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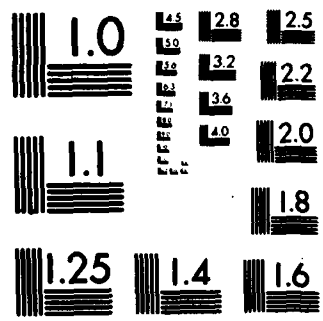


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College of Engineering
Department of Naval Architecture and Marine Engineering
Ship Hydrodynamics Laboratory



# Relationship of Underkeel Clearance and Vessel Speed to Groundings



Armin W. Troesch PhD., PE
Project Director

Stuart Cohen
Principal Investigator



for
Comdr. 2nd USCG District (DCW)
St. Louis, MO



April, 1980

Model 1427

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# ABSTRACT

The sinkage, trim, and underkeel clearance of the lead barges in a 3 x 3 barge train were measured. The barges represented typical Mississippi River barges. The tests were conducted in response to a USCG request to investigate groundings due to channel depth decreases. The water depth varied from 2.6 to 1.05 times the barges' draft. There were two bottom contours: one with constant depth, and one with an underwater obstacle in the form of a step. The speed of the barge train was varied from 2 kts to 8 kts, full scale.

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## Symbols and Abbreviations

| | |
|---|---|
| L | Vessel Length (ft) |
| B | Vessel Beam (ft) |
| T | Vessel Draft (ft) |
| $h_1$ | Water Depth in Flat Bottom Test (ft) |
| $h_2$ | Water Depth Over Step in Stepped Test (ft) |
| b | Step Height (ft) |
| $S_x$ | Sinkage of Lead Barge at $x$ (ft) |
| $\theta$ | Trim Angle of Lead Barge (deg) |
| A | Under Keel Clearance of Lead Barge (ft) |

## List of Figures

### Relationship of Underkeel Clearance and Vessel Speed to Groundings

THE UNIVERSIT ? MICHIGAN

NA&ME BUILDING, NORTH CAMPUS
ANN ARBOR, MICHIGAN 48109
(313) 764-6470

April 18, 1980

CDR R.C. Walton
Second Coast Guard District
Transportation Work Group
1430 Olive St.
St. Louis, MO 63103

Dear CDR Walton:

As requested by you in our telephone conversation of April 14, I have reviewed Figures 5, 6, and 7 of the report "Relationship of Underkeel Clearance and Vessel Speed to Groundings." The stepped bottom tests were run at depths over the step ($h_2$) of 10, 11, 13, and 18 ft. The results for the 10 ft depth were plotted in Figure 7 only. The sinkage and trim results for $h_2$=10 ft plotted on top of the other curves in the low speed range making adequate resolution impossible. Consequently, only Figure 7 shows the test condition $h_2$=10 ft.

When extrapolating the experimental results to actual full scale conditions, care must be taken to account for the differences between the laboratory and outside environment. For example, the tank bottom consisted of poured concrete, covered with a protective paint covering. It is unlikely that this kind of surface will occur in the river. Variations in the actual river bottom contour, and changes in its makeup should be considered when using the test results for full scale applications.

If you have any further questions on the study, I will be happy to hear them.

Sincerely yours,

Armin Troesch

Armin Troesch
Assistant Professor

AWT/pb

## SUMMARY OF RESULTS

Three models of a standard 1 x 3 barge flotilla were made of wood. An individual barge had a full scale length of 195 ft, a beam of 35 ft, and a draft of 9 ft. Figure 1 shows a side sketch of the type of barge used. The three models were connected to each other by stiff rubber bands; the intent being to approximate the elastic behavior of typical connecting cables.

Figure 2 defines the paramaters of the experiment. In all cases, the length, L, was 195 ft and the draft, T, was 9 ft. The depth of the water over the level bottom, $h_1$, varied from 24 ft to 9.5 ft. The depth over the step, $h_2$, varied from 18 ft to 10 ft. The step height, b, was 8 ft. Two types of tests were conducted. One, the "flat bottom" test, had the depth, $h_1$, remain a constant over the entire test length. This represented a steady state condition. The second, the "stepped bottom" test, had the barge train approach a step where the water depth decreased suddenly by 8 ft. This test represented a transient condition.

