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"GENERAL" MAIN-SPRAY TESTS OF FLYING-BOAT MODELS IN THE DISPLACEMENT RANGE

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ADVANCE RESTRICTED REPORT

"GENERAL" MAIN-SPRAY TESTS OF FLYING-BOAT MODELS IN THE DISPLACEMENT RANGE

By F. W. S. Locke, Jr.

SUMMARY

This report presents a method for showing, by means of three curves, the locations of the points of tangency to the envelope of the main-spray blisters generated by flying-boat-hull models, as obtained from "general" tests in the speed range up through the hump (displacement-speed range). For a given model there is one curve each for the longitudinal position, the lateral position, and the vertical position of the point of tangency of the main-spray blister with the crest of the envelope; each curve represents all the data taken at all combinations of load and speed, in free-to-trim tests with a given position of the center of gravity. The relationships used are

$$C_X/C_\Delta{}^{1/3} = \phi_1 \; (C_V{}^2/C_\Delta{}^{1/3}) \quad \text{for longitudinal position} \qquad (1)$$

$$C_Y/C_\Delta{}^{1/3} = \phi_2 \; (C_V{}^2/C_\Delta{}^{1/3}) \quad \text{for lateral position} \qquad (2)$$

$$C_Z/C_\Delta = \phi_3 \; (C_V{}^2/C_\Delta{}^{1/3}) \quad \text{for vertical position} \qquad (3)$$

in which the left-hand side represents the position in terms of the size of the hull and the right-hand side is a form of the Froude number. These three relationships are tested by applying them to the data for seven different models and are found to be reasonably satisfactory for all of them.

The method should be useful for extrapolating the limited data ordinarily obtained from specific tests, for reducing the number of tests required to obtain adequate indications from general tests, and for comparisons between hull forms of the same general type. It is intended to supplement, rather than to supplant, the method involving two-view drawings of the

spray, previously developed and described in reference 1 - a method which provides a very vivid presentation of the results and is not easily supplanted.

INTRODUCTION

This report may be considered to be the third of a series, of which references 2 and 3 are the others, describing the development of methods of presenting the results of general tests of hydrodynamic characteristics of flying-boat-hull models in as compact a form as possible. These methods facilitate comparisons between different hull forms and permit the fullest possible use of limited test data.

With completion of this report, methods of presenting data in collapsed form have now been developed for the three primary hydrodynamic characteristics: resistance, dynamic stability, and main-spray blister. Figure 23 shows a presentation in summary form of data on all three of these characteristics, for a particular flying-boat model. This chart is a modification of a chart originally shown in reference 4. In the earlier form of the chart, only the resistance and dynamic stability data were collapsed; in the present form the main-spray data are also collapsed. On figure 23 there are shown

At the top -
Main-spray data for the displacement range

In the middle -
Free-to-trim resistance and trim data for the displacement range

At the bottom -
Resistance, moment, and stability data in the planing range

For purposes of demonstration, the method for handling the main-spray data is applied in this report to the actual test data for seven different flying-boat-hull models. All the test data have been reported previously; they were obtained by the method described in reference 1.

NOTATION

The following notation and nondimensional coefficients are used:

Load coefficient	$C_\Delta = \Delta/wb^3$
Speed coefficient	$C_V = V/\sqrt{gb}$
Longitudinal spray coefficient	$C_X = X/b$
Lateral spray coefficient	$C_Y = Y/b$
Vertical spray coefficient	$C_Z = Z/b$

where

Δ load on water, pounds

w specific weight of water, pounds per cubic foot (62.3 for Stevens)

b beam at main step, feet

V speed, feet per second

g acceleration of gravity, 32.2 feet per second per second

X longitudinal position of main-spray point of tangency with reference to the main step, feet

Y lateral position of main-spray point of tangency measured from the hull center line, feet

Z vertical position of main-spray point of tangency, measured from the tangent to the forebody keel at the main step, feet

METHOD AND ANALYSIS

The method herein described for handling main-spray data is to a large extent an extension of the method for handling resistance data for the displacement range described in reference 3.

In the displacement range of speeds, the main-spray blister is a form of wave-making. Hence, reasoning by analogy to surface vessels of the displacement type, the geometric configuration of the spray blister would be expected to be a function of the Froude number. The distances X, Y, and Z define an important aspect of the geometric configuration: namely, the position of the peak of the blister at a particular speed. Under conditions of geometric similarity, therefore, it should be possible to write:

$$\frac{X}{\lambda} = \phi_1 \left(\frac{V^2}{g\lambda}\right) \qquad (1')$$

$$\frac{Y}{\lambda} = \phi_2 \left(\frac{V^2}{g\lambda}\right) \qquad (2')$$

$$\frac{Z}{\lambda} = \phi_3' \left(\frac{V^2}{g\lambda}\right) \qquad (3')$$

where λ is a linear dimension of the hull.

In reference 3 it is concluded that, in the case of resistance, data from general tests on a particular hull are in most cases collapsed quite satisfactorily if λ is taken as $(Vol)^{1/3}$, even when geometric similarity is lacking because of changes of either loading or trim. Anticipating that the same thing might apply in the case of spray data and therefore inserting $\lambda = (Vol)^{1/3}$ in equations (1') through (3'), the following equations are obtained when the usual NACA coefficients are substituted:

$$C_X/C_\Delta{}^{1/3} = \phi_1 \left(C_V{}^2/C_\Delta{}^{1/3}\right) \qquad (1)$$

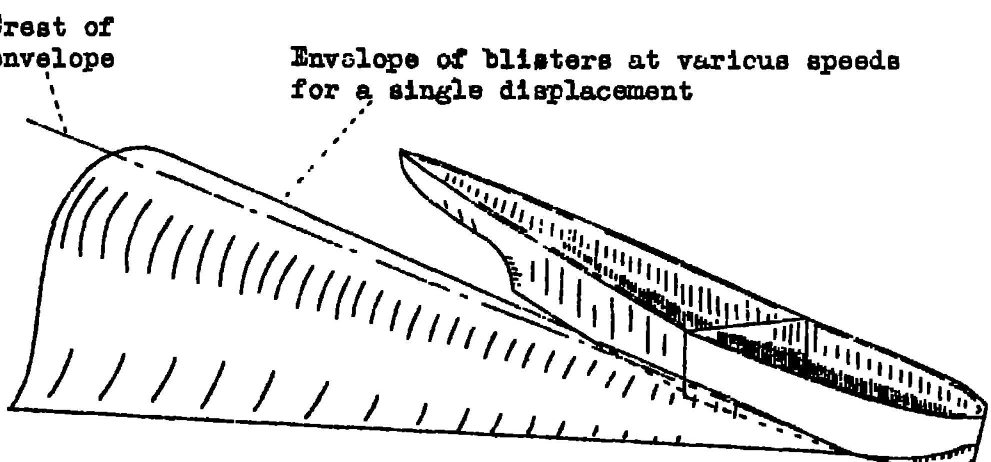
$$C_Y/C_\Delta{}^{1/3} = \phi_2 \left(C_V{}^2/C_\Delta{}^{1/3}\right) \qquad (2)$$

$$C_Z/C_\Delta{}^{1/3} = \phi_3'\left(C_V{}^2/C_\Delta{}^{1/3}\right) \qquad (3")$$

The first two equations are seen to agree with the first two equations given on page 1; the third equation differs, however, in having $C_\Delta{}^{1/3}$ in the denominator of the left-hand side; whereas C_Δ appears in the form actually used.

The use of the criterion C_Z/C_Δ for the Z dimension, instead of the more rational criterion $C_Z/C_\Delta{}^{1/3}$, is a matter of pure empiricism. It was adopted because it was found to do a better job of collapsing the data than the more rational criterion. This does not mean that the same physical principles which govern the X and Y dimensions do not govern the Z dimension of the spray blister; the explanation probably lies in the definition of the spray height Z. Practical considerations clearly indicate the desirability of defining this height as the distance above the forebody keel rather than the distance above the free water surface. But this definition has no direct connection with the physics of the matter, since at the present time, the determination of a practicable empirical criterion is considered to be the point of major interest, and the fact that as simple a criterion as C_Z/C_Δ can be used successfully is obviously an advantage.

In practice, the three coordinate dimensions, X, Y, Z, refer to the point of tangency of the spray blister at a particular speed to the crest of the surface enveloping the spray blisters for all speeds within the range covered, at a single displacement. The following sketch shows the envelope for one displacement. The coordinates are shown in figure 1.



Relation of schematic envelope to model

Use of the point of tangency rather than of the actual peak of the blister is believed to put the results into a more useful form for practical purposes.

TRIAL APPLICATIONS

Equations (1), (2), and (3) are applied to the data from general spray tests on seven models in the charts on figures 1 to 22.

Equation (1) - $C_X/C_\Delta^{1/3} = \Phi_1 \left(C_V^2/C_\Delta^{1/3}\right)$ (figs. 1 through 8)

Equation (2) - $C_Y/C_\Delta^{1/3} = \Phi_2 \left(C_V^2/C_\Delta^{1/3}\right)$ (figs. 9 through 15)

Equation (3) - $C_Z/C_\Delta = \Phi_3 \left(C_V^2/C_\Delta^{1/3}\right)$ (figs. 16 through 22)

The seven models comprise two consistent series of models derived from the XPB2M-1 as the parent hull. The first three models involved changes of dead-rise angle; 10°, 20°, and 30° at the main step, respectively. The second four models involved changes of length-beam ratios, 5.07, 6.19, 7.32, and 8.45, respectively. Spray tests previously were reported for these two series of models, for the first series in reference 1, and for the second series in reference 4. It will be seen that the models cover a reasonably wide range of over-all variation from the form of the parent XPB2M-1 and thus provide a fairly rigorous trial of the proposed method. It may be noted that all the models were tested free-to-trim, with the center of gravity at the same position relative to the step.

Reference to the charts (figs. 2 through 22) shows that it has been possible to draw a single mean curve in every case except one. The exception is the 30°-dead-rise model, which, however, is a fairly extreme model and might well be inconsistent in behavior with more conventional models. Prior to drawing the charts, it had been supposed that the Y was the most difficult of the three measurements to obtain from the tests. However, the scatter of the individual test points actually found is generally no greater on the charts relating to the Y dimension, than on the other charts.

CONCLUDING REMARKS

A study of the curves for the different models considered indicates that if a fixed longitudinal position (the main step, for example) and a fixed C_Δ are taken, the variation of the Y criterion among the models is small, and the variations of the Z criterion relatively large. The implication is clear that the principal consequence of altering the hull form is to alter the spray height, and that the position of the envelope to the blister is more or less fixed in the horizontal plane.

