TAYLOR MODEL BASIN
WASHINGTON, D.C.

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REDUCTION OF PLANING BOAT RESISTANCE BY DEFLECTION OF THE WHISKER SPRAY

[redacted]

by

Eugene P. Clement

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

November 1964

Report 1929

PRNC–TMB–648 (Rev 1–64)

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NOTATION

A	Aspect ratio, b/ℓ_m
A_P	Projected planing bottom area, excluding area of external spray strips
B_{PX}	Maximum breadth over chines, excluding external spray strips
CG	Center of gravity
C_{Lb}	Lift coefficient based on breadth of planing surface
F_∇	Froude number based on volume of water displaced at rest in any consistent units, $v/\sqrt{g\nabla^{1/3}}$
g	Acceleration due to gravity
LCG	Distance of the CG forward of the transom
L_P	Projected chine length
L_P/B_{PX}	Length/beam ratio
ℓ_{cp}	Center-of-pressure location (measured from aft end of planing surface), ft
ℓ_m	Mean wetted length (distance from aft end of planing surface to the mean of the heavy spray line), ft
V	Boat speed, knots
v	Boat speed, ft/sec
W	Gross weight of boat, lb
α	Angle of attack of after portion of planing bottom, deg
β	Deadrise angle of planing bottom, deg
γ	Angle of stagnation line with centerline in plan view, deg
θ	Angle of spray direction with centerline in plan view, deg
ρ	Mass density of water, slugs/cu ft
∇	Volume of water displaced at rest, cu ft

ABSTRACT

Additional experimental verification is presented of the reduction of planing boat drag which can be achieved by using longitudinal strips forward of the stagnation line to deflect the whisker spray from the hull surface. In addition, graphs for determining the high-speed positions of the spray boundary and stagnation lines are given, to assist designers in locating spray deflectors on planing boats in the most effective positions.

ADMINISTRATIVE INFORMATION

This work was sponsored by the Bureau of Ships under Project S-R009-0101, Task 0103.

INTRODUCTION

A previous Model Basin report[1] has explained how the resistance of planing boats can be effectively reduced by an arrangement of longitudinal strips on the hull bottom which deflect the "whisker spray" from the hull surface. That report pointed out that for maximum effectiveness, such strips should be located only ahead of the high-speed stagnation line. The flow ahead of the stagnation line on the bottom of a planing hull consists of a thin sheet of water which flows diagonally across the hull bottom. This flow (the whisker spray) contributes a component of frictional resistance. Therefore, a reduction in drag results from deflecting all or a part of the spray from the hull surface. This can be accomplished by means of longitudinal strips which act as spray deflectors. Behind the stagnation line, however, the flow is essentially parallel to the centerline, and the effect of any spray deflector length which extends into this region would

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[1] References are listed on page 6.

be to increase rather than decrease the resistance. Experimental verification of the effectiveness of spray deflectors forward of the stagnation line was presented in Reference 1.

The present report gives the results of tests of two models fitted with spray deflectors located forward of the stagnation line. These models were tested up to considerably higher speeds than the model reported on in Reference 1. This present report also verifies that full effectiveness of the strips at a particular design speed can be obtained with strips of very short length. In addition, graphs for determining the high-speed positions of the spray boundary and stagnation lines are included to assist designers in locating spray deflectors on planing boats in the most effective positions.

MODELS AND TEST CONDITIONS

TMB Models 4666 and 4667-1, which had been used previously for the tests reported in Reference 2, were utilized for these additional tests with spray deflectors. Figure 1 presents a plan of Model 4666 which shows the two arrangements of spray deflectors tested. The spray deflectors extended forward of the location of the stagnation line at volume Froude number equal to 5 for the test conditions of weight and center of gravity location. These test conditions were the TMB standard conditions for planing boats, corresponding to $A_p/\nabla^{2/3} = 7.0$, and with the LCG located at 6 percent L_p aft of the centroid of A_p. After testing this model with the spray deflectors which extended from the stagnation line forward to the bow, the forward portions were removed back to the dashed lines shown on the figure, and the model was retested with the short minimum-length spray deflectors indicated.

The arrangement of spray deflectors tested on Model 4667-1 is shown in Figure 2. These deflectors started at the location of the stagnation line for the design condition indicated in the figure and extended forward approximately twice the minimum length for effectiveness in smooth water at the design speed, load, and LCG location.

TEST RESULTS

The test results for Model 4666 were corrected to full scale for a boat weight of 100,000 lb and the resulting values are presented in Figure 3. This figure shows that the resistance was increased somewhat in the intermediate speed range by the addition of the spray deflectors, but at high speed, the resistance was reduced appreciably. At $F_{\nabla} = 6.0$, the resistance with the long spray deflectors was 15 percent below the bare-hull resistance. Both the long and short spray deflectors were designed for a speed corresponding to $F_{\nabla} = 5.0$, and it is interesting to note that a resistance reduction of about 7 percent was obtained in each case. This verifies the point made in Reference 1 that at a particular design speed, the full effect can be attained with spray deflectors of very short length if they are designed with appropriate consideration of the direction of flow of the whisker spray. Since each spray deflector produces a dry area which extends from the deflector to the chine (the sides of the dry area are parallel to the spray direction), it is possible to achieve the full effect for a particular design speed (in smooth water) by means of short lengths disposed as shown in Figure 4. In any practical case, there will, of course, be a range of variation of the operating speed and also of the weight and LCG of the boat. These factors, and also the motion in rough water, will produce fluctuations in the positions of the stagnation and spray-boundary lines. Accordingly, the lengths of the deflectors should generally be greater than the minimum lengths indicated in Figure 4. The important point indicated by that figure, however, is that the full high-speed benefit can be attained with spray deflectors which start considerably aft of the bow. Therefore, they need not be fitted in that portion of the bottom where the curvature is greatest, and where the fitting of the deflectors would be particularly difficult and expensive.

The effect of the spray deflectors on the resistance of a boat corresponding to Model 4667-1 is shown in Figure 5. It can be seen that the deflectors increased the resistance about 2 percent at $F_{\nabla} = 3.0$, but decreased it 4 percent at $F_{\nabla} = 5.0$ and 6 percent at $F_{\nabla} = 5.5$. The photographs in Figure 6 show the appearance of the whisker spray on Model 4667-1 (with the spray deflectors) for two different running conditions. Figure 6a shows the model at a running condition close to the design point for the spray deflectors. Note that the whisker spray is effectively diverted from the hull surface and that it leaves the spray deflectors in an approximately horizontal direction. Figure 6b shows the model at a running condition such that the stagnation line is ahead of the spray deflectors and does not intersect them. Here the whisker spray wets a considerable area of the hull bottom and rises as high as the sheer line of the hull after leaving the chine spray strip.

A comparison of Figures 4 and 5 indicates that the spray deflectors are more effective in reducing resistance in the case of Model 4666, which has a length/beam ratio (L_p/B_{PX}) of 3.06, than in the case of Model 4667-1, which has a length/beam ratio of 4.09. This is to be expected since the area wetted by whisker spray (for a hull without spray deflectors) increases approximately as the square of the hull width; therefore, the potential gain from use of the deflectors is greater for a relatively short wide hull than for a relatively long narrow hull.

LOCATING THE POSITIONS OF THE SPRAY BOUNDARY AND STAGNATION LINES

It has been explained that for best effect at a particular design speed, the spray deflectors should extend only forward of the location of the stagnation line at that speed. Also, the location of the forward boundary of the spray is of interest in connection with determining appropriate lengths for the deflectors. A procedure for determining the positions of the spray boundary and stagnation lines follows:

The first step is to assemble the following needed information:

W	the gross weight of the boat,
β	the deadrise angle of the planing bottom,
LCG	the distance of the CG forward of the transom,
b	the width over the chines (or over the spray strips if fitted) at the LCG location, and
v	the boat speed in ft/sec.

