# THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
Department of Naval Architecture and Marine Engineering
Ship Hydrodynamics Laboratory

## RESISTANCE AND DIRECTIONAL STABILITY TESTS FOR A 1:40 SCALE GENERAL CARGO BARGE

by

Peter A. Fisher

Project Director
R. B. Couch

for

L. R. Glosten and Associates, Inc.
Colman Building
Seattle, Washington 98104

Administered through:

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## Introduction

Under authorization of L. R. Glosten & Associates, Inc. resistance and directional stability tests were conducted on a 1:40 scale model of a 400' x 100' x 25' general deck cargo barge. The model was constructed in accordance with L. R. Glosten drawing no. 7434-1. A small sketch of these lines is provided in figure 1. Ship principal dimensions are listed in table 1. Test conditions are listed for both ship and model in table 2.

Table 1
Principal Characteristics

| | |
|---|---|
| Length overall | 400'-0" |
| Length on load waterline | 392'-0" |
| Beam | 100'-0" |
| Depth | 25'-0" |
| Draft | 20'-0" |
| Displacement | 18284 LTSW |
| $C_B$ | .816 |
| Wetted surface | 49050 |
| w/appendages | 50740 |

Turbulence stimulation was provided in the form of a .036 inch diameter girth wire located .075 LBP aft of the forward perpendicular. Model data was expanded to full scale using the ATTC friction line with a correlation allowance $C_A$ of 0.0004.

## Model tests

Bare hull resistance was first measured in still water at the full load draft corresponding to 20'-0" full scale. Tests covered a full scale speed range of 5 to 13 knots.

A flow line test performed in the usual manner was conducted for the purpose of final skeg orientation. The actual flow direction indicated an angle of 6 1/2° with respect to the centerline and is illustrated on figure 2 at the point where the flow tab was placed.

Skegs were constructed in accordance with the lines plan, except that the trailing edge was made movable so that optimum skeg-flap angle could be determined for stability characteristics. The leading edge was placed so that it had one degree in excess of the flow line to provide a positive angle of attack. A sketch indicating skeg dimensions and alignment is provided in figure 2.

Stabilization tests were performed at a speed-length ratio of .45 (9 knots full scale) on a hawser corresponding to about 1000 feet in length. The skeg-flap angle providing substantial directional control was observed as 20°.

Resistance measurements were taken at three drafts (even keel) for the stable condition. These correspond to 20'-0", 16'-0" and 9'-0". Results are presented as curves of full scale resistance and effective power versus speed in knots in figure 4 and 5, respectively. Computer output expanding model data to full scale predictions for each condition is found in the appendix.

Because the stabilized resistance was somewhat excessive in view of the bare hull test results. The skegs were reoriented to give them 4 degrees of additional attack angle and

the barge was stabilized again. This stable 2 condition had a skeg-flap angle of 13° for the same degree of stability. This orientation is illustrated in figure 3. Only the full load condition was tested and resulted in a reduction in resistance of about 8 percent.

When compared to barges of similar dimensions tested previously at The University of Michigan the bare hull resistance was somewhat lower than its predecessors. It also was felt that the degree of directional stability was a bit greater than some others tested. These two facts would tend to increase the percentage of resistance augment.

Table 2
Ship and Model Test Conditions

Sponsor: L. R. Glosten & Associates, Inc.

Model No.: 1331

Ship Type: 400' x 100' x 25' Deck Cargo Barge

Linear Scale Ratio: $\lambda = 40.0$

| | Ship | Model |
|---|---|---|
| Full Load Condition | | |
| LOA (ft) | 400.0 | 10.0 |
| LWL (ft) | 392.0 | 9.8 |
| B (ft) | 100.0 | 2.5 |
| T (ft) | 20.0 | .5 |
| $C_B$ | .816 | |
| Displacement | 18290. LTSW | 622.8 lbs.@70°F |
| Wetted Surface ($ft^2$) | 49025. | 30.64 |
| w/appendages | 50740. | 31.71 |
| Medium Ballast Condition | | |
| LOA (ft) | 400.0 | 10.0 |
| LWL (ft) | 384.25 | 9.61 |
| B (ft) | 100.0 | 2.5 |
| T (ft) | 16.0 | .4 |
| $C_B$ | .804 | |
| Displacement | 14130. LTSW | 481.2 lbs.@70°F |
| Wetted Surface w/appendages | 45920. | 28.70 |

Table 2 (Continued)
Ship and Model Test Conditions

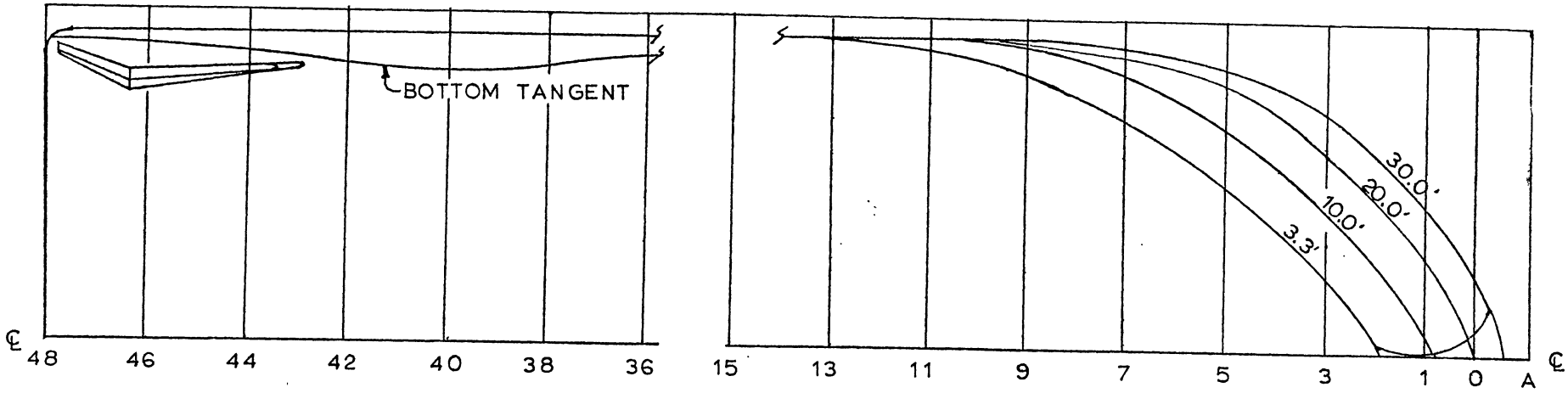
| | Ship | Model |
|---|---|---|
| Light Ballast Condition | | |
| LOA (ft) | 400.0 | 10.0 |
| LWL (ft) | 353.0 | 8.83 |
| B (ft) | 100.0 | 2.5 |
| T (ft) | 9.0 | .225 |
| $C_B$ | .795 | |
| Displacement | 7220. LTSW | 245.9 lbs.@70°F |
| Wetted Surface w/appendages ($ft^2$) | 37712. | 23.57 |

