Carderock Division

Naval Surface Warfare Center

Bethesda, Maryland 20814

CRDKNSWC-HD-1424-02 January 1996
Hydromechanics Directorate
Research and Development Report

Seakeeping Assessment for 270 and 378 Foot Coast Guard Cutters in Alaskan Waters

By
William L. Thomas III
Robert J. Bachman
Wah T. Lee
Terrence R. Applebee

CRDKNSWC-HD-1424-02 Seakeeping Assessment for 270 and 378 Foot Coast Guard Cutters in Alaskan Waters

MAJOR CARDEROCK DIVISION TECHNICAL COMPONENTS

CODE	011	Director of Technology
	10	Machinery Systems/Programs and Logistics Directorate
	20	Ship Systems and Programs Directorate
	50	Hydromechanics Directorate
	60	Survivability, Structures and Materials Directorate
	70	Signatures Directorate
	80	Machinery Research and Development Directorate
	90	Machinery In-Service Engineering Directorate

CARDEROCK DIVISION, NSWC, ISSUES THREE TYPES OF REPORTS:

1. **CARDEROCKDIV reports, a formal series,** contain information of permanent technical value. They carry a consecutive numerical identification regardless of their classification or the originating directorate.

2. **Directorate reports, a semiformal series,** contain information of a preliminary, temporary, or proprietary nature or of limited interest or significance. They carry an alphanumerical identification issued by the originating directorate.

3. **Technical memoranda, an informal series,** contain technical documentation of limited use and interest. They are primarily working papers intended for internal use. They carry an identifying number which indicates their type and the numerical code of the originating directorate. Any distribution outside CARDEROCKDIV must be approved by the head of the originating directorate on a case-by-case basis.

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for Public Release, Distribution Unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CRDKNSWC-HD-1424-02	5. MONITORING ORGANIZATION REPORT NUMBER
6a. NAME OF PERFORMING ORGANIZATION Carderock Division, Naval Surface Warfare Center	6b. OFFICE SYMBOL Code 5610
7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP code) Bethesda, Maryland 20084-5000	7b. ADDRESS (City, Sate, and ZIP code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION USCG Naval Engineering Division	8b. OFFICE SYMBOL G-ENE-5B
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DTCG23-95-X-EN5095, DTCG23-95-X-ENE233	
8c. ADDRESS (City, State, and ZIP code) 707 E. Ordinance Rd. Baltimore, Md. 21226-1741	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNITS ACCESSION NO.

11. TITLE (Including Security Classification)
Seakeeping Assessment for 270 and 378 Foot Coast Guard Cutters in Alaskan Waters (U)

12. PERSONAL AUTHOR(S)
W. L. Thomas III, W. T. Lee, R. J. Bachman, T. R. Applebee

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT	15. PAGE COUNT
Final		January 1996	81

16. SUPPLEMENTAL NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Ship Motion Measurements, Side-by-Side Trials, WHEC, WMEC, Seakeeping Assessments, Operability, Motion Limiting Criteria, Human Factors, Seakeeping Evaluation Program

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The question of whether or not the 270 foot WMEC might serve as a suitable replacement for the 378 foot WHEC in Alaskan Waters is addressed in this report. In comparison to the relatively benign Caribbean region, where these two vessels act in almost an inter-changeable fashion, the Bering Sea and North Pacific Ocean areas experience much rougher weather, especially during the winter season. Therefore a seakeeping assessment study of the two vessels was carried out.

A comparison of ship motions measured in side-by-side trials between USCGC HARRIET LANE, a 270 foot cutter, and the USCGC BOUTWELL, a 378 foot cutter is presented. An operability assessment for the winter season for three geographic locations which represent Alaskan waters is presented for seakeeping-sensitive missions that are related to Search and Rescue and Law Enforcement. Annualized (four season) operability assessment is also presented.

The findings indicate that the 270 foot cutter is less seakindly than the 378 foot cutter and is less capable in terms of maximum speed. The 270 foot cutter is projected to carry out its duties approximately 14 percent less often in the winter than the 378 foot cutter with excessive roll and pitch motions serving as the principal source of performance degradation. On an annual (four season) basis, the 270 foot cutter is projected to carry out its duties approximately 11 percent less often than the 378 foot cutter

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT Unlimited	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL William L. Thomas III	22b. TELEPHONE (Including Area Code) 301-227-5165	22c. OFFICE SYMBOL Code 5610

UNCLASSIFIED

CONTENTS

FIGURES

TABLES

NOMENCLATURE

A_{WP}	Area of the Waterplane
B	Beam
Boat	Boat Launching Station
C_B	Block Coefficient
C_M	Midships Sectional Area Coefficient
GM_T	Tranverse Metacentric Height
Ht	Height
HL	USCGC HARRIET LANE
$H_{1/3}$	Calculated Significant Wave Height
$H'_{1/3}$	True Significant Wave Height
KG	Height of the Center of Gravity above the Keel
KM	Height of the Metacenter above the Keel
Kn	Knots
L_{PP}	Length Between Perpendiculars
Nom	Nominal
P/H	Pilot House
Sig	Signficant
SSA	Signficant Single Amplitude
T	Draft
TACC	Transverse Acceleration
$T\phi$	Roll Period
VACC	Vertical Acceleration
WHEC	High Endurance Coast Guard Cutter
WMEC	Medium Endurance Coast Guard Cutter
α	Confidence Level
Δ	Displacement
χ^2	Chi-squared value
$\ddot{\xi}_{3(x,y)}$	Vertical Acceleration at point (x,y)
$\ddot{\eta}_3$	Heave Acceleration at the center of gravity
$\ddot{\eta}_4$	Angular Acceleration of roll
$\ddot{\eta}_5$	Angular Acceleration of pitch
ν	Degrees of Freedom

ABSTRACT

The question of whether or not the 270 foot WMEC might serve as a suitable replacement for the 378 foot WHEC in Alaskan waters is addressed in this report. In comparison to the relatively benign Caribbean region, where these two vessels act in almost an inter-changeable fashion, the Bering Sea and North Pacific Ocean areas experience much rougher weather, especially during the winter season. Therefore a seakeeping assessment study of the two vessels was carried out.

A comparison of ship motions measured in side-by-side trials between USCGC HARRIET LANE, *a 270 foot cutter, and* USCGC BOUTWELL, *a 378 foot cutter, is presented. An operability assessment for the winter season for three geographic locations which represent Alaskan waters is presented for seakeeping-sensitive missions that are related to Search and Rescue and Law Enforcement. An annualized (four season) operability assessment is also presented.*

The findings indicate that the 270 foot cutter is less seakindly than the 378 foot cutter and is less capable in terms of maximum speed. The 270 foot cutter is projected to carry out its duties approximately 14 percent less often in the winter than the 378 foot cutter with excessive roll and pitch motions serving as the principal source of performance degradation. On an annual (four season) basis, the 270 foot cutter is projected to carry out its duties approximately 11 percent less often than the 378 foot cutter.

ADMINISTRATIVE INFORMATION

The work reported herein was sponsored by the Hull Section of the U. S. Coast Guard Technical Branch, G-ENE-5B. This work is referenced in Project Orders DTCG23-95-X-EN5095 and DTCG23-95-X-ENE233. It is identified by Work Unit Numbers 5610-435 and 5610-438 respectively at the David Taylor Model Basin, Carderock Division, Naval Surface Warfare Center (CARDEROCKDIV, NSWC).

BACKGROUND

Search and Rescue (SAR) and Law Enforcement operations make up the primary peace time mission of High Endurance (WHEC) and Medium Endurance (WMEC) Coast Guard Cutters. In the relatively calm waters of the Caribbean, 270 foot Medium Endurance (WMEC) and 378 foot High Endurance (WHEC) cutters often perform interchangeable roles in the protection of U. S. interests. During the present Post-Cold War era, a fiscally conservative budgetary climate has developed emphasizing the need for government agencies to better utilize existing resources, as opposed to the procurement of new ones. Under these circumstances, questions have been raised regarding whether the 270 foot WMEC might serve as a suitable replacement for the 378 foot

WHEC in Alaskan waters. This report will address this issue by comparing the operational capabilities of the 270-foot *(FAMOUS Class)* with the 378-foot *(HAMILTON Class)* Coast Guard Cutters in the Bering Sea.

INTRODUCTION

The central issue regarding the performance of the 270-foot cutter is whether this vessel can operate in a satisfactory manner in a different geographic location. Unlike the Caribbean, the Bering Sea and North Pacific Ocean experience heavy seas much more frequently, especially during the winter season. For example, during the winter season, seas in excess of 20 feet significant wave height can be expected to occur less than 1 percent of the time in the Caribbean. In the Bering Sea, waves in excess of 20 feet can be expected 35 percent of the time during winter months[1, 2].

In heavy sea conditions, the operational capability of a ship often decreases due to excessive ship motions. Degradations can range from mild cases of motion sickness to severe restrictions on the ability to carry out specific missions. Ship performance degradations arise from habitability, equipment operability, and survivability considerations[3, 4].

As sea conditions worsen, the level of performance degradation varies with the "seakindliness" of the vessel and the experience level of the crew. Differences in crew training and experience are beyond the scope of this report. Differences in seakeeping capabilities will be addressed and are very relevant due to substantial differences in vessel size and hull form.

Earlier seakeeping experiments aboard the *USCGC BEAR* (WMEC 901)[5] in 1984 indicated that, while the design of this cutter results in increased deck wetness and difficult motion conditions in the forward areas, the 270-foot WMEC experiences no more or less problems in the area of seakeeping than any comparable vessel of its size. And while it was concluded from this effort that the anti-roll fins are undersized, it was also determined that the control algorithm exhibited certain deficiencies that prevented the system's full roll reduction capability to be realized[6]. Hence a fin correction/grooming program was initiated by the U.S. Coast Guard to ensure the proper functioning of the fin system. The result has been roll reduction on the order of 50+ percent.

The 270-foot cutter is substantially smaller in displacement than the 378-foot cutter. See Table 1. The 378-foot cutter has a long and slender "Frigate-Type" hull form having a length to beam ratio (L/B) of 8.4. See Figure 1. Roll reduction in the WHEC is accomplished using bilge keels in the middle third of the hull. In comparison, the 270-foot cutter is short and wide with a L/B of 6.8. See Figure 2. Anti-roll fins in conjunction with bilge keels serve as the main mode of roll reduction in the WMEC.

APPROACH

Since the *FAMOUS Class* and *HAMILTION Class* Cutters have hull forms that are different, and the proposed operating region (Alaskan Waters) contains rougher seas than the Caribbean, a seakeeping assessment methodology is indicated. The approach must be comparative in terms of ship response and account for :

- Ship Configuration
- Sea and Wind Climatologies
- Limiting Ship Motions

Thus, not only is it important to compare measured motions of both vessels in side-by side comparisons, it is important to perform mission related assessments which define how often the WMEC and WHEC can perform mission related operations in Alaskan waters.

This report will focus on the comparative seakeeping performance for Medium Endurance and High Endurance Coast Guard Cutters in Alaskan waters. Comparisons will be made in terms of simultaneous ship motion measurements and operability predictions. The ship motion comparison will utilize ship motion measurements taken in full-scale side-by-side trials of the *USCGC HARRIET LANE* (WMEC-903) and *USCGC BOUTWELL* (WHEC-719).

The operability assessment will focus on two critical peacetime missions for the cutters in Alaskan waters. This will include Search and Rescue (SAR) and Law Enforcement.

The ability to perform the above missions can be defined in terms of specific operations which are sensitive to excessive ship motions. These include:

- The ability to **Transit** from one point to another.
- The ability to conduct **Helicopter Launch and Recovery**.
- The ability to conduct **Small Boat Launch and Recovery**.

FULL-SCALE SIDE-BY-SIDE TRIALS

Side-by-side trials were conducted by the *USCGC BOUTWELL* and *USCGC HARRIET LANE* in the Bering Sea in late September through early October 1995. One purpose of the trials was to provide supporting data for this report, including:

1. Direct Side-by-Side Comparison of Ship Motions in a given seaway.
2. Comparison of WMEC ship motions in Anti-Roll Fins ON/OFF mode.
3. Establish/Update motion limiting criteria for mission related operations.
4. Collect and archive human performance information.

Instrumentation

USCGC BOUTWELL and *USCGC HARRIET LANE* were equipped with state-of-the-art Ship Motion Recorders (SMRs) developed by Code 561 of the David Taylor Model Basin, Carderock Division, Naval Surface Warfare Center. The SMRs provided real-time measurements of ship motions including roll and pitch along with vertical, lateral and longitudinal accelerations at the pilot house, center of gravity, and boat launching stations. *USCGC HARRIET LANE* was also outfitted with a TSK over-the-bow wave sensor for the purpose of collecting wave measurements. *USCGC BOUTWELL* was equipped with disposable waves buoys which were to be used in the event of TSK failure. Since no TSK failures occurred during the trial, the disposable buoys were not used to measure the waves.

USCGC BOUTWELL

The Ship Motion Recorder (SMR) system was comprised of a COMPAQ 386/20 Deskpro^{TM} computer with two hard drives (C & D) of 40 and 120 Mbytes, respectively; an IOMEGA dual 230 Mbyte Bernoulli Box^{TM}; an interface box which included signal conditioning and analog-to-digital capability; and a wave buoy receiver. This equipment was located in the Combat Information Center (CIC) where the following channels were tapped: wind speed and direction, and wave height (from the receiver). A remote monitor with keyboard was located in the pilothouse which displayed the data in real time. Three COLUMBIA triaxial accelerometers were used to measure accelerations in the pilothouse, at the port boat station, and aft of CIC in the Machine Shop at the LCG. The ship's gyrocompass located in the forward IC gyro room provided roll and pitch angles as well as ship's heading. Additionally, the ship's Doppler speed log was monitored to record ship speed. Table 2 provides the breakdown of recorded channels.

USCGC HARRIET LANE

The Ship Motion Recorder (SMR) system was comprised of a COMPAQ 486/50 MHz Deskpro^{TM} computer with 320 Mbyte hard disk divided into two drives (C and D) of approximately 160 MB+ each; an IOMEGA dual 230 Mbyte Bernoulli Box^{TM}; an interface box which included signal conditioning, synchro-to-digital and analog-to-digital capability; and a TSK shipborne wave meter. This equipment was located in the CIC where the following channels were tapped: wind speed and direction, roll and pitch angles, ship speed and ship course. A remote monitor was located in the pilothouse which displayed the data in real time. COLUMBIA triaxial accelerometers measured longitudinal, transverse and vertical accelerations and were located in the overhead of the pilothouse, in the engine room near the nominal LCG location, and in the port steering gear room under the aft boat station. Table 3 provides the breakdown of the 18 recorded channels.

Wave Measurements

Wave measurements were obtained at the bow of the *USCGC HARRIET LANE* using a commercially available wave recorder manufactured by TSK America Inc. The TSK over-the-bow wave height sensor system consists of the following components: a down-looking bow mounted Doppler radar unit which measures water surface velocity, a stabilized vertical accelerometer which measures bow acceleration, and a real-time processing unit. The processor performed a single integration on the surface velocity time history to yield relative bow displacement. The processor also performed a double integration on the bow acceleration time history to yield absolute bow displacement. These two time histories were combined to yield a time history of wave height. This time history was recorded by the Ship Motion Recorder (SMR).

Personnel Questionnaires

Personnel questionnaires were distributed to selected members of the crew to elicit an evaluation of performance and to provide reasons for any performance degradations. Three types of questionnaires were used. The first was a one-time-only personal history questionnaire which was completed prior to or at the beginning of the patrol. A second questionnaire for watchstanders was completed every watch. A third questionnaire was completed during dedicated seakeeping maneuvers. In addition, separate questionnaires were provided to Department Heads and the Commanding Officers of both vessels to obtain the top-down view of crew and ship performance. Sample questionnaires can be found in the instrumentation and test program report published by the U. S. Coast Guard Naval Engineering Technical Branch.[7]

Trial Procedures

The trial plan called for defining the wave height and direction prior to measuring ship motions for both ships. Ship loading conditions were recorded daily. Twenty to thirty minute wave measurements were taken using the TSK on *HARRIET LANE* at zero speed. During the side-by-side trials *USCGC BOUTWELL* and *USCGC HARRIET LANE* ran parallel courses in an octagon trial pattern, maintaining a minimum distance between the ships of 2000 yards. Speeds of 10 and 15 knots were selected for the octagons. Each octagon began in head seas with each leg lasting between 20 and 30 minutes. Successive octagon headings were performed in 45 degree increments in a complete circle to include head seas, bow quartering seas, beam seas, stern quartering seas, and following seas. *USCGC HARRIET LANE* used active anti-roll fins during the side-by-side trials. *HARRIET LANE* also ran some independent octagons in “fins-on” and “fins-off” modes. A complete description of the trials procedures and instructions was prepared for the U. S. Coast Guard by NSWC, and is reported in Reference 7.[7]

DATA ANALYSIS

Wave Measurements

Analog time history data of the TSK wave height time history measurements were processed and filtered using analysis routines developed by Code 561 of the David Taylor Model Basin.[8] Fast Fourier Transformation (FFT) processing was used to calculate spectral densities. The significant wave height was calculated as:

$$H_{1/3} = 4(TotalVariance)^{1/2} \tag{1}$$

The total variance, is obtained by integrating the wave spectrum over all frequencies. Calculated wave spectra are shown in Figures 3 through 15. A summary of wave measurements is presented in Table 4.

The ninety percent confidence bands for the wave measurements displayed in Table 4 were calculated using statistical techniques which apply to FFT processing[9]. Briefly stated, for significant wave height measurements:

$$(\frac{\nu}{\chi^2_\nu(100-\alpha)/2})^{1/2}H_{1/3} \leq H'_{1/3} \leq (\frac{\nu}{\chi^2_\nu(100+\alpha)/2})^{1/2}H_{1/3} \tag{2}$$

Ship Motion Measurements

The test matrix carried out for this trial is summarized in Table 5. Summaries of Roll, Pitch and Vertical Acceleration ship motion statistics are presented in Figures 16 through 22 and in Tables 6 through 12. Unfortunately, the Roll channel in the SMR on *BOUTWELL* malfunctioned. These data were lost.

The summary tables are organized such that ship motion runs are displayed with the applicable wave measurements. Note that in the Tables associated with the *HARRIET LANE*, significant wave height measurements are presented along with a notation that indicates whether or not the active fins have been turned on. The first and last measurements in the *HARRIET LANE* Tables are zero-speed TSK wave measurements which were performed to record the wave spectra. The reader should also note that wave height measurements were also taken during each leg of an octagon, while the ship was moving at speed. Since TSK wave measurements taken while the ship was moving produce wave encountered spectra, these measurements were not presented for analysis in this report. However, one must realize that the value of the significant wave height can still be obtained in terms of the variance, as described in the equation (1). Hence, values for significant wave height during each octagon leg have been recorded in the *HARRIET LANE* ship motion summary tables.

Each summary table displays ship motion statistics of standard deviation, and maximum value for Roll, Pitch and Vertical Acceleration responses, as a function of heading and speed, based on direct analysis of the time-series data. Ship motion data for this report were collected during instances when the ship was on a constant heading and speed for a minimum 20 minutes. Typical runs were 30 minutes in duration. The data sample rate was 0.25 Hz.

Measurement Uncertainty

The uncertainty of the measured motions is based on a combination of accuracy and resolution of the instrumentation, resolution of the analog-to-digital converter, and sampling variability. Roll and Pitch were measured using the ship's gyrocompass. A typical gyro such as the Sperry Mark 29 has an accuracy of 0.029 degrees. Vertical acceleration was measured using a COLUMBIA triaxial accelerometer having an accuracy of ±0.1% full-scale.

The sampling variability of the time-series data is much greater than the accuracy or resolution of the instrumentation. This is an inherent consequence of sampling time-series data. The uncertainty of measured motions is presented in the form of 90% confidence limits. At a 90% confidence limit, the mean uncertainty levels for the ship motions are approximately ±10%.

The sampling variability is about two orders of magnitude larger than the instrument error. This is not surprising. With an adequate sample rate, the width uncertainty bands are driven by duration (size) of the measurement sample. In order to reduce the uncertainty to about ±5%, each leg of the octagon would have to be more than 1 hour in duration. This is clearly an unrealistic request for full-scale trials where consideration must be given to changing wave and wind conditions and tight ship schedules.

Discussion

USCGC BOUTWELL and *USCGC HARRIET LANE* performed four Octagons in side-by-side trials in Sea States 4 through 6 at speeds of 10 and 15 knots. Two additional Octagons in Sea State 5 were performed by *HARRIET LANE* to compare ship motions with the anti-roll fins turned on and off. Comparison of the ship motion measurements indicate:

- Pitch experienced by the 270-foot cutter *HARRIET LANE* is typically 20 to 50 percent greater than the 378-foot cutter *BOUTWELL.*

- Vertical Accelerations at the center of gravity of both ships are nearly the same, usually falling within the limits of uncertainty.

- Vertical Accelerations at the Pilot House of *HARRIET LANE* are often 40 to 50 percent larger than *BOUTWELL*, especially when seas are forward of the beam.

- *HARRIET LANE* experiences roll reductions as high as 50 percent when the fins are activated.

It is interesting to note that although significant amplitude vertical accelerations at the center of gravity for both ships are similar, the vertical accelerations at the pilot house of both ships are quite different. The pilot house vertical accelerations at the centerline experienced by *HARRIET LANE* are often significantly larger than what is measured on *BOUTWELL*. This relationship might better be understood by giving consideration to the motions which contribute to vertical acceleration. Vertical acceleration at a point location aboard ship is driven as follows:

$$\ddot{\xi}_{3_{(x,y)}} = \ddot{\eta}_3 + y\ddot{\eta}_4 - x\ddot{\eta}_5 \tag{3}$$

where $\ddot{\xi}_{3_{(x,y)}}$ represents the vertical acceleration at a point location (x,y) in reference to the ship's center of gravity; $\ddot{\eta}_3$ is heave acceleration; $\ddot{\eta}_4$ and $\ddot{\eta}_5$ are angular accelerations of roll and pitch; y and x are lateral and longitudinal distances of the point of interest from the center of gravity.

An inspection of Equation (3) reveals the pitch angular acceleration in conjunction with distance from the ship's center of gravity $x\ddot{\eta}_5$ can be a dominant contributor to vertical acceleration especially in head and bow quartering seas where pitch is large. This indicates to the authors that *HARRIET LANE* experiences substantially higher pitch accelerations which significantly contributed to the higher measured values of pilot house vertical acceleration at the centerline. This is not a surprising finding since *HARRIET LANE* is substantially shorter in length than *BOUTWELL*.

Ship loading conditions for both ships did not significantly change during the trial period. Maximum variation in displacement for both ships was approximately 2 percent. Maximum variation in KG for both ships was approximately 3 percent. These variations provided no discernible impact on the measured ship motions.

HUMAN FACTORS

In an effort to relate human factors to the seakeeping qualities of both ships, questionnaires were distributed among select members of the crew in departments of particular interest. These departments were the operations, engineering, aviation, support, and deck departments.

The questionnaires were arranged into five different categories: commanding officer, department head, seakeeping, watch stander, and personal history. The personal history questionnaire was filled out once by each crew member involved prior to answering the other questionnaires. The personal history questions were intended to provide background information about personnel in the area of sensitivity toward motion sickness.