Figure 3 shows the quantities that are given as measured results. The sinkage at the midships of the lead barge is $S_M$. Positive sinkage is defined as an increase in draft. The trim of the lead barge is $\theta$. Positive trim is represented by the bow down condition. The clearance between the bow of the lead barge and the bottom is A. For the flat bottom tests, A was constant after the steady state condition was reached. For the stepped bottom, A changed continually over the test section. A typical transient record is shown in Figure 4. Also, included for comparison is a steady state record for the case when the flat bottom depth was the same as that for the stepped depth. In plotting the results for the transient tests, the maximum value was used.

Figure 5 is a plot of $S_{\phi}$, the sinkage at midships in feet, of the lead barge. The sinkage is plotted as a function of barge velocity. The solid line represents the steady state, flat bottom tests and the dashed line represents the transient, stepped bottom tests. The various water depths are labeled.

Figure 6 is a plot of $\theta$, the pitch angle of the lead barge in degrees. It is plotted as a function of velocity in miles per hour. The transient and stepped bottom tests are labeled as described above.

Figure 7 shows the clearance under the bow of the lead barge in feet. The labeling is consistent with Figures 5 and 6.

A general trend shown in Figures 5, 6, and 7 is that the underkeel clearance resulting from sinkage and trim decreased at a faster rate as water depth decreased or the forward speed increased.