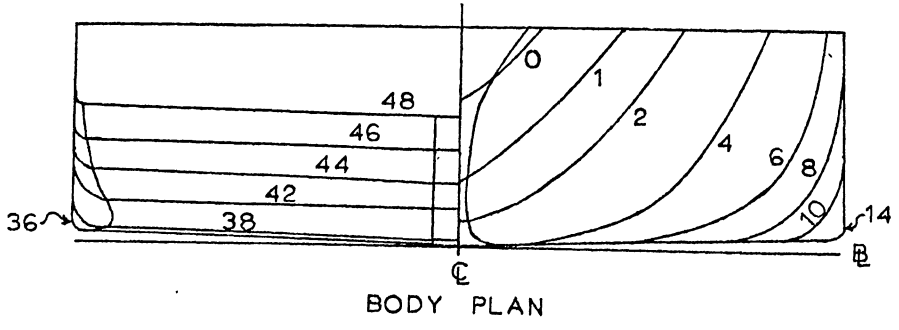
Turbulence Stimulation: .036" trip wire located .075 LBP aft of the forward perpendicular

Friction line: 1947 ATTC friction coefficient

$C_A = 0.0004$

Drawing Reference: L. R. Glosten & Associates, Inc. Drawing No. 7434-1




BODY PLAN

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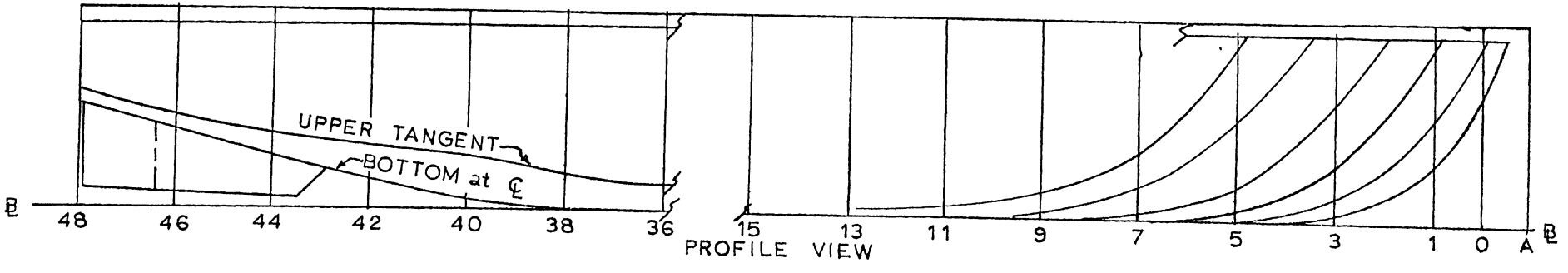
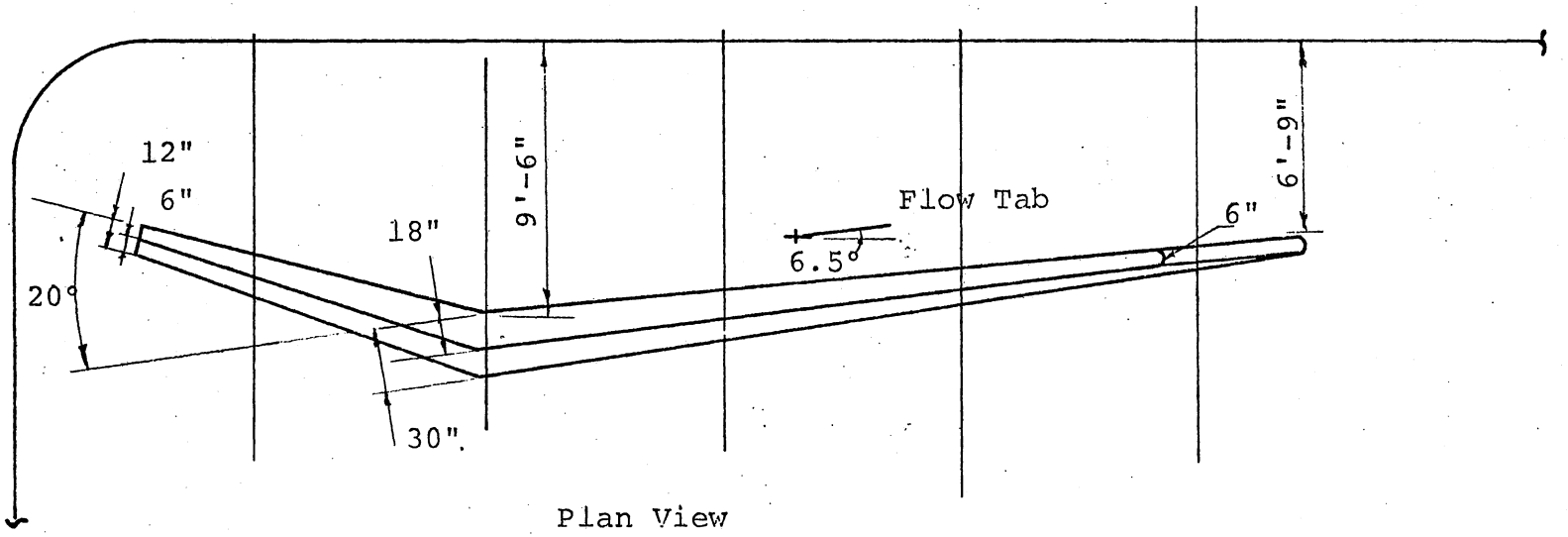
SPONSOR: L.R. GLOSTEN & ASSOC. INC.

