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MODEL EXPERIMENTS OF RO/RO SHIPS OFF-LOADING SYSTEM IN WAVES AND CURRENT

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

MODEL EXPERIMENTS OF RO/RO SHIPS OFF-LOADING SYSTEM IN WAVES AND CURRENT

by

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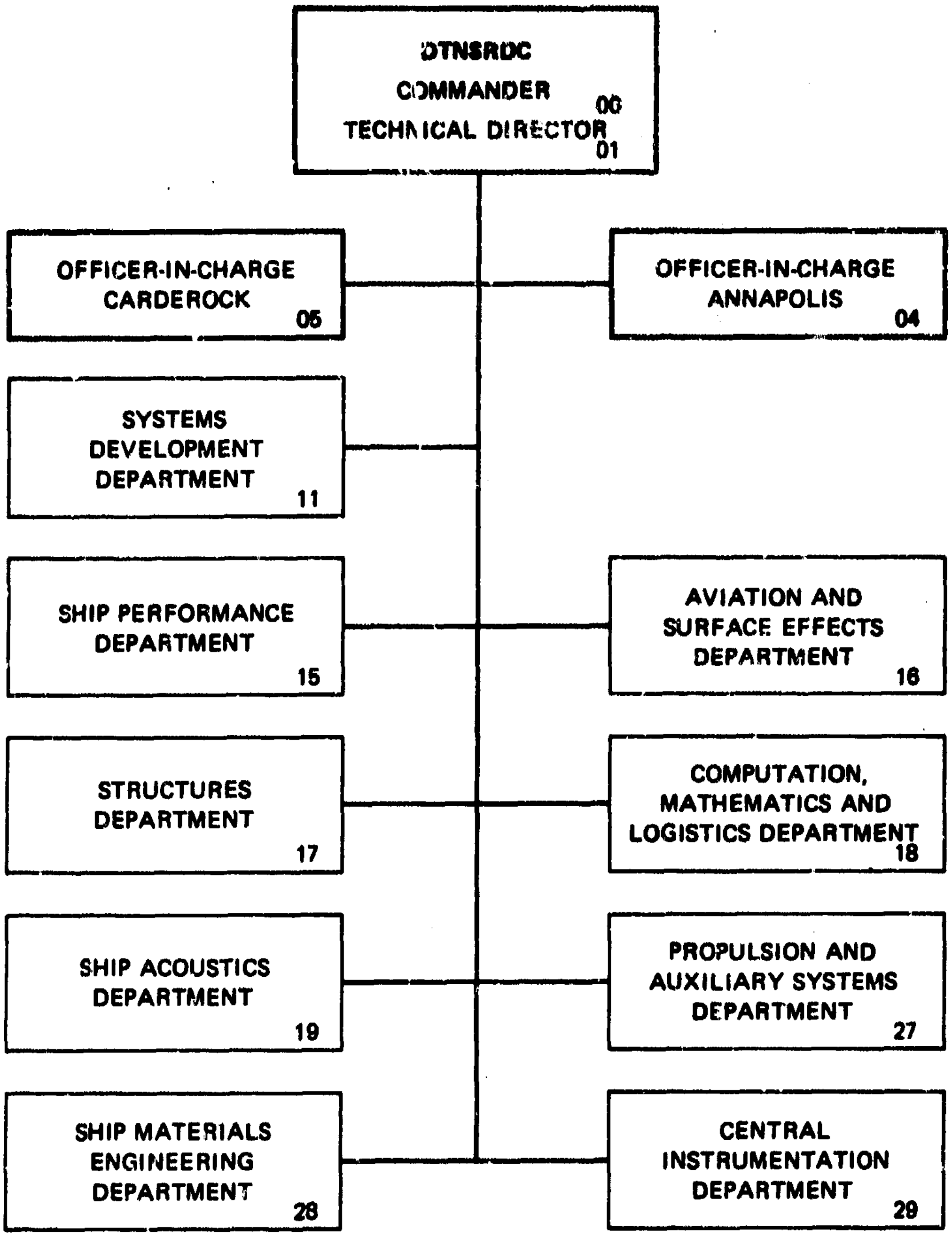

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Experiments were conducted in waves and calm water to evaluate the performance of several platforms made up to pontoon barges for offloading RO/RO ships in support of Assault Operations where port facilities are not available. A ferry/causeway consisting of three barges in line was attached to each platform. The experiments were conducted in sea and swell with and without current and measurements obtained of the platform motions and the mooring forces. The mooring forces or drag of the platform in current without waves

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Cont'd ABSTRACT

was also measured. The results of the experiments in waves and calm water are presented in graphs and tables in the report. The platform configuration designed for the SS GREAT LAND CLASS appeared to be superior to the other platforms examined. However, relative motion between the barges and the mooring forces were large, significant values of 10 degrees and 150 KIPS, respectively (single amplitude), when waves and current were coming abeam to the platform/causeway system.

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ABSTRACT

Experiments were conducted in waves and calm water to evaluate the performance of several platforms made up of pontoon barges for offloading RO/RO ships in support of Assault Operations where port facilities are not available. A ferry/causeway consisting of three barges in line was attached to each platform. The experiments were conducted in sea and swell with and without current and measurements obtained of the platform motions and the mooring forces. The mooring forces or drag of the platform in current without waves was also measured. The results of the experiments in waves and calm water are presented in graphs and tables in the report. The platform configuration designed for the SS GREAT LAND CLASS appeared to be superior to the other platforms examined. However, relative motion between the barges and the mooring forces were large, significant values of 10 degrees and 150 KIPS, respectively (single amplitude), when waves and current were coming abeam to the platform/causeway system.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

Present Department of Defense planning for logistical support necessary to sustain major contingency operations such as Amphibious Assault Operations Landings and Logistic Over-the-Shore evolutions, relies upon the utilization of U.S. Flag commercial shipping. Assault Follow-On Echelon equipment which consists of vehicles or equipment ultimately intended to be carried on vehicles is ideally suited for transport on RO/RO ships. However, loading and unloading of RO/RO vehicles is normally carried out at pier facilities; whereas, Amphibious Assault operations or other contingency operations will most likely be conducted over undeveloped beaches where port facilities are not available. Consequently, there is a need for a special facility or system to offload vehicles from RO/RO ships at undeveloped assault beaches.

A system presently under consideration for offloading RO/RO ships offshore consists of a transportable ramp and a platform made up of interconnecting barges or causeway sections which can readily be transported to the scene of action. Vehicles are driven off the ship onto the platform via the ramp and onto a string of barges (causeway), one of which is self-propelled, which ferry the equipment to shore. Figure 1 is an artist sketch of a possible scenario of such a system for the stern offloading of the RO/RO ship SS GREAT LAND.

The system was developed for calm water operations, however, the structure was designed for Sea State 2-3 with a current of 2 knots. In order to be able to more precisely define the operational envelope of such offloading systems and to anticipate any problem that may occur in waves or current, model experiments were conducted in the Harold E. Saunders Maneuvering and Seakeeping Facility at the David W. Taylor Naval Ship Research and Development Center. Several platform configurations were examined in various sea, swell and current conditions to determine the optimum configuration for the most efficient utilization of the available pontoons and equipment. The results of these experiments are summarized in tables and figures in this report.

DESCRIPTION OF MODEL AND INSTRUMENTATION

The full-scale barges which make up the platform and/or ferry are 90 feet long and 21 feet wide. Other barge characteristics are listed in Table 1. The barges are assembled from watertight cans or pontoons made of 3/16 inch thick steel with nominal planform dimensions of 5 feet by 7 feet and a nominal depth of 5 feet. Three rows of 15 cans each are bolted together to form the standard barge.

Nine 1/15 scale model barges were constructed out of 1/4 inch plywood as fully assembled units, i.e., no attempt was made to scale the individual cans since this would have been very costly and would not have significantly altered the results. A 1/15 scale ratio was selected to accommodate the wave generation capabilities of the facility while minimizing model construction cost and facilitating model handling during the experiments. Figure 2 is a sketch of the barge model.

The full-scale barges are interconnected to form the platform or causeway/ferry using special flexible connectors (flexors). In the model experiments the barges were interconnected using simple door hinges. The hinge line was located to provide a 1 in. (25.4 mm) separation between the model barges which closely corresponds to the equivalent full-scale (0.4 m) and allows at least 15 degrees of relative motion between barges. The models were capable of being hinged together side-by-side or end-to-end to form any desirable platform configuration. Each barge was ballasted to the conditions listed in Table 1. The radii of gyration and center of gravity were calculated assuming that the weight was uniformly distributed on the surface area of the individual cans or pontoons. Additional ballasting was required after the barges were assembled into a platform to represent the weight of the ramp and supporting plate plus an XM1 battle tank, dunnage and fender weight.

Four different platform configurations were examined during these experiments and are referred to as configurations 1 through 4. Configuration 1 corresponds to that considered for the port stern offloading of the SS MAINE CLASS. Configuration 2 corresponds to that for both the stern and side offloading of the SS GREAT LAND CLASS and, configurations 3 and 4 are somewhat extreme exploratory variants of configuration 2. Association of a particular configuration with a specific ship class is used only to facilitate identification and may not necessarily be the configuration that will be eventually utilized.

Configuration 1 for the stern port offloading of the SS MAINE CLASS consisted of four barges connected side-by-side representing the platform and three barges in line representing the ferry as shown in Figure 3. Figure 4 is a photograph of the model platform in the test facility. Ballasting for this configuration was in accordance with specifications presented by J. J. Henry Company, Inc., Drawing 1969-00-7 dated 5 May 1981. This drawing indicates that the lower end of the stern ramp is in contact with the platform at a distance approximately one-third of the barge length from the forward end (closest to the ship) with equal weight on the inner two barges. The load at this point was taken to be the sum of the weights of half of the ship's stern ramp, 185,000 lb (83,900 kg), the XM1 tank, 134,000 lb (60,800 kg), and the supporting plate, 21,000 lb (9,500 kg). To approximate this loading, weights were placed on the model platform so that the required load was divided equally between the two center barges with the resulting force acting at a distance of one-third of the craft length from the forward end. The weight of the external attachment (heave staff) used to restrain the transverse motion of the platform was duly compensated for in the above ballasting. An additional weight was placed at approximately two-thirds of the length from the forward end on the platform barge in line with the causeway to model the weight of the driveway dunnage, 8,000 lb (3,600 kg).

The platform configuration for the stern and side offloading of the SS GREAT LAND CLASS (configuration 2) consisted of six barges arranged three abreast and two in line with three additional barges representing the ferry/causeway trailing behind the center as shown in Figure 5. A photograph of the platform model is shown in Figure 6. Ballasting for this configuration was specified in accordance with J. J. Henry Company, Inc., Drawing 1969-00-9 dated 12 May 1981. According to this drawing, the lower end of the ramp rests on the center barge in the second row of barges at a distance of approximately one-third of the barge length from the forward end (closest to the ship). The load at this point was taken to be the sum of the weights of half the light weight ramp, 57,500 lb (26,100 kg), the XM1 tank, 134,000 lb (60,800 kg), platform dunnage, 5,000 lb (2,300 kg), and a steel plate, 3,600 lb (1,600 kg). The ballasting took into account the weight of the heave staff. An additional weight equivalent to 11,200 lb (5,080 kg) full-scale was placed at a point two-thirds of the barge length from the forward end to represent the driveway dunnage weight. Weights were also placed at the forward edge of the barges closest to the ship to represent the weight of the fenders (equivalent to 11,000 lb (4,990 kg) full-scale per barge).

Configuration 3 and 4 were derived by removing barges from configuration 2. No changes were made in the ballasting of the remaining barges. Sketches and photographs of these configurations are shown in Figures 7 through 10.

A gimballed heave staff that permitted freedom in pitch, heave, and roll and restraint in yaw, surge, and sway was attached to one of the barge models making up the platform near the center of the barge. The platform was towed by the heave staff to simulate the effects of current. Pitch, heave and roll motion of this barge were measured by potentiometer type transducers mounted on the heave staff. DTNSRDC designed block gages were also attached to the heave staff to measure mooring forces and moments required to restrain the platform and ferry/causeway system in waves and current. Three additional potentiometer type gages were mounted on hinges to measure relative angular motion between the barges. The location of these gages varied with the platform configuration as shown on the corresponding sketches in Figures 3, 5, 7, and 9. Wave height was measured by an ultrasonic transceiver mounted ahead of the model at a position dependent upon the configuration being tested and located to minimize the undesired measurement of waves generated by diffraction or deflection of incipient waves from the causeway or waves generated by the motion of the causeway.

Data were recorded on an Interdata Model 70 digital computer for on line and off line processing. The data were sampled at a rate of 30 samples per second after being passed through a four pole low pass Butterworth filter with a 6 Hz cutoff frequency. Sanborn recorders were used to visually monitor the data during the experiments.

EXPERIMENTAL PROGRAM AND PROCEDURES

The performance of the various platform/causeway configurations was examined in a variety of sea, swell and current conditions. Three different wave making programs were utilized to generate long crested irregular waves corresponding to full-scale sea conditions with significant wave heights of 2 1/2, 4 and 6 feet (0.76, 1.22 and 1.83 meters). Figure 11 shows representative wave spectra measured during the experiments converted to full-scale values. All values in this report, unless otherwise specified, refer to the equivalent full-scale.

Swell was simulated by monochromatic waves with wave lengths equivalent to full-scale values of 75, 180, 270, and 540 feet (23, 54, 82 and 164 meters). The equivalent wave heights were 2.5 feet (1.76 meters) for the 75 and 180 foot wave lengths and 5 feet (1.5 meters) for the 270 and 540 foot wave lengths. Current was simulated by towing the platform with the heave staff at speeds corresponding to either 2 or 4 knots (full-scale).

Several different angles of wave heading and current relative to the platform were examined. The direction of the current relative to the platform was determined by assuming that the ship would be anchored with a single point moor and would align itself like a weather vane in the current. The orientation of the platform to the current under the above assumption depended upon its orientation to the ship, i.e., stern or side offloading. The wave and current directions examined for the various platform configurations are illustrated in Figures 12 through 15.

The presence of the RO/RO ship hull was not included in these experiments because a suitably scaled model of the immense size and displacement required did not exist and was too costly and impractical to construct. This is not considered a serious omission since the motions of the ship are negligible in most of the wave conditions examined, with the possible exception of roll excitation in beam swell; and, the dynamics of the system is dependent primarily upon the motions of the platform/causeway system. However, the ship can influence the motion of the platform by acting as a barrier or reflector of the waves. As a gross first order approximation, a simple barrier or wave reflector made up of sheets of marine plywood was placed along side of the platform to simulate the effect of the ship's hull for some of the wave conditions examined. These conditions are indicated in the same figures showing the wave and current direction by a heavy line. The plywood barrier was submerged to a depth equivalent of 28 feet (8.5 meters) full-scale which corresponds to the draft of a typical RO/RO ship. For the stern offloading condition where the plywood was used as a barrier, the width corresponded to 105 feet (32 meters) full-scale which is the approximate beam of a RO/RO ship. In the side offloading conditions where the plywood acted as a wave reflector, the width corresponded to approximately 255 feet (78 meters) which was the maximum length that could be fastened to the carriage without major rigging problems.

Experiments were conducted in random seas for platform configuration 1 at two different heading angles relative to the wave direction (referred to as configurations 1A and 1B) with significant wave heights of 2 1/2, 4 and 6 feet and in currents of 0, 2 and 4 knots. Experiments were also conducted in three different swell conditions represented by monochromatic waves with wave lengths of 180, 270 and 540 feet. An additional swell condition corresponding to a 75 foot wave length was examined for configuration 1B. Platform configuration 2 was examined at two different wave heading angles (configurations 2A and 2B) simulating stern offloading conditions in random seas with significant wave heights of 2.5 and 4 feet and in swell conditions with wave lengths of 180, 270 and 540 feet for 0, 2 and 4 knot currents. Configurations 2C and 2D, representing side offloading conditions at two different wave headings, were examined in seas with significant wave heights of 2 1/2, 4, and 6 feet and in swell with wave lengths of 180, 270 and 540 feet for currents of 0 and 2 knots. Configurations 3 and 4 which were derived by removing barges from configuration 2 in the side offloading condition were examined at one heading angle relative to the waves in seas with significant wave heights of 2 1/2 and 4 feet and in swell corresponding to wave lenghts of

75, 180, 270 and 540 feet with currents of 0 and 2 knots. A 4 knot current was included in the 180 foot swell condition for configuration 3.

Calm water experiments were also conducted to determine the drag forces or mooring forces in current of the various platform/causeway configurations. In all, six configurations were examined; three in head current and three in beam current. Configurations 1 and 2 were examined in head current and configurations 2, 3, and 4 were examined in beam current. In addition, the platform for configuration 1 was tested without the causeway/ferry attached. The principal characteristics of the various platform configurations as tested in current are presented in Tables 2 through 7. A detailed description of the method employed to extrapolate model drag data to full-scale is given in the appendix.

PRESENTATION AND DISCUSSION OF EXPERIMENTAL RESULTS

RESULTS IN WAVES

The results from the experiments in waves are presented in Tables 8 through 23 and in Figures 16 through 35. The tables present, for the random wave conditions, the average of the 1/3 highest amplitudes (significant values) of heave, roll, pitch, relative angular motion, surge force, sway force and yaw moment. For swell conditions, the waves and responses were both sinusoidal and the tables present the amplitudes of the resulting sinusoidal motions, forces and moments at wave frequency. The random sea results are also plotted in figures showing the variation of the significant values of amplitude with respect to current velocity or significant wave height. It should be noted that significant wave height by convention is twice the significant wave amplitude. It should also be noted that the forces and moments in the tables and figures are only the oscillatory components and that the contributions resulting from the current and second order wave forces (drift forces) must be added to obtain the total values.

Tables 8 and 9 present the data results for platform configuration 1A in sea and swell, respectively. The random sea results are also plotted in Figures 16 through 18. As expected, the motions and forces in random waves for this configuration as in all configurations examined increased with increasing wave height. Also, as can be seen in the figures, the pitch and heave motions are not significantly affected by the current velocity, but the roll motion and relative motions show an increasing trend with increasing current velocity. When in swell represented by long wave lengths, the platform tended to contour the free surface. In the shorter wave length (180 feet) the motions were influenced by the dynamical properties of the platform. This observed performance in swell was generally consistent for all of the platform configurations examined. During the experiments with configuration 1A, it was observed that waves were breaking and spilling over the deck and in the higher sea states water splashed up over the deck from the space between the barges. This may present a problem to men and equipment on the platform and ferry/causeway. This condition was possibly aggravated by the buoyancy support of the causeway/ferry section which tilted the platform down into the waves. The full-scale platform will probably receive some protection from the presence of the ship for this wave heading, but it may not be enough to eliminate the problem completely.

The corresponding results for configuration 1B are presented in Tables 10 and 11 and in Figures 19 through 21. In general the trends with respect to current are very similar to those of configuration 1A. The pitch motion decreased and the roll and relative motions increased when compared to the previous condition. This is consistent with the change in wave heading relative to the platform. Water over the deck appeared to be more severe than in the previous condition and the ship is not expected to afford as much protection from the waves.

Experimental results for configurations 2A and 2B representing stern offloading conditions for the SS GREAT LAND CLASS are presented in Tables 12 through 15 and in Figures 22 through 27. Examination of these data shows that current has little effect upon the responses of platform configuration 2A; whereas, platform configuration 2B shows a definite increase with increasing current velocity. Configuration 2A experiments incorporated a plywood barrier to simulate the ship's effect upon the waves. The diffraction pattern about the plywood resulted in small waves impacting the side of the platform and causeway/ferry sections producing significant side loads and moments. The diffraction pattern appeared to be much more severe than that which would be expected behind the full-scale ship and it is believed that the side forces and moments measured are exaggerated.

Data for platform configuration 2C and configuration 2D representing side offloading conditions for the SS GREAT LAND CLASS are presented in Tables 16 through 19 and in Figures 28 through 31. For configuration 2C the heave, roll and corresponding relative motions appear to be large and may present problems in maintaining ramp contact with the platform and insuring vehicle side traction. For configuration 2D which represents a change in wave heading angle of 45 degrees the pitch motion and the corresponding relative motion are large and similar problems may exist. The moments required to restrain the platform/causeway in these side offloading conditions exceeded the capacity of the gages when runs were made with current. Consequently, force and moment data as reported in the tables for these conditions contain some error due to the occasional saturation of the gages and clipping of the peak amplitudes. In those cases where clipping occurred more than 10 percent of the time the force and moment data are not reported. Platform configuration 2C did not experience water over the deck, but some wetness was observed for configuration 2D on a few occasions.

The results for configurations 3 and 4 are presented in Tables 20 through 23 and in Figures 32 through 35. These configurations were obtained by removing barges from (configuration 2D). A noticeable difference in performance of these platform configurations and the parent platform configuration 2D was the increase in deck wetness as barges were removed from the platform.

Configuration 4 was extremely wet in all sea conditions and in very short wave lengths (swell). Removing barges from the platform increased its sinkage making it more susceptible to deck wetness. In general, the wetness depends upon the freeboard presented by the platform to the oncoming waves. In this regard the loaded ferry/causeway system will probably experience difficulties in waves much sooner than the platform and will be the governing factor for safe offloading operations.

RESULTS IN CALM WATER

The resistance or mooring forces acting on the various platform/causeway configurations in calm water with current are presented in Tables 24 through 29 and in Figures 36 through 41. The drag force indicated in these tables corresponds to the force along the surge axis which is defined as parallel to the longitudinal axes of the barges making up the platform. With this definition, the maximum resistance acts along the sway axis in beam current. The tables also include the yaw moments, center of effort, and the static displacements recorded on the motion measuring gages. Heave is measured positive upward and relative angular motions between the barges are positive when the corresponding barges form a V shape.

Examination of the data in the tables and figures do not reveal any unusual results. The resistance or mooring forces and moments in beam current, as might be expected, are relatively large and a major portion of the drag can be attributed to the causeway/ferry being attached to the platform broad side to the current. Consideration should be given to the use of warping tugs to oppose the current forces and moments acting on the causeway/ ferry which would reduce the mooring line forces required to restrain the platform.

In a combined waves and current environment the total mooring force required to restrain the platform/causeway system is the sum of current forces and wave forces. The magnitude of the oscillatory wave forces is a complicated function of the stiffness of the mooring system. In these experiments the tow system essentially represented a completely rigid mooring system and the measured forces are much larger than that which will be experienced by a more realistic elastic mooring system of ropes and cables.

SUMMARY AND CONCLUSIONS

Experiments were conducted in waves and calm water to evaluate the performance of several platform configurations made up of pontoon barges for offloading RO/RO ships in support of Assault Operations where port facilities are not available. Four different platform configurations were examined. Configuration 1 consisted of four standard pontoon barges interconnected side-by-side as was originally conceived for the stern offloading of the SS MAINE CLASS. Configuration 2 consisted of six barges (2 rows - 3 abreast) which was designed for stern and side offloading of the SS GREAT LAND GLASS and configurations 3 and 4 were exploratory variants of configuration 2 which were derived by systematically removing barges (two at a time) from the side of the platform. A ferry/causeway consisting of three barges in line was attached to each platform during all experiments in waves. The experiments were conducted in sea and swell with and without current and measurements obtained of the platform motions and the mooring forces. Calm water runs were also made to determine the mooring forces in current without waves.

The results of the calm water experiments have been extrapolated to full-scale values using the Schoenherr friction line to correct for the differences in Reynolds number between model and full-scale. A description of the procedure used to do this is presented in the appendix to this report along with tables and plots of the data.

The results from the experiments in waves and are also summarized on plots and tables in this report. These data show that the motions of the basic platforms (configurations 1 and 2) in a seaway with a significant wave height of 2 1/2 feet and current not exceeding 2 knots are relatively small in the stern offloading conditions examined. In side offloading conditions which were examined for configuration 2, roll motions of about 6 degrees significant amplitude and relative motions as much as 10 degrees significant amplitude were measured when the platform was abeam to the waves (head waves relative to the ship). This would indicate that the relative motion can exceed 15 degrees in these conditions. A 45 degree change in wave direction resulted in much lower roll motion, but pitch motion increased significantly. In swell conditions represented by monochromatic waves all platforms tended to contour the free surface in long waves. In short waves (180 feet and less) the motions were obviously influenced by the dynamical characteristics of the platform/causeway system. The effect of current on platform behavior in waves was not significant in most of the conditions examined except for the relative motion between the platform and the causeway/ferry section which increased noticeably with increasing current in the stern offloading test conditions in a seaway.

Wave breaking over the edge of the platform and spilling across the deck was observed during these experiments which may be a potentially troublesome problem for both men and equipment on the platforms. Specifically, it was observed that waves spilled over the deck of configuration 1 for all conditions examined in irregular waves and became worse as the significant wave height increased. This condition was possibly aggravated by the buoyancy support the causeway/ferry section contributed to the platform which tilted the platform down into the waves. Configuration 2 was essentially dry for all conditions examined and water over the deck was observed only in a few rare instances in the highest sea conditions. Removing barges from configuration 2 to form configurations 3 and 4 resulted in a drastic deterioration of wetness performance with water spilling over the deck in all sea conditions examined.

Quantitative measurements of wetness were not made, but estimates based on visual observations indicates that water over the deck may exceed a height of one foot on the full-scale platform. Configuration 4 which simply consisted of five barges in line was by far the worst configuration with regard to wetness and should be excluded from any consideration as a viable system for operations in waves.

Mooring forces measured for configuration 2 in the side offloading position were extremely large in the sea conditions examined. In these conditions the maximum amount of frontal area of the platform/causeway system was presented to the oncoming waves and current, and it may be necessary to utilize warping tugs and/or change the orientation of the causeway with respect to the platform to alleviate some of the strain on the platform mooring lines. Consideration should also be given to the use of a multipoint mooring system to enable the platform to be placed in the lee or protected side of the ship. This procedure would also be useful in the stern offloading conditions.

In summary it appears that the platform designed for the SS GREAT LAND CLASS is superior to all other platforms examined. Relative motions and mooring forces may present problems when waves are coming from abeam even in low sea states. The causeway/ferry capability to transit from platform to shore will most likely be the limiting factor for offloading operations.