Figure 7 shows typical positions of the spray boundary and stagnation lines for a planing hull, together with the items which define the positions of these lines. It can be seen that the position of the stagnation line is defined by the values of ℓ_m and γ. The next step is to calculate the values of $C_{Lb} = \frac{W}{\rho/2 V^2 b^2}$ and ℓ_{cp}/b (assumed equal to LCG/b) from the information which has been assembled. It is pertinent to note here that all planing conditions are established when particular values of β, C_{Lb}, and ℓ_{cp}/b have been specified. The next step is to enter the graphs of Figure 8* with the known values of β, C_{Lb}, and ℓ_{cp}/b to determine the corresponding values of aspect ratio A and angle of attack α. Then calculate ℓ_m from the relationship, $\ell_m = b/A$ (since $A = b/\ell_m$). The value of γ (angle of stagnation line with centerline in plan view) can be read from Figure 9,** so that the position of the stagnation line is now defined. The value of θ (angle of spray direction with centerline in plan view) can be read from Figure 10.*** The spray boundary and stagnation lines intersect the keel at the same point, so that the position of the spray boundary line is now defined also.

The method just explained was used to calculate the positions of the spray boundary and stagnation lines for one of the conditions at which Model 4666 (without spray deflectors) had been tested. The conditions of the model test were as follows:

$W = 101.8$ lb,

$\beta = 12.5$ deg,

LCG forward of the transom = 2.53 ft,

$b = 1.87$ ft,

$v = 30.8$ fps (18.25 knots), and

$\rho = 1.9362$ (since the model was tested in fresh water at 70° F).

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* These graphs were prepared from the equations for lift and center of pressure of planing surfaces which are presented in Reference 3.

** This graph was prepared from an equation presented in Reference 4.

*** This graph was prepared from equations which are presented in Reference 4

From this information, the values of C_{Lb} and ℓ_{cp}/b were calculated. Then, values of A and α were determined for deadrise angles of both 10 and 15 deg (using Figures 8b and 8c), and their means were then taken to give values of A and α for a deadrise angle of 12.5 deg. Next, the value of ℓ_m was calculated, and the values of the angles γ and θ were determined using Figures 9 and 10.

Figure 11 compares the resulting "calculated" positions of the spray boundary and stagnation lines with the positions determined experimentally during the test of Model 4666. The agreement is considered to be sufficiently close to verify the suitability of using the proposed calculation method for positioning spray deflectors on the bottoms of actual planing boats. Exact agreement could not reasonably be expected in the present case since the equations on which the calculation method is based are for constant-width planing surfaces, whereas the planing bottom of Model 4666 has a considerable amount of taper in plan view. The calculation method can be expected to be more accurate for hulls having planing bottoms of more nearly constant width.

REFERENCES

1. Clement, E. P., "Effects of Longitudinal Bottom Spray Strips on Planing Boat Resistance," David Taylor Model Basin Report 1818 (Feb 1964).

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3. Shuford, C. L., Jr., "A Theoretical and Experimental Study of Planing Surfaces Including Effects of Cross Section and Plan Form," National Aeronautics and Space Administration Report 1355 (1958).

4. Savitsky, D., "Hydrodynamic Design of Planing Hulls," Davidson Laboratory Report 1000 (Dec 1963).

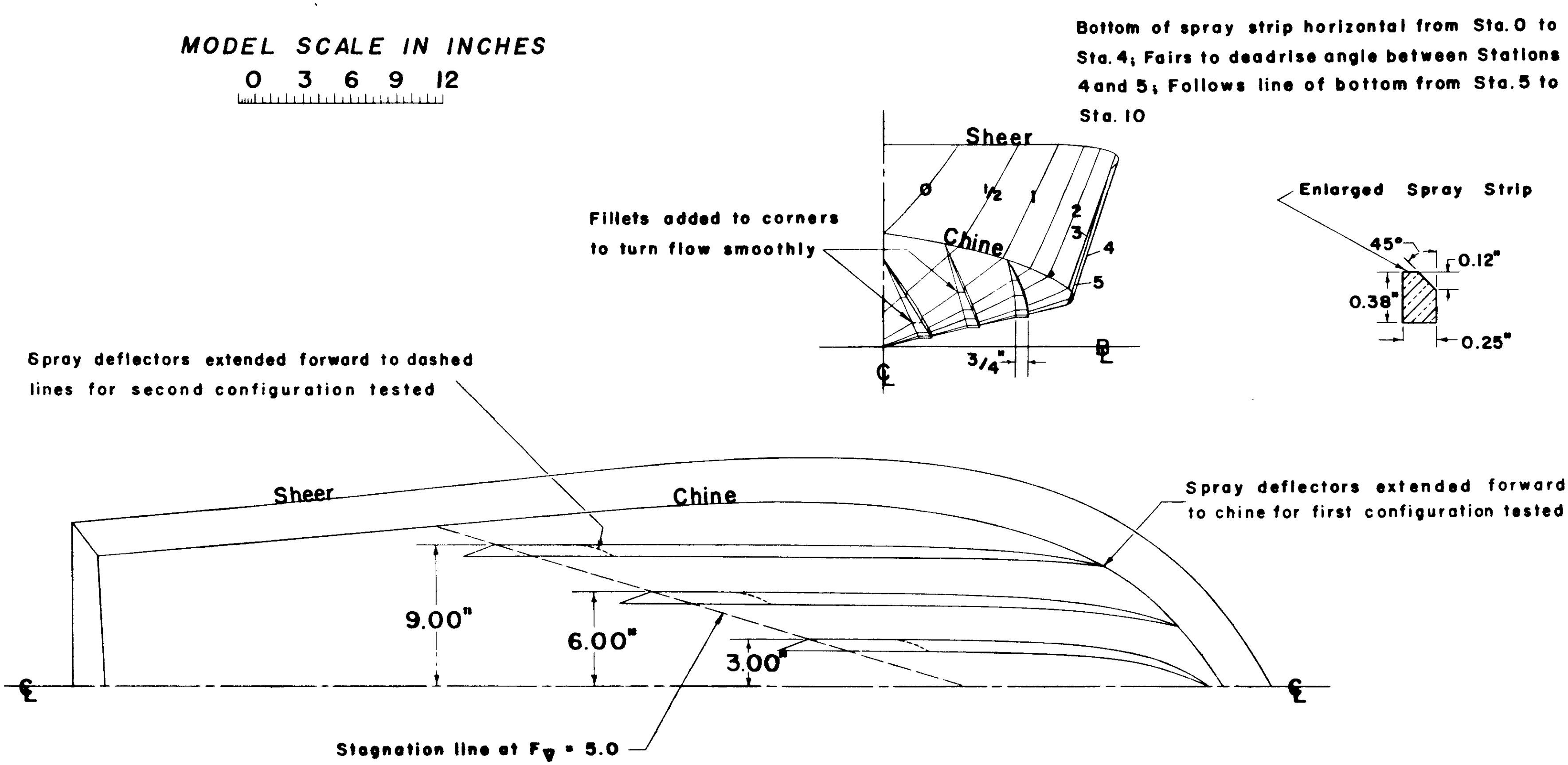
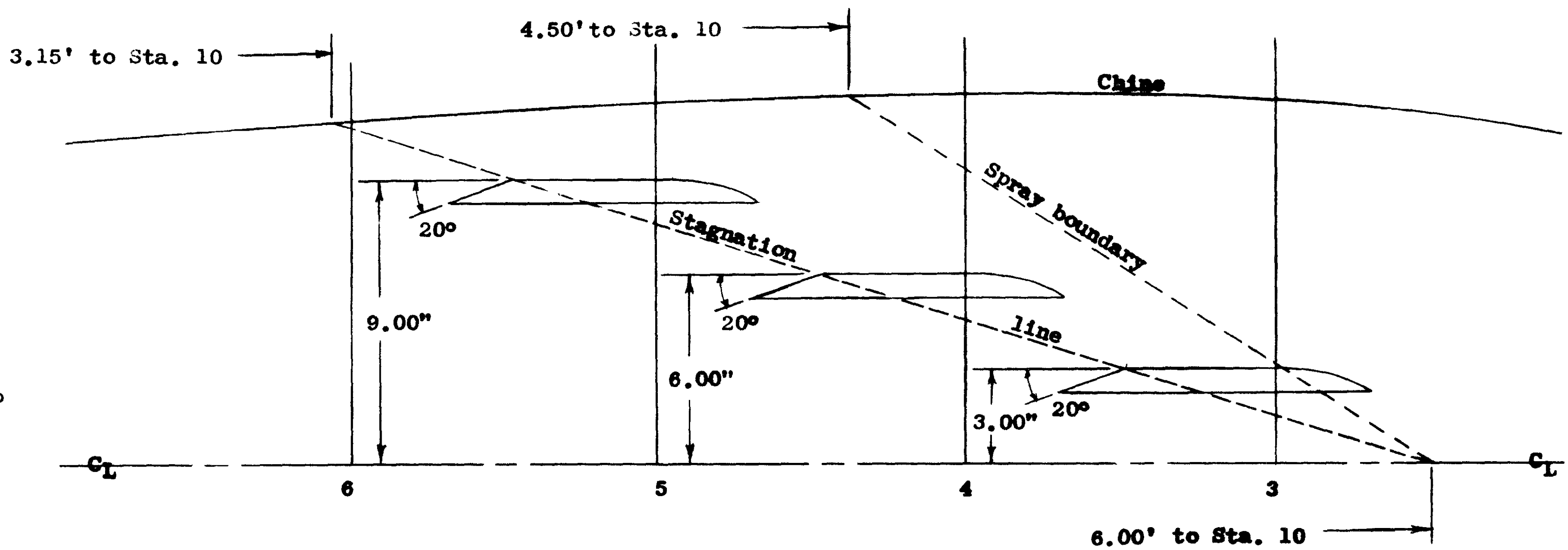


