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RESULTS OF ROUGH WATER TRIALS ON A FSHV (FULL SCALE HYDRODYNAMIC VEHICLE) REPRESENTING AN LVA PLANING HULL CONCEPT

by

Alvin Gersten
William B. Dixon and
J. Brooks Peters

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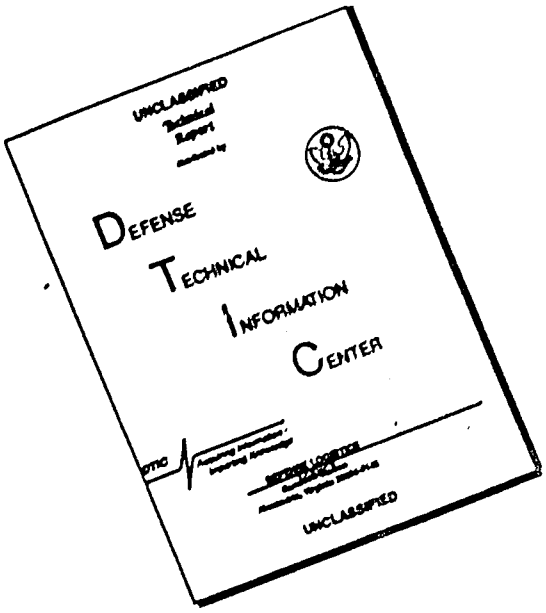

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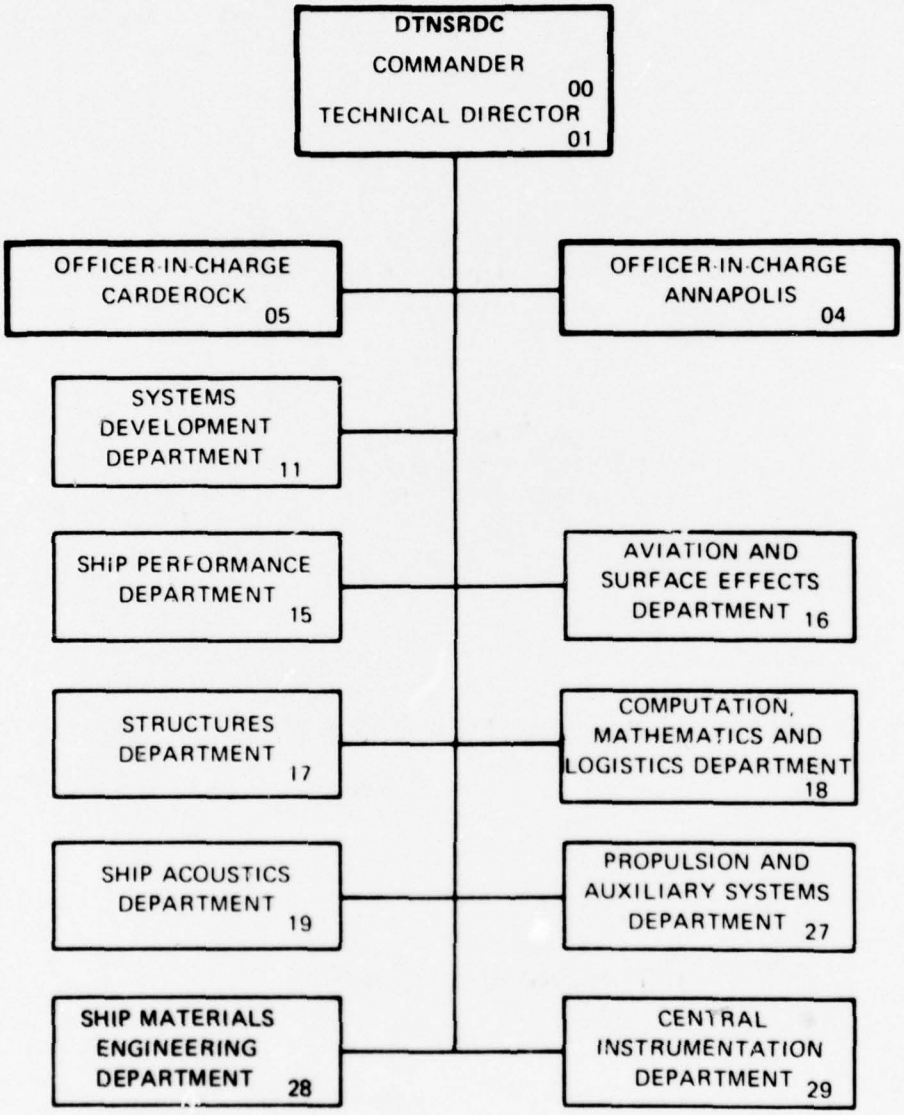

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ABSTRACT

A full scale hydrodynamic vehicle (FSHV) representing an experimental LVA planing hull, but without tracks installed, has undergone coastal trials in the Camp Pendleton, California area. This report presents data on vehicle accelerations and motions during the trials. Of particular usefulness are the one-third octave bandwidth plots of acceleration energy levels, which compare measured accelerations with a modified MIL-STD-1472B. These plots show that the tolerance criteria were rarely exceeded, although in several cases RMS vertical accelerations were rather high.

ADMINISTRATIVE INFORMATION

This investigation was funded by the Landing Vehicle Assault Program Office, Task Area SF 43411210, Element Number 62543N. It is identified as Work Unit Number 1-1120-018-44.

INTRODUCTION

An advanced amphibious personnel carrier, Landing Vehicle Assault (LVA), is being developed jointly by the Naval Sea Systems Command and the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). This U. S. Marine Corps craft is to replace the Landing Vehicle, Tracked, Personnel, Model 7 (LVTP-7) which is the current fleet vehicle. The major performance improvement called for over that of the LVTP-7 is high speed [in excess of 25 mph (40.2 km/hr)] over the water. The LVA will be launched from an amphibious ship maintaining an "over the horizon" distance from the shore line of up to 25 miles.

Among the LVA candidate concepts, there are planing hull designs. It is considered extremely important to evaluate the ride quality of the planing hull concept, that is, its ability to transport Marine infantrymen from ship to shore and deliver them in fighting condition. This must be done (according to the requirements document) at designed maximum speed in seas consisting of locally generated random waves having a significant wave height of 2.2 feet (0.7 m) superposed on long period swell (maximum energy at 11.0 sec) having a significant wave height of 5.5 feet (1.7 m).*

A full scale hydrodynamic vehicle (FSHV) representing a proposed planing hull configuration was built. In order to minimize cost, capability for land operations was not provided. In addition, troop carrying capacity was limited to nine men to permit installation of four commercially available diesel engines (Detroit Diesel 8V-71TI), test instrumentation and underway observers. The space provided per man is, however, equivalent to that available on the LVTP-7. During its simulated mission the FSHV should spend at least one hour in open water operating at cruise speed. It must then come alongside a pier where the troops can debark, negotiate an obstacle course, and fire rifles on a firing range. The fighting condition of troops debarking from an LVTP-7 is known to be acceptable. The benchmark performance in FSHV tests is taken as the performance of infantrymen who have ridden in the LVTP-7 during the most demanding operation the Marine Corps would plan for it.

During the period 4-8 April 1977 and on 25 April 1977 personnel of the Ship Performance Department of DTNSRDC participated in preliminary seakeeping trials on an LVTP-7. The main purpose of these trials was to check out procedures for evaluating troop performance. Vehicle habitability data were also obtained, and the results were presented in a DTNSRDC report for internal distribution only.

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* The craft must also operate at designed maximum speed in either the random waves or swell when present alone.

FSHV tests were also conducted out of the Del Mar Boat Basin at Camp Pendleton, California during the period 8 February to 2 August 1978. Motions and accelerations in the test vehicle were recorded along with wave time-histories in the trials area. This was done primarily to aid in correlating troop performance with the severity of the ride they experienced, but also to characterize the FSHV for comparison with other vessels.

DESCRIPTION OF BOAT

The FSHV has a zero deadrise hull over most of its length. Approximately 24 feet (7.3 m) forward of the transom its bottom surface curves upward and is faired into a ship-shape bow with 11 degree deadrise. The ship-shape bow was added to the original straight across bow to deflect water downward and improve visibility and wetness. This increased the craft's overall length from 30 feet (9.1 m) to 36.5 feet (11.1 m).

Table 1 is a list of FSHV particulars. Vehicle dimensions are also given in Figure 1. A photograph of the boat can be seen in Figure 2 which provides a good external view of the pilot house on the starboard side (with seats for the pilot and test director) and the Marine driver's station on the port side. Hull dimensions were fixed by mission-related specifications involving the eventual number of troops to be transported in the LVA (about 25 in each vehicle) and the need for size compatibility with the amphibious ship's well deck storage space. With the above limitations in mind, the hull shape had to be suitable for reaching the desired speed with the power available, and be adequately stable and seaworthy in moderate sea states. The configuration must also be appropriate for installation of tracks so that it can operate as an armored personnel carrier upon landing.

The layout of engines and spaces in the FSHV is shown in Figure 3. Two engines are located forward of the troop compartment and two aft of it; each engine drives a 3-bladed propeller of 32 inch (0.8 m) diameter. Observer spaces are located to port and starboard of the troop capsule. The Marine driver's station is located roughly 26.5 feet (8.1 m) forward of the transom. It will be the principal operating location for the LVA. Figure 1 shows that the center of gravity of the boat is located within the troop compartment. An adjustable transom flap 11.0 feet (3.4 m) wide by 2.6 feet (0.8 m) in chord is installed on the FSHV to control trim for optimum ride and/or resistance.

INSTRUMENTATION

Instrumenting the FSHV to determine its motions and accelerations when operating in waves was difficult because space was very limited and the shock and vibration environment was severe. The two observer compartments (see Figure 1) were used for housing signal conditioning and recording equipment and operators: the starboard space was fitted with a rack in which amplifiers, calibration units, etc. were placed; a Sangamo Sabre VI tape recorder was installed in the port space. All of this equipment was shock mounted. The main source of electrical power for the instrumentation was a 3KVA Westerbeke diesel fueled generator located in a lazaret near the stern.

Several accelerometers were mounted in the FSHV to measure vertical, lateral and longitudinal acceleration. Their locations are given in Figure 1. Greater detail of the accelerometer layout in the troop compartment is shown in Figure 4: the $\pm$ 5 g vertical accelerometer and $\pm$ 2 g surge accelerometer were positioned on the boat centerline, while the $\pm$ 1 g lateral accelerometer was mounted 3 feet (0.9 m) from the starboard side. All of these were Donner

Model 4310 force balance servo-type transducers which are accurate to 0.1 percent and have a natural frequency in the 70 to 90 Hz range. They were powered and conditioned by a DTNSRDC Accelerometer Control Unit Model 415-1A.

Two accelerometers were also located in the pilot house: one Statham Model A69-TC and one Statham Model A45. The Model A69-TC has an unbonded 350 ohm strain gage bridge, a range of ± 100 g's, and a natural frequency of 1.8 kHz; it was used to measure vertical acceleration. The ± 2 g Model A45, with a natural frequency of 110 Hz, was employed for sensing lateral acceleration in the pilot house. It is also of the unbonded strain gage type. These accelerometers were mounted on the deck below the control console as indicated in Figure 5.

Another Statham Model A45 accelerometer -- this one with a range of ± 10 g's -- was fixed to the bottom side of the Marine driver's seat, above the shock alleviating pedestal assembly (see Figures 5 and 6). Its natural frequency is 190 Hz.

The three Statham accelerometers were powered by Endevco SRB-200 strain gage modules. These units can provide up to 15 volts d.c., regulated to better than 0.1 percent from no load to full load. They also provide a means of calibration, since inside the module is a 0.25 percent resistor which can be switch-activated to offset the accelerometer bridge. The output of the module was fed to a Dynamics Amplifier Model 7521B, and then to a tape recorder calibration unit before final recording on the Sabre VI. The cal unit contains modified Model 7521B differential amplifiers which can provide a gain of 0.2 to 2.5 K and a frequency response of d.c. to 10 kHz. It is used to feed exactly ± 1.0 volts into the 14 channels of the tape recorder as a reference for subsequent data signals. Figure 7 contains a flow chart for the instrumentation.

Pitch and roll were measured by a Minneapolis-Honeywell Model JG7044 gyro. This gyro requires 115 volt, 400 Hz power for the spin motor, which was obtained from an Elgar Model 251 power source. The gyro was bolted to the deck in the starboard observer's space. A 28 volt erection voltage is required to keep the gyro vertical within $\pm$ 0.125 deg. The gimbals have wire-wound potentiometers on them to sense angular motion of the units housing. These are excited by a DTNSRDC Model 419-1A potentiometer control unit which also acts as a signal conditioner.

A readout for speed was located in the pilot house in addition to it being recorded on magnetic tape. The pickup for speed was an impeller mounted on the centerline through an opening in the bottom of the boat, near the forward bulkhead of the aft engine room. The impeller emits pulses which increase in number with speed. The pulses are input to a Vidar Model 326 frequency-to-voltage converter. The Vidar signal output is d.c., which goes through a Dynamics 7521B amplifier for conditioning, and then to the pilot house console and the analog recording equipment. Speed was calibrated initially off Point Loma, California and periodically during the trials at Camp Pendleton by employing a Decatur radar unit as a reference for speed measurement. The signal was reflected off large, fixed objects in the area.

Transom flap angle could also be read out on the console in the pilot house and recorded on magnetic tape. To obtain the necessary signal, a Computer Instrument Corp. linear potentiometer had been waterproofed and one end fixed to the outside surface of the transom stern, with the other end attached to the flap via a turnbuckle. The potentiometer was excited and its output signal conditioned by a 419-1A potentiometer control unit.

Rudder angle was also measured with a potentiometer. To drive the linear potentiometer, its actuating wire was attached to the periphery of

a semi-circular plywood disk which had been epoxied to the top of the rudder stock. A channel in the 419-1A potentiometer control unit was used to power the transducer.

The Sabre VI tape recorder was run at 3-3/4 ips (9.5 cm/sec), which gave each of its 14 FM channels a data bandwidth of 1.25 kHz. Thirteen of the channels were available for data, and one for the ½ volt reference signal (mode) which was employed for designating the usable portion of each record, and for time correlation. The tape recorders were set up for a signal deviation of 1.414 volts, and the head configuration was IRIG standard.

A Datawell Waverider buoy (see Figure 8) was employed for measuring wave height. The buoy follows the movement of the water surface, and measures the waves by sensing its own vertical acceleration. Self-contained electronics double integrate the acceleration signal so that the signal transmitted to the shore station is proportional to displacement. The discrepancy between vertical movement of the Waverider and movement of the sea surface is generally small unless the wave length is less than 16 feet (5 m). The transmitted signal is received by a Dutch-built WAREP-05 receiver. The original carrier frequency of 27.9 mHz was increased in the field to 29.9 mHz (just above the CB range) because radio interference was corrupting large segments of the time-history. The received signal was passed through a DTNSRDC 10 Hz, 8 pole Butterworth filter and paralleled to a CP 100 Ampex FM tape recorder and a Technirite TR-888 strip chart recorder. Buoy deployment was performed by personnel in the chase boat |either the 45 foot (13.7 m) LARC or the 65 foot (19.9 m) PB Mark III|.

TRIALS PROGRAM AND PROCEDURE

The main objective of the trials program was to evaluate troop performance after a one hour, high speed open ocean transit in the FSHV/LVA. In addition, it was desired to characterize the boat's performance (habitability) in a seaway. The emphasis in this report is on the latter goal. Therefore, data obtained from runs made with and without troops on board have been included.

Usually, the procedure followed was to have the chase boat launch the wave buoy, and a wave sample was taken prior to the FSHV mission to ensure that acceptable wave conditions existed. If such was the case, the FSHV made a low speed transit at about 10 mph (16 km/hr) through Oceanside Harbor Channel; this took about five minutes. Open ocean maneuvers were then conducted for approximately one hour in the area partially encircled in Figure 9. Numbers within the test area indicate water depth in fathoms. Data were recorded for as much of this one hour period as possible. Proper functioning of the instrumentation was, of course, a critical factor.

Most sorties were made in a random path; some were, however, made in a series of straight line segments of constant heading. In all cases, an attempt was made to stay as close to the wave buoy and chase boat as possible. The wave buoy was located within the trials area, at the point indicated by a darkened circle in Figure 9. Recording of wave height continued during the entire sortie, and usually somewhat beyond. If troops were on board, they proceeded to carry out their on-shore performance tests after the craft returned to the debarking area.

Table 2 lists the test conditions for the runs made, including those for which data were not recorded. For the first nine runs, wave statistics are not available because excessive local voice transmissions interfered with reception of the buoy output.

There were no runs made between numbers 18 and 40. The gap in numbers was permitted to avoid overlap. Two groups of trials personnel were involved in this program (viz. from DTNSRDC and AVTB*) and it was not known at exactly which point the latter group would take over from the former.

The significant wave height given in Table 2 is the average of the one-third highest crest to trough values. The period of maximum wave energy corresponds to the peak of the energy density spectrum. The approximate wave length corresponding to this period can be computed from

$$\text{Wave length} = 5.12\ (\text{Period})^2 \text{ in feet}$$

$$= 1.56\ (\text{Period})^2 \text{ in meters.}$$

The Comments column shows the boat heading relative to the waves for some of the earlier sorties. Where "Circles" is entered, a fixed heading was not held, and the FSHV was steered in an unordered path in the vicinity of the buoy. The few short duration runs, for which results are questionable, are also indicated. In some cases -- such as Runs 59, 64 and 65 -- there is a big difference between the measured speed listed and the nominal speed given in the log books.

The LVA Required Operating Conditions (R.O.C.) document** calls for operation in a seaway combining swell having a significant wave height of 5.5 feet (1.7 m) in deep water and a period of 11 sec***, with

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* Amphibian Vehicle Test Branch, Marine Corps Tactical Systems Support Activity, Marine Corps Base, Camp Pendleton.

** CMC ltr RDD-26-mrc of 2 February 1978 (LVA ROC).

*** The swell is assumed to consist of a relatively narrow range of wave lengths with peak energy at an 11 sec period.

wind-generated waves (Sea State 2) having a significant wave height of 2.2 feet (0.7 m). Coastal wave data for Huntington, California (just north of the trials area) were reviewed. These data are based on measurements made by the U. S. Army Coastal Engineering Research Center, Fort Belvoir, Virginia. As can be seen in Figure 10, the spectrum representing average annual swell conditions for Huntington can be approximated fairly well by the theoretical Bretschneider spectral formulation. The latter is given by

$$s(\omega) = \frac{\left(A \ \bar{h}_{1/3}^{2} / T_0^{4}\right)}{\omega^5} \exp\left(\frac{-B}{T_0^4 \ \omega^4}\right) \text{ in ft}^2\text{-sec (m}^2\text{-sec)}$$

where: $A = 487.1$
$B = 1,948.2$
$\bar{h}_{1/3}$ = significant wave height, ft (m)
T_0 = *modal period, sec*

This two parameter formulation permits one to select both the significant wave height and period of maximum energy.

It was desired to establish a wave spectral standard that closely corresponds to the R.O.C. spectrum, but also allows for a reasonable deviation (envelope) from R.O.C. Because, as shown above, the Bretschneider spectrum is useful in representing west coast United States swell, it was used for part of the standard. However, a range of $\bar{h}_{1/3}$ and T_0 was established as follows:

$\bar{h}_{1/3}$, ft	$\bar{h}_{1/3}$, m	T_0, sec
5.5	1.7	11.0
5.0	1.5	10.0
6.0	1.8	10.0
5.0	1.5	12.0
6.0	1.8	12.0

The wind-generated sea portion of the R.O.C. spectrum -- having an $\bar{h}_{1/3}$ of only 2.2 feet (0.7 m) -- contains little energy compared to the swell, and

has a high frequency peak corresponding to a period of approximately 4.1 sec. The one parameter Pierson-Moskowitz (P-M) wave spectrum was selected to represent this component of the standard. The equation representing the P-M spectrum is

$$s(\omega) = \frac{A'}{\omega^5} e^{-B'/\omega^4} \text{ in ft}^2\text{-sec (m}^2\text{-sec)}$$

where $A' = 8.1 \times 10^{-3} g^2 = 8.4 \text{ ft}^2/\text{sec}^4 = 0.78 \text{ m}^2/\text{sec}^4$

$B' = 33.56/\overline{h}_{1/3}^2$ in $\text{ft}^{-2} = 3.08/\overline{h}_{1/3}^2$ in m^{-2}

g = acceleration due to gravity in ft/sec^2 (m/sec^2)

The composite of Bretschneider and Pierson-Moskowitz spectra is presented in Figure 11 with upper and lower bounds indicated. Also shown for comparison is the most severe wave condition encountered during these trials (on 19 July 1978). It falls within the established bounds at its peak and for lower frequencies, and also has a significant wave height close to that of the lower bound. Most of the other runs were made in wave conditions considerably milder than the standard. Typical examples are given in Figure 12; these were recorded on the dates indicated.

DIGITAL DATA REDUCTION

The digital system consisted of an Interdata Model 70 computer with 64k bytes of memory, a nine-track Kennedy 3110 digital tape drive, a Tektronix 4006 CRT terminal, an Analogic 5800 14-bit analog to digital converter, a Versatec 1100A line printer, and a Tri-Data 1024 cartridge tape recorder. The software utilized consists of programs and subroutines developed over the course of several years by DTNSRDC Ship Performance Department personnel. This system carried out the digitization of the recorded measurements.

Because of the predominance of low frequency components in the rigid body vehicle motions and accelerations and also in the wave height records, it was possible, during digitization, to replay the analog tapes at a speed higher than the speed at which they were recorded. The "time compression" used was a factor of four for vehicle motions and eight for wave height.

A real-time sample rate of sixty per channel per sec (therefore, 15 per channel per sec for time compressed motions) was used to digitize each analog signal after it had been fed through a six pole Butterworth low-pass filter with a half-power point at 15 Hz. This combination of sample rate and filtering prevented aliasing of high frequency noise into the data bandwidth.

The computer operator used the ½ volt mode channel to locate the "good" data and employed the mini-computer to sample the incoming data at regular intervals. The data were then stored in a buffer, and the buffer was periodically written on a nine-track tape. Subsequent analysis of the data could then proceed either on the mini-computer, as was done for the wave height spectra, or within the Center's main computer facility, on a Control Data Corporation Series 60 computer. The latter procedure was used for more extensive analysis of rigid body motions and accelerations.

In either case, power spectral density (PSD) functions were produced utilizing a Fast Fourier Transform program capable of analyzing up to 256 frequencies. In addition, a program was developed which, in operating on the PSD's, produces standard one-third octave bandwidth energy RMS levels for the linear acceleration channels.

A third analysis program was used to examine the peak and trough single amplitudes of the vehicle motions. Upon recognizing a cycle, defined by three crossings of the mean, this program would log the extreme peak and

trough values in an amplitude versus number of occurrence histogram. The histograms were then used in computing a series of statistical parameters characteristic of each distribution.

TRIALS RESULTS

Analog tapes recorded on board the FSHV (boat data) and in the shore station at Camp Pendleton (wave data) were digitized at DTNSRDC as they became available. They were then processed on a computer as discussed in the previous section.

A sample computer printout of the wave height results is contained in Figure 13. A complete set, in microfiche form, is provided inside the back cover of this report (see Appendix A). All printouts have also been forwarded to the LVA Program Office. For many runs -- particularly the first eighteen -- the wave record run number listed on these printouts does not correspond to the principal run number given in Table 2, and dates should be used to match wave and boat results.

