#1

DEPARTMENT OF THE NAVY
DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

○

AERODYNAMICS

○

STRUCTURAL MECHANICS

○

APPLIED MATHEMATICS

EFFECT ON HULL VIBRATIONS OF VARIOUS BOW ANTI-PITCHING FIN CONFIGURATIONS

by

G. P. Stefun and F. M. Schwartz

[redacted]

Hydromechanics Laboratory

RESEARCH AND DEVELOPMENT REPORT

November 1962 Report 1659

PRNC-TMB-648 (Rev. 3-58)

EFFECT ON HULL VIBRATIONS OF VARIOUS BOW ANTI-PITCHING FIN CONFIGURATIONS

by

G. P. Stefun and F. M. Schwartz

November 1962 Report 1659

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Results from model and full-scale observations and measurements indicate that serious transverse hull vibrations are induced by bow antipitching fins. The vibrations are believed to be caused by hydrodynamic impacts due to flow separation effects that occur for large amplitudes of fin motion. Model experiments of various fin configurations were conducted in waves to determine the effects of changes in fin shape, orientation, and depth of submergence on vibrations and pitching. Minimum vibrations were obtained for fins with high aspect ratios, tip fences, and deep submergence.

INTRODUCTION

The first antipitching fins to be used on a United States vessel were installed on the USS COMPASS ISLAND (EAG 153) late in 1957. Subsequent sea trials indicated that the fins were effective in reducing pitch amplitudes and that their strength was adequate even under slamming conditions.[1] However, the serious transverse hull vibrations encountered were considered sufficiently detrimental to normal ship operation to warrant removal of the fins.[2]

Because of the potential importance of antipitching fins for certain U. S. Navy applications, the Bureau of Ships requested the David Taylor Model Basin to obtain model and full-scale measurements in order to determine the nature and cause of fin-induced vibrations, and to suggest means for reducing them to an acceptable magnitude.[3,4] Some success was obtained in reducing the magnitude of vibrations in moderate seas through the use of relatively minor design modifications which were applied to the existing fins.[5,6,7] The modifications were not sufficient, however to prevent objectionable vibrations in severe seas.[8]

Since the fin investigation on COMPASS ISLAND had disclosed a lack of adequate information on the vibration problem, a fundamental research program was initiated at the Model Basin to study the effects on vibrations of various fin configurations. Inasmuch as the characteristics of the vibration records obtained during COMPASS ISLAND trials were similar in most respects to those obtained from preliminary model tests,[5] it was decided to conduct this investigation on model scale.

BACKGROUND: VIBRATION CHARACTERISTICS

A portion of a typical record obtained during full-scale trials aboard the USS COMPASS ISLAND is reproduced in Figure 1. The record contains pitch, roll, and wave height measurements, together with the transverse accelerations at various locations on the ship. Transverse accelerometers were used as hull vibration indicators. They were installed at three deck levels at Frame 6 (bow) and at the main deck level at Frame 57 (quarter point), Frame 117 (amidships), Frame 159 (three-quarter point) and Frame 205 (stern).

An examination of vibration records, such as the sample given in Figure 1, and visual observations at sea indicated that the incidence of transverse vibrations corresponded to a flow breakdown over the top fin surfaces as they moved downward during the ship's pitching cycle. The breakdown was observed to result in a large transverse flow component which was directed against the side of the ship with enough force to excite serious transverse hull vibrations. The vibration records are consistent with these observations since they have the characteristic features of impact phenomena, such as the large initial deflection followed by the decay in amplitude according to the appropriate damping law. The frequency of vibrations at bow, midship, and stern locations was 2 cps, corresponding to the first horizontal mode.[9] Vibrations with the frequency of the second harmonic (4 cps) were recorded at Frames 57 and 159, locations which correspond roughly to the nodal points for the fundamental mode of vibration.

Vibration measurements were obtained for three deck levels at the bow in order to determine whether transverse vibrations were generated or influenced by torsional effects which might be attributed to unsymmetrical loads on port and starboard fins. An analysis of the records disclosed that no torsional effects could be detected at the bow. The vibrations at all three levels had exactly the same phase, frequency and amplitude, contrary to what would be expected if the torsional deflection were large.

PROCEDURE

Since the purpose of the model experiments was to obtain comparative vibration data for various changes in fin size, shape, and orientation, no attempt was made to reproduce realistic full-scale operating conditions, nor to predict the magnitude of full-scale vibrations from those obtained for a wood model. Thus, tests were restricted to regular head seas with specified wave heights so that each condition could be accurately repeated for each different fin configuration.

The experiments were conducted in the 140-ft basin using gravity tow methods for model propulsion.[10] A 6-ft model of the CVE 55-class aircraft carrier was tested at a range of speeds in waves with length λ equal to the model length L and with wave heights h equal to $\lambda/40$, $\lambda/30$, and $\lambda/24$. Ship and model characteristics are listed in Table I and the body plan is shown in Figure 3.

TABLE 1

Ship and Model Characteristics

	Ship	Model
LBP, ft	490	6.05
Beam, ft	65	0.802
Draft, ft	20	0.247
Displacement	10,400 tons	42.56 lb
Block Coefficient	0.571	0.571
Water Plane Coefficient	0.747	0.747
Natural Heave Period, sec	----	0.765
Natural Pitch Period, sec	----	0.782

Antipitching fins, consisting of simple flat plates with rectangular cross sections, were mounted on the forefoot at keel depth, except where noted. Vibrations were recorded using a velocity transducer which was mounted to measure transverse velocity at the bow of the model. Measurements included wave heights, pitch angles, heave accelerations, and transverse vibrations. A typical model record is given in Figure 2 for comparison with the full-scale vibrations shown in Figure 1.

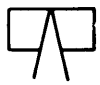
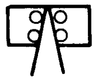
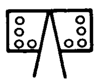
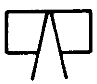
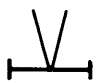
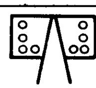
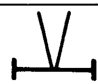
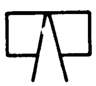
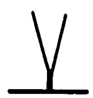
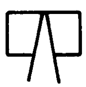
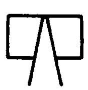
FIN CONFIGURATION

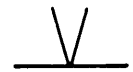
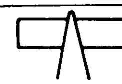
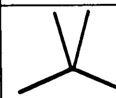
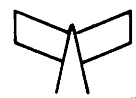
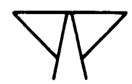
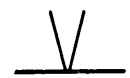
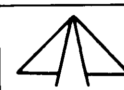
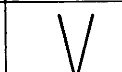
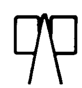
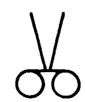
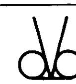
The various fins used in this investigation can be grouped roughly into five basic designs. Various modifications for these designs resulted in 16 different configurations whose dimensions and particulars are given in Table 2. Major characteristics were as follows:

Fin 1 was a simple rectangular aluminum plate of low aspect ratio equal to 2.0 (total span equal to twice the chord) and area equal to

TABLE 2

Antipitching Fin Configurations

Fin	Plan View	End View	Particulars
1			Span = 6.8 in., Chord = 3.4 in. Area = 4.4 percent of waterplane area Aspect Ratio = 2.0
1(a)			Same as Fin 1 except for four 1.0-in.-diameter holes.
1(b)			Same as Fin 1 except for eight 0.5-in.-diameter holes.
1(c)			Fin 1 with tip fences. Fence height = 1.0 in.
1(d)			Fin 1(b) with tip fences.
1(e)			Fin 1 with strut to increase depth of submergence by 50 percent.
1(f)			Fin 1 with 25-deg positive dihedral.
1(g)			Fin 1 with 25-deg negative dihedral.

Fin	Plan View	End View	Particulars
2			Span = 9.6 in., Chord = 2.4 in. Area = 4.4 percent of waterplane area Aspect Ratio = 4.0
2(a)			Fin 2 with 25-deg negative dihedral.
3			Fin 2 with 25-deg sweep-back.
3(a)			Fin 2 with 25-deg sweep-forward. (Fin 3 reversed)
4			Maximum Span = 9.6 in. Maximum Chord = 4.8 in. Area = 4.4 percent of waterplane area
4(a)			Fin 4 reversed
5			Circular Cylinders: Diameter = 2.0 in. Length = 3.0 in.
5(a)			Fin 5 mounted above keel line.

4.4 percent of the model's waterplane area. The primary purpose of this fin was to establish a basis for evaluating the relative merits of the various design modifications.

Fin 1 (a) was the same as Fin 1 except that four 1.0-in.-diameter holes were drilled as shown in Table 2. The holes were located near the juncture of fin and hull to determine the effect on vibrations of altering the flow characteristics near the fin root. Similarly, Fin(b), with eight 0.5-in. diameter holes located along the fin tips and trailing edges, was used to determine the effect of altering the flow about the fin's outer edges.

Fins 1(c) and 1(d) were obtained by attaching fences to the tips of Fins 1 and 1(b), respectively. Fences were intended to alter flow breakdown characteristics by reducing tip vorticity.

Fin 1(e) consisted of Fin 1 together with a strut which increased its depth of submergence by 50 percent. Greater fin submergence was expected to result in reduced adverse free surface effects, especially for large amplitudes of motion.

Fins 1(f) and 1(g) were used to investigate the effects of positive and negative dihedral. Fin 1(f) had a positive dihedral angle of 25 deg measured from the horizontal, and Fin 1(g) had negative dihedral of 25 deg. The fins were oriented as shown in the sketches of Table 2.

Fin 2 was constructed to have the same plan area as Fin 1, but its aspect ratio was increased to 4.0. Other features of the Fin 2 configuration were the same as those for Fin 1. Fin 2(a), with 25-deg negative dihedral, was used to obtain additional information to supplement the results from Fin 1(g) experiments.

Fins 3 and 3(a) were used to determine the effects on hull vibrations of fins with nonrectangular plan shapes. Fin 3 had 25-deg backward sweep for both leading and trailing edges. The total span, measured from tip to tip, and the chord, measured perpendicular to the leading edge, were the same as for Fin 2. This configuration resulted in a slightly larger area than that of the other fins. Fin 3(a) was given a similar sweep forward.

Fins 4 and 4(a) were triangular in shape. The base of the triangle was equal in length to the span of Fin 2, and its height was one half the base. The plan are was 4.4 percent of the model's waterplane area. The base of the triangle was forward and its apex aft for Fin 4 and this orientation was reversed for Fin 4(a).

Fin 5 and 5(a) consisted of two circular cylinders with open ends, one on each side of the forefoot. The axes of the cylinders were located 1 in. below keel depth for Fin 5, and 1 in. above for Fin 5(a). The projected plan area was 2.7 percent of the waterplane area.

DATA ANALYSIS

Hull vibration records were obtained from an instrument whose output was proportional to the velocity of motion perpendicular to its base. For simplicity, the maximum deflection of the recording instrument was taken as a measure of the severity of vibration and its associated impact. Deflections were read in terms of consistant but arbitrary units and averaged over several cycles of motion.

In addition to vibrations, measurements were made of wave heights, model speed, resistance, pitch angles, and heave accelerations. These quantities provided the basis for evaluating changes in vibration magnitudes with respect to changes in model speed, amplitudes of motion, and wave conditions.

The analysis of test data was complicated by the fact that fin-induced vibrations were often obscured by a more or less "normal" type of vibration that was generated from slamming impacts, wave slap at bow flare or deck overhang, and shipping of green water on deck. These effects were especially serious for test conditions corresponding to high model speeds (greater than 1.5 knots) in waves with large amplitudes. The characteristics of "normal" transverse vibrations were similar to the fin-induced vibrations. Attempts to separate the two effects were largely unsuccessful.

In the following sections, vibration and pitching characteristics of the various fin configurations are evaluated through the use of faired curves to avoid confusion resulting from plotting a large number of test points. The original test data from which the curves were obtained are plotted against speed in Appendix A for vibration and pitch measurements, and in Appendix B for resistance, heave acceleration, and phase lag of heave after pitch.

Vibration measurements obtained for the model without fins were not used as the basis for evaluating the performance of the various fin configurations. At high speeds, large vibrations were obtained for the model under these conditions. In some instances, these vibrations were more than twice as large as the maximum for the model equipped with fins. Extreme bow flare and large deck overhang, characteristic features of carrier-class vessels, together with increased pitching motion compared with the fin-equipped model, are factors which contribute to large wave impacts in severe seas at high speeds. High speeds in severe sea conditions, however, are highly unrealistic because speed reductions are generally quite large for such waves. For example, the resistance results given in Figure B-17 of Appendix B indicate that the tow force required to maintain a model speed of 2.4 knots in low amplitude waves corresponding to $\lambda/60$ was sufficient to maintain a speed of only 1.06 knots in high waves corresponding to $\lambda/24$. Vibrations of the model were roughly 50 percent of vibrations with Fin 1 at a speed of 1.06 knots. However, at this speed, the bare-hull vibrations were only 30 percent of their maxima which occurred at a speed of 1.7 knots.

Because of considerations such as those given above the various configurations were evaluated by comparing their performance with Fin 1 results in order to obtain a more realistic measure of the effects on the magnitude of the vibrations.

TEST RESULTS

Transverse vibration levels, in arbitrary units, are plotted against speed in Figure 4 for the bare hull and for several of the fin configurations. Three groups of curves are shown, one for each of the three different wave heights used in the experiments. (Wave lengths were equal to model length for all tests.) The curves indicate that vibrations were relatively minor in low amplitude waves but rapidly became more serious as wave height increased. The largest fin-induced vibrations generally occurred for low speeds which correspond to the region of maximum pitch motion (see Appendix A). For the model without fins, however, maximum vibrations occurred at high speeds because of wave impacts. These high-speed effects were considerably more serious for the bare hull than for the hull with fins because motion amplitudes were much larger for the bare hull. Pitch amplitudes, for example, were in some instances more than twice those for the model with fins in corresponding wave conditions.

The results given in Figure 4 were normalized by dividing each curve by the appropriate Fin 1 curve and replotting in Figure 5. This procedure was adopted for all the various fin configurations in order to facilitate comparisons among the different designs and to indicate the effectiveness of various modifications for reducing vibrations. Typical relative vibration curves are presented in Figure 5 for Fins 2, 3, and 4 in waves with heights corresponding to λ/h = 40, 30, and 24. As can be seen from the figure, relative vibration levels for Fins 2 and 3 were independent of wave height, while those for Fin 4 indicated a large relative increase in vibrations for high-amplitude waves compared to the two lower wave heights. The results for Fins 1(c), 1(d), 1(e), 1(f), 1(g) and 3(a) were similar to those of Fins 2 and 3, while Fins 1(a), 1(b) and 2(a) showed variations similar to those of Fin 4. Fins 4(a) and 5 showed variations with wave height at the higher speeds, and Fin 5(a) showed scatter at all speeds.

For fins where there was variation in relative vibrations with wave height, an average value of vibrations was used in succeeding figures as being representative of all three wave conditions.

Average vibration levels, relative to the Fin 1 vibration level, are plotted against speed in Figures 6 through 10 together with corresponding pitch reduction curves. The amount of pitch reduction is given as $(100(1 - \psi F/\psi 0)$, where ψF is the pitch amplitude of the fin-equipped model and $\psi 0$ is the amplitude of the model without fins.

The comparative performance of fins with various plan shapes is indicated in Figure 6. Vibration and pitch data are given for Fin 1 (low-aspect-ratio rectangle), Fin 2 (high-aspect-ratio rectangle), Fin 3 (swept edges), Fin 4 (triangle), and Fin 5(a) (circular cylinders). The results indicate that Fins 2, 3, and 4 achieved roughly the same order of reduction of vibration while preserving the same reduced pitching amplitude, as the Fin 1 configuration. Vibrations were about 50 percent of Fin 1 values. Maximum pitch reductions were about 55 percent of barehull pitch amplitudes. Vibrations induced by Fin 5(a), however, were less than those for Fin 1 only for slow speeds, and were as much as 175 percent of Fin 1 values at high speed. The large vibrations at high speeds probably result from wave impacts and effects due to large motion amplitudes. Maximum pitch reductions were about 35 percent for Fin 5(a), compared with 45 percent for Fin 1.

