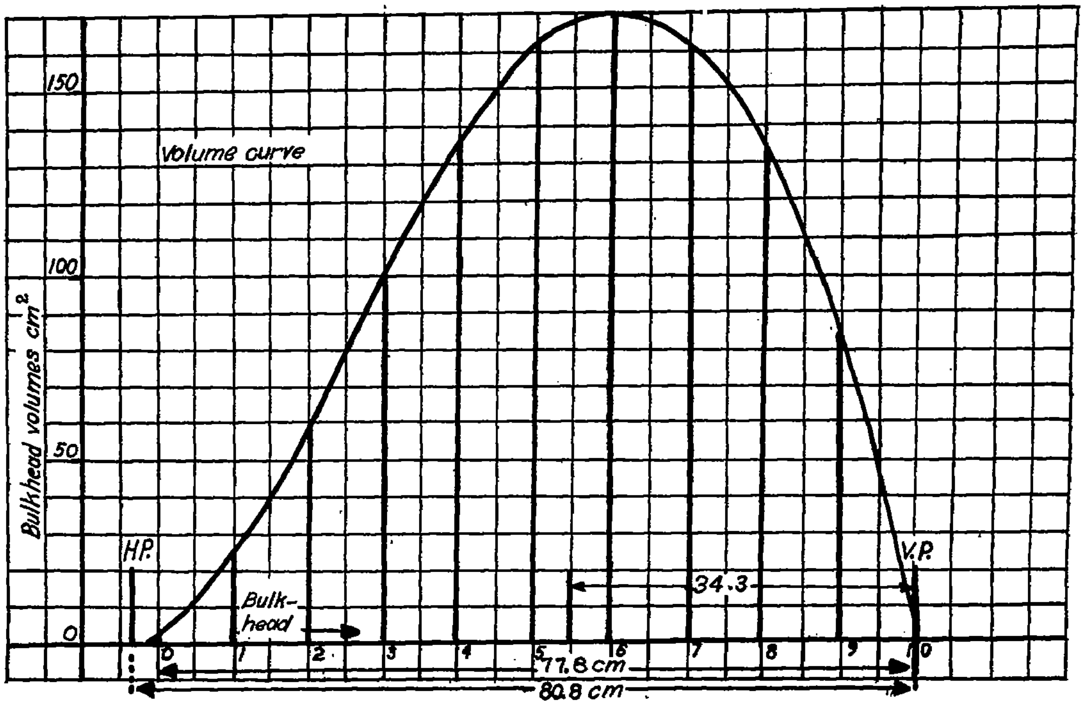

Figure 1

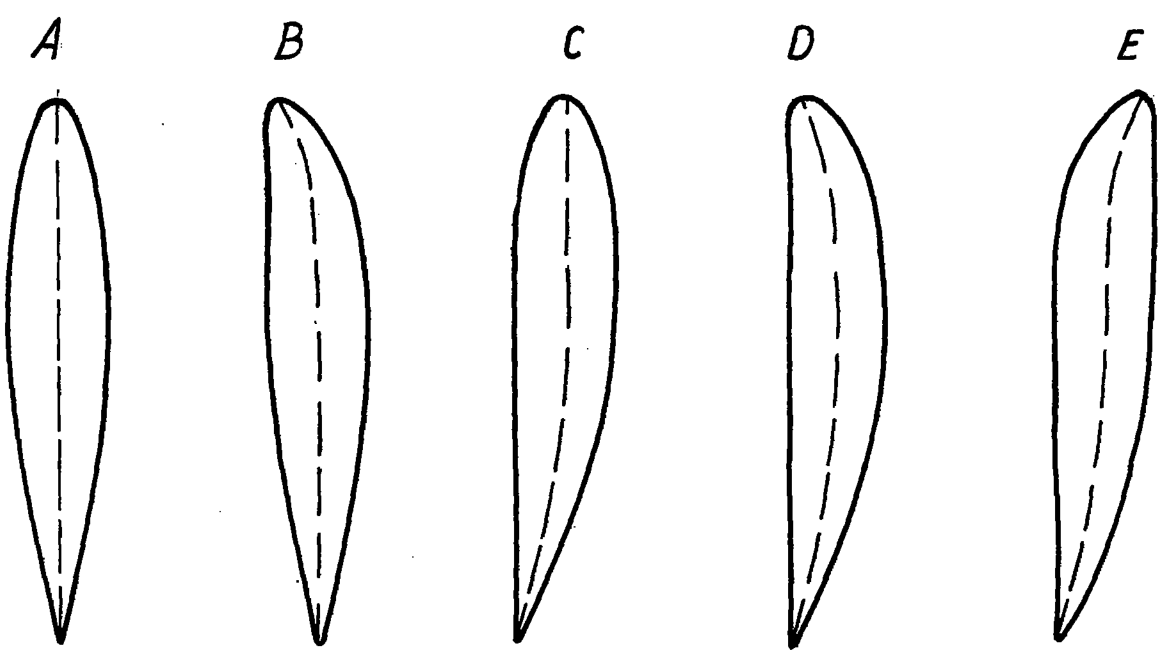

Figure 2

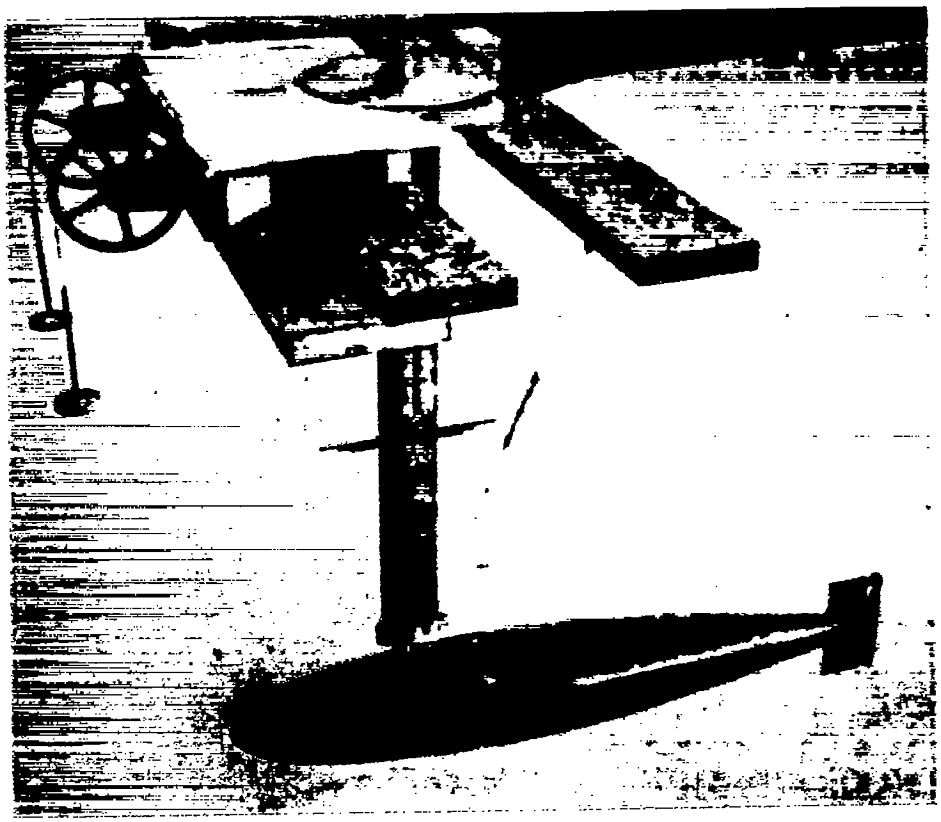

Figure 3