Figure 1 – Model 4666 Showing the Two Spray Deflector Configurations Tested



<u>Design Condition</u>:

$A_p/\nabla^{2/3} = 7.0$ LCG at 6 Percent L_p aft
$F_\nabla = 5.0$ of centroid of A_p

Figure 2 - Arrangement of Spray Deflectors Tested on Model 4667-1

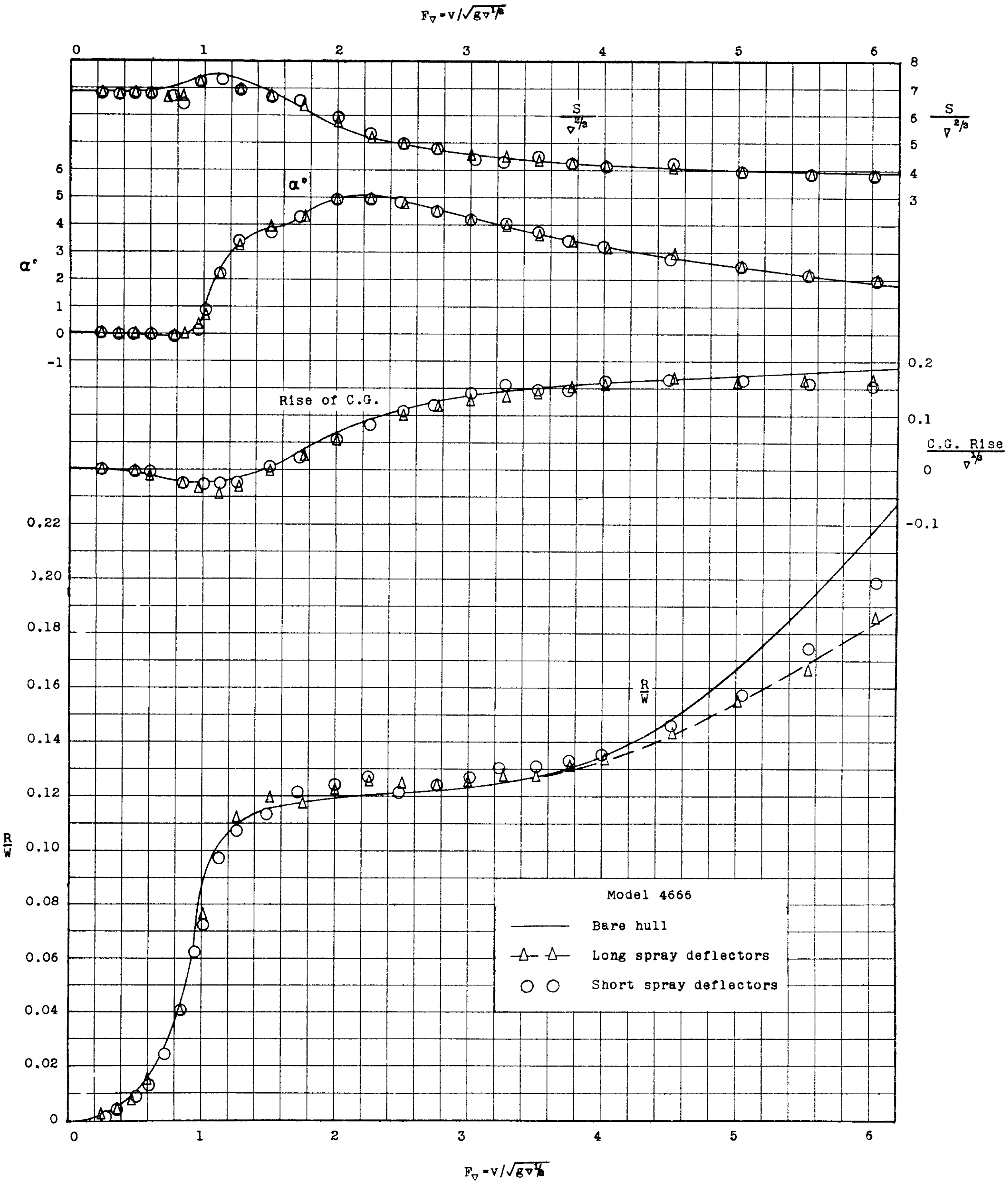


Figure 3 - Effects of Two Configurations of Spray Deflectors on the Smooth-Water Performance of a Planing Boat

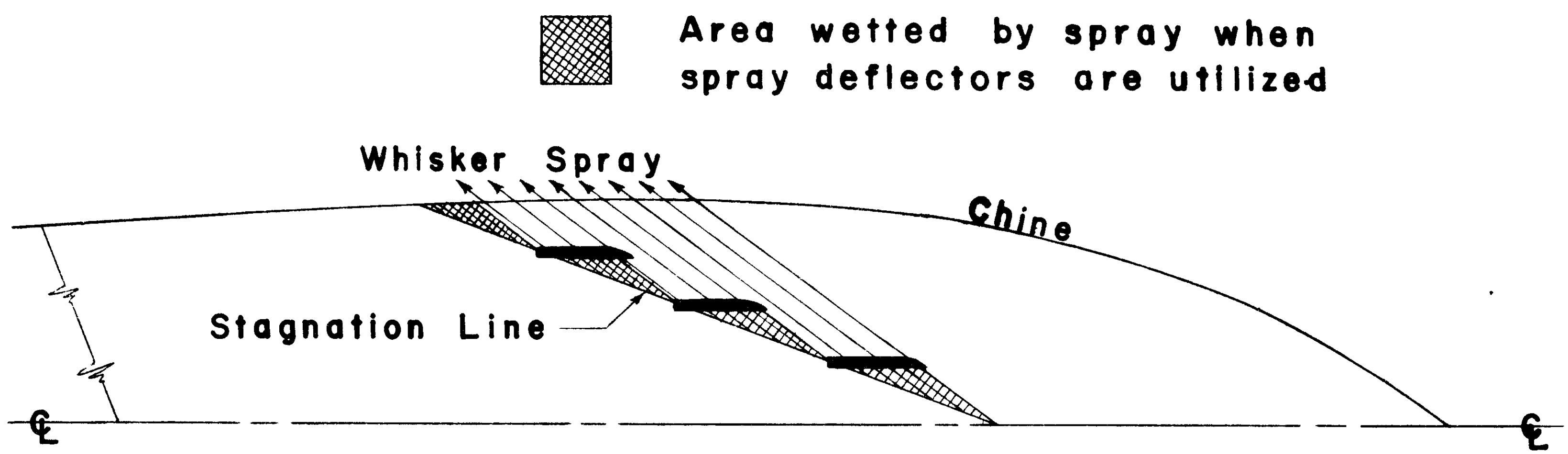


Figure 4 - Full Effect of Spray Deflectors Achieved with Short Lengths
Disposed as Shown