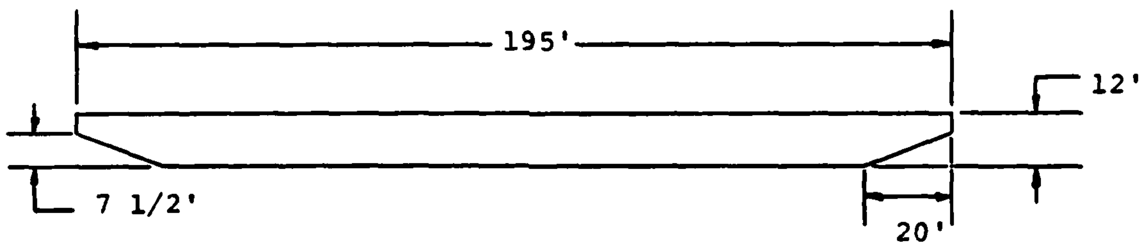


Figure 1: Full Scale Dimensions of Barge Type Tested

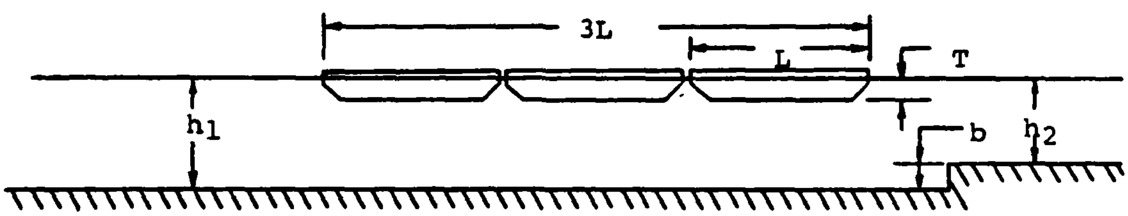


Figure 2: Definition of Test Parameters

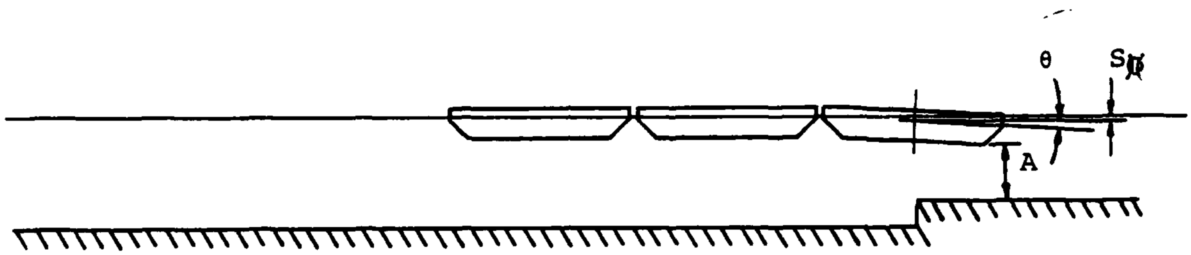


Figure 3: Quantities Measured