MODEL NO. 1331

FIGURE 1




PROFILE VIEW




Plan View

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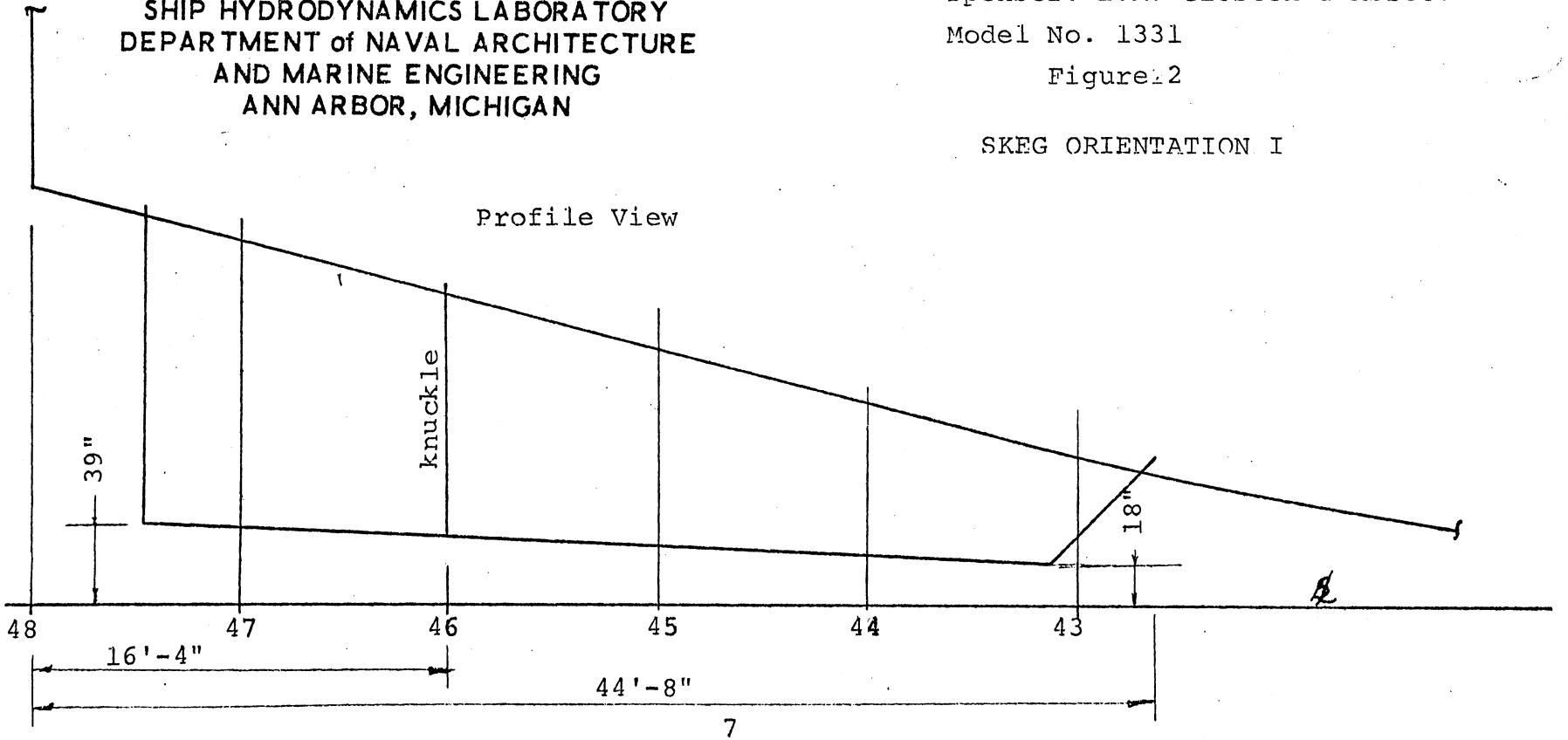
