

AD 637838

CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION			
Hardcopy	Microfiche		
\$2.00	\$.50	44	7X
PP			
1 ARCHIVE COPY			

UNIVERSITY OF CALIFORNIA SCRIPPS INSTITUTION OF OCEANOGRAPHY

Model Studies for an
Oceanographic Ship
Derived from an
Offshore Supply Vessel

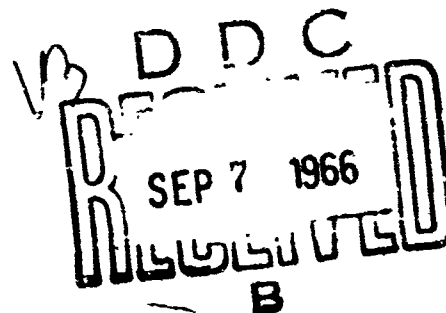
by

J. R. Paulling, Jr.
and
Maxwell Silverman

Supported by
Faculty Research Grant
University of California, Berkeley
and
Contract Nonr 2216(23)

SIO REFERENCE 66-19
18 August 1966

Distribution of this
document is unlimited.



UNIVERSITY OF CALIFORNIA BERKELEY

and

SCRIPPS INSTITUTION OF OCEANOGRAPHY

Model Studies for an Oceanographic Ship
Derived from an Offshore Supply Vessel

by
J. R. Paulling, Jr.
and
Maxwell Silverman

Sponsored by

Office of Naval Research
Department of the Navy
Washington, D. C.
Contract Nonr 2216(23)

Faculty Research grant
University of California,
Berkeley

SIO REFERENCE 66-19

18 August 1966

Approved for distribution


William A. Nierenberg
Director

Reproduction in whole or in part is permitted for any
purpose of the United States Government.
Distribution of this document is unlimited.

MODEL STUDIES FOR AN OCEANOGRAPHIC SHIP
DERIVED FROM AN OFFSHORE SUPPLY VESSEL

by

J. R. Paulling, Jr.¹

Maxwell Silverman²

¹Associate Professor, Department of Naval Architecture,
University of California, Berkeley, California

²Associate Engineer, Scripps Institution of Oceanography,
University of California, San Diego, La Jolla, California

ABSTRACT

During the last few years, a number of operators of oceanographic research ships have considered the Gulf Coast offshore oil well supply vessel type for possible conversion to a research vessel. Such a ship of 155 to 165 feet length offers a number of attractive features, chiefly reduced operating costs, and space for mounting portable or interchangeable equipment. The vessels' principal disadvantages are reputedly a lack of seakindliness and limited stability.

An investigation of such vessels has recently been conducted by the Scripps Institution of Oceanography and the Department of Naval Architecture of the University of California. Model experiments were conducted to determine the resistance and powering characteristics, the motions in head seas, and rolling in beam seas. The transverse stability was computed for calm water and following seas. Four different hull forms were considered in these studies: one, a typical 155-foot long single chine supply boat; two, a round bilge version of the same; three, a single chine design developed to overcome several of the suspected deficiencies of form one while still retaining the principal proportions; and, four, an affine variation of one produced by multiplying transverse dimensions by 0.75 and increasing vertical dimensions by the same amount.

It is concluded that the most serious deficiency of the vessel type is the tendency to slam in a head sea. This may limit the maximum speed in head seas. The small saving in resistance exhibited by both the narrower and round bilge versions is insufficient to justify choosing either of these on this basis alone. In addition, both of these forms roll more severely than the two wide, single chine forms. Finally, the increased freeboard of the third form results in an ample margin of stability.

It is felt, therefore, that form three provides a suitable basis for developing a research ship design.

LIST OF SYMBOLS

<u>Symbol</u>	<u>Definition</u>
a	Wave height, trough to crest
A_t	Tangential acceleration at desk edge
b	Roll damping coefficient
B	Ship beam
f_e	Frequency of wave encounter cycles/second
GM	Metacentric height
k_x	Mass radius of gyration of ship plus "added mass" in roll
L	Length of ship
R	Non-dimensional amplitude of roll
Δ	Ship displacement
ζ	Non-dimensional roll damping coefficient
λ	Wave length
φ	Roll angle
ω	Circular frequency of wave or motion
Ω	Non-dimensional frequency

INTRODUCTION

Within the last several years oceanographers have been considering the applicability of the typical gulf coast large (155-165 foot l.o.a.) offshore oil rig supply vessel as a platform for oceanographic research service in the open ocean. This application has become increasingly attractive because:

1. The construction costs of the chine hull and simplified structure of this type vessel are extremely competitive when compared to recent prototype and follow-on research vessels of conventional type.
2. Typical supply vessels operate with minimal crews because of the simplified machinery plant and arrangement of the vessel. Since crew costs approximate forty per cent or so of research vessel operating costs at present, a reduction in this item results in a substantial reduction in total operational costs.
3. The large open deck area typical of the supply boat lends itself well to rapid interchange of scientific experiments and gear set up in advance in portable pods, structures, and vans.

At present, several commercial operators have modified and placed in service a number of such supply vessels for oceanographic and seismographic exploration, both in restricted waters and in the open ocean.

Nevertheless, oceanographers have been concerned with reported disadvantages of these supply vessels which conceivably would compromise the application of the vessel type to open

ocean research service. The first cause for concern is that the vessel class historically has been used for service within a hundred miles or so of land, while the usefulness of the vessel for oceanographic investigations would be severely limited by such a restriction. Other possible objections stem from:

1. A more limited range of transverse stability than is usual in narrower, deeper draft forms.
2. Less seakindly behavior than characteristic of more conventional ships. Several factors contribute to this including the shallow draft combined with flat sections forward which results in pounding in head seas, and a quicker roll resulting from the necessarily high initial GM.
3. Insufficient freeboard to meet new Coast Guard requirements for subdivision and damaged stability.

A joint program between the Scripps Institution of Oceanography and the Department of Naval Architecture at the University of California, Berkeley, was recently undertaken to investigate offshore supply vessels as research ships. This investigation had two principal objectives: first, to determine the reality and severity of the above deficiencies of the ship type, and, second, to determine the changes in hull form necessary and sufficient to overcome them without compromising the vessel's desirable characteristics. The study included both model tests and theoretical computations of vessel characteristics.

The direct application of this study is a Scripps proposed 165-foot oceanographic supply boat modification, intended as a potential replacement for an older war-built

vessel currently completing sixteen years of oceanographic service for Scripps. The replacement vessel is intended to perform the following functions:

1. Support general oceanographic research techniques such as coring, dredging, trawling, and water sampling from portable, van-supported laboratories. Scientific deck machinery and gear-handling apparatus would be readily removable through application of bolt-down fittings.
2. Perform shallow core drilling to an approximate total hole and water depth of 4,000 to 5,000 feet.
3. Perform seismic refraction operations utilizing large quantities of explosives.
4. Tow and service unpowered vehicles and platforms such as FLIP.

At the outset of this program, it was clearly neither possible nor desirable to test all variations in hull form which have been used in the supply vessel type. Instead, the procedure followed was to choose a typical hull form and to make several substantial modifications in it. Each modification was designed to overcome one or more of the specific deficiencies of this type. Four models were tested:

1. A standard supply vessel representative of many craft now in service. Lines drawings of a single-chine 154 foot long boat were provided by a major supply boat operator. This was designated model one.
2. Model two is a round bilge version of model one. In developing the lines, the same beam and section

areas were maintained but the draft is slightly reduced for the same displacement. Also, the average deadrise angle at each station is slightly less than that for the chine hull.

3. Model three is the Scripps version, a single chine hull having the same length and midship section as the parent form, model one. This version possesses:

a. Greater freeboard to enable the vessel to meet the requirement for a one-compartment standard of subdivision stipulated in new Coast Guard regulations for inspected oceanographic research vessels.

b. Deeper, fuller afterbody with drag. This serves a twofold purpose. First, it allows the vessel to employ a propeller diameter significantly greater than the five and one-half foot wheels common on supply vessels in this size range. This is necessary for efficient towing of FLIP-like vehicles which require bollard pulls of around 28,000 pounds. Second, drag is introduced to improve vessel controllability when on an oceanographic station with cables streamed.

c. A finer entrance and lengthened forecastle superstructure. This modification is incorporated in an attempt to provide drier decks forward as well as more accommodation space.

4. Model four is a single chine hull, developed by reducing all transverse dimensions of model one to 75% of their value and increasing vertical dimensions by