As noted, Figure 11 shows the most severe wave condition encountered (Run 63*). Other runs of comparable severity were numbers 64, 62, 54, 48 and 41 [all with significant wave heights of roughly 4 feet (1.2 m)]. These were not necessarily the runs with maximum boat response, since heading relative to the waves, speed, trim, etc. all influence habitability. It should also be noted that high frequency wind waves will tend to induce boat motions more than longer (10sec-To-20sec) swells. This is true because the swells range from 14 to 56 times the length of the FSHV, while the

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* Only principal, that is, FSHV sortie run numbers will be used in the text.

wind waves are only about 3 times as long as the craft. Extremely long waves usually do not excite the natural frequency of a vessel, and because of their mild slopes should not cause severe accelerations.

Items listed in the headings of Figure 13 are defined as follows:

TOTAL TIME	=	length of wave sample in sec
MEAN	=	"d.c. level" of the signal
STDDEV	=	root-mean-square (RMS) about the mean
SIG DA	=	significant (average of the highest one-third) double amplitudes
AMP.MAX	=	maximum ordinate of the wave auto-spectrum*
FREQ.MAX	=	frequency in rad/sec at which the maximum spectral ordinate occurs
ROOTE	=	square root of area under spectrum
ROOTQO	=	$\sqrt{2}$ x STD DEV = single amplitude for sine wave
RATIO	=	ROOTE/ROOTQO = 1.0 for a linear system
STAT.ERR.(%)	=	a measure of confidence in the computed spectrum*
DOF	=	degrees of freedom = another measure of confidence in the computed spectrum*
EFF.SCAN RT.	=	the number of digitized samples per sec used in carrying out the analysis

The heading of 0.0 deg shown on the computer listing is unimportant for the wave data.

Just as in the sample (Figure 13), auto-spectra for the waves are tabulated and plotted on the microfiche for all wave records. In many cases, the peak of the wave spectrum occurs at a frequency of 0.35 to 0.50 rad/sec, which is lower than that of the standard (Figure 11); the latter peaks in the range of 0.55 to 0.60 rad/sec. The measured spectra do often have a secondary peak occurring at a higher frequency than the primary one. Also, as discussed above, the measured significant wave height is usually appreciably lower than called for in the standard. A summary of significant wave heights is given in Table 2. Values could not be given for the runs in which interference severely affected the transmitted signal.

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* Confidence increases as the statistical error decreases and the degrees of freedom increase.

An example of computer output obtained for the boat data is presented in Figure 14. MINIMUM and MAXIMUM values tabulated on Sheet a are relative to the zero value of the variable, not the mean. Pitch is a good example of a measurement which generally has a large MEAN value; this represents bow up trim, which in the sample is 8.9 deg.

A negative (-) sign convention (-voltage) has been adopted on the computer listing for the following directions of motion and acceleration:

PITCH	-	bow down
ROLL	-	port up
HEAVE ACC	-	down
SURGE ACC	-	forward
SWAY ACC	-	starboard
MDS VERT (accel)	-	up
PH VERT (accel)	-	up
PH LAT (accel)	-	starboard
FLAP ANG	-	down
RUDDER	-	port

For example, in Figure 14-Sheet a, the 0.4169 g *MINIMUM* value of heave acceleration is acting down.

For most of the first 18 runs, a constant heading relative to the waves is indicated on the computer printout, with 180 deg being head seas. In some cases the boat heading was changed frequently on an irregular schedule, and this type of sortie is designated as "TROOP CIRCLE MANEUVERS". Run 40 and succeeding runs are comprised of several constant but unknown headings that have been grouped together for analysis, and these are designated as "N CONDITIONS" (where only heading was changed) or "N CONDITIONS-N SPEEDS" (where both heading and speed were changed).

It is important to note that for those runs in which heading and/or speed were varied in some unknown order, the results presented here cannot be generalized (e.g. by deriving transfer functions and applying them to other sea conditions); they apply only to the particular operating sequence

followed during the sortie. Moreover, if the FSHV were operating in the same seaway, but following a different schedule of heading changes, its response statistics could be somewhat different from those presented in this report.

Auto-spectra for craft motions and accelerations are given on Sheets b and c of Figure 14. These constitute the results of the frequency domain analysis, which actually yielded spectral ordinates to a frequency of 15.6 rad/sec rather than the 4.2 rad/sec shown in the sample for brevity of presentation.

Sheet d summarizes statistical data computed from time-domain analysis (histograms). The number of data points referred to pertains to individual points on the time-history Δt apart, where Δt = 1/sample rate. Peak and trough data were treated separately; thus, for vertical accelerations, statistics for upward maxima are listed separately from those for downward maxima. Definitions for row headings are

AVG = average of the maximum values

$$= \sum_{i=1}^{N\ Cycles} x_i / N\ Cycles = \bar{x}$$

where x_i = individual values of the maxima

N Cycles = number of cycles

$$M_2 = \left[\sum_{i=1}^{N\ Cycles} (x_i - \bar{x})^2\right] / N\ Cycles$$

= variance of maximum values

$$M_k = \left[\sum_{i=1}^{N\ Cycles} (x_i - \bar{x})^k\right] / N\ Cycles$$

= k^{th} moment

SKEW = $M_3 / (M_2)^{3/2}$ = measure of skewness of probability distribution

KURT = kurtosis = $M_4 / (M_2)^2$ = a shape parameter for the probability distribution

HIGHEST, 2ND, 3RD....5TH = magnitude of the 1st highest amplitude, 2nd highest amplitude, etc. relative to the mean or "d.c. level."

1/3RD = average of the highest one-third amplitudes

1/10TH = average of the highest one-tenth amplitudes

Sheets e, f and g of Figure 14 contain tabulations of the histograms. The row labeled "O-R" indicates the number of values that fall beyond the maximum range established for the analysis. These are generally few in number compared to the total number of values in the sample. The number of cycles of acceleration is usually high compared to those for pitch and roll -- probably because of vibration of the craft's structure. Cumulative probability distributions have also been included in the histogram tabulations.

RMS one-third octave bandwidth energy levels for the linear accelerations are given in numerical form on Sheet h. These have also been graphed, and a complete set will be presented later in this report since they are an important indicator of vehicle habitability. The center frequency for intervals above 0.1 Hz (the lowest one selected for this analysis) was computed by using

$$\text{Center frequency multiple} = \frac{f_{i+1}}{f_i} = 2^{1/3} = 1.26$$

The bounds of each interval are established from the following relationships:

$$\text{Upper frequency bound multiple} = \frac{f_{Hi}}{f_i} = \sqrt{2^{1/3}} = 1.12$$

$$\text{Lower frequency bound multiple} = \frac{f_{Li}}{f_i} = \frac{1}{\sqrt{2^{1/3}}} = 0.89$$

SUMMARY OF ACCELERATIONS AND MOTIONS

Tabulated Results

Statistical data on accelerations and motions are summarized in Table 3. Runs have been omitted where instrumentation problems prevented the recording of valid data. The mean vehicle trim was found to be fairly high; for many runs it was about 7 to 8 deg bow up, and sometimes exceeded that. Standard deviation and average of the highest one-tenth ($\overline{HI\ 1/10}$) values for oscillatory pitch and roll are also contained in Table 3. Maximum $\overline{HI\ 1/10}$ for pitch reached 9.4 deg bow up and 11.0 deg bow down during Run 3; this is substantially higher than the values for most other runs which are in the 2.0 to 6.0 deg range. Maximum $\overline{HI\ 1/10}$ for roll is 5.9 deg port side down and 6.9 deg starboard side down -- also during Run 3.

The worst ride in the troop compartment clearly occurred during Runs 45, 52, 54 and 55*, with $\overline{HI\ 1/10}$ for heave acceleration ranging from 0.65 to 1.14 g's and RMS acceleration reaching 0.31 g's. Although habitability was poor, these sorties were not conducted in the most severe wave conditions (see Table 2). Pilot house and Marine driver's seat accelerations are not available for these runs because of instrumentation failures.

Pilot house vertical accelerations for Run 1 are among the severest recorded: the $\overline{HI\ 1/10}$ upward acceleration was 1.04 g's and the value for downward acceleration was 0.66 g's. The RMS pilot house acceleration of 0.32 g's for Run 1 was, however, exceeded during two other runs, namely 66 and 72, with the latter reaching 0.48 g's.

---

* Run 55 was short.

Vertical acceleration at the Marine driver's seat was also high during Run 1. $\overline{\text{HI 1/10}}$ was 0.93 g's up and 0.61 g's down, with an RMS value of 0.29 g's. These values were almost duplicated during Run 72.

Comparison Between Measured Accelerations in One-Third Octave Energy Levels and LVA Tolerance Criteria

Acceleration Exposure criteria contained in MIL-STD-1472B of 31 December 1974 have been extrapolated to frequencies below 1 Hz to establish limits for LVA habitability. The criteria are for vertical and horizontal accelerations, and indicate the maximum allowable exposure for personnel to maintain proficiency for one hour. Figure 15 compares the measured wave induced craft accelerations with the standard.* The latter is designated by alternating long and short dashed lines for accelerations taken directly from the MIL-STD, and by short dashes for extrapolated values.

Although the RMS pilot house vertical accelerations for Runs 1, 66 and 72 are high enough to be uncomfortable (0.32, 0.39 and 0.48 g's, respectively), none of these has one-third octave plots that exceed the LVA criterion (see Figures 15a, 15ee and 15kk). The first sortie to have accelerations which exceed the extended MIL-STD is Run 45 shown in Figure 15u. The exceedance is slight, and occurs for heave acceleration only, at approximately 0.4 Hz. The fact that heave acceleration is greater than Marine driver's seat acceleration in this case is strange, and leads one to suspect an instrumentation problem during this run. Turning now to Runs 52, 54 and 55 -- all of which have high RMS values of heave (troop compartment) acceleration -- the following facts are gleaned from the one-third octave plots: for Run 52 (Figure 15v) the heave acceleration curve falls close to the standard at roughly 0.3 Hz, but never exceeds it;

* The ordinate label "lateral acceleration" should have been "horizontal acceleration," since surge acceleration is also included on these plots.

for Runs 54 and 55 (short run), there is clear-cut exceedance in the 0.25 Hz to 0.5 Hz range. Some runs, such as 62 and 63 (Figures 15aa and 15bb), have acceleration curves with unusual shapes since they increase without reaching a distinct peak. For no sortie does the one-third octave lateral or longitudinal acceleration curve exceed the MIL-STD.

Impact Accelerations

Accelerations recorded on magnetic tape during the trials were subsequently re-recorded on strip chart by means of a high frequency response "string-oscillograph" recorder.* This was done to permit hand reading of impact accelerations. No filtering was used to avoid possible attenuation of desired signals. Figure 16 shows a sample of the type of impacts derived from the earlier sorties (Runs 1 to 18). These have the commonly encountered triangular pulse shape, in some cases with ringing after the initial pulse. In Figure 17, we see what appears to be another type of impact record; these pulses, having a more narrow spike-like appearance, were derived from some runs in the 40 to 75 group. One should note that the change in time base from Figure 16 to Figure 17 acts to narrow the visual pulse width in the latter figure; however, the actual pulse width is not narrowed as drastically.

Reduction of the FSHV slam records was carried out for most channels by reading the maximum deflection of the acceleration pulse from the "zero" level. The one exception was surge acceleration which, because its magnitude is relatively small, had a significant offset in its zero due to a gravitational component introduced by trim. In this case, the zero used to determine impact levels was the mean of the trace just prior to the slam.

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* The device used has a flat response in the kHz range.

The results are presented in Table 4 for those sorties where impacts did occur. This table lists only the largest acceleration recorded during a run; usually, there were many more in evidence on the time-history. Where no values are given, instrumentation malfunction, inadequate sensitivity, or a calibration error precluded their obtainment. The most severe impact was sustained by the FSHV in the pilot house during Run 73. It was roughly 8.8 g's but, as exemplified by Figure 17, of very short duration. Another severe impact of 6.1 g's occurred in the pilot house during Run 69. Marine driver's seat impact levels were lower than those in the pilot house because of the load alleviation capability of the shock mounted seat to which the accelerometer was mounted. The maximum value recorded here was 4.8 g's -- also during Run 73. Troop compartment impacts were even milder (note, these accelerations were measured on the aft bulkhead in the troop compartment), with the largest slam reaching 3.3 g's during Run 54.

When the craft slams, it usually slows down because the bow is entering the water (sometimes the flank or crest of a wave). These longitudinal decelerations are also contained in Table 4. Although the largest values of 0.5 g's are severe enough to throw a person off his feet if he were standing without a secure hand-hold, the seated troops in FSHV should not be bothered by them.

CONCLUSIONS

A full scale hydrodynamic vehicle (FSHV) representing a planing hull concept for the Landing Vehicle Assault (LVA), but without tracks for amphibious capability, has undergone seakeeping trials. The following conclusions can be drawn from the results of this program:

1. The most severe conditions in the troop compartment occurred during four sorties for which the average of the highest one-tenth ($\overline{HI\ 1/10}$) heave acceleration ranged from approximately 0.7 to 1.1 g's single amplitude, and RMS acceleration reached 0.31 g's.

2. $\overline{HI\ 1/10}$ pilot house vertical acceleration went as high as 1.0 g's upward and 0.7 g's downward. Maximum RMS acceleration in this location was 0.48 g's.

3. In the Marine driver's station the maximum $\overline{HI\ 1/10}$ vertical acceleration was slightly lower than in the pilot house, reaching about 0.9 g's upward and 0.6 g's downward. Maximum RMS acceleration in this location for a single sortie was 0.29 g's.

4. The LVA acceleration tolerance criteria based on an extrapolation of MIL-STD 1472B were rarely exceeded during these trials. Only two sorties had heave acceleration (one-third octave) plots that were clearly more severe than the standard for vertical acceleration, and one of these was a short run. The standard for horizontal acceleration was never exceeded.

5. The most severe impact acceleration recorded during the trials was 8.8 g's on the pilot house deck. Because the shock-mounted seat reduced the load, 4.8 g's was the largest impact measured in the Marine driver's station. On the troop compartment bulkhead, a 3.3 g slam was the largest recorded.

6. Deceleration (aft surge acceleration) during slamming reached 0.5 g's.

7. Running trim was usually about 7 to 8 deg.

8. The results presented in this report are, in most cases, for an unknown sequence of headings relative to the waves. It should be realized that a different sequence in the same wave conditions could lead to somewhat different average craft responses.

9. Most runs were carried out in wave conditions significantly less severe than those called for in the Required Operating Conditions (R.O.C.) Document. The R.O.C. wave specification is not typical of offshore conditions in southern California.

ACKNOWLEDGMENTS

The authors wish to thank D. Halper of the Landing Vehicle Assault Office who played a major role during these trials in his capacity as Test Director (organizing and implementing the FSHV Test Plan) and performing the myriad tasks necessary to keep a trials program going. Mr. Halper was also actively involved in the data reduction phase. D. Gregory and J. Kallio of the Ship Performance Department are also due thanks for contributions during their terms as Test Coordinator and Project Engineer, respectively. R. Busby, G. Minard and J. Hardison participated in assembling and operating the electronic instrumentation.

APPENDIX A

DIRECTIONS FOR USING MICROFICHE

Two sets of microfiche have been provided as a supplement to this report (see inside of back cover). One set contains computer printouts of the boat data; the other contains computer printouts of the wave data.

Each sheet of boat data microfiche contains an index at its lower right-hand corner which gives the location (LOC) of a particular type of data for a particular run. For example, the designation

F02 HIST STAT RUNS 2-2

states that if the pointer on the microfiche reader is placed at box F_2 on the reader's locator chart, statistical data from the time-histories of run 2 will be seen on the screen. Individual frames also have their locations (e.g., F02) printed in the bottom left-hand corner of the frame. Successive runs are listed in columnar fashion.

The wave data microfiche do not have an index, but runs are listed in order. Dates should be used to match wave runs with boat runs (especially for the first 18) since the run numbers don't always coincide. Table listings in the main body of this report are based on boat data run numbers.

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APPENDIX B

ENGLISH TO METRIC CONVERSION FACTORS

This appendix provides factors for converting from English Units to Metric Units. Conversion factors are provided only for the English units referenced in the figures and tables of this report.

CONVERSION TABLE - ENGLISH TO METRIC

Multiply	by	To Obtain
degrees	1.745 E-02	radians
feet	3.048 E-01	metres (M)
$feet^2$	9.290 E-02	$metres^2$ (M^2)
feet/second	3.048 E-01	metres/ second (M/sec)
$feet^3$/second	2.832 E-02	$metres^3$/second (M^3/sec)
inches	2.540 E+00	centimeters (CM)
inches	2.540 E-02	metres (M)
knots	5.144 E-01	metres/second (M/sec)
pound·inches (lb·in)	1.152	kilogram centimeters(kg·cm)
pound·feet (lb·ft)	1.383 E-01	kilogram·metres (kg·m)
pound·feet/degree (lb·ft/deg)	1.383 3E-01	kilogram· metres/deg (kg·m/deg)
pound/$feet^2$(lb/ft^2)	4.882	kilogram/ $metres^2$ (kg/m^2)
degrees Fahrenheit	$t_c = (t_f - 32)/1.8$	degrees Centigrade
Short Tons	9.072 E+02	kilograms (kg)

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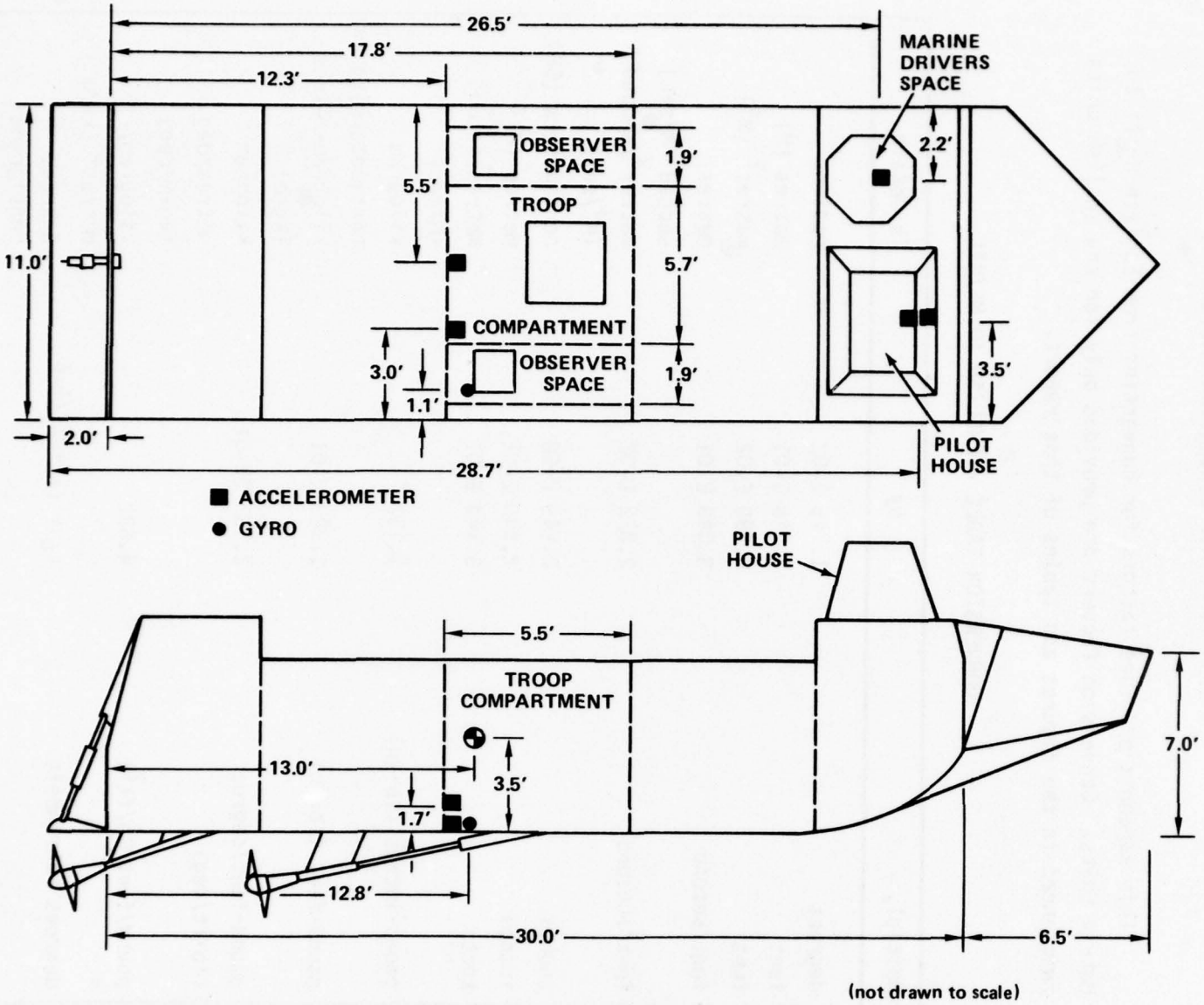