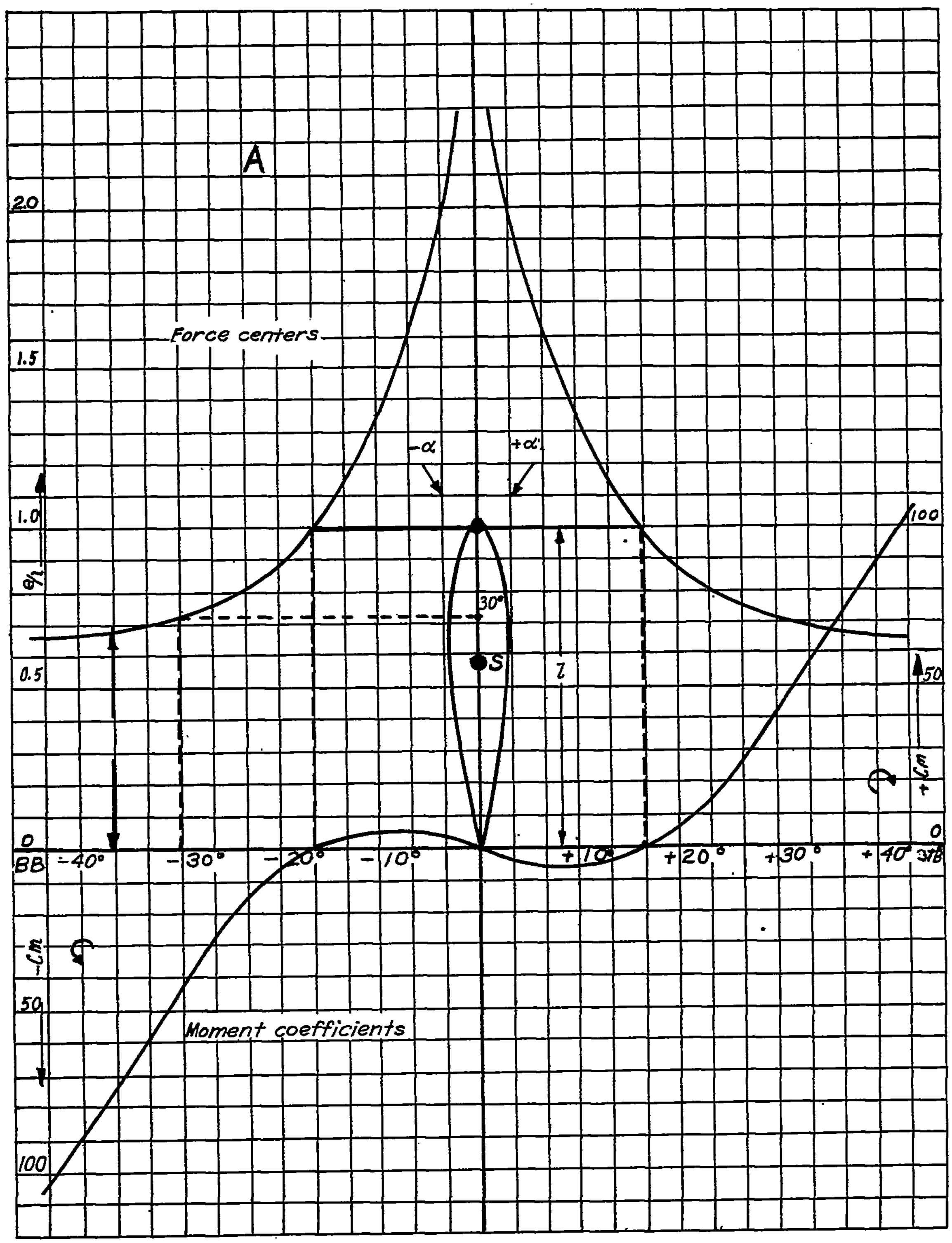
A
Force centers
2.0
1.5
1.0
0.5
0
-α
+α
30°
S
l
e/l
100
50
0
+Cm
-Cm
BB
-40°
-30°
-20°
-10°
+10°
+20°
+30°
+40°
Moment coefficients
100