It is desired to emphasize once more that the method of collapsing spray data herein considered is not intended to replace, but rather to supplement, charts of the type presented in references 1 and 4. The purpose of the method is to facilitate comparisons between hull forms, and to help in reducing the number of tests needed to establish properly the spray characteristics of individual models.

Experimental Towing Tank,
Stevens Institute of Technology,
Hoboken, N. J., September 20, 1944.

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4. Davidson, Kenneth S. M., and Locke, F. W. S., Jr.,: General Tank Tests on the Hydrodynamic Characteristics of Four Flying-Boat Hull Models of Differing Length-Beam Ratio. NACA ARR No. 4F15, 1944.

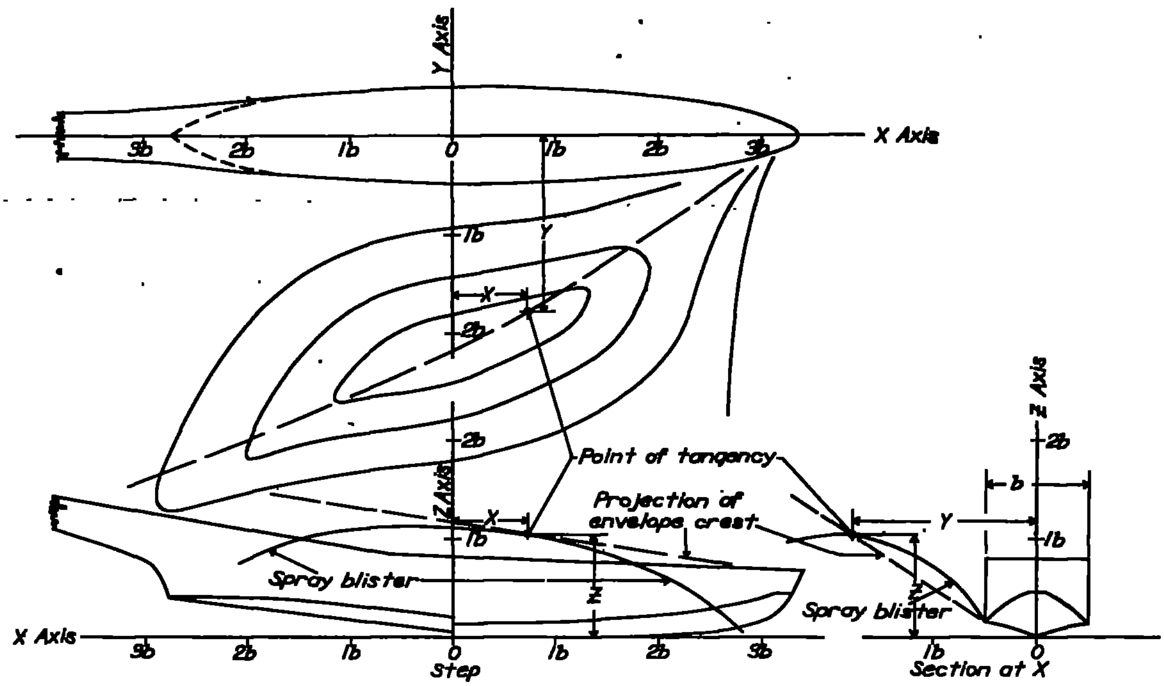


Figure 1.- Schematic sketch to show location on main spray blister of point of tangency to spray envelope.

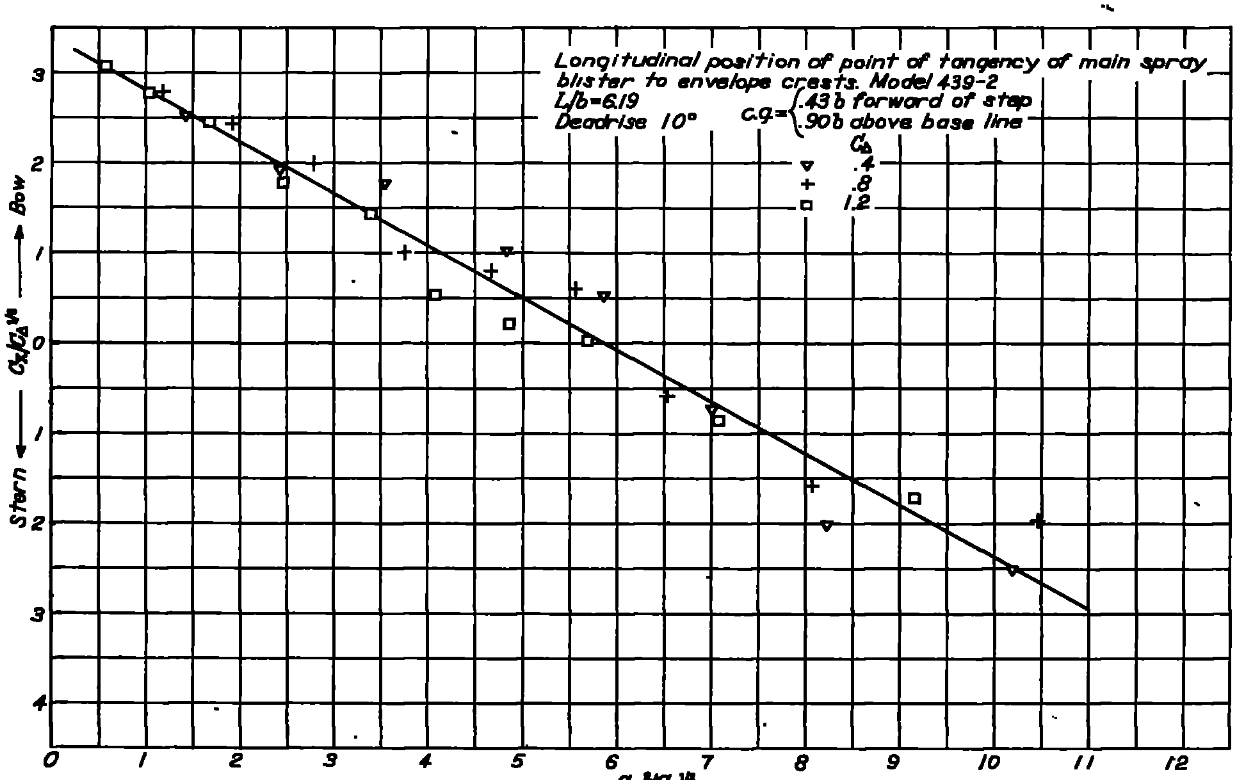
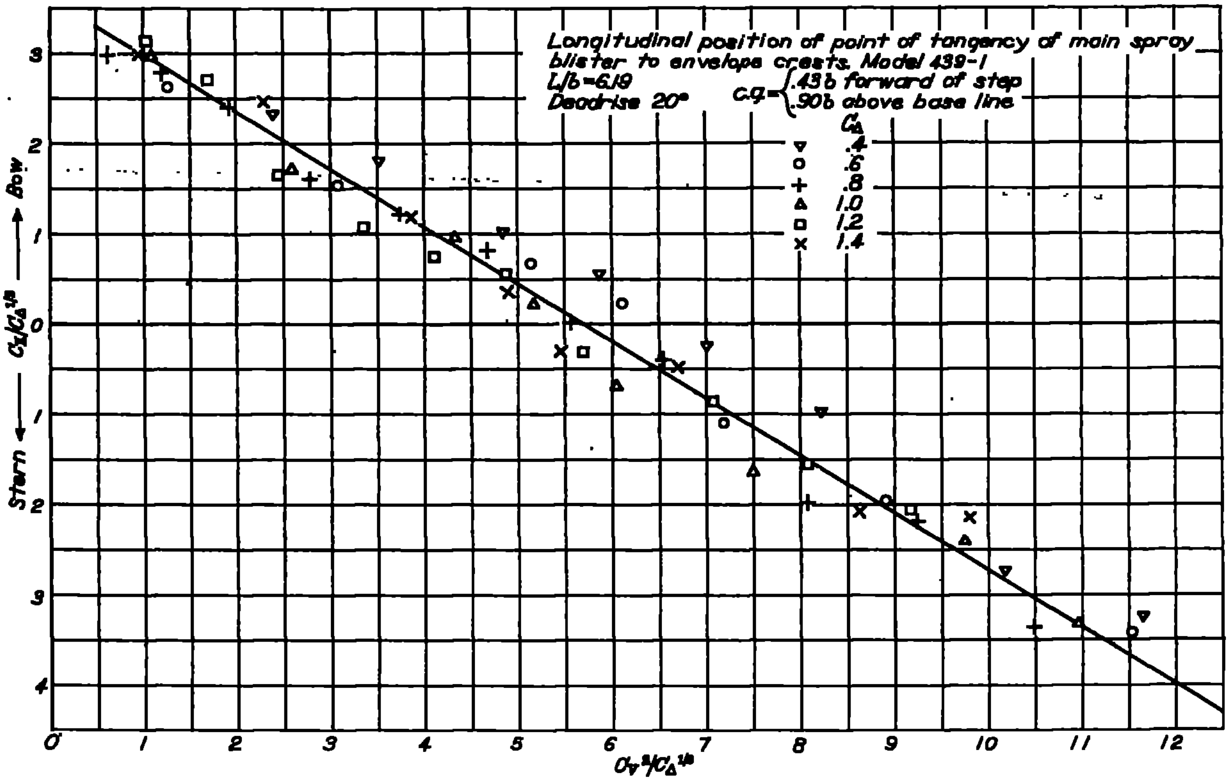


Figure 2.



