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NAVY DEPARTMENT
THE DAVID W. TAYLOR MODEL BASIN
Washington 7, D.C.

TESTS OF TWENTY RELATED MODELS OF
V-BOTTOM MOTOR BOATS
EMB SERIES 50

MARCH 1949
Revised Edition
REPORT R-47
Tests of Twenty Related Models of
V-Bottom Motor Boats

E.M.B. SERIES 50

for

The David Taylor Model Basin

REPORT NO. 170
by
Kenneth S. M. Davidson
and
Anthony Suarez

October 28, 1941
Revised December 1948

EXPERIMENTAL TOWING TANK
Stevens Institute of Technology
Hoboken, New Jersey
FOREWORD

This report is a revision of a former report, bearing the same title and number, published by the David Taylor Model Basin in October 1941. The original report was compiled by the Stevens Institute of Technology and dealt with a series of tests conducted in the Stevens Experimental Towing Tank at the request of Taylor Model Basin. The revision, based on subsequent work done at Stevens, consisted principally in the addition of charts showing running trim and a drawing of the parent form, together with conversion factors for the other models. The original text has also been modified slightly to include suitable references to the new data.
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INTRODUCTION

This report presents the principal results of an investigation of the effects on the performance of V-bottom boats of variations in proportions and loading, in a form for ready use by designers. Tabulations of the complete test data are on file for reference at the Experimental Towing Tank, Stevens Institute of Technology, Hoboken, New Jersey, and at the David W. Taylor Model Basin, Carderock, Maryland.

Tests were made of a series of twenty models derived from a single parent form. The models were designed at the United States Experimental Model Basin, Washington, D. C., and are designated U.S.E.M.B. Series 50.

The models were 40 inches in length and had:

- displacement-length ratios, $A/\left(\frac{L}{100}\right)^3$ 40, 80, 120, 160
- beam-draft ratios, $B/H$ 4, 6, 8, 11, 15

Page 8 gives the dimensions and particulars of the twenty models together with the multipliers used to obtain the offsets of the series models from the parent model. The lines and offsets of the parent design, $A/\left(\frac{L}{100}\right)^3 = 110; B/H = 5.3$, are shown on page 9. A photograph of the twenty models is included, page 11.

The tow point for all models was 1/2 inch above the designed L.W.L. and at the midlength.

The investigation was made for the David W. Taylor Model Basin, Carderock, Maryland, under United States Navy Contracts Nos. N171s-50126 and N171s-54701.
SIX LOADING CONDITIONS ARE SHOWN FOR EACH MODEL.

\[
\frac{R_{\text{total}}}{\Delta} \text{ vs. } \frac{V}{\sqrt{L}}
\]

FOR THE CENTRAL AND THE EIGHT EXTREME MODELS OF THE SERIES.
resistances

The chart on page 1 provides a comprehensive overall view of the resistances. This chart brings out clearly:

1) The major importance of static trim,
2) The pronounced importance of displacement-length ratio,
3) The relatively lesser importance of both beam-draft ratio and excess displacement.

The contour charts on pages 13-45, incl., define the resistances in detail. These charts provide a broad system of resistance data for V-bottom forms, comparable in general to that provided for steamship forms by the contour charts for Taylor's Standard Series in THE SPEED AND POWER OF SHIPS.

There are three sets of contour charts:

- For normal displacement, \( N \) pages 13-23
- For 10% excess displacement, \( N + 10 \% \) pages 24-34
- For 20% excess displacement, \( N + 20 \% \) pages 35-45

The three charts on each page are for three values of static trim by the stern, \( \tau \), at constant speed-length ratio, \( V/V_L \).

It will be seen that, in laying out the Series 50 models, the procedure for systematically varying the model proportions followed the precedent established by Taylor's Standard Series of steamship forms in that variations were made in displacement-length ratio and beam-draft ratio, both factors being based upon the designed L.W.L. of the parent form. This procedure, with the logical extension of the test program to include given angular changes of static trim, fixed the form of presentation for the resistance contour charts.

