NOAA Technical Report NOS 108
Charting and Geodetic Services Series CGS 4

Shock and Vibration Environmental Test of NOAA 29-Foot Hydrographic Survey Launch

By
James W. Lewis
Naval Sea Combat Systems Engineering Station
Norfolk, Virginia 23511

Rockville, Md.
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U.S. DEPARTMENT OF COMMERCE
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U.S. DEPARTMENT OF COMMERCE
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Charting and Geodetic Services
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SHOCK AND VIBRATION ENVIRONMENTAL TEST OF NOAA 29-FOOT HYDROGRAPHIC SURVEY LAUNCH

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ABSTRACT: Shock and vibration measurements were made on a NOAA 29-foot hydrographic survey launch for the purpose of defining the shock and vibration specifications for the new Shipboard Data System III. This report describes the tests, analyzes the data, and recommends a shock and vibration specification.

INTRODUCTION

The National Ocean Service (NOS), National Oceanic and Atmospheric Administration (NOAA), operates a fleet of small boats and ocean-going ships to gather hydrographic data. In gathering these data, NOS uses various computer systems. The present computer systems are more than 10 years old and are approaching the end of their useful lives. NOS is replacing the present equipment with commercially available computer hardware. In order to specify thoroughly the environment in which this equipment must operate, NOS funded the Naval Sea Combat Systems Engineering Station, NAVSEACOMBATSYSENGSTA Norfolk, Virginia, to measure the shock and vibration environment aboard a representative 29-foot aluminum Jensen hydrographic survey launch. The resulting measurements of shock and vibration will be incorporated in the procurement specification of the new NOAA Shipboard Data System III.

In January 1984, NAVSEACOMBATSYSENGSTA instrumented the 29-foot Jensen launch, hull 1020, for shock and vibration measurements. This report describes the tests conducted and analyzes the data gathered.

TEST OBJECTIVES

The objective of this test was to gather and analyze data to provide a description of the shock and vibration environment aboard a 29-foot hydrographic launch. The ultimate goal is to use the environmental description to define the shock and vibration specifications for the new National Oceanic and Atmospheric Administration's (NOAA) Shipboard Data System III (SDS III).

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[1] Research was performed by the U.S. Navy for, and with the cooperation of, the National Charting Research and Development Laboratory, Nautical Charting Division, Charting and Geodetic Services, National Ocean Service, NOAA, Rockville, Maryland 20852. Also assisting was the NOAA Atlantic Marine Center, Norfolk, Virginia.

TESTING

Instrumentation

Triaxial piezoelectric accelerometers and single-axis vertical servo accelerometers were hard-mounted at two locations in the cabin area: (1) on frame 2 directly over the keel on centerline, and (2) on frame 4 directly over the fourth longitudinal outboard of the keel (one longitudinal inboard of the chine) on the starboard side (figure 1). The piezoelectric accelerometers used are linear over a frequency range of 1 to 3,000 Hz. These accelerometers were used for measuring vibration and short duration shocks. The servo accelerometers are linear over a frequency range of 0 Hz to 200 Hz. These accelerometers provided the capability to measure low frequency vertical accelerations such as boat heave and long duration shock waveforms.

A magnetic pickup was used to measure accurately propeller shaft rpm. The pickup sensed the presence of a magnet strapped to the shaft and generated a 1-pulse-per-revolution signal. Propeller blade rate, engine rpm, and cylinder firing rate were determined by multiplying the measured shaft rpm by the proper ratio. (See table 1.)

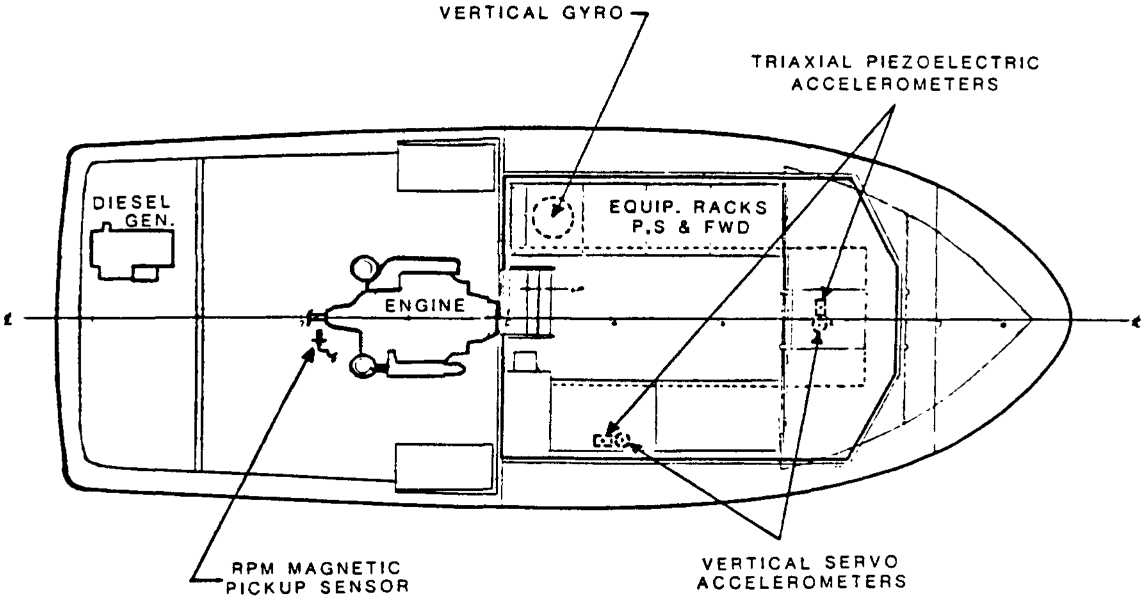


Figure 1. Location of transducers.

Vibration Source	Frequency Formula (Hz)	Frequency Range (Hz)
Propeller shaft	$\frac{\text{Shaft rpm}}{60}$ (measured)	5-24
Propeller blade	$\frac{\text{Shaft rpm}}{60} \times 4$	20-96
Propulsion engine crankshaft	$\frac{\text{Shaft rpm}}{60} \times 1.97$	10-47
Propulsion engine cylinder firing	$\frac{\text{Shaft rpm}}{60} \times 1.97 \times 4$	40-188
Diesel generator	$\frac{1800 \text{ rpm}}{60}$	30

Table 1. Formulas for determining machinery-related vibration frequencies.

A vertical gyro was installed to measure roll and pitch when the launch was operated in rough seas. A Datawell Waverider buoy was deployed during the rough water test to measure wave height and period in the test area. The buoy receiver was located on board the survey launch.

The above-mentioned transducer signals were recorded on magnetic tape for later computer analysis. The magnetic tape recorders were 14 channel, 1-inch tape, FM, intermediate band instruments. The data were recorded at either 3-3/4 or 7-1/2 inches per second which provides a frequency response of 625 Hz and 1.25 KHz respectively.

Instruments

The following instruments were employed in the shock and vibration measurements.

TRANSDUCERS	QUANTITY
PCB Piezotronics, Inc., model 308B accelerometer	4
PCB Piezotronics, Inc., model 302B accelerometer	2
Kistler model 305T servo accelerometer	1
Sundstrand Model 303B servo accelerometer	1
Singer Kearfott model C70 4101 023 vertical gyro	1
Datawell Waverider Buoy	1
Airpax 1-0003 magnetic rpm pickup	

RECORDERS	QUANTITY
EMI 7000 magnetic tape recorder	1
Sangamo SABRE XII Magnetic Tape Recorder	1

ANALYZERS	
Gen Rad 2510 micro modal analyzer	1
Nicolet 442B spectrum analyzer	1
DEC PDP-8/e minicomputer	1

Operating Conditions

Data were recorded during calm water, rough seas, pier-bump, and davit lift operating conditions. During the calm water test, vibration measurements were taken with only the diesel generator running and while the boat was operated through its revolutions-per-minute (rpm) range. The purpose of the calm water test was to measure the levels of machinery vibration transmitted to the cabin space and to identify any structural resonant vibrations that are machinery excited.

During the rough seas test, the boat was operated at four headings to the sea (i.e., head, beam, quartering, and stern seas) and while turning 360 degrees, at three speeds of advance (i.e., 1,400, 2,400, and 2,800 maximum rpm). The purpose of the rough seas test was to determine the shock levels experienced by the cabin equipment space when the boat is operated in rough seas. Roll and pitch data were also recorded to document these motions in the rough sea environment.

The pier-bump test was conducted to characterize possible shock levels that would be encountered when the boat accidently bumps a ship or pier. To simulate this condition without damaging the boat, the launch was operated ahead at 800 rpm and then allowed to coast in neutral to the pier. The pier impact area was a wood dolphin against the concrete quay wall at the NOAA Atlantic Marine Center (AMC), Norfolk, Virginia. The pier was bumped with glancing blows and head-on.

The davit lift test was conducted to measure the shocks encountered when the boat is davit lifted onto the ship. This test was conducted with the NOAA Ship MT. MITCHELL at AMC. Pickups were made in calm water and rough water simulated by a 2- to 3-foot wake from another 29-foot survey launch.

TEST RESULTS AND ANALYSIS

Calm Water Vibration Test

The diesel generator and the propulsion system are the two major sources of vibration on the 29-foot survey launch. The generator has a single cycle diesel engine with a rotational speed of 1,800 rpm (30 Hz).

The generator is located in the stern compartment of the boat, port of the centerline. The diesel engine vibrations are transferred through soft engine mounts to the boat hull. Figures 2 and 3 show the spectral vibrations measured by the two triaxial accelerometers when only the diesel generator was operating. As shown in the spectral acceleration plots, very little diesel generator vibration is transferred to the boat's cabin space. The maximum discrete frequency vibration measured was 0.014 g rms, 30 Hz at the starboard-mounted vertical accelerometer.

The propulsion system consists of a V8/4-cycle model 3208 Caterpiller diesel engine, a Twin Disc MG506 marine gear (1.97:1 reduction), a four-bladed propeller, and associated shafting. Vibration measurements were recorded while the propulsion engine was operated slowly through its full rpm range (670 to 2,860 rpm). Figures 4 and 5 are rpm spectrum maps of each accelerometer, showing how the vibration amplitude and frequency change as the engine rpm is varied. These spectrum maps are plotted over the 1,500 to 2,860 rpm range. Below 1,500 rpm the acceleration amplitudes were extremely small and for this reason were omitted to gain better plotting resolution in the range where significant vibrations exist. Throughout the rpm range the plots show acceleration levels of less than 0.1 g rms, 5 to 300 Hz at all accelerometer locations except the bow longitudinal (z) axis. The bow Z-axis rpm spectrum map in figure 4 shows a hull resonance in the 160 Hz region. At 2,460 rpm the engine cylinder firing frequency coincides with this hull resonance, and large amplitude vibrations are produced.

Figure 6 is a frequency spectrum plot of the maximum bow Z-axis acceleration measured. The peak acceleration was 0.558 g rms at 164 Hz. The average 164 Hz value measured at 2460 rpm was 0.474 g rms. Figure 7 is the displacement spectrum at 2460 rpm produced by double integrating acceleration data from figure 6. The maximum peak-to-peak displacement at 164 Hz was 574 microinches.

Figure 8 is a peak displacement spectrum of the bow Z-axis vibration produced by capturing the maximum spectrum peaks as the engine rpm was varied over its full range. The spectrum plot shows that over the full rpm operating range of the boat, the bow Z-axis vibration never exceeds 574 microinches of displacement in the frequency range of 10 to 200 Hz. The maximum displacement at 5 Hz was 2,000 microinches. In general, these displacements are small and will not have a significant effect upon structures and machinery. However, they could become significant if they are transmitted through the structure of an electronic disk drive in which the ceramic head normally flies only 100 microinches above the disk.