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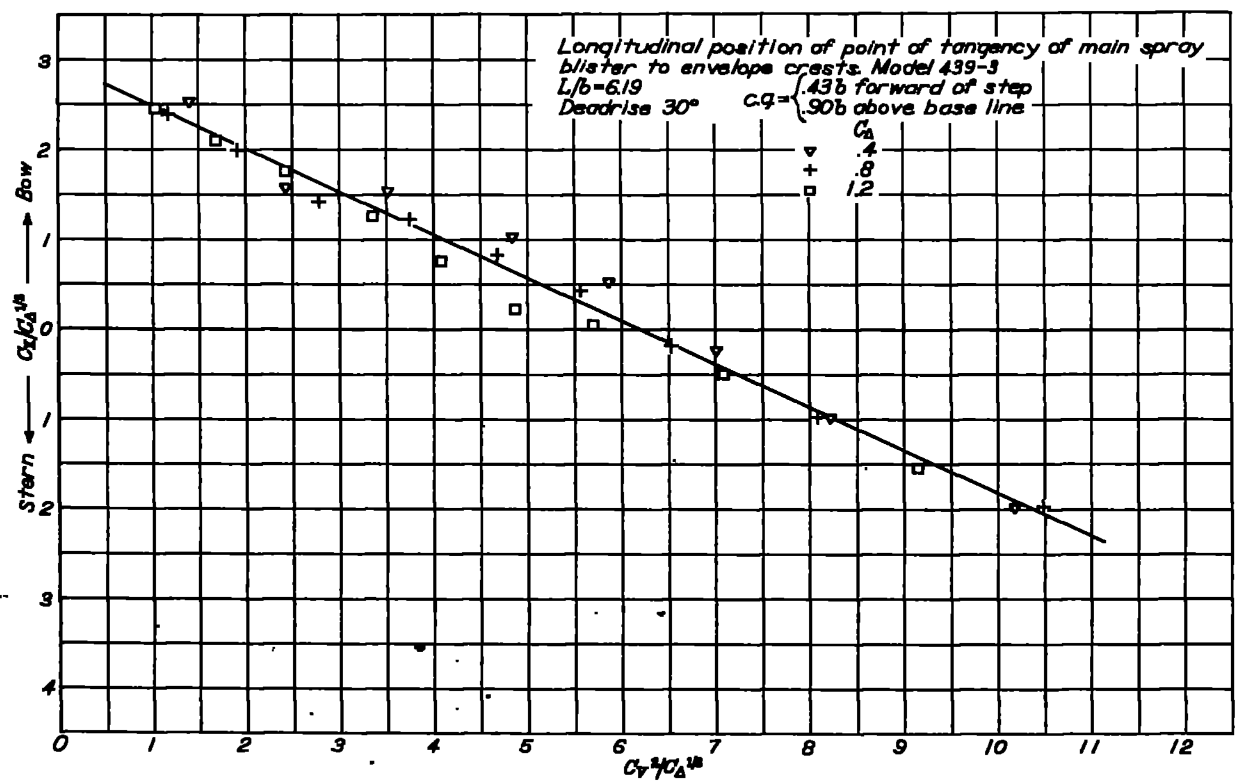

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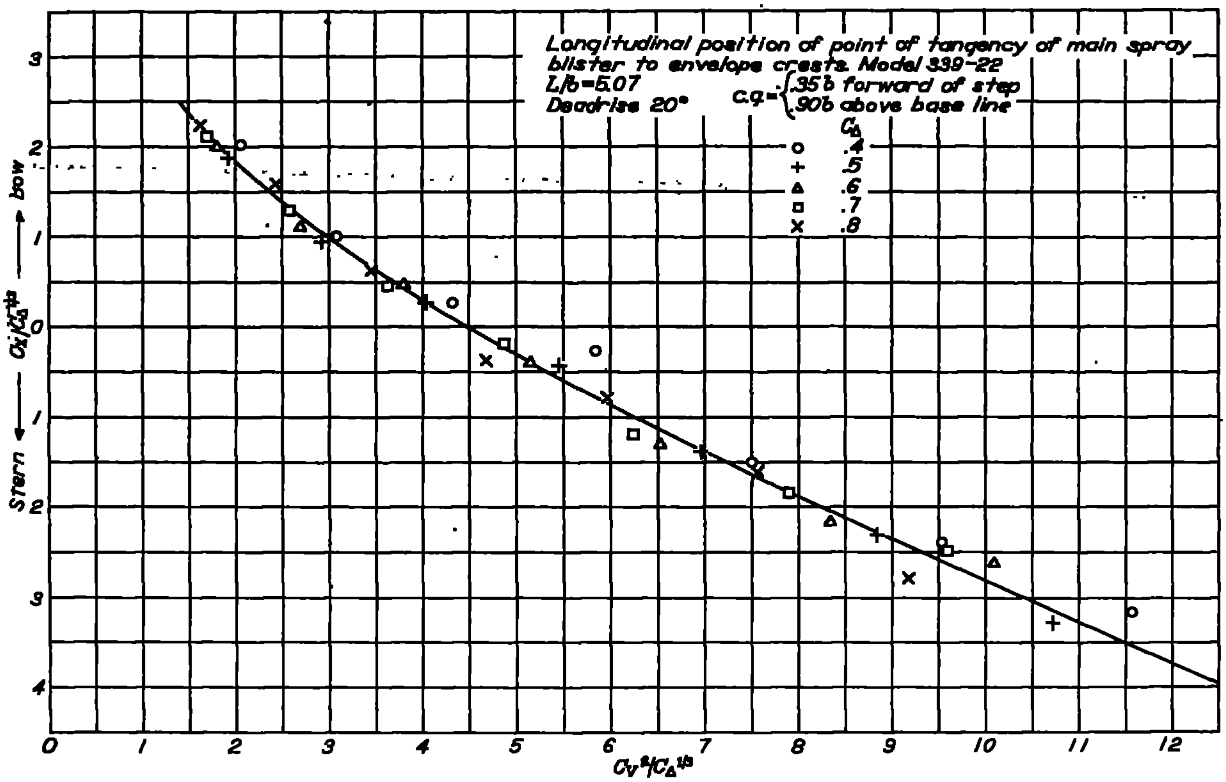

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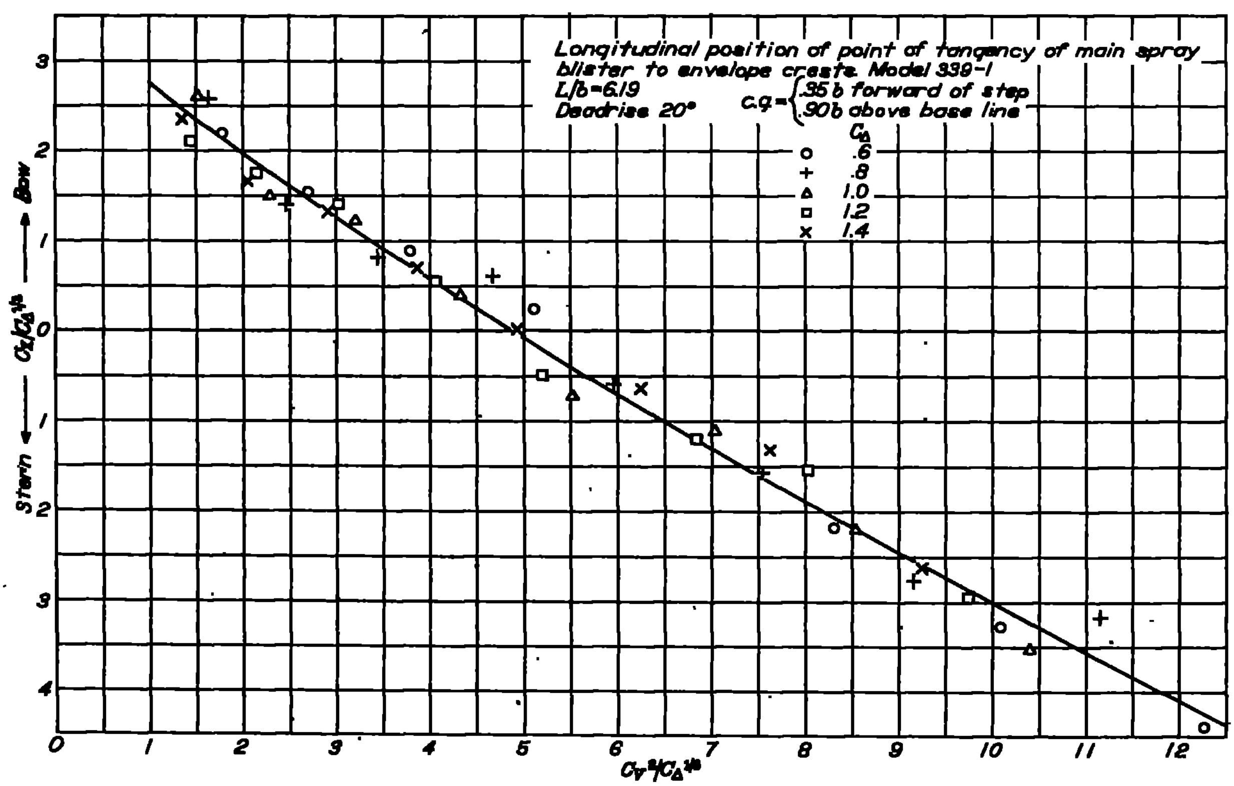

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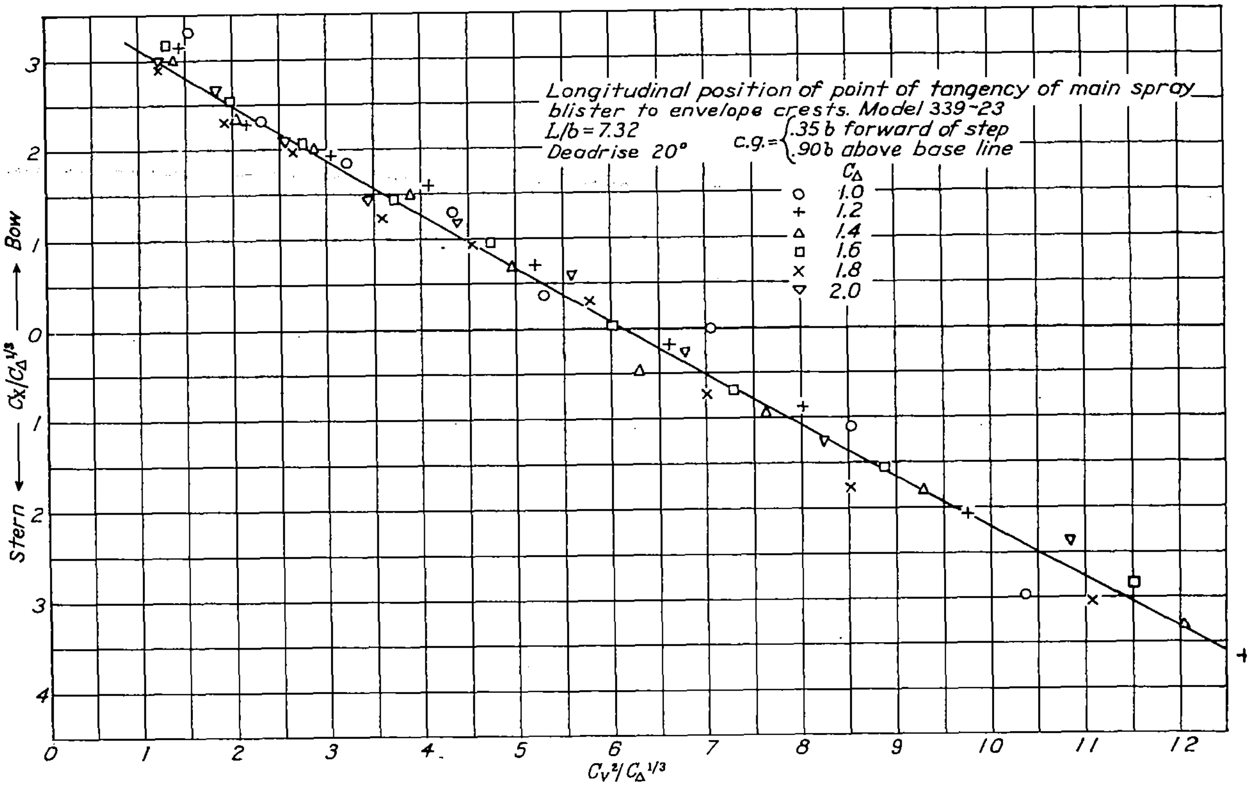