In the actual design of a V-bottom boat, however, the factors most readily fixed in the early stages will usually be:

a) Length \( L \),
b) Displacement \( \Delta \),
c) Longitudinal Center of Gravity \( L.C.G. \),
d) Beam \( B \);

a) and b) emerging first, followed by c) when a preliminary weight distribution has been worked out, and then by d). These factors fix:

\[ \Delta / (L_c)^3, \ L.C.G. / L, \ \text{and} \ B / L; \]

but they do not fix:

\[ B / H \ \text{or} \ \tau \]

both of which necessarily appear as parameters on the resistance contour charts. Hence, to make a preliminary estimate of power required, on the basis of the Series 50 resistance contours, it will usually be necessary, first, to transform
given values of B/L and L.C.G./L into the equivalent values of B/H and τ for
the Series 50 form.

The same problem may often arise in selecting the Series 50 form which
corresponds to a given finished design, for the purpose of comparing the power
requirements. For V-bottom forms in general, neither B/H nor τ has the simple,
straightforward significance either has for steamship forms; H depends upon
the amount and longitudinal variation of the deadrise, and τ upon the transom
beam and the up-sweep of the buttocks aft. It will usually be desirable, then,
to define correspondence between the two forms in terms of the same basic fac-
tors, a), b), c), d), listed in the previous paragraph.

The following notes relate to the transformation of B/L to B/H, and
of L.C.G./L to τ, for Series 50 forms.

B/L to B/H
Writing Volume = K₁ x B x H x L, where K₁ is the block coefficient
for the Series 50 form = 0.407

and H = \( \frac{B}{B/H} \)

then Volume = K₁ \( \frac{B^2}{B/H} \) L

or \( B/H = K₂ \frac{B^2 L}{\text{Volume}} \)

dividing the righthand side by \( L^4/1,5 \)

\( B/H = K₁ \left( \frac{B/L}{\text{Volume/L}} \right)^{1/5} \)

or \( B/H = K₂ \left( \frac{B/L}{A/\left( \frac{L}{100} \right)} \right)^{1/5} \), where \( K₂ = 1.16 \times 10^4 \).

This formula contains the necessary factors for the transformation.

L.C.G./L to τ
The static trim can be obtained by interpolation from the contour
charts of L.C.G. described in the next section. Although an equa-
tion could be worked out for this relationship, it would be much
less simple to use than the contour charts.

Example of E.H.P. Estimate. Suppose it is desired to find the E.H.P.
of a Series 50 form having the following particulars (or of the Series 50 form
corresponding to a given form having the same particulars), at the indicated
speed:

\[ V = 35 \text{ knots} \]

\[ L = 60.00 \text{ feet} \]

\[ A \text{ (sea water)} \]

\[ \begin{cases} 23.75 \text{ tons, designed} \\ 26.13 \text{ tons, actual (10\% excess)} \end{cases} \]

\[ \text{L.C.G.} \]

\[ 64\% \text{ of } L \text{ from F.P.} \]

\[ B = 13.45 \text{ feet} \]
1. \[ \Delta = \left( \frac{L}{100} \right)^3 = \frac{A}{(100)^3} = \frac{35}{100} = 0.35 \]

2. \[ \frac{E}{L} = \frac{13.5}{0.00} = 13.5 \]

3. \[ V/\sqrt{\Delta} = \frac{35}{\sqrt{60.00}} = 4.5 \]

4. From the formula, \[ \frac{E}{\sqrt{\Delta}} = \frac{1.16 \times 124 \times (0.725)^2}{110} = 5.3 \]

5. From the L.C.G. contour chart on page 82, when \( \tau = 0^\circ \) (level trim), L.C.G. = 64.5 \%
   when \( \tau = 2^\circ \) (by the stern), L.C.G. = 65.3 \%