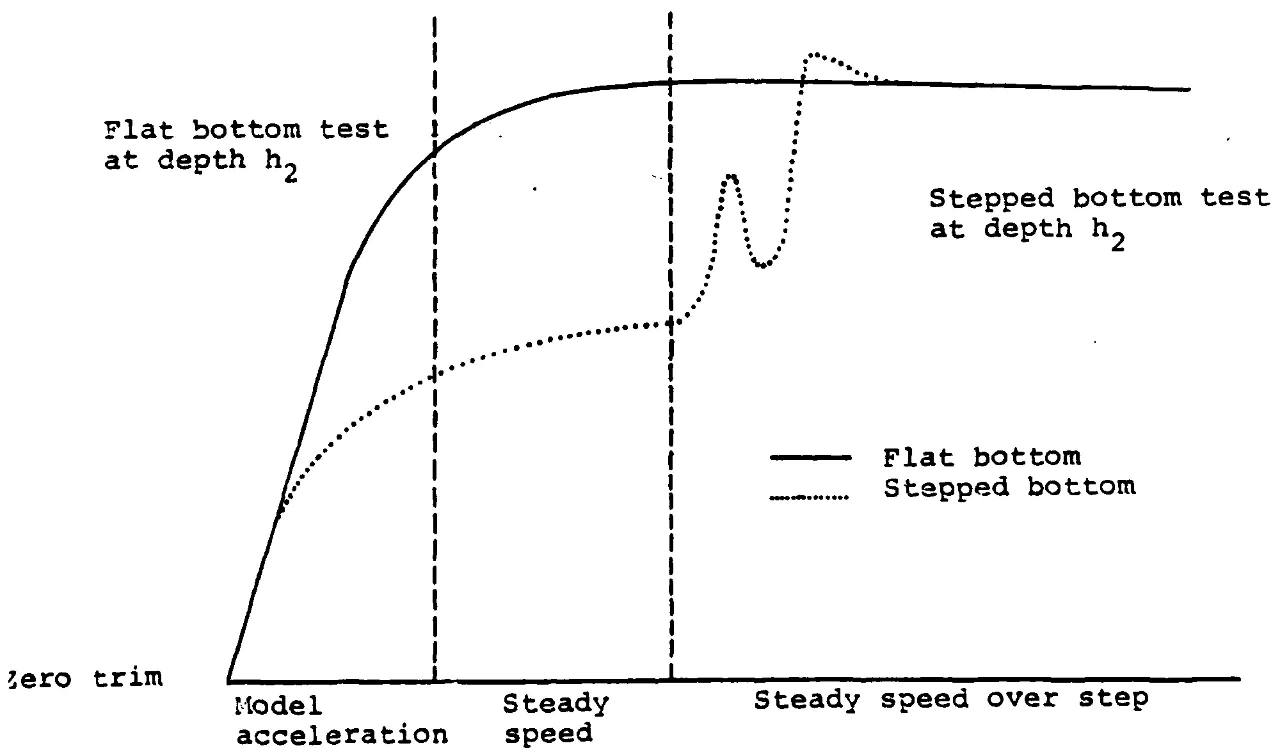


Figure 4: Typical Test Records

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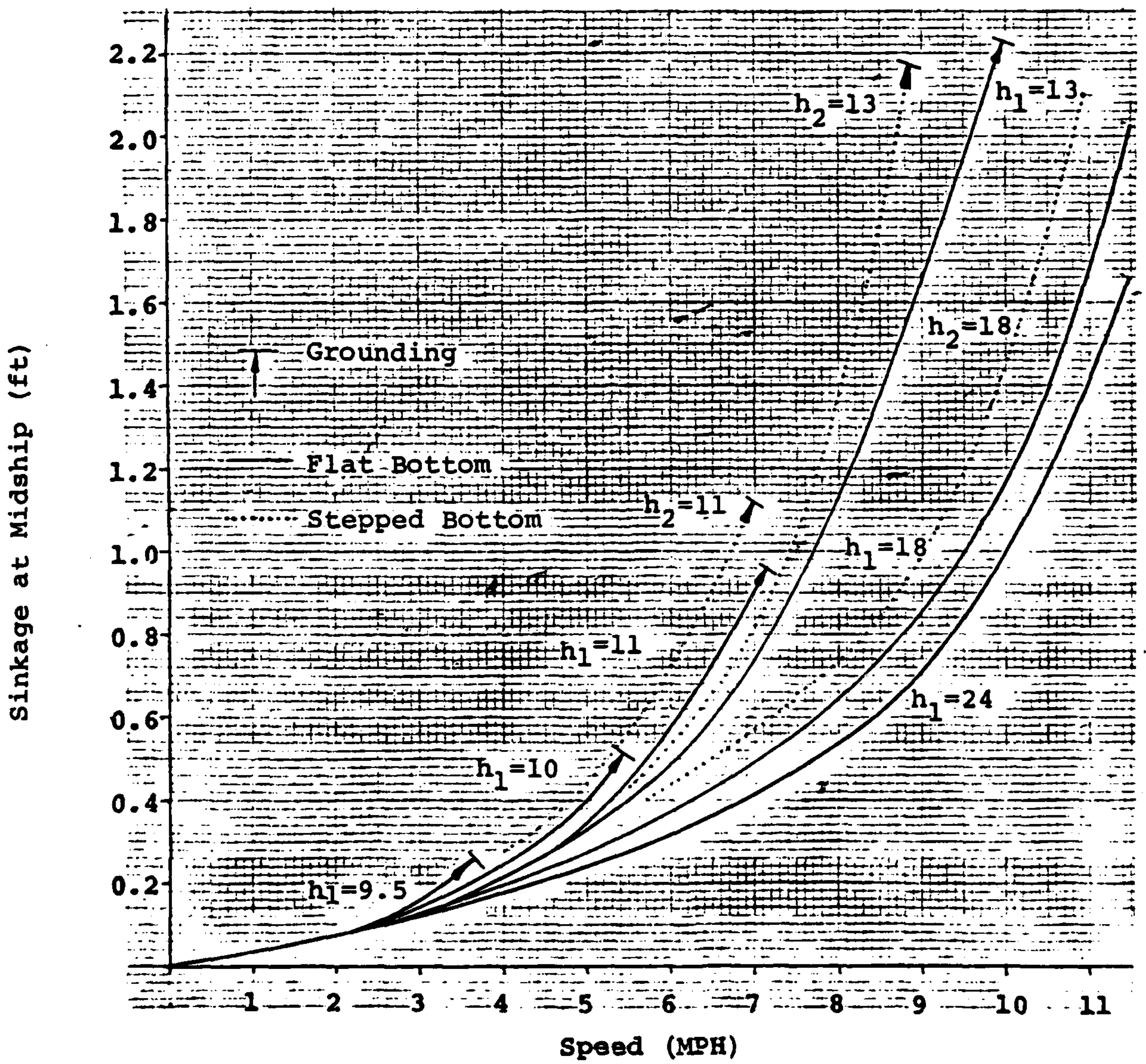


Figure 5: Sinkage of Lead Barge in a 3 x 3 Barge Flotilla (Model 1427)