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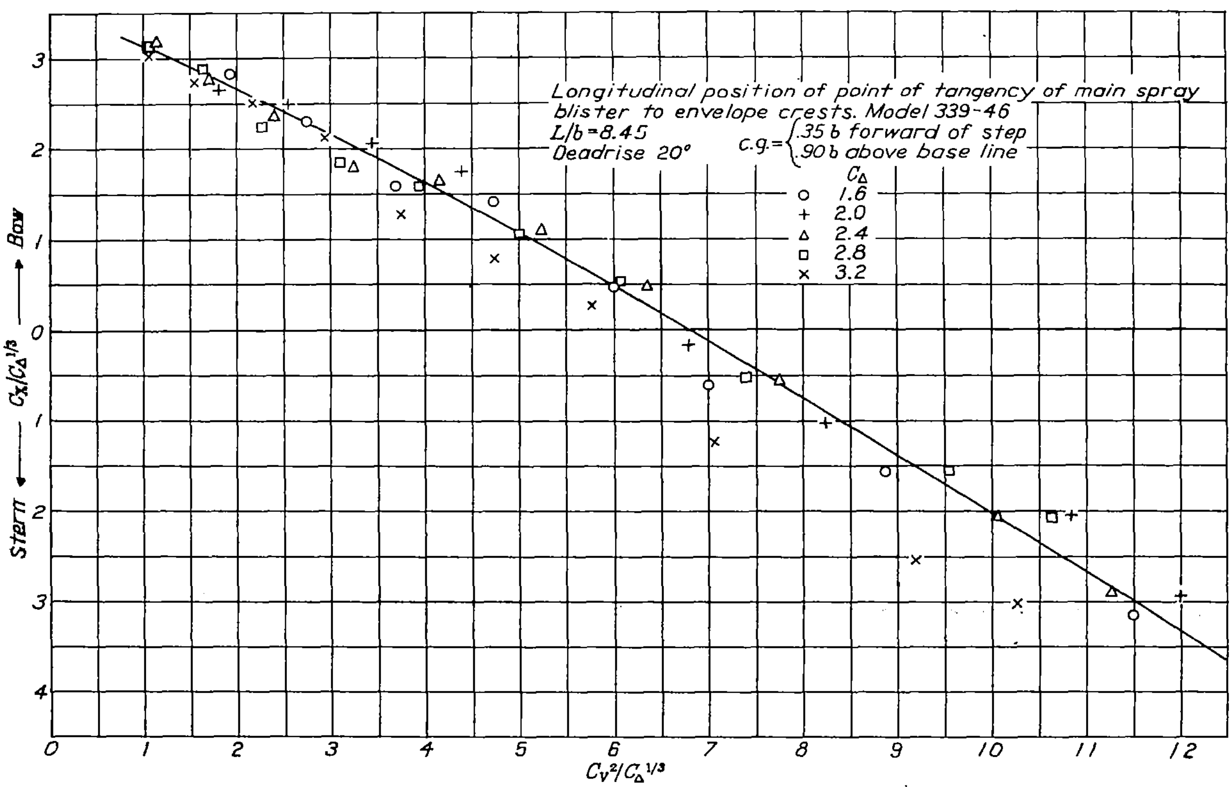

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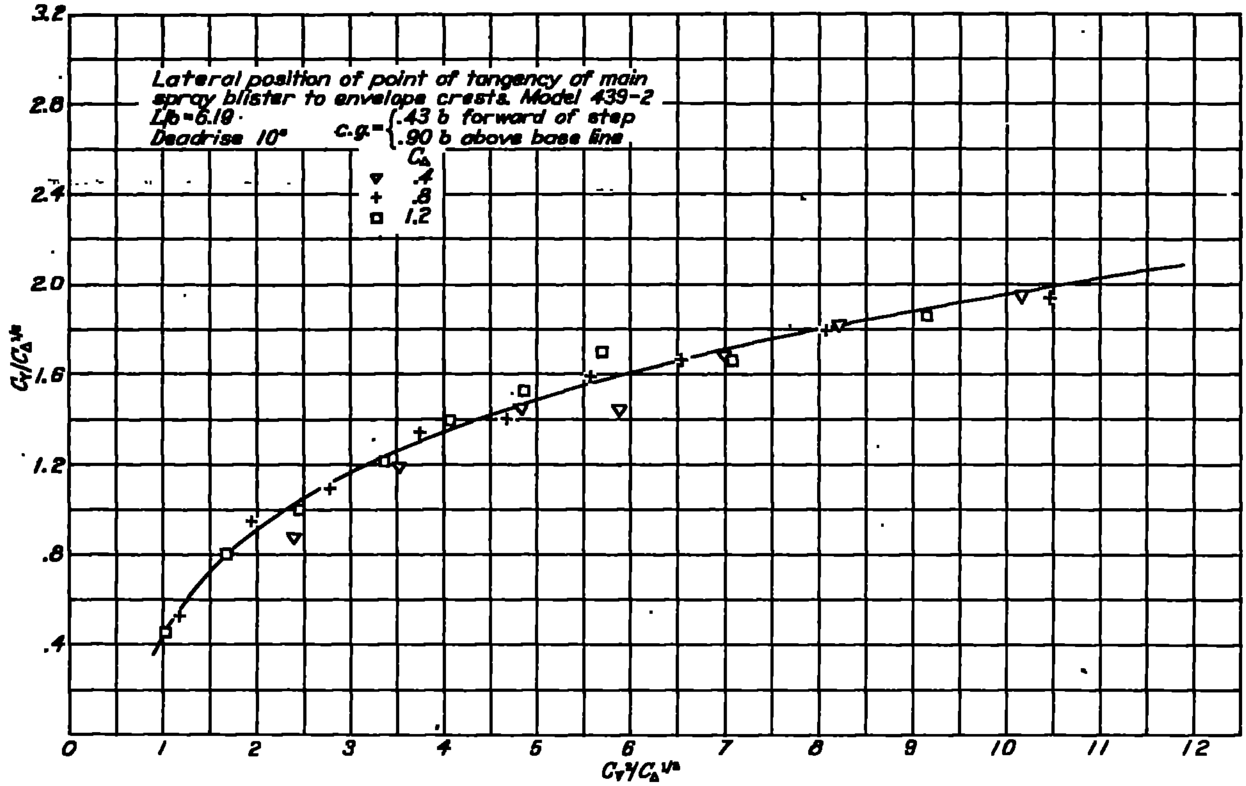


Figure 9

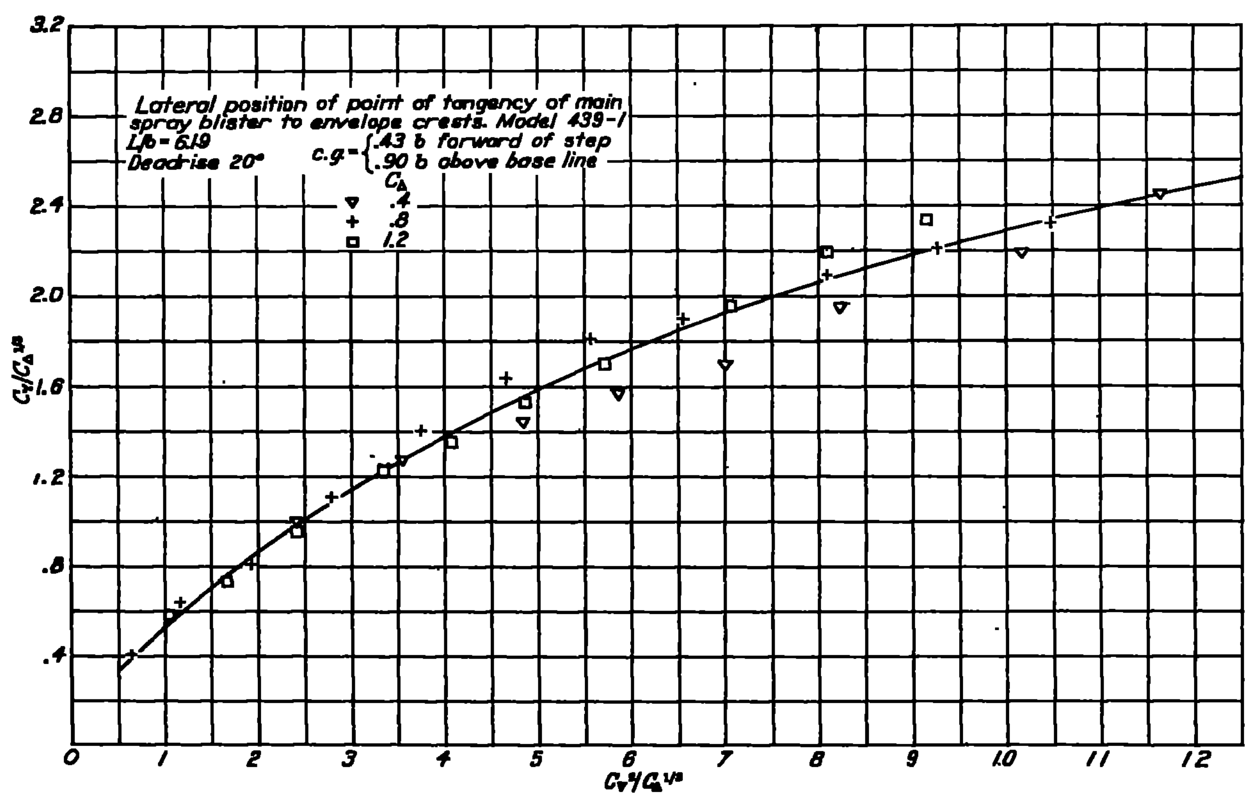
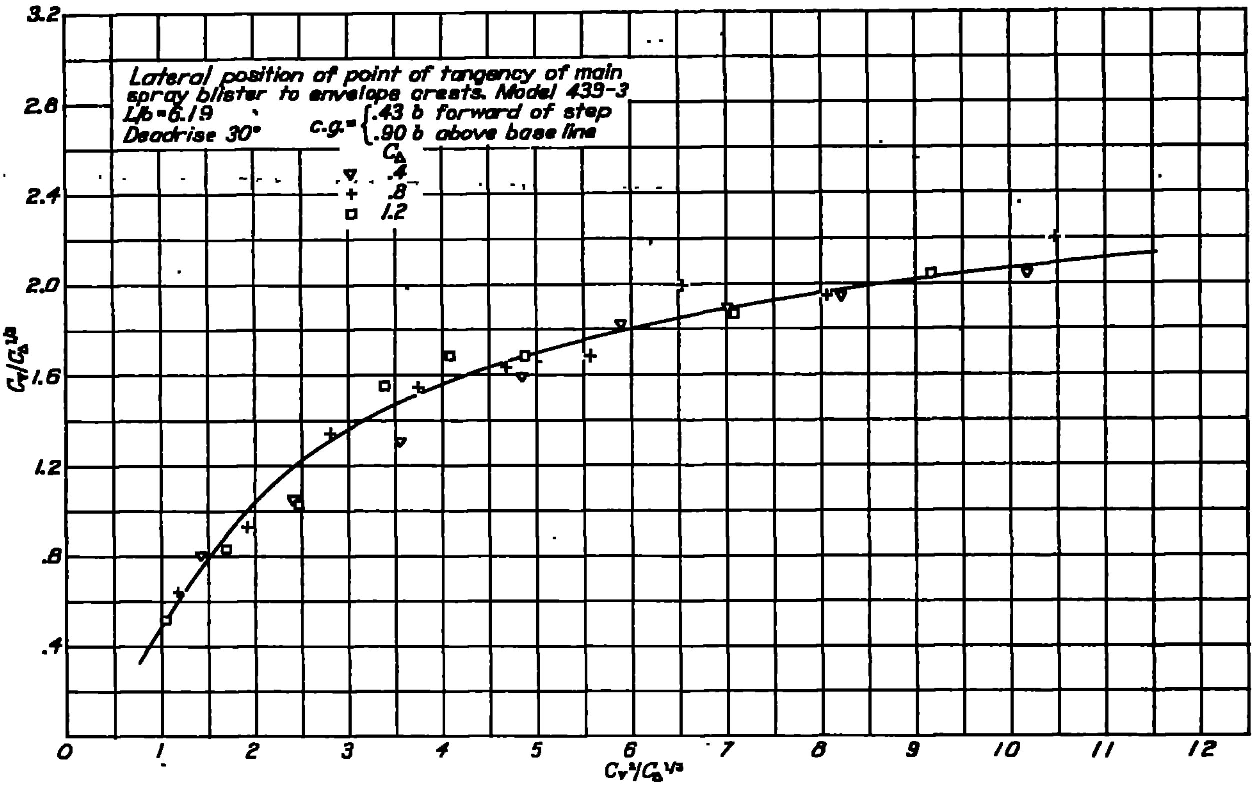