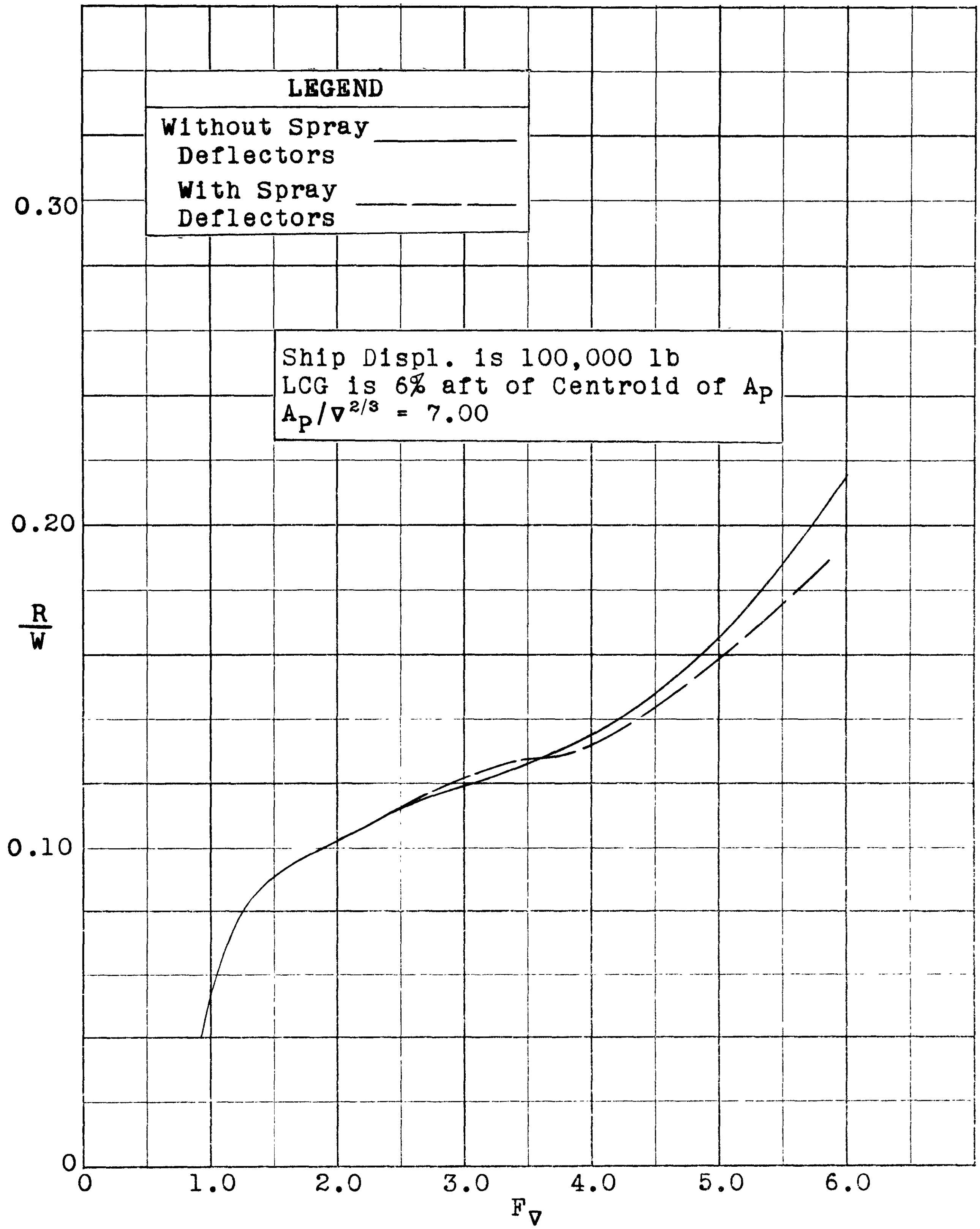


Figure 5 - Effect of Spray Deflectors on the Resistance of a Boat Corresponding to Model 4667-1

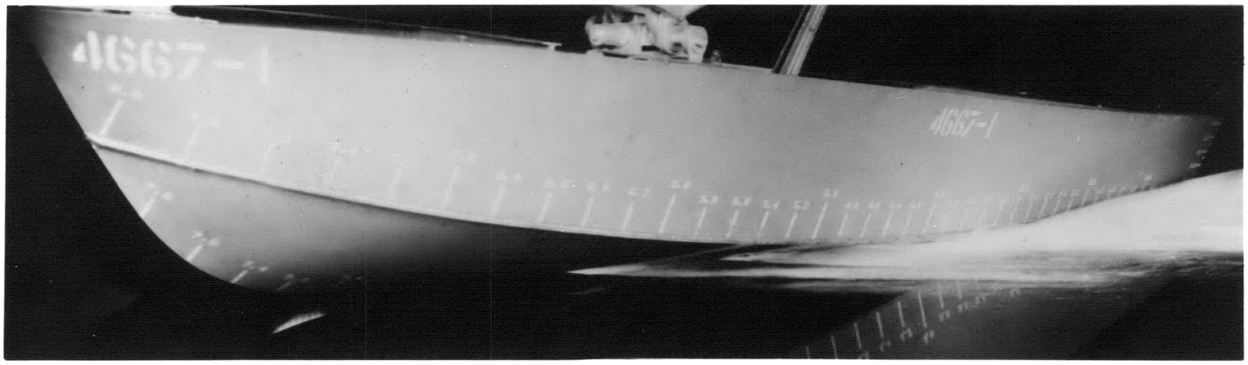


Figure 6a - F_∇ = 4.7; LCG at 6 Percent L_p Aft of Centroid of A_p

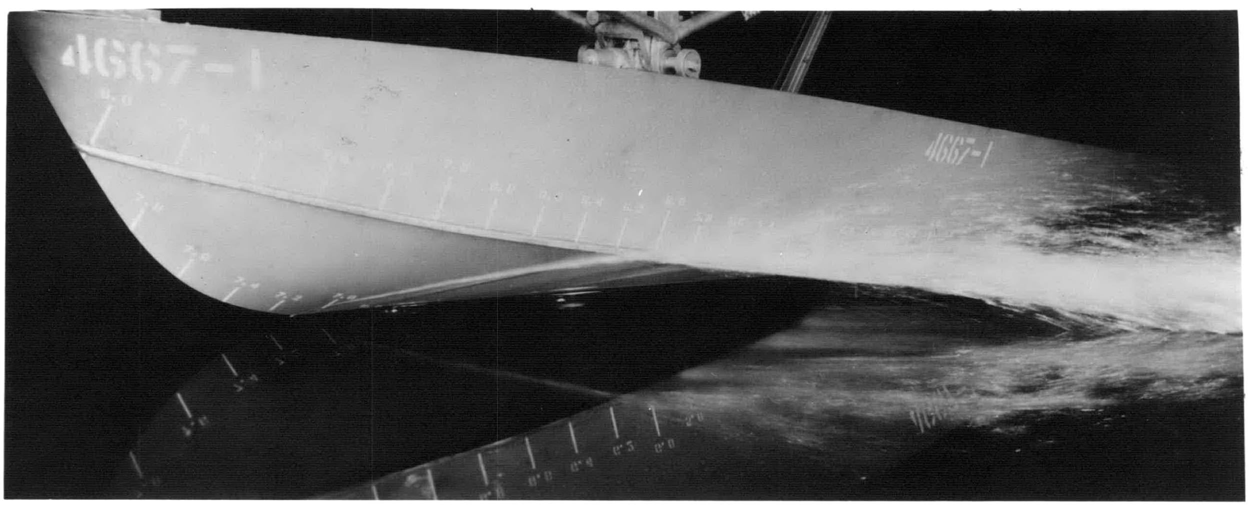


Figure 6b - F_∇ = 2.7; LCG at 4 Percent L_p Aft of Centroid of A_p

Figure 6 - Whisker Spray on Model 4667-1 (with Spray Deflectors) at Two Different Conditions of Speed and LCG Location, $A_p/\nabla^{2/3}$ = 7.00