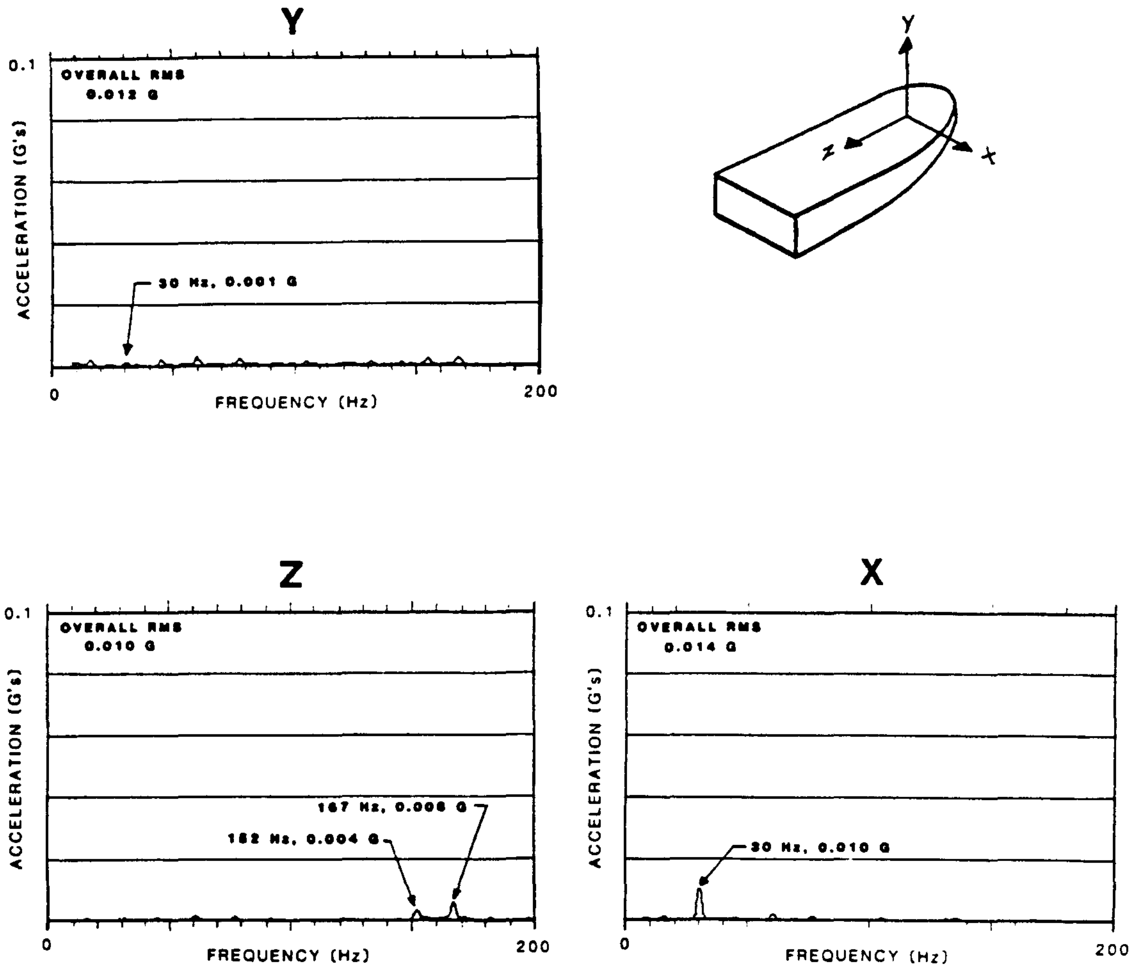


Figure 2. Frequency spectrum of bow triaxial accelerometer with only diesel generator operating.

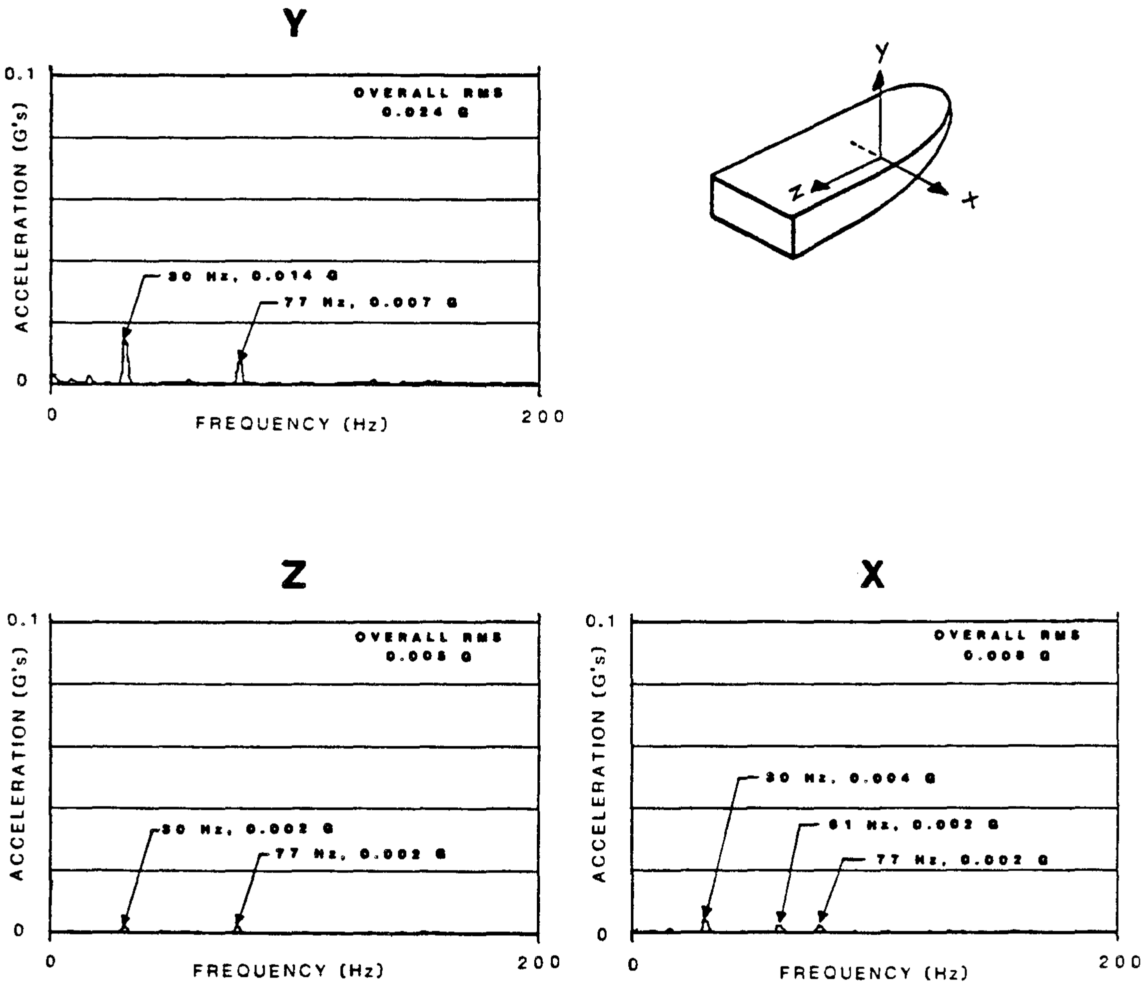


Figure 3. Frequency spectrum of starboard triaxial accelerometer with only diesel generator operating.

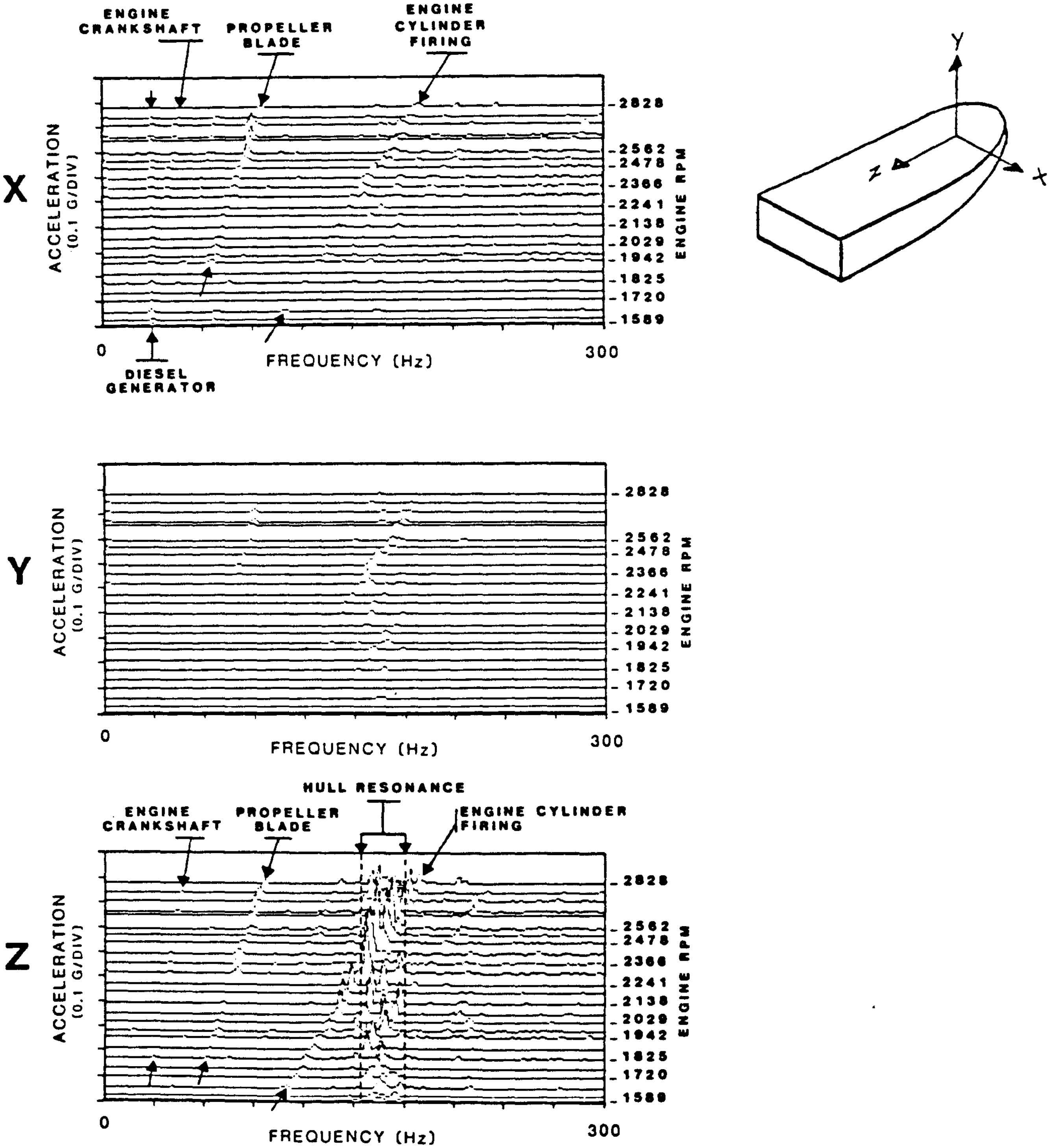


Figure 4. Spectrum map (in rpm) of bow vibration, 1,589 to 2,830 rpm.