Figure 1 - Sketch of FSHV Showing Dimensions and Transducer Layout

Figure 2 - Photograph of FSHV

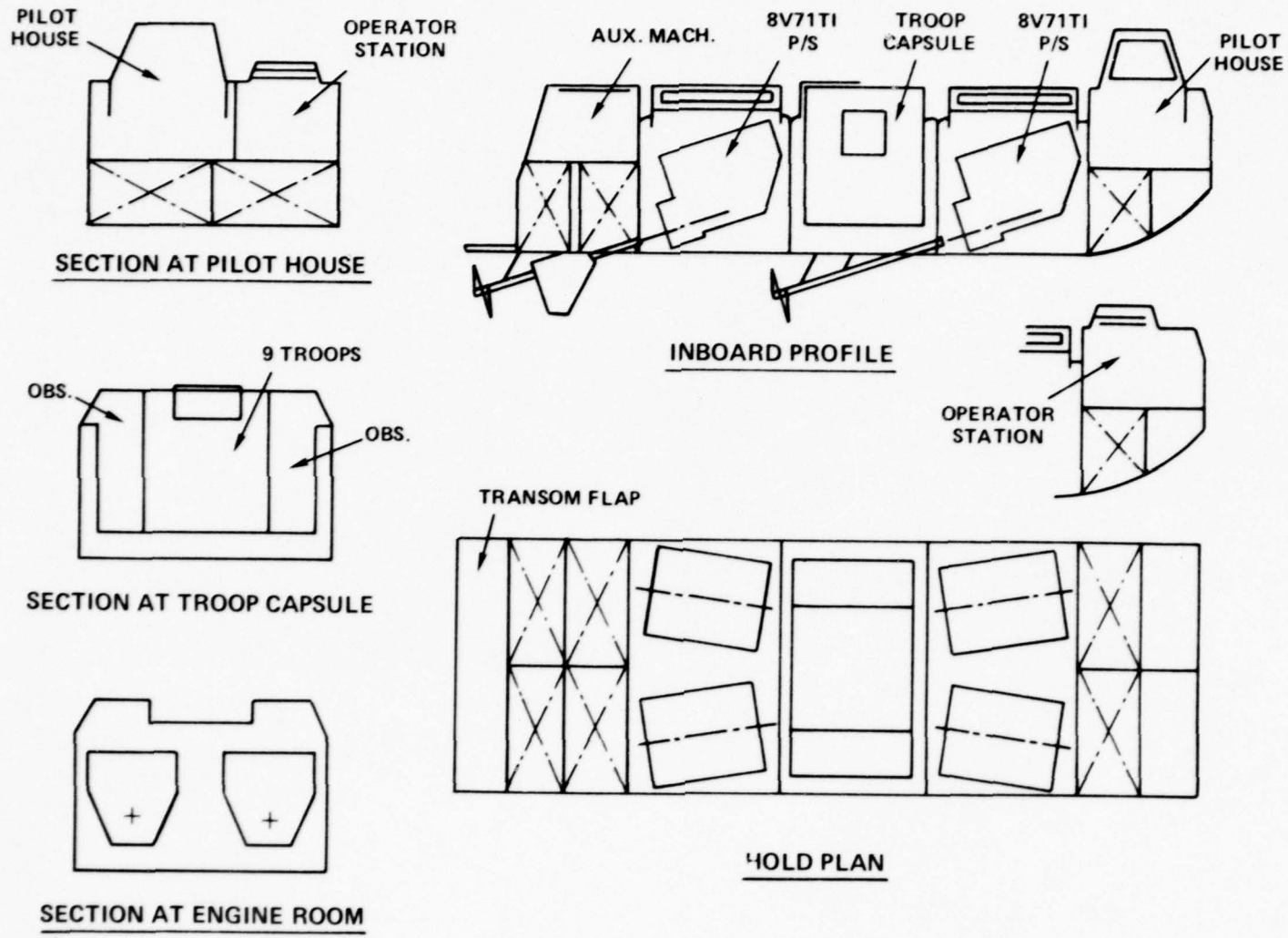

Figure 3 - Layout of FSHV Personnel and Engine Spaces

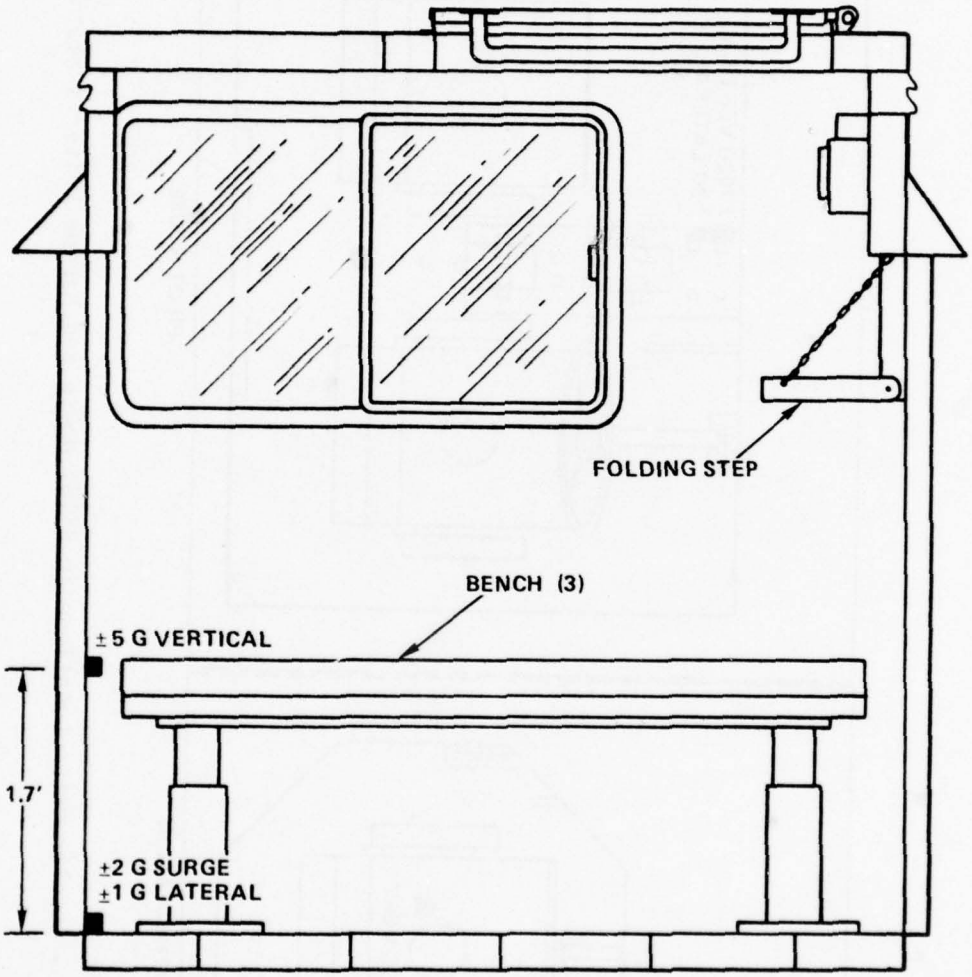

Figure 4 - Accelerometer Locations in the Troop Compartment

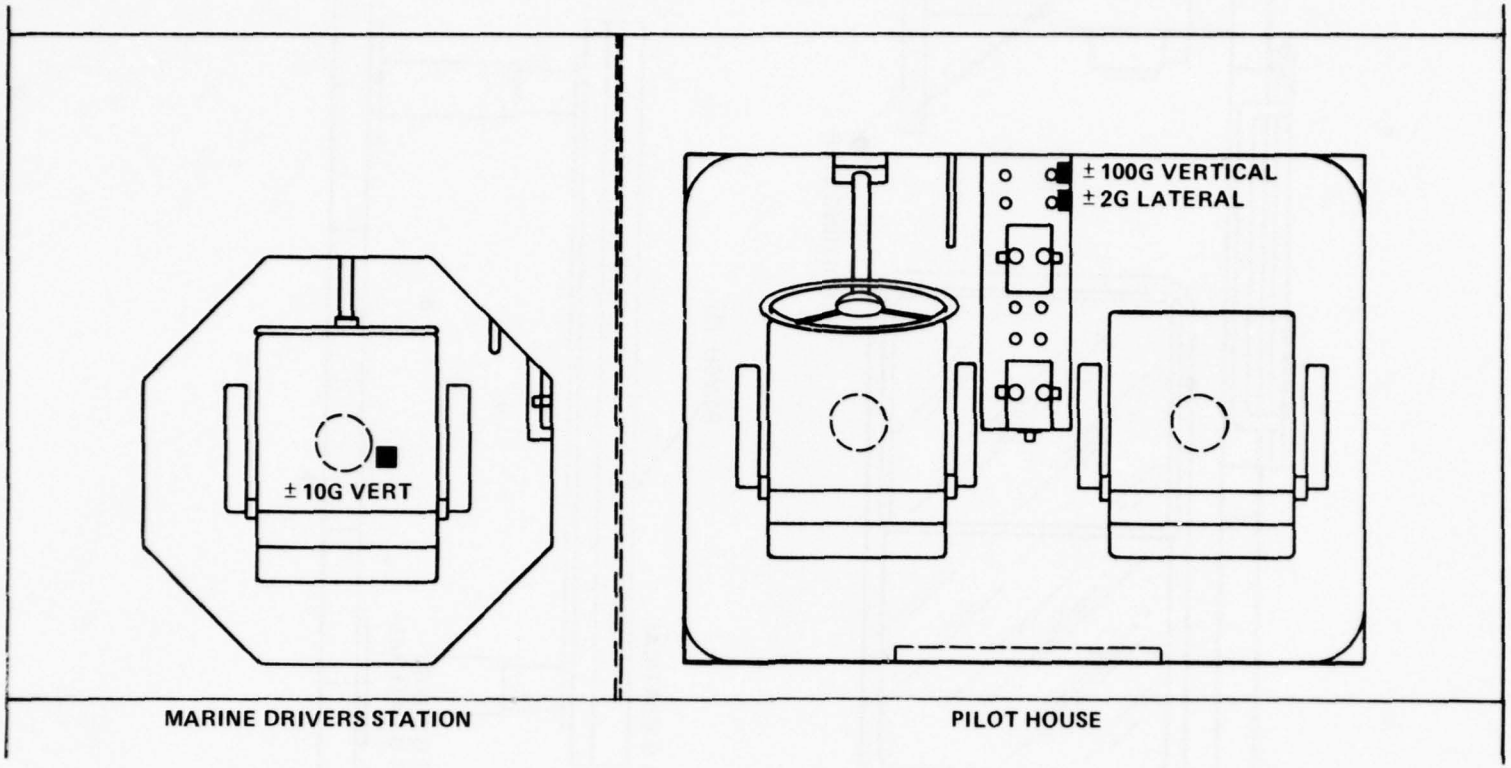

Figure 5 - Accelerometer Locations in Pilot House and Marine Driver's Station

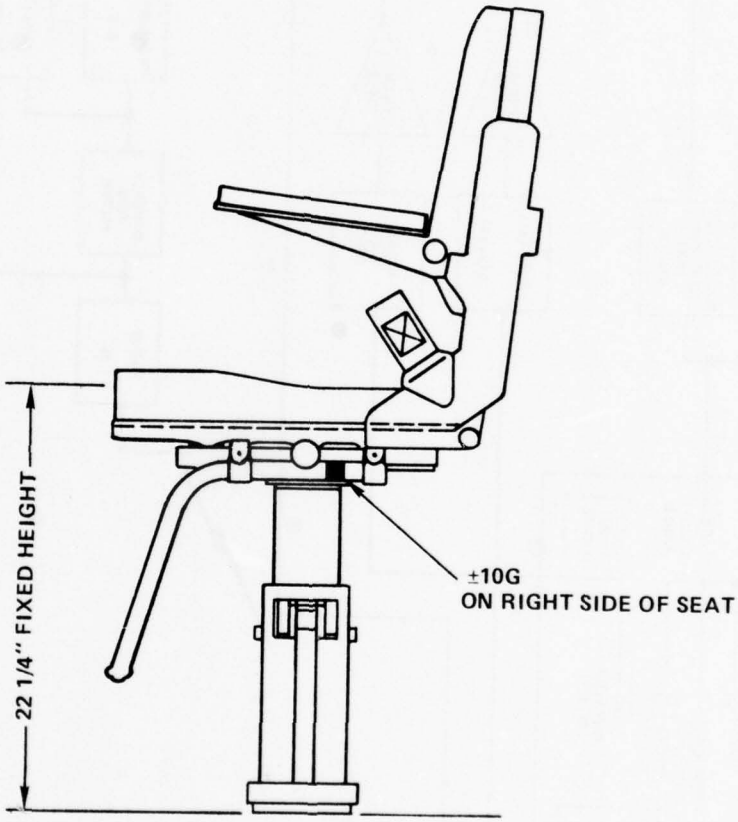

Figure 6 - Accelerometer Mounting on Marine Driver's Seat

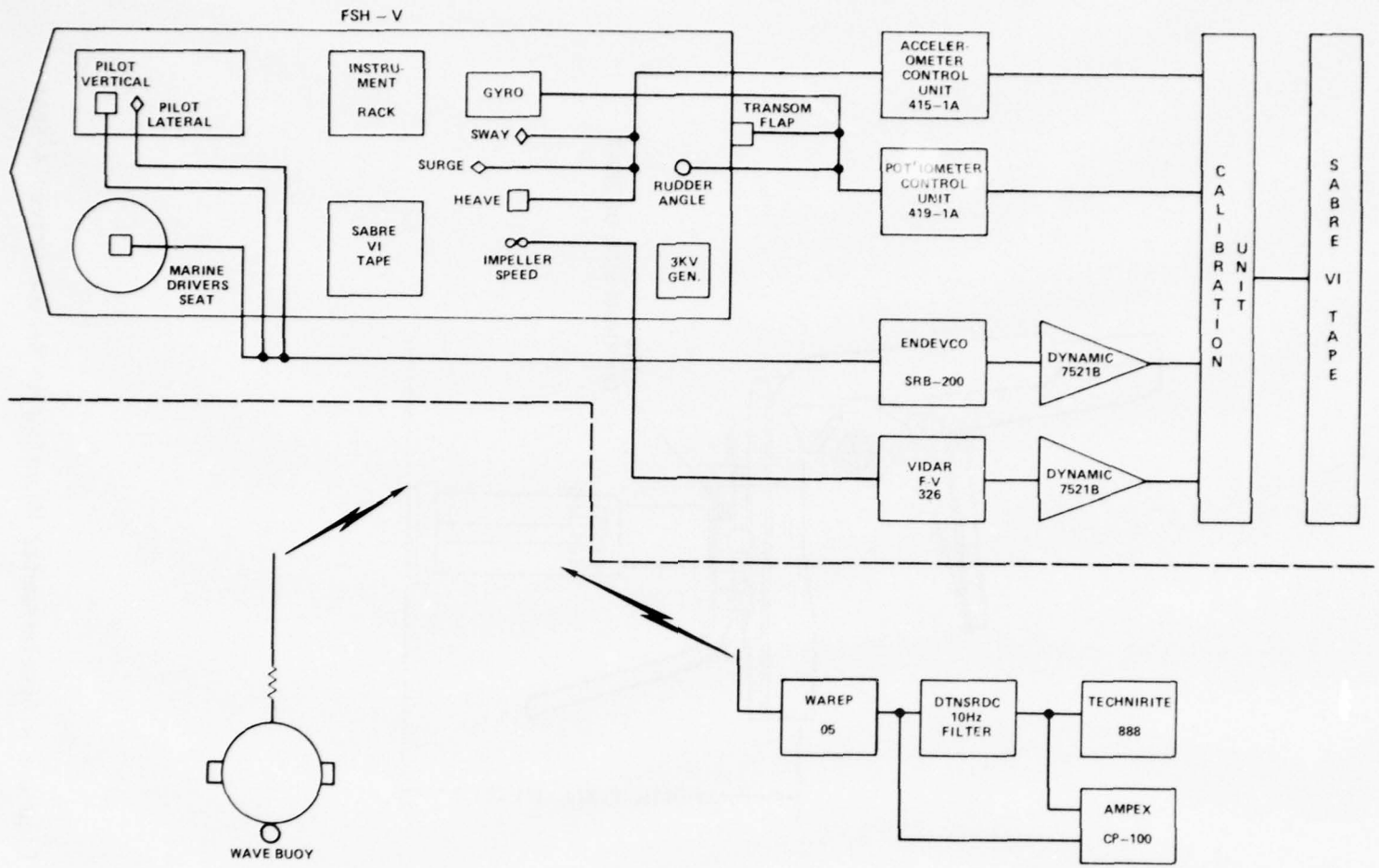

Figure 7 - Instrumentation Flow Chart

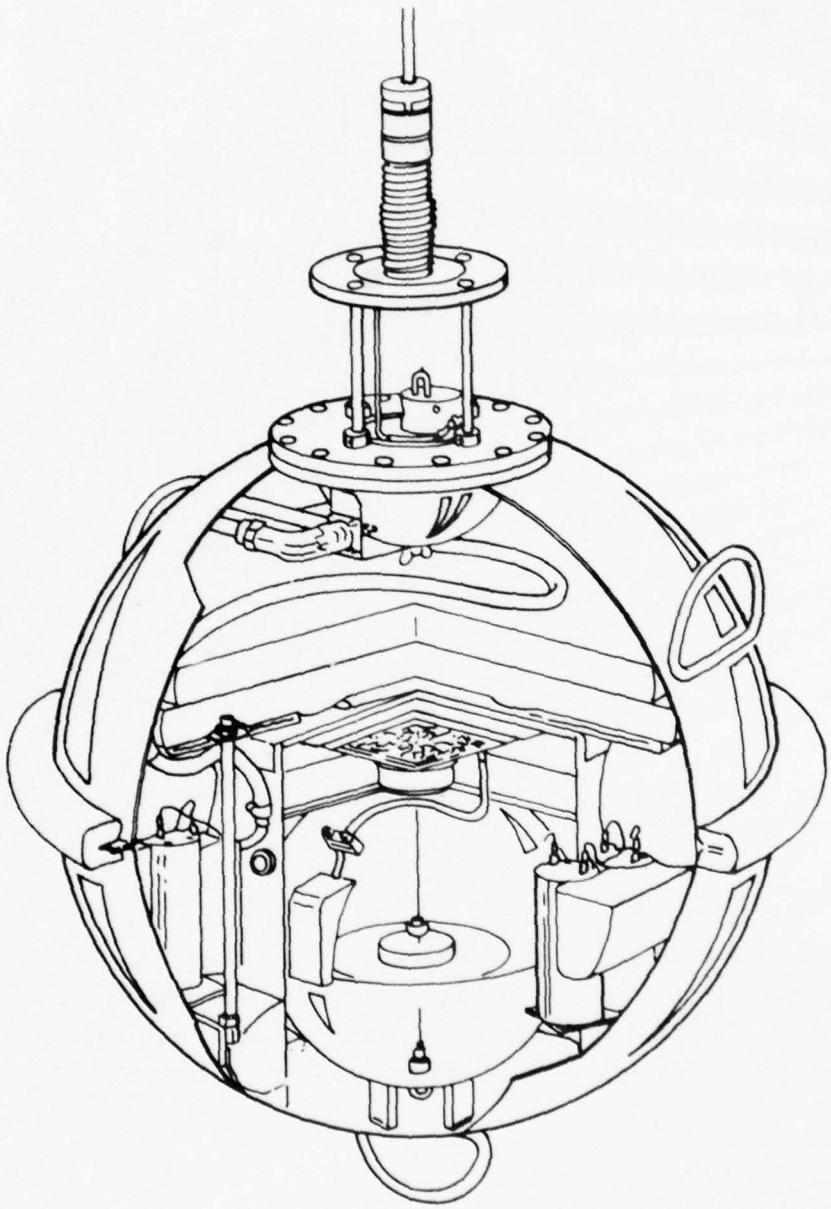

Figure 8 - Datawell Waverider Buoy

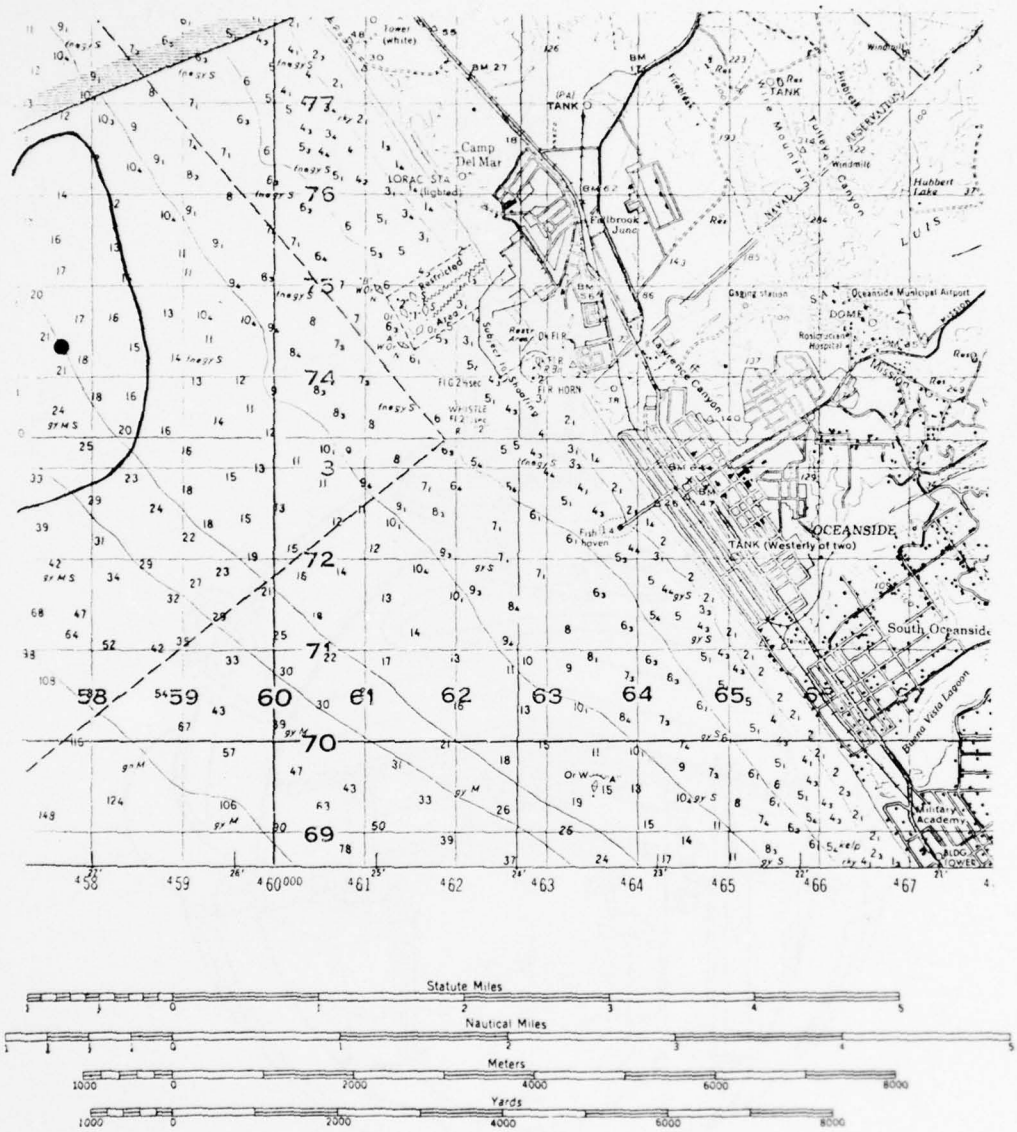

Figure 9 - Operation Area for Open Ocean Maneuvers

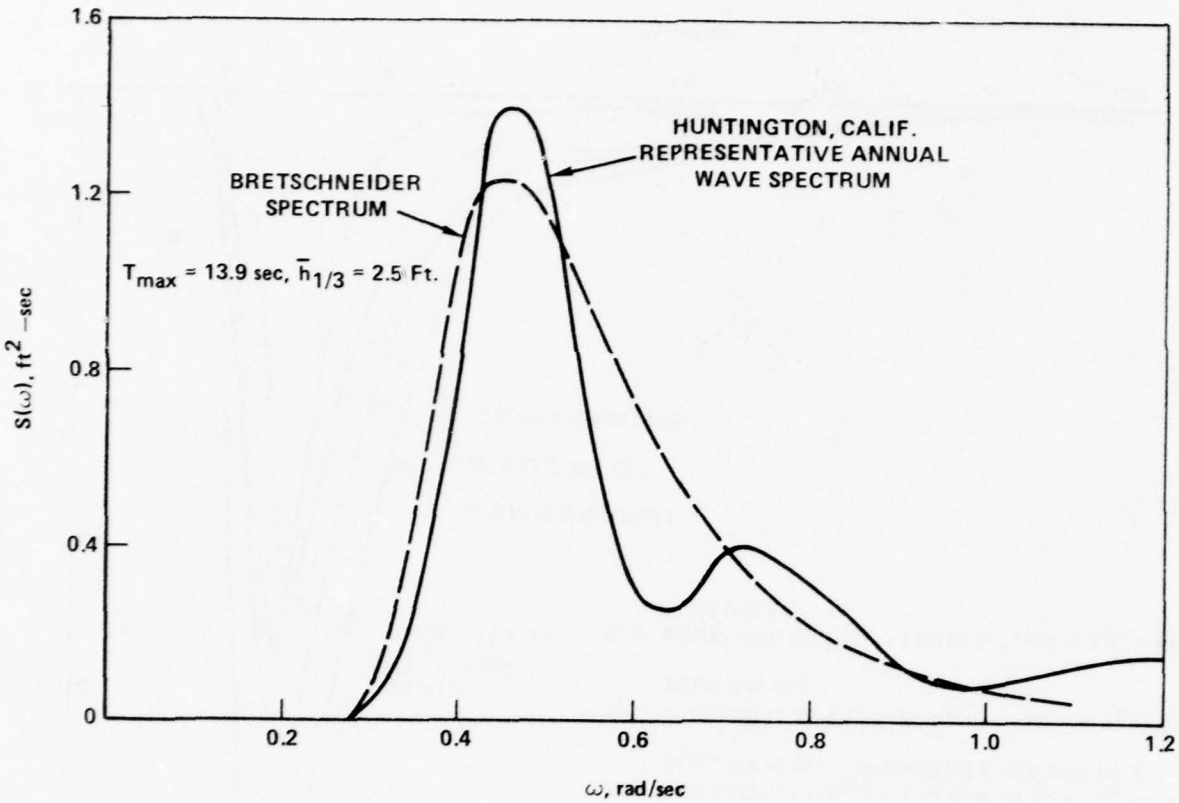

Figure 10 - Comparison Between Typical West Coast U.S. Wave Spectrum and Bretschneider Theoretical Spectrum