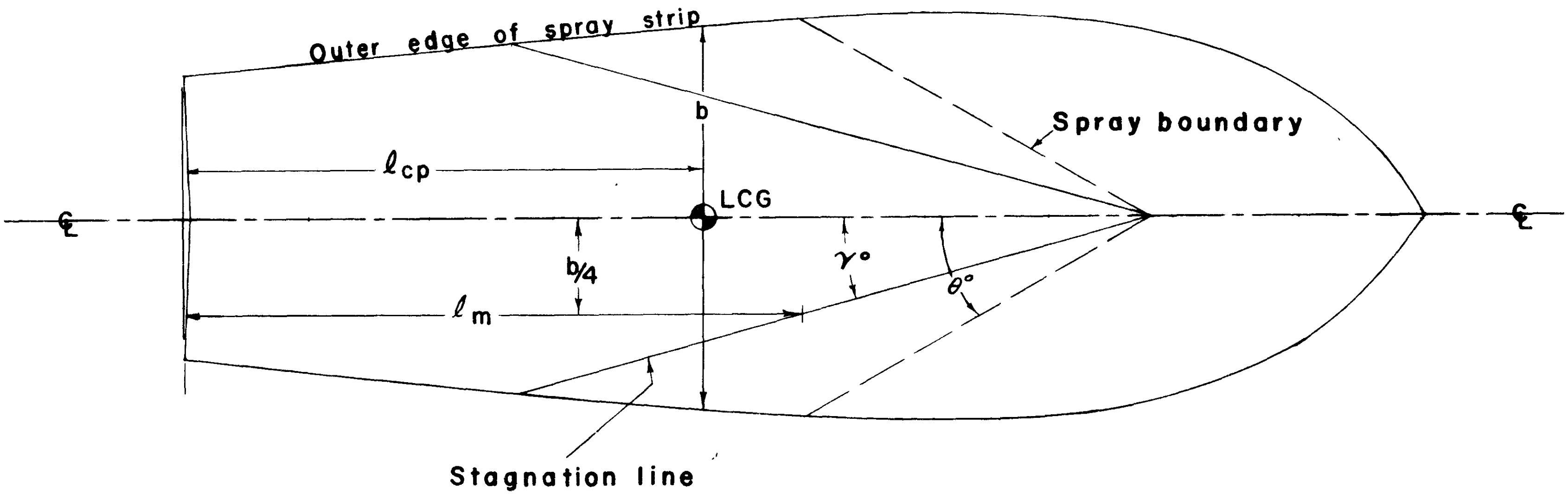


Figure 7 – Typical Positions of Spray Boundary and Stagnation Lines on a Planing Hull at High Speed

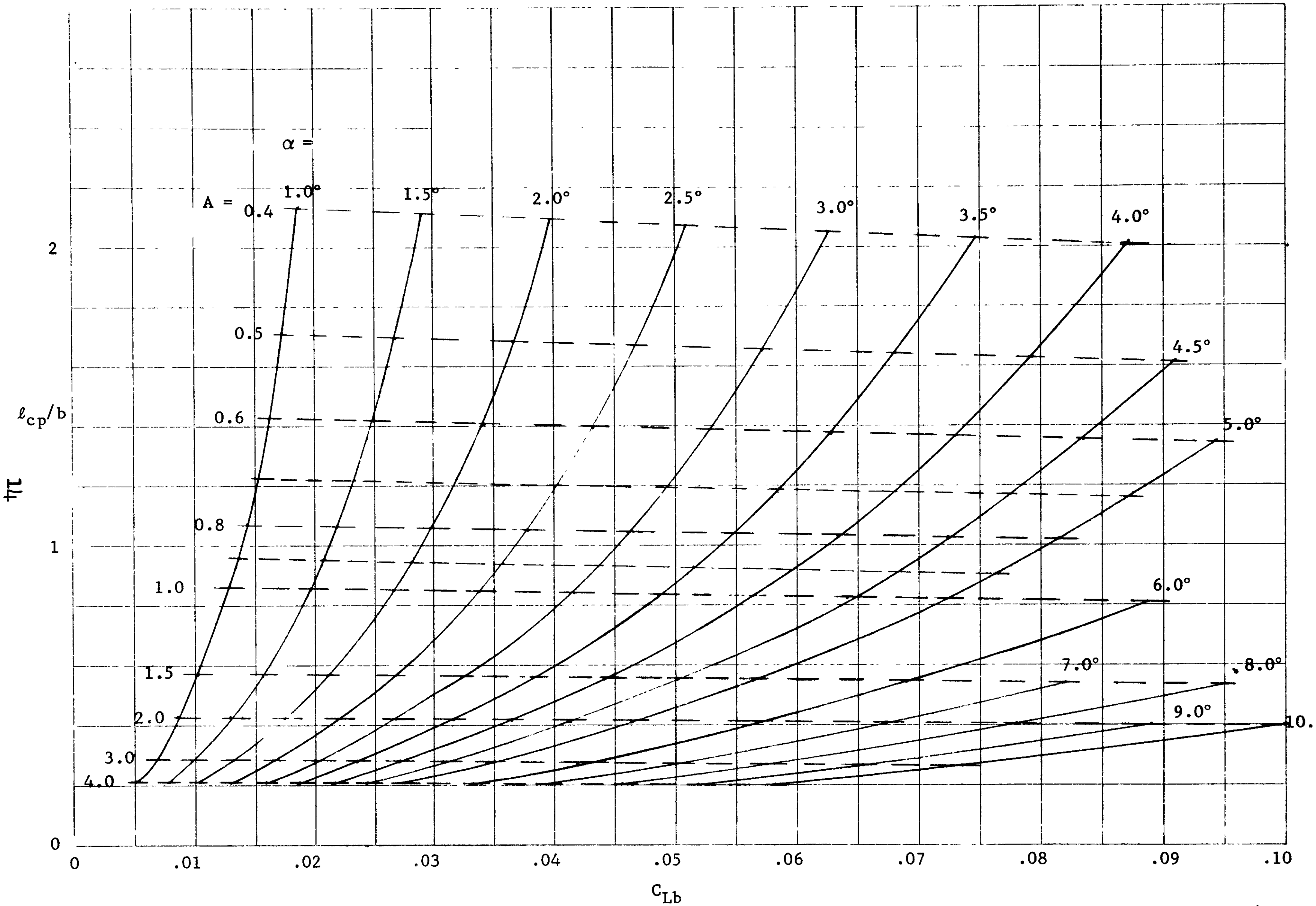


Figure 8a β = 5 Degrees

Figure 8 - Contours of Aspect Ratio and Angle of Attack for Planing Hulls as Functions of Lift Coefficient and Center-of-Pressure/Beam Ratio