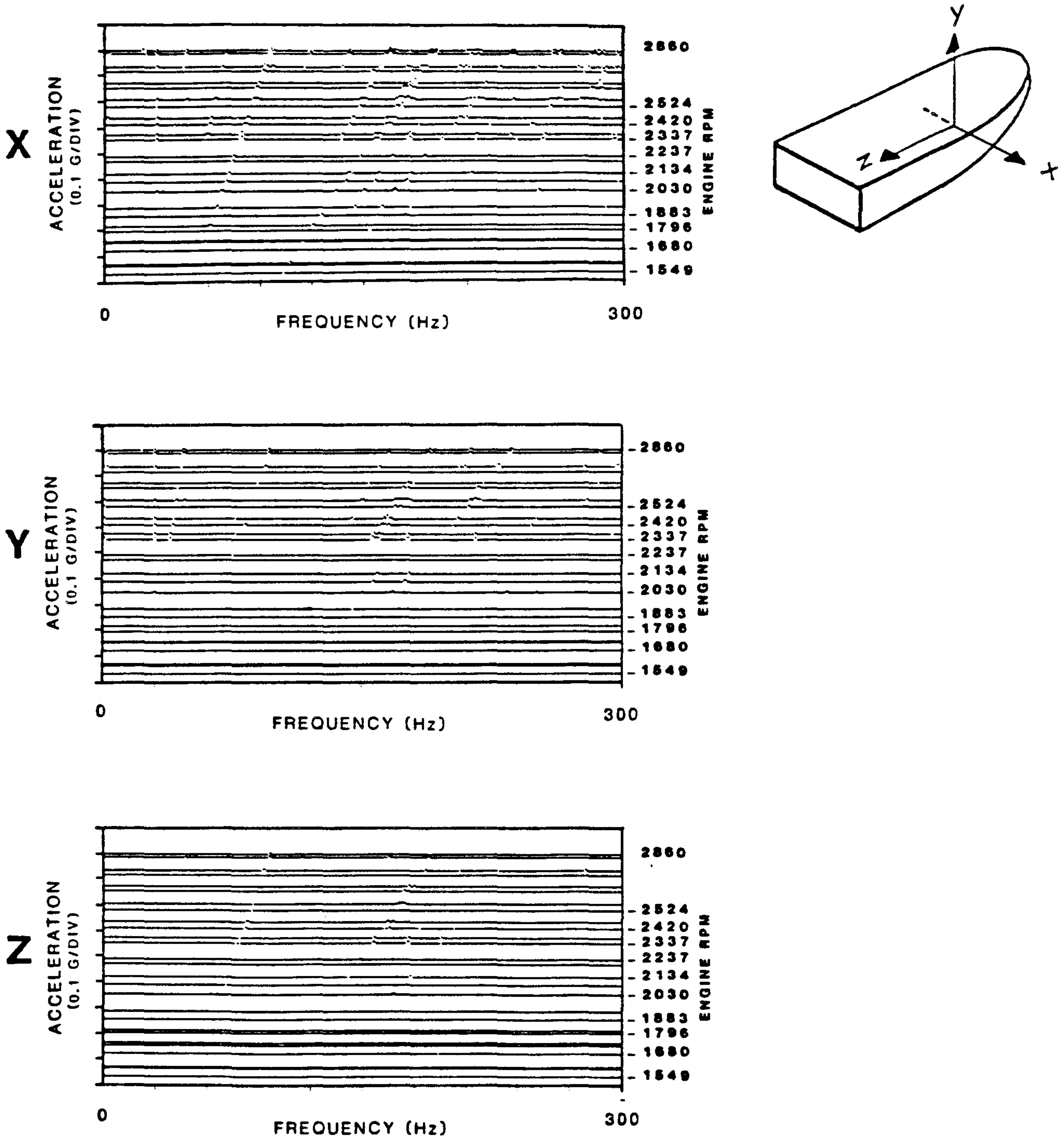


Figure 5. Spectrum map (in rpm) of starboard vibration, 1,549 to 2,860 rpm.

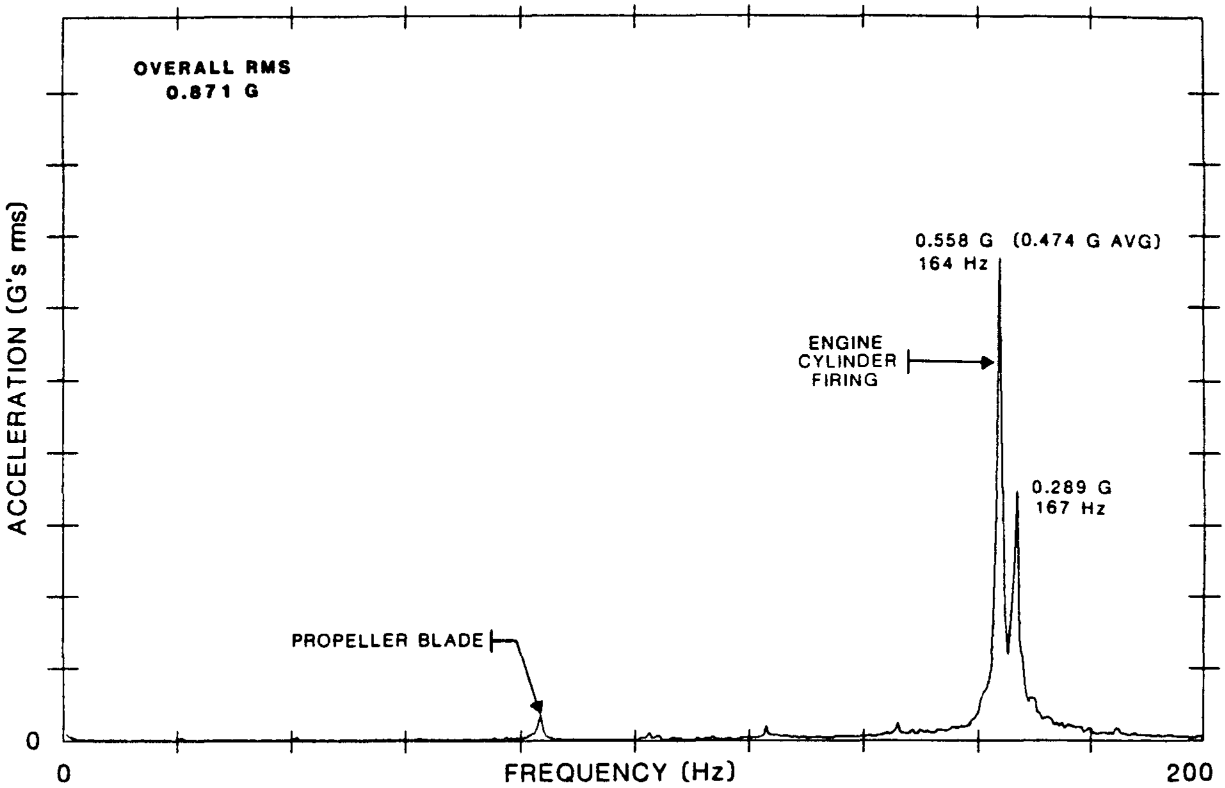


Figure 6. Bow Z-axis peak acceleration spectrum at 2,460 rpm.

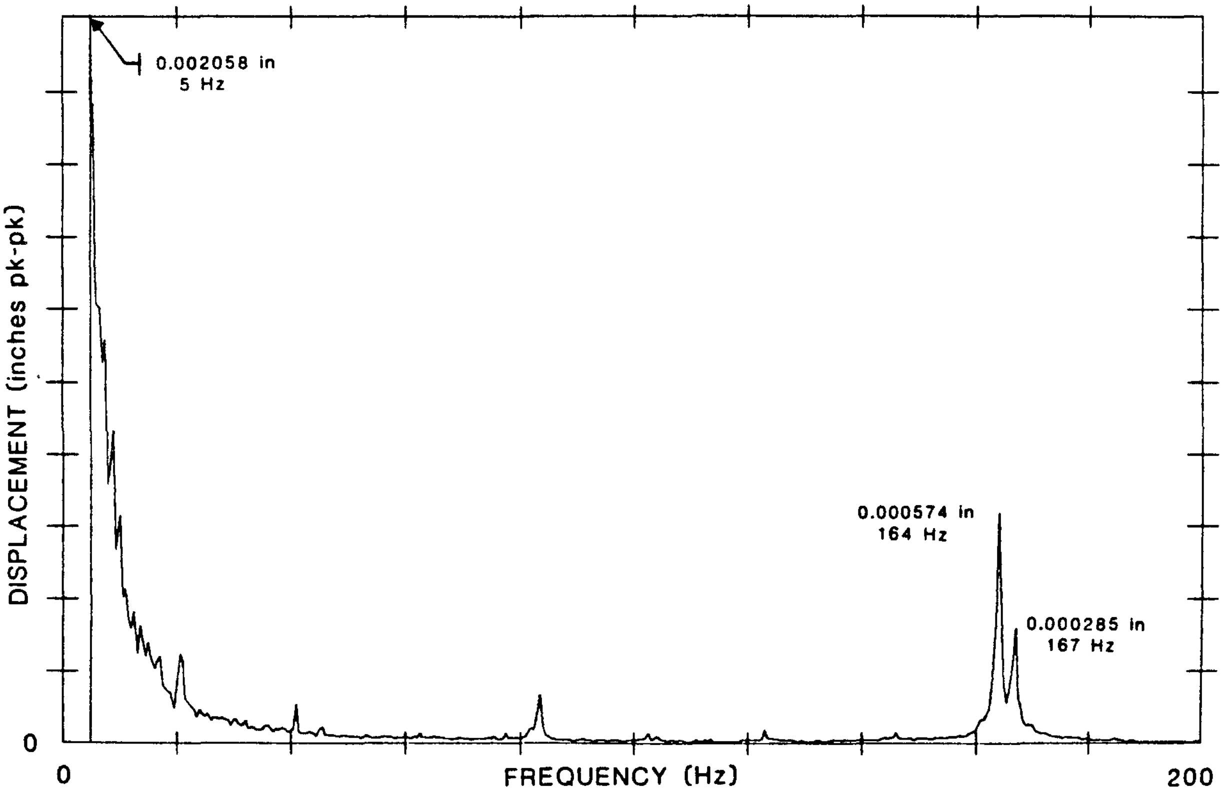


Figure 7. Bow Z-axis vibration peak displacement spectrum at 2,460 rpm.

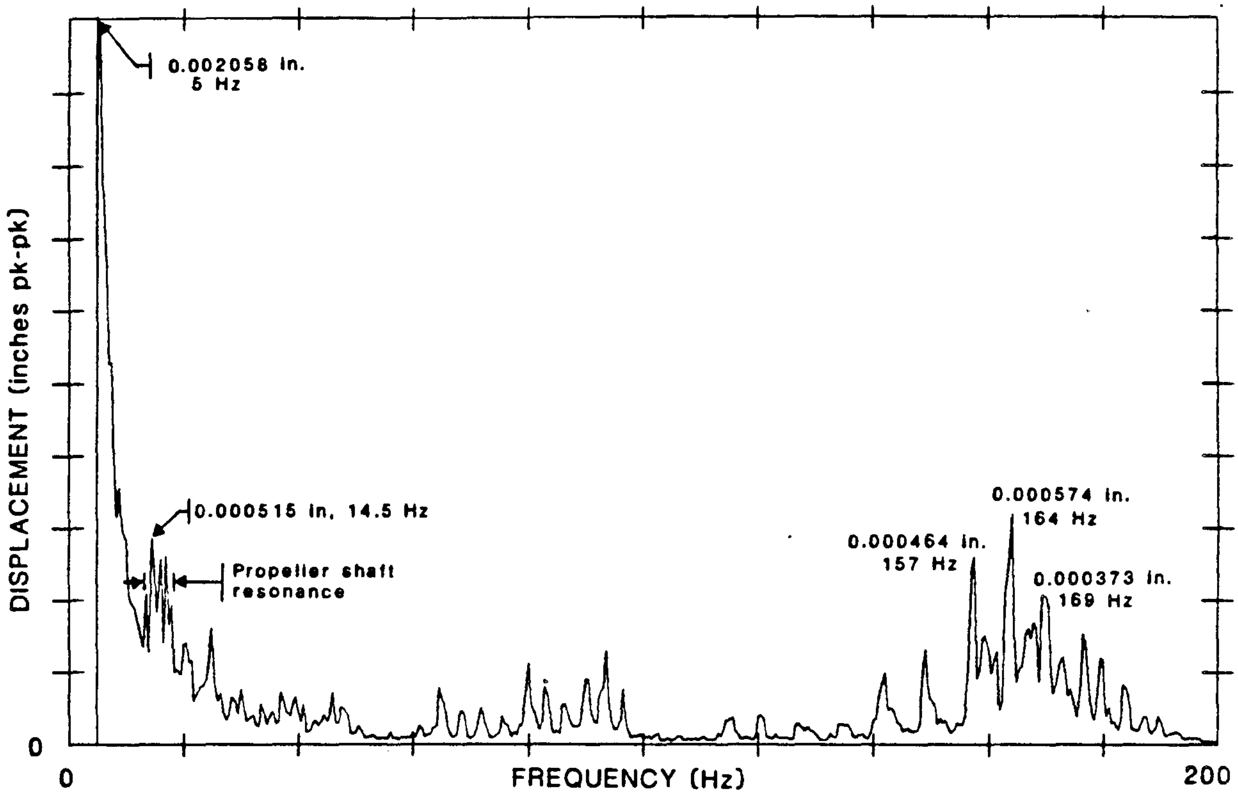


Figure 8. Bow Z-axis vibration peak displacement spectrum with varied rpm.