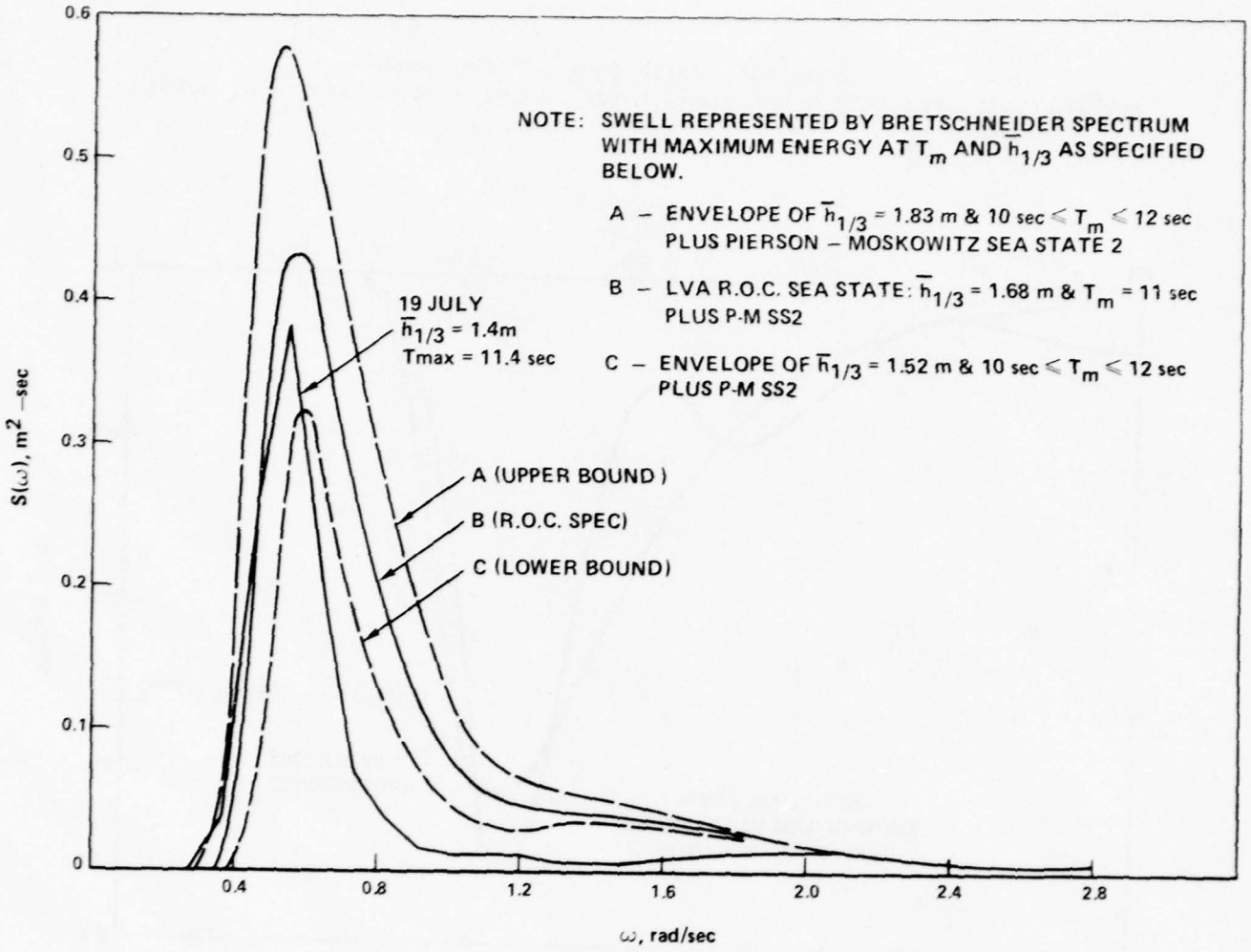

Figure 11 - Wave Energy Spectral Standard for Swell Plus Wind-Generated Waves

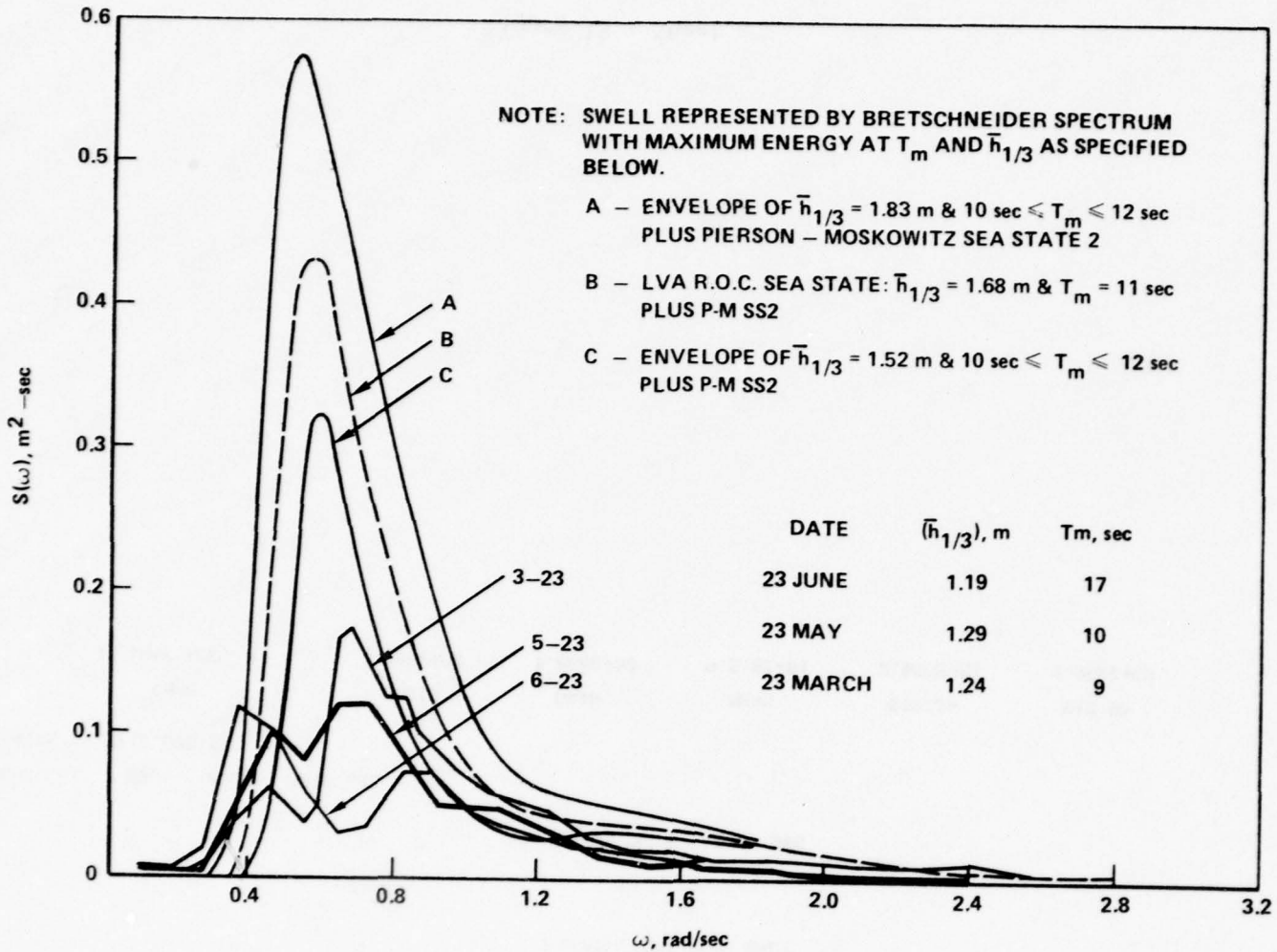

Figure 12 - Comparison of Typical Wave Spectra with LVA Standard

Figure 13 - Sample of FSHV Wave Data Analysis

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

17 JULY 1978
WAVEHEIGHT DATA ONLY

HEADING = 0.0 DEG

RUNS : 59.: 0.000 -3216.000
TOTAL TIME : 3216.000 SEC

CHAN	CALIB	GAIN	MEAN	STDDEV	SIG DA
1 WAVE AMP M	1.000E+00	1.000E+00	-9.510E-01	2.905E-01	1.162E+00

Figure 13 - Sheet a

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

RUNS : 59.: 0.000 -3216.000

TOTAL TIME : 3216.000 SEC

EFF. SCAN RT. = 1.875 176.2 DOF

	WAVE AMP	WAVE AMP
AMP. MAX	1.469E-01	1.469E-01
FREQ. MAX	3.682E-01	3.682E-01
ROOTE	3.974E-01	3.974E-01
ROOT00	4.108E-01	4.108E-01
RATIO	0.967	0.967
STAT.ERR.(%)	13.607	13.607

FREQUENCY	A U T O	S P E C T R A	
RAD/SEC	(M)**2-SEC	(M)**2-SEC	
0.000	6.101E-02	6.101E-02	1.000E+00
0.092	2.374E-02	2.374E-02	1.000E+00
0.184	8.308E-03	8.308E-03	1.000E+00
0.276	3.484E-02	3.484E-02	1.000E+00
0.368	1.469E-01	1.469E-01	1.000E+00
0.460	8.876E-02	8.876E-02	1.000E+00
0.552	7.017E-02	7.017E-02	1.000E+00
0.644	6.248E-02	6.248E-02	1.000E+00
0.736	4.918E-02	4.918E-02	1.000E+00
0.828	3.686E-02	3.686E-02	1.000E+00
0.920	2.821E-02	2.821E-02	1.000E+00
1.012	3.013E-02	3.013E-02	1.000E+00
1.104	2.695E-02	2.695E-02	1.000E+00
1.197	2.084E-02	2.084E-02	1.000E+00
1.289	1.433E-02	1.433E-02	1.000E+00
1.381	1.054E-02	1.053E-02	1.000E+00
1.473	7.936E-03	7.936E-03	1.000E+00
1.565	6.669E-03	6.669E-03	1.000E+00
1.657	5.575E-03	5.575E-03	1.000E+00
1.749	5.632E-03	5.632E-03	1.000E+00
1.841	8.444E-03	8.444E-03	1.000E+00
1.933	1.287E-02	1.287E-02	1.000E+00
2.025	1.605E-02	1.605E-02	1.000E+00
2.117	1.742E-02	1.742E-02	1.000E+00
2.209	1.903E-02	1.903E-02	1.000E+00
2.301	1.675E-02	1.675E-02	1.000E+00
2.393	1.380E-02	1.380E-02	1.000E+00
2.485	9.309E-03	9.309E-03	1.000E+00
2.577	6.303E-03	6.303E-03	1.000E+00
2.669	5.599E-03	5.599E-03	1.000E+00
2.761	5.175E-03	5.175E-03	1.000E+00
2.853	5.302E-03	5.302E-03	1.000E+00
2.945	4.059E-03	4.059E-03	1.000E+00
3.037	2.724E-03	2.724E-03	1.000E+00
3.129	2.448E-03	2.448E-03	1.000E+00
3.221	1.964E-03	1.964E-03	1.000E+00
3.313	2.059E-03	2.059E-03	1.000E+00
3.405	1.986E-03	1.986E-03	1.000E+00

Figure 13 - Sheet b

3.4	2.370E-03	2.370E-03	1.000E+00
3.589	2.730E-03	2.730E-03	1.000E+00
3.682	2.308E-03	2.308E-03	1.000E+00
3.774	2.255E-03	2.255E-03	1.000E+00
3.866	2.198E-03	2.198E-03	1.000E+00
3.958	2.130E-03	2.130E-03	1.000E+00
4.050	2.094E-03	2.094E-03	1.000E+00
4.142	1.937E-03	1.937E-03	1.000E+00
4.234	1.887E-03	1.887E-03	1.000E+00
4.326	1.942E-03	1.942E-03	1.000E+00
4.418	1.840E-03	1.840E-03	1.000E+00
4.510	1.689E-03	1.689E-03	1.000E+00
4.602	1.776E-03	1.776E-03	1.000E+00
4.694	2.112E-03	2.111E-03	1.000E+00
4.786	1.703E-03	1.703E-03	1.000E+00
4.878	1.479E-03	1.479E-03	1.000E+00
4.970	1.252E-03	1.252E-03	1.000E+00
5.062	1.136E-03	1.136E-03	1.000E+00
5.154	1.036E-03	1.036E-03	1.000E+00
5.246	7.504E-04	7.504E-04	1.000E+00
5.338	6.234E-04	6.234E-04	1.000E+00
5.430	6.625E-04	6.625E-04	1.000E+00
5.522	5.157E-04	5.157E-04	1.000E+00
5.614	4.574E-04	4.574E-04	1.000E+00
5.706	4.385E-04	4.385E-04	1.000E+00
5.798	4.542E-04	4.541E-04	1.000E+00

Figure 13 - Sheet c

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

RUNS : 59.: 0.000 -3216.000

TOTAL TIME : 3216.000 SEC

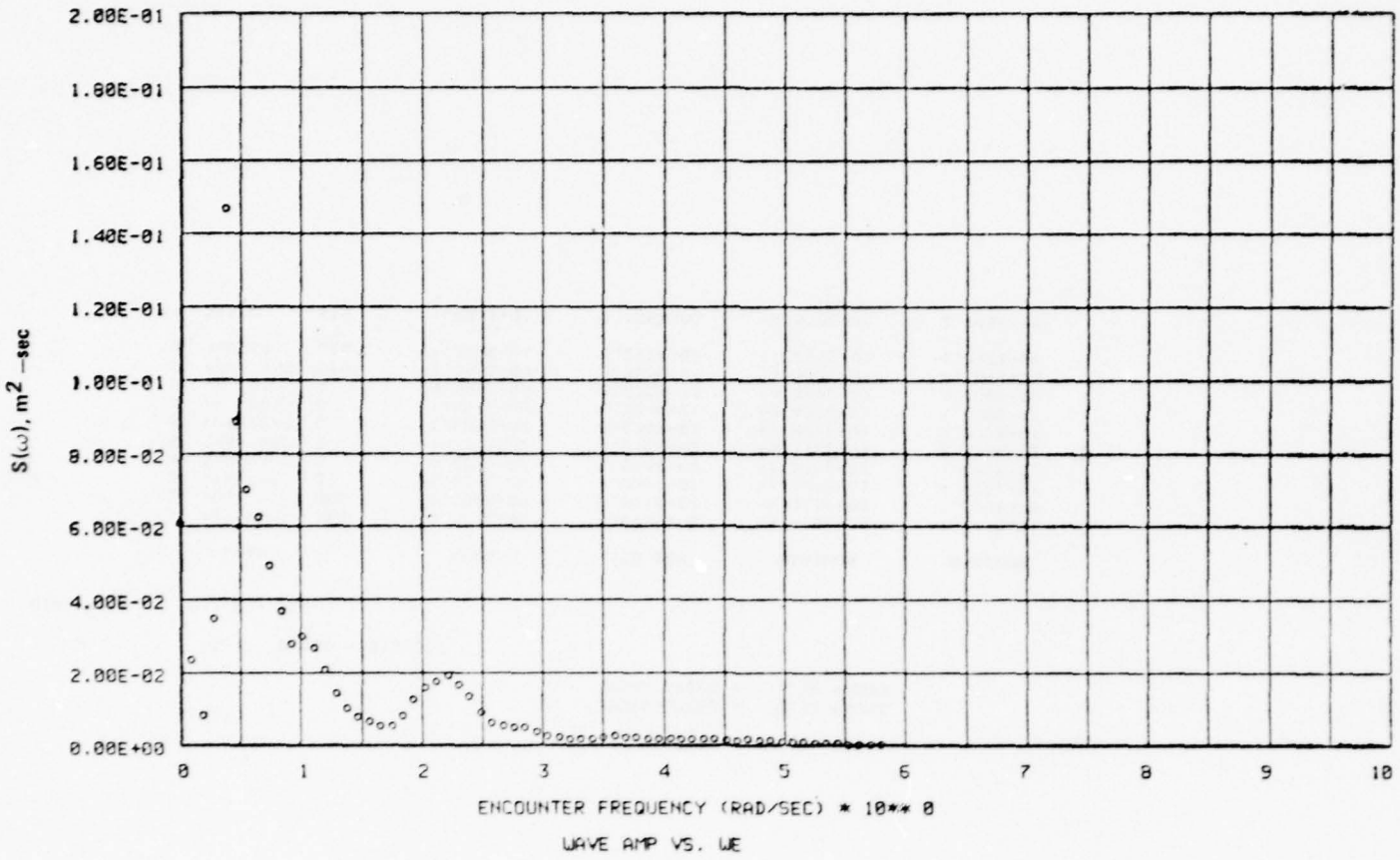

Figure 13 - Sheet d

Figure 14 - Sample of FSHV Boat Data Analysis

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

14 MARCH 1978

HEADING = 180.0 DEG

MEAS SPEED = 18.36 KNOTS
NOMN SPEED = 20.00 KNOTS

RUNS : 6.: 0.000 - 913.067

TOTAL TIME : 913.067 SEC

	CHAN		MEAN	STD DEV	MINIMUM	MAXIMUM
1	PITCH	DEG	8.913E+00	1.443E+00	3.456E+00	1.417E+01
2	ROLL	DEG	-1.926E+00	8.861E-01	-5.313E+00	1.279E+00
3	HEAVEACC	G	-1.024E-02	1.000E-01	-4.169E-01	4.346E-01
4	SURGEACC	G	9.623E-02	3.023E-02	-7.395E-02	1.632E-01
5	SWAY ACC	G	-1.781E-02	1.216E-02	-5.719E-02	2.936E-02
6	NDS VERT	G	1.684E-02	8.038E-02	-3.807E-01	2.932E-01
7	PH VERT	G	-1.851E-02	1.734E-01	-8.470E-01	5.476E-01
8	PH LAT	G	-4.806E-04	8.632E-03	-3.650E-02	3.088E-02
9	FLAP ANG	DEG	1.398E+00	3.353E-01	4.333E-01	2.167E+00
10	RUDDER	DEG	-1.385E+01	1.277E+00	-1.859E+01	-6.940E+00
11	SPEED	KTS	1.836E+01	1.166E+00	9.533E+00	2.245E+01

Figure 14 - Sheet a

AUTO-SPEC RUNS 6- 6

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

RUNS : 6.: 0.000 - 913.067

TOTAL TIME : 913.067 SEC

SCAN RATE : 5.000/ 15.00 64.4 DOF

	PITCH	ROLL	HEAVEACC	SURGEACC	SWAY ACC	MDS VERT
AMP. MAX	1.156E+00	9.324E-01	4.904E-03	4.749E-04	7.091E-05	2.514E-03
FREQ.MAX	1.841E+00	1.718E+00	2.823E+00	2.823E+00	2.066E+00	2.945E+00
ROOTE	1.962E+00	1.256E+00	1.415E-01	4.236E-02	1.729E-02	1.140E-01
ROOTQO	2.040E+00	1.253E+00	1.415E-01	4.275E-02	1.720E-02	1.137E-01
RATIO	.962	1.002	1.000	.991	1.005	1.003
STAT.ERROR	12.303	15.184	16.570	16.570	13.698	14.090

FREQUENCY A U T O S P E C T R A

RAD.SEC	(DEG)**2-SEC	(DEG)**2-SEC	(G)**2-SEC	(G)**2-SEC	(G)**2-SEC	(G)**2-SEC
0.000	1.609E+00	9.176E-02	3.282E-05	1.587E-04	1.460E-05	1.264E-05
.123	4.621E-01	9.535E-02	2.135E-05	5.504E-05	1.525E-05	9.768E-06
.245	3.979E-02	1.263E-01	1.774E-05	1.834E-05	1.173E-05	9.292E-06
.368	3.512E-02	1.087E-01	2.212E-05	2.161E-05	9.127E-06	1.138E-05
.491	3.763E-02	1.044E-01	3.323E-05	1.675E-05	9.633E-06	1.370E-05
.614	3.644E-02	1.175E-01	5.408E-05	1.410E-05	6.832E-06	1.791E-05
.736	5.381E-02	1.211E-01	8.397E-05	1.752E-05	5.039E-06	2.660E-05
.859	7.539E-02	1.047E-01	1.107E-04	2.005E-05	5.026E-06	3.757E-05
.982	1.299E-01	9.445E-02	2.083E-04	2.528E-05	5.433E-06	6.886E-05
1.104	1.706E-01	1.272E-01	3.367E-04	2.842E-05	5.876E-06	1.078E-04
1.227	1.804E-01	1.834E-01	4.265E-04	2.714E-05	7.694E-06	1.304E-04
1.350	2.641E-01	2.011E-01	6.187E-04	4.172E-05	1.078E-05	1.796E-04
1.473	3.806E-01	4.123E-01	9.836E-04	4.930E-05	1.771E-05	2.758E-04
1.595	7.207E-01	7.082E-01	2.057E-03	9.228E-05	1.789E-05	5.431E-04
1.718	1.095E+00	9.324E-01	3.216E-03	1.601E-04	3.211E-05	8.899E-04
1.841	1.156E+00	7.578E-01	3.531E-03	2.118E-04	4.303E-05	1.030E-03
1.963	1.079E+00	5.475E-01	3.409E-03	2.340E-04	5.775E-05	1.056E-03
2.086	1.011E+00	5.083E-01	3.436E-03	2.551E-04	7.091E-05	1.112E-03
2.209	8.379E-01	2.432E-01	3.038E-03	2.203E-04	4.763E-05	1.073E-03
2.332	8.223E-01	1.777E-01	3.283E-03	2.626E-04	4.521E-05	1.257E-03
2.454	7.784E-01	1.279E-01	3.519E-03	3.038E-04	4.286E-05	1.423E-03
2.577	6.828E-01	1.094E-01	3.471E-03	2.979E-04	3.292E-05	1.494E-03
2.700	6.965E-01	1.034E-01	3.614E-03	3.302E-04	3.701E-05	1.643E-03
2.823	9.323E-01	7.080E-02	4.934E-03	4.749E-04	3.612E-05	2.468E-03
2.945	8.414E-01	3.257E-02	4.833E-03	4.419E-04	2.538E-05	2.514E-03
3.068	6.173E-01	2.859E-02	3.826E-03	3.428E-04	2.532E-05	2.122E-03
3.191	5.907E-01	3.264E-02	3.958E-03	3.444E-04	2.718E-05	2.357E-03
3.313	4.553E-01	2.209E-02	3.262E-03	2.817E-04	1.793E-05	2.037E-03
3.436	3.031E-01	1.899E-02	2.411E-03	1.988E-04	1.330E-05	1.597E-03
3.559	1.697E-01	1.864E-02	1.398E-03	1.207E-04	1.476E-05	9.761E-04
3.682	1.801E-01	1.292E-02	1.539E-03	1.120E-04	1.676E-05	1.137E-03
3.804	2.212E-01	1.586E-02	1.966E-03	1.590E-04	1.064E-05	1.525E-03
3.927	1.716E-01	1.137E-02	1.619E-03	1.397E-04	7.512E-06	1.318E-03
4.050	1.314E-01	1.090E-02	1.333E-03	1.119E-04	9.167E-06	1.137E-03
4.172	1.123E-01	8.716E-03	1.188E-03	1.110E-04	8.628E-06	1.098E-03