Figure 10



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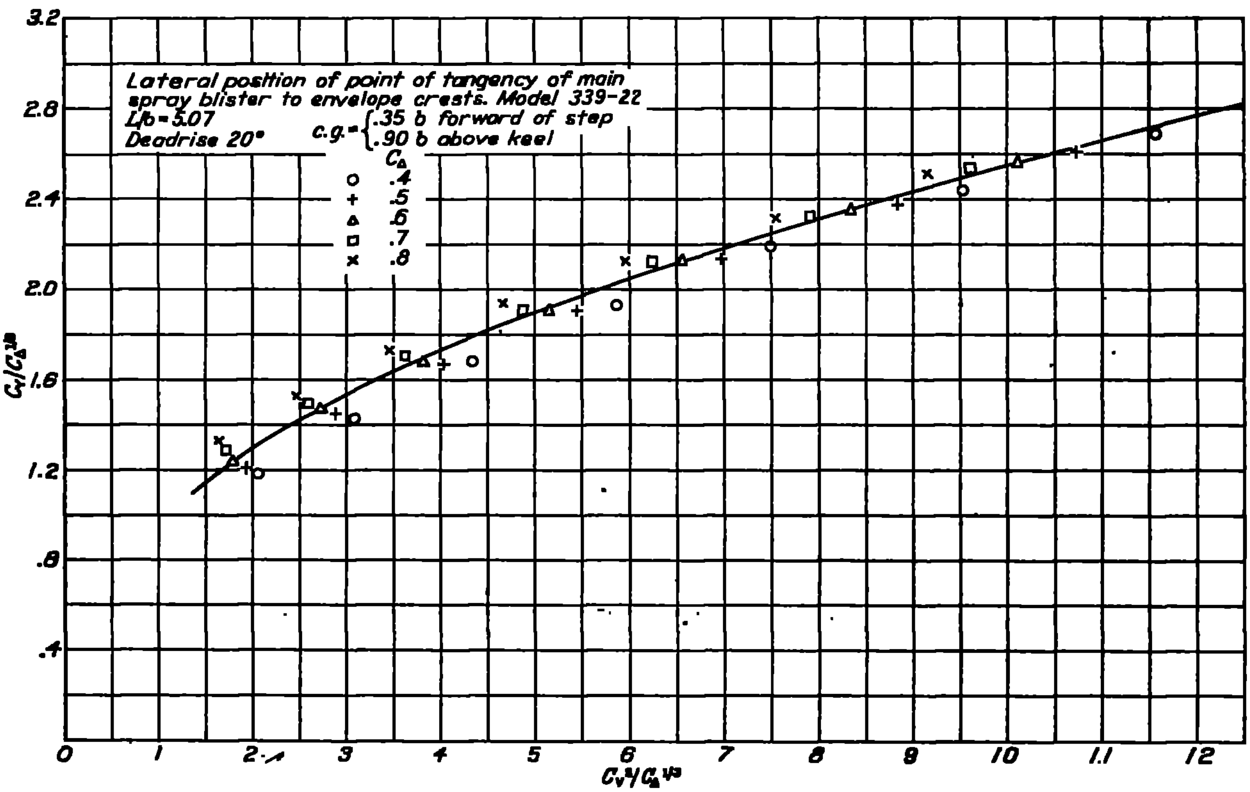

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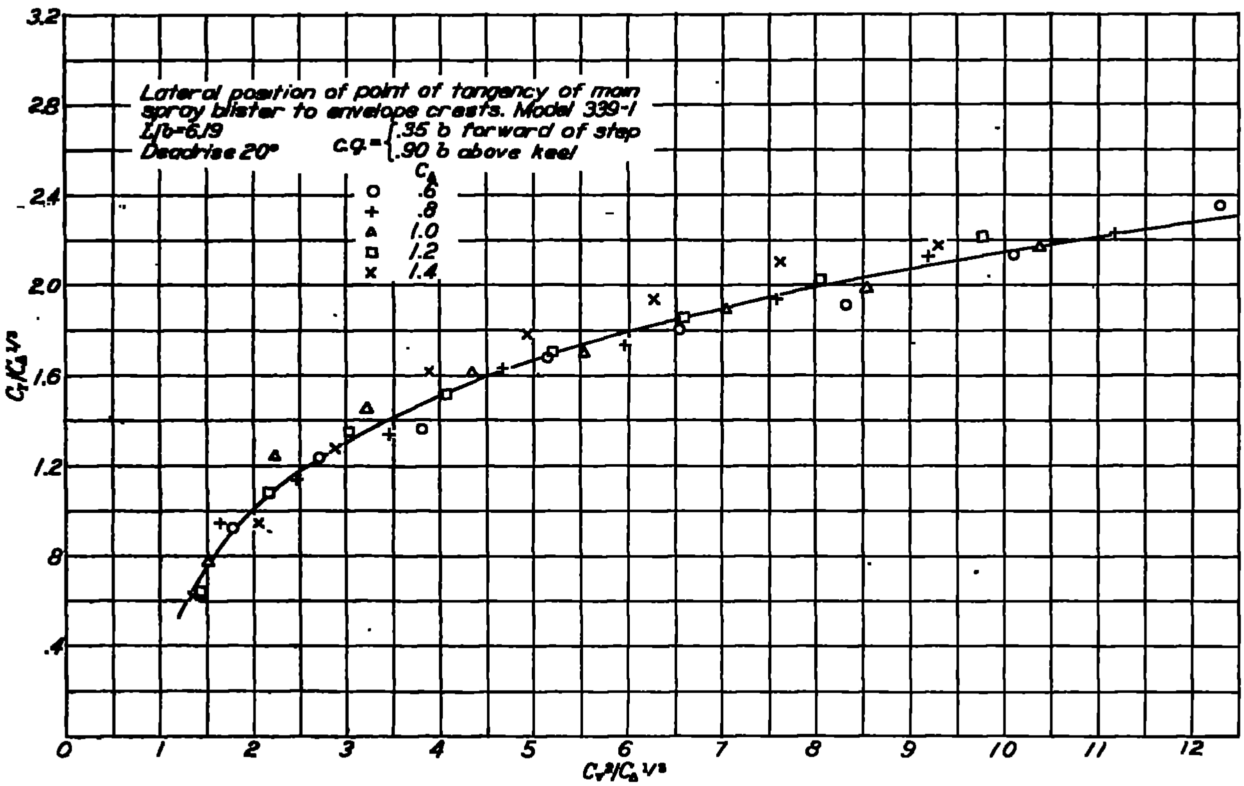

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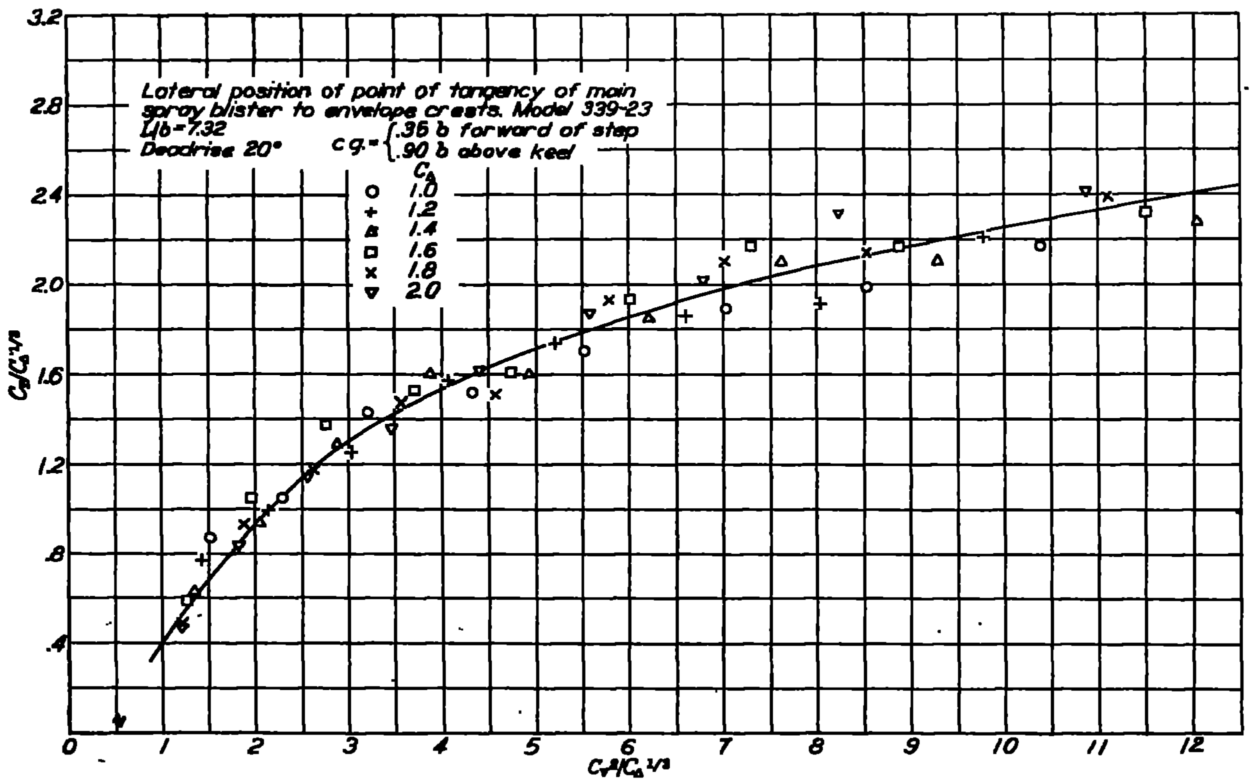


Figure 14.