The effects on vibrations and pitching of increased depth of fin submersion are shown in Figure 7 where Fin 1(e) mounted below keel depth a distance equal to half the draft is compared with Fin 1 mounted at keel depth, and Fin 5 with the <u>top</u> of the circular cylinders at keel depth is compared with Fin 5(a) with the <u>bottom</u> of the cylinders at keel depth. The results indicate that increased depth of submersion had little effect on pitching performance, but that it reduced vibrations considerably, especially at slow speeds. For speeds corresponding to Froude numbers less than 0.15, vibrations were about 20 percent of corresponding Fin 1 values.

Comparative results for fins with large dihedral angles are shown in Figure 8. Fin 1(g) with 25-deg <u>negative</u> dihedral produced smaller vibrations than Fin 1(f) with 25-deg positive dihedral. Vibrations induced by Fin 1(g) were roughly 40 percent of corresponding Fin 1 values. Fin 2 (a) with 25-deg negative dihedral produced smaller vibrations than Fin 2 at slow speeds, but larger vibrations at high speeds. All fins with dihedral provided slightly less pitch reduction than did similar fins with zero dihedral angle.

The results shown in Figure 9 indicate that tip fences were more effective for reducing transverse vibrations than were flow access holes through the fin surface. Fin 1(c) with tip fences showed more improvement relative to Fin 1 than did Fin 1(a) with 1.0-in diameter holes near the fin root, or Fin 1(b) with 0.5-in diameter holes along fin tips and trailing edges. Fins 1(d) with both tip fences and holes induced somewhat larger vibrations than did fins with fences alone, probably because of the larger pitch amplitudes of the Fin 1(d) configuration. In general, Fins 1(a) and 1(d) were less effective for pitch reduction than Fin 1. Fins 1(b) and 1(c) were essentially the same as Fin 1.

The results obtained for fins with forward and backward sweep are shown in Figure 10 where Fin 3 with 25-deg backward sweep at leading and trailing edges is compared with Fin 3(a) with 25-deg forward sweep, and Fin 4, a triangle mounted so that its base is the fin's leading edge, is compared with Fin 4(a), the same triangle mounted so that its base is the trailing edge. The results indicate that the reversed fins produced only minor changes in the vibration and pitching characteristics of the original configurations.

DISCUSSION AND CONCLUSIONS

Broad applications of the results given in this report are severely limited because test conditions were restricted to regular head seas. The natural athwartship symmetry of such conditions resulted in pitch, surge, and heave motions but not in roll, sway, or yaw motions which probably have a considerable effect on fin-induced hull vibrations. These effects will be investigated in the near future when new test facilities are completed which will permit experiments at oblique headings and in shortcrested seas.

Since the evaluation of fin effectiveness requires consideration of the pitch reduction as well as the vibration level, an arbitrary figure of merit has been chosen which measures fin effectiveness relative to the basic Fin 1 configuration. The figure of merit for a fin, N, at each speed has been chosen to be

$$\frac{\dfrac{\text{Pitch Reduction (Fin N)}}{\text{Pitch Reduction (Fin 1)}}}{\dfrac{\text{Vibration Level (Fin N)}}{\text{Vibration Level (Fin 1)}}} = \frac{\dfrac{\text{Pitch Reduction (Fin N)}}{\text{Pitch Reduction (Fin 1)}}}{\text{Relative Vibration}}$$

This relationship yields a qualitative indication of the merit of the various configurations. The figure for Fin 1 is unity and a higher value indicates improved performance. In Figure 11, the figure of merit is plotted as a bar graph summarizing the results for three distinct speeds (Froude numbers 0, 0.15, 0.30.)

The results of the experiments in head seas indicate that none of the various fin modifications were completely effective in eliminating transverse hull vibrations. Considerable improvement relative to the basic Fin 1 configuration was obtained, however, through the use of fins with higher aspect ratio, tip fences, or increased depth of submersion. Less improvement was found for fins with holes, dihedral angles, or swept edges. Cylindrical (annular) fins showed considerable promise for minimum vibrations provided they were mounted deep enough to eliminate adverse free surface effects. Additional research is needed, however, to improve their pitch damping characteristics.

Other fin configurations which were not included in the present study should also be investigated. These include fins with movable flaps at trailing edges and fins with large initial negative angles of attack. Both of these devices should result in less vibration since flow separation (breakdown) due to large positive (upward) flow angles would be minimized. An additional reduction in vibration would be obtained by positioning the fins considerably aft of the present forefoot location in order to eliminate lateral impacts at relatively weak bow sections. Such locations may be impractical, however, because of reduced effectiveness for pitch reduction.

Based on the fact that maximum fin-induced vibrations generally occur for speeds which correspond to the region of maximum pitching motion, forward speed is believed to affect vibration magnitudes only in so far as pitch amplitudes are affected by frequency of encounter. In other words, vibration magnitudes are directly related to vertical fin velocities which depend on motion amplitudes and frequencies. Similarly, the large increase in vibrations with increasing wave height is due primarily to the increase in motion amplitudes in high waves.

The investigations described in this report should be considered only as a first step toward the solution of the vibration problem. Additional research is needed to determine whether results obtained from experiments in regular head seas can be extended with confidence to more realistic operating conditions such as oblique headings or shortcrested random seas. Considerably more information is also needed with respect to normal transverse hull vibrations in order to determine whether fin induced vibrations exceed acceptable limits and to correlate model measurements with full-scale results.

ACKNOWLEDGMENT

The authors are indebted to Miss Martha J. Watts who assisted in the model experiments and analysis of the data.