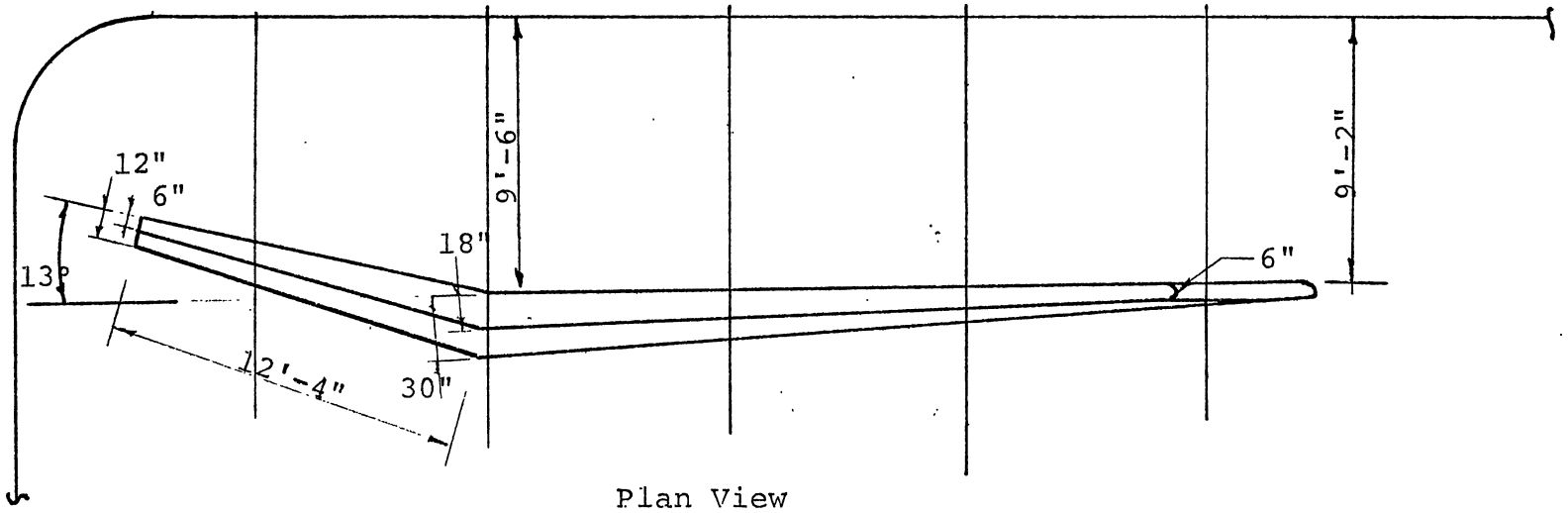
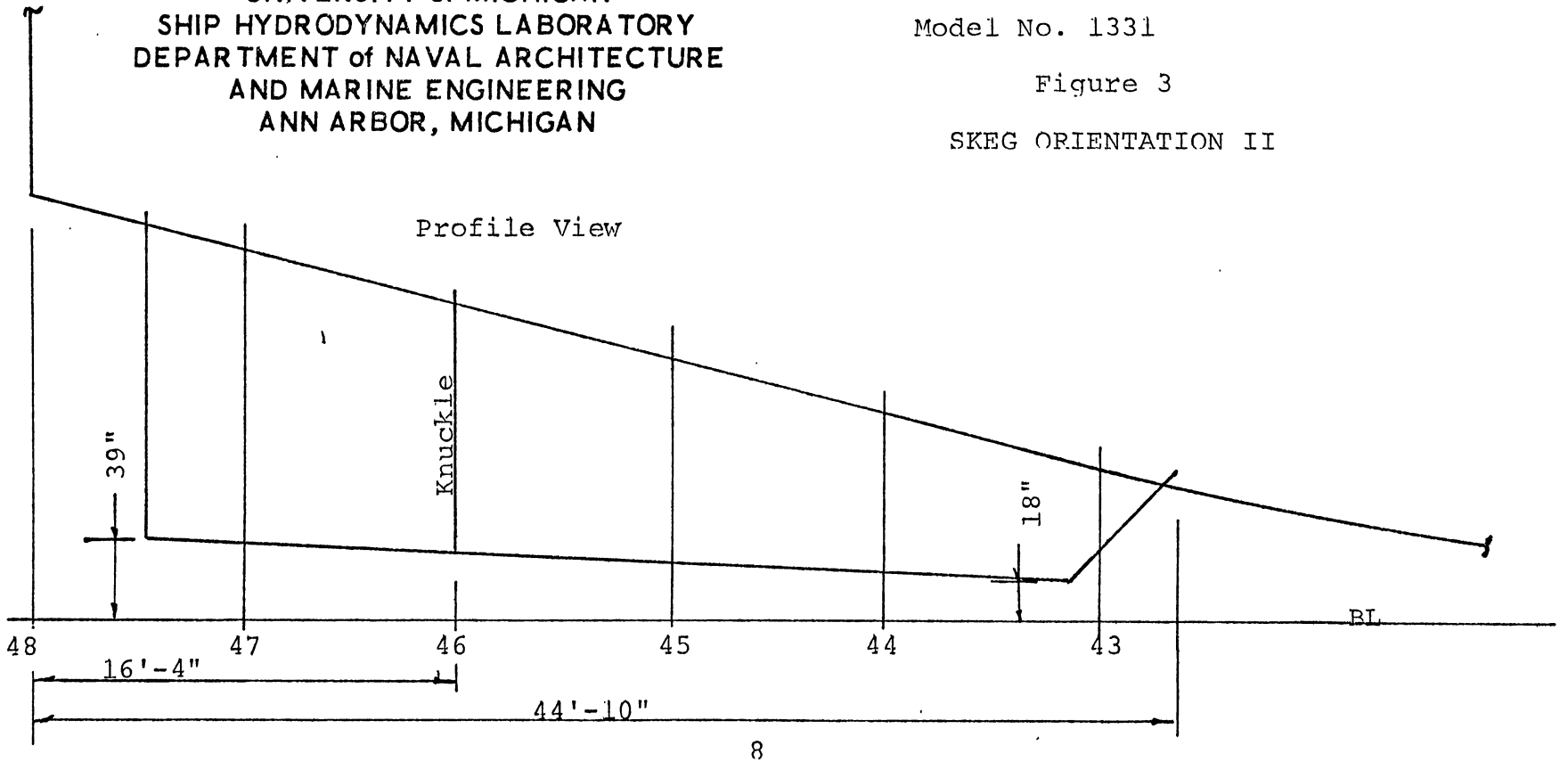
Sponsor: L.R. Glosten & Assoc.
Model No. 1331
Figure 2