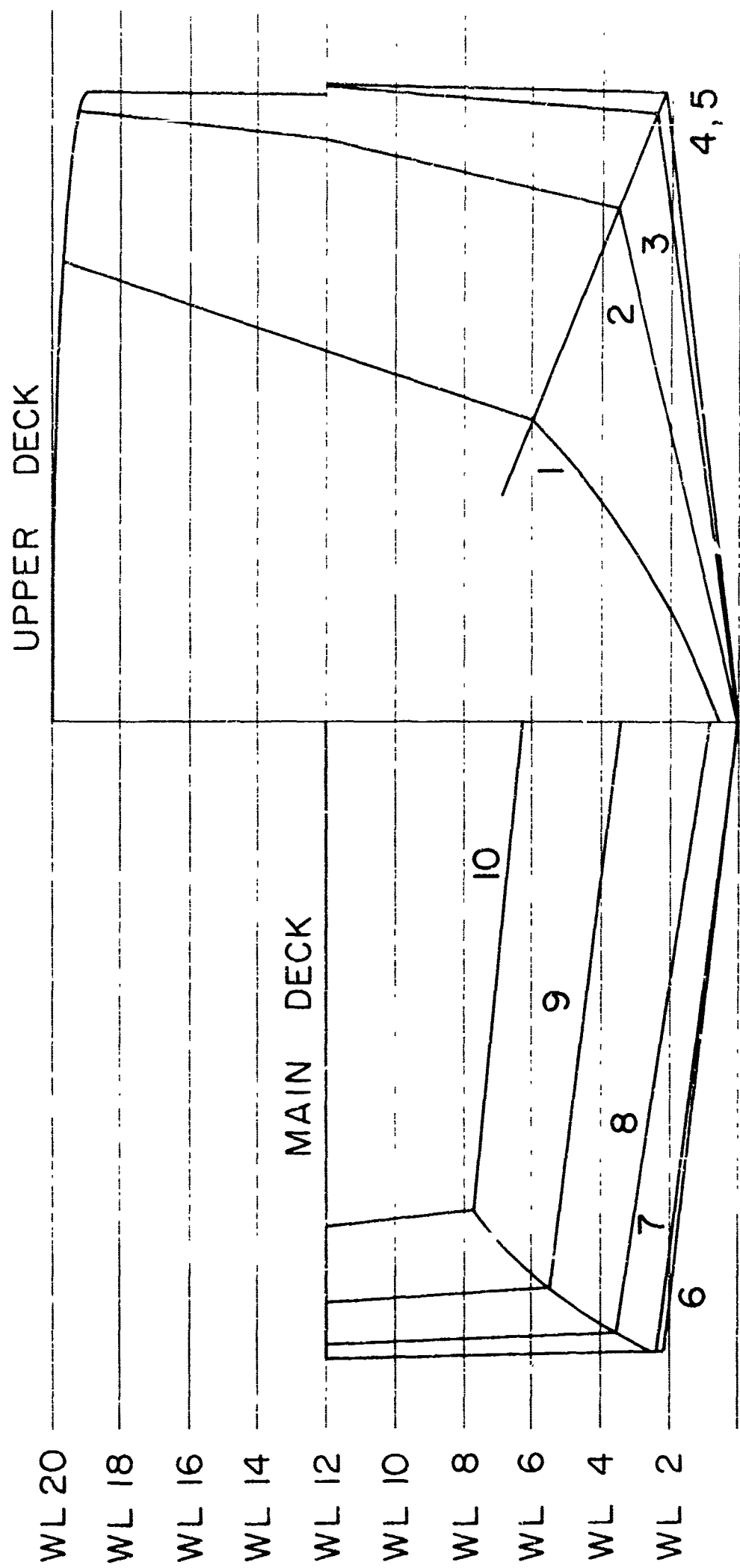


fig. 1
body plan
model 1

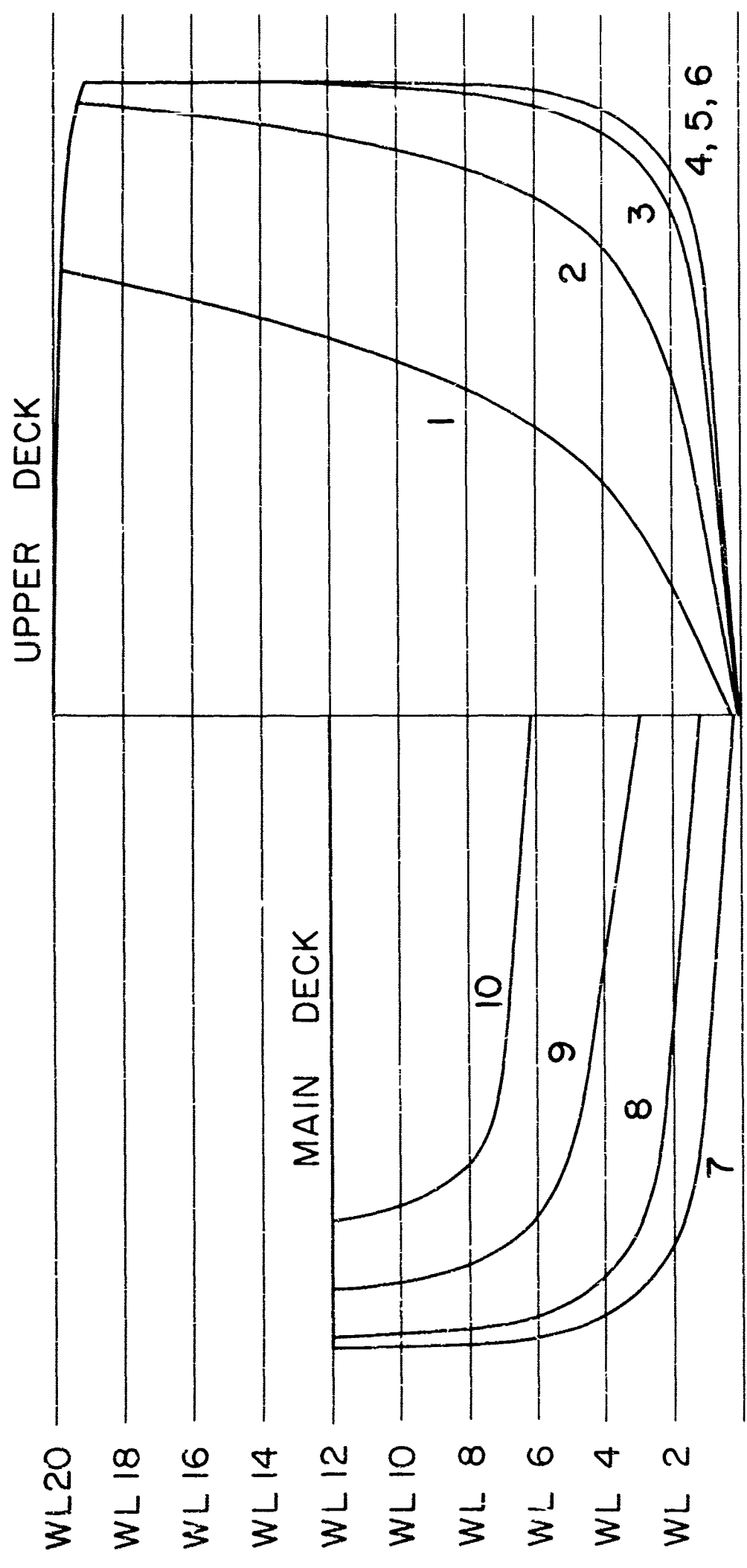


fig. 2
body plan
model 2

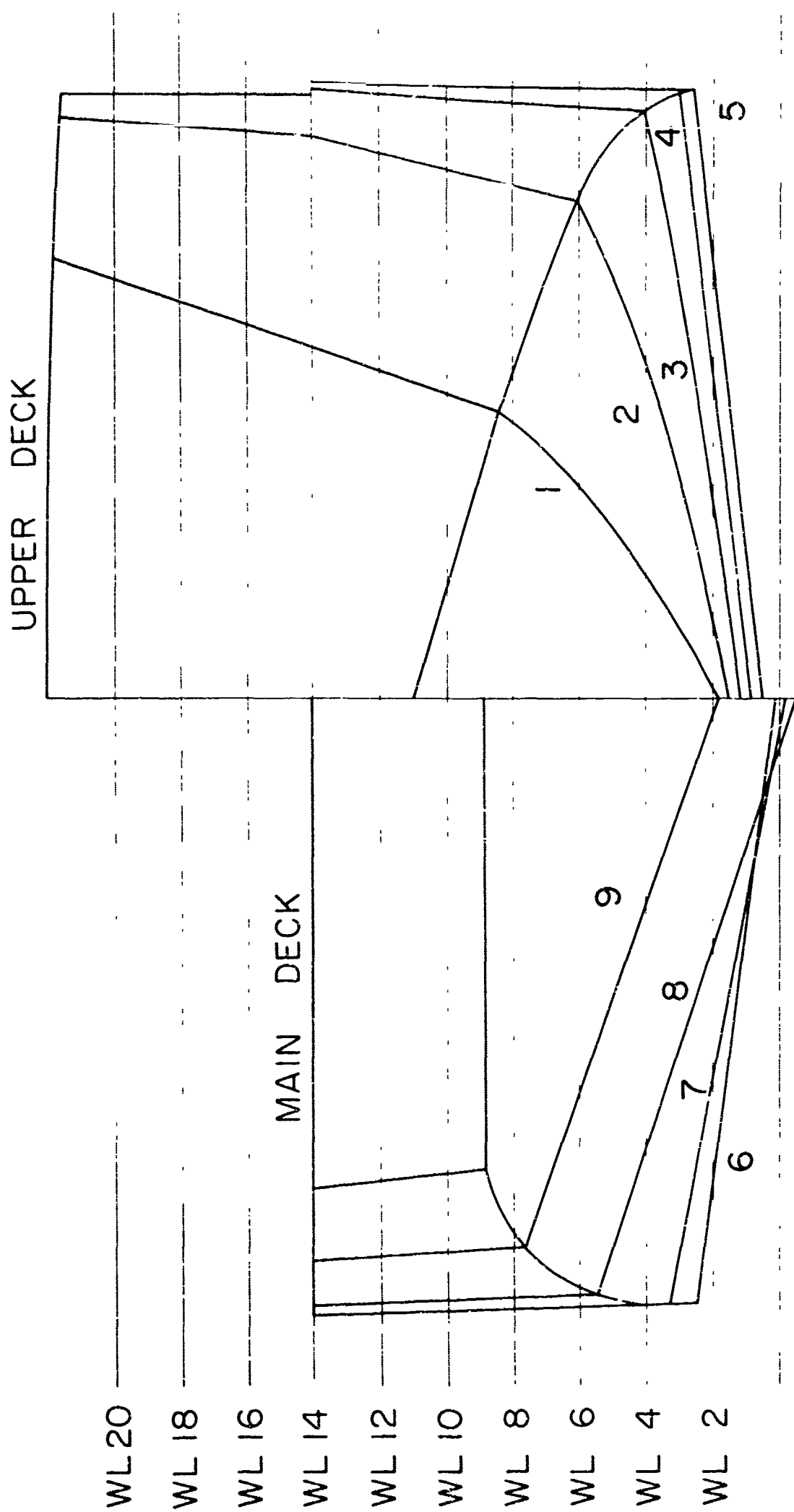


fig. 3
body plan
model 3

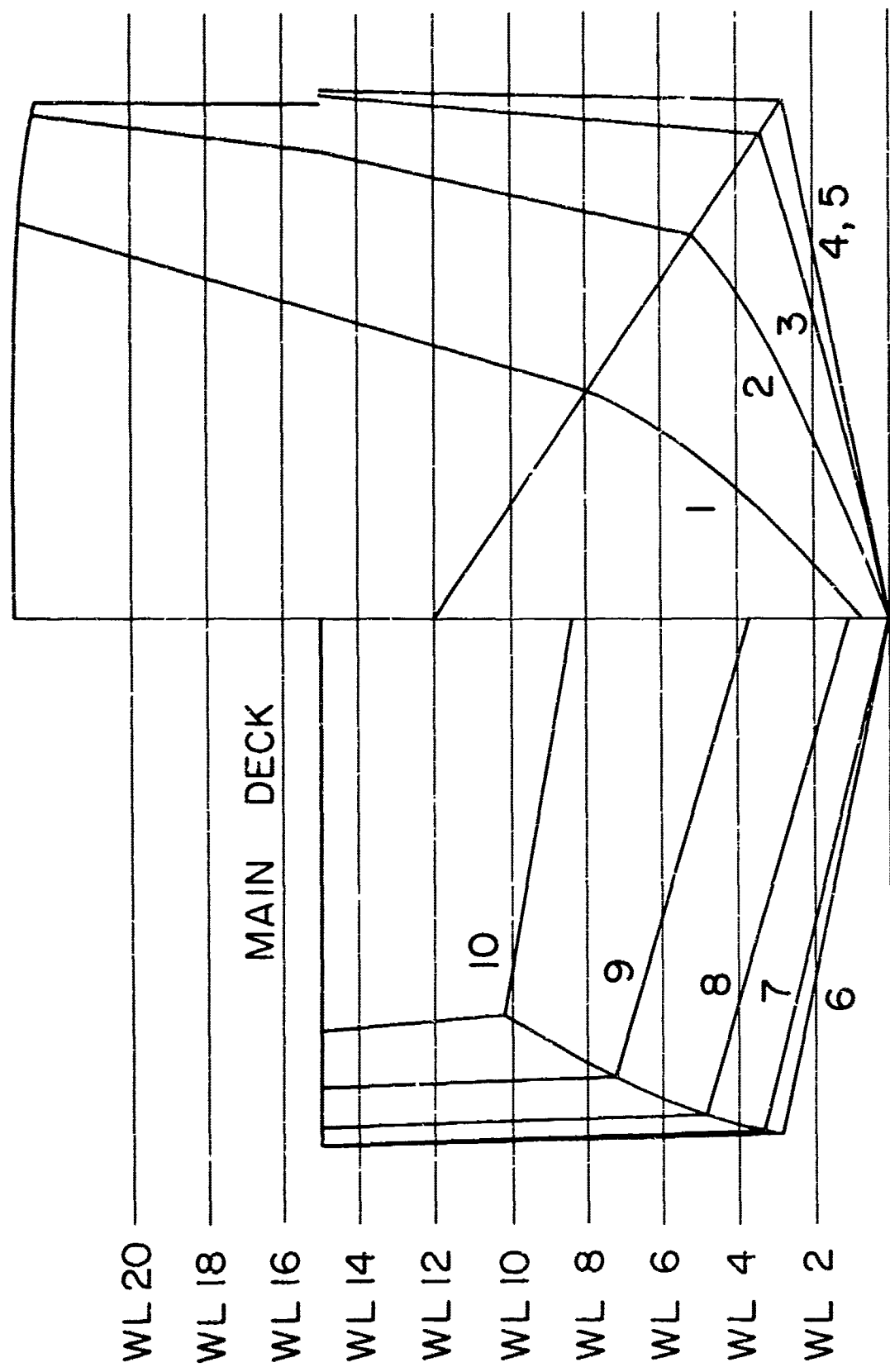
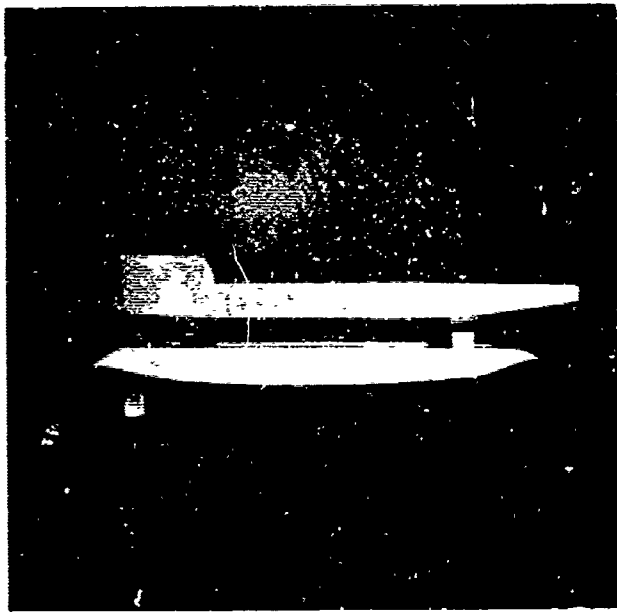
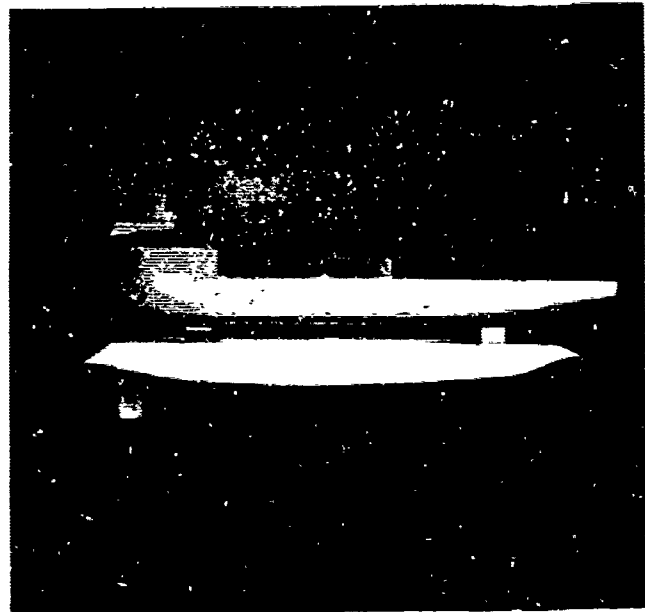


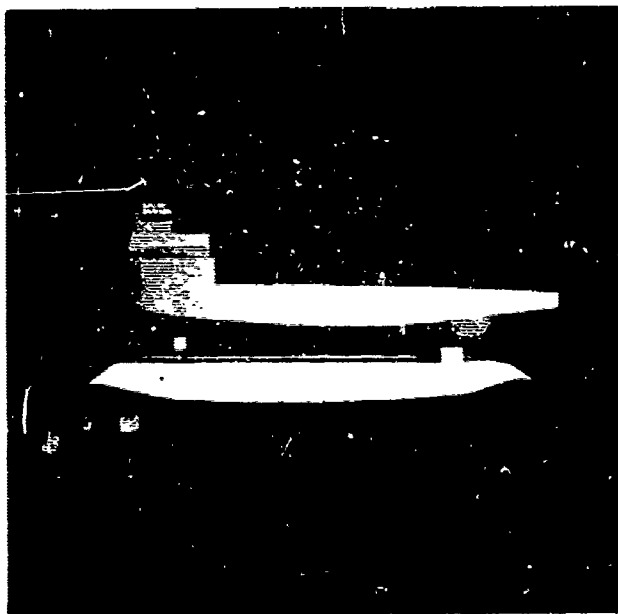
fig. 4
body plan
model 4



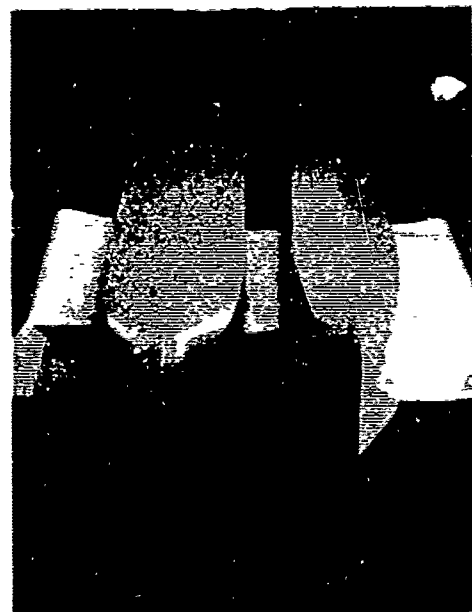
MODEL 1



MODEL 2



MODEL 3



MODEL 1 & 4

Fig. 5 Photographs of the four models

1/0.75, thus keeping the displacement and coefficients constant. The proportions of this form approximate those of a more conventional hull form.