Figure 4

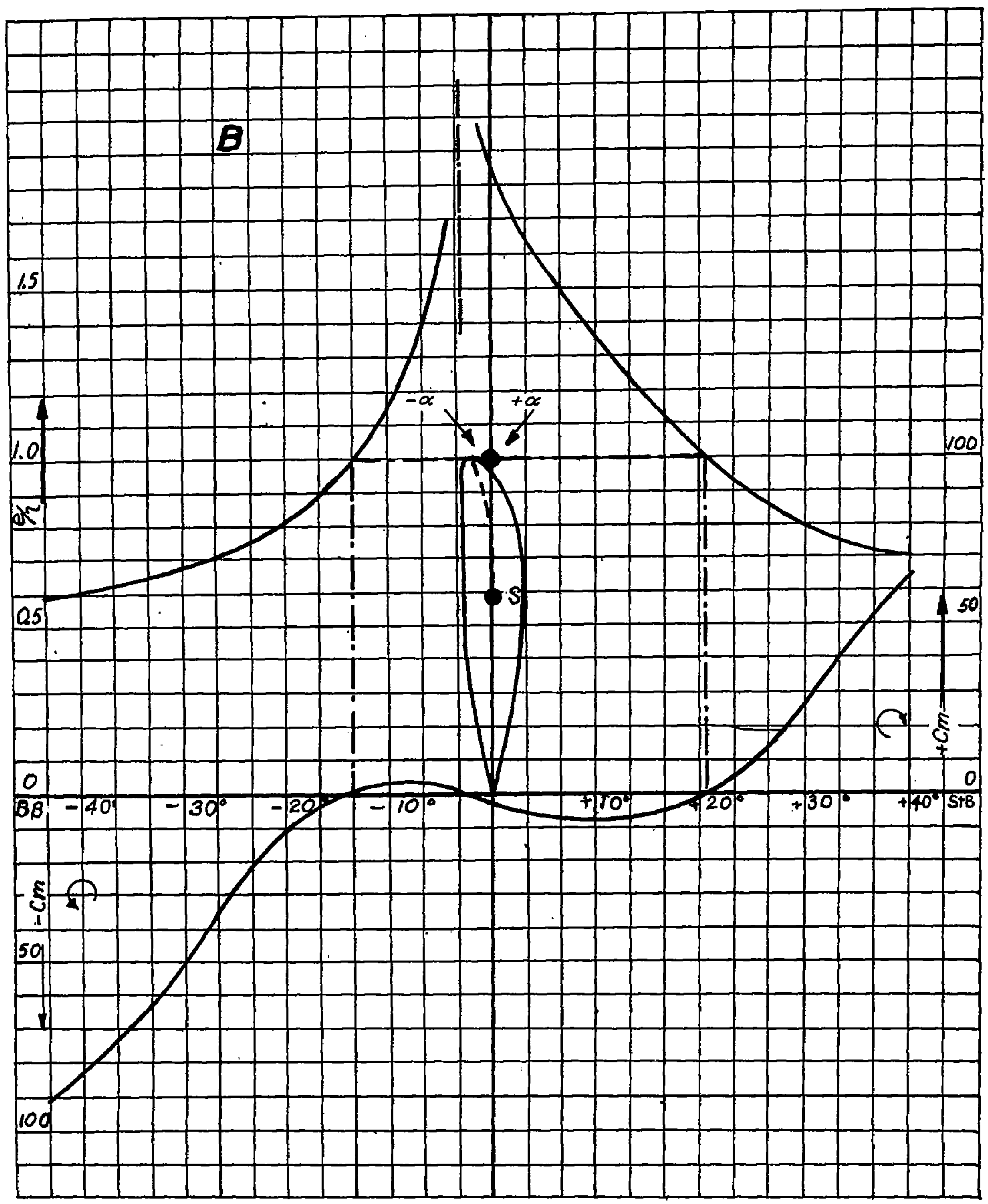

Figure 5

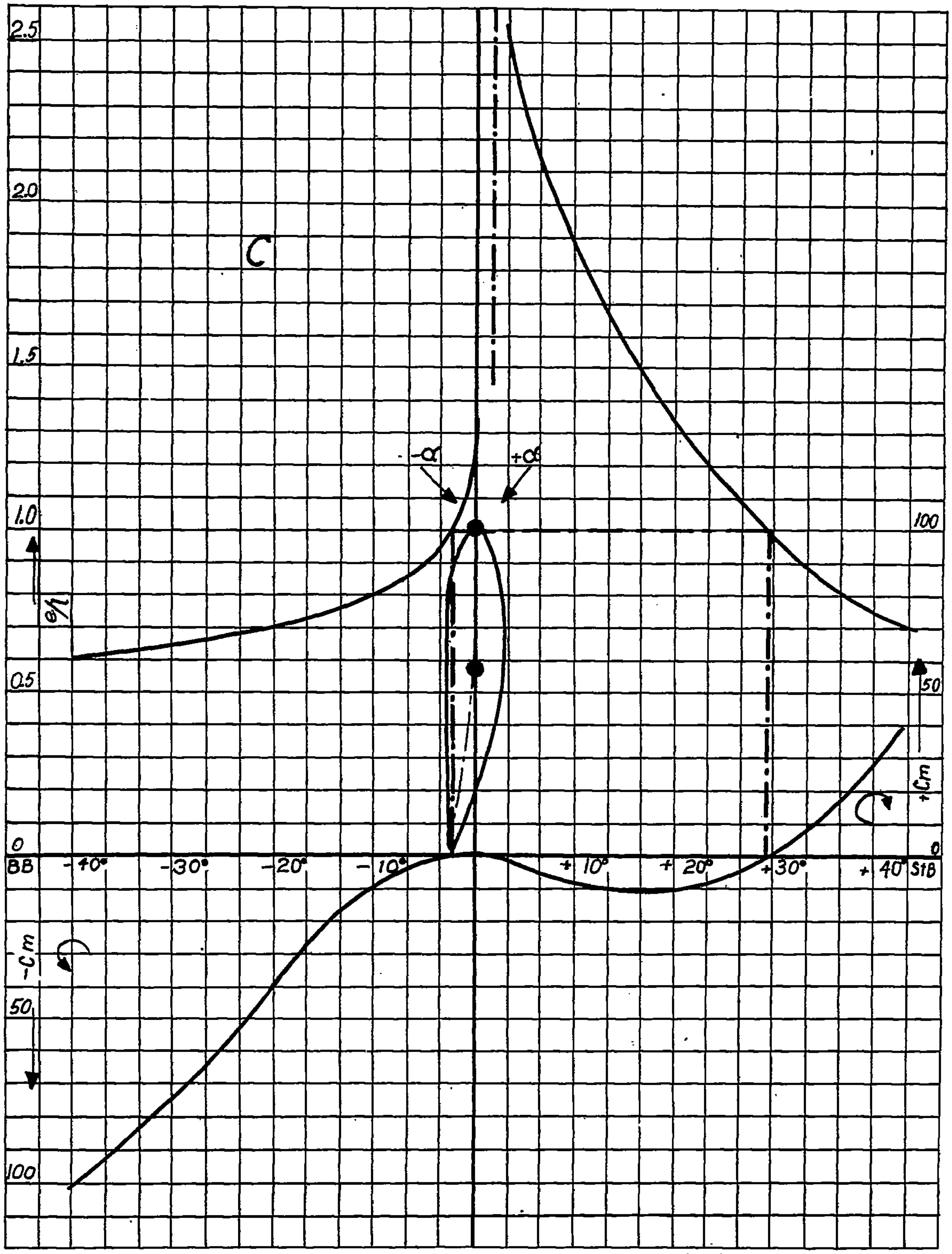
2.5
2.0
C
1.5
-α
+α
1.0
e/η
0.5
0
BB
-40°
-30°
-20°
-10°
+10°
+20°
+30°
+40°