SKEG ORIENTATION I






Plan View




Profile View

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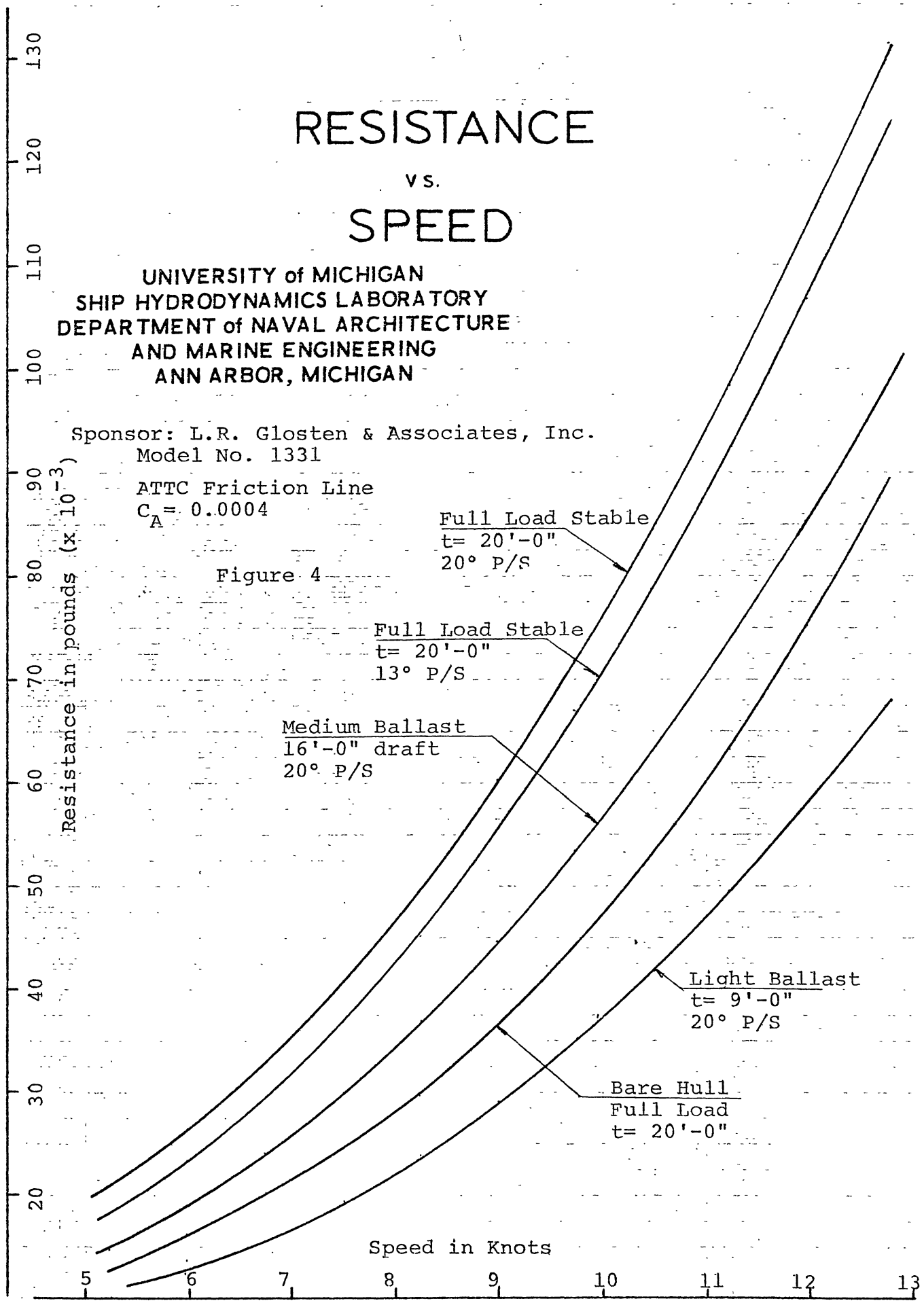
Sponsor: L.R. Glosten & Assoc.

Model No. 1331

Figure 3

SKEG ORIENTATION II


RESISTANCE
VS.
SPEED
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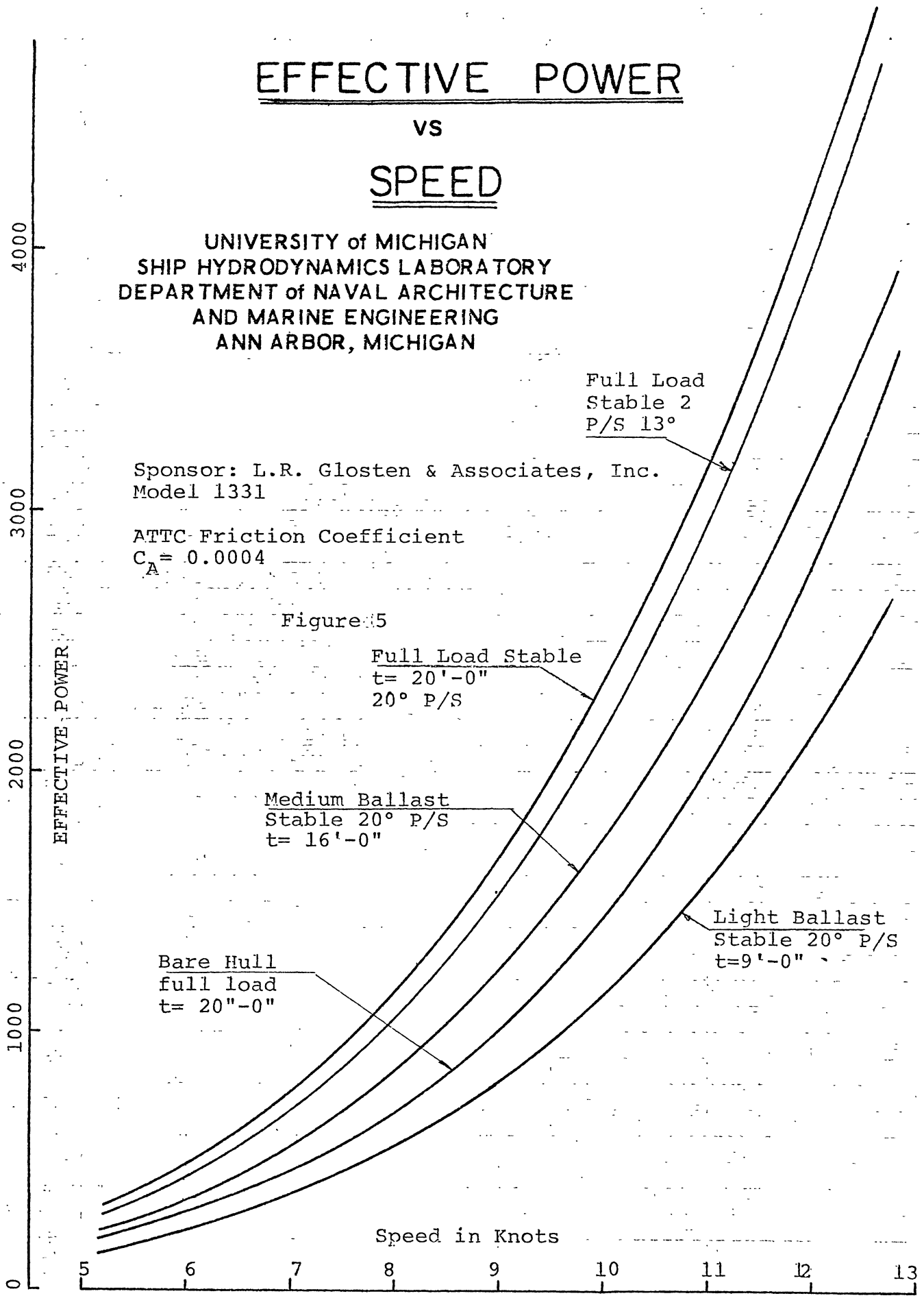
Sponsor: L.R. Glosten & Associates, Inc.
Model No. 1331
ATTC Friction Line
$C_A$ = 0.0004
Figure 4
Full Load Stable
t= 20'-0"
20° P/S
Full Load Stable
t= 20'-0"
13° P/S
Medium Ballast
16'-0" draft
20° P/S
Light Ballast
t= 9'-0"
20° P/S
Bare Hull
Full Load
t= 20'-0"
Resistance in pounds (x $10^{-3}$)
20
30
40
50
60
70
80
90
100
110
120
130
Speed in Knots
5
6
7
8
9
10
11
12
13