The questionnaires for the Commanding Officer (CO) and the Department Heads (DH) consisted of two parts each. The first part of the CO's questionnaire was comprised of general questions about the ship and crew, while the DH's questionnaire was comprised of general questions about the members of the respective department. The second part of these two questionnaires comprised of questions relating to the CO's or DH's observation of crewmember responses during the seakeeping trials.

The questionnaires for the seakeeping trials were filled out by the selected members of the crew on duty at the time the seakeeping octagons were conducted. Each octagon consisted of eight legs at 45 degree intervals about 360 degrees. The crew was to indicate their physical and mental condition as a result of the ship motions for each leg, i.e., heading with respect to the predominant wave direction.

The last set of questionnaires (watch standing) was to be filled out daily for the duration of the at-sea period. During every watch, the selected members of the five departments were to answer the questions.

Much human factor data were collected on both ships. However, at this time, the Commanding Officer's observations are the extent of the data reported on.

Joint Octagons

The seakeeping part of the Commanding Officer's questionnaire was intended to provide a record of the CO's observations concerning degradations of the ship or crew as a result of sea-induced ship motions. The levels of degradation, as observed by the commanding officers of both *BOUTWELL* and *HARRIET LANE*, are summarized in Tables 13 to 16. The ship motions that are generally considered appropriate to the investigation of ship and crew degradation are included in each table. Accompanying each degradation is a cause of the degradation and an associated level of the cause. This level is a relative measure of the cause and is a contributing, but not the sole factor to the level of crew or ship degradation. The reader is reminded that the crew's assessment of level of degradation may vary under similar conditions and the CO's perspective might also change with conditions. There are cases in which a cause is attributed to a zero, or no, degradation. These apparent causes have no meaning in light of the degradation being established as 'none'. The discussion that follows examines the degradations observed by the commanding officers of each ship. The discussion includes the ship motions as they apply to the observed degradations within the context of each octagon.

The octagon conducted on 24 Sep 95 was performed in sea conditions with a significant wave height of less than five feet. As could be expected with ship motions of a small magnitude, the overall crew and ship degradation levels for both ships were considered to be 'none'. The nominal ship speed for both ships was 10 knots. For both *HARRIET LANE* and *BOUTWELL*, crew and ship degradations were none, and there were no long term performance degradations. *HARRIET LANE's* CO indicated his ship was not speed limited at 10 knots and he would maintain speed. *BOUTWELL's* CO indicated his ship was not speed limited at 10 knots for head, port beam and port bow. The remainder of the heading and all of the maintain speed column were not indicated. However, based on the accompanying information, it is inferred that *BOUTWELL* was not speed limited for all headings and that the speed would be maintained.

During the octagon conducted on 26 Sep 95, the seas grew from a significant wave height of 8.7 feet to 12.1 feet. There was a level of degradation for both ships with *HARRIET LANE* experiencing the greater degradation. The nominal ship speed was

15 knots with both ships generally making less nominal speed. For *HARRIET LANE*, the level of degradation tended to increase toward the end of the octagon, in keeping with the increase in wave height. The crew performance degradation was split between pitching for the first half and rolling/MII (Motion Induced Interruption - loss of balance) for the second half of the octagon. The measured roll, relative to heading, is about as severe during the first half of the octagon as the second half, while pitching is larger in the second half than the first half. It is interesting to note that the cause of crew degradation was attributed to pitching during the first half of the octagon and the measured pitch was greater during the second half of the octagon. Though pitching increased in the second half, the CO indicated that roll was a greater contributor to crew degradation.

In all stated cases of the cause of ship degradation, speed was the contributing factor. However, at starboard beam and rear quartering seas, there were no degradations. No answer was given for port beam seas condition. Long term performance degradation occurred in all but beam seas and starboard quartering seas, with severe degradation at port bow seas and moderate degradation at head seas. The ship was speed limited in head and bow seas. The CO felt he would maintain speed in starboard beam to port quartering seas and only in following and port quartering seas if he was conducting a search and rescue (SAR).

For *USCGC BOUTWELL*, little or no degradation was experienced for the octagon conducted on 26 Sep 95. Pitch motion and accelerations were less than for *USCGC HARRIET LANE*. No degradation was attributed to ship's crew, though a 35-knot wind was indicated as a cause during the second half of the octagon. This apparently was a nuisance, not a cause of degradation to the crew. A high wind was indicated to have caused a mild ship degradation during the first half of the octagon, but not during the second half. During the first half of the octagon, there was a mild long term performance degradation. The ship was not speed limited, which suggests that the long term degradation was wind associated.

During the joint octagon conducted on 27 Sep 95, the seas were steady at about 13.5 feet. The levels of overall ship and crew degradation for both ships were mild to none. Although the main causes of ship degradation for both ships appeared to be roll, pitch, deck wetness, and vertical acceleration, it should be noted that many of the ship degradation levels are non-existent. *HARRIET LANE* 's fins were active for all but the last two legs, runs 182 and 183. The nominal ship speed was 15 knots, yet both ships were making less speed, particularly *HARRIET LANE*. For *HARRIET LANE*, the overall crew degradation was mild for head, starboard bow and both beam sea headings, attributed to MII. Overall ship degradation was mild for head and starboard bow seas. Bow wetness was the cause of degradation in head seas and both pitch and roll caused degradation in starboard bow seas. There was a moderate cause indicated for port bow seas, but no level of ship degradation was reported. *HARRIET LANE's* CO indicated that the long term performance degradation at speed in these conditions would produce a mild degradation at head and bow seas. It was felt that the ship was speed limited at these headings. However, the CO would maintain speed to respond to an urgent SAR. For the starboard beam sea leg, the ship was not considered to be speed limited, albeit, the mean ship speed at the time was only 9.2 knots.

For *BOUTWELL*, the overall crew degradation was mild for all but following and starboard quartering seas. MII was a cause of degradation for head, starboard beam and port bow seas, while vertical acceleration was the cause for starboard bow seas. This was the only occasion in which acceleration was reported to be a cause of degradation for all headings in an octagons. Vertical acceleration was reported in the ship degradation category, but no ship degradation levels were indicated/recorded. The CO indicated that the long term performance degradation at speed in these conditions would produce a mild degradation at all headings. The ship was not speed limited, except for starboard quartering seas. This sole case occurred on the heading for which no ship or crew degradation was reported.

During the octagon conducted on 28 Sep 95, the seas decreased from 15.0 to 13.4 feet. During this octagon, *HARRIET LANE's* anti-roll fins were off due to a casualty. Neither CO felt their ship experienced degradation that was more than mild. The nominal ship speed was 10 knots, but *HARRIET LANE's* speed was well below that for the first three legs of the octagon (runs 199 to 201). Aboard *HARRIET LANE*, the overall crew degradation was considered mild for all headings, with fatigue reported to be the cause. The CO reported, "Crew fatigue apparent due to minimal rest after the ship experienced 25-deg rolls throughout the night." The reported fatigue cannot be associated directly with the motions experienced during this octagon, but it is attributed to motions associated with the near past sea conditions. The overall ship degradation was mild for head, starboard bow and beam, port beam and quartering seas, with roll reported to be the cause of degradation. Long term performance degradation was reported for head, starboard bow and starboard beam seas. The CO did not feel the ship was speed limited, but remember that the ship was not making nominal speed for the three above described headings.

Aboard *BOUTWELL*, the overall crew degradation was mild in head, port bow, beam and quartering seas, and starboard bow seas. MII was reported to be the cause of degradation for head and starboard bow seas. The overall ship degradation also was mild for the same heading, with the exception of starboard bow seas, with heave and pitch the only report cause (for head sea). *BOUTWELL's* CO felt there would be mild long term performance degradation also at all but starboard quartering seas. The CO felt that his ship was not speed limited in these conditions, however, the speed at which the octagons were conducted was nominally 10 knots, versus 15 knots for the other octagons.

USCGC HARRIET LANE Fins On and Fins Off

Three additional seakeeping octagons were conducted independently by *HARRIET LANE.* Those conducted on 27 September 95 and 6 October 95 were intended to compare ship response for fins-on and fins-off conditions. The last condition, 25 October 95, was for the fins-on condition. Since the CO's human factors observations were recorded only for the 6 Oct 95 fins on/off octagon, it is the only data presented in this human factors section (Table 17).

On 6 Oct 95, the seas decreased slightly over the course of the octagon, from 11.0 to 9.8 feet. The overall degradation was mild to moderate. The nominal ship speed was 13 knots. It should be noted that one observation was made for both fins-on and fins-off condition. Once a heading was steadied on, the ship collected data with a fins-on condition, then a fins-off condition. The CO's observation was provided once for a given heading to assess overall ship performance during the octagon.

The overall crew degradation was considered mild for starboard bow and beam, port bow and head seas. There was moderate degradation in both rear quartering seas and no degradation in following seas. In all cases of degradation, MII was the stated cause. Overall ship degradation was reported only for the starboard quartering seas condition and was rated as moderate. The long term performance degradation mimicked the overall crew degradation. The CO considered the ship to be speed limited only in starboard bow seas, yet would maintain speed at this heading to conduct an urgent SAR. The CO would not maintain speed at the two quartering seas condition, due to roll induced crew fatigue.

Observations

There were three octagons for which the seas and resulting ship responses warranted human factors comments by the Commanding Officers - 26, 27, and 28 September 95. On 26 September, the primary cause of ship degradation for *HARRIET LANE* was speed, with pitch and roll/MII as the primary causes of crew degradation. There would be long term performance degradation in head and bow seas. The severity increased with increasing wave height that day. *BOUTWELL* experienced mild ship degradation due to high winds, but only in the first half of the octagon.

On 27 September, although the wave height increased, the reported degradation aboard *HARRIET LANE* did not increase, in fact, it decreased in some cases. There was an increase in crew degradation reported aboard *BOUTWELL* from none the previous day to mild this day. *BOUTWELL* was reported to experience mild long term degradation on more headings than *HARRIET LANE.*

On 28 September, the highest wave heights were measured. However, the level of the primary ship and crew degradation did not increase. The difference is that *HARRIET LANE* reported mild degradation at more headings and of this, the crew degradation is attributed to previously induced fatigue. Again *BOUTWELL* was reported to experience long term performance degradation for more headings than *HARRIET LANE.*

During fins-on, fins-off octagon conducted by *HARRIET LANE* on 6 Oct 95, the combined overall crew degradations was reported to be greater than for any of the octagons conducted in coordination with *BOUTWELL.* It should be noted that the seas were generally less than during the coordinated octagons. However, the nominal ship speed was less on 28 Sep.

It is difficult to draw conclusions regarding comparisons of human factors between the crew members of *BOUTWELL* and *HARRIET LANE* with a limited data base. The human factors information is subjective to the observers. Based on the information presented, there appears to be no significant difference in degradation between the two ships and crews as reported by the commanding officers, even though HARRIET LANE ship responses are consistently greater than *BOUTWELL's* ship responses.

PILOT HOUSE ACCELERATIONS

For the octagon runs performed simultaneously by *USCGC BOUTWELL* and *HARRIET LANE*, a comparison of the measured transverse and vertical accelerations at the pilothouses (see Tables 13 through 17) shows some interesting trends. First, the statistical values of vertical acceleration on the *HARRIET LANE* are **always** greater than the *BOUTWELL.* For head and bow headings relative to the seas, the difference between the two cutters for heavy seas often exceeds 0.1g. Transverse accelerations follow a similar pattern, although not as consistently. For instance, for the first octagon conducted in mild sea conditions (significant wave height of about 4.5 feet), the *HARRIET LANE* exhibits smaller transverse accelerations in all wave headings except head and bow. This may be a result of active roll stabilization since the primary component of transverse acceleration is the g-force induced by roll. For the less benign wave conditions of the last three octagons, where the fins stabilizers evidently cannot compensate enough, the *BOUTWELL* almost always experiences less transverse acceleration at her pilothouse.

The magnitudes of vertical acceleration in the pilothouses, particularly on the *USCGC HARRIET LANE* should be put into context. Extensive study of the USNS T-AGOS monohulls resulted in the refinement of limiting backdeck criteria for the launch and recovery of towed arrays. That investigation defined as a "severe" limiting condition vertical accelerations in excess of 0.15g significant single amplitude.* The USN standard limiting criteria for vertical acceleration is 0.4g significant single amplitude. Furthermore, the study to develop seakeeping criteria for USCG small boats[10] expanded the definition of limits to include 0.5g significant single amplitude and greater as unacceptable because of the real possibility of attaining or exceeding a peak value of 1g. For the sea states encountered, both cutters routinely exceed 0.15g vertical acceleration in the

---

*Thomas, William L., Terrence R. Applebee and Alan W. Abbs,"A Method to Define Ship Motion Limiting Criteria,"NSWC Report CARDEROCKDIV, NSWC/SHD-1338-04 October 1992 (Limited Distribution).

pilothouses. But while the *BOUTWELL* never exceeded a significant single amplitude vertical acceleration of 0.28g, the *HARRIET LANE* exceeded 0.3g during five different legs, and exceeded 0.4g during one leg. From a human factors standpoint, these are indeed severe conditions.

The result of more transverse and vertical acceleration is generally higher crew workload. Work done over the years on Motion-Induced Interruptions (MII)[11, 12] indicate that high levels of transverse and vertical accelerations increase the crews' need to hang on to prevent stumbling (tipping and sliding) as well as contributing to crew fatigue due to constantly shifting body weight to maintain balance. The results of current work in this area, now being completed and soon to be reported, will enable the prediction of the occurrence and severity of MII in real time. Figure 23 presents an example of MII prediction during recent experiments with subjects in a ship motion simulator in Bedford, England with actual loss of balance occurrences. The three upper lines represent the MII potential levels, from possible (the top line) to likely (the lowest line). The "spikes" occurring along these lines indicate the times when motion conditions should produce MII. The bottom line represents an actual subject and the spikes show MII occurring. This type of analysis can also be performed subsequent to full-scale data collection to predict the incidence and severity of MII. Future study of the side-by-side trials could produce a better and more useful indication of what the differences in magnitudes of accelerations between these two ships means in terms of crew degradation and overall mission performance.

Another debilitating aspect of high accelerations is motion sickness. A model for predicting the occurrence of Motion Sickness Incidence (MSI) was developed by McCauley[13] as a function of vertical acceleration and associated period. While it has been found from other full-scale trials analysis[14, 5] that the trend in MSI prediction appears to be reliable, the model tends to under-predict actual observed sickness incidence. This is most likely due to the fact that the McCauley model is based on sickness resulting in emesis (vomiting) while ship crew members will typically experience and report a wide range of seasickness symptoms, from mild stomach awareness to total incapacitation. Regardless of its precision in predicting the MSI percentages, for comparison purposes, the model is valid and useful in investigating the relative seakeeping performance of the two cutters.

A summary of the spectral analysis of the vertical acceleration data at the pilothouses for both the 270 foot and 378 foot cutters during the last three side-by-side, head/near-head seas runs is presented in Table 18.

The McCauley model predicts 50% or greater MSI at approximately 0.19g rms and a period range of 4-6 seconds. For the same period range, 25% motion sickness incidence is predicted for vertical acceleration magnitudes of about 0.11g rms. From the above Table 18 it can be seen that, while the predominant vertical acceleration peak periods for both cutters are nearly identical (and in the most provocative range), the *USCGC HARRIET LANE's* rms vertical accelerations for these most severe headings are 30 to

40 percent higher than the *USCGC BOUTWELL.* This equates, for example, to an estimated MSI for run 149 of the *USCGC HARRIET LANE* of about 65% while the *USCGC BOUTWELL's* run 137 equals approximately a 35% MSI.

Higher vertical accelerations for the *USCGC HARRIET LANE* would not be unexpected due to its smaller size and displacement. However, as originally reported in Reference [5], the location of the pilothouse contributes to crew performance degradation. Vertical acceleration at any location on a ship is influenced by its distance from the longitudinal center of gravity (LCG). While the LCG location for both cutters is approximately the same in terms of percentage of L_{PP}, for the 378 foot cutter, the distance from LCG to the pilothouse is about 20% of L_{PP} while the same distance on 270 foot cutter is approximately 30% of L_{PP}. Thus, the crew of the 270 foot cutter will experience larger vertical motions (and resulting MII and MSI) due to the fact that the pilothouse has been placed so far forward.

Finally, there is the subtle issue of crew fatigue. While the technical definition of fatigue is "weariness after exertion," shipboard fatigue may be a combination of many factors including the constant motion environment, sickness, lack of sleep, etc. There have been efforts made to quantify fatigue as the crew workload imposed by the continual "adjustments" in balance due to ship motions. This Motion-Induced Fatigue (MIF) concept is based on the magnitude and frequency of center of gravity shifts that shipboard personnel routinely (and unconsciously) make, and equate this action to energy expended. While this model is not yet fully developed, it is obvious from the premise that accelerations (longitudinal, transverse and vertical) of increasing magnitude and high frequency will produce larger values of MIF, and therefore be the most debilitating. In general, for typical monohulls, the smaller the vessel, the greater the MIF. Thus, a higher fatigue factor would be expected on the 270 foot cutter, particularly in forward areas such as the pilothouse, than on the 378 foot cutter.

MOTION LIMITING CRITERIA FOR SMALL BOAT OPERATIONS

One of the major goals of this side-by-side trial was to determine ship motion limiting criteria for conducting small boat operations (boat ops). This was done by taking measurements of ship motion during times when small boat operations were conducted as well as recording instances during the octagon trials when either ship indicated when excessive ship motions would not permit small boat operations to occur.

On both *BOUTWELL* and *HARRIET LANE*, standard practice is to create a lee for launching the boat. The relative wave heading and ship speed that both ships make to launch the boats are significantly different due to the differing locations of the boat station on each ship along with roll reduction considerations. For *HARRIET LANE*, the minimum speed at which the roll stabilization fins are effective is a prime consideration. Therefore a lee is established with a relative heading of 135 degrees and a speed of eight knots.

On the other hand, *BOUTWELL*, which uses bilge keels to reduce roll motions, launches boats by taking a relative wave heading of 30 degrees with a speed of six knots. The general guidance given both ships dictate that boat launchings are generally not conducted in significant wave heights in excess of eight feet. However, *BOUTWELL* indicated that it would launch small boats in waves higher than eight feet for a Search and Rescue case.[†]

The data collected during this part of the trial had several interesting characteristics. First, data for which small boat operations could take place came exclusively from the *HARRIET LANE*. There was no assessment of difficulty associated with this data. Hence a difficulty level of zero was assigned. Second, the only indication of times when small boat operations were not possible came from *BOUTWELL* during two legs of an octagon. The corresponding ship motions were assigned a difficulty level of 1.0, which indicates a "no-go" situation. Since *HARRIET LANE* was traveling with *BOUTWELL* when *BOUTWELL* indicated a "no-go" situation, the ship motions of *HARRIET LANE* were also assumed to denote a "no-go" situation. This seemed to be sensible since *HARRIET LANE* was experiencing greater ship motions than *BOUTWELL*.

Given the above limitations in the data, it was necessary to assume that the same motion limits for the 378-foot WHEC applied to the 270-foot WMEC.

Ship motion measurements pertaining to small boat operations are displayed in Table 19. The ship motions extracted for boat ops were pitch, roll, lateral and vertical accelerations at the pilothouse, and lateral and vertical accelerations at the boat location. As stated earlier, the boat ops "go" or "no-go" information was assigned numerical values ranging from 0 for "go" to 1 for "no-go". The data have been sorted in descending order according to the measured pitch motion. The results in Table 19 indicated small boats have been launched in significant wave heights in excess of eight feet for the *HARRIET LANE*. Table 20 shows the maximum measured significant single amplitude (SSA) motions during which *HARRIET LANE* conducted boat operations. The minimum "no-go" ship motion measurements are presented in Table 21.

An inspection of Tables 19 through 21 indicate that transverse acceleration is not directly associated with the "no-go" situations. The limiting parameters appear to be pitch, roll, and vertical acceleration at the pilot house or boat deployment site. It was not possible to determine if the motions at the pilot house took precedence over the measured motions at the boat launching station. This was because, the "no-go" situation was determined in the pilot house of *BOUTWELL*. The motion limiting criteria are presented in Table 22.

Speed and heading profiles were developed for operability assessments for the WHEC and the WMEC based on the profiles listed earlier in this section. Since the practice for *BOUTWELL* was to launch boats on a heading with the waves 30 degrees off the

---

[†] Interestingly enough, *HARRIET LANE* launched small boats in significant wave heights as high as 11.5 feet in this trial.

bow, at a speed of six knots, an envelope was defined to include waves 30 degrees off the bow with ± 15 degrees leeway with a speed envelope between zero and six knots. This procedure made an allowance for uncertainties associated with the estimation of wave direction and speed.

In order to take advantage of the active anti-roll fins, *HARRIET LANE* launched boats in stern quartering seas at speeds suitable for the fin system. The envelop for the operability assessment for *HARRIET LANE* was defined as stern quartering seas ± 15 degrees at speed between 5 and 10 knots.

SEAKEEPING ASSESSMENT

In practice, it is impossible to conduct comparative ship motion measurements in full scale trials over an infinite range of speed and heading combinations in conjunction with a comprehensive range of sea conditions. Therefore, it is logical to turn to state-of-the-art seakeeping assessment tools that can thoroughly compare performance predictions of the the 270 foot *FAMOUS Class* WMEC and the 378 foot *HAMILTON Class* WHEC. For this report, it is necessary to choose an assessment tool that evaluates the ability of a ship to carry out a mission in terms of the:

- Motion characteristics of the ship
- Ocean environment, including wind and wave climatologies for the region of interest
- Limiting motions for the mission

Thus, it is desirable to know how often the 270 foot *FAMOUS Class* WMEC can perform a particular operation in Alaskan Waters in comparison to the 378 foot *HAMILTON Class* WHEC, given the wide range of wind and wave conditions that exist. The approach taken in this report will utilize Percent Time Operability calculations using the methodology defined by McCreight and Stahl.[15]

Percent Time Operability

Background

Percent Time Operability (PTOs) estimates are calculated by comparing motion limiting criteria for particular operations with strip theory ship motion predictions in representative seaways for specific geographic regions. The ship motion predictions utilize ship motion transfer functions generated by the U. S. Navy's Ship Motion Program (SMP)[16], which models appendages including bilge keels, skegs, propeller shaft brackets and active anti-roll fins using methods presented by Cox and Lloyd.[17] In essence, a PTO defines how often sea conditions exist in a region that allow a ship to refrain from exceeding particular ship motions limits.

For this report, the seaway is modeled using Bretschneider wave spectral formulations with cosine-squared spreading to denote deep water wind driven shortcrested seas. The parameters for the seaway are derived from seasonal wave hindcast climatologies produced by the U. S. Navy's Global Spectral Ocean Wave Model (GSOWM). For each region, the joint probability of significant wave height, modal period, and wind speed are compiled on a seasonal basis. The GSOWM database contains archived wind data sets compiled by the Fleet Numerical Oceanography Center (FNOC) to hindcast wave field for approximately 1500 locations throughout the northern hemisphere.[18, 15]

The accuracy and validity PTO calculations are based on the accuracy of the ship motion transfer functions, the motion limiting criteria, and the wave climatologies used in the evaluation. The PTOs represent statistical values and should be treated accordingly. For example, a PTO of 80 percent represents 80 percent operability of a long period of time such as 20 years. It does not present a value for a short period of time such as 2 weeks. The best use of PTOs is on a comparative basis. This procedure will be followed in this report.