Lengths of all four models were made the same.

The following tests were conducted:

1. Resistance and effective horsepower in calm water.
2. Motions, wetness, and slamming tendency in head seas.
3. Rolling in beam seas.

Transverse stability computations were carried out for the calm water and following sea conditions. Loading conditions for each test were chosen primarily for those situations which created the most severe requirement for the particular characteristic being investigated and, therefore, the test conditions are not necessarily consistent between resistance, motions, and rolling.

The model program was performed in the ship model towing tank of the Department of Naval Architecture of the University of California, Berkeley. The work was supported by the Office of Naval Research, Contract Nonr 2216/23 and a faculty research grant from the University of California, Berkeley. The authors wish to acknowledge the assistance of Messrs. Arun K. Dongre and George Nassopoulos, graduate students in the Department of Naval Architecture. Thanks are due to Mr. William Bright of Tidex, Inc., Morgan City, Louisiana, who supplied the lines of the parent form.

SMOOTH WATER RESISTANCE TESTS

Each model was tested at two displacements: 1082 and 944 tons. The higher of these was selected to represent a loading condition typical of supply boat service. The second, a reduction of about 15 per cent in displacement, is a more realistic upper limit of the displacement when the vessel is operated as a research ship. All tests were run at even keel drafts measured from the respective model's molded base line.

For turbulence stimulation, each model was fitted with a row of 3/32 inch diameter by 1/32 inch cylindrical studs spaced 1/2 inch apart around the girth at five per cent of the length abaft the forward perpendicular. Model resistance data were extrapolated to ship scale using the 1957 ITTC extrapolator and a ship roughness allowance of 0.0004. These results in the form of effective horsepower versus speed for the 154 foot long ship are shown in Figures 6 and 7.

At both displacements, the spread in the resistance and effective horsepowers among the four models is quite small. As expected, the molded form, model 2, and narrow form, model 4, exhibited the lowest values and were nearly equal at all speeds. The original supply boat, model 1, appears the worst at both displacements. Surprisingly, the Scripps modification, model 3, is nearly equal to the former two models at the light displacement. This is probably a result of the smaller transom immersion and finer entrance of this form.

For either research or supply service there appears little justification, on the basis of resistance alone, to choose the more expensive molded hull over the single chine

0117

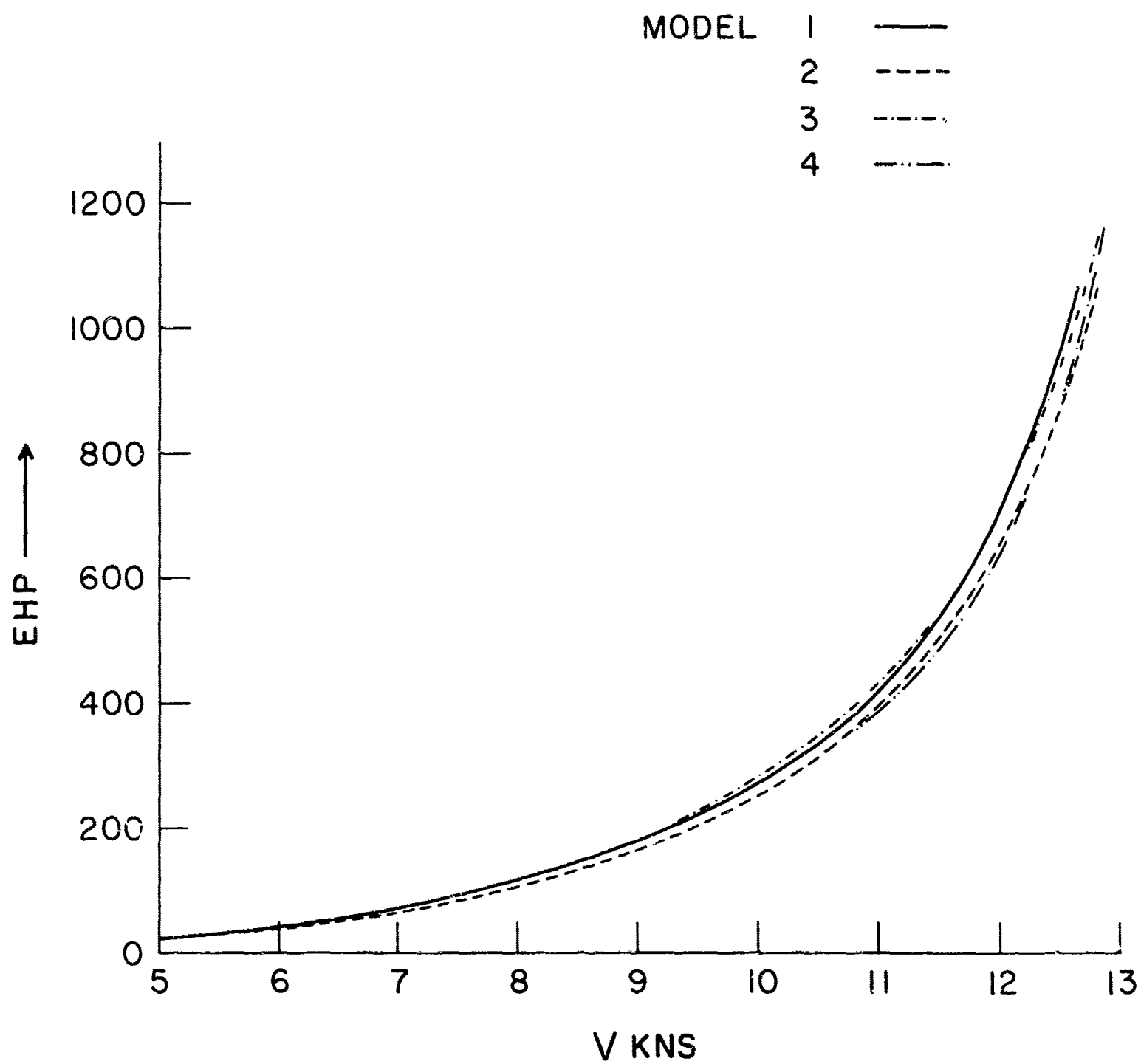


Fig. 6 Effective horsepower vs. speed at 1100 tons displacement

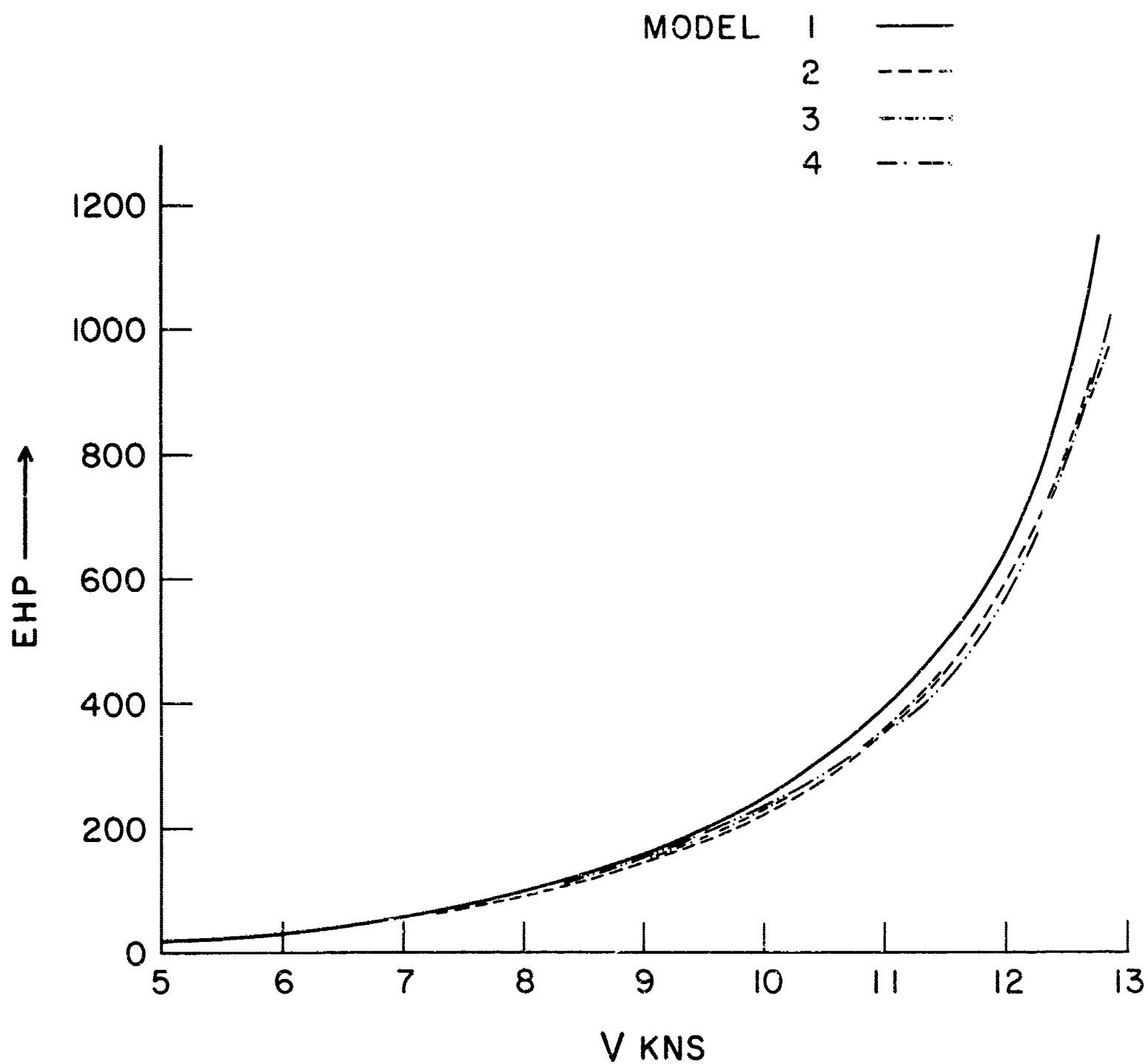


Fig. 7 Effective horsepower vs. speed at 950 tons displacement

hull. If one examines the propulsive coefficient and towline pull which can be developed by model 3 equipped with larger propellers, the advantage of this form becomes immediately evident. The full scale ship represented by model 3 can be fitted with twin propellers of about 6-1/2 feet diameter. Model 2 can swing about 5-foot propellers. Let us assume controllable pitch propellers which can be adjusted to permit the engines to develop their rated power and RPM regardless of ship speed. We assume that the propeller RPM is chosen to give maximum efficiency for the given diameter at a ship speed of 12 knots. Under these conditions the two ships perform as shown in Table I. Column 1 gives the propulsive coefficient at 12 knots speed and Column 2 gives the corresponding shaft horsepower. Columns 3 and 4 give the maximum free running speed and the towline pull at a speed of 8 knots, assuming a typical installed total shaft horsepower of 1700 for each ship.

Table I.				
Free Running and Towing Performance of Ship 1 and Ship 3				
Ship	P.C. at 12 knots	Net SHP at 12 knots	Max Speed on 1700 SHP	Towline pull at 8 knots and 1700 SHP
1	.52	1210	13.4 knots	27,500 lbs.
3	.69	915	14.75 knots	31,100 lbs.

Motion measurements in head seas.