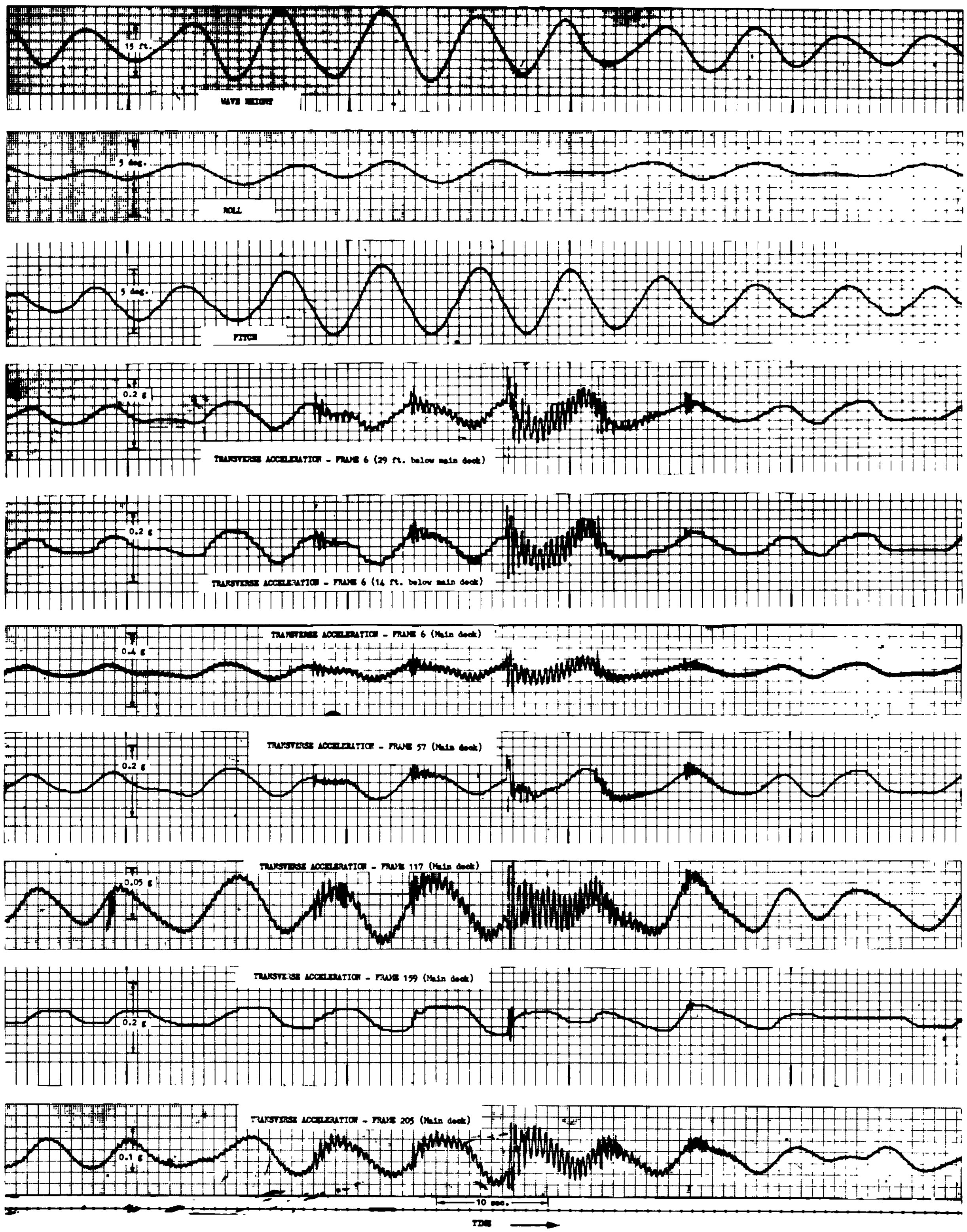


Figure 1 – Typical Vibration Records from Full-Scale Investigations

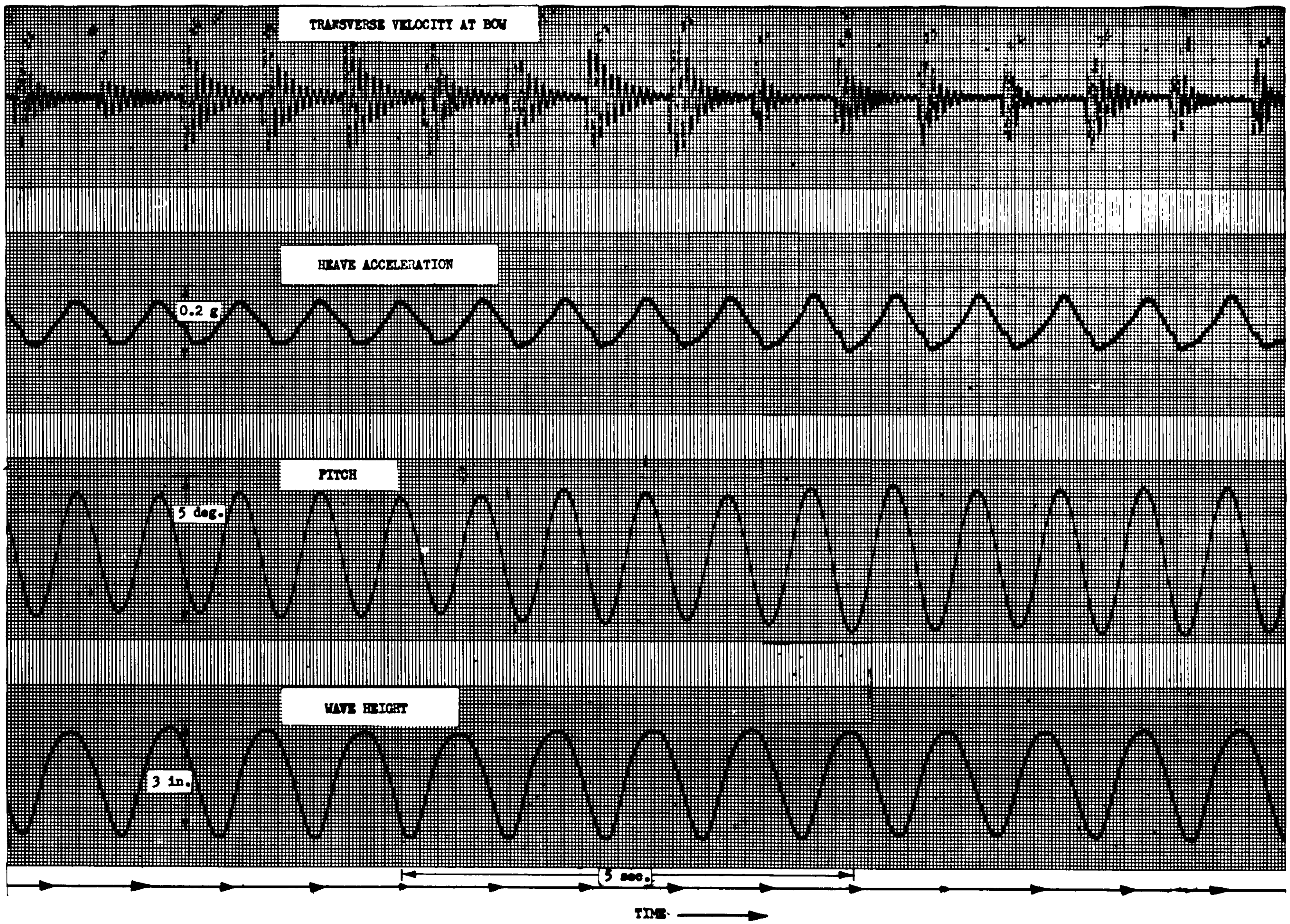


Figure 2 – Typical Vibration Records from Model Experiments

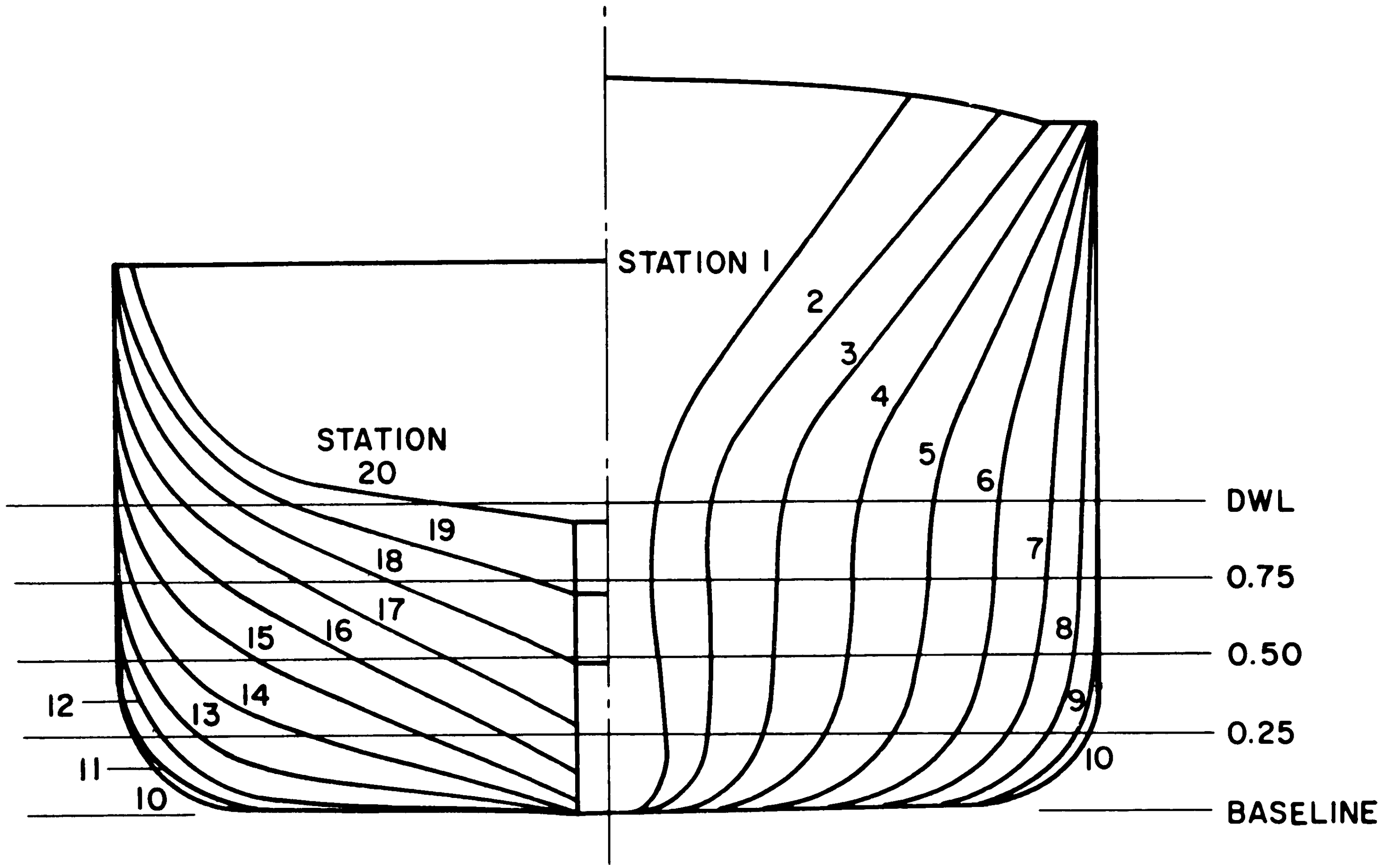


Figure 3 – Body Plan of CVE 55-Class Aircraft Carrier

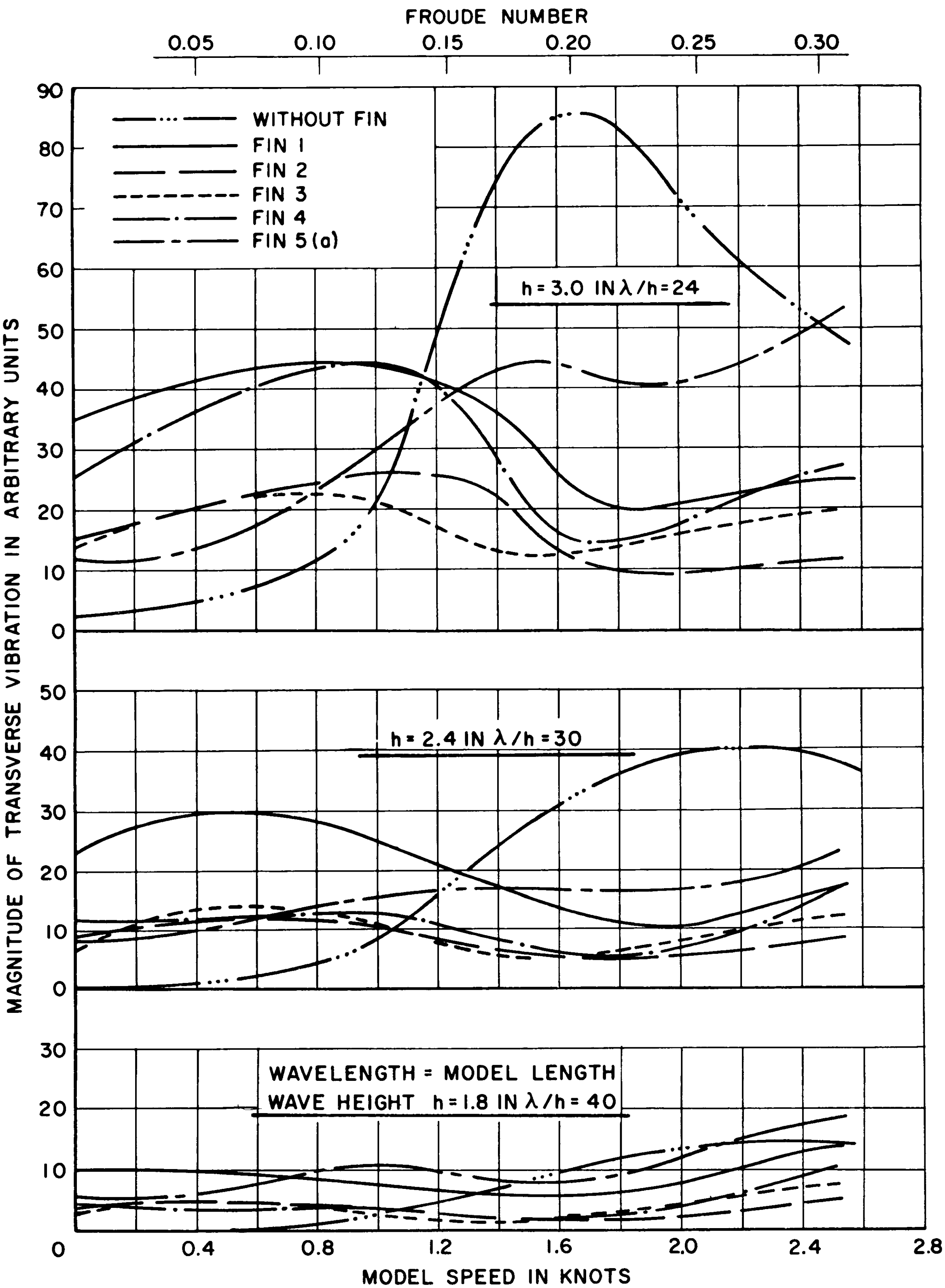


Figure 4 – Influence of Wave Height on Vibration Magnitudes

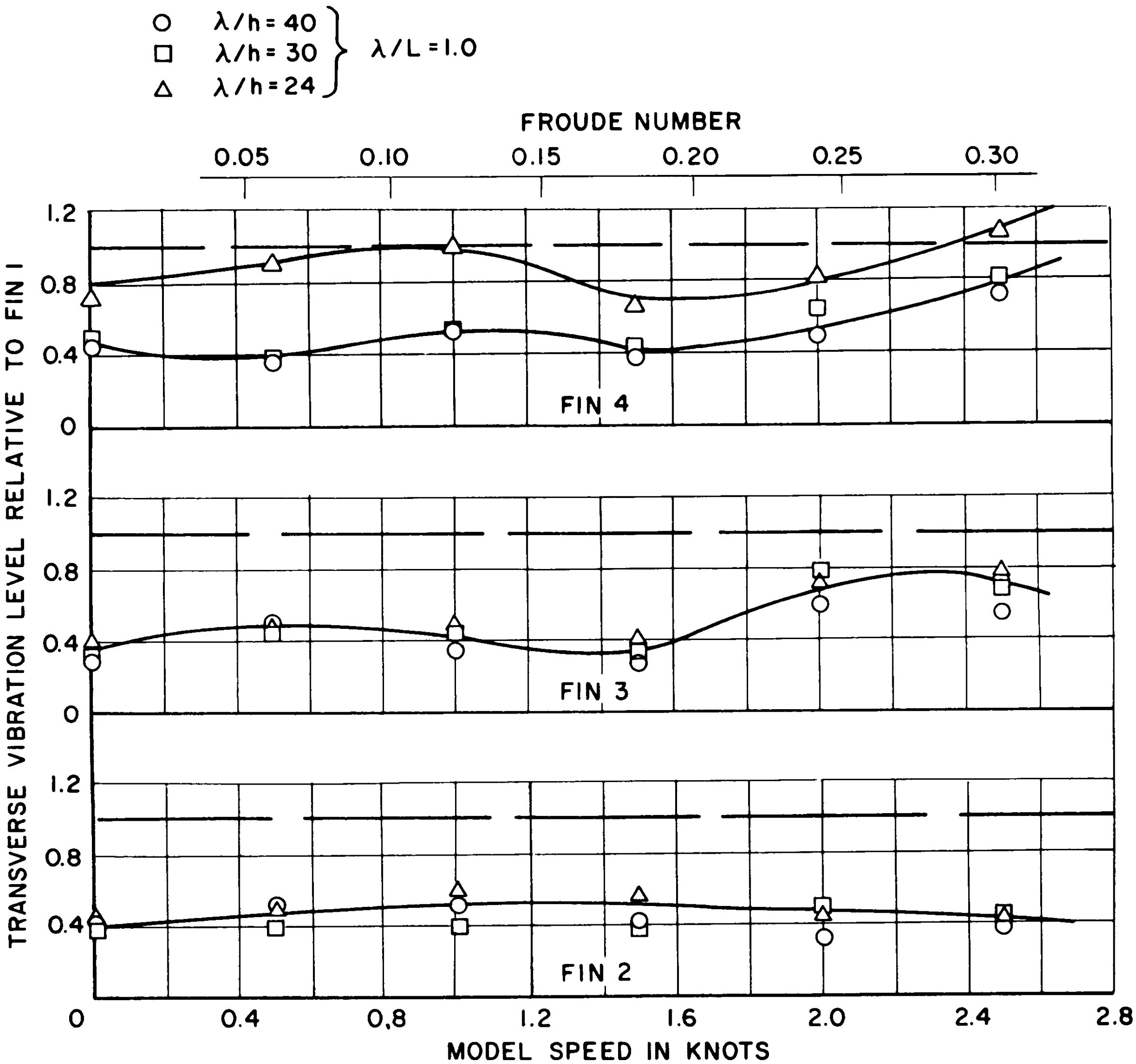


Figure 5 – Influence of Wave Height on "Relative" Vibration Magnitudes

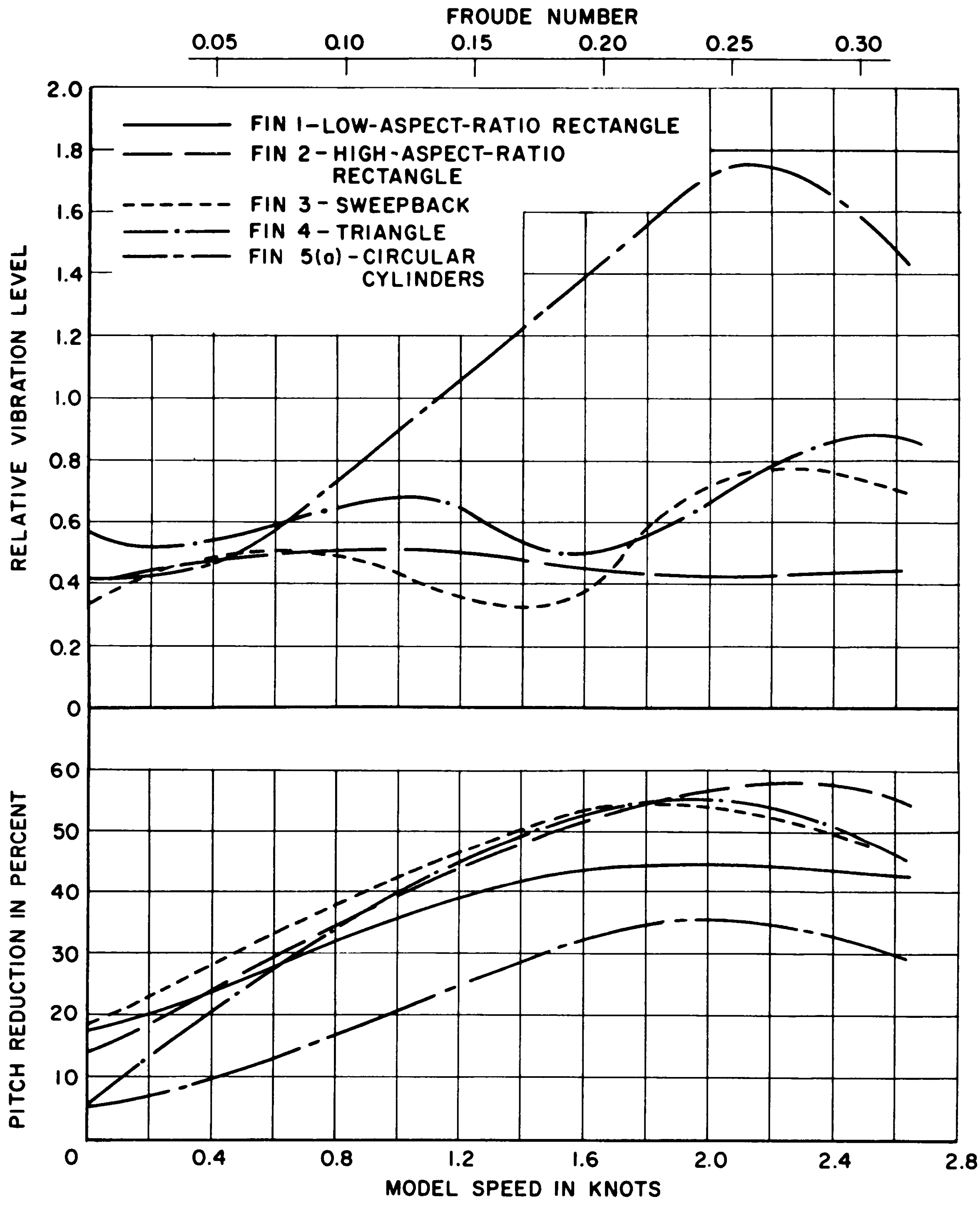