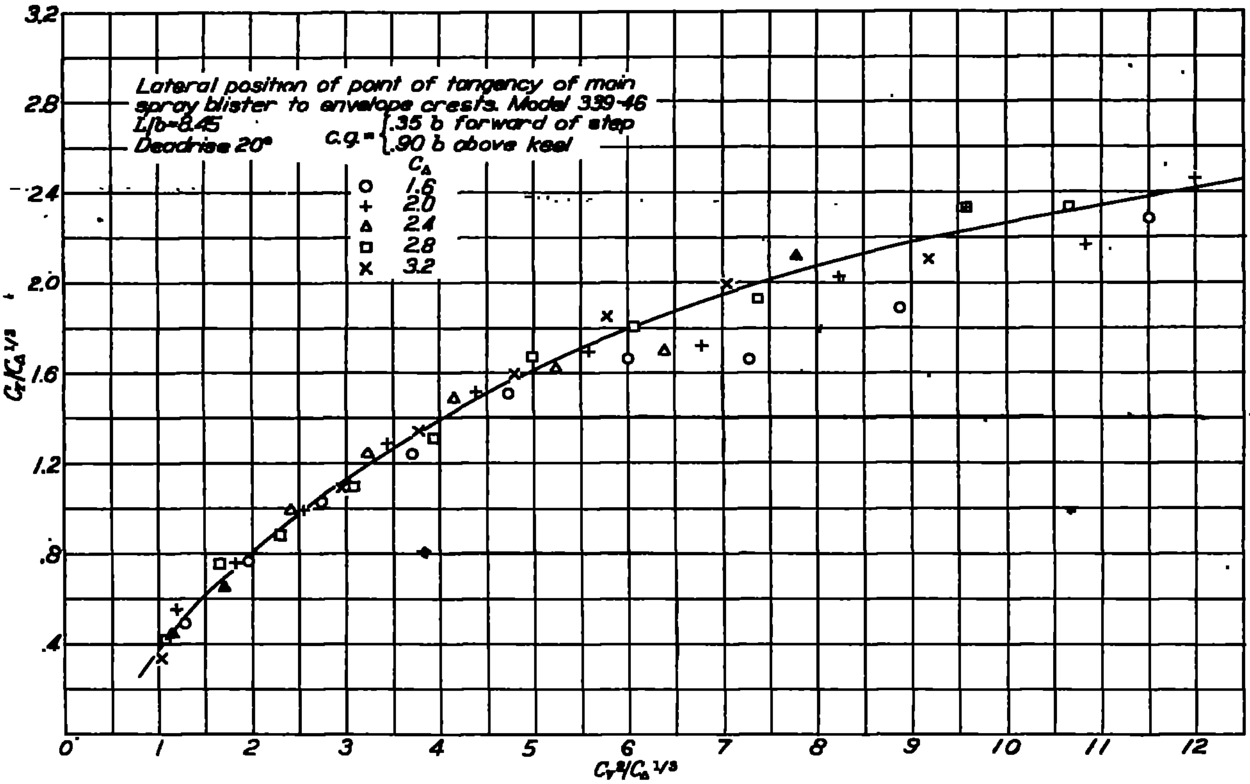


Figure 15.

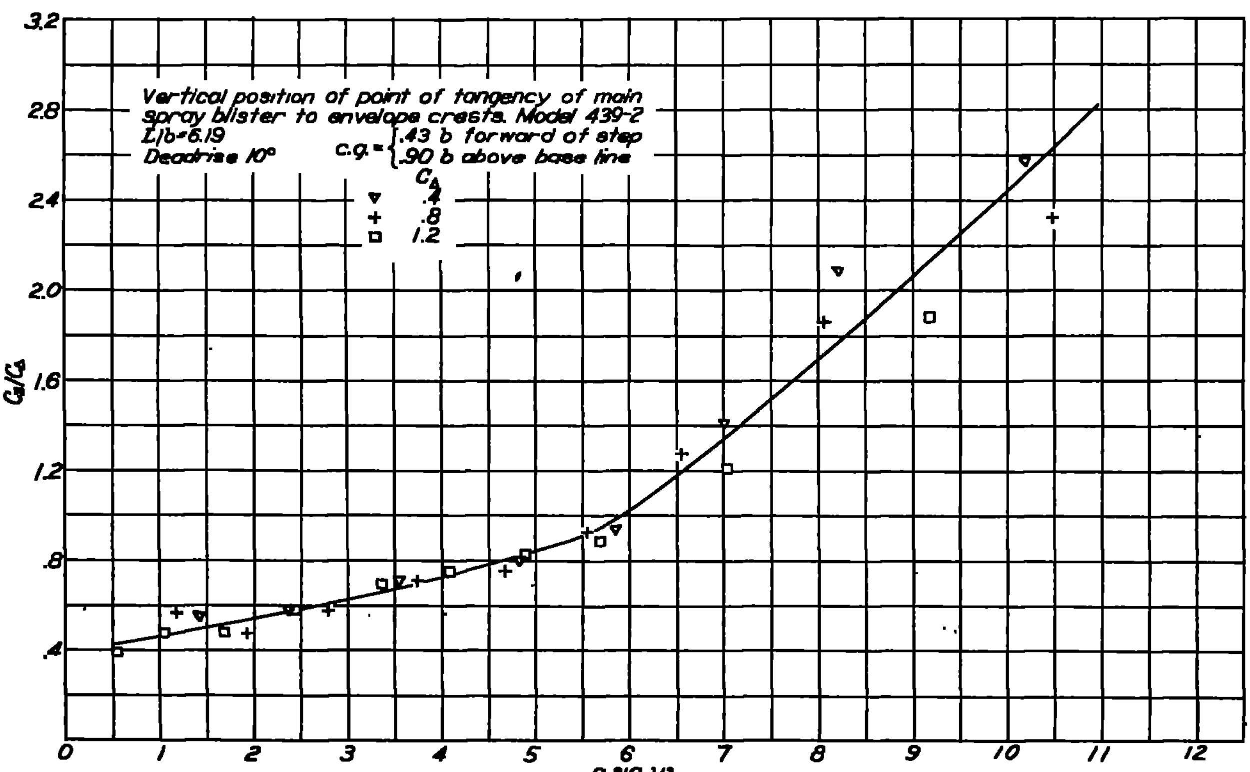


Figure 16.