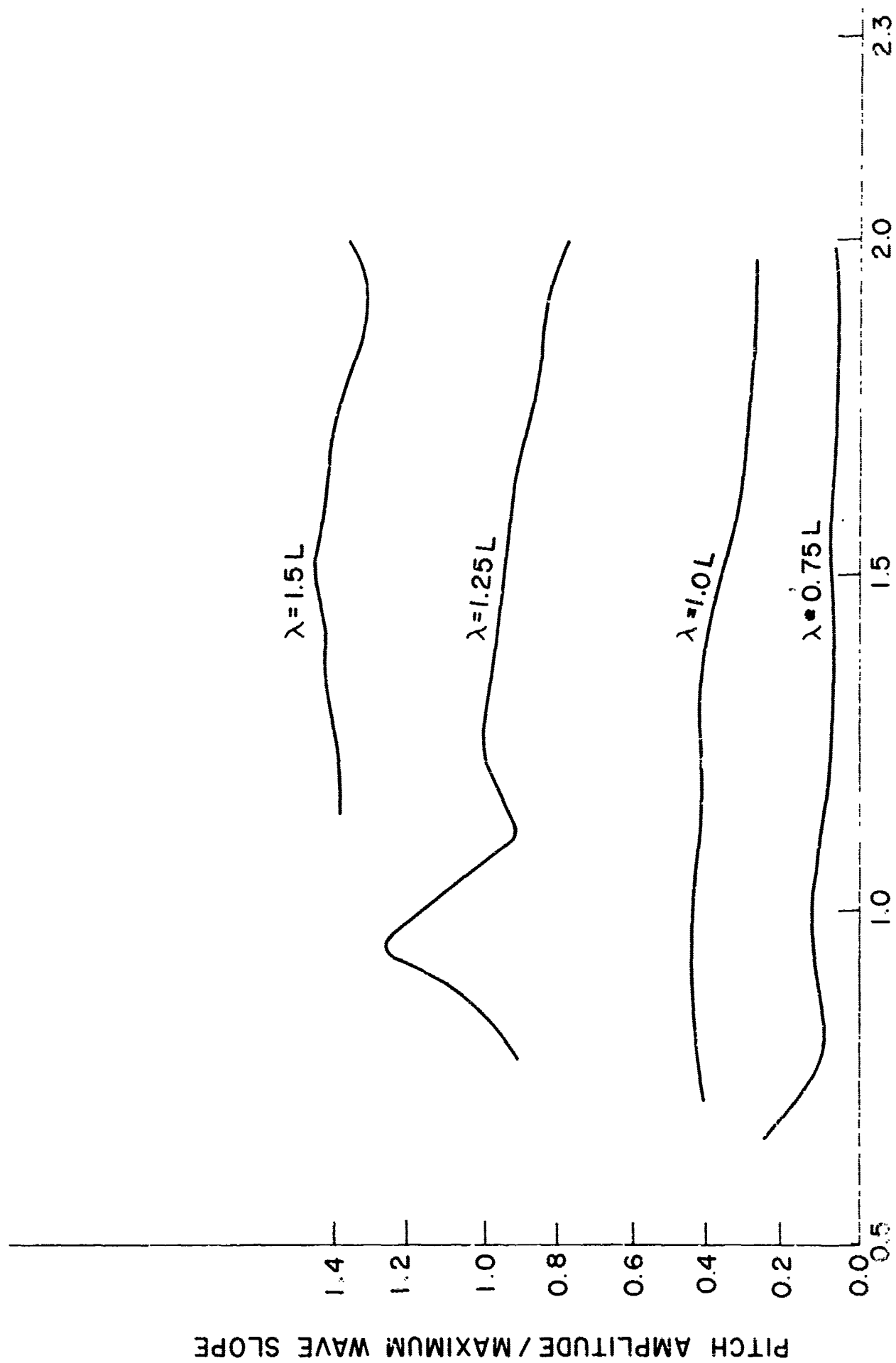
In order to evaluate the relative seakeeping performance of the four forms, the four models were towed in head seas and their pitch and heave motions recorded. All four were towed at four different speeds in irregular waves of severity approximating sea state 3. In addition, models 2 and 3 were towed in regular head seas. These latter tests were conducted

primarily to provide a more immediate comparison of the sea behavior of the Scripps design, model 3, with model 2, which is expected to have characteristics somewhat improved over the basic form, model 1. These regular wave results were also used as a check on the results from irregular waves.

The models were towed using a constant thrust dynamometer. This apparatus, which provides the attachment between the model and towing carriage, applies a nearly constant towing force to the model while permitting it freedom to pitch, heave, and surge. These motions are converted to electrical signals by means of miniature potentiometers mechanically linked to appropriate pivot points in the apparatus. Their outputs, together with that of a resistance-type wave meter, are amplified and recorded using a multi-channel oscillograph. The wave probe was mounted on the towing carriage slightly ahead and to one side of the model.

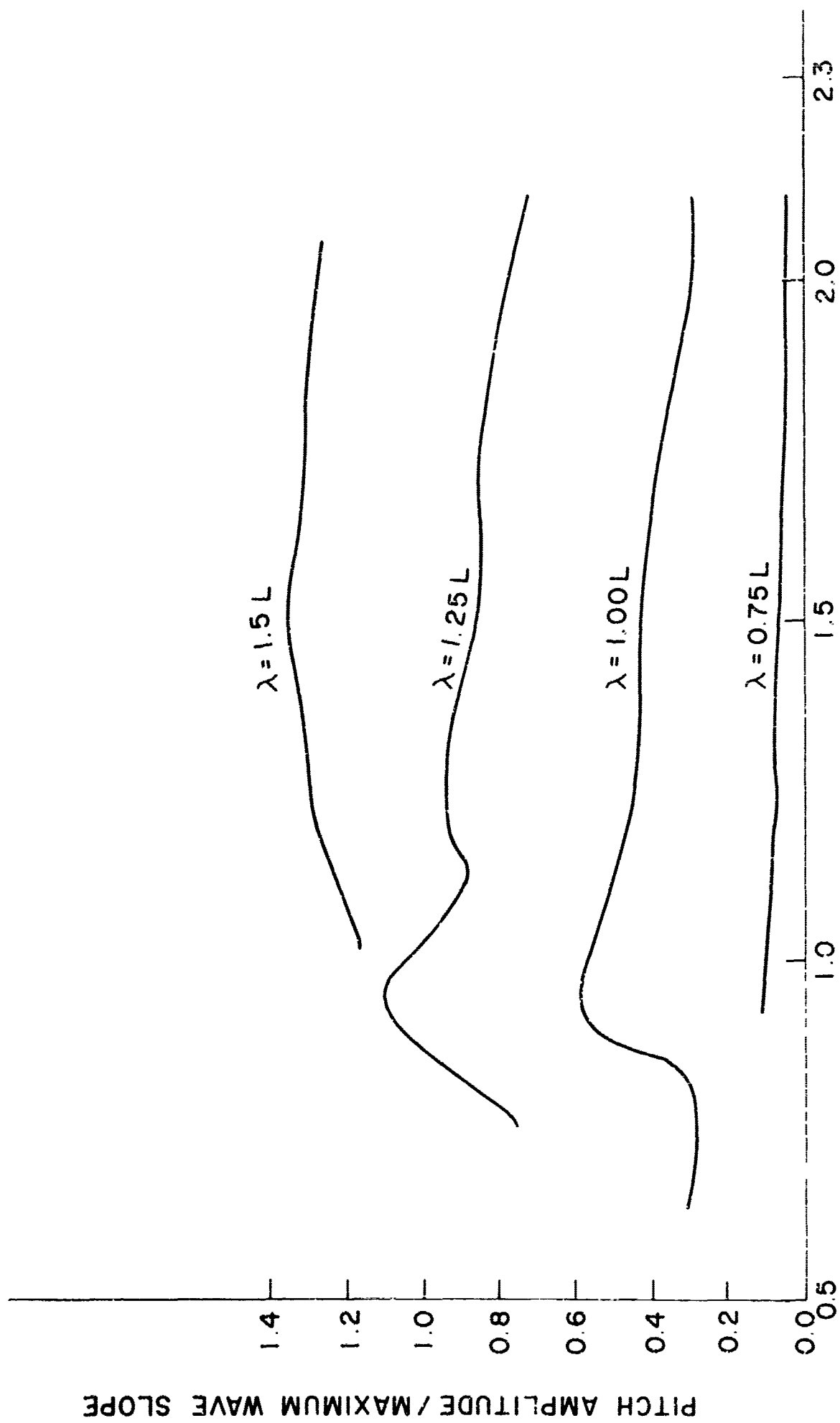
All four models were ballasted to a condition representing 1000 tons full scale displacement. The radius of gyration in pitch was adjusted to one-quarter of the length in each case. This value is normally accepted as representative for the average longitudinal weight distribution of most ships. While it would have been desirable to test each model at two drafts, the tedious nature of these sea-keeping tests prevented doing so and instead the compromise displacement was chosen.

The results of the regular sea tests are presented as graphs of non-dimensional heave and pitch amplitude versus ship speed for several different wave lengths in Figures 8, 9, 10, and 11. These quantities are non-dimensionalized