Figure 6 – Comparative Results for Fins with Various Shapes

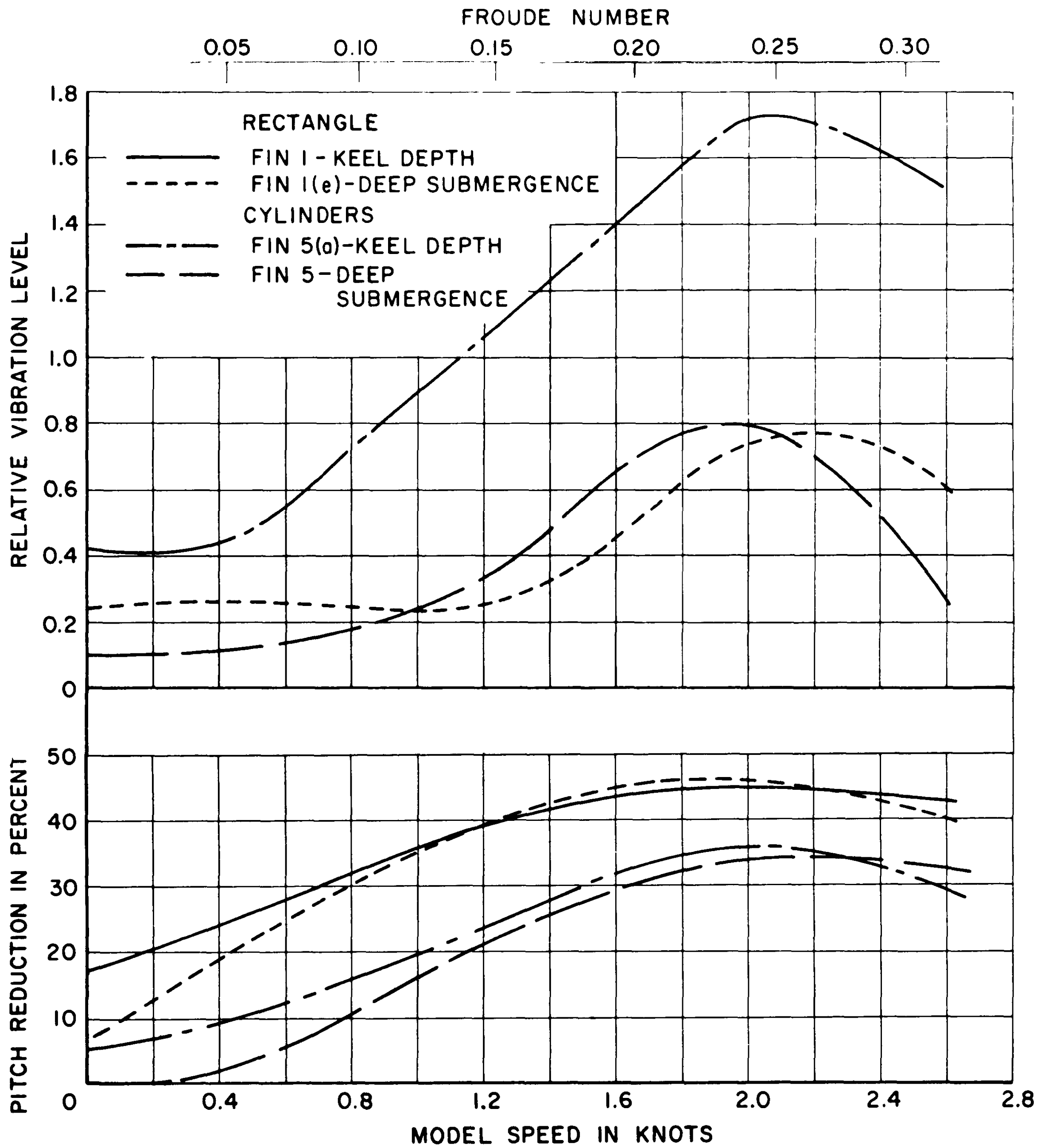


Figure 7 – Effects of Depth of Submergence

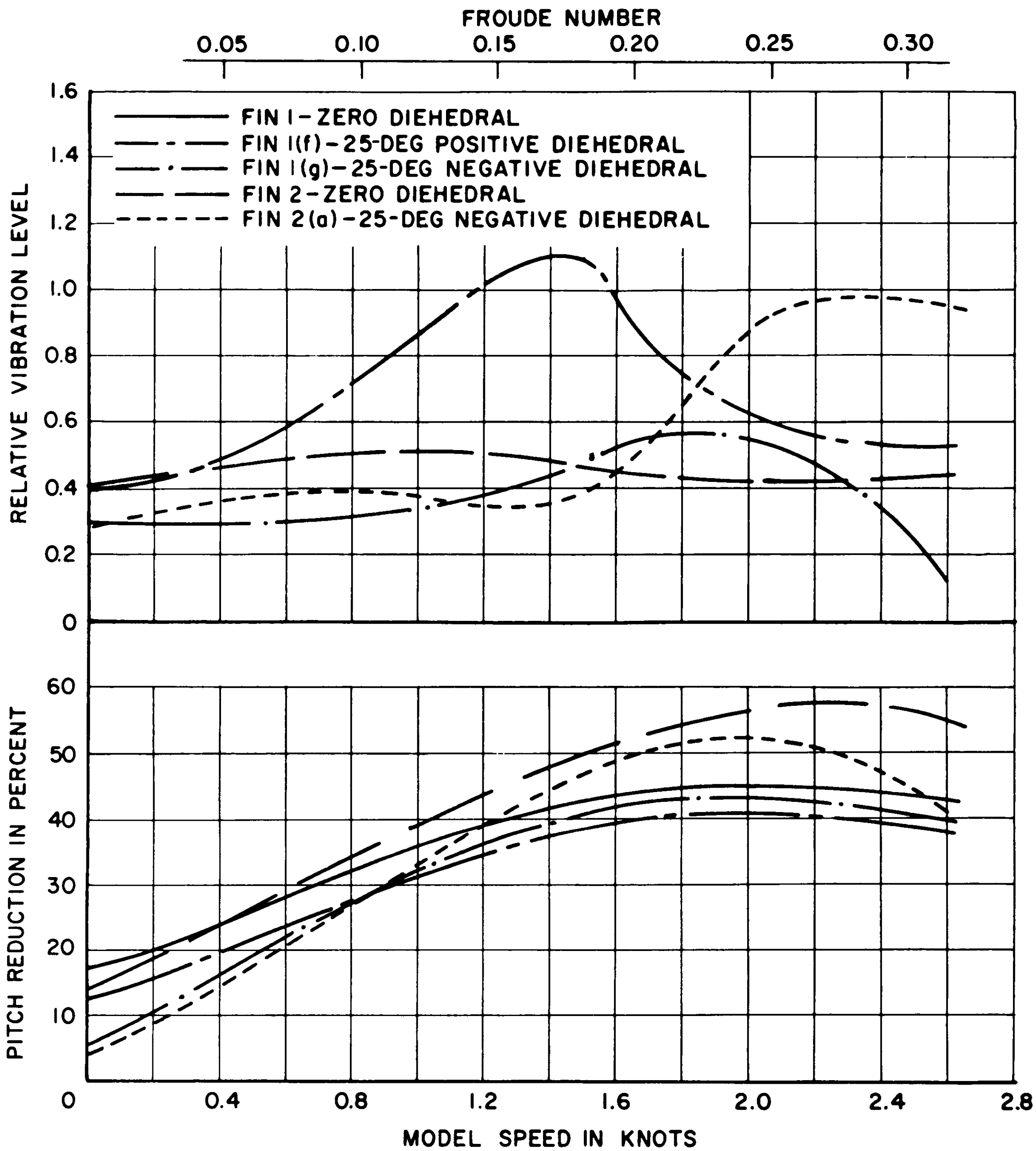


Figure 8 – Results for Fins with Dihedral

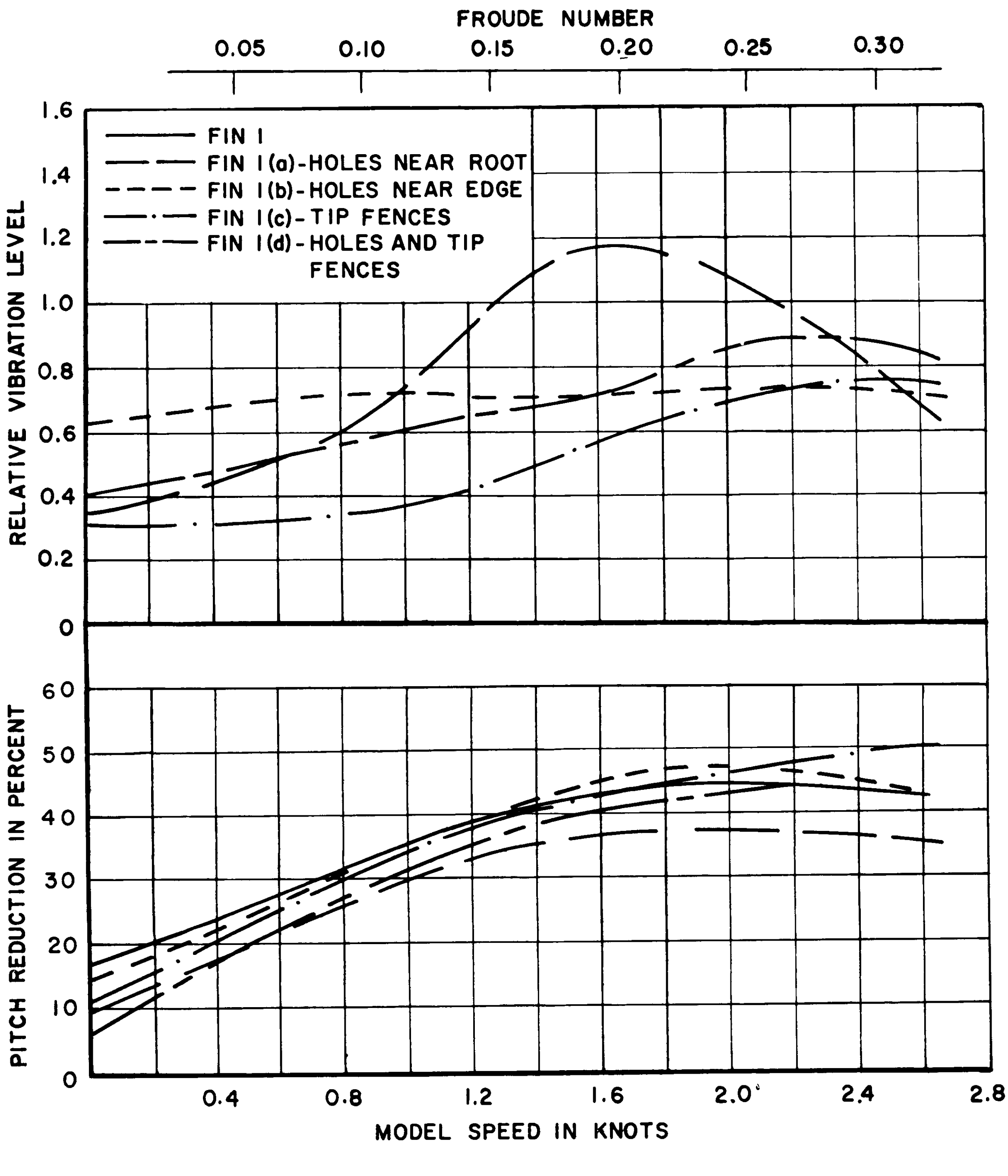


Figure 9 – Results for Fins with Holes and Tip Fences

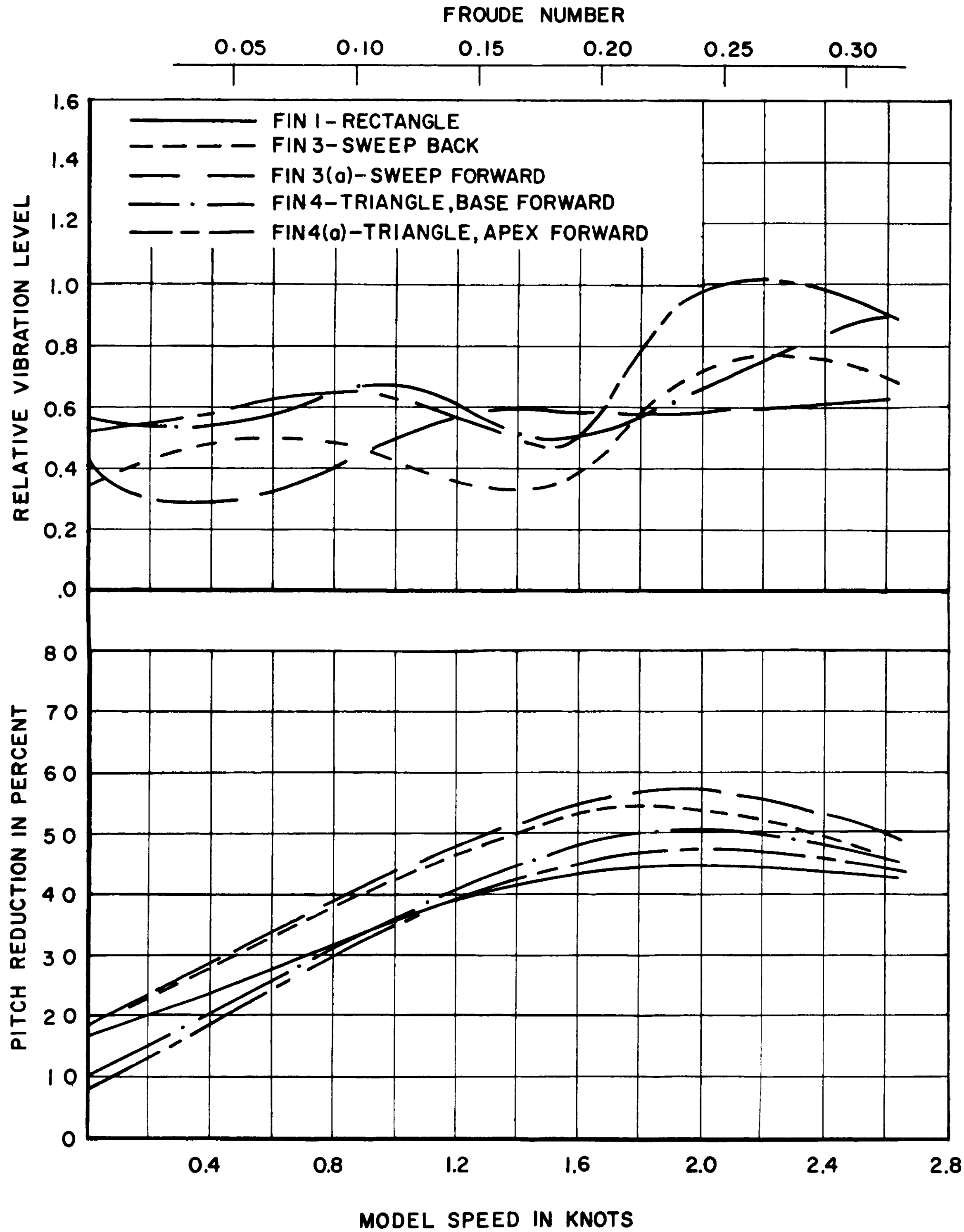


Figure 10 – Results for Fins with Swept Edges

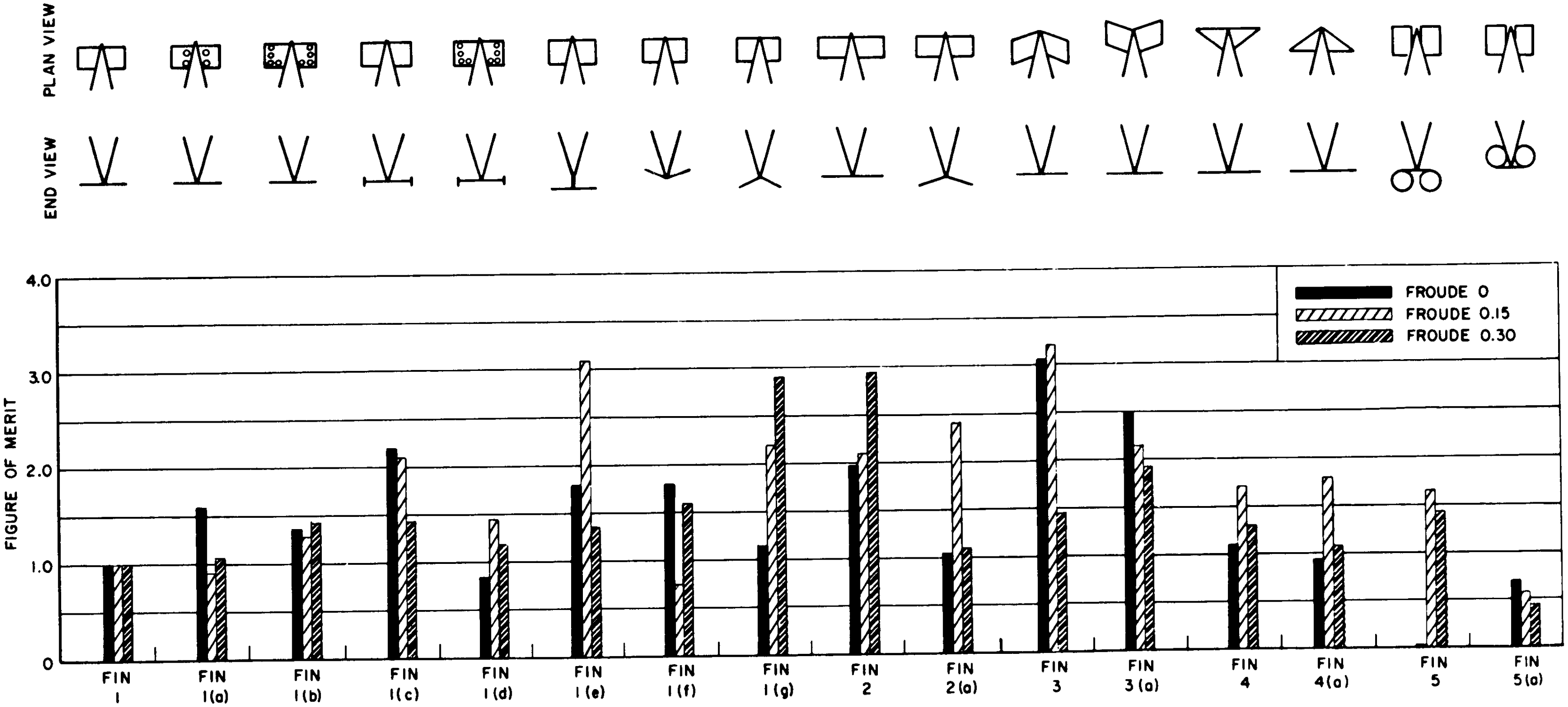


Figure 11 – Qualitative Evaluation of Fin Performance

APPENDIX A

EXPERIMENTAL DATA FROM VIBRATION AND PITCH ANGLE MEASUREMENTS