EFFECTIVE POWER
VS
SPEED
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DEPARTMENT of NAVAL ARCHITECTURE
AND MARINE ENGINEERING
ANN ARBOR, MICHIGAN
Full Load
Stable 2
P/S 13°
Sponsor: L.R. Glosten & Associates, Inc.
Model 1331
ATTC Friction Coefficient
$C_A$ = 0.0004
Figure 5
Full Load Stable
t= 20'-0"
20° P/S
Medium Ballast
Stable 20° P/S
t= 16'-0"
Light Ballast
Stable 20° P/S
t=9'-0"
Bare Hull
full load
t= 20"-0"
EFFECTIVE POWER
0
1000
2000
3000
4000
Speed in Knots
5
6
7
8
9
10
11
12
13

# APPENDIX

| | |
|---|---|
| B | Beam |
| $C_B$ | Block coefficient = $\frac{\text{Displaced Volume}}{L \times B \times T}$ |
| $C_{FM}$ | Model frictional resistance coefficient |
| $C_{FS}$ | Ship frictional resistance coefficient |
| $C_{RM}$ | Model residuary resistance coefficient |
| $C_{RS}$ | Ship residuary resistance coefficient |
| $C_{TM}$ | Model total resistance coefficient |
| $C_{TS}$ | Ship total resistance coefficient |
| DISPL | Displacement (long tons - salt water) |
| EHP | Effective horsepower = $\frac{V_K \times R_{TS}}{326}$ |
| FN | Froude number = $V_K * 1.6889/\sqrt{g*LWL}$ (dimensionless) |
| LWL | Design waterline (ft) |
| NU | $\nu$ - kinematic viscosity |
| RHO | $\rho$ - mass density |
| $R_{NM}$ | Model Reynolds number (dimensionless) |
| $R_{NS}$ | Ship Reynolds number |
| $R_{TM}$ | Model total resistance (lbs) |
| $R_{TS}$ | Ship total resistance |
| SLR | Speed-length ratio ($V_K/\sqrt{LWL}$) |
| T | Draft (ft) |
| VCG | Vertical center of gravity (ft) |
| $V_K$ | Ship speed (knots) |
| $V_M$ | Model speed (ft/sec) |
| $V_W$ | Wake speed (ft/sec) |
| W | Taylor wake fraction w = $\frac{V_M - V_W}{V_M}$ |

L. R. Glosten & Assoc.
Model 1331
Full Load t=20'-0"
Bare Hull

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## EXTRAPOLATION OF MODEL TEST DATA

### SHIP DATA

| | | | | | |
|---|---|---|---|---|---|
| MODEL NO. | 1331 | LWL | 392.00 | DISP LTSW | 18290. |
| CONDITION: | BARE HULL | BEAM | 100.00 | WET'D SURF | 49024. |
| LAMBDA | 40.000 | DRAFT FWD | 20.00 | TEMP | 59.00 |
| FRICTION LINE | ATTC | DRAFT AFT | 20.00 | RHO | 1.9905 |
| CORR. ALLOW. | 0.00040 | BLOCK COEF. | 0.816 | NU*10**5 | 1.27908 |

| VK | RNS/10**8 | CFS*1000 | CTS*1000 | RTS | EHP |
|---|---|---|---|---|---|
| 5.243 | 2.714 | 1.808 | 3.358 | 12846. | 207. |
| 5.992 | 3.101 | 1.777 | 3.275 | 16360. | 301. |
| 6.741 | 3.489 | 1.750 | 3.221 | 20365. | 421. |
| 7.490 | 3.877 | 1.726 | 3.162 | 24683. | 568. |
| 8.239 | 4.264 | 1.705 | 3.127 | 29538. | 747. |
| 8.987 | 4.652 | 1.686 | 3.239 | 36411. | 1005. |
| 9.736 | 5.040 | 1.668 | 3.337 | 44019. | 1316. |
| 10.485 | 5.427 | 1.653 | 3.471 | 53110. | 1710. |
| 11.234 | 5.815 | 1.638 | 3.603 | 63280. | 2183. |
| 11.983 | 6.203 | 1.625 | 3.766 | 75253. | 2768. |
| 12.732 | 6.590 | 1.613 | 3.930 | 88655. | 3465. |

| VK | EHP | SLR | FROUDE NO. | RR/DISP | RT/DISP |
|---|---|---|---|---|---|
| 5.243 | 207. | 0.265 | 0.079 | 0.240 | 0.702 |
| 5.992 | 301. | 0.303 | 0.090 | 0.300 | 0.894 |
| 6.741 | 421. | 0.340 | 0.101 | 0.370 | 1.113 |
| 7.490 | 568. | 0.378 | 0.113 | 0.442 | 1.350 |
| 8.239 | 747. | 0.416 | 0.124 | 0.528 | 1.615 |
| 8.987 | 1005. | 0.454 | 0.135 | 0.709 | 1.991 |
| 9.736 | 1316. | 0.492 | 0.146 | 0.915 | 2.407 |
| 10.485 | 1710. | 0.530 | 0.158 | 1.187 | 2.904 |
| 11.234 | 2183. | 0.567 | 0.169 | 1.502 | 3.460 |
| 11.983 | 2768. | 0.605 | 0.180 | 1.902 | 4.114 |
| 12.732 | 3465. | 0.643 | 0.191 | 2.365 | 4.847 |