Rough Seas Test

The rough seas test was conducted in the Chesapeake Bay near Little Creek, Virginia. The shock and motion data acquired were analyzed by statistical and mathematical means since they varied with time due to the oscillatory and unsteady reaction of the boat to the random seaway. The analysis consisted of measuring the magnitude above and below a nominal zero value of each peak and each trough in the time history of each parameter for each approximate 10-minute duration run. The resulting groups of peak and trough values were then ranked by magnitude and the average values (average of the 1/3 highest (significant) values and average of the 1/10 highest values) and the extreme consecutive peak to trough values were computed and listed. The sea state data were also anlayzed by this method.

Data were acquired over a 2½-hour time period. During this time the average sea conditions were as follows:

Average wave height	2.28 ft.
Average of 1/3 highest waves	3.16 ft.
Average of 1/10 highest waves	3.84 ft.
Wind speed	12-17 kt.

The wind and sea state scale of table 2 classifies these sea conditions as a low sea state 3.

Results of the analysis for roll, pitch, and vertical acceleration data are listed in appendix A. Table 3 summarizes the maximum values listed in appendix A. As expected, the maximum roll (25.5 degree peak-to-peak) occurred during beam sea conditions, and the maximum pitch (17.5 degree peak-to-peak) and acceleration (4.42 g peak-to-peak) occured during bow seas. Figure 9 shows a plot of the average of the 1/10 highest roll and pitch values in head seas at 1,400, 2,400, and 2,800 rpm.

The largest accelerations measured were at the bow in the vertical direction caused by hull slamming. Figure 10 shows the average of the 1/10 highest vertical accelerations measured in head seas at 1,400, 2,400, and 2,800 rpm.

The starboard vertical piezoelectric accelerometer failed during the test and, therefore, is not plotted. The plot shows the shock levels to be significantly more severe at the bow accelerometer location. The difference between the plotted bow servo·accelerometer value and the bow piezoelectric accelerometer value is due to the piezoelectric accelerometer not registering boat heave. The servo accelerometer responds to acceleration frequencies down to 0 Hz and, therefore, measures heave and shock compositely. The piezoelectric accelerometers respond only to frequencies above 1 Hz, and, thus, only measure the shock component.

Figure 11 is a time plot of the maximum vertical shock measured by the bow vertical servo accelerometer during the test. The plot is filtered to 50 Hz to eliminate the high frequency vibrations and to show only the high energy, low frequency shock waveform. The shock pulse is very similar to a leading edge sawtooth waveform with a 4 g peak amplitude and 270 msec duration. The acceleration level measured from the previous trough to the peak of this shock pulse is 4.42 g peak-to-peak.

Figure 12 shows an 8-second sample of pitch and bow vertical acceleration data recorded during the starboard bow seas run at 2,800 rpm. The plot shows the frequency of shocks encountered to be approximately once every 1.3 seconds. It also shows an increase in the deceleration time at the lower g shock levels.

Figure 13 depicts a sample plot of the bow vertical acceleration during the 2,400 rpm head sea run. The plot is filtered to 20 Hz and 200 Hz to show the effect of the vertical vibration (predominantly 160 Hz resonance) upon the heave and shock accelerations.

WIND AND SEA SCALE FOR FULLY ARISEN SEA

SEA-GENERAL		WIND 2)				SEA 3)								
						WAVE HEIGHT FEET								
SEA STATE 1)	DESCRIPTION 2)	(BEAUFORT) WIND FORCE	DESCRIPTION	RANGE (KNOTS)	WIND VELOCITY (KNOTS)	AVERAGE	SIGNIFICANT	AVERAGE $\frac{1}{10}$ HIGHEST	SIGNIFICANT RANGE OF PERIODS (SECONDS)	T_{max} PERIOD OF MAXIMUM ENERGY OF SPECTRUM	$\bar{T}$ (AVERAGE PERIOD)	$\bar{L}$ (AVERAGE WAVE LENGTH)	MINIMUM FETCH (NAUTICAL MILES)	MINIMUM DURATION (HOURS)
0	Sea like a mirror.	0	Calm	Less than 1	a) 0	0	0	0	-	-	-	-	-	-
	Ripples with the appearance of scales are formed, but without foam crests.	1	Light Airs	1 - 3	2	0.05	0.08	0.10	up to 1.2 sec	0.7	0.5	10 in.	5	18 min
1	Small wavelets, still short but more pronounced; crests have a glassy appearance, but do not break.	2	Light Breeze	4 - 6	5	0.18	0.29	0.37	0.4-2.8	2.0	1.4	6.7 ft	8	39 min
	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.	3	Gentle Breeze	7 - 10	8.5	0.6	1.0	1.2	0.8-5.0	3.4	2.4	20	9.8	1.7 hrs
2					10	0.88	1.4	1.8	1.0-6.0	4	2.9	27	10	2.4
	Small waves, becoming larger; fairly frequent white horses.	4	Moderate Breeze	11-16	12	1.4	2.2	2.8	1.0-7.0	4.8	3.4	40	18	3.8
					13.5	1.8	2.9	3.7	1.4-7.6	5.4	3.9	52	24	4.8
3					14	2.0	3.3	4.2	1.5-7.8	5.6	4.0	59	28	5.2
					16	2.9	4.6	5.8	2.0-8.8	6.5	4.6	71	40	6.6
4	Moderate waves, taking a more pronounced long form; many white horses are formed. (Chance of some spray).	5	Fresh Breeze	17-21	18	3.8	6.1	7.8	2.5-10.0	7.2	5.1	90	55	8.3
					19	4.3	6.9	8.7	2.8-10.6	7.7	5.4	99	65	9.2
5					20	5.0	8.0	10	3.0-11.1	8.1	5.7	111	75	10
	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray).	6	Strong Breeze	22-27	22	6.4	10	13	3.4-12.2	8.9	6.3	134	100	12
					24	7.9	12	16	3.7-13.5	9.7	6.8	160	130	14
6					24.5	8.2	13	17	3.8-13.6	9.9	7.0	164	140	15
					26	9.6	15	20	4.0-14.5	10.5	7.4	188	180	17
	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. (Spindrift begins to be seen).	7	Moderate Gale	28-33	28	11	18	23	4.5-15.5	11.3	7.9	212	230	20
7					30	14	22	28	4.7-16.7	12.1	8.6	250	280	23
					30.5	14	23	29	4.8-17.0	12.4	8.7	258	290	24
					32	16	26	33	5.0-17.5	12.9	9.1	285	340	27
	Moderately high waves of greater length; edges of crests break into spindrift. The foam is blown in well marked streaks along the direction of the wind. Spray affects visibility.	8	Fresh Gale	34-40	34	19	30	38	5.5-18.5	13.6	9.7	322	420	30
					36	21	35	44	5.8-19.7	14.5	10.3	363	500	34
					37	23	37	46.7	6-20.5	14.9	10.5	376	530	37
					38	25	40	50	6.2-20.8	15.4	10.7	392	600	38
8					40	28	45	58	6.5-21.7	16.1	11.4	444	710	42
	High waves. Dense streaks of foam along the direction of the wind. Sea begins to roll. Visibility affected.	9	Strong Gale	41-47	42	31	50	64	7-23	17.0	12.0	492	830	47
					44	36	58	73	7-24.2	17.7	12.5	534	960	52
9					46	40	64	81	7-25	18.6	13.1	590	1110	57
	Very high waves with long overhanging crests. The resulting foam is in great patches and is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes a white appearance. The rolling of the sea becomes heavy and shocklike. Visibility is affected.	10	Whole Gale*	48-55	48	44	71	90	7.5-26	19.4	13.8	650	1250	63
					50	49	78	99	7.5-27	20.2	14.3	700	1420	69
					51.5	52	83	106	8-28.2	20.8	14.7	736	1560	73
					52	54	87	110	8-28.5	21.0	14.8	750	1610	75
					54	59	95	121	8-29.5	21.8	15.4	810	1800	81
	Exceptionally high waves (Small and medium-sized ships might for a long time be lost to view behind the waves.) The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	11	Storm*	56-63	56	64	103	130	8.5-31	22.6	16.3	910	2100	88
					59.5	73	116	148	10-32	24	17.0	985	2500	101
	Air filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	12	Hurricane*	64-71	> 64	> 80 b)	> 128 b)	> 164 b)	10-(35)	(26)	(18)	~	~	~

*For hurricane winds (and often whole gale and storm winds) required durations and fetches are rarely attained. Seas are therefore not fully arisen.

a) A heavy box around this value means that the values tabulated are at the center of the Beaufort range.

b) For such high winds, the seas are confused. The wave crests blow off, and the water and the air mix.

1) Encyclopedia of Nautical Knowledge, W.A. McEwen and A.H. Lewis, Cornell Maritime Press, Cambridge, Maryland, 1953, p. 483

2) Manual of Seamanship, Volume II, Admiralty, London, H.M. Stationery Office, 1952, pp. 717-718

3) Practical methods for observing and forecasting Ocean waves, Pierson, Neumann, James, N.Y. Univ., College of Engin. 1953.

This table compiled by Wilbur Marks, David Taylor Model Basin

Table 2. Wind and sea scale for fully arisen sea.

Test Parameter	Avg. of 1/3 Highest (Pk-Pk)	Avg. of 1/10 Highest (Pk-Pk)	Extreme (Pk-Pk)	Test Conditions
Roll Bow -	15.4°	19.0°		1,400 rpm port quartering sea
			25.5°	2,400 rpm, port beam sea
Pitch	10.9°	13.5°	17.5°	1,400 rpm, head sea
Bow vertical servo accelerometer	1.80 g	2.83 g	4.42 g	2,800 rpm, stbd bow sea
Bow vertical piezo-electric accelerometer	1.45 g	2.40 g	4.04 g	2,800 rpm, stbd bow sea
Stbd vertical piezo-electric accelerometer	1.32 g	1.91 g	2.91 g	2,800 rpm, stbd bow sea

Table 3. Maximum measured values for roll, pitch, and vertical acceleration during rough seas test.