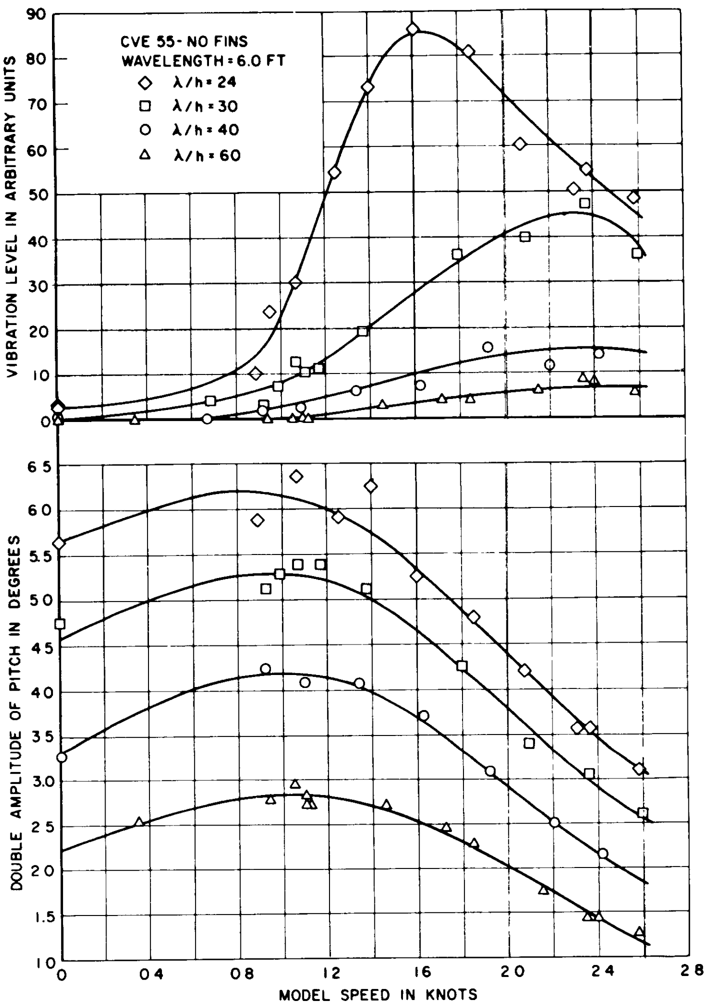


Figure A-1 – No Fins

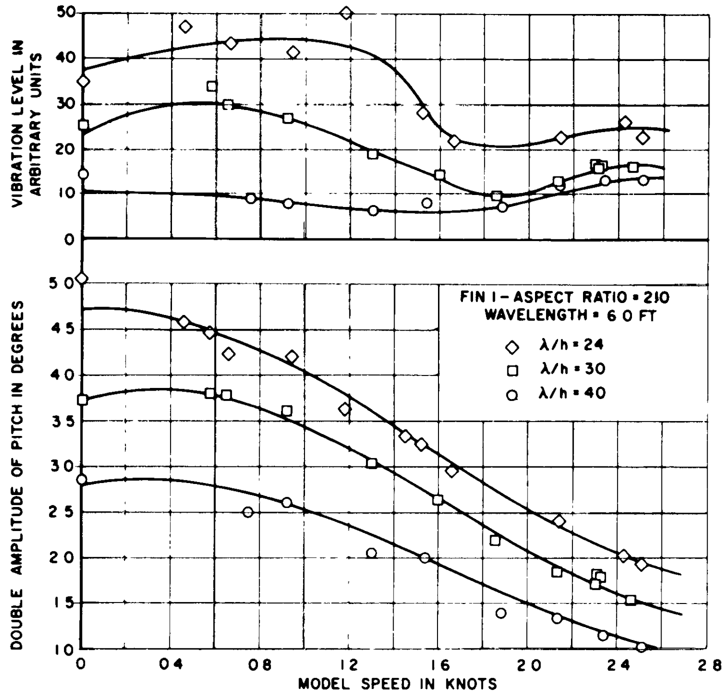


Figure A-2 — Fin 1

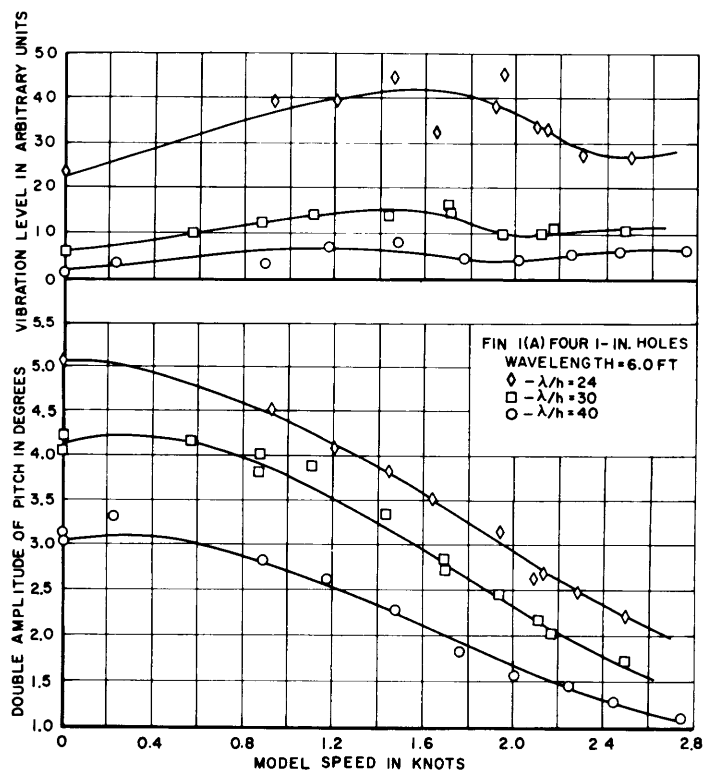


Figure A-3 — Fin 1(a)

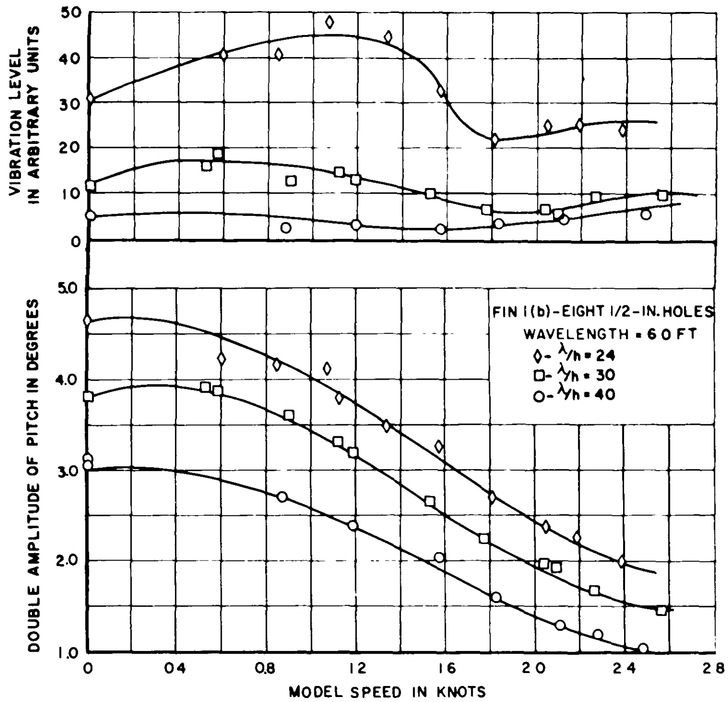


Figure A-4

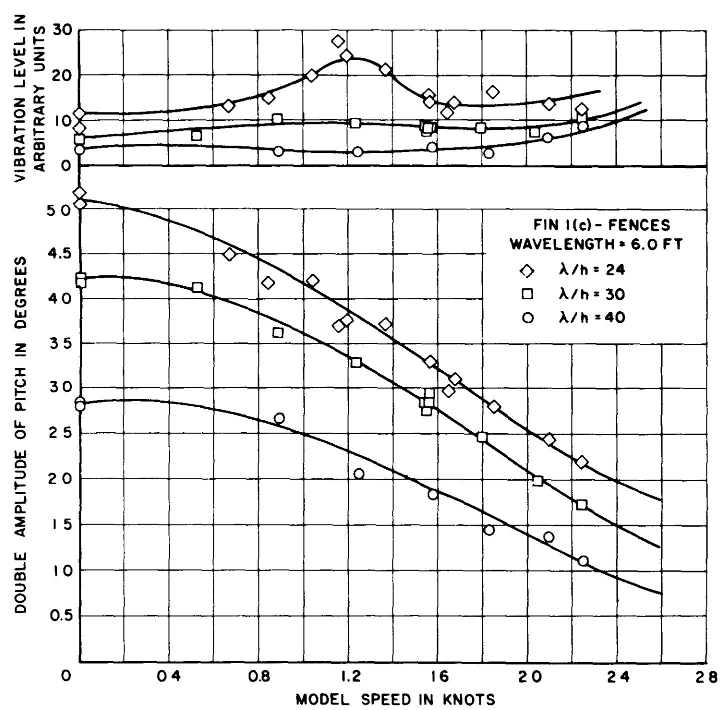


Figure A-5 — Fin 1(c)

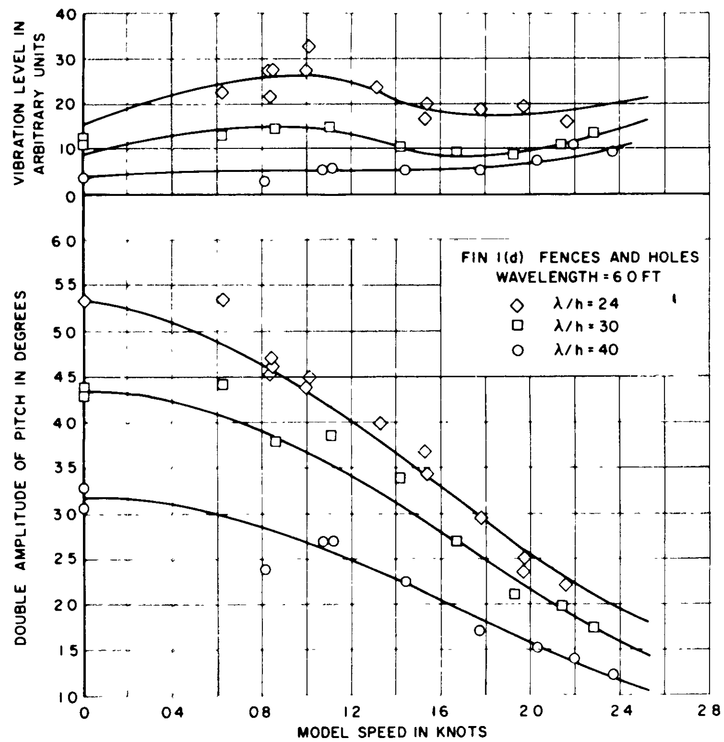


Figure A-6 — Fin 1(d)

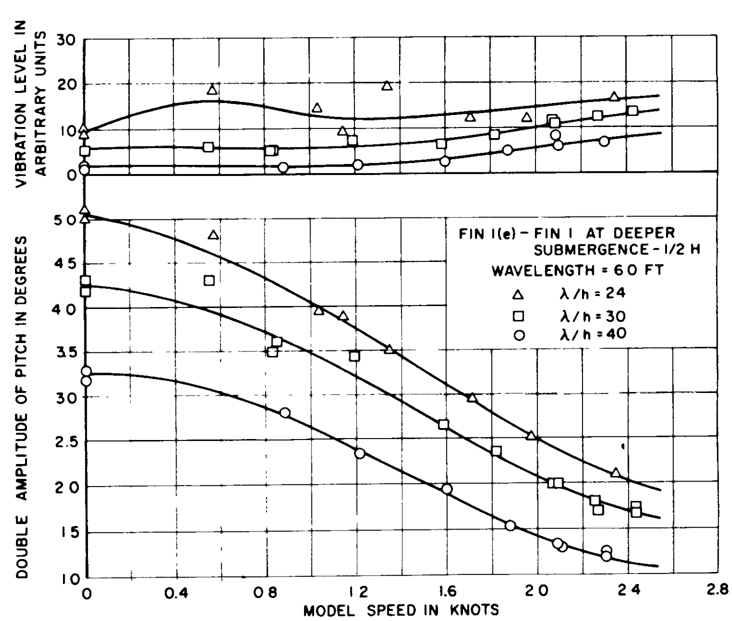


Figure A-7 — Fin 1(e)

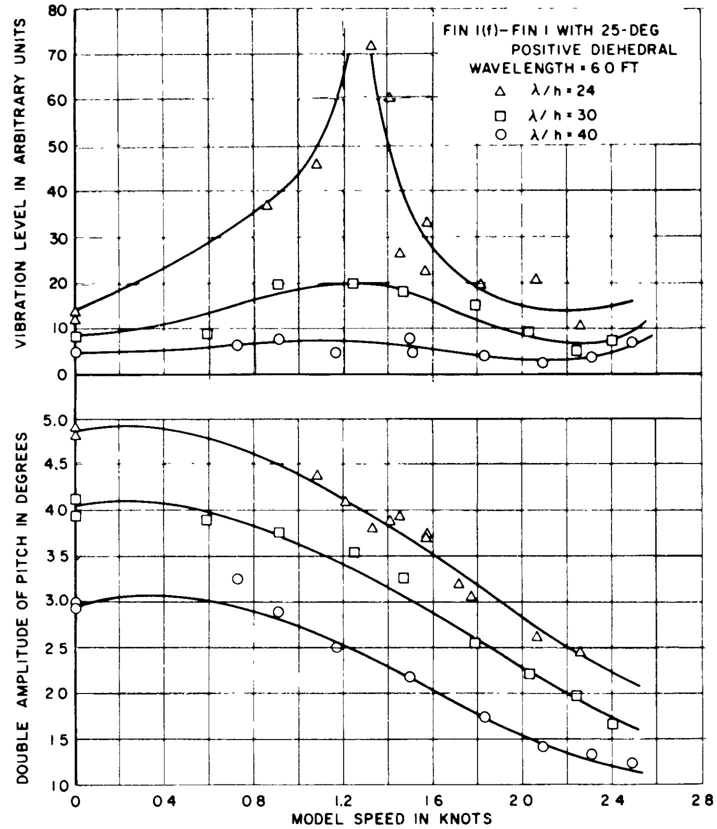


Figure A-8 – Fin 1(f)

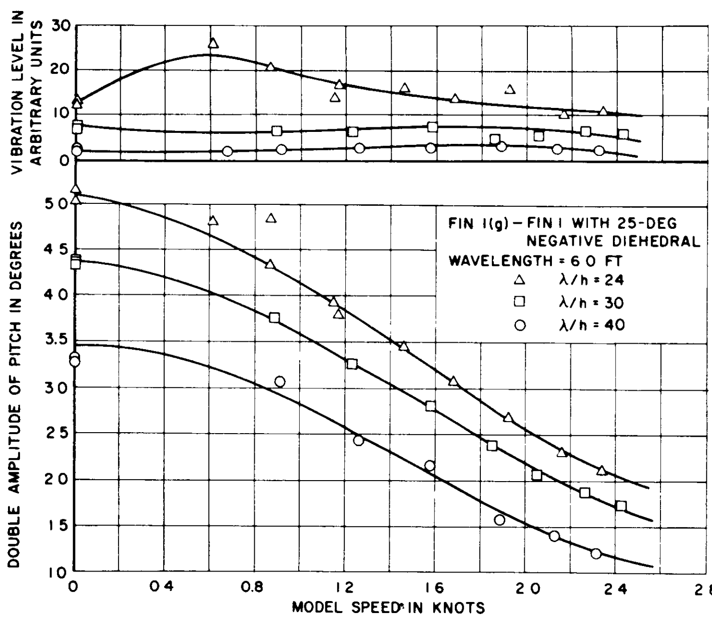


Figure A-9 – Fin 1(g)