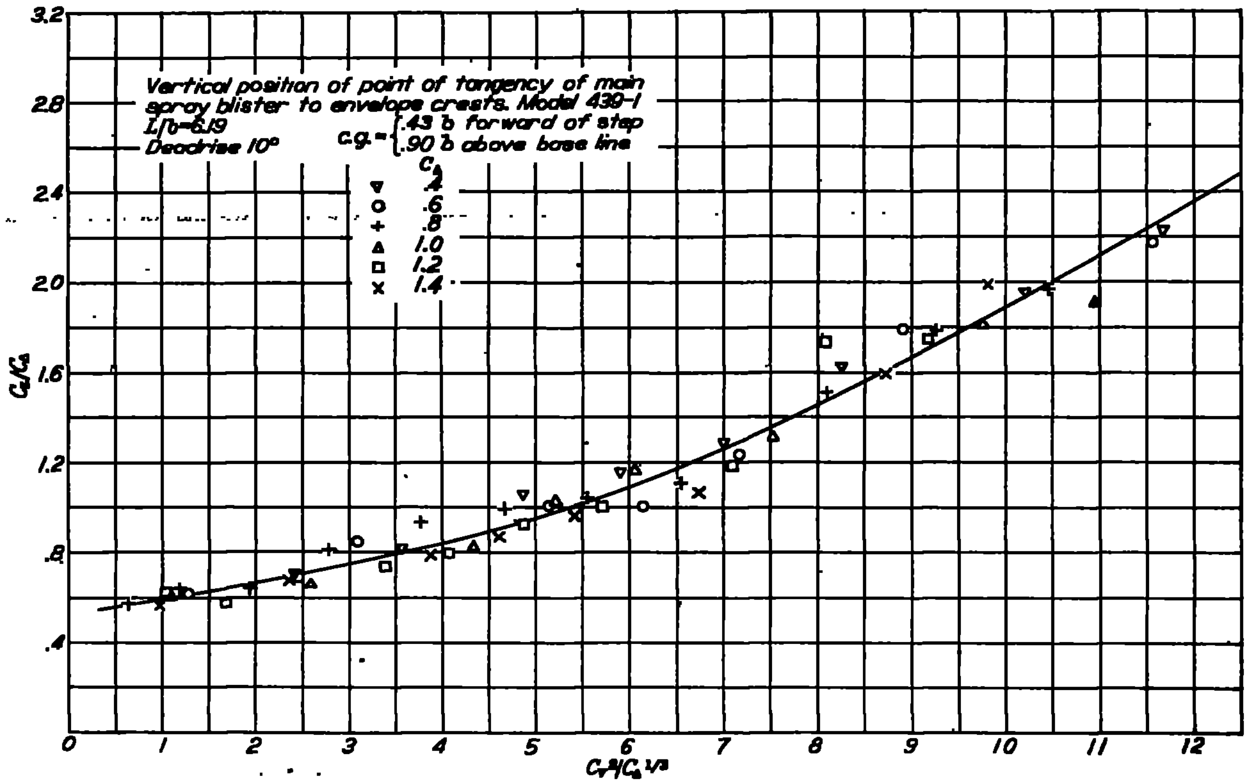
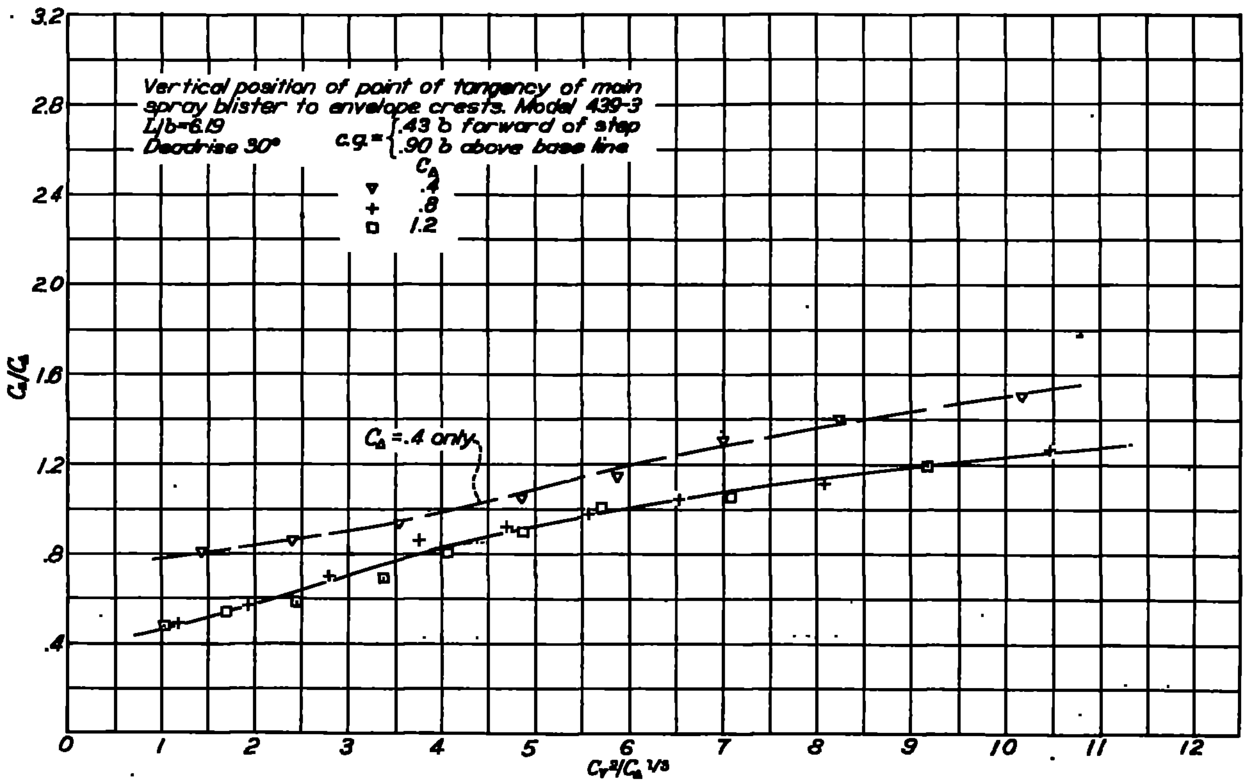


Figure 17.



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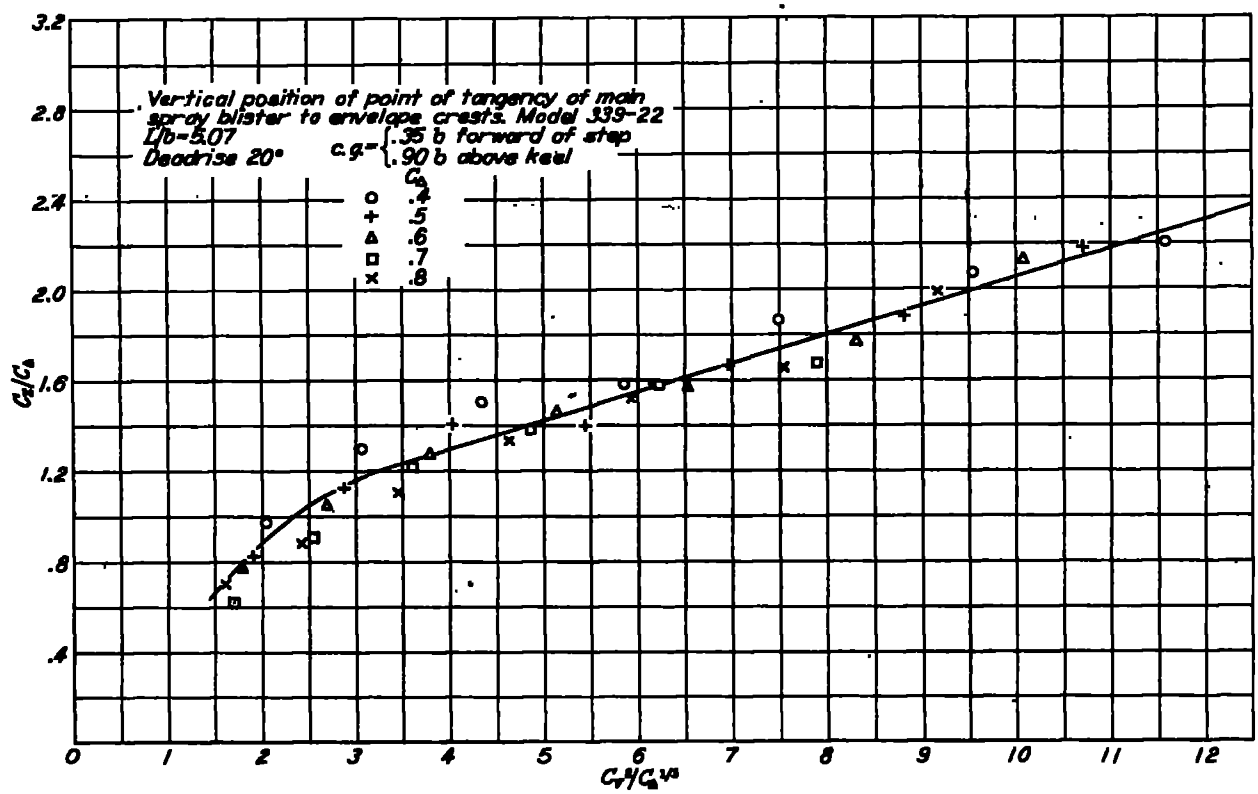

Figure 19.

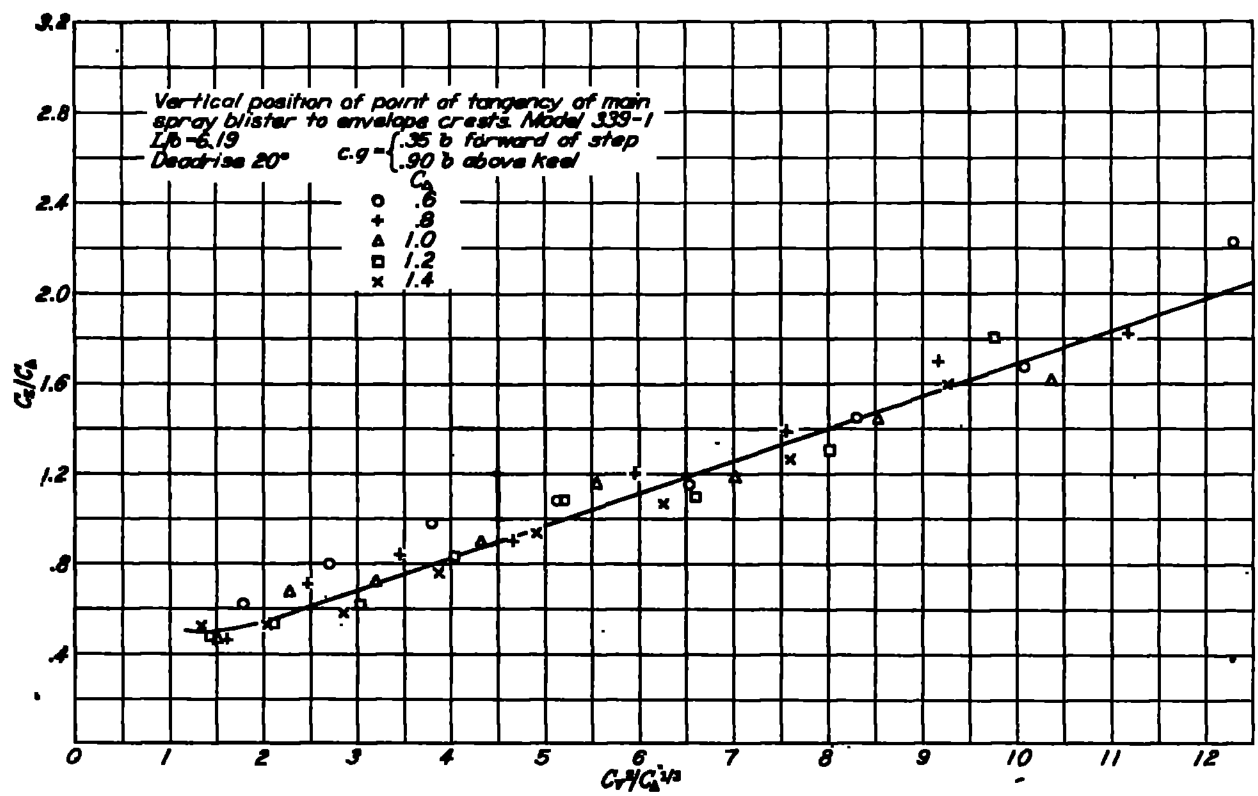

Figure 20.