L. R. Glosten & Assoc.
Model 1331
Full Load t=20'-0"
Stable condition P/S=20°

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# EXTRAPOLATION OF MODEL TEST DATA

## SHIP DATA

| | | | | | |
|---|---|---|---|---|---|
| MODEL NO. | 1331 | LWL | 392.00 | DISP LTSW | 18300. |
| CONDITION: | STABLE | BEAM | 100.00 | WET'D SURF | 50740. |
| LAMBDA | 40.000 | DRAFT FWD | 20.00 | TEMP | 59.00 |
| FRICTION LINE | ATTC | DRAFT AFT | 20.00 | RHO | 1.9905 |
| CORR. ALLOW. | 0.00040 | BLOCK COEF. | 0.816 | NU*10**5 | 1.27908 |

| VK | RNS/10**8 | CFS*1000 | CTS*1000 | RTS | EHP |
|---|---|---|---|---|---|
| 5.243 | 2.714 | 1.808 | 5.345 | 20953. | 337. |
| 5.992 | 3.101 | 1.777 | 5.153 | 26386. | 485. |
| 6.741 | 3.489 | 1.750 | 5.089 | 32977. | 682. |
| 7.490 | 3.877 | 1.726 | 5.102 | 40817. | 939. |
| 8.239 | 4.264 | 1.705 | 5.151 | 49868. | 1261. |
| 8.987 | 4.652 | 1.686 | 5.229 | 60237. | 1662. |
| 9.736 | 5.040 | 1.668 | 5.315 | 71860. | 2148. |
| 10.485 | 5.427 | 1.653 | 5.391 | 84535. | 2721. |
| 11.234 | 5.815 | 1.638 | 5.468 | 98420. | 3394. |
| 11.983 | 6.203 | 1.625 | 5.561 | 113901. | 4190. |
| 12.732 | 6.590 | 1.613 | 5.673 | 131158. | 5127. |

| VK | EHP | SLR | FROUDE NO. | RR/DISP | RT/DISP |
|---|---|---|---|---|---|
| 5.243 | 337. | 0.265 | 0.079 | 0.672 | 1.145 |
| 5.992 | 485. | 0.303 | 0.090 | 0.833 | 1.442 |
| 6.741 | 682. | 0.340 | 0.101 | 1.041 | 1.802 |
| 7.490 | 939. | 0.378 | 0.113 | 1.301 | 2.230 |
| 8.239 | 1261. | 0.416 | 0.124 | 1.612 | 2.725 |
| 8.987 | 1662. | 0.454 | 0.135 | 1.979 | 3.292 |
| 9.736 | 2148. | 0.492 | 0.146 | 2.399 | 3.927 |
| 10.485 | 2721. | 0.530 | 0.158 | 2.861 | 4.619 |
| 11.234 | 3394. | 0.567 | 0.169 | 3.373 | 5.378 |
| 11.983 | 4190. | 0.605 | 0.180 | 3.958 | 6.224 |
| 12.732 | 5127. | 0.643 | 0.191 | 4.624 | 7.167 |

L.R. Glosten & Assoc.
Model 1331
Full Load
Stable Condition P/S=13°

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EXTRAPOLATION OF MODEL TEST DATA

SHIP DATA

| | | | | | |
|---|---|---|---|---|---|
| MODEL NO. | 1331 | LWL | 392.00 | DISP LTSW | 18290. |
| CONDITION: | STABLE 2 | BEAM | 100.00 | WET'D SURF | 50240. |
| LAMBDA | 40.000 | DRAFT FWD | 20.00 | TEMP | 59.00 |
| FRICTION LINE | ATTC | DRAFT AFT | 20.00 | RHO | 1.9905 |
| CORR. ALLOW. | 0.00040 | BLOCK COEF. | 0.816 | NU*10**5 | 1.27908 |

| VK | RNS/10**8 | CFS*1000 | CTS*1000 | RTS | EHP |
|---|---|---|---|---|---|
| 5.243 | 2.714 | 1.808 | 4.648 | 18219. | 293. |
| 5.992 | 3.101 | 1.777 | 4.587 | 23488. | 432. |
| 6.741 | 3.489 | 1.750 | 4.579 | 29672. | 614. |
| 7.490 | 3.877 | 1.726 | 4.605 | 36843. | 847. |
| 8.239 | 4.264 | 1.705 | 4.668 | 45186. | 1143. |
| 8.987 | 4.652 | 1.686 | 4.906 | 56522. | 1560. |
| 9.736 | 5.040 | 1.668 | 4.956 | 67011. | 2003. |
| 10.485 | 5.427 | 1.653 | 5.023 | 78756. | 2535. |
| 11.234 | 5.815 | 1.638 | 5.139 | 92498. | 3190. |
| 11.983 | 6.203 | 1.625 | 5.216 | 106825. | 3930. |
| 12.732 | 6.590 | 1.613 | 5.324 | 123094. | 4811. |

| VK | EHP | SLR | FROUDE NO. | RR/DISP | RT/DISP |
|---|---|---|---|---|---|
| 5.243 | 293. | 0.265 | 0.079 | 0.523 | 0.996 |
| 5.992 | 432. | 0.303 | 0.090 | 0.675 | 1.284 |
| 6.741 | 614. | 0.340 | 0.101 | 0.861 | 1.622 |
| 7.490 | 847. | 0.378 | 0.113 | 1.085 | 2.014 |
| 8.239 | 1143. | 0.416 | 0.124 | 1.357 | 2.471 |
| 8.987 | 1560. | 0.454 | 0.135 | 1.777 | 3.090 |
| 9.736 | 2003. | 0.492 | 0.146 | 2.135 | 3.664 |
| 10.485 | 2535. | 0.530 | 0.158 | 2.546 | 4.306 |
| 11.234 | 3190. | 0.567 | 0.169 | 3.051 | 5.057 |
| 11.983 | 3930. | 0.605 | 0.180 | 3.573 | 5.841 |
| 12.732 | 4811. | 0.643 | 0.191 | 4.186 | 6.730 |