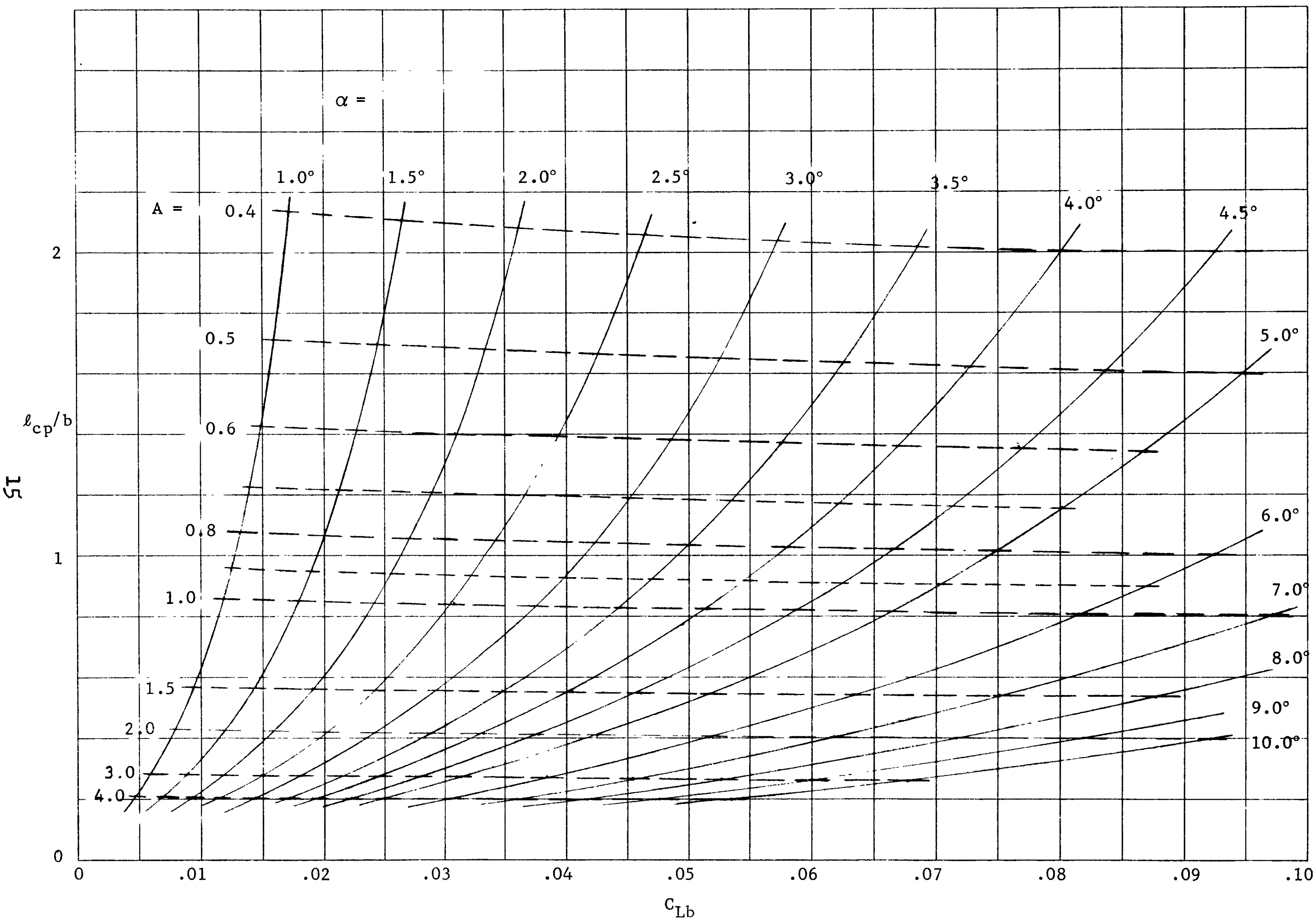


Figure 8b β = 10 Degrees

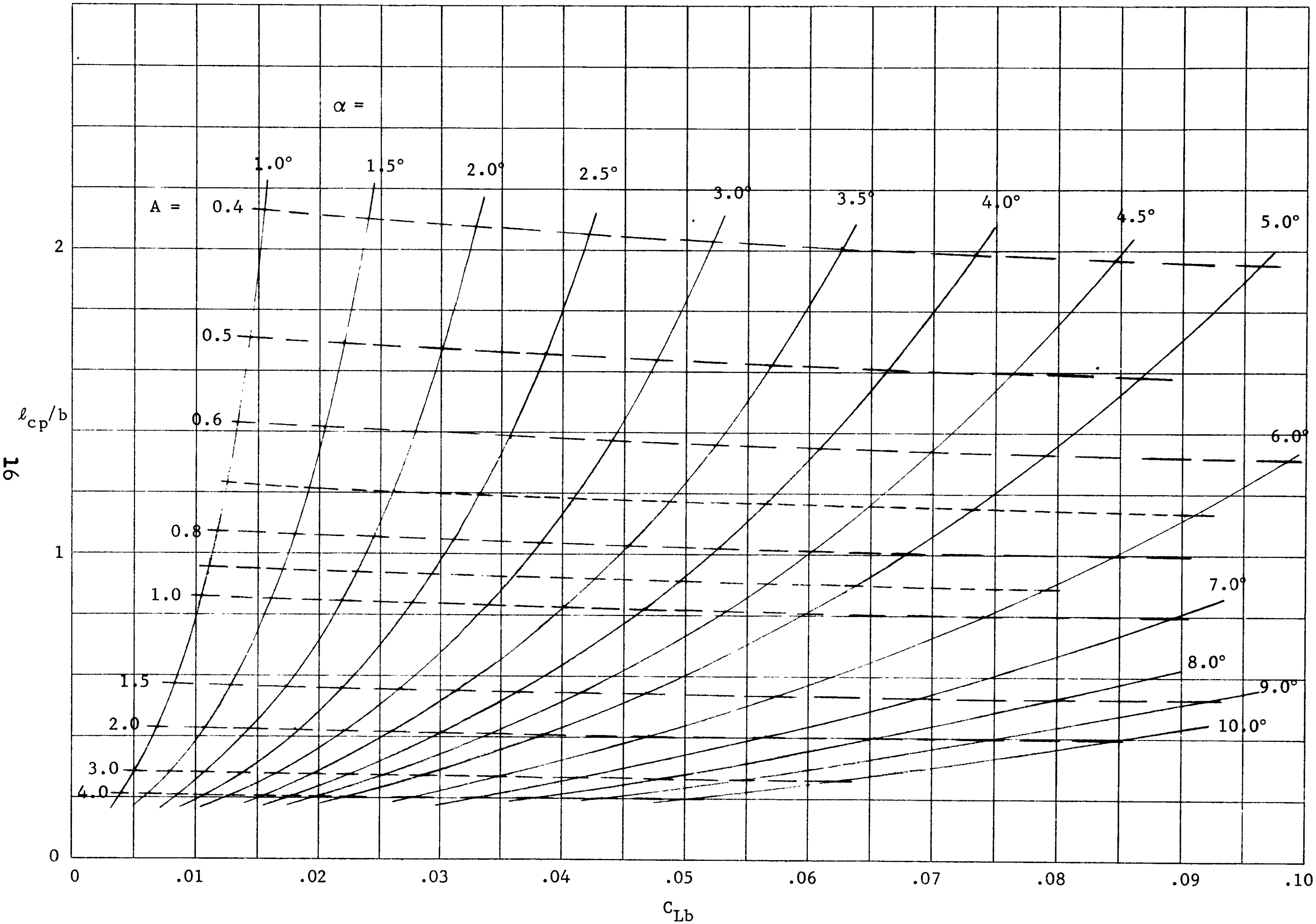


Figure 8c β = 15 Degrees

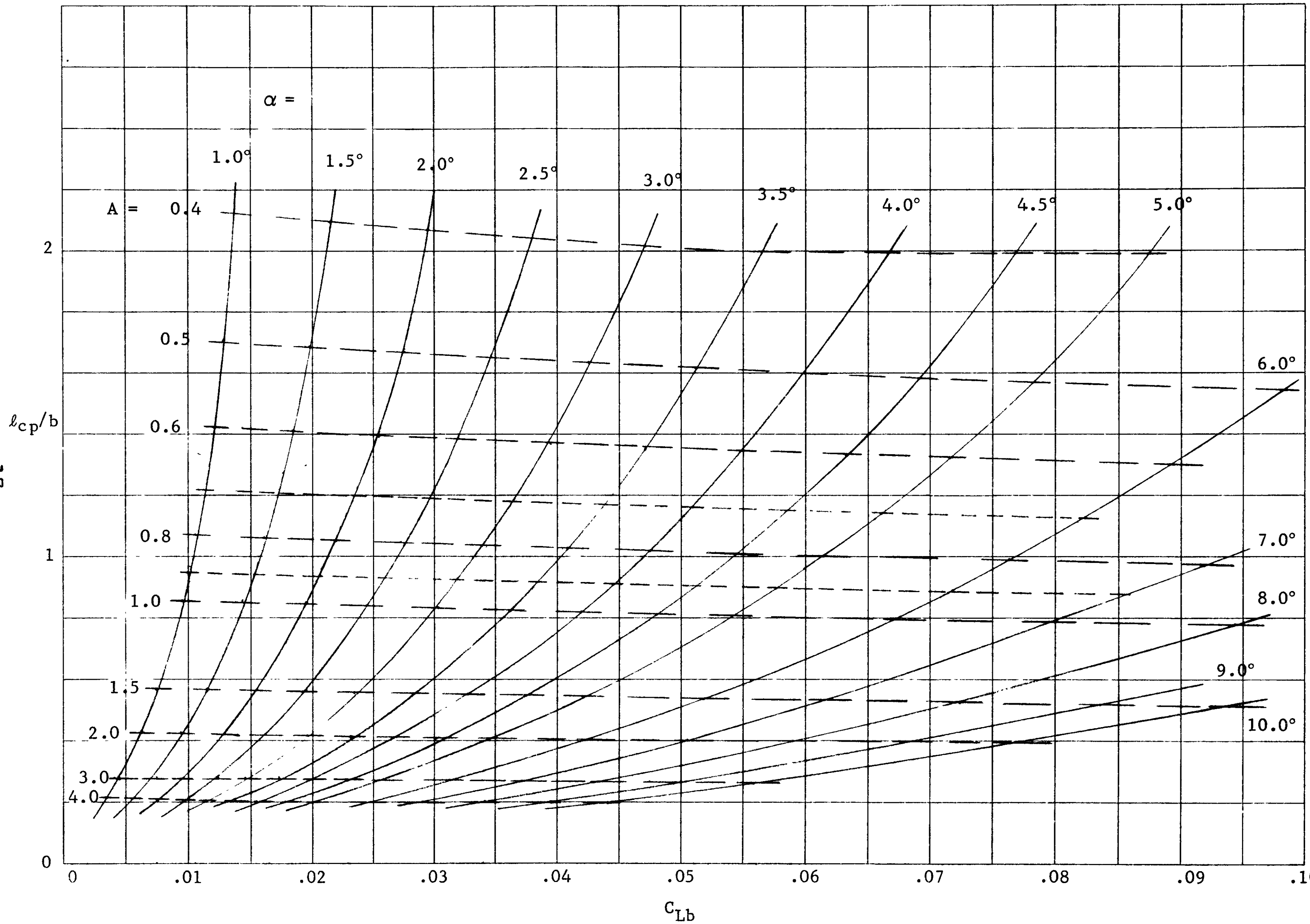


Figure 8d β = 20 Degrees

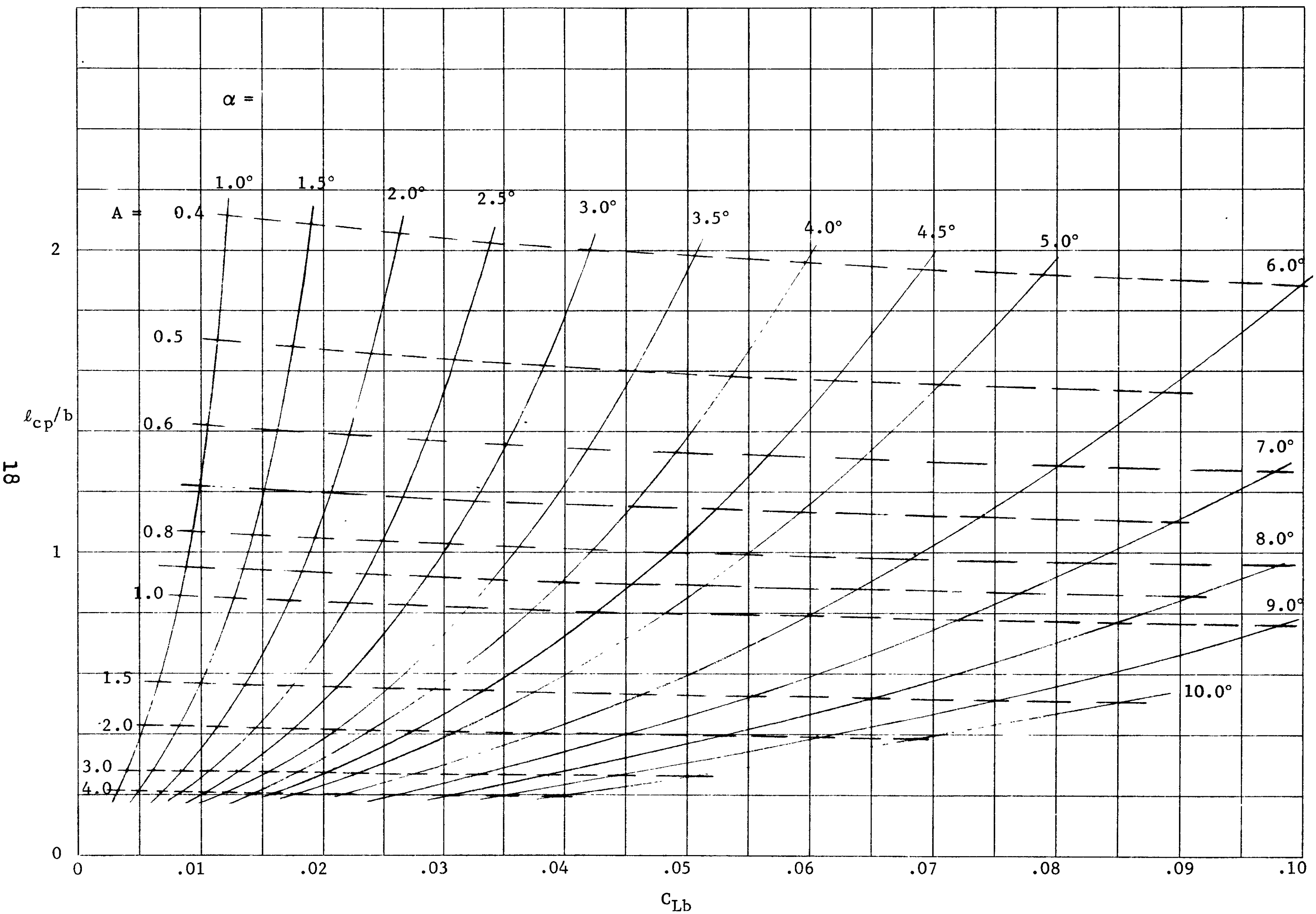


Figure 8e β = 25 Degrees

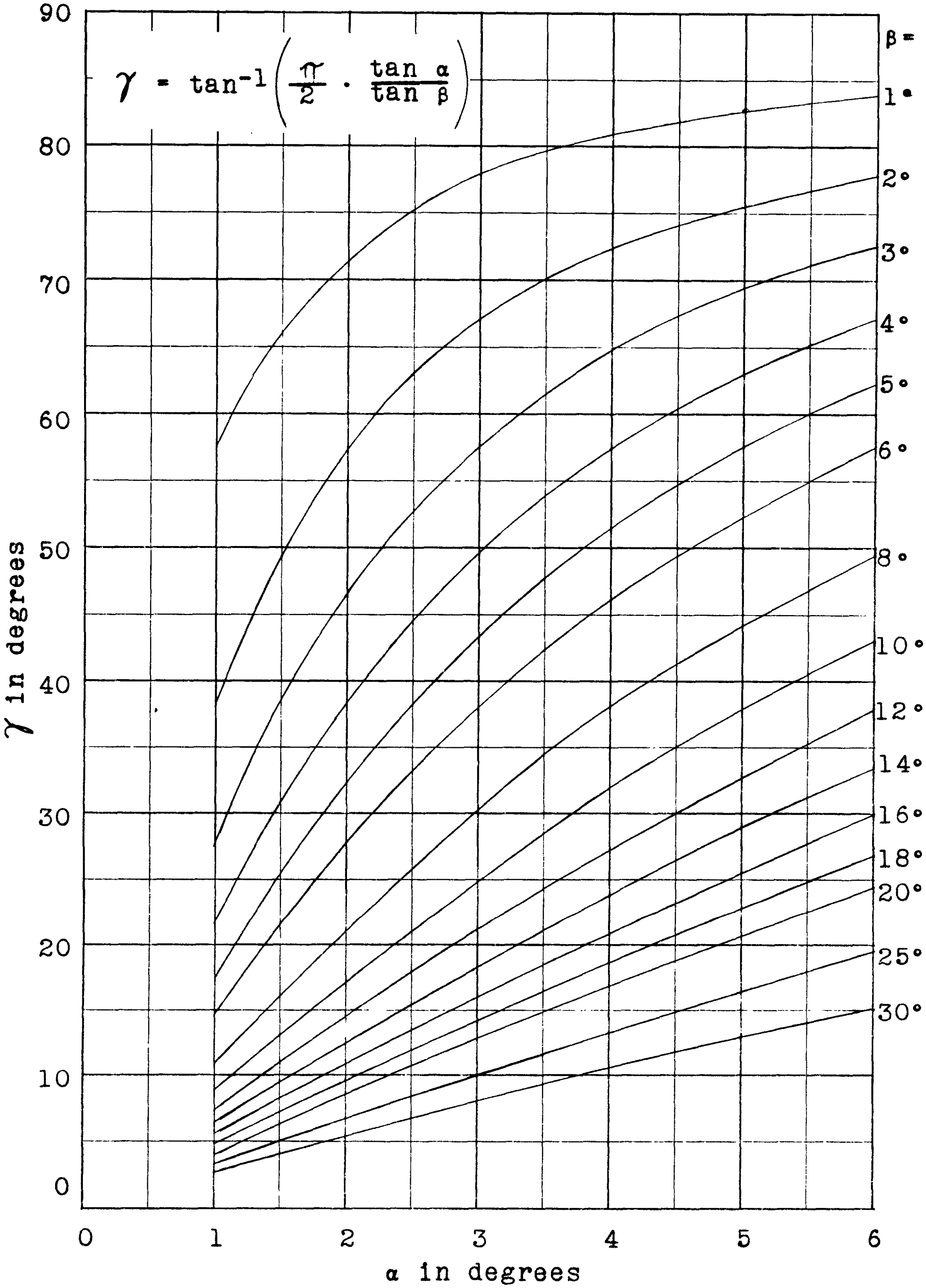


Figure 9 - Angle γ between Stagnation Line and Centerline in Plan View

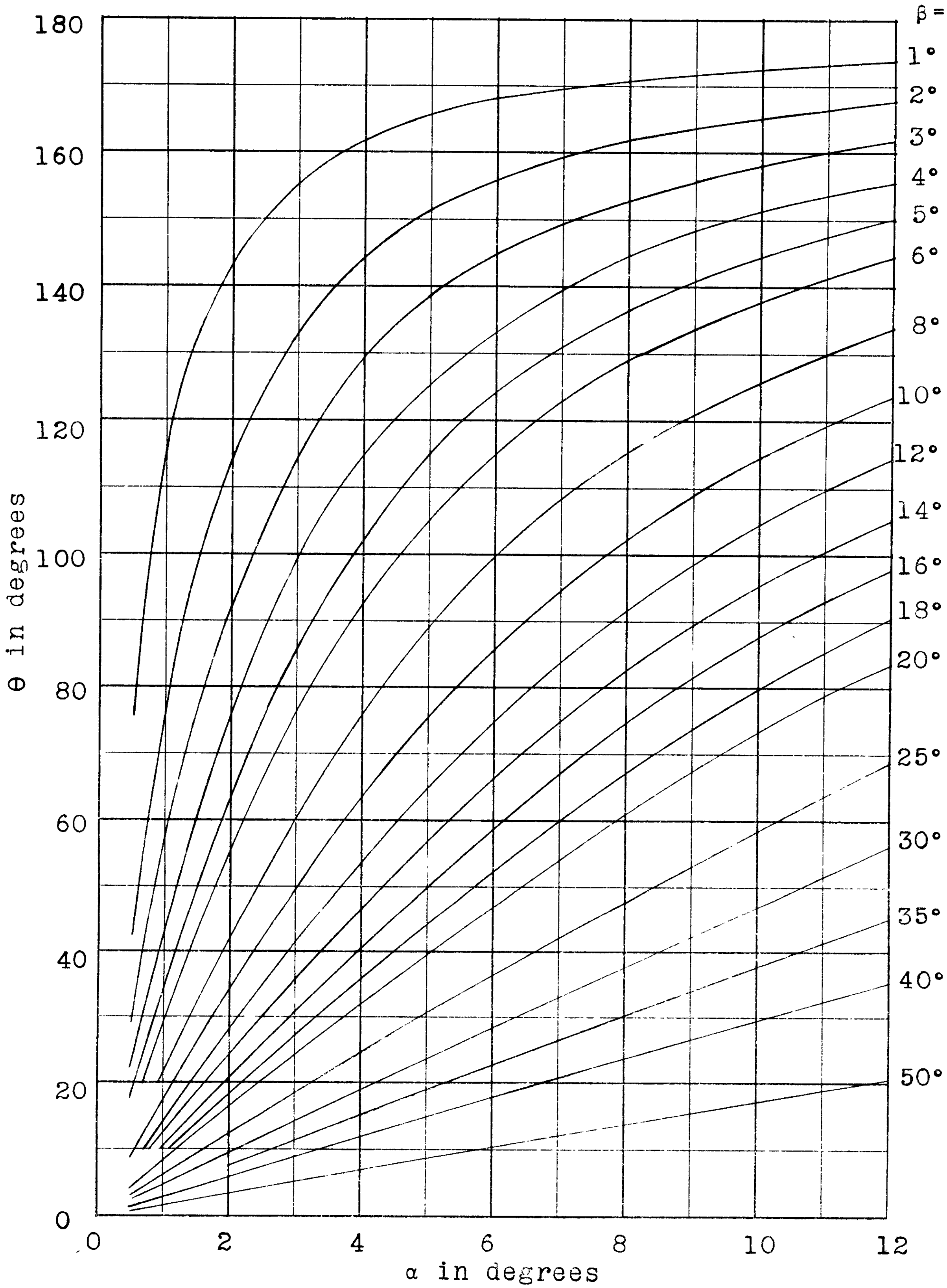


Figure 10 - Angle θ between Spray Direction and Centerline in Plan View

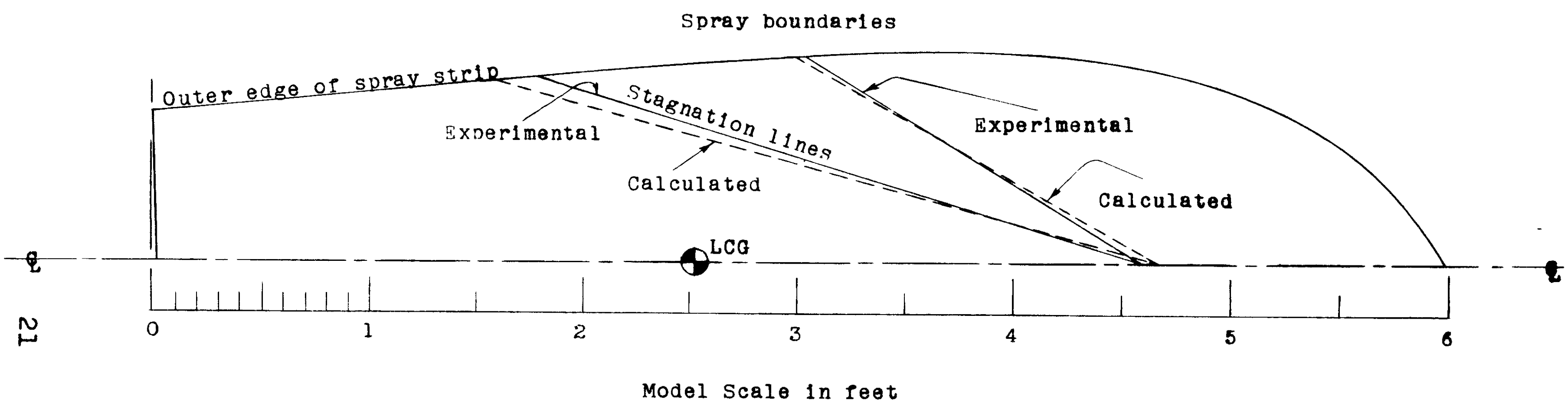


Figure 11 - Calculated and Experimental Positions of Spray Boundary and Stagnation Lines

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DOCUMENT CONTROL DATA - R&D