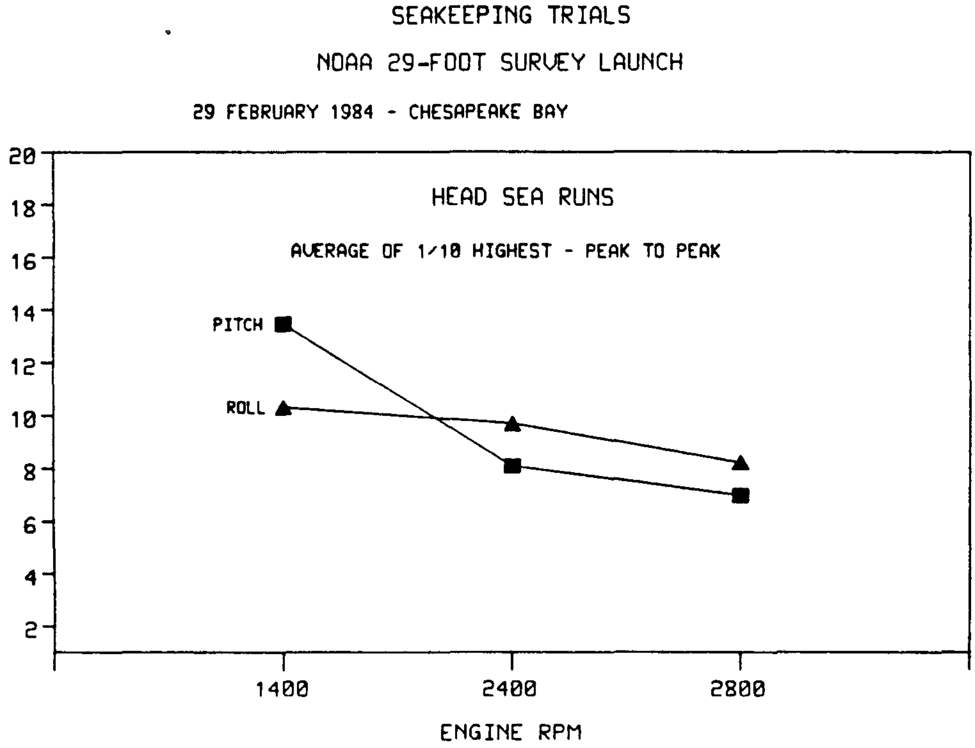


Figure 9. Plot of the averages of the 1/10 highest roll and pitch values measured in a head sea at 1,400, 2,400, and 2,800 rpm.

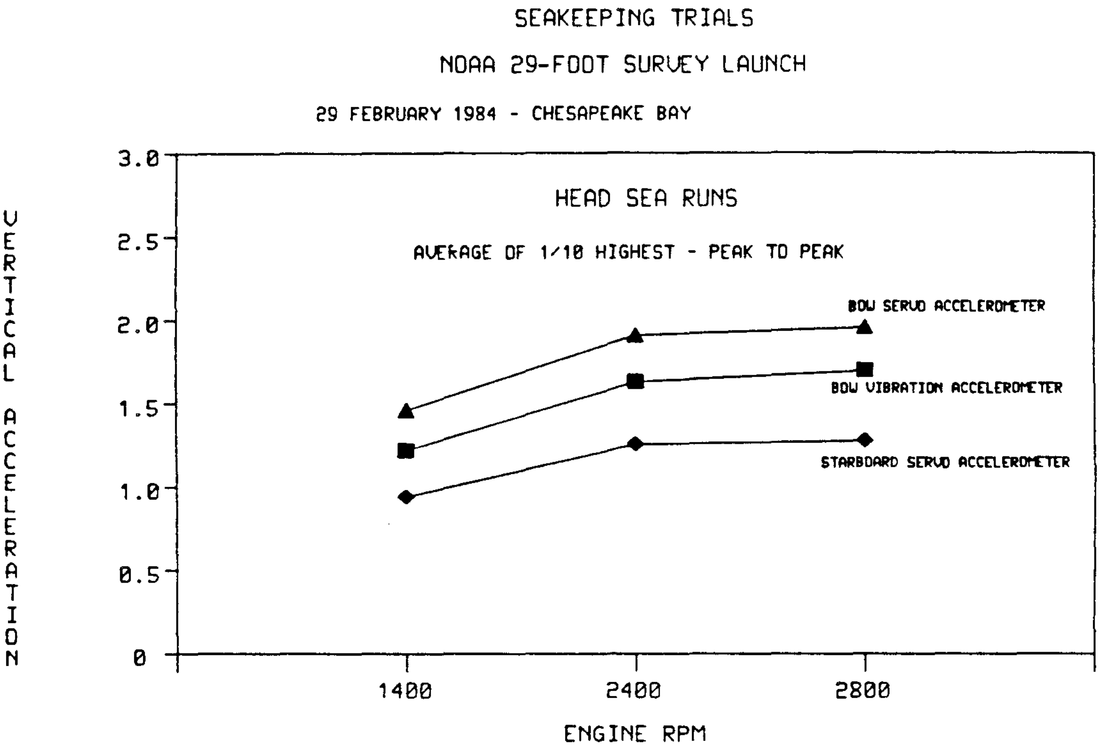


Figure 10. Plot of the average of the 1/10 highest vertical accelerations measured in a head sea at 1,400; 2,400; and 2,800 rpm.

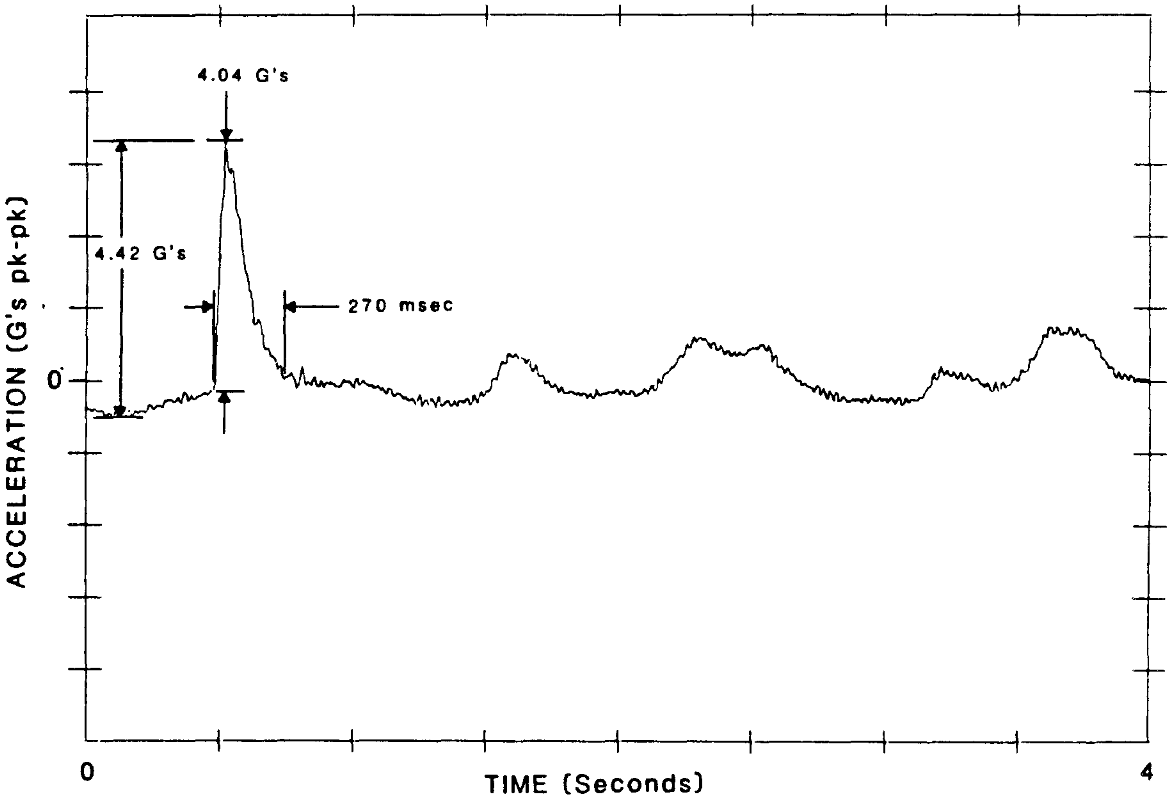


Figure 11. Time plot of maximum bow shock filtered to 50 Hz at 2,800 rpm, starboard bow sea.

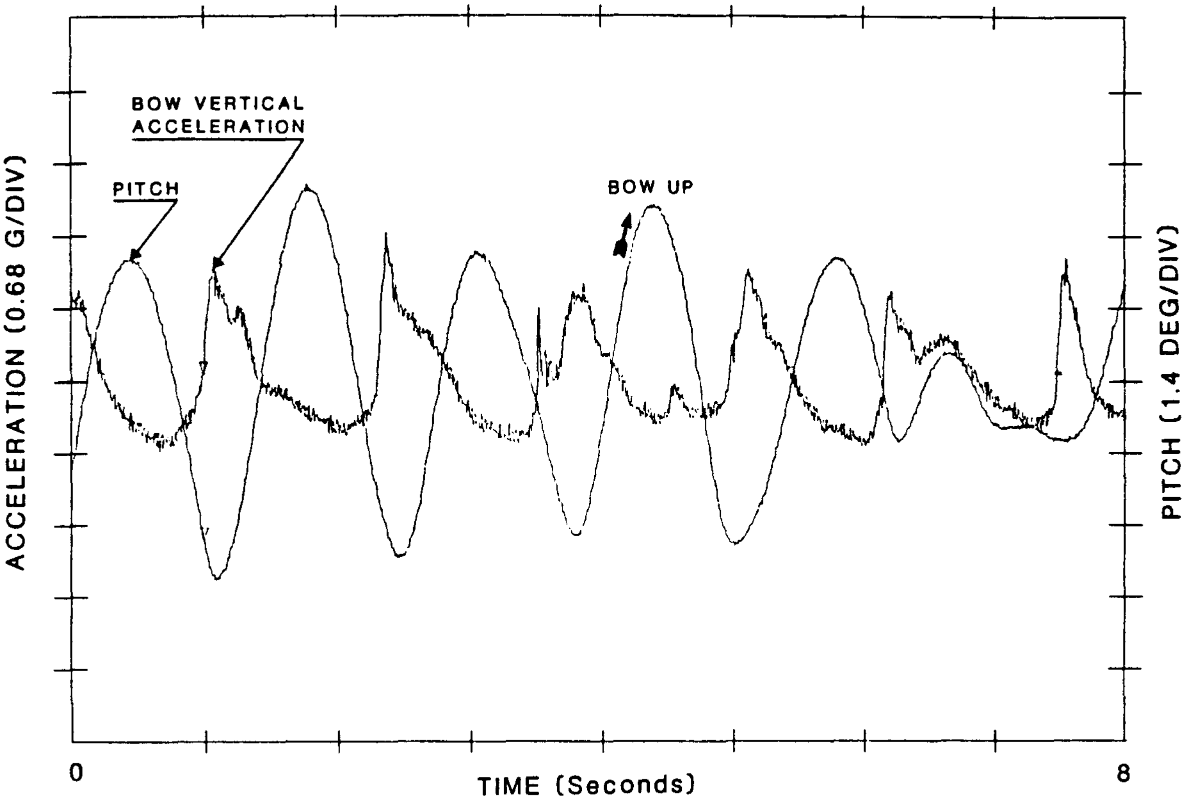


Figure 12. Typical data sample of bow vertical acceleration and pitch filtered to 100 Hz at 2,800 rpm, starboard bow sea.