   Interpolating, \( \tau = \frac{0^\circ \times 64.5 - 2^\circ \times 65.5}{0^\circ - 2^\circ} \times 2^\circ = 1.7^\circ \) (for L.C.G. = 64\%)

6. Entering the resistance contour charts on page 30 (for \( V/\sqrt{\Delta} = 4.5 \)) with the above values of \( \frac{A}{(100)^3} \), and \( E/\sqrt{\Delta} 

   when \( \tau = 0^\circ \), \( R/A = 0.185 \) pounds per pound of displacement,
   when \( \tau = 2^\circ \), \( R/A = 0.168 \)

   Interpolating for \( \tau = 1.7^\circ \)

   \[ 0.185 - \frac{1.7}{2.0} (0.185 - 0.168) = 0.185 - 0.014 = 0.171 \text{ lbs./lb.} \]

7. Then,

   \[ E.H.P. = 0.003071 \times \frac{R}{A \text{ lbs.}} \times A \text{ lbs.} \times V \]

   \[ E.H.P. = 0.003071 \times (0.171 \times 0.13 \times 2240) \times 35 = 1076 \text{ lbs.} \]

**Shaft Angle and Position.** The necessary data for taking into consideration the effect of any prescribed shaft line are available in the test results. The contours of running trim angle on pages 47-79 are necessary for this purpose.

L.C.G., \( R/A \), will be known, and the trim angle \( \alpha \) can be obtained by adding the static trim to the running trim obtained from the contours. Let \( \beta \) be the shaft angle. The vector diagram shown below will then illustrate the disposition of the forces, where \( F_v \) is the vertical component of the thrust, which was not present in the model tests. From inspection, it is seen that

\[ \alpha = \tau + \Delta \] (static trim + running trim).
the new displacement and the new percentage of normal displacement (N %) at the new percentage of normal displacement. A new value of resistance, corresponding to the changed conditions, can now be found by the procedure in (6) on page 5. A second approximation can be made if necessary.

**Contours of Running Trim**

The contour charts on pages 47-79 give running trims for the whole series. Running trim is defined as the change of trim, \( A \tau \), due to the forward motion of the model.

Again, there are three sets of contour charts:

- for normal displacement, \( N \)  
  - pages 47-57
- for 10% excess displacement, \( N + 10\% \)  
  - pages 58-68
- for 20% excess displacement, \( N + 20\% \)  
  - pages 69-79

As for the resistance contours, there are three charts on each page for three values of static trimming the stern.

**Longitudinal Centers of Gravity**

The contour charts on pages 81-83 define the relationship between the static trim by the stern, \( \tau \), and the position of the longitudinal center of gravity, L.C.G., for all of the models of the series. The purpose of these charts is explained in the preceding section, page 4.

There are three sets of contour charts:

- for normal displacement, \( N \)  
  - page 81
- for 10% excess displacement, \( N + 10\% \)  
  - page 82
- for 20% excess displacement, \( N + 20\% \)  
  - page 83

**Wetted Surfaces**

The contour charts on pages 85-94 define the wetted surfaces. These charts are included to permit making expansions to full size by treating the friction and residual components independently (as is usual for displacement-type vessels), if this is desired. They are necessary, in the case of V-bottom forms, because of the large variation of the wetted surface with speed.

There are two sets of contour charts:

- for normal displacement, \( N \)  
  - pages 85-89
- for 20% excess displacement, \( N + 20\% \)  
  - pages 90-94

* (L.C.G.)' is the position of the resultant of \( d \) and \( F \).
Once the wetted surface is determined, the expansion to full size can be carried out by the usual procedures employed for large ships, except that a friction formulation which provides satisfactory turbulent friction data for 40-inch models, such as the Schenker, must necessarily be adopted.

Porpoising.