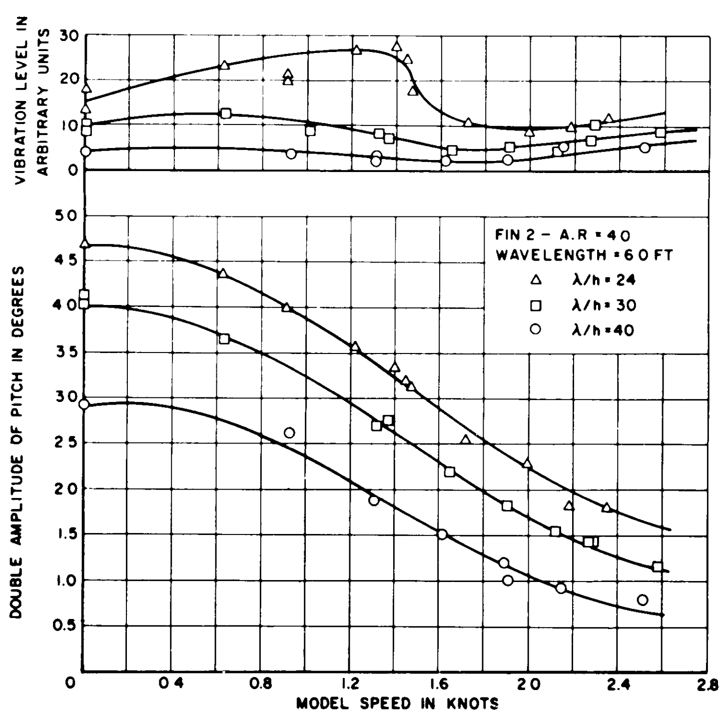


Figure A-10 – Fin 2

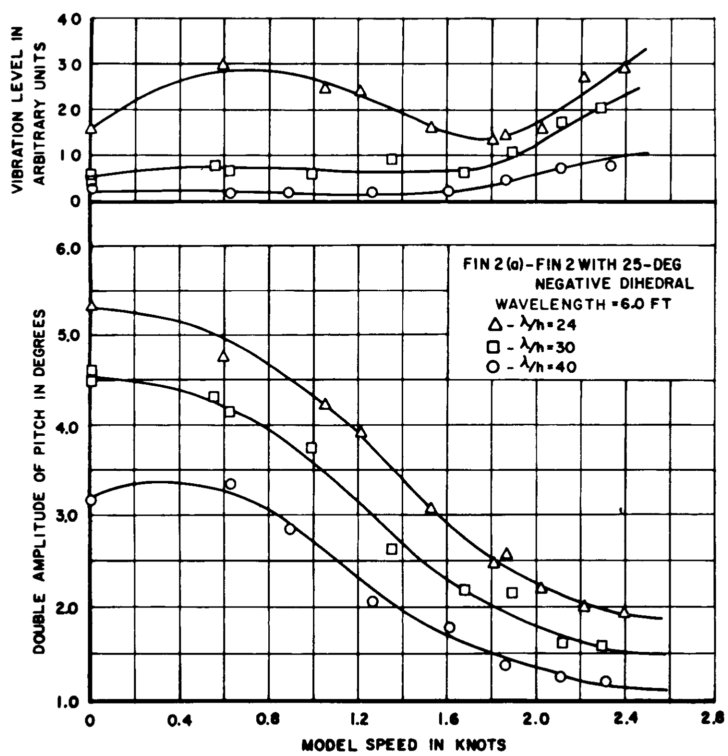


Figure A-11 – Fin 2(a)

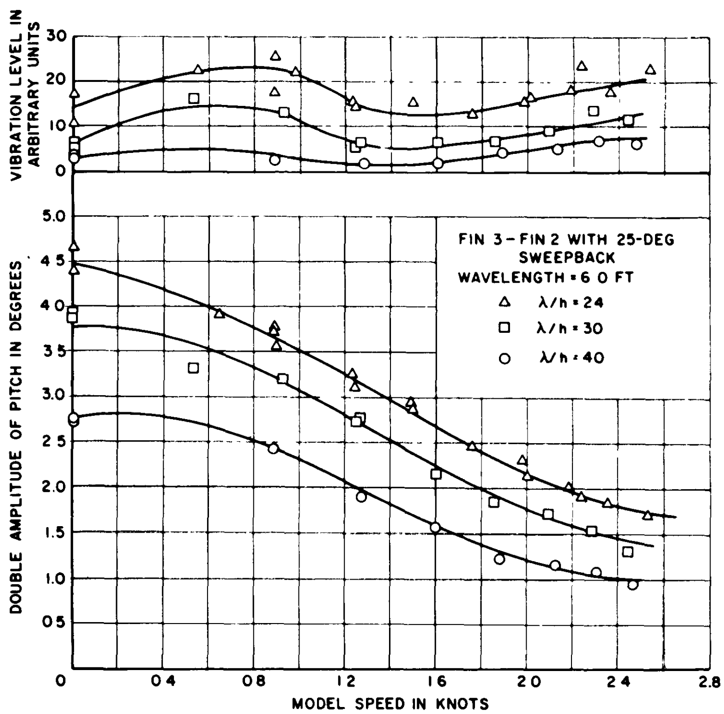


Figure A-12 – Fin 3

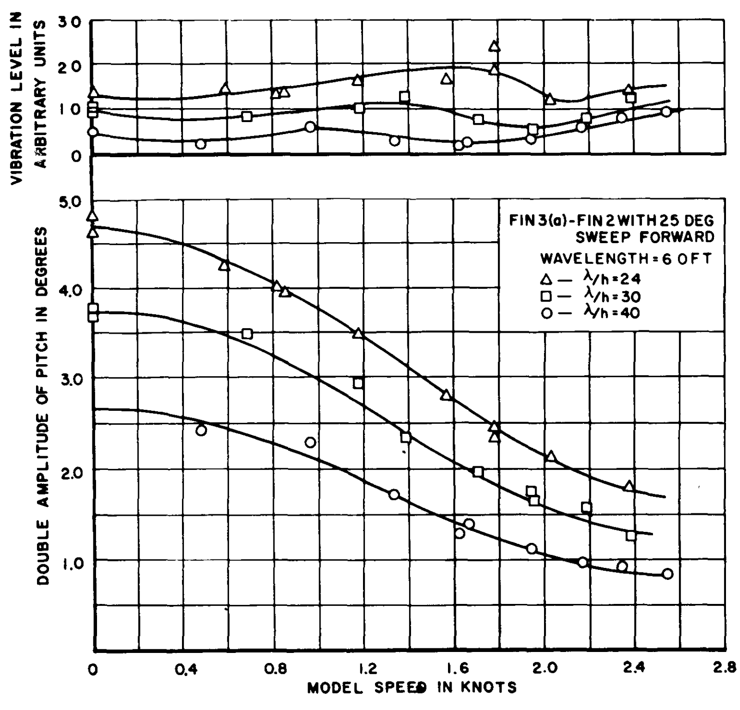


Figure A-13 – Fin 3(a)

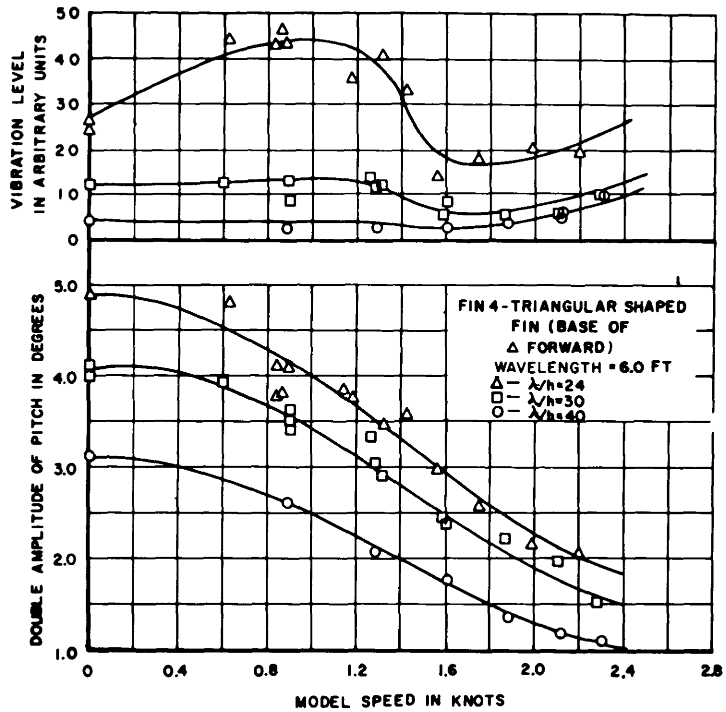


Figure A-14 – Fin 4

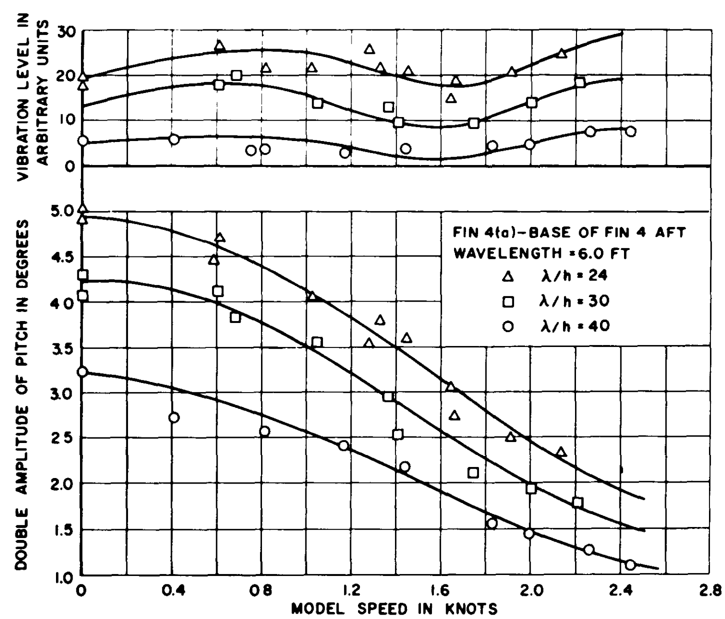


Figure A-15 – Fin 4(a)

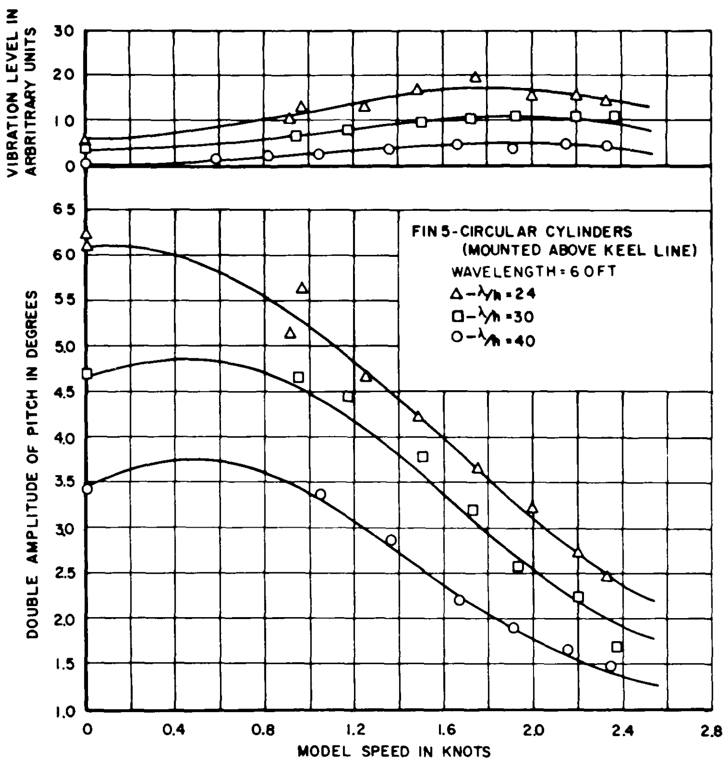


Figure A-16 – Fin 5

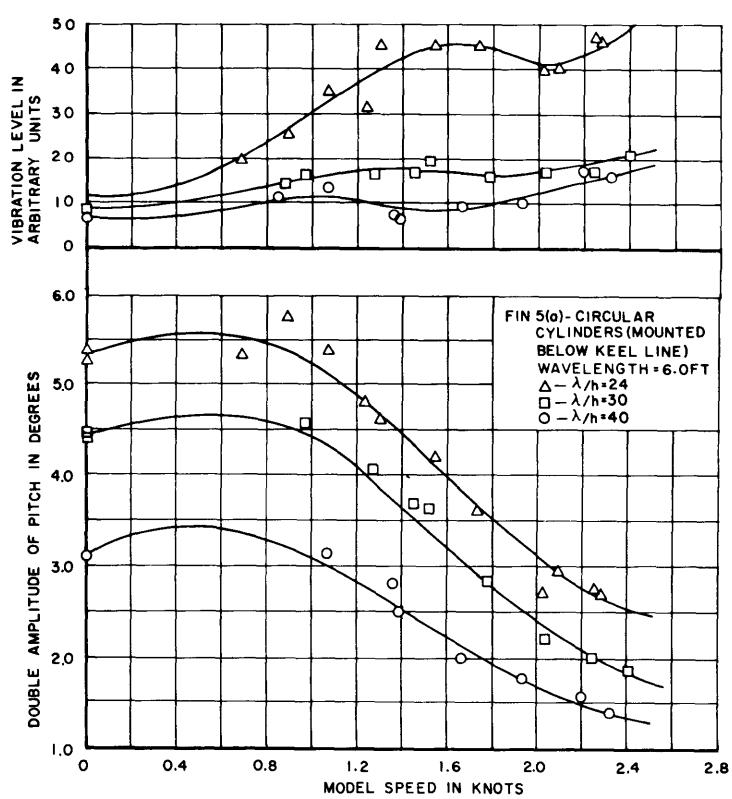


Figure A-17 – Fin 5(a)

APPENDIX B

EXPERIMENTAL DATA FROM RESISTANCE, HEAVE ACCELERATION AND PHASE ANGLE MEASUREMENTS

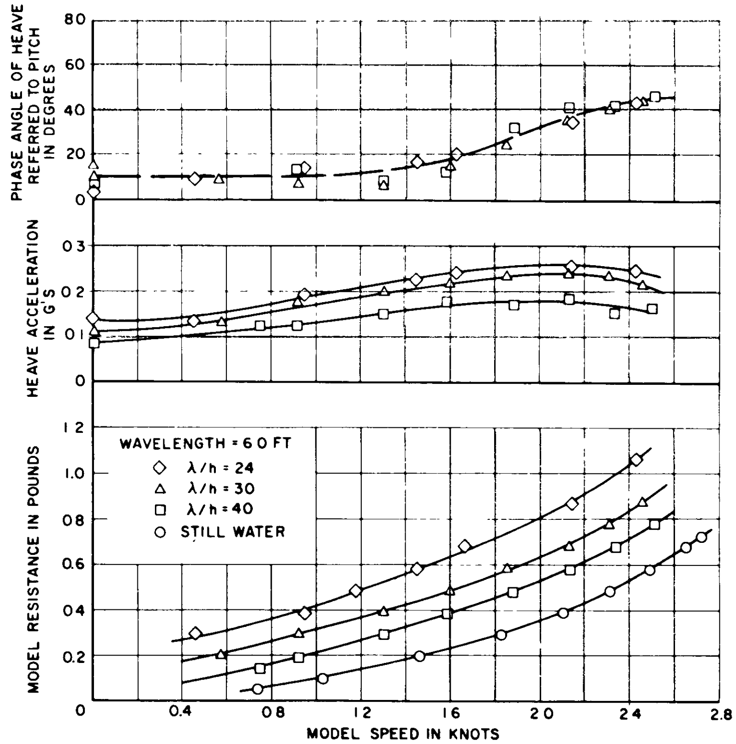


Figure B-1 — Fin 1

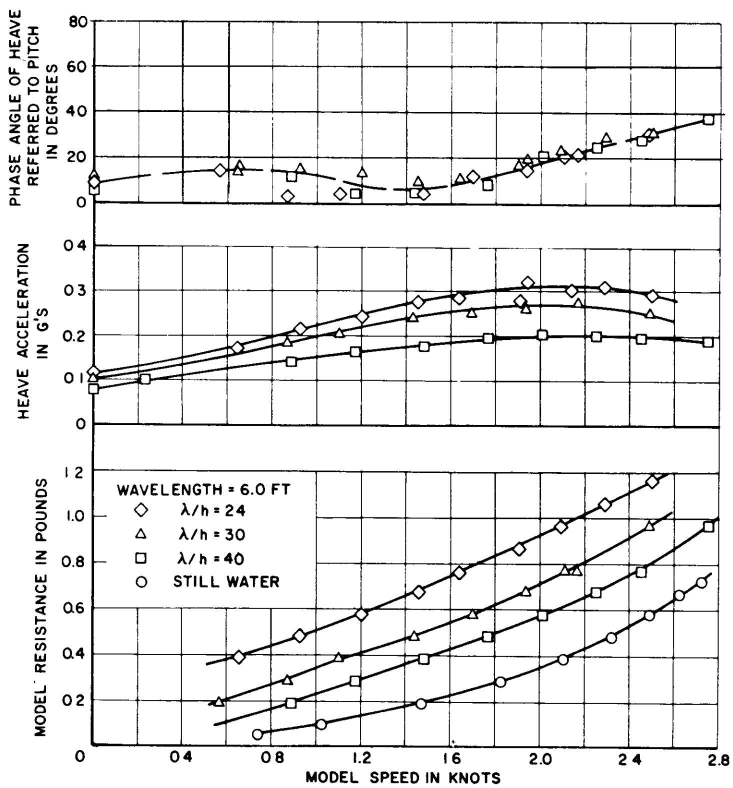


Figure B-2 — Fin 1(a)