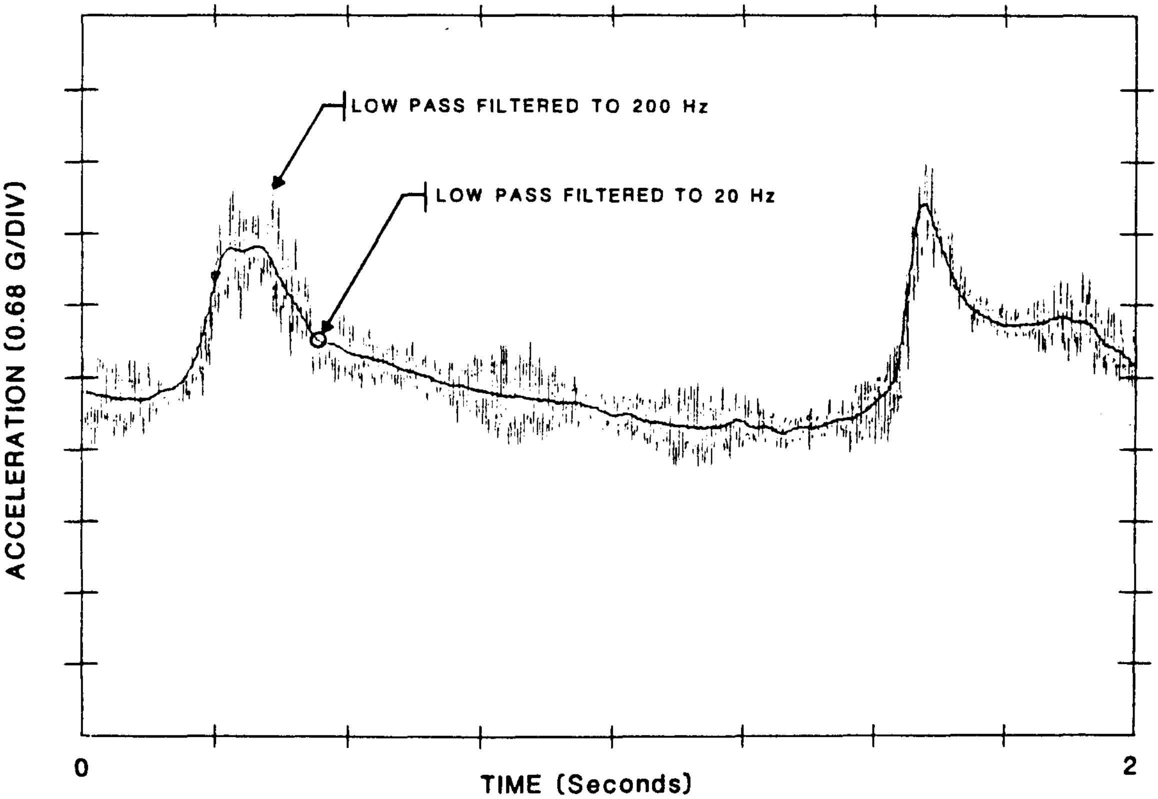


Figure 13. Sample of bow vertical acceleration during head seas at 2,400 rpm.

Pier-Bump Test

The maximum acceleration measured during the pier-bump test was in the longitudinal Z-axis as the boat hit the pier head-on. Figure 14 shows a time plot of the impact acceleration. The shock waveform approaches a half-sine with a 1.09 g peak acceleration and of 100 msec duration. It is estimated that the boat was traveling at approximately 4 knots prior to the impact. The low g level measured during the impact shows the high shock absorbing properties of the rubber rub rail around the launch.

Davit Lift Test

The bow accelerations measured during the davit lift with wave action are shown in figure 15. The highest zero to peak acceleration was 0.86 g for 328 msec (half sine type of waveform). The acceleration was produced when the upward moving lifting cables became taut as the boat was moving downward in a wave.

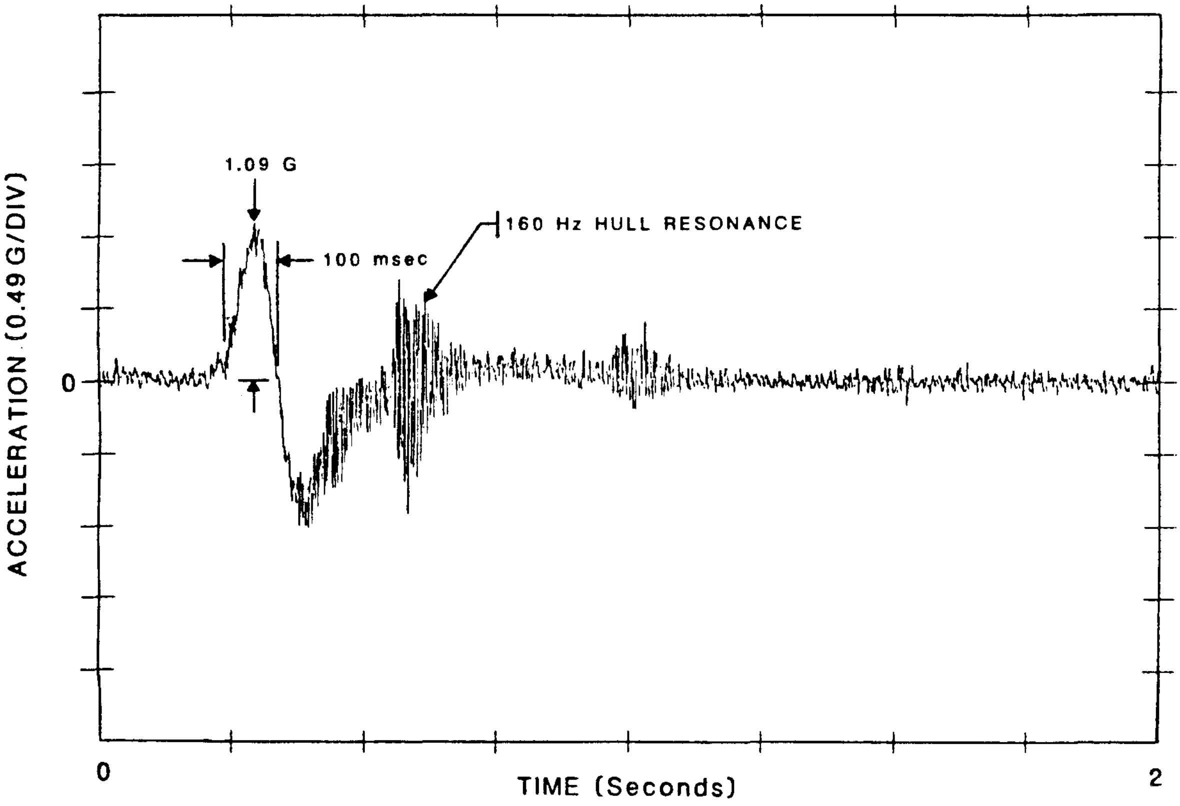


Figure 14. Pier-bump test, bow longitudinal impact acceleration vs. time bow-on condition.

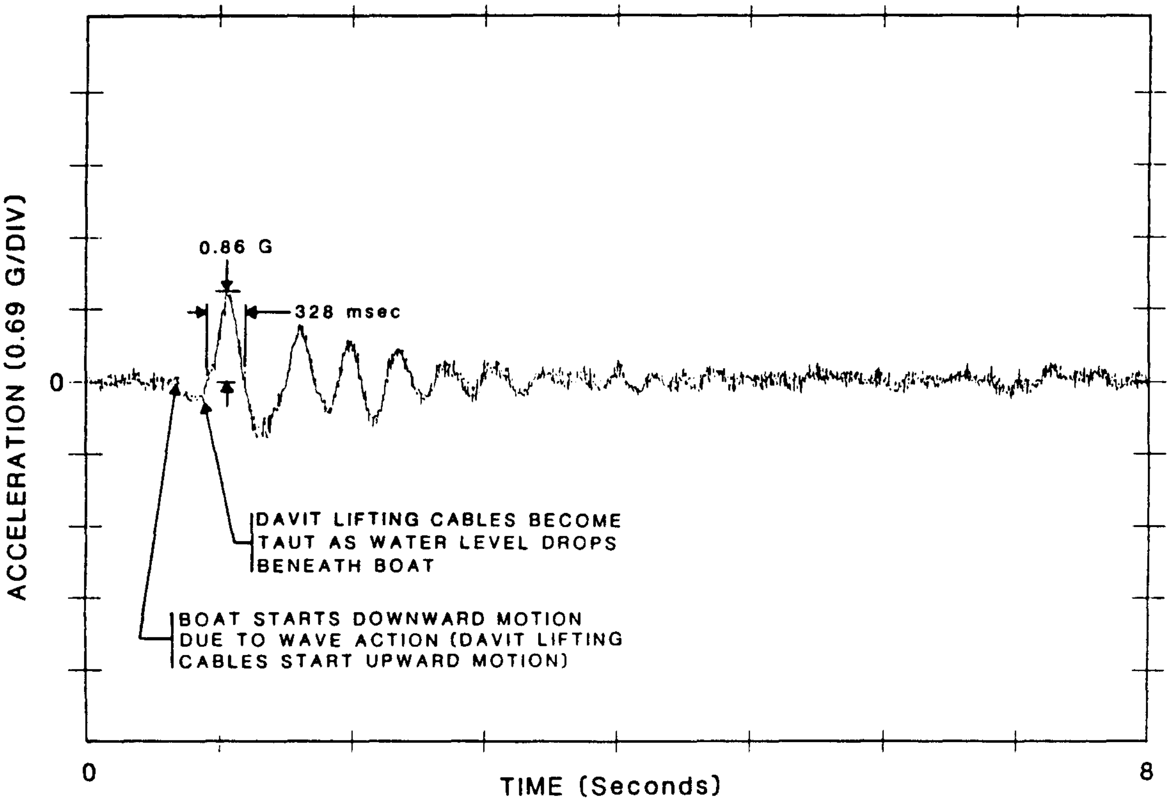


Figure 15. Bow vertical acceleration during davit lift with wave action.

CONCLUSIONS AND RECOMMENDATIONS

Since the ultimate goal is to use the data acquired during this test to define the shock and vibration specifications for the NOAA Shipboard Data System III (SDS III), the following conclusions and recommendations are directed toward that objective.

The purpose of the shock and vibration specification is to ensure that SDS III will operate satisfactorily in its service environment. It will be incumbent upon the system manufacturer to demonstrate conformance to these specifications. Since it is usually difficult to duplicate exactly in a laboratory test an actual shock and vibration environment, test methods are normally devised to try to ensure that effects of the test applied to equipments are similar to the effects of the shock and vibration occurring in practice. Test conditions somewhat more severe than those anticipated are normally prescribed to ensure, with a limited number of tests, that there is a reasonable margin of safety in the equipment design.

The vibrations measured in the equipment area of the 29-foot survey launch were low in amplitude and should be easily duplicated using an equipment shaker. In the 5 to 35 Hz frequency range the maximum displacement measured was 0.002 inches double amplitude at 5 Hz. However, the boat's propeller shaft rotates at 5 to 24 Hz, and in the event that one or two propeller blades became bent from striking a waterborne object the vibration level in the 5 to 35 Hz frequency range would increase significantly. There is no sure way of predicting what the vibration levels would become, but it is believed that they should not exceed 0.015 inches peak-to-peak. Normally, a boat operator will inherently decrease engine rpm when such events do occur in order to reduce the vibration level.

The vibrations measured in the 35 to 200 Hz frequency range were less than 0.1 g rms for all frequencies except for a narrow band centered about 164 Hz. The 164 Hz vibration appears to be due to a hull resonance that is excited by the engine firing rate at 2,460 rpm. The maximum vibration measured at 164 Hz was 0.558 g rms. On the basis of this data and allowing for a comfortable safety margin, 1 g rms would be a realistic vibration specification for the 35 to 200 Hz range. A test duration of 10 to 15 minutes should also be specified.

The shocks observed during the pier-bump test and the davit lift test were of similar waveform. They both had half-sine type impact waveforms which are typical of rebounding type impacts. Bumping the pier produced a 1 g zero-to-peak, 100 msec waveform, and the davit lift test produced an 0.86 g zero-to-peak, 328 msec waveform.

The severest shocks occurred from hull slamming during the test in rough seas. The shock waveforms closely matched a leading edge sawtooth which is typical for nonrebounding types of impact. The maximum shock encountered measured 4.04 g peak-to-peak (4.42 g peak-to-peak with heave) for 270 msec. The shock occured while operating in a low sea state 3 at 2,800 rpm with starboard bow seas. The shock amplitudes at the bow transducer location were approximately 1.4 times larger than those at the starboard transducer location.