MODEL SPEED KNOTS

FIG. 8 PITCH IN REGULAR WAVES - MODEL 2



MODEL SPEED - KNOTS

FIG. 9 PITCH IN REGULAR WAVES - MODEL 3

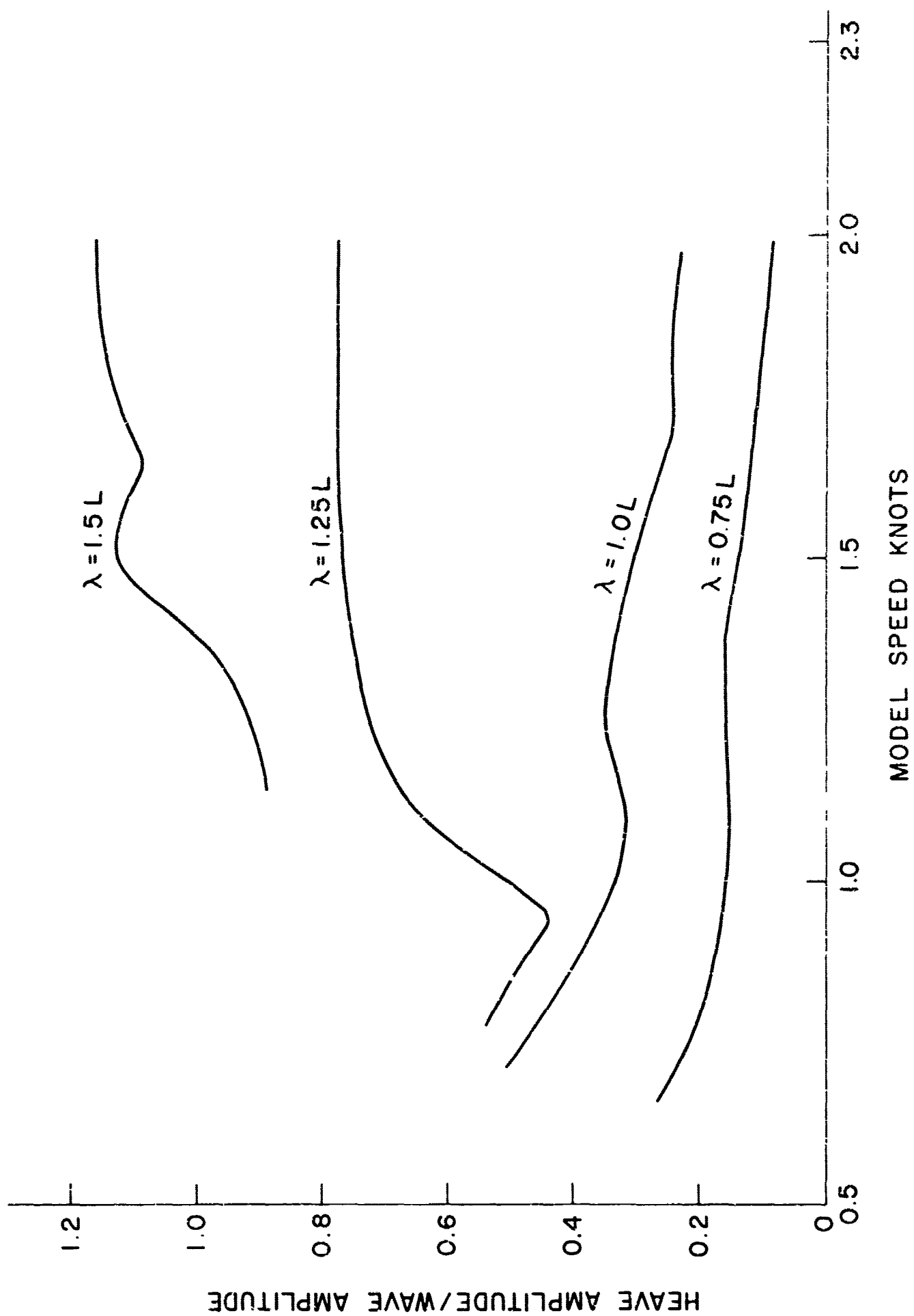


FIG. 10 HEAVE IN REGULAR WAVES - MODEL 2

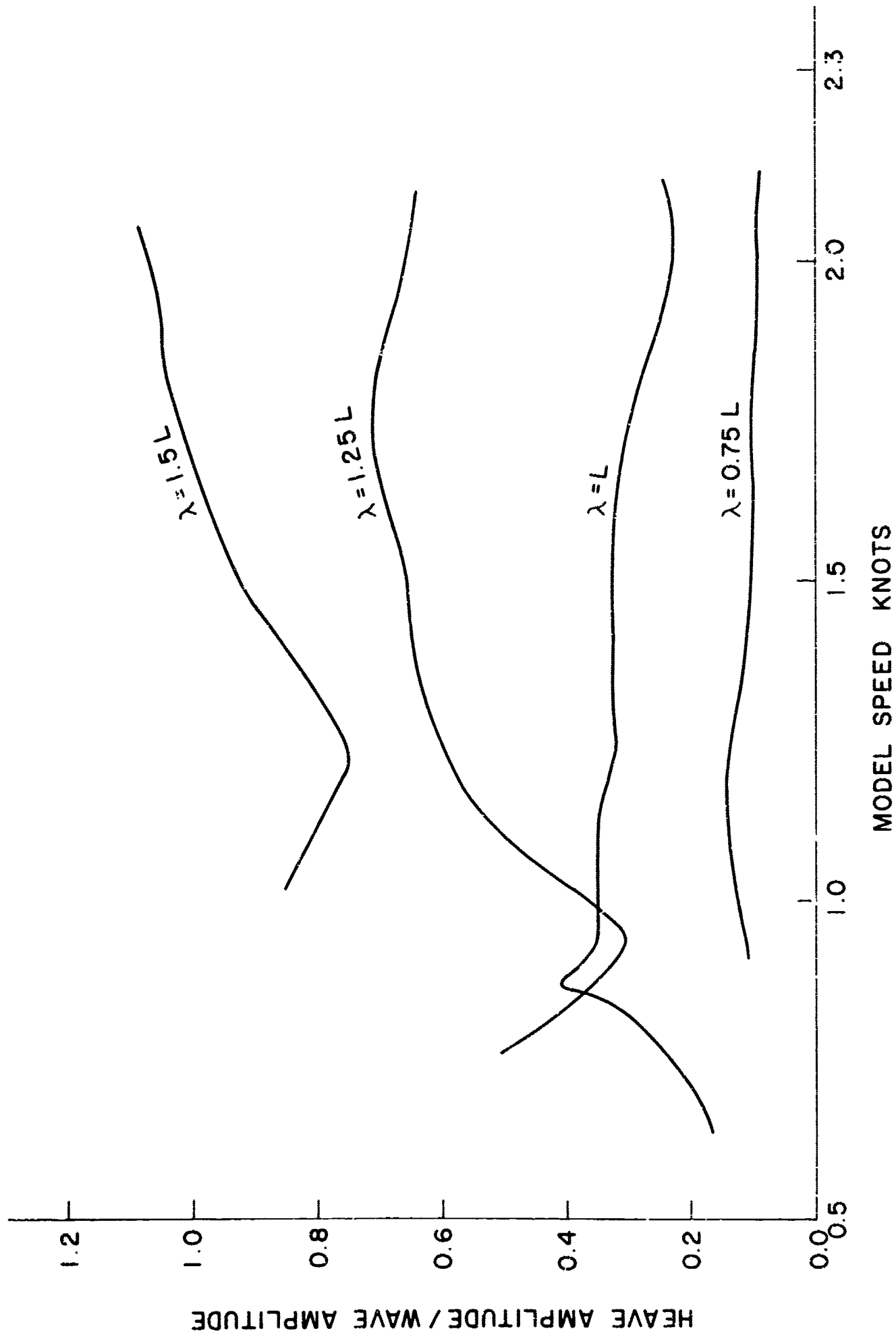


FIG. 11 HEAVE IN REGULAR WAVES - MODEL 3

by dividing heave by wave amplitude, $\frac{a}{2}$ (one half the trough to crest height) and pitch by the maximum wave slope, $\frac{\pi a}{\lambda}$.

The irregular sea results were analyzed by first estimating the power spectra of motion and wave. The amplitude response function for the model was then determined by dividing the motion spectrum by the wave spectrum. This function was then combined with a standard sea spectrum (Neumann, 20 knot wind) to determine the response of each ship in the same sea conditions. These model response functions and response spectra are shown in Figures 12, 13, 14 and 15.

In regular waves it is seen that the motions of models 2 and 3 are similar in amplitude in the shorter waves while model 2 pitches and heaves slightly more in longer waves. This larger motion of the molded hull form is to be expected since the heave and pitch forcing term, which depends primarily on waterplane shape, is nearly the same for both ships, while the damping in both heave and pitch, which depends more on the section shape, will be larger for the chine hull.

In irregular waves, the relative behavior of models 2 and 3 is reversed, i.e., model 2 has slightly less motion in the longer waves. However, the response functions and spectra are so nearly identical that, in view of the probable errors in the motion measurements and data reduction, the two models must be considered nearly identical. Only the narrow model, number 4, clearly shows a substantially greater pitching response.

All four models were observed to slam occasionally in head seas. This is an inherent defect stemming from the shallow draft and resultant low deadrise angle. The narrow form, model 4, appeared to slam the least, as would be expected.