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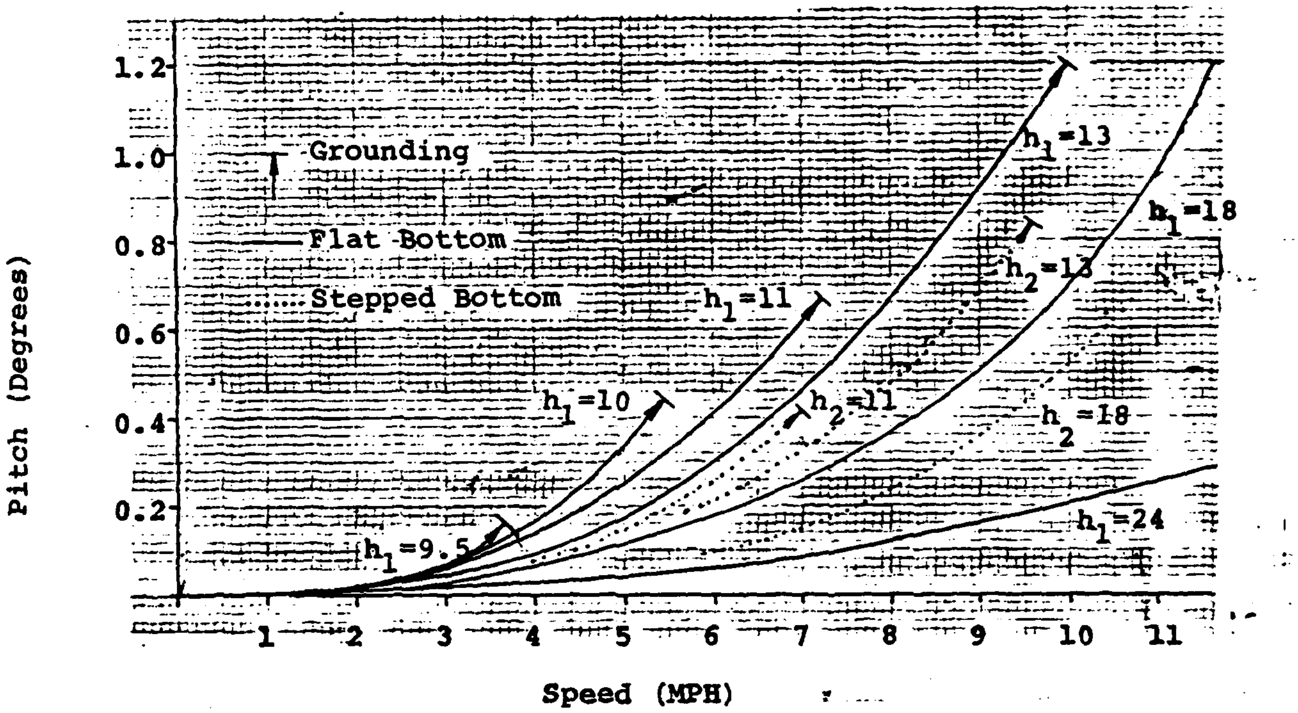


Figure 6: Pitch Angle of Lead Barge in a 3 x 3 Barge Flotilla (Model 1427)