The test plan called for measurements to be made through a sea state 4. However, a low sea state 3 was the largest sea to develop during the test period. The shock amplitudes would certainly increase with the higher sea states, but safety constraints would limit boat speed and tend to reduce the chance of significantly larger shocks.

Another important factor that should be considered is that boats operating in rough seas experience repeated shock during their life span. Damage to equipment may accumulate progressively during several repetitions of shock until failure ultimately occurs. For this reason it is advisable that the test include a series of repeated shocks.

On the basis of the maximum shock measured in the low sea state 3, the anticipation of slightly higher shock levels in higher sea states, the repeated shock environment, and allowing for some safety margin, the following shock specifications are recommended:

Waveform - Sawtooth
Amplitude - 6 g
Duration - 350 msec
(a minimum of three impacts in each direction)

The above specification describes a fairly severe shock, but it is a realistic requirement for ensuring that the Shipboard Data System III will operate satisfactorily during its life span in the 29-foot survey launch without restricting boat operating conditions.

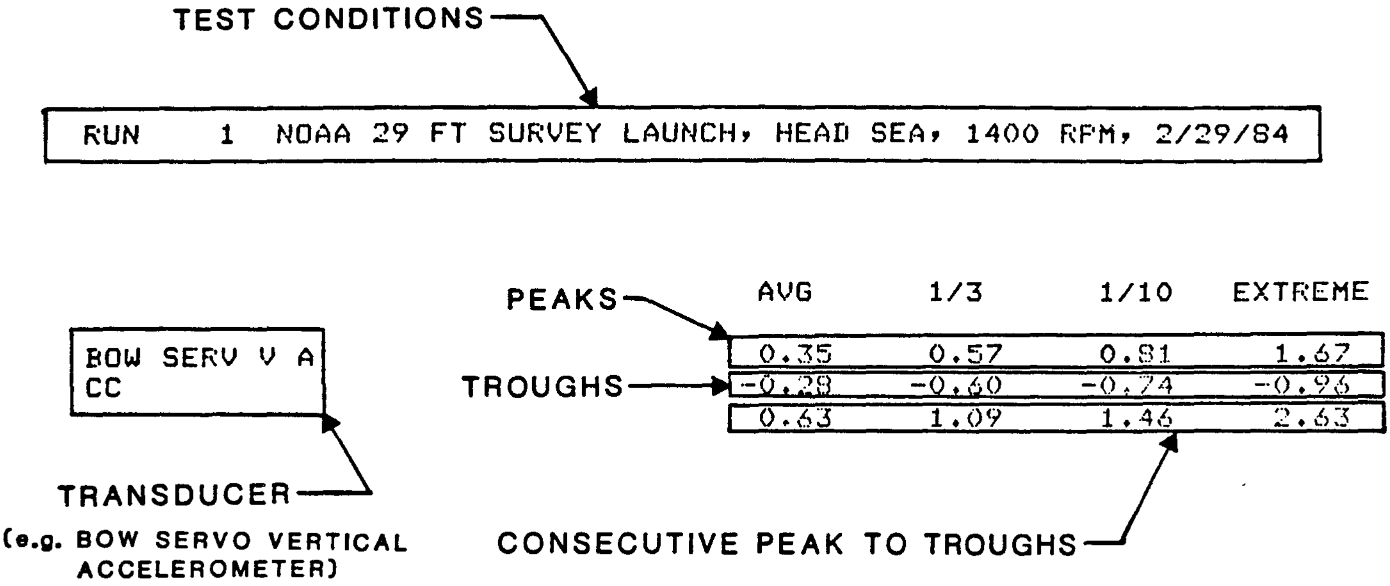
ACKNOWLEDGEMENT

Measurement of the shock and vibration environment on the NOAA 29-foot hydrographic survey launch was performed under NOAA Purchase Order No. NA84AAG01538, dated December 20, 1983.

APPENDIX A. Statistical Values for Roll, Pitch, and Vertical Acceleration During Rough Seas.

EXAMPLE

31-MAR-84



RUN 1 NOAA 29 FT SURVEY LAUNCH, HEAD SEA, 1400 RPM, 2/29/84

BOW SERV V A
CC

AVG	1/3	1/10	EXTREME
0.35	0.57	0.81	1.67
-0.28	-0.60	-0.74	-0.96
0.63	1.09	1.46	2.63

MEASUREMENT UNITS

Acceleration	- G's
Roll	- Degrees
Pitch	- Degrees

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                         31-MAR-84



RUN      1  NOAA 29 FT SURVEY LAUNCH, HEAD SEA, 1400 RPM, 2/29/84


                                       AVG       1/3       1/10   EXTREME

BOW SERV V A                          0.35      0.57      0.81      1.67
CC                                   -0.28     -0.60     -0.74     -0.96
                                      0.63      1.09      1.46      2.63

BOW VIB V AC                          0.23      0.51      0.93      2.31
C                                    -0.19     -0.27     -0.31     -0.43
                                      0.41      0.76      1.22      2.71

STBD SERV V                           0.23      0.35      0.47      0.94
ACC                                  -0.25     -0.44     -0.56     -0.69
                                      0.48      0.75      0.97      1.62

ROLL                                  3.99      5.37      6.31      9.09
                                     -2.23     -3.68     -4.61     -5.86
                                      6.22      8.67     10.31     14.10

PITCH                                 4.34      6.47      8.02     10.79
                                     -2.91     -4.64     -5.67     -7.82
                                      7.26     10.90     13.45     17.53
```

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                        31-MAR-84




RUN    2  NOAA 29 FT SURVEY LAUNCH, PQTR SEA, 1400 RPM, 2/29/84



                                         AVG       1/3       1/10    EXTREME

BOW SERV V A                             0.08      0.13      0.17      0.24
CC                                      -0.13     -0.18     -0.21     -0.33
                                         0.21      0.29      0.35      0.45

BOW VIB V AC                             0.03      0.05      0.08      0.12
C                                       -0.13     -0.14     -0.16     -0.18
                                         0.15      0.19      0.23      0.28

STBD SERV V                              0.08      0.11      0.13      0.16
ACC                                     -0.07     -0.09     -0.12     -0.18
                                         0.15      0.19      0.22      0.26

ROLL                                     4.93      7.20      9.04     12.82
                                        -3.77     -6.38     -8.72    -10.56
                                         8.71     12.24     15.66     22.06

PITCH                                    3.00      4.43      5.32      6.57
                                        -2.39     -3.77     -4.71     -5.81
                                         5.41      7.73      9.28     11.51
```

31-MAR-84

RUN 4 NOAA 29 FT SURVEY LAUNCH, BFQTR. SEA, 1400 RPM, 2/29/84

	AVG	1/3	1/10	EXTREME
BOW SERV V ACC	0.24	0.39	0.51	0.69
	-0.33	-0.53	-0.65	-0.78
	0.57	0.89	1.09	1.34
BOW VIB V ACC	0.17	0.30	0.46	1.02
	-0.17	-0.23	-0.26	-0.31
	0.34	0.52	0.69	1.26
STBD SERV V ACC	0.20	0.28	0.33	0.42
	-0.15	-0.26	-0.36	-0.47
	0.35	0.52	0.66	0.88
ROLL	5.23	7.74	9.33	11.47
	-5.08	-7.96	-10.20	-12.15
	10.33	15.43	19.03	22.28
PITCH	3.90	5.77	7.11	9.36
	-2.86	-4.61	-5.79	-7.25
	6.77	10.21	12.73	15.81

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                         31-MAR-84




RUN    6  NOAA 29 FT SURVEY LAUNCH, SQTR. SEA, 2400 RPM, 2/29/84



                                     AVG        1/3       1/10    EXTREME

BOW SERV V A                         0.02       0.05      0.08      0.18
CC                                  -0.15      -0.18     -0.20     -0.27
                                     0.17       0.22      0.27      0.39

BOW VIB V AC                         0.03       0.06      0.08      0.12
C                                   -0.12      -0.13     -0.14     -0.18
                                     0.15       0.18      0.22      0.28

STBD SERV V                          0.12       0.15      0.18      0.24
ACC                                 -0.04      -0.06     -0.09     -0.16
                                     0.15       0.20      0.25      0.31

ROLL                                 6.12       9.07     11.18     15.26
                                    -0.70      -2.75     -4.20     -7.35
                                     6.77       9.74     11.69     17.67

PITCH                                6.30       8.01      8.82      9.03
                                     1.00      -0.87     -1.99     -2.45
                                     5.24       7.60      8.90      9.20
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                    31-MAR-84




RUN     7  NOAA 29 FT SURVEY LAUNCH, PBEAM SEA, 2400 RPM, 2/29/84



                                    AVG        1/3        1/10    EXTREME

BOW SERV V A                        0.17       0.31       0.42       0.81
CC                                 -0.29      -0.45      -0.55      -0.72
                                    0.46       0.72       0.90       1.43

BOW VIB V AC                        0.14       0.26       0.40       0.92
C                                  -0.16      -0.22      -0.25      -0.31
                                    0.30       0.46       0.62       1.17

STBD SERV V                         0.21       0.29       0.35       0.51
ACC                                -0.12      -0.21      -0.29      -0.42
                                    0.32       0.47       0.60       0.90

ROLL                                6.34       9.21      11.63      15.56
                                   -3.97      -7.03      -9.03     -13.79
                                   10.28      14.87      18.65      25.51

PITCH                               6.31       7.49       8.22       9.48
                                    1.92       0.67      -0.29      -1.84
                                    4.37       6.06       7.41      10.67
```

31-MAR-84

RUN 8 NOAA 29 FT SURVEY LAUNCH, S BOW SEA, 2400 RPM, 2/29/84

	AVG	1/3	1/10	EXTREME
BOW SERV V ACC	0.30	0.58	0.83	1.61
	-0.34	-0.59	-0.73	-0.90
	0.63	1.12	1.52	2.51
BOW VIB V ACC	0.27	0.57	0.98	2.10
	-0.21	-0.29	-0.33	-0.34
	0.47	0.84	1.28	2.44
STBD SERV V ACC	0.35	0.53	0.66	1.03
	-0.20	-0.42	-0.55	-0.66
	0.56	0.90	1.15	1.68
ROLL	6.05	8.86	10.23	11.57
	-2.18	-4.10	-5.47	-8.15
	8.18	12.06	14.26	17.24
PITCH	6.70	7.90	8.64	9.25
	1.60	0.18	-0.63	-1.09
	5.10	7.36	8.41	9.62

```
                          31-MAR-84




RUN      9  NOAA 29 FT SURVEY LAUNCH, HEAD SEA, 2400 RPM,  2/29/84


                                        AVG       1/3       1/10    EXTREME

BOW SERV V A                            0.34      0.71      1.14      2.45
CC                                     -0.40     -0.64     -0.82     -1.07
                                        0.73      1.29      1.91      3.46

BOW VIB V AC                            0.32      0.70      1.29      2.71
C                                      -0.24     -0.32     -0.36     -0.40
                                        0.56      1.00      1.63      3.08

STBD SERV V                             0.35      0.56      0.80      1.44
ACC                                    -0.19     -0.39     -0.54     -0.72
                                        0.54      0.90      1.26      2.17

ROLL                                    4.65      5.94      7.02      8.48
                                       -1.09     -2.23     -3.11     -4.39
                                        5.75      7.94      9.69     12.63

PITCH                                   6.43      7.54      8.30      9.45
                                        1.93      0.80     -0.06     -1.54
                                        4.50      6.53      8.09      9.63
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                    31-MAR-84




RUN    11 NOAA 29 FT SURVEY LAUNCH, FOLLOWING SEA, 2800 RPM, 2/29/84



                                     AVG        1/3         1/10    EXTREME

BOW SERV V A                       -0.02       0.04        0.08       0.21
CC                                 -0.21      -0.25       -0.28      -0.36
                                    0.19       0.27        0.34       0.45