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1 ORIGINATING ACTIVITY (Corporate author) David Taylor Model Basin Washington, D. C., 20007	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3. REPORT TITLE

Reduction of Planing Boat Resistance by Deflection of the Whisker Spray

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final

5. AUTHOR(S) (Last name, first name, initial)

Clement, Eugene P.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO OF REFS
November 1964	24	4

8a. CONTRACT OR GRANT NO. b. PROJECT NO. S-R009-0101 c. Task 0103 d.	9a. ORIGINATOR'S REPORT NUMBER(S) 1929 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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1. Planing boats--Resistance--Spray
2. Spray strips--Location--Effectiveness
3. Ship models--Model TMB 4666, 4667-1.
I. Clement, Eugene P.

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David Taylor Model Basin. Report 1929.
REDUCTION OF PLANING BOAT RESISTANCE BY DEFLECTION OF THE WHISKER SPRAY, by Eugene P. Clement. Nov 1964. iii, 6p. illus., graphs, diags., refs. UNCLASSIFIED

Additional experimental verification is presented of the reduction of planing boat drag which can be achieved by using longitudinal strips forward of the stagnation line to deflect the whisker spray from the hull surface. In addition, graphs for determining the high-speed positions of the spray boundary and stagnation lines are given, to assist designers in locating spray deflectors on planing boats in the most effective positions.

1. Planing boats--Resistance--Spray
2. Spray strips--Location--Effectiveness
3. Ship models--Model TMB 4666, 4667-1.
I. Clement, Eugene P.