R930501

Spar Model Test Joint Industry Project

Final Report

September, 1995

Participants

ABS Americas
Amoco Production Poduction Company
BP EXPLORATION Inc.
Chevron Petroleum Technology Company
Elf Aquitaine Production
Exxon Production Research Company
Minerals Management Service
Mobil Research & Development Company
Offshore Technology Research Center
Oryx Energy Company
Shell Development Company
Texaco Inc.

Prepared by

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2182 DuPont Drive
Irvine, CA 92715

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1. Executive Summary

This test program was conducted between March and June, 1994. A total of 305 tests were performed involving fourteen different configurations of two basic Spar designs, four random wave sea states, three current profiles, three wind spectra, 12 different regular waves and 14 combinations of bi-chromatic waves for measurement of slowly varying drift forces. The test environments encompassed Gulf of Mexico, North Atlantic and West African survival conditions as well as operational conditions. The two Spar designs tested included a deep draft catenary moored spar and a tethered "mini" spar.

The tests have been fully documented on Video. All raw and processed data is available to participants on magnetic tape.

The primary test objective was to provide a high quality data set with emphasis on:

a) Wind, Wave & Current interaction effects
b) Slowly varying forces and responses
c) Vortex Induced Vibrations (VIV)
d) Heave natural periods, including center well/riser effects
e) Extremal Statistics

Another objective was to demonstrate concept feasibility for:

a) Float-on Deck
b) Shuttle Tanker Bow Moored to Spar

All of these objectives have been met except those related to Vortex Induced Motions (VIV). A high level of free stream turbulence with frequencies in the range of the Spar's natural surge frequency masked the vortex induced responses making it impossible to evaluate any VIV effects, or the effectiveness of strakes in mitigation. Slowly varying

forces due to second order wave effects were measured in waves only. The effect of current on wave responses was difficult to isolate because of this turbulence, nevertheless the tests did demonstrate significant damping of slow drift responses in current verifying the importance of viscous effects.

The behavior of the Spar was consistent with our previous tests and analysis. No surprises were found. Perhaps the most remarkable finding was the influence strakes play on the slowly varying responses and heave motions. Compared to a bare spar, the straked spar had reductions in dynamic surge (at the cg) of 25%, heave of 40% and pitch motions of about 10%. Motions were further reduced with risers present.

Pretest numerical simulations using TDSIM6 showed generally good agreement with the results. The differences between test responses and numerical simulations were primarily in the prediction of 2nd order, slowly varying surge motions. Predictions were good in some environments (e.g. the 100 year Gulf of Mexico Hurricane), less so in others (the 10 year Gulf of Mexico storm and the North Atlantic storm). These motions are a result of resonant responses and thus very sensitive to damping. Post test simulations suggest the differences may be related to numerical methods for characterizing the waves, as well as the amount of viscous drag assumed in the modeling, i.e. the drag coefficient. A specific recommendation is that for any numerical or physical model simulation, the quadratic or envelope spectrum of the wave be checked against the theoretical envelope spectrum. This is discussed in Section 4.5.

There remains a need for full scale data to confirm the scaleability of these results. Data available from the FLIP (see next Section) indicates that the model damping is indeed representative and offers some confidence in these results.

The float-on deck tests proved qualitatively the feasibility of the approach. Both the Spar and the deck were very stable and the rigging worked exceptionally well.

The following section provides a description of the prototype designs upon which the model designs were based, and a description of the test program. Section 3 provides an overview of the original test objectives and a brief synopsis of the conclusions

reached with respect to each objective as a result of the review of the data accomplished to date. We believe this data provides an important and substantial basis upon which to proceed with site specific Spar designs.

2. Introduction

The Spar Floating Drilling and Production System (the SPAR) provides an alternative for deep water oil and gas recovery. A Spar in this context consists of a vertical cylinder which provides buoyancy to support facilities above the water surface. Its stability is derived from the location of its center of gravity below its center of buoyancy. Station keeping is provided by lateral, catenary anchor lines which may be attached to the hull near its center of pitch for low dynamic loadings. Lateral moorings may be augmented by vertical tethers to restrain heave response.

Spar Buoy type structures have been used in the ocean before. For example, the Floating Instrument Platform (FLIP)[1] was built in 1961 to perform oceanographic research. The Brent Spar was built by Royal Dutch Shell as a storage and offloading platform in the North Sea[2]. Table 2-1 and Table 2-2 show the particulars for these Spar designs. References on these Spars may be found in Appendix E.

Two Spar designs form the basis for these tests:

- A deep draft drilling & production spar configured for twenty steel risers with dry Christmas trees, and
- A tethered mini spar designed for production only with either steel or flexible risers.

There is obviously more data than can be assimilated within the scope of this project. This report attempts to interpret the most important results from the standpoint of Spar design. A description of the tests and a presentation of the data is included in a separate 29 Volume report prepared by the Offshore Technology Research Center[3].

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[1] Fisher, F. H. and Spiess, F. N., "Flip-Floating Instrument Platform", Journal of the Acoustical Society of America, Vol. 35, No. 10, pp. 1633-1644, Oct. 1963; see also Philip Rudnick, "Motion of a Large Spar Buoy in Sea Waves", Journal of Ship Research, Vol. 11, No. 4, pp. 257-267 [reprinted in Appendix E]
[2] Bax, J.D., Werk, K.J.C. de, "A Floating Storage Unit Designed Specifically for the Severest Environmental Conditions", SPE Paper 4853, 1974
[3] Offshore Technology Research Center, "Spar Model Test Joint Industry Project Report", May 1995.

The descriptions included in that report will not be duplicated here. Appendix A contains a test listing. Appendix D contains selected data describing the test specifications. The sections following this will describe the full scale Spar designs upon which the model designs were based.

Appendix E contains references related to the Spar designs and this project.

2.1. Drilling & Production Spar (Consortium Spar)

The drilling and production spar is based on a design prepared by the Spar Consortium of Deep Oil Technology, Inc., McDermott Inc., Reading & Bates Development and Rauma Offshore Contracting[4]. An inboard profile of this Spar is shown in Figure 2-1. This spar, referred to as the C-Spar for Consortium Spar, is designed for a total payload of 20,600 tons including:

Item	Weight tons
Drilling Rig & Utilities	6916
Accommodation Module	2048
Production Module	4894
Variable Loads	3754
Live Loads	50
Trim Ballast at maximum operating weight	2932
Total	20594

Principle characteristics are listed in Table 2-3.

[4] "Consortium 20 Well Drilling/Production Spar for the Gulf of Mexico Water Depth 3000 Feet", Prepared by The Spar Consortium, April, 1993. See also Halkyard, J. E., "Design of a Large Spar Floating Driling, Production and Storage System for Deepwater Oil & Gas Projects", Proceedings, Jont Meeting of the California Sections of the Society of Naval Architects and Marine Engineers, April, 1994.

The C-Spar has a 133 ft outside diameter and a 50 by 60 ft center well. The center well contains 20 - 10x10 slots for the production risers and buoyancy cans to support their weight, plus a 20 by 50 ft slot for the drilling riser and BOP stack. Figure 2-2 shows the well pattern. The sea floor wellheads are arranged on a 128 ft diameter circle with 20 ft spacing. Drilling is accomplished by positioning the spar over each well by use of the Spar mooring winches.

The mooring system is a 16 line, taut catenary system consisting of 5" diameter 6x76 IWRC wire rope (Figure 2-3). Station keeping is provided by linear winches on the top deck of the spar hull.

The advantages of the deep draft spar design include:

- Minimal heave and pitch motions compared to other floaters,
- Minimal accelerations during operational sea states.

Figure 2-4 shows the heave Response Amplitude Operators (RAOs) for the deep draft spar, a deep water semi, a drill ship and a shallow draft stepped spar. Recent model tests with a deep draft spar and a deep water semi resulted in the following heave and pitch/roll motions for a 100 year hurricane wave condition.

	MODU	Deep Draft Spar
Maximum Heave (ft)	+/- 35	+/- 6
Maximum Pitch/Roll (deg)	20	4

As a general rule the motions of the Spar are improved continuously by an increase in draft[5]. The draft is limited by the bending moments during upending, and by the cost

[5] A discussion of the influence of geometry on motions of Spars is included in van Santen and de Werk, "On the Typical Qualities of SPAR Type Structures for Initial or Permanent Field Development", Offshore Technology Conference paper 76-2716.

of fabrication. The 650 ft. draft was selected for the C-Spar design based on studies which indicated a point of diminishing returns with respect to motions.

Figures 2-5 and 2-6 show the horizontal and vertical accelerations of the deep draft spar compared to a semi and TLP. The horizontal acceleration includes the effect of gravity along the horizontal axis. These calculations were made with the Frequency Domain program SPLASHT. Details are included in Appendix G.

At low sea states (below Hs = 15 ft) the horizontal accelerations of the spar are 50 - 75% of the accelerations for the semi or TLP. This would result in less downtime for process facilities and lower their costs. This will also facilitate drilling and well maintenance operations.

Interestingly, the horizontal accelerations for both the TLP and the Spar exceed those of the semi for extreme sea states. The reason for this is the phase relationship between the gravitational component and the surge (or sway) acceleration. For the case analyzed, a semi in beam seas, the roll is 180 degrees out of phase with the sway. The gravitational component cancels the sway acceleration. For the Spar these motions are in phase. The TLP has almost no gravtitational component.

2.2. Mini Spar

Another Spar concept is the Mini Spar with a shallower draft and tether. This design is shown in Figure 2-7. Table 2-4 shows the principal characteristics. This design has larger pitch responses than a deep draft spar, however heave is restrained by the tether. The mini-spar does not have a center well. Risers are placed on the outside of the hull. Either rigid or flexible risers may be used, although none were modeled in these tests.

The results of tests of the mini spar have been reported however we have not performed any numerical simulations within the scope of this report.

2.3. Float-On Deck

A deep draft spar would be built in a shipyard in a horizontal position. It would be transported to the deep water site and upended by flooding of ballast compartments.

This procedure does not allow preinstallation and commissioning of the decks, hence the deck must be installed by a derrick barge at a deep water site. One concept which would eliminate the need for a multi-lift deck installation is the float on deck. The deck is constructed to be self floating. This is achieved by plating in the lower deck level(s). The deck may be installed by ballasting the hull so that the top of the spar is below the waterline. For stability and alignment, the Spar hull is outfitted with two sponsons which provide waterplane area while the main hull is submerged.

The deck may be floated over the top of the hull and mated by deballasting the hull. This process is essentially the same as that used by dry transport vessels such as the Mighty Servant class.

The deck has a built in notch which captures the Spar sponsons as the deck floats over the Spar hull. Figure 2-8 illustrates this concept.

Tests were performed to demonstrate the float-on deck concept. Remote controlled winches were used to simulate control of the deck as it floated onto the Spar in operational sea conditions.

Another variation of this concept, the slide on deck was also demonstrated. In this case the deck was mounted on a transportation barge and skidded onto the Spar hull which was ballasted to the same freeboard as the barge. The advantage of the slide on concept is that the deck does not need to be self floating and would be cheaper to build and easier to transport.

Procedures for these operations are detailed in Appendix H.

2.4. The Oryx Spar

Following completion of the JIP model tests, the Spar Consortium received a contract to perform final engineering on a production/workover Spar for Oryx Energy Company's Neptune Project. As part of that project we performed another series of model tests at the Offshore Technology Research Center. Those model tests benefited from some of the lessons learned as part of the JIP project. Specifically:

- The pitch sensor which did not function properly as part of the JIP program was repaired and worked properly for the Oryx tests,
- Current measurements taken during calibration for the JIP project were not archived. Examination of the turbulence spectrum could not be performed. This analysis was performed for the Oryx project allowing us to evaluate the influence of turbulence on the slow drift motions.

Since the results of the Oryx Spar tests are of interest to the participants in the JIP project, Oryx has agreed to allow us to use portions of their data for the JIP project. Particularly, we have included in this report a discussion of the effect of free stream turbulence on the Spar responses and we have included comparisons of analytical simulations with the global responses.

Particulars of the Oryx Spar as tested are shown in Table 2-5. Figure 2-9 shows the outboard profile and Figure 2-10 shows the full scale mooring system modeled.

2.5. *Test Configurations and Test Identification*

Fourteen different configurations were included in the JIP tests as listed in Table 2-6. These included different configurations of the deep draft spar, the mini-spar and the float-on deck. The purpose of the various configurations is summarized below.

Configuration	Description	Purpose
A	C-Spar, No Strakes, 4 pt Mooring	Baseline data for bare cylinder
B	C-Spar, No Strakes, Lateral restraints	Baseline data for bare cylinder without out of plane motions, e.g. VIV
C	C-Spar, No Strakes, Lateral and In-Line Restraints	For measuring drift forces directly (see Section 5)
D	C-Spar, No Strakes, In-Line Restraints, Lateral Mooring	For measuring drift forces in the presence of sway motions.
F	C-Spar, No Strakes, 20 Risers, 4 pt Mooring	Influence of risers on motions, riser loads and motions (drawdown)
F1	As above with strakes	
F2	As above with catenary riser	
H	C-Spar, Helical strakes, 4 pt mooring	Responses with strakes
J	As above with tanker attached by hawser to lee of Spar	Demonstrate offloading mechanics
L	Mini-spar, tethered and 6 pt Mooring	Global responses
M	As above with lateral restraints	In-line responses
N	Floating deck	Seakeeping
O	C-Spar ballasted below waterline	Seakeeping
P	Float-on and Slide On Operations	Demonstrate feasibility of concept and procedures

Tests are identified by the configuration, environment and run number, e.g. if more than one run was made for the same conditions. The first letter identifying the test is the configuration letter as above. The type environment is identified as:

Wind Only	WIN
Current Only	CUR
Random Waves Only	RAN

Regular Waves	RG
BiChromatic Waves	BC
Random Waves and Current	RC
Random Waves, Wind and Current	RCW

A number following the type of environment designates the exact conditions, e.g for random wave environments:

1	Long Crested Operating Sea
2	10 Year GOM Storm
3	100 Year GOM Hurricane, Realization 1
4	100 Year GOM Hurricane, Realization 2
5	100 Year North Atlantic Storm
6	Short Crested Operating Sea
7	100 Year West Africa Storm

Specifications for the various environments may be found in the OTRC Test report. Selected tables and figures are replicated here in Appendix D.

A list of all tests is included as Appendix A. Tabulated statistics for most of the tests are included in Appendix B, and Pre-Test Simulation Results are included in Appendix C.

Displacement, tons	2104
Hull Diameter, ft	
Above Cone	12.5
Below Cone	20.0
Depth below normal waterline, ft, to:	
Bottom of buoy	300
bottom of cone	150
top of cone	60
center of mass	183.5 (est)
center of buoyancy	176.5
Natural Periods, sec:	
Pitch/Roll	48
Heave	27

Table 2-1 Particulars for FLIP

Displacement, tons	**74000.**
Hull Diameter, ft.	
Above transition deck	55.8
Below Transition deck	95.5
Distance from Normal Waterline, ft., to:	
Bottom of Hull	357.6
Transition deck	52.5
Center of Mass	219.6
Center of Buoyancy	59.5
Water Depth, ft.	**450**
Mooring System	**Concrete Gravity Anchors**
	2625 ft. - 3.5 inch wire rope
	935 ft. 4" chain
	Chain stoppers 144 ft. above keel
Natural Periods, sec.	
Surge/Sway	210
Heave	36
Roll/Pitch	30
Yaw	80

Table 2-2 Particulars for Brent Spar

Equipment		
1 Skiddable Drilling Rig		
1 Drilling Riser (21")		
1 Subsea BOP Stack, 10,000 psi		
20 Production Risers (9-5/8", 7" csg, 3-1/2" tbg)		
Oil Production Facilities	60,000	BOPD
Gas Production Facilities	100,000	MSCFD
Water Injection Facilities	60,000	BWPD
Main Dimensions and Capacities		
Hull Outside Diameter	133	Ft
Draft	650	Ft
Freeboard at Cellar Deck	60	Ft
Centerwell	60 x 50	Ft
Deck Dimensions	200 x 270	Ft
Deck Load (Operating)	11,700	Tons
Hull Structural Weight	23,790	Tons
Hull Outfitting and Marine Systems	5,080	Tons
Variable Ballast Capacity	30,740	Tons
Module Support Frame	2,330	Tons
Mooring - 16 Leg Anchor/Chain/Wire		
Wire Rope (IWRC), Dia 5 inches, Length	5,550	Ft
Chain (NV K4 Rig), Dia 4 inches, Length	400	Ft
Anchor, Vryhof Stevmanta, Weight	13.7	Tons

Table 2-3 Principal Characteristics for Consortium Spar

	Prototype	Model
	Hull	
Diameter	52.5 ft	0.95 ft
Draft	443 ft	8.05 ft
Length	506 ft	9.20 ft
Fairlead Depth	41.8 ft	0.76 ft
	Deck	
Length	165.0 ft	3.0 ft
Width	165 .0 ft	3.0 ft
Height	64.2 ft	1.17 ft

	Prototype Target	Prototype Achieved	Model Achieved
Weight	58,492 kips	58,530 kips	343.00 lbs
KG	203.51 ft	203.50 ft	44.40 in
Pitch Gyradius	201.70 ft	201.07 ft	43.87 in
Roll Gyradius	201.70 ft	196.17 ft	42.80 in

Table 2-4 Principal Characteristics for The Mini-Spar

MAIN DIMENSIONS & CAPACITIES		
Hull Outside Diameter	68	Ft
Draft	650	Ft
Freeboard at Cellar Deck	55	Ft
Centerwell	32 x 32	Ft
Deck Dimensions	60 x 90	Ft
Design Deck Load	2,500	Tons
Hull Structural Weight	10,955	Tons
Hull Outfitting & Marine Systems	981	Tons
Variable Ballast Capacity	3,160	Tons
MOORING - 6 LEG CHAIN/WIRE/CHAIN/ANCHOR		
Chain (RQ3+20%) Dia 3 inches, BS 1,253 kips, Length	1,750	Ft
Wire Rope (IWRC), Dia 3-1/2 inches, BS 1,250 kips, Length	5,300	Ft
Chain, Grade 2, Dia 4-1/8 inches, BS 1,207 kips, Length	1,000	Ft
Anchor, Bruce, FFTS	15	MT

Table 2-5 Particulars for Oryx Spar

	Spar Diameter	Spar Draft	Mooring	Vortex Suppression	Lateral Restraints	In-Line Restraints	Comments
A	133	650	4 Lines	None	None	None	
B	133	650	2 Lines	None	Yes	None	
C	133	650	None	None	Yes	Yes	
D	133	650	2 Lines	None	None	Yes	
F	133	650	4 Lines	None	None	None	Vertical Risers
F1	133	650	4 Lines	Strakes	None	None	Vertical Risers
F2	133	650	4 Lines	Strakes	None	None	Vertical Risers & Catenary Riser
H	133	650	4 Lines	Strakes	None	None	
J	133	650	4 Lines	Strakes	None	None	Moored Tanker
L	52.5	443	6 Lines	None	None	None	
M	52.5	443	6 Lines	None	Yes	None	
N	-	-	-	-	-	-	Floating Deck Alone
O	133	700	4 Lines	Strakes	None	None	Flooded Hull Alone
P	133	700	4 Lines	Strakes	None	None	Float-On & Slide-On Deck

Table 2-6 Test Configurations

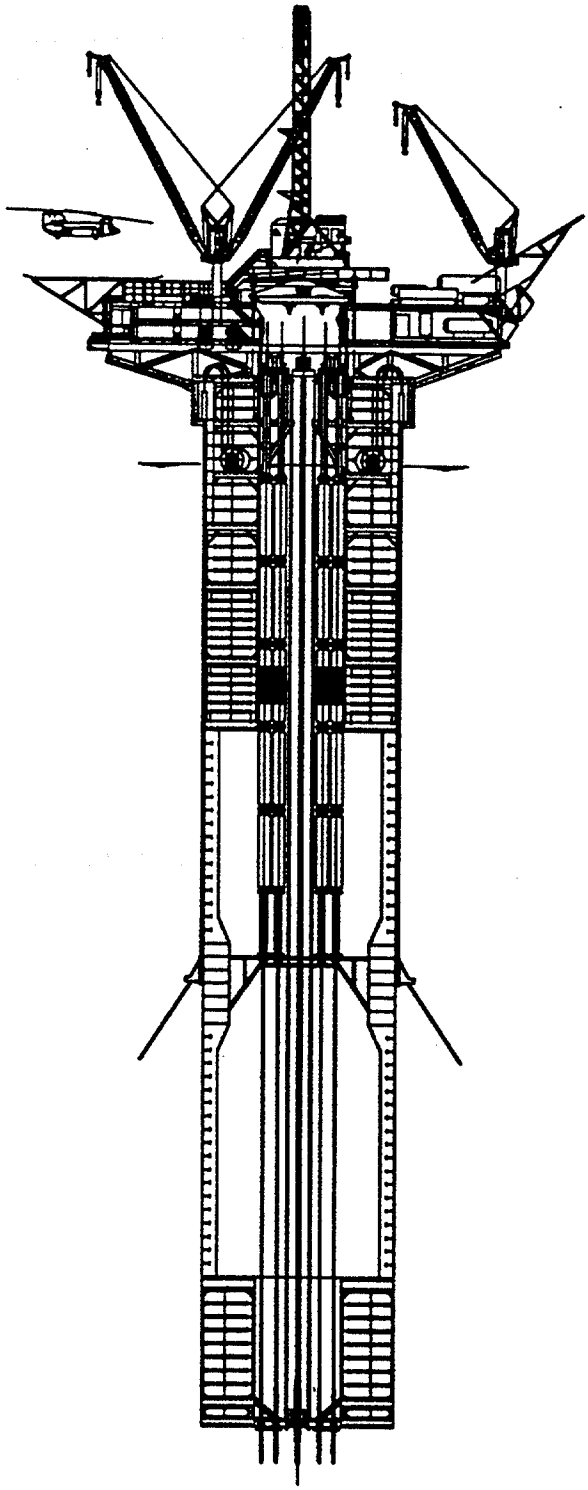

Figure 2-1 Inboard Profile of Consortium Spar

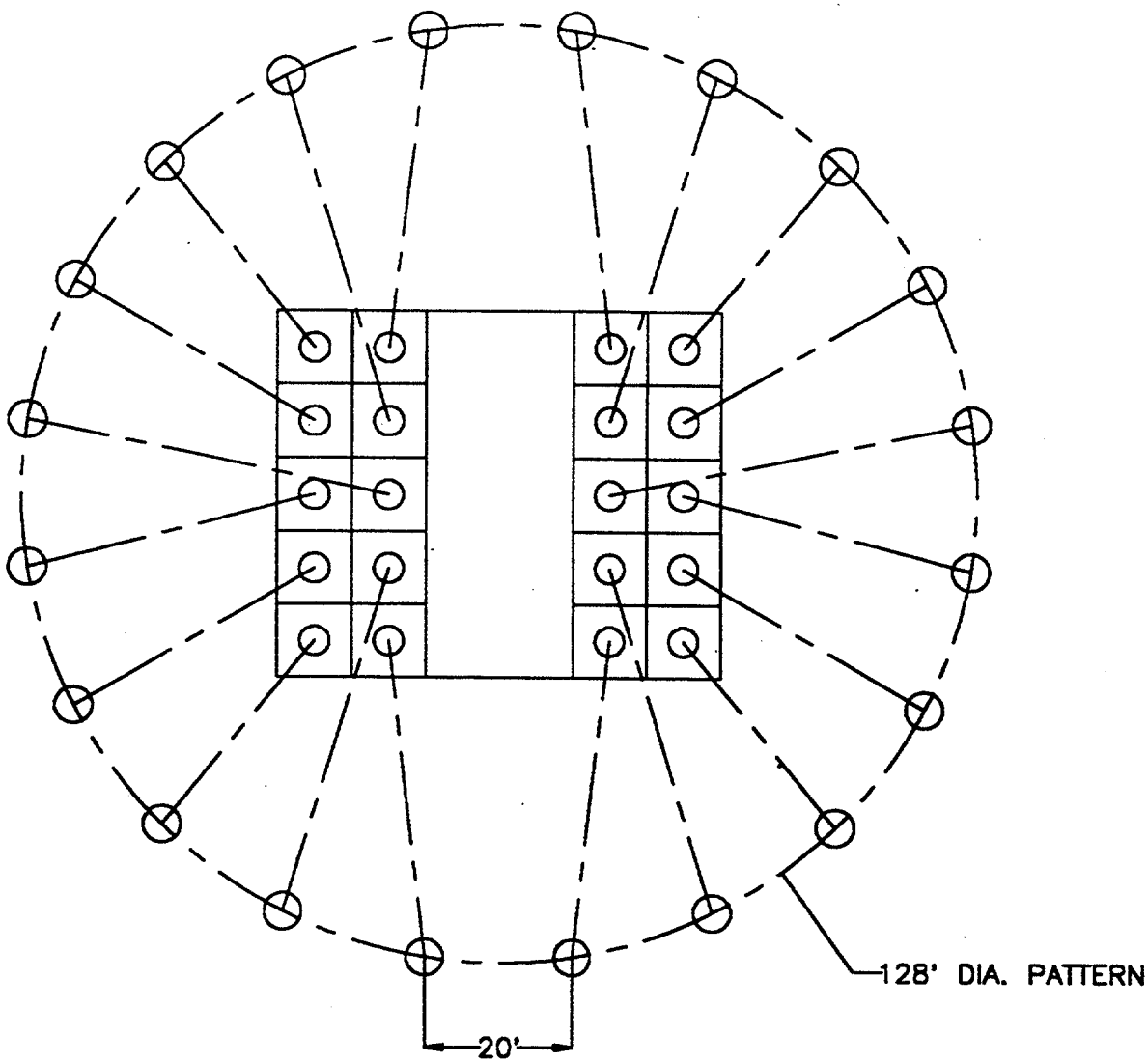

Figure 2-2 Well Pattern for Consortium Spar

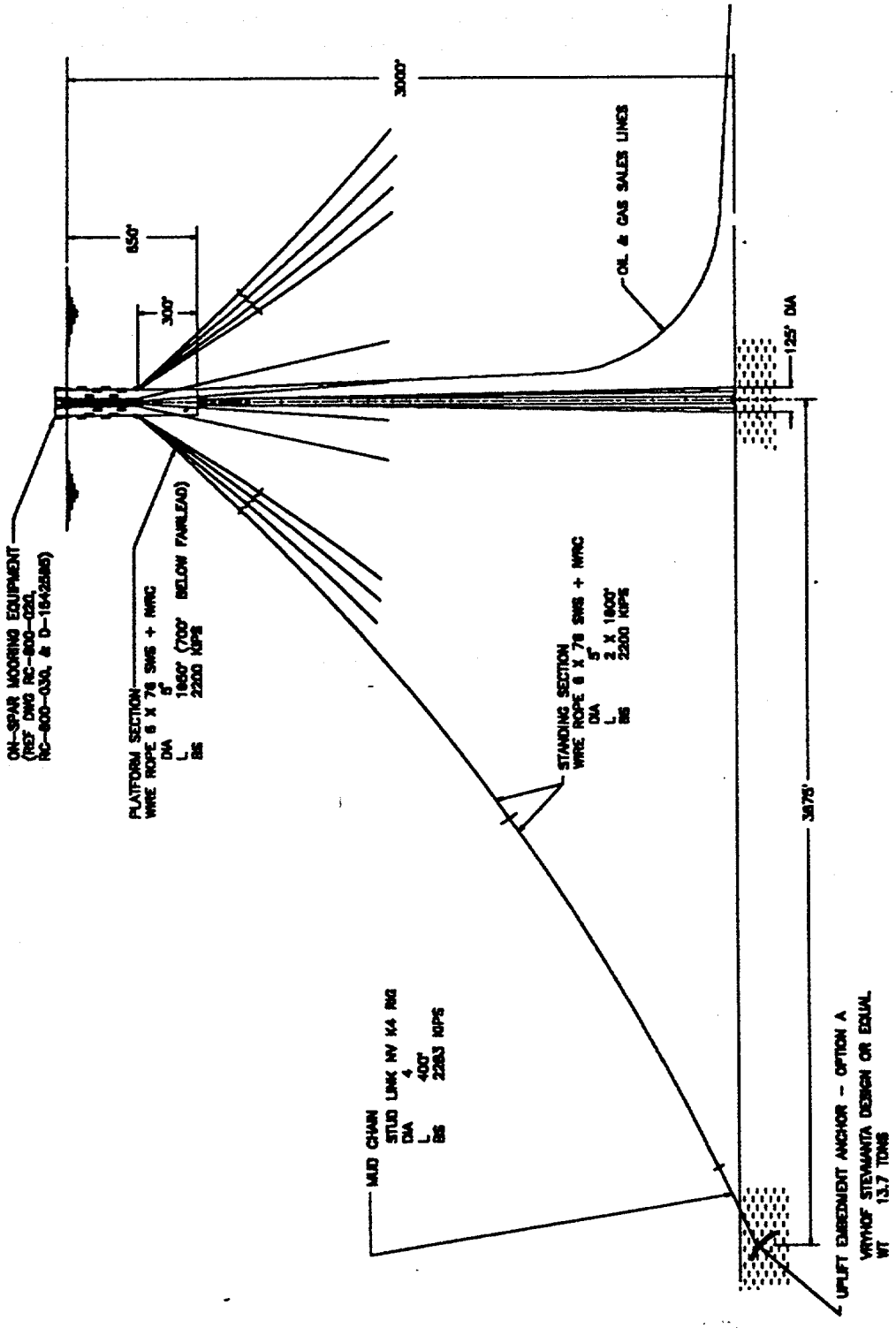

Figure 2-3 Mooring System for Consortium Spar

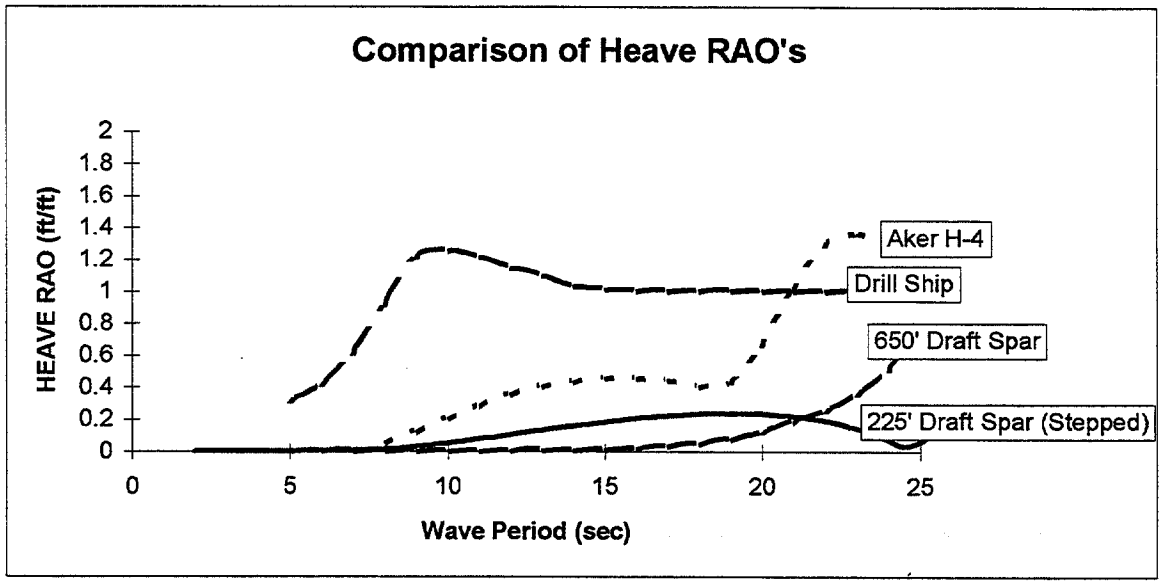

Figure 2-4 Heave RAO Comparison

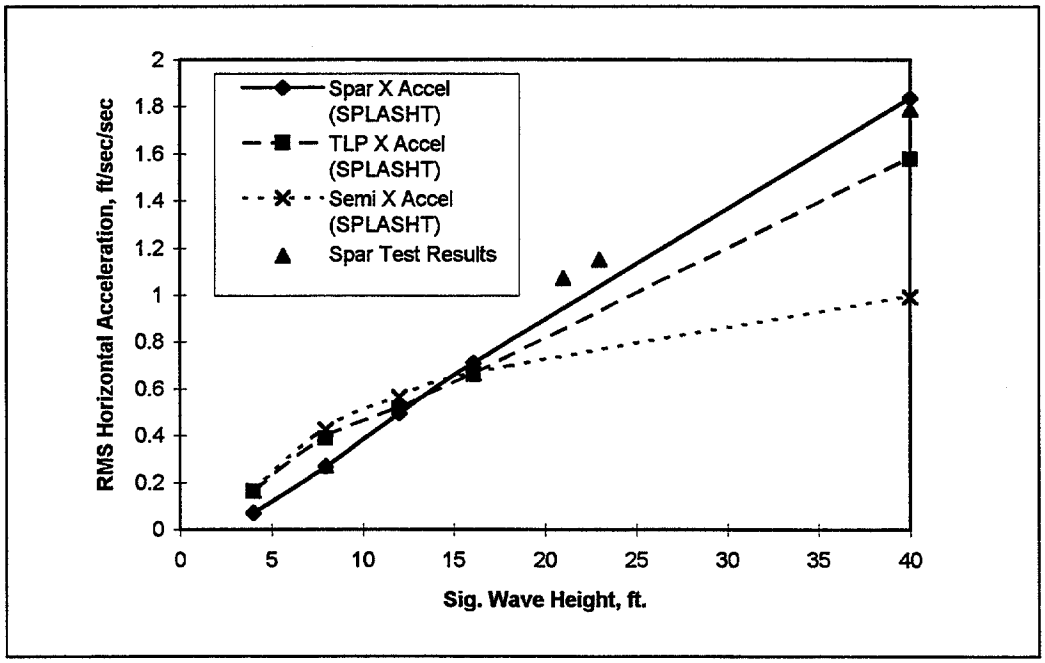

Figure 2-5 Horizontal Acceleration at Deck Comparison

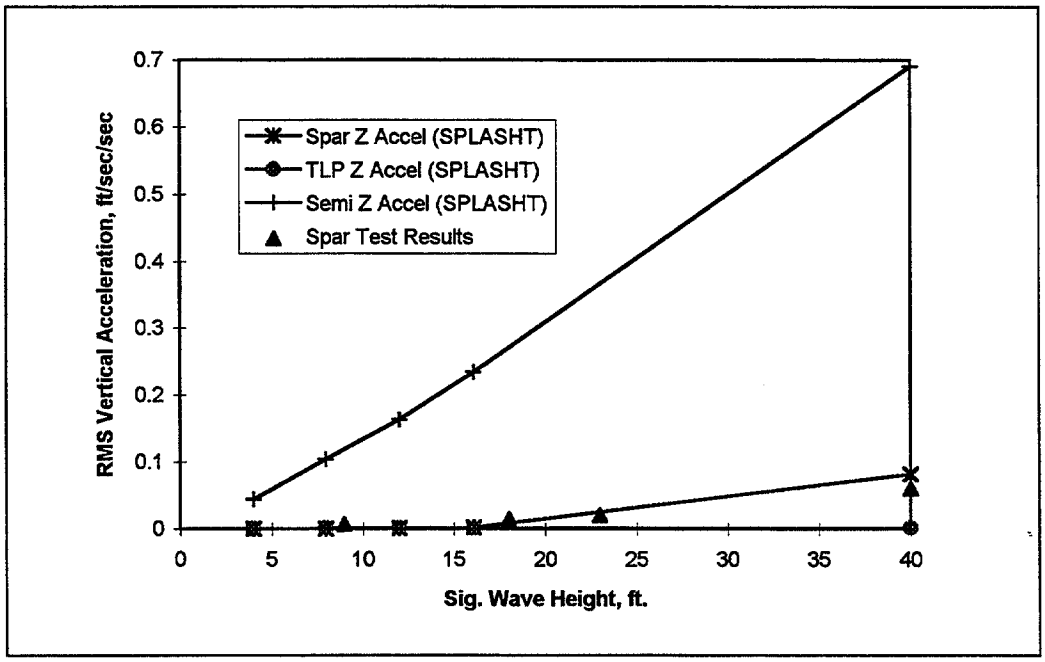

Figure 2-6 Vertical Acceleration Comparison

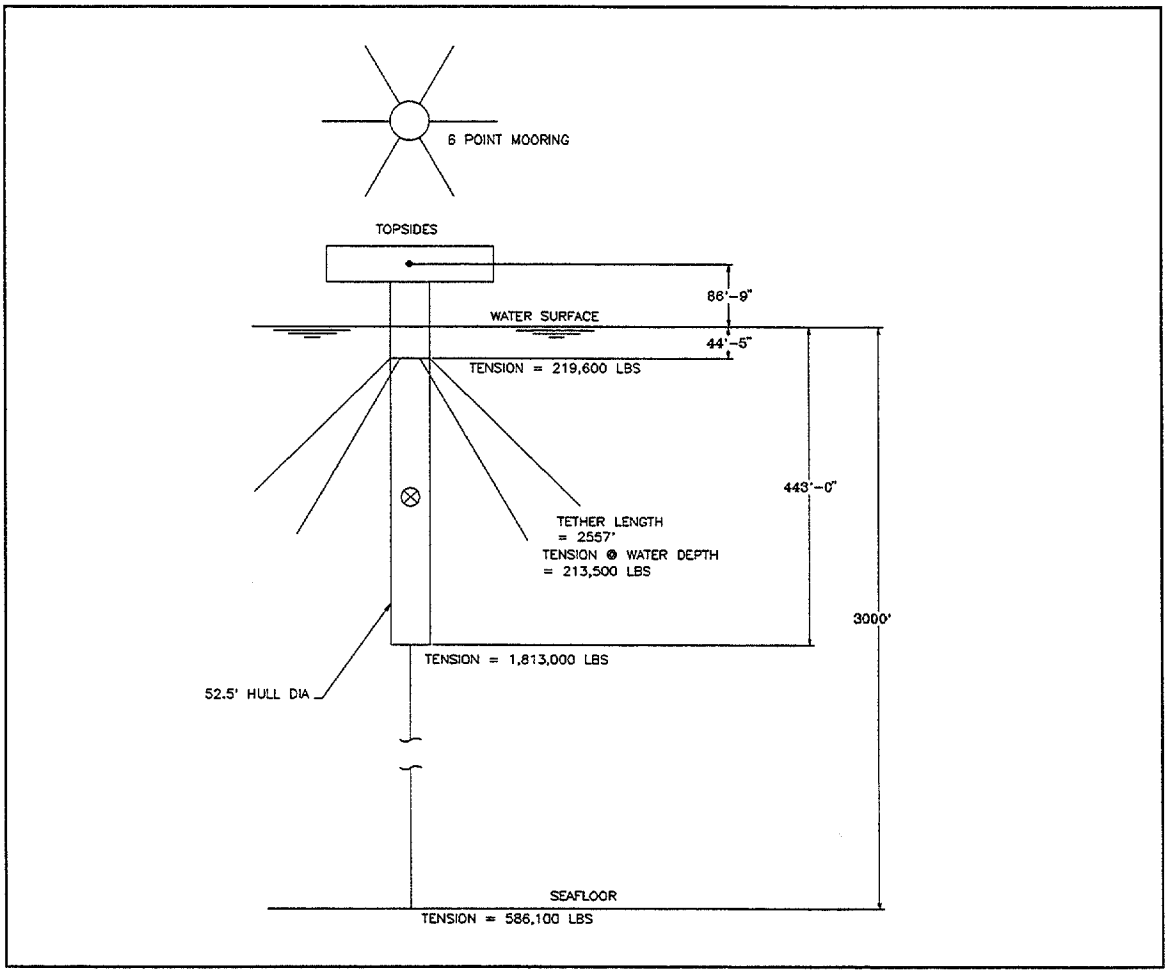

Figure 2-7 Tethered Mini-Spar

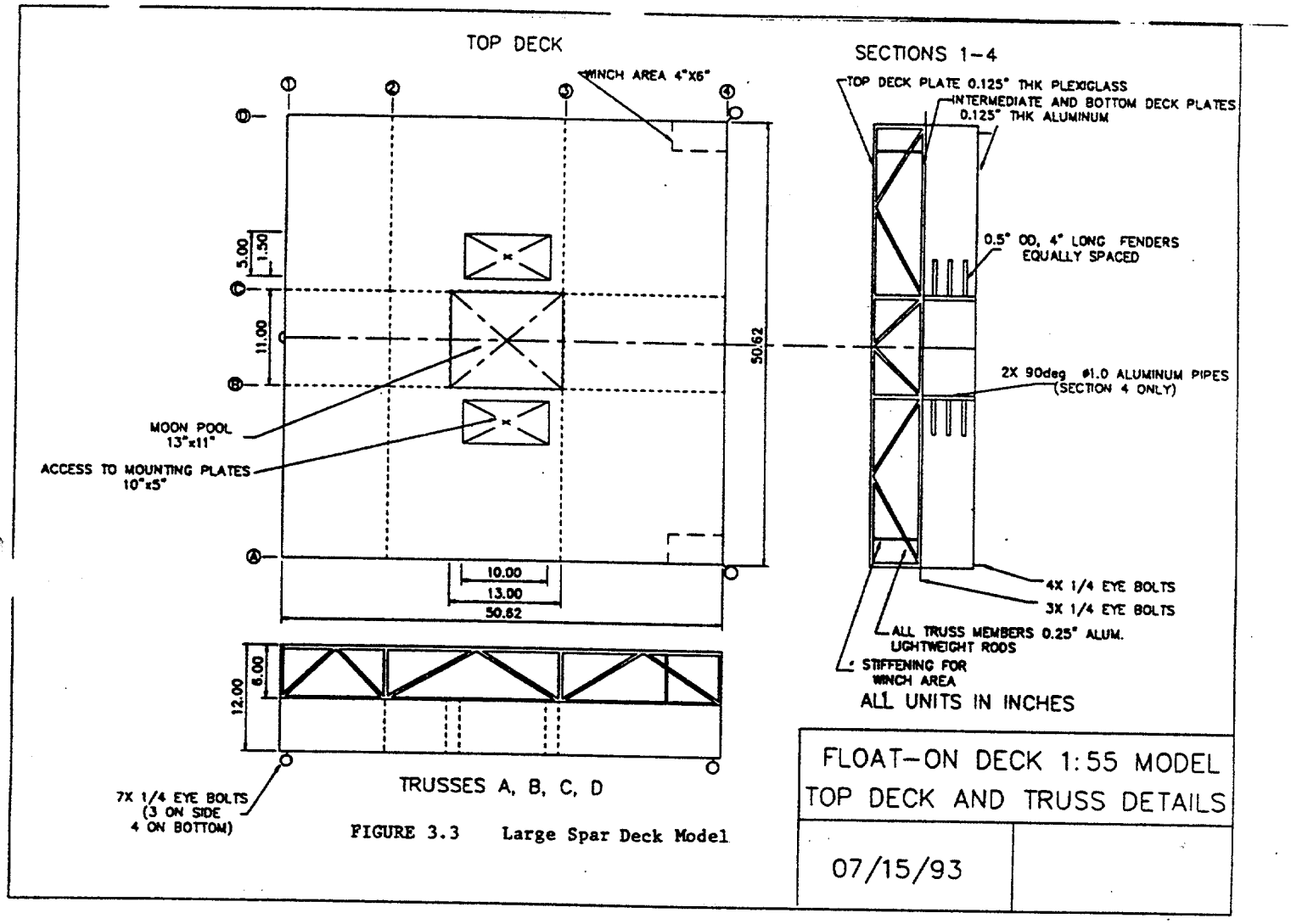

FIGURE 3.3 Large Spar Deck Model

Figure 2-8 Float-On Deck

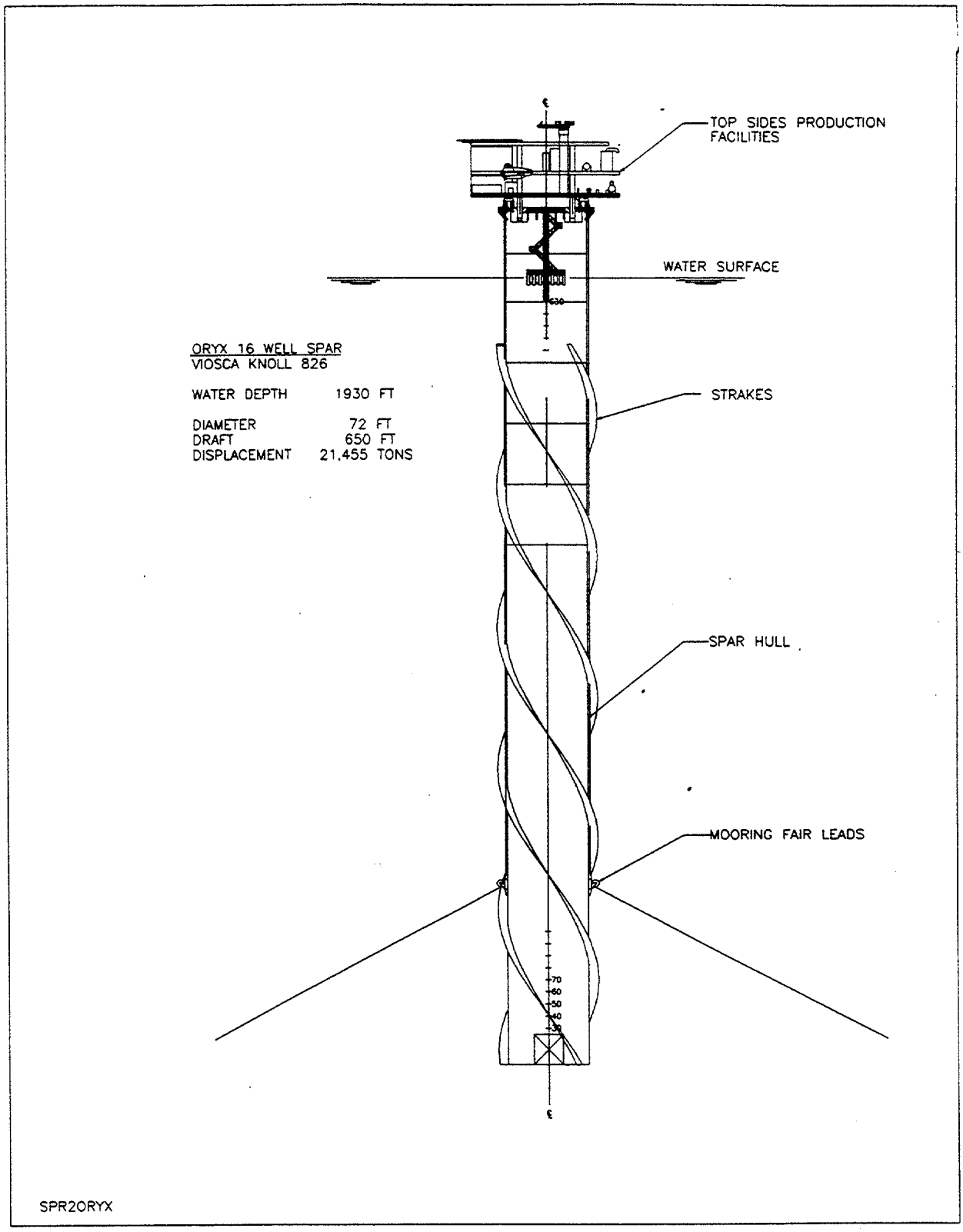

Figure 2-9 Oryx Spar Outboard Profile

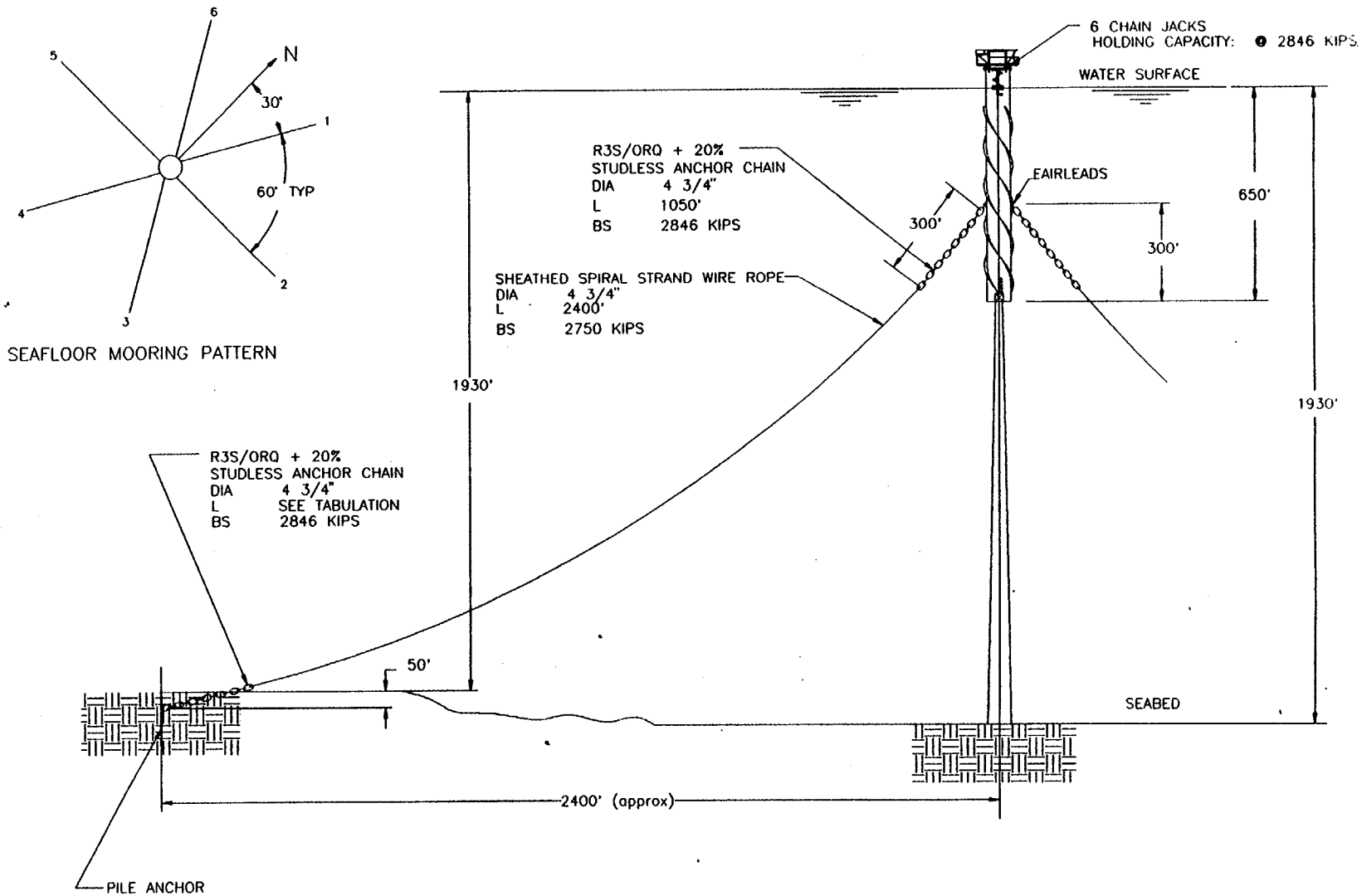

Figure 2-10 Oryx Spar Mooring

3. Objectives and Conclusions

The specific test objectives were to

1. Provide a high quality data set with emphasis on:

   a) Wind, Wave & Current interaction effects
   b) Slowly varying forces and responses
   c) Vortex Induced Vibrations (VIV)
   d) Heave natural periods, including center well/riser effects
   e) Extremal Statistics

2. Demonstrate Concept Feasibility

   a) Float-on Deck
   b) Shuttle Tanker Bow Moored to Spar
   c) Rigid risers in centerwell

Underlying these specific objectives is the overall objective of reducing uncertainties in the understanding of Spar behavior to the point that site specific designs can be approached with confidence.

3.1. Wind/Wave/Current Interactions

The kinematics of waves and current acting together are the subject of much study and interest. Questions such as whether the wave and current velocities are additive at the wave crest, or at some depth below the crest, are common. Different math models have been used. Comparing test results with numerical simulations is important to verify the accuracy of the math models.

A difficulty in verifying these models for spars moored in deep water is the occurrence of vortex induced motions which are unrelated to the wave/current interaction effects discussed above. In deep water, the Spar has a long natural period in sway and a resonant sideways sway motion occurs for moderate current velocity. This sway motion alters the flow field, creating augmented drag forces which mask the wave/current effect under study.

This has been a problem in previous model tests of both the Spar and the Tension Buoyant Tower.

In order to mitigate this problem, some means of vortex induced vibration (VIV) suppression is required. The DOT Spar design employs strakes along a partial length. These strakes break up the spanwise correlation of the vortices and thus reduce (but don't eliminate) VIV. The strakes also change the general hydrodynamic characteristics of the Spar cylinder. In order to obtain data for a pure circular cylinder, another means of suppressing VIV is employed in the tests (Configurations B, C and M in the Test Matrix): a stiff lateral restraint (mooring) is employed which raises the natural sway frequency above the range at which VIV would take place.

Figure 3-1 shows the motion responses for various combinations of wave, wind and current associated with the 100 Year Gulf of Mexico Storm. These results are for Configuration B. The trends remained the same for other configurations.

The dynamic responses to wave only are as large or larger than any other combination. Even the turbulent current, which causes large surge motions with no waves or wind, results in a damping of the wave induced motions.

Figure 3-2 shows the mean and RMS Tension variations associated with the motions shown in Figure 3-1. Because of the non-linear stiffness of the mooring, the dynamic mooring line tension results are affected by the mean tension and hence are maximum for the wave, wind and current combined environments.

Comparison of test results to analytical predictions generally showed good correlation and were consistent with the observed interaction effects. Heave response and slowly varying surge were sensitive to the spar configuration. Strakes and risers tended to dampen the motions significantly. The comparisons between the measured and simulated slowly varying surge motions showed the most variability. Better simulation results in large wave environments were achieved by increasing the number of waves used to discretize the spectrum, and by reducing the viscous drag coefficient in the Morison equation. Further discussion is included in Section 4.

3.2. Slowly Varying Forces and Responses

Deep water spars are characterized by long natural periods: 60 - 90 seconds in pitch and 200 seconds or more in surge and sway. The Spar is relatively insensitive (compared to most other floaters) to wave frequency forces, especially under operational sea states. The Spar is more prone to slowly varying motions from both VIV and 2nd order wave effects as the Figure 3-3 shows.

These results are for the combined wave/wind/current environments. Roughly 90% of the response is low frequency.

Numerical models used to analyze the slowly varying wave effects have certain assumptions and approximations built into them which need to be verified. One of them is the approximation of the slowly varying drift force as being equal in magnitude to the steady drift force at the average frequency of the wave components contributing to the slow drift frequency in question (i.e. either the surge or pitch natural frequency). This is the so-called Newman approximation[6]. Another approximation related to computing

[6] Newman, J.N., "Second Order Slowly Varying Forces on Vessels in Irregular Waves," International Symposium on Dynamics of Marine Vehicles and Structures in Waves, University College London, Pub. I. Mech. E., 1975. See also, Taylor, Eatock R and Sincock, P., "Comparison of Analysis for Moored Systems in Random Waves", Journal of Offshore Mechanics and Arctic Engineering, Vol. 09, May 1987.

pitch motions is that the center of action of the slowly varying surge force is at the mean free surface.

Since most of the dynamic surge and pitch motions are computed to arise from these slowly varying forces, a check on these approximations is particularly important. This applies to mooring line tensions as well.

Measurement of these slowly varying forces presents some experimental challenges. The forces themselves are very small compared to wave frequency forces. If the model were mounted on a dynamometer and held fixed, the first order forces would be several orders of magnitude larger than the slowly varying forces. Additionally, restricting the wave frequency motions of the body is known to change the magnitude of the drift forces. A technique for measuring the slowly varying drift forces, first employed by Dr. Pinkster at MARIN in the early 1980's, involves restraining the model in such a way that it is free to move with the wave frequencies but is restricted from moving at the periods for which slow drift forces are desired[7]. This technique has been employed in Configurations C & D where the in-line restraints are designed to yield natural periods for surge and pitch of 35 and 40 seconds, respectively. This means the slow drift forces at 75 seconds (pitch period) and 190 seconds (surge period) will not be affected by resonance responses and can be derived directly from the load measurements. Also, by comparing the force measurements from these configurations with the motions measured with Configuration B, the amount of damping in the tests can be inferred.

Slowly varying drift forces are caused by two wave components of different frequencies interacting. The slowly varying frequency is equal to the difference in frequencies between two wave components. In a spectrum, there are an infinite number of infinitely small wave components interacting with each other. In the numerical model, these wave components are approximated by a finite number of wave components.

In this paper the Newman approximation appears to show good agreement with a fully 2nd order solution for an articulated tower which would be similar to a Spar.

[7] Pinkster, J. A., "Low Frequency Second Order Wave Exciting Forces on Floating Structures", Ph. D. Thesis, Delft University, 1980

Figure 3-4 shows a matrix of wave periods from one such simulated wave spectrum (based on 50 wave components). Each array element corresponds to a difference frequency between two components. The diagonal of the array corresponds to a difference frequency of zero. The second order forces arising from the diagonal terms represent the steady drift force. The second order forces arising from the off diagonal terms represent the slow drift forces. The steady drift forces are readily obtainable from a first order diffraction model or from regular wave tests. Experimental and analytical results suggest it provides a good approximation for the contribution to slow drift provided the natural frequency of the floater is sufficiently low and the frequency of dominant wave energy is sufficiently high[8].

The array elements in Figure 3-4 corresponding to pitch and surge natural frequencies are marked by P and S, respectively. Note that the slow drift forces arising from relatively high frequency waves (e.g. pitch forces arising from 7.7 and 8.6 second wave pairs) are close to the diagonal. The Newman approximation might be expected to work well here. On the other hand, slow drift forces for pitch from, say, a 14.0 and 17.1 second wave, fall relatively far from the diagonal and may not be approximated very well by the Newman approximation. Pinkster's experimental work on semi-submersibles, for example, suggests the difference between the off-diagonal drift force terms and the diagonal terms may be 20 - 40%.

The experimental method most easily employed to measure these force terms utilizes two regular waves superimposed to present a wave group effect. These bi-chromatic waves are employed here in Configurations B and C.

The results of these experiments are discussed in Section 5. Table 3-1 shows the results in terms of the Quadratic Transfer Function (QTF) tabulated against the two wave periods tested. The QTF is a non-dimensional value given by:

[8] Pinkster (op. cit.) suggests that this approximation is valid for semi's with periods in excess of 63 seconds and for tankers with periods in excess of 250 seconds. The Spar surge period certainly satisfies this criterion.

$$QTF = \frac{F_{wave}}{\rho g R A_1 A_2}$$

Where F_{wave} = Force Amplitude, kips

A_1, A_2 = Wave Amplitude, ft

ρg = Density, lb/cu ft

R= Radius of Spar, ft

Comparison of the off-diagonal terms would suggest that use of Newman's approximation may be unconservative. However, this may not be a valid conclusion when considering the validity of numerical simulations:

- These results based on model tests are comparing 2nd order effects in a viscous media with computed inviscid fluid results. In effect both viscous and potential drift are combined in the model tests.
- The mitigating effect of slow drift damping has not been considered. In TDSIM6, for example, slow drift damping is ignored. This might offset an underestimate in the drift force implied in Newman's approximation.
- The post test simulations in Section 4 suggest that numerical methods and the selection of a viscous drag coefficient may influence results (of 2nd order slow drift) as much as the differences in the QTFs shown above.

Specifically, post test simulations suggest the differences may be related to one or more of the following:

- The method of modeling the irregular wave spectra, specifically the manner in which the spectra is discretized in numerical approaches,
- The amount of viscous or drift damping assumed,
- Modeling of the Quadratic Transfer Function

In general, it is difficult to determine whether differences between test results and numerical results are because of a theoretical deficiency in the analytical approach,

numerical modeling inaccuracies, or whether the test is flawed. The results of these tests suggest that present analytical methods give reasonable results as long as the numerical inaccuracies are minimized and that the expressions which affect damping and second order forces are calibrated against model and full scale data.

Full scale data remains the most critical information required to validate the approach used to predict drift responses. Very limited data of this type exists. The only data available to the JIP is the data collected on the FLIP[9]. In this reference free decay tests were caried out on the FLIP as well as analysis responses in irregular seas. From this data an effective damping ratio could be derived for FLIP which is given below together with test results:

	FLIP	Configuration A (Bare Spar)	Configuration H (Straked Spar)	Configuration F1 (Straked Spar with Risers)
Heave	.4 - .6%	.5%	.9%	2.8%
Pitch/Roll	2. - 4.%	.9 - 1.1%	1.5 - 1.6%	2.9 - 3.1%

FLIP has no strakes or other dominant below water appendages. The relevant comparison would thus be with Configuration A which would suggest that we are achieving good representation of the viscous damping.

Further review of more recent data from FLIP or from other Spars such as Brent (if any data was taken during its operations) or the Draughin Spar would be invaluable in firming up this conclusion.

[9] See Rudnick, op cit, reproduced in Appendix E. We also have some more recent data from FLIP but Rudnick's data collected in the 1960's seems the most reliable!

3.3. *Vortex Suppression*

Vortex suppression was discussed above in the context of experimental determination of wave/current effects. Vortex suppression is also a practical design consideration since VIV, especially if associated with high currents such as the loop current, can result in higher than expected drag coefficients and associated high mooring loads. Also, frequent occurrence of VIV, or lock-in, might lead to fatigue of mooring components and possibly the hull.

Helical strakes are commonly employed to suppress VIV in air. DOT has previously tested helical strakes as part of a Spar design effort and as part of a JIP on Vortex Induced Motions. Longitudinal slats were originally proposed for this project because they would be easier to install, and they would facilitate a wet tow. Tests conducted at the Offshore Model Basin in March, 1994 (not part of this JIP) indicated that the proposed slat design would not effectively suppress VIV. Hence, the JIP plan was changed to include helical strakes in Configuration H rather than slats.

Vertical slats of another configuration might suppress VIV but we did not have time to test other configurations in a tow tank[10].

As discussed in Section 4, no conclusions regarding the effect of VIV could be reached from these tests because the free stream turbulence dominated the Spar responses in current independent of VIV suppression devices.

[10] The use of helical strakes did result in a bonus which slats probably wouldn't have yielded. The damping effect of the strakes reduced dynamic heave motions by about 40%. These results are discussed in a later section of this report. It also turned out that VIV effects in these tests were largely masked by the ambient turbulence. The effectiveness of strakes could not be verified.

3.4. Center Well Water Motion

The relative motion between the center well water and the spar could have an influence on heave period, pitch responses and riser loads. This effect was first studied by DOT in an early Joint Industry Project[11].

The model for the present tests is designed to realistically simulate the center well and riser guide geometries so that hydraulic coupling between the center well water and the Spar can be evaluated.

The results show a high degree of coupling between the water in the center well and the Spar. In effect the center well water moves with the Spar and there is little relative motion. This result was verified by data taken in the absence of risers. With risers present there is some constriction in the flow of the center well water which introduces damping to the motion of the center well water which could be higher than damping on the spar. Water motions in the center well were not measured with the risers present, however observations suggested that there was more *relative* motion during a free decay test than previously observed without risers. This observation is substantiated by a simple two degree of freedom oscillator model discussed in Section 4.

The design consequence of this phenomenon is that the risers, acting as dampers for the center well water motion, must experience some axial loadings in addition to the friction at the guides. Measurements of the axial loads on the risers tend to support this conclusion. The effects still result in a relatively benign loading condition on the risers compared to risers for an FPS or TLP which are directly exposed to the wave action and subject to the resulting bending loads.

[11] Deep Oil Technology, Inc. "Joint Industry Program for Investigating Motions of a Spar Type Floating Oil Production Platform", C-871201 and C-871201.1, Aug., 1989. Tests were conducted on a Spar with a uniform center well and with an orifice plate restricting flow at the keel.

3.5. *Extremal Statistics*

Design of the Spar requires estimation for the extreme responses (e.g. surge, pitch, line tension) in the design life, or some multiple of the design life. The estimates for the extreme values lead directly to the selection of a mooring system and scantlings for the hull, as well as requirements for topsides equipment and riser components.

In fixed structures it is recognized that the extreme values of wave induced responses closely follow a Rayleigh probability distribution. This gives rise to the common requirement to design for 1.86 times the significant height of the response which is the expected value for the highest 1/1000 responses, or about the expected highest value in a three hour event based on wave frequency responses.

Floating structures subject to non-linear interactions, e.g. from non-linear mooring lines and slow drift responses, do not exhibit the same Rayleigh distribution of their extreme responses. The actual distribution of extreme values needs to be examined for each response. For example, the surge motion of moored semi's is commonly known to be Rayleigh distributed, but the associated mooring line tensions, being highly non-linear, are not Rayleigh distributed.

In order to evaluate these statistics a large number of cycles are needed. For slow drift responses, previous model test studies have suggested that a minimum of 30 cycles should be included to arrive at reliable extremal statistics[12]. The Spar in its offset position has a surge period of about 230 seconds, hence a minimum of 6900 seconds of data is desired (about 16 minutes model scale).

Tests of more than about 8 minutes model scale (60 minutes full scale) lead to a degradation in the wave spectrum due to reflections and breaking waves. In order to compile adequate statistics for determination of extreme value probabilities, it was

[12] McDowell, J.E., "Analysis of the Slowly Varying Motions of a Floating Production System", Offshore Technology Conference paper 86-5205, 1986

specified that two separate tests be performed for the 100 year storm with different wave makeup (although with the same spectral properties). These two wave makeups are called different realizations of the same spectrum. This results in two statistically independent tests equivalent to 120 minutes full scale. The extreme values from both tests can be combined to determine the appropriate probability distribution.

Section 4 contains a discussion of the extremal statistics as derived from these tests and from multi - three hour numerical simulations. Extreme pitch and heave motions appear to follow Rayleigh distribution, Surge (mainly slowly varying surge) and tensions follow an exponential distribution.

With a 120 minute test sample it is impossible to determine the validity of extrapolation to a 3 hour extreme design requirement. However, results of multiple 3 hr numerical simulations indicate that extrapolations based on Weibull curve fits for a single three hour event are conservative, provided the data selected for the fit represent values associated with the extreme events, or the tail of the distribution. In the work presented in Section 4 this typically involved fitting the 20 highest out of 80 or more responses to a Weibull curve.

3.6. *Other Test Objectives*

The above discussion focuses on the scientific objectives of the program, i.e. the makeup of the high quality data set which can be used to verify the design analysis approaches.

Other objectives may be defined as proof of concept. This applies, specifically, to the float-on deck tests (Configurations N, O and P) as well as the tanker loading tests (Configuration J). Here the emphasis is on subjective evaluation of the results and observation of the behavior to determine if unexpected and/or undesirable behavior occurs.

Specifically, the float-on deck tests are designed to simulate the mating of the deck to a partially submerged spar in a seaway which might be characteristic of an installation sea state. The ability to pull in the deck and the impacts at the time of engagement were observed. Impact loads were not directly measured, but high speed video helps to quantify the effects. Determination of the Response Amplitude Operators for the two vessels in proximity also helps with future analytical work on the design.

Results of the tests were generally favorable.

The tanker did not appear to fishtail and did not lead to any undesirable spar motions.

The float-on deck and the partially submerged spar exhibited very little motion in the Gulf of Mexico installation sea state. The float-on operation was conducted flawlessly several times using remote controlled winches.

Period	4	4.5	5	5.6	6	6.5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
4	0.55																					
4.5		0.32																				
5			0.67																			
5.6				0.73																		
6					0.71																	
6.5						0.75																
7							0.7															
8								0.44														
9									0.3													
10										0.22	0.3332											
11											0.15											
12												0.1	0.14	0.1								
13													0.06		0.0659							
14														0.033	0.0888/.1256		.1356/1868					
15															0.023							
16																0.017	0.0606			0.152		
17																	0.01	0.0832				0.18
18																		0.006				
19																			0.002			
20																				5E-04		
21																					0	
22																						0

Table 3-1 Results of Quadratic Transfer Functions from BiChromatic Wave Tests

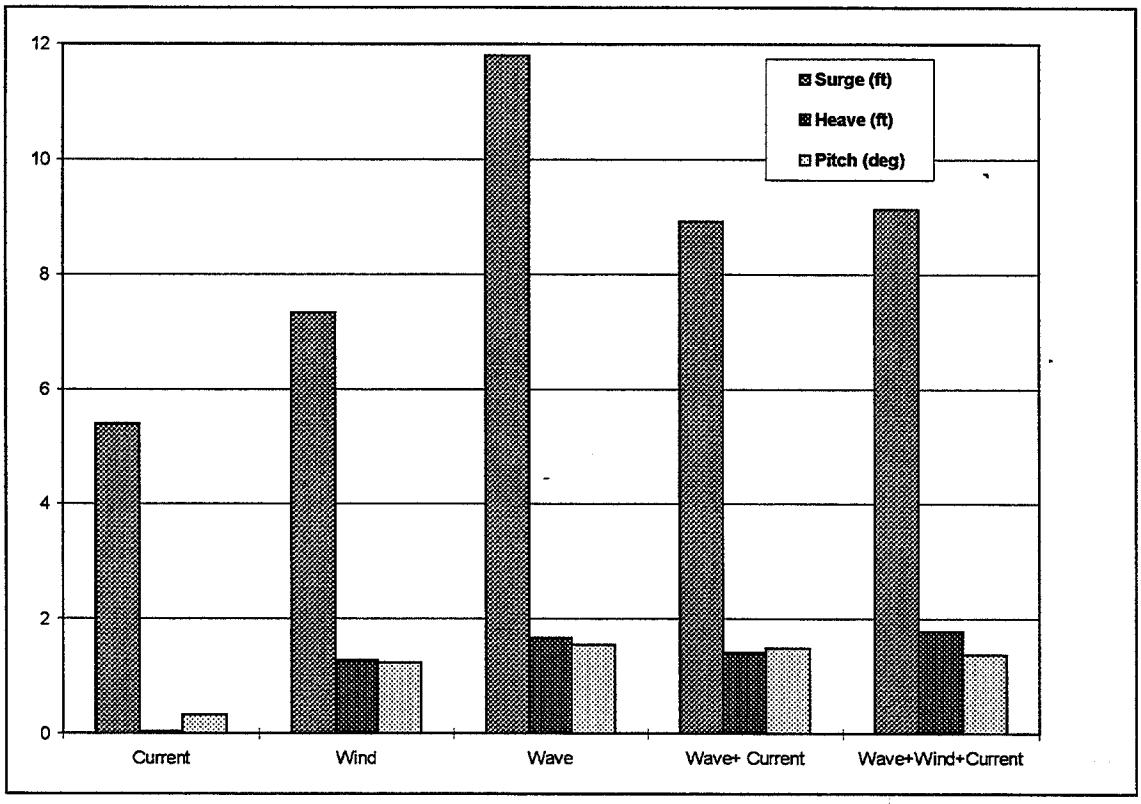

Figure 3-1 100 Year RMS Motions With Different Environmental Combinations

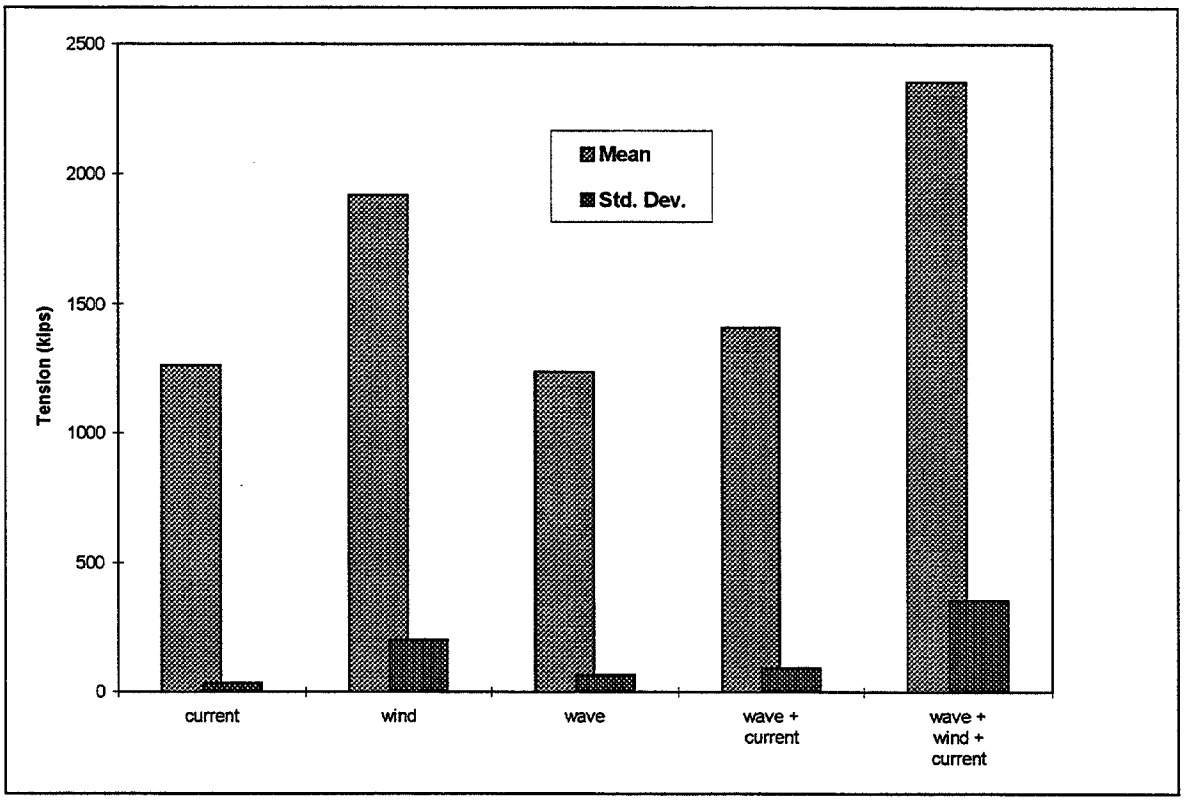

Figure 3-2 Mean and RMS Tensions For Various Environmental Combinations

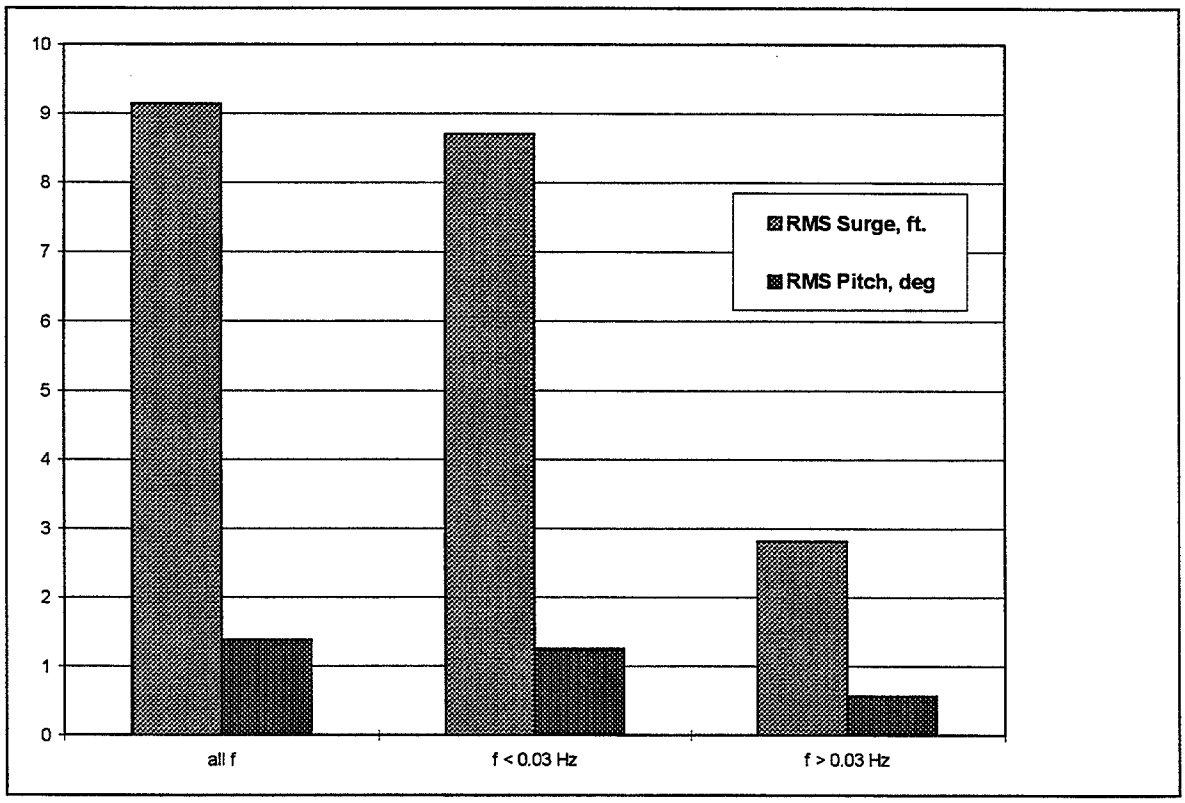

Figure 3-3 Filtered Responses, 100 Year Hurricane

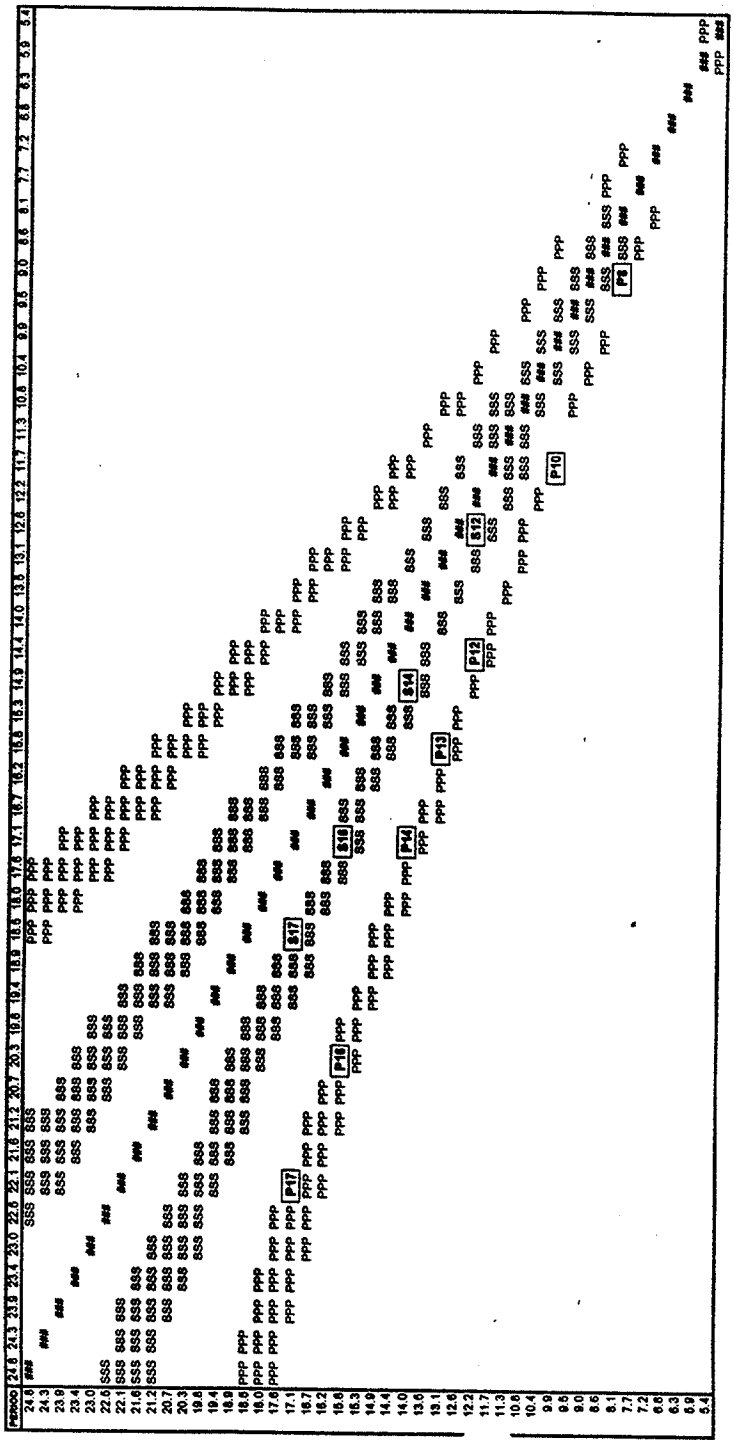

Figure 3-4 Matrix of Wave Period Combinations

4. Discussion

4.1. Numerical Simulations

Pre test simulations are summarized in Appendix C. Simulations were performed using the time domain program TDSIM6[1,2]. This program, written by Prof. J. R. Paulling, Jr., incorporates several important categories of non linear responses or excitations which may be encountered by the Spar:

- Non linear terms in the exact equations of motion,
- Nonlinear fluid forces,
- Mooring system effects,
- Current and wind effects,
- Nonlinear combinations of two or more of these

Fluid forces are modeled by a form of Morison's equation which accounts for interactions between waves, current and body motion. Steady and slow drift forces are based on Newman's approximation[3]. Drift forces are computed from a panel diffraction program, HYDRO3, also written by Paulling.

Pretest simulations were made with the following assumed hydrodynamic properties for the Spar:

Surge/Sway/Roll/Pitch Responses

---

[1] The theory of this program is summarized in Offshore Technology Conference paper 91-6701: Glanville, R.S., Paulling, J.R., Halkyard, J.E., and Lehtinen, T.J., "Analysis of the Spar Floating Drilling Production and Storage System",. (see Appendix E)

[2] J . R. Paulling and Y.S. Sin, "On the Simulation of Large-Amplitude Motions of Floating Ocean Structures," Proceedings, Symposium on Ocean Space Utilization, Nihon University, Tokyo, 1995 pp. 235 - 243.

[3] Newman, J.N., "Second Order Slowly Varying Forces on Vessels in Irregular Waves," International Symposium on Dynamics of Marine Vehicles and Structures in Waves, University College London, Pub. I. Mech. E., 1975.

Cd (drag coefficient)	1.0 based on the nominal Spar diameter
Cm (added mass coefficient)	1.0 based on the nominal Spar diameter

Heave Responses

- Cd = 1.0 applied to the area of the keel acting only when the heave velocity is downward,
- Cm: Added mass is equal to $1/\pi$*volume of a sphere with diameter equal to the Spar.

These values were derived from previous towing and free decay tests run on a spar with a similar aspect ratio.

Random waves were simulated using 50 discrete sinusoidal wave components with random phase angles. Frequencies were selected based on equal period spacing. Wind spectra were simulated using 50 sinusoidal components. The mooring system stiffness matrix was derived from the specified spring characteristics for the tests. Look-up tables were derived which were used by TDSIM6 to determine mooring forces. Figure 4-1 shows the restoring force and line tension characteristics of the mooring system. Three springs in series were used to simulate the 3000 ft. taut catenary mooring system described in Section 2.

Some simulation comparisons are also included here from the Oryx Spar tests as discussed previously[4]. In these simulations the mooring characteristics were adjusted to match the model mooring. This is particularly important when comparing offsets and mooring line tensions where a small difference in pre-tension or in the soft spring tie-off point can result in a large difference in offset.

For the Oryx Spar simulations, Cd is set at 1.4 which corresponds to the drag coefficient measured in towing tests for the Oryx Spar. The drag coefficient for the Oryx Spar is larger than the JIP Spar for two reasons:

[4] Deep Oil Technology, Inc., "Model Test Correlation Report - In Place Tests, Oryx VK826 - Neptune Project", Report issued May, 1995.

1. The aspect ratio[5] of the Oryx Spar is 18:1 compared to 9.8:1 for the JIP Spar. This corresponds to about 10% reduction in drag for the lower aspect ratio not considering VIV effects which are more pronounced for the higher aspect ratio.

2. The Oryx Spar has "blisters" running its full length on the edge perpendicular to the flow. These blisters cause flow separation at the 90 degree chord and render the helical strakes less effective in suppressing VIV.

4.2. Natural Periods and Damping

Table 4-1 and Table 4-2 show pre-test simulation results for the natural Periods and Damping for the Deep Draft Spar. Table 4-3 shows a similar comparison for the Oryx Spar.

Agreement is good except for the surge/sway periods which suggest that the added mass used in TDSIM6 may be too large, or that the mooring system as modeled is stiffer than that used in the simulations. The observed surge/sway periods of 330 and 309 seconds would suggest an added mass coefficient of .6 or less. However, spectral analysis of the random wave test (ARAN1- Vol. II, HRAN1 - Vol. XIX[6]) indicates a peak spectral period of 360 seconds. Time histories from these tests indicate a period of 340 seconds. Sarpkaya[7] reports a zero frequency added mass of 0.96 and 0.90 for cylinders with aspect ratios of 9.0 and 5.0, respectively. HYDRO3, on the other hand, computes added mass coefficients at 32 second periods (the highest period computed) of 1.08 and 1.09 for the 133 and 72 ft spar diameters, respectively.

The various surge periods, e.g. in calm water, in waves, in waves and current, are not surprisingly different considering the variation in Keulegan Carpenter number and reduced velocity which have a significant effect on the flow and aded mass characteristics. These results would suggest that an added mass coefficient of around

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[5] The aspect ratio for the Spar is normally defined to be 2*draft/diameter. The factor of 2 accounts for the free surface condition which acts like a rigid boundary, i.e. flow normal to the surface is zero. Hence the effective length of the spar is doubled.
[6] Vol. numbers refer to OTRC Test Report appndices.
[7] Sarpkaya, T and Isaacson, M., Mechanics of Wave Forces on Offshore Structures, Van Nostrand Reinhold, NY 1981, Table 2.3, p. 51

0.7 (without strakes) to 0.9 (with strakes) might be appropriate for Spars with aspect ratios similar to the C-Spar.

4.3. Tests in Current

Tables 4-4 shows comparisons for tests in current only:

CUR2 100 Year Surface Current (6.3 ft/sec at surface)
CUR3 100 Year Storm Current (4.4 ft/sec at surface)
CUR5 North Atlantic Storm Current (5.3 ft/sec at surface)

CUR2 represents the surface velocity for a 100 year loop current although the profile is steeper.

Results are shown for Configurations A, B and H. Apparent drag coefficients from the current only tests are shown in Table 4-5. The strakes result in the highest drag load in these tests. This is contrary to the results of towing tank tests. Figure 4-2 shows the results of drag coefficients determined from various towing tests on Spars and cylinders of finite aspect ratios, both fixed and oscillating and with and without strakes[8].

In these tests, the mean drag coefficient for a partially straked cylinder of an aspect ratio similar to the C-Spar, was measured between 0.8 and 1.1. The mean drag coefficient of the same spar without strakes varied from .8 to 1.55 depending on the reduced velocity.

[8] Data for the fixed cylinder was taken form a previous Joint Industry Program, "Vortex Induced Motions of Large Floating Structures", Deep Oil Technology, 1991. Other data for Spars was taken from towing tests conducted for various projects.

A Joint Industry Project was initiated by DOT to develop a math model for VIV of Spars with or without strakes. Predicted sway motion amplitudes based on this program, Modal Vortex Analysis (MVA), are shown below together with the corresponding measured amplitudes[9].

	Max. Reduced Velocity	Amplitude Computed	Amplitude Measured	Amplitude/ Diameter
ACUR3 - Bare Cylinder, 4.3 ft/sec surface current	10.0	13.0	15.3	.12
HCUR3 - Strakes, 4.3 ft/sec surface current	10.0	0.0	13.6	.10
ACUR2 - Bare Cylinder, 6.3 ft/sec surface current	14.6	4.3	21.4	.16

The maximum reduced velocities are based on calm water natural periods[10]:

$$Ur = \frac{\text{Velocity} * \text{Natural Period}}{\text{Diameter}}$$

Chung[11] shows the RMS amplitude/diameter ratio for a neutrally buoyant cylinder reaches a maximum at Ur ~ 10. Towing tank tests on Spars with a similar aspect ratio showed a peak amplitude/diameter ratio of about 0.4 at Ur=8[12].

MVA is predicting a lower amplitude for the higher current because a greater portion of the Spar is outside the range of lock-in, i.e. at a higher reduced velocity. This is consistent with towing tank test results.

The addition of strakes did not mitigate sway motion even though MVA and previous towing tests would suggest that they should.

Examination of the current measurements in the basin indicate that there is significant turbulence in both the surge and sway directions.

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[9] MVA was developed and verified in the above referenced Joint Industry Project.
[10] The reduced velocity is sometimes computed using the natural period in air instead of in water. Assuming an added mass coefficient of 1.0, the reduced velocity using the calm water period would be 1.414 times the reduced velocity using the "in air" period. Data presented here will use the calm water period.
[11] Chung, Tae-Young, "Vortex Induced Vibration of Flexible Cylinders in Sheared Currents", Ph. D. Dissertation, Massachusetts Institute of Technology, Ocean Engineering Department, May, 1987. Fig. 3.1, p. 27.
[12] Tests conducted for another project.

Current generated by the jets in the basin produce a level of turbulence which is apparently an order of magnitude greater than natural boundary layer currents in the ocean. Figure 4-3 shows a plot of the in-line current for the CUR1 tests.

An empirical current velocity spectrum for turbulence in the equilibrium range was fit to measured currents for HCUR2, HCUR3 and HCUR5 tests[13]. Plots are shown in Figure 4-4. The spectral curves are characterized by a parameter called the energy dissipation rate, ε, which is related to the variance in the turbulent velocity. Data for ε in ocean currents suggests values between .00004 and .003 cm**2/sec**2. The highest value tabulated in Ref. 13 is 1.0 for flow in a tidal channel. The corresponding values derived from the OTRC current measurements range from 5 to 400.

Another measure of turbulence is the turbulence intensity, or the Standard Deviation of the current speed divided by the mean speed. In these tests it is between 20 - 30% compared to values of about between 2 and 20% reported for ocean currents.

Of particular importance is the level of turbulence at the resonant period of the Spar, i.e. at around .003 Hz. Figure 4-5 shows the Spectrum for HCUR3 compared to the spectrum of a measured ocean current[14]. The level of energy in the basin at .003 Hz. is about ten times that of the ocean current. This is equivalent to about three times the turbulence intensity.

The magnitude of the transverse current and its effect is illustrated in Figure 4-6. The measured transverse current has been low pass filtered at .005 Hz. and plotted against sway motion. There appears to be a clear relationship between the current and the motion. If we consider a forcing function associated with a 0.5 ft/sec current as it appears from Figure 4-6, fluctuation at resonance, acting over 300 ft. of the hull, the peak force is about 10 kips. Using a mooring stiffness of 10 kips/ft and a damping ratio of 5% yields motion of 10 ft. This is about the magnitude of motions observed.

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[13] Notes prepared by Rick Mercier of Shell Development for the JIP review meeting of April 27, 1994, included as Appendix F in this report.
[14] Data provided by E. Huse, Marintek.

In order to draw a better comparison between test results and TDSIM6, the program was modified so that an unsteady current could be modeled. This was done in a similar manner to the modeling of the wind gust spectrum. Because of the limited amount of data on the spatial variability of the current, certain assumptions about the spanwise coherence had to be built into the model.

This model was applied to the Oryx data set. Table 4-6 shows the results for tests with current only.

The conclusion from the above is that VIV is probably not causing the sway motion and is not a factor in these tests. Towing tests with uniform current are obviously a worst case test for VIV and probably result in conservative values for drag. An experimental method for reasonably modeling shear current is not known. The semi empirical approach taken by MVA is the state of the art in this area, particularly with respect to capturing the effect of strakes. For design purposes towing tests, or tests in a flume, represent the most practical method to study VIV and its associated drag.

4.4. *Wave, Wind and Current Interactions*

An objective of this program was to examine the effect of wave, wind and current interactions. This objective was compromised by the turbulent current. Nevertheless, the following presents the observed results and conclusions.

Figures 4-7 through 4-14 show a comparison of responses for the 100 Year Gulf of Mexico Storm. Each response is given for the different environments tested:

Response	Test
Current Only	BCUR3 or HCUR3
Wind Only	BWIN3 or HWIN3
Wave Only	BRAN3 or HRAN3
Wave + Current	BRC3 or HRC3
Wave + Wind + Current	BRCW3 or HRCW3

Configuration B (without strakes) shows greater dynamic responses than Configuration H (with strakes) because of the lower damping. The TDSIM6 results tend to agree better with Configuration H.

Both mean and standard deviation values are shown, except that mean heave is omitted (it is very small).

From these figures it is evident that, in spite of the turbulence in the current, the current has a dampening effect on the motions in waves and wind. These effects appear well modeled by the simulations.

Table 4-7 shows statistical comparisons of Configurations B and H for tests with wind only and three different storm environments. The wind speed was Froude scaled and the model sail

area was adjusted to achieve the "design" steady offset for the 100 year Gulf of Mexico condition[15].

Table 4-7 shows good response predictions for the wind only cases. Surge responses are generally lower for Configuration H, presumably because of the added damping due to strakes.

Tables 4-8 to 4-10 show statistical comparisons of the results with waves only for all frequencies, high frequencies and low frequencies, respectively. The following observations regarding responses in waves only may be made:

- TDSIM6 underpredicts slowly varying surge for the 10 Year and North Atlantic Storm, but it predicts well for the 100 Year Storm. Its predictions are closer to Configuration H, which obviously has more viscous damping due to the strakes. Slow drift surge is 10 - 20% less with the strakes. The possible reasons for this are discussed in the following section.

- The same comment applies to slowly varying tension variations which are simply related to surge by way of the mooring springs.

- Heave and Pitch comparisons are good. Heave is slightly underpredicted for no strakes and slightly over predicted with strakes. The difference in heave for the 10 year storm is not significant since the measurement are in the noise level of the instrumentation. The same might be said for the surge measurements.

Comparisons for the ORYX test results which were based on post test simulations which matched the actual wave spectra yielded very good results (see below).

[15] The wind generators in the wave tank did not produce a uniform wind field in the upstream and downstream directions, hence modelling of the "true" topsides area would not produce the same force as would be measured in a wind tunnel, or as modelled in TDSIM. Adjusting the sail area to achieve the desired mean force at the nominal offset should produce comparable dynamic responses.

Statistical comparisons for waves, wind and current combined are shown in Tables 4-11, 4-12 and 4-13. The same general comments about the comparisons can be made as above. The presence of current provides considerable damping to the surge motions in spite of the turbulent excitation discussed above.

Table 4-14 shows the Standard Deviation of the Slow Drift surge response for Configuration A & H and the pre-test simulations. The following observations regarding prediction of slow drift may be made:

- **Wind only:** The GOM comparisons are good, the North Atlantic response for configuration A is much larger than predicted. Note the large damping effect of the strakes for the North Atlantic case.

- **Wave only:** Again the GOM comparisons are good and the North Atlantic not so good. Examination of the North Atlantic waves showed a non stationary character with the spectrum growing and widening as the test progressed[16]. As the spectrum broadened the 2nd order excitation would certainly increase which might explain the responses. Examination of the time history for ARAN5 surge response (Vol. II of the OTRC report) shows a regular slow drift response with amplitudes ranging from 12 to 25 ft, the larger amplitudes coming at the end of the tests. The 12 ft. amplitude (8.5 ft. standard deviation) is consistent with the predictions by TDSIM6.

- **Wave and Current:** The same comments as above apply. The GOM predictions are very good while those for the North Atlantic conditions are not as good. In all cases the addition of current reduced the response by about 30%.

- **Wave, Wind & Current:** Slow drift is least with wave, wind and current due in part to the damping effect of the wind, and also the reduced natural period, i.e. less 2nd order energy. For example, the slow drift period for test ARCW3 was 133.4 seconds versus 318 seconds for test ARAN3. The lower natural period is due to the stiffening of the mooring system with the greater mean offset. TDSIM6 simulations correlate well with the test results in this case.

In order to investigate the causes for the differences in the predicted and observed slow drift responses several variables were examined in TDSIM6. This investigation is discussed in the next section.

[16] See Report No. 6, April 10, 1994 for a discussion of this and a plot of the spectra windowed for different segments of the test.

4.5. Discussion of Modeling Related to Slow Drift Responses

The second order forcing function is given by (Pinkster[17]):

$$F^{(2)}(t) = \sum_{i=1}^{N}\sum_{j=1}^{N} \zeta_i^{(1)} \bullet \zeta_j^{(1)} \bullet P_{ij} \bullet \cos\{(\omega_i - \omega_j) \bullet t + (\varepsilon_i - \varepsilon_j)\} +$$
$$\sum_{i=1}^{N}\sum_{j=1}^{N} \zeta_i^{(1)} \bullet \zeta_j^{(1)} \bullet Q_{ij} \bullet \sin\{(\omega_i - \omega_j) \bullet t + (\varepsilon_i - \varepsilon_j)\}$$

Where the wave elevation is given as:

$$\zeta^{(1)}(t) = \sum_{i=1}^{N} \zeta_i^{(1)} \bullet \cos(\omega_i + \varepsilon_i)$$

P and Q are the quadratic transfer function in-phase and out of phase components, respectively.

In TDSIM6, this force is approximated by

$$F_s(t) = \sum_{i=1}^{N} \sum_{j=i+1}^{N} D_{kk} \zeta_i \zeta_j \cos[(\omega_i - \omega_j)t + (\varepsilon_i - \varepsilon_j)] \ .$$

Where,

D_{kk} = the mean drift coefficient for $\omega = .5*(\omega_i + \omega_j)$

The force at the natural frequency is thus related to the value $\sum\sum \zeta_i \cdot \zeta_j$ for values of i and j where $|\varpi_i - \varpi_j|$ is in the bandwidth of the natural frequency of interest, e.g. surge or pitch.

[17] Pinkster, J.A., "Low Frequency Second Order Wave Exciting Forces on Floating Structures", Delft University Ph. D. Dissertation, 1980

We take the bandwidth to be the half power bandwidth equal to:

$$2 \cdot \xi \cdot \omega_n$$

Where,

ξ =Critical Damping Ratio

ω_n =Natural Frequency (rad/sec)

For a numerical or physical simulation, the magnitude of the second order force is dependent upon the method of discretizing the wave spectrum, whether for numerical or physical simulations. Figures 4-15 - 4-18 show the tabulated values of $.5 \cdot \zeta_i \cdot \zeta_j$ as a function of the difference frequency in Hertz for two different methods of discretizing the waves in TDSIM6.

The wave spectrum corresponds to RAN5 tests:

Hs = 46 ft

Tp = 16.3 sec

Spectrum = Jonswap, γ = 2.0

The spectrum has been discretized by dividing the frequency range corresponding to periods of about 3 to 36 seconds into a number of frequency bands. In each case shown in Figures 4-15 to 4-18 the wave spectrum is divided into 60 intervals. The difference is in the method of selecting the central frequency of each interval.

In Figures 4-15 and 4-16, the frequencies were selected based on equal period spacing of the central frequencies. This insures an irregular grouping of difference frequencies in the 2nd order forcing function.

In Figure 4-17 and 4-18, the spectra was first divided into equal frequency divisions, then the central frequencies were adjusted randomly within the previous divisions. Thus a random division of frequency bands was achieved.

In Figures 4-15 to 4-18 the square symbols represent the value of $\zeta_i \cdot \zeta_j \cdot .5$ while the x's correspond to the bandwidth associated with a natural period of 330 seconds and ξ = .05, i.e. a bandwidth = .0003 Hz. The equal period discretization results in a more uniform distribution of 2nd order energy.

To compare these results with a continuous representation, the second order, or quad spectra were compared. Following Pinkster's formulation, the second order spectrum is defined as:

$$S2(\mu) = 8 \cdot \int_0^\infty S(f) \cdot S(f+\mu) df$$

The discrete quad spectrum is defined as

$$A2(f) = \frac{1}{\Delta f} \sum_i \sum_j .5 \cdot \left(\zeta_i \cdot \zeta_j\right)^2$$

Where the summation over i and j is limited to values where $\left|f_i - f_j\right| \le \frac{\Delta f}{2}$, and $\Delta f = 2 \cdot \xi \cdot f_n$. The frequency is expressed in Hertz to be consistent with the expressions for the spectra.

Variables studied include the bandwidth and the number of discrete wave components used. Each bandwidth corresponds to a different damping ratio corresponding to the surge or pitch period as indicated below.

Figure	No. Waves	Bandwidth	ξ (surge, Tn = 330 sec)	ξ (pitch, Tn = 75 sec)
4-19	60	.0004	.066	.015
4-20	60	.001	.165	.0375
4-21	120	.0004	.066	.015
4-22	120	.001	.165	.0375

Comparing Figures 4-19 and 4-21 indicates that, at a frequency of .003 Hz., discretization with 60 waves results in a Quad spectrum about 50% that of the continuos spectrum compared with 100% for 120 waves. A similar comparison is seen at a natural frequency of .0133 Hz (pitch). At .001 Hz. bandwidth the 60 wave case has a spectrum value about 75% of the continuous spectrum.

Examination of these results suggests that the variation in 2nd order responses, particularly surge, resulting from the method of discretizing the wave spectrum, could be on the order of +/- 50% or more (note that the response is related to the square root of the spectrum). This could explain differences in the pre-test simulation results (50 wave components) and the test results.

To check this theory several TDSIM6 runs were made with different wave discretizations. In addition, the drag coefficient was also varied from 1.0 to 0.0 to gage the importance of viscous effects in these simulations. It is well known that the value of Cd in unsteady flow is different than steady flow, hence there is a need to find a reasonable compromise Cd in numerical simulations when a single Cd is used for both cases.

Tables 4-15 to 4-17 show the results of these simulations along with the test results for configurations A, B, F and H.

From these tables the following observations may be made:

- TDSIM6 predicts mean surge values larger than those measured in the tests, although the absolute values are small. This could be due to a small difference in pretension resulting in a difference in mooring stiffness and is not considered significant.

- High frequency surge, pitch and tension responses are insensitive to any of the variations.

- Heave response is sensitive to the method of selecting frequencies. Responses are higher for the equal period spacing because the spar has low damping in heave and a narrow bandwidth. The equal period spacing yields a higher density of frequencies near the heave natural period. There is more excitation. This pertains to first order energy and is not related to the 2nd order forces discussed above.

- Low frequency surge is most sensitive to the variables addressed here.

- Viscous effects reduce low frequency response: Comparing ARAN5_1 to ARAN5_2 shows a 35% increase in the RMS low frequency response by reducing Cd to 0. comparing ARAN5_4 to ARAN5_6 shows a similar relationship with equal frequency spacing.

- More wave components reduce low frequency response: Comparing ARAN5_2 and ARAN5_3 (equal period spacing) shows that the low frequency surge is reduced by about 45% by increasing the number of wave components. Similar results are seen for cases with equal frequency spacing[18]

- Equal frequency spacing increased low frequency responses: Comparing ARAN5_1 and ARAN5_6 indicates a 21% increase in slow drift with Cd=1.0, and comparing ARAN5_2 and ARAN5_4 indicates a 29% increase for Cd=0.0. Examination of Figures 4-16 and 4-18 suggests that there may be frequencies where this would not be true, i.e. where equal period discretization would result in higher 2nd order forces. For example, consider the 2nd order energy in Figures 4-16 and 4-18 at f=.0038 Hz. (263 sec).

Overall the type of variations in slow drift surge responses predicted by the spectral results above are borne out by the TDSIM6 simulations.

The above suggests that numerical issues such as the number of waves and their method of discretization might outweigh theoretical considerations such as the validity of Newman's Approximation, for example. It also shows that viscous effects have equal importance. The issue remains as to the correlation of model tests with real ocean waves. Comparison of the quad spectra from real ocean storm waves with waves in model basins and in numerical simulations is required to verify either approach.

[18] Note that filtering was not carried out for runs ARAN5_4A and ARAN5_5A so the percentages do not relate exactly to the low frequency values comparing these cases.

4.6. ORYX Spar Response Comparisons

Table 4-18 shows a statistical comparison of the ORYX Spar responses to TDSIM6 post test simulations. Simulations with current were run with unsteady current in both the surge and sway directions, hence the sway motions have been simulated as well as surge.

Figure 4-23 and 4-24 show the spectra of the response for surge and line tension for waves only. The agreement is very good for both wave and slowly varying responses.

Figures 4-25 through 4-28 show a comparison for waves and current, and with waves, wind and current.

There is still slight underprediction of the low frequency responses with current, although as above the current tends to greatly dampen the slow drift response. The magnitudes of the responses are small.

4.7. Extreme Statistics

Extreme responses were determined from the tests by performing a zero-downcrossing analysis. The analysis consists of the following:

- Subtracting the mean value from the data,
- Tabulating peak values (maximum, minimum and/or trough to crest height) for each zero-upcrossing,
- Deriving probabilities associated with the peak values by ranking them in descending order and assigning a probability (of exceedance) value of (m-1/2)/N to the mth value where m is the rank (1 = largest value) and N is the total number of samples,
- Fitting a curve to the 20 highest peaks to describe the tail of the probability curve for purposes of extrapolation.

The Weibull curve yields a probability of exceedance equal to

$$\Pr(x > X) = \exp\left(-\left(\frac{X}{\alpha}\right)^{\beta}\right).$$

The parameters α and β define the characteristics of the curve from which various statistical values may be derived. The case for $\beta = 2.0$ and $\alpha = \sqrt{2} * \sigma$ corresponds to the Rayleigh distribution. σ is the standard deviation of the response.

The maximum value for N values is typically taken to be the value for which

$$\Pr(x>X) = 1/N, \text{ or}$$

$$X = \alpha * (\ln(N))^{\frac{1}{\beta}}$$

The value for N depends on the storm duration and the average period (Zero Crossing Period) of the response. For a Gulf of Mexico hurricane this usually is equal to three hours.

The maximum test duration was limited to 1-1/2 hours (full scale) because of the stability of waves generated in the basin. In order to derive statistics for a 3 hour duration, two different realizations of the 3 hour hurricane conditions were run. These realizations had the same statistical parameters (i.e. the same spectral makeup) but had different phase relationships to represent statistically independent events.

The zero-upcrossing results of these tests were combined to yield a larger population upon which to base extreme value probabilities.

For comparison, a three hour numerical simulation using TDSIM6 was run and a zero-upcrossing analysis of its results was also performed. The results for the wave/wind and current case (Tests HRCW3-4) are summarized in Table 4-19.

The corresponding Probability curves are shown in Figures 4-29 through 4-36. Two plots are included for each response: a linearly scaled plot and a log scaled plot. The log plot highlights the tail of the curves.

Surge at the CG and tension are close to an exponential distribution. Pitch and heave, being very narrow banded, are closest to the Rayleigh distribution. The distributions derived from TDSIM6 closely match the distributions derived from the tests except for surge. In this case the Standard Deviation for the tests is 30% higher than TDSIM6 (6.6 vs. 5.1) and the peak responses are correspondingly higher. This is due to the excitation from the turbulent current. Also, the Weibull fit of the test data might not accurately represent the tail of the distribution. From Figure 4-30 it appears that the last point (the maximum surge from the tests) is falling below the Weibull curve. If more data were available the slope of the curve might match the TDSIM6 curve more closely.

Interestingly, the distributions for tension variations are almost the same for the simulation and tests, even though the tension is primarily related to surge. The reason is the higher mean tension for the simulation which results in greater stiffness for the mooring system.

A problem with this discussion is that the Weibull curves are fit to the extremes from a single 3 hour simulation (or test). A better estimate of extremes would require statistics for the maximum value from several 3 hour simulations or tests. This would allow determination of the risks of the maximum from one event exceeding a specified maximum design value.

While multiple 3 hour simulations have not been for this project, the results for another project are shown in the following table.

	95% Confidence Interval (single sample)
Surge	1.0%
Heave	29.3%
Sway	1.3%
Pitch	12.3%
Tension	5.7%

Thus, a single 3 hour simulation might be expected to yield, for example, a maximum value that is within +/- 1% of the expected surge maximum and 29.3% of the expected heave maximum. These results are based on analysis of six - three hour simulations.

Multiple 3 hour tests w ould need to be run to verify these statistics experimentally. The current test program, by confirming the general Weibull distribution of the simulations, would suggest that these are reasonable values.

Examining the Weibull plots, especially the log scale plots, suggests that an estimate of the extreme value based on the Weibull curve fit generally is higher than the actual maximum for the test. Using the Weibull formula to estimate the extreme would thus be conservative.

4.8. Tests With Risers

Table 4-20 and Table 4-21 show the effects of risers on Spar motions for wave only cases and full environmental cases, respectively. The effects are generally not significant except for the reduction in heave response and to a lesser degree pitch response. Risers reduce the responses by approximately:

Dynamic Heave:	50%
Slowly Varying Pitch:	25%
Maximum Pitch:	15%

The reduction in heave is a result of friction between the riser and its guides, plus hydraulic damping caused by constricted centerwell water flow around the guides. The damping force gives rise to tension variations in the risers. Since the risers are protected from wave and current force, these tension variations are the primary fatigue factor in the selection of

couplings for the riser[19]. Figure 4-37 shows the relation between the RMS tension and significant wave height. Fatigue studies have shown these loads to be relatively benign.

[19] This applies to the majority of the riser. Local bending effects control fatigue in the vicintiy of the keel and the mudline.

4.9. Centerwell Water Motion

Centerwell water motions were measured on the centerline for tests without risers. Figure 4-38 shows the relative motion during the free decay heave test. Figure 4-39 shows the motion during the 100 Year North Atlantic Storm.

The plots include motions of the Spar and the moonpool relative to the earth, along with the motion of the water outside the spar. In the free decay test the centerwell lags the heave motion of the spar for about 1/2 cycle but then becomes tightly coupled. For the storm case the centerwell motion is almost identical to that of the Spar, i.e. there is no relative motion.

A simplified dynamic model for the interaction of the centerwell water, the hull and the riser is illustrated in Figure 4-40. The centerwell water is in effect another Spar floating within the spar. Its mass is represented by M2, its waterplane stiffness is represented by K2 and the energy dissipated by passing around the buoyancy cans (which are attached to the earth) is represented by C2.

Coupling between the centerwell water and the hull is represented by Cx. This is due to the force on the guides as the centerwell water flows past them. Note if there is no relative motion there is no flow past the guides.

There are some interesting limiting cases. If the buoyancy cans were sealed (i.e. serving as pistons) a large damping force would be introduced proportional to the opening at the guide plates. This would be equivalent to a dashpot. Typical dashpots used as shock absorbers have orifices equal to 2 - 5% of the cylinder area. In these tests the orifice opening of the upper guide plates is 25% of the centerwell opening, hence the damping effect might be expected to be small.

If the guide plates also sealed the buoyancy can sleeves, then the spar hull would be hydraulically locked. The risers would behave like tendons.

Several cases representing different amounts of damping have been run:

	C1	C2	Cx	Comment
Figure 4-41	Moderate	Moderate	Very Low	No Guide Plates
Figure 4-42	Moderate	High	Very High	Risers and Large Guide Plates
Figure 4-43	Low	Moderate	Moderate	No Strakes (low hull damping)
Figure 4-44	Moderate	High	Low	Buoyancy Cans Somewhat Restrictive

The figures plot the ratio of centerwell motion to spar motion for two force models:

1) Force acting on spar and centerwell in phase, i.e. wave energy,

2) Force acting on spar only, i.e. free decay tests

The first case (Figure 4-41) has almost no coupling between the centerwell water and the spar (Cx very low). During free decay tests there is no force acting on the centerwell so its motion is nil compared to the Spar. This is not consistent with our observations, hence there is obviously some coupling between the centerwell and the hull.

When a force acts on both bodies, as in the case of wave pressure acting on the bottom of both, the centerwell moves in unison with the Spar. This is consistent with our observations.

Figure 4-42 shows the case with riser and guide plates, both with small clearances, i.e. the centerwell is hydraulically coupled to both the Spar hull and the earth. In this case, at resonance the centerwell is almost in unison with the hull motions. In waves the centerwell also moves with the hull.

In Figure 4-43, the damping ratios have been reduced all around. The spar is lightly damped but the centerwell water is moderately damped due to the constrictions of the buoyancy cans. During free decay action, for example, the centerwell model moves about half as much as the spar. This seems consistent with observations made in the basin.

Figure 4-44 is the same as Figure 4-42 except that the value for Cx is reduced, i.e. low coupling through the guide plates. There is still a dashpot effect from the buoyancy cans (C2) even though Cx is reduced somewhat (though still significant).

These results allow us to explain in a qualitative way the behavior of the water in the centerwell. To utilize this model quantiatively requires calculation of the pressure drops and associated damping through the centerwell openings. This would require empirical data on the pressure drops.

From a design standpoint, the important considerations include:

- Is there any instability or resonance which could cause flooding in the well bay?
- Do the risers experience extra loadings which could lead to fatigue or strength problems?
- Are there extraordinary hydraulic loads on the guides?

The deep draft results in a natural period for the centerwell water about the same as the spar, 28 seconds. This is beyond the range of wave action and, like the spar, we see no large resonant oscillations. In fact the centerwell water heave motion is virtually the same as the spar. Interestingly, model tests have recently been run on other spar designs with shallower draft hulls, on the order of 200 ft, and large oscillations in the centerwell were observed in that case. The resonant period was about 13 seconds.

Some analysis was performed on model test results for another spar with risers and it was concluded that the axial loadings on the risers are indeed greater than would be predicted on the basis of friction at the guides alone. Motion of the centerwell water produces a force on the buoyancy cans which is related to the pressure drop as the water flows past them. This is minimized by keeping the blockage of the buoyancy cans low. In these tests the blockage of the cans was 62%. For comparison, dashpots typically are designed with orifice openings about 5% or less of the cylinder, i.e. a blockage of 95%. The largest blockage conceivable for the buoyancy cans would be 79%, i.e. the cans would be touching the edge of the guide. In this case the flow past the cans would reach a velocity five times that of the heave velocity which is a maximum of about 2 ft/sec in a 100 year storm. The resulting flow would be 10

ft/sec around the cans. This should be taken into account in the guide design but does not present any problem. For example, the load on a 12" Flange attached to buoyancy can, would be on the order of 200 lb/ft. The total load on a 10 ft. buoyancy can could be 6,000 lbs out of a buoyancy, typically, of more than 150,000 lbs.

This load would be reduced by the square of the blockage factor.

Fatigue loadings on the risers from these tests and the Oryx tests have been found to be relatively benign even with the added loads due to centerwell water motion.

4.10. Deck Accelerations

Deck acceleration is an important design parameter for both operational and survival conditions. Figure 4-45 shows computed and measured deck accelerations for a Spar, Tension Leg Platform and a Six Column Semi. Values were computed using the frequncy domain program SPLASHT. Only first order responses were included. Horizontal accelerations include the component of gravity along the deck. Details of the computations are included in Appendix E.

Accelerations from the Oryx tests were used as they were not measured directly on the JIP tests. The plotted values are RMS values.

Calculated horizontal accelerations for the Spar are 50 - 100% lower than those of the TLP for wave heights less than around 15 ft. Under the 100 year hurricane conditions (Hs = 40 ft) the Spar accelerations are about 12% higher than the TLP and about 80% higher than the semi.

The reason for the semi's lower accelerations in the survival condition appears to be associated with the phase relationship between surge and pitch. In the case of the semi these

motions are 180 deg out of phase, while for the Spar they are in phase. Thus the gravitational effect is additive for the Spar.

Vertical accelerations are shown in Figure 4-46. In this case the TLP and Spar accelerations are almost nil while the Semi reaches an RMS value of .7 ft/sec/sec (.02 g).

4.11. Observations From Spar Float-On Deck Tests

The float-on deck and partially submerged spar were tested separately as configurations N and O, respectively. Mating tests were designated Configuration P.

The spar hull was very stable and steady when ballasted down to 10 ft. of freeboard on the two 25 ft. square sponsons. The natural periods were:

Heave: 57 sec, $\xi = .06$
Roll/Pitch: 49 sec, $\xi = .015$

Measured RMS motions are shown below. These are primarily slow-drift responses.

	Hs = 4 (shortcrested) Tp = 7.7 sec	Hs = 8 (Long Crested) Tp = 7.7 sec	Hs = 8 (Short Crested) Tp = 7.7 sec
Surge, ft	1.00	2.09	2.45
Sway, ft	0.20	0.18	0.56
Heave, ft	0.30	0.79	0.68
Roll, deg	.02	.02	.04
Pitch, deg	.04	.12	.09

No heave motions or pitch motions were perceptible in any of the sea states tested.

The float-on deck was also very stable but did exhibit some motions in the highest sea state tested.

The natural periods were:

Heave: 6.0 sec, $\xi = .05$
Roll: 8.0 sec, $\xi = .14$
Pitch: 8.5 sec, $\xi = .17$

	Hs = 4 (shortcrested) Tp = 7.7 sec	Hs = 8 (Long Crested) Tp = 7.7 sec	Hs = 8 (Short Crested) Tp = 7.7 sec
Surge, ft	4.9 (0.5)*	17.7 (2.0)	14.7 (2.4)
Sway, ft	1.1 (.2)	1.12 (.3)	2.94 (0.3)
Heave, ft	0.4	0.72	.68
Roll, deg	.2	.2	.3
Pitch, deg	.2	.4	.4

* - Surge & sway are predominantly slow drift due to soft mooring. Numbers in parenthesis are approximate wave frequency RMS values estimated from time histories (Vol. XXVIII of OTRC Test Report).

The rigging between the spar and the deck worked exceptionally well. The rigging consisted of four individual lines connected from winches on the deck to padeyes on the spar. Two of the lines were used mainly for pulling and two were used mainly for steering. Each pair of lines were crossed to provide added length and thus flexibility.

The winches were operated by remote control from a platform suspended above the spar hull. Untrained operators were used to operate the winches. The docking operation was successful every time it was tried. None of the sea states tested were limiting to the operation.

There was never a case of Impacting the bow of the deck with a sponson. The sponson engaged the slot in the deck perfectly every single time. The reasons for this were:

a) the steering winches made maneuvering of the deck very easy,

b) the spar hull did not move relative to the deck

There was never any impact between the underside of the deck and the top of the spar at a clearance of 4 ft. except in the highest sea state tested.

No winch lines were ever broken in any of the tests nor were any docking attempts unsuccessful.

The operation was much like docking a boat in a slip. There was plenty of clearance between the slot and the sponsons and there was very little contact between the bumpers on the sides of the sponsons and the sides of the slot.

Final positioning was accomplished with the winches after the sponsons were fully engaged in the slot.

Configuration	Surge		Sway		Heave	
	Period	Damping	Period	Damping	Period	Damping
	sec	%	sec	%	sec	%
TDSIM6	368.8	9.7	368.8	9.7	28.5	.3
A	331.9	5.3	309.0	9.1	29.0	0.5
B	291.4	2.7			29.0	0.5
C	36.9	0.4			28.6	0.6
D			166.4	1.5	28.5	0.8
F	326.6	3.0	327.6	3.6	29.3	2.3
F1	326.0	5.6	336.0	4.2	29.6	2.8
H	336.6	3.6	345.8	5.3	29.2	0.9

Table 4-1 Comparison of Natural Period and Damping, Motions

Configuration	Roll		Pitch		Yaw	
	Period	Damping	Period	Damping	Period	Damping
	sec	%	sec	%	sec	%
TDSIM6	72.1	2.6	72.1	2.6	78.0	0.1
A	66.9	1.1	66.8	0.9	57.8	2.3
B			67.8	1.0		
C			30.5	0.8		
D	64.3	1.1				
F	60.7	2.5	61.0	2.5	57.6	2.6
F1	61.2	3.1	61.4	2.9	59.8	5.7
H	66.1	1.6	66.0	1.5		

Table 4-2 Comparison of Natural Periods and Motions, Rotations

	TDSIM		TESTS					
	TDSIM - Config E		Configuration E		Configuration F		Configuration G	
	All Mooring Lines				Broken Line		All Lines & Risers	
	Nat. Per.	Damping	Nat. Per.	Damping	Nat. Per.	Damping	Nat. Per.	Damping
Surge	331.0	5.34%	323.33	6.56%	284.16	4.65%	283.00	9.34%
Sway	331.0	5.39%	299.06	8.96%	301.89	10.30%	251.60	7.55%
Heave	28.0	0.49%	28.41	1.98%	28.58	2.18%	29.12	9.61%
Roll	85.0	1.60%	85.86	4.88%	84.45	6.98%	65.27	4.80%
Pitch	85.0	1.10%	83.46	3.95%	85.00	5.60%	67.01	3.87%
Yaw	60.0	0.00%	99.42	11.26%	65.69	11.36%		

Table 4-3 Comparison of Natural Periods and Damping, Oryx Spar Tests

		acur2	bcur2	hcur2	TDSIM	acur3	bcur3	hcur3	TDSIM	acur5	bcur5	hcur5	bcur5
		all f	all f	all f	all f	all f	all f	all f	all f	all f	all f	all f	all f
WIND	Mean												
Knots	Std. Dev.												
	Max												
	Min												
SURGE_CG	Mean	-38.55	-36.89	-58.25	-49.14	-20.85	-18.1	-37.52	-28.61	-29	-27.59	-49.68	-44.44
Ft	Std. Dev.	7.32	6.92	6.72	0.21	5.67	5.4	4.65	0.04	7.68	6.65	3.47	0.24
	Max	-20.33	-17.72	-37.59	-48.86	-7.41	-4.77	-26.07	-28.21	-10.23	-12.17	-37.7	-44.04
	Min	-56.92	-50.84	-72.18	-49.61	-37.66	-33.33	-48.71	-28.8	-44.43	-45.43	-62.2	-45.3
HEAVE_CG	Mean	-0.03	-0.15	-0.28	-0.04	-0.02	-0.02	0.15	0.01	-0.13	-0.07	-0.01	0.01
Ft	Std. Dev.	0.31	0.04	0.19	0.05	0.07	0.04	0.06	0.41	0.13	0.06	0.1	0.17
	Max	1.35	0.06	0.45	0.05	0.24	0.25	0.39	0.79	0.49	0.12	0.27	0.33
	Min	-1.16	-0.31	-0.88	-0.13	-0.21	-0.17	-0.07	-0.78	-0.56	-0.29	-0.46	-0.31
SWAY_CG	Mean	-0.33	0.44	-18.17		3.47	-0.07	-10.87		-5.04	0.67	-18.57	
Ft	Std. Dev.	15.12	0.31	16.45		10.76	0.15	9.6		20.75	0.22	13.25	
	Max	33.58	1.33	19.17		27.21	0.46	13.04		50.81	1.33	10.62	
	Min	-39.12	-1.25	-60.78		-24.24	-0.58	-46.59		-49.27	-0.99	-47.08	
ROLL	Mean	0.01	0.08	0.19		0.01	0	0.11		0.06	0.09	0.17	
deg	Std. Dev.	1.16	0.12	0.51		0.32	0.05	0.23		0.57	0.08	0.27	
	Max	2.84	0.41	1.83		0.88	0.16	0.8		2.02	0.31	0.93	
	Min	-3.13	-0.3	-1.44		-0.77	-0.16	-0.43		-1.76	-0.15	-0.55	
YAW	Mean	-0.06	0.33	1.3		-0.15	-0.11	0.51		-0.19	-0.22	0.77	
deg	Std. Dev.	0.48	0.25	0.73		0.21	0.07	0.35		0.39	0.13	0.37	
	Max	1.37	1.21	3.49		0.4	0.12	1.44		1.19	0.22	1.89	
	Min	-1.43	-0.57	-0.75		-0.75	-0.64	-0.93		-1.4	-0.73	-0.38	
PITCH	Mean	-0.42	-0.46	-0.75	-0.74	-0.24	-0.22	-0.4	-0.37	-0.34	-0.29	-0.57	-0.59
deg	Std. Dev.	0.44	0.22	0.23	0	0.29	0.32	0.14	0.03	0.41	0.41	0.14	0.01
	Max	0.75	0.05	-0.04	-0.72	0.39	0.43	-0.03	-0.15	0.54	0.64	-0.17	-0.53
	Min	-1.9	-1.11	-1.51	-0.75	-0.82	-0.85	-0.76	-0.55	-1.14	-1.23	-0.98	-0.62
TENS-1	Mean	1433	1387	1809	1518.01	1249	1261	1353	1303.52	1298	1315	1553	1399.49
Kips	Std. Dev.	107.2	52.45	177.4	2.58	35.26	32.79	47.3	3.77	50.97	42.71	83.22	1.34
	Max	1806	1548	2187	1529	1362	1359	1528	1308	1419	1437	1885	1416
	Min	1271	1259	1378	1509	1168	1185	1274	1299	1183	1225	1352	1391

Table 4-4 Comparisons for Current Only Tests, All Frequencies, Configuration B & H

TEST	OFFSET	FORCE	Apparent Cd
	ft.	kips	
ACUR2	38.6	408.6	0.68
ACUR3	20.9	221.0	0.70
ACUR5	29.0	307.4	0.63
BCUR2	36.9	405.9	0.67
BCUR3	18.1	199.1	0.63
BCUR5	27.6	303.6	0.62
HCUR2	58.3	869.1	1.44
HCUR3	37.5	397.7	1.25
HCUR4	49.7	615.3	1.26

Table 4-5 Drag Coefficients Inferred from Current Only Tests

		CONFIG E - ALL MOORING LINES INTACT															
		e2cur1		e2rc1						e2rcw1							
		all f		all f		f < 0.03 Hz		f > 0.03 Hz		all f		f < 0.03 Hz		f > 0.03 Hz			
		TDSIM	Tests	TDSIM	Tests	TDSIM	Tests	TDSIM	Tests	TDSIM	Tests	TDSIM	Tests	TDSIM	Tests		
WAVE	H1/3	0	0.10	39.44	38.90	0.00	1.20	0.00	38.90	39.68	38.20	0.00	1.20	0.00	38.10		
Ft	Std. Dev.	0	0.03	9.86	9.74	0.00	0.31	0.00	9.73	9.92	9.55	0.00	0.29	0.00	9.54		
	Max	0	0.04	36.33	44.32	0.00	2.62	0.00	41.53	38.94	42.48	0.00	1.36	0.00	41.00		
	Min	0	-0.16	-36.84	-31.93	0.00	-1.05	0.00	-34.24	-31.81	-30.36	0.00	-1.13	0.00	-31.92		
WIND	Mean	0	0.00	0	0.00	0.00	0.00	0.00	0.00	78.16	86.86	0.00	0.00	0.00	0.00		
Knots	Std. Dev.	0	0.00	0	0.00	0.00	0.00	0.00	0.00	10.73	15.91	5.51	0.00	9.20	0.00		
	Max	0	0.00	0	0.00	0.00	0.00	0.00	0.00	122.94	140.24	15.24	0.00	30.80	0.00		
	Min	0	0.00	0	0.00	0.00	0.00	0.00	0.00	37.67	26.56	-19.81	0.00	-33.32	0.00		
SURGE	Mean	-43.07	-40.94	-55.8	-53.91	0.00	0.00	0.00	0.00	-68.99	-68.94	0.00	0.00	0.00	0.00		
Ft	Std. Dev.	4.87	3.37	3.86	5.60	3.32	5.18	1.97	2.13	2.68	3.02	1.79	2.09	1.99	2.18		
	Max	-33.4	-34.67	-44.92	-30.36	8.57	19.94	6.28	7.72	-62.36	-57.14	4.35	9.08	7.25	8.40		
	Min	-50.98	-49.34	-66.25	-67.80	-6.78	-9.62	-6.55	-6.75	-78.92	-80.60	-6.00	-5.80	-6.73	-8.37		
HEAVE	Mean	0.02	-0.19	0.04	0.00	0.00	0.00	0.00	0.00	-0.25	-0.97	0.00	0.00	0.00	0.00		
Ft	Std. Dev.	0.04	0.08	0.41	0.74	0.18	0.70	0.36	0.25	0.83	0.90	0.35	0.75	0.75	0.50		
	Max	0.12	0.07	1.63	2.76	0.73	2.52	0.93	0.95	2.63	2.35	0.85	2.31	2.49	2.13		
	Min	-0.08	-0.43	-1.21	-2.58	-0.35	-2.45	-1.12	-1.07	-2.63	-4.37	-0.78	-2.41	-2.18	-2.16		
SWAY	Mean	7.45	7.15	-5.49	8.38	0.00	0.00	0.00	0.00	7.41	11.92	0.00	0.00	0.00	0.00		
Ft	Std. Dev.	6.21	5.32	5.99	9.22	5.99	9.22	0.13	0.34	3.71	6.75	3.70	6.71	0.19	0.73		
	Max	19.38	24.76	9.37	31.68	14.86	23.27	1.76	1.45	15.88	31.60	8.46	19.22	2.89	8.46		
	Min	-6.01	-6.66	-17.7	-14.07	-12.19	-22.24	-2.20	-1.75	-0.66	-9.75	-8.09	-19.69	-2.65	-11.20		
ROLL	Mean	-0.18	-0.22	-0.22	-0.04	0.00	0.00	0.00	0.00	-0.32	0.20	0.00	0.00	0.00	0.00		
deg	Std. Dev.	0.33	0.43	0.31	0.43	0.31	0.43	0.03	0.05	0.51	0.56	0.50	0.56	0.08	0.08		
	Max	0.51	0.77	0.57	1.20	0.79	1.20	0.28	0.61	0.94	2.37	1.31	2.10	0.32	0.51		
	Min	-0.95	-1.28	-1.04	-1.25	-0.77	-1.18	-0.24	-0.59	-2.36	-1.94	-1.53	-2.11	-0.53	-0.46		
YAW	Mean	-0.88	-3.05	-1.71	-3.70	0.00	0.00	0.00	0.00	-5.24	-8.20	0.00	0.00	0.00	0.00		
deg	Std. Dev.	0.43	0.73	1.01	1.61	1.01	1.43	0.11	0.73	3.97	1.80	3.97	1.64	0.21	0.75		
	Max	0.15	-1.28	0.7	0.95	2.45	3.58	1.69	2.93	3.1	-1.56	8.49	6.07	0.67	3.13		
	Min	-1.96	-4.84	-4.74	-9.50	-2.94	-5.01	-1.45	-3.01	-13.79	-14.19	-8.25	-5.08	-1.61	-3.15		
PITCH	Mean	-1.01	-0.80	-1.67	-1.22	0.00	0.00	0.00	0.00	-5.31	-4.45	0.00	0.00	0.00	0.00		
deg	Std. Dev.	0.21	0.18	0.92	0.94	0.75	0.70	0.52	0.63	1.16	1.29	1.03	1.13	0.53	0.62		
	Max	-0.47	-0.25	1.3	2.28	2.15	2.52	1.72	2.37	-2.44	-0.03	2.35	3.99	1.99	2.62		
	Min	-1.51	-1.22	-4.93	-4.55	-2.34	-2.45	-1.90	-2.10	-9.45	-10.08	-3.09	-3.96	-2.00	-2.41		
TENS-1	Mean	172.48	164.30	156.76	147.30	0.00	0.00	0.00	0.00	142.3	129.60	0.00	-0.01	0.00	0.00		
Kips	Std. Dev.	7.01	5.30	5.25	7.70	4.39	7.20	2.87	2.67	4.53	4.97	3.19	4.25	3.21	2.50		
	Max	187.42	177.80	171.52	173.30	10.83	23.13	9.63	9.78	154.86	150.00	5.73	14.35	12.08	10.16		
	Min	161.6	148.50	145.19	126.00	-8.79	-15.71	-10.54	-9.24	124.81	110.90	-12.32	-12.06	-12.15	-10.29		
TENS-2	Mean	199.79	193.90	186.83	182.50	0.00	0.00	0.00	0.00	161.88	166.60	0.00	0.00	0.00	0.00		
Kips	Std. Dev.	6.9	6.04	7.61	10.63	7.36	10.46	1.95	1.81	4.9	7.44	4.31	7.23	2.33	1.65		
	Max	213.78	212.60	203.87	211.20	14.52	26.25	6.62	7.25	177.04	192.10	11.47	22.26	9.02	16.54		
	Min	181.95	173.80	167.06	157.70	-17.03	-21.70	-7.19	-6.40	148.99	142.20	-10.13	-21.74	-8.88	-9.55		
TENS-3	Mean	261.47	252.10	265.59	258.60	0.00	0.00	0.00	0.00	257.54	263.30	0.00	0.00	0.00	0.00		
Kips	Std. Dev.	9.09	7.36	7.78	12.36	7.66	12.16	1.38	2.12	5.6	9.64	5.33	9.26	1.73	2.61		
	Max	276.98	271.80	282.53	294.00	16.16	31.68	4.52	7.87	274.31	295.50	16.08	26.10	5.20	10.94		
	Min	243.17	227.30	242.69	221.90	-21.02	-34.12	-4.19	-9.11	244.38	229.60	-12.02	-31.24	-5.63	-11.14		
TENS-4	Mean	297.41	296.30	375.37	354.50	0.00	0.00	0.00	0.00	829.8	856.00	0.00	-0.01	0.00	0.00		
Kips	Std. Dev.	10.55	6.10	67.61	83.43	46.49	56.17	49.09	61.69	202.57	229.00	142.04	142.80	144.43	178.90		
	Max	320.64	315.50	754.98	925.00	144.16	231.30	254.38	371.20	1646.3	1817.00	564.89	549.10	443.62	646.80		
	Min	279.16	280.90	298.35	282.30	-77.23	-65.74	-146.72	-244.10	409.29	315.50	-246.41	-469.30	-508.01	-598.10		
TENS-5	Mean	270.68	266.50	286.94	291.30	0.00	0.00	0.00	0.00	428.33	437.40	0.00	0.00	0.00	0.00		
Kips	Std. Dev.	7.06	7.59	8.26	38.99	7.70	33.86	2.99	19.34	91.54	175.30	71.71	150.40	56.89	89.98		
	Max	288.46	289.90	335.54	627.40	25.82	216.20	27.05	179.10	913.35	1427.00	240.60	758.20	265.88	407.80		
	Min	257.17	241.30	269.98	245.90	-14.64	-42.69	-13.31	-117.40	300.37	270.90	-122.62	-186.70	-242.35	-429.00		
TENS-6	Mean	209.18	200.70	209.11	198.40	0.00	0.00	0.00	0.00	223.56	196.20	0.00	0.00	0.00	0.00		
Kips	Std. Dev.	8.73	7.87	8.13	13.47	8.08	13.45	0.92	0.71	5.63	10.17	5.42	10.12	1.53	0.92		
	Max	227.77	227.40	230.53	235.20	20.71	36.71	3.27	3.38	237.81	228.50	11.88	31.48	6.66	12.72		
	Min	193.49	180.70	192.02	165.80	-16.56	-31.47	-4.23	-2.68	207.85	166.90	-14.71	-28.83	-6.56	-13.60		

Table 4-6 Comparison Using TDSIM6 with Unsteady Current (Table ETC1)

		Wind Only								
		bwin2	hwin2	TDSIM	bwin3	hwin3	TDSIM	bwin5	hwin5	TDSIM
Wave	H1/3	0.34	0.64		0.45	1.62		0.68	1.02	
Ft	Std. Dev.	0.09	0.16		0.11	0.4		0.17	0.26	
	Max	0.54	0.57		0.37	0.26		0.37	0.28	
	Min	-0.2	-0.53		-2.05	-2.79		-1.29	-1.58	
WIND	Mean	34.27	42.09		67.34	82.31		48.2	58.67	
Knots	Std. Dev.	3.62	4.69		7.81	8.75		5.68	6.28	
	Max	48.53	55.99		97.4	113.02		70.47	80.53	
	Min	24	27.72		44.93	54.12		33.01	37.94	
SURGE_CG	Mean	-21.59	-21.22	-26.73	-60.52	-57.8	-65.12	-40.35	-38.17	-43.69
Ft	Std. Dev.	7.61	6.6	7.72	7.34	7.76	9.87	11.8	9.1	8.5
	Max	-2.06	-5.02	-14.17	-40.75	-38.33	-45.32	-10.76	-14.49	-25.15
	Min	-38.66	-36.55	-43.14	-76.43	-74.19	-86.49	-65.1	-61.1	-59.96
HEAVE_CG	Mean	0.03	0.09	0.04	0.6	0.48	0.18	0.35	0.19	0.06
Ft	Std. Dev.	0.39	0.39	0.09	1.28	1.21	0.83	0.55	0.78	0.24
	Max	1.02	1.03	0.32	3.84	4.05	2.93	1.99	2.26	0.68
	Min	-0.95	-0.94	-0.16	-2.45	-2.57	-1.7	-1.39	-1.81	-0.53
SWAY_CG	Mean	0.48	0.47		1.28	3.29		0.75	1.06	
Ft	Std. Dev.	0.15	0.4		0.46	1.47		0.29	0.73	
	Max	0.98	1.47		2.78	7.1		1.76	3.04	
	Min	-0.8	-0.56		-0.67	-0.46		-0.9	-0.87	
ROLL	Mean	0.03	0.01		0.14	0.03		0.06	0.01	
deg	Std. Dev.	0.03	0.13		0.07	0.81		0.04	0.25	
	Max	0.11	0.33		0.43	1.74		0.19	0.64	
	Min	-0.05	-0.3		-0.09	-1.69		-0.08	-0.63	
YAW	Mean	-0.07	-0.6		-1.3	-1.6		-0.61	-0.9	
deg	Std. Dev.	0.37	0.33		0.75	1.2		0.63	0.49	
	Max	0.89	0.46		1.1	1.84		1.39	0.51	
	Min	-1.38	-1.62		-3.49	-4.89		-2.57	-2.2	
PITCH	Mean	-0.55	-0.51	-0.61	-2.49	-2.17	-2.36	-1.29	-1.09	-1.16
deg	Std. Dev.	0.46	0.36	0.5	1.24	1.11	1.98	0.7	0.63	0.84
	Max	0.59	0.4	0.45	0.71	0.93	2.12	0.41	0.49	0.95
	Min	-1.67	-1.52	-1.83	-5.43	-5.03	-6.45	-3.07	-2.55	-3.4
TENS-1	Mean	1301	1271	1005.96	1918	1843	2005.6	1481	1426	1463.95
Kips	Std. Dev.	48.41	40.76	40.54	201.6	211.2	288.2	183.1	123.4	139.13
	Max	1430	1374	1075	2409	2298	2986	2044	1913	1809
	Min	1183	1170	916.9	1436	1419	1444	1221	1229	1286
TENS-2	Mean		1119			1123			1124	
Kips	Std. Dev.		4.93			11.63			7.05	
	Max		1135			1162			1149	
	Min		1105			1092			1103	
TENS-3	Mean	918.2	1057		732.5	861		837.7	965.9	
Kips	Std. Dev.	40.42	35.33		38.11	41.01		62.53	48.68	
	Max	1019	1149		826.8	948.6		986	1091	
	Min	826.3	973		641.5	768.6		703.8	841.8	
TENS-4	Mean		1143			1171			1151	
Kips	Std. Dev.		5.73			16			9.46	
	Max		1159			1211			1176	
	Min		1126			1137			1130	
REL. MOT.	Mean	-0.61	-0.55		-6.74	-5.02		-3.38	-2.23	
Ft	Std. Dev.	1.17	0.95		3.26	3.02		1.8	1.71	
	Max	2.55	2.02		1.14	2.83		0.91	2.2	
	Min	-4.12	-3.56		-15.43	-14.24		-8.69	-7.03	
RUNUP	Mean		-1.87			-5.82			-3.88	
Ft	Std. Dev.		0.62			1.81			1.06	
	Max		-0.08			-1.08			-0.92	
	Min		-3.96			-12.07			-7.04	
MOONPOOL	Mean	0.06	-0.01		0.05	-0.52		0.32	-0.26	
Ft	Std. Dev.	0.07	0.05		0.32	0.25		0.18	0.13	
	Max	0.34	0.23		1.2	0.41		0.86	0.22	
	Min	-0.22	-0.21		-0.99	-1.26		-0.19	-0.65	

Table 4-7 Comparisons for Wind Only, All Frequencies, Configuration B & H

		Waves only								
		bran2	hran2	TDSIM	bran3	hran3	TDSIM	bran5	hran5	TDSIM
Wave	H1/3	20.92	21.74		44.2	45.8		45.08	48.36	
Ft	Std. Dev.	5.23	5.43		11.05	11.45		11.27	12.09	
	Max	21.92	22.89		40.81	44.47		59.68	52.78	
	Min	-16.25	-16.76		-28.35	-30.14		-32.74	-35.42	
SURGE_CG	Mean	-6.87	-7.06	-9.82	-13.98	-15.01	-24.67	-9.59	-11.34	-19.51
Ft	Std. Dev.	7.36	6.52	3.43	11.8	9.59	10.38	13.59	11.79	7.51
	Max	13.3	12.82	-2.23	20.12	12.91	1.14	24.1	24.26	-1.13
	Min	-26.32	-25.92	-17.07	-47.93	-40.11	-52.97	-45.06	-45.78	-37.79
HEAVE_CG	Mean	-0.01	-0.01	0.05	0.04	0.07	0.22	0.1	0.15	0.25
Ft	Std. Dev.	0.39	0.27	0.16	1.67	1.12	1.28	3.06	1.57	3.13
	Max	0.96	0.91	0.52	4.68	4.53	3.79	10.59	4.93	8.38
	Min	-0.93	-0.87	-0.44	-4.51	-3.6	-2.83	-10.92	-5.39	-7.84
SWAY_CG	Mean	-0.1	-0.43		-0.01	0.15		0.03	0.9	
Ft	Std. Dev.	0.19	0.58		0.47	1.79		0.52	2.39	
	Max	0.55	1.37		1.97	6.68		2.71	8.85	
	Min	-1.47	-2.24		-1.48	-4.49		-2.84	-5.18	
ROLL	Mean	0	-0.01		0.01	0		0.01	0.02	
deg	Std. Dev.	0.03	0.11		0.08	0.19		0.08	0.29	
	Max	0.11	0.28		0.32	0.56		0.4	1.22	
	Min	-0.11	-0.3		-0.29	-0.47		-0.23	-0.79	
YAW	Mean	-0.13	-0.28		-0.18	-0.34		-0.1	-0.3	
deg	Std. Dev.	0.13	0.18		0.29	0.69		0.56	1	
	Max	0.44	0.3		1.09	1.98		2.42	3.16	
	Min	-0.63	-1.09		-1.25	-2.67		-2.41	-4.29	
PITCH	Mean	-0.14	-0.14	-0.16	-0.3	-0.29	-0.41	-0.2	-0.22	-0.33
deg	Std. Dev.	0.52	0.52	0.65	1.55	1.2	1.43	1.76	1.59	1.51
	Max	1.58	1.74	1.71	4.04	3.03	3.97	5.59	4.95	3.78
	Min	-1.86	-1.83	-1.62	-5.13	-4.09	-4.89	-5.74	-5.26	-5.64
TENS-1	Mean	1193	1194	1202.25	1237	1244	1287.52	1215	1221	1255.81
Kips	Std. Dev.	42.75	37.11	18.83	67.51	54.9	66.93	77.22	67.63	43.19
	Max	1303	1302	1245	1470	1402	1624	1548	1496	1367
	Min	1082	1088	1158	1068	1107	1136	1033	1053	1148

Table 4-8 Comparisons for Waves Only, Configurations B & H, All Frequencies

		bran2	hran2	TDSIM	bran3	hran3	TDSIM	bran5	hran5	TDSIM
		f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	20.88	21.72		44.12	45.8		45	48.32	
Ft	Std. Dev.	5.22	5.43		11.03	11.45		11.25	12.08	
	Max	20.67	22.3		39.13	41.79		56.65	53.63	
	Min	-16.31	-17.11		-29.61	-30.23		-35.39	-36.2	
SURGE_CG	Mean			0			0			0
Ft	Std. Dev.	0.87	0.88	0.69	2.99	3.02	2.17	3.96	4.04	3.02
	Max	5.39	2.98	2.34	9.34	9.3	7.75	12.21	13.68	10.53
	Min	-3.14	-3.13	-2.75	-8.97	-8.95	-7.6	-14.73	-14.97	-10.39
HEAVE_CG	Mean			0			0			0
Ft	Std. Dev.	0.39	0.26	0.15	1.62	1.08	1.24	3.03	1.53	3.02
	Max	0.89	0.84	0.46	5.17	4.53	2.96	9.52	5.09	10.53
	Min	-0.9	-0.8	-0.44	-4.37	-3.67	-3.01	-9.54	-5.62	-10.39
SWAY_CG	Mean									
Ft	Std. Dev.	0.16	0.22		0.39	0.62		0.39	0.76	
	Max	0.54	0.89		1.51	2.68		1.59	3.36	
	Min	-0.76	-0.87		-1.63	-2.24		-1.7	-2.5	
ROLL	Mean									
deg	Std. Dev.	0.03	0.03		0.07	0.11		0.06	0.12	
	Max	0.1	0.13		0.27	0.45		0.23	0.57	
	Min	-0.1	-0.14		-0.28	-0.4		-0.19	-0.6	
YAW	Mean									
deg	Std. Dev.	0.05	0.11		0.13	0.43		0.15	0.6	
	Max	0.21	0.52		0.54	1.69		0.64	2.38	
	Min	-0.59	-0.53		-0.52	-1.72		-0.56	-2.53	
PITCH	Mean			0			0			0
deg	Std. Dev.	0.22	0.22	0.26	0.62	0.62	0.63	0.73	0.73	0.73
	Max	0.75	0.72	1.01	1.97	1.98	2.19	2.39	2.4	2.51
	Min	-0.73	-0.73	-0.86	-1.81	-1.77	-2.06	-2.57	-2.59	-2.49
TENS-1	Mean			0			0			0
Kips	Std. Dev.	2.87	3.93	4.78	15.38	15.9	21.34	23.95	22.95	22.8
	Max	12.78	12.68	16.56	86.97	59.82	158.35	168.7	109.2	60.76
	Min	-14.53	-13.29	-20.07	-52.6	-50.39	-116.79	-77.16	-70.43	-67.29

Table 4-9 Comparisons for Waves Only, Configurations B & H, High Frequencies

		bran2	hran2	TDSIM	bran3	hran3	TDSIM	bran5	hran5	TDSIM
		f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz
WAVE	H1/3	0.89	0.47		1.91	1.06		2.19	1.13	
Ft	Std. Dev.	0.22	0.12		0.48	0.26		0.55	0.28	
	Max	0.98	0.38		1.93	1.2		1.85	1.05	
	Min	-0.9	-0.84		-1.01	-0.77		-1.47	-2.47	
SURGE_CG	Mean									
Ft	Std. Dev.	7.31	6.46	3.36	11.41	9.1	10.15	13	11.07	6.88
	Max	18.5	18.13	6.55	27.73	21.59	21.01	27.71	26.19	11.58
	Min	-18.48	-17.94	-6.49	-27.58	-21.25	-23.9	-25.55	-27.24	-15.29
HEAVE_CG	Mean									
Ft	Std. Dev.	0.06	0.06	0.05	0.43	0.3	0.31	0.55	0.46	0.33
	Max	0.19	0.2	0.17	1.65	1.05	1.35	2.21	1.85	1.38
	Min	-0.17	-0.18	-0.13	-1.39	-1.17	-0.67	-2.04	-1.8	-0.92
SWAY_CG	Mean									
Ft	Std. Dev.	0.09	0.53		0.27	1.68		0.35	2.26	
	Max	0.43	1.44		1.06	5.15		1.89	5.61	
	Min	-0.25	-1.39		-0.58	-4.2		-1.24	-5.82	
ROLL	Mean									
deg	Std. Dev.	0.02	0.11		0.05	0.16		0.05	0.27	
	Max	0.06	0.24		0.16	0.41		0.29	0.87	
	Min	-0.05	-0.22		-0.14	-0.38		-0.14	-0.68	
YAW	Mean									
deg	Std. Dev.	0.12	0.14		0.25	0.54		0.54	0.8	
	Max	0.49	0.35		0.86	1.98		2.1	3.71	
	Min	-0.4	-0.5		-0.87	-1.94		-2.06	-3.82	
PITCH	Mean			-0.16			-0.41			-0.33
deg	Std. Dev.	0.48	0.48	0.59	1.42	1.03	1.29	1.6	1.41	1.32
	Max	1.4	1.44	1.47	3.86	2.82	3.59	5.26	4.81	3.1
	Min	-1.41	-1.45	-1.31	-3.59	-2.68	-4.15	-4.97	-4.18	-4.01
TENS-1	Mean									
Kips	Std. Dev.	42.65	36.89	18.06	65.73	52.54	63.4	73.44	63.64	36.61
	Max	105	102	36.82	161.2	117.3	210.95	167.5	169.7	83.1
	Min	-104	-100.6	-34.48	-142.9	-124	-114.34	-147.9	-139.2	-63.65

Table 4-10 Comparisons for Waves Only, Configurations B & H, Low Frequencies

		brcw2	hrcw2	TDSIM	brcw3	hrcw3	TDSIM	brcw5	hrcw5	TDSIM
		all f	all f	all f	all f	all f	all f	all f	all f	all f
WAVE	H1/3	19.22	19.97		39.88	39.58		44.28	43.76	
Ft	Std. Dev.	4.8	4.99		9.97	9.9		11.07	10.94	
	Max	19	25.34		44.02	43.06		47.71	51.48	
	Min	-15.63	-16.21		-28.98	-29.06		-35.47	-35.56	
WIND	Mean	42.88	41.67		82.96	82.07		59.53	59.59	
Knots	Std. Dev.	4.13	4.7		9.84	9.16		7.33	7.26	
	Max	54.5	60.47		120.06	113.25		84.97	82.72	
	Min	29.29	25.89		54.66	58.25		39.47	37.24	
CUR 1	Mean	4.97	1.13		4.11	4.21		4.67	4.9	
Ft/Sec	Std. Dev.	1.4	1.23		2.13	2.33		2.54	2.73	
	Max	10.16	5.42		10.9	12.39		12.61	15.35	
	Min	-1.26	-3.45		-3.72	-5.32		-5.5	-4.66	
CUR 2	Mean	-0.14	-1.46		1.05	1.57		1.27	2.32	
Ft/Sec	Std. Dev.	0.24	1.4		0.71	1.93		0.78	2.3	
	Max	0.64	2.61		3.1	7.04		4.15	8.91	
	Min	-6.35	-10.85		-5.84	-8.62		-5.09	-12.56	
SURGE_CG	Mean	-57.9	-70.4	-63.05	-77.05	-79.83	-82.09	-64.28	-73	-71.82
Ft	Std. Dev.	10.25	5.95	3.21	9.14	6.58	7.03	9.06	7.64	5.94
	Max	-30.27	-55.88	-55.29	-48.27	-53.95	-61.36	-40.57	-52.02	-53.45
	Min	-91.89	-85.12	-70.49	-99.86	-100.8	-102.38	-89.09	-105.2	-93.03
HEAVE_CG	Mean	-0.18	-0.36	-0.14	0.29	0.23	0.06	0.14	-0.15	-0.04
Ft	Std. Dev.	0.48	0.42	0.2	1.78	1.1	0.98	3.1	1.44	1.19
	Max	1.41	0.81	0.46	5.57	4.7	3.65	12.05	4.17	3.82
	Min	-1.88	-1.78	-0.6	-5.13	-3.86	-2.34	-12.12	-4.67	-3.16
SWAY_CG	Mean	0.7	-9.72		1.12	1.52		1.53	-0.81	
Ft	Std. Dev.	0.63	18.1		0.74	28.02		0.69	32.05	
	Max	3.43	42.46		4.17	59.13		4.34	72.27	
	Min	-1.74	-55.86		-1.64	-61.95		-1.3	-68.04	
ROLL	Mean	0.08	0.12		0.12	-0.02		0.16	0.05	
deg	Std. Dev.	0.16	0.5		0.14	0.59		0.16	0.5	
	Max	0.69	1.43		0.65	1.89		0.72	1.58	
	Min	-0.47	-1.24		-0.35	-1.68		-0.55	-1.51	
YAW	Mean	0.17	0.94		-0.35	-0.7		-0.04	-0.09	
deg	Std. Dev.	0.61	0.84		0.83	1.02		0.56	1.2	
	Max	2.09	3.81		2.03	2.5		1.8	6.19	
	Min	-1.9	-1.58		-2.9	-3.82		-1.87	-5.23	
PITCH	Mean	-1.29	-1.41	-1.51	-2.87	-2.8	-3.18	-1.67	-1.74	-2.09
deg	Std. Dev.	0.74	0.44	0.51	1.38	1.23	1.68	1.69	1.25	1
	Max	0.97	0.13	-0.06	1.25	0.89	0.79	4.46	2.35	0.49
	Min	-3.38	-2.84	-3	-7.89	-6.93	-7.72	-7.42	-6.23	-5.48
TENS-1	Mean	1764	2140	1915.73	2353	2556	2667.39	1916	2233	2179.93
Kips	Std. Dev.	255.7	183	88.11	354.6	355.4	432.57	248.3	310.5	192
	Max	3083	2816	2139	3739	4069	4457	2959	4308	3697
	Min	1345	1720	1700	1515	1703	1844	1391	1588	1633

Table 4-11 Comparison of Tests with Wave, Wind & Current, All Frequencies

		brcw2	hrcw2	TDSIM	brcw3	hrcw3	TDSIM	brcw5	hrcw5	TDSIM
		f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	19.19	19.95		39.84	39.54		44.24	43.72	
Ft	Std. Dev.	4.8	4.99		9.96	9.89		11.06	10.93	
	Max	18.49	24.42		42.57	40.05		45.53	50.29	
	Min	-15.76	-16.38		-29.18	-29.13		-35.71	-35.11	
WIND	Mean									
Knots	Std. Dev.	2.27	2.4		6.63	6.27		5.23	5.2	
	Max	7.62	7.7		24.95	19.31		15.06	16.44	
	Min	-6.66	-7.41		-20.43	-20.4		-15.58	-12.91	
CUR 1	Mean									
Ft/Sec	Std. Dev.	0.95	1.02		1.97	2.13		2.4	2.53	
	Max	3.65	3.68		6.91	7.2		8.14	10.53	
	Min	-3.59	-3.89		-7.34	-8.05		-8.71	-8.98	
CUR 2	Mean									
Ft/Sec	Std. Dev.	0.1	1.05		0.35	1.77		0.53	2.06	
	Max	0.98	3.86		1.28	5.28		1.64	6.65	
	Min	-3.22	-5.83		-4.11	-8.01		-2.88	-9.94	
SURGE_CG	Mean			0			0			0
Ft	Std. Dev.	0.95	0.89	0.57	2.81	2.87	1.95	3.85	3.94	2.6
	Max	11.17	3.67	2.09	12.13	10.29	8.01	12.33	12.55	10.55
	Min	-13.19	-8.24	-1.83	-24.49	-14.7	-6.94	-15.31	-23.59	-10.31
HEAVE_CG	Mean			0			0			0
Ft	Std. Dev.	0.44	0.37	0.18	1.67	0.93	0.71	3.05	1.34	1.15
	Max	1.45	0.94	0.4	4.81	3.64	2.34	11.44	3.74	3.13
	Min	-1.52	-1.02	-0.41	-5.54	-4.11	-2.33	-11.41	-4.12	-3.07
SWAY_CG	Mean									
Ft	Std. Dev.	0.5	0.53		0.53	0.73		0.54	1.8	
	Max	2.03	6.7		3.55	9.8		2.05	40.67	
	Min	-1.93	-5.91		-2.23	-9.3		-1.92	-40.62	
ROLL	Mean									
deg	Std. Dev.	0.08	0.08		0.1	0.1		0.1	0.12	
	Max	0.3	0.34		0.44	0.37		0.42	0.43	
	Min	-0.34	-0.34		-0.37	-0.38		-0.48	-0.51	
YAW	Mean									
deg	Std. Dev.	0.13	0.18		0.21	0.35		0.19	0.55	
	Max	0.45	0.81		2.89	1.55		0.62	2.67	
	Min	-0.48	-0.64		-1.43	-1.32		-0.87	-2.14	
PITCH	Mean			0			0			0
deg	Std. Dev.	0.21	0.22	0.21	0.57	0.58	0.57	0.69	0.69	0.62
	Max	0.74	0.75	0.71	2.09	2.14	1.91	2.25	2.32	2.42
	Min	-0.71	-0.69	-0.72	-1.65	-1.73	-2.25	-2.52	-2.55	-2.43
TENS-1	Mean			0			0			0
Kips	Std. Dev.	22.79	27.03	19.86	128.9	172	159.44	122.8	169.6	102.68
	Max	217.7	161.1	69.46	608.1	724.9	765.65	809.5	1292	908.59
	Min	-222.9	-132.6	-65.09	-498.5	-592.2	-659.68	-370.2	-856.5	-601.59

Table 4-12 Comparison of Tests with Wave, Wind & Current, High Frequencies

		brcw2	hrcw2	TDSIM	brcw3	hrcw3	TDSIM	brcw5	hrcw5	TDSIM
		f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz	f < 0.03 Hz
WAVE	H1/3	0.67	0.63		1.27	1.52		1.39	1.64	
Ft	Std. Dev.	0.17	0.16		0.32	0.38		0.35	0.41	
	Max	1.13	0.96		2.73	2.6		3.34	3.54	
	Min	-0.5	-0.58		-0.81	-0.83		-1.06	-1.04	
WIND	Mean									
Knots	Std. Dev.	3.42	4.02		7.27	6.69		5.12	5.07	
	Max	8.04	11.07		23.16	19.14		13.26	12.3	
	Min	-9.42	-14.79		-20.22	-16.57		-15.23	-16.07	
CUR 1	Mean									
Ft/Sec	Std. Dev.	1.02	0.55		0.7	0.74		0.77	0.97	
	Max	2.94	1.48		2.01	1.85		1.76	2.35	
	Min	-3.63	-1.67		-1.99	-2.14		-2.71	-2.62	
CUR 2	Mean									
Ft/Sec	Std. Dev.	0.21	0.77		0.61	0.65		0.57	0.9	
	Max	0.55	2.33		1.22	1.66		2.17	2.04	
	Min	-0.67	-2.34		-1.4	-1.98		-1.73	-2.4	
SURGE_CG	Mean									
Ft	Std. Dev.	10.21	5.88	3.16	8.7	5.92	6.76	8.2	6.54	5.34
	Max	26.26	13.05	6.68	24.23	22.32	16.01	21.73	17.23	14.4
	Min	-32.41	-13.87	-6.19	-17.88	-16.33	-18.72	-18.56	-16.56	-12.87
HEAVE_CG	Mean									
Ft	Std. Dev.	0.2	0.2	0.1	0.62	0.59	0.67	0.57	0.53	0.28
	Max	0.53	0.59	0.32	3.11	2.28	1.94	2.51	1.57	0.92
	Min	-0.91	-0.75	-0.19	-1.42	-1.75	-1.49	-1.55	-2.06	-0.71
SWAY_CG	Mean									
Ft	Std. Dev.	0.39	18.09		0.51	28.01		0.43	32	
	Max	1.25	52.06		1.63	57.54		1.75	72.94	
	Min	-1.14	-45.03		-1.7	-62.34		-1.44	-66.13	
ROLL	Mean									
deg	Std. Dev.	0.14	0.49		0.09	0.58		0.13	0.49	
	Max	0.41	1.19		0.25	1.8		0.36	1.47	
	Min	-0.38	-1.36		-0.28	-1.6		-0.38	-1.42	
YAW	Mean									
deg	Std. Dev.	0.6	0.82		0.81	0.96		0.52	1.06	
	Max	1.75	2.49		2.32	2.88		1.65	6.06	
	Min	-1.93	-2.19		-2.4	-2.59		-1.5	-3.55	
PITCH	Mean			-1.51			-3.18			-2.09
deg	Std. Dev.	0.71	0.39	0.47	1.25	1.08	1.58	1.54	1.04	0.79
	Max	1.78	1.15	1.13	3.52	3.16	3.74	5.61	3.53	1.98
	Min	-1.89	-0.95	-1.23	-3.89	-3.6	-3.7	-4.8	-3.58	-2.52
TENS-1	Mean									
Kips	Std. Dev.	254.7	181	85.84	330.4	311.1	402.11	215.8	259.9	162.23
	Max	1211	635.1	174.84	1024	1147	1437.6	562.3	1002	615.34
	Min	-418.9	-380.5	-172.92	-748.3	-776.9	-682.09	-490	-501.1	-424.01

Table 4-13 Comparison of Tests with Wave, Wind & Current, Low Frequencies

	TDSIM6 (Conf. A)	Config. A	Config. H
100 Year GOM Storm			
Current Only (ACUR3)	0	5.7	4.7
Wind Only (AWIN3)	10.1	9.6	7.8
Wave Only (ARAN3)	10.2	12.0	9.1
Wave & Current (ARC3)	8.4	10.3	7.9
Wave, Wind & Current (ARCW3)	6.7	7.3	5.9
100 Year N. Atlantic Storm			
Current Only (ACUR5)	0	7.7	3.5
Wind Only (AWIN5)	8.3	16.4	9.1
Wave Only (ARAN5)	6.9	15.6	11.5
Wave & Current (ARC5)	4.0	10.1	8.8
Wave, Wind & Current (ARCW5)	5.4	8.8	6.5

Table 4-14 Std. Dev. of Low Frequency Surge Responses

		Tests				TDSIM Runs								
		aran5	bran5	f1ran5	hran5		bran5 (pretest)	ARAN5_1	ARAN5_2	ARAN5_3	ARAN5_4	ARAN5_4A	ARAN5_5A	ARAN5_6
						No. waves	50	60	60	100	60	100	100	60
						Spacing	Period	Period	Period	Period	Freq	Freq	Freq	Freq
						Cd (horiz)	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0
						T run (sec)	2500	2500	2500	2500	2500	8500	8500	2500
SURGE_CG	Mean	-9.36	-9.59	-10.72	-11.34		19.51	19.49	19.69	20.08	19.12	18.3	18	18.6
Ft	Std. Dev.	15.62	13.59	11.24	11.79		7.51	8.47	11.12	7.97	13.51	11.57	8.25	10.04
	Max	39.66	24.1	19.89	24.26		37.79	42.94	46.62	39.4	57.21	57.31	45.9	45.88
	Min	-48.2	-45.06	-46.6	-45.78		1.13	-0.56	-8.33	2.15	-16.42	-16.49	-8.01	-7.99
HEAVE_CG	Mean	0.17	0.1	0.1	0.15		0.25	-0.12	-0.05	-0.02	-0.11	-0.14	-0.17	-0.15
Ft	Std. Dev.	3.24	3.06	0.75	1.57		3.13	2.32	2.49	2.4	1.48	1.57	1.64	1.3
	Max	10.85	10.59	2.69	4.93		8.38	5.9	6.6	7.31	4.29	5.55	5.49	4.33
	Min	-11	-10.92	-2.52	-5.39		-7.84	-6.5	-6.85	-8	-4.6	-6.29	-6.58	-4.5
SWAY_CG	Mean	0.49	0.03	0.92	0.9									
Ft	Std. Dev.	2.23	0.52	1.41	2.39									
	Max	8.68	2.71	6.63	8.85									
	Min	-5.38	-2.84	-2.55	-5.18									
PITCH	Mean	-0.2	-0.2	-0.21	-0.22		-0.33	-0.36	-0.36	-0.38	-0.35	-0.34	-0.34	-0.35
deg	Std. Dev.	1.95	1.76	1.08	1.59		1.51	1.47	1.93	2.01	1.52	1.36	1.16	1.23
	Max	6.13	5.59	3.19	4.95		3.78	3.5	4.61	4.95	3.37	3.59	3.21	2.68
	Min	-6.25	-5.74	-4.9	-5.26		-5.64	-4.85	-5.66	-6.28	-4.45	-6.66	-6.29	-3.9
TENS-1	Mean	1217	1215	1220	1221		1255.81	1254.28	1256.09	1258.08	1256.39	1248.83	1245.96	1249.7
Kips	Std. Dev.	91.73	77.22	64.58	67.63		43.19	47.67	62.66	45.3	86.23	67.37	45.84	56.11
	Max	1685	1548	1519	1496		1367	1434.8	1532.8	1467.9	1835.4	1837.7	1541.2	1541
	Min	1016	1033	1071	1053		1148	1133.9	1102	1140.9	1057.3	1055.4	1101.4	1101.4

Table 4-15 RAN5 Comparisons, All Frequencies

		Tests				TDSIM Runs								
		aran5	bran5	f1ran5	hran5		bran5 (pretest)	ARAN5_1	ARAN5_2	ARAN5_3	ARAN5_4	ARAN5_4A	ARAN5_5A	ARAN5_6
						No. waves	50	60	60	100	60	100	100	60
						Spacing	Period	Period	Period	Period	Freq	Freq	Freq	Freq
						Cd (horiz)	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0
						T run (sec)	2500	2500	2500	2500	2500	8500	8500	2500
SURGE_CG	Mean													
Ft	Std. Dev.	15.1	13	10.47	11.07		6.88	7.93	10.71	7.39	13.17			9.58
	Max	33.97	27.71	22.14	26.19		15.29	18.61	22.23	16.21	31.1			19.94
	Min	-33.09	-25.55	-26.09	-27.24		-11.58	-15.82	-22.86	-12.99	-30.89			-22.52
HEAVE_CG	Mean													
Ft	Std. Dev.	0.64	0.55	0.26	0.46		0.33	0.24	0.37	0.47	0.26			0.23
	Max	2.91	2.21	0.91	1.85		1.38	1	1.26	2.32	0.81			1.24
	Min	-2.33	-2.04	-0.92	-1.8		-0.92	-0.48	-0.77	-0.99	-0.6			-0.65
SWAY_CG	Mean													
Ft	Std. Dev.	2.14	0.35	1.3	2.26									
	Max	6.14	1.89	3.88	5.61									
	Min	-5.99	-1.24	-3.3	-5.82									
PITCH	Mean													
deg	Std. Dev.	1.81	1.6	0.79	1.41		1.32	1.29	1.8	1.88	1.34			1
	Max	5.99	5.26	2.89	4.81		3.1	3.28	4.39	4.6	3.01			2.48
	Min	-4.97	-4.97	-2.51	-4.18		-4.01	-3.03	-3.93	-4.14	-3.15			-2.46
TENS-1	Mean													
Kips	Std. Dev.	87.07	73.44	60.81	63.64		36.61	42.9	58.71	40.07	80.92			52.12
	Max	238.1	167.5	172.1	169.7		83.1	112.01	162.93	103.62	305.86			134.52
	Min	-169.4	-147.9	-126.6	-139.2		-63.65	-88.98	-130.15	-75.69	-166.8			-117.75

Table 4-16 RAN5 Comparisons, Low Frequencies

		Tests				TDSIM Runs								
		aran5	bran5	f1ran5	hran5		bran5 (pretest)	ARAN5_1	ARAN5_2	ARAN5_3	ARAN5_4	ARAN5_4A	ARAN5_5A	ARAN5_6
						No. waves	50	60	60	100	60	100	100	60
						Spacing	Period	Period	Period	Period	Freq	Freq	Freq	Freq
						Cd (horiz)	1.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0
						T run (sec)	2500	2500	2500	2500	2500	8500	8500	2500
SURGE_CG	Mean						0	0	0	0	0			0
Ft	Std. Dev.	3.97	3.96	4.1	4.04		3.02	2.99	3	3.01	3.02			3
	Max	18.49	12.21	12.93	13.68		10.53	8.43	8.43	8.66	9.11			8.82
	Min	-14.98	-14.73	-14.91	-14.97		-10.39	-8.39	-8.94	-9.22	-9.54			-9.56
HEAVE_CG	Mean						0	0	0	0	0			0
Ft	Std. Dev.	3.21	3.03	0.71	1.53		3.11	2.31	2.46	2.35	1.45			1.28
	Max	10.29	9.52	2.32	5.09		8.07	6.06	6.52	7.14	4.33			4.22
	Min	-10.14	-9.54	-2.58	-5.62		-7.71	-6.26	-6.67	-7.42	-4.63			-4.36
SWAY_CG	Mean													
Ft	Std. Dev.	0.63	0.39	0.55	0.76									
	Max	3.6	1.59	2.49	3.36									
	Min	-2.57	-1.7	-2.34	-2.5									
PITCH	Mean						0	0	0	0	0			0
deg	Std. Dev.	0.73	0.73	0.74	0.73		0.73	0.69	0.69	0.71	0.71			0.71
	Max	2.4	2.39	2.44	2.4		2.51	1.9	1.91	2.16	2.19			2.19
	Min	-2.52	-2.57	-2.54	-2.59		-2.49	-2	-1.99	-2.1	-2.07			-2.03
TENS-1	Mean						0	0	0	0	0			0
Kips	Std. Dev.	29	23.95	21.75	22.95		22.8	20.77	21.9	21.13	29.81			20.79
	Max	238.7	168.7	132.7	109.2		60.76	68.77	113.78	109.96	273.52			156.78
	Min	-118.2	-77.16	-73.07	-70.43		-67.29	-63.78	-64.39	-54.02	-180.35			-81.06

Table 4-17 RAN5 Comparisons High Frequencies

		all f		f < 0.03 Hz		f > 0.03 Hz	
		TDSIM	Tests	TDSIM	Tests	TDSIM	Tests
E2RAN1 - Waves Only							
SURGE	Mean	-10.46	-6.98	-10.46	0.00	0.00	0.00
Ft	Std. Dev.	7.38	5.83	7.08	5.43	2.11	2.13
	Max	6.87	14.89	1.64	16.18	6.74	7.77
	Min	-28.89	-22.92	-26.54	-13.62	-6.35	-6.96
SWAY	Mean	0.03	-0.40	0.03	0.00	0.00	0.00
Ft	Std. Dev.	0.04	1.75	0.04	1.73	0.00	0.28
	Max	0.13	5.21	0.13	5.28	0.06	1.14
	Min	-0.08	-5.27	-0.08	-4.28	-0.07	-1.35
TENS-4	Mean	246.92	255.90	246.92	0.00	0.00	0.00
Kips	Std. Dev.	10.23	8.38	9.64	7.35	3.42	3.97
	Max	274.26	284.10	268.21	19.54	10.18	12.85
	Min	223.36	227.90	230.63	-19.37	-10.19	-15.31
E2RC1 - Waves and Current							
SURGE	Mean	-55.8	-53.91	0.00	0.00	0.00	0.00
Ft	Std. Dev.	3.86	5.60	3.32	5.18	1.97	2.13
	Max	-44.92	-30.36	-47.23	19.94	6.28	7.72
	Min	-66.25	-67.80	-62.58	-9.62	-6.55	-6.75
SWAY	Mean	5.49	8.38	0.00	0.00	0.00	0.00
Ft	Std. Dev.	5.99	9.22	5.99	9.22	0.13	0.34
	Max	9.37	31.68	9.37	23.27	1.76	1.45
	Min	-17.7	-14.07	-17.68	-22.24	-2.20	-1.75
TENS-4	Mean	375.37	354.50	0.00	0.00	0.00	0.00
Kips	Std. Dev.	67.61	83.43	46.49	56.17	49.09	61.69
	Max	754.98	925.00	519.53	231.30	254.38	371.20
	Min	298.35	282.30	298.14	-65.74	-146.72	-244.10
E2RCW1 - Waves, Wind and Current							
SURGE	Mean	-68.99	-68.94	0.00	0.00	0.00	0.00
Ft	Std. Dev.	2.68	3.02	1.79	2.09	1.99	2.18
	Max	-62.36	-57.14	-64.64	9.08	7.25	8.40
	Min	-78.92	-80.60	-74.99	-5.80	-6.73	-8.37
SWAY	Mean	7.41	11.92	0.00	0.00	0.00	0.00
Ft	Std. Dev.	3.71	6.75	3.70	6.71	0.19	0.73
	Max	15.88	31.60	15.87	19.22	2.89	8.46
	Min	-0.66	-9.75	-0.68	-19.69	-2.65	-11.20
TENS-4	Mean	829.8	856.00	0.00	-0.01	0.00	0.00
Kips	Std. Dev.	202.57	229.00	142.04	142.80	144.43	178.90
	Max	1646.3	1817.00	1394.69	549.10	443.62	646.80
	Min	409.29	315.50	583.39	-469.30	-508.01	-598.10

Table 4-18 Comparisons for ORYX Spar, GOM 100 year Hurricane (Table 4.2)

		Statistics			Weibull Coefficients		3 Hr Max		
		Mean	Std Dev	Tz	Beta	Alpha	N	Max	Max/RMS
Tension (kips)									
TDSIM	Combined	2728.8	360.3	28.2	1.3	420.4	383.4	1690.6	4.7
Test	Combined	2621.4	388.4	30.8	1.1	394.6	350.6	1876.4	4.8
Test	Low Freq	2621.4	342.4	150.2	1.4	535.4	71.9	1470.5	4.3
Test	High Freq	0.0	183.7	14.7	2.1	296.1	735.9	729.1	4.0
Surge (ft)									
TDSIM	Combined	83.8	5.1	32.3	1.7	5.8	334.5	16.3	3.2
Test	Combined	80.9	6.6	30.3	1.2	5.9	356.4	24.9	3.8
Test	Low Freq	80.9	6.0	139.8	1.8	8.2	77.3	18.3	3.1
Test	High Freq	0.0	2.9	13.8	3.0	5.0	784.8	9.6	3.3
Heave Crest (ft)									
TDSIM	Combined	0.1	1.4	27.8	2.3	2.1	389.0	4.6	3.2
Test	Combined	0.2	1.3	28.4	1.6	1.7	380.3	5.2	4.1
Test	Low Freq	0.2	0.6	61.0	1.4	0.8	177.2	2.6	4.4
Test	High Freq	0.0	1.1	24.8	2.9	2.2	435.5	4.0	3.6
Pitch (deg)									
TDSIM	Combined	3.2	1.2	26.0	1.4	1.3	415.0	5.0	4.1
Test	Combined	2.8	1.3	27.3	1.9	1.8	395.5	4.5	3.5
Test	Low Freq	2.8	1.1	67.6	1.9	1.6	159.9	3.9	3.4
Test	High Freq	0.0	0.6	13.2	4.0	1.1	819.7	1.8	3.0

Table 4-19 Summary of Weibull Curve Fit Parameter

		Waves Only					
		hran3 No Risers			f1ran3 With Risers		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	45.8	1.06	45.8	46.08	1.29	46.04
Ft	Std. Dev.	11.45	0.26	11.45	11.52	0.32	11.51
	Max	44.47	1.2	41.79	43.09	1.74	41.4
	Min	-30.14	-0.77	-30.23	-31.84	-0.6	-32.19
SURGE_CG	Mean	-15.01			-15.27		
Ft	Std. Dev.	9.59	9.1	3.02	9.11	8.57	3.1
	Max	12.91	21.59	9.3	11.55	20.54	9.81
	Min	-40.11	-21.25	-8.95	-39.31	-19.32	-9.13
HEAVE_CG	Mean	0.07			-0.08		
Ft	Std. Dev.	1.12	0.3	1.08	0.47	0.21	0.42
	Max	4.53	1.05	4.53	2.1	0.59	1.79
	Min	-3.6	-1.17	-3.67	-2.13	-0.62	-1.92
SWAY_CG	Mean	0.15			1.28		
Ft	Std. Dev.	1.79	1.68	0.62	2.56	2.52	0.43
	Max	6.68	5.15	2.68	10.8	8.52	2.03
	Min	-4.49	-4.2	-2.24	-4.17	-4.86	-1.76
ROLL	Mean	0			0.01		
deg	Std. Dev.	0.19	0.16	0.11	0.15	0.12	0.09
	Max	0.56	0.41	0.45	0.55	0.52	0.34
	Min	-0.47	-0.38	-0.4	-0.55	-0.51	-0.36
YAW	Mean	-0.34			0.01		
deg	Std. Dev.	0.69	0.54	0.43	0.8	0.71	0.36
	Max	1.98	1.98	1.69	2.49	1.99	1.27
	Min	-2.67	-1.94	-1.72	-2.48	-2.08	-1.3
PITCH	Mean	-0.29			-0.29		
deg	Std. Dev.	1.2	1.03	0.62	0.99	0.76	0.63
	Max	3.03	2.82	1.98	2.71	2.17	2
	Min	-4.09	-2.68	-1.77	-3.23	-1.88	-1.8
TENS-1	Mean	1244			1239		
Kips	Std. Dev.	54.9	52.54	15.9	51.63	49.42	14.93
	Max	1402	117.3	59.82	1382	111.7	53.57
	Min	1107	-124	-50.39	1102	-113.4	-46.92

Table 4-20 Effect of Risers: Waves Only, 100 year GOM Storm

		hrcw3, No Risers			f1rcw3, 20 Production Risers			f2rcw3, Production and Catenary Risers		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
SURGE_CG	Mean	-79.83			-78.83			-85.74		
Ft	Std. Dev.	6.58	5.92	2.87	6.14	5.44	2.84	6.65	5.99	2.88
	Max	-53.95	22.32	10.29	-60.84	14.8	10.74	-58.96	21.92	10.77
	Min	-100.8	-16.33	-14.7	-96.17	-12.35	-9.83	-102.6	-13.04	-12.87
HEAVE_CG	Mean	0.23			-0.19			0.02		
Ft	Std. Dev.	1.1	0.59	0.93	0.67	0.45	0.49	0.71	0.46	0.54
	Max	4.7	2.28	3.64	2.62	1.63	1.87	2.98	1.59	2.13
	Min	-3.86	-1.75	-4.11	-2.64	-1.34	-2.07	-2.51	-1.35	-2.26
SWAY_CG	Mean	1.52			-1.97			1.2		
Ft	Std. Dev.	28.02	28.01	0.73	25.07	25.06	0.65	22.86	22.85	0.58
	Max	59.13	57.54	9.8	56.82	57.87	4.66	44.59	42.98	3.62
	Min	-61.95	-62.34	-9.3	-52.36	-48.76	-4.43	-49.37	-49.89	-1.94
ROLL	Mean	-0.02			-0.04			-0.04		
deg	Std. Dev.	0.59	0.58	0.1	0.29	0.27	0.1	0.31	0.29	0.1
	Max	1.89	1.8	0.37	0.82	0.71	0.37	0.96	1.01	0.36
	Min	-1.68	-1.6	-0.38	-0.92	-0.69	-0.37	-0.94	-0.76	-0.39
YAW	Mean	-0.7			1.15			1.36		
deg	Std. Dev.	1.02	0.96	0.35	0.79	0.71	0.34	0.75	0.66	0.35
	Max	2.5	2.88	1.55	3.9	2.04	1.45	4.22	1.95	1.79
	Min	-3.82	-2.59	-1.32	-1.04	-1.86	-1.24	-1.07	-2.16	-1.27
PITCH	Mean	-2.8			-2.47			-2.48		
deg	Std. Dev.	1.23	1.08	0.58	0.98	0.78	0.58	1.02	0.84	0.59
	Max	0.89	3.16	2.14	0.31	2.1	2.1	0.75	2.67	2.07
	Min	-6.93	-3.6	-1.73	-5.79	-2.54	-1.66	-6.31	-2.73	-1.71
TENS-1	Mean	2556			2658			2460		
Kips	Std. Dev.	355.4	311.1	172	383	338.2	179.7	321.8	276.2	164.6
	Max	4069	1147	724.9	4021	866.7	629.1	3576	856.2	623.4
	Min	1703	-776.9	-592.2	1964	-613.9	-604.7	1600	-731.7	-522.4

Table 4-21 Riser Effects with Waves, Wind & Current, 100 Year GOM Storm

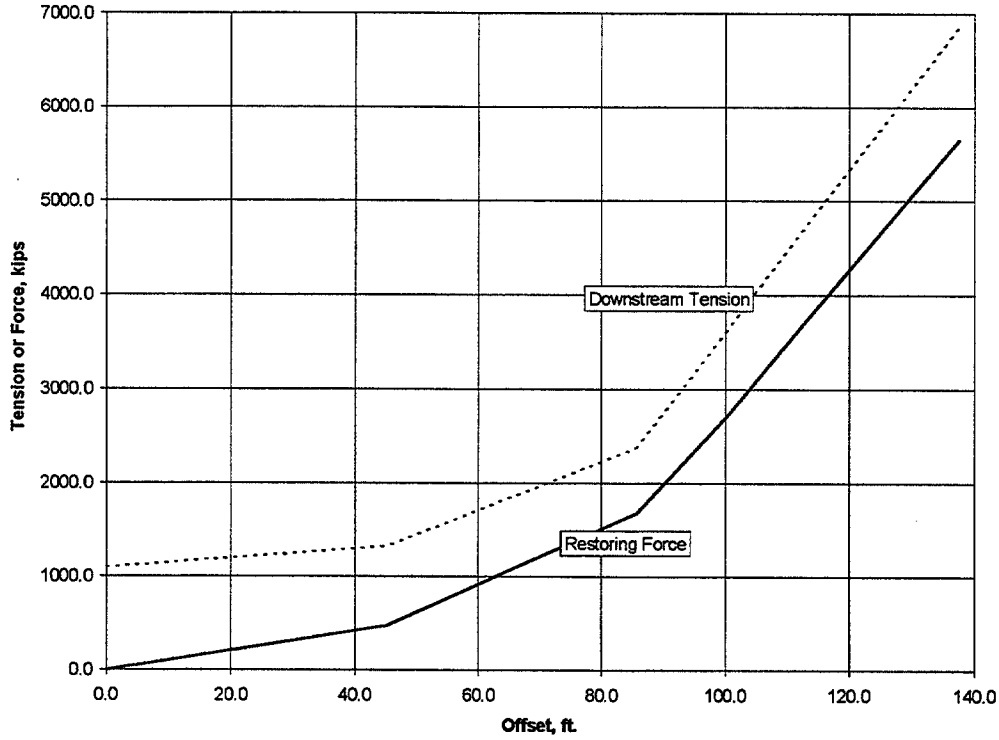


Figure 4-1 Mooring System Characteristics Used in Pre-Test Simulations

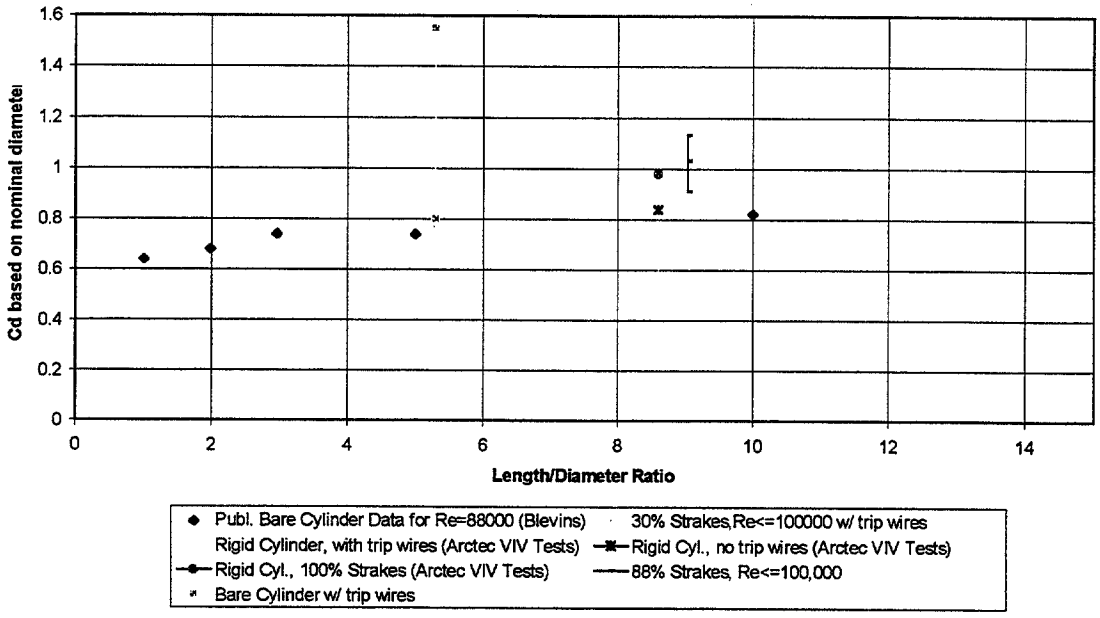


Figure 4-2 Drag Coefficients from Various Towing or Drag Tests

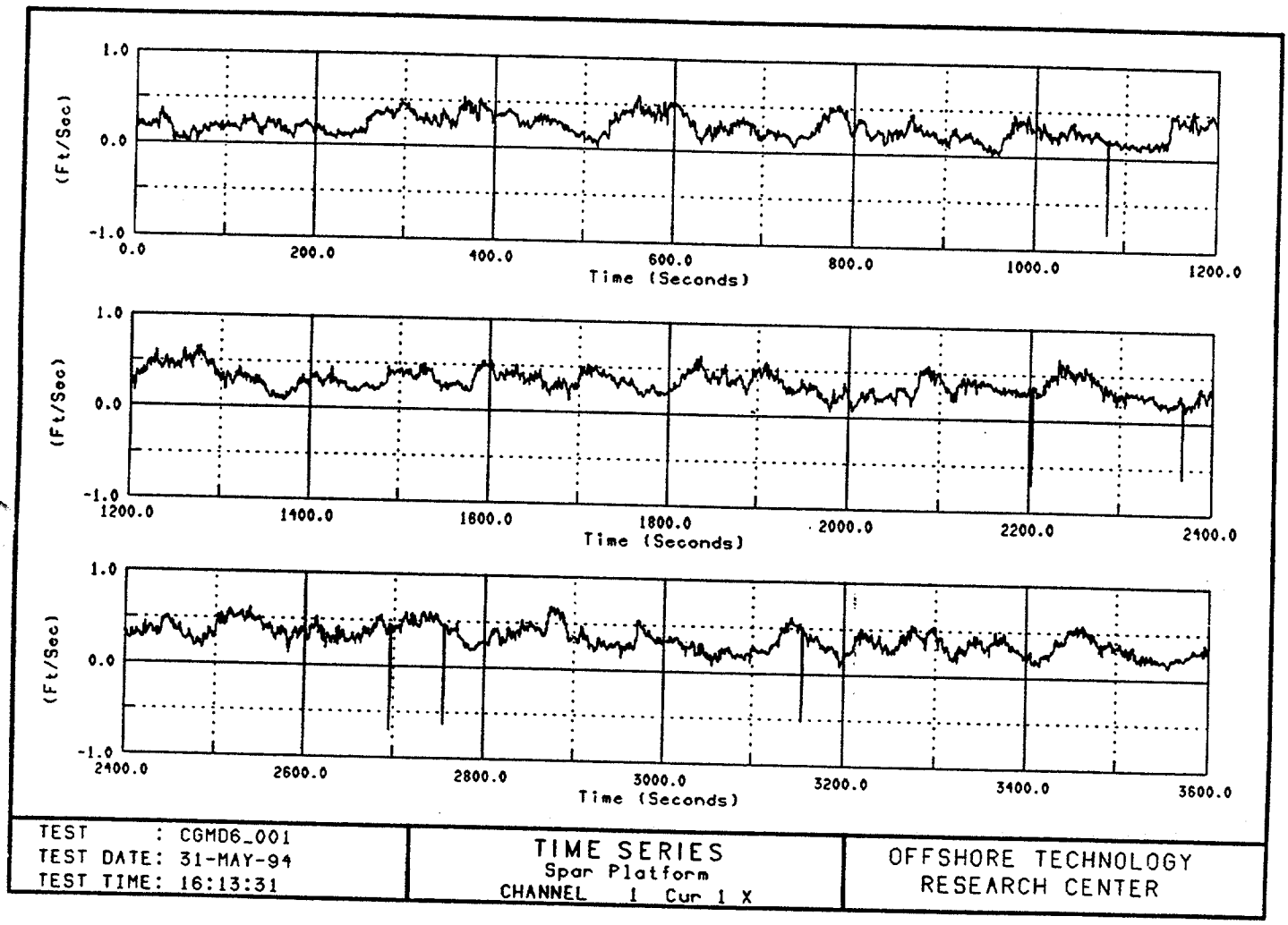


Figure 4-3 Current Time History

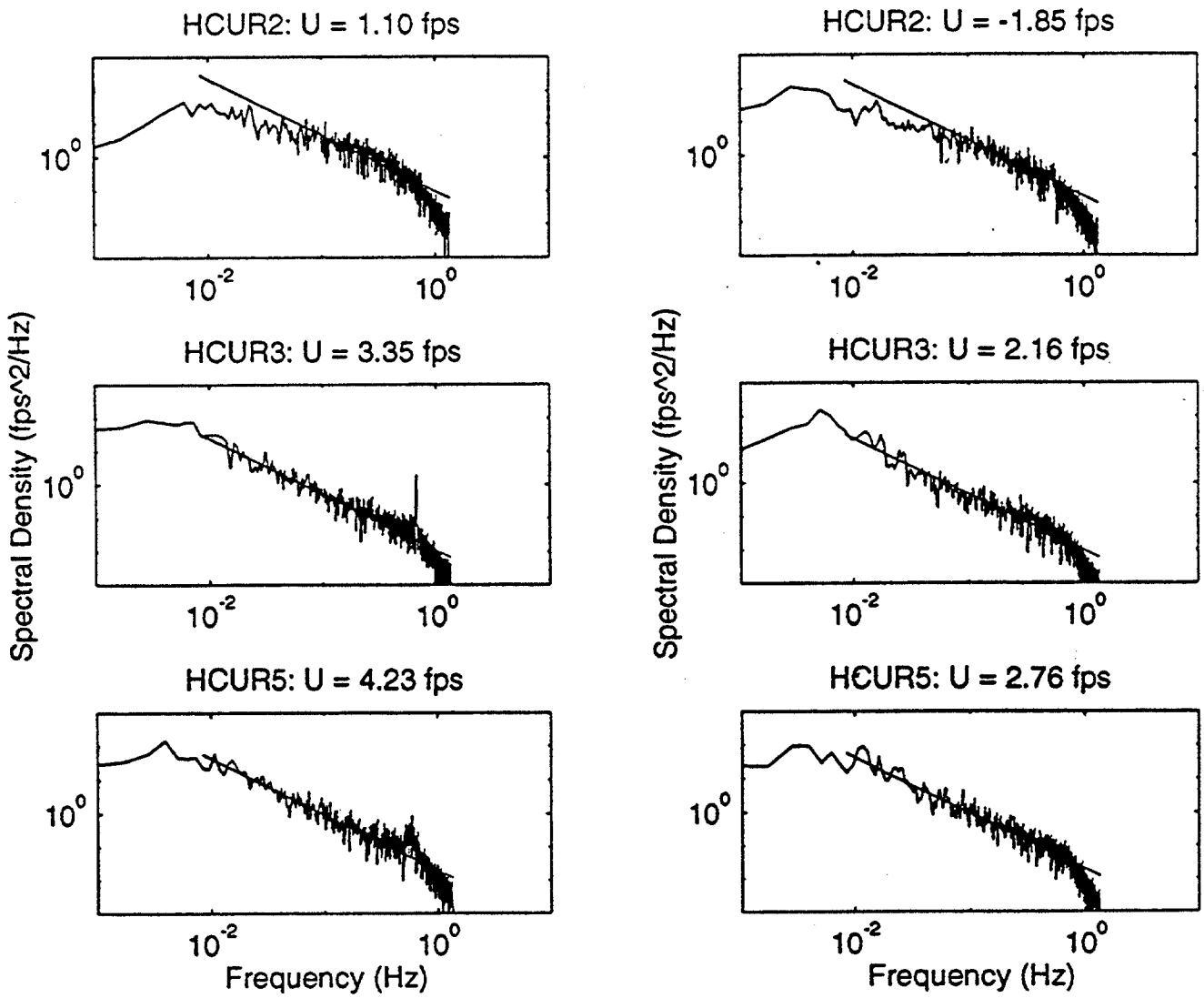


Figure 4-4 Plots of Current Spectra (Mercier)

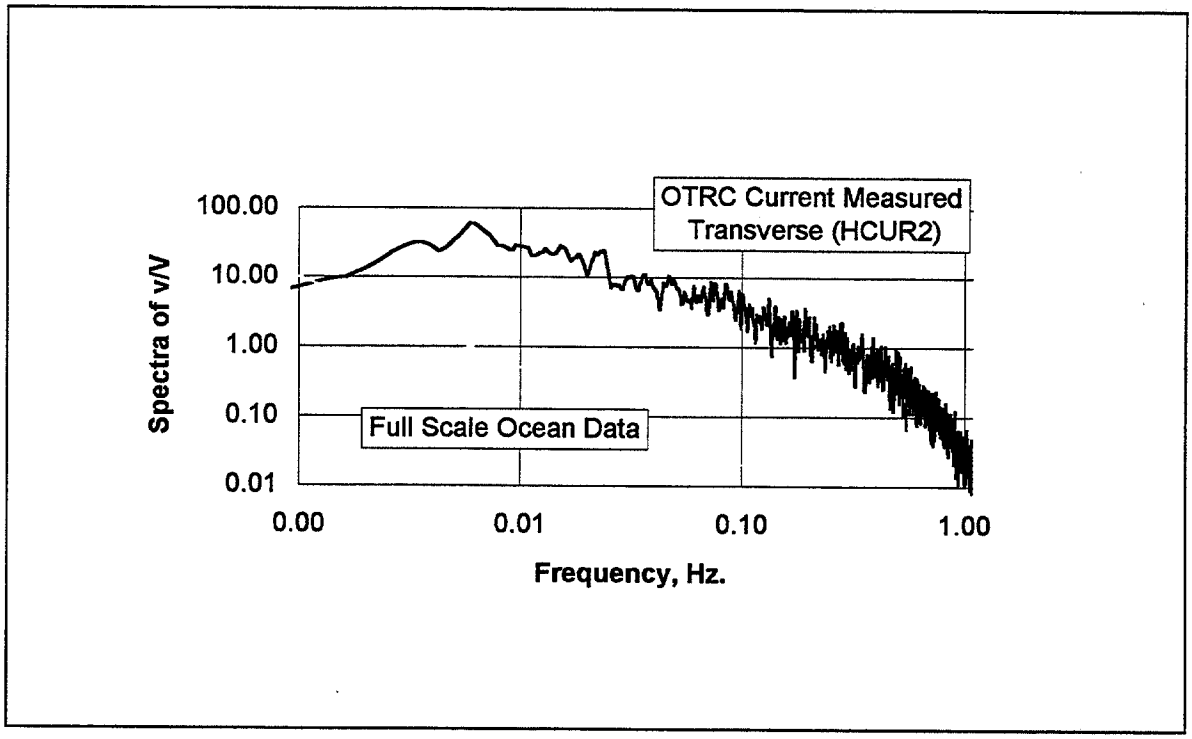


Figure 4-5 Current Power Spectrum

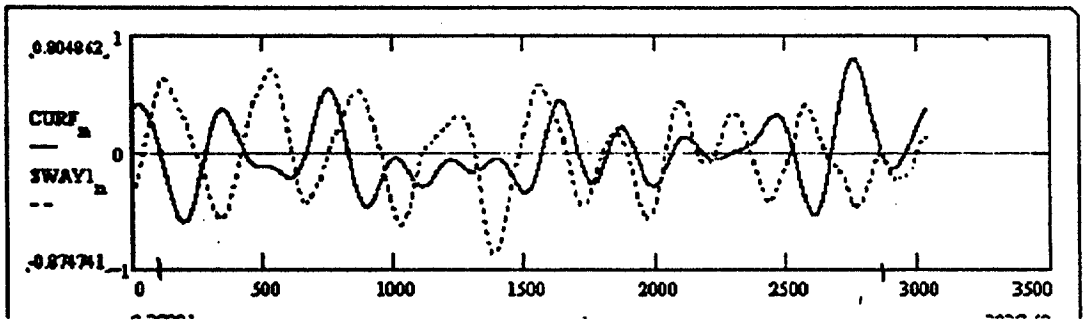


Figure 4-6 Plot of Low Frequency Part of Transverse Current and Sway Motion (HCUR2)

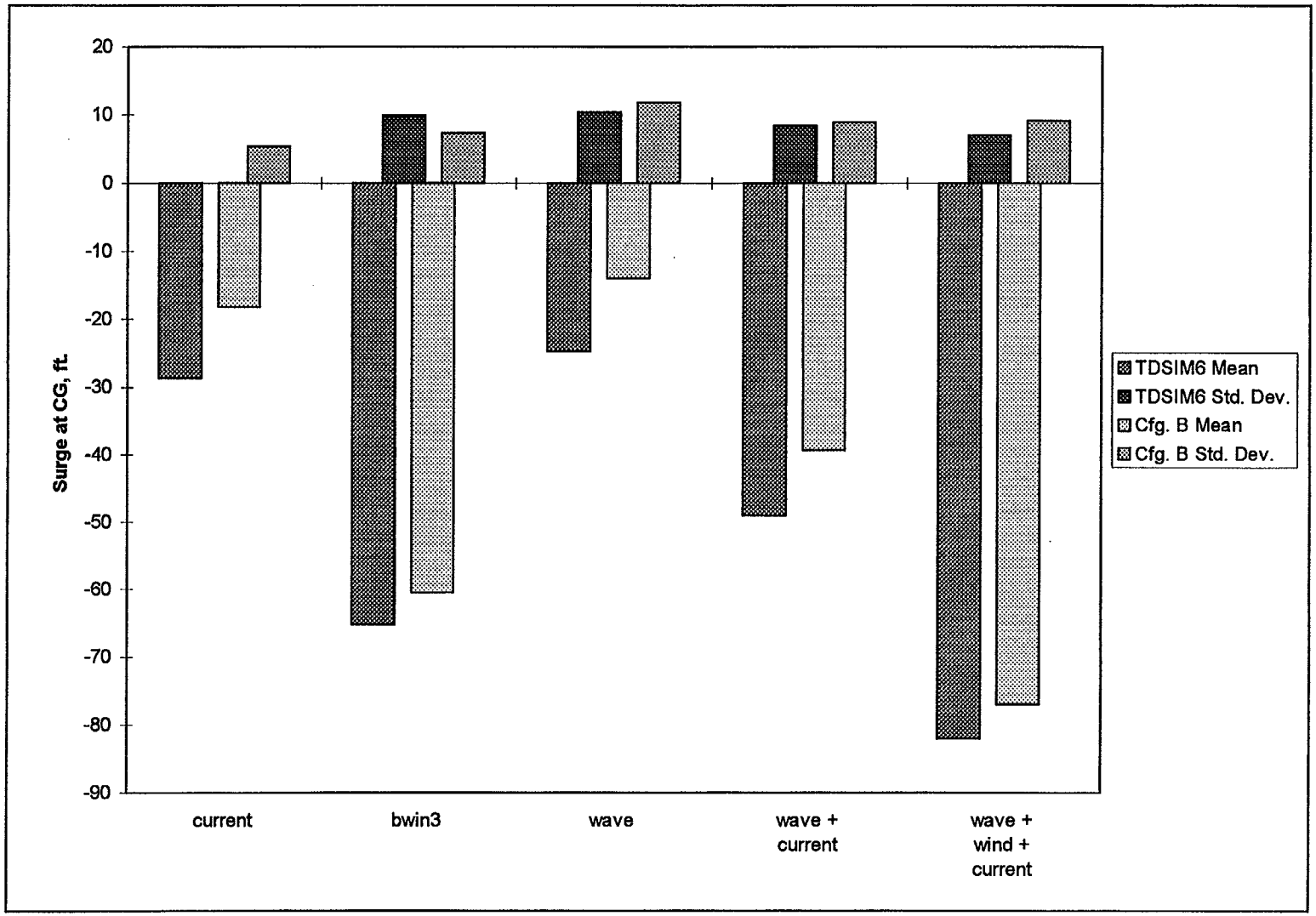


Figure 4-7 Surge at CG Comparisons, Configuration B, 100 Year GOM Storm

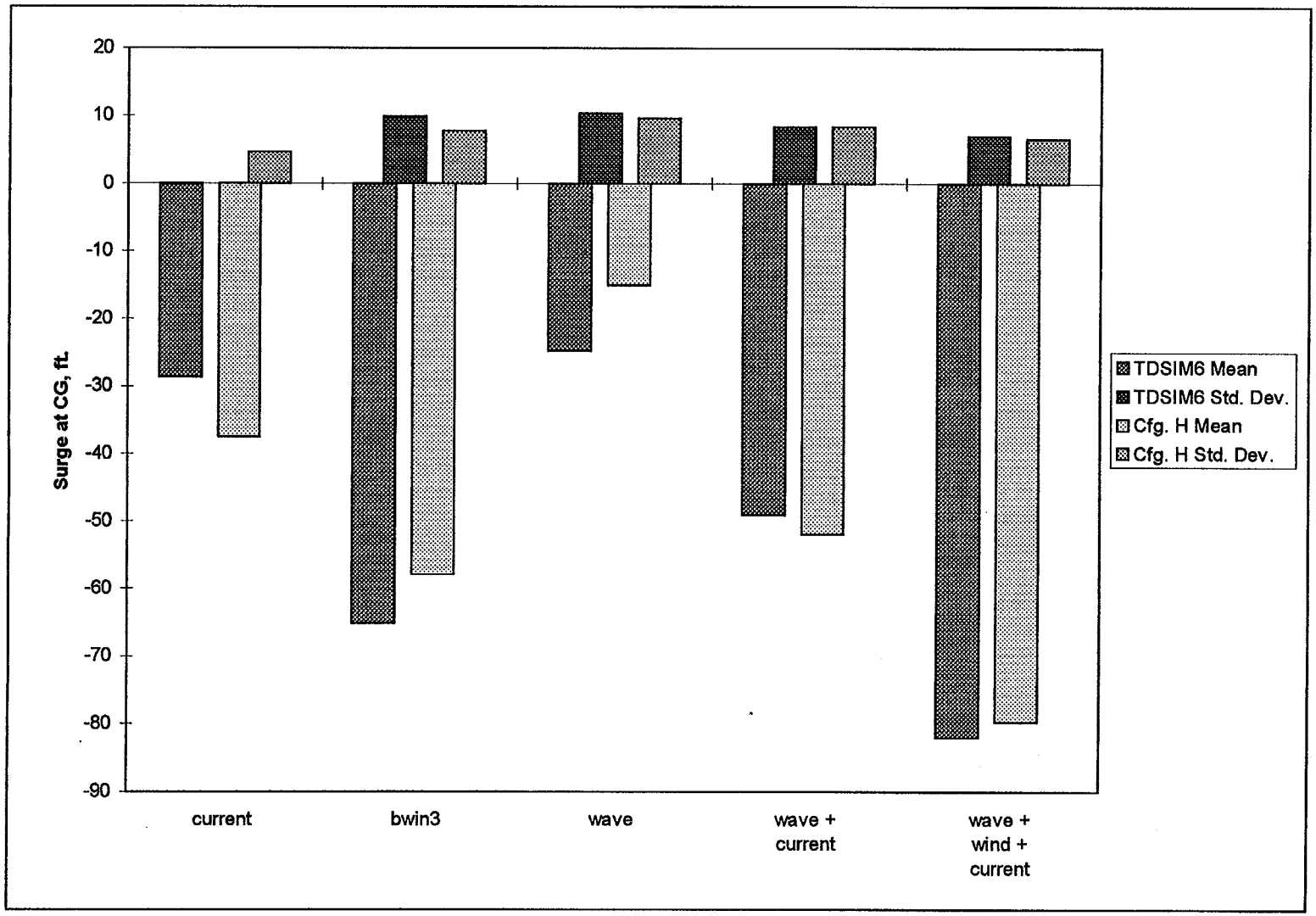


Figure 4-8 Surge at CG Comparisons, Configuration H, 100 Year GOM Storm

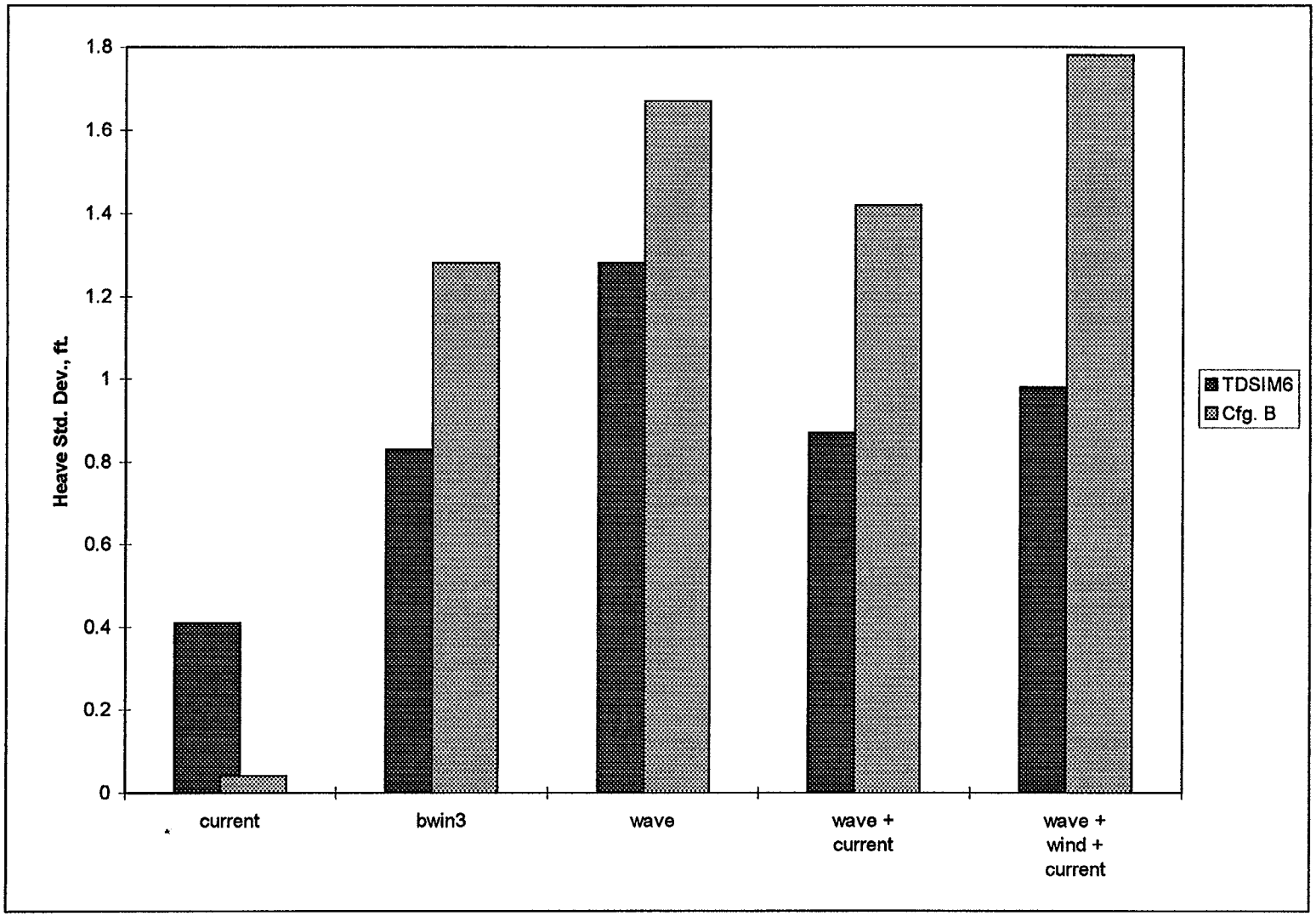


Figure 4-9 Comparison of Heave Motions, Configuration B, 100 Year GOM Storm

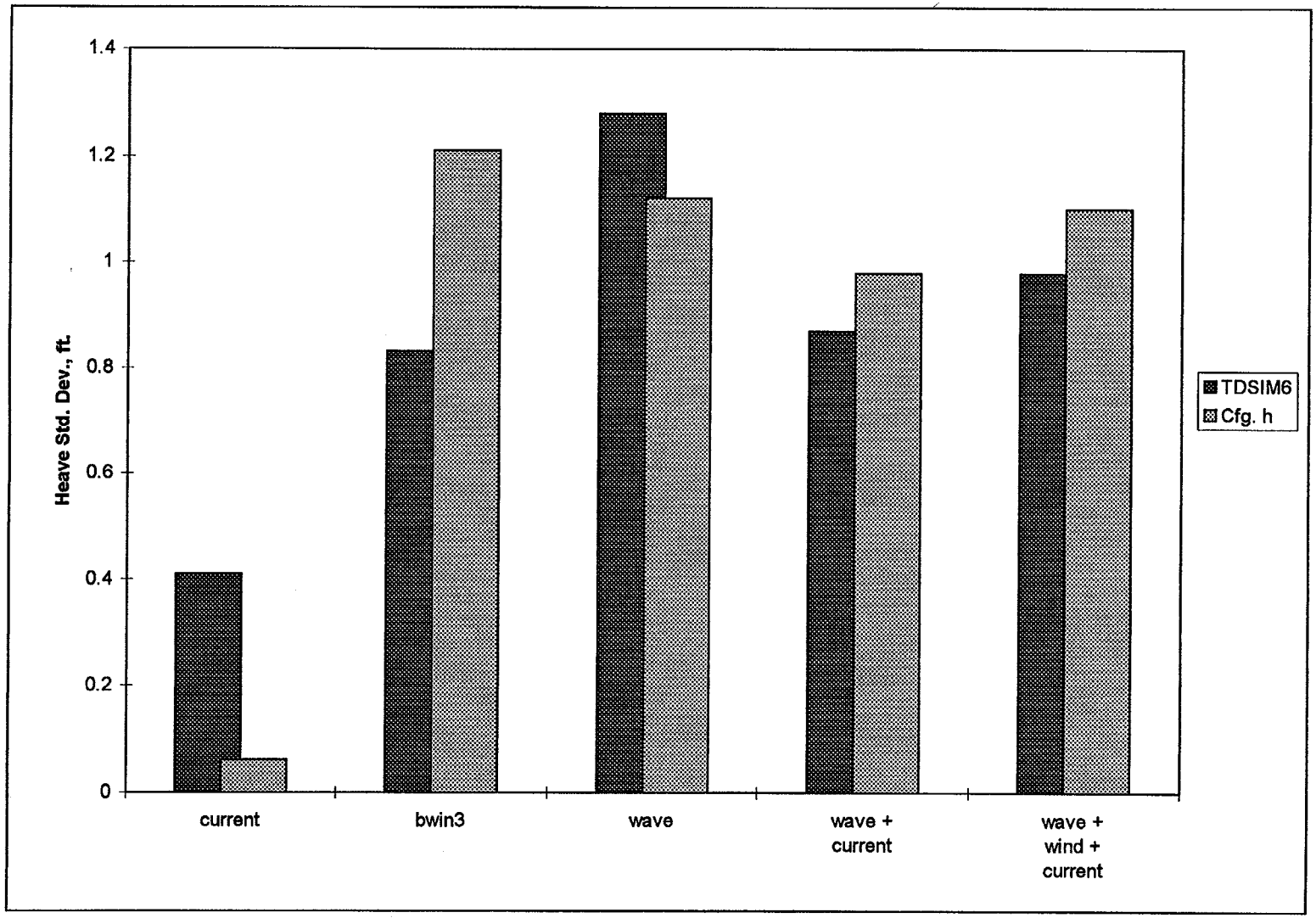


Figure 4-10 Comparison of Heave Motions, Configuration H, 100 Year GOM Storm

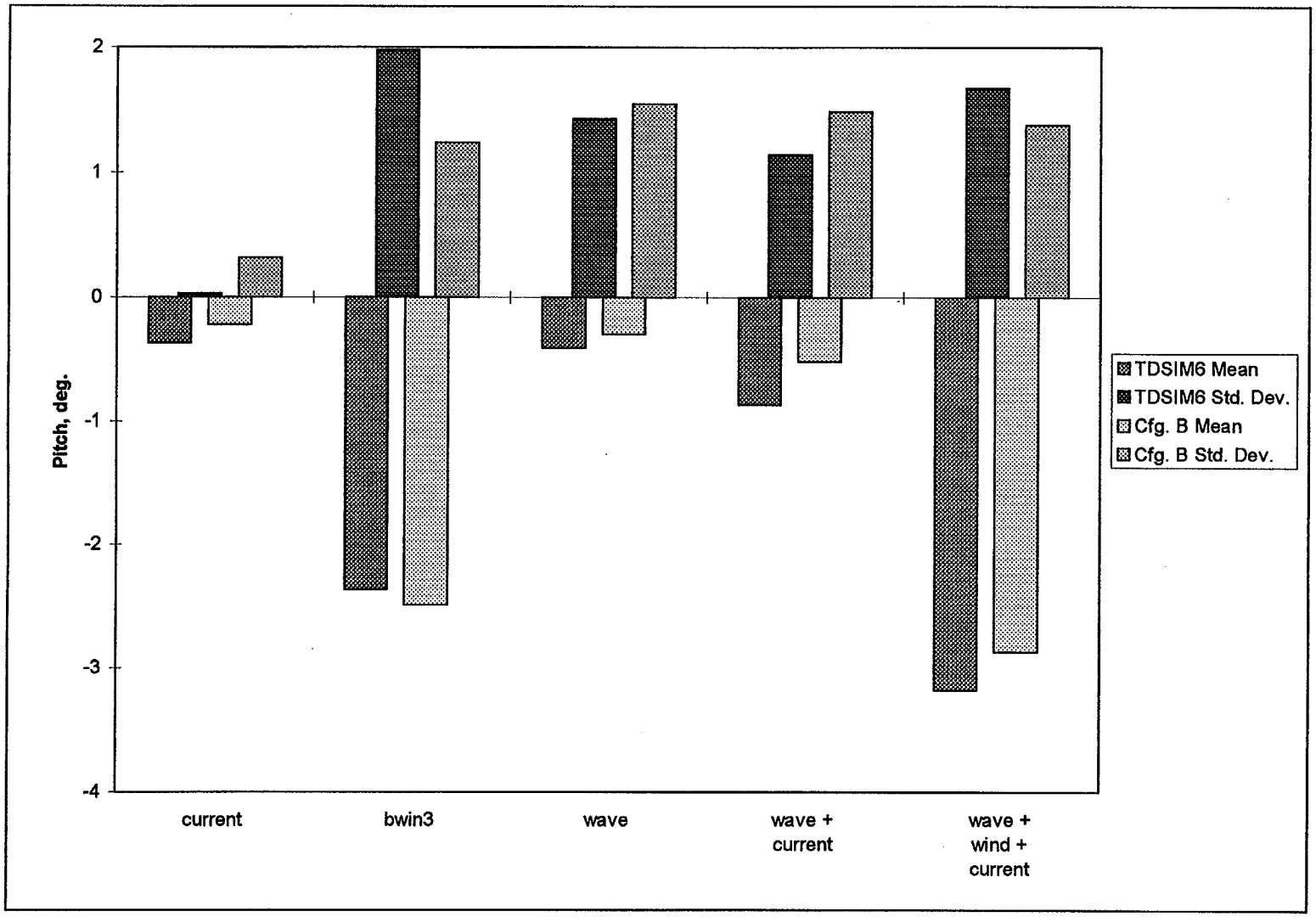


Figure 4-11 Comparison of Pitch Motions, Configuration B, 100 Year GOM Storm

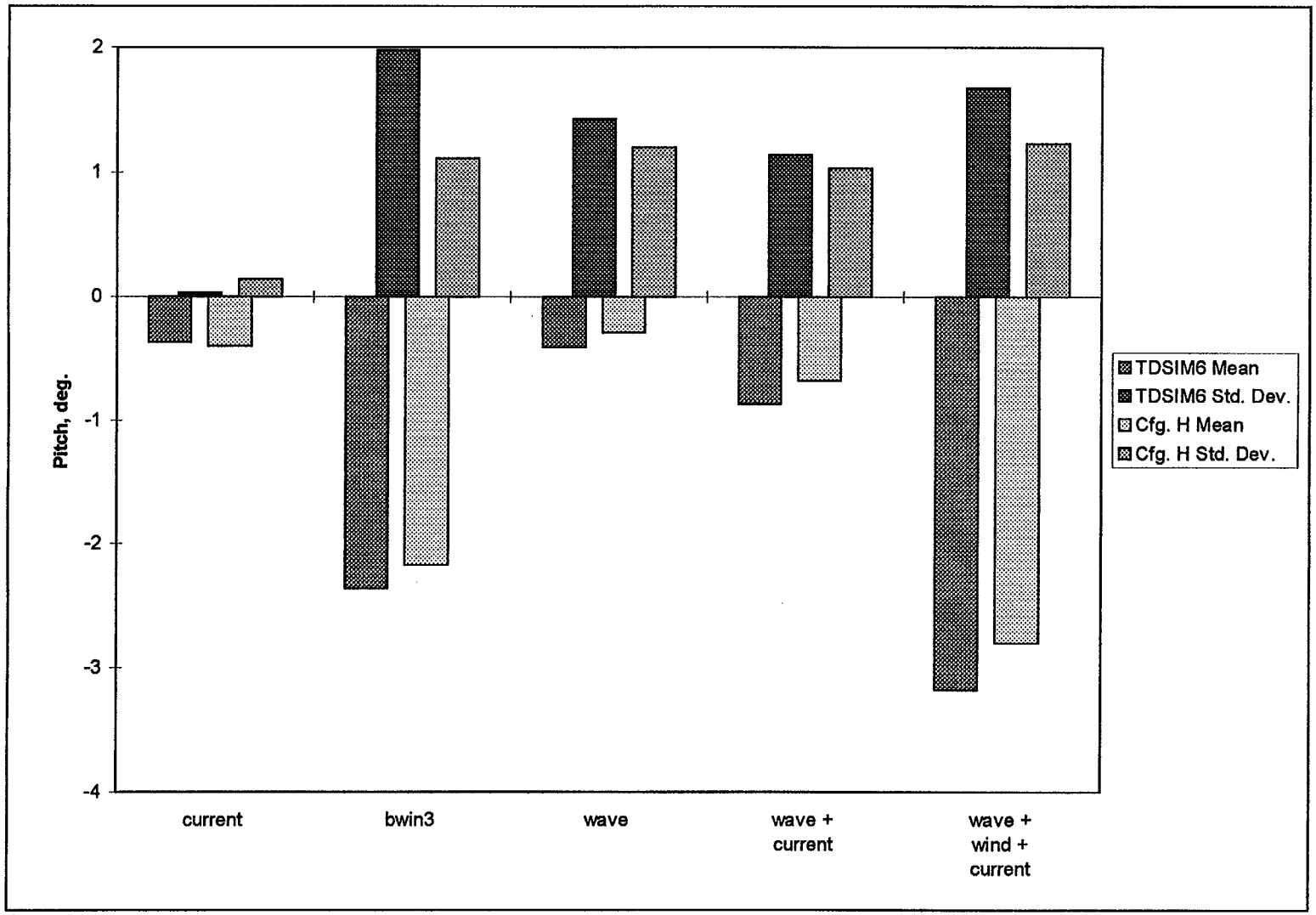


Figure 4-12 Pitch Comparison, Configuration H, 100 Year GOM Storm

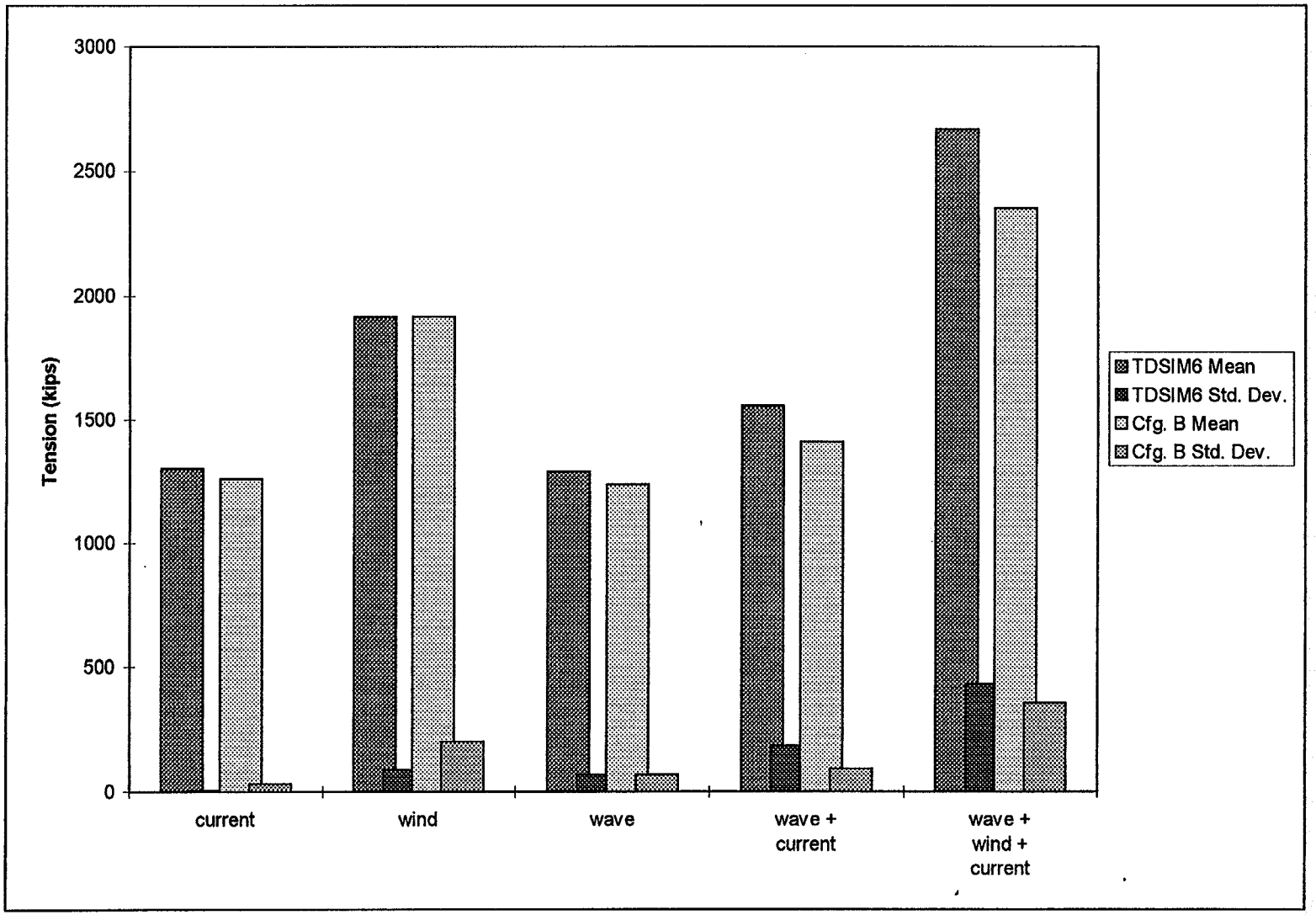


Figure 4-13 Comparison of Tension, Configuration B, 100 Year GOM Storm

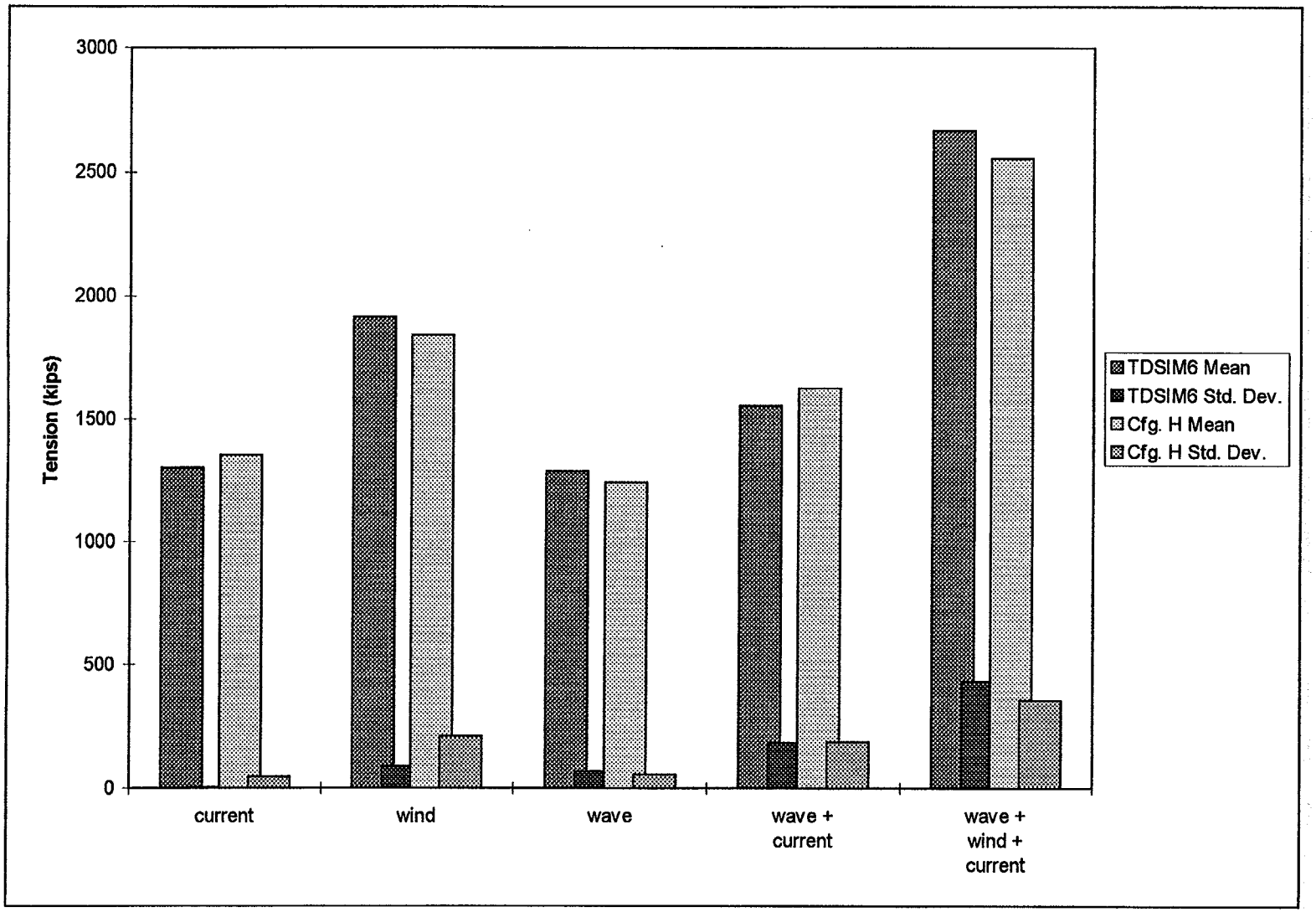
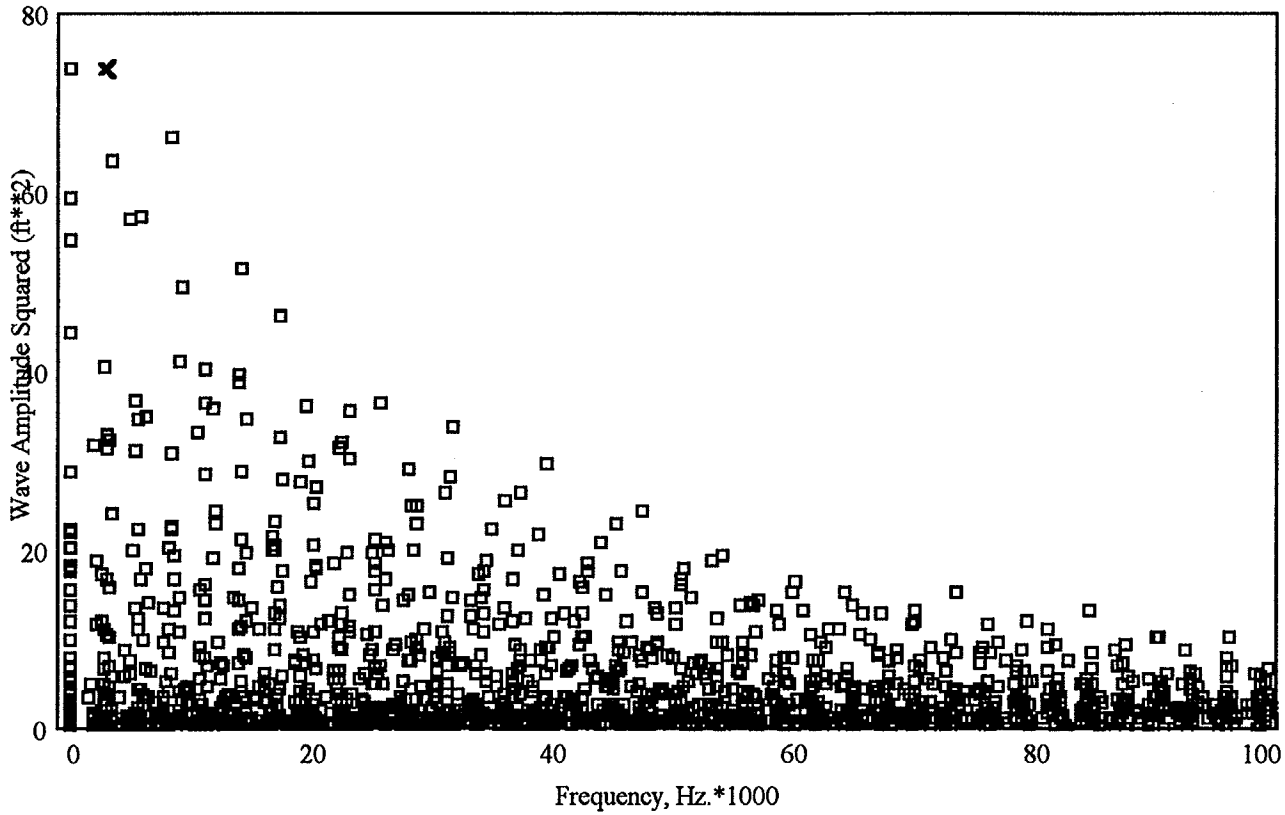
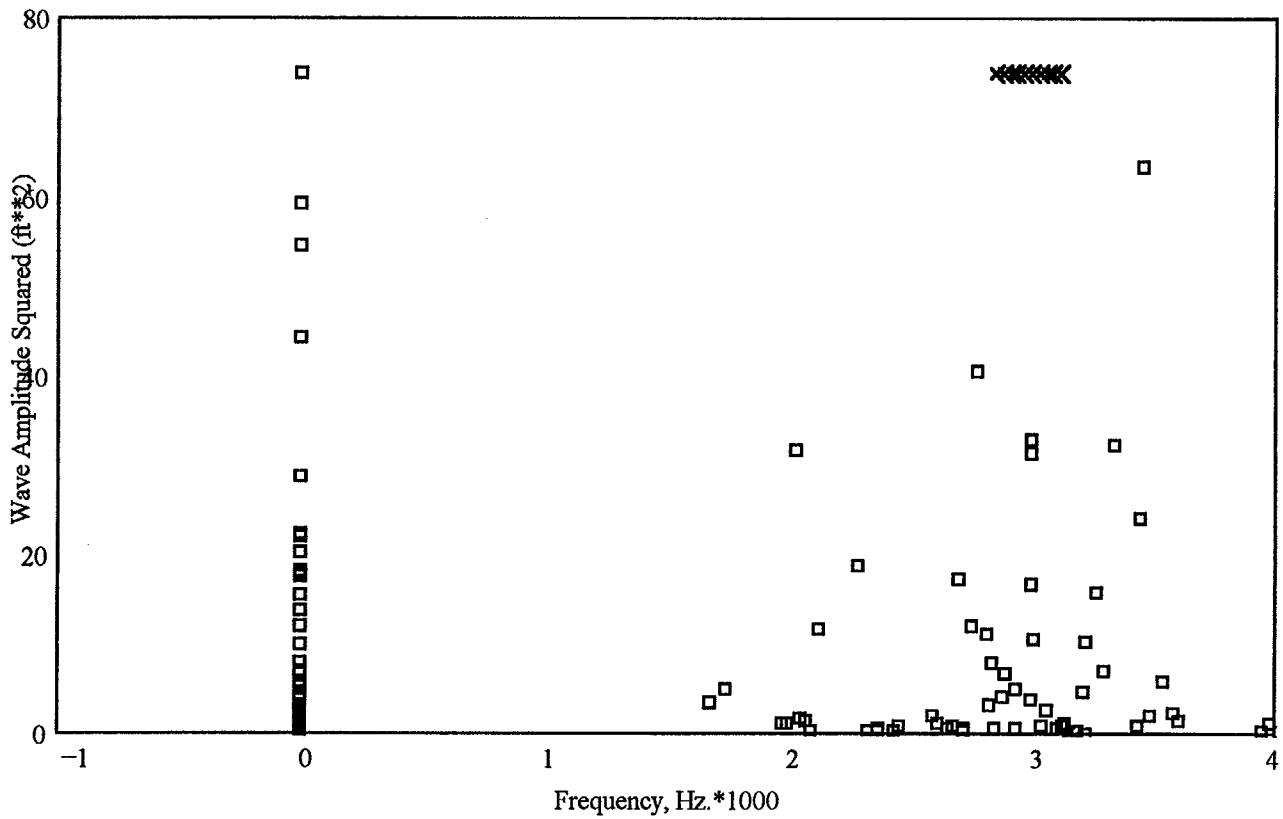


Figure 4-14 Comparison of Tensions, Configuration H, 100 Year GOM Storm



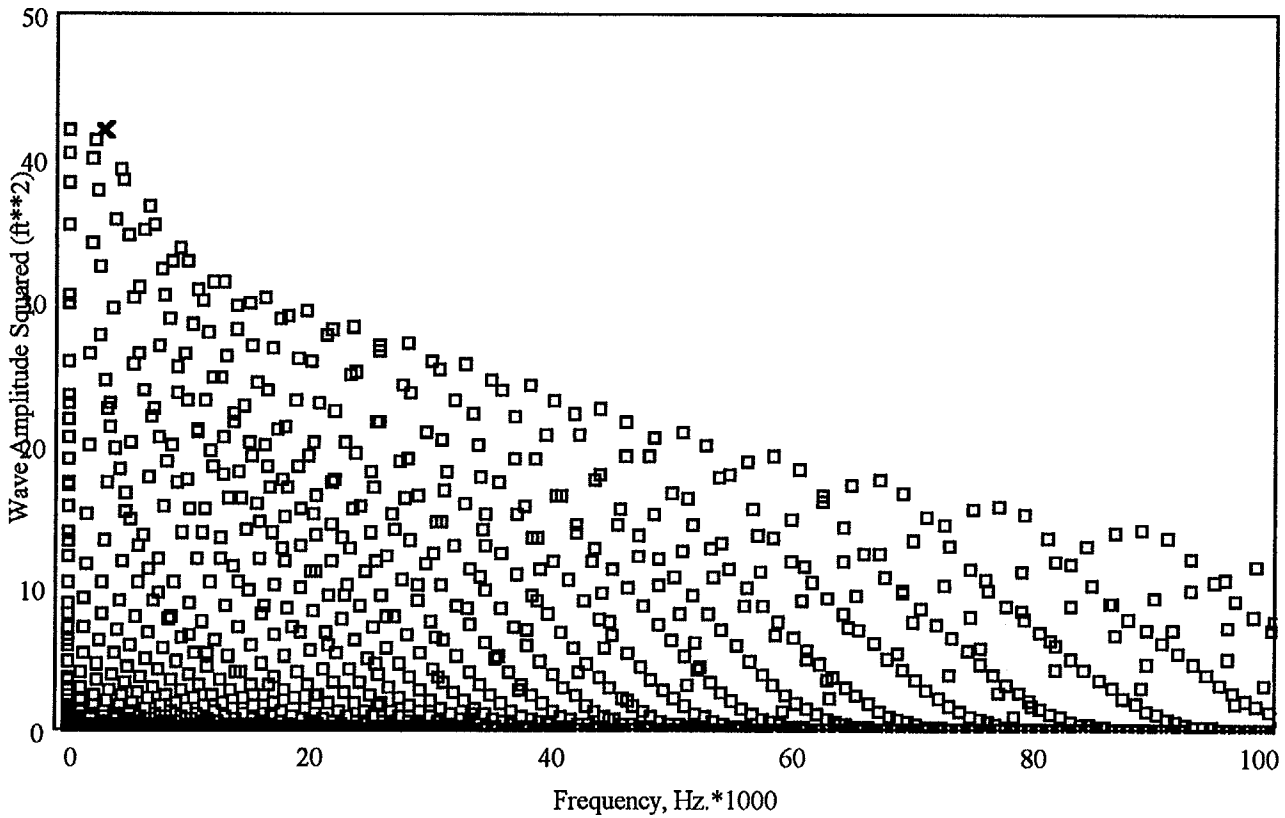
fnat ≡ .003

Figure 4-15 Wave Amplitude Products vs. Difference Frequency, N=60, "Equal" freq. (ARAN5)



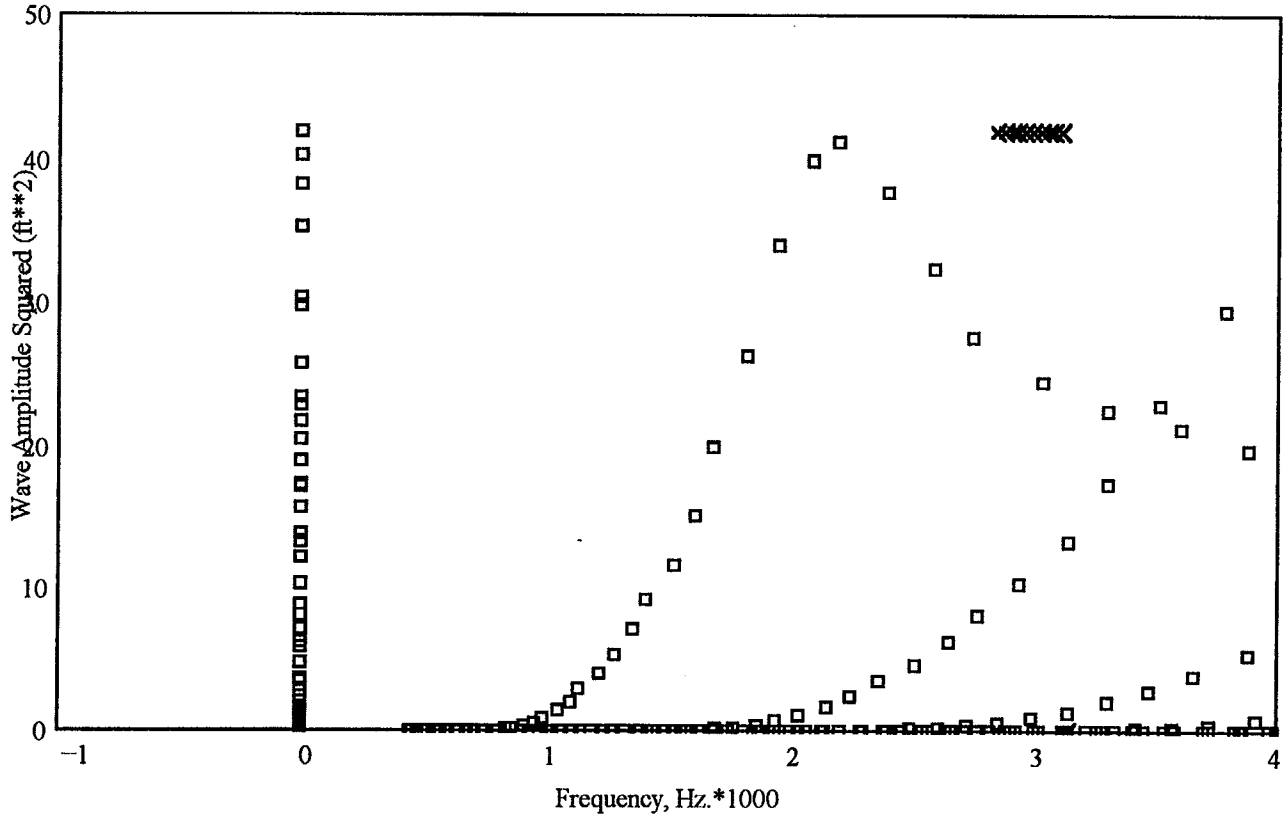
fnat ≡ .003

Figure 4-16 Wave Amplitude Products (zoomed) N=60, "Equal" freq. (ARAN5)



fnat ≡ .003

Figure 4-17 Wave Amplitude Products, N=60, Equal Period spacing (ARAN5)



fnat ≡ .003

Figure 4-18 Wave Amplitude Products (zoomed), N=60, Equal Period spacing, (ARAN5)

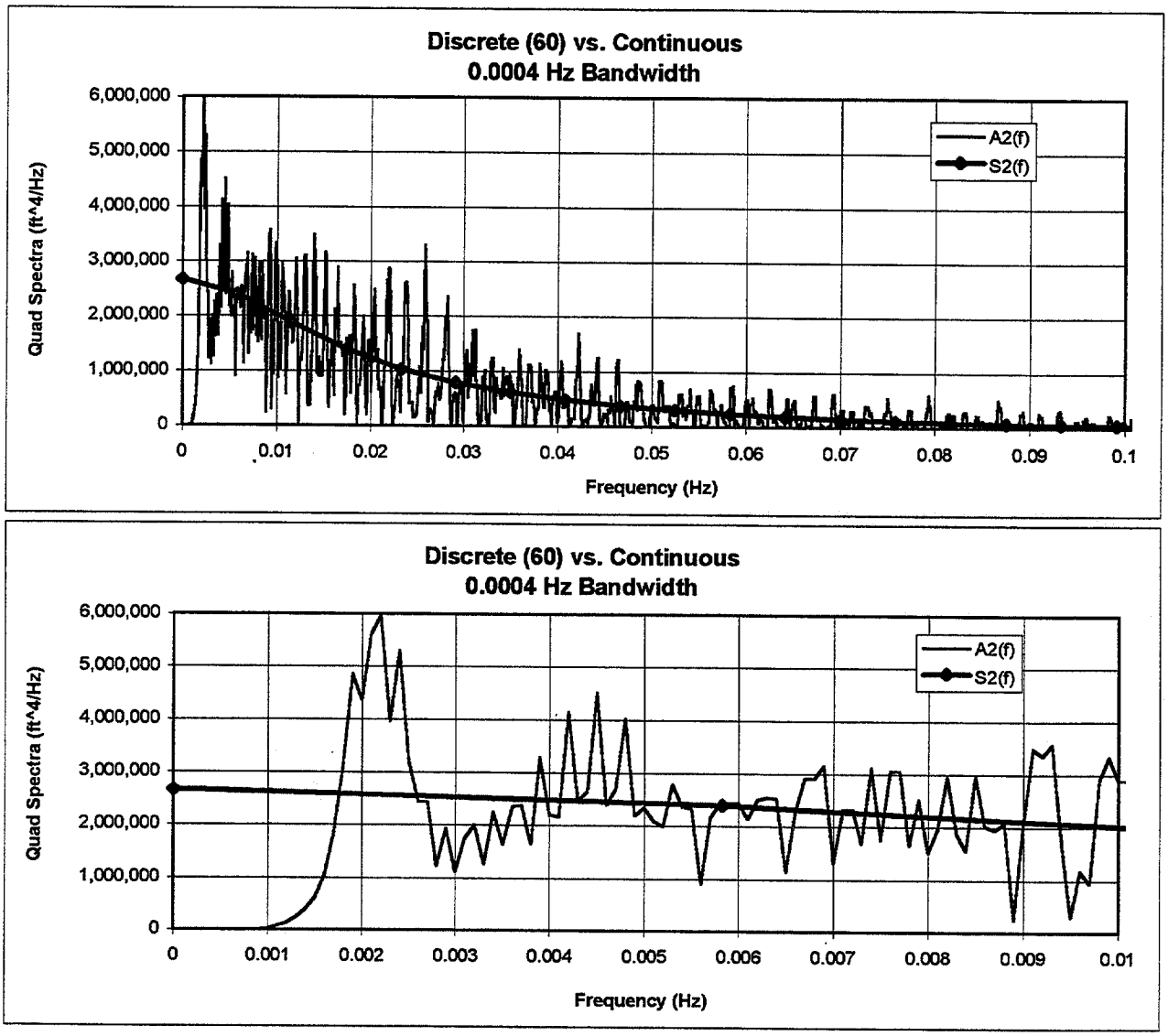


Figure 4-19 Discrete vs. Continuous Spectrum, 60 waves, .0004 Hz. Bandwidth

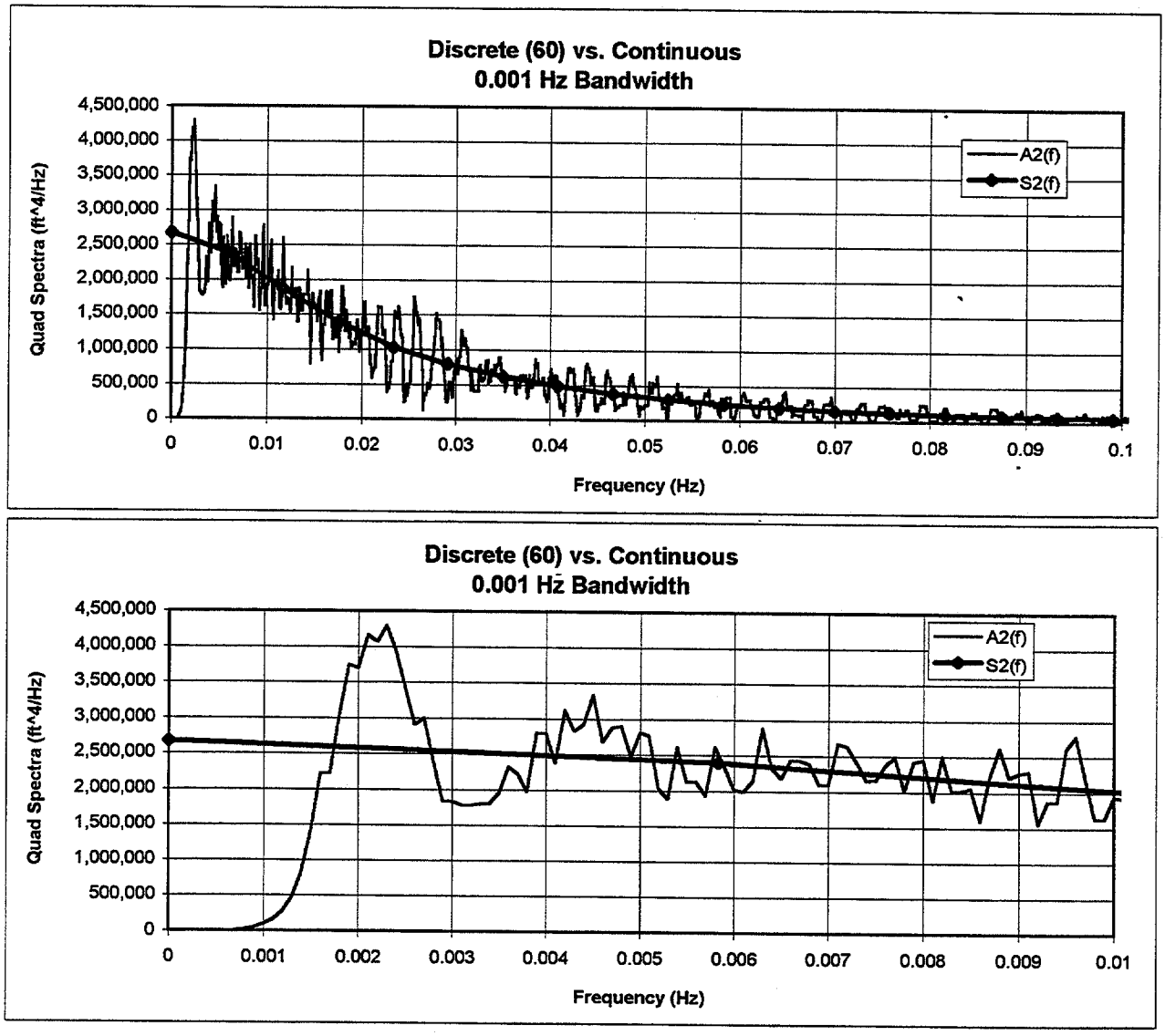


Figure 4-20 Discrete vs. Continuous Spectrum, 60 waves, .001 Hz. Bandwidth

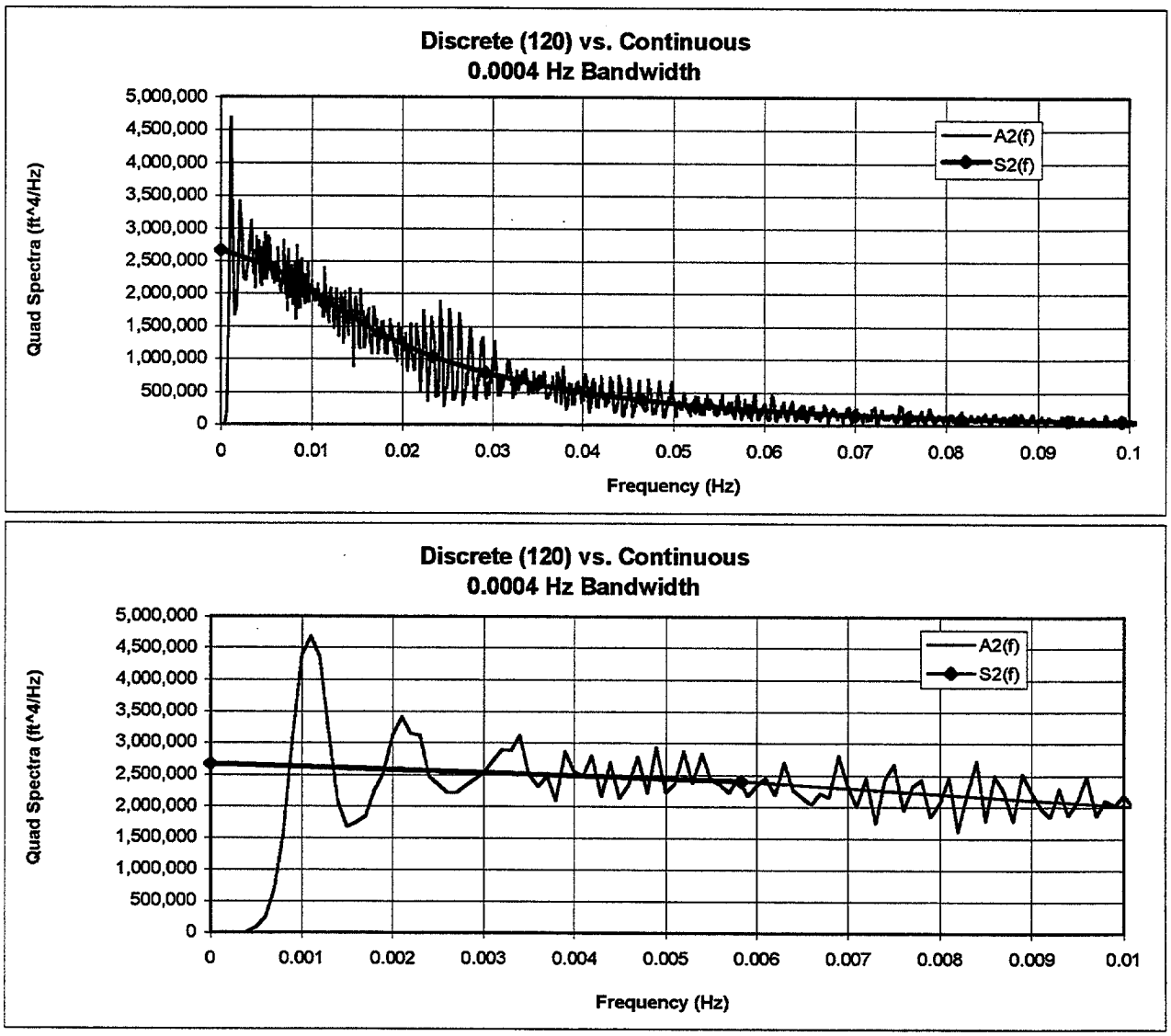


Figure 4-21 Discrete vs. Continuous Spectrum, 120 waves, .0004 Hz. Bandwidth

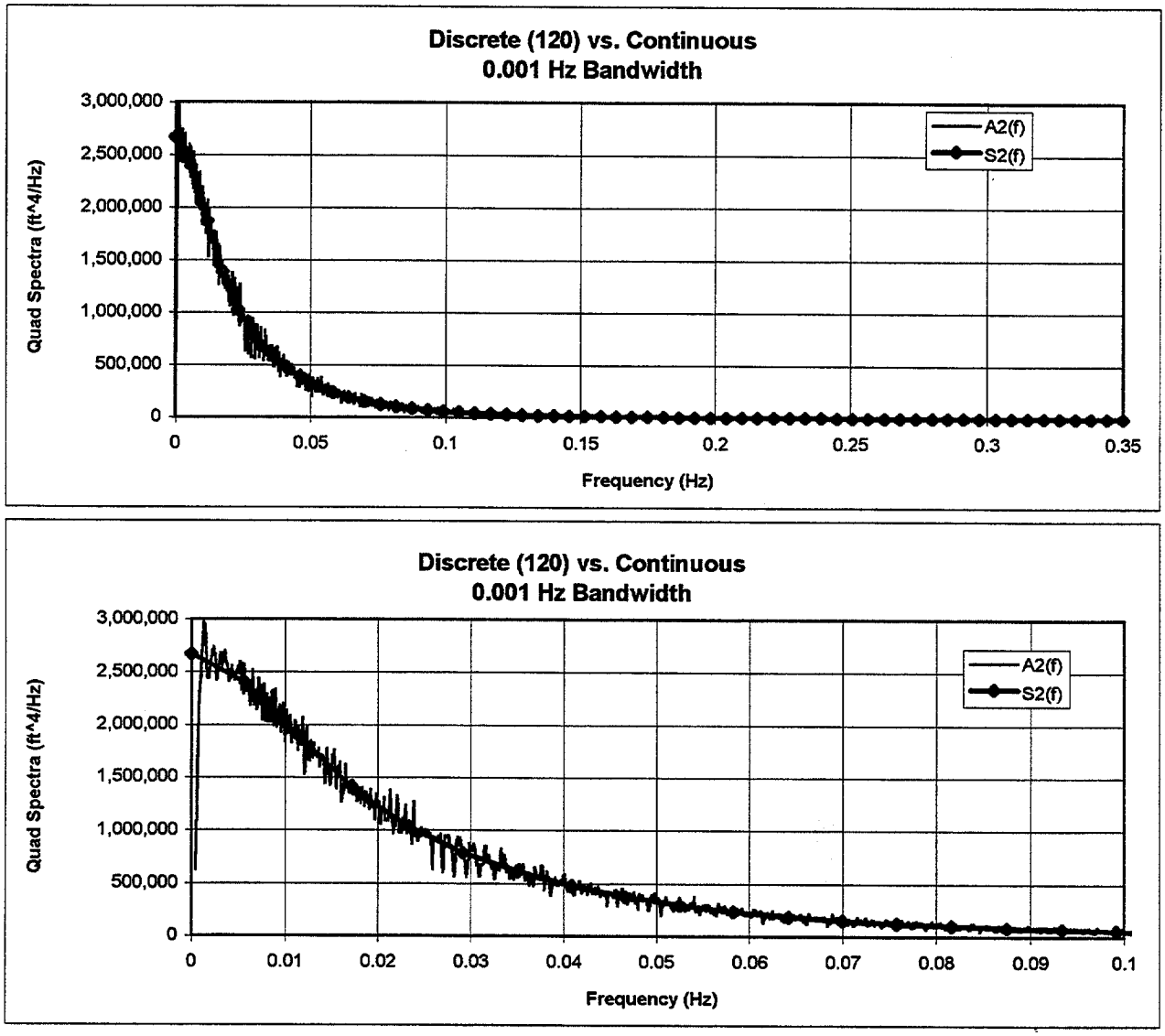


Figure 4-22 Discrete vs. Continuous Spectrum, 120 waves, .001 Hz. Bandwidth

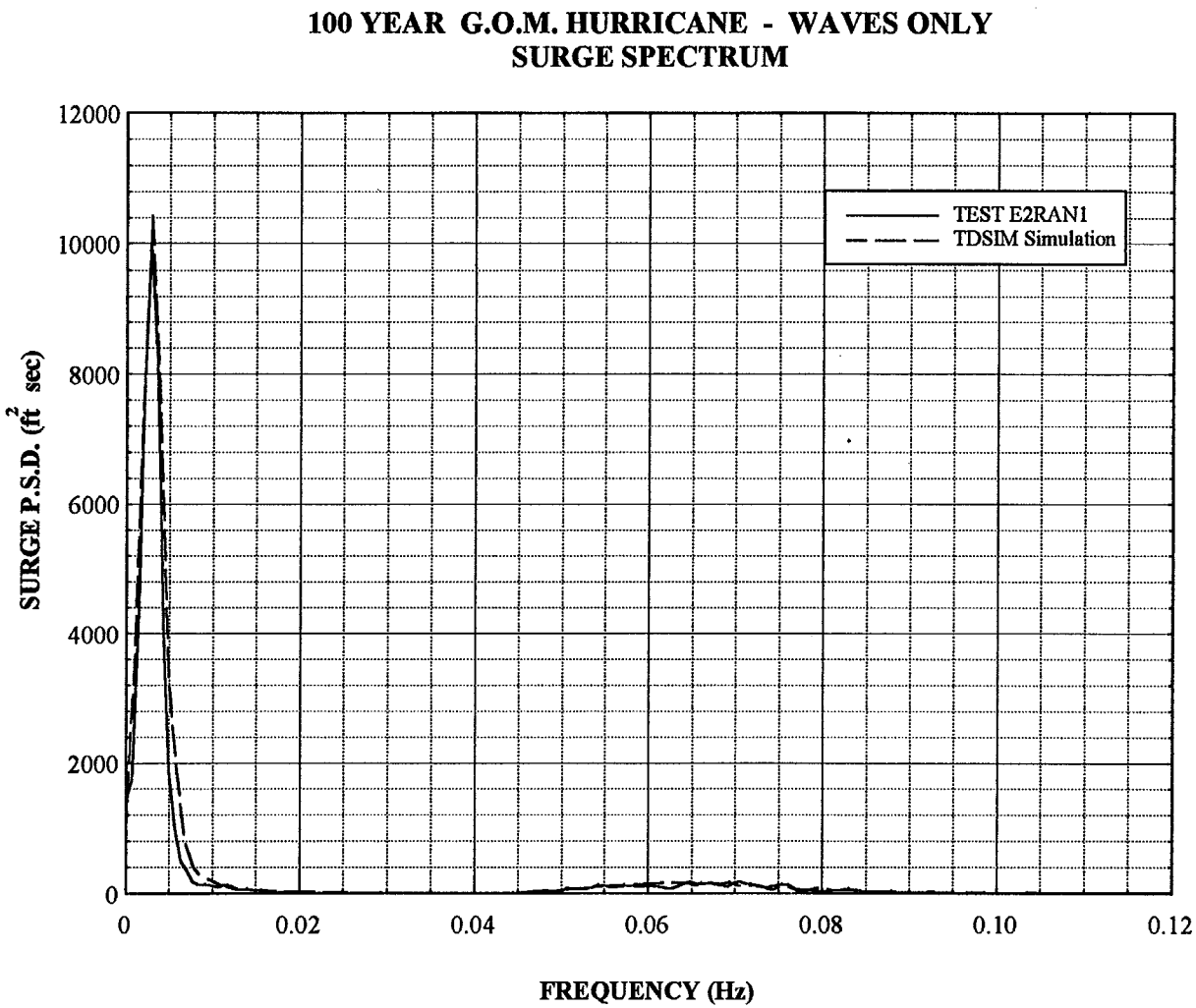


Figure 4-23 Surge Spectrum Comparison, Waves Only (Oryx Graph 4.2)

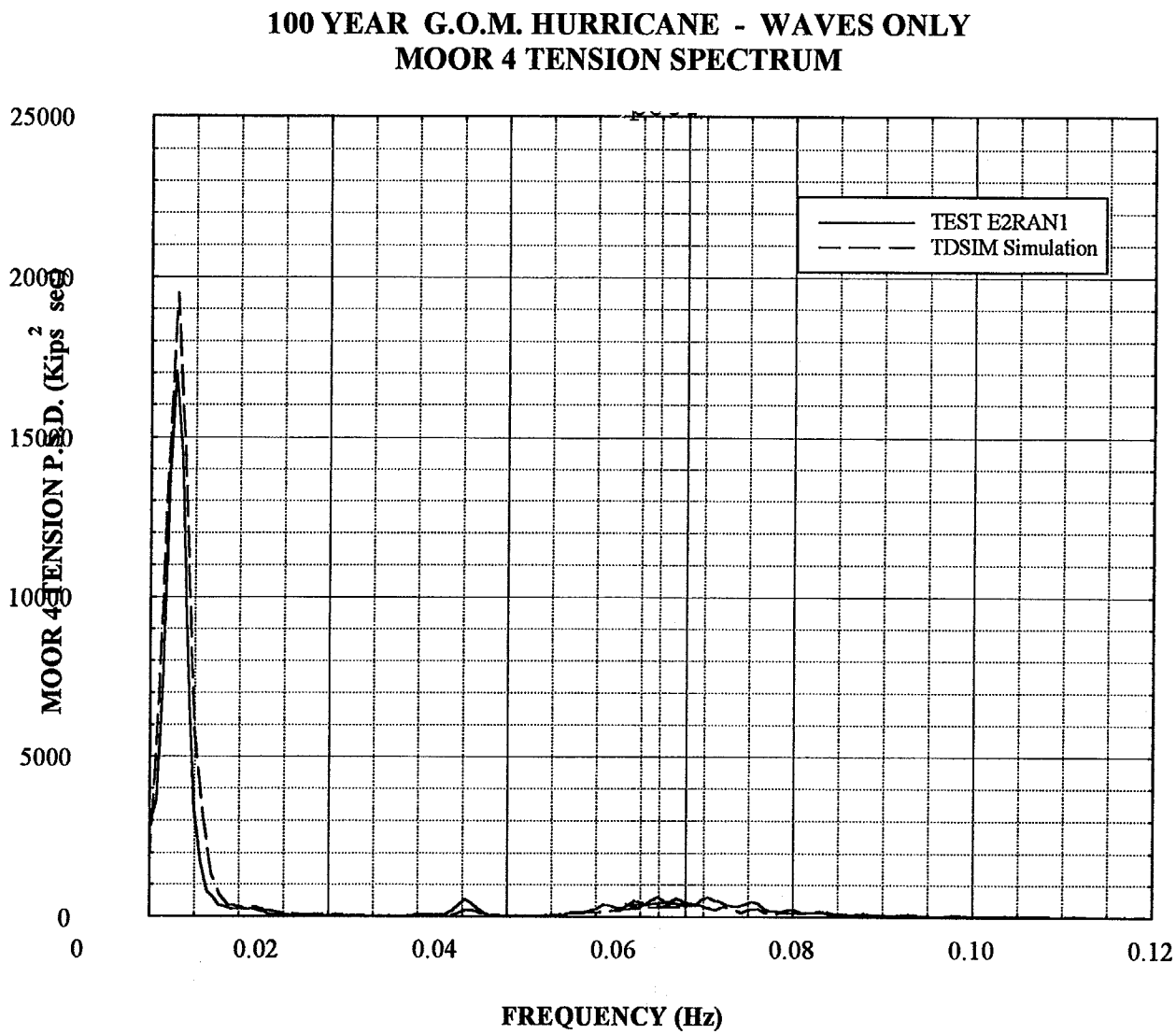


Figure 4-24 Upstream Tension Spectrum Comparison, Waves Only (ORYX Graph 4.3)

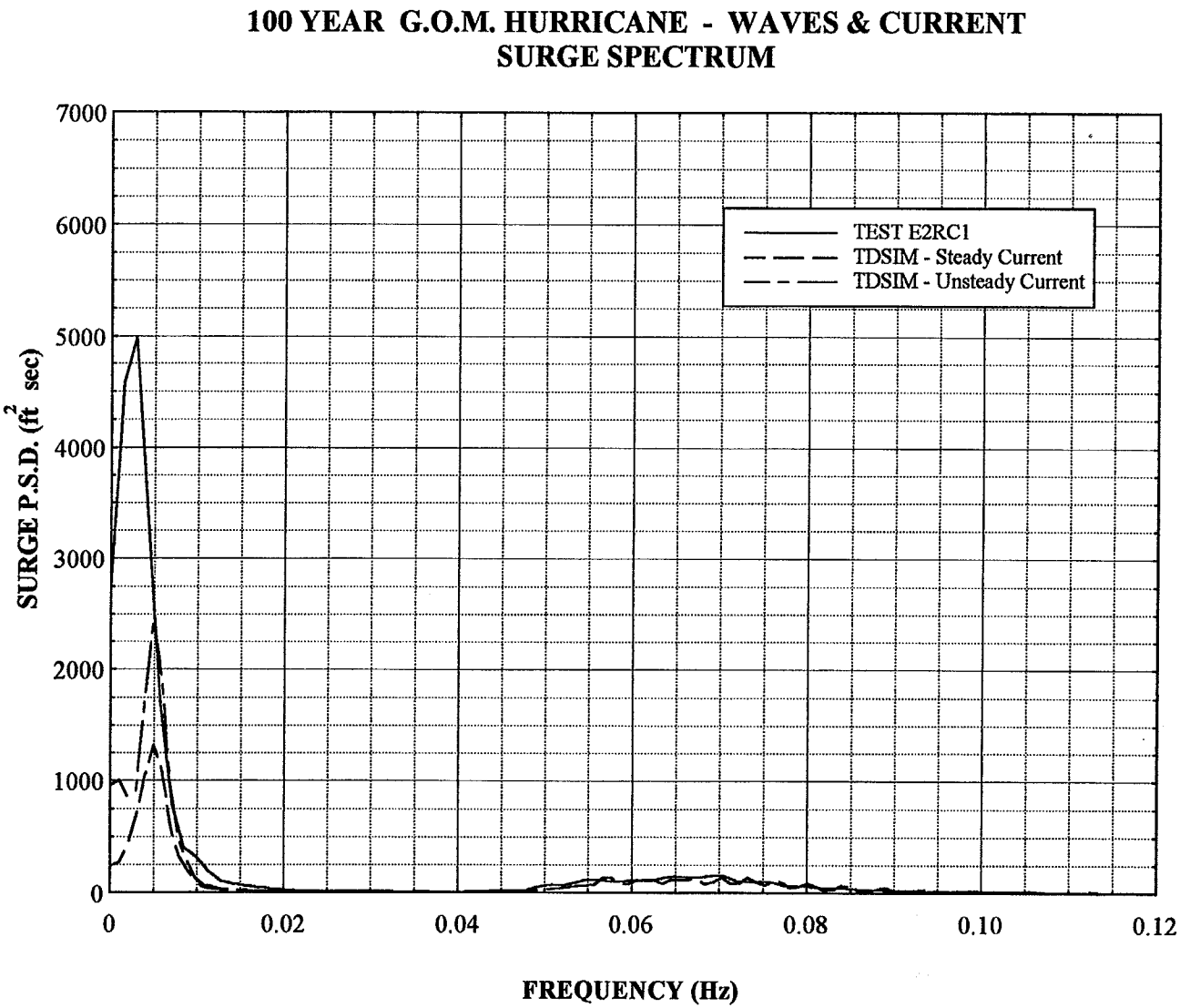


Figure 4-25 Surge Spectrum Comparison, Waves & Current (ORYX Graph 4.4)

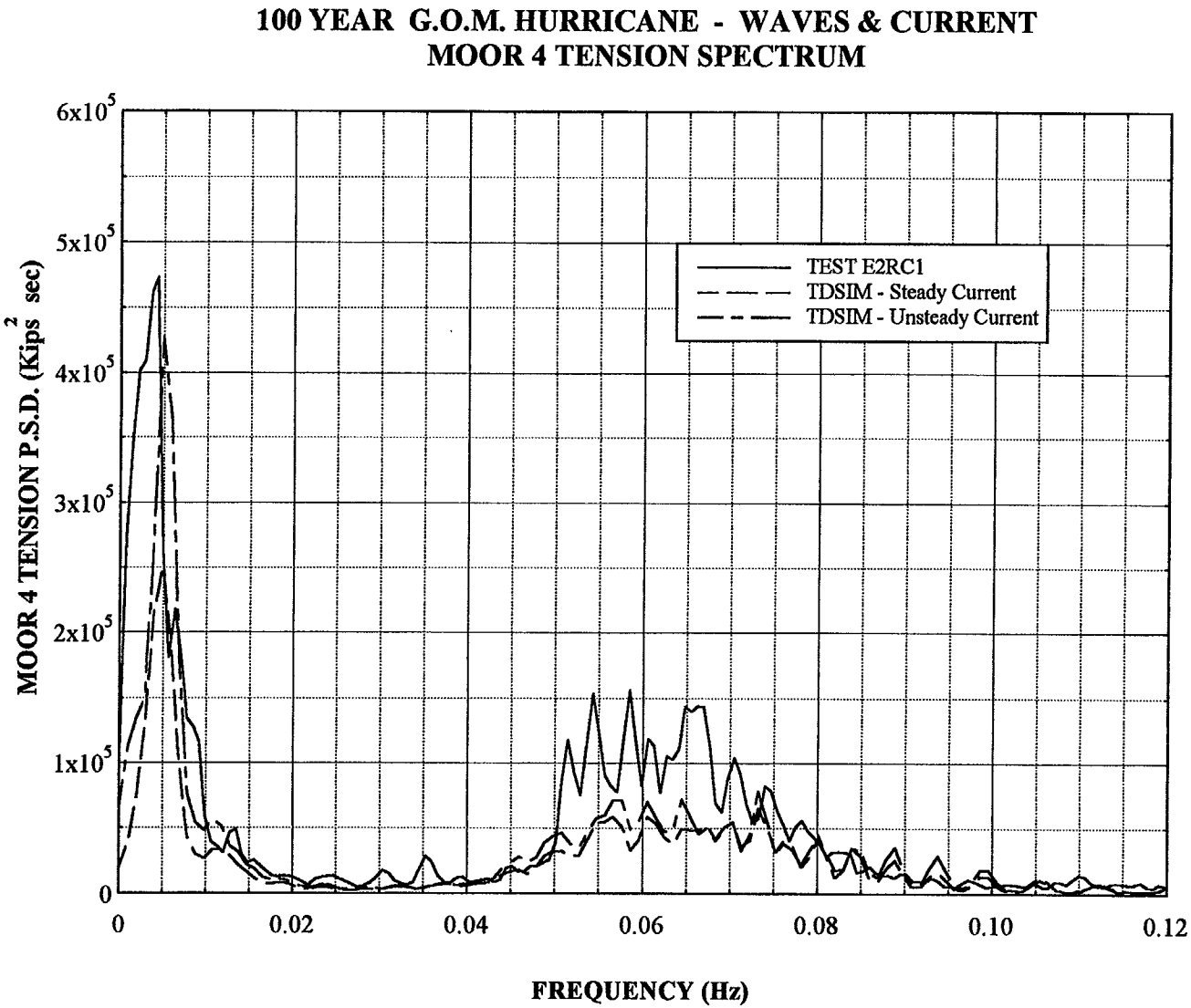


Figure 4-26 Upstream Tension Comparison, Waves & Current (ORYX Graph 4.5)

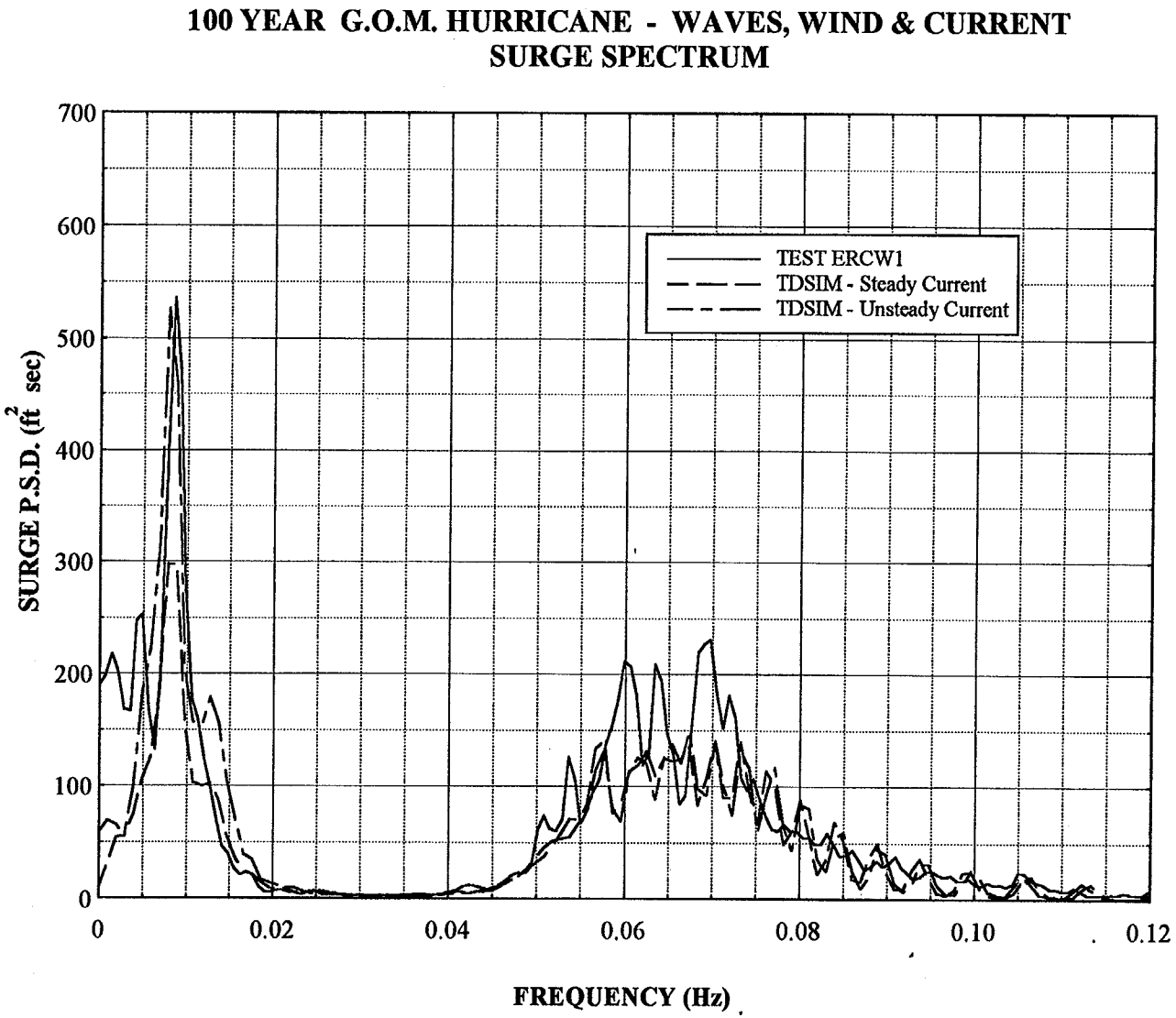


Figure 4-27 Surge Spectrum Comparison, Waves, Wind & Current (ORYX Graph 4.6)

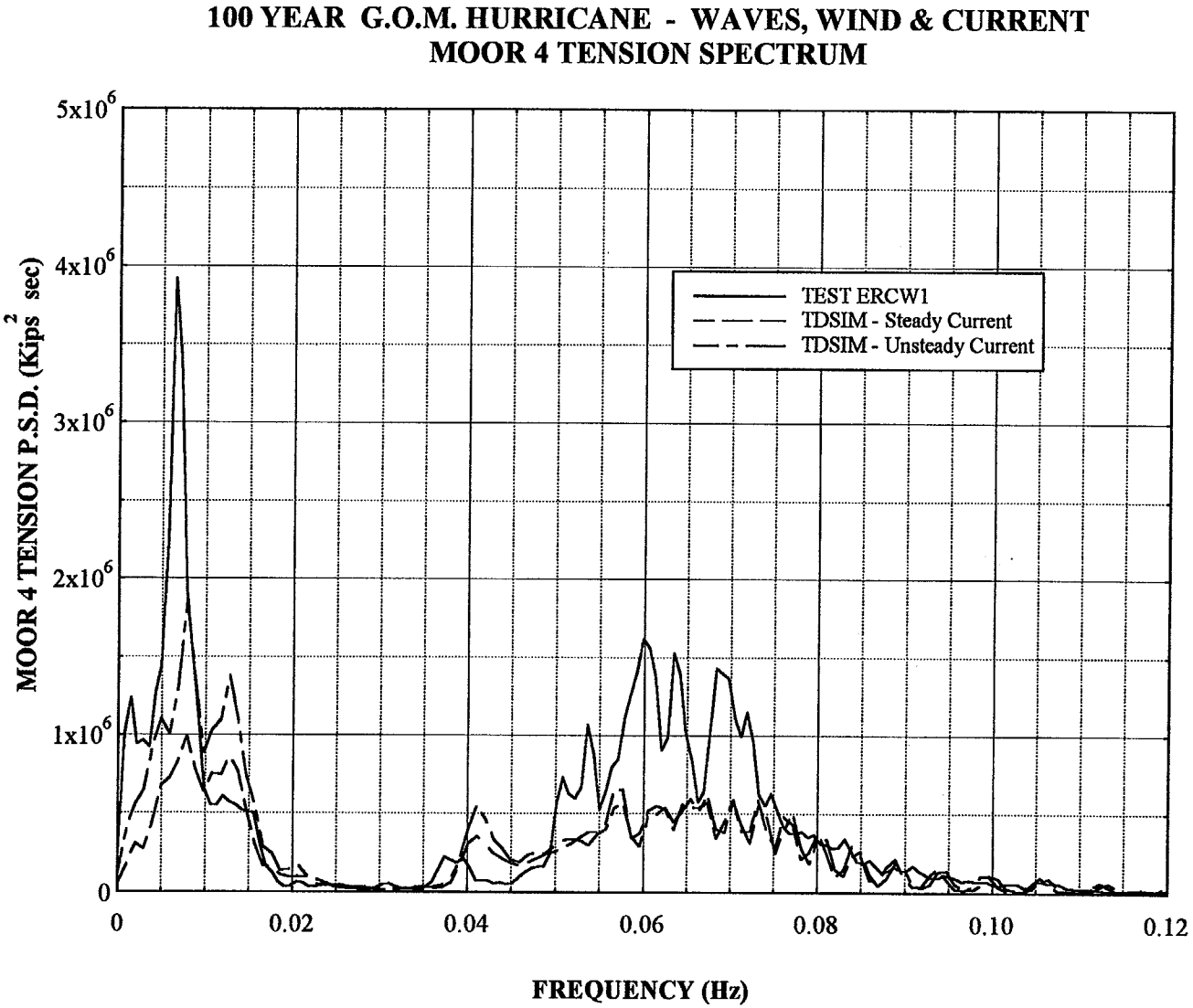


Figure 4-28 Upstream Tension Comparison, Waves, Wind & Current (ORYX 4.7)

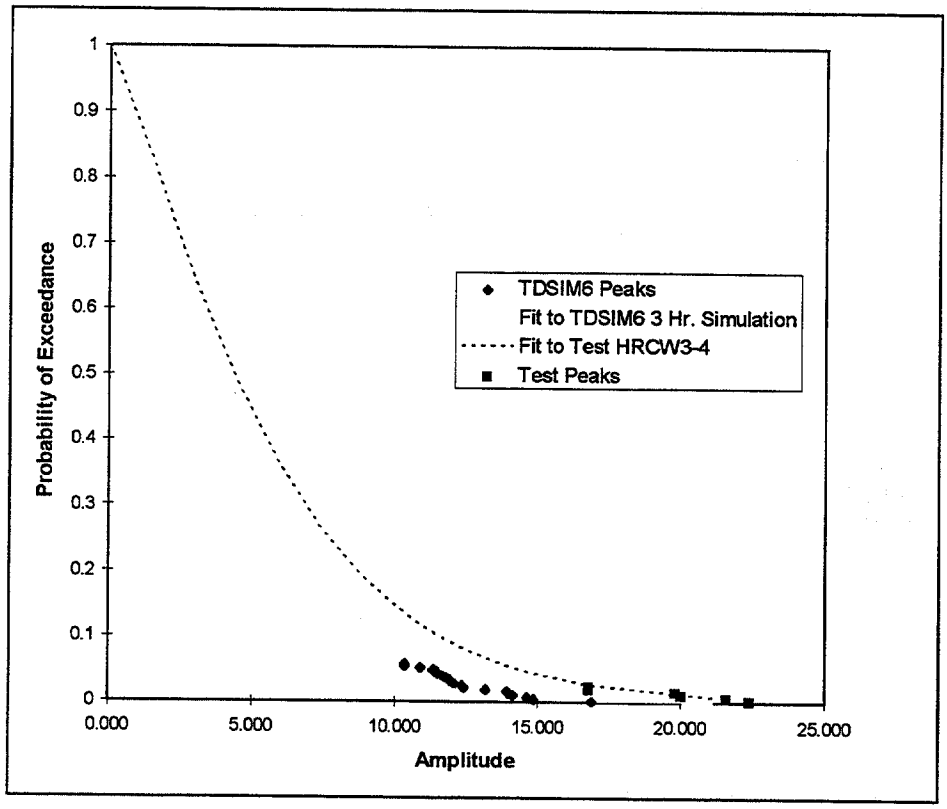


Figure 4-29 Probability of Exceedance, Surge at CG

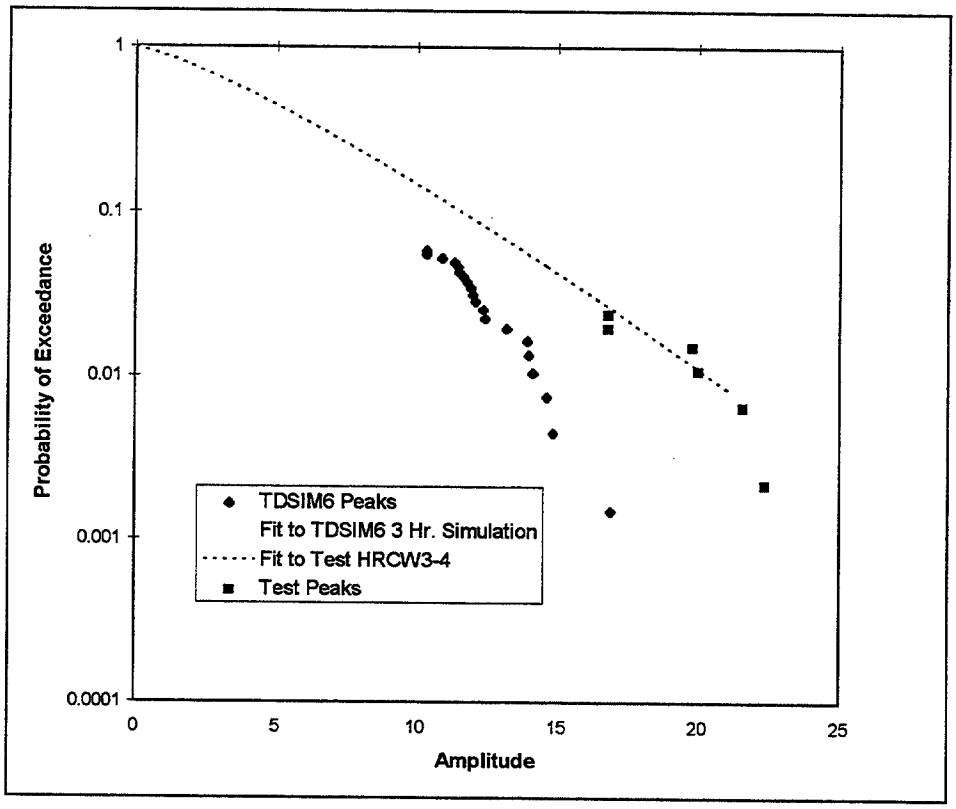


Figure 4-30 Probability of Exceedance, Surge at CG (log scale)

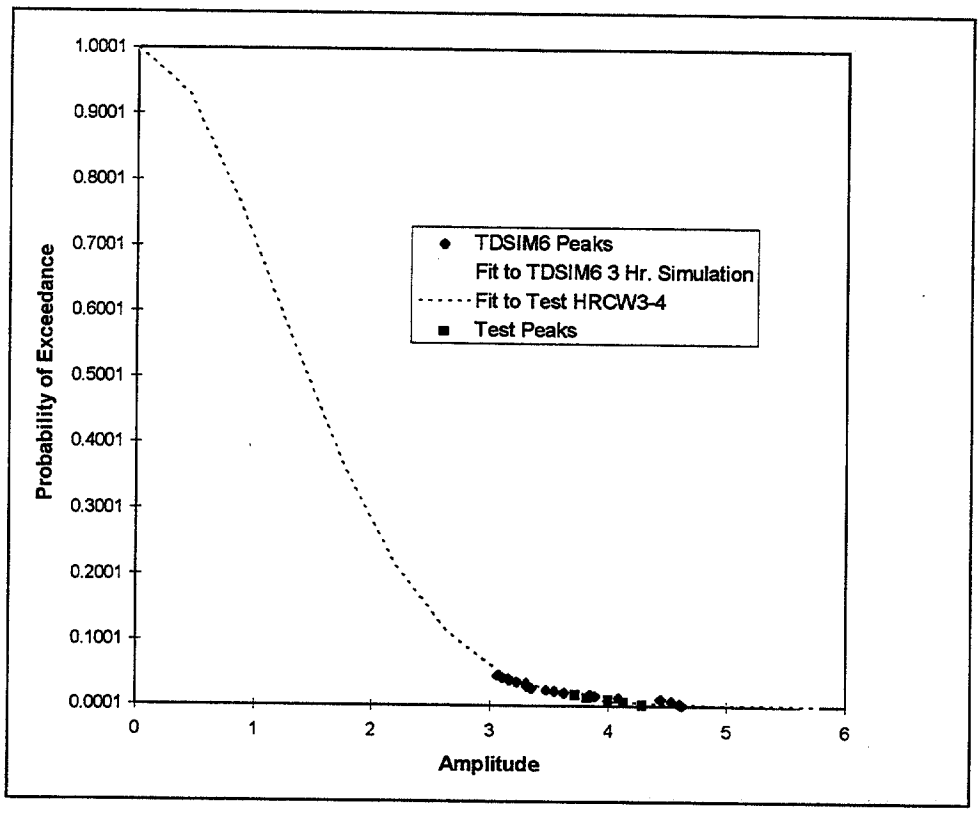


Figure 4-31 Probability of Exceedance, Pitch

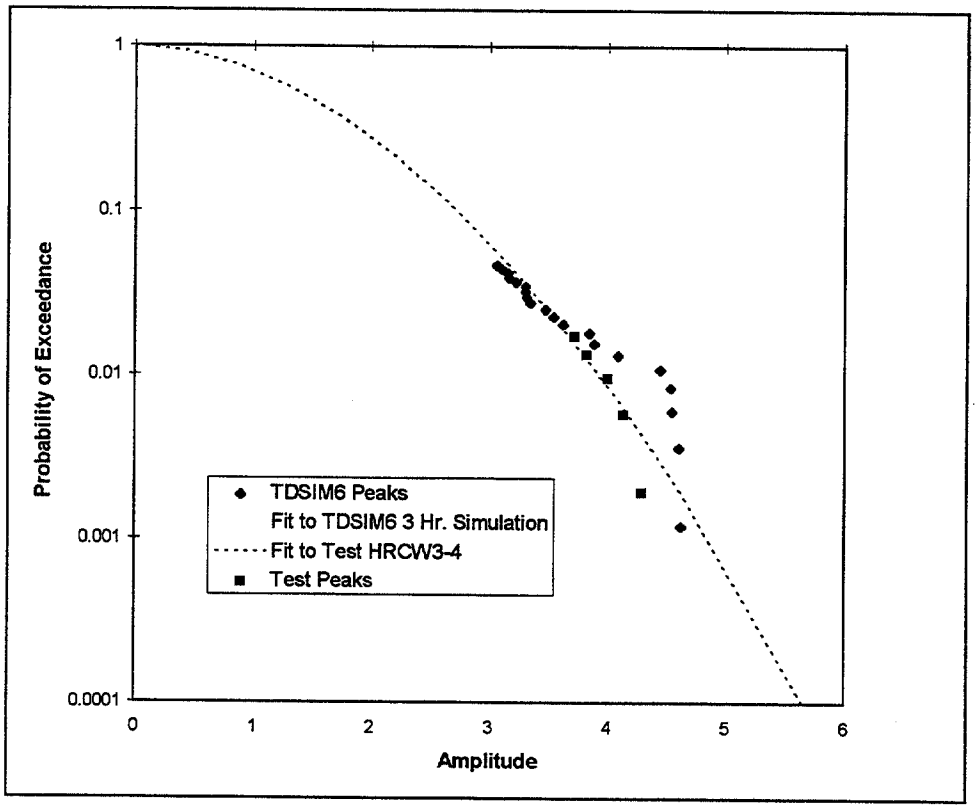


Figure 4-32 Probability of Exceedance, Pitch (Log Scale)

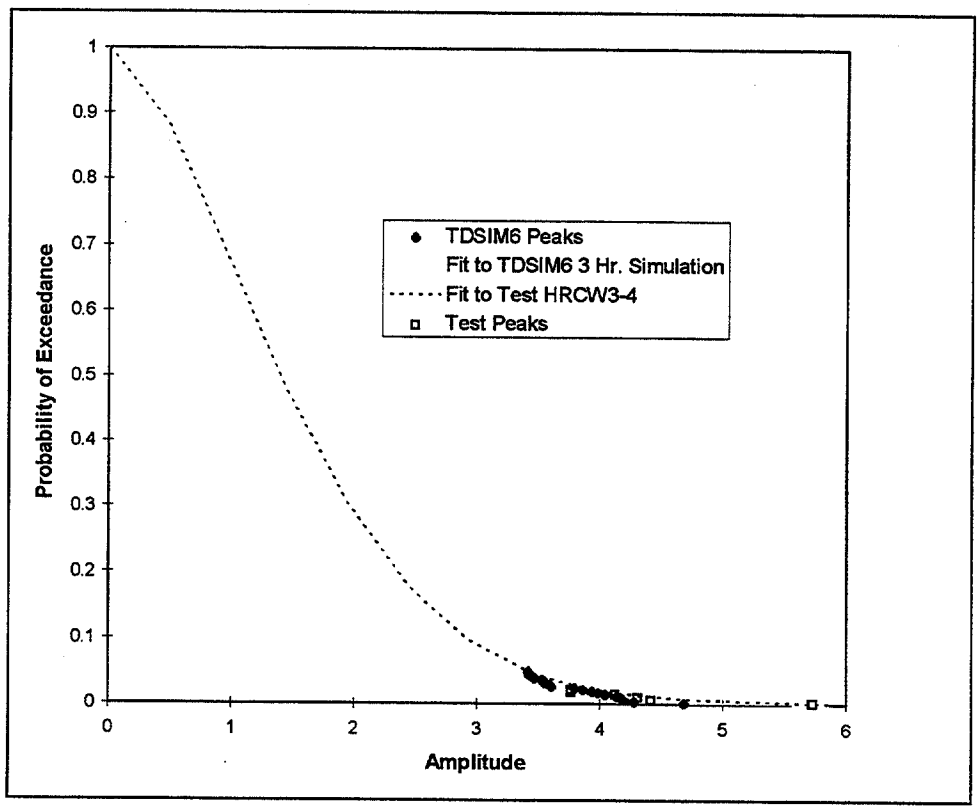


Figure 4-33 Probability of Exceedance, Heave Crest

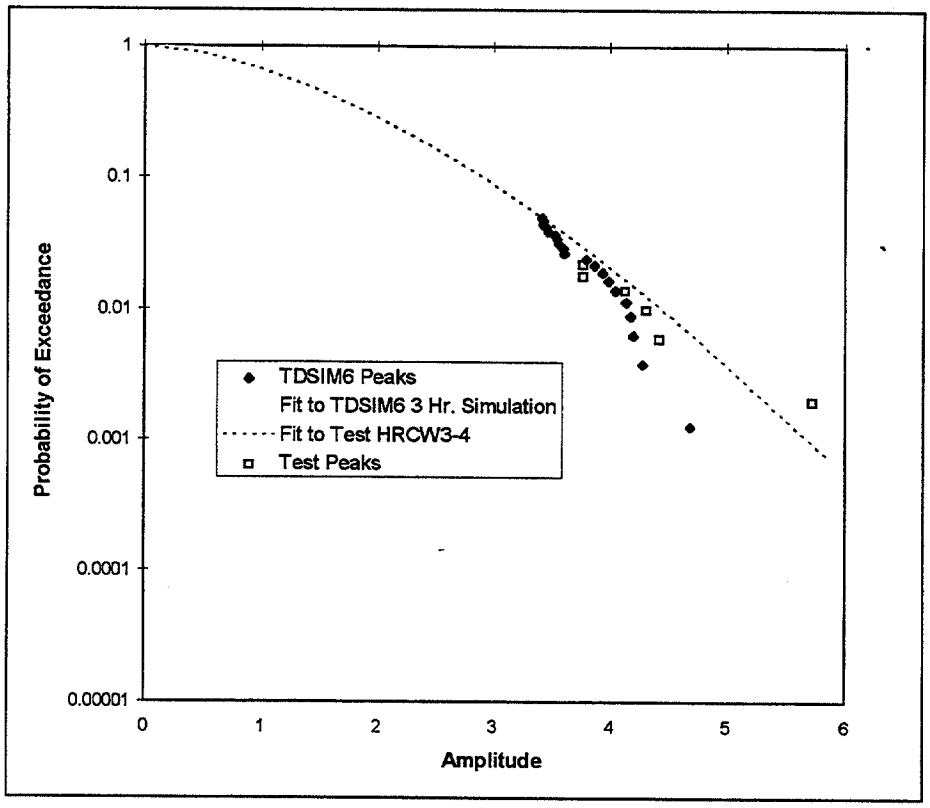


Figure 4-34 Probability of Exceedance, Heave (Log Scale)

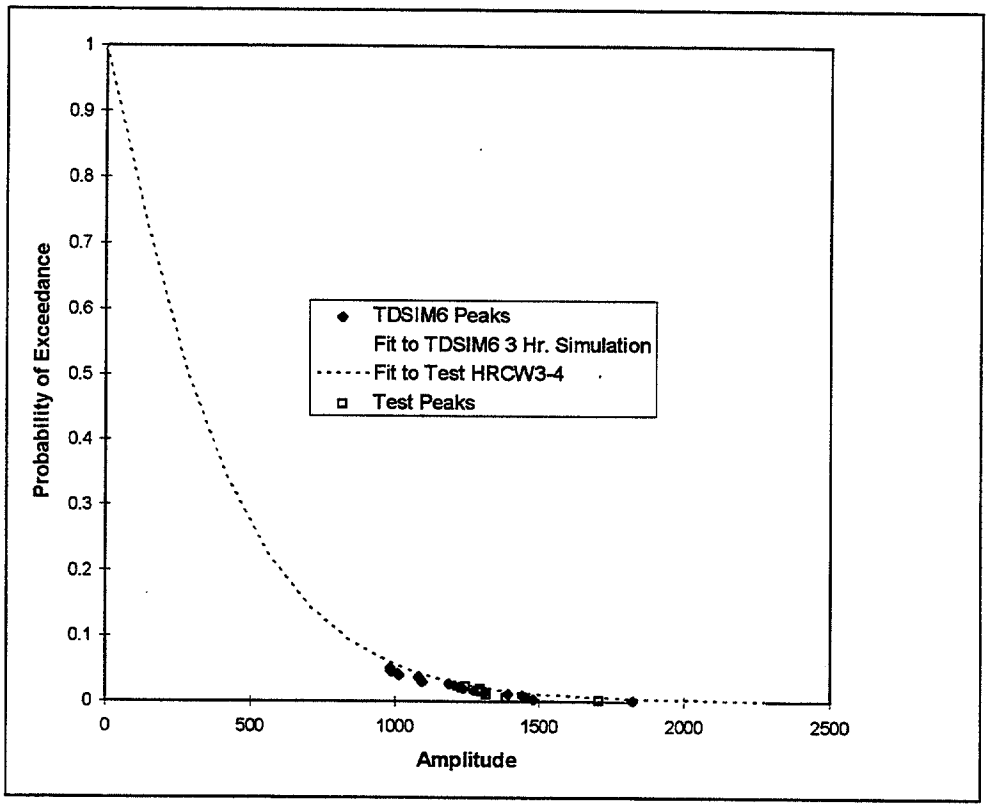


Figure 4-35 Probability of Exceedance, Tension

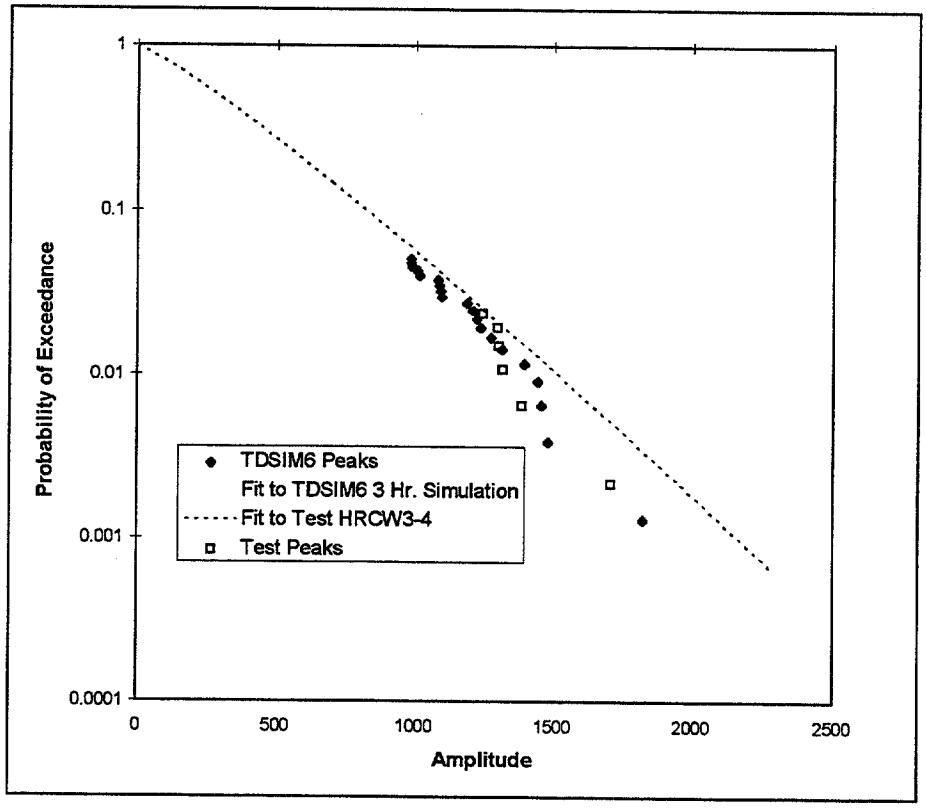


Figure 4-36 Probability of Exceedance, Tension (Log Scale)

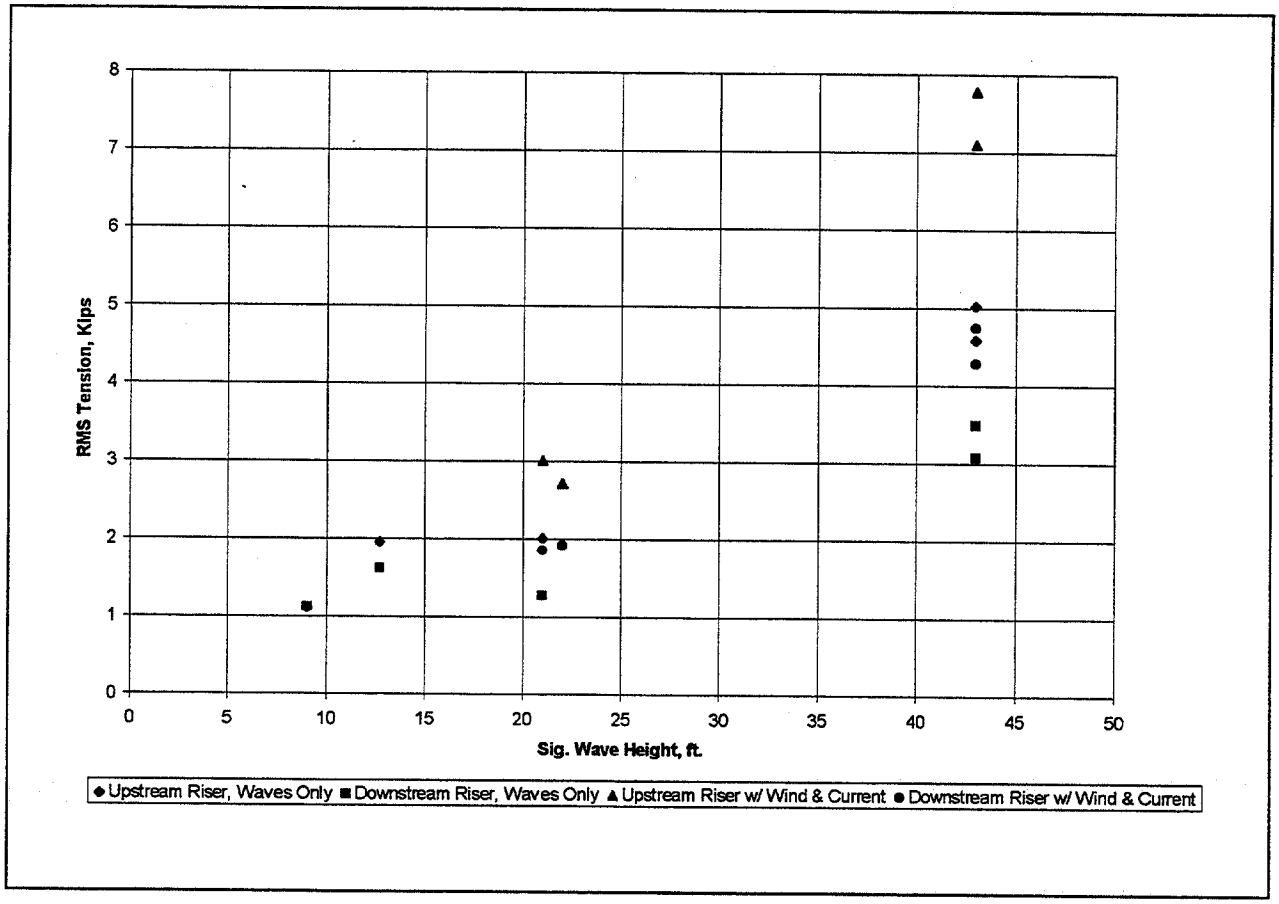


Figure 4-37 RMS Tension in Risers

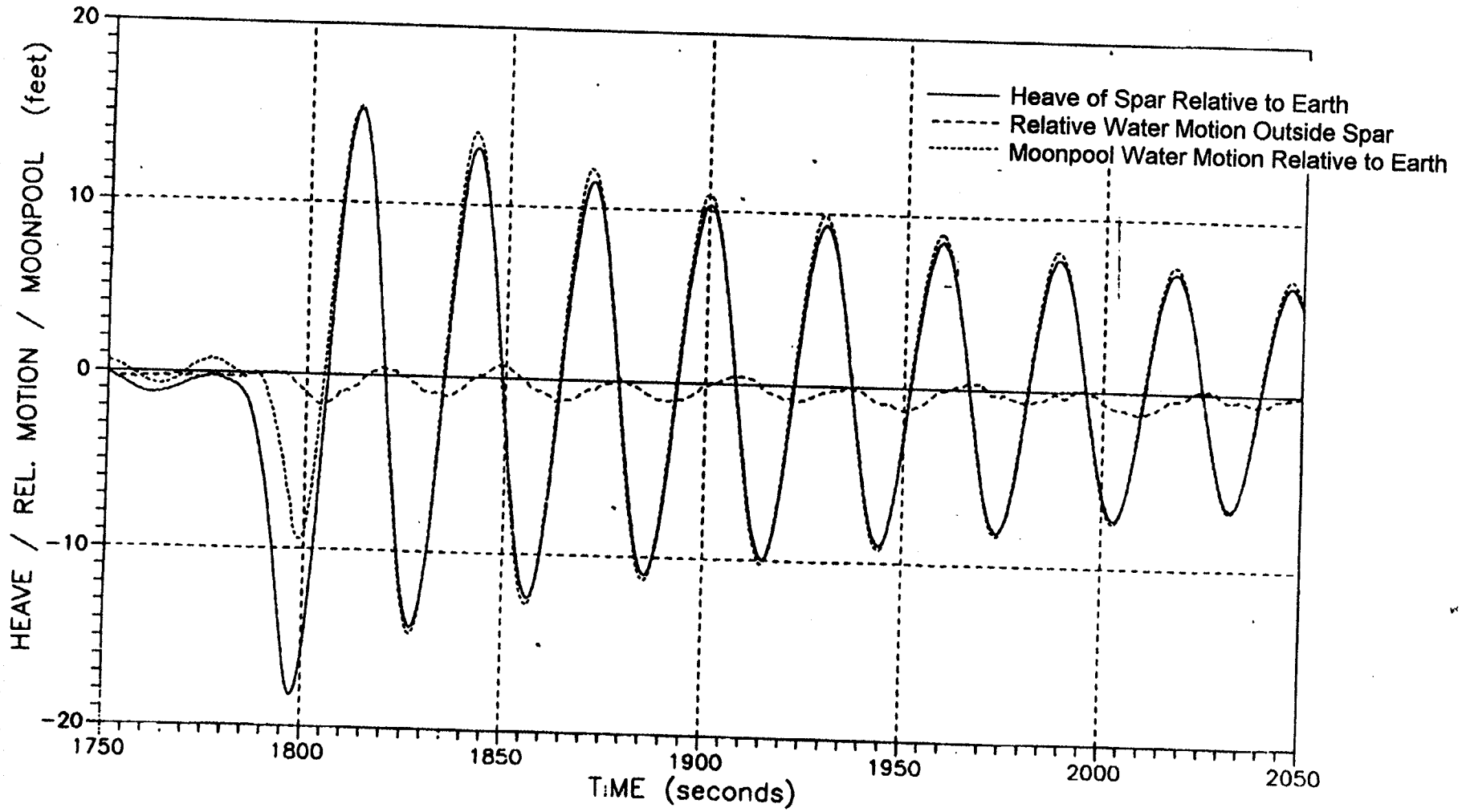


Figure 4-38 Centerwell Water Motion for Free Oscillation Test

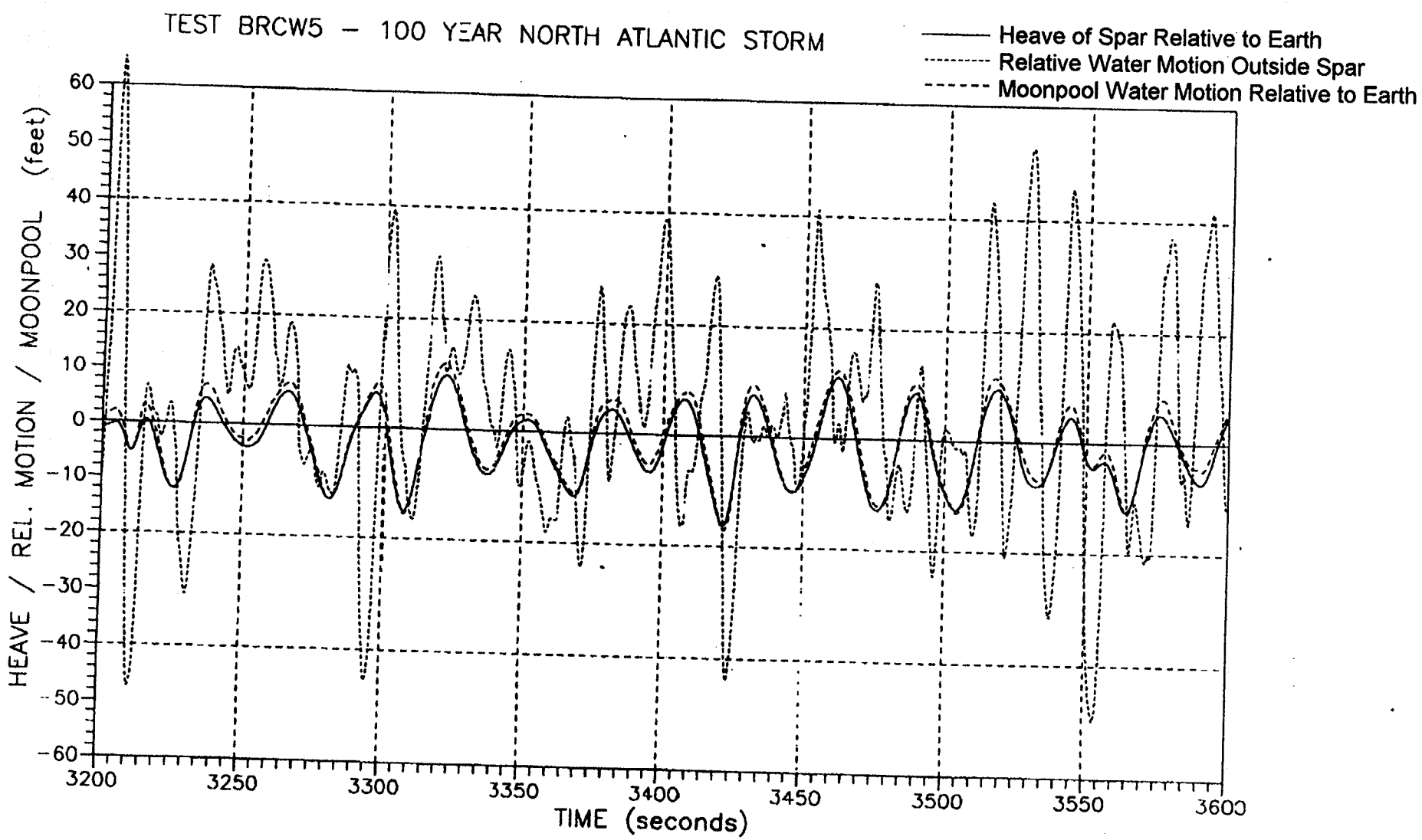


Figure 4-39 Centerwell Water Motion for Test BRCW5 (North Atlantic Storm)

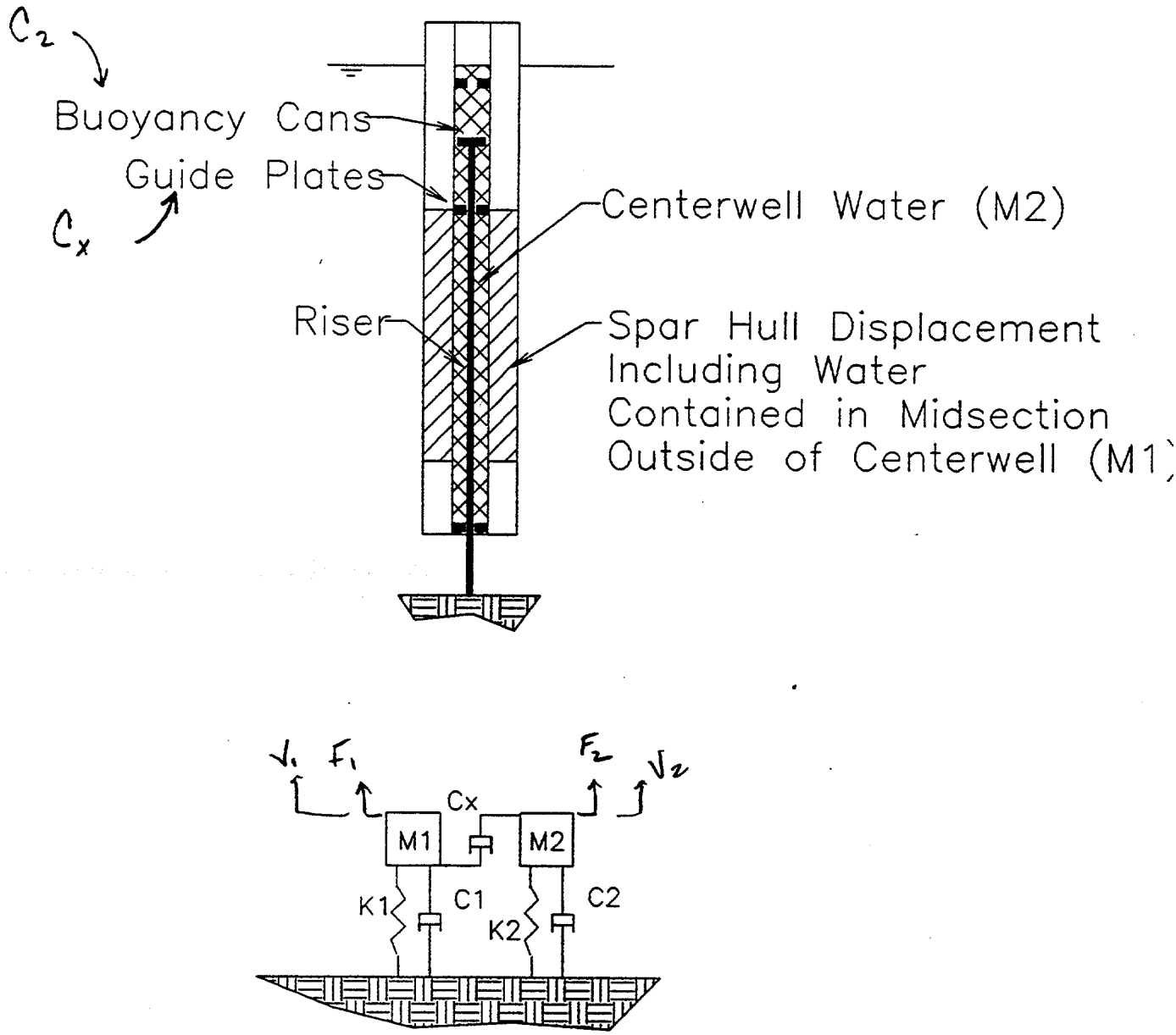
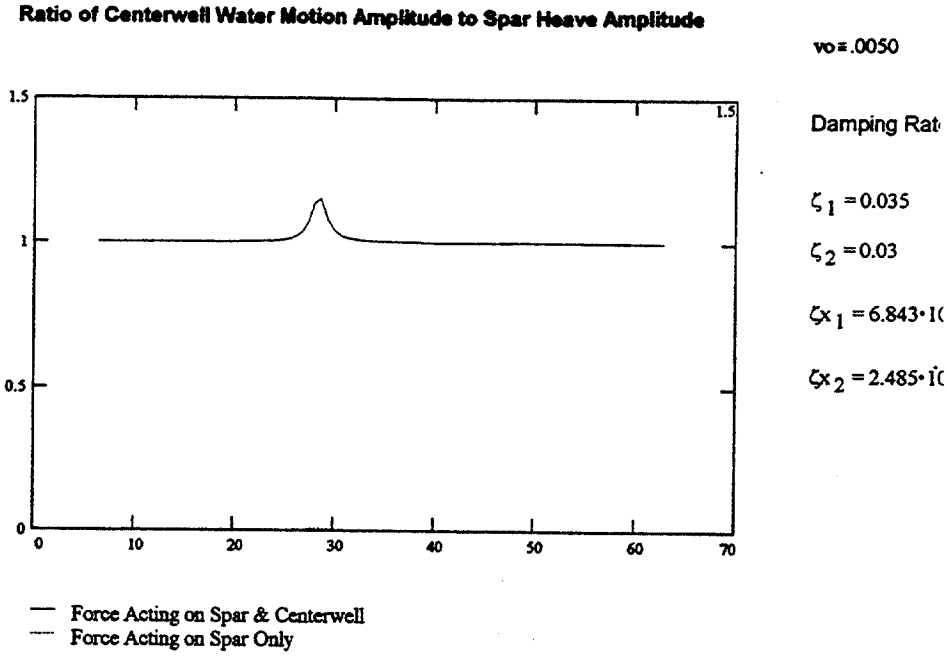


Figure 4-40 Model for Centerwell, Hull and Riser Interactions



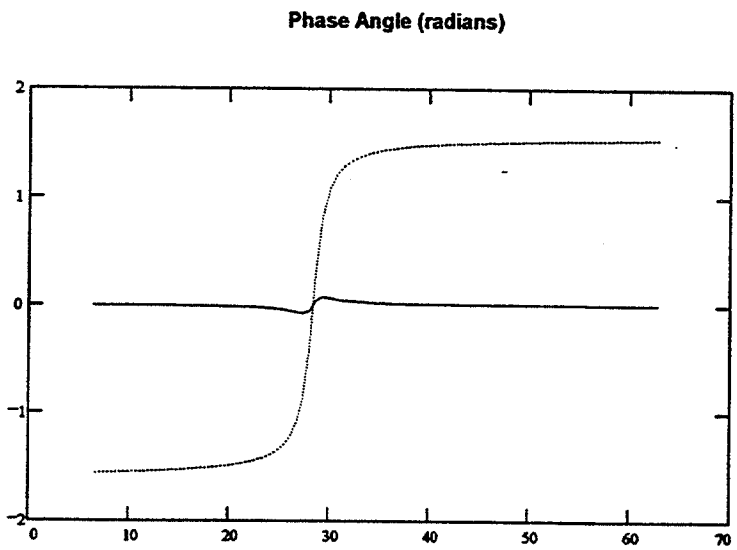
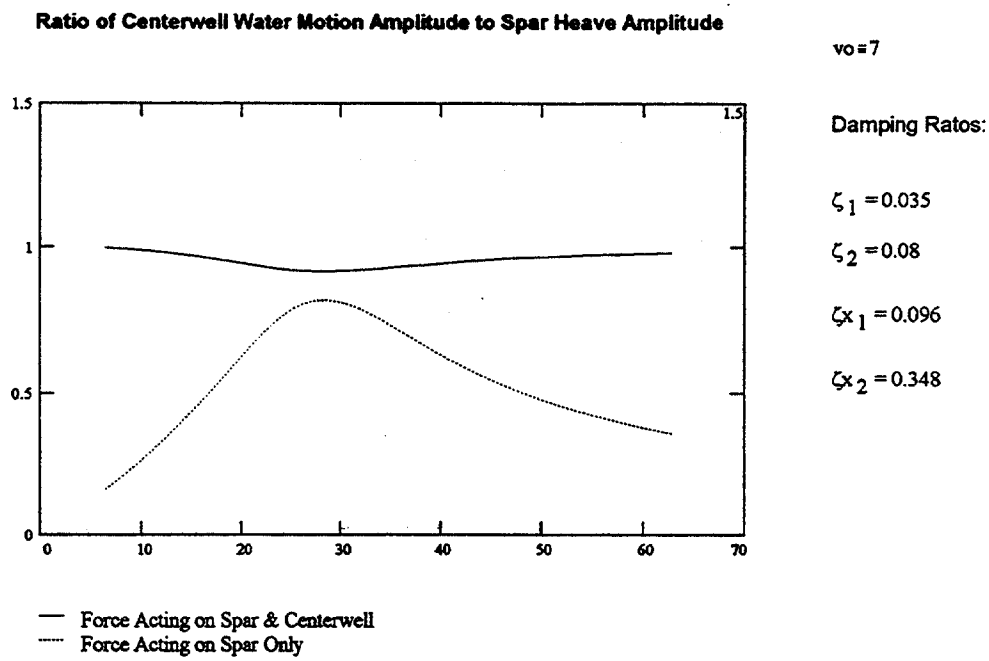


Figure 4-41 Centerwell Water Model Results: C1 Moderate, C2 Moderate, Cx Low



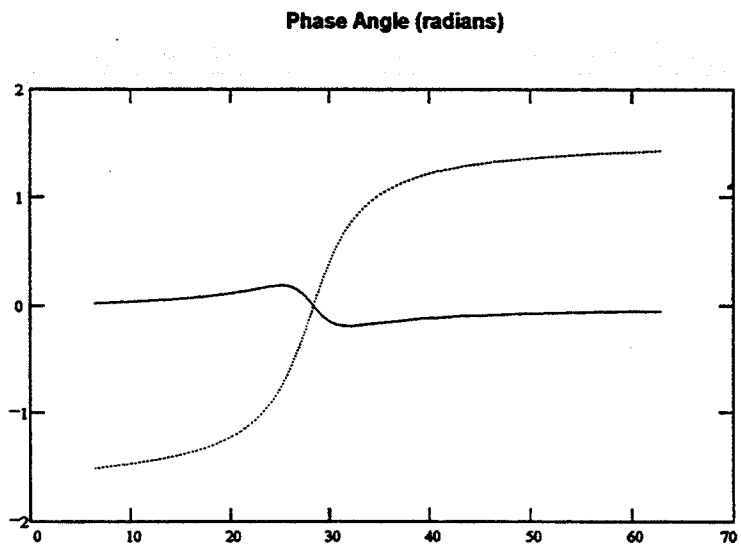
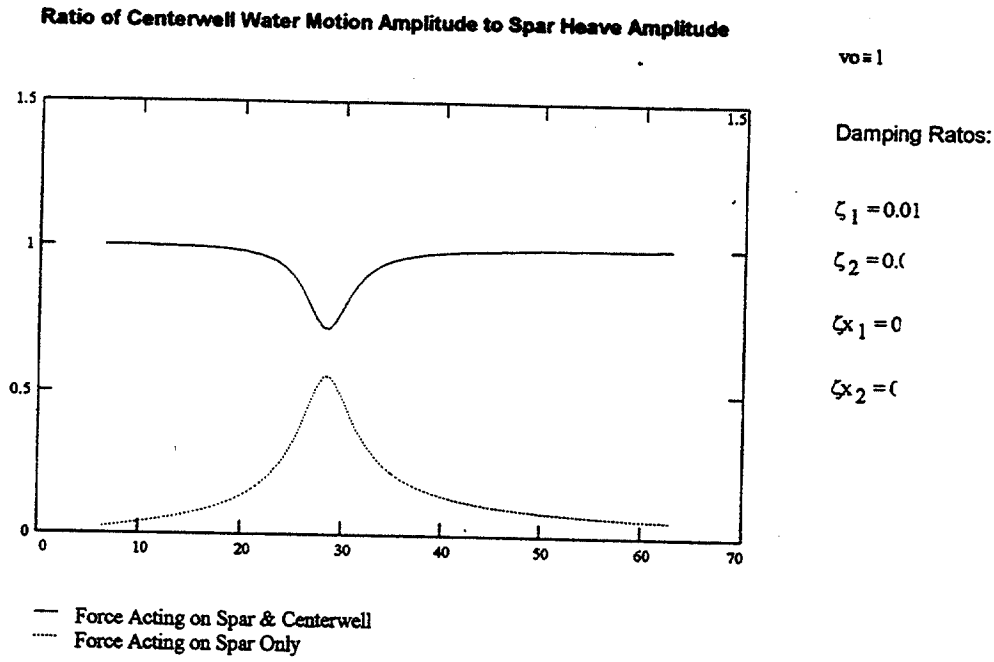


Figure 4-42 Centerwell Water Model Results: C1 Moderate, C2 High, Cx High



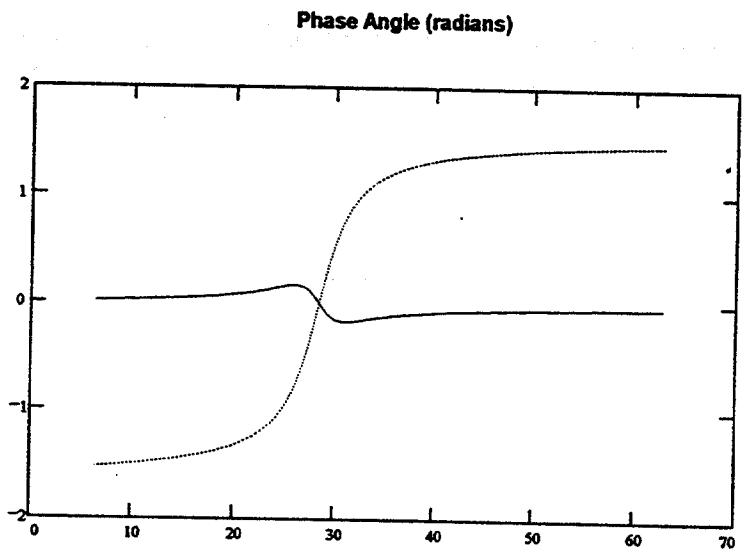
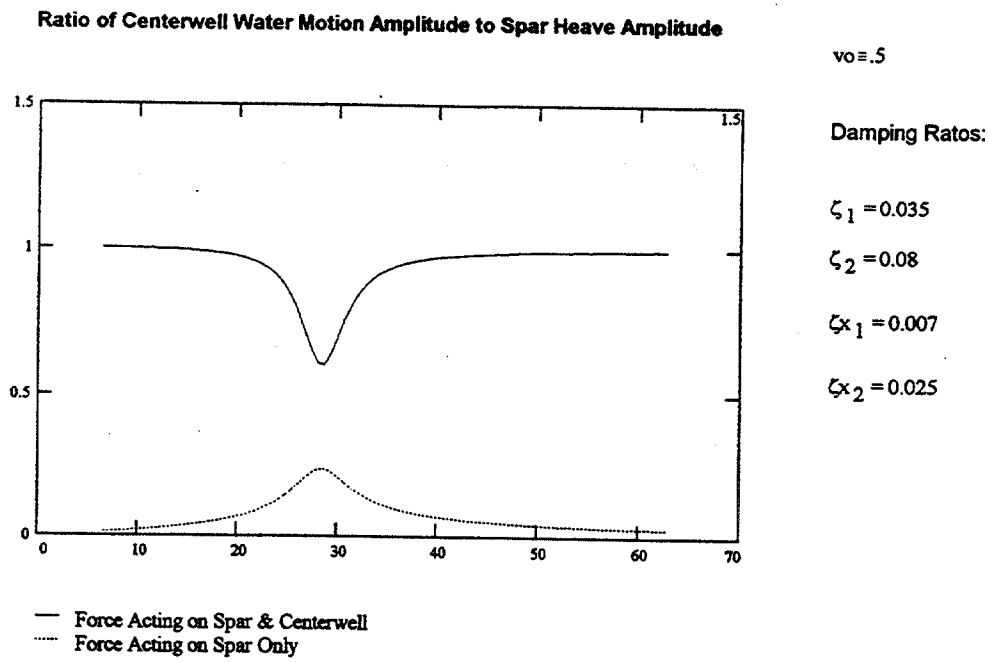


Figure 4-43 Centerwell Water Model Results: C1 Low, C2 Moderate, Cx Moderate