Figure 14 - Sheet b

AUTO-SPEC RUNS 6- 6

DIGITIZATION

FSHV - FULL SCALE TRIAL - SAN DIEGO, CA

6 JULY 1978

RUNS : 6.: 0.000 - 913.067

TOTAL TIME : 913.067 SEC

SCAN RATE : 5.000/ 15.00

64.4 DOF

	PH VERT	PH LAT
AMP. MAX	1.148E-02	2.287E-05
FREQ.MAX	2.945E+00	1.718E+00
ROOTE	2.453E-01	1.230E-02
ROOTOO	2.453E-01	1.221E-02
RATIO	1.000	1.008
STAT.ERROR	14.140	14.677

FREQUENCY	A U T O S P E C T R A	
RAD/SEC	(G)**2-SEC	(G)**2-SEC
0.000	1.361E-03	1.489E-05
.123	3.948E-04	1.510E-05
.245	5.343E-05	1.040E-05
.368	5.986E-05	6.916E-06
.491	6.767E-05	5.766E-06
.614	8.275E-05	4.547E-06
.736	1.143E-04	3.827E-06
.859	1.615E-04	3.077E-06
.982	2.806E-04	2.329E-06
1.104	4.531E-04	2.033E-06
1.227	5.625E-04	3.218E-06
1.350	7.533E-04	4.370E-06
1.473	1.120E-03	6.577E-06
1.595	2.446E-03	1.491E-05
1.718	4.105E-03	2.287E-05
1.841	4.775E-03	2.133E-05
1.963	5.012E-03	2.048E-05
2.086	5.383E-03	1.844E-05
2.209	4.895E-03	1.192E-05
2.332	5.698E-03	1.254E-05
2.454	6.516E-03	1.203E-05
2.577	6.885E-03	9.709E-06
2.700	7.570E-03	7.942E-06
2.823	1.136E-02	1.364E-05
2.945	1.148E-02	1.241E-05
3.068	9.603E-03	1.100E-05
3.191	1.071E-02	1.093E-05
3.313	9.343E-03	9.164E-06
3.436	7.216E-03	7.473E-06
3.559	4.412E-03	5.969E-06
3.682	5.323E-03	5.157E-06
3.804	7.016E-03	7.667E-06
3.927	6.080E-03	7.549E-06
4.050	5.137E-03	8.311E-06
4.172	4.904E-03	9.199E-06

Figure 14 - Sheet c

HISTOGRAM RUNS 6- 6

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

RUNS : 6.: 0.000 - 913.067

TOTAL TIME : 913.067 SEC

STATISTICAL PROPERTIES

(COMPUTED FROM HISTOGRAM RESULTS)

CHANNEL	PITCH DEG	ROLL DEG	HEAVEACC G	SURGEACC G	SWAY ACC G	MDS VERT G	PH VERT G	PH LAT G
# OF CYCLES	355	275	606	609	941	950	971	1107
# OF DATA PTS	13696.	13696.	13696.	13696.	13696.	13696.	13696.	13696.
MEAN	8.9131E+00	-1.9260E+00	-1.0244E-02	9.6226E-02	-1.7808E-02	1.6835E-02	-1.8509E-02	-4.8063E-04
STDDEV	1.4428E+00	8.8610E-01	1.0003E-01	3.0227E-02	1.2160E-02	8.0378E-02	1.7342E-01	8.6316E-03
PEAK AVG	1.7219E+00	1.0647E+00	1.0888E-01	2.7704E-02	1.2492E-02	7.7008E-02	1.6562E-01	8.3901E-03
M2	9.5385E-01	4.0416E-01	5.5193E-03	2.3838E-04	9.1621E-05	3.1323E-03	1.4823E-02	3.3402E-05
M3	5.0348E-01	1.8346E-01	2.2085E-04	-3.5965E-07	7.2379E-07	1.1118E-04	1.1724E-03	1.5110E-07
M4	2.7954E+00	5.3849E-01	9.3354E-05	1.2576E-07	2.7030E-08	2.6201E-05	5.8225E-04	3.6367E-09
SKEW	5.4044E-01	7.1404E-01	5.3859E-01	-9.7720E-02	8.2730E-01	6.3417E-01	6.4912E-01	7.8272E-01
KURT	3.0724E+00	3.2967E+00	3.0645E+00	2.2132E+00	3.2199E+00	2.6704E+00	2.6498E+00	3.2595E+00
HIGHEST	5.2547E+00	3.2046E+00	4.4481E-01	6.6938E-02	4.7166E-02	2.7640E-01	5.6607E-01	3.1364E-02
2ND	4.8580E+00	2.8567E+00	3.7584E-01	6.4774E-02	4.6922E-02	2.4505E-01	5.3736E-01	3.0241E-02
3RD	4.2781E+00	2.8201E+00	3.1481E-01	6.3572E-02	4.6956E-02	2.4244E-01	5.2505E-01	2.9118E-02
4TH	4.1866E+00	2.7057E+00	3.0504E-01	6.2369E-02	4.5091E-02	2.4244E-01	5.0855E-01	2.9118E-02
5TH	4.1408E+00	2.7286E+00	3.0016E-01	6.2120E-02	4.4069E-02	2.3982E-01	5.0855E-01	2.9118E-02
1/3 RD	2.8448E+00	1.7921E+00	1.9195E-01	4.4510E-02	2.3045E-02	1.4220E-01	3.0858E-01	1.5336E-02
1/10 TH	3.5843E+00	2.4161E+00	2.3814E-01	5.2661E-02	3.1525E-02	1.8119E-01	3.9607E-01	2.0090E-02
TROUGH AVG	-1.7773E+00	-1.0674E+00	-1.0874E-01	-4.0610E-02	-1.1995E-02	-8.7592E-02	-1.8664E-01	-8.9390E-03
M2	1.1379E+00	3.8507E-01	6.2391E-03	8.5928E-04	8.1602E-05	4.5204E-03	2.1085E-02	4.7559E-05
M3	-6.8206E-01	-1.0604E-01	-2.9530E-04	-1.9073E-05	-5.1767E-07	-2.6015E-04	-2.7210E-03	-3.0611E-07
M4	3.9969E+00	4.3939E-01	1.0595E-04	2.5833E-06	1.8407E-08	7.2326E-05	1.5661E-03	8.2144E-09
SKEW	-5.6193E-01	-4.4244E-01	-5.9921E-01	-7.5723E-01	-7.1008E-01	-8.5342E-01	-8.8809E-01	-9.3332E-01
KURT	3.0870E+00	2.9494E+00	2.7217E+00	3.4987E+00	2.8054E+00	3.5254E+00	3.5270E+00	3.6317E+00
HIGHEST	-5.4570E+00	-3.3872E+00	-4.0663E-01	-1.7017E-01	-3.9182E-02	-3.9758E-01	-8.2846E-01	-3.6018E-02
2ND	-5.1900E+00	-2.6914E+00	-3.5414E-01	-1.5238E-01	-3.9260E-02	-3.5839E-01	-7.6284E-01	-3.6018E-02
3RD	-4.9611E+00	-2.4838E+00	-3.2240E-01	-1.4685E-01	-3.8394E-02	-3.5056E-01	-7.4233E-01	-3.3772E-02
4TH	-4.4499E+00	-2.4045E+00	-3.1996E-01	-1.2737E-01	-3.8894E-02	-3.1660E-01	-6.7671E-01	-3.3772E-02
5TH	-4.3126E+00	-2.3984E+00	-3.1263E-01	-1.2617E-01	-3.8650E-02	-3.0484E-01	-6.6030E-01	-3.2649E-02
1/3 RD	-2.9780E+00	-1.7994E+00	-1.9876E-01	-7.4270E-02	-2.2188E-02	-1.6373E-01	-3.5546E-01	-1.6742E-02
1/10 TH	-3.8745E+00	-2.3154E+00	-2.5031E-01	-9.9114E-02	-2.8895E-02	-2.0997E-01	-4.7661E-01	-2.2303E-02

Figure 14 - Sheet d

CONTINUED RUNS 6- 6

DIGITIZATION

FSHV - FULL SCALE TRIAL - SAN DIEGO, CA

6 JULY 1978

RUNS : 6.: 0.000 - 913.067

TOTAL TIME : 913.067 SEC

SINGLE AMPLITUDES

FREQUENCY DISTRIBUTION		CUMULATIVE DISTRIBUTIONS	
PITCH :DEG	NO OF ENCT	LESS THAN	MORE THAN
0-R	0	355	0
5.80E+00	0	355	0
5.40E+00	1	354	0
5.00E+00	1	353	1
4.60E+00	0	353	2
4.20E+00	7	346	2
3.80E+00	5	341	9
3.40E+00	14	327	14
3.00E+00	18	309	28
2.60E+00	45	264	46
2.20E+00	39	225	91
1.80E+00	47	178	130
1.40E+00	64	114	177
1.00E+00	43	71	241
6.00E-01	48	23	284
2.00E-01	23	0	332
-2.00E-01	37	0	318
-6.00E-01	34	37	284
-1.00E+00	45	71	239
-1.40E+00	39	116	200
-1.80E+00	66	155	134
-2.20E+00	48	221	86
-2.60E+00	25	269	61
-3.00E+00	25	294	36
-3.40E+00	15	319	21
-3.80E+00	8	334	13
-4.20E+00	9	342	4
-4.60E+00	1	351	3
-5.00E+00	2	352	1
-5.40E+00	1	354	0
-5.80E+00	0	355	0
0-R	0	355	0

SINGLE AMPLITUDES

FREQUENCY DISTRIBUTION		CUMULATIVE DISTRIBUTIONS	
ROLL :DEG	NO OF ENCT	LESS THAN	MORE THAN
0-R	0	275	0
4.35E+00	0	275	0
4.05E+00	0	275	0
3.75E+00	0	275	0
3.45E+00	0	275	0
3.15E+00	1	274	0
2.85E+00	6	268	1
2.55E+00	3	265	7
2.25E+00	8	257	10
1.95E+00	12	245	18
1.65E+00	26	219	30
1.35E+00	48	171	56
1.05E+00	47	124	104
7.50E-01	51	73	151
4.50E-01	49	24	202
1.50E-01	24	0	251
-1.50E-01	36	0	239
-4.50E-01	35	36	204
-7.50E-01	43	71	161
-1.05E+00	57	114	104
-1.35E+00	42	171	62
-1.65E+00	22	213	40
-1.95E+00	21	235	19
-2.25E+00	15	256	4
-2.55E+00	3	271	1
-2.85E+00	0	274	1
-3.15E+00	0	274	1
-3.45E+00	1	274	0
-3.75E+00	0	275	0
-4.05E+00	0	275	0
-4.35E+00	0	275	0
0-R	0	275	0

SINGLE AMPLITUDES

FREQUENCY DISTRIBUTION		CUMULATIVE DISTRIBUTIONS	
HEAVEACC:G	NO OF ENCT	LESS THAN	MORE THAN
0-R	0	606	0
4.35E-01	1	605	0
4.05E-01	0	605	1
3.75E-01	1	604	1
3.45E-01	0	604	2
3.15E-01	3	601	2
2.85E-01	6	595	5
2.55E-01	16	579	11
2.25E-01	32	547	27
1.95E-01	47	500	59
1.65E-01	78	422	106
1.35E-01	85	337	184
1.05E-01	74	263	269
7.50E-02	70	193	343
4.50E-02	82	111	413
1.50E-02	111	0	495
-1.50E-02	117	0	489
-4.50E-02	82	117	407
-7.50E-02	86	199	321
-1.05E-01	67	285	254
-1.35E-01	70	352	184
-1.65E-01	64	422	120
-1.95E-01	49	486	71
-2.25E-01	32	535	39
-2.55E-01	17	567	22
-2.85E-01	13	584	9
-3.15E-01	7	597	2
-3.45E-01	1	604	1
-3.75E-01	0	605	1
-4.05E-01	1	605	0
-4.35E-01	0	606	0
0-R	0	606	0

Figure 14 - Sheet e

CONTINUED RUNS 6- 6

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

RUNS : 6.: 0.000 - 913.067

TOTAL TIME : 913.067 SEC

SINGLE AMPLITUDES

FREQUENCY DISTRIBUTION		CUMULATIVE DISTRIBUTIONS	
PH VERT :G	NO OF ENCT	LESS THAN	MORE THAN
0-R	0	971	0
7.25E-01	0	971	0
6.75E-01	0	971	0
6.25E-01	0	971	0
5.75E-01	1	970	0
5.25E-01	7	963	1
4.75E-01	10	953	8
4.25E-01	33	920	18
3.75E-01	33	887	51
3.25E-01	66	821	84
2.75E-01	92	729	150
2.25E-01	120	609	242
1.75E-01	105	504	362
1.25E-01	137	367	467
7.50E-02	169	198	604
2.50E-02	198	0	773
-2.50E-02	211	0	760
-7.50E-02	128	211	632
-1.25E-01	122	339	510
-1.75E-01	107	461	403
-2.25E-01	108	568	295
-2.75E-01	86	676	209
-3.25E-01	72	762	137
-3.75E-01	51	834	86
-4.25E-01	29	885	57
-4.75E-01	21	914	36
-5.25E-01	20	935	16
-5.75E-01	9	955	7
-6.25E-01	2	964	5
-6.75E-01	2	966	3
-7.25E-01	1	968	2
0-R	2	969	0

SINGLE AMPLITUDES

FREQUENCY DISTRIBUTION		CUMULATIVE DISTRIBUTIONS	
PH LAT :G	NO OF ENCT	LESS THAN	MORE THAN
0-R	0	1107	0
4.35E-02	0	1107	0
4.05E-02	0	1107	0
3.75E-02	0	1107	0
3.45E-02	0	1107	0
3.15E-02	2	1105	0
2.85E-02	3	1102	2
2.55E-02	8	1094	5
2.25E-02	19	1075	13
1.95E-02	28	1047	32
1.65E-02	104	943	60
1.35E-02	136	807	164
1.05E-02	103	704	300
7.50E-03	248	456	403
4.50E-03	254	202	651
1.50E-03	202	0	905
-1.50E-03	245	0	862
-4.50E-03	216	245	646
-7.50E-03	159	461	487
-1.05E-02	169	620	318
-1.35E-02	113	789	205
-1.65E-02	75	902	130
-1.95E-02	58	977	72
-2.25E-02	37	1035	35
-2.55E-02	16	1072	19
-2.85E-02	7	1088	12
-3.15E-02	8	1095	4
-3.45E-02	2	1103	2
-3.75E-02	2	1105	0
-4.05E-02	0	1107	0
-4.35E-02	0	1107	0
0-R	0	1107	0

Figure 14 - Sheet g

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1/3RD OCTV RUNS 6- 6

DIGITIZATION FSHV - FULL SCALE TRIAL - SAN DIEGO, CA 6 JULY 1978

14 MARCH 1978

HEADING = 180.0 DEG

MEAS SPEED = 18.36 KNOTS
NOMN SPEED = 20.00 KNOTS

RUNS : 6.: 0.000 - 913.067

TOTAL TIME : 913.067 SEC

1/3RD OCTAVE BANDWIDTH LEVELS

CENTER FREQUENCY (HZ)	3 HEAVEACC M/SEC**2	4 SURGEACC M/SEC**2	5 SWAY ACC M/SEC**2	6 MDS VERT M/SEC**2	7 PH VERT M/SEC**2	8 PH LAT M/SEC**2
.100	2.88E-02	1.45E-02	9.64E-03	1.66E-02	3.53E-02	7.91E-03
.126	4.17E-02	1.82E-02	9.46E-03	2.39E-02	4.96E-02	7.81E-03
.159	7.24E-02	2.38E-02	1.11E-02	4.14E-02	8.43E-02	7.22E-03
.200	1.20E-01	3.08E-02	1.50E-02	6.53E-02	1.34E-01	1.01E-02
.252	2.70E-01	5.09E-02	2.82E-02	1.42E-01	3.00E-01	2.27E-02
.317	3.87E-01	1.01E-01	4.94E-02	2.18E-01	4.72E-01	2.87E-02
.400	4.49E-01	1.32E-01	4.71E-02	2.93E-01	6.28E-01	2.47E-02
.504	5.04E-01	1.50E-01	3.90E-02	3.82E-01	8.15E-01	2.68E-02
.635	3.48E-01	1.01E-01	2.97E-02	3.17E-01	6.79E-01	2.54E-02
.800	2.42E-01	7.34E-02	4.02E-02	2.61E-01	5.61E-01	2.38E-02
1.008	1.66E-01	7.39E-02	3.12E-02	2.07E-01	4.47E-01	2.26E-02
1.270	1.28E-01	5.95E-02	2.40E-02	1.69E-01	3.67E-01	2.45E-02
1.600	1.13E-01	4.73E-02	2.64E-02	1.58E-01	3.47E-01	2.44E-02
2.016	1.24E-01	4.34E-02	3.01E-02	1.81E-01	3.97E-01	2.42E-02

Figure 14 - Sheet h

Figure 15 - Comparison of Measured Wave Induced Craft Accelerations
With the LVA Acceleration Standard

LATERAL ACC **VERTICAL ACC**

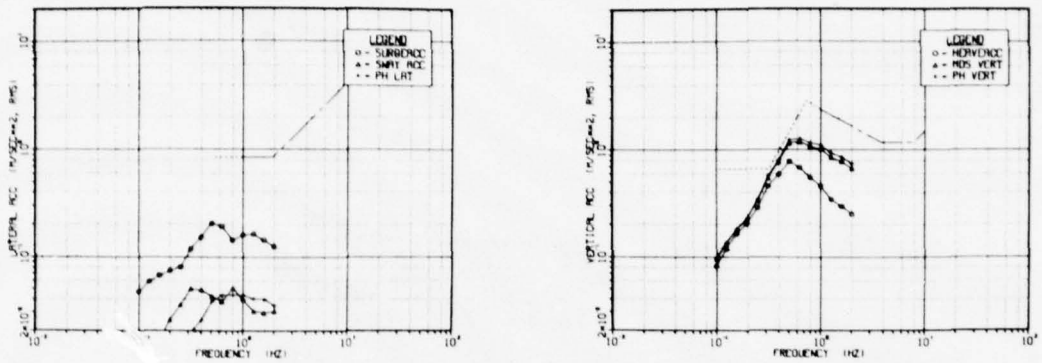


Figure 15a — Run 1, Significant Wave Height = *
Speed = 22.4 Knots

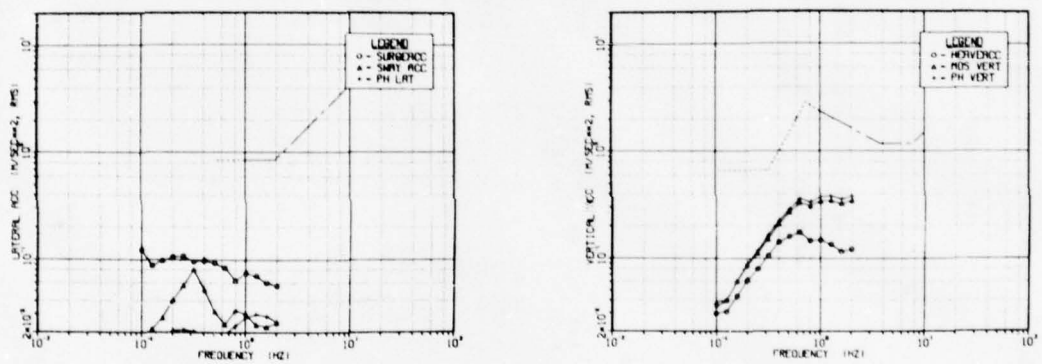


Figure 15b — Run 2, Significant Wave Height = *
Speed = 23.6 Knots

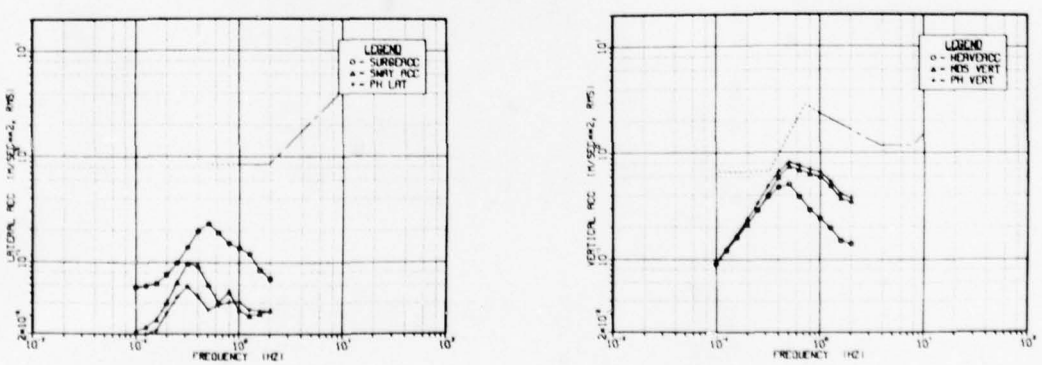


Figure 15c — Run 3, Significant Wave Height = *
Speed = 18.9 Knots

*** No wave statistics available because signal corrupted by local voice transmissions of unknown origin.**

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

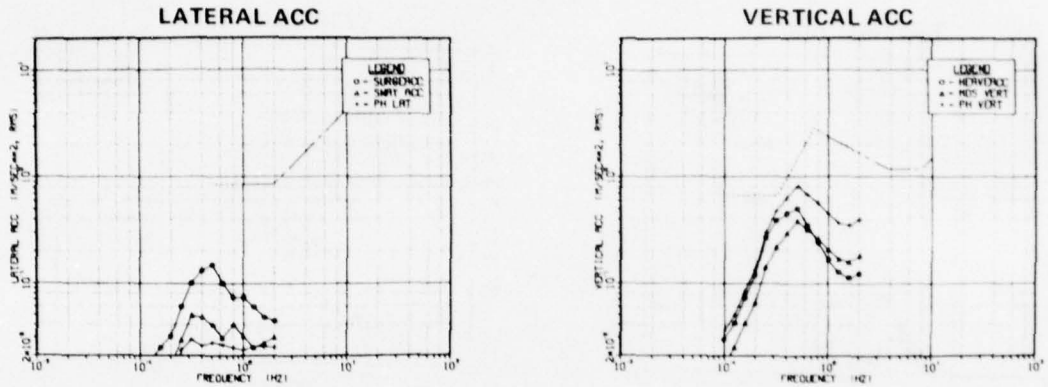


Figure 15d — Run 6, Significant Wave Height = *
Speed = 18.4 Knots

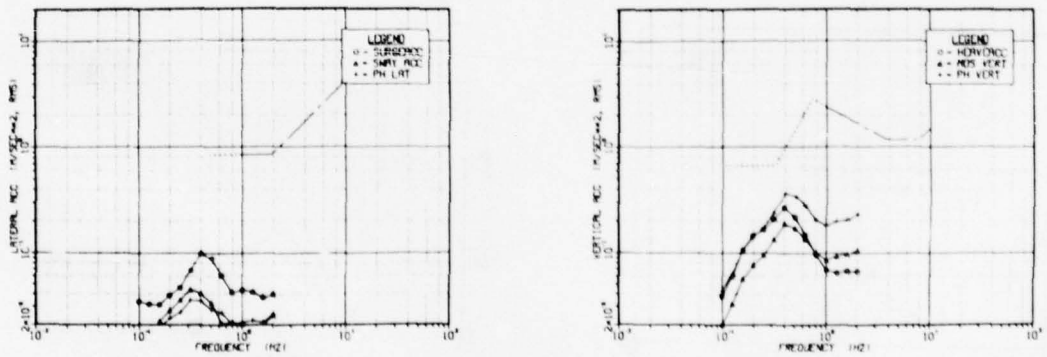


Figure 15e — Run 7, Significant Wave Height = *
Speed = 18.2 Knots

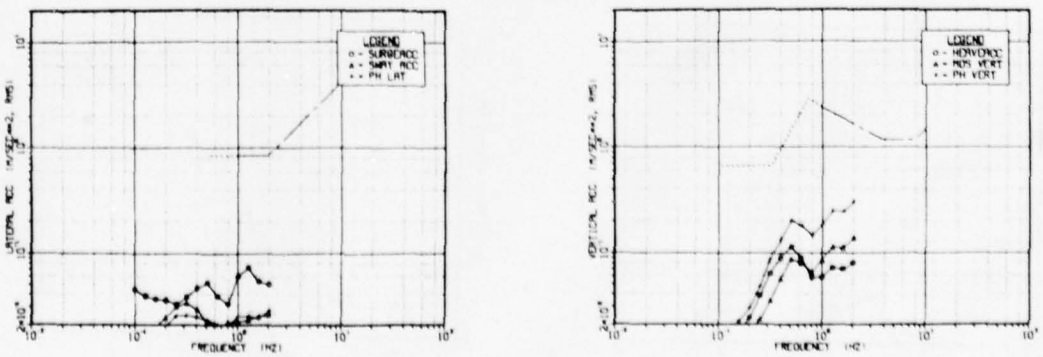


Figure 15f — Run 8, Significant Wave Height = *
Speed = 17.9 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC **VERTICAL ACC**