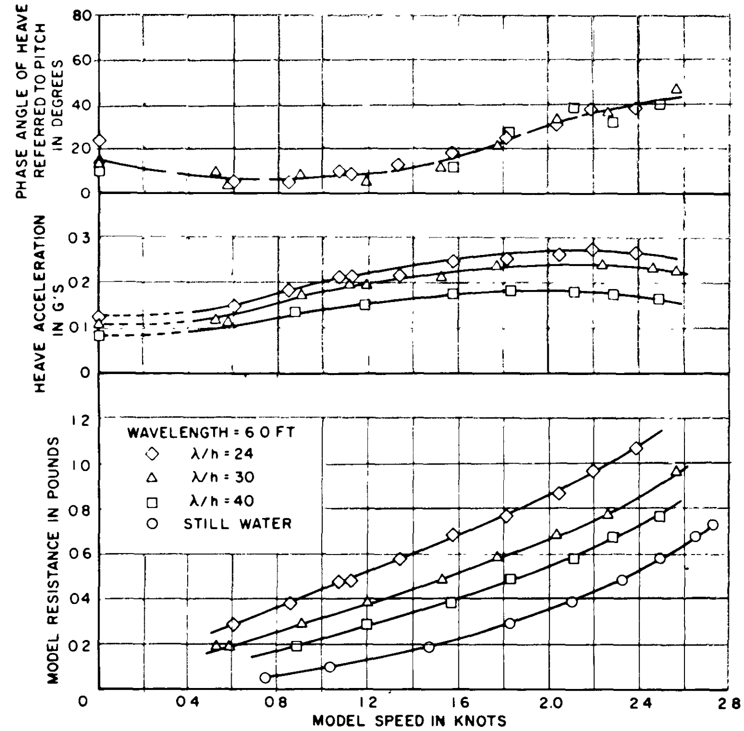


Figure B-3 – Fin 1(b)

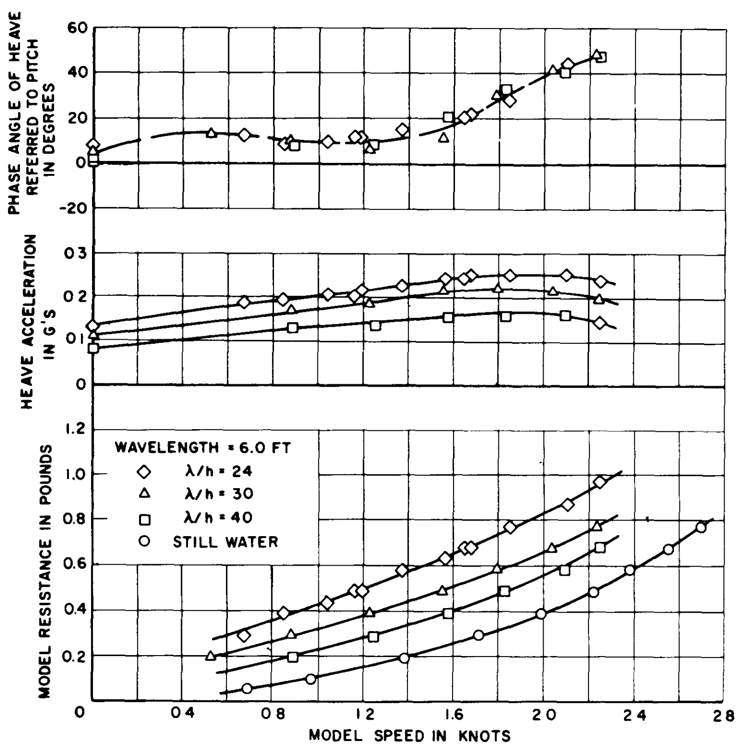


Figure B-4 – Fin 1(c)

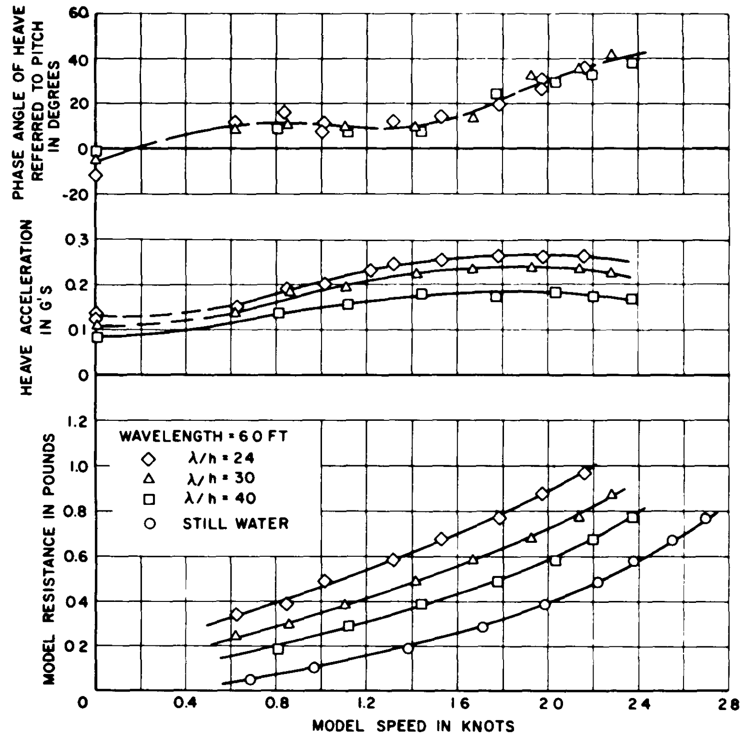


Figure B-5 – Fin 1(d)

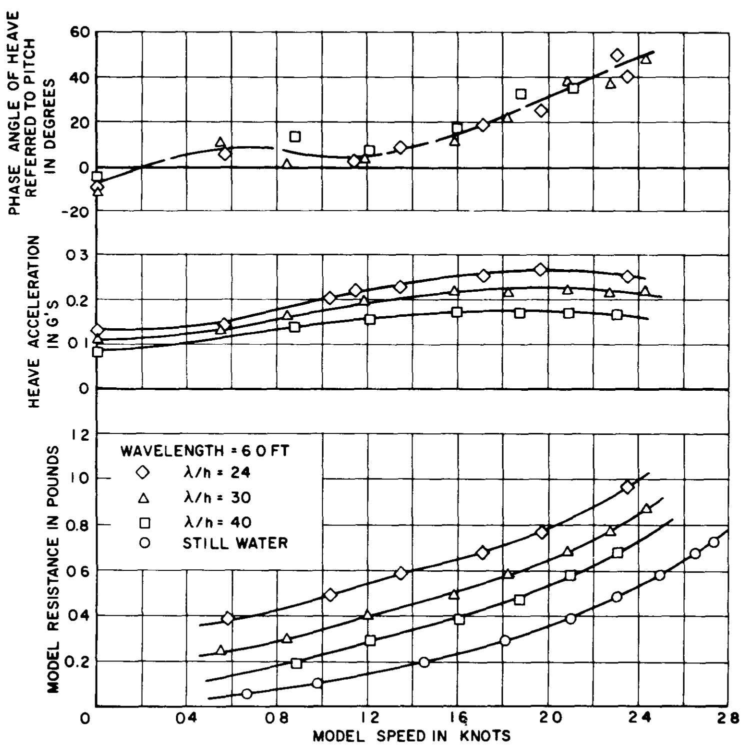


Figure B-6 – Fin 1(e)

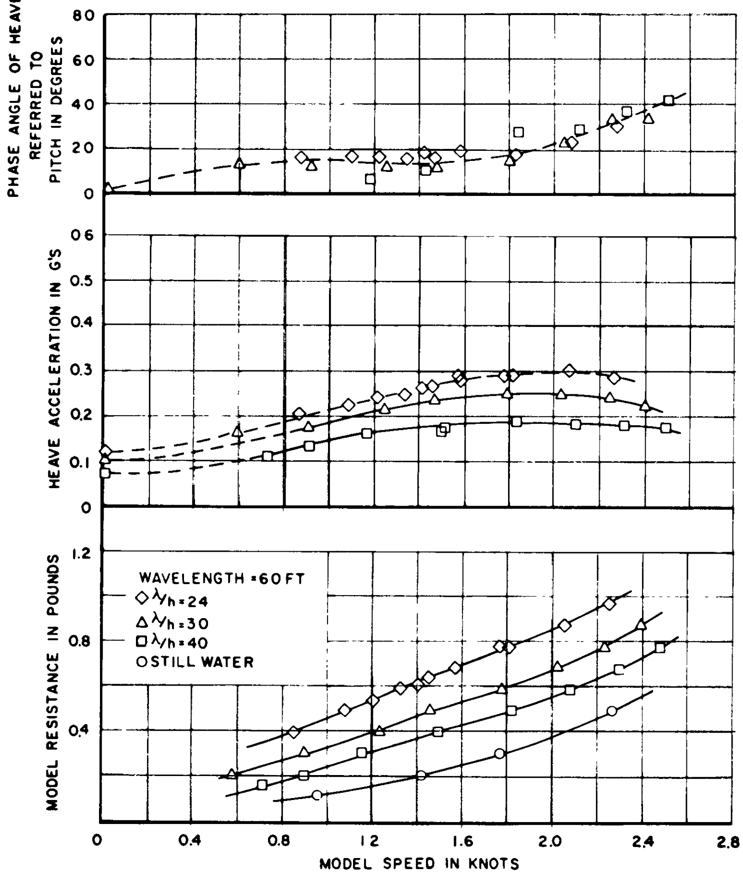


Figure B-7 – Fin 1(f)

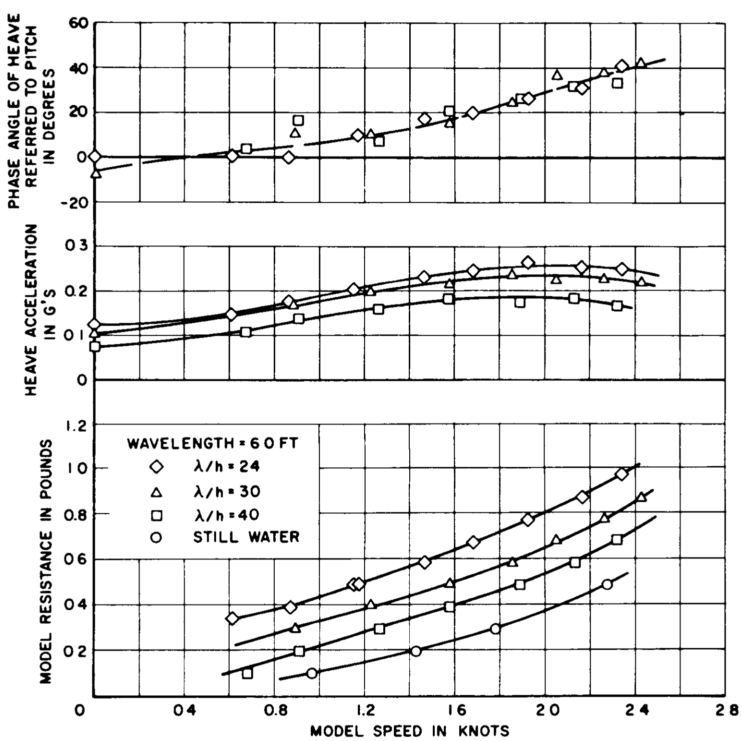


Figure B-8 – Fin 1(g)

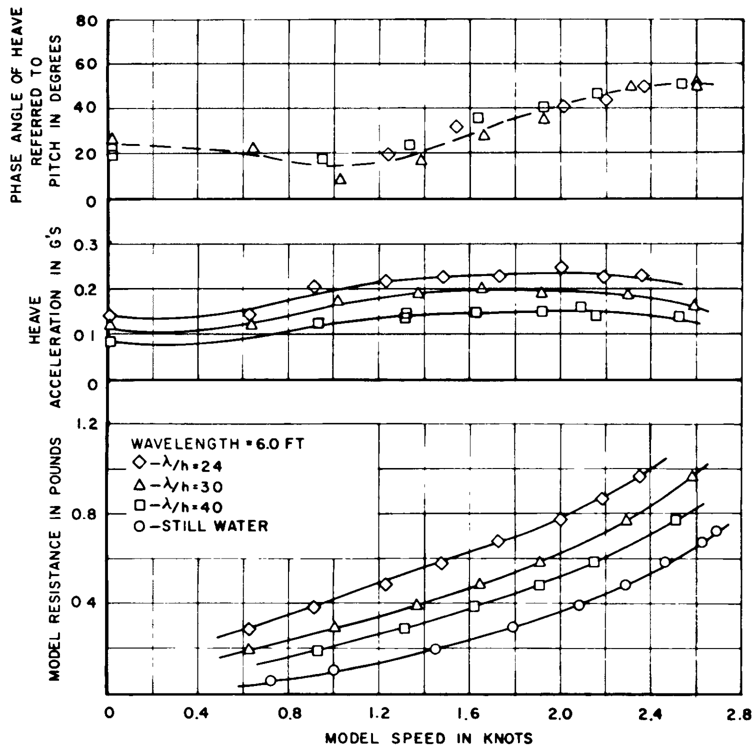


Figure B-9 – Fin 2

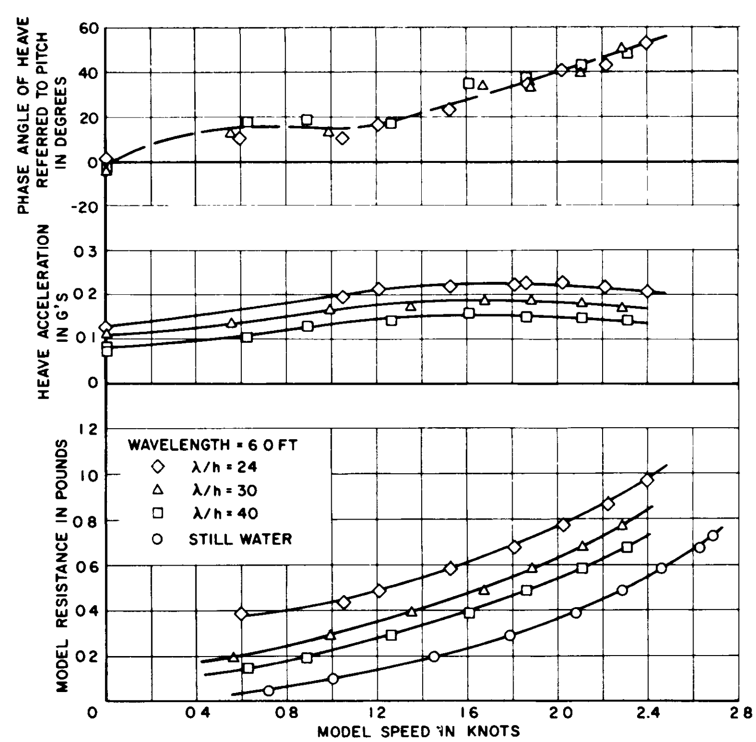


Figure B-10 – Fin 2(a)