StB
100
50
+Cm
0
-Cm
50
100

Figure 6

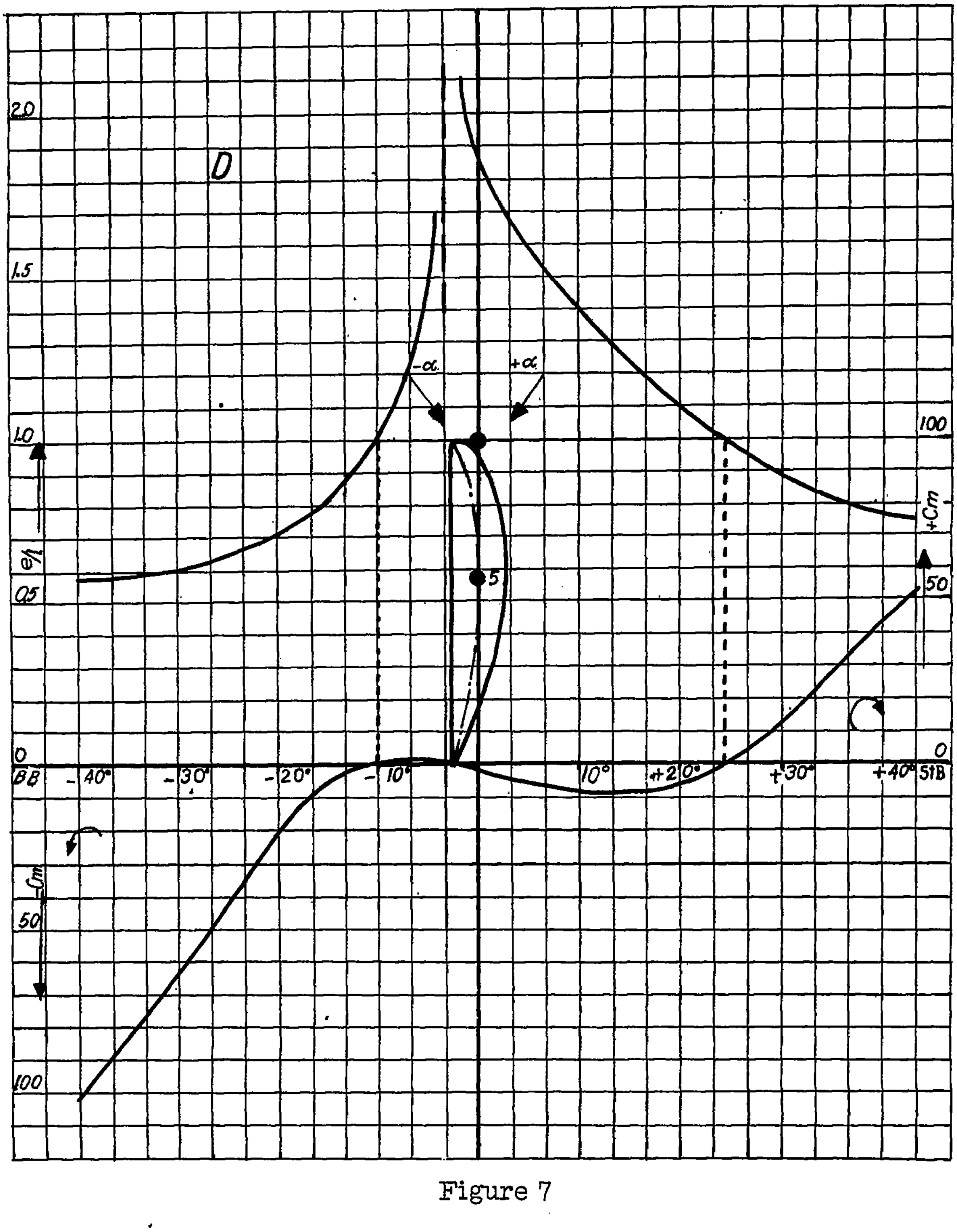
2.0
D
1.5
-α
+α
1.0
100
+Cm
e/l
5
0.5
50
0
0
BB
-40°
-30°
-20°
-10°
10°
+20°
+30°
+40°
51B
-Cm
50
100