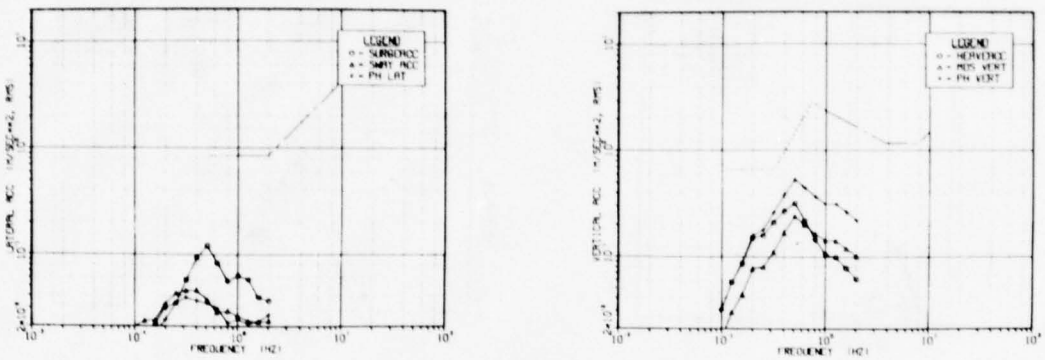


Figure 15g — Run 9, Significant Wave Height = *
Speed = 17.9 Knots

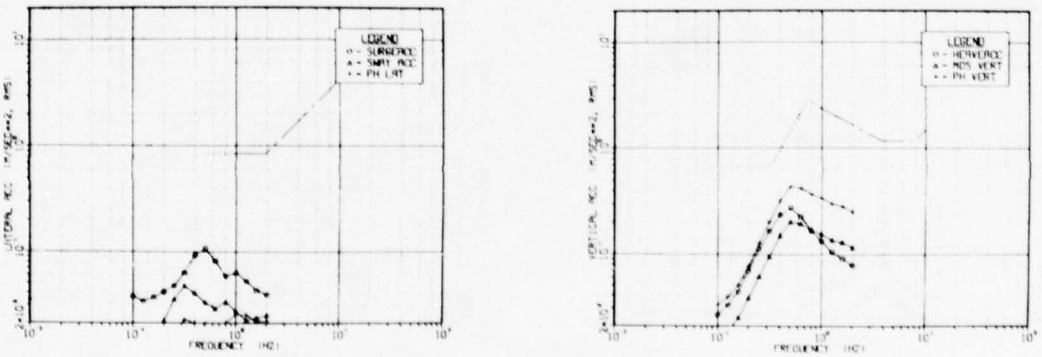


Figure 15h — Run 10, Significant Wave Height = 2.13 ft (0.65m)
Speed = 21.0 Knots

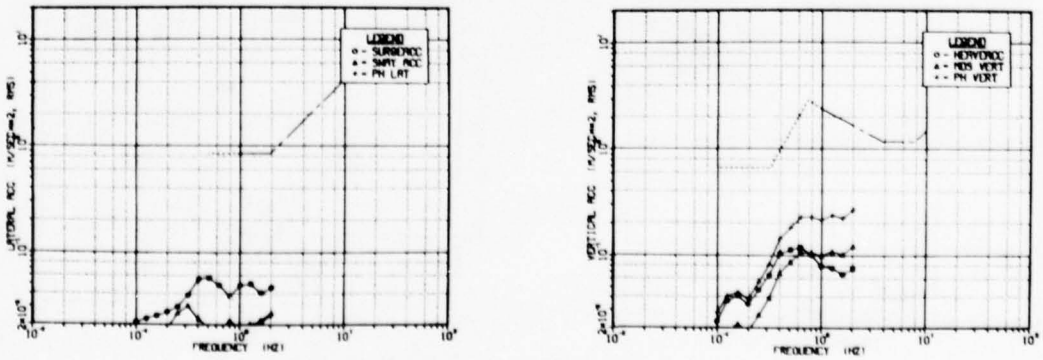


Figure 15i — Run 11, Significant Wave Height = 1.79 ft. (0.55m)
Speed = 20.1 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

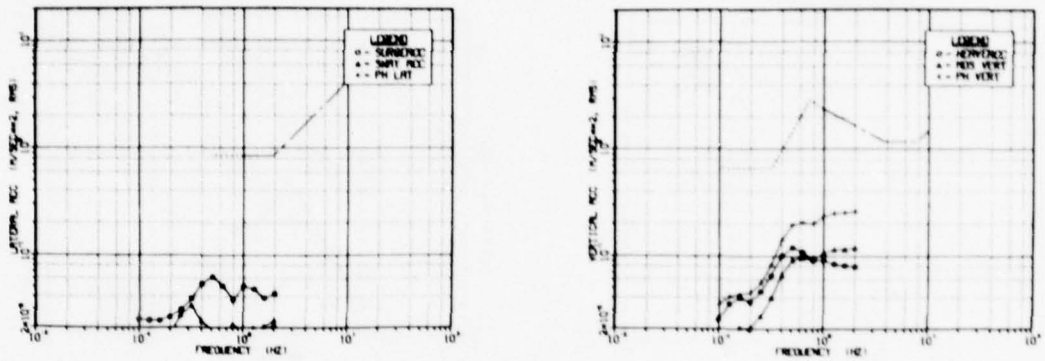


Figure 15j — Run 12, Significant Wave Height = 1.79 ft. (0.55m)
Speed = 21.7 Knots

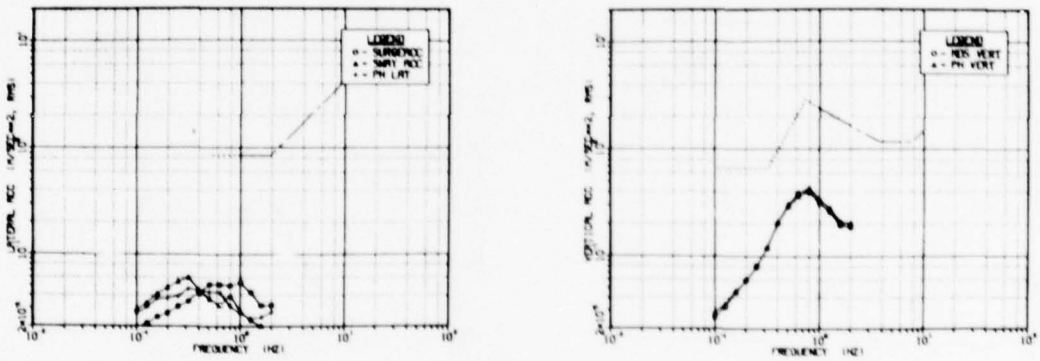


Figure 15k — Run 13, Significant Wave Height = 2.15 ft. (0.66m)
Speed = 16.2 Knots

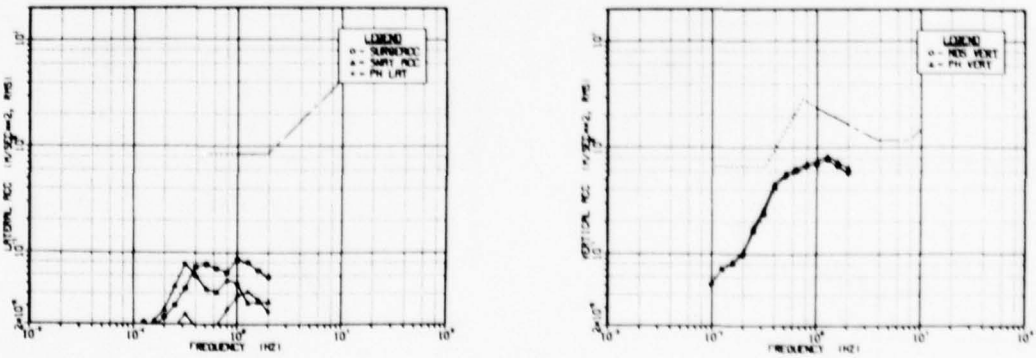


Figure 15l — Run 14, Significant Wave Height = 3.28 ft. (1.00m)
Speed = 21.0 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

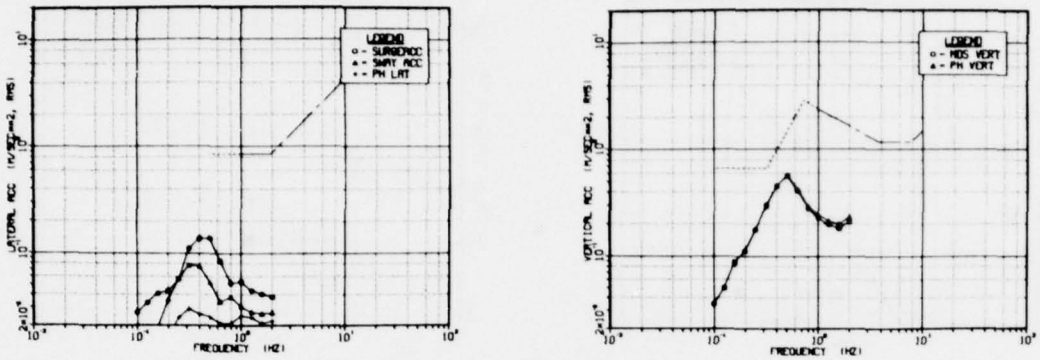


Figure 15m — Run 15, Significant Wave Height = 3.28 ft.(1.00m)
Speed = 20.0 Knots

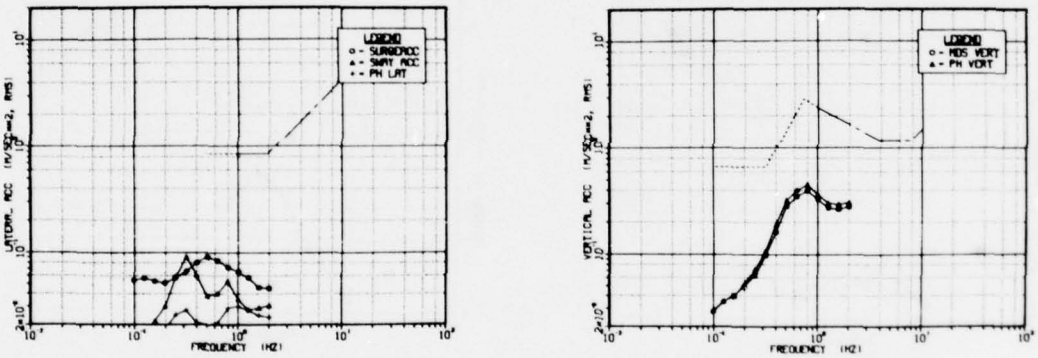


Figure 15n — Run 16, Significant Wave Height = 3.28 ft. (1.00m)
Speed = 20.8 Knots

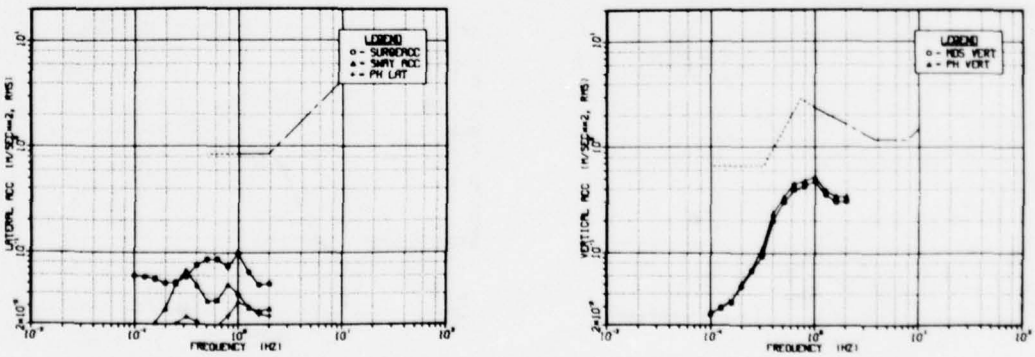


Figure 15o — Run 17, Significant Wave Height = 3.28 ft.(1.00m)
Speed = 20.7 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

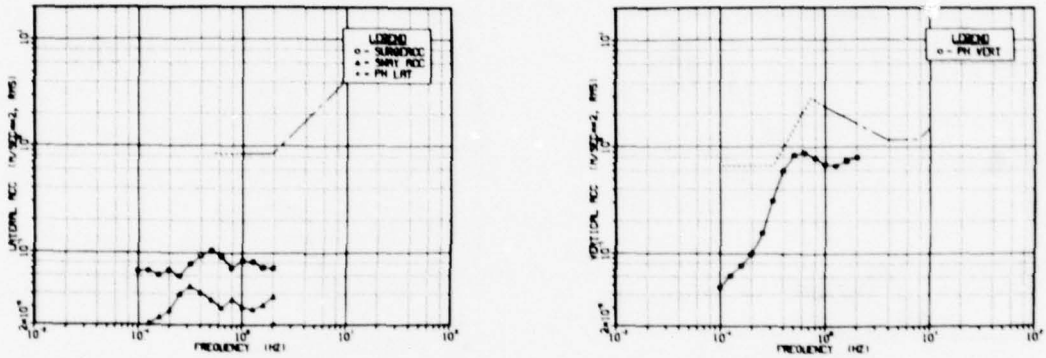


Figure 15p — Run 18, Significant Wave Height = 2.88 ft. (0.88m)
Speed = 24.7 Knots

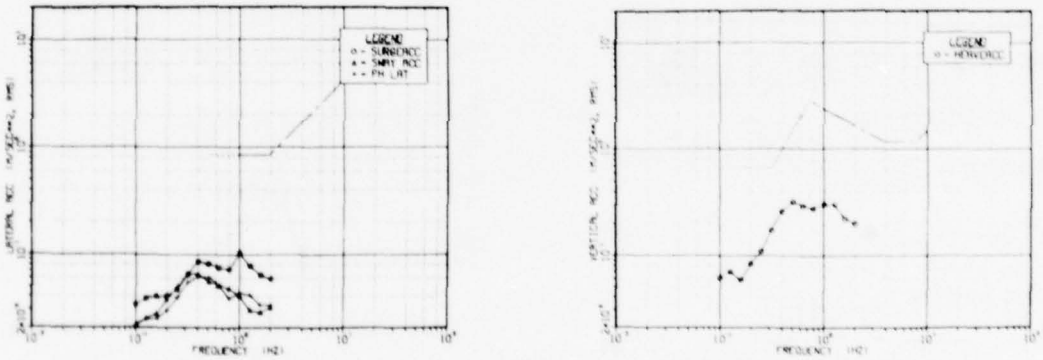


Figure 15q — Run 40, Significant Wave Height = *
Speed = 17.4 Knots

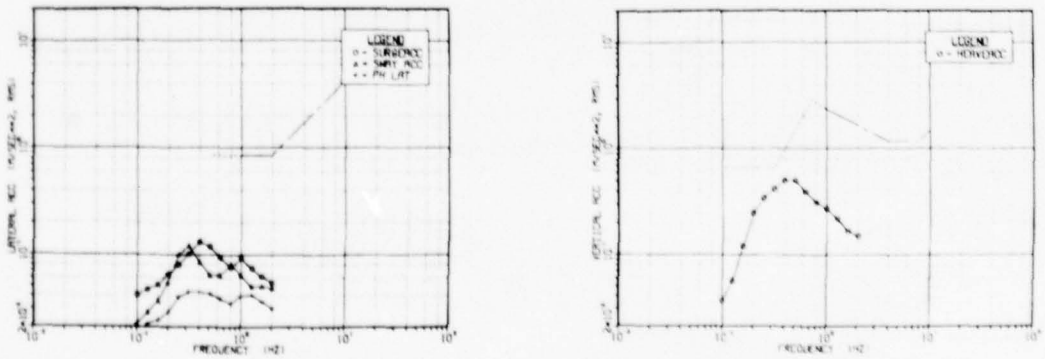


Figure 15r — Run 41, Significant Wave Height = 4.36 ft. (1.33m)
Speed = 19.3 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC **VERTICAL ACC**

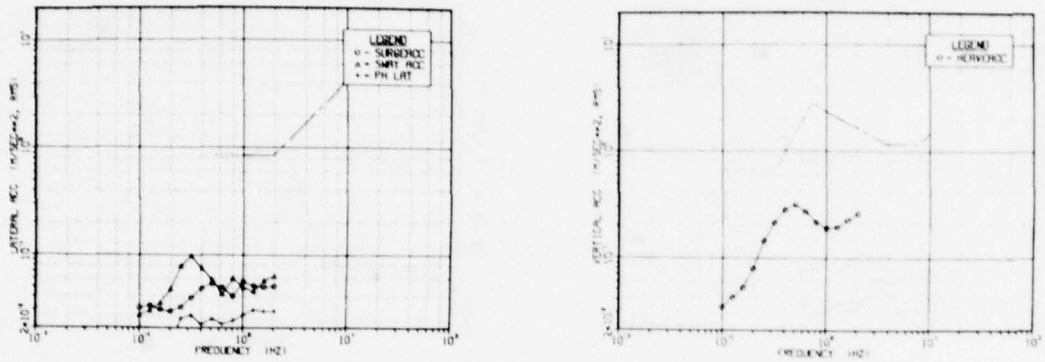


Figure 15s — Run 42, Significant Wave Height = 2.66 ft. (0.81m)
Speed = 21.7 Knots

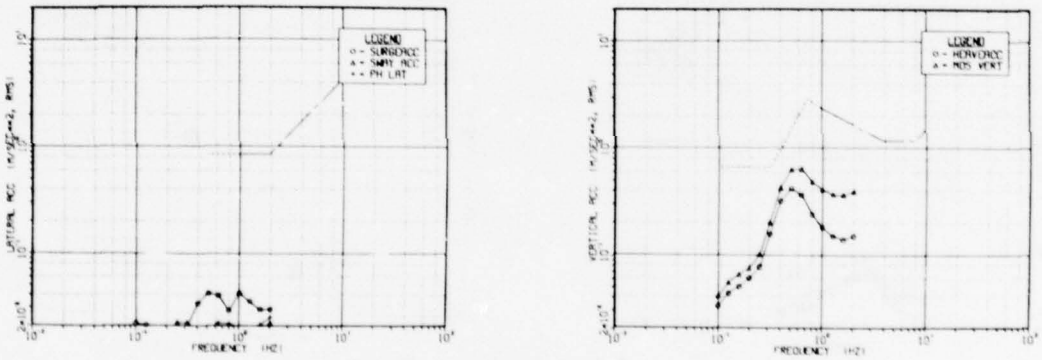


Figure 15t — Run 43, Significant Wave Height = 2.32 ft. (0.71m)
Speed = 23.4 Knots

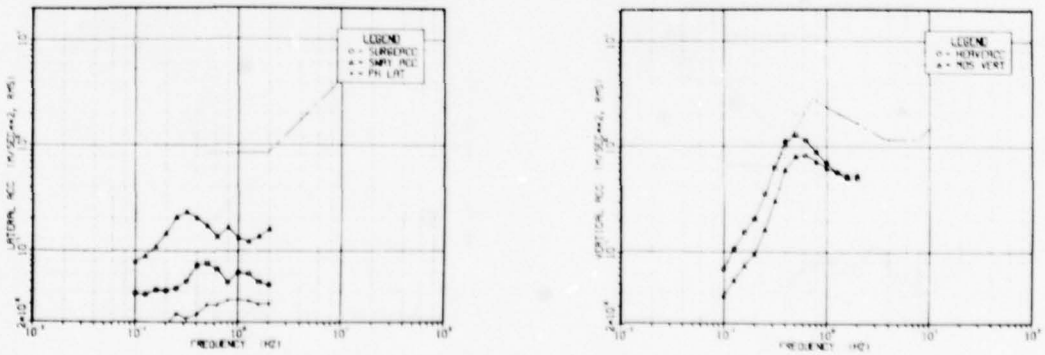


Figure 15u — Run 45, Significant Wave Height = 2.33 ft. (0.71m)
Speed = 23.4 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