It was found in the course of the resistance tests that, in many instances, a longitudinal instability developed with increase of speed, similar in character to that ordinarily described in connection with seaplanes as porpoising. Damped out for the resistance tests, this condition was subsequently studied more carefully in a separate series of tests on seven selected models of the series.

The results of these tests are summarized in the charts on page 96, which indicate limiting speed-length ratios for longitudinal stability. They are shown in detail in the graphical records of the porpoising motion of each model tested, on pages 97-103.

There is no evidence that these porpoising tests for Series 50 forms necessarily describe the porpoising characteristics of other forms of different shapes. It is believed, however, that they are reasonably indicative for most forms.
### PARTICULARS AND DIMENSIONS

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Values of beam and draft in inches.
Beam of LWL, and draft to the rabbet.
Model Length, 40 inches.

### ENLARGEMENTS FROM PARENT MODEL

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THE STERN, $\gamma = 0^\circ$

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**DIAGRAM**

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- **4**
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- **7**
- **8**
- **9**
- **10**

**NOTES:**
- **A B C**
- **Buttocks**

**DIMENSIONS:**
- **48.00**
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CONTOURS
OF
RESISTANCE
PER POUND OF DISPLACEMENT

Speed-Length Ratios 1.5-6.5 in Steps of 0.5

<table>
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<th>Displacement</th>
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<td>100% (N)</td>
<td>13 to 23</td>
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<tr>
<td>110% (N + 10%)</td>
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<tr>
<td>120% (N + 20%)</td>
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Contour of Total Model Resistances, Lbs./L of Displ.

1. For $\frac{V}{L} = 3.5$
2. For $\Delta = N$ (Nose Down)
3. For $\tau = 0^\circ$, $2^\circ$, and $4^\circ$

Beam Draft Ratio vs. Displacement Length Ratio
Contour plots of total model resistances, lbs/ft^2 of displacement, for different beam draft ratios with displacement length ratio $\frac{V}{L} = 4.0$, $\Delta = N+20\%$, and displacement angles $\theta = 0^\circ$, $\theta = 2^\circ$, and $\theta = 4^\circ$. The plots show the variation of resistance with beam draft ratio for these conditions.
CONTOURS

OF

RUNNING TRIM

Speed-Length Ratios: 1.5-0.5 in Steps of 0.5

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<td>47 to 57</td>
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</table>


Contour plots showing running trim angle in degrees for different values of \( \frac{V}{\sqrt{L}} \) and \( \Delta \), with displacement length ratio on the y-axis and beam draft ratio on the x-axis.
\[ \frac{v}{\sqrt{L}} = 4.0 \]

\( \Delta = N \)

\( \beta = 0^\circ \)

\[ \frac{v}{\sqrt{L}} = 4.0 \]

\( \Delta = N \)

\( \beta = 2^\circ \)

\[ \frac{v}{\sqrt{L}} = 4.0 \]

\( \Delta = N \)

\( \beta = 4^\circ \)
\[
\frac{V}{L} = 6.0
\]

\[\Delta = N\]

\[\theta = 0^\circ\]

\[
\frac{V}{L} = 6.0
\]

\[\Delta = N\]

\[\theta = 2^\circ\]

\[
\frac{V}{L} = 6.0
\]

\[\Delta = N\]

\[\theta = 4^\circ\]
\[ \frac{V}{\sqrt{L}} = 1.5 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 0^\circ \]

\[ \frac{V}{\sqrt{L}} = 1.5 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 2^\circ \]

\[ \frac{V}{\sqrt{L}} = 1.5 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 4^\circ \]
\[ \frac{V}{L} = 2.5 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 0^\circ \]

\[ \frac{V}{L} = 2.5 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 2^\circ \]

\[ \frac{V}{L} = 2.5 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 4^\circ \]
\[ \frac{V}{L} = 3.0 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 0^\circ \]

\[ \frac{V}{L} = 3.0 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 2^\circ \]

\[ \frac{V}{L} = 3.0 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 4^\circ \]
\[ \frac{V}{T} = 3.5 \]

\[ \Delta = N + 10\% \]

\[ \phi = 0^\circ \]

\[ \frac{V}{T} = 3.5 \]

\[ \Delta = N + 10\% \]

\[ \phi = 2^\circ \]

\[ \frac{V}{T} = 3.5 \]

\[ \Delta = N + 10\% \]

\[ \phi = 4^\circ \]
Contour of Running Trim Angle in Degrees

\[ \frac{V}{\sqrt{h}} = 5.0 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 0^\circ \]