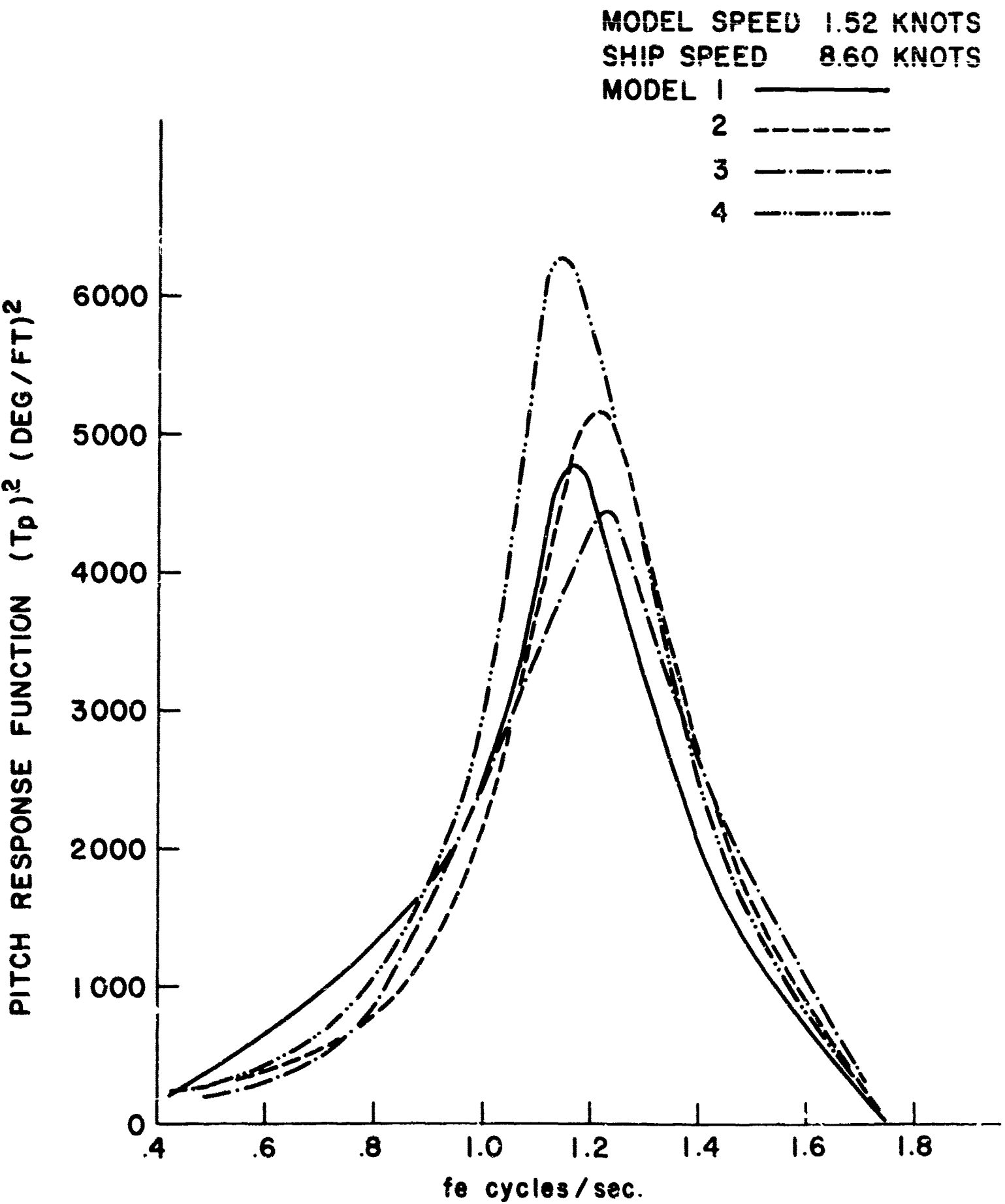


FIG.12 PITCH RESPONSE FUNCTION

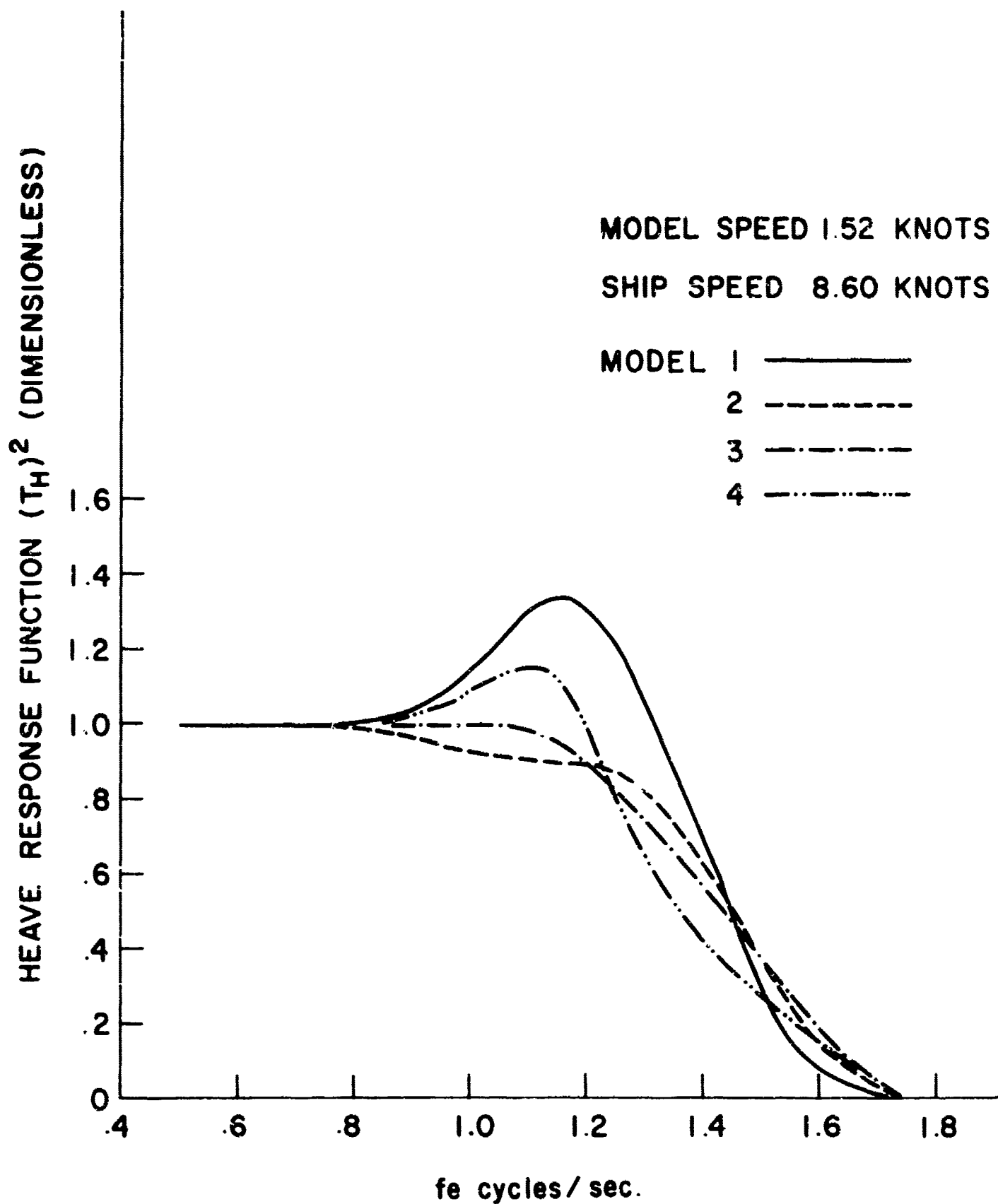


FIG. 13 HEAVE RESPONSE FUNCTION

MODEL SPEED 1.52 KNOTS
SHIP SPEED 8.60 KNOTS

MODEL 1 —————
2 - - - - -
3 - · - · - ·
4 - · - - - -

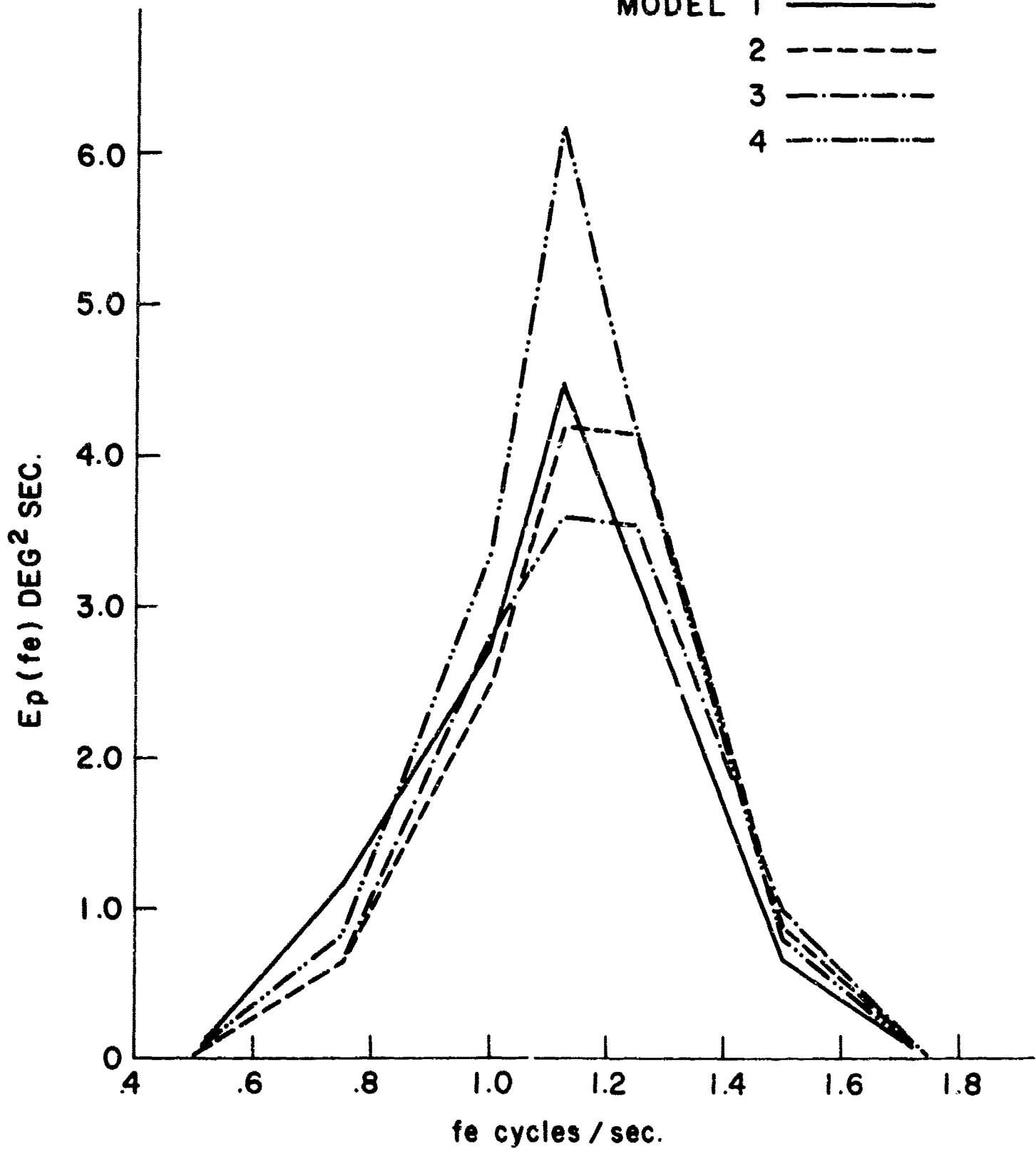


FIG.14 ESTIMATED MODEL PITCH SPECTRA IN STATE 5 SEA

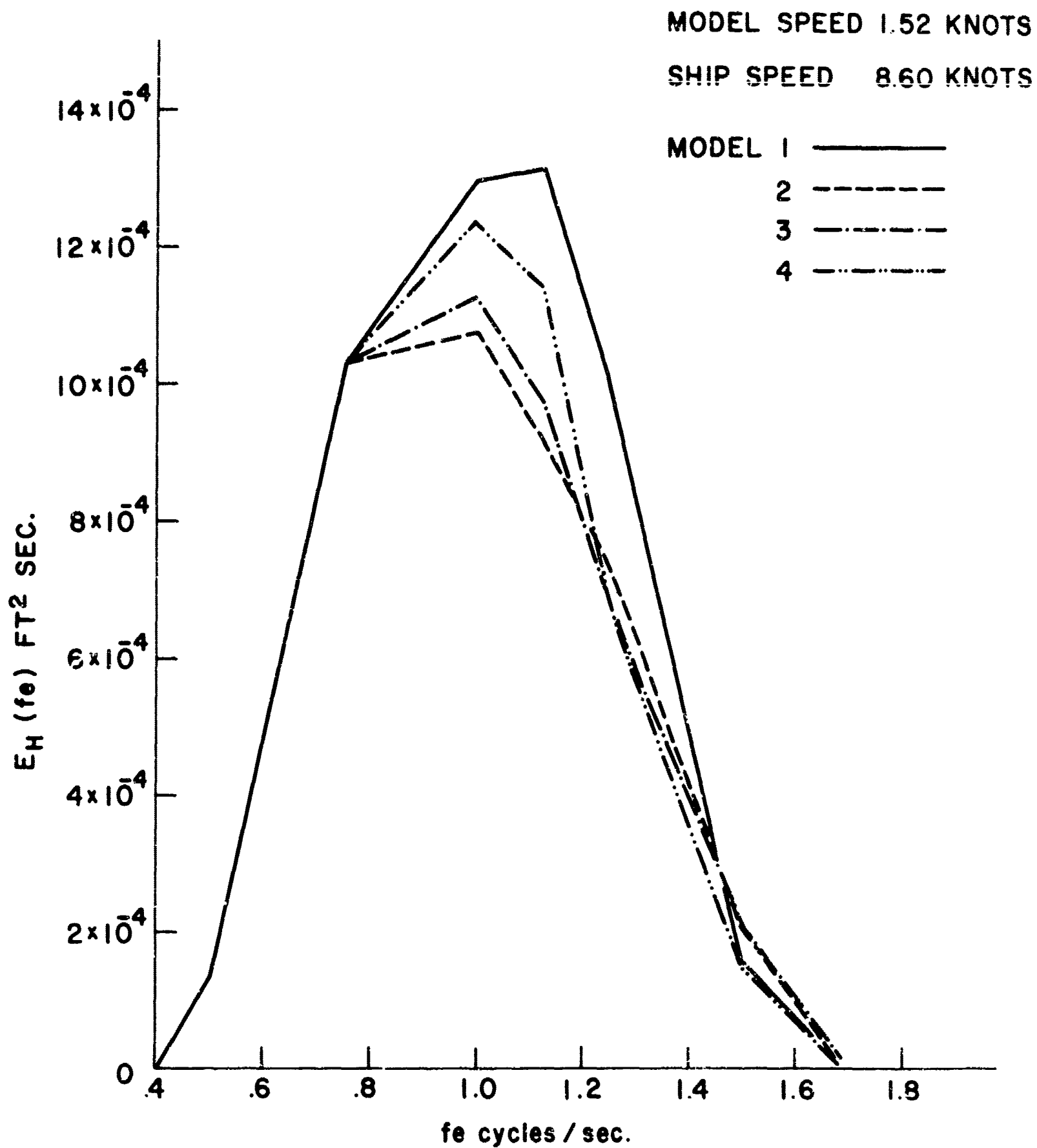


FIG.15 ESTIMATED MODEL HEAVE SPECTRA IN STATE 5 SEA

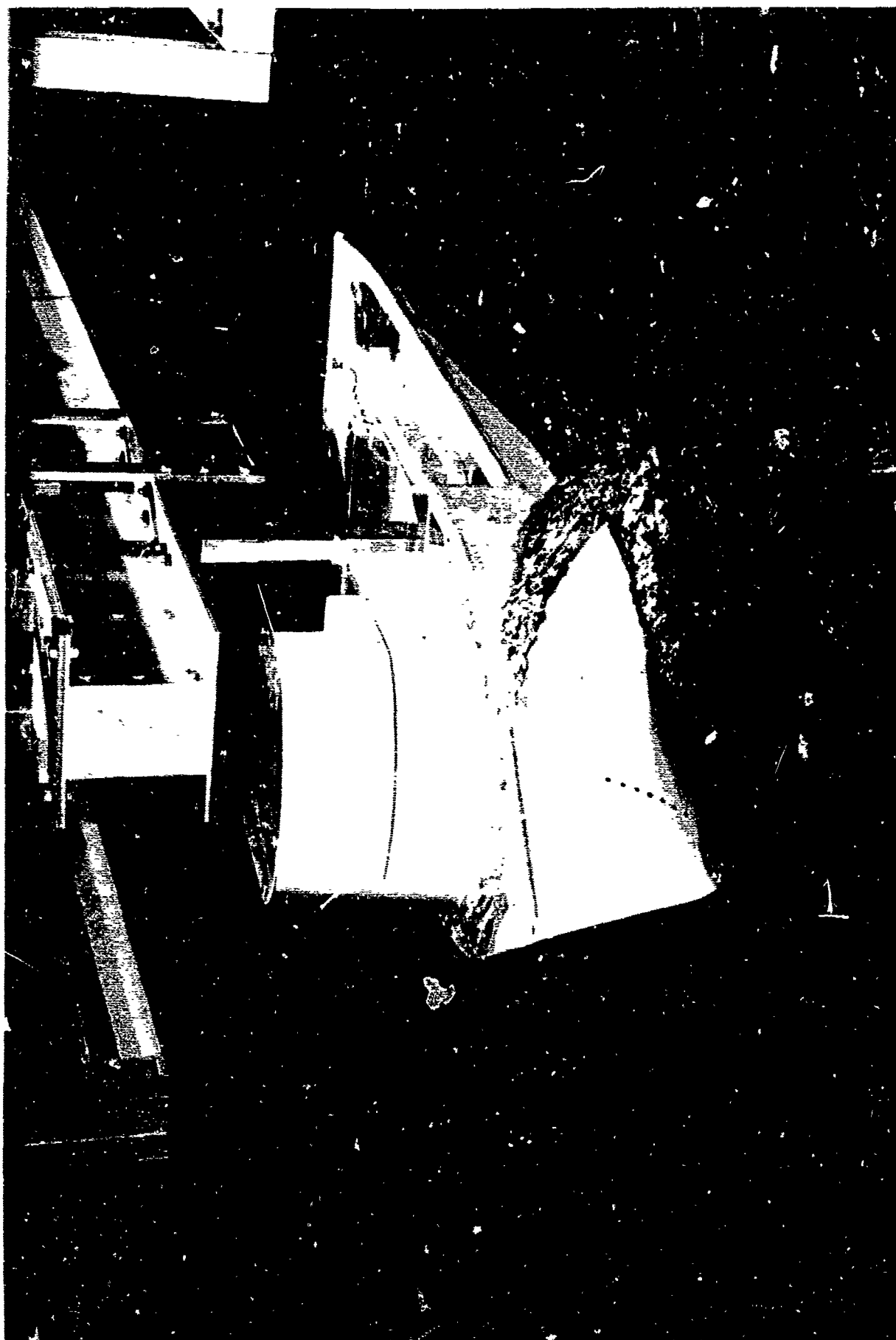


Figure 16. Model 3 at 8 knots (full scale) in State 3 Seaway.

At low speeds, the slamming tendency was much less pronounced and is not expected to hinder the station keeping ability of the vessel. A limitation would probably be imposed on the speed when proceeding in severe head seas, however.

Qualitatively, the slamming tendency did not seem appreciably worse than that of other ships, such as fishing vessels, of similar length, but different proportions.

Rolling in beam seas.

Experiments to measure the rolling motion in beam seas were carried out at a displacement representing 750 tons for the full scale ships. This is expected to be about the average displacement when operated as research ships and was chosen because the rolling characteristics of the ship under average rather than the most severe conditions were felt to be of greatest interest.

From weight and loading information on similar vessels, the metacentric heights of models 1, 2, and 3 were adjusted to represent 12.55 feet full scale, or 35% of the beam. This is well in excess of minimum Coast Guard requirements but is consistent with the anticipated load distribution. Model 4 was ballasted to give a metacentric height of 10% of the beam or 2.70 feet. This corresponds to a center of gravity height relative to the depth somewhat less than that for the first three vessels. In practice, the reverse would probably be the case, but in view of the speculative nature of this design, it is felt that this value is suitable for comparative purposes.

The transverse radius of gyration of each model was adjusted to 40 per cent of the beam. The corresponding natural periods of roll for the models were as follows: Models 1, 2, and 3: .794 seconds; Model 4: 1.27 seconds.

In these experiments, the model was oriented at 90° to the centerline of the tank and its rolling motion in regular beam seas recorded. Waves having a constant length to height ratio of approximately 40 were used throughout. Two wave probes were used, one near the model, the other several model lengths away in the direction of the wave generator.

Results from these experiments are given in Figure 17 as curves of the nondimensional roll amplitude (maximum roll angle divided by maximum wave slope) versus the ratio of wave frequency to model natural frequency of roll.

Here, marked differences among the four hull forms are immediately apparent. If the rolling model is viewed as a simple linear oscillator, the essential property distinguishing the behavior of each of the four forms is the damping ratio, i.e., the ratio of damping in roll to critical damping. We may determine the damping ratio by the following considerations. The equation of motion for rolling in regular beam seas is given by

$$\frac{\Delta}{g} k_x^2 \ddot{\varphi} + b \dot{\varphi} + \Delta GM \varphi = \Delta GM \frac{\pi a}{\lambda} \cos \omega t ,$$

whose solution is of the form $\varphi(t) = \varphi_0 \cos(\omega t + \epsilon)$. We define a nondimensional exciting frequency by $\Omega = \omega/\omega_n$ where