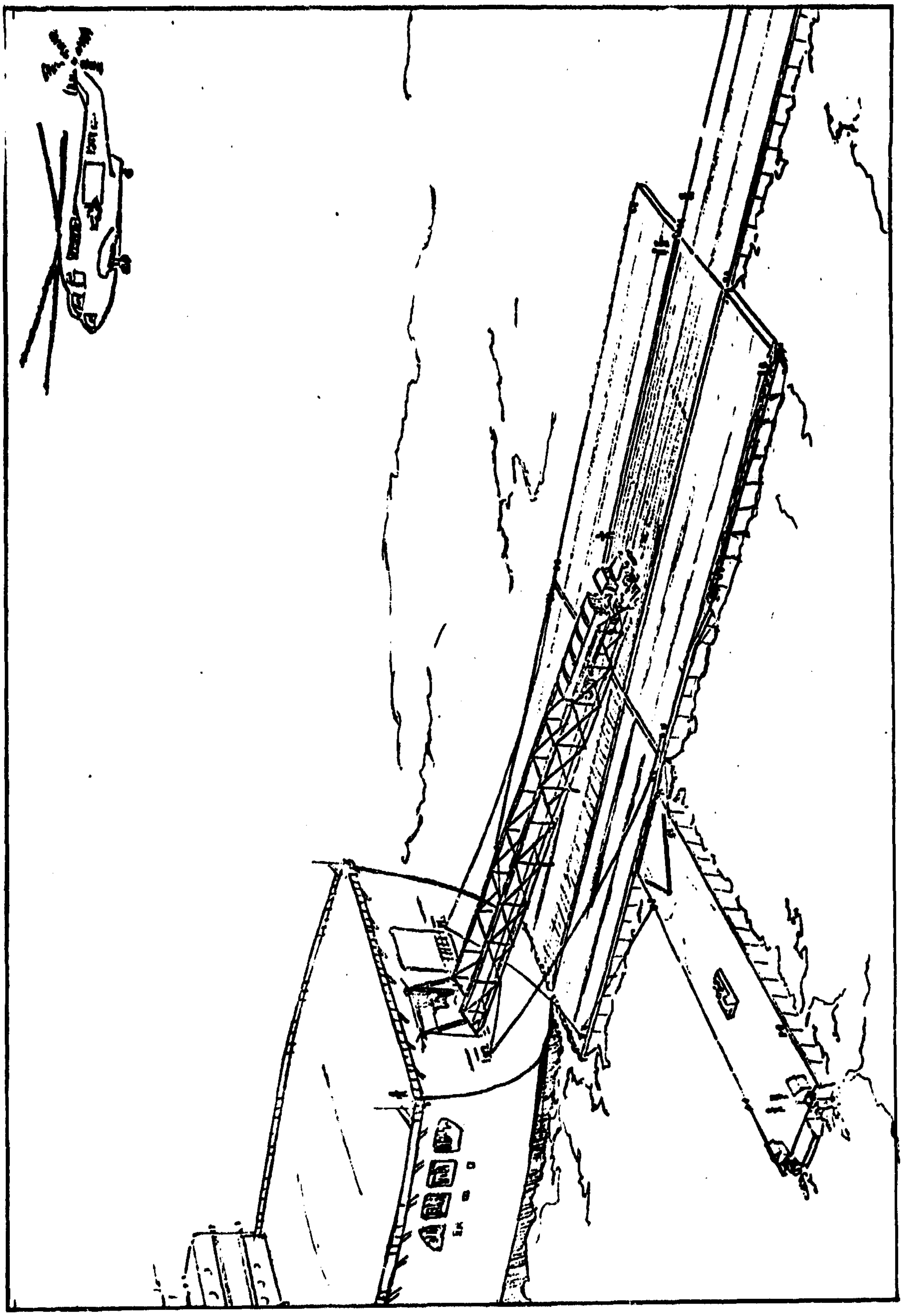


Figure 1 - Ramp Facility--SS GREAT LAND

Length:	6.0 ft (183 cm)
Beam:	1.41 ft (43 cm)
Depth:	4.0 in. (10 cm)
Displacement:	44.5 lbs (20.2 kg)

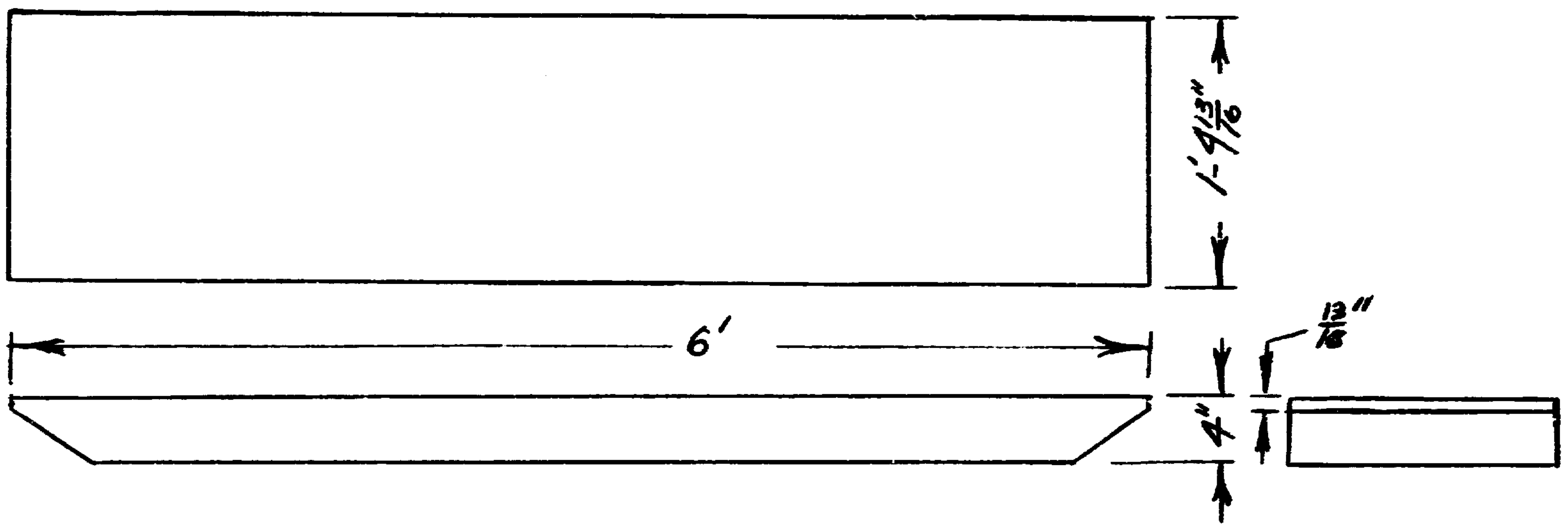


Figure 2 - Sketch of Barge Model

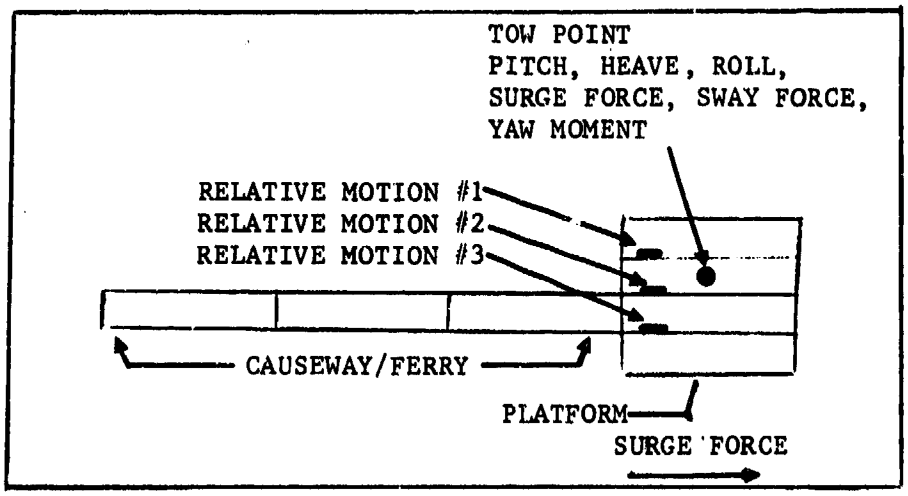


Figure 3 - Sketch of Configuration 1

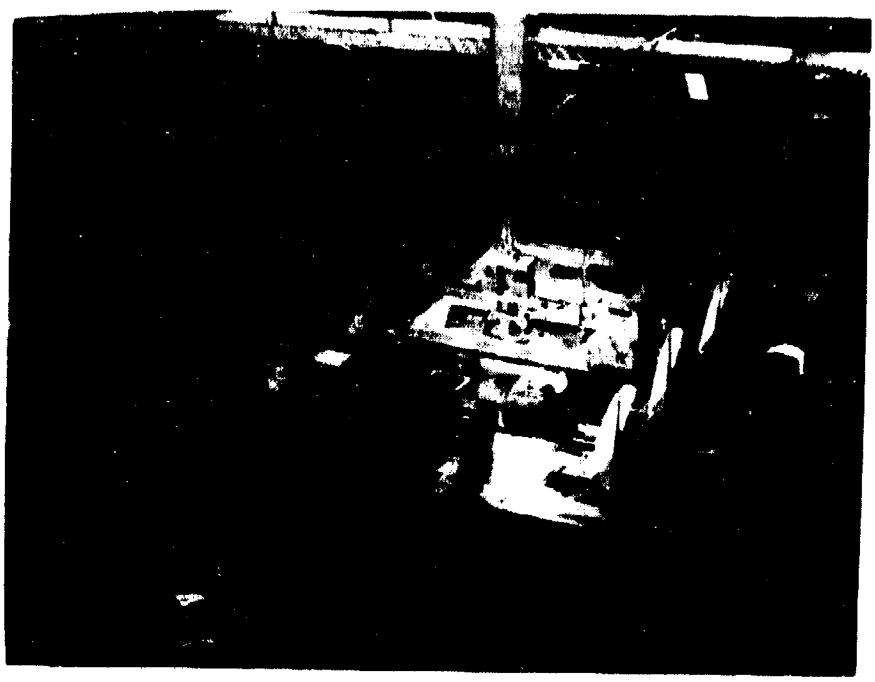


Figure 4 - Photograph of Configuration 1

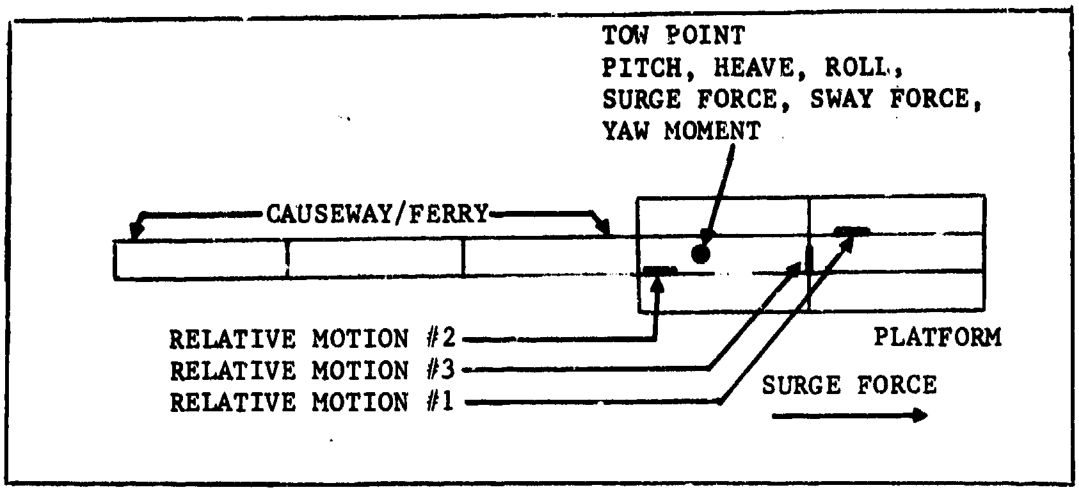


Figure 5 - Sketch of Configuration 2

Figure 6 - Photograph of Configuration 2

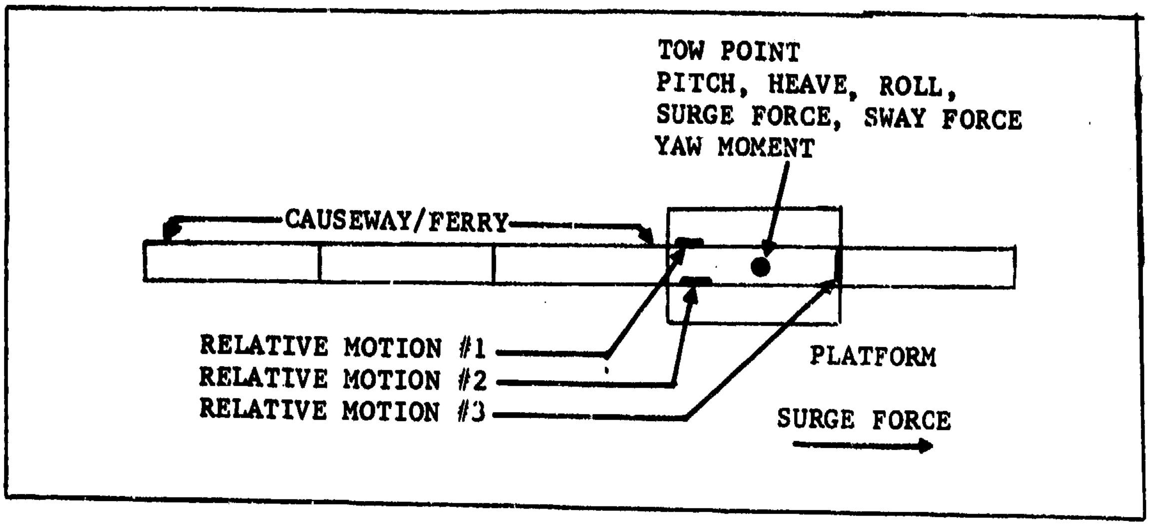


Figure 7 - Sketch of Configuration 3

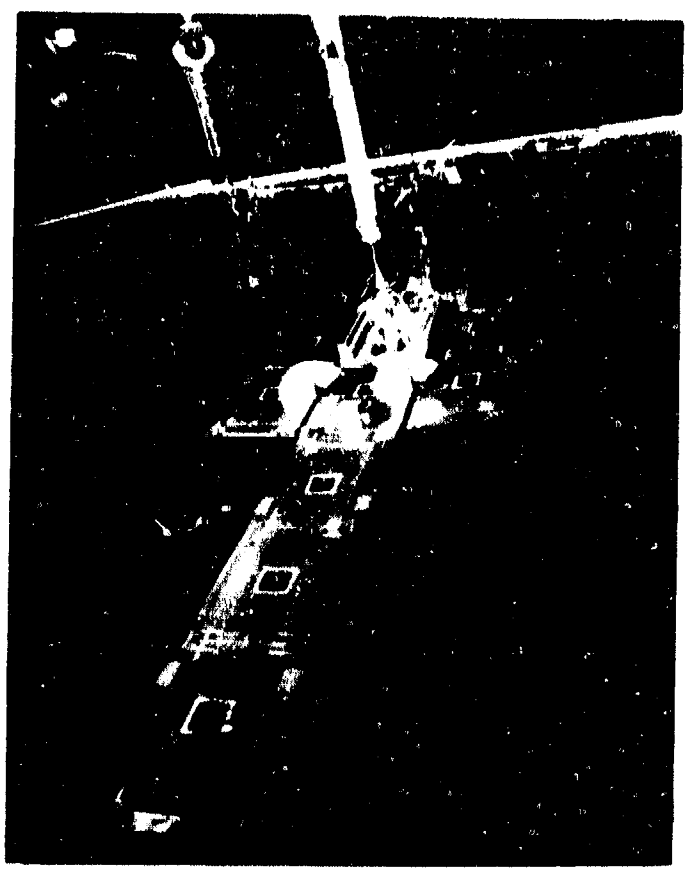


Figure 8 - Photograph of Configuration 3

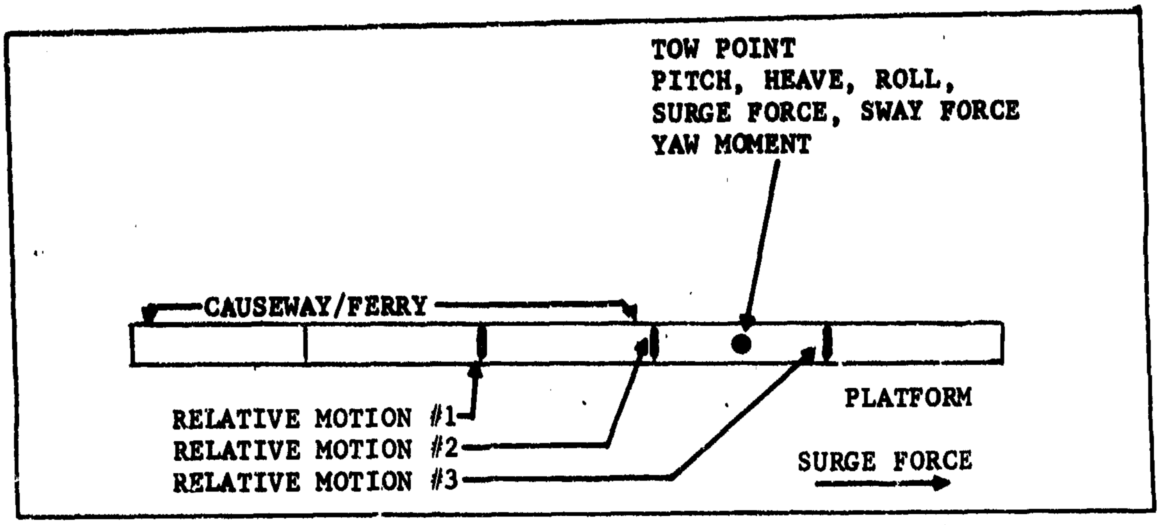


Figure 9 - Sketch of Configuration 4

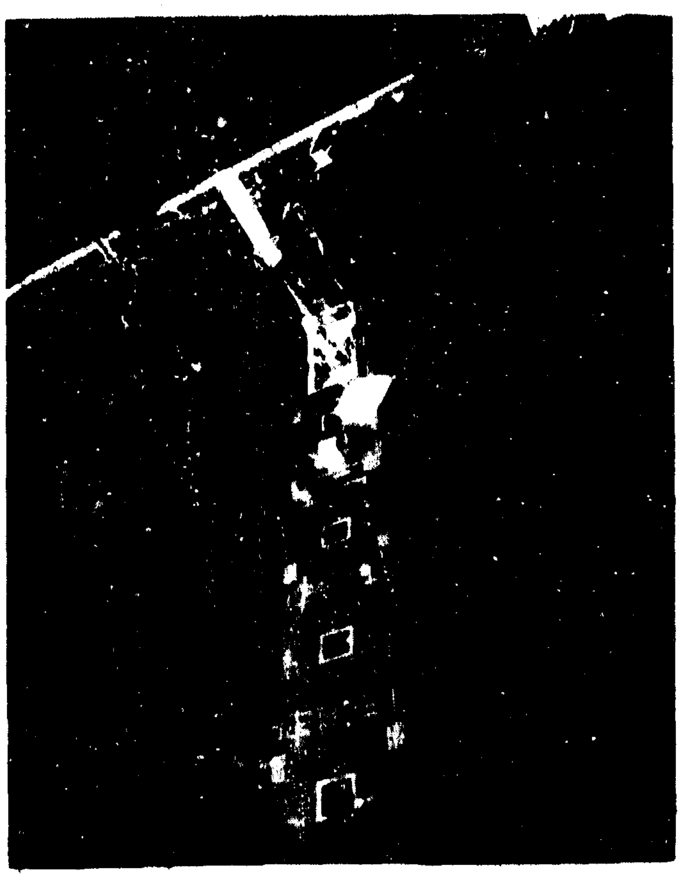


Figure 10 - Photograph of Configuration 4

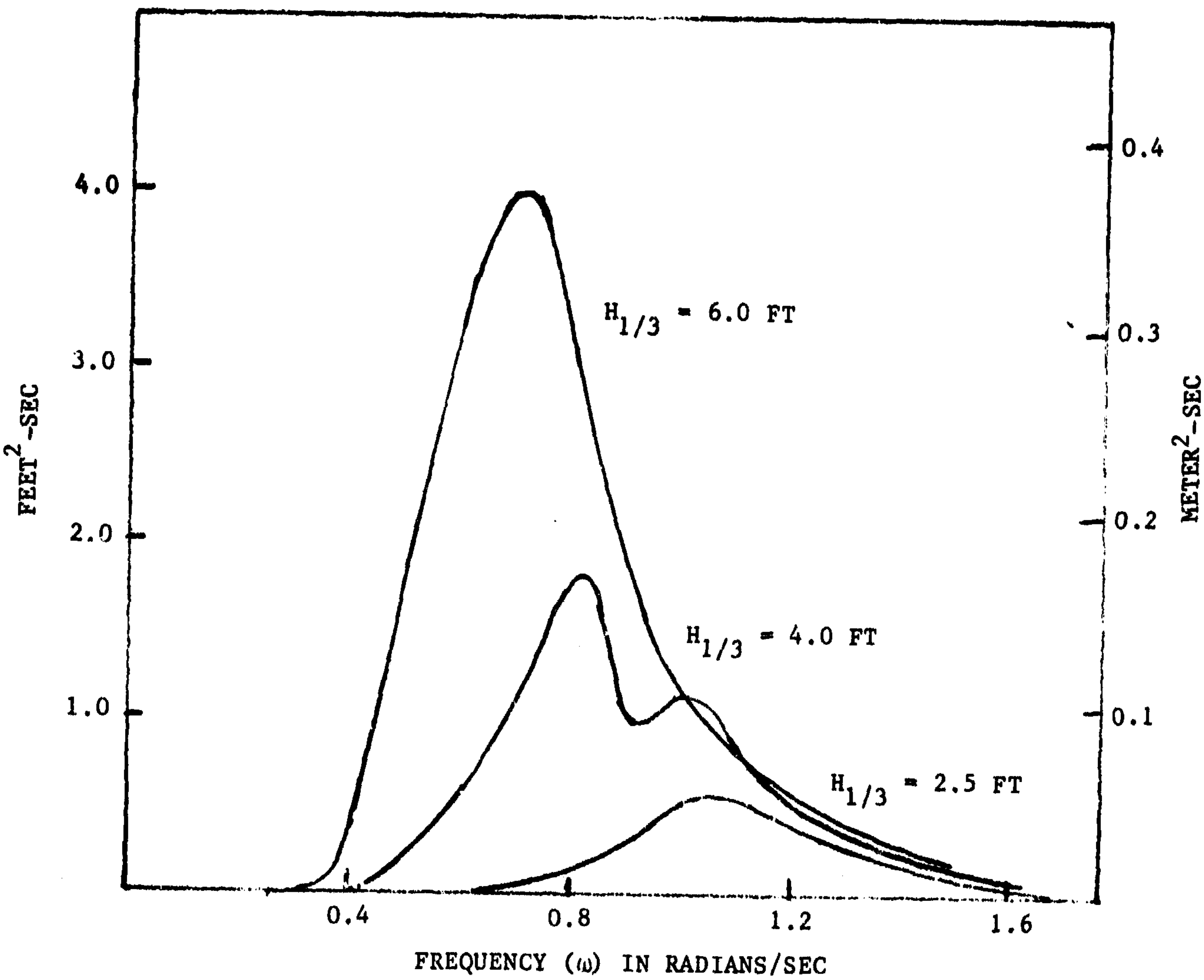
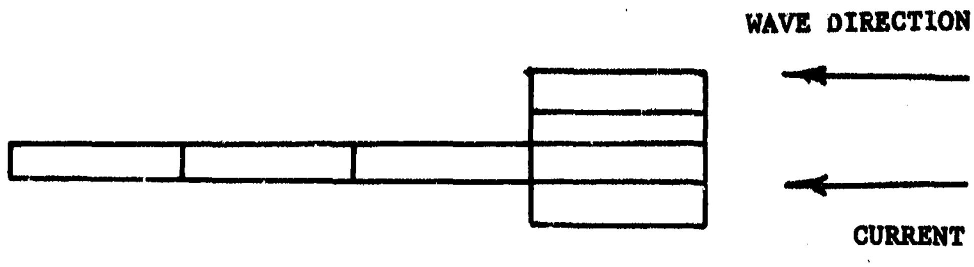
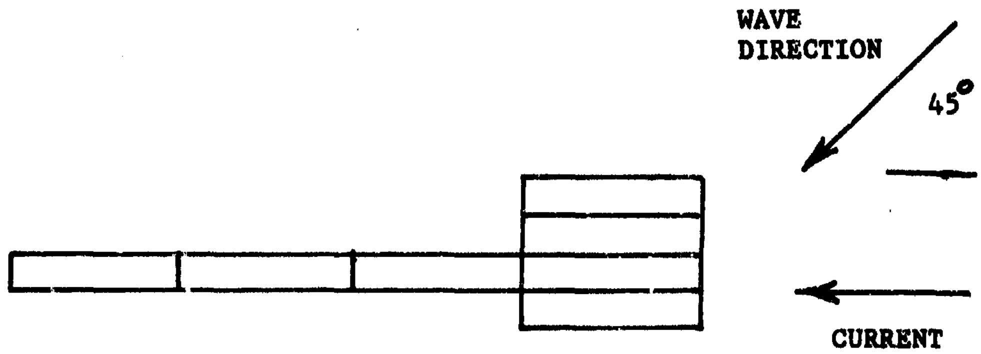