Figure 7

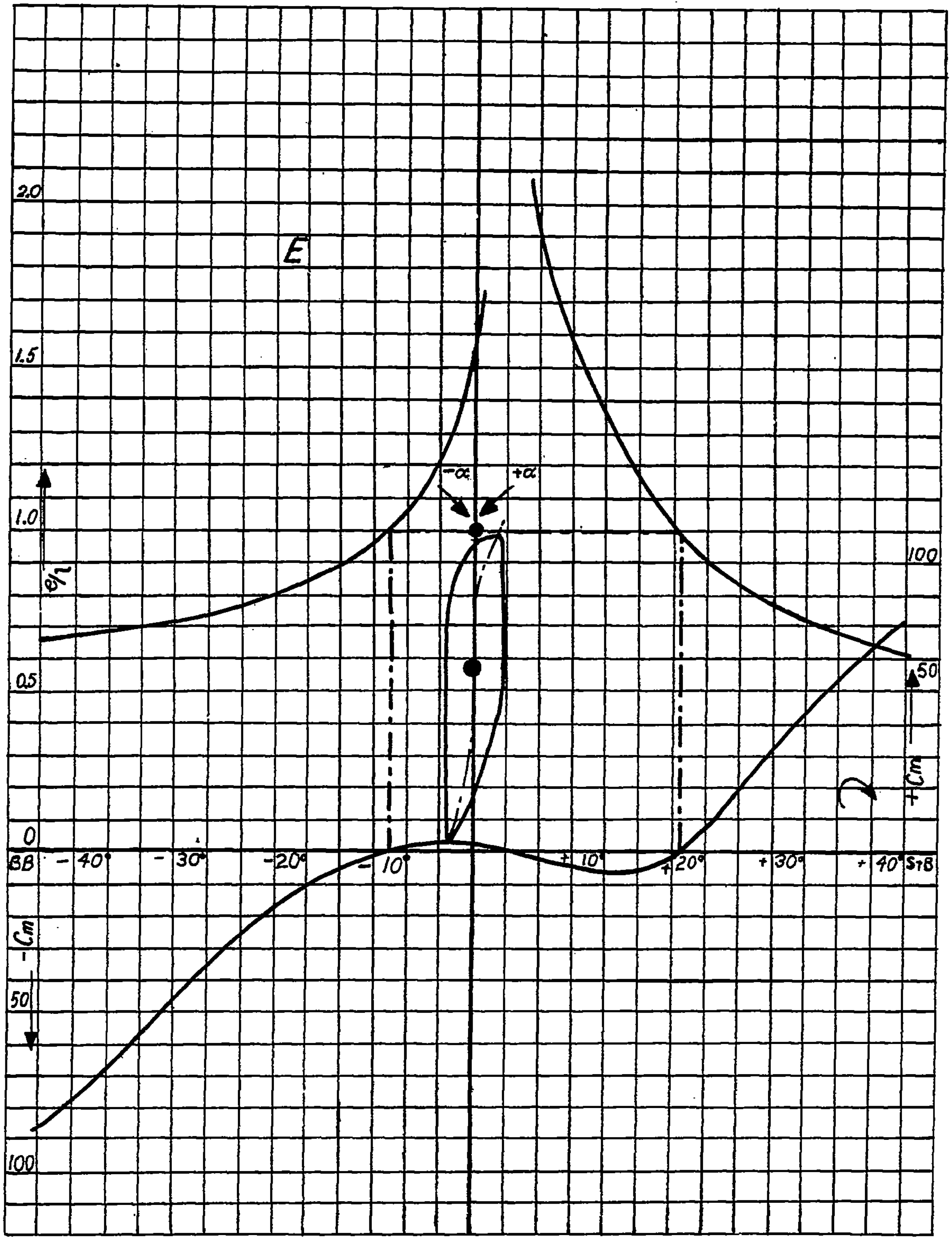

Figure 8

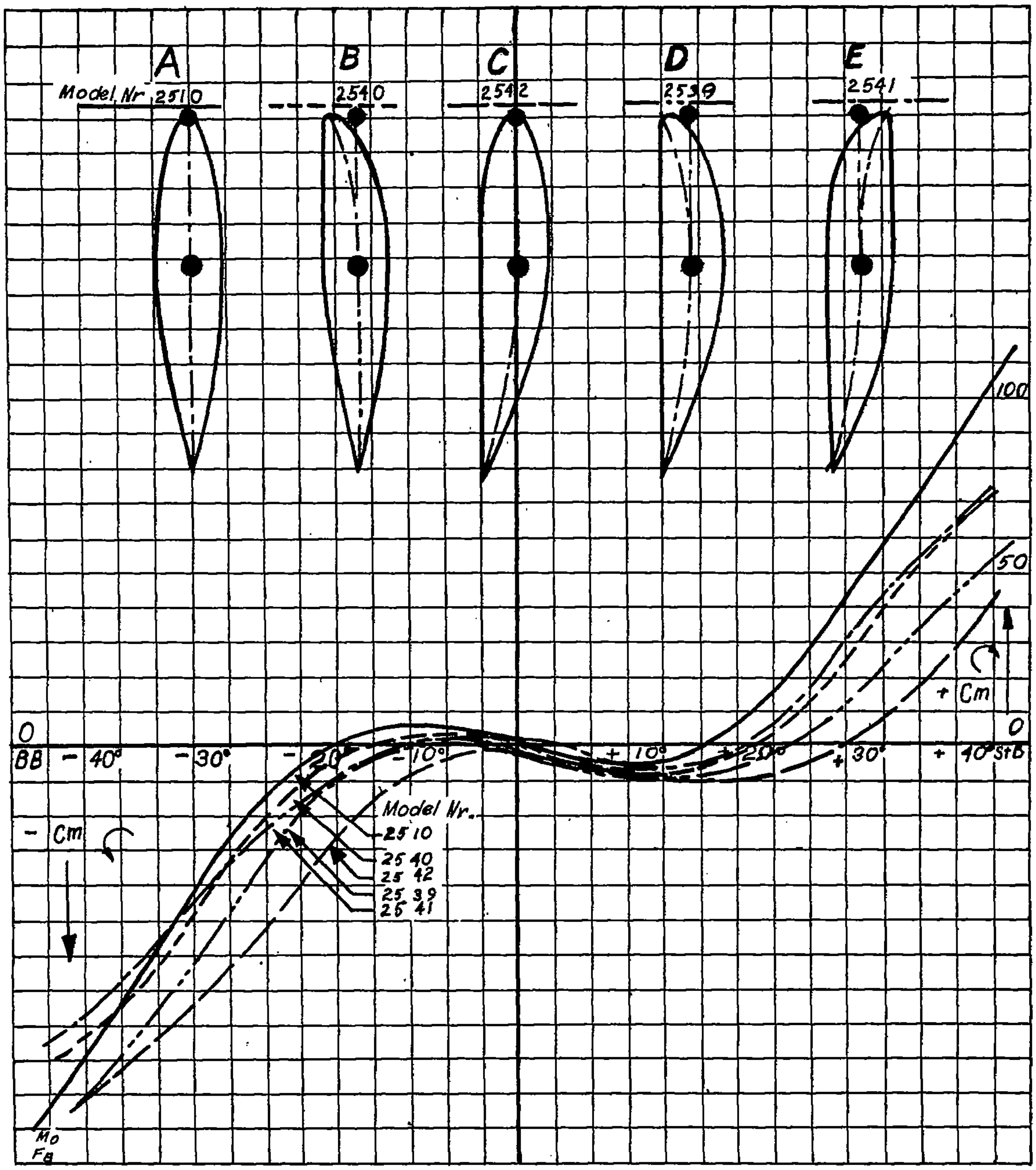
A
B
C
D
E
Model Nr 2510
2540
2542
2539
2541
100
50
+ Cm
- Cm
0
BB
- 40°
- 30°
- 20°
- 10°
+ 10°
+ 20°
+ 30°
+ 40° StB
Model Nr.
25 10
25 40
25 42
25 39
25 41
Mo
Fa