BOW VIB V AC                        0.01       0.04        0.10       0.25
C                                  -0.14      -0.16       -0.18      -0.22
                                    0.15       0.20        0.25       0.40

STBD SERV V                         0.13       0.16        0.19       0.23
ACC                                -0.02      -0.05       -0.07      -0.15
                                    0.15       0.20        0.25       0.36

ROLL                                5.01       6.31        7.12       7.90
                                   -0.78      -1.88       -2.68      -3.66
                                    5.80       7.55        8.28       9.37

PITCH                               6.38       7.50        8.22       8.97
                                    2.37       1.53        0.88       0.45
                                    3.99       5.36        6.45       6.95
```

31-MAR-84

RUN 12 NOAA 29 FT SURVEY LAUNCH, PQTR. SEA, 2800 RPM, 2/29/84

	AVG	1/3	1/10	EXTREME
BOW SERV V ACC	0.05	0.15	0.24	0.63
	-0.27	-0.37	-0.46	-0.69
	0.32	0.50	0.67	1.25
BOW VIB V ACC	0.05	0.14	0.23	0.71
	-0.17	-0.22	-0.26	-0.31
	0.23	0.34	0.46	0.99
STBD SERV V ACC	0.17	0.22	0.27	0.41
	-0.06	-0.13	-0.19	-0.33
	0.23	0.34	0.44	0.72
ROLL	5.88	8.35	9.90	11.63
	-1.82	-4.28	-6.34	-10.47
	7.67	11.06	13.69	18.43
PITCH	6.27	7.63	8.45	10.23
	2.14	0.87	-0.11	-1.60
	4.11	5.75	6.97	8.68

31-MAR-84

RUN 13 NOAA 29 FT SURVEY LAUNCH, SBOW SEA, 2800 RPM, 2/29/84

	AVG	1/3	1/10	EXTREME
BOW SERV V ACC	0.51	1.06	1.89	3.31
	-0.48	-0.83	-1.02	-1.13
	0.99	1.80	2.83	4.42
BOW VIB V ACC	0.48	1.09	2.01	3.61
	-0.29	-0.42	-0.50	-0.77
	0.76	1.45	2.40	4.04
STBD SERV V ACC	0.52	0.87	1.30	2.15
	-0.21	-0.54	-0.69	-0.76
	0.74	1.32	1.91	2.91
ROLL	5.86	7.39	8.45	9.49
	-1.58	-3.25	-4.69	-6.62
	7.47	9.92	12.08	14.56
PITCH	7.41	8.85	10.02	10.64
	1.03	-0.66	-1.69	-3.22
	6.41	8.93	10.94	13.23

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                         31-MAR-84




RUN   14 NOAA 29 FT SURVEY LAUNCH, HEAD SEA, 2800 RPM, 2/29/84


                                          AVG       1/3       1/10    EXTREME

BOW SERV V A                             0.34      0.73      1.14      2.51
CC                                      -0.45     -0.71     -0.86     -1.07
                                         0.79      1.38      1.96      3.52

BOW VIB V AC                             0.33      0.76      1.29      2.56
C                                       -0.30     -0.41     -0.46     -0.55
                                         0.63      1.13      1.70      3.05

STBD SERV V                              0.38      0.60      0.82      1.66
ACC                                     -0.18     -0.41     -0.54     -0.74
                                         0.57      0.94      1.28      2.33

ROLL                                     4.53      5.57      6.62      9.67
                                        -0.54     -1.44     -2.00     -3.66
                                         5.08      6.61      8.23     10.96

PITCH                                    6.41      7.35      8.08      9.40
                                         2.23      1.37      0.73     -1.40
                                         4.17      5.69      6.97      9.80
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                              18-APR-84



RUN   17 NOAA 29 FT SURVEY LAUNCH, SQTR. SEA, 2800 RPM, 2/29/84


                                       AVG      1/3      1/10    EXTREME

BOW SERV V A                          0.01     0.13     0.26     1.85
CC                                   -0.26    -0.36    -0.45    -0.90
                                      0.27     0.45     0.65     2.75

BOW VIB V AC                          0.06     0.15     0.26     2.56
C                                    -0.17    -0.22    -0.27    -0.49
                                      0.22     0.35     0.50     3.05

STBD SERV V                           0.19     0.30     0.41     1.42
ACC                                  -0.08    -0.16    -0.25    -0.57
                                      0.27     0.43     0.61     1.99

ROLL                                  6.19     8.50    10.34    12.88
                                     -1.38    -3.56    -4.94    -6.20
                                      7.59    10.82    13.47    17.91

PITCH                                 6.30     7.79     8.57     9.29
                                      2.07     0.74    -0.14    -0.89
                                      4.23     5.81     6.99     8.70
```

APPENDIX B. Launch Shock Test Project Report by Lt.(jg) Craig McLean, Project OIC, NOAA Ship MT. MITCHELL.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SURVEY

B-2

NOAA SHIP MT. MITCHELL S-222
439 WEST YORK STREET
NORFOLK, VIRGINIA 23510

March 08, 1984

TO: Mr. David Enabnit N/CG2x4

THROUGH: Capt. J. Dropp, Commanding Officer
NOAA Ship Mt. Mitchell

THROUGH: Rear Admiral W. Hull, Director
Marine Operations Atlantic

FROM: LTjg C. McLean, Project OIC
NOAA Ship Mt. Mitchell

RE: Launch Shock Testing Project Report

A Memorandum dated 19 January, 1984 from Mr. Enabnit presented a written plan and instructions for the design and completion of a shock test of the 29' Jensen aluminum launch. This vessel is commonly used throughout the NOAA hydrographic fleet, and will receive the new SDS III data system. Representative of these vessels is hull 1020, which was used through the test period. The given task was to determine the shock environment of a survey launch under operational conditions in a sea state of 0-4.

Launch 1020 was delivered to the Naval Amphibious Base at Little Creek, Va., and this facility was used as the base for operations during the rough water phase of testing. Cooperation with the Command at the Small Boat Training Center facilitated the security and maintenance of the vessel. Mr. Pete Spangler of the Naval Sea Combat System Engineering Division oversaw the installation of the test electronics, the operational tests, and was most responsible and helpful in the care of hull 1020. The following personnel from Mt. Mitchell were involved in the test:

Lt.(jg) McLean
Ens. Miller
Ens. Sites
BA Dimartino
ST Gardner
OS Wait
OS Lehman

NSCSED personnel aboard hull 1020 during testing were Mr. Spangler and Mr. Lewis. Both of these gentlemen contributed significantly to the success of the test through their experience in similar tasks, their professionalism, and enthusiasm. NSCSED also supplied two persons to crew their launch, which tended and deployed the USN Wave Bouy.

A typical test session began at 0800, with NSCSED engineers conducting a systems check alongside the pier at Little Creek. Shore power, supplied by the USN training facility, was disconnected and launch power energized. NOAA OIC and coxswain took 1020 away from the pier and toward the working grounds. All rough water tests were conducted in the waters north of Little Creed NAB, in the area of Thimble Shoal Channel and east to the Chesapeake Bay Bridge Tunnel. The NSCSED launch deployed and tended the USN Wave Bouy. All test procedures followed the desired plan as indicated in the memo of Jan 19, and followed directly the plan detailed by NSCSED. Headings were maintained for 10 minutes while data were recorded, and voice over data annotations were made by Mr. Lewis from aboard hull 1020. Two data recorders were used to solve a power problem initially encountered. Test runs were made for all desired conditions including emergency stops and starts, calm water baselines, and rough water runs with seas taken in 45° increments of heading. Following the completion of each heading desired, the procedure was repeated at a new speed, until 1500, 2400, and 2800 rpm trials had been recorded. The Wave Bouy was then recovered and both vessels returned to Little Creek for berthing. Systems were shut down and secured for the day.

Difficulties encountered during the test period were mostly weather dependant. When calm water was needed for baseline measurements, rough water prevailed, and the predictable was encountered when rough water testing was scheduled. In addition to weather, a power problem was cause for delay. All calm water and start/ stop trials were recorded without incident. On 30 January, the rough water testing began and data was collected at all desired speeds except 2800 rpm. Sea conditions were too extreme for this speed, with regard to safety of the vessel and personnel. When these data were reviewed by NSCSED engineers, a frequent lapse of 30 micro-seconds appeared at the peak of many shocks. Power supply problems were suspect and a solution found by installing a second recorder on 24 volt supply in addition to the 110 volt recorder initially installed. The problems were overcome after careful and timely evaluation by NSCSED personnel.

A brief chronology of events follows:

12 Jan: LTjg McLean and ENS Miller transport hull 1020 to Little Creed from AMC.
23 Jan: Calm water baseline and emergency start/ stop tests conducted.
30 Jan: Rough water testing begins.
02 Feb: Trouble with data recordings; power supply suspect.
03 Feb: Calm water systems trial and trouble shooting.
09 Feb: Continue trouble shooting of system recording problem on line.
13 Feb: Continue testing and trouble shooting on line in rough water.
29 Feb: Rough water testing conducted and completed.
05 Mar: Hull 1020 transported to AMC.
07 Mar: Davit pick-up test completed and bump test completed. All tests successful and test gear removed.

During all phases of the rough weather testing, the opinion of the OIC finds all test conditions to be in excess of any weather favorable to survey work. The conditions would have yielded a poor or non-existant fathometer trace and would have been non-productive. The test launch did not have a fathometer installed to provide direct evidence of this opinion, but this conclusion is based on the experiences of the OIC. All test weather was more severe than encountered during hydrographic operations. As in all operational settings, there exist conditions or events which are atypical and extreme. After more than two years of almost daily operation, the opinion of the OIC is that shock measured during test conditions should certainly define the extremes of, and go beyond the operational setting, but did not happen to measure or experience the maximum shocks that this OIC has wittnessed. Any attempt to duplicate such events would certainly go beyond good judgement, the mandates of safety, and the intent of this test. An understanding should be made that in the operational setting, conditions may arrise which threaten not only the shock tested electronics but the launch itself. The SDS III system will be exposed to the same near capsizings, waves breaking accross the top of the launch, and other similar conditions that other launch OIC's would not like to repeat but have certainly been exposed.

An attempt was made to include an actual launch pick up and deployment through cooperation with a NOAA ship at sea. Weather conditions and safety considerations regarding an overboard power line caused concern for test personnel and the test was modified alongside the Mt. Mitchell at AMC. In this test, a calm water pick up was made with no sea or chop, and simply the shock caused by the lift was measured. A second launch was then used to generate a 2 to 3 foot sea as the launch was recovered and achieved the desired phonomenon of the falls shocking the boat out of the water as the wave falls away from the boat. This exercise was an approximation of an average launch recovery at sea in moderate launch weather.

A bump test was made, simulating the shock of many conditions under which the launch is bumped along side the ship, obtaining detached positions during survey, or landing parties at make-shift piers. This was done at AMC, by bumping the launch without damage, into the bulkhead along the waterfront. The launch was powered at 800 rpm (idle ahead) and then coasted in neutral to the pier.

All phases of this test served well to approximate the shock environment of a survey launch under average to moderate conditions. While the events of the rough water testing have already been addressed, the conclusion for the entire experiment is the same. The greatest shocks that the launch and the SDS III system will be exposed to are certainly ones that are not safe operationally, not safe experimentally, but realisticly experienced on occasion in the field.

Should any additional information or need for contact arise the OIC can be reached at the following office, as tour of duty on Mt. Mitchell will terminate 09 March, 1984.

LTjg Craig McLean
NMFS/F
Room 400
Page 2 Bldg.
3300 Whitehaven St. NW
Washington, D.C.

cc: N/MOA1 CAPT SPEER
N/MOA12 CDR WILSON
N/MOA13 Mr. PARDUE
NSCSED Mr. SPANGLER
NSCSED Mr. LEWIS