Figure 11 - Equivalent Full-Scale Wave Spectra Generated in Test Facility



CONFIGURATION 1A



CONFIGURATION 1B

Figure 12 - Sea and Swell Condition Examined for Configuration 1

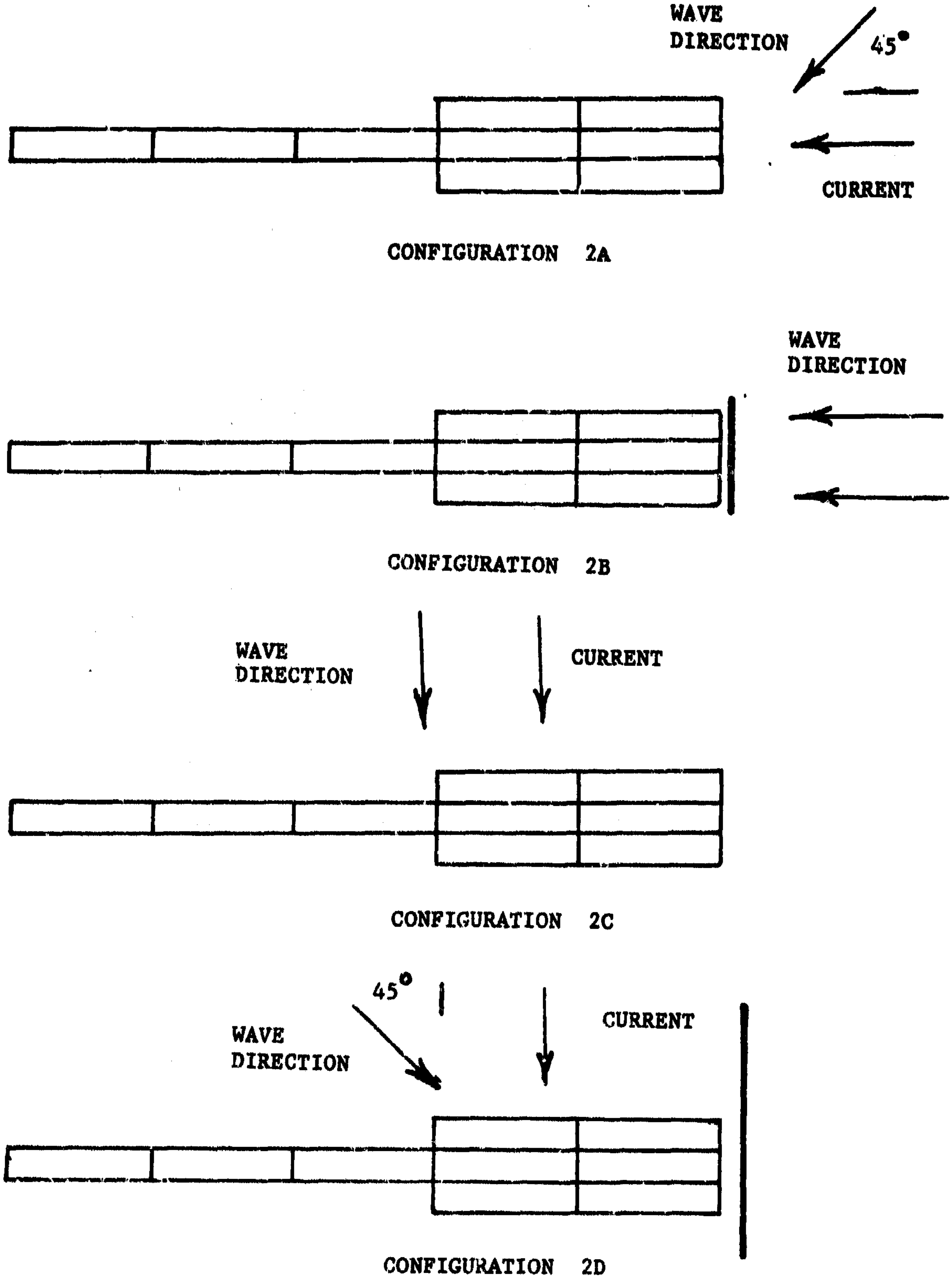


Figure 13 - Sea and Swell Condition Examined for Configuration 2

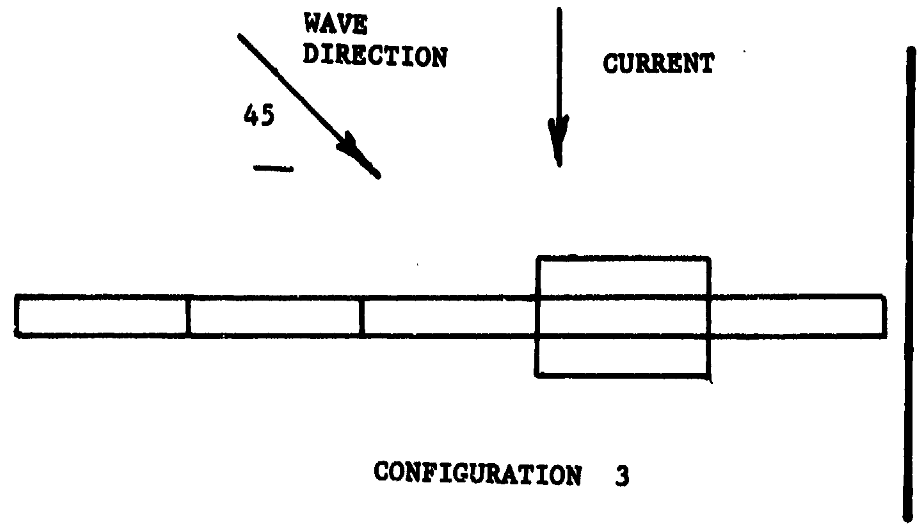


Figure 14 - Sea and Swell Condition Examined for Configuration 3

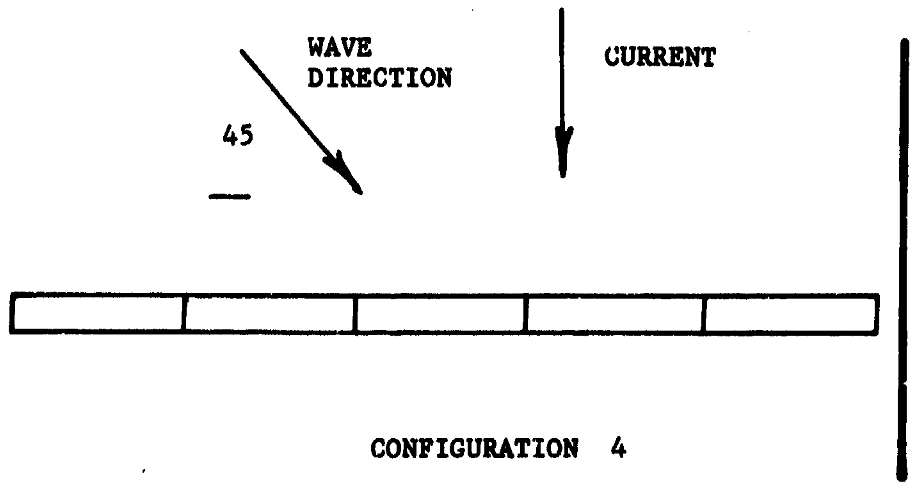


Figure 15 - Sea and Swell Condition Examined for Configuration 4

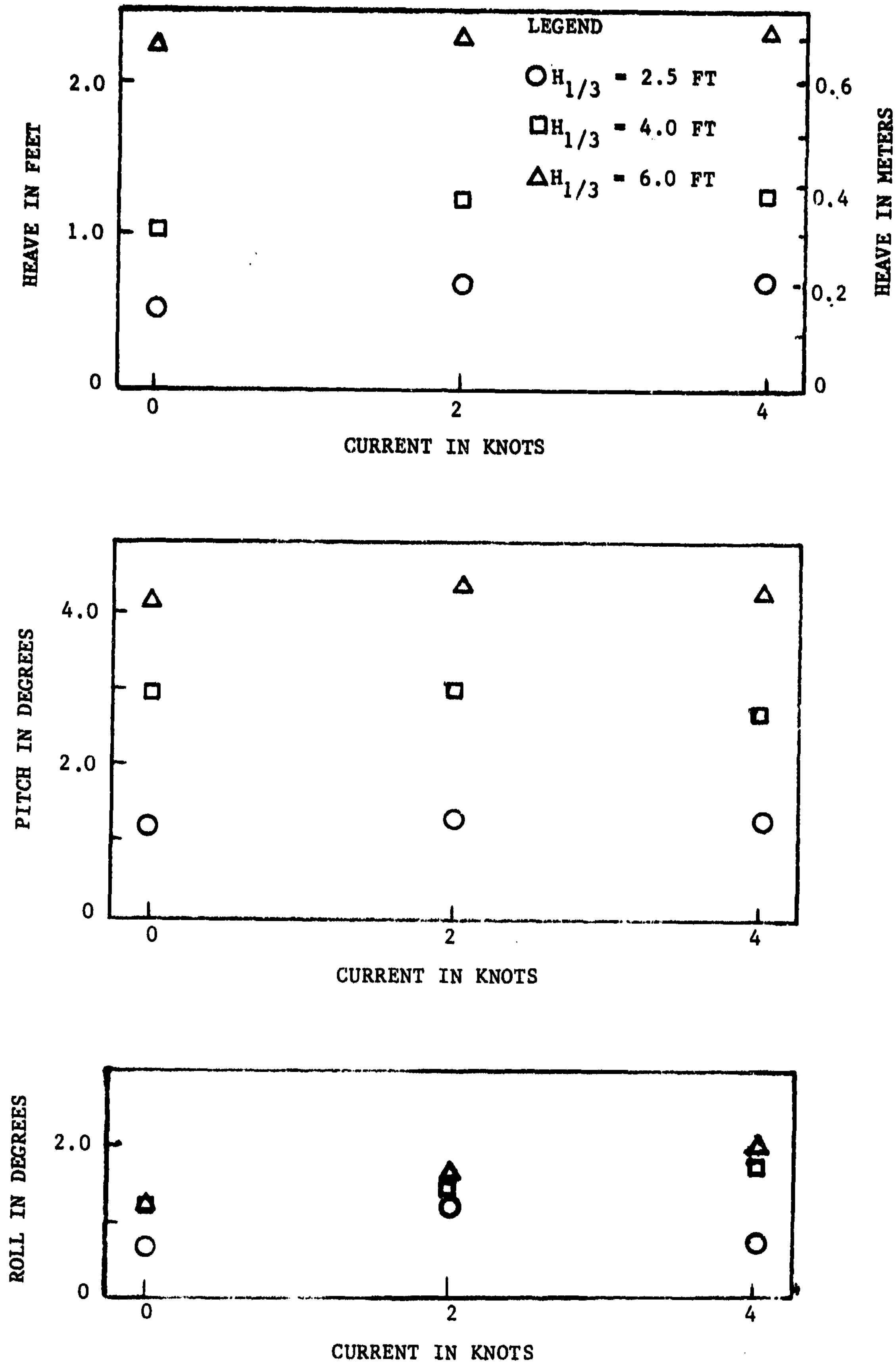


Figure 16 - Configuration 1A Heave, Pitch and Roll Motion in Combined Sea and Current

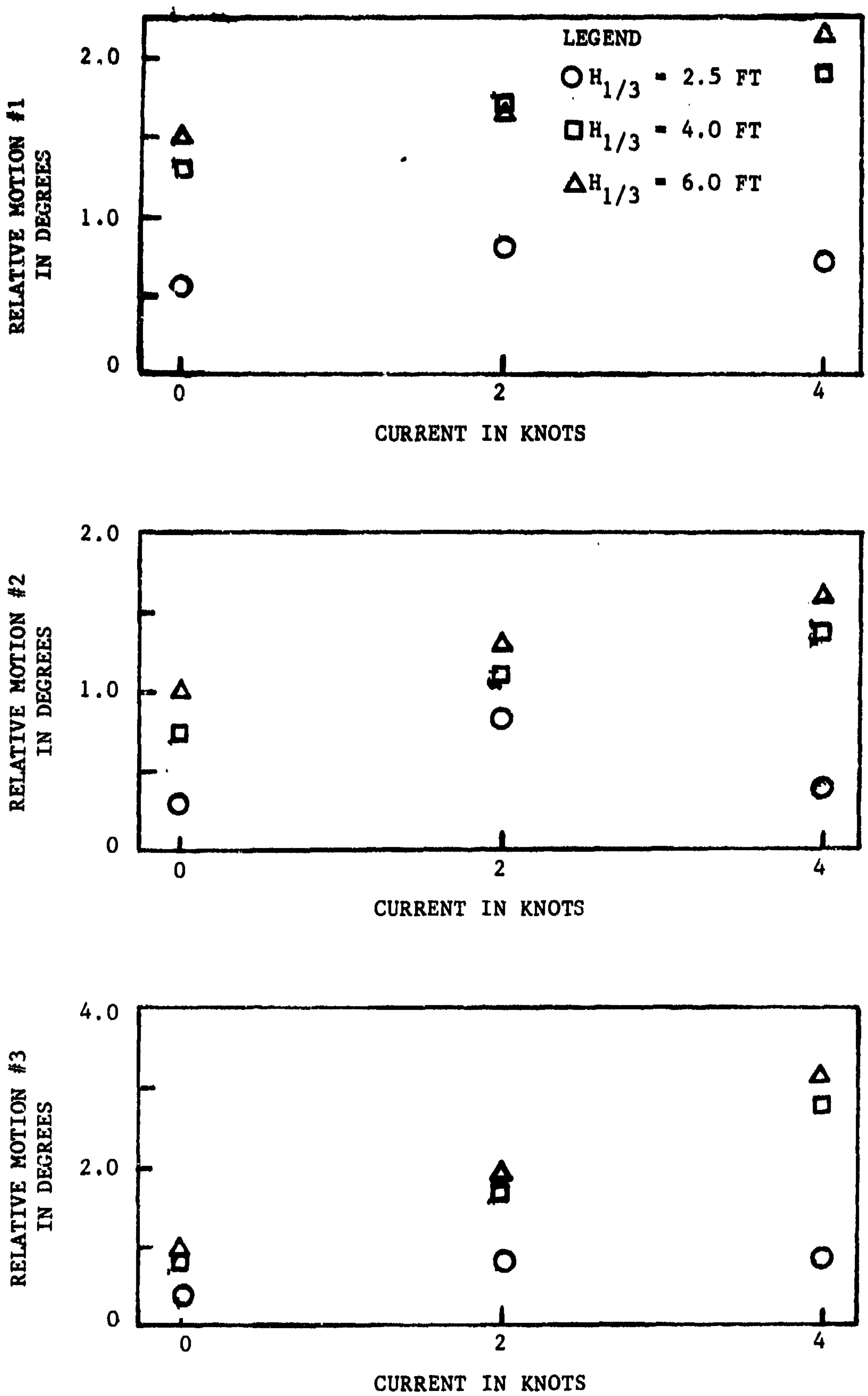


Figure 17 - Configuration 1A Relative Angular Motion in Combined Sea and Current

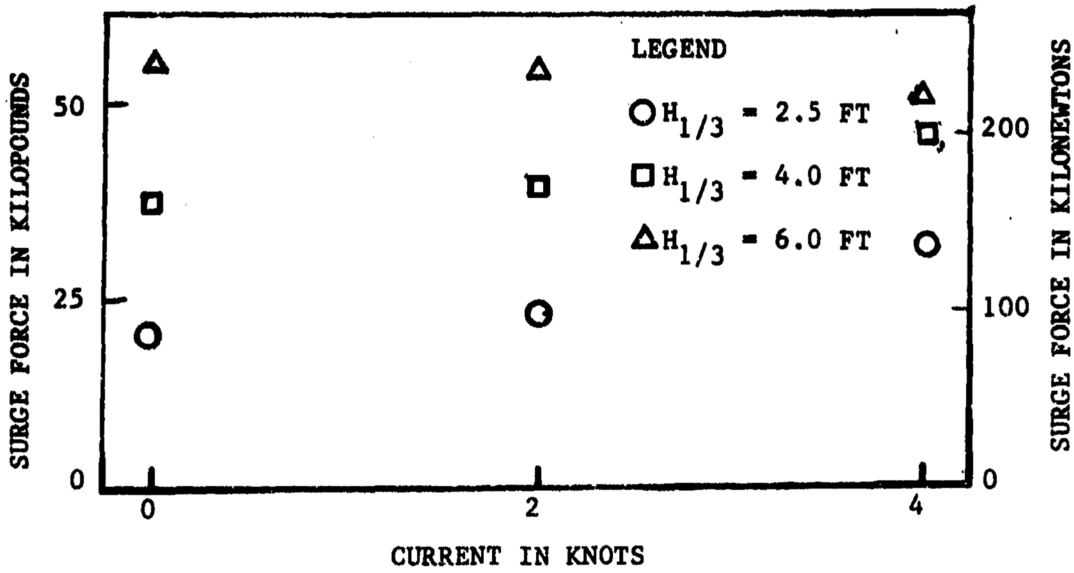


Figure 18 - Configuration 1A Surge Oscillation Force in Combined Sea and Current

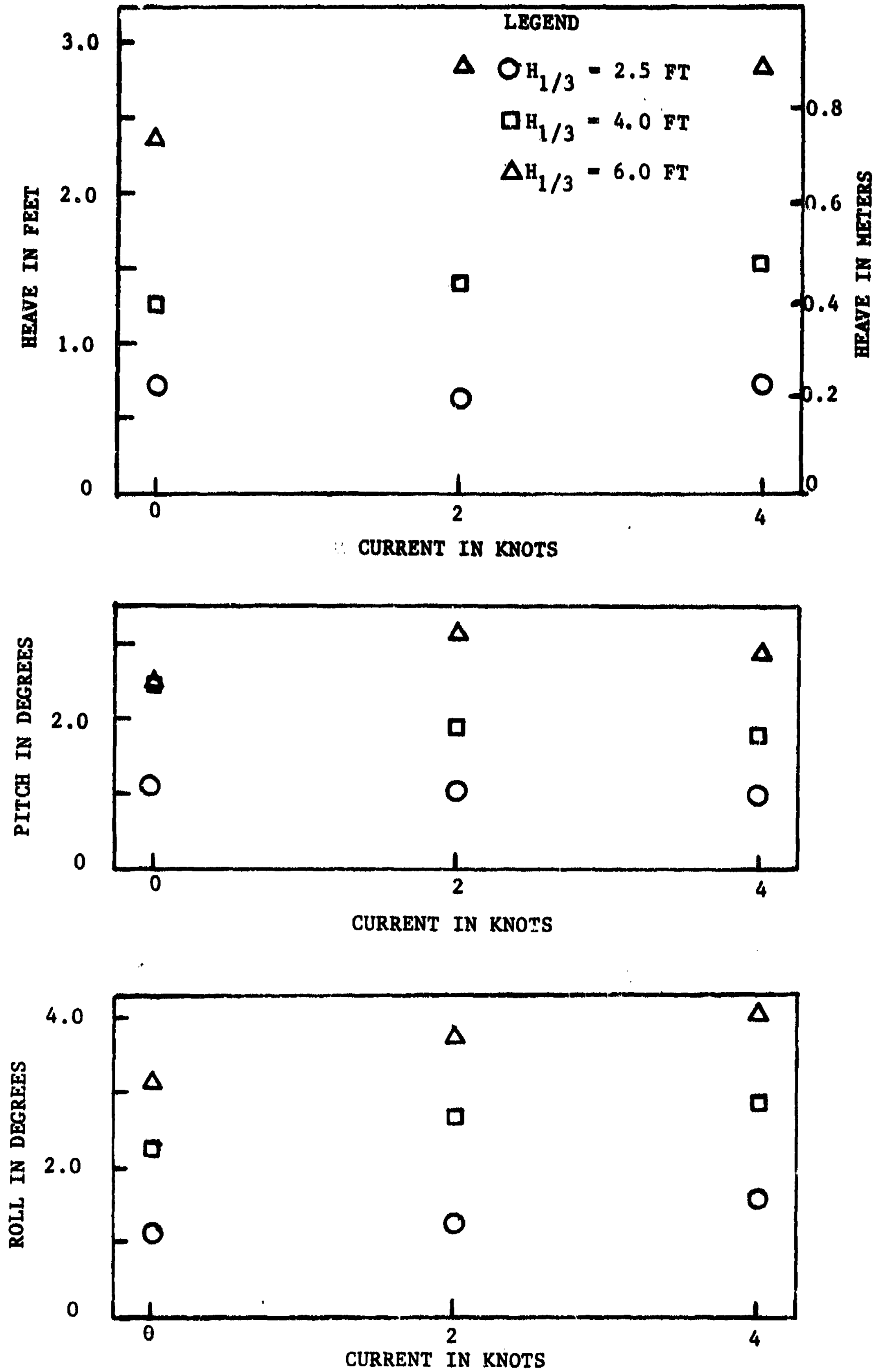


Figure 19 - Configuration 1B Heave, Pitch and Roll Motion in Combined Sea and Current

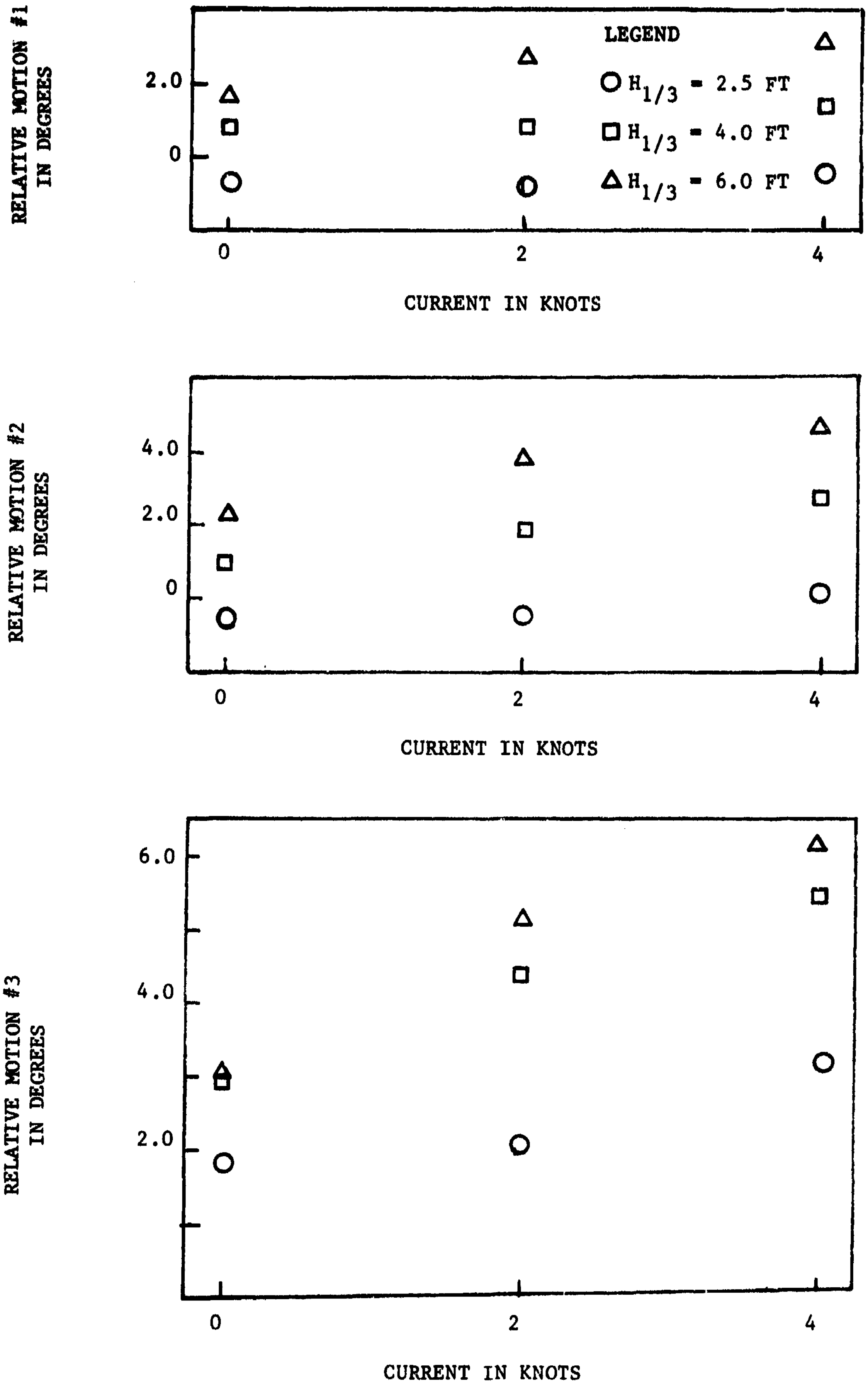


Figure 20 - Configuration 1B Relative Angular Motions in Combined Sea and Current

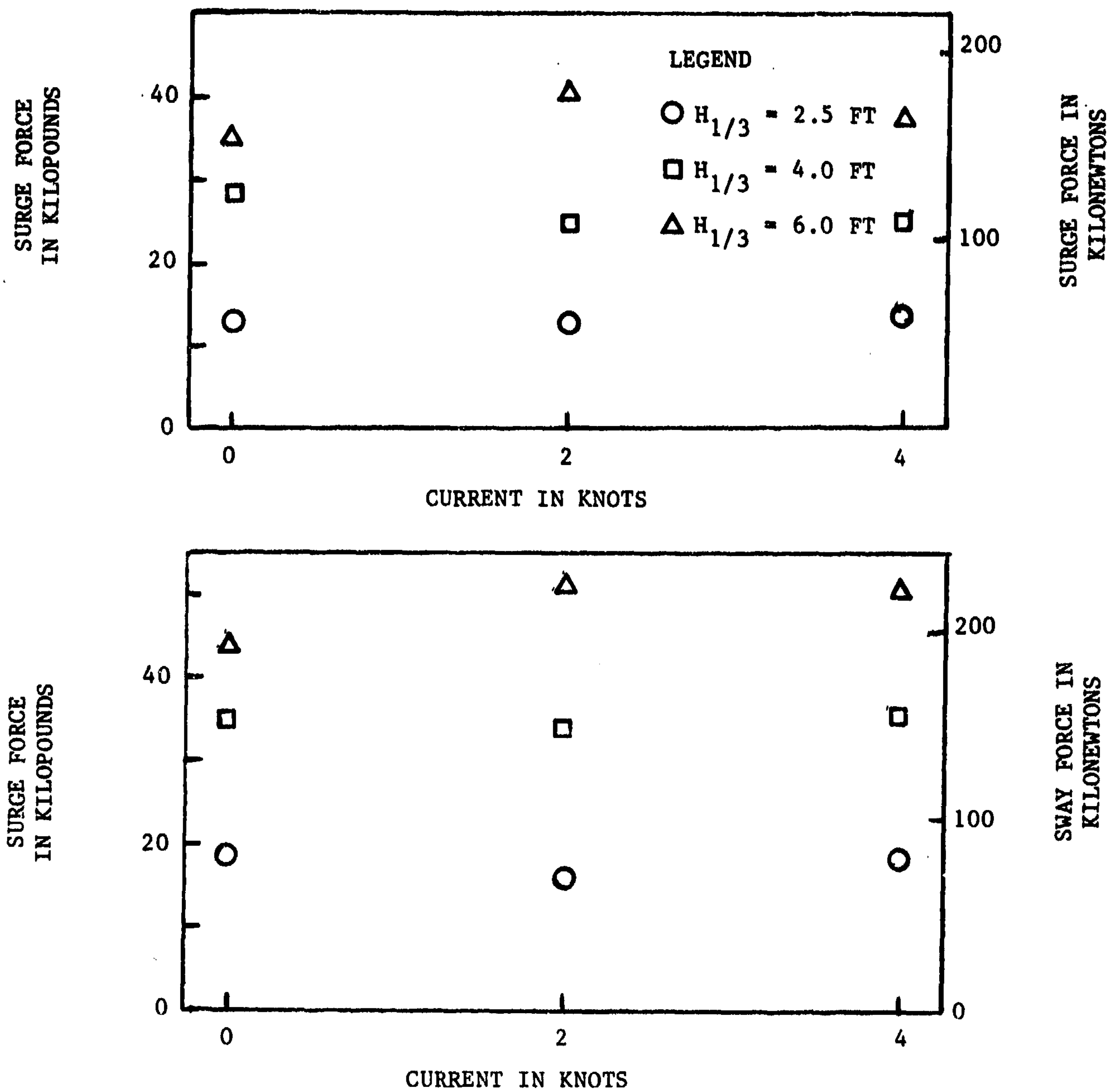


Figure 21 - Configuration 1B Surge and Sway Oscillatory Forces in Combined Sea and Current

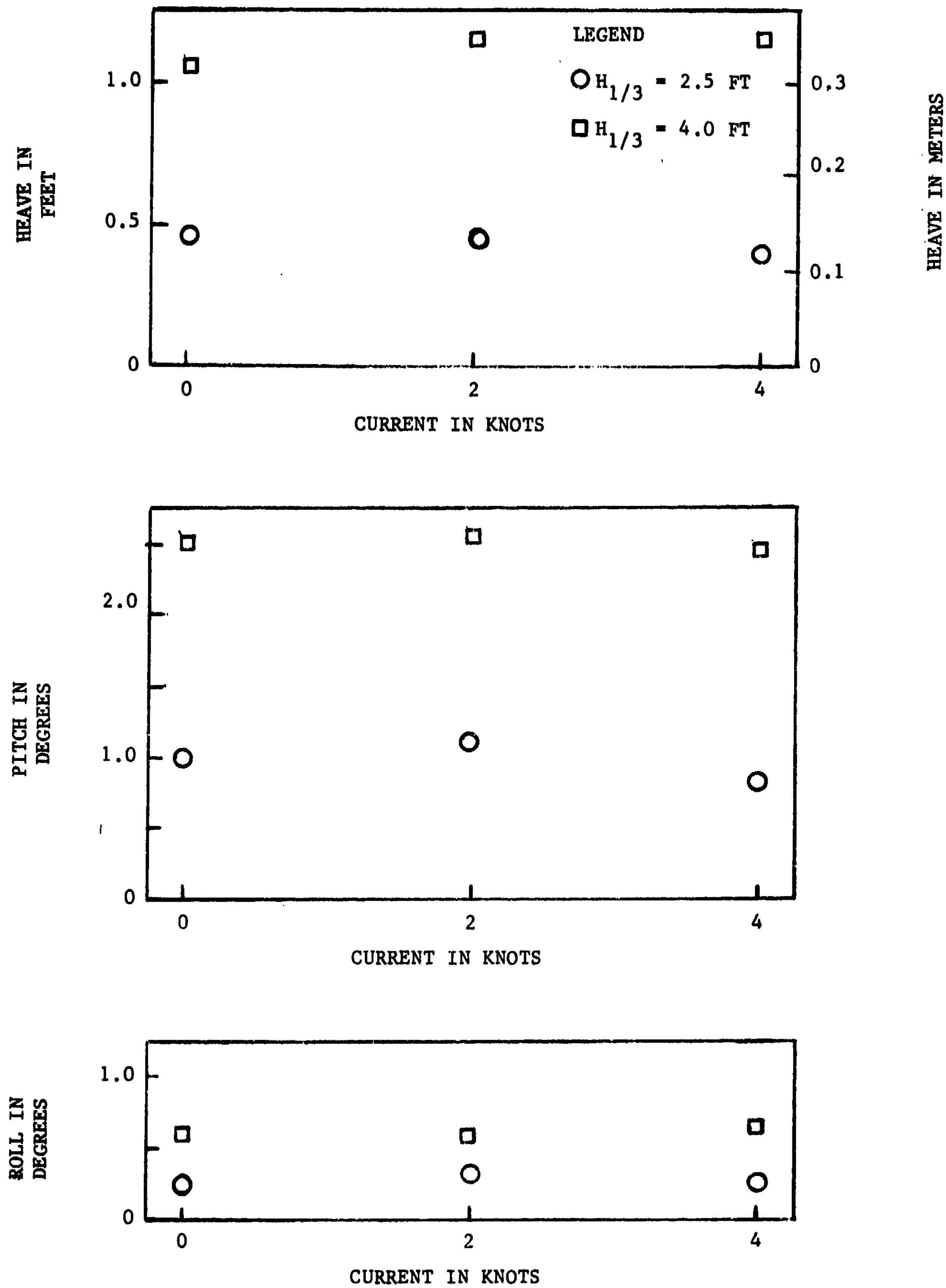


Figure 22 - Configuration 2A Heave, Pitch and Roll Motion in Combined Sea and Current

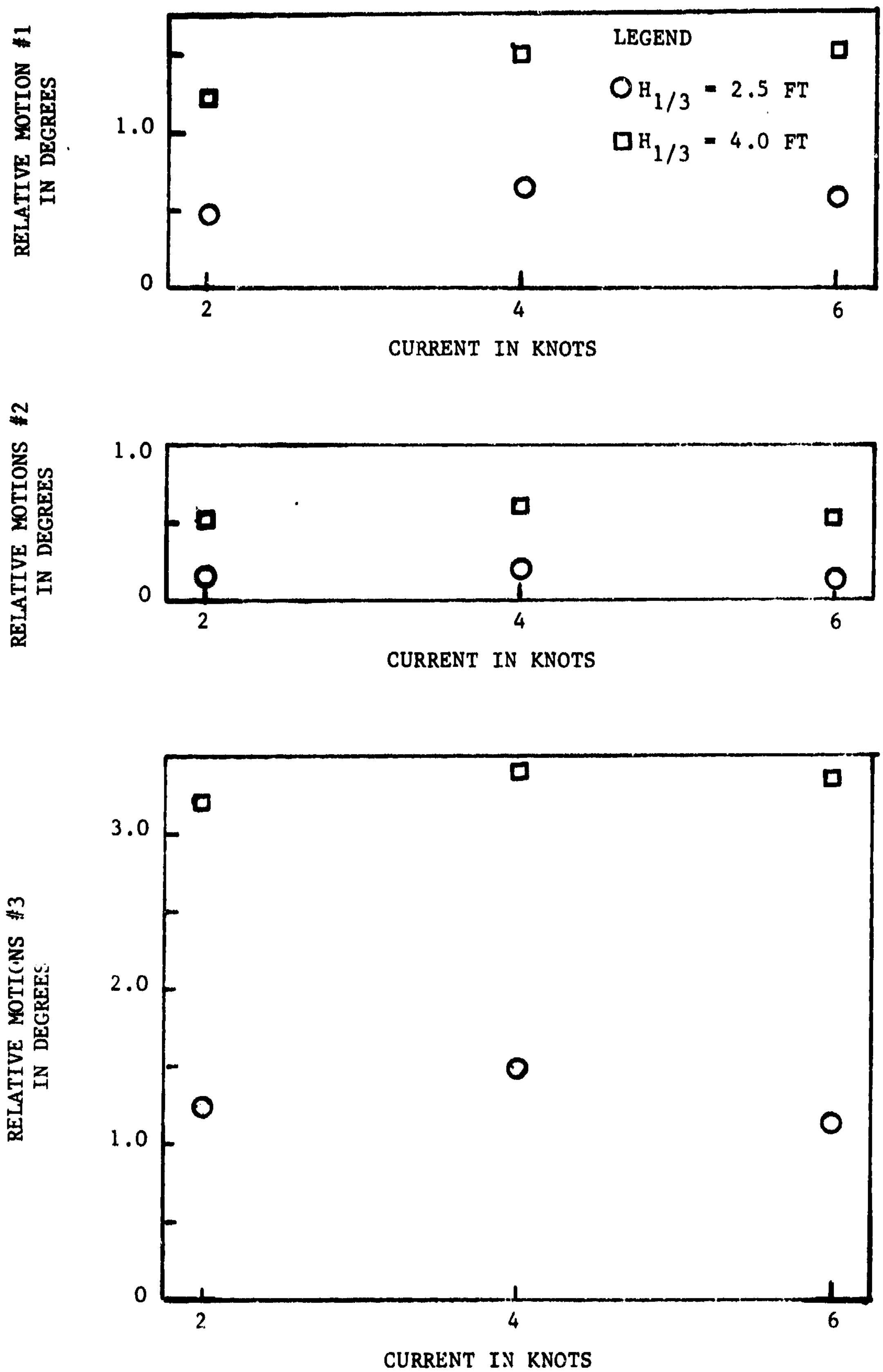


Figure 23 - Configuration 2A Relative Angular Motions in Combined Sea and Current