Figure 9

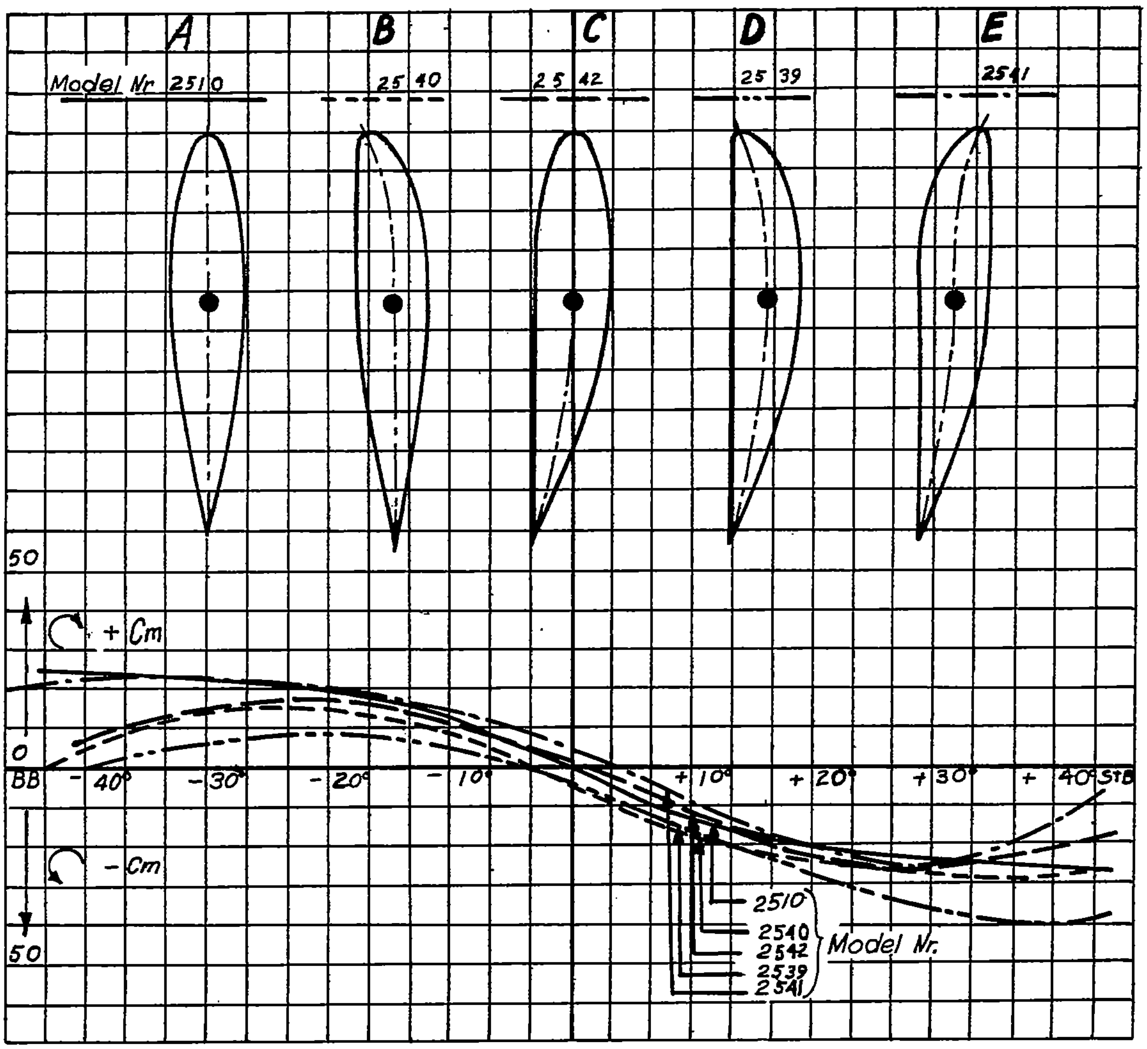
A
B
C
D
E
Model Nr 2510
2540
2542
2539
2541
50
+ Cm
0
BB
- 40°
- 30°
- 20°
- 10°
+ 10°
+ 20°
+ 30°
+ 40°
STB
- Cm
50
2510
2540
2542
2539
2541
Model Nr.