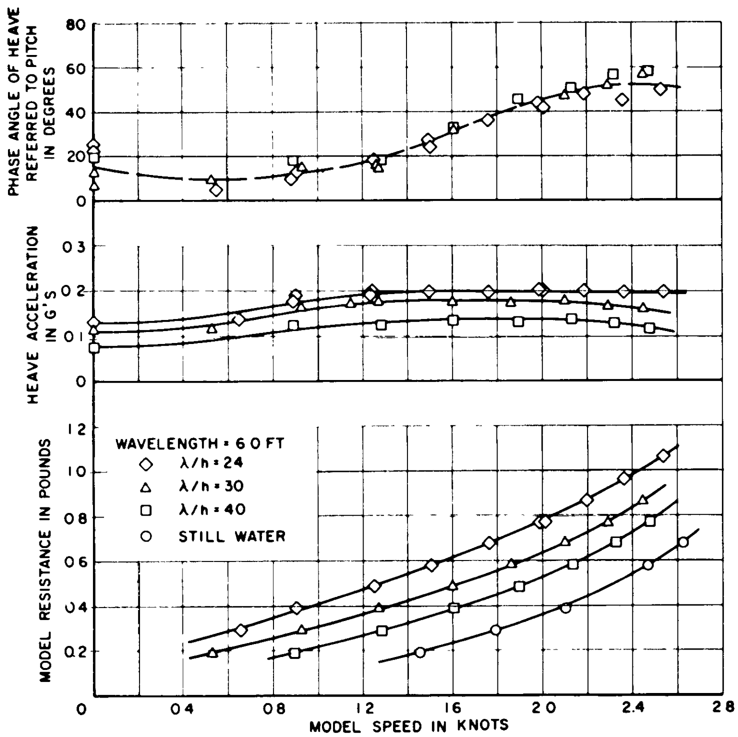


Figure B-11 – Fin 3

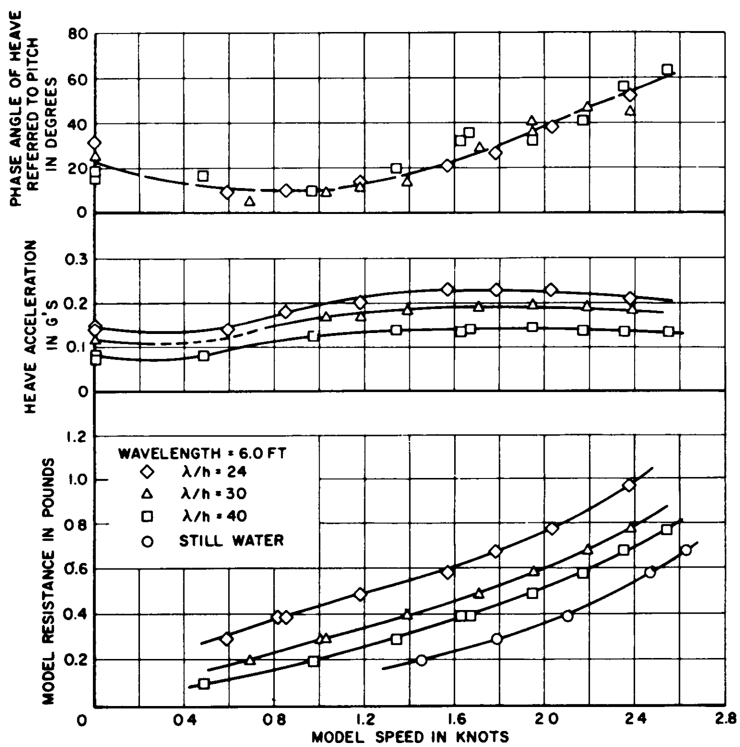


Figure B-12 – Fin 3(a)

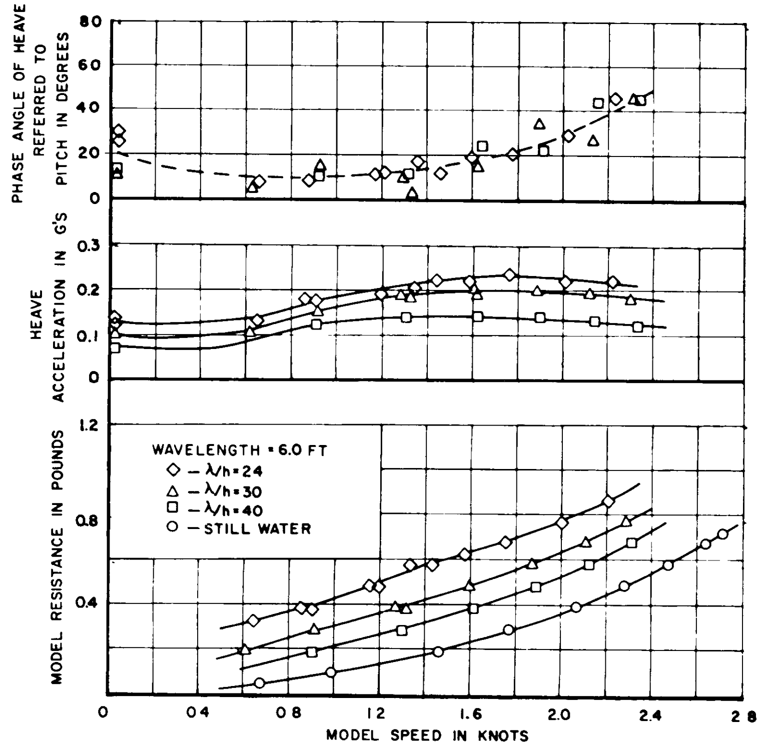


Figure B-13 – Fin 4

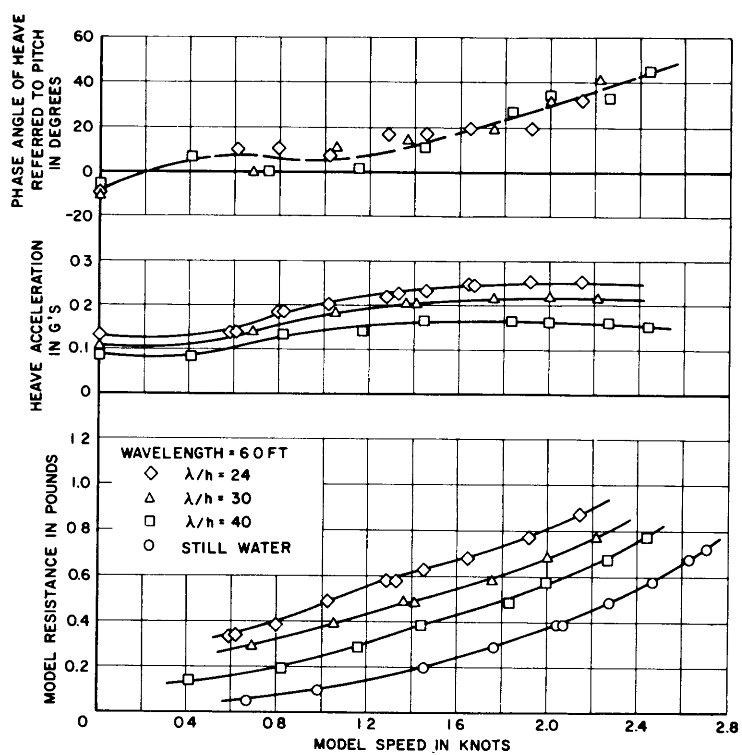


Figure B-14 – Fin 4(a)

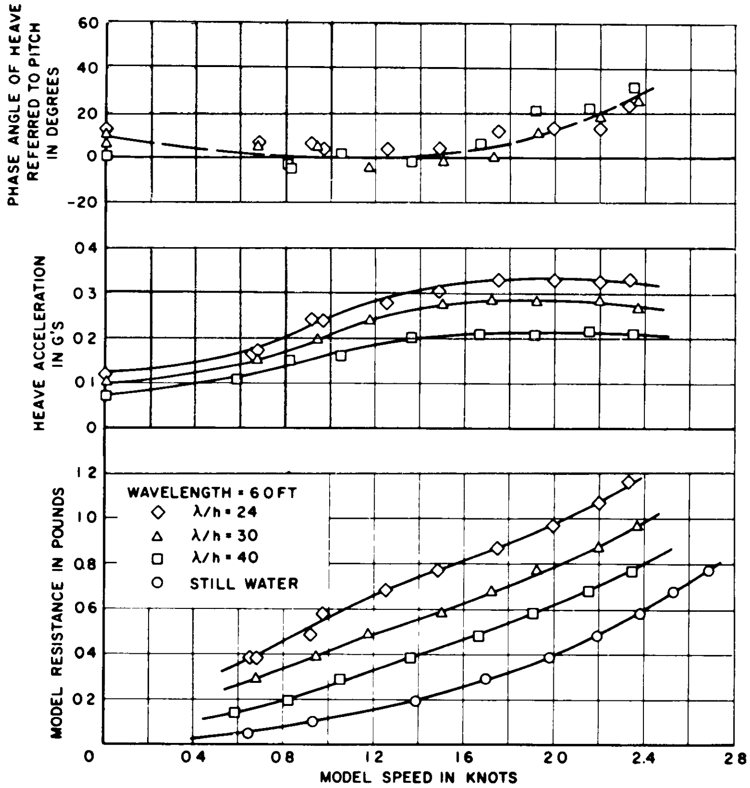


Figure B-15 – Fin 5

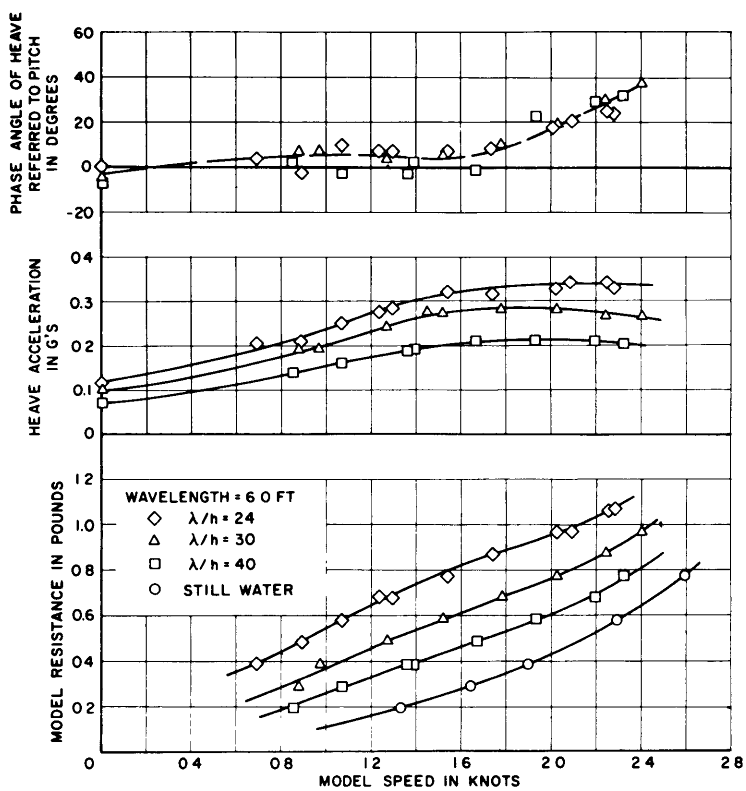


Figure B-16 – Fin 5(a)

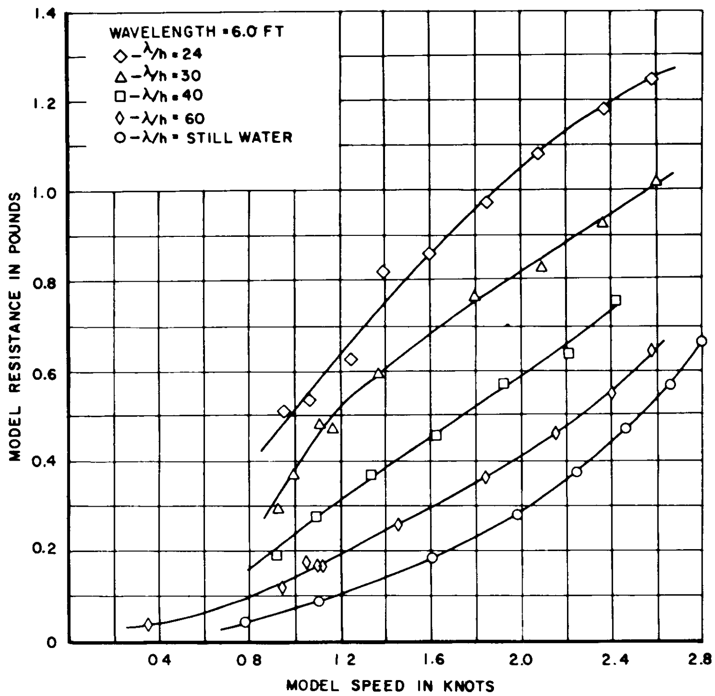


Figure B-17 – Resistance of Model without Fins

References

1. Becker, L. A. and Duffy, D. J., "Strength of Antipitching Fins and Ship Motions Measured on USS COMPASS ISLAND (EAG 153)," DTMB Report 1282 (Apr 1959).

2. COMPASS ISLAND letter 00:SAD:nag, S29, ser 53 of 21 Feb 1958.

3. BUSHIPS ltr AG 153 (442) ser 442-31 of 28 Mar 1958.

4. BUSHIPS ltr AG 153 (442) ser 442-45 of 25 Apr 1958.

5. DTMB ltr S8/COMPASS ISLAND, S87/Vibration of 10 Apr 1958.

6. DTMB ltr S8/COMPASS ISLAND of 27 June 1958.

7. DTMB ltr S8/COMPASS ISLAND of 25 Mar 1959.

8. COMPASS ISLAND ltr EAG:JHB:mlr, S1, ser 155 of 13 Apr 1959.

9. Birmingham, J. T. and McGoldrick, R. T., "Vibration Generator Experiments on SS GOPHER MARINER," DTMB Report 1011 (Mar 1956).

10. Todd, F. H., "Resistance Tests and Motion Observations on Models in a Seaway," DTMB Report 931 (Nov 1954).

INITIAL DISTRIBUTION

Copies	
10	CHBUSHIPS 3 Tech Info Br (Code 335) 1 Lab Mgt (Code 320) 1 Appl Res (Code 340) 1 Asst Ch, Des, Shipbldg & Fleet Maint (Code 400) 1 Prelim Des Br (Code 420) 1 Sub Br (Code 525) 1 Minesweeping Br (Code 631) 1 Torpedo Countermeas (Code 631 M)
2	CHBUWEPS 1 Weapon Handling Br (RSWI-5) 1 Aero & Hydro Br (RAAD-3)
5	CHONR 1 Nav Applications (Code 406) 1 Math Br (Code 432) 1 Fluid Dyn Br (Code 438) 1 Undersea Programs (Code 466)
1	ONR, New York
1	ONR, Pasadena
1	ONR, Chicago
1	ONR, Boston
1	ONR, London
1	NAVSHIPYD NORVA
1	NAVSHIPYD BSN
1	NAVSHIPYD PTSMH
1	NAVSHIPYD PUG
1	COMSURASDEVDET
1	CDR, USNOL
1	DIR, USNRL
1	CDR, USNOTS, China Lake
1	CDR, USNOTS, Pasadena
1	CO & DIR, USNMDL
1	CO, USNUOS
1	SUPSHIP, USN, Quincy
2	SUPSHIP, USN, Camden 1 Mr. J.W. Thompson, Nav Arch (Des)

Copies	
1	CDR, USNAMISTESTCEN
1	CG, Frankford Arsenal, Phila
1	BUWEPS Rep, Teterboro
1	DIR, Natl BuStand
10	CDR, ASTIA Attn: TIPDR
1	Dir Def R & E
1	Tech Dir, NRC, Com on Ship Struc
1	Dir, Alden Hydrau Lab, Worcester Polytech Inst
1	Dir, APL, JHUniv
1	Dir, Fluid Mech Lab, Columbia Univ
1	Dir, Fluid Mech Lab, Univ of California, Berkeley
1	Dir, Davidson Lab, SIT
1	Dir, Exptl Nav Tank, Univ of Michigan
1	Dir, Inst for Fluid Dyn & Appl Math, Univ of Maryland
1	Dir, Hydrau Lab, Univ of Colorado
1	Dir, Hydrau Res Lab, Univ of Connecticut
1	Dir, Scripps Inst of Oceanography
1	Dir, Fluid Mech Lab, New York Univ
1	Dir, Robinson Hydrau Lab, Ohio St Univ
1	Dir, Hydrau Lab, Penn St Univ
1	Dir, ORL
1	Dir, WHOI
1	Dir, Hydrau Lab, Univ of Wisconsin
1	Dir, Hydrau Lab, Univ of Washington
1	O in C, PGSCOL, Webb
2	Dir, Iowa Inst of Hydrau Res 1 Dr. L. Landweber
1	Dir, St. Anthony Falls Hydrau Lab

Copies

1 Dir of Res, Tech Inst, Northwestern Univ

3 Head, Dept NAME, MIT
 1 Prof. M.A. Abkowitz
 1 Prof. F.M. Lewis

3 NNSB & DD Co
 1 Asst Nav Arch
 2 Dir, Hydrau Lab

1 James Forrestal Res Ctr Libr
 Attn: Mr. M.H. Smith, Asst to Dir

1 Dr. M.L. Albertson, Dir, Colorado
 St Univ Res Fdtn

1 Dr. V.G. Szebehely, Gen Elec Co,
 Aero Sci Lab, Phila

1 Dr. B.V. Korvin-Kroukovsky
 P.O. Box 247, E. Randolph, Vermont