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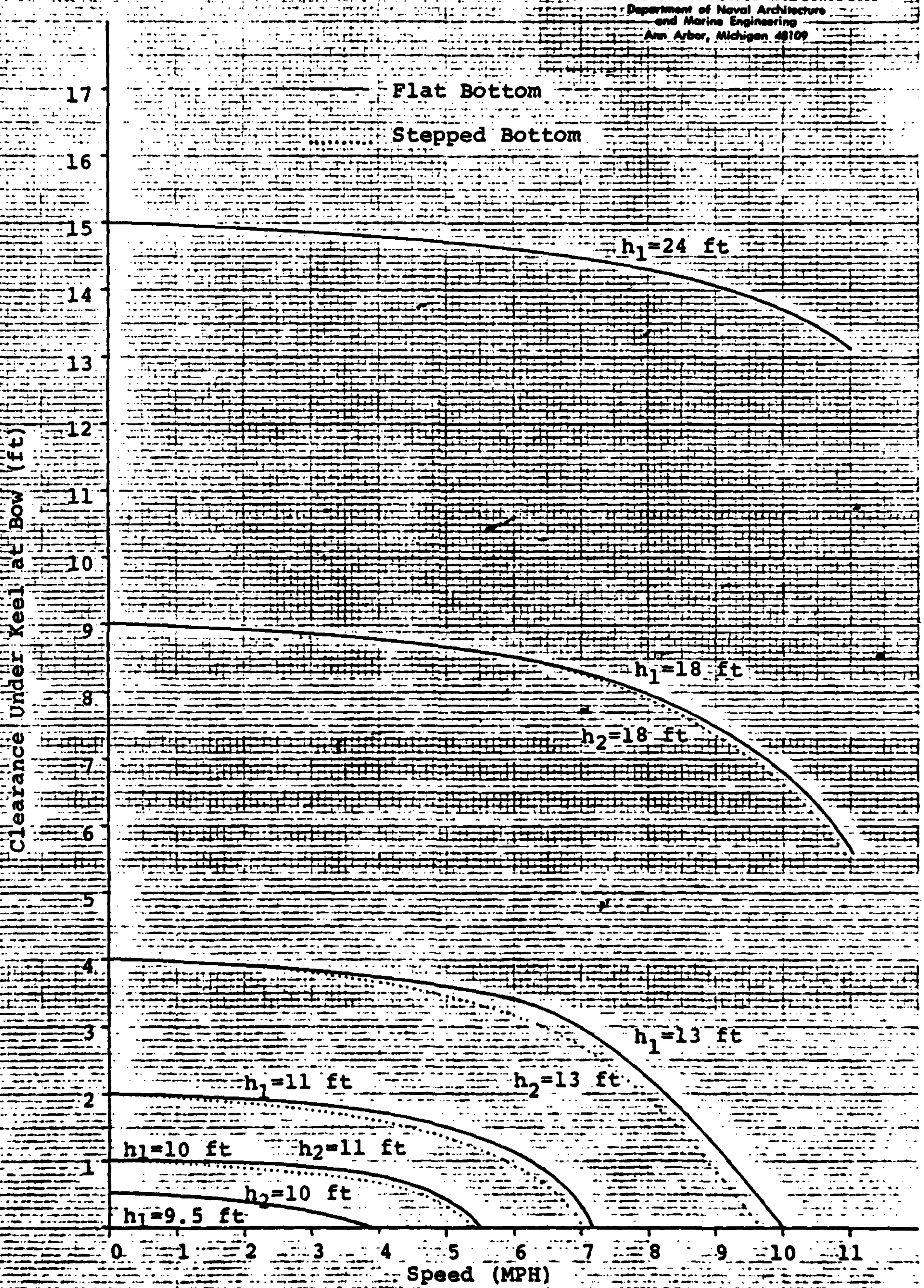


Figure 7: Underkeel Clearance of Lead Barge in a 3 x 3 Barge Flotilla (Model 1427)

# DISCUSSION OF TEST PROCEDURES AND RESULTS

The barge train was towed from a point located at the center of gravity of the lead barge. The tow point was in the same plane as the deck level. This configuration was chosen to minimize the influence of the tow force on the sinkage and trim measurements.

The method of connecting the barges together posed a particular problem. If the connection were completely rigid, then the train would behave as one large barge. This is physically unrealistic. Cables are generally elastic and act as springs. In order to include this behavior in a qualitative sense, rubber bands were selected as the connection mechanism. No effort was made to actually match the spring constants of the model to full scale. The only criterion for the selection of the stiffness was to keep the three barge train sections in contact during the acceleration of the models at the start of the test.

The transient test results indicate the influence of the trailing barges on the lead barge. The underkeel clearance of the lead barge in the transient test was smaller than that measured in the steady state test. Specifically, when A from a transient test in a water depth over the step of $h_2$ is compared to A of a steady state test of depth $h_1=h_2$, the transient value is smaller. It slowly approaches the steady state value as the trailing barges cross over the step. The exact nature of this interaction is unclear and merits further study.