$\omega_n = \sqrt{gGM/k_x^2}$, a damping ratio by $\zeta = b/b_c$, where $b_c = 2 \Delta k_x \sqrt{GM/g}$, and a nondimensional motion amplitude by $R = \frac{\varphi_0}{\pi a/\lambda}$. Then the amplitude of motion is given by

$$R = \frac{1}{\sqrt{(1-\Omega^2)^2 + (2\zeta\Omega)^2}} .$$

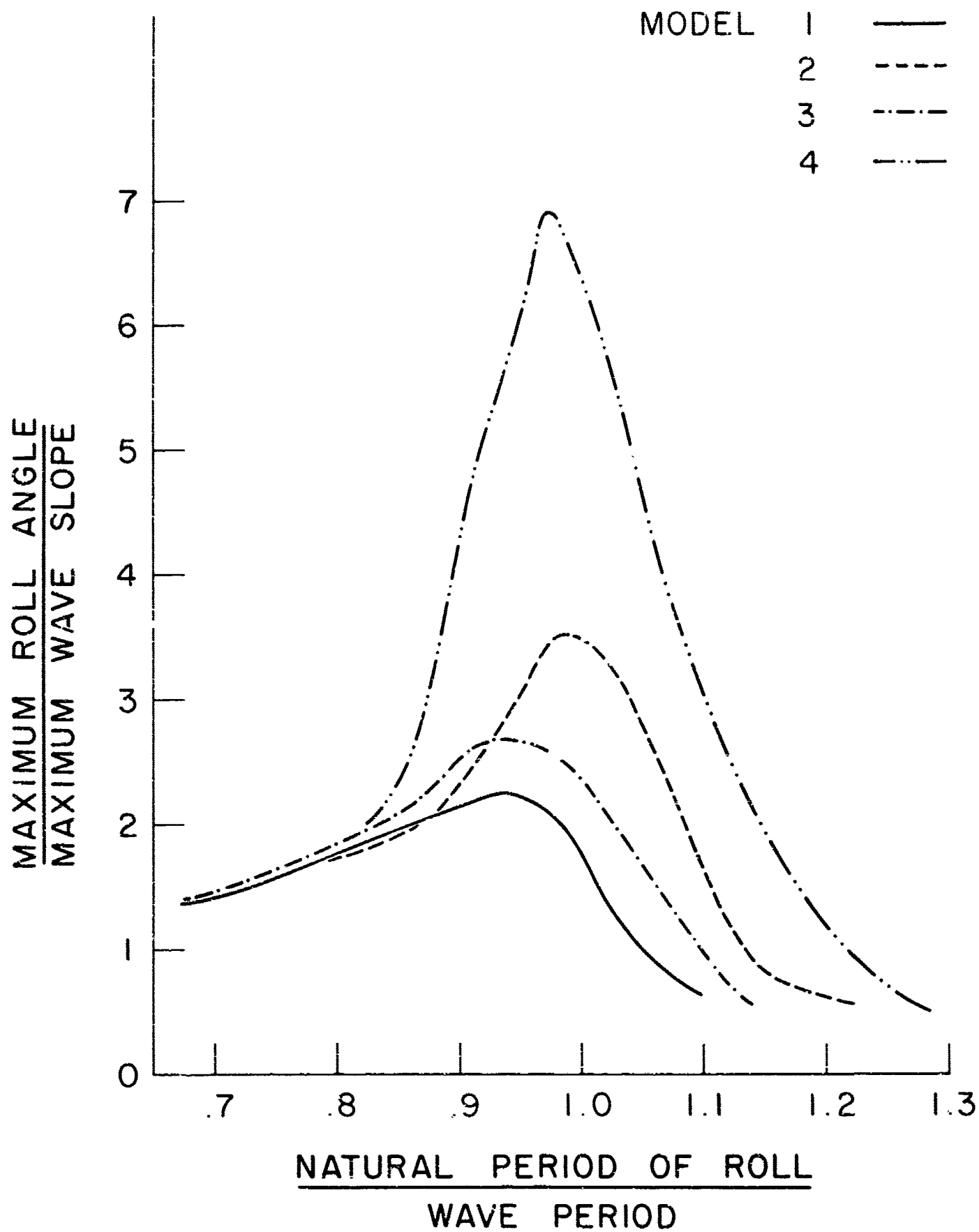


Fig. 17 Non-dimensional roll vs. period ratio in beam seas.

If ζ^2 is small compared to unity, then at resonance $\Omega = 1$, and we have

$$R = \frac{1}{2\zeta}.$$

The damping ratios for each of the four models are listed in Table II.

Table II. Roll damping coefficients		
Model	R (resonance)	ζ
1	2.3	0.22
2	3.5	.14
3	2.7	.19
4	6.9	.073

It is interesting to note that the broad shallow forms have two to three times the damping in roll of the narrow form. Further, the two wide chine forms, models 1 and 2, have substantially higher damping than the molded hull. Of these two chine forms, the Scripps design, model 3, has slightly lower damping, probably because of its higher average deadrise angle.

In comparison with other ships, the damping coefficient for model 4 is in the same range quoted by Vossers [1962] for normal, seagoing ships of the same general proportions with bilge keels. Data for ships having the proportions of models 1 through 4 are not given by Vossers.

A possible objection to the broad-shallow vessel in comparison to the narrow one stems from its shorter period of roll. However, as a result of the greater damping and consequent reduced amplitude, the roll-induced accelerations are about the same as may be seen by the following considerations.

The angular acceleration in roll is given by

$$\ddot{\varphi} = -\varphi_0 \omega^2 \cos(\omega t + \epsilon) .$$

The magnitude of the corresponding tangential acceleration at the deck edge is

$$A_t = \frac{B}{2} \omega^2 \varphi_0 .$$

Let us consider the motion at resonance for which $\omega = \omega_n = \sqrt{g GM} / k_x$. We note that the radius of gyration, k_x , has been assumed equal to 0.4 B, a figure typical for most ships. The ratio of these accelerations for models 1 and 4 in the same waves is given by

$$\begin{aligned} \frac{A_{t1}}{A_{t4}} &= \frac{B_1 \omega_1^2 \varphi_{01}}{B_4 \omega_4^2 \varphi_{04}} \\ &= \frac{B_1}{B_4} \frac{GM_1}{GM_4} \left(\frac{k_{x4}}{k_{x1}} \right)^2 \frac{R_1}{R_4} . \end{aligned}$$

Substituting $GM_1 = .35B_1$, $GM_4 = .10B_4$, $k_{x1} = .40B_1$, and R_1 and R_4 from Table II, we obtain

$$\frac{A_{t1}}{A_{t4}} = 1.03 .$$

Thus the wide ship has nearly the same tangential acceleration and a substantially reduced maximum roll angle.

During the rolling experiments, it was observed that all models rolled the deck edge under when near resonance in waves of sufficient steepness. This tendency was much less severe for model 3 because of its greater freeboard.

Transverse stability calculations.

Standard cross curves of stability and stability in a following sea were computed for all four hull forms. In each case the raised forecastle was assumed watertight back to station 3. This would slightly underestimate the stability for model 3, since its forecastle is somewhat longer, but would be reasonably accurate for the others.

For the following sea condition stability was computed in a manner similar to that given by Faulling [1960], assuming a wave of length equal to the ship length, and wave height equal to one-twentieth the length. Only the worst wave position, wave crest amidship, was computed. These stability computations, both in calm water and in waves, have been programmed for machine computation. These computations, as well as much of the experimental data reduction, were carried out using the facilities of the Computer Center at the Berkeley Campus of the University of California.

Static stability curves in calm water and in the above described waves for two displacements, 750 tons and 1,000 tons, are given in Figures 18, 19, 20, and 21. The initial GM in each case is the same as that used for the rolling experiments. The appropriate minimum GM required by Coast Guard regulations is shown in each case also.

Of the three broad shallow hulls, model 3 has the greater maximum righting arms and range of stability. However, all three vessels could reasonably be expected to meet U. S. Coast Guard stability requirements at these displacements, even when loaded in such a manner that the center of gravity is somewhat higher. Model 4, on the other hand, could present greater difficulty in obtaining adequate

<u>DISP.</u>	<u>GM</u>	<u>KG</u>
1000 tons	10.0 ft	8.6 ft.
750 tons	12.55 ft.	8.6 ft

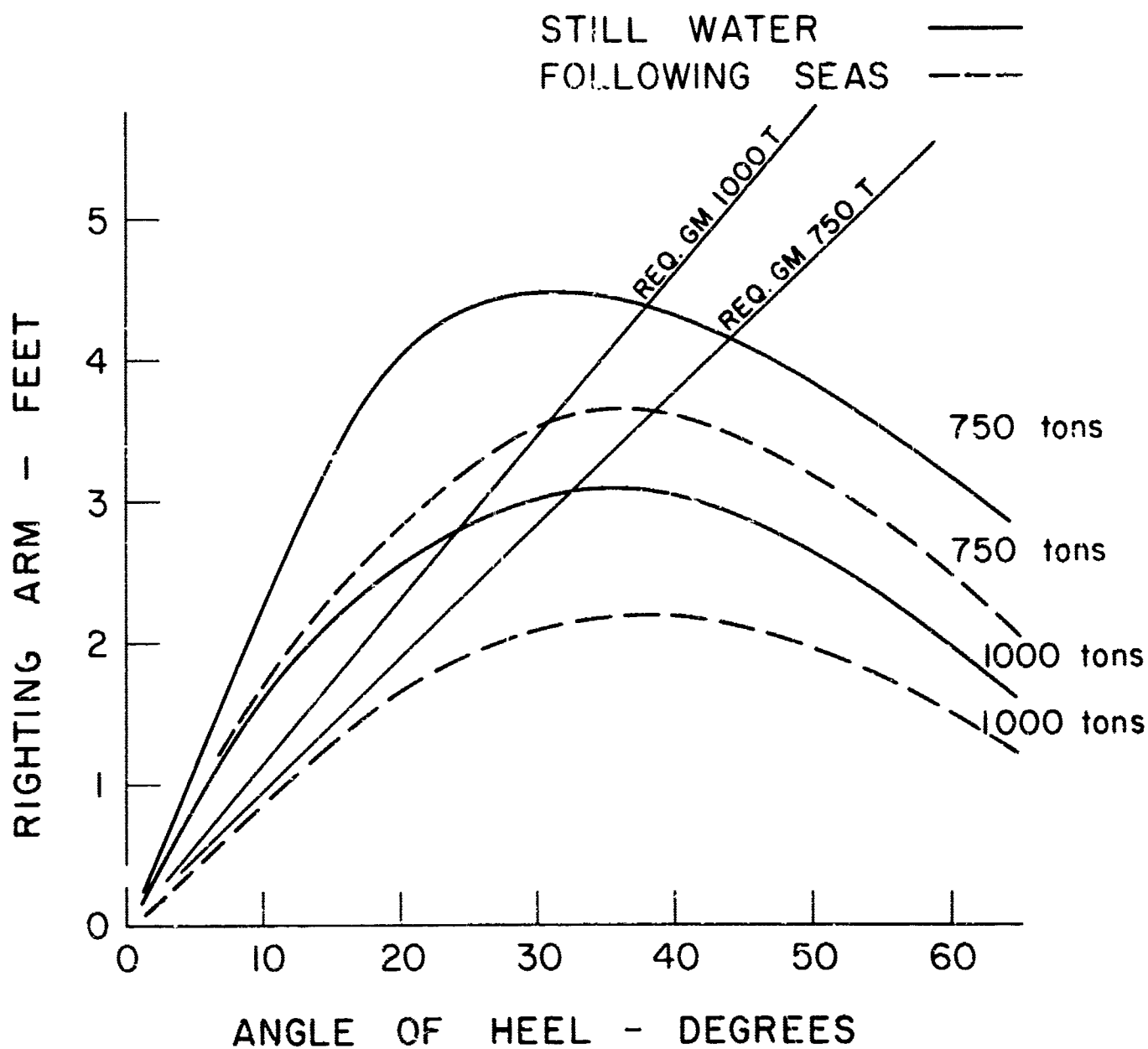


Fig. 18 Transverse stability in calm water and waves, Model I

<u>DISP.</u>	<u>GM</u>	<u>KG</u>
1000 tons	10.0 ft.	8.4 ft.
750 tons	12.55 ft.	8.2 ft.

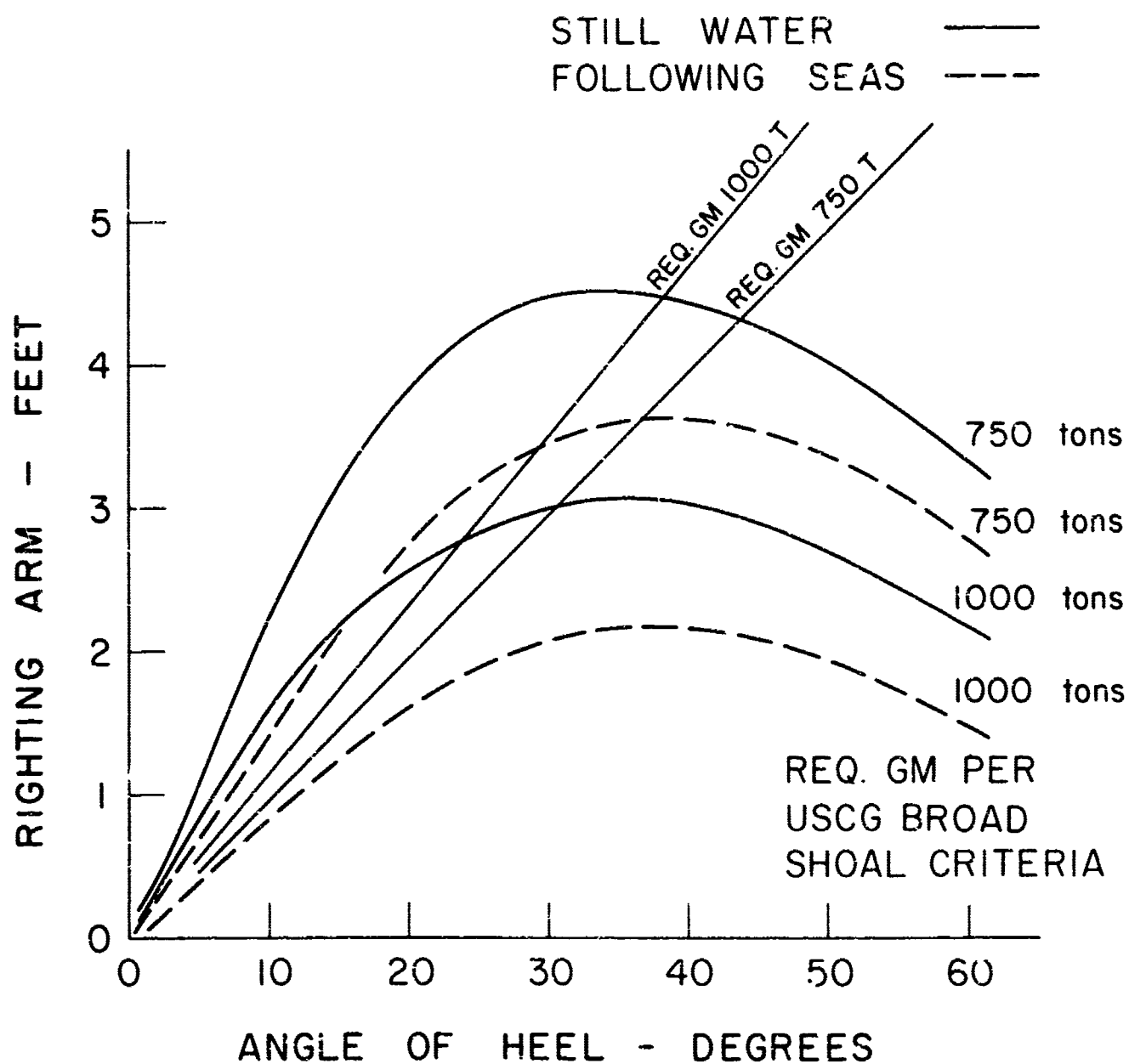


Fig. 19 Transverse stability in calm water and waves, Model 2

<u>DISP.</u>	<u>GM</u>	<u>KG</u>
1000 tons	10.0 ft.	9.9 ft.
750 tons	12.55 ft.	10.25 ft.