STOP OR GO

L. R. Glosten & Assoc.
Model 1331
Medium Ballast t=16'-0"
Stable Condition P/S=20°

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EXTRAPOLATION OF MODEL TEST DATA

SHIP DATA

| | | | | | |
|---|---|---|---|---|---|
| MODEL NO. | 1331 | LWL | 384.24 | DISP LTSW | 14130. |
| CONDITION: | STABLE | BEAM | 100.00 | WET'D SURF | 45920. |
| LAMBDA | 40.000 | DRAFT FWD | 16.00 | TEMP | 59.00 |
| FRICTION LINE | ATTC | DRAFT AFT | 16.00 | RHO | 1.9905 |
| CORR. ALLOW. | 0.00040 | BLOCK COEF. | 0.804 | NU*10**5 | 1.27908 |

| VK | RNS/10**3 | CFS*1000 | CTS*1000 | RTS | EHP |
|---|---|---|---|---|---|
| 5.243 | 2.660 | 1.813 | 4.117 | 14752. | 237. |
| 5.992 | 3.040 | 1.781 | 4.060 | 18998. | 349. |
| 6.741 | 3.420 | 1.754 | 4.063 | 24065. | 498. |
| 7.490 | 3.800 | 1.730 | 4.112 | 30070. | 691. |
| 8.239 | 4.180 | 1.709 | 4.173 | 36923. | 934. |
| 8.987 | 4.560 | 1.690 | 4.243 | 44680. | 1233. |
| 9.736 | 4.940 | 1.673 | 4.316 | 53340. | 1594. |
| 10.485 | 5.320 | 1.657 | 4.400 | 63065. | 2030. |
| 11.234 | 5.700 | 1.642 | 4.481 | 73730. | 2543. |
| 11.983 | 6.080 | 1.629 | 4.560 | 85358. | 3140. |
| 12.732 | 6.460 | 1.617 | 4.651 | 98278. | 3842. |

| VK | EHP | SLR | FROUDE NO. | RR/DISP | RT/DISP |
|---|---|---|---|---|---|
| 5.243 | 237. | 0.267 | 0.080 | 0.483 | 1.044 |
| 5.992 | 349. | 0.306 | 0.091 | 0.622 | 1.345 |
| 6.741 | 498. | 0.344 | 0.102 | 0.800 | 1.703 |
| 7.490 | 691. | 0.382 | 0.114 | 1.026 | 2.128 |
| 8.239 | 934. | 0.420 | 0.125 | 1.293 | 2.613 |
| 8.987 | 1233. | 0.458 | 0.137 | 1.605 | 3.162 |
| 9.736 | 1594. | 0.497 | 0.148 | 1.962 | 3.775 |
| 10.485 | 2030. | 0.535 | 0.159 | 2.377 | 4.463 |
| 11.234 | 2543. | 0.573 | 0.171 | 2.840 | 5.218 |
| 11.983 | 3140. | 0.611 | 0.182 | 3.353 | 6.041 |
| 12.732 | 3842. | 0.650 | 0.193 | 3.939 | 6.955 |

L. R. Glosten & Assoc.
Model 1331
Light Ballast t=9'-0"
Stable Condition P/S=20°

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## EXTRAPOLATION OF MODEL TEST DATA

### SHIP DATA

| | | | | | |
|---|---|---|---|---|---|
| MODEL NO. | 1331 | LWL | 353.00 | DISP LTSW | 7220. |
| CONDITION: | STABLE | BEAM | 100.00 | WET'D SURF | 37712. |
| LAMBDA | 40.000 | DRAFT FWD | 9.00 | TEMP | 59.00 |
| FRICTION LINE | ATTC | DRAFT AFT | 9.00 | RHO | 1.9905 |
| CORR. ALLOW. | 0.00040 | BLOCK COEF. | 0.795 | NU*10**5 | 1.27908 |

| VK | RNS/10**8 | CFS*1000 | CTS*1000 | RTS | EHP |
|---|---|---|---|---|---|
| 5.243 | 2.444 | 1.834 | 3.323 | 9777. | 157. |
| 5.992 | 2.793 | 1.801 | 3.230 | 12413. | 228. |
| 6.741 | 3.142 | 1.774 | 3.205 | 15588. | 323. |
| 7.490 | 3.491 | 1.749 | 3.246 | 19491. | 448. |
| 8.239 | 3.840 | 1.728 | 3.302 | 23994. | 607. |
| 8.987 | 4.189 | 1.709 | 3.366 | 29110. | 803. |
| 9.736 | 4.538 | 1.691 | 3.466 | 35172. | 1051. |
| 10.485 | 4.887 | 1.675 | 3.557 | 41867. | 1348. |
| 11.234 | 5.236 | 1.660 | 3.672 | 49611. | 1711. |
| 11.983 | 5.585 | 1.647 | 3.775 | 58035. | 2135. |
| 12.732 | 5.935 | 1.634 | 3.894 | 67575. | 2641. |

| VK | EHP | SLR FROUDE NO. | | RR/DISP | RT/DISP |
|---|---|---|---|---|---|
| 5.243 | 157. | 0.279 | 0.083 | 0.444 | 1.354 |
| 5.992 | 228. | 0.319 | 0.095 | 0.547 | 1.719 |
| 6.741 | 323. | 0.359 | 0.107 | 0.695 | 2.159 |
| 7.490 | 448. | 0.399 | 0.119 | 0.912 | 2.700 |
| 8.239 | 607. | 0.438 | 0.131 | 1.182 | 3.323 |
| 8.987 | 803. | 0.478 | 0.142 | 1.506 | 4.032 |
| 9.736 | 1051. | 0.518 | 0.154 | 1.932 | 4.871 |
| 10.485 | 1348. | 0.558 | 0.166 | 2.416 | 5.799 |
| 11.234 | 1711. | 0.598 | 0.178 | 3.016 | 6.871 |
| 11.983 | 2135. | 0.638 | 0.190 | 3.680 | 8.038 |
| 12.732 | 2641. | 0.678 | 0.202 | 4.470 | 9.359 |