Figure 10

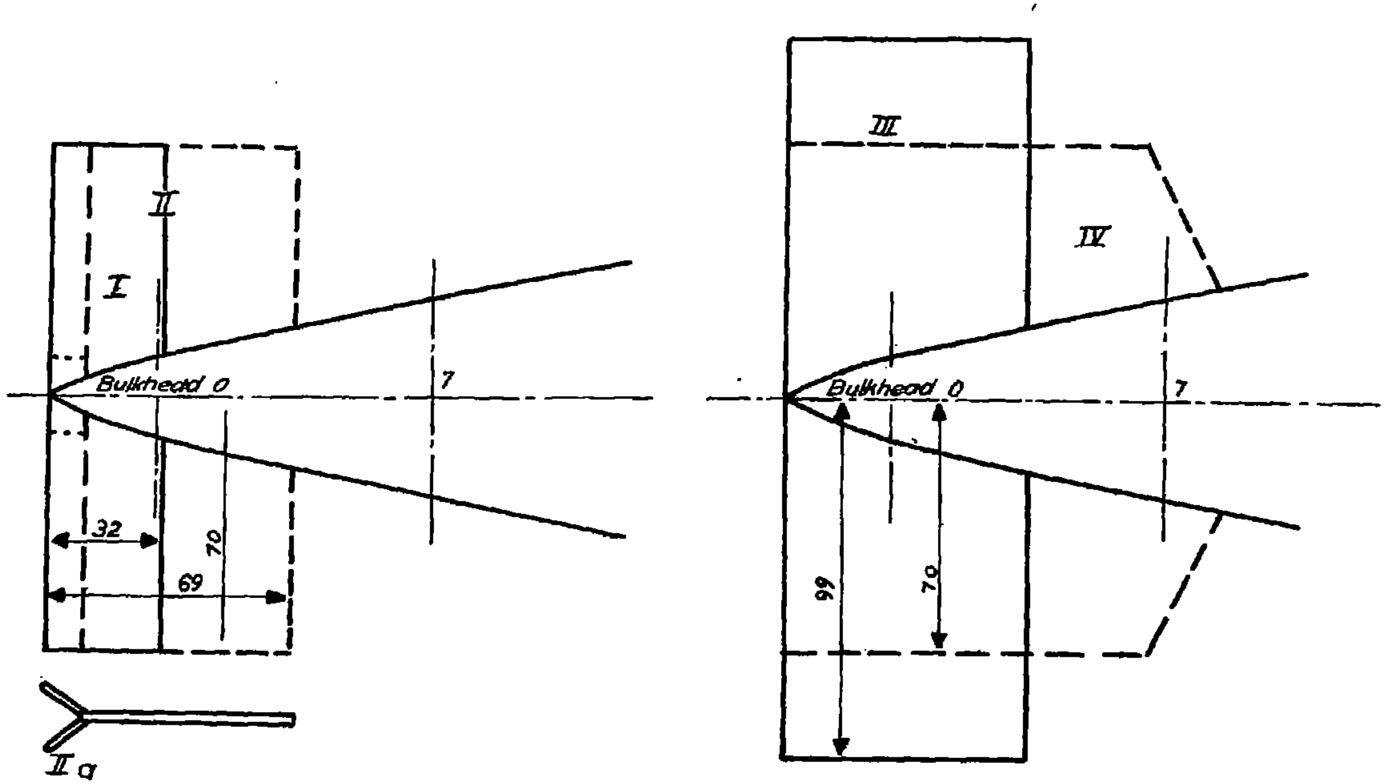

Figure 11

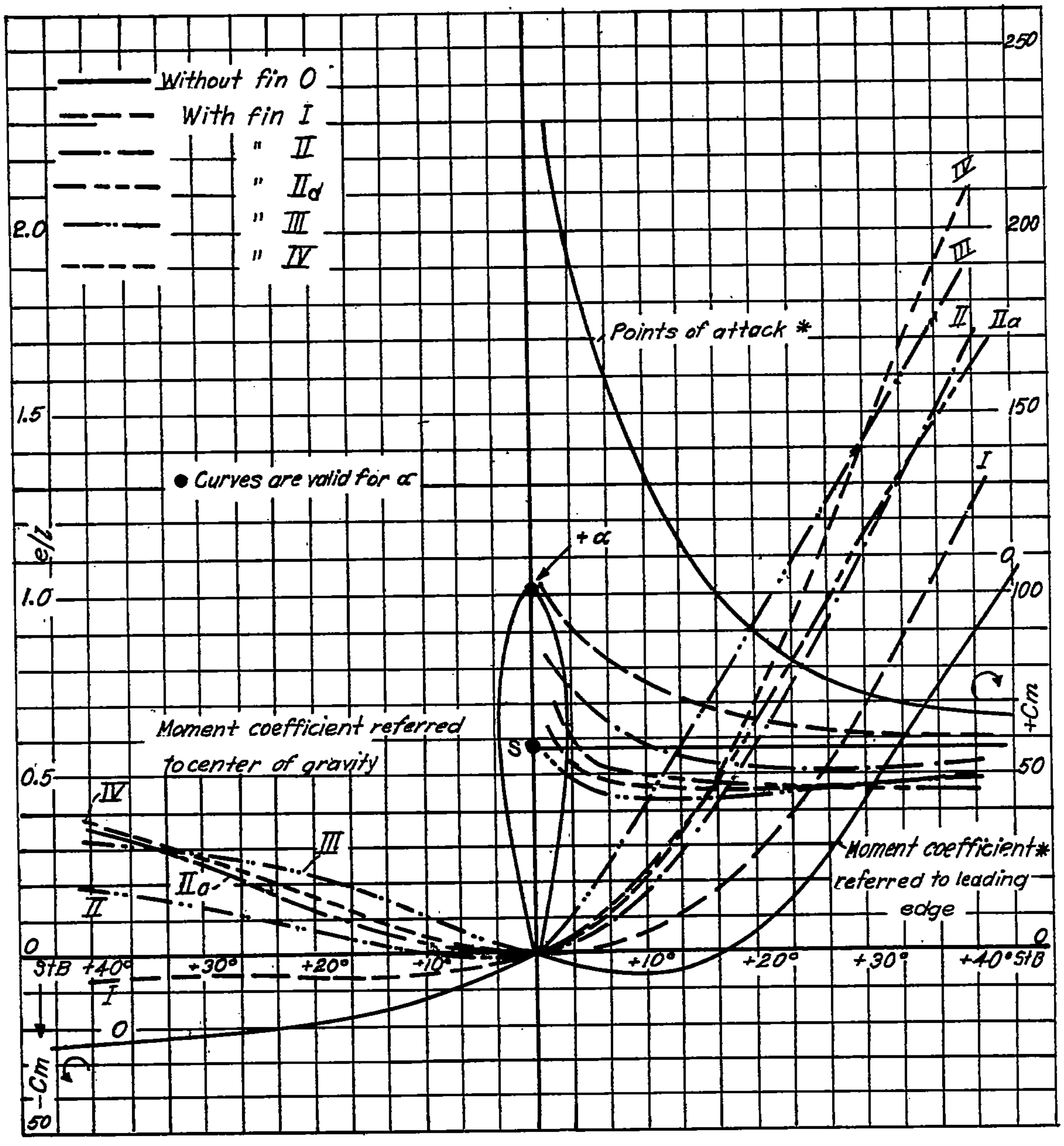
Without fin O
With fin I
" II
" IIa
" III
" IV
Points of attack *
Curves are valid for α
+α
S
Moment coefficient referred
to center of gravity
Moment coefficient*
referred to leading
edge
e/l
+Cm
-Cm
2.0
1.5
1.0
0.5
0
50
250
200
150
100
50
0
StB +40°
+30°
+20°
+10°
+10°
+20°
+30°
+40° StB

Figure 12