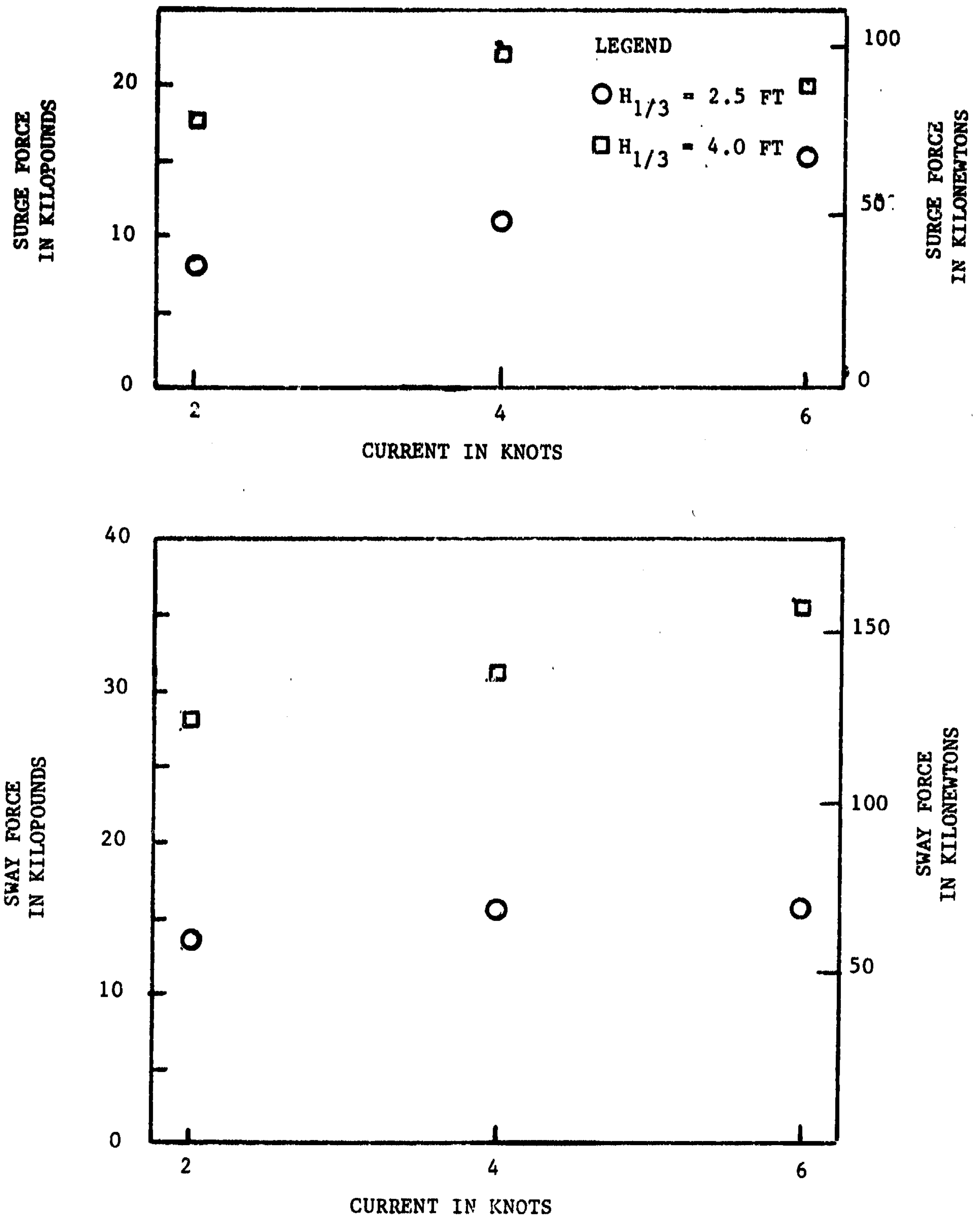


Figure 24 - Configuration 2A Surge and Sway Oscillatory Forces in Combined Sea and Current

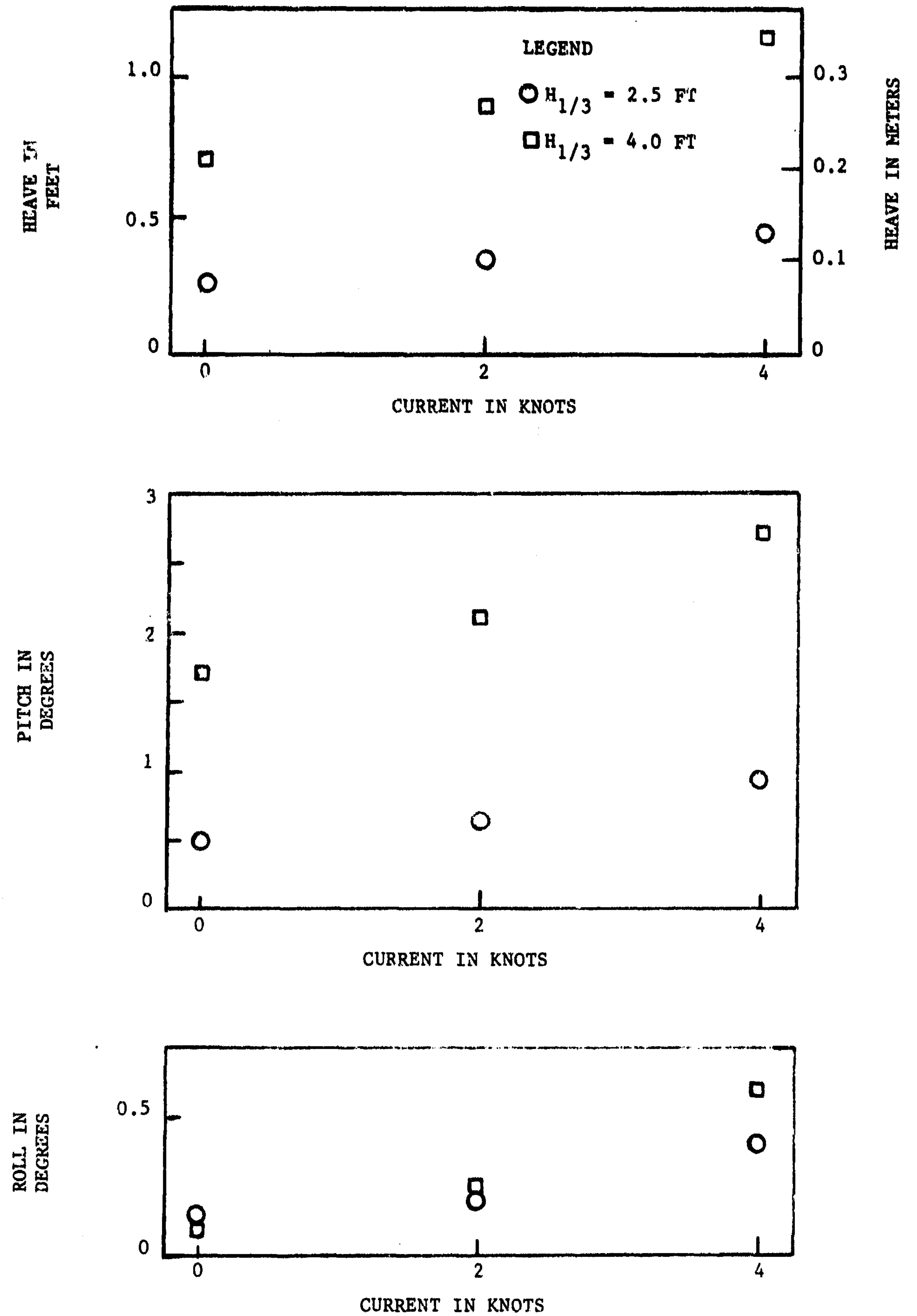


Figure 25 - Configuration 2B Heave, Pitch and Roll Motion in Combined Sea and Current

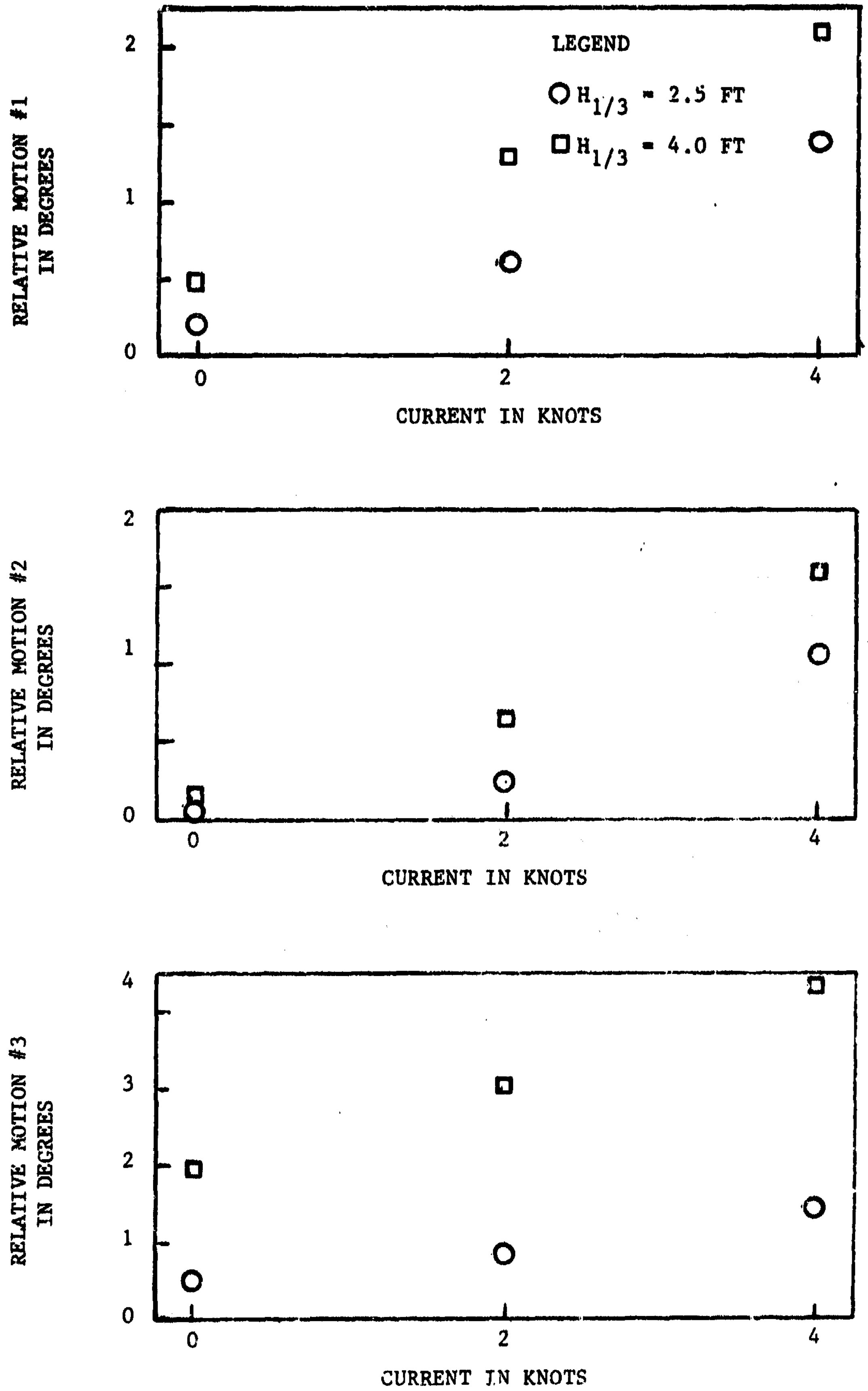
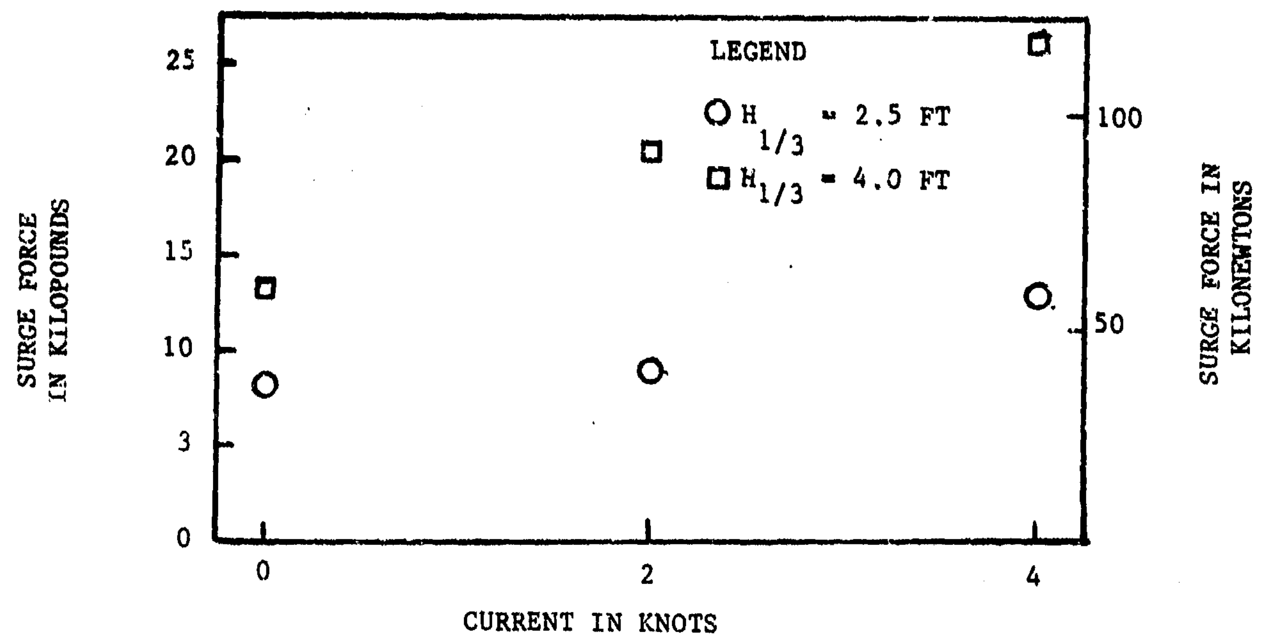


Figure 26 - Configuration 2B Relative Angular Motions in Combined Sea and Current



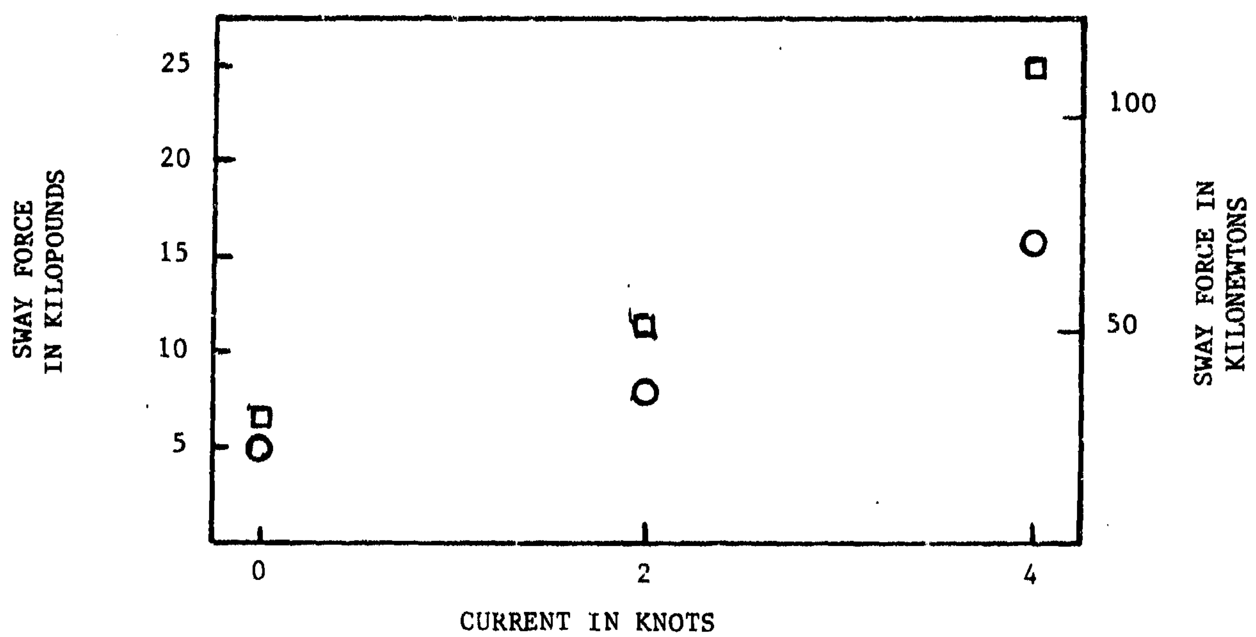


Figure 27 - Configuration 2B Surge and Sway Oscillatory Force in Combined Sea and Current

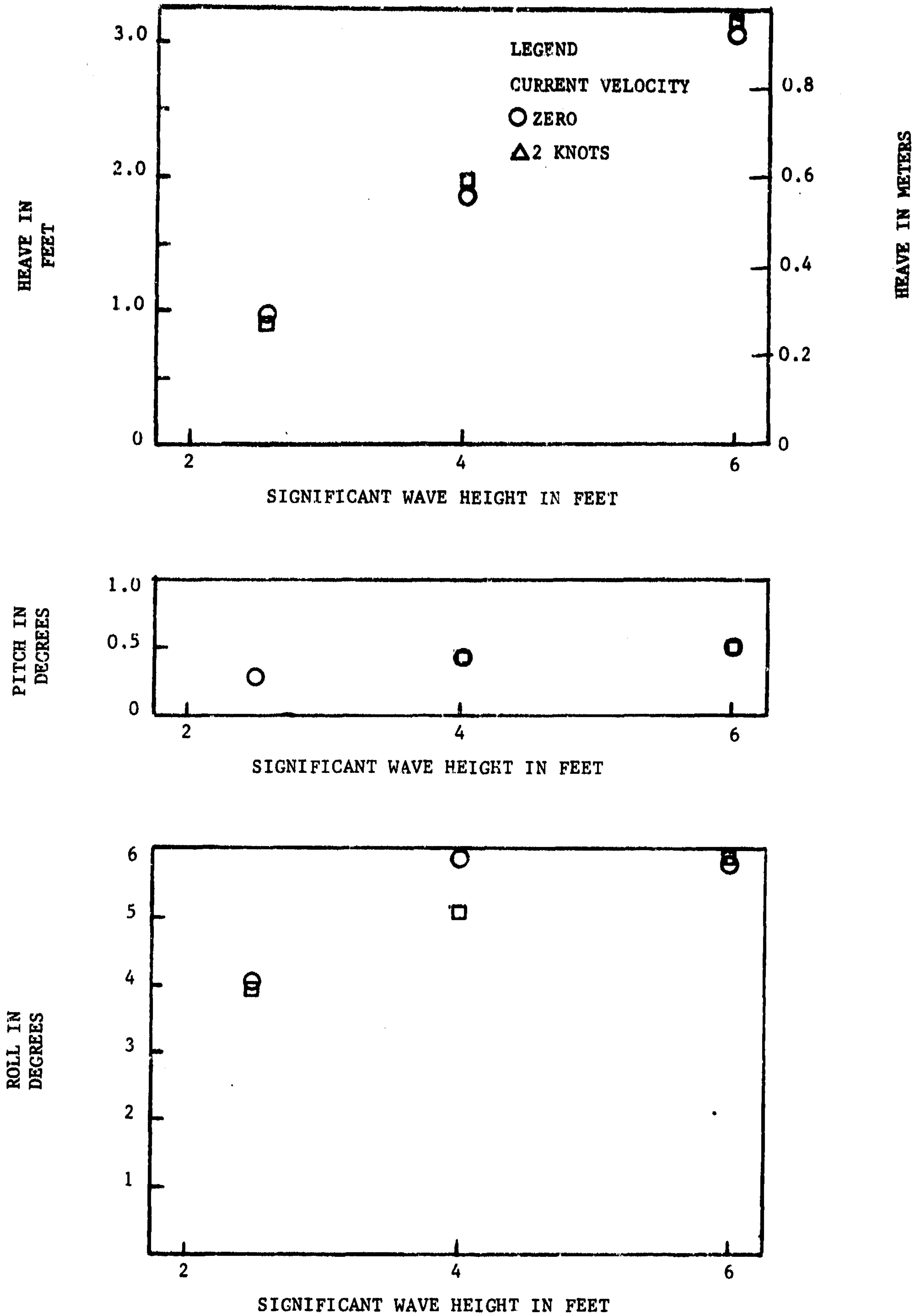


Figure 28 - Configuration 2C Heave, Pitch and Roll Motion in Combined Sea and Current

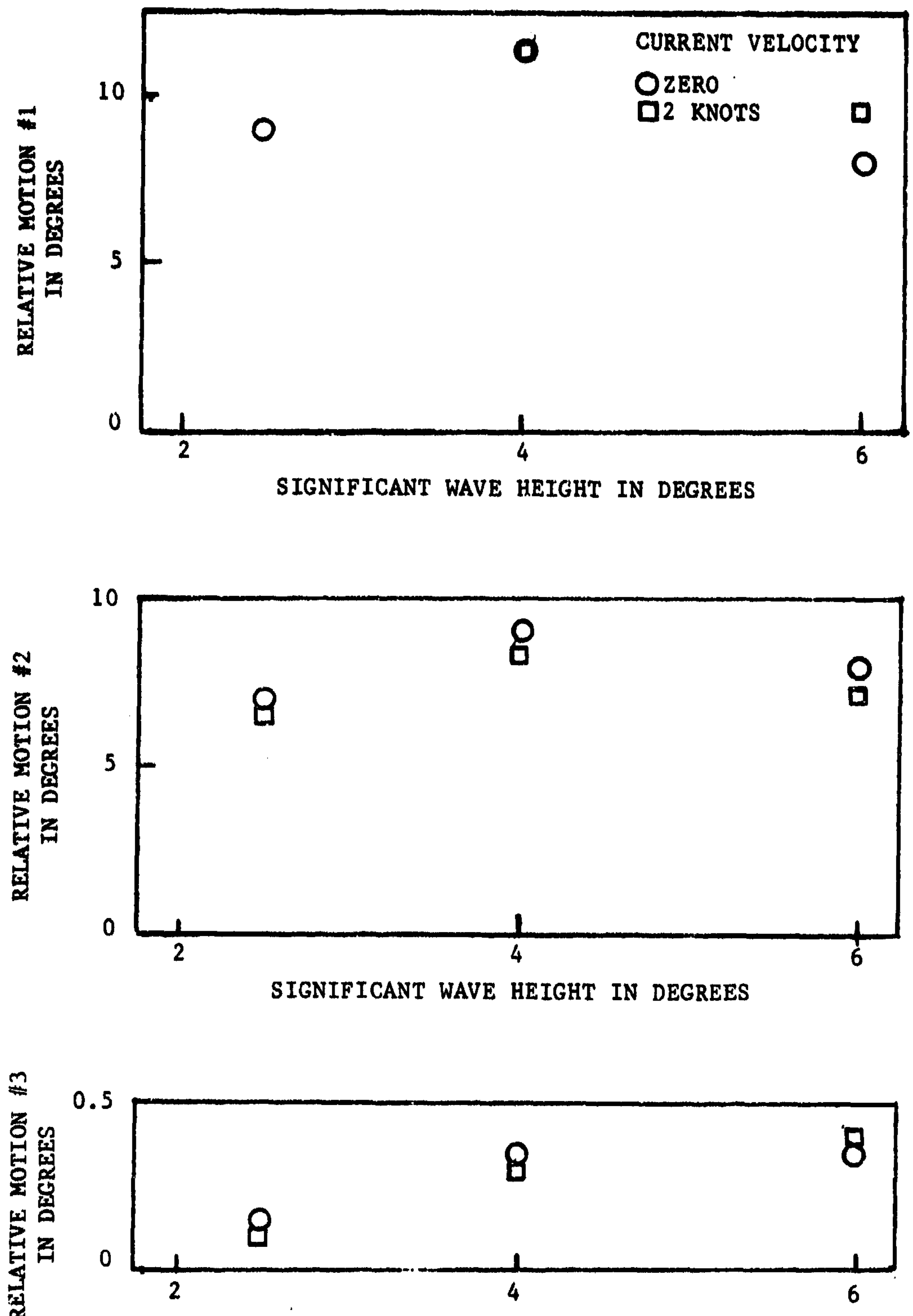


Figure 29 - Configuration 2C Relative Angular Motion
Combined Sea and Current

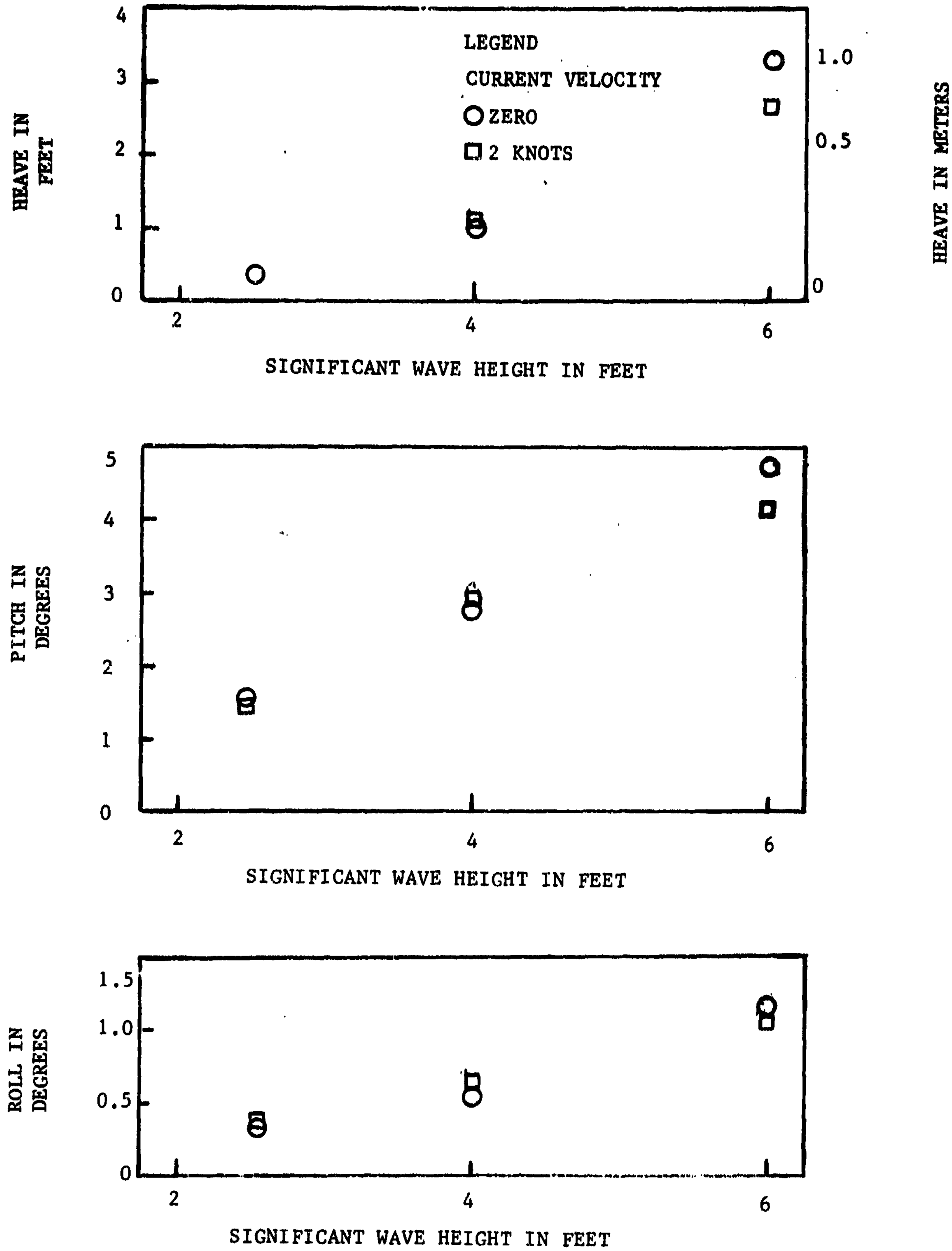


Figure 30 - Configuration 2D Heave, Pitch and Roll Motion in Combined Sea and Current