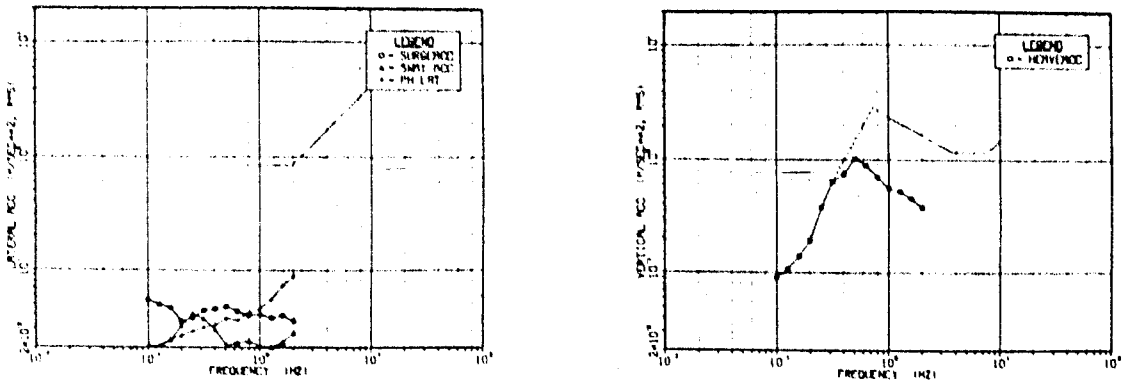


Figure 15v — Run 52, Significant Wave Height = 2.69 ft. (0.82m)
Speed = 23.3 Knots

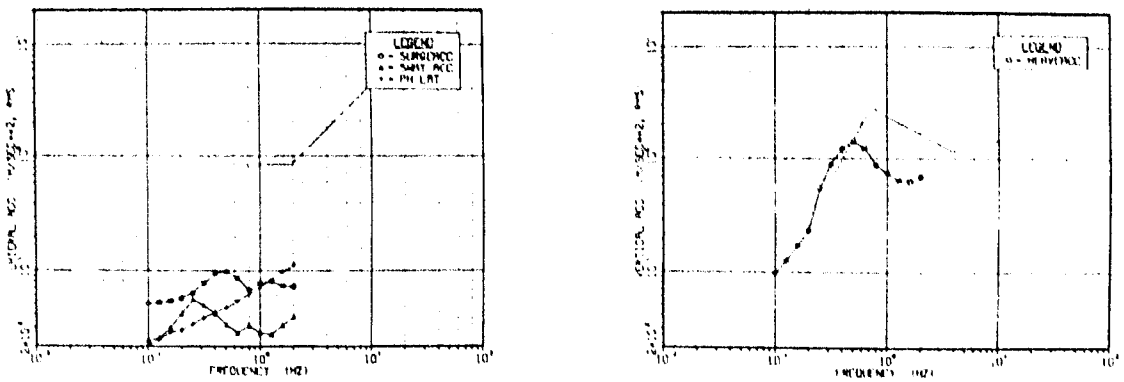


Figure 15w — Run 54, Significant Wave Height = 3.92 ft. (1.19m)
Speed = 23.1 Knots

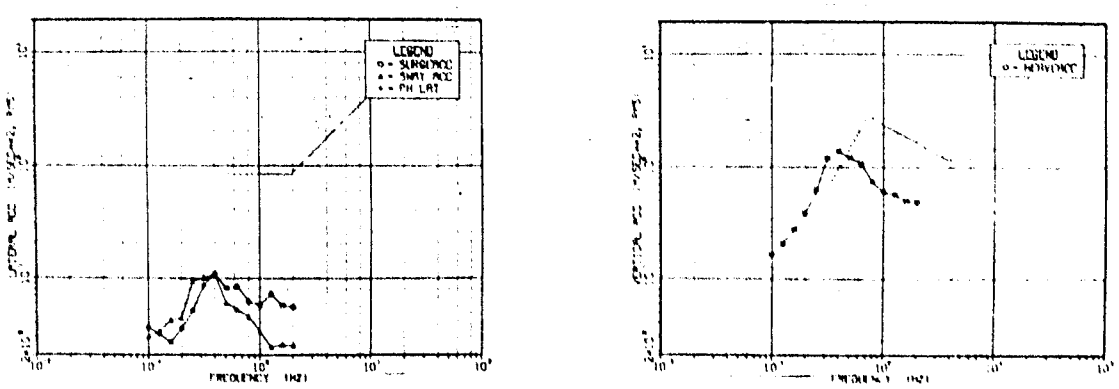


Figure 15x — Run 55, Significant Wave Height = *
Speed = 13.8 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC **VERTICAL ACC**

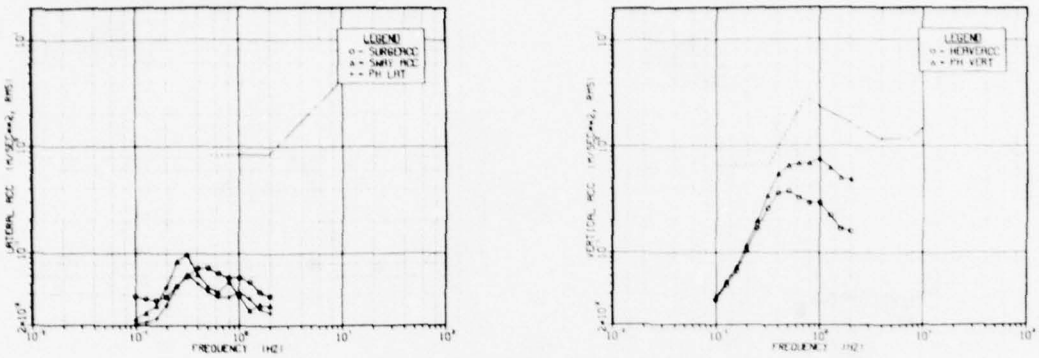


Figure 15y — Run 59, Significant Wave Height = 3.69 ft. (1.12m)
Speed = 17.5 Knots

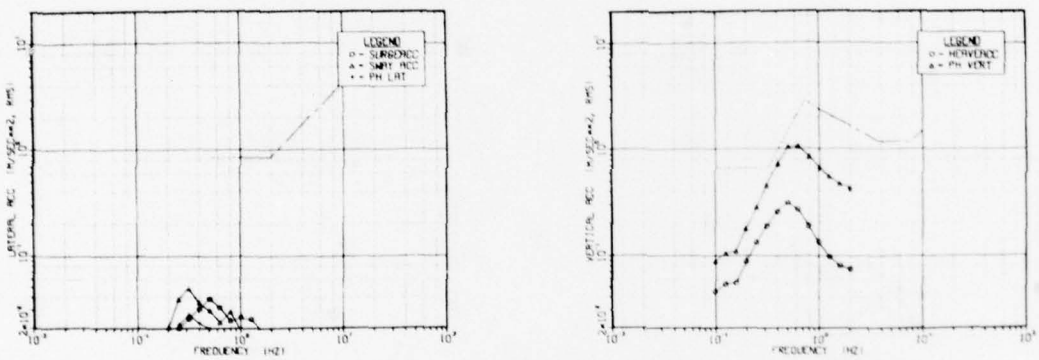


Figure 15z — Run 61, Significant Wave Height = 3.37 ft. (1.03m)
Speed = 19.1 Knots

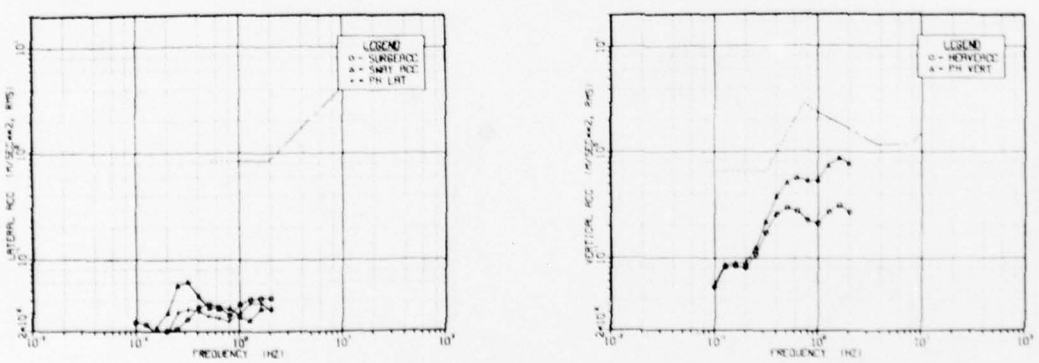


Figure 15aa — Run 62, Significant Wave Height = 4.14 ft. (1.26m)
Speed = 18.8 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

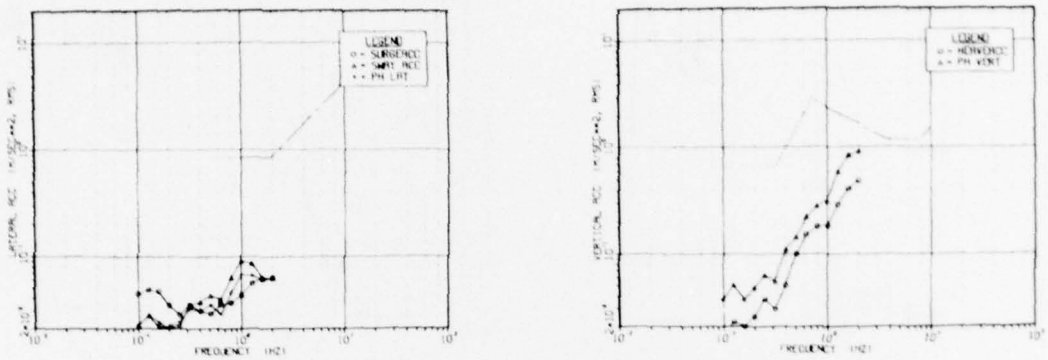


Figure 15bb — Run 63, Significant Wave Height = 4.44 ft. (1.35m)
Speed = 18.4 Knots

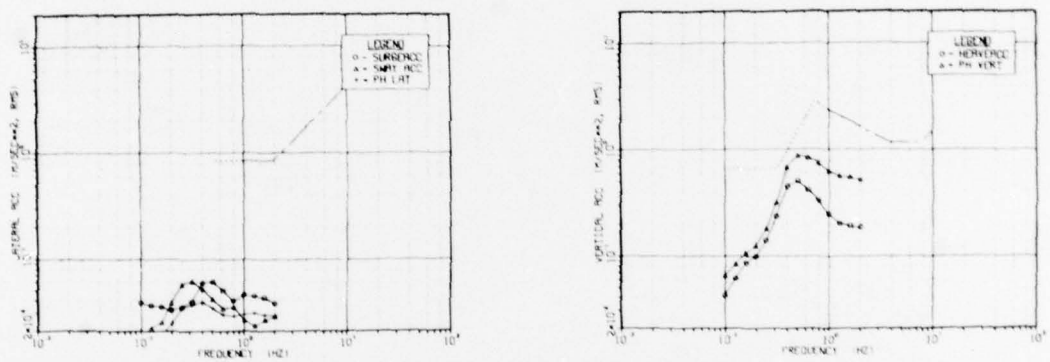


Figure 15cc — Run 64, Significant Wave Height = 4.10 ft. (1.25m)
Speed = 18.5 Knots

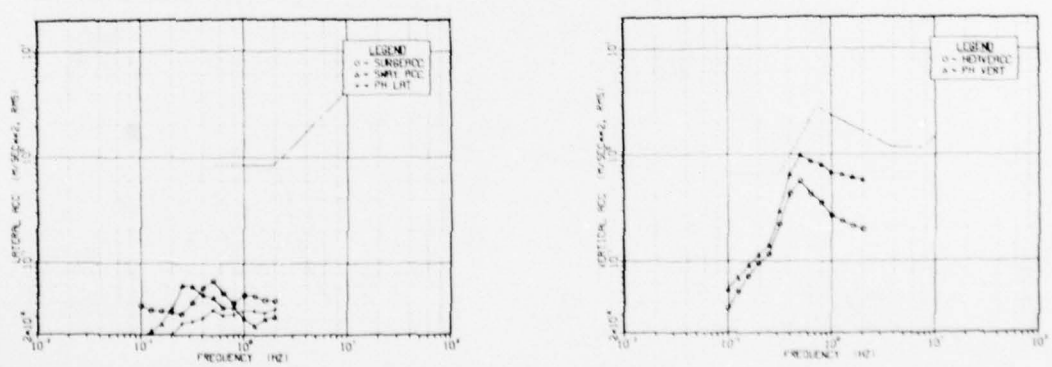


Figure 15dd — Run 65, Significant Wave Height = 3.40 ft. (1.04m)
Speed = 18.7 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

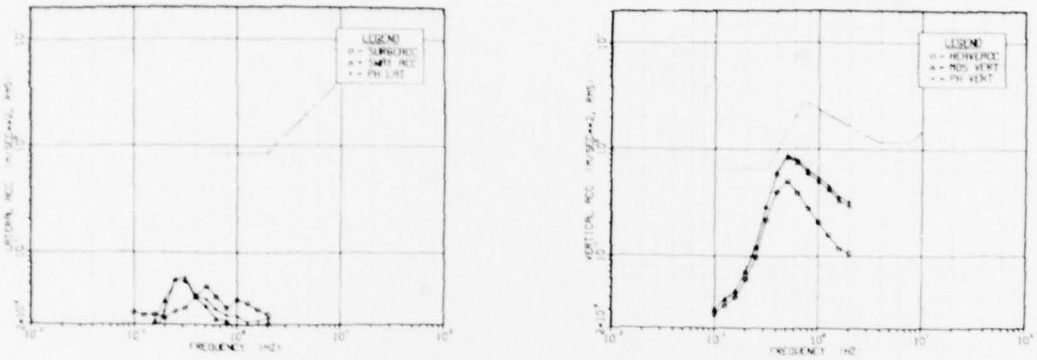


Figure 15ee — Run 66, Significant Wave Height = 2.15 ft. (0.66m)
Speed = 20.2 Knots

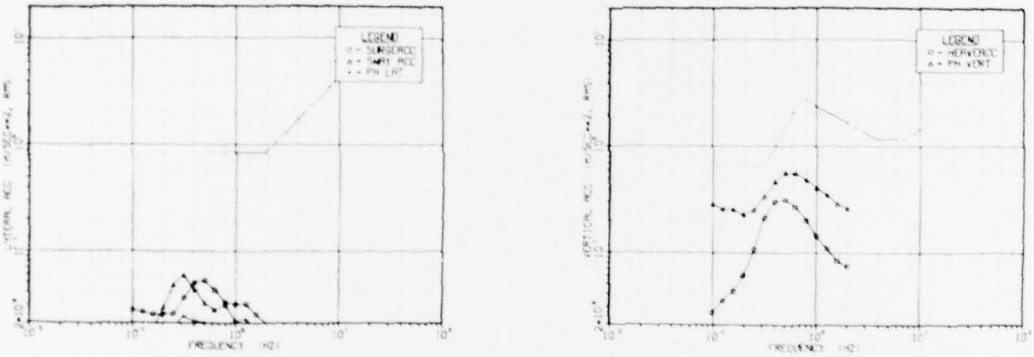


Figure 15ff — Run 67, Significant Wave Height = 2.11 ft. (0.64m)
Speed = 22.0 Knots

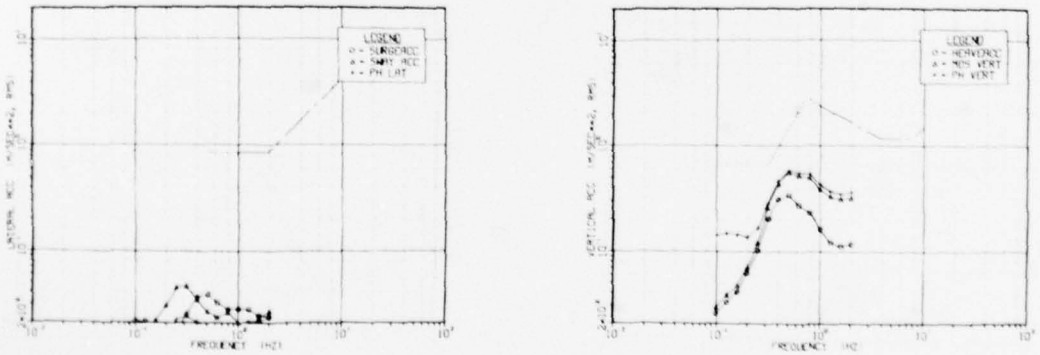


Figure 15gg — Run 68, Significant Wave Height = 2.28 ft. (0.69m)
Speed = 22.0 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

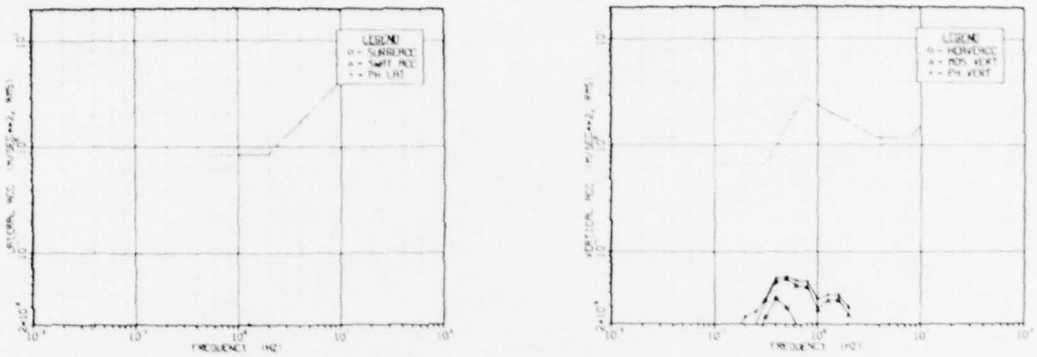


Figure 15hh – Run 69, Significant Wave Height = 2.33 ft. (0.71m)
Speed = 22.0 Knots

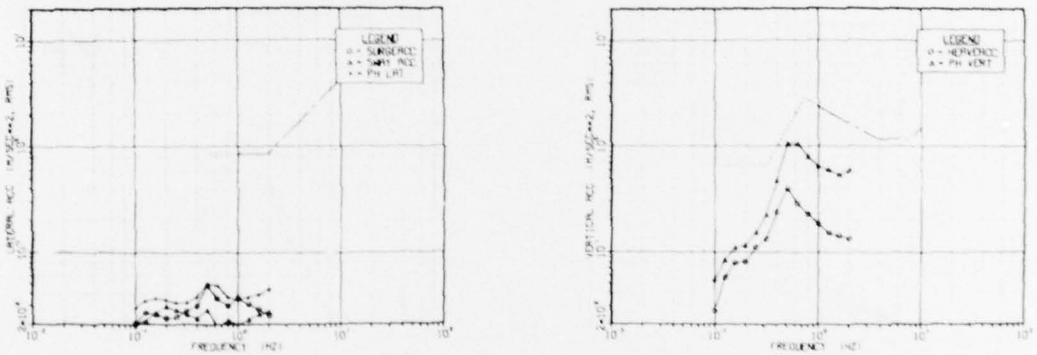


Figure 15ii – Run 70, Significant Wave Height = 3.39 ft. (1.03m)
Speed = 30.0 Knots

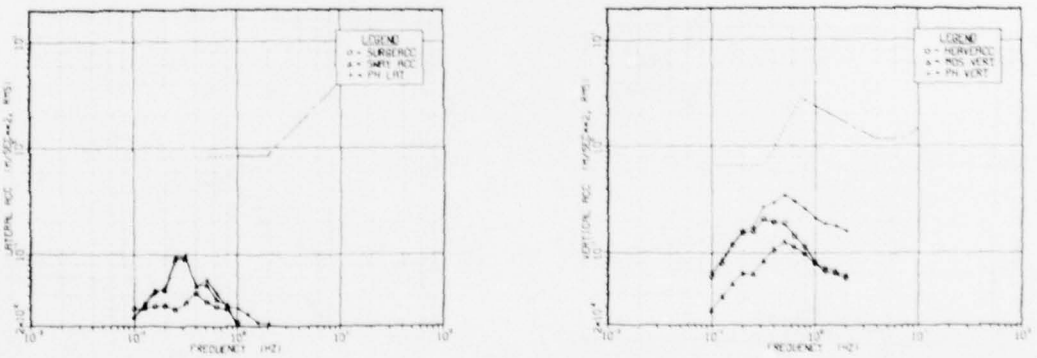


Figure 15jj – Run 71, Significant Wave Height = 3.05 ft. (0.93m)
Speed = 30.0 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

LATERAL ACC

VERTICAL ACC

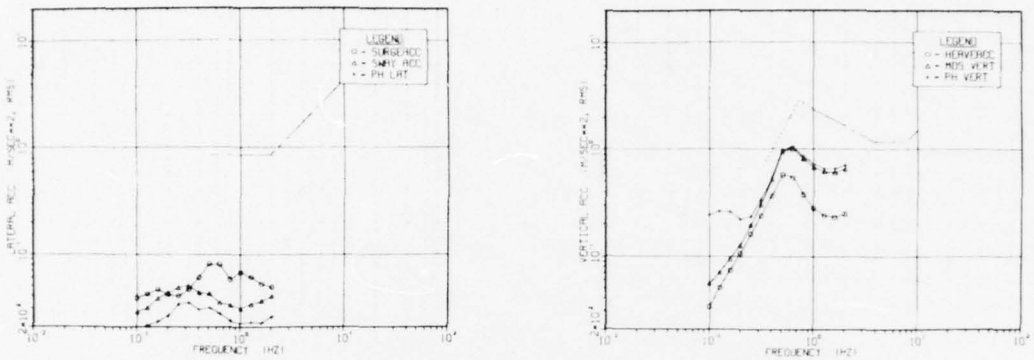


Figure 15kk — Run 72, Significant Wave Height = 2.57 ft. (0.78m)
Speed = 30.0 Knots

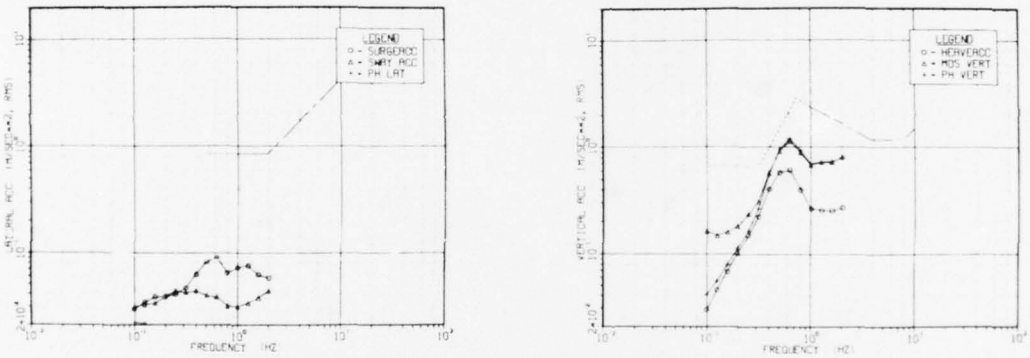


Figure 15ll — Run 73, Significant Wave Height = 2.51 ft. (0.77m)
Speed = 30.0 Knots