Contour of Running Trim Angle in Degrees

\[ \frac{V}{\sqrt{h}} = 5.0 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 2^\circ \]

Contour of Running Trim Angle in Degrees

\[ \frac{V}{\sqrt{h}} = 5.0 \]
\[ \Delta = N + 10\% \]
\[ \gamma = 4^\circ \]
\[ \frac{\sqrt{V}}{L} = 5.5 \]
\[ \Delta = N + 10\% \]
\[ \theta = 0^\circ \]

\[ \frac{\sqrt{V}}{L} = 5.5 \]
\[ \Delta = N + 10\% \]
\[ \theta = 2^\circ \]

\[ \frac{\sqrt{V}}{L} = 5.5 \]
\[ \Delta = N + 10\% \]
\[ \theta = 4^\circ \]
Contours of Running Trim Angle in Degrees

\[ \frac{V}{L} = 6.0 \]

\[ \Delta = N + 10\% \]

\[ \vartheta = 0^\circ \]

Contours of Running Trim Angle in Degrees

\[ \frac{V}{L} = 6.0 \]

\[ \Delta = N + 10\% \]

\[ \vartheta = 2^\circ \]

Contours of Running Trim Angle in Degrees

\[ \frac{V}{L} = 6.0 \]

\[ \Delta = N + 10\% \]

\[ \vartheta = 4^\circ \]
\[ \frac{V}{l} = 6.5 \]
\[ \Delta = N + 10\% \]
\[ \varphi = 0^\circ \]

\[ \frac{V}{l} = 6.5 \]
\[ \Delta = N + 10\% \]
\[ \varphi = 2^\circ \]

\[ \frac{V}{l} = 6.5 \]
\[ \Delta = N + 10\% \]
\[ \varphi = 4^\circ \]
\[
\frac{V}{\sqrt{L}} = 1.5 \\
\Delta = N + 20\% \\
\gamma = 0^\circ
\]

\[
\frac{V}{\sqrt{L}} = 1.5 \\
\Delta = N + 20\% \\
\gamma = 2^\circ
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\frac{V}{\sqrt{L}} = 1.5 \\
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\( \Delta = N + 20\% \)

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\frac{V}{\sqrt{L}} = 3.5
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\frac{V}{\sqrt{L}} = 4.5 \\
\Delta = N + 20\% \\
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\[ \frac{V}{\sqrt{L}} = 5.0 \]
\[ \Delta = N + 20\% \]
\[ \tau = 0^\circ \]

\[ \frac{V}{\sqrt{L}} = 5.0 \]
\[ \Delta = N + 20\% \]
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\[
\frac{V}{\sqrt{L}} = 6.5
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\[\Delta = N + 20\%
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<td>(W + 10%)</td>
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<tr>
<td>12°C</td>
<td>(W + 20%)</td>
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CONTOURS

OF

AERIAL AREAS

Speed-Length Ratio 2.0-6.0 in Steps of 1.0

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<td>120% (N + 20%)</td>
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Charts of limiting speed-length ratio for longitudinal stability and charts of graphical records of porpoising cycles.

Pages 96 to 103
NOTE:
K = Longitudinal Radius
of Gyration
(Heel as closely as possible to 10in.)
Scale = 1/4 Size for Model
Initial Distribution for Revised Edition
of TMB Report R-47

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