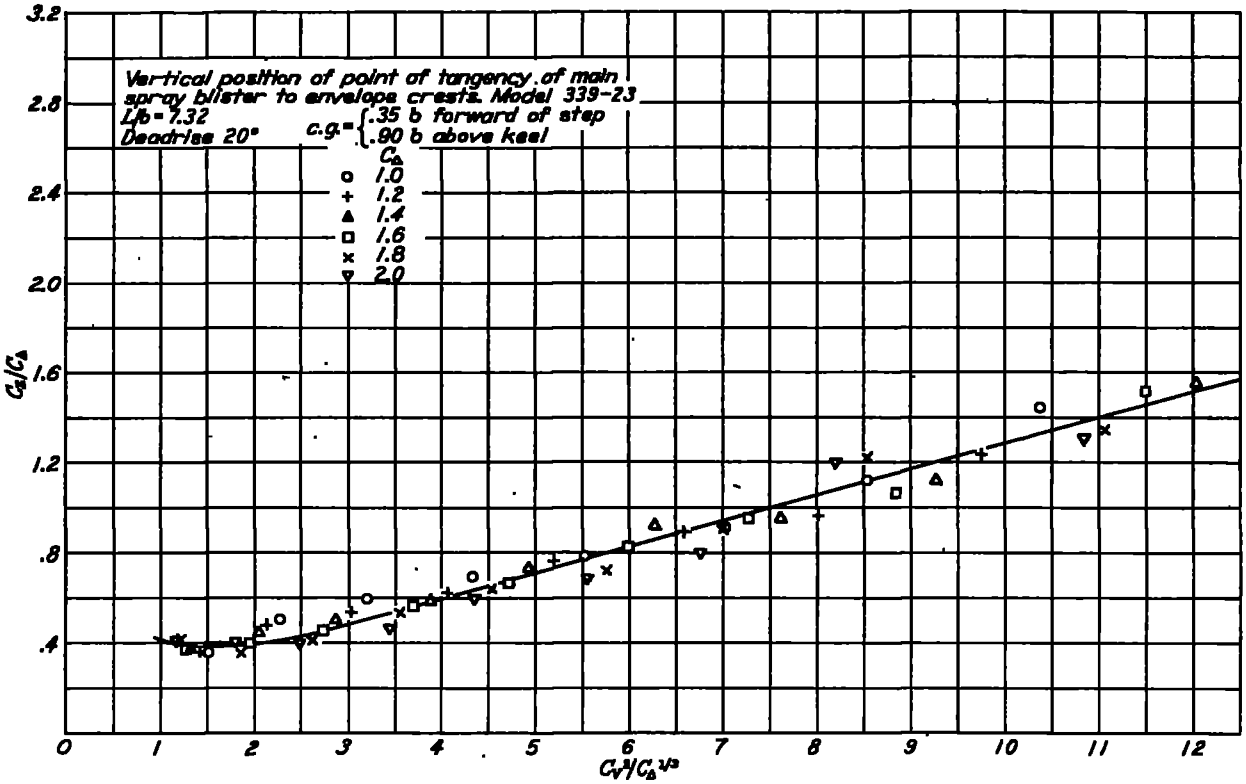

Figure 21.

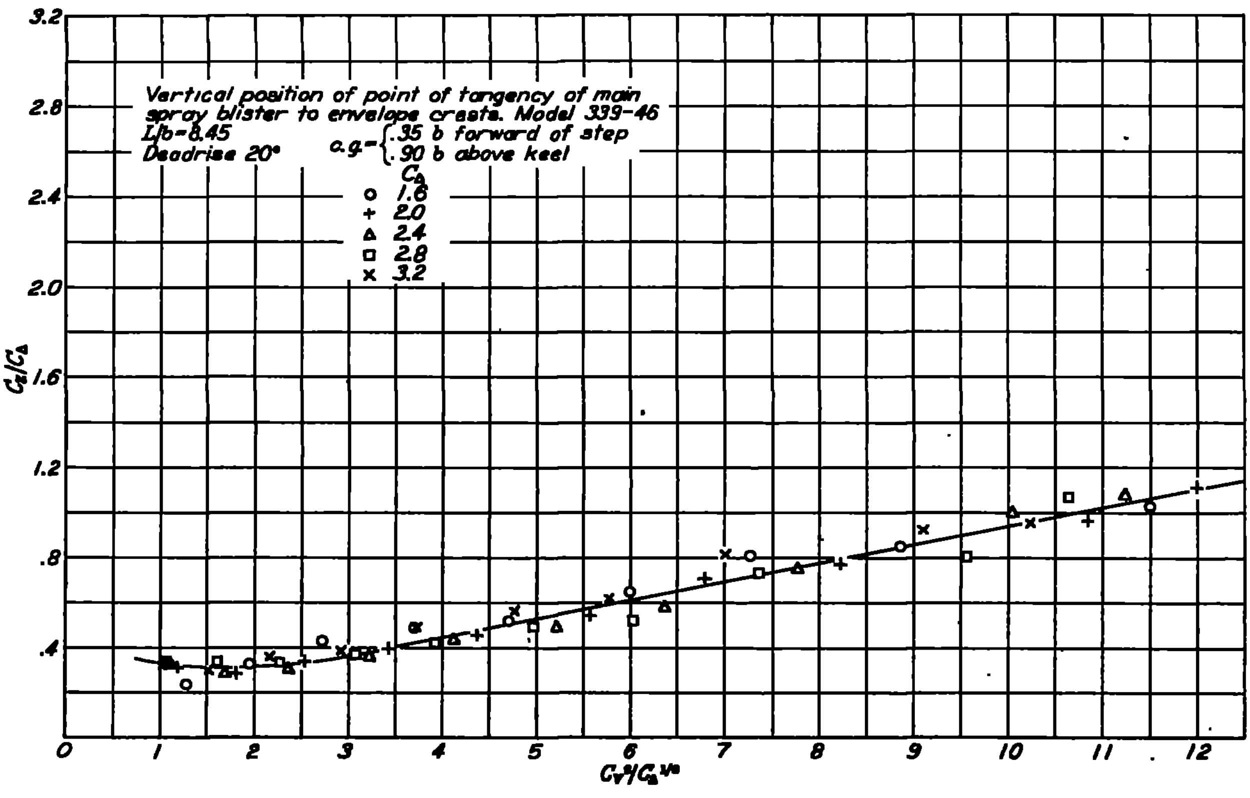

Figure 22.

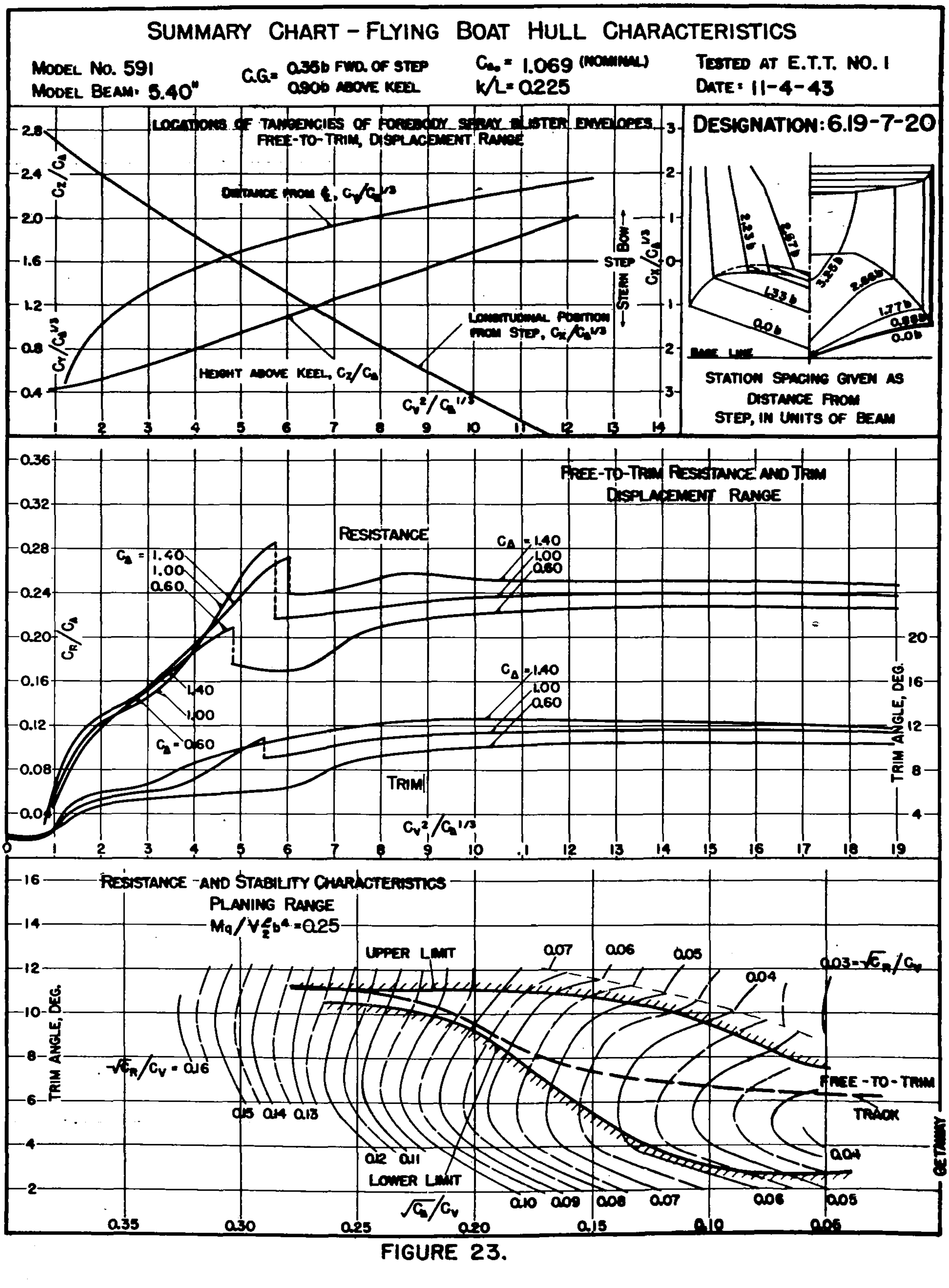
SUMMARY CHART - FLYING BOAT HULL CHARACTERISTICS
MODEL No. 591
MODEL BEAM: 5.40"
C.G.= 0.35b FWD. OF STEP
0.90b ABOVE KEEL
C_Δ0 = 1.069 (NOMINAL)
k/L = 0.225
TESTED AT E.T.T. NO. 1
DATE: 11-4-43
LOCATIONS OF TANGENCIES OF FOREBODY SPRAY BLISTER ENVELOPES
FREE-TO-TRIM, DISPLACEMENT RANGE
DISTANCE FROM ℄, C_Y/C_Δ^1/3
LONGITUDINAL POSITION FROM STEP, C_X/C_Δ^1/3
HEIGHT ABOVE KEEL, C_Z/C_Δ
STEP
BOW
STERN
DESIGNATION: 6.19-7-20
BASE LINE
STATION SPACING GIVEN AS DISTANCE FROM STEP, IN UNITS OF BEAM
FREE-TO-TRIM RESISTANCE AND TRIM
DISPLACEMENT RANGE
RESISTANCE
TRIM
C_R/C_Δ
TRIM ANGLE, DEG.
C_V^2/C_Δ^1/3
RESISTANCE AND STABILITY CHARACTERISTICS
PLANING RANGE
Mq/V_2^2b^4 = 0.25
UPPER LIMIT
LOWER LIMIT
FREE-TO-TRIM TRACK
√C_Δ/C_V
√C_R/C_V = 0.16
0.03 = √C_R/C_V

FIGURE 23.

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