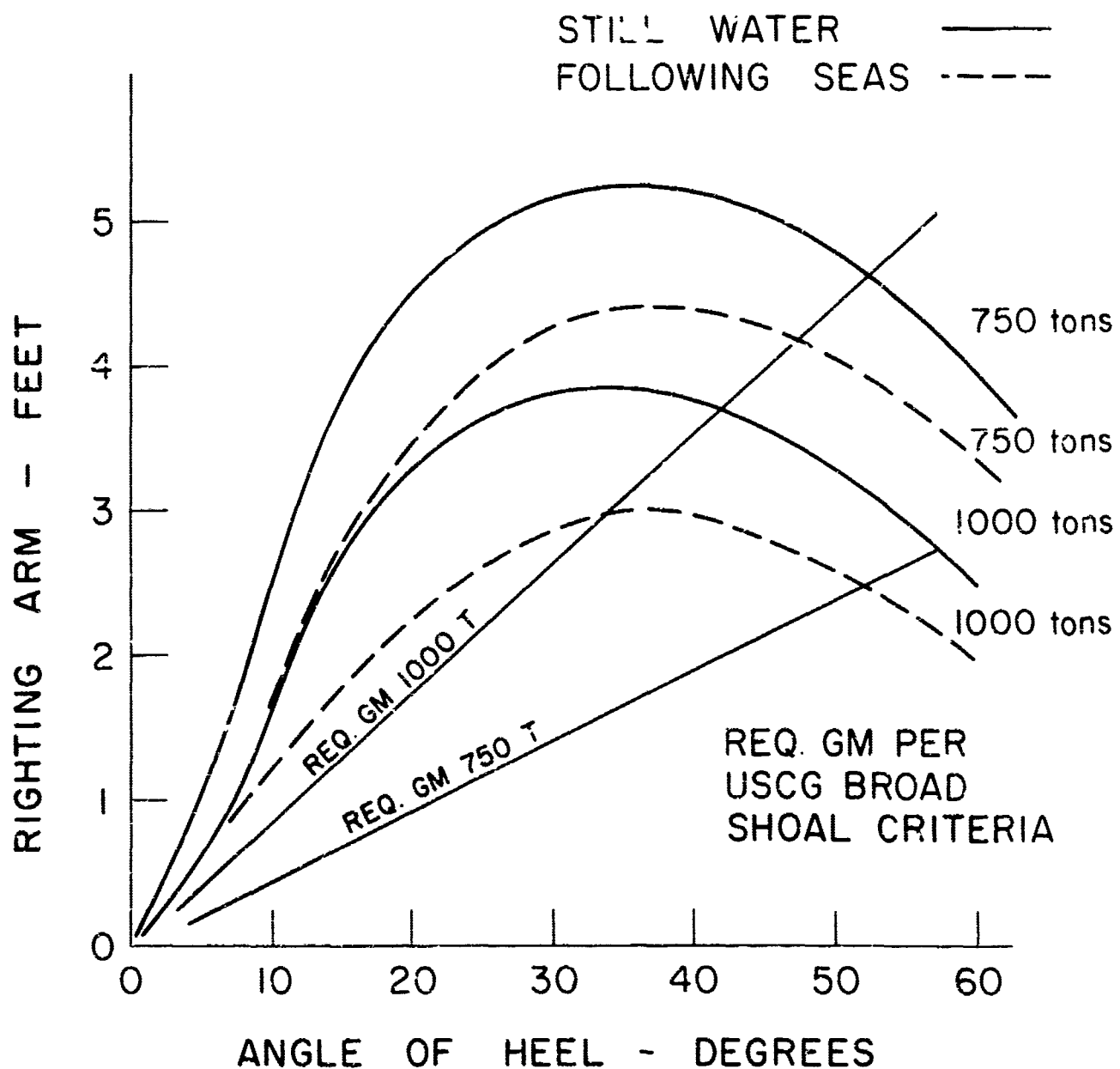


Fig. 20 Transverse stability in calm water and waves, Model 3

<u>DISP.</u>	<u>GM</u>	<u>KG</u>
1000 tons	2.70 ft.	10.2 ft.
750 tons	2.70 ft.	10.4 ft.

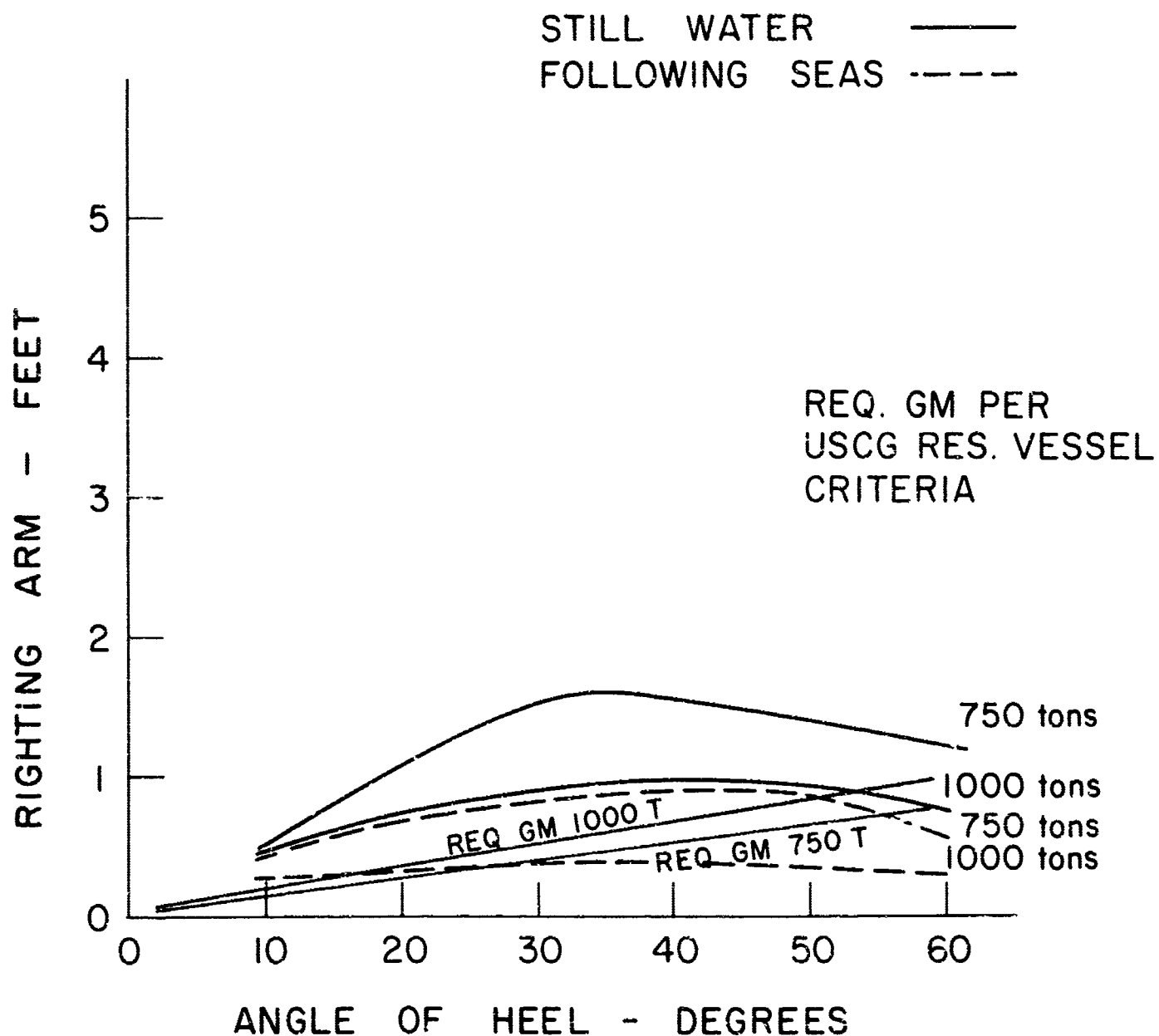


Fig. 2i Transverse stability in calm water and waves, Model 4

stability. One might hesitate to compare model 4 with the first three models because the initial GM is not the same in each case. As stated earlier, however, it is felt that the assumed position of the center of gravity realistically represents that which might be encountered in the actual ship.

In passing it might be noted that the U. S. Coast Guard requirements for the broad shallow supply boats formerly required an increase in GM of 0.4 foot over that needed to satisfy the basic still water stability criterion in order to compensate for the loss in righting arms in following waves. From the present computation, it appears that about two feet of additional GM would be required to completely offset the reduction caused by the $\lambda=L$, $a=\lambda/20$ waves. Presumably, an allowance for this is built into the basic stability criterion and it is no longer required.

Conclusions

1. While the molded form and the narrow form have somewhat less resistance in calm water than the wide chine hulls, the difference is not sufficient to warrant considering, on this basis alone, these two forms for a research vessel. Further, at the lighter draft, the difference between these two and hull form 3 nearly vanishes.
 2. In head seas the pitching and heaving motions of the first three forms is essentially the same. Model 4 shows slightly greater pitch amplitudes. Slamming would probably limit the maximum speed in head seas.
 3. When rolling in beam seas, the broad shallow ships have considerably smaller roll amplitudes than the narrow form. Further, the chine hulls have substantially greater roll damping than the molded hull. Apparently the chines are quite effective as bilge keels.
 4. The increased freeboard of model 3 is desirable to insure drier decks when rolling in beam seas.
 5. The broad shallow hulls, and especially the increased freeboard version, model 3, will experience no difficulty meeting transverse stability requirements when operated as research ships. Model 4, on the other hand, has only marginal stability and might require some fixed ballast.
 6. The loss of stability in following seas experienced by the broad shallow hulls is substantial. However, no difficulty is expected if the initial GM can be made to equal or exceed U. S. Coast Guard requirements. This can be accomplished by proper attention to the weight distribution and is not expected to hamper the ship's operation.
-

REFERENCES

J. R. Paulling [1960]

"The Transverse Stability of a Ship in Longitudinal Seaway", Journal of Ship Research, Vol. 4, No. 4, 1961, pp. 37-49.

G. Vossers [1962]

"Behaviour of Ships in Waves", The Technical Publishing Company, H. Stam N.V., Haarlem, The Netherlands, 1962, p. 59.

United States Coast Guard

Merchant Marine Technical Note No. 4-64, "Offshore Supply Vessels - Stability", 31 July, 1964.

Subchapter U "Proposed Rules and Regulations for Oceanographic Research Vessels."

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) University of California, Berkeley and Scripps Institution of Oceanography, UCSD California		2a REPORT SECURITY CLASSIFICATION Unclassified	
		2b GROUP	
3 REPORT TITLE Model Studies for an Oceanographic Ship Derived from an Offshore Supply Vessel			
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) Model Studies for an Oceanographic Ship derived from an offshore supply vessel			
5 AUTHOR(S) (Last name, first name, initial) J. R. Paulling, Jr. Dept of Naval Architecture, Univ. Calif. Berkeley and Maxwell Silverman Scripps Institution of Oceanography, UCSD			
6 REPORT DATE 18 August 1966		7a TOTAL NO OF PAGES	7b NO OF REFS
8a CONTRACT OR GRANT NO NONR 2216(23) & faculty grant, Berkeley		9a ORIGINATOR'S REPORT NUMBER(S) SIO Reference 66-19	
b PROJECT NO		9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c			
d			
10 AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from Scripps Institution of Oceanography. Attention: Maxwell Silverman.			
11 SUPPLEMENTARY NOTES		12 SPONSORING MILITARY ACTIVITY Department of the Navy Office of Naval Research Washington, D. C.	
13 ABSTRACT During the last few years, a number of operators of oceanographic research ships have considered the Gulf Coast offshore oil well supply vessel type for possible conversion to a research vessel. Such a ship of 155 to 165' length offers a number of attractive features, chiefly reduced operating costs and space for mounting portable or interchangeable equipment. The vessels' principal disadvantages are reputedly a lack of seakindliness and limited stability. An investigation of such vessels has recently been conducted by SIO and the Dept of Naval Architecture of the Univ. of Calif. The results of the model experiments are presented in this paper, and indicate that a simple modification in form will prove acceptable for research services.			

DD FORM 1473

1 JAN 64

0101-907-6800

Unclassified
Security Classification

14	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT

INSTRUCTIONS

1. ORIGINATING ACTIVITY Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES. If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE. Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those

imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT. Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph represented as: TS, S, C, or U.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.