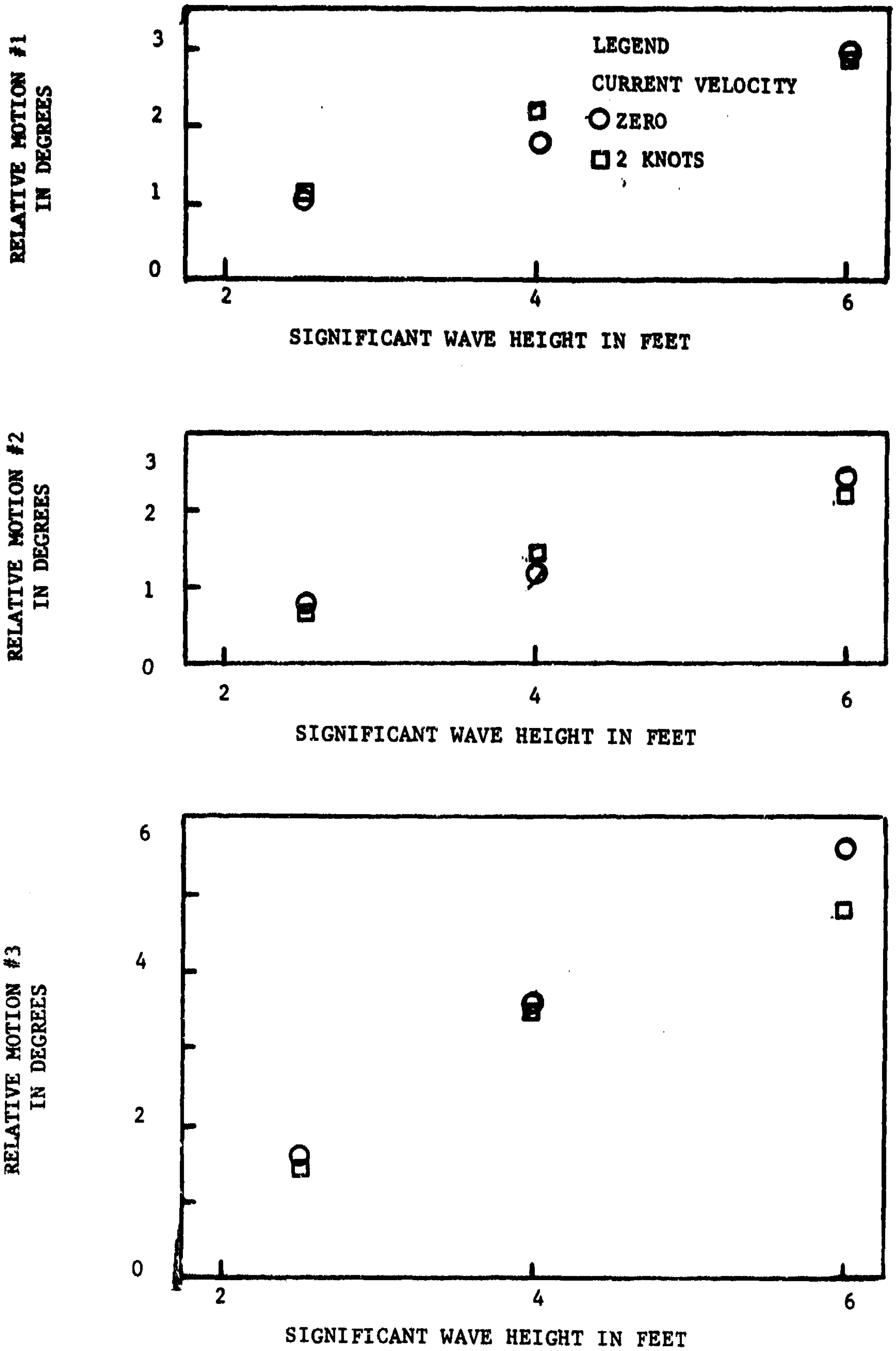


Figure 31 - Configuration 2D Relative Angular Motions in Combined Sea and Current

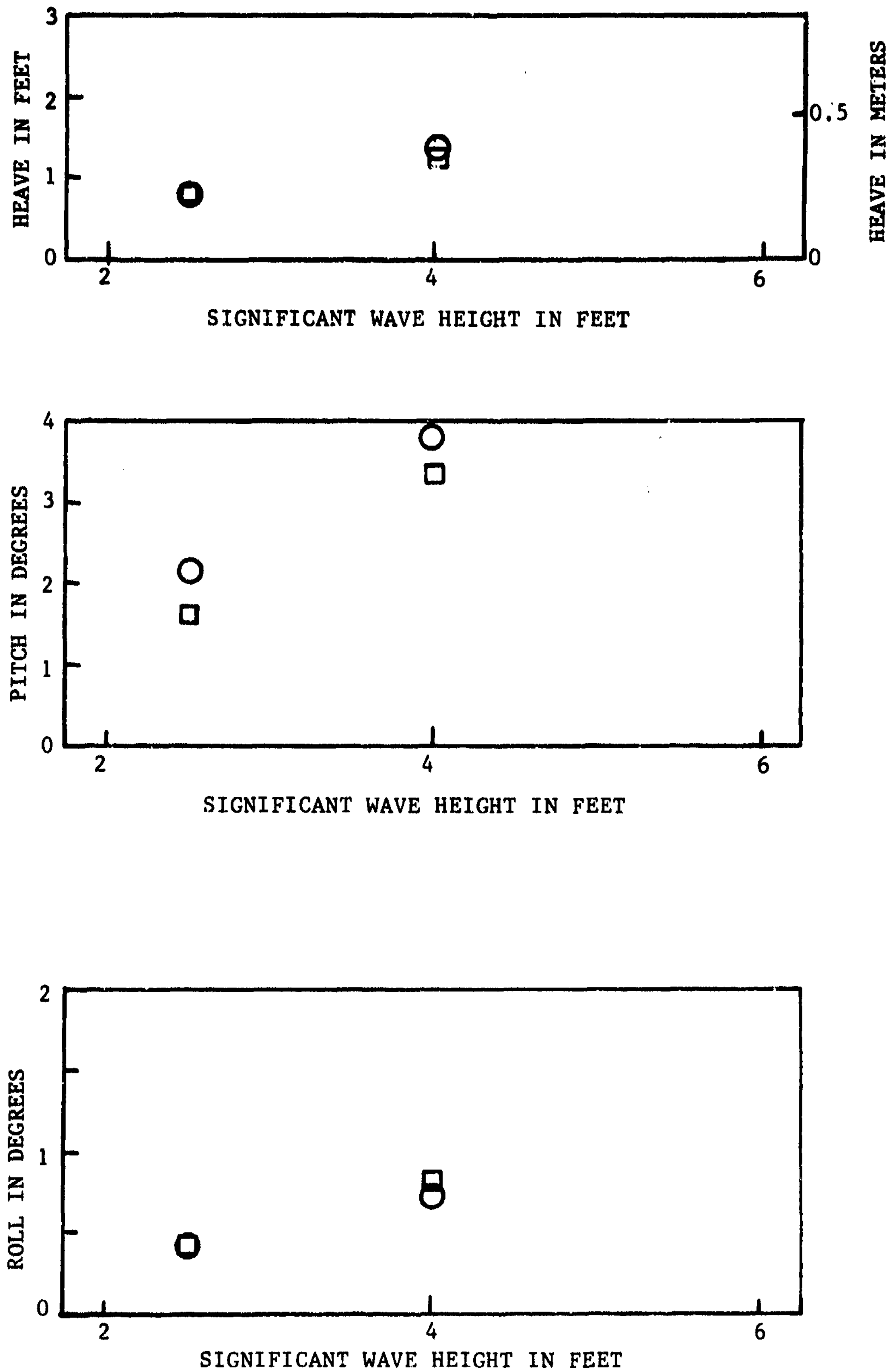


Figure 32 - Configuration 3 Heave, Pitch and Roll Motion in Combined Sea and Current

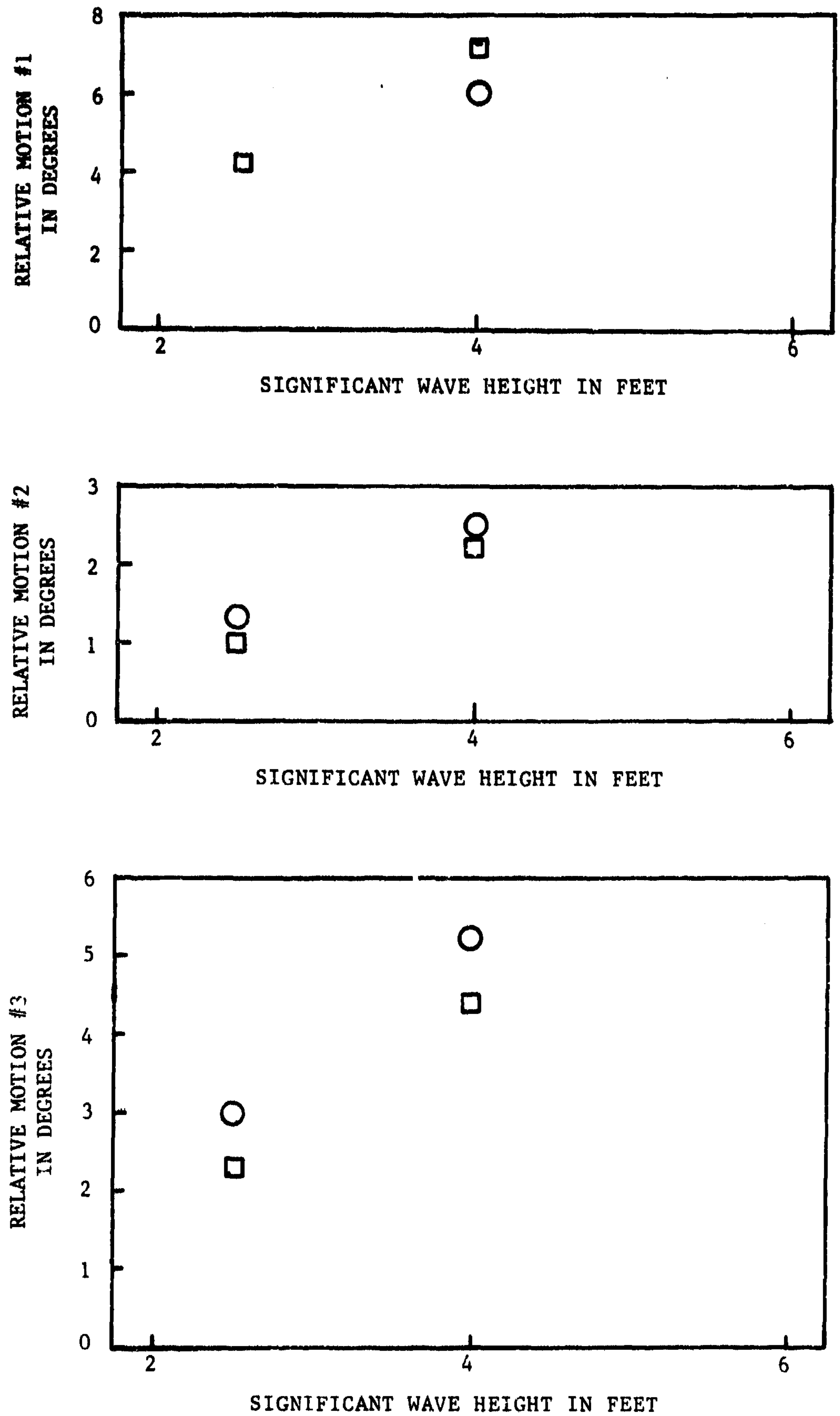


Figure 33 - Configuration 3 Relative Angular Motions in Combined Sea and Current

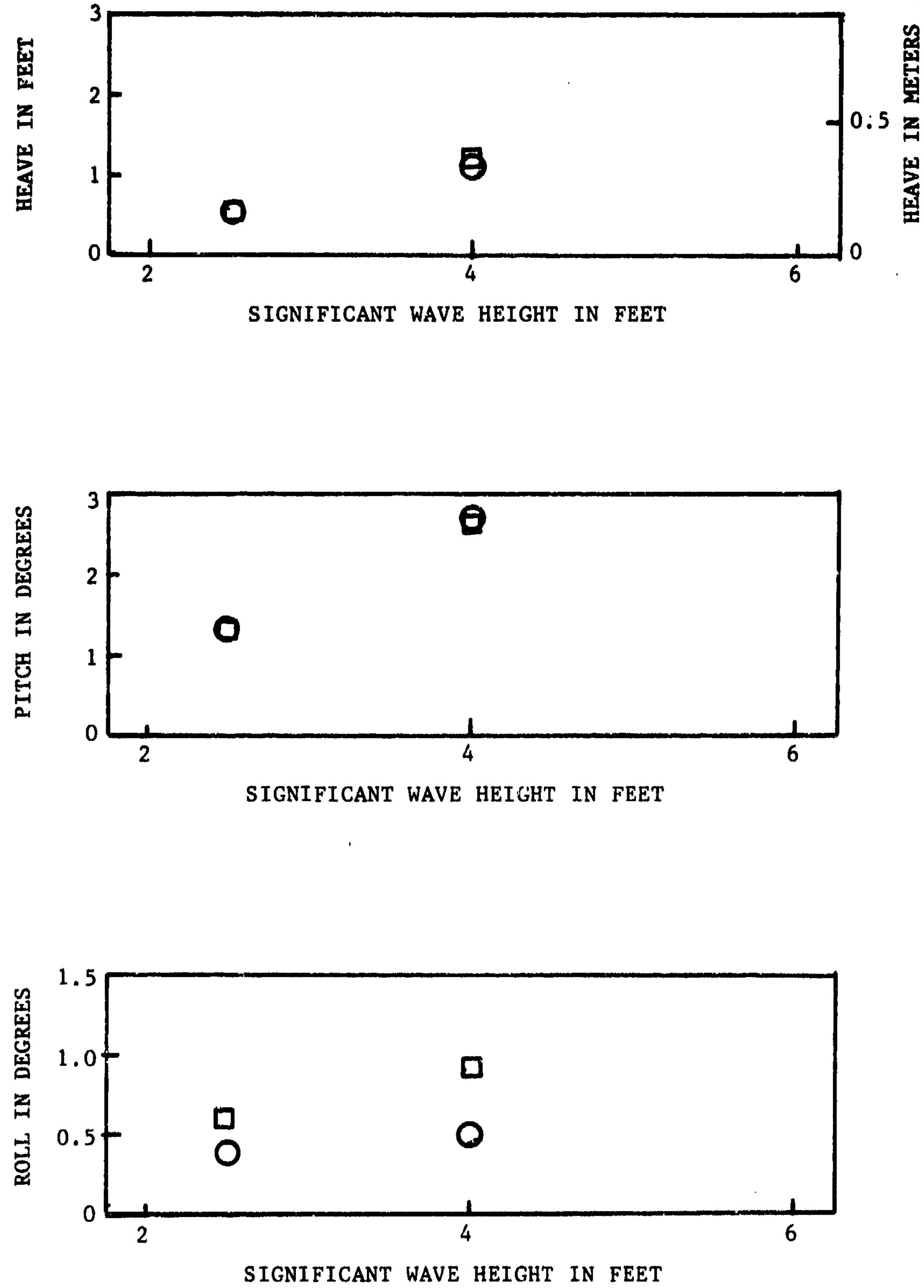


Figure 34 - Configuration 4 Heave, Pitch and Roll Motion in Combined Sea and Current

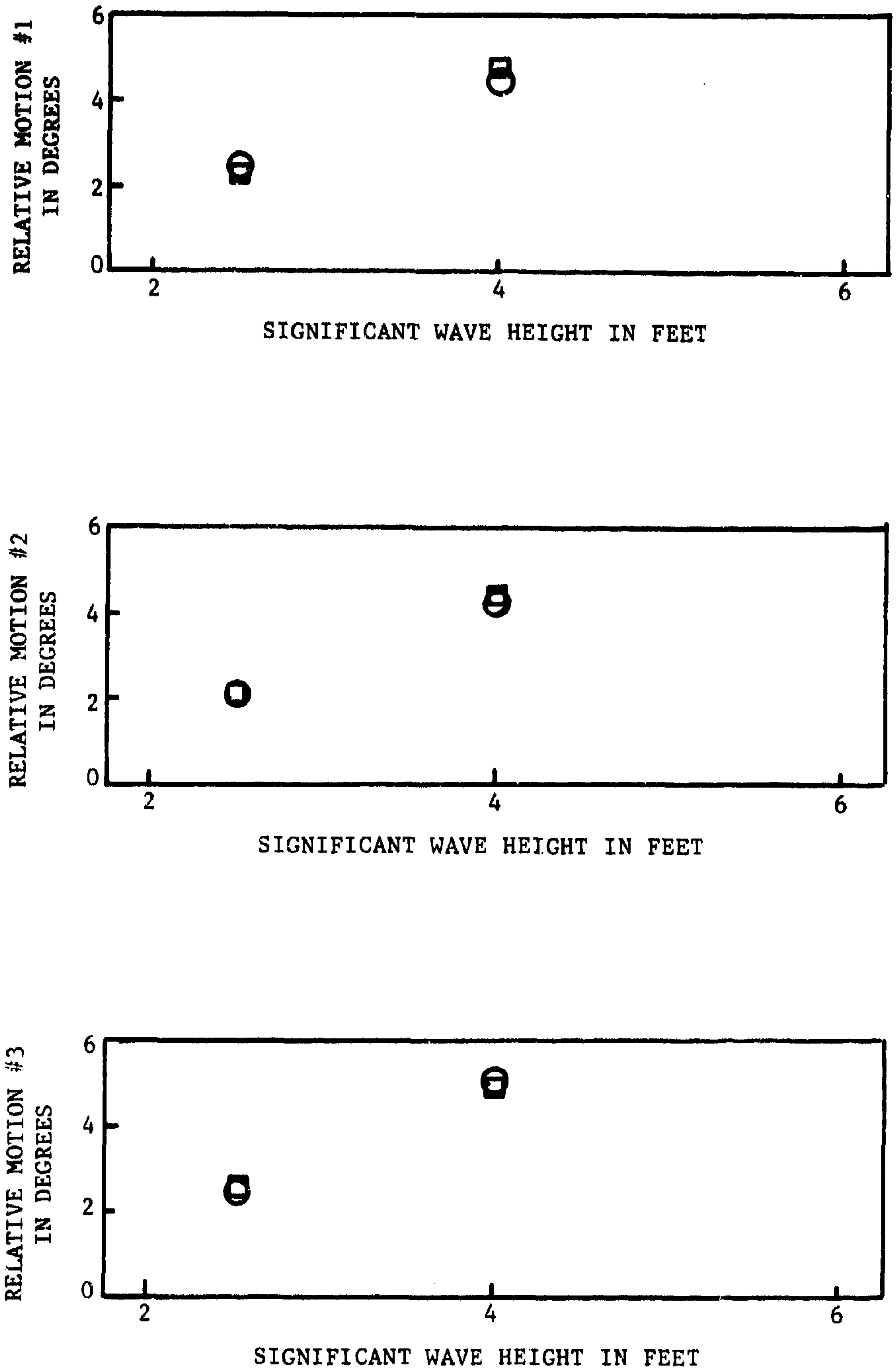


Figure 35 - Configuration 4 Relative Angular Motions in Combined Sea and Current

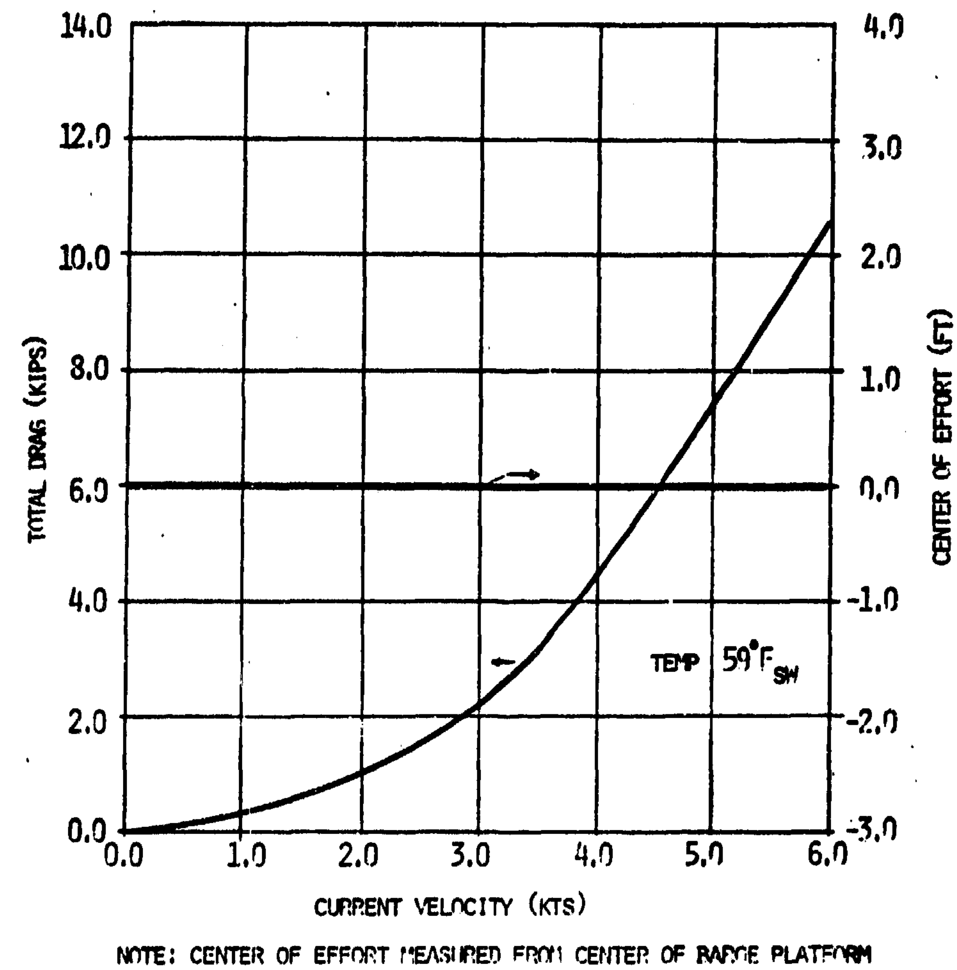
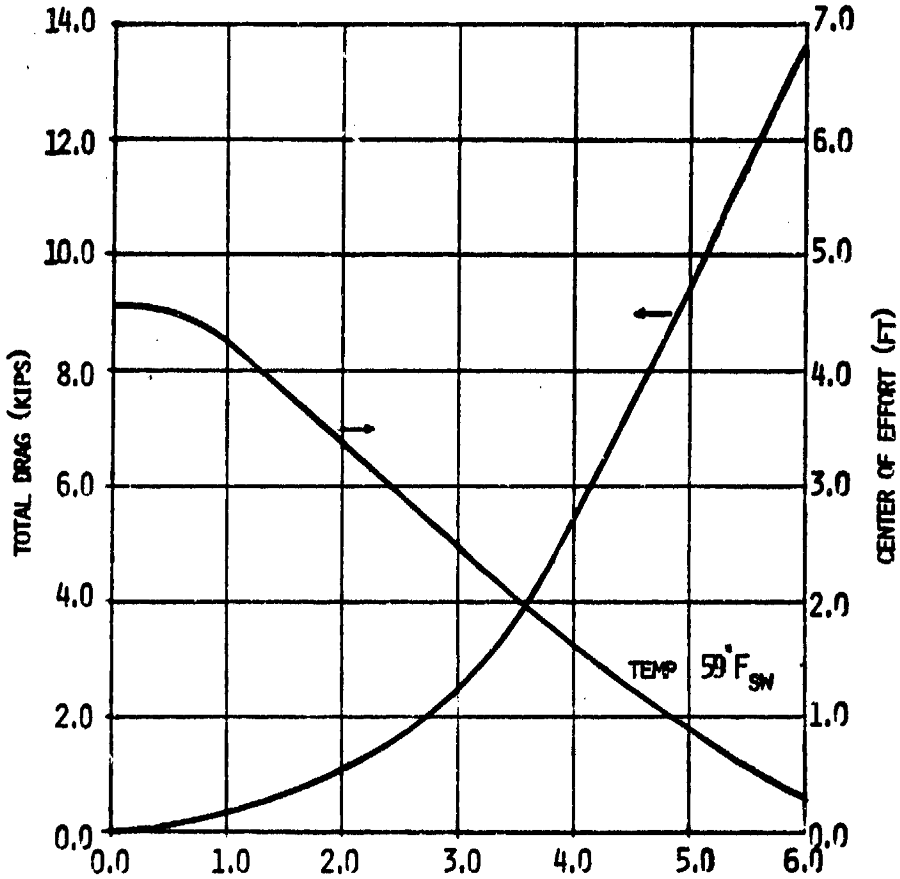


Figure 36 - Current Induced Drag Force for "MAINE" Class Barge Platform Alone (Head Current)



NOTE: CENTER OF EFFORT MEASURED FROM CENTER OF BARGE PLATFORM

Figure 37 - Current Induced Drag Force for "MAINE" Class Barge Platform Configuration 1 (Head Current)

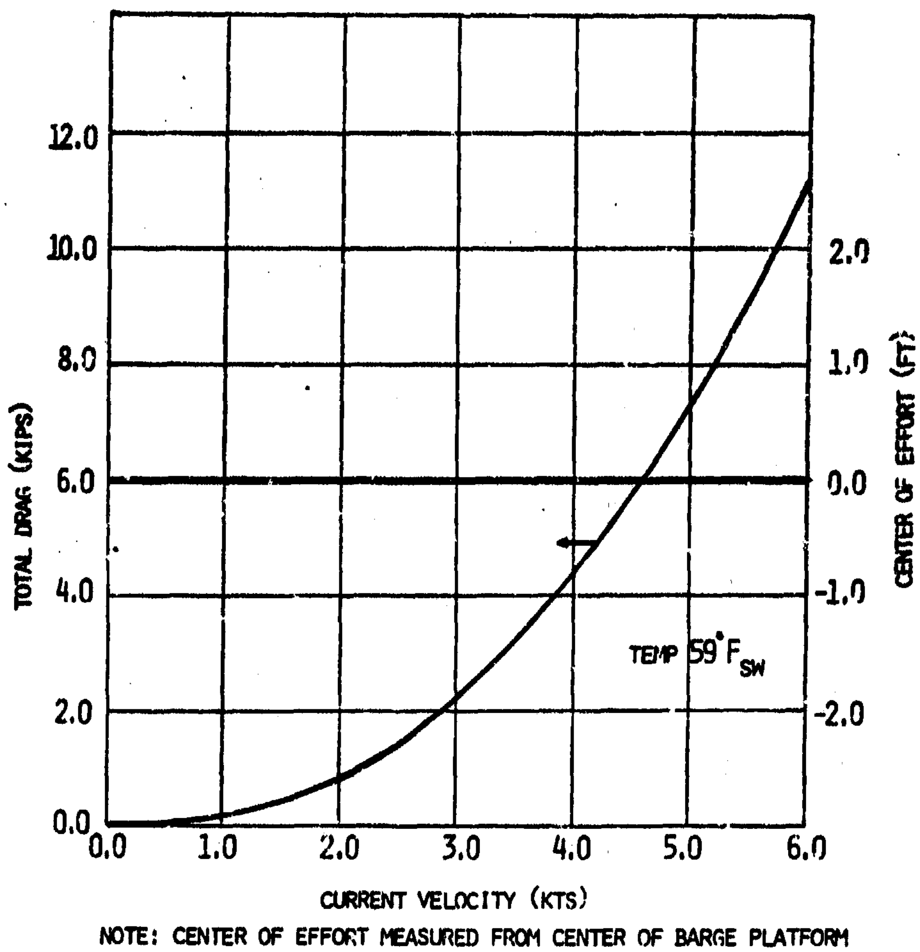


Figure 38 - Current Induced Drag Force for "SS GREAT LAND"
Class Barge Platform Configuration 2
(Head Current)

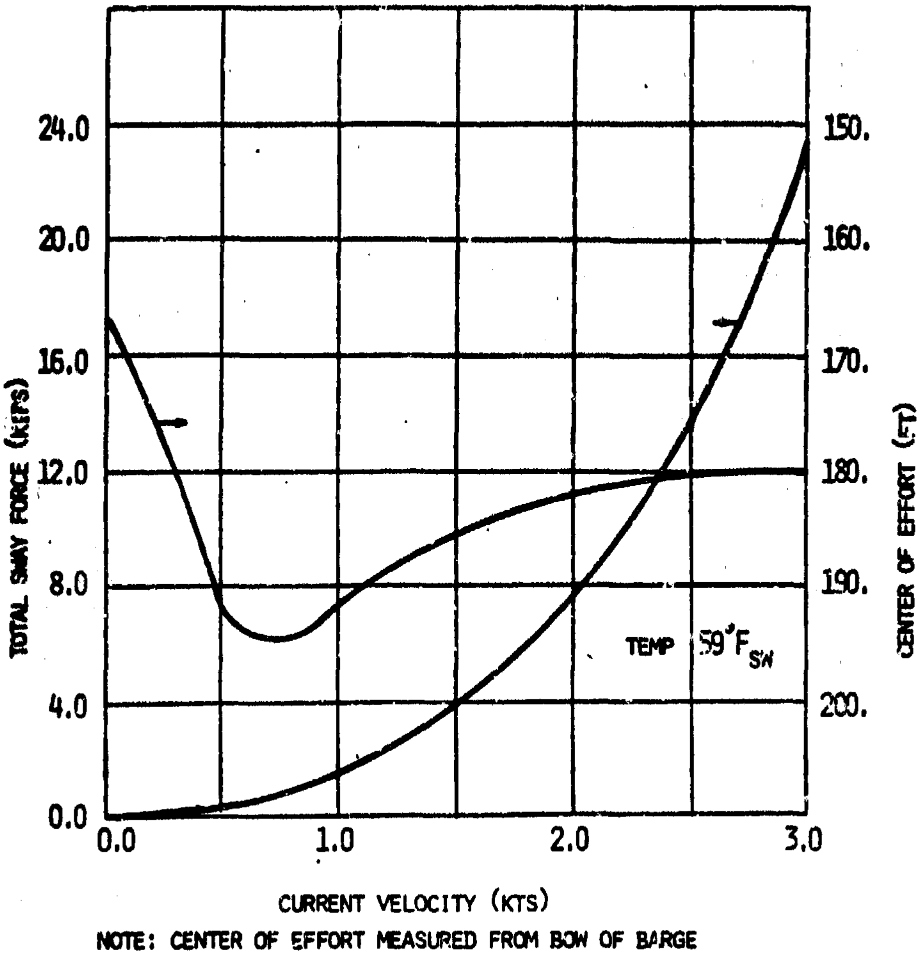


Figure 39 - Current Induced Sway Force for "SS GREAT LAND" Class Barge Platform Configuration 2 (Beam Current)

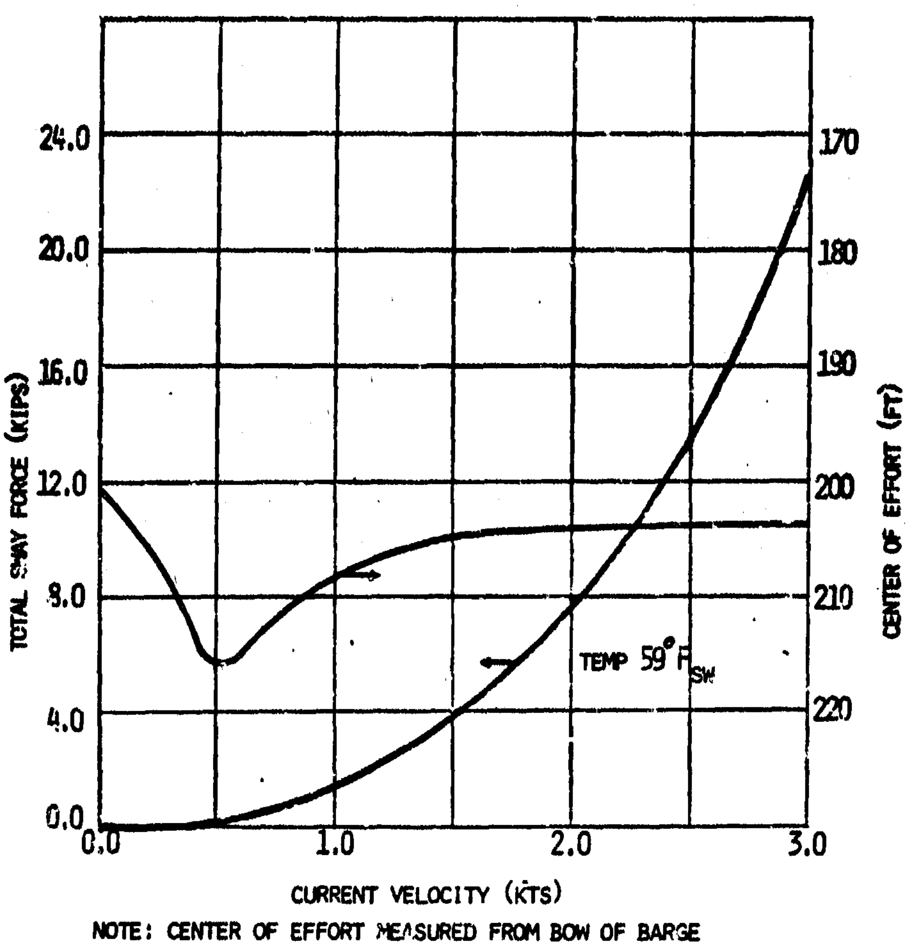


Figure 40 - Current Induced Sway Force for Modified "SS GREAT LAND" Class Barge Platform Configuration 3 (Beam Current)

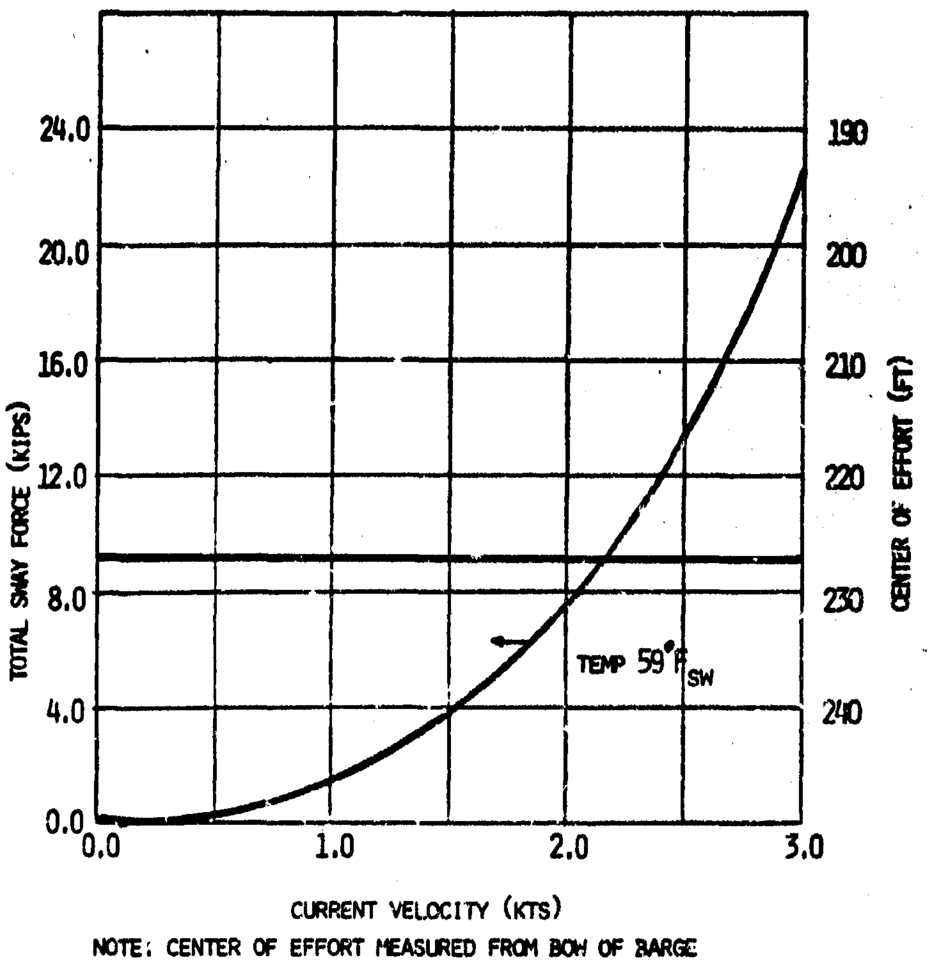


Figure 41 - Current Induced Sway Force for Barge Train Alone (Beam Current)

Table 1 - Characteristics of a 3x15 Standard Barge

Length	90 ft (27.4 m)
Beam	21 ft (6.4 m)
Depth	5 ft (1.5 m)
Draft (unloaded)	20 in. (50.8 cm)
Displacement (unloaded)	67 tons (68,100 kg)
Center of gravity,* KG	2.75 ft (84 cm)
Pitch moment of inertia*	41,000 tons-ft^2 (3,880,000 kg-m^2)
Roll moment of inertia*	2,800 tons-ft^2 (1,269,000 kg-m^2)

*Computed, see text.

Table 2 - Full-Scale Model Particulars for "MAINE" Class Barge Platform Alone (Head Current)

SCALE RATIO: 15

	FULL SCALE	MODEL
MAXIMUM LENGTH	90.00 FT	6.00 FT
MAXIMUM WIDTH	87.75 FT	5.85 FT
EFFECTIVE LENGTH*	80.40 FT	5.36 FT
WETTED SURFACE AREA	7758.00 FT^2	34.48 FT^2
TOW POINT OFFSET:		
FROM BOW		3.0 FT AFT
FROM CENTER OF BARGE PLATFORM		.74 FT PORT

* USED FOR REYNOLD'S NUMBER CALCULATION

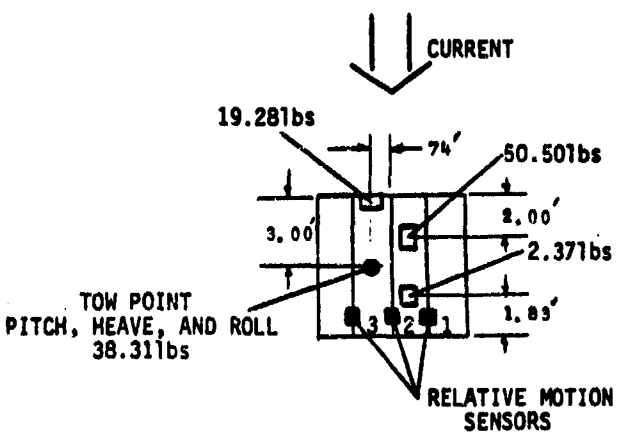


Table 3 - Full-Scale Model Particulars for "MAINE" Class Barge Platform Configuration 1 (Head Current)

SCALE RATIO: 15

	FULL SCALE	MODEL
MAXIMUM LENGTH	363.75 FT	24.25 FT
MAXIMUM WIDTH	87.75 FT	5.85 FT
EFFECTIVE LENGTH*	140.70 FT	9.38 FT
WETTED SURFACE AREA	13869.00 FT^2	61.64 FT^2
TOW POINT OFFSET:		
FROM BOW		3.0 FT AFT
FROM CENTER OF BARGE PLATFORM		.74 FT PORT

*USED FOR REYNOLD'S NUMBER CALCULATION

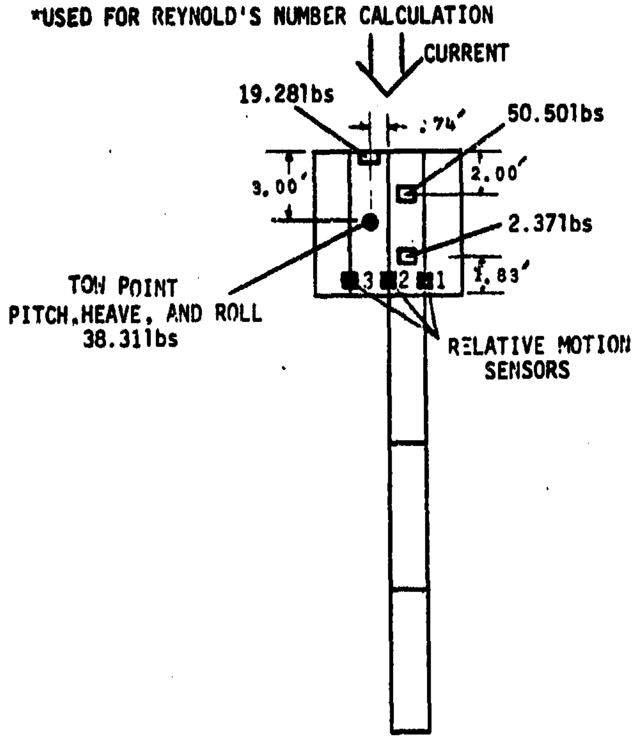


Table 4 - Full-Scale Model Particulars for "SS GREAT LAND" Class Barge Platform Configuration 2 (Head Current)

SCALE RATIO: 15

	FULL SCALE	MODEL
MAXIMUM LENGTH	450.00 FT	30.00 FT
MAXIMUM WIDTH	65.50 FT	4.37 FT
EFFECTIVE LENGTH*	241.20 FT	16.08 FT
WETTED SURFACE AREA	15864.75 FT^2	70.51 FT^2
TOW POINT OFFSET:		
FROM BOW		9.0 FT AFT
FROM CENTER OF BARGE PLATFORM		0.0 FT

*USED FOR REYNOLD'S NUMBER CALCULATION

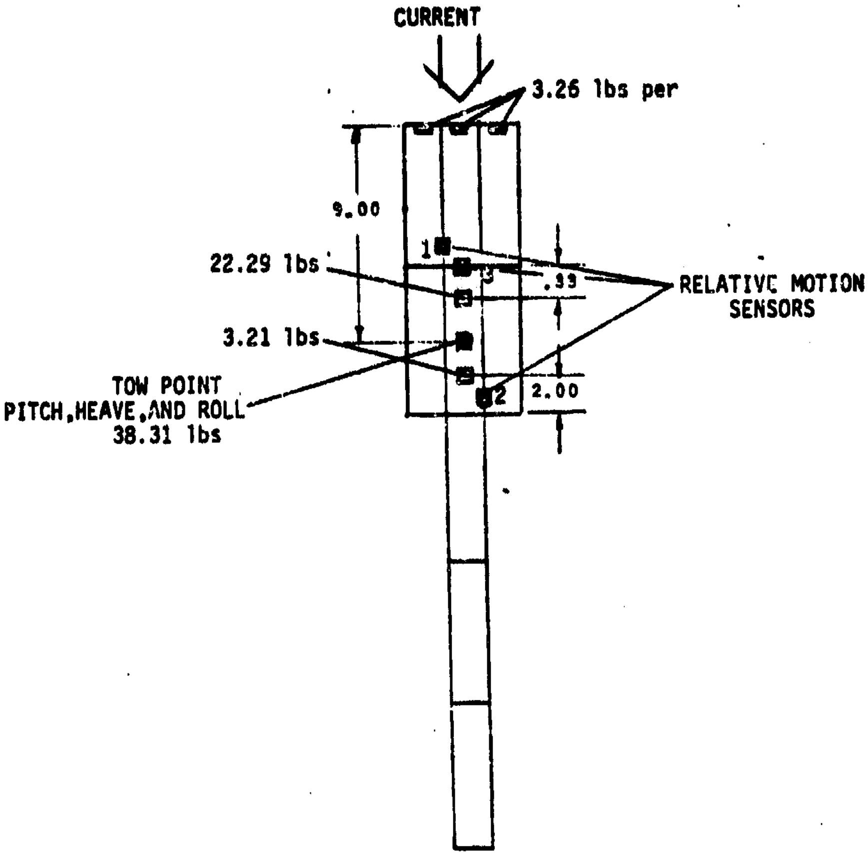


Table 5 - Full-Scale Model Particulars for "SS GREAT LAND" Class Barge Platform Configuration 2 (Beam Current)

SCALE RATIO: 15

	FULL SCALE	MODEL
MAXIMUM LENGTH	450.00 FT	30.00 FT
MAXIMUM WIDTH	65.50 FT	4.37 FT
EFFECTIVE LENGTH*	37.80 FT	2.52 FT
WETTED SURFACE AREA	16537.50 FT^2	73.50 FT^2
TOW POINT OFFSET:		
FROM BOW		9.0 FT AFT
FROM CENTER OF BARGE PLATFORM		0.0 FT

*USED FOR REYNOLD'S NUMBER CALCULATION

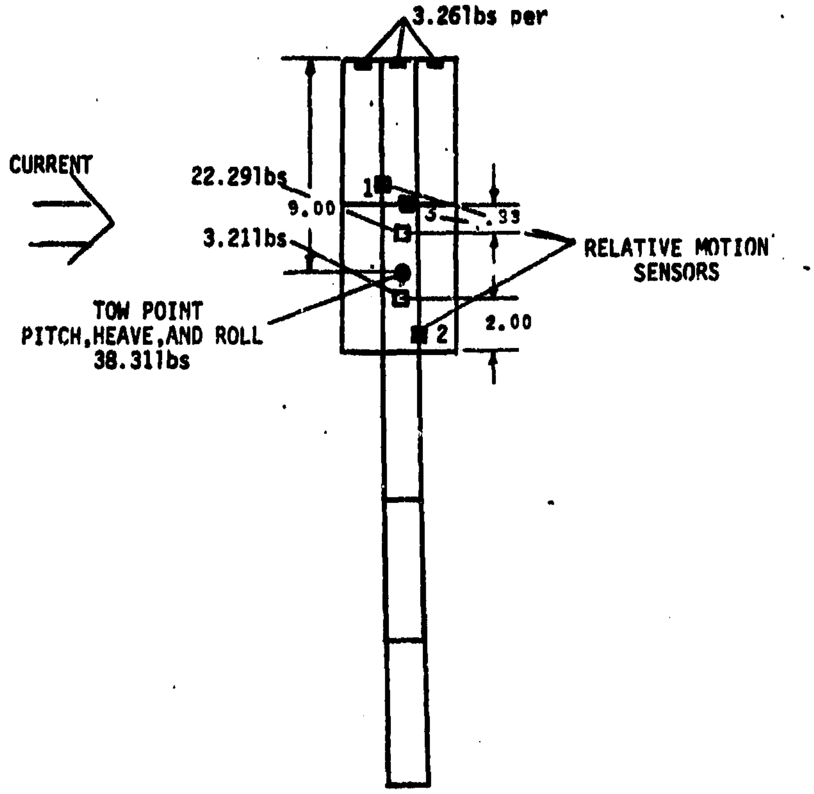


Table 6 - Full-Scale Model Particulars for Modified "SS GREAT LAND" Class Barge Platform Configuration 3 (Beam Current)

SCALE RATIO: 15

	FULL SCALE	MODEL
MAXIMUM LENGTH	450.00 FT	30.00 FT
MAXIMUM WIDTH	65.00 FT	4.37 FT
EFFECTIVE LENGTH*	29.40 FT	1.96 FT
WETTED SURFACE AREA	12863.25 FT^2	57.17 FT^2
TOW POINT OFFSET:		
FROM BOW		9.0 FT AFT
FROM CENTER OF BARGE PLATFORM		0.0 FT

* USED FOR REYNOLD'S NUMBER CALCULATION

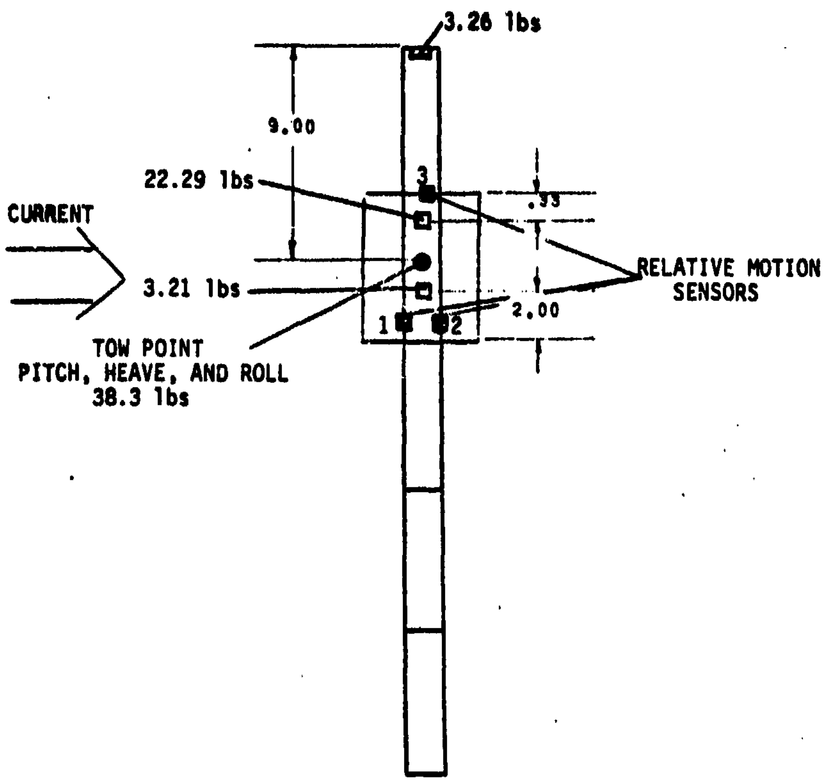


Table 7 - Full-Scale Model Particulars for Barge Train Alone (Beam Current)

SCALE RATIO: 15

	FULL SCALE	MODEL
MAXIMUM LENGTH	450.00 FT	30.00 FT
MAXIMUM WIDTH	21.00 FT	1.40 FT
EFFECTIVE LENGTH*	21.00 FT	1.40 FT
WETTED SURFACE AREA	9186.75 FT^2	40.83 FT^2
TOW POINT OFFSET:		
FROM BOW		9.0 FT AFT
FROM CENTER OF BARGE PLATFORM		0.0 FT

* USED FOR REYNOLD'S NUMBER CALCULATION

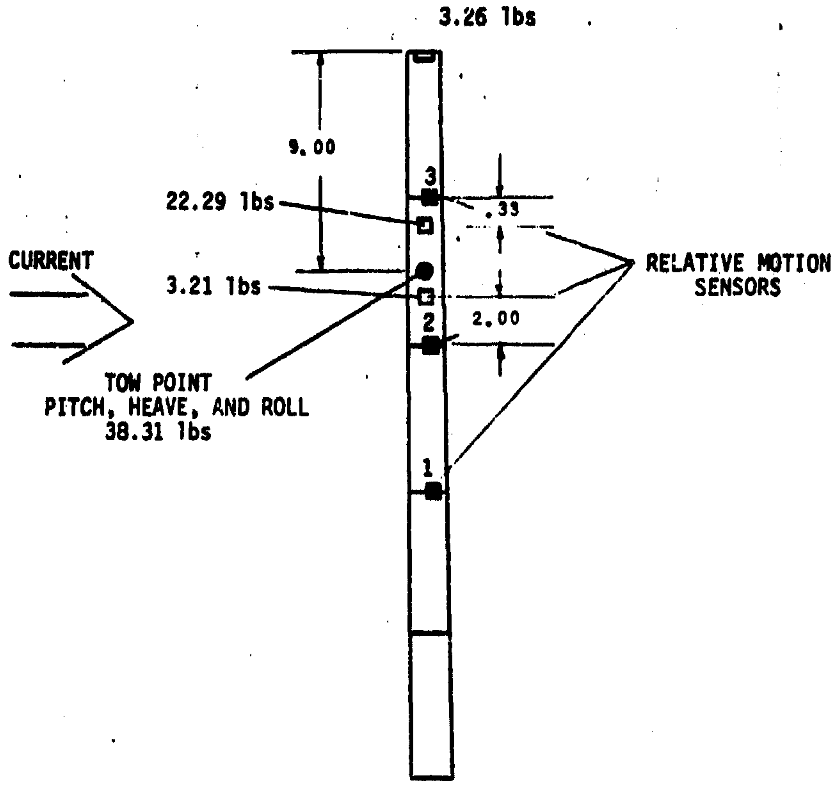


Table 8 - Summary of Configuration 1A Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Significant Wave Height = 2.5 Feet									
0	0.6	0.7	1.3	0.6	0.3	0.4	20	6	103
2	0.7	1.2	1.9	0.8	0.8	0.8	23	8	110
4	0.7	0.7	1.3	0.7	0.4	0.9	32	13	115
Significant Wave Height = 5.0 Feet									
0	1.1	1.2	3.0	1.3	0.8	0.8	38	8	206
2	1.3	1.4	3.1	1.7	1.1	1.7	39	12	219
4	1.3	1.7	2.7	1.9	1.4	2.8	46	17	255
Significant Wave Height = 5.0 Feet									
0	2.8	1.1	4.2	1.5	1.0	1.0	56	12	272
2	2.3	1.7	4.5	1.7	1.3	1.9	56	14	314
4	2.4	2.0	4.3	2.4	1.6	3.2	51	16	356

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton, 1 KIP = 1000 lbs.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter, 1 KIP = 1000 lbs.

Table 9 - Summary of Configuration 1A Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 180 Feet				Wave Height = 2.5 Feet					
0	0.4	0.3	2.6	0.9	0.1	0.1	26	--	--
2	1.0	1.3	2.7	1.2	0.9	1.3	16	--	--
4	1.0	1.3	2.1	1.7	1.0	2.2	1	--	--
Wave Length = 270 Feet				Wave Height = 5.0 Feet					
0	1.9	0.6	3.7	0.1	0.2	0.3	50	--	--
2	2.1	0.7	4.9	0.2	0.3	0.3	65	--	--
4	1.8	0.9	4.1	0.2	0.5	0.6	48	--	--
Wave Length = 540 Feet				Wave Height = 5.0 Feet					
0	2.3	0.3	2.9	0.3	0.1	0.1	32	--	--
2	2.3	0.2	2.6	0.2	0.1	0.1	27	--	--
4	2.4	0.2	2.6	0.3	0.3	0.3	28	--	--

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 10 - Summary of Configuration 1B Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Significant Wave Height = 2.5 Feet									
0	0.7	1.2	1.1	0.7	0.7	1.8	13	--	--
2	0.7	1.3	1.1	0.6	0.8	2.1	12	--	--
4	0.8	1.6	1.0	0.8	1.1	3.2	14	--	--
Significant Wave Height = 4.0 Feet									
0	1.3	2.3	2.4	1.4	1.5	2.9	29	--	--
2	1.4	2.7	1.9	1.4	2.0	4.4	25	--	--
4	1.6	2.9	1.8	1.7	2.4	5.5	25	--	--
Significant Wave Height = 6.0 Feet									
0	2.4	3.2	2.5	1.9	2.1	3.1	35	--	--
2	2.9	3.8	3.2	2.4	2.9	5.2	40	--	--
4	2.9	4.1	2.8	2.6	3.9	6.2	38	--	--

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 11 - Summary of Configuration 1B Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 75 Feet Wave Height = 2.5 Feet									
0	0.2	0.7	0.2	0.7	0.3	1.5	2	3	10
2	0.1	0.1	0.1	0.1	0.1	0.5	4	5	29
4	0.1	0.3	0.1	0.6	0.4	0.4	2	5	67
Wave Length = 180 Feet Wave Height = 2.5 Feet									
0	0.6	1.4	2.0	0.6	0.5	1.3	25	25	35
2	0.7	1.5	1.5	0.2	0.8	1.4	16	20	47
4	1.3	3.0	2.1	0.7	2.3	3.3	17	29	50
Wave Length = 270 Feet Wave Height = 5.0 Feet									
0	1.6	2.4	2.5	1.9	2.1	1.7	26	35	333
2	1.5	1.9	2.1	1.4	1.2	1.4	22	31	281
4	1.8	2.5	2.5	2.2	2.0	1.8	24	38	342
Wave Length = 540 Feet Wave Height = 5.0 Feet									
0	2.6	1.4	2.2	1.2	1.6	0.9	27	24	432
2	2.8	1.5	1.7	1.1	1.3	0.6	24	30	325
4	2.2	1.3	1.4	0.9	1.1	0.5	20	27	286

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 12 - Summary of Configuration 2A Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Significant Wave Height = 2.5 Feet									
0	0.5	0.3	1.0	0.5	0.2	1.3	8	14	432
2	0.5	0.3	1.1	0.7	0.2	1.5	11	16	516
4	0.4	0.3	0.9	0.6	0.2	1.4	16	16	485
Significant Wave Height = 4.0 Feet									
0	1.1	0.6	2.5	1.2	0.5	3.2	18	28	836
2	1.2	0.6	2.6	1.5	0.6	3.4	22	31	897
4	1.2	0.7	2.5	1.6	0.6	3.4	20	36	973

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 13 - Summary of Configuration 2A Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 180 Feet Wave Height = 2.5 Feet									
0	1.1	0.3	3.0	0.6	0.3	3.0	15	19	132
2	1.0	0.4	2.6	0.9	0.3	2.8	16	21	143
4	0.8	0.4	1.9	0.5	0.1	2.5	14	17	56
Wave Length = 270 Feet Wave Height = 5.0 Feet									
0	3.5	1.3	4.5	1.9	1.4	3.6	39	52	327
2	3.5	1.1	4.5	2.2	1.6	3.5	36	48	409
4	2.2	1.0	3.0	1.4	0.9	2.8	28	37	210
Wave Length = 540 Feet Wave Height = 5.0 Feet									
0	1.8	0.5	1.2	0.7	0.3	0.6	14	24	296
2	2.0	0.7	1.5	0.8	0.4	0.6	20	31	270
4	2.3	0.6	1.4	0.9	0.3	0.6	19	32	383

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 14 - Summary of Configuration 2B Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Significant Wave Height = 2.5 Feet									
0	0.3	0.2	0.5	0.2	0.1	0.5	8	5	53
2	0.4	0.2	0.7	0.6	0.3	0.9	9	8	123
4	0.5	0.4	1.0	1.4	1.1	1.5	13	16	252
Significant Wave Height = 4.0 Feet									
0	0.7	0.1	1.7	0.5	0.2	2.0	13	7	75
2	0.9	0.3	2.1	1.3	0.7	3.1	21	12	217
4	1.7	0.6	2.7	2.1	1.6	4.4	26	25	345

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 15 - Summary of Configuration 2B Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 180 Feet Wave Height = 2.5 Feet									
0	0.3	0.0	1.7	0.4	0.0	2.2	4	1	11
2	0.4	0.0	1.6	1.5	0.4	0.3	7	2	17
4	0.4	0.1	1.1	0.5	0.6	1.8	2	1	33
Wave Length = 270 Feet Wave Height = 5.0 Feet									
0	3.1	0.3	5.5	0.4	1.1	6.6	44	10	26
2	2.5	0.1	5.0	0.9	0.9	5.7	51	4	41
4	5.5	0.5	11.6	2.7	2.6	14.6	107	14	40
Wave Length = 540 Feet Wave Height = 5.0 Feet									
0	2.4	0.1	2.5	0.2	0.1	1.4	27	4	59
2	2.8	0.0	2.2	0.0	0.0	0.5	30	3	44
4	2.9	0.1	2.5	0.5	0.5	1.9	31	4	90

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 16 - Summary of Configuration 2C Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-FT***
Significant Wave Height = 2.5 Feet									
0	1.0	4.1	0.3	9.1	7.1	0.2	8	71	533
2	1.0	3.9	0.3	8.5	6.1	0.1	9	73	818
Significant Wave Height = 4.0 Feet									
0	1.8	5.7	0.4	11.3	9.1	0.4	13	120	212
2	2.0	5.1	0.4	11.2	8.4	0.3	12	120	1048
Significant Wave Height = 6.0 Feet									
0	3.1	5.8	0.5	8.1	8.0	0.4	15	152	542
2	3.2	5.9	0.5	10.0	7.2	0.4	13	145	951

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 17 - Summary of Configuration 2C Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 75 Feet Wave Height = 2.5 Feet									
0	1.2	4.8	0.2	9.5	8.2	0.1	1	66	370
2	1.1	5.8	0.2	12.9	9.7	0.1	3	57	452
Wave Length = 180 Feet Wave Height = 2.5 Feet									
0	1.4	2.6	0.2	2.4	1.7	0.0	0	84	328
2	1.4	2.3	0.2	2.8	1.6	0.0	10	72	441
Wave Length = 270 Feet Wave Height = 5.0 Feet									
0	2.4	3.0	0.2	1.6	1.5	0.0	4	100	447
2	2.8	3.4	0.3	1.9	1.6	0.0	6	104	863
Wave Length = 540 Feet Wave Height = 5.0 Feet									
0	2.9	1.5	0.3	0.6	0.6	0.2	6	16	186
2	2.6	1.5	0.2	0.6	0.4	0.0	4	55	429

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 18 - Summary of Configuration 2D Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-FT***
Significant Wave Height = 2.5 Feet									
0	0.4	0.4	1.3	1.1	0.7	1.6	11	18	545
2	0.4	0.4	1.3	1.2	0.7	1.5	13	36	1002
Significant Wave Height = 4.0 Feet									
0	1.0	0.6	2.8	1.8	1.2	3.6	20	34	927
2	1.0	0.7	2.9	2.2	1.5	3.5	28	67	1232
Significant Wave Height = 6.0 Feet									
0	3.3	1.2	4.8	3.0	2.5	5.6	48	59	1287
2	2.7	1.1	4.2	2.9	2.2	4.8	44	77	—

*Multipiy foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 19 - Summary of Configuration 2D Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 75 Feet Wave Height = 2.5 Feet									
0	0.1	0.4	0.8	2.0	0.9	0.6	2	16	18
2	0.2	0.4	0.7	0.8	0.3	0.8	7	—	—
Wave Length = 180 Feet Wave Height = 2.5 Feet									
0	0.8	0.3	3.0	0.8	0.7	3.2	12	15	95
2	0.8	0.6	2.0	1.5	0.7	1.8	18	27	83
Wave Length = 270 Feet Wave Height = 5.0 Feet									
0	1.7	0.5	1.9	1.2	1.3	1.9	24	30	248
2	1.4	0.4	1.2	1.0	1.0	1.4	20	27	366
Wave Length = 540 Feet Wave Height = 5.0 Feet									
0	2.1	0.4	1.3	0.7	0.7	0.8	19	18	367
2	2.6	0.5	1.7	0.7	0.9	0.8	25	26	974

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 20 - Summary of Configuration 3 Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Significant Wave Height = 2.5 Feet									
0	0.7	0.4	2.1	4.1	1.3	3.0	6	21	881
2	0.6	0.4	1.6	4.2	1.0	2.3	14	47	1102
Significant Wave Height = 4.0 Feet									
0	1.4	0.7	3.8	6.0	2.5	5.2	29	34	1132
2	1.2	0.8	3.3	7.1	2.2	4.4	—	—	—

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 21 - Summary of Configuration 3 Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 75 Feet Wave Height = 2.5 Feet									
0	0.2	0.4	0.5	1.4	0.7	0.5	5	7	23
2	0.1	0.6	0.7	3.3	1.0	1.1	6	0	12
Wave Length = 180 Feet Wave Height = 2.5 Feet									
0	0.9	0.4	3.4	2.6	1.6	3.4	20	17	112
2	0.9	0.4	1.7	1.7	0.5	2.1	14	17	31
4	1.4	0.5	2.5	3.9	0.3	4.2	17	18	71
Wave Length = 270 Feet Wave Height = 5.0 Feet									
0	2.8	0.7	3.7	3.9	3.2	3.5	29	40	147
2	2.3	0.6	2.3	2.5	1.7	3.1	17	24	268
Wave Length = 540 Feet Wave Height = 5.0 Feet									
0	1.7	0.2	1.1	0.7	0.5	0.6	13	13	260
2	1.8	0.4	1.3	0.8	0.5	0.6	15	17	629

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 22 - Summary of Configuration 4 Results in Random Seas (Significant Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Significant Wave Height = 2.5 Feet									
0	0.5	0.4	1.3	2.4	2.0	2.4	7	13	610
2	0.5	0.6	1.3	2.2	2.0	2.5	9	40	—
Significant Wave Height = 4.0 Feet									
0	1.1	0.5	2.7	4.4	4.2	4.9	15	30	893
2	1.2	0.9	2.6	4.6	4.3	4.7	18	—	—

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 23 - Summary of Configuration 4 Results in Swell (Amplitudes)

Current Knots	Heave Feet*	Roll Degrees	Pitch Degrees	Relative Motion #1 Degrees	Relative Motion #2 Degrees	Relative Motion #3 Degrees	Surge Force KIPS**	Sway Force KIPS	Yaw Moment KIP-Ft***
Wave Length = 75 Feet Wave Height = 2.5 Feet									
0	0.1	0.2	0.2	0.5	0.2	1.2	2	3	7
2	0.1	0.2	0.6	0.5	0.6	1.5	0	0	5
Wave Length = 180 Feet Wave Height = 2.5 Feet									
0	0.5	0.1	2.5	3.8	4.1	3.3	8	14	145
2	0.6	0.4	1.4	4.0	2.8	2.6	8	16	110
Wave Length = 270 Feet Wave Height = 5.0 Feet									
0	1.5	0.1	1.6	2.9	2.3	1.6	8	13	168
2	3.1	0.1	2.6	5.3	3.7	3.9	11	27	603
Wave Length = 540 Feet Wave Height = 5.0 Feet									
0	2.4	0.3	1.4	1.0	1.0	0.9	12	18	282
2	2.6	0.8	1.4	1.1	1.0	0.8	13	19	799

*Multiply foot by 3.048006 E-01 to convert to meter.
**Multiply pound-force by 4.448222 E+00 to convert to newton.
***Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 24 - Faired Full-Scale Calm Water Data for "MAINE" Class Barge Platform Alone (Head Current)

WATER TEMP: 59° F_{SW} ρ: 1.9905 SLUGS/FT^3 ν: $1.27908 \times 10^{-5} FT^2/SEC$

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT FT-LBS	CENTER OF EFFORT FT	PITCH ANGLE DEG	HEAVE DISP. FT	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
0.0	0.	0.00	0.00	0.00	- 1.23	.000	2.94	.82	5.64	1.05
.5	- 64.	.00	844.0	0.00	- 1.23	.000	2.94	.82	5.64	1.05
1.0	- 252.	.00	3038.0	0.00	- 1.23	.013	2.94	.82	5.64	1.05
1.5	- 563.	.00	6581.0	0.00	- 1.23	.019	2.94	.82	5.64	1.05
2.0	- 994.	.00	11391.0	0.00	- 1.24	.031	2.94	.82	5.64	1.05
2.5	- 1571.	.00	17761.0	0.00	- 1.25	.044	2.94	.82	5.64	1.05
3.0	- 2300.	.00	25777.0	0.00	- 1.27	.063	2.94	.82	5.64	1.05
3.5	- 3301.	.00	36661.0	0.00	- 1.30	.081	2.94	.82	5.64	1.05
4.0	- 4563.	.00	50330.0	0.00	- 1.32	.100	2.95	.82	5.64	1.05
4.5	- 5989.	.00	65728.0	0.00	- 1.35	.125	2.95	.82	5.64	1.05
5.0	- 7565.	.00	82688.0	0.00	- 1.42	.150	2.95	.82	5.64	1.05
5.5	- 9230.	.00	100659.	0.00	- 1.50	.181	2.98	.82	5.64	1.05
6.0	-10886.	.00	118420.	0.00	- 1.57	.213	3.00	.82	5.64	1.05

NOTE: YAW MOMENT MEASURED RELATIVE TO MODEL TOW POINT
CENTER OF EFFORT MEASURED RELATIVE TO CENTER OF BARGE PLATFORM

Multiply foot by 3.048006 E-01 to convert to meter,
Multiply pound-force by 4.448222 E+00 to convert to newton.
Multiply pound force-foot by 1.355818 to convert to newton meter.

Table 25 - Faired Full-Scale Calm Water Data for "MAINE" Class Barge Platform Configuration 1 (Head Current)

WATER TEMP: 59°F_{SW} ρ: 1.9905 SLUGS/FT^3 ν: 1.27908x10^{-5} FT^2/SEC

VELO KTS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT FT-LBS	CENTER OF EFFORT FT	PITCH ANGLE DEG	HEAVE DISP. FT	ROLL ANGLE DEG	REL. MOT. 1 DEG	REL. MOT. 2 DEG	REL. MOT. 3 DEG
0.0	00	0.0	00	4.55	- 1.28	.000	2.08	2.80	3.15	2.28
.5	- 72	0.0	1125	4.50	- 1.28	.006	2.08	2.80	3.15	2.28
1.0	- 283	0.0	4351	4.25	- 1.28	.013	2.08	2.80	3.15	2.28
1.5	- 632	0.0	9401	3.75	- 1.28	.019	2.08	2.80	3.15	2.28
2.0	- 1119	0.0	16175	3.33	- 1.28	.028	2.08	2.80	3.15	2.28
2.5	- 1752	0.0	24572	2.90	- 1.30	.035	2.08	2.80	3.15	2.28
3.0	- 2588	0.0	35417	2.56	- 1.31	.044	2.08	2.80	3.15	2.28
3.5	- 3763	0.0	49427	2.01	- 1.35	.056	2.08	2.80	3.15	2.28
4.0	- 5505	- 45.0	70051	1.60	- 1.38	.070	2.08	2.80	3.15	2.28
4.5	- 7324	- 86.7	90488	1.23	- 1.44	.088	2.08	2.80	3.15	2.28
5.0	- 9342	-173.4	111870	.85	- 1.51	.103	2.08	2.80	3.15	2.28
5.5	-11484	-260.2	134076	.55	- 1.60	.121	2.15	2.80	3.15	2.28
6.0	-13655	-346.9	156418	.33	- 1.75	.144	2.25	2.80	3.15	2.28

NOTE: YAW MOMENT MEASURED RELATIVE TO MODEL TOW POINT
CENTER OF EFFORT MEASURED RELATIVE TO CENTER OF BARGE PLATFORM

Multiply foot by 3.048006 E-01 to convert to meter.
Multiply pound-force by 4.448222 E+00 to convert to newton.
Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 26 - Faired Full-Scale Calm Water Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Head Current)

WATER TEMP: 59° F_{SW} ρ: 1.9905 SLUGS/FT^3 ν: 1.27908x10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT FT-LBS	CENTER OF EFFORT	PITCH ANGLE DEG	HEAVE DISP. FT	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
0.0	00	0.0	0.0	0.0	-.04	.000	0.0	.04	1.48	3.51
.5	62	0.0	0.0	0.0	-.04	-.010	0.0	.04	1.48	3.51
1.0	239	0.0	0.0	0.0	-.05	-.016	0.0	.04	1.48	3.51
1.5	537	0.0	0.0	0.0	-.05	-.008	0.0	.04	1.48	3.51
2.0	935	0.0	0.0	0.0	-.05	-.003	0.0	.04	1.48	3.51
2.5	1474	0.0	0.0	0.0	-.05	.000	0.0	.04	1.48	3.51
3.0	2195	0.0	0.0	0.0	-.05	.006	0.0	.04	1.48	3.51
3.5	317[illegible]	0.0	0.0	0.0	-.03	.010	0.0	.04	1.48	3.51
4.0	4472	0.0	0.0	0.0	-.02	.013	0.0	.04	1.48	3.51
4.5	5941	0.0	0.0	0.0	-.01	.018	0.0	.04	1.48	3.51
5.0	7538	0.0	0.0	0.0	.00	.021	0.0	.04	1.48	3.51
5.5	9286	0.0	0.0	0.0	.04	.028	0.0	.04	1.48	3.51
6.0	11096	0.0	0.0	0.0	.08	.038	0.0	.04	1.48	3.51

NOTE: YAW MOMENT MEASURED RELATIVE TO MODEL TOW POINT
CENTER OF EFFORT MEASURED RELATIVE TO CENTER OF BARGE PLATFORM

Multiply foot by 3.048006 E-01 to convert to meter.
Multiply pound-force by 4.448222 E+00 to convert to newton.
Multiply pound force-foot by 1.355818 E+00 to convert to newton meter.

Table 27 - Faired Full-Scale Calm Water Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Beam Current)

WATER TEMP: 59° F_{SW} ρ: 1.9905 SLUGS/FT^3 ν: 1.27908 x 10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT FT-LBS	CENTER OF EFFORT FT	PITCH ANGLE DEG	HEAVE DISP. FT	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
.00	00	00	000	166.7	-.47	.000	.14	3.17	2.49	.97
.25	- .3	195	- 8438	179.2	-.47	.000	.12	3.17	2.49	.97
.50	- 2.	480	- 26784	192.0	-.47	.001	.09	3.17	2.49	.97
.75	- 5.	974	- 57271	195.0	-.47	.003	.06	3.17	2.49	.97
1.00	- 13	1664	- 92813	192.0	-.47	.006	.03	3.17	2.49	.97
1.25	- 29	2634	-139075	189.0	-.47	.013	.00	3.17	2.49	.97
1.50	- 58	3979	-198154	186.0	-.47	.019	-.03	3.17	2.49	.97
1.75	-103	5693	-266432	183.0	-.47	.028	-.06	3.17	2.49	.97
2.00	-174	7829	-358594	182.0	-.47	.035	-.09	3.17	2.49	.97
2.25	-279	10513	-470982	181.0	-.47	.044	-.13	3.17	2.49	.97
2.50	-413	13750	-609125	180.5	-.48	.053	-.17	3.17	2.49	.97
2.75	-577	18059	-790985	180.0	-.49	.063	-.21	3.17	2.49	.97
3.00	-791	23848	-1039773	179.8	-.50	.075	-.25	3.17	2.49	.97

NOTE: YAW MOMENT MEASURED RELATIVE TO MODEL TOW POINT
CENTER OF EFFORT MEASURED RELATIVE TO BOW OF BARGE TRAIN

Multiply foot by 3.048006 E-01 to convert to meter.
Multiply pound-force by 4.44822 E+00 to convert to newton.
Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 28 - Faired Full-Scale Calm Water Data for Modified "SS GREAT LAND" Class Barge Platform Configuration 3 (Beam Current)

WATER TEMP: 59°F_{SW} ρ: 1.9905 SLUGS/FT^3 ν: 1.27908 x 10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT FT-LBS	CENTER OF EFFORT FT	PITCH ANGLE DEG	HEAVE DISP. FT	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
0.00	00	00	000	201.4	-.70	.000	.34	4.36	3.46	2.03
.25	00	188	-13038	205.6	-.70	.000	.34	4.37	3.46	2.03
.50	00	462	-36845	216.0	-.70	.004	.34	4.42	3.46	2.03
.75	44	934	-70003	211.2	-.70	.006	.34	4.50	3.46	2.03
1.00	57	1603	-114374	207.6	-.70	.010	.33	4.57	3.46	2.03
1.25	71	2540	-176657	205.8	-.70	.015	.30	4.66	3.46	2.03
1.50	84	3976	-272952	204.9	-.70	.023	.27	4.76	3.46	2.03
1.75	105	5668	-386841	204.5	-.70	.031	.25	4.90	3.45	2.03
2.00	125	7776	-528379	204.2	-.71	.045	.20	5.02	3.42	2.03
2.25	149	10422	-704531	203.9	-.72	.063	.15	5.18	3.35	2.03
2.50	172	13613	-919558	203.8	-.73	.081	.06	5.35	3.25	2.03
2.75	196	17867	-1205129	203.7	-.74	.106	-.02	5.58	3.12	2.03
3.00	219	23586	-1588517	203.6	-.75	.131	-.15	5.82	2.92	2.03

NOTE: YAW MOMENT MEASURED RELATIVE TO MODEL TOW POINT
CENTER OF EFFORT MEASURED RELATIVE TO BARGE TRAIN

Multiply foot by 3.048006 E-01 to convert to meter.
Multiply pound-force by 4.44822 E+00 to convert to newton.
Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

Table 29 - Faired Full-Scale Calm Water Data for Barge Train Alone (Beam Current)

WATER TEMP: 59 F_{SW} ρ: 1.9905 $^{SLUGS}/FT^3$ ν: 1.27908 x 10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT FT-LBS	CENTER OF EFFORT FT	PITCH ANGLE DEG	HEAVE DISP. FT	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
0.00	0.00	000	000	227.5	-.61	.000	.00	-1.09	-.60	2.34
.25	0.00	185	-16881	227.5	-.61	.000	.00	-1.09	-.60	2.34
.50	0.00	453	-41336	227.5	-.61	.000	.00	-1.09	-.60	2.34
.75	0.00	915	-83494	227.5	-.61	.000	.00	-1.09	-.60	2.34
1.00	0.00	1571	-143354	227.5	-.61	.006	.00	-1.09	-.60	2.34
1.25	0.00	2500	-228125	227.5	-.61	.019	-.02	-1.09	-.60	2.34
1.50	0.00	3906	-356423	227.5	-.61	.034	-.08	-1.09	-.60	2.34
1.75	0.00	5574	-508628	227.5	-.61	.056	-.15	-1.09	-.60	2.34
2.00	0.00	7655	-698519	227.5	-.61	.081	-.22	-1.09	-.60	2.34
2.25	0.00	10270	-937138	227.5	-.62	.113	-.32	-1.09	-.60	2.34
2.50	0.00	13428	-1225305	227.5	-.63	.144	-.46	-1.09	-.60	2.34
2.75	0.00	17644	-1610015	227.5	-.65	.188	-.67	-1.09	-.60	2.34
3.00	0.00	23319	-2127859	227.5	-.68	.231	-.80	-1.09	-.60	2.36

NOTE: YAW MOMENT MEASURED RELATIVE TO MODEL TOW POINT
CENTER OF EFFORT MEASURED RELATIVE TO BOW OF BARGE TRAIN

Multiply foot by 3.048006 E-01 to convert to meter.
Multiply pound-force by 4.448222 E+00 to convert to newton.
Multiply pound force-foot by 1.355818 E+00 to convert to newton-meter.

APPENDIX

EXTRAPOLATION OF MODEL CURRENT DRAG TO FULL-SCALE

Model drag data in current, as simulated by towing in calm water, was extrapolated to full-scale utilizing Froude scaling and applying a correction for the difference in skin friction resulting from the corresponding lack of Reynolds similiarity. The drag data were nondimensionalized and the corrections applied in coefficient form as follows:

$$C_{TS} = C_{TM} - C_{FM} + C_{FS} + \Delta C_{FML}$$

where C_{TS} = total full-scale drag coefficient

C_{TM} = total model drag coefficient

C_{FM} = model frictional drag coefficient

C_{FS} = full-scale frictional drag coefficient

ΔC_{FML} = laminar deficit

The total model drag coefficient was derived from the measured values of total drag obtained during the experiments, i.e.,

$$C_{TM} = \frac{R_{TM}}{\rho_M/2 \; S_M \; V_M^2}$$

where R_{TM} = total model drag force

ρ_M = density of water (model)

S_M = wetted surface (model)

V_M = velocity of current (model)

The wetted surface in the above equation included the bottom of the barges and the side surfaces comprising the perimeter of the platform causeway system. In the beam current conditions, only the sides parallel to the current were included. It was assumed that areas normal to the flow would not contribute to the frictional drag (1). Coefficients for the frictional resistance for both model and full-scale were computed using the Schoenherr flat plate formulation since the more widely used ITTC formulation has a form factor implied in it. The models Reynold's number was well below 10^6, this was a region where the ITTC's form factor would have affected the extrapolated data. Schoenherr flat plate friction is computed as follows:

$$\frac{.242}{\sqrt{C_F}} = \text{Log}_{10}(R_n \times C_F)$$

where R_n is the Reynolds number and is defined as

$$R_n = \frac{VL}{\nu}$$

where V = current velocity
L = characteristic length
ν = kinematic viscosity

The characteristic length was taken as the average length of the platform/causeway in the direction of the flow. Because of the low model Reynolds number no turbulence stimulation was attempted, instead a laminar deficit correction was applied to the frictional resistance for the results obtained in head current. It was assumed that 30 percent of the length of the forward barges would maintain laminar flow. The 30 percent assumption was based upon a 5×10^5 arc-length Reynolds number criteria for the lowest simulated current. The laminar deficit was defined as,

$$\Delta C_{FL_M} = \frac{1}{3}(C_{FM} - C_{FML})$$

where C_{FML} is Blasius's exact solution for flat plate laminar flow and is equal to

$$C_{FML} = \frac{1.328}{\sqrt{R_n}}$$

A laminar deficit correction was not applied in beam current conditions because it was assumed that the bluff sides and square corners of the barges were sufficient to induce turbulent flow (1). Transition was verified on the after barges in the head current case by comparison of measured and computed incremental frictional drag of barge platform alone with and without it's train. The summation of measured barge platform drag and computed added frictional drag of the barge train was found to be within 4 percent. At a model speed of .44 ft/sec the computed drag of platform and train was .10 lbs vs a measured .10 lbs; at 2.49 ft/sec the computed drag was 2.49 lbs vs a measured 2.50. The total full-scale drag, R_{TS}, was computed by dimensionalizing the derived total full-scale drag coefficient according to

$$R_{TS} = C_{TS} \frac{\rho_s}{2} S_s V_s^2$$

where the subscript "s" denotes full-scale values.

For the most part, the Froude number of the configurations tested were below 0.1. Below this is is assumed that the majority of the residual drag is due to form now wave making resistance. In all cases the residual component was greater than the computed frictional. Since the major portion of the form drag is due to the viscous wake, the form drag coefficient will gradually decrease with increased Reynolds number (3). These expanded results will be conservative over estimates of actual current induced force.

Forces normal to the current resulting from asymmetry of the platform/causeway system were scaled directly without corrections for Reynolds effects. However, a correction was applied to the normal forces measured in beam current for a slight twisting of the tow strut (about 2 degrees maximum). It was assumed that application of cross-flow principle (Horner Reference 2) would be applicable as follows:

$$R_{y_\lambda} = R_{y_0} \cos^3\lambda$$

$$R_{x_\lambda} = R_{y_0} (\sin \lambda \cos^2\lambda)$$

converting from body axis

$$R_{y_\lambda} = \sqrt{R_{y_m}^2 + R_{x_m}^2} \cos \lambda$$

$$R_{x_\lambda} = \sqrt{R_{y_m}^2 + R_{x_m}^2} \sin \lambda$$

so that

$$R = \sqrt{R_{y_m}^2 + R_{x_m}^2 \cos^2\lambda}$$

$$R_{y_0}^2 \cong \sqrt{R_{y_m}^2 + R_{x_m}^2}$$

since $\lambda_{max} = 2^o$ and $\cos^2 2^o = .9988$.

R_{y_λ} = sway force with twist angle

R_{y_θ} = sway force with no twist angle

R_{y_m} = measured body axis sway force

R_{x_λ} = surge force with twist angle

R_{x_θ} = surge force with no twist angle

R_{x_m} = measured body axis surge force

λ = angle of twist

The measured model experimental data and corresponding faired values are presented in Tables A.1 through A.12 and in Figures A.1 through A.12. The extrapolated full-scale data are presented in the text.

(1) Hoerner, Fluid Dynamic Drag, published by author, 1958, pages 3-14 section 6 "Drag of Various Types of Plates."

(2) Hoerner, Fluid Dynamic Drag, published by author, 1958, pages 3-11, section 5 "Cross-Flow Principle."

(3) Hughes, G., Friction and Form Resistance in Turbulent Flow; and a proposed Formulation for use in Model and Ship Correlations, RINA, 1954.

Table A.1 - Model Calm Water Experimental Data for "MAINE" Class Barge Platform Alone (Head Current)

TEST DATE: 29 JAN 82 TANK TEMP: 68.4°F_{FW}

RUN NO.	VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
	0.00	0.00	0.00	0.00	- 1.22	0.00	2.94	.82	5.64	1.05
26	.44	- .08	.00	.75	-1.24	.01	2.92	.82	5.64	1.05
29	.85	- .32	.00	2.85	-1.25	.06	2.94	.82	5.64	1.05
30	1.287	- .74	- .01	6.33	-1.28	.06	2.34	.82	5.64	1.05
32	1.689	-1.29	.01	10.46	-1.32	.11	2.95	.82	5.64	1.05
33	2.101	-2.08	.01	17.06	-1.40	.12	2.97	.82	5.64	1.05

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

Table A.2 - Model Faired Calm Water Data for "MAINE" Class Barge Platform Alone (Head Current)

WATER TEMP: 68.4°F_{FW} ρ: 1.9367 SLUGS/FT^3 ν: 1.0746×10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
0.00	0.000	0.00	0.00	- 1.23	0.00	2.94	.82	5.64	1.05
.22	-.022	0.00	.20	- 1.23	.00	2.94	.82	5.64	1.05
.44	-.081	0.00	.72	- 1.23	.01	2.94	.82	5.64	1.05
.65	- .175	0.00	1.56	- 1.23	.02	2.94	.82	5.64	1.05
.87	- .303	0.00	2.70	- 1.24	.03	2.94	.82	5.64	1.05
1.09	- .473	0.00	4.21	- 1.25	.04	2.94	.82	5.64	1.05
1.31	- .686	0.00	6.11	- 1.27	.05	2.94	.82	5.64	1.04
1.53	- .976	0.00	8.69	- 1.30	.07	2.94	.82	5.64	1.03
1.74	-1.340	0.00	11.93	- 1.32	.08	2.95	.82	5.64	1.02
1.96	-1.750	0.00	15.58	- 1.35	.10	2.96	.82	5.64	1.01
2.18	-2.202	0.00	19.60	- 1.42	.12	2.97	.82	5.64	.99
2.40	-2.681	0.00	23.86	- 1.50	.15	2.98	.82	5.44	.97
2.62	-3.154	0.00	28.07	- 1.57	.17	3.00	.82	5.64	.95

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

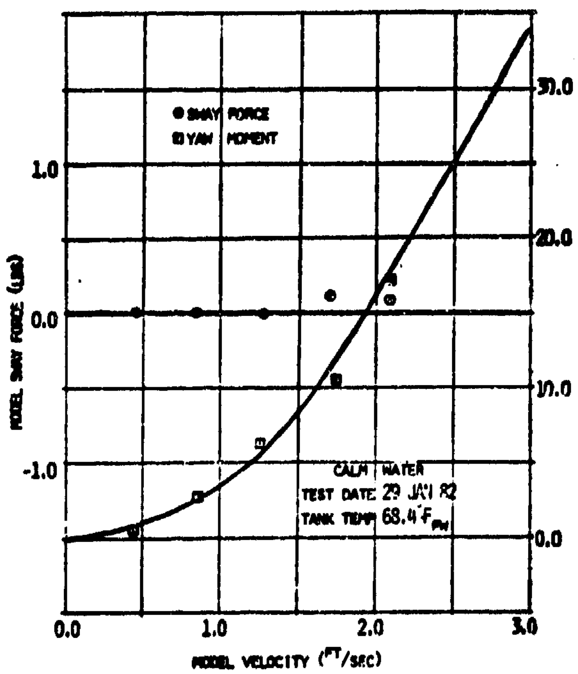


Figure A.1 - Model Faired Sway Force and Yaw Moment Data for "MAINE" Class Barge Platform Alone (Head Current)

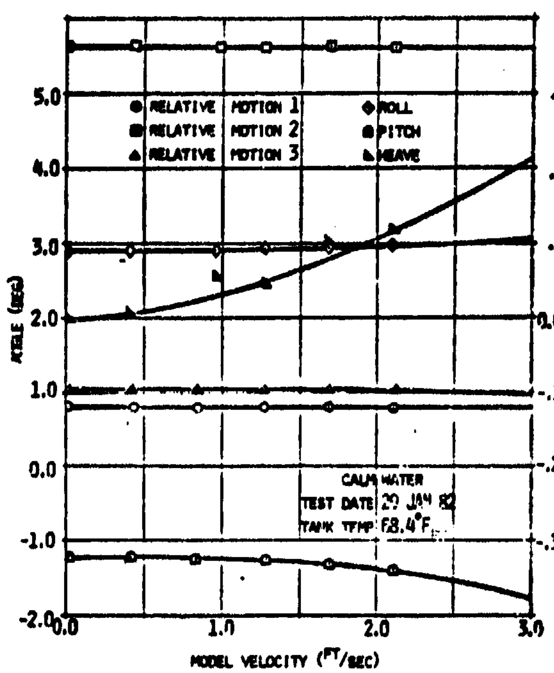


Figure A.2 - Model Faired Motion Data for "MAINE" Class Barge Platform Alone (Head Current)

Table A.3 - Model Calm Water Experimental Data for "MAINE" Class Barge Platform Configuration 1 (Head Current)

TEST DATE: 29 JAN 82 TANK TEMP: 68.4°F_{FW}

RUN NO.	VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
	0.00	0.00	0.00	0.00	-1.28	0.00	2.08	2.80	3.15	2.28
8	.43	- .091	- .02	- .88	-1.29	.02	2.02	2.80	3.15	2.28
4	.43	- .110	.00	- .86	-1.34	.02	2.04	2.80	3.15	2.28
23	.46	- .101	- .02	1.56	-1.29	.00	2.00	2.80	3.15	2.28
11	.84	- .366	.01	3.62	-1.31	.01	2.04	2.80	3.15	2.28
20	1.25	- .776	.00	7.92	-1.35	.04	2.03	2.80	3.15	2.28
5	1.26	- .827	- .03	8.07	-1.36	.05	2.06	2.80	3.15	2.28
21	1.42	-1.127	- .03	9.75	-1.37	.03	2.04	2.80	3.15	2.28
9	1.68	-1.580	- .03	13.81	-1.38	.08	2.06	2.80	3.15	2.28
14	1.68	-1.648	.00	14.10	-1.39	.08	2.10	2.80	3.15	2.28
12	2.09	-2.581	- .06	21.36	-1.46	.08	2.08	2.80	3.15	2.28
17	2.10	-2.495	.03	22.43	-1.40	.11	2.06	2.80	3.15	2.28
24	2.20	-2.920	- .08	23.73	-1.53	.10	2.08	2.80	3.15	2.28
15	2.51	-4.007	- .07	31.45	-1.69	.18	2.26	2.80	3.15	2.28

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

Table A.4 - Model Faired Calm Water Data for "MAINE" Class Barge Platform Configuration 1 (Head Current)

WATER TEMP: 68.4 F_{FW} ρ: 1.9367 SLUGS/FT^3 ν: 1.0746x10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
0.00	0.000	0.00	0.00	- 1.28	0.00	2.08	2.80	3.15	2.28
.22	- .027	.00	.27	- 1.28	.01	2.08	2.80	3.15	2.28
.44	- .100	.00	1.03	- 1.28	.01	2.08	2.80	3.15	2.28
.65	- .217	.00	2.23	- 1.28	.02	2.08	2.80	3.15	2.28
.87	- .378	.00	3.83	- 1.29	.02	2.08	2.80	3.15	2.28
1.09	- .583	.00	5.82	- 1.30	.03	2.08	2.80	3.15	2.28
1.31	- .860	.00	8.40	- 1.31	.04	2.08	2.80	3.15	2.28
1.53	-1.217	.00	11.72	- 1.35	.05	2.08	2.80	3.15	2.28
1.74	-1.750	- .01	16.60	- 1.38	.06	2.08	2.80	3.15	2.28
1.96	-2.308	- .03	21.45	- 1.44	.07	2.08	2.80	3.15	2.28
2.18	-2.925	- .05	26.52	- 1.51	.08	2.08	2.80	3.15	2.28
2.40	-3.584	- .08	31.78	- 1.60	.10	2.15	2.80	3.15	2.28
2.62	-4.250	- .10	37.08	- 1.75	.12	2.25	2.80	3.15	2.28

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

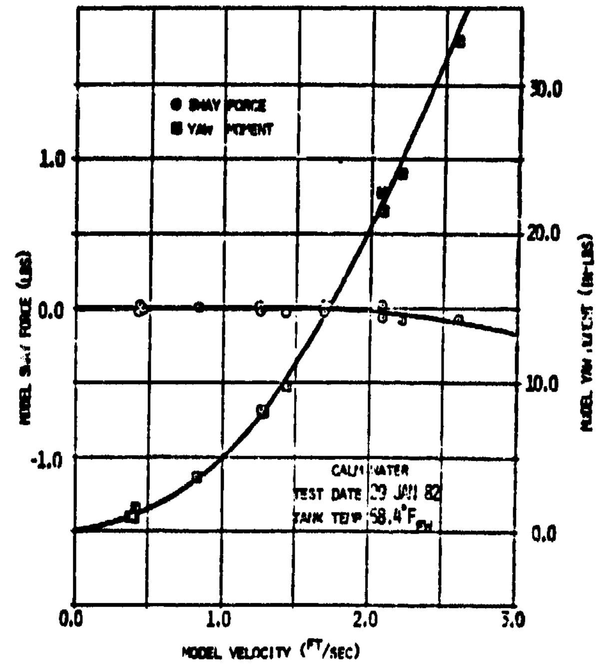


Figure A.3 - Model Faired Sway Force and Yaw Moment for "MAINE" Class Barge Platform Configuration 1 (Head Current)

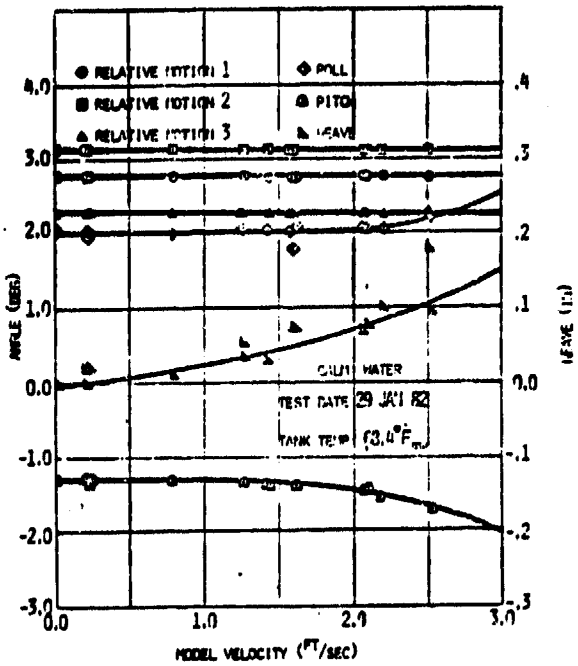


Figure A.4 - Model Faired Motion Data for "MAINE" Class Barge Platform Configuration 1 (Head Current)

Table A.5 - Model Calm Water Experimental Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Head Current)

TEST DATE: 4 FEB 82 TANK TEMP: 68.4°F_{FW}

RUN NO.	VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT. 1 DEG	REL. MOT. 2 DEG	REL. MOT. 3 DEG
	0.00	0.000	0.00	0.00	-.04	0.000	0.00	.04	1.48	3.51
133	.43	-.087	-4.84	9.60	-.05	-.018	.02	.04	1.48	3.51
141	.44	-.085	-.01	.14	-.05	-.008	-.02	.04	1.48	3.51
136	.86	-.374	-2.48	5.46	-.03	.000	-.01	.04	1.48	3.51
144	.87	-.393	-3.53	7.23	-.05	-.004	.00	.04	1.48	3.51
134	1.26	-.812	-4.81	11.03	-.06	.012	.04	.04	1.48	3.51
139	1.27	-.824	-2.41	6.59	-.04	.011	.01	.04	1.48	3.51
146	1.54	-4.851	-3.05	.72	.05	.035	-.04	.04	1.48	3.51
137	1.69	-1.467	-2.14	7.36	-.01	.018	.02	.04	1.48	3.51
147	2.12	-2.364	.04	4.50	.03	.020	.02	.04	1.48	3.50
142	2.27	-3.409	-.55	4.07	.02	.035	-.01	.04	1.48	3.51
148	2.94	-4.835	-.06	7.80	.08	.034	.02	.04	1.48	3.50

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

Table A.6 - Model Faired Calm Water Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Head Current)

WATER TEMP: 68.4°F_{FW} ρ: 1.9367 SLUGS/FT^3 ν: 1.0746×10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT. 1 DEG	REL. MOT. 2 DEG	REL. MOT. 3 DEG
0.00	.000	.00	.00	-.04	.000	.00	.04	1.48	3.51
.22	-.026	.00	.00	-.04	-.008	.00	.04	1.48	3.51
.44	-.090	.00	.00	-.05	-.013	.00	.04	1.48	3.51
.65	-.195	.00	.00	-.06	-.006	.00	.04	1.48	3.51
.87	-.337	.00	.00	-.04	-.002	.00	.04	1.48	3.51
1.09	-.523	.00	.00	-.04	.000	.00	.04	1.48	3.51
1.31	-.766	.00	.00	-.04	.005	.00	.04	1.48	3.51
1.53	-1.089	.00	.00	-.03	.008	.00	.04	1.48	3.51
1.74	-1.506	.00	.00	-.02	.010	.00	.04	1.48	3.51
1.96	-1.977	.00	.00	-.01	.014	.00	.04	1.48	3.51
2.18	-2.489	.00	.00	.00	.017	.00	.04	1.48	3.51
2.40	-3.050	.00	.00	.04	.022	.00	.04	1.48	3.51
2.62	-3.632	.00	.00	.08	.030	.00	.04	1.48	3.51

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

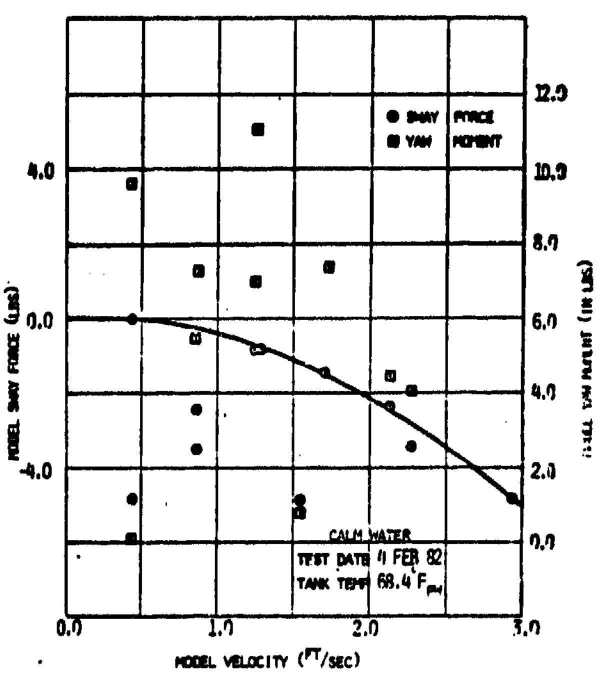


Figure A.5 - Model Faired Sway Force and Yaw Moment for "SS GREAT LAND" Class Barge Platform Configuration 2 (Head Current)

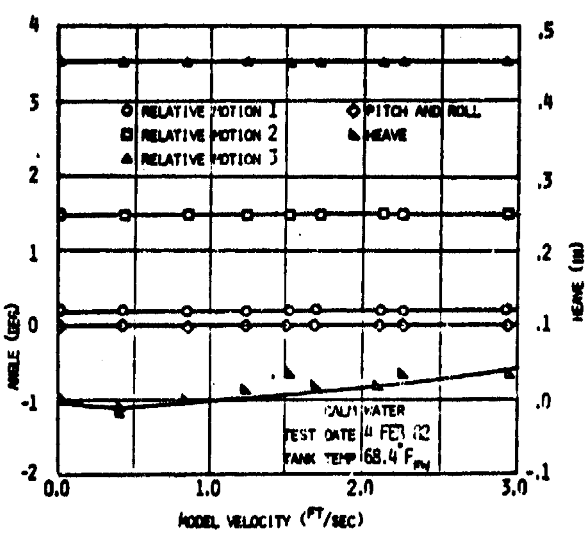


Figure A.6 - Model Faired Motion Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Head Current)

Table A.7 - Model Calm Water Experimental Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Beam Current)

Table A.8 - Model Faired Calm Water Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Beam Current)

TEST DATE: 10 FEB 82 TANK TEMP: 68.4°F_{FW}

RUN NO.	VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
	.00	.00	.00	.00	-.47	.000	.14	3.16	2.49	.97
251	.43	-.02	.54	- 23.9	-.48	.011	-.05	3.16	2.49	.97
247	.43	.01	.55	- 21.2	-.48	.017	-.06	3.17	2.49	.97
256	.43	-.02	.85	- 23.3	-.49	.005	-.01	3.17	2.49	.97
241	.44	.03	1.56	- 23.8	-.46	.021	-.04	3.17	2.49	.97
252	.85	-.05	2.42	- 78.8	-.45	.061	-.03	3.17	2.49	.97
244	.86	.14	.23	- 73.0	-.43	.051	-.02	3.17	2.49	.97
257	.86	-.07	3.28	- 88.8	-.45	.060	-.06	3.17	2.49	.97
242	1.27	-.14	6.43	-223.9	-.46	.058	-.04	3.17	2.49	.97
258	1.27	-.29	6.68	-278.0	-.47	.057	-.14	3.20	2.49	.97
248	1.27	-.20	5.85	-240.3	-.46	.064	-.19	3.16	2.49	.97
261	1.27	-.11	6.58	-283.3	-.45	.050	-.20	3.22	2.49	.97
253	1.27	-.27	6.75	-270.7	-.47	.053	-.11	3.20	2.49	.97
245	1.70	-.55	17.0	-508.6	-.56	.076	-.48	3.36	1.39	.97

NOTE YAW MOMENT MEASURED RELATIVE TO HEAVE POST

WATER TEMP: 68.4°F_{FW} ρ: 1.9367 SLUGS/FT^3 ν: 1.0746×10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
.000	.000	.00	0.0	-.47	.000	.14	3.17	2.49	.97
.109	.000	.06	- 2.0	-.47	.000	.12	3.17	2.49	.97
.218	.000	.15	- 6.3	-.47	.001	.09	3.17	2.49	.97
.327	-.001	.31	- 13.6	-.47	.002	.06	3.17	2.49	.97
.436	-.004	.53	- 22.0	-.47	.005	.03	3.17	2.49	.97
.545	-.009	.83	- 33.0	-.47	.010	.00	3.17	2.49	.97
.654	-.017	1.25	- 47.0	-.47	.015	-.03	3.17	2.49	.97
.763	-.031	1.77	- 63.2	-.47	.022	-.06	3.17	2.49	.97
.872	-.052	2.42	- 85.0	-.47	.028	-.09	3.17	2.49	.97
.981	-.083	3.24	-11.6	-.47	.035	-.13	3.17	2.49	.97
1.090	-.122	4.21	-144.4	-.48	.042	-.17	3.17	2.49	.97
1.199	-.171	5.50	-187.5	-.47	.050	-.21	3.17	2.49	.97
1.308	-.234	7.21	-247.0	-.50	.060	-.25	3.17	2.49	.97

NOTE: YAW MOMENT RELATIVE TO HEAVE POST

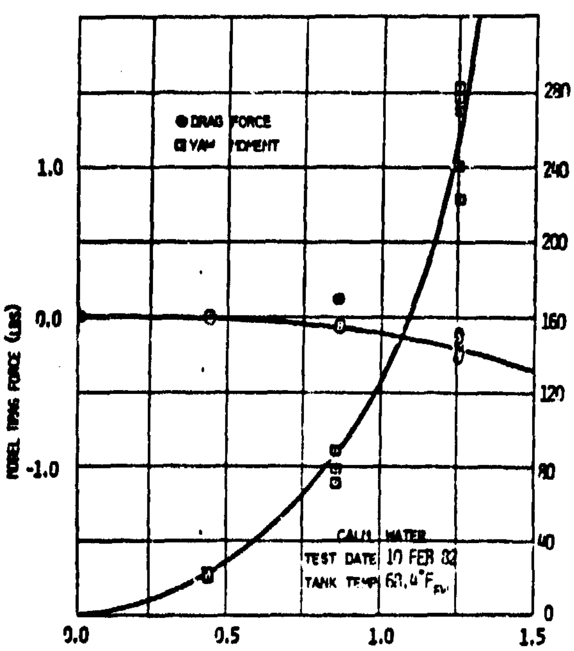


Figure A.7 - Model Faired Drag Force and Yaw Moment for "SS GREAT LAND" Class Barge Platform Configuration 2 (Beam Current)

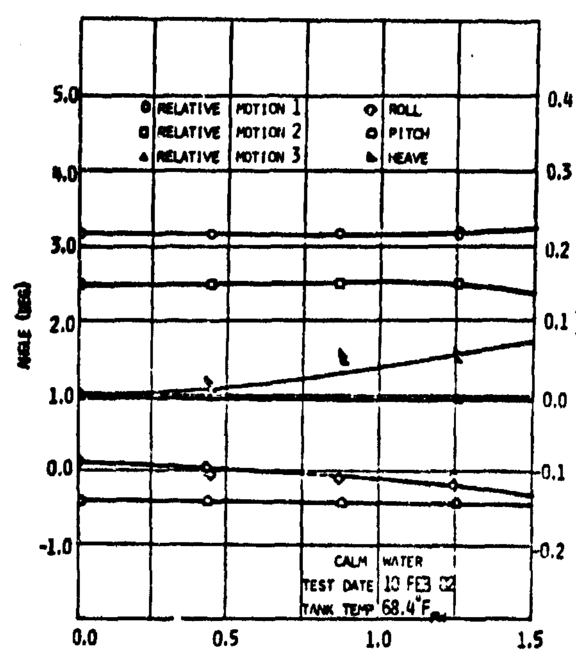


Figure A.8 - Model Faired Motion Data for "SS GREAT LAND" Class Barge Platform Configuration 2 (Beam Current)

Table A.9 - Model Calm Water Experimental Data for Modified "SS GREAT LAND" Class Barge Platform Configuration 3 (Beam Current)

TEST DATE: 12 FEB 82 TANK TEMP: 68.4°F_{FW}

RUN NO.	VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
	.00	.00	.00	.00	-.70	.000	.34	4.36	3.46	2.03
312	.85	-.117	3.279	-86.77	-.68	.028	.21	5.04	3.42	2.03
313	1.26	-.280	4.725	-214.	-.72	.117	.01	5.62	3.03	2.03
314	1.69	-.692	-17.0	-524.	-.92	.167	-.69	7.30	1.43	2.03

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

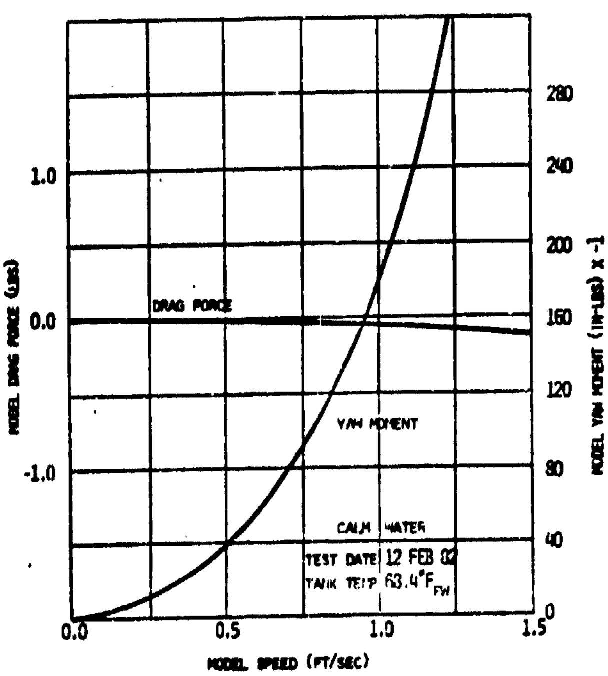


Figure A.9 - Model Faired Drag Force and Yaw Moment for Modified "SS GREAT LAND" Class Barge Platform Configuration 3 (Beam Current)

Table A.10 - Model Faired Calm Water Data for Modified "SS GREAT LAND" Class Barge Platform Configuration 3 (Beam Current)

WATER TEMP: 68.4°F_{FW} ρ: 1.9367 SLUGS/FT^3 ν: 1.0746 x 10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
.000	.000	.000	0.0	-.70	.000	.34	4.36	3.46	2.03
.109	.000	.059	- 3.1	-.70	.000	.34	4.37	3.46	2.03
.218	.000	.149	- 8.7	-.70	.003	.34	4.42	3.46	2.03
.327	-.013	.301	- 16.6	-.70	.005	.34	4.50	3.46	2.03
.436	-.017	.515	- 27.1	-.70	.008	.33	4.57	3.46	2.03
.545	-.021	.810	- 41.9	-.70	.012	.30	4.66	3.46	2.03
.654	-.025	1.218	- 64.7	-.70	.018	.27	4.76	3.46	2.03
.763	-.031	1.734	- 91.7	-.70	.025	.25	4.90	3.45	2.03
.872	-.037	2.373	-125.2	-.71	.036	.20	5.02	3.42	2.03
.981	-.044	3.172	-167.0	-.72	.050	.15	5.18	3.35	2.03
1.090	-.051	4.133	-218.0	-.73	.065	.06	5.35	3.25	2.03
1.199	-.058	5.410	-285.7	-.74	.085	-.02	5.58	3.12	2.03
1.308	-.065	7.106	-376.5	-.75	.105	-.15	5.82	2.92	2.03

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

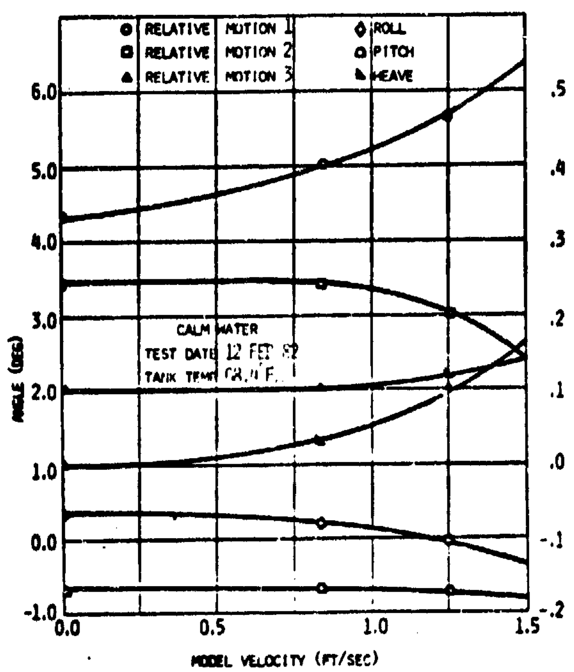


Figure A.10 - Model Faired Motion Data for Modified "SS GREAT LAND" Class Barge Platform Configuration 3 (Beam Current)

Table A.11 - Model Calm Water Experimental Data for Barge Train Alone (Beam Current)

TEST DATE: 16 FEB 82 TANK TEMP: 68.4°F_{FW}

RUN NO.	VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
	.00	.000	.000	.0	-.61	.000	-.22	-1.09	-.60	2.34
334	.43	-.031	.427	- 19.0	-.61	.010	-.24	-1.09	-.60	2.34
343	.85	-.166	.807	- 65.4	-.63	.058	-.44	-1.09	-.60	2.34
335	.86	-.114	1.675	- 56.5	-.61	.081	-.29	-1.09	-.60	2.34
336	1.26	-.220	4.372	-163.1	-.64	.142	-.78	-1.09	-.60	2.34
344	1.27	-.314	4.694	-188.8	-.66	.196	-.98	-1.09	-.60	2.35
346	1.70	-.672	-19.00	-518.6	-.80	.353	-2.00	-1.09	-.60	2.43

NOTE: YAW MOMENT MEASURED RELATIVE TO HEAVE POST

Table A.12 - Model Faired Calm Water Data for Barge Train Alone (Beam Current)

WATER TEMP: 68.4 F_{FW} ρ: 1.9367 SLUGS/FT^3 ν: 1.0746 x 10^{-5} FT^2/SEC

VELO FPS	DRAG FORCE LBS	SWAY FORCE LBS	YAW MOMENT IN-LBS	PITCH ANGLE DEG	HEAVE DISP. IN	ROLL ANGLE DEG	REL. MOT.1 DEG	REL. MOT.2 DEG	REL. MOT.3 DEG
.000	.000	.000	0.0	-.61	.000	.00	-1.09	-.60	2.34
.109	.000	.053	- 4.0	-.61	.000	.00	-1.09	-.60	2.34
.218	.000	.144	- 9.8	-.61	.000	.00	-1.09	-.60	2.34
.327	.000	.290	- 19.8	-.61	.000	.00	-1.09	-.60	2.34
.436	.000	.496	- 34.0	-.61	.006	.00	-1.09	-.60	2.34
.545	.000	.782	- 54.1	-.61	.016	-.02	-1.09	-.60	2.34
.654	.000	1.180	- 84.5	-.61	.027	-.08	-1.09	-.60	2.34
.763	.000	1.682	-120.6	-.61	.045	-.15	-1.09	-.60	2.34
.872	.000	2.308	-165.6	-.61	.065	-.22	-1.09	-.60	2.34
.981	.000	3.091	-222.1	-.62	.090	-.32	-1.09	-.60	2.34
1.090	.000	4.034	-290.4	-.63	.118	-.44	-1.08	-.60	2.34
1.199	.000	5.287	-381.6	-.65	.150	-.67	-1.09	-.60	2.34
1.308	.000	6.966	-504.4	-.68	.185	-.80	-1.09	-.60	2.36

NOTE: YAW MOMENT RELATIVE TO HEAVE POST

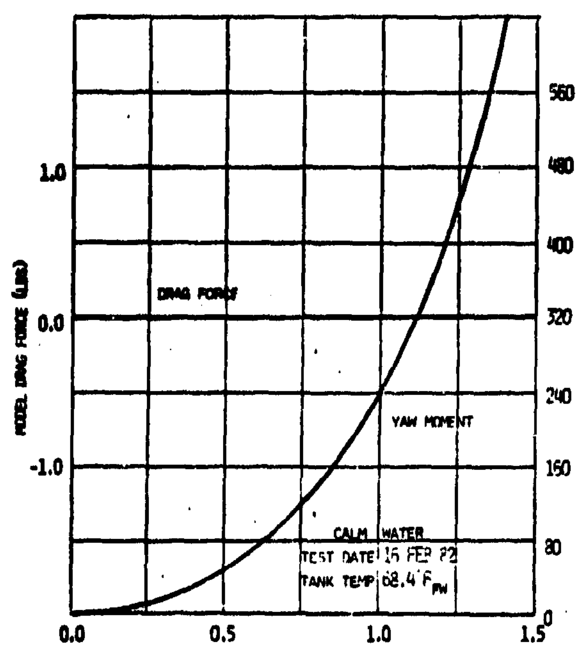


Figure A.11 - Model Faired Drag Force and Yaw Moment for Barge Train Alone (Beam Current)

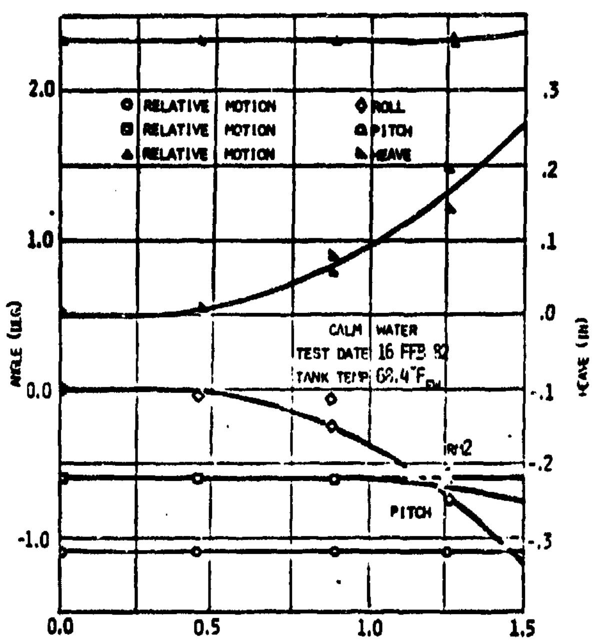


Figure A.12 - Model Faired Motion Data for Barge Train Alone (Beam Current)

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