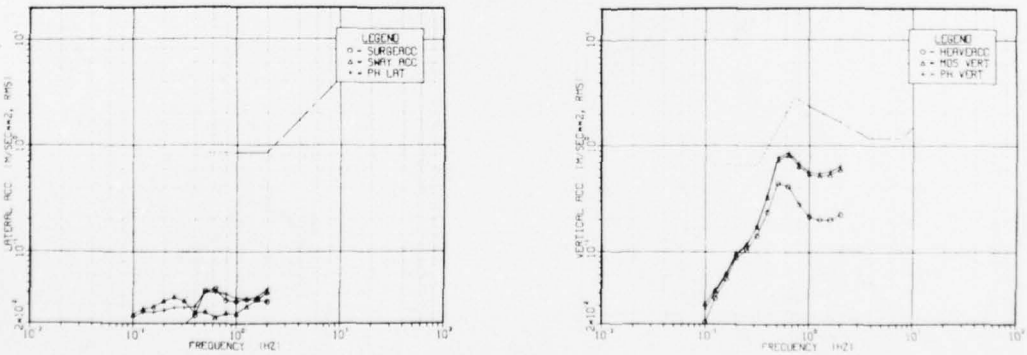
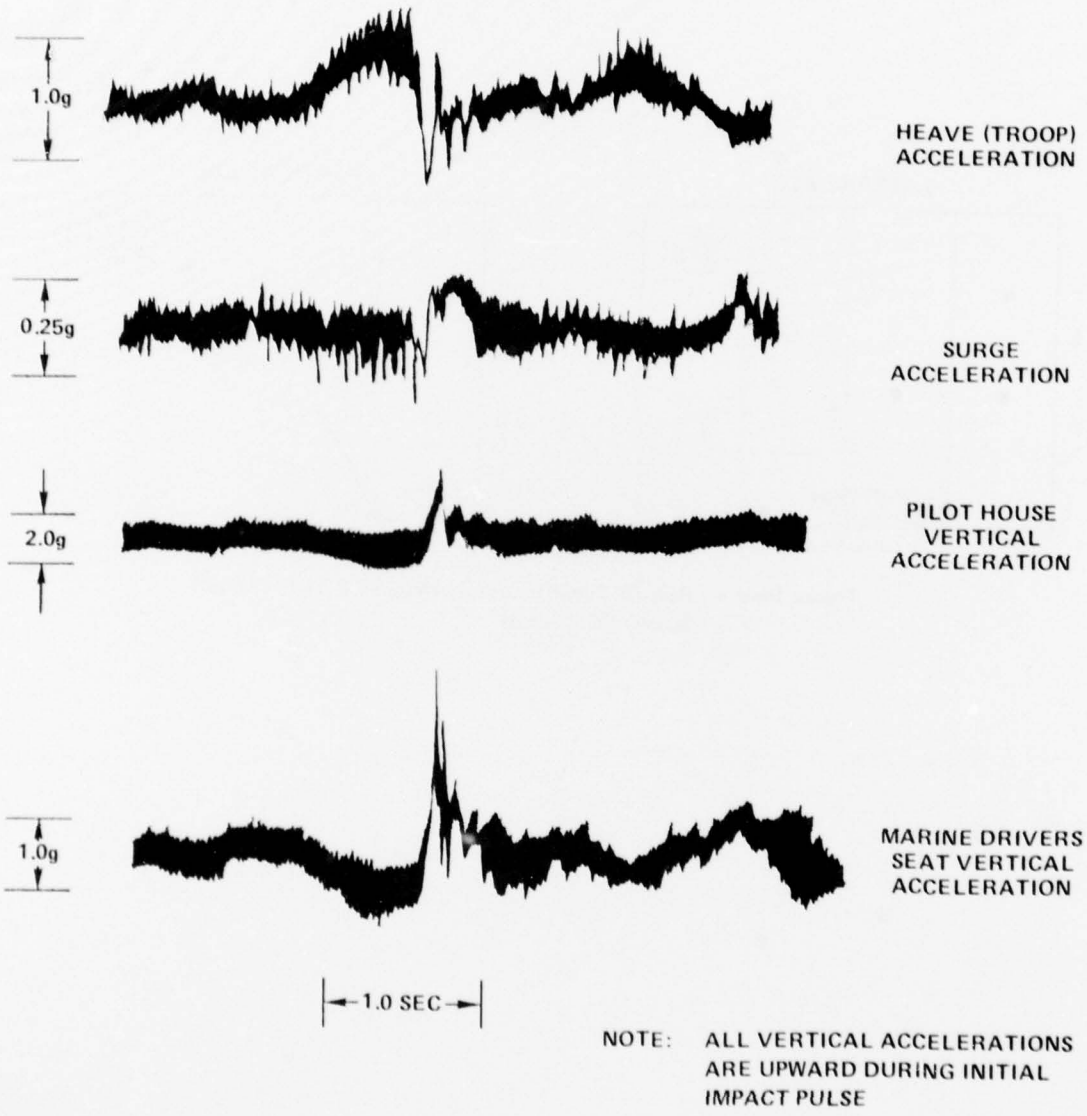


Figure 15mm — Run 74, Significant Wave Height = 2.16 ft. (0.66m)
Speed = 30.0 Knots

Figure 15. Comparison of Measured Wave Induced Craft Accelerations With the LVA Acceleration Standard (Continued)

Figure 15nn — Run 75, Significant Wave Height = 2.11 ft. (0.64m)
Speed = 30.0 Knots



NOTE: ALL VERTICAL ACCELERATIONS ARE UPWARD DURING INITIAL IMPACT PULSE

Figure 16 - Sample Record of Impact Accelerations During Earlier Runs

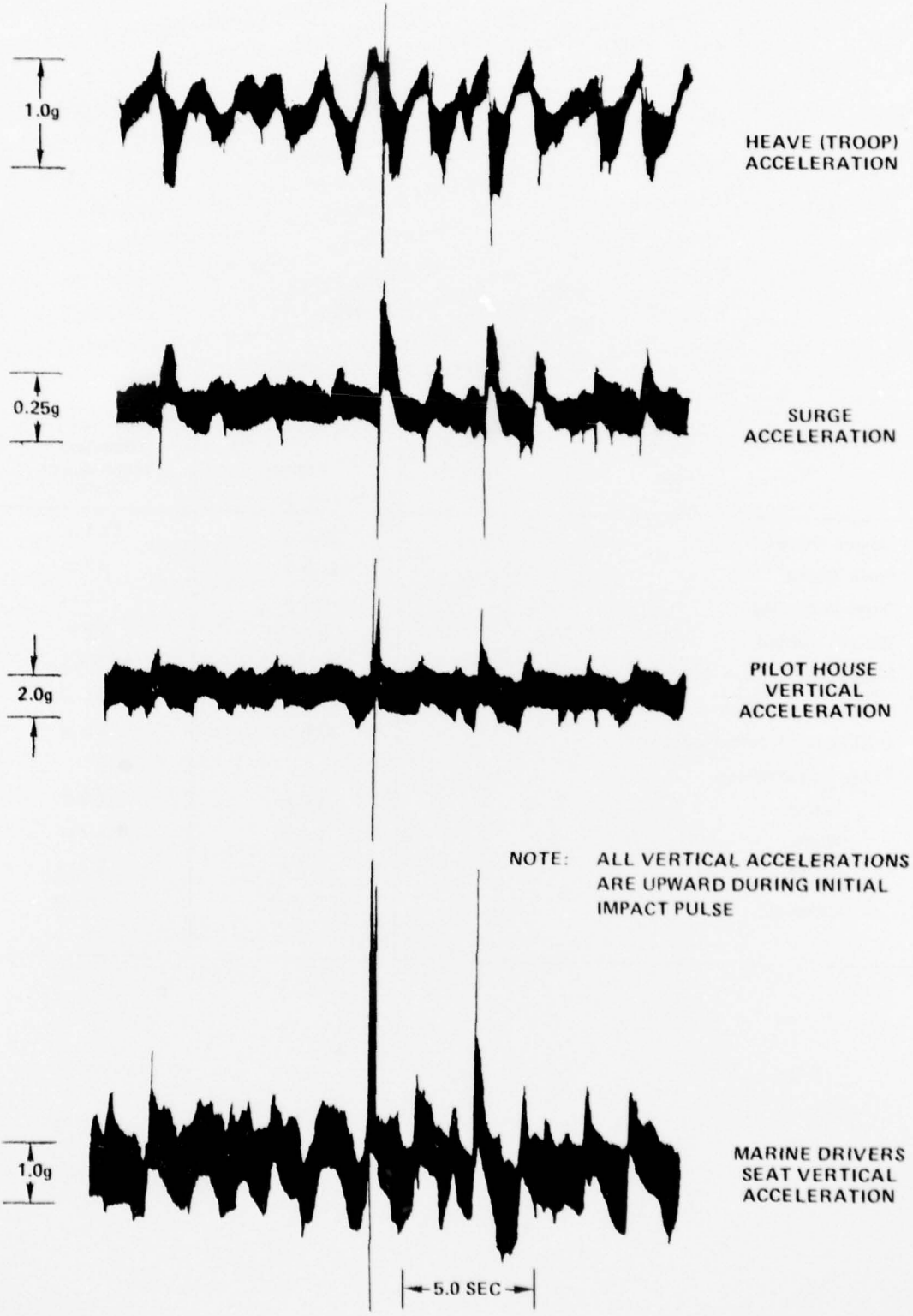


Figure 17 - Sample Record of Impact Accelerations During Later Runs

Table 1 - FSHV PARTICULARS

Item	English	Standard International Units
Length, Overall	36.5 ft	11.1 m
Beam, Overall	11.0 ft	3.4 m
Depth at Midship	6.0 ft	1.8 m
Draft at Midship	2.8 ft	0.9 m
Weight (with approx. ½ full fuel tank)	52,900 lb	23,995 kg
VCG Above Baseline	3.5 ft	1.1 m
LCG fwd of Transom Stern	13.0 ft	4.0 m
Troop Compartment:		
Length	5.4 ft	1.6 m
Width	5.7 ft	1.7 m
Height	5.7 ft	1.7 m
Capacity	9 Troops	9 Troops

Table 2 - SUMMARY OF TEST CONDITIONS

Run Number	Date	Boat Data Duration, Minutes	Significant Wave Height, M	Significant Wave Height, FT	Period of Maximum Wave Energy, SEC	Boat Speed, KTS	Data Recorded	Comments
1	2-8-78	9.3	–	–	–	22.4	Yes	Head Sea
2	2-8-78	11.4	–	–	–	23.6	Yes	Following Sea
3	2-14	4.1	–	–	–	18.9	Yes	Bow Sea, Short Run
4	2-14	0	–	–	–	25[1]	No	Bow Sea
5	2-14	0	–	–	–	30[1]	No	Following Sea
6	3-14	15.2	–	–	–	18.4	Yes	Head Sea
7	3-14	10.5	–	–	–	18.2	Yes	Beam Sea
8	3-14	9.5	–	–	–	17.9	Yes	Following Sea
9	3-14	10.3	–	–	–	17.9	Yes	Bow Sea
10A	3-15	–	–	–	–	24[1]	Yes	Circles
10B	3-15	34.6	0.65	2.13	13.7	21.0	Yes	Circles
11	3-17	57.9	0.54	1.79	13.7	20.1	Yes	Circles
12	3-17	53.6	0.54	1.79	13.7	21.7	Yes	Circles
13	3-21	44.0	0.66	2.15	13.7	16.2	Yes	Circles
14	3-29	16.2	1.00	3.28	17.1	21.0	Yes	Head Sea
15	3-29	9.9	1.00	3.28	17.1	20.0	Yes	Beam Sea
16	3-29	10.3	1.00	3.28	17.1	20.8	Yes	Following Sea
17	3-29	9.4	1.00	3.28	17.1	20.7	Yes	Quartering Sea
–	4-3	–	0.78	2.56	13.7	22[1]	Yes	Circles
18	4-3	56.5	0.88	2.88	13.7	24.7	Yes	Circles
40	5-19	21.9	–	–	–	17.4	Yes	Circles
41	5-23	36.3	1.29	4.36	9.8	19.3	Yes	Circles
42	6-5	35.9	0.81	2.66	17.1	21.7	Yes	Circles
43	6-8	18.1	0.71	2.32	13.7	23.4	Yes	Circles
44	6-12	0	0.69	2.24	13.7	26[1]	No	Circles
45	6-12	32.6	0.71	2.33	13.7	23.4	Yes	Circles
46	6-13	0	0.82	2.69	17.1	26[1]	No	Circles
47	6-13	0	0.97	3.19	22.8	26[1]	No	Circles

[1] Nominal Speed, Data Not Available

Table 2 - SUMMARY OF TEST CONDITIONS (CONTINUED)

Run Number	Date	Boat Data Duration, Minutes	Significant Wave Height, M	Significant Wave Height, FT	Period of Maximum Wave Energy, SEC	Boat Speed, KTS	Data Recorded	Comments
48	6-14	0	1.19	3.91	17.1	26[1]	No	Circles
49	6-14	0	1.07	3.50	17.1	26[1]	No	Circles
50	6-16	0	1.00	3.29	17.1	26[1]	No	Circles
51	6-16	0	1.05	3.44	17.1	26[1]	No	Circles
52	6-19	16.6	0.82	2.69	17.1	23.3	Yes	Circles
53	6-19	0	0.89	2.93	17.1	26[1]	No	Circles
54	6-23	23.1	1.20	3.92	17.1	23.1	Yes	Circles
55	6-23	5.8	–	–	–	13.8	Yes	Short Run
56	6-27	0	0.91	2.97	17.1	26[1]	No	Circles
57	6-27	0	0.82	2.70	8.5	26[1]	No	Circles
58	6-28	0	0.73	2.39	17.1	26[1]	No	Circles
59	7-17	65.1	1.12	3.69	17.1	17.5	Yes	Circles
60	7-17	0	–	–	–	22[1]	No	Circles
61	7-18	47.4	1.03	3.37	11.4	19.1	Yes	Circles
62	7-19	59.2	1.26	4.14	11.4	18.8	Yes	Circles
63	7-19	6.3	1.35	4.44	11.4	18.4	Yes	Short Run
64	7-20	56.4	1.25	4.10	9.75	18.5	Yes	Circles
65	7-20	40.8	1.04	3.40	9.75	18.7	Yes	Circles
66	7-24	40.9	0.65	2.15	13.6	20.2	Yes	Circles
67	7-24	53.5	0.64	2.11	13.6	22[1]	Yes	Circles
68	7-26	46.8	0.69	2.28	13.6	22[1]	Yes	Circles
69	7-26	4.7	0.71	2.33	13.6	22[1]	Yes	Short Run
70	7-27	16.3	1.03	3.39	13.6	30[1]	Yes	Circles
71	7-27	4.7	0.93	3.05	13.6	30[1]	Yes	Short Run
72	7-31	41.0	0.78	2.57	11.4	30[1]	Yes	Circles
73	7-31	49.3	0.76	2.51	11.4	30[1]	Yes	Circles
74	8-3	39.1	0.66	2.16	11.4	30[1]	Yes	Circles
75	8-3	49.9	0.64	2.11	11.4	30[1]	Yes	Circles

[1] Nominal Speed, Data Not Available

Table 3 - SUMMARY OF VERTICAL ACCELERATION AND MOTIONS RESULTS

Run Number	Trim, deg	$\overline{\text{HI 1/10}}$ Pitch, deg		Standard Dev Pitch, deg	$\overline{\text{HI 1/10}}$ Roll, deg		Standard Dev Roll, deg	$\overline{\text{HI 1/10}}$ Heave (Troop) Accel, g's		RMS Heave (Troop) Accel, g's	$\overline{\text{HI 1/10}}$ MDS Vert Accel, g's		RMS MDS Vert Accel, g's	$\overline{\text{HI 1/10}}$ Pilot House Vert Accel, g's		RMS Pilot House Vert Accel, g's	Comments
		Bow Up	Bow Dwn		Port Dwn	Stbd Dwn		Up	Dwn		Up	Dwn		Up	Dwn		
1	7.3	4.6	5.3	1.92	2.1	2.1	0.86	0.38	0.43	0.17	0.93	0.61	0.29	1.04	0.66	0.32	
2	6.1	2.9	3.5	1.30	2.9	2.7	1.13	0.11	0.12	0.05	0.27	0.21	0.10	0.30	0.24	0.11	
3	15.7	0.4	11.0	3.86	5.9	6.9	2.51	0.26	0.29	0.11	0.47	0.47	0.18	0.52	0.52	0.20	Short Run
6	8.9	3.6	3.9	1.44	2.4	2.3	0.89	0.24	0.25	0.10	0.21	0.18	0.08	0.48	0.40	0.17	
7	7.5	2.1	2.1	0.83	3.4	3.3	1.33	0.12	0.13	0.05	0.11	0.10	0.04	0.22	0.20	0.08	
8	6.9	1.6	1.5	0.76	2.0	2.0	0.76	0.07	0.06	0.03	0.08	0.07	0.03	0.18	0.15	0.07	
9	7.3	2.3	2.3	0.88	3.0	3.4	1.35	0.16	0.15	–	0.13	0.12	0.05	0.29	0.26	0.11	
10	7.6	2.6	2.1	1.07	2.5	2.7	1.20	0.15	0.15	0.06	0.14	0.12	0.05	0.32	0.26	0.11	
11	6.7	1.6	1.3	0.89	2.2	2.0	1.02	0.08	0.07	0.03	0.09	0.07	0.03	0.18	0.16	0.07	
12	6.9	1.6	1.4	0.75	2.2	2.2	1.19	0.08	0.07	0.03	0.09	0.07	0.03	0.20	0.16	0.07	
13	6.0	3.2	1.2	2.68	3.6	3.4	1.26	–	–	–	0.25	0.22	0.09	0.28	0.24	0.09	
14	8.4	2.4	2.6	0.99	3.2	3.3	1.29	–	–	–	0.55	0.39	0.19	0.61	0.43	0.20	
15	8.2	2.4	2.6	1.01	2.9	2.7	1.11	–	–	–	0.28	0.24	0.11	0.29	0.25	0.11	
16	7.4	2.0	2.1	0.82	3.2	3.2	1.22	–	–	–	0.25	0.21	0.09	0.28	0.23	0.10	
17	7.0	2.0	1.9	0.79	2.9	3.2	1.16	–	–	–	0.30	0.26	0.11	0.35	0.28	0.12	
18	7.6	4.5	3.7	1.55	3.7	3.7	1.46	–	–	–	–	–	–	0.78	0.53	0.23	
40	6.9	3.7	4.0	1.79	3.3	3.2	1.31	0.15	0.12	0.04	–	–	–	–	–	–	
41	7.7	5.8	4.5	2.23	4.3	4.3	1.61	0.15	0.16	0.06	–	–	–	–	–	–	
42	6.2	3.5	3.0	1.33	2.8	2.8	1.13	0.12	0.11	0.04	–	–	–	–	–	–	
43	6.9	3.3	3.0	1.15	2.4	2.1	1.05	0.04	0.05	0.02	0.23	0.17	0.07	–	–	–	
45	7.5	4.1	3.9	1.56	2.9	2.8	1.43	0.73	0.75	0.28	0.66	0.47	0.20	–	–	–	

Table 3 - SUMMARY OF VERTICAL ACCELERATION AND MOTIONS RESULTS (CONTINUED)

Run Number	Trim, deg	$\overline{\text{HI 1/10}}$ Pitch, deg		Standard Dev Pitch, deg	$\overline{\text{HI 1/10}}$ Roll, deg		Standard Dev Roll, deg	$\overline{\text{HI 1/10}}$ Heave (Troop) Accel, g's		RMS Heave (Troop) Accel, g's	$\overline{\text{HI 1/10}}$ MDS Vert Accel, g's		RMS MDS Vert Accel, g's	$\overline{\text{HI 1/10}}$ Pilot House Vert Accel, g's		RMS Pilot House Vert Accel, g's	Comments
		Bow Up	Bow Dwn		Port Dwn	Stbd Dwn		Up	Dwn		Up	Dwn		Up	Dwn		
52	6.1	5.9	6.3	2.22	3.3	2.9	1.36	0.66	0.65	0.23	–	–	–	–	–	–	
54	5.8	6.0	6.7	2.10	4.5	4.7	1.81	0.94	0.91	0.31	–	–	–	–	–	–	
55	6.8	5.9	5.8	2.30	5.4	4.9	1.68	1.14	0.99	0.31	–	–	–	–	–	–	Short Run
59	8.9	5.2	4.0	2.47	4.4	4.4	1.80	0.25	0.24	0.08	–	–	–	0.66	0.44	0.19	
61	8.9	2.9	2.7	1.18	2.9	2.8	1.20	0.16	0.17	0.06	–	–	–	0.65	0.54	0.23	
62	7.3	3.0	3.0	1.26	3.8	3.5	1.57	0.27	0.22	0.08	–	–	–	0.73	0.43	0.19	
63	7.0	3.6	4.1	1.75	4.9	4.8	1.87	0.22	0.23	0.08	–	–	–	0.45	0.44	0.16	Short Run
64	6.3	4.9	4.5	1.77	4.0	4.0	1.90	0.32	0.30	0.11	–	–	–	0.81	0.50	0.21	
65	8.1	6.0	5.9	3.02	5.2	4.9	2.77	0.33	0.31	0.11	–	–	–	0.88	0.51	0.22	
66	6.9	3.2	2.8	1.22	3.0	2.9	1.30	0.17	0.19	0.07	–	–	–	0.50	0.68	0.39	
67	9.5	3.1	2.6	1.30	3.5	3.4	1.39	0.19	0.20	0.07	0.40	0.32	0.13	0.51	0.36	0.27	
68	6.2	5.5	3.0	2.60	3.2	3.0	1.32	0.25	0.27	0.09	0.60	0.41	0.17	0.65	0.43	0.18	
69	8.1	1.2	1.7	1.35	1.1	0.9	0.40	0.03	0.03	0.01	0.05	0.05	0.02	0.05	0.05	0.02	Short Run
70	5.0	4.3	4.7	1.89	4.3	4.2	1.69	0.15	0.15	0.07	–	–	–	0.76	0.53	0.23	
71	4.7	4.5	4.0	1.60	4.2	3.9	1.66	0.14	0.14	0.05	0.14	0.08	0.04	0.29	0.24	0.09	Short Run
72	3.1	4.5	6.0	2.23	3.9	4.8	1.59	0.29	0.33	0.12	0.84	0.54	0.28	0.90	0.52	0.48	
73	3.0	4.0	4.3	1.54	3.8	4.2	1.57	0.30	0.33	0.12	0.79	0.61	0.27	0.83	0.53	0.26	
74	7.0	3.0	3.7	1.56	2.6	2.8	1.29	0.23	0.23	0.09	0.57	0.41	0.18	0.60	0.44	0.19	
75	3.0	3.3	3.5	1.39	2.9	2.8	1.24	0.24	0.26	0.09	0.62	0.45	0.18	0.65	0.46	0.19	

Table 4 - MAXIMUM VALUES OF IMPACT ACCELERATION

Run Number	Heave (Troop) Accel., g's	MDS Vertical Accel., g's	Pilot House Accel., g's	Longit. Decel., g's
1	1.3	3.3	3.9	0.4
2	0.6	0.9	1.4	0.2
3	0.5	1.2	2.1	0.4
6	0.4	0.8	2.1	0.3
8	–	0.4	1.1	–
10	–	0.6	–	0.3
12	0.6	0.9	2.4	0.2
13	–	1.0	–	0.1
14	–	1.5	2.8	0.2
15	–	1.1	1.7	–
16	–	1.3	1.9	–
17	–	1.0	1.4	–
18	–	1.2	5.6	0.5
40	–	1.5	–	0.2
41	1.3	2.6	–	0.4
42	1.6	–	–	0.4
43	–	1.9	–	–
45	2.9	2.6	–	0.5
54	3.3	–	–	0.4
59	–	–	3.2	–
65	–	–	3.2	–
68	1.1	2.5	3.7	0.4
69	1.4	2.9	6.1	0.4
71	0.7	–	–	–
72	1.4	4.1	–	0.4
73	1.4	4.8	8.8	0.5
74	1.2	2.6	4.5	0.5
75	1.3	4.4	5.7	0.5