Methodology

The operability assessment focused on the two critical missions of Search and Rescue (SAR) and Law Enforcement for the WHEC and the WMEC. For this evaluation, motion limiting criteria data sets were compiled for the following seakeeping-sensitive operations, which, if they cannot be performed, indicate that degradations will be experienced in the capability to carry out both SAR and Law Enforcement duties:

- Transit Mission
- Helicopter Launch and Recovery (Daylight Hours)
- Small Boat Launch and Recovery

PTO's were calculated using winter season data to represent the most severe season in Alaskan waters at three representative locations. PTO's were also calculated on an annualized (four season) basis. The first location is in the southern Bering Sea. The second location is in the northern Pacific Ocean in the vicinity of the Aleutians. The third location is in the Gulf of Alaska.

Transit Mission

The Transit mission describes that ability of a ship to transit from one location to another. A ship that exceeds Transit Mission ship motion limits can be expected to change heading or speed to reduce excessive motions. If this does not happen degradations can be expected in terms of personal comfort, motion sickness and fatigue. Excessive slamming can result in structural damage. Transit mission limiting criteria for naval vessels are listed below as defined by Comstock et al:[19, 18‡]

CRITERION	LIMIT
Roll	8.0 degrees SSA
Pitch	3.0 degrees SSA
Bow Wetness	30 per hour
Slams at Station 3	20 per hour
Vertical Acceleration	0.4 g's SSA at the Pilot House
Lateral Acceleration	0.2 g's SSA at the Pilot House

The PTO calculations gave equal weight to all heading and speed combinations based on the assumption that at any time, the commanding officer would like to have his choice of heading and speed. The reader is reminded that the maximum speed capability of the WHEC is approximately 50 percent higher than the WMEC. The PTO calculations do not penalize the slower ship for shortcomings in speed capability. In other words, 100 percent operability in the Transit Mission for *HARRIET LANE* applies to *HARRIET LANE's* speed capability. For *BOUTWELL*, 100 percent operability applies to *BOUTWELL's* range of speed capabilities, which are larger than *HARRIET LANE's*. Results are presented in Tables 23 and 24.

Helicopter Launch and Recovery

The ability to launch and recover helicopters relates directly to SAR and Law Enforcement capabilities. The motion limiting criteria are listed below are used in conjunction with the WHEC and WMEC day time relative wind envelope for the HH-65 helicopter.[§]

CRITERION	WHEC LIMIT	WMEC LIMIT
Roll	3.5 degrees SSA	4.0 degrees SSA
Pitch	2.5 degrees SSA	2.5 degrees SSA

The PTO calculations assume that the ship has already achieved the correct relative wind in accordance with the wind envelope. The PTO's do not penalize either ship for instances when the correct relative wind cannot be achieved. See Tables 25 and 26.

[‡] It is interesting to note that the value of 0.4 g's vertical acceleration at the Pilot House was based originally on Motion Sickness Incidence (MSI), and has been shown to vastly overestimate limiting vertical acceleration conditions.

[§] Motion Limits and Wind Envelope are defined in Commandant Coast Guard Instruction COMDINST M3710.2 (Limited Distribution).

Small Boat Launch and Recovery

The ability to launch and recover Small Boats relates directly to SAR and Law Enforcement capabilities. The motion limiting criteria as derived from Tables 19 through 21 are listed below and used in conjunction with the WHEC and WMEC speed and heading profiles.

CRITERION	LIMIT
Roll	8.0 degrees SSA
Pitch	2.5 degrees SSA
Vertical Acceleration	0.2 g's SSA at the Pilot House
Vertical Acceleration	0.2 g's SSA at the Boat Launch Station

The PTO calculations assume that the WHEC and the WMEC are in their respective heading and speed envelopes required to conduct small boat launch and recovery operations. See Tables 27 and 28.

Discussion

For the Transit Mission, it appears that the 270-foot Coast Guard cutter can perform on the average of 16.9 percent less often than the 378-foot cutter in Alaskan waters during the winter and 14.5 percent less often annually. In the Helicopter Launch and Recovery Mission, the 270-foot cutter can perform on the average of 11 percent less often in comparison to the 378-foot cutter during the winter and 13.7 percent less often annually. In the Small Boat Launch and Recovery Mission, the 270-foot cutter is predicted to perform on the average of 3 percent less often than the 378-foot cutter in Alaskan waters during the winter and 4 percent less often annually. Exceedance of the Roll and Pitch criteria for both missions served as the dominant source of failure for both ships.

CONCLUSIONS

A comparison of measured ship motions in side-by-side trials of a 378 and 270-foot cutter indicates that the 270 is significantly less "seakindly" than the 378. Specifically:

- Significant Single Amplitude Pitch experienced by 270-foot cutter is typically 20 to 50 percent greater than the 378.
- Significant Single Amplitude Vertical Accelerations at the Pilot House of the 270-foot cutter are often 40 to 50 percent larger than the 378, especially when seas are forward of the beam.
- The 270-foot cutter experiences roll reductions as high as 50 percent when the anti-roll fins are activated.

- Roll experienced by the 270-foot cutter appeared to be greater than for the 378 foot cutter, but definitive measurements were not possible.

A winter season and annual (four season) operability assessment was conducted for both ships for three locations that represent Alaskan Waters.

For the Transit Mission, it appears that the 270-foot Coast Guard cutter can perform on the average of 16.9 percent less often than the 378-foot cutter in Alaskan waters in the winter ant 14.5 percent less annually. In the Helicopter Launch and Recovery Mission, the 270-foot cutter can perform on the average of 11 percent less often in comparison to the 378-foot cutter in the winter and 13.7 percent less annually. In the Small Boat Launch and Recovery Mission, the 270-foot cutter is predicted to perform on the average of 3 percent less often than the 378-foot cutter during the winter and 4 percent less annually. Exceedance of the Roll and Pitch criteria for both missions served as the dominant source of failure for both ships. The reader is reminded that the top speed of the 378 foot cutter is significantly higher than the 270 foot cutter.

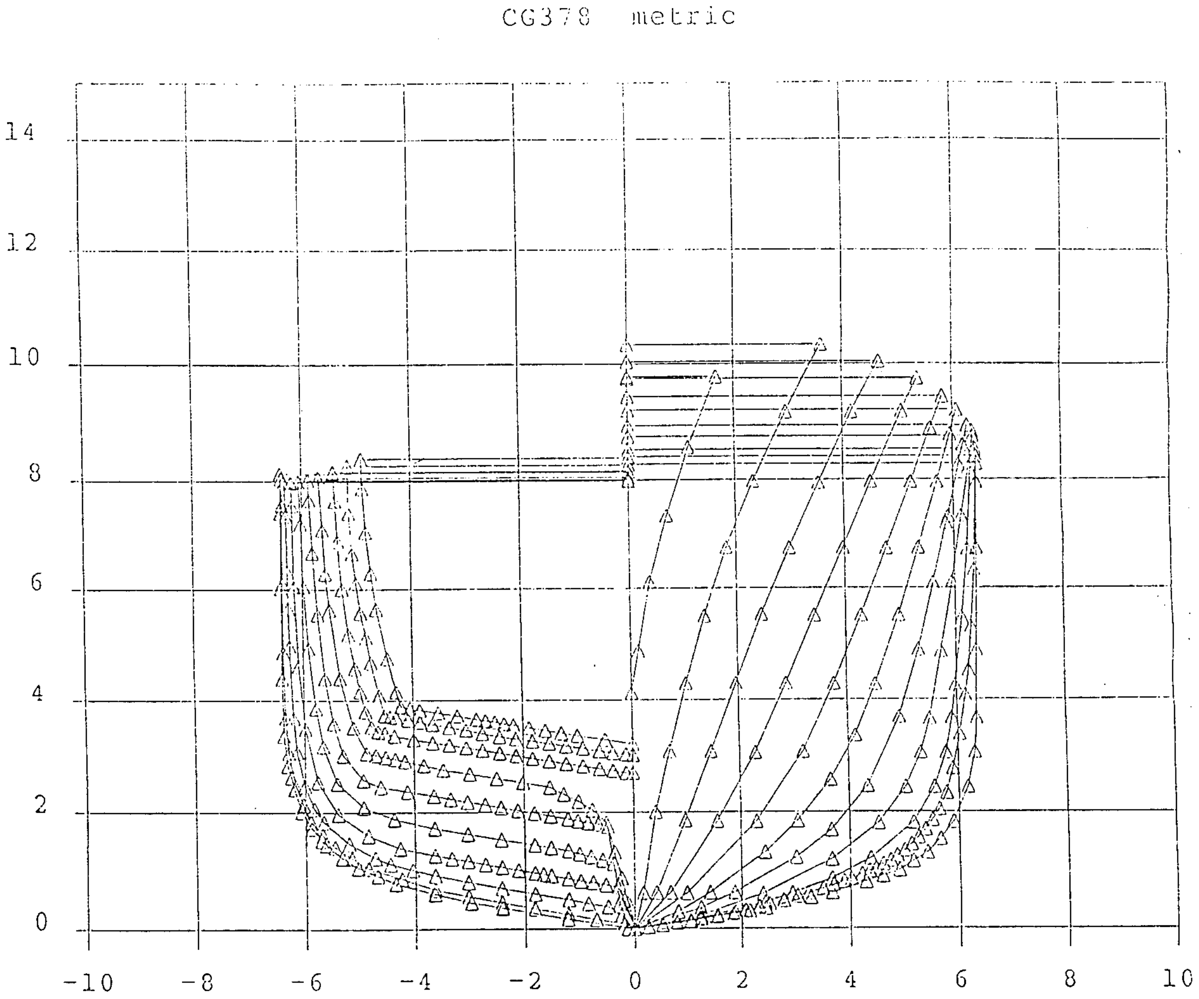

Fig. 1. HAMILTON Class 378 foot Coast Guard Cutter Body Plan.

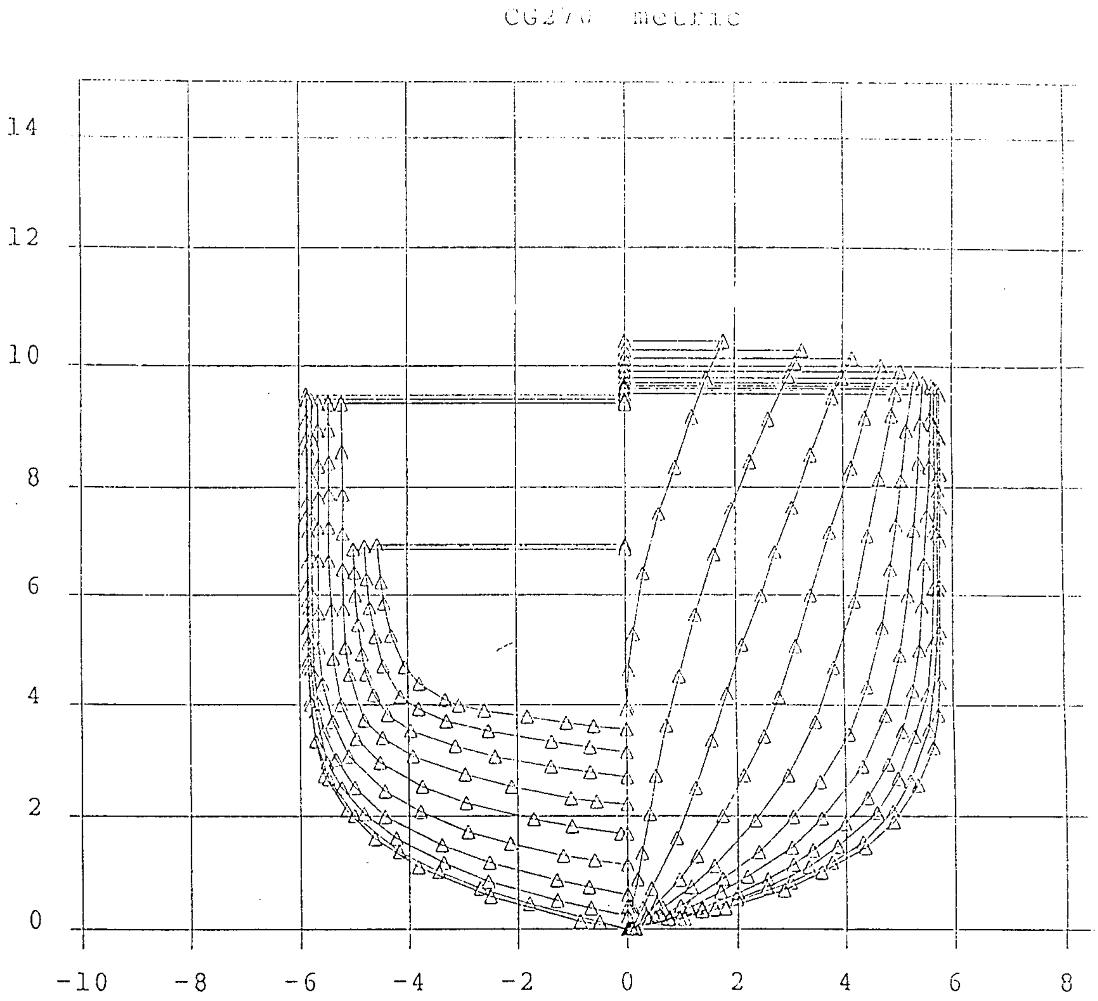

Fig. 2. FAMOUS Class 270 foot Coast Guard Cutter Body Plan.

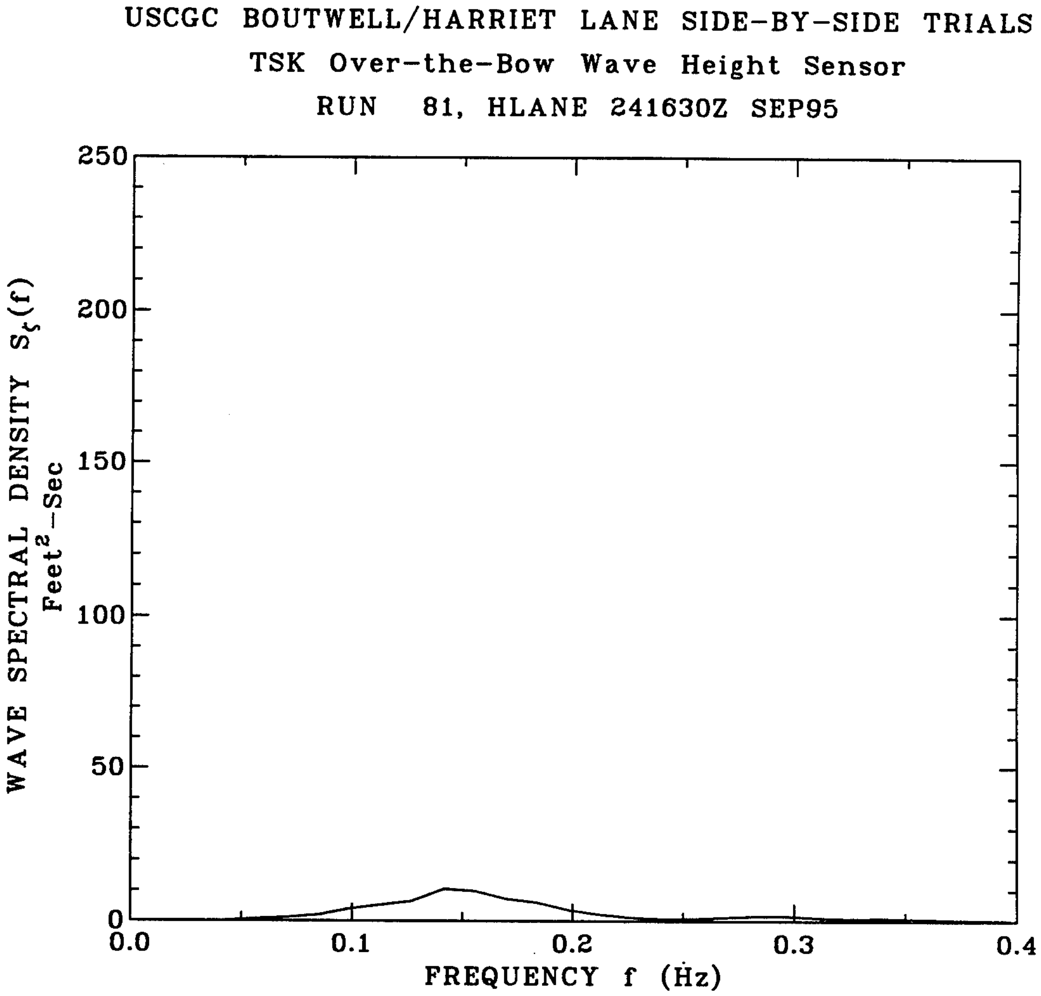

Fig. 3. USCGC HARRIET LANE Wave Measurement 81 $H_{1/3}$= 4.0 feet, T_o= 7.1 seconds.

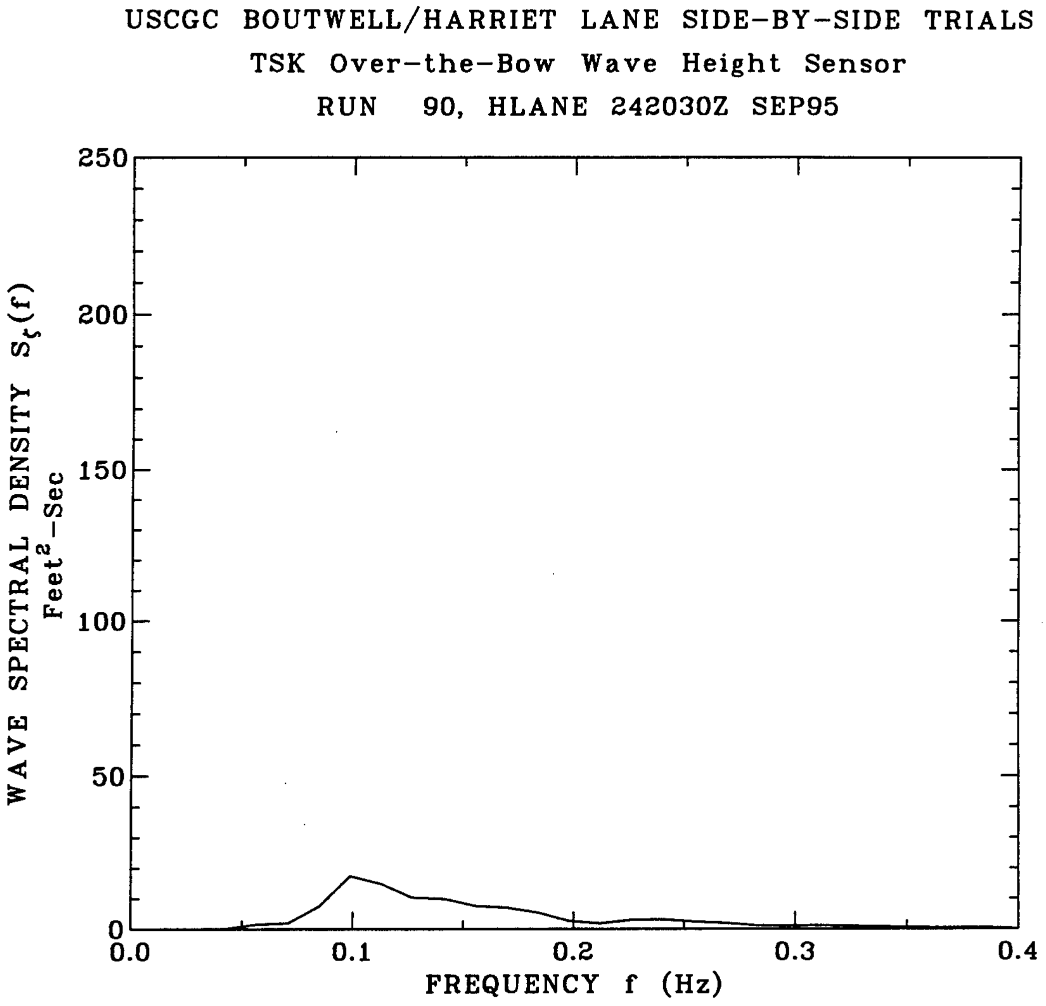

Fig. 4. USCGC HARRIET LANE Wave Measurement 90 $H_{1/3}$= 4.9 feet, T_o= 10.1 seconds.

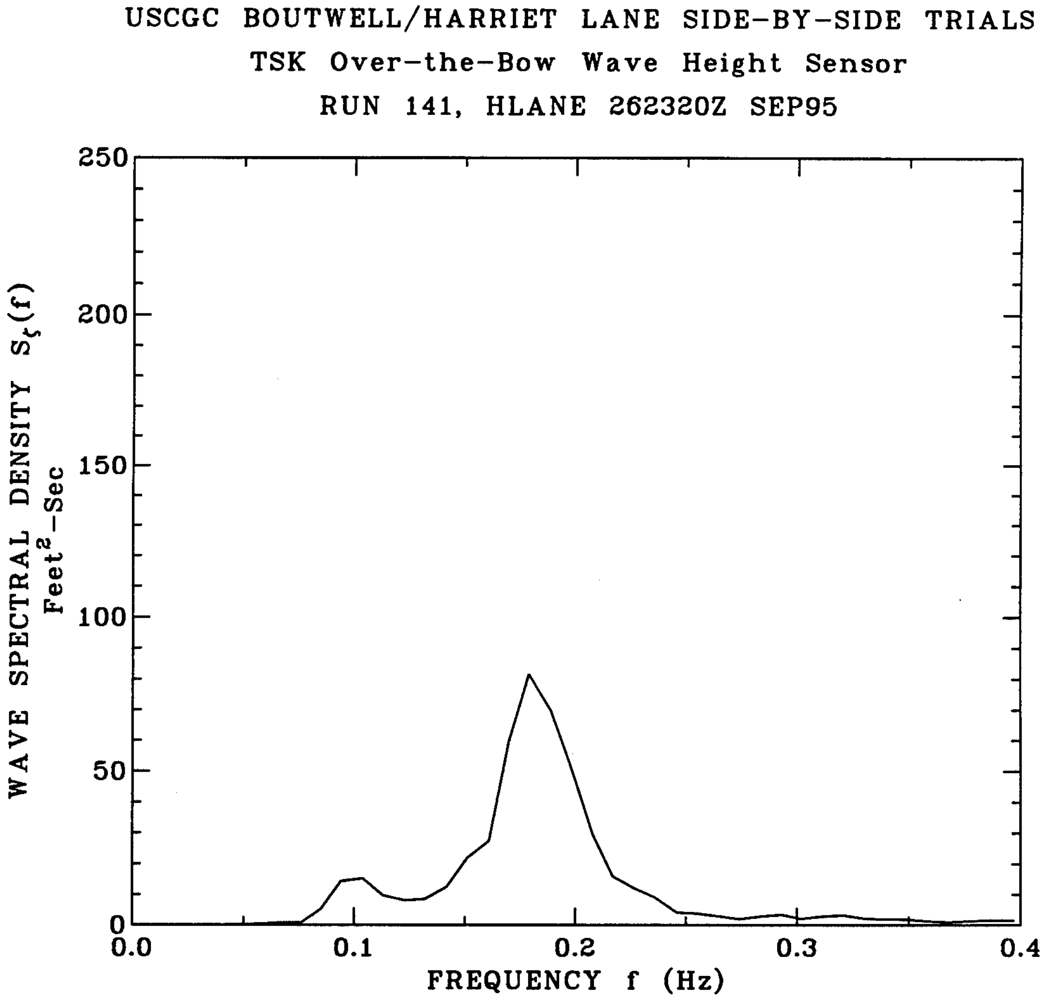

Fig. 5. USCGC HARRIET LANE Wave Measurement 141 $H_{1/3}$= 8.7 feet, T_o= 9.6 seconds.

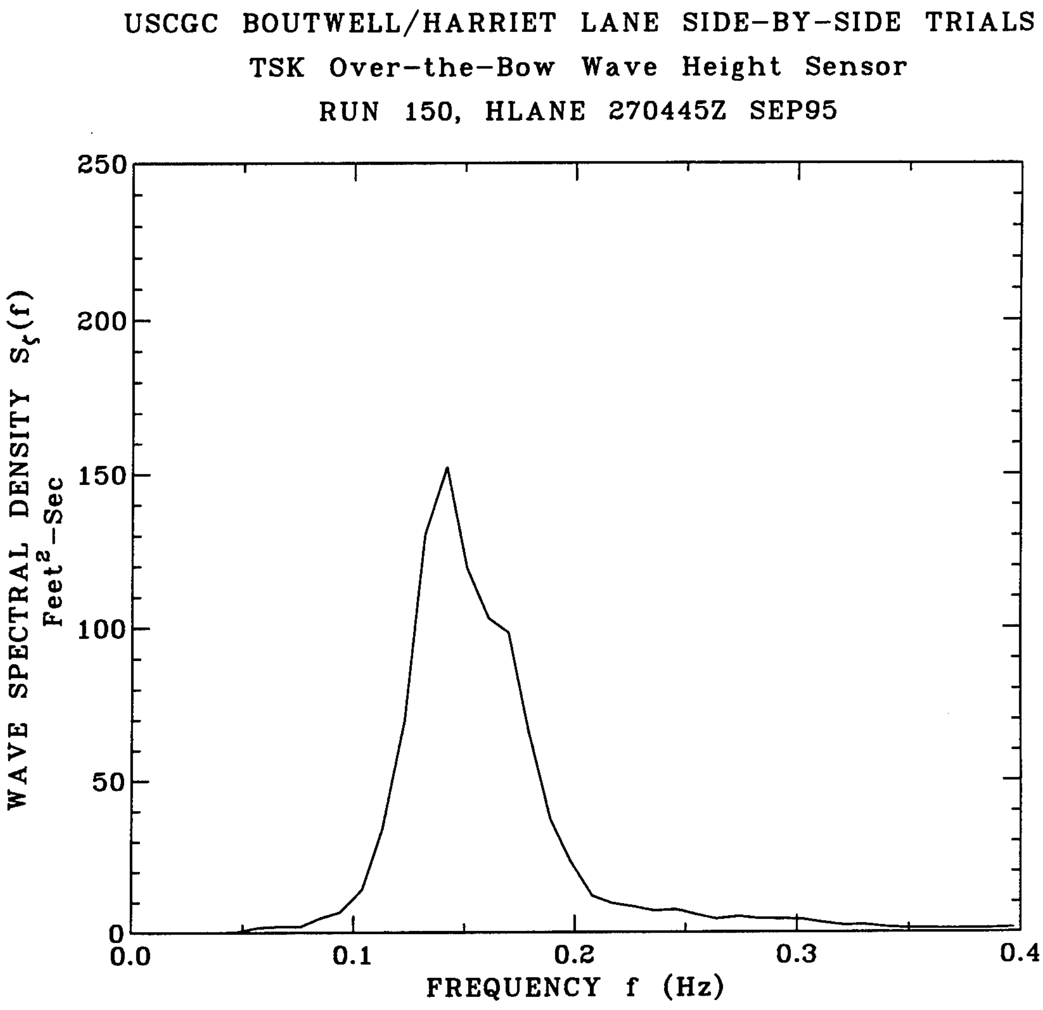

Fig. 6. USCGC HARRIET LANE Wave Measurement 150 $H_{1/3}$= 12.1 feet, T_o= 7.1 seconds.

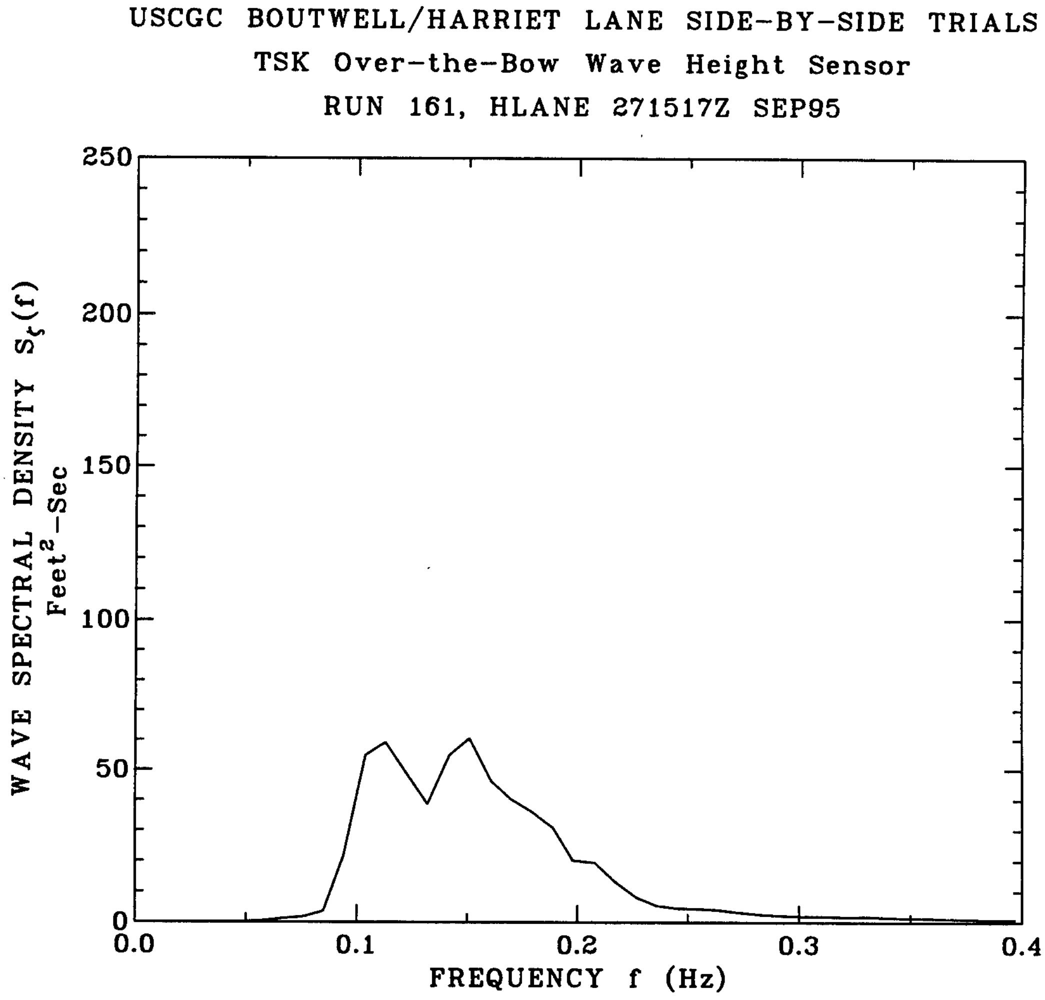

Fig. 7. USCGC HARRIET LANE Wave Measurement 161 $H_{1/3}$= 9.6 feet, T_o= 8.8 seconds.

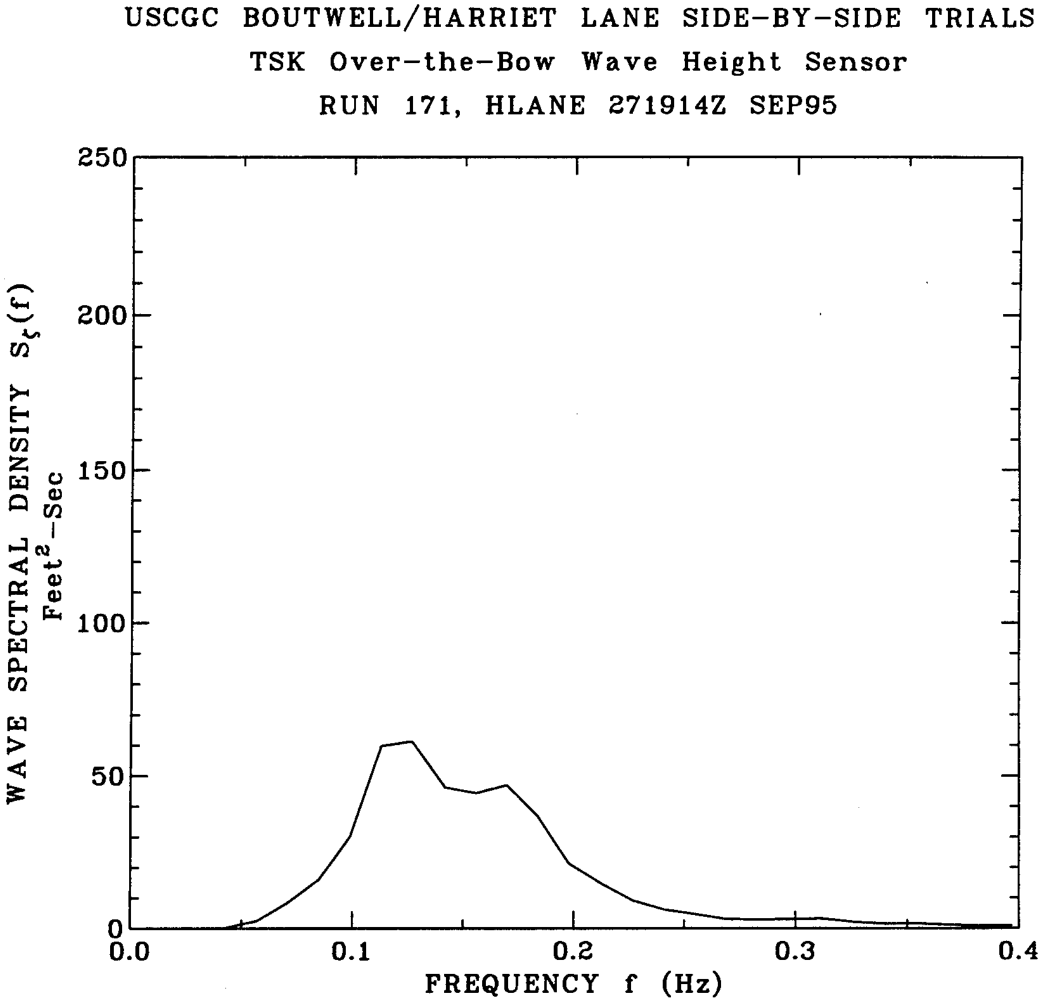

Fig. 8. USCGC HARRIET LANE Wave Measurement 171 $H_{1/3}$= 9.9 feet, T_o= 7.8 seconds.

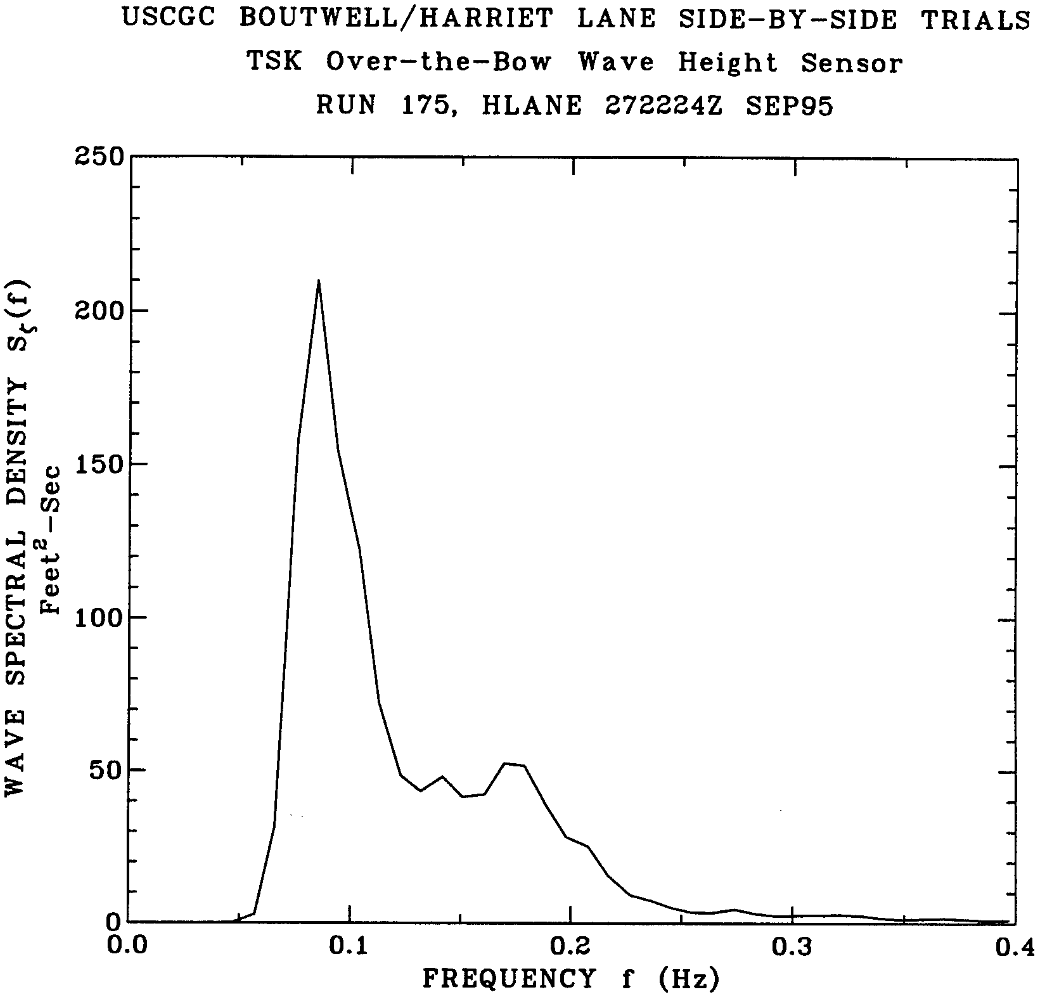

Fig. 9. USCGC HARRIET LANE Wave Measurement 175 $H_{1/3}$= 13.8 feet, T_o= 11.8 seconds.

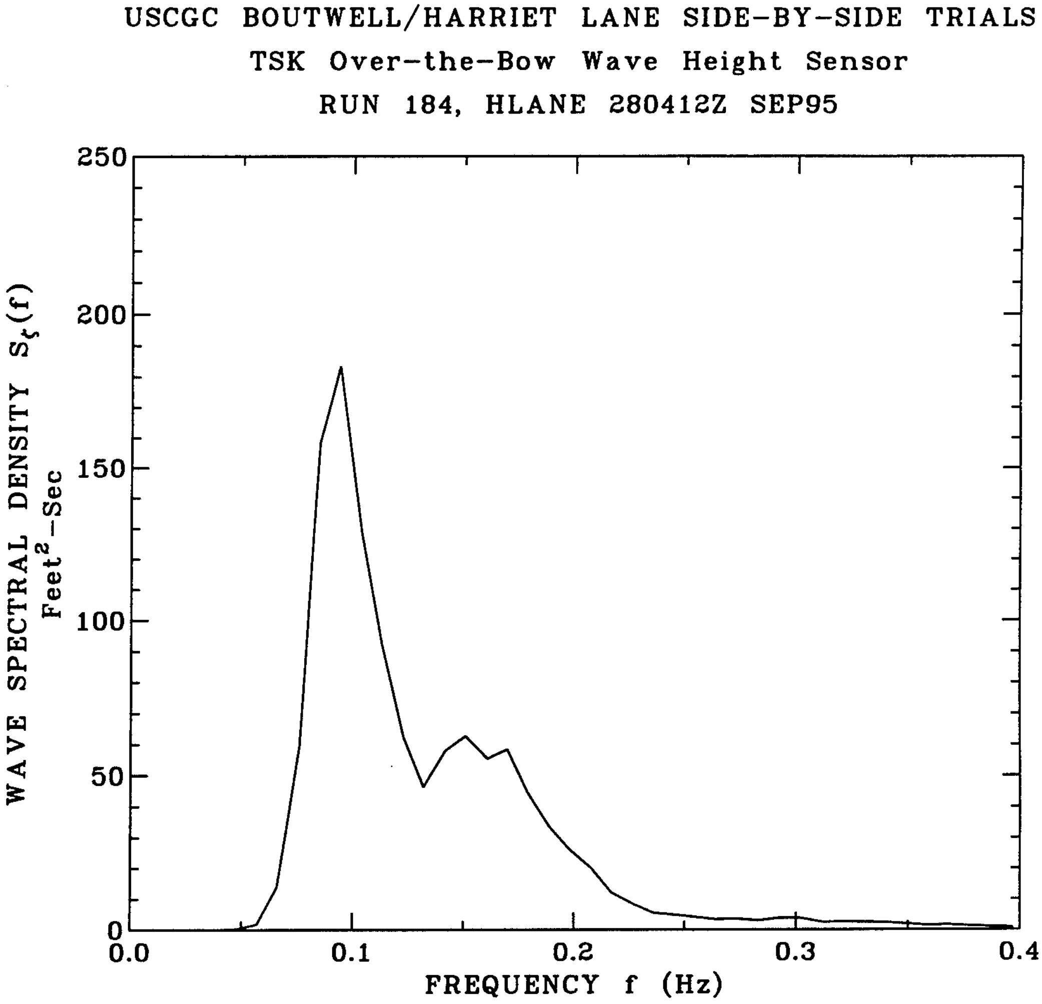

Fig. 10. USCGC HARRIET LANE Wave Measurement 184 $H_{1/3}$= 13.4 feet, T_o= 10.6 seconds.

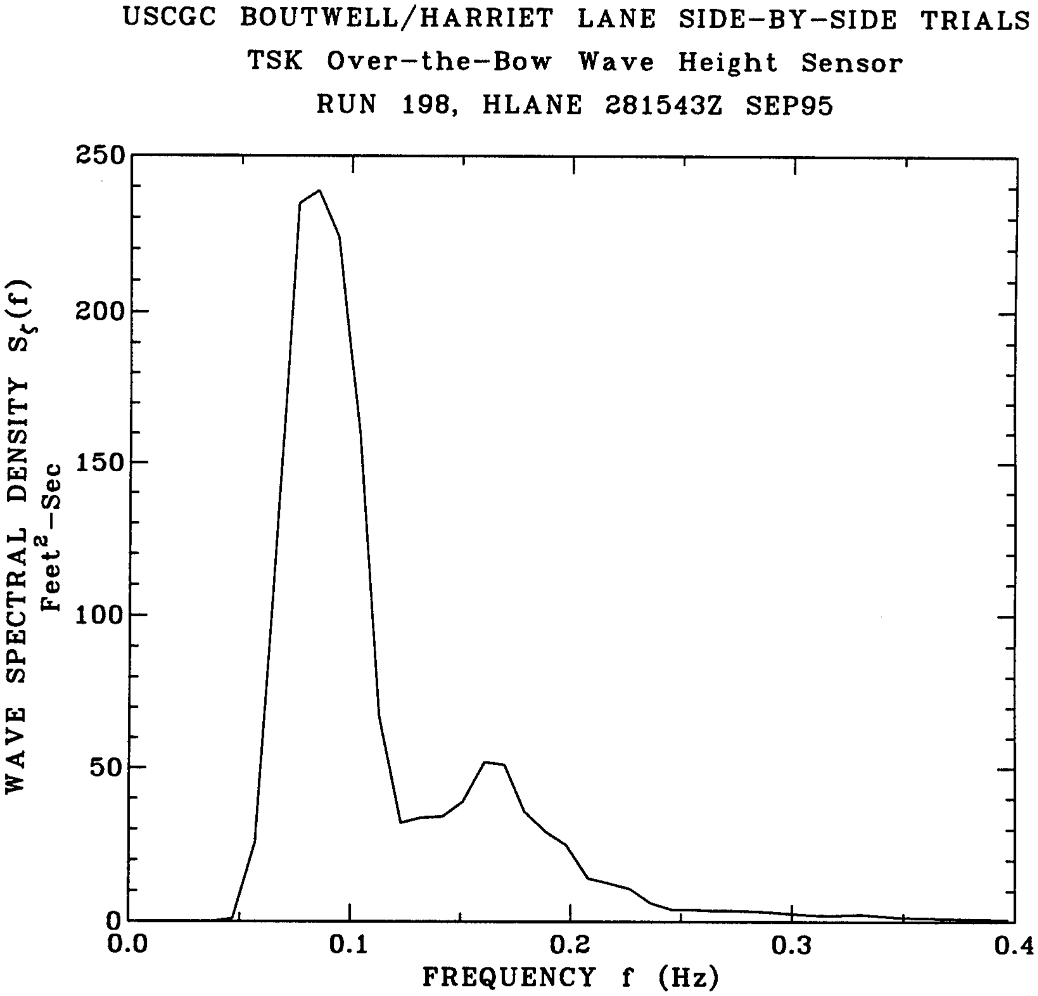

Fig. 11. USCGC HARRIET LANE Wave Measurement 198 $H_{1/3}$= 15.0 feet, T_o= 11.8 seconds.

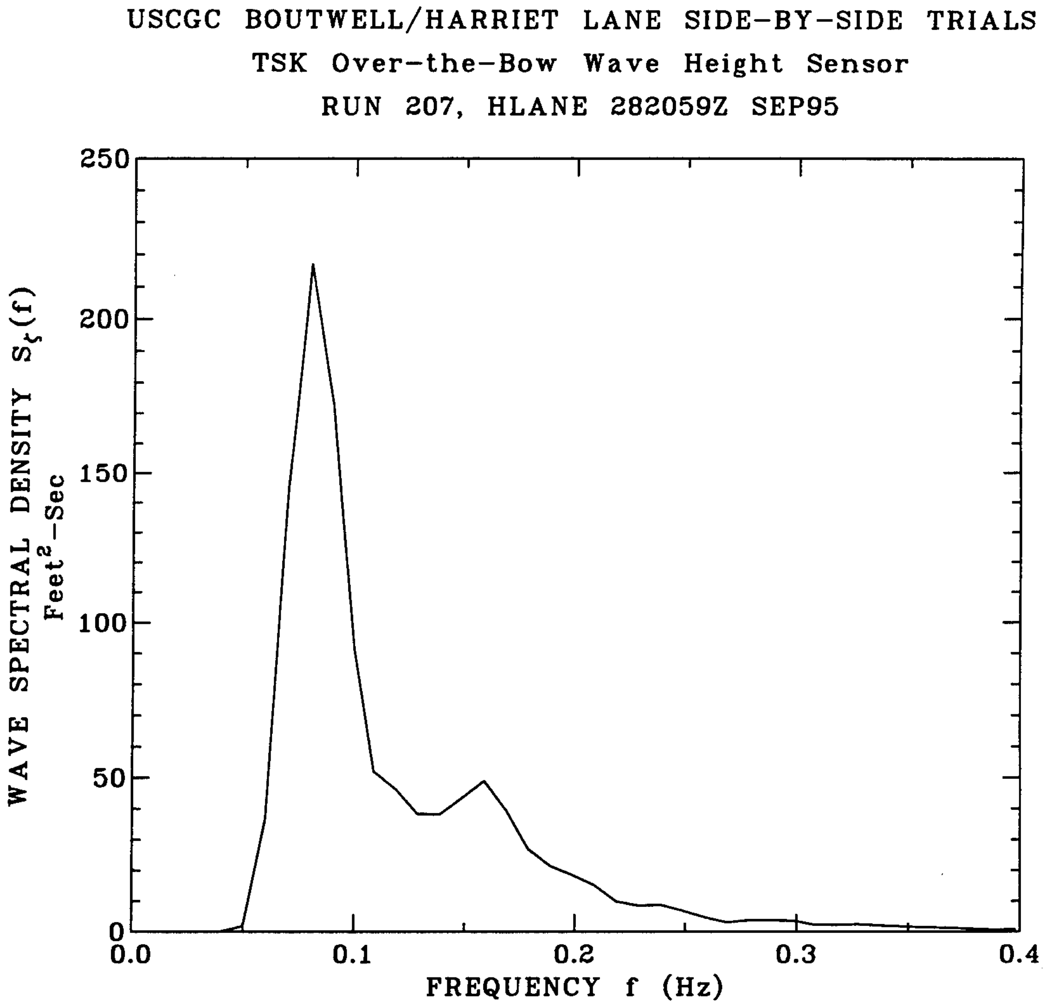

Fig. 12. USCGC HARRIET LANE Wave Measurement 207 $H_{1/3}$= 13.4 feet, T_o= 12.6 seconds.

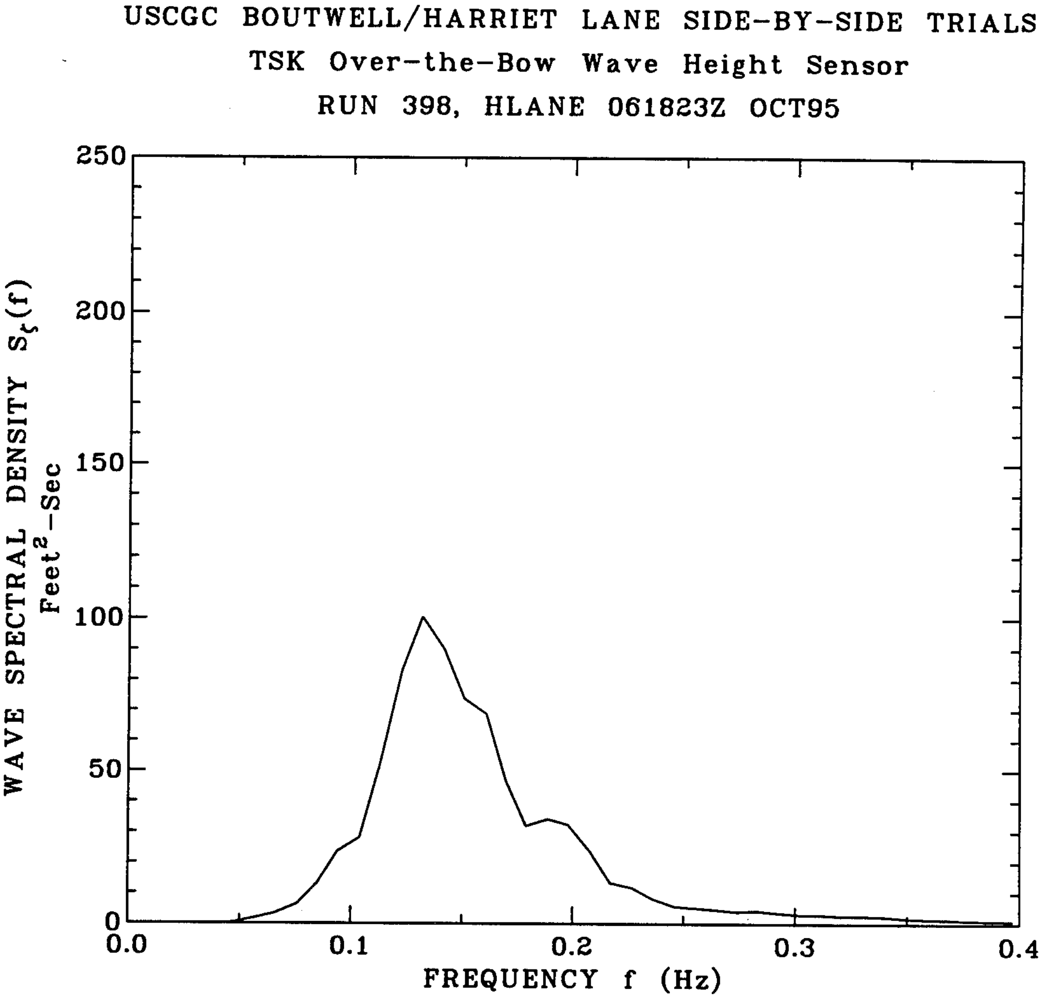

Fig. 13. USCGC HARRIET LANE Wave Measurement 398 $H_{1/3}$= 13.8 feet, T_o= 7.6 seconds.

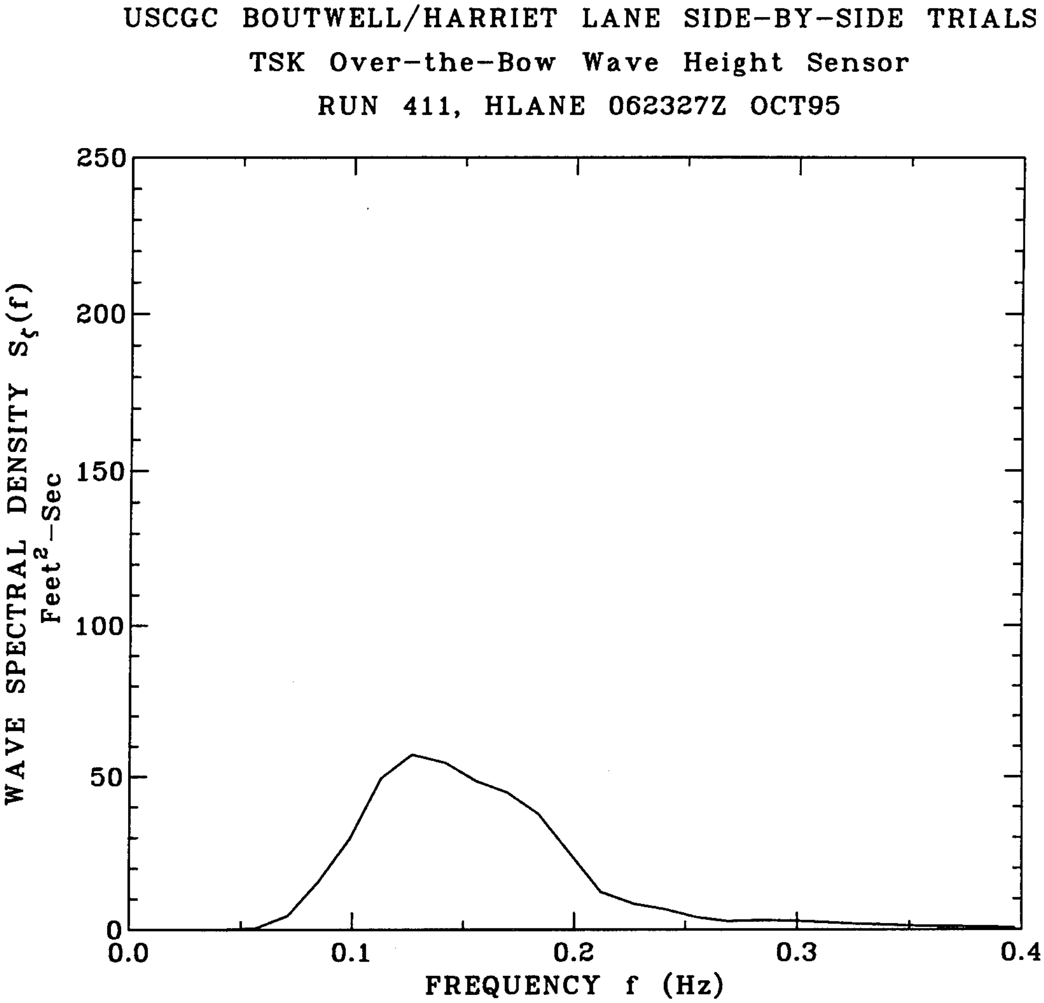

Fig. 14. USCGC HARRIET LANE Wave Measurement 411 $H_{1/3}$= 9.8 feet, T_o= 7.8 seconds.

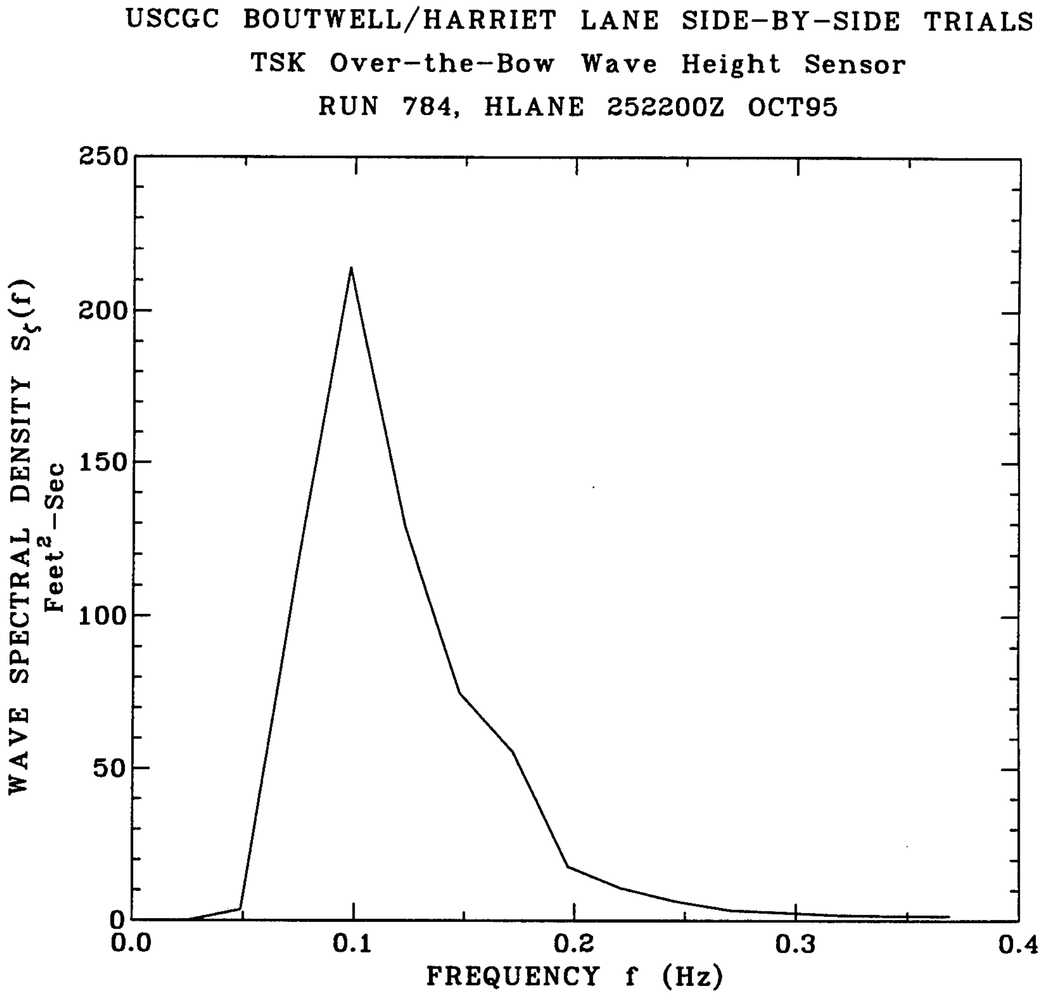

Fig. 15. USCGC HARRIET LANE Wave Measurement 784 $H_{1/3}$= 15.8 feet, T_o= 13.5 seconds.

24 Sep 95 Nom Ship Speed 10 Kn
HL Fins On Sig Wave Ht: 4.0 - 4.9 ft

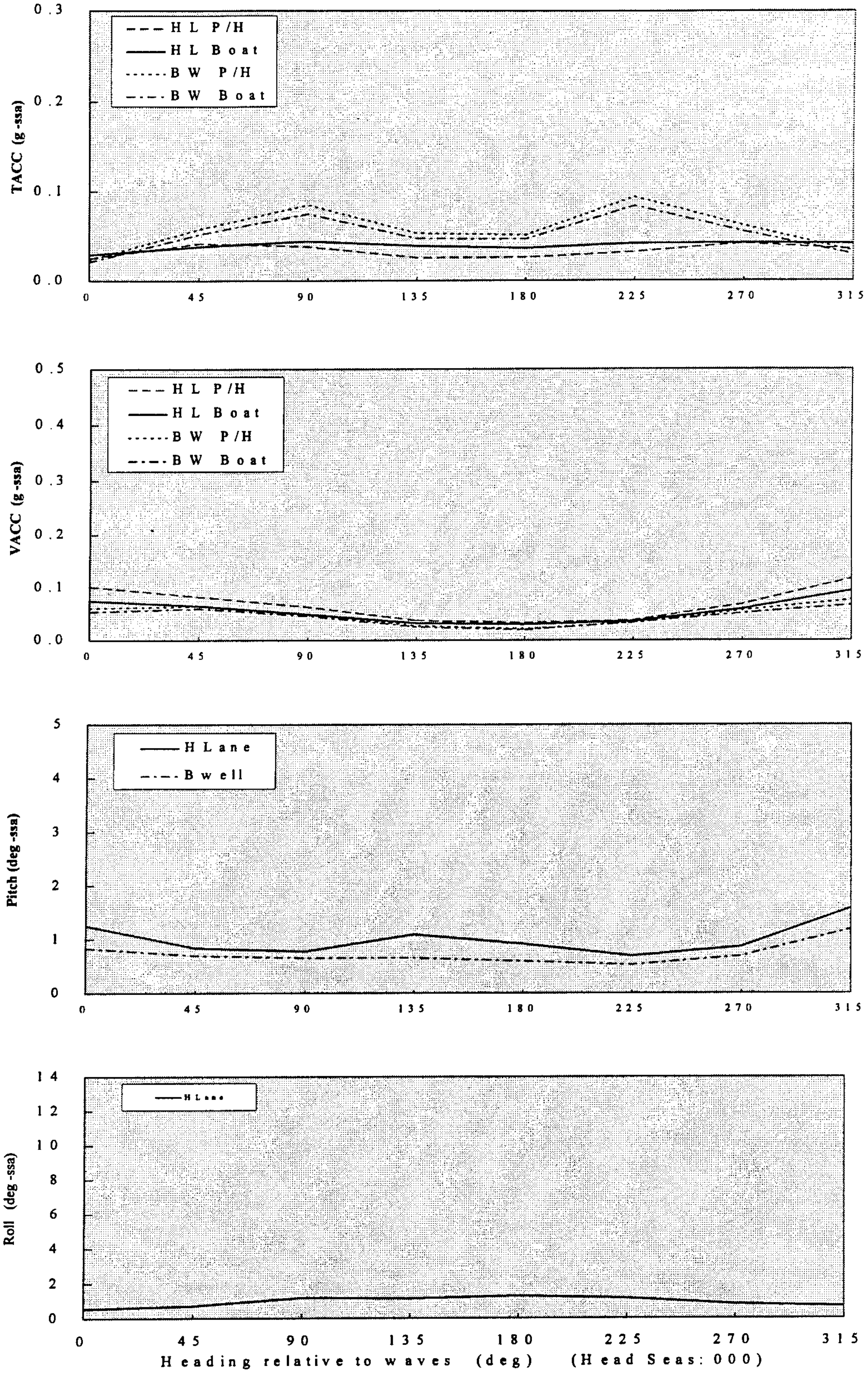

Figure 16- USCGC BOUTWELL and HARRIET LANE Ship Motion Comparisons for Octagon 1.

26 Sep 95 Nom Ship Speed 15 Kn
HL Fins On Sig Wave Ht: 8.7 - 12.1 ft

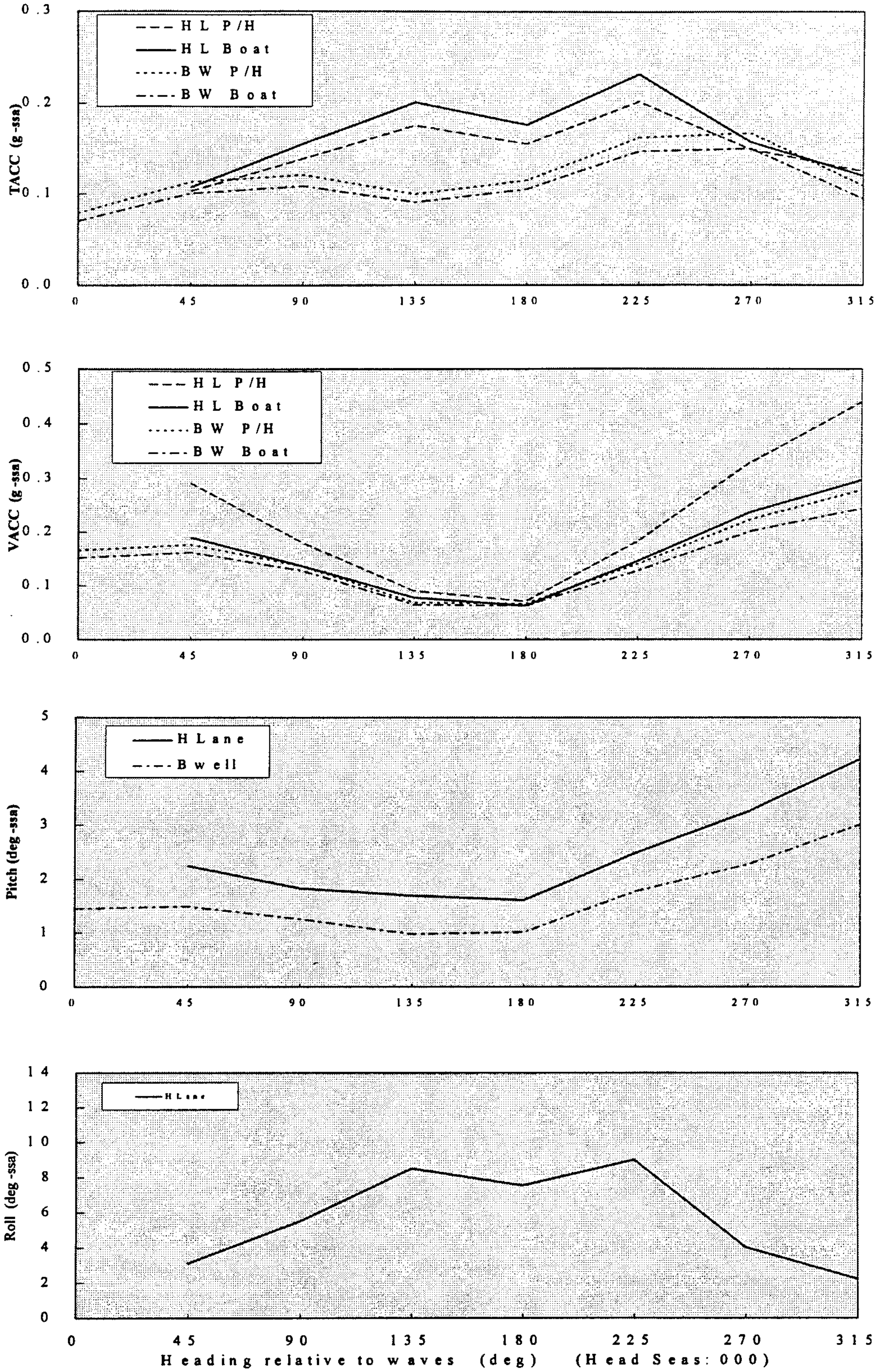

Figure 17- USCGC BOUTWELL and HARRIET LANE Ship Motion Comparisons for Octagon 2.

27 Sep 95 pm Nom Ship Speed 15 Kn
HL Fins On* Sig Wave Ht: 13.8 - 13.4 ft *Fins Off for 270 and 315 degrees

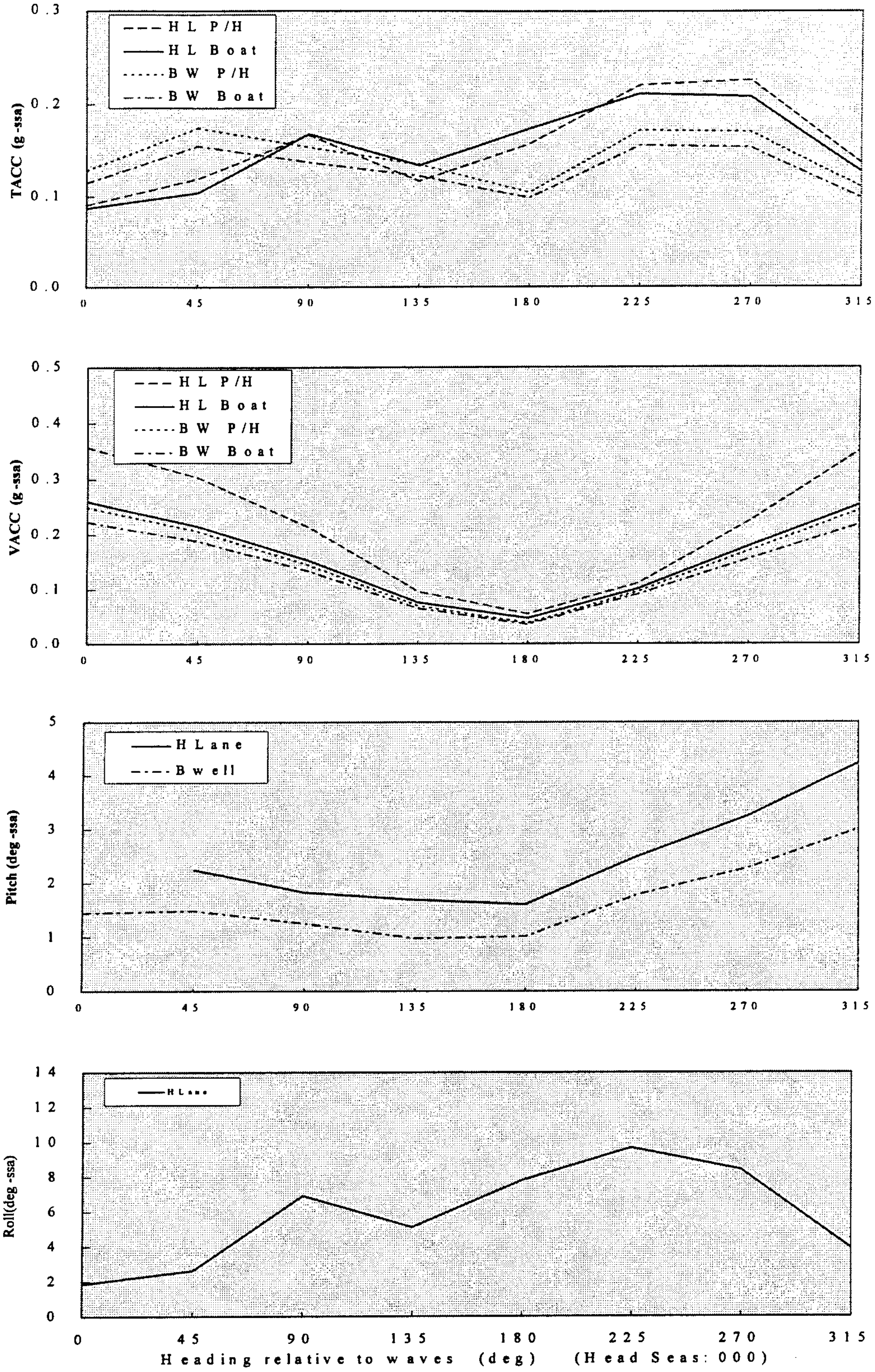

Figure 18. USCGC BOUTWELL and HARRIET LANE Ship Motion Comparisons for Octagon 4.

28 Sep 95 Nom Ship Speed 10 Kn
HL Fins Off Sig Wave Ht: 15.0 - 13.4 ft

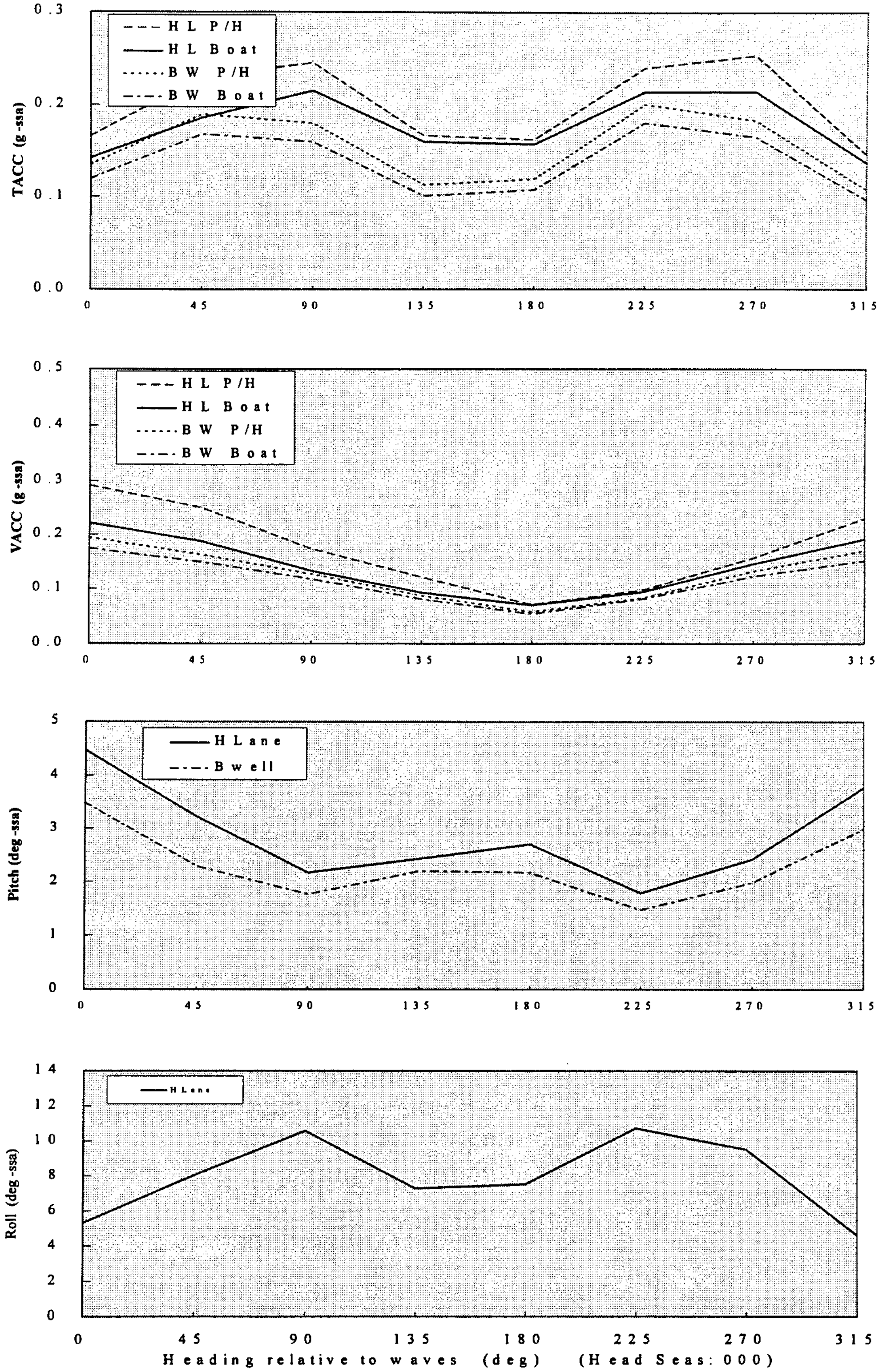

Figure 19. USCGC BOUTWELL and HARRIET LANE Ship Motion Comparisons for Octagon 5.

27 Sep 95 am Nom Ship Speed 15 Kn
HL Fins Var Sig Wave Ht: 9.6 - 9.9 ft

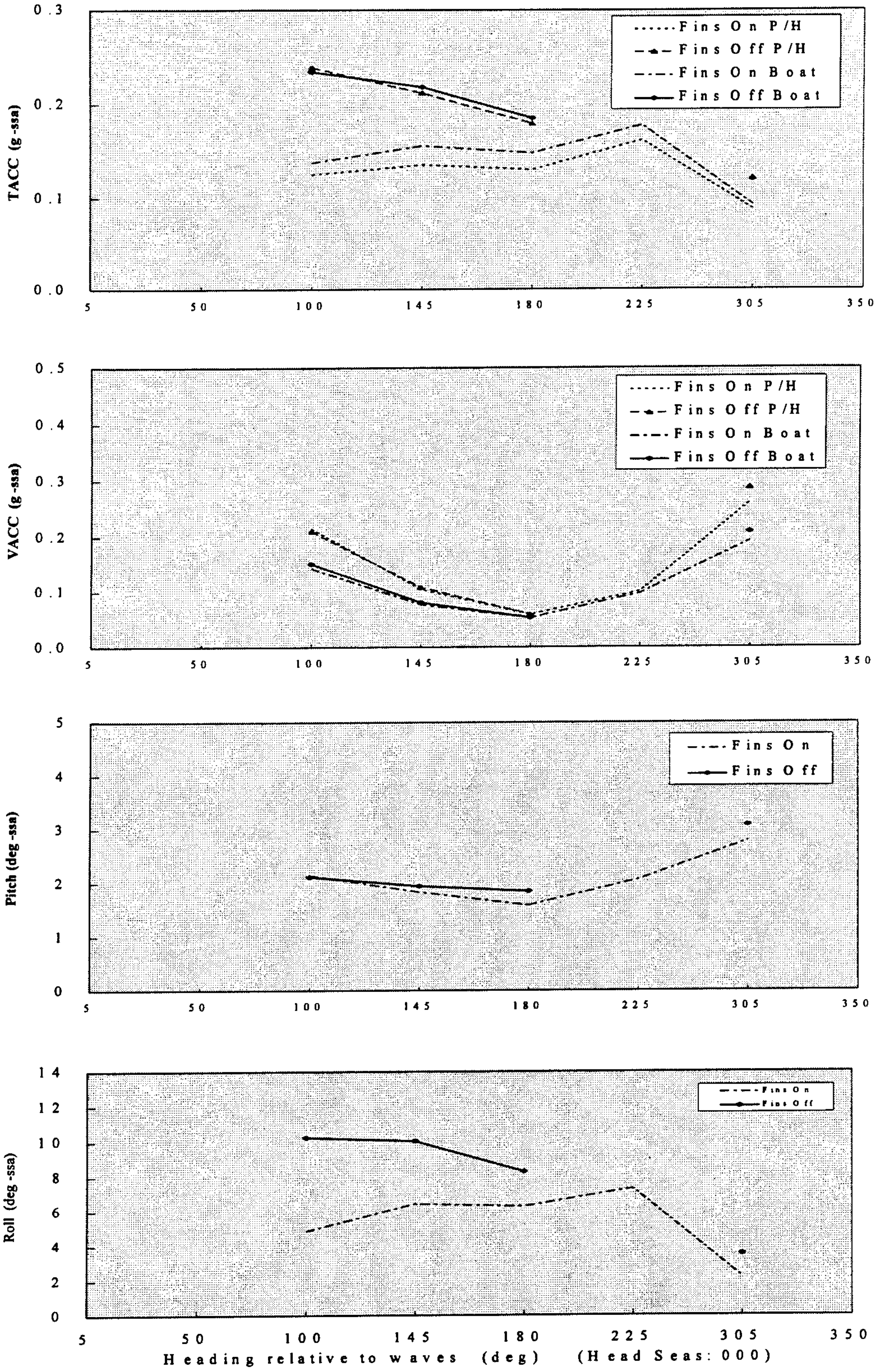

Figure 20- USCGC HARRIET LANE Fins On and Fins Off Ship Motion Comparisons for Octagon 3.

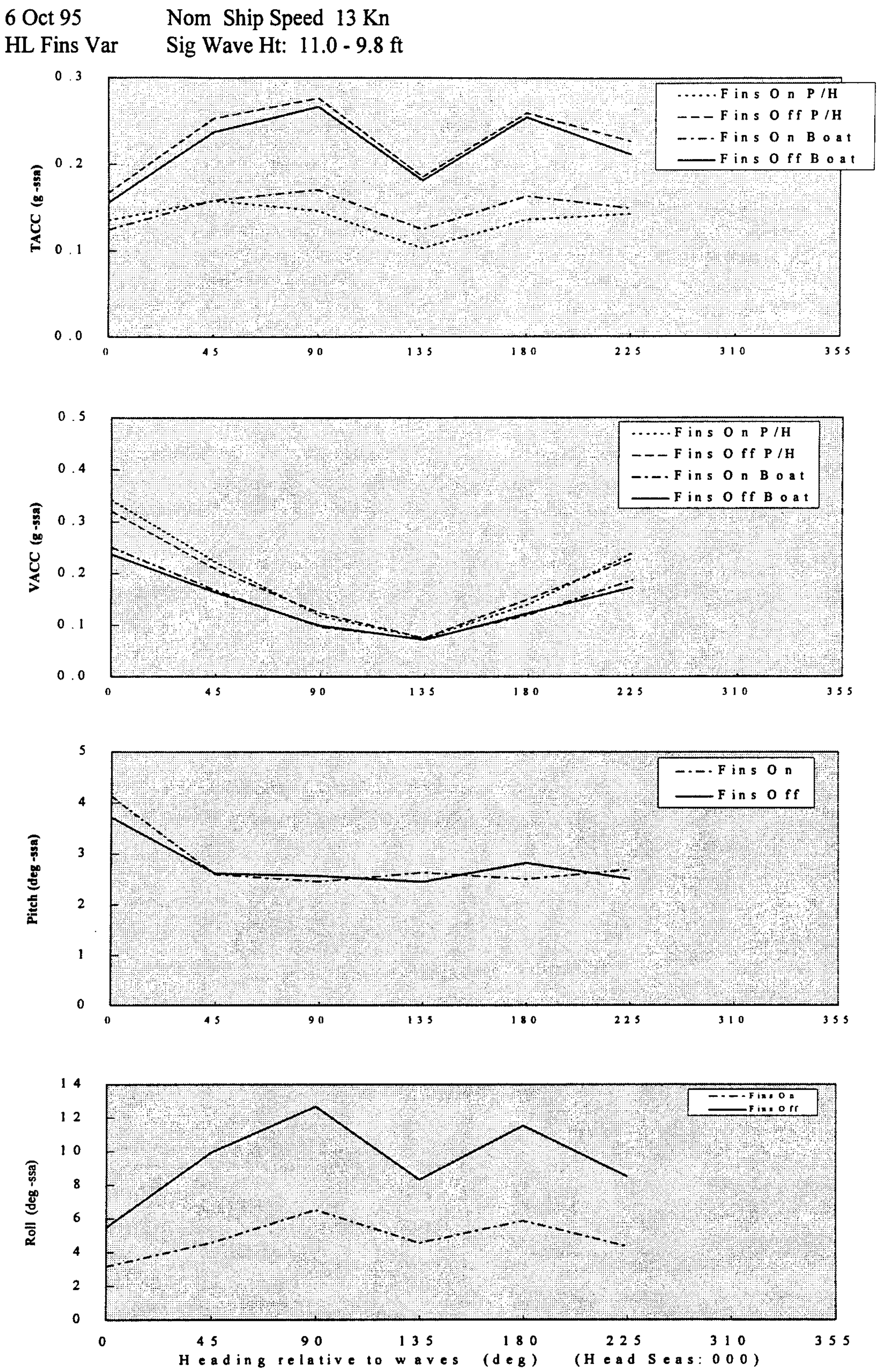

Figure 21- USCGC HARRIET LANE Fins On and Fins Off Ship Motion Comparison for Octagon 6.

25 Oct 95		Nom Ship Speed 8 Kn
HL Fins On		Sig Wave Ht: 15.8 ft

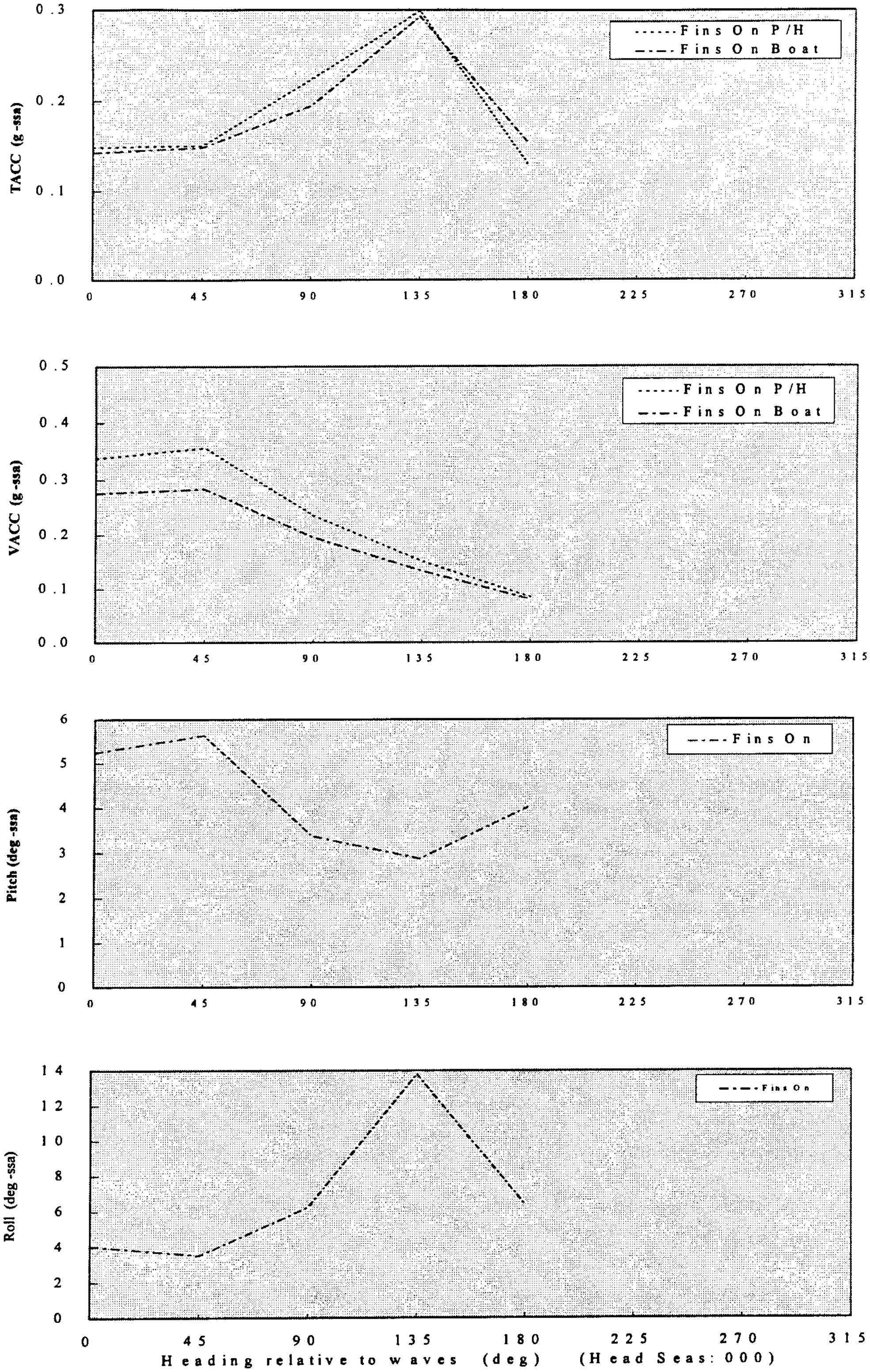

Figure 22- USCGC HARRIET LANE Fins On Ship Motion Measurement for Octagon 7.

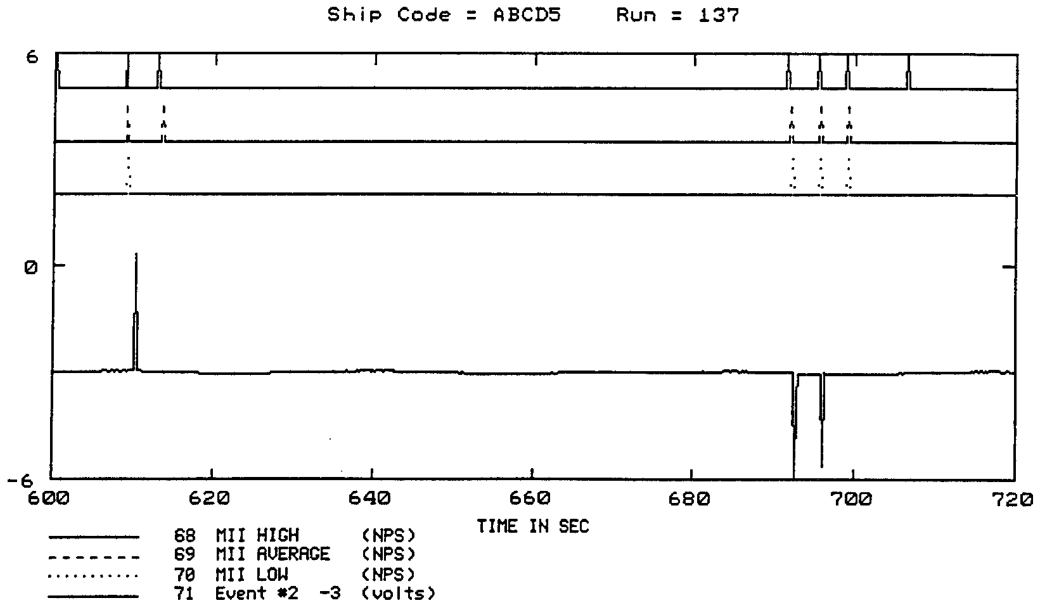

Fig. 23. Example of MII prediction model with actual occurrences.

Table 1. Comparison of the Full Load Hydrostatics for a 270 foot and 378 foot Coast Guard Cutters.

WMEC AND WHEC HYDROSTATICS

- Full Load Configuration

Parameter[†]	270 ft WMEC	378 ft WHEC
L_{PP}(ft)	255.0	350.0
B(ft)	37.7	41.9
T(ft)	13.8	15.1
A_{WP} (ft^2)	7562.2	11290.0
C_B	0.474	0.512
C_M	0.773	0.846
KG	17.60	17.69
GM_T	2.77	2.80
KM	20.37	20.49
$T\phi$ (sec)	10.7	11.6
Δ(LT)	1801	3238

[†] Note: 1 foot= 0.3048 meters.

Table 2. USCGC BOUTWELL SMR Data Channel Summary.

CHANNEL	UNITS	SOURCE	LOCATION
Wave height	feet	Wave buoys, receiver & antenna	Fantail, CIC, Aft mast (port yardarm)
Roll angle	degrees	Ship's gyrocompass	Forward IC
Pitch angle	degrees	Ship's gyrocompass	Forward IC
Ship's course	degrees	Ship's gyrocompass	Forward IC
Ship's speed	knots	Ship's speed log	Sewage treatment room
Wind speed	knots	Ship's anemometer	CIC
Wind direction	degrees	Ship's anemometer	CIC
Longitudinal accel.	g's	Triaxial accelerometer	Pilothouse
Transverse accel.	g's	Triaxial accelerometer	Pilothouse
Vertical accel.	g's	Triaxial accelerometer	Pilothouse
Longitudinal accel.	g's	Triaxial accelerometer	Hydraulic pump room [Port boat station]
Transverse accel.	g's	Triaxial accelerometer	Hydraulic pump room [Port boat station]
Vertical accel.	g's	Triaxial accelerometer	Hydraulic pump room [Port boat station]
Longitudinal accel.	g's	Triaxial accelerometer	Machinery room [CG]
Transverse accel.	g's	Triaxial accelerometer	Machinery room [CG]
Vertical accel.	g's	Triaxial accelerometer	Machinery room [CG]

Table 3. USCGC HARRIET LANE SMR Data Channel Summary.

CHANNEL	UNITS	SOURCE	LOCATION
Wave height, Relative bow motion (RBM), Vertical bow accel.	feet	TSK wave meter	Bow mount (radar head), paint locker (accelerometer), boatswain's locker (connector box), CIC (processor)
Roll angle	degrees	Ship's gyrocompass	CIC IC switchboard
Pitch angle	degrees	Ship's gyrocompass	CIC IC switchboard
Ship's course	degrees	Ship's gyrocompass	CIC IC switchboard
Ship's speed	knots	Ship's doppler speed log	CIC IC switchboard
Wind speed	knots	Ship's anemometer	CIC IC switchboard
Wind direction	degrees	Ship's anemometer	CIC IC switchboard
Longitudinal accel.	g's	Triaxial accelerometer	Pilothouse
Transverse accel.	g's	Triaxial accelerometer	Pilothouse
Vertical accel.	g's	Triaxial accelerometer	Pilothouse
Longitudinal accel.	g's	Triaxial accelerometer	Engine room [CG]
Transverse accel.	g's	Triaxial accelerometer	Engine room [CG]
Vertical accel.	g's	Triaxial accelerometer	Engine room [CG]
Longitudinal accel.	g's	Triaxial accelerometer	Steering gear room [Boat Sta]
Transverse accel.	g's	Triaxial accelerometer	Steering gear room [Boat Sta]
Vertical accel.	g's	Triaxial accelerometer	Steering gear room [Boat Sta]

Table 4. USCGC HARRIET LANE Wave Measurement Summary.

TSK OVER-THE-BOW WAVE HEIGHT SENSOR

- Significant Double Amplitude Statistics

Measurement	Date (1995)	Time (Z)	$H_{1/3}$ [90% conf. range] (ft)[†]	T_o (sec) primary/secondary	Sample Time (min)
81	24 Sep	1630	4.0 [3.6-4.5]	7.1	20
90	24 Sep	2030	4.9 [4.4-5.6]	10.1	20
141	26 Sep	2320	8.7 [7.7-9.9]	5.6/9.6	30
150	27 Sep	O445	12.1 [10.8-13.8]	7.1	30
161	27 Sep	1517	9.6 [8.6-10.7]	8.8/6.6	30
171	27 Sep	1914	9.9 [8.8-11.2]	7.8/5.9	20
175	27 Sep	2224	13.8 [12.3-15.42]	11.8/5.6	30
184	28 Sep	0412	13.4 [12.0-14.5]	10.6/6.6	30
198	28 Sep	1543	15.0 [13.4-17.1]	11.8/6.2	30
207	28 Sep	2059	13.4 [11.9-15.3]	12.6/6.3	30
398	06 Oct	1823	11.0 [9.9-12.4]	7.6	30
411	06 Oct	2327	9.8 [8.7-11.1]	7.8	20
784	25 Oct	2200	15.8[19.2-13.4]	13.5	12

[†] Note: 1 foot = .3048 meters.

Table 5. USCGC BOUTWELL and HARRIET LANE Trials Test Matrix.

TRIALS TEST MATRIX

OCTAGON	DATE (1995)	SPEED (knots)	SHIPS		SEA STATE	COMMENTS
			BOUTWELL	HARRIET LANE		
1	24 Sep	10	X[†]	X	4	Fins On
2	26 Sep	15	X	X	5	Fins On
3	27 Sep	15		X	5	Fins On/Off
4	27 Sep	15	X	X	6	Fins On
5	28 Sep	10	X	X	6	Fins On
6	06 Oct	13		X	5	Fins On/Off
7	25 Oct	8		X	6	Fins On

[†] Note: X Indicates test was performed.

Table 6 - USCGC HARRIET LANE and USCGC BOUTWELL Octagon 1 Ship Motion Measurement Summary.

USCGC HARRIET LANE (WHEC 903)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
81	241630Z	000	1.00	-2.46	1.54	-4.04	0.002	0.004	1.88	4.0		0
82	241707Z	000	1.26	-2.46	0.56	-1.54	0.038	-0.069	9.99	4.1	ON	1
83	241740Z	045	0.84	-1.85	0.72	-2.07	0.044	-0.079	10.55	4.3	ON	2
84	241813Z	090	0.78	1.45	1.19	-2.86	0.039	-0.079	10.25	4.3	ON	3
85	241836Z	135	1.09	1.63	1.13	2.51	0.023	-0.039	9.98	6.7	ON	4
86	241858Z	180	0.92	1.63	1.28	3.47	0.018	-0.032	9.82	5.9	ON	5
87	241921Z	225	0.70	-1.19	1.16	3.16	0.028	-0.063	10.08	5.8	ON	6
88	241944Z	270	0.86	-1.71	0.81	1.58	0.043	-0.080	10.79	4.7	ON	7
89	242006Z	315	1.58	-3.30	0.69	-1.71	0.054	0.102	10.76	4.9	ON	8
90	242030Z	010	1.39	-2.73	2.71	-4.48	0.032	-0.059	1.35	4.9		9

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

USCGC BOUTWELL (WHEC 719)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
75	241644Z	000	0.83	1.56	N/A	N/A	0.030	0.052	10.73	N/A	N/A	1
76	241742Z	040	0.70	1.33	N/A	N/A	0.043	0.083	10.78	N/A	N/A	2
77	241816Z	090	0.66	1.03	N/A	N/A	0.035	0.058	10.72	N/A	N/A	3
78	241838Z	135	0.66	1.03	N/A	N/A	0.019	-0.037	10.75	N/A	N/A	4
79	241900Z	180	0.60	0.98	N/A	N/A	0.013	-0.022	10.78	N/A	N/A	5
80	241923Z	225	0.53	1.03	N/A	N/A	0.028	0.049	11.01	N/A	N/A	6
81	241946Z	270	0.69	1.03	N/A	N/A	0.041	0.079	11.05	N/A	N/A	7
82	242008Z	315	1.19	1.91	N/A	N/A	0.040	-0.065	10.84	N/A	N/A	8

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

Table 7- USCGC HARRIET LANE and USCGC BOUTWELL Octagon 2 Ship Motion Measurement Summary.

USCGC HARRIET LANE (WHEC 903)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK	(kn)			
141	262320Z	000	1.90	4.04	4.56	8.09	0.055	-0.106	1.53	8.7		0
143	270044Z	045	2.25	-4.00	3.13	10.81	0.142	-0.272	13.91	9.4	ON	2
144	270118Z	090	1.84	3.56	5.51	15.82	0.117	-0.238	14.67	10.1	ON	3
145	270154Z	135	1.70	2.68	8.52	19.03	0.064	-0.124	15.09	14.1	ON	4
146	270229Z	180	1.61	-2.42	7.56	13.14	0.049	-0.111	14.75	12.3	ON	5
147	270305Z	225	2.48	-4.09	9.02	-22.81	0.111	0.217	14.71	12.4	ON	6
148	270340Z	270	3.25	5.71	4.02	-12.40	0.169	-0.293	14.83	12.3	ON	7
149	270414Z	315	4.23	-7.43	2.24	-9.93	0.190	-0.354	13.91	11.9	ON	8
150	270445Z	000	3.87	6.42	4.07	7.65	0.073	-0.120	1.61	12.1		9

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

USCGC BOUTWELL (WHEC 719)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK	(kn)			
130	270016Z	355	1.45	2.75	N/A	N/A	0.098	-0.170	14.10	N/A	N/A	1
131	270044Z	040	1.49	2.79	N/A	N/A	0.110	-0.195	13.30	N/A	N/A	2
132	270121Z	085	1.26	-2.71	N/A	N/A	0.101	-0.184	14.08	N/A	N/A	3
133	270156Z	130	0.98	-2.31	N/A	N/A	0.053	-0.126	14.72	N/A	N/A	4
134	270233Z	175	1.02	-1.83	N/A	N/A	0.051	0.108	15.03	N/A	N/A	5
135	270308Z	220	1.78	-3.06	N/A	N/A	0.096	0.182	14.34	N/A	N/A	6
136	270343Z	265	2.28	4.50	N/A	N/A	0.142	0.261	13.54	N/A	N/A	7
137	270417Z	310	3.01	-5.17	N/A	N/A	0.146	0.250	10.78	N/A	N/A	8

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

Table 8 - USCGC HARRIET LANE Octagon 3 Ship Motion Measurement Summary.

USCGC HARRIET LANE (WHEC 903)

Run #	Time	RELATIVE HEADING	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED	SIGNIFICANT WAVE HT.	FINS	LEG
		(deg)	SSA	PEAK	SSA	PEAK	SSA	PEAK	(kn)	(ft)		
161	271517Z	355	2.86	-5.10	3.52	6.20	0.067	0.127	0.80	9.6		0
162	271553Z	100	2.15	3.38	4.88	14.20	0.111	-0.206	13.28	10.2	ON	1
163	271622Z	100	2.12	3.87	10.26	22.15	0.114	-0.234	14.52	11.1	OFF	1
164	271645Z	145	1.84	2.81	6.45	14.55	0.065	-0.123	12.05	10.6	ON	2
165	271711Z	145	1.95	-3.52	10.05	17.71	0.066	-0.118	8.70	9.6	OFF	2
166	271733Z	180	1.59	-2.33	6.30	10.29	0.042	-0.076	8.94	9.9	ON	3
167	271758Z	180	1.86	-2.55	8.30	12.26	0.041	-0.084	14.78	11.5	OFF	3
168	271820Z	225	2.07	2.64	7.33	-10.68	0.076	0.106	13.73	10.1	ON	4
169	271828Z	305	2.79	-4.84	2.23	-5.23	0.128	0.195	13.93	8.8	ON	5
170	271850Z	305	3.08	-5.36	3.55	-8.44	0.143	-0.246	15.42	9.1	OFF	5
171	271914Z	355	3.38	-5.23	5.15	14.46	0.068	-0.122	7.30	9.9		9

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

Table 9- USCGC HARRIET LANE and USCGC BOUTWELL Octagon 4 Ship Motion Measurement Summary.

USCGC HARRIET LANE (WHEC 903)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
175	272224Z	000	4.06	-7.03	9.11	-14.77	0.087	0.148	1.40	13.8		0
176	272323Z	000	4.49	7.69	1.87	-4.35	0.164	-0.346	12.76	14.1	ON	1
177	280011Z	045	3.22	-6.42	2.63	7.60	0.153	-0.246	12.21	12.0	ON	2
178	280044Z	090	2.49	-5.05	6.93	18.59	0.123	0.228	9.17	11.5	ON	3
179	280120Z	135	2.17	-4.53	5.13	11.52	0.067	-0.123	13.84	11.4	ON	4
180	280156Z	180	2.44	3.69	7.80	11.47	0.035	-0.066	15.05	12.9	ON	5
181	280231Z	225	1.67	-3.56	9.69	-16.53	0.080	-0.190	14.45	11.8	ON	6
182	280305Z	270	2.76	-5.54	8.44	-21.49	0.137	-0.238	14.33	12.0	OFF	7
183	280338Z	315	4.32	-8.09	3.93	-10.99	0.175	0.311	13.95	14.8	OFF	8
184	280412Z	350	4.08	-7.74	9.45	-15.08	0.093	0.222	2.25	13.4		9

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

USCGC BOUTWELL (WHEC 719)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
153	272252Z	000	3.77	5.73	N/A	N/A	0.142	0.231	13.05	N/A	N/A	1
154	280015Z	045	2.55	4.55	N/A	N/A	0.129	-0.233	13.71	N/A	N/A	2
155	280047Z	090	1.86	3.14	N/A	N/A	0.099	0.197	14.46	N/A	N/A	3
156	280124Z	135	2.02	4.01	N/A	N/A	0.055	0.102	14.92	N/A	N/A	4
157	280157Z	180	1.69	3.10	N/A	N/A	0.028	-0.051	15.15	N/A	N/A	5
158	280233Z	225	1.43	2.79	N/A	N/A	0.076	0.128	15.10	N/A	N/A	6
159	280307Z	270	2.42	-4.11	N/A	N/A	0.120	-0.229	14.65	N/A	N/A	7
160	280340Z	315	3.73	7.36	N/A	N/A	0.147	-0.304	13.45	N/A	N/A	8

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

Table 10- USCGC HARRIET LANE and USCGC BOUTWELL Octagon 5 Ship Motion Measurement Summary.

USCGC HARRIET LANE (WHEC 903)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
198	281543Z	000	4.07	8.62	9.86	-17.63	0.091	0.161	1.16	15.0		0
199	281618Z	000	4.47	8.31	5.32	-13.05	0.136	-0.240	4.37	15.6	OFF	1
200	281700Z	045	3.23	6.55	8.05	13.19	0.126	0.224	5.58	13.7	OFF	2
201	281736Z	090	2.17	-3.78	10.60	19.21	0.100	-0.168	6.36	12.4	OFF	3
202	281810Z	135	2.43	-4.75	7.29	13.71	0.074	-0.163	9.02	12.8	OFF	4
203	281844Z	180	2.70	4.62	7.53	13.14	0.048	-0.106	8.67	13.7	OFF	5
204	281918Z	225	1.78	-3.30	10.73	-16.62	0.076	-0.135	9.96	14.1	OFF	6
205	281952Z	270	2.42	-4.44	9.53	-18.81	0.108	0.187	10.14	14.0	OFF	7
206	282025Z	315	3.77	-6.77	4.62	-11.60	0.125	-0.226	9.64	12.9	OFF	8
207	282059Z	005	3.53	5.76	9.63	-15.52	0.083	-0.144	0.61	13.4		9

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

USCGC BOUTWELL (WHEC 719)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
172	281542Z	000	3.49	-5.65	N/A	N/A	0.113	-0.180	9.32	N/A	N/A	1
173	281703Z	045	2.29	4.15	N/A	N/A	0.107	0.207	10.00	N/A	N/A	2
174	281738Z	090	1.76	2.92	N/A	N/A	0.091	-0.151	10.26	N/A	N/A	3
175	281813Z	135	2.20	3.49	N/A	N/A	0.063	-0.111	10.58	N/A	N/A	4
176	281846Z	180	2.17	3.66	N/A	N/A	0.042	-0.076	10.74	N/A	N/A	5
177	281920Z	225	1.47	2.08	N/A	N/A	0.071	-0.160	11.04	N/A	N/A	6
178	281953Z	270	1.98	3.31	N/A	N/A	0.098	0.166	10.73	N/A	N/A	7
179	282026Z	315	2.99	-5.88	N/A	N/A	0.104	-0.170	9.98	N/A	N/A	8

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

Table 11 - USCGC HARRIET LANE Octagon 6 Ship Motion Measurement Summary.

USCGC HARRIET LANE (WHEC 903)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
398	061823Z	315	3.57	-7.25	5.72	-10.73	0.072	0.177	1.64	11.0		0
399	061903Z	000	4.13	-7.30	3.18	8.57	0.160	-0.295	12.17	13.5	ON	1
400	061924Z	000	3.72	-6.02	5.48	11.69	0.148	-0.237	12.39	12.2	OFF	1
401	061946Z	045	2.60	-4.88	4.58	15.08	0.135	0.272	12.98	12.5	ON	2
402	062009Z	045	2.62	-4.44	9.95	24.40	0.127	-0.207	13.02	13.1	OFF	2
403	062030Z	090	2.46	3.96	6.51	17.93	0.075	-0.152	13.00	13.9	ON	3
404	062053Z	090	2.57	-4.44	12.67	20.66	0.078	0.149	13.13	13.7	OFF	3
405	062115Z	135	2.64	-3.60	4.56	8.13	0.054	-0.097	13.12	16.6	ON	4
406	062136Z	135	2.46	-3.74	8.31	-11.30	0.054	-0.087	13.27	14.5	OFF	4
407	062158Z	180	2.51	4.79	5.87	-14.73	0.081	-0.150	12.98	12.2	ON	5
408	062221Z	180	2.83	-4.44	11.54	-24.57	0.089	-0.143	13.21	13.4	OFF	5
409	062243Z	225	2.69	-5.58	4.34	-13.19	0.130	0.221	12.74	11.6	ON	6
410	062306Z	225	2.51	4.75	8.50	-15.21	0.123	0.214	13.17	11.1	OFF	6
411	062327Z	315	2.84	-5.14	6.68	-12.22	0.064	0.115	1.13	9.8		9

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

Table 12 - USCGC HARRIET LANE Octagon 7 Ship Motion Measurement Summary.

USCGC HARRIET LANE (WHEC 903)

Run #	Time	RELATIVE HEADING (deg)	PITCH (deg)		ROLL (deg)		COG V ACC (g)		SHIP SPEED (kn)	SIGNIFICANT WAVE HT. (ft)	FINS	LEG
			SSA	PEAK	SSA	PEAK	SSA	PEAK				
784	252200Z	000	4.95	-7.91	12.31	18.73	0.109	-0.179	0.80	15.8		0
785	252217Z	000	5.24	10.51	4.06	8.22	0.141	-0.257	7.43	15.6	ON	1
786	252249Z	045	5.63	-10.59	3.53	14.46	0.164	-0.356	7.28	15.6	ON	2
787	252312Z	090	3.38	6.90	6.24	26.64	0.149	-0.305	8.12	14.9	ON	3
788	252334Z	135	2.88	-4.92	13.78	31.08	0.120	-0.228	7.42	20.1	ON	4
789	252356Z	180	4.02	-5.54	6.40	12.22	0.058	0.112	9.21	20.6	ON	5

Note: 000 is head seas. SSA is single significant amplitude values. (2 * measured stdv) COG is the Center of Gravity.

Table 13- USCGC BOUTWELL and HARRIET LANE
SHIP MOTIONS AND COMMANDING OFFICERS' OBSERVATIONS
for 24 SEP 95

24-Sep-95 **Significant Wave Height:** 4.0 ft Before Octagon
4.9 ft After Octagon

HARRIET LANE

Degradation Level: none - 0; mild - 1; moderate - 2; severe - 3

RUN #	REL HDG (deg)	Ship Speed (kn)	Pitch (deg)	Roll (deg)	Pilot House (deg - ssa)		Boat Station (g - ssa)		FINS	Overall Crew Degr	Cause	Level	Overall Ship Degr	Cause	Level	If Spd Maintained what is long term perf degradation?	Was ship speed limited?	Would maintain speed?	Why?
			ssa	ssa	TACC	VACC	TACC	VACC											
82	000	10.0	1.26	0.56	0.025	0.10	0.029	0.075	on	0	X	X	0	X	X	0	n	y	X
83	045	10.5	0.84	0.72	0.042	0.082	0.038	0.064	on	0	X	X	0	X	X	0	n	y	X
84	090	10.2	0.78	1.1	0.038	0.063	0.044	0.049	on	0	X	X	0	X	X	0	n	y	X
85	135	10.0	1.09	1.1	0.026	0.037	0.039	0.032	on	0	X	X	0	X	X	0	n	y	X
86	180	9.8	0.92	1.28	0.026	0.033	0.036	0.029	on	0	X	X	0	X	X	0	n	y	X
87	225	10.	0.70	1.1	0.032	0.037	0.042	0.035	on	0	X	X	0	X	X	0	n	y	X
88	270	10.8	0.86	0.81	0.042	0.068	0.042	0.058	on	0	X	X	0	X	X	0	n	y	X
89	315	10.8	1.58	0.69	0.036	0.11	0.042	0.094	on	0	X	X	0	X	X	0	n	y	X

BOUTWELL

75	000	10.7	0.83	X	0.023	0.060	0.021	0.053	n/a	0	X	X	0	X	X	0	n	X	X
76	040	10.8	0.70	X	0.058	0.064	0.052	0.060	n/a	0	X	X	0	X	X	0	X	X	X
77	090	10.7	0.66	X	0.085	0.049	0.075	0.046	n/a	0	X	X	0	X	X	0	X	X	X
78	135	10.7	0.66	X	0.053	0.027	0.047	0.025	n/a	0	X	X	0	X	X	0	X	X	X
79	180	10.8	0.60	X	0.051	0.021	0.047	0.019	n/a	0	X	X	0	X	X	0	X	X	X
80	225	11.	0.53	X	0.094	0.033	0.084	0.033	n/a	0	X	X	0	X	X	0	X	X	X
81	270	11.	0.69	X	0.062	0.056	0.055	0.051	n/a	0	X	X	0	X	X	0	n	X	X
82	315	10.8	1.1	X	0.033	0.076	0.030	0.066	n/a	0	X	X	0	X	X	0	n	X	X

Table 14- USCGC BOUTWELL and HARRIET LANE
SHIP MOTIONS AND COMMANDING OFFICERS' OBSERVATIONS
for 26 SEP 95

26-Sep-95 **Significant Wave Height:** 8.7 ft Before Octagon
HARRIET LANE 12.1 ft After Octagon **Degradation Level:** none - 0; mild - 1; moderate - 2; severe - 3

RUN #	REL HDG (deg)	Ship Speed (kn)	Pitch (deg)	Roll (deg)	Pilot House (deg - ssa)		Boat Station (g - ssa)		FINS	Overall Crew Degr	Cause	Level	Overall Ship Degr	Cause	Level	If Spd Maintained what is long term perf degradation?	Was ship speed limited?	Would maintain speed?	Why?
			ssa	ssa	TACC	VACC	TACC	VACC											
142	000	X	X	X	X	X	X	X	X	1	pitching	2	1	speed	2	2	y	n	X
143	045	13.9	2.25	3.13	0.103	0.291	0.108	0.190	on	1	pitching	1	1	speed	1	1	y	n	X
144	090	14.7	1.84	5.51	0.139	0.180	0.156	0.136	on	0	pitching	0	0	speed	0	0	n	y	X
145	135	15.1	1.70	8.52	0.176	0.090	0.201	0.078	on	0	pitching	0	0	speed	0	0	n	y	X
146	180	14.8	1.61	7.56	0.155	0.071	0.176	0.062	on	1	roll/MII	2	0	X	X	1	n	y	to conduct SAR
147	225	14.7	2.48	9.02	0.202	0.183	0.231	0.146	on	X	roll/MII	3	1	speed	1	1	n	y	to conduct SAR
148	270	14.8	3.25	4.02	0.150	0.329	0.158	0.236	on	X	X	X	X	X	X	X	X	X	X
149	315	13.9	4.23	2.24	0.125	0.440	0.121	0.297	on	2	roll/MII	2	2	speed	2	3	y	n	X

BOUTWELL

130	355	14.1	1.45	X	0.079	0.166	0.070	0.152	n/a	0	X	X	1	wind	1	1	n	y	X
131	040	13.3	1.49	X	0.113	0.177	0.101	0.162	n/a	0	X	X	1	wind	1	1	n	y	X
132	085	14.1	1.26	X	0.121	0.136	0.109	0.128	n/a	0	X	X	1	wind	1	1	n	y	X
133	130	14.7	0.98	X	0.100	0.069	0.091	0.065	n/a	0	X	X	1	wind	1	1	n	y	X
134	175	15.0	1.02	X	0.115	0.066	0.105	0.063	n/a	0	35k wnd	0	0	X	X	0	n	y	X
135	220	14.3	1.78	X	0.163	0.140	0.148	0.128	n/a	0	35k wnd	0	0	X	X	0	n	y	X
136	265	13.5	2.28	X	0.168	0.222	0.151	0.201	n/a	0	35k wnd	0	0	X	X	0	n	y	X
137	310	10.8	3.01	X	0.109	0.278	0.095	0.244	n/a	0	35k wnd	0	0	X	X	0	n	y	X

Table 15- USCGC BOUTWELL and HARRIET LANE
SHIP MOTIONS AND COMMANDING OFFICERS' OBSERVATIONS
for 27 SEP 95

27-Sep-95 **Significant Wave Height:** 13.8 ft Before Octagon

HARRIET LANE 13.4 ft After Octagon

Degradation Level: none - 0; mild - 1; moderate - 2; severe - 3

RUN #	REL HDG (deg)	Ship Speed (kn)	Pitch (deg)	Roll (deg)	Pilot House (deg - ssa)		Boat Station (g - ssa)		FINS	Overall Crew Degr	Cause	Level	Overall Ship Degr	Cause	Level	If Spd Maintained what is long term perf degradation?	Was ship speed limited?	Would maintain speed?	Why?
			ssa	ssa	TACC	VACC	TACC	VACC											
176	000	12.8	4.49	1.87	0.091	0.357	0.087	0.260	on	1	MII	1	1	Wetness	2	1	y	y	urgent SAR
177	045	12.2	3.22	2.63	0.120	0.303	0.104	0.215	on	1	MII	1	1	Pit/Roll	1	1	y	y	urgent SAR
178	090	9.2	2.49	6.93	0.168	0.215	0.169	0.153	on	1	MII	1	0	X	X	0	n	y	as fuel state permits
179	135	13.8	2.17	5.13	0.117	0.097	0.134	0.077	on	0	MII	0	0	Pit/Roll	0	0	n	y	as fuel state permits
180	180	15.1	2.44	7.80	0.157	0.056	0.174	0.048	on	0	MII	0	X	Pit/Roll	0	0	n	y	as fuel state permits
181	225	14.4	1.67	9.69	0.221	0.111	0.211	0.101	on	0	MII	0	X	Wetness	1	0	n	y	as fuel state permits
182	270	14.3	2.76	8.44	0.226	0.224	0.208	0.179	off	0	MII	1	X	P/R/Wet	1,1	0	n	y	as fuel state permits
183	315	13.9	4.32	3.93	0.137	0.351	0.128	0.254	off	1	MII	1	X	P/R/MII	2,2	1	y	y	urgent SAR
BOUTWELL																			
153	000	13.0	3.77	X	0.129	0.250	0.115	0.223	n/a	1	MII	1	X	VACC	1	1	n	y	X
154	045	13.7	2.55	X	0.175	0.206	0.155	0.189	n/a	1	VACC	1	X	VACC	1	1	n	y	X
155	090	14.5	1.86	X	0.154	0.145	0.138	0.134	n/a	1	MII	1	X	Roll	1	1	n	y	X
156	135	14.9	2.02	X	0.136	0.071	0.123	0.066	n/a	0	X	X	0	Roll	1	1	y	y	X
157	180	15.1	1.69	X	0.105	0.038	0.099	0.036	n/a	0	X	X	X	Roll	1	1	n	y	X
158	225	15.1	1.43	X	0.172	0.096	0.156	0.091	n/a	1	X	X	X	Roll	1	1	n	y	X
159	270	14.7	2.42	X	0.171	0.170	0.154	0.155	n/a	1	X	X	X	Roll	1	1	n	y	X
160	315	13.4	3.73	X	0.111	0.245	0.099	0.219	n/a	1	MII	1	X	Heave	1	1	n	y	X

Table 16- USCGC BOUTWELL and HARRIET LANE
SHIP MOTIONS AND COMMANDING OFFICERS' OBSERVATIONS
for 28 SEP 95

28-Sep-95 **Significant Wave Height:** 15.0 ft Before Octagon

HARRIET LANE 13.4 ft After Octagon

Degradation Level: none - 0; mild - 1; moderate - 2; severe - 3

RUN #	REL HDG (deg)	Ship Speed (kn)	Pitch (deg)	Roll (deg)	Pilot House (deg - ssa)		Boat Station (g - ssa)		FINS	Overall Crew Degr	Cause	Level	Overall Ship Degr	Cause	Level	If Spd Maintained what is long term perf degradation?	Was ship speed limited?	Would maintain speed?	Why?
			ssa	ssa	TACC	VACC	TACC	VACC											
199	000	4.4	4.47	5.32	0.166	0.292	0.143	0.222	off	1	Fatigue	1	1	Roll	1	1	n	y	most fuel efficient speed
200	045	5.6	3.23	8.05	0.230	0.251	0.186	0.188	off	1	Fatigue	1	1	Roll	2	1	n	y	most fuel efficient speed
201	090	6.4	2.17	10.60	0.245	0.174	0.215	0.133	off	1	Fatigue	1	1	Roll	1	1	n	y	most fuel efficient speed
202	135	9.0	2.43	7.29	0.167	0.121	0.160	0.093	off	1	Fatigue	1	X	Roll	0	0	n	y	most fuel efficient speed
203	180	8.7	2.70	7.53	0.163	0.071	0.157	0.070	off	1	Fatigue	1	0	Roll	0	0	n	y	most fuel efficient speed
204	225	10.0	1.78	10.73	0.240	0.097	0.214	0.093	off	1	Fatigue	1	1	Roll	1	0	n	y	most fuel efficient speed
205	270	10.1	2.42	9.53	0.253	0.156	0.215	0.145	off	1	Fat/MII	1,1	1	Roll	1	0	n	y	most fuel efficient speed
206	315	9.6	3.77	4.62	0.146	0.231	0.137	0.192	off	1	Fatigue	1	0	Roll	0	0	n	y	most fuel efficient speed

BOUTWELL

172	000	9.3	3.49	X	0.135	0.195	0.120	0.175	n/a	1	MII	1	1	Hev/Pit	1	1	n	y	X
173	045	10.0	2.29	X	0.190	0.163	0.168	0.150	n/a	1	MII	1	X	Roll	1	1	n	y	X
174	090	10.3	1.76	X	0.180	0.127	0.160	0.118	n/a	0	X	X	0	X	X	1	n	y	X
175	135	10.6	2.20	X	0.113	0.087	0.101	0.081	n/a	0	X	X	0	X	X	X	n	y	X
176	180	10.7	2.17	X	0.120	0.058	0.108	0.054	n/a	0	X	X	0	X	X	1	n	y	X
177	225	11.0	1.47	X	0.201	0.082	0.180	0.080	n/a	1	X	1	1	X	1	1	n	y	X
178	270	10.7	1.98	X	0.184	0.132	0.166	0.122	n/a	1	X	1	1	X	1	1	n	y	X
179	315	10.0	2.99	X	0.108	0.170	0.097	0.151	n/a	1	X	1	1	X	1	1	n	y	X

Table 17- USCGC HARRIET LANE FINS ON and FINS OFF
SHIP MOTIONS AND COMMANDING OFFICER'S OBSERVATIONS
for 6 OCT 95

6-Oct-95 **Significant Wave Height:** 11.0 ft Before Octagon
HARRIET LANE 9.8 ft After Octagon **Degradation Level:** none - 0; mild - 1; moderate - 2; severe - 3

RUN #	REL HDG (deg)	Ship Speed (kn)	Pitch (deg)	Roll (deg)	Pilot House (deg - ssa)		Boat Station (g - ssa)		FINS	Overall Crew Degr	Cause	Level	Overall Ship Degr	Cause	Level	If Spd Maintained what is long term perf degradation?	Was ship speed limited?	Would maintain speed?	Why?
			ssa	ssa	TACC	VACC	TACC	VACC											
399	000	12.2	4.13	3.18	0.136	0.342	0.125	0.251	on	X	X	X	X	X	X	X	X	X	X
401	045	13.0	2.60	4.58	0.158	0.222	0.159	0.168	on	1	MII	1	X	Roll	1	1	y	y	urgent SAR
403	090	13.0	2.46	6.51	0.147	0.118	0.171	0.097	on	1	MII	1	X	Roll	1	1	n	y	X
405	135	13.1	2.64	4.56	0.103	0.075	0.125	0.073	on	2	MII	2	2	Roll	2	2	n	n	roll would induce fatigue
407	180	13.0	2.51	5.87	0.136	0.140	0.164	0.120	on	0	MII	0	0	Roll	0	0	n	y	X
409	225	12.7	2.69	4.34	0.143	0.240	0.149	0.188	on	2	MII	2	X	Roll	2	2	n	n	fatigue
X	310	X	X	X	X	X	X	X	X	1	MII	1	X	Roll	1	1	n	y	X
X	355	X	X	X	X	X	X	X	X	1	MII	1	X	Roll	1	1	n	y	X

HARRIET LANE

400	000	12.4	3.72	5.48	0.167	0.320	0.156	0.238	off	X	X	X	X	X	X	X	X	X	X
402	045	13.0	2.62	9.95	0.253	0.209	0.237	0.164	off	1	MII	1	X	Roll	1	1	y	y	urgent SAR
404	090	13.1	2.57	12.67	0.276	0.124	0.266	0.100	off	1	MII	1	X	Roll	1	1	n	y	X
406	135	13.3	2.46	8.31	0.186	0.076	0.182	0.072	off	2	MII	2	2	Roll	2	2	n	n	roll would induce fatigue
408	180	13.2	2.83	11.54	0.259	0.150	0.255	0.123	off	0	MII	0	0	Roll	0	0	n	y	X
410	225	13.2	2.51	8.50	0.227	0.230	0.212	0.174	off	2	MII	2	X	Roll	2	2	n	n	fatigue
X	310	X	X	X	X	X	X	X	X	1	MII	1	X	Roll	1	1	n	y	X
X	355	X	X	X	X	X	X	X	X	1	MII	1	X	Roll	1	1	n	y	X

Table 18. Summary of Spectral Analysis of Pilot House Vertical Acceleration in Head Seas for 3 Octagons.

PILOT HOUSE VERTICAL ACCELERATION

OCTAGON	SHIP	RUN	VERTICAL ACCELERATION	
			(g-rms)	Modal Period (sec)
2	HARRIET LANE	149	.215	5.33
2	BOUTWELL	137	.134	5.33
4	HARRIET LANE	176	.176	5.16
4	BOUTWELL	153	.124	5.71
5	HARRIET LANE	199	.144	5.16
5	BOUTWELL	172	.097	5.52

Table 19 - USCGC HARRIET LANE and USCGC BOUTWELL ship motion measurements relating to Small Boat Deployment/Retrieval.

Run #	Time	PITCH (deg) SSA	ROLL (deg) SSA	PILOTHOUSE		BOAT LOCATION		TSK	GO OR NO-GO	SHIP
				TRANSVERSE ACC (g-SSA)	VERTICAL ACC (g-SSA)	TRANSVERSE ACC (g-SSA)	VERTICAL ACC (g-SSA)	SIGNIFICANT WAVE HT (ft)		
43	230218Z	2.435	1.927	0.069	0.191	0.081	0.15	8.231	0	HAR. LANE
44	230318Z	2.312	2.708	0.074	0.193	0.087	0.144	8.032	0	HAR. LANE
42	230118Z	2.218	5.172	0.137	0.154	0.128	0.128	8.055	0	HAR. LANE
37	222018Z	1.782	5.452	0.139	0.102	0.125	0.088	6.929	0	HAR. LANE
38	222118Z	1.754	7.021	0.179	0.088	0.153	0.088	6.677	0	HAR. LANE
257	302212Z	1.735	4.429	0.115	0.123	0.138	0.106	11.497	0	HAR. LANE
39	222218Z	1.73	6.23	0.165	0.088	0.143	0.091	6.424	0	HAR. LANE
240	300511Z	1.702	5.086	0.123	0.102	0.114	0.094	6.878	0	HAR. LANE
230	291911Z	1.646	5.604	0.145	0.101	0.126	0.092	6.559	0	HAR. LANE
256	302112Z	1.59	4.191	0.109	0.13	0.131	0.105	11.642	0	HAR. LANE
238	300311Z	1.515	5.994	0.14	0.082	0.124	0.078	6.116	0	HAR. LANE
255	302012Z	1.422	3.269	0.085	0.118	0.112	0.097	10.241	0	HAR. LANE
111	251757Z	1.413	2.936	0.079	0.095	0.089	0.086	6.394	0	HAR. LANE
239	300411Z	1.385	6.036	0.14	0.078	0.127	0.079	6.429	0	HAR. LANE
231	292011Z	1.333	7.645	0.181	0.071	0.16	0.074	6.919	0	HAR. LANE
252	301711Z	1.316	2.674	0.073	0.124	0.085	0.099	7.228	0	HAR. LANE
251	301611Z	1.188	3.194	0.075	0.093	0.083	0.081	7.232	0	HAR. LANE
110	251657Z	1.083	2.534	0.069	0.077	0.077	0.069	7.087	0	HAR. LANE
334	040159Z	0.881	0.948	0.037	0.083	0.041	0.062	3.27	0	HAR. LANE
328	031959Z	0.808	1.754	0.05	0.059	0.058	0.054	4.163	0	HAR. LANE
335	040324Z	0.664	1.698	0.042	0.038	0.05	0.04	3.038	0	HAR. LANE
336	040424Z	0.6	1.512	0.038	0.032	0.046	0.035	3.2	0	HAR. LANE
183	280338Z	4.319	3.927	0.137	0.351	0.128	0.254	14.83	1	HAR. LANE
148	270340Z	3.246	4.021	0.15	0.329	0.158	0.236	12.307	1	HAR. LANE
160	280340Z	3.728		0.111	0.245	0.099	0.219		1	BOUTWELL
136	270343Z	2.275		0.168	0.222	0.151	0.201		1	BOUTWELL

Table 20 - Largest Significant Single Amplitude Motion values measured during Small Boat Deployment/Retrieval.

PITCH (deg) SSA	ROLL (deg) SSA	PILOTHOUSE		BOAT LOCATION		TSK SIGNIFICANT WAVE HT (ft)	GO OR NO-GO	SHIP
		TRANSVERSE ACC (g-SSA)	VERTICAL ACC (g-SSA)	TRANSVERSE ACC (g-SSA)	VERTICAL ACC (g-SSA)			
2.435	7.645	0.181	0.193	0.153	0.15	11.642	0	HAR. LANE

Table 21 - Smallest Significant Single Amplitude Motion values measured during “No-Go” conditions.

PITCH (deg) SSA	ROLL (deg) SSA	PILOTHOUSE		BOAT LOCATION		TSK SIGNIFICANT WAVE HT (ft)	GO OR NO-GO	SHIP
		TRANSVERSE ACC (g-SSA)	VERTICAL ACC (g-SSA)	TRANSVERSE ACC (g-SSA)	VERTICAL ACC (g-SSA)			
3.246	3.927	0.137	0.329	0.128	0.236	12.307	1	HAR. LANE
2.275		0.111	0.222	0.099	0.201		1	BOUTWELL

Table 22 - Coast Guard Cutter Small Boat Launch and Recovery motion limiting criteria.

PITCH (deg) SSA	**ROLL** (deg) SSA	**PILOTHOUSE**	**BOAT LOCATION**	**SHIP**
		VERTICAL ACC (g-SSA)	**VERTICAL ACC** (g-SSA)	
2.5	8	0.2	0.2	BOTH

Table 23. Winter Transit Mission Percent Time Operability Calculations.

TRANSIT MISSION

- Ship Characteristics†

	CG378	CG270 with active fins
Disp (LT)	3229	1802
Length (ft)	350	255
Beam (ft)	42	37
Draft (ft)	15	14
• Percent Time Operable		
Bering Sea[1]	66.6	50.8
N. Pacific (Aleutians).[2]	59.9	41.6
Gulf of Alaska[3]	54.4	37.7
• Percent Time Limited by each Criteria (Bering Sea)		
Roll (8°SSA[4])[5]	14.3	31.4
Pitch (3°SSA[4])[5]	19.1	17.8

[1] (56°N 171°W) [2] (50°N 179°W) [3] (51°N 159°W) [4] Significant Single Amplitude

[5] Limiting value

†Note: 1 foot=0.3048 meters

Table 24. Annual Transit Mission Percent Time Operability Calculations.

TRANSIT MISSION

- Ship Characteristics†

	CG378	CG270 with active fins
Disp (LT)	3229	1802
Length (ft)	350	255
Beam (ft)	42	37
Draft (ft)	15	14

- Percent Time Operable

Bering Sea[1]	78.2	65.7
N. Pacific (Aleutians).[2]	72.2	57.1
Gulf of Alaska[3]	68.7	52.8

- Percent Time Limited by each Criteria (Bering Sea)

Roll (8°SSA[4])[5]	9.3	21.9
Pitch (3°SSA[4])[5]	12.5	12.5

[1] (56°N 171°W) [2] (50°N 179°W) [3] (51°N 159°W) [4] Significant Single Amplitude

[5] Limiting value

†Note: 1 foot=0.3048 meters

Table 25. Winter Helicopter Launch and Recovery Percent Time Operability Calculations.

HELICOPTER LAUNCH AND RECOVERY MISSION

- Ship Characteristics†

	CG378	CG270 with active fins
Disp (LT)	3229	1802
Length (ft)	350	255
Beam (ft)	42	37
Draft (ft)	15	14

- Percent Time Operable

Bering Sea[1]	35.7	23.2
N. Pacific (Aleutians).[2]	27.4	17.1
Gulf of Alaska[3]	25.2	14.9

- Percent Time Limited by each Criteria (Bering Sea)

Roll (5°SSA[4])[5]	54.7	65.9
Pitch (2°SSA[4])[5]	9.5	11.0

[1] (56°N 171°W) [2] (50°N 179°W) [3] (51°N 159°W) [4] Significant Single Amplitude
[5] Limiting value.
†Note: 1 foot=0.3048 meters

Table 26. Annual Helicopter Launch and Recovery Percent Time Operability Calculations.

HELICOPTER LAUNCH AND RECOVERY MISSION

- Ship Characteristics†

	CG378	CG270 with active fins
Disp (LT)	3229	1802
Length (ft)	350	255
Beam (ft)	42	37
Draft (ft)	15	14

- Percent Time Operable

Bering Sea[1]	56.2	42.6
N. Pacific (Aleutians).[2]	46.7	32.7
Gulf of Alaska[3]	43.6	30.0

- Percent Time Limited by each Criteria (Bering Sea)

Roll (5°SSA[4])[5]	36.9	48.8
Pitch (2°SSA[4])[5]	7.0	8.6

[1] (56°N 171°W) [2] (50°N 179°W) [3] (51°N 159°W) [4] Significant Single Amplitude
[5] Limiting value.
†Note: 1 foot=0.3048 meters

Table 27. Winter Small Boat Launch and Recovery Mission Percent Time Operability Calculations.

SMALL BOAT LAUNCH AND RECOVERY MISSION

- Ship Characteristics†

	CG378	CG270 with active fins
Disp (LT)	3229	1802
Length (ft)	350	255
Beam (ft)	42	37
Draft (ft)	15	14

- Percent Time Operable

Bering Sea[1]	54.1	50.4
N. Pacific (Aleutians).[2]	44.7	41.0
Gulf of Alaska[3]	40.0	36.7

- Percent Time Limited by each Criteria (Bering Sea)

Roll (8°SSA[4])[5]	4.2	31.2
Pitch (2.5°SSA[4])[5]	41.8	18.4

[1] (56°N 171°W) [2] (50°N 179°W) [3] (51°N 159°W) [4] Significant Single Amplitude

[5] Limiting value

†Note: 1 foot=0.3048 meters

Table 28. Annual Small Boat Launch and Recovery Mission Percent Time Operability Calculations.

SMALL BOAT LAUNCH AND RECOVERY MISSION

- Ship Characteristics†

	CG378	CG270 with active fins
Disp (LT)	3229	1802
Length (ft)	350	255
Beam (ft)	42	37
Draft (ft)	15	14

- Percent Time Operable

Bering Sea[1]	69.0	65.2
N. Pacific (Aleutians).[2]	60.8	56.2
Gulf of Alaska[3]	56.3	51.6

- Percent Time Limited by each Criteria (Bering Sea)

Roll (8°SSA[4])[5]	2.8	22.5
Pitch (2.5°SSA[4])[5]	28.2	12.3

[1] (56°N 171°W) [2] (50°N 179°W) [3] (51°N 159°W) [4] Significant Single Amplitude
[5] Limiting value
†Note: 1 foot=0.3048 meters

REFERENCES

1. Thomas III, William L. and Wah T. Lee, "Ship Designer's Atlas for Cold Weather Regions," DTRC Report DTRC/SPD-1212-01 (Feb 1987).

2. Director, Naval Oceanography and Meteorology, "U. S. Navy Marine Climatic Atlas of the World - Volume II - North Pacific Ocean, NAVAIR 50-1C-529," (March 1977).

3. Bales, S. L., L. R. Elliot, and W. L. Thomas III, "Degradation of Surface Ship Operation in Arctic/Cold Weather Regions," Paper presented at the U. S. Navy Symposium on Arctic/Cold Weather Operations of Surface Ships (Dec 1985).

4. Diamond, R. E., "Operational Experience in Northern Latitudes," In: *U. S. Navy Symposium on Arctic/Cold Weather Operations of Surface Ships*, Deputy Chief of Naval Operations for Surface Warfare (19-20Nov 1987).

5. Applebee, T. R. and A. E. Baitis, "Seakeeping Investigation of the U. S. Coast Guard 270-Ft Medium Edurance Class Cutters: Sea Trials Aboard the USCGC Bear (WMEC 901)," DTNSRDC Report DTNSRDC/SPD-1120-01 (Aug 1984).

6. Baitis, A. E. and T. R. Applebee, "U. S. Coast Guard 270-Ft Medium Edurance Cutters Fin Stabilizer Performance," DTNSRDC Report DTNSRDC/SPD-1120-02 (Oct 1985).

7. Applebee, T. R. and D. Burton, "Comparison of Operational Capabilities for Alaskan Patrol (ALPAT 95)- Instrumentation and Test Program for WMEC and WHEC," USCG Naval Engineering Report CG-ENE5-95-0001 (Sep 1995).

8. Lai, R. J. and R. J. Bachman, "Directional Wave Measurement and Analysis," DTNSRDC Report DTNSRDC/SPD-1167-01 (Sept 1985).

9. Marshall, D. E. and J. M. Bishop, *A Practical Guide to Ocean Wave Measurement and Analysis*, Endeco Inc., Marion, Mass (1984).

10. Baitis, A. E., C. C. Bennet, and W. G. Meyers, "Seakeeping Criteria for Mission Performance Capability Assessment USCGC 47-Ft and the 110-Ft Unstabilized and Stabilized in 10 Typical Operational Areas," NSWC Report CRDNSWC-HD-1424-01 (Nov 1994).

11. Baitis, A. E., T. R. Applebee, and T. M. McNamara, "Human Factors Considerations Applied to Operations of the FFG-8 and the LAMPS MK III," *Naval Engineers Journal*, Vol. 96, No. 3 (May 1984).

12. Graham, R., A. E. Baitis, and W. G. Meyers, "On the Development of Seakeeping Criteria," *Naval Engineers Journal*, Vol. 104, No. 3 (May 1992).

13. McCauley, M. E., "Motion Sickness Incidence: Exploratory Studies of Habitation, Pitch and Roll, and the Refinement of Mathematical Model," Human Factors Research Inc. Report 1733-2 (April 1976).

14. Applebee, T. R., T. M. McNamara, and A. E. Baitis, "Investigation into the Seakeeping Characteristics of the U. S. Coast Guard 140-Ft WTGB Class Cutters: Sea Trial Aboard the USCGC Mobile Bay," DTNSRDC Report DTNSRDC/SPD-0938-01 (March 1980).

15. McCreight, K. K. and R. G. Stahl, "Seakeeping Evaluation Program (SEP)- Revision 1: User's Manual," DTNSRDC Report DTNSRDC/SHD-1223-02 (Aug 1987).

16. Meyers, W. G., T. R. Applebee, and A. E. Baitis, "User's Manual for the Standard Ship Motion Program, SMP," DTNSRDC Report DTNSRDC/SPD-0936-01 (Sep 1981).

17. Cox, G. G. and A. R. Lloyd, "Hydrodynamic Design Basis for Navy Ship Roll Motion Stabilization," *Trans. SNAME*, Vol. 78 (1977).

18. Smith, T. C. and W. L. Thomas III, "A Survey and Comparison of Criteria for Naval Missions," DTRC Report DTRC/SHD-1312-01 (Oct 1989).

19. Comstock, E. N., S. L. Bales, and D. M. Gentile, "Seakeeping Performance Comparison of Air Capabale Ships," *Naval Engineers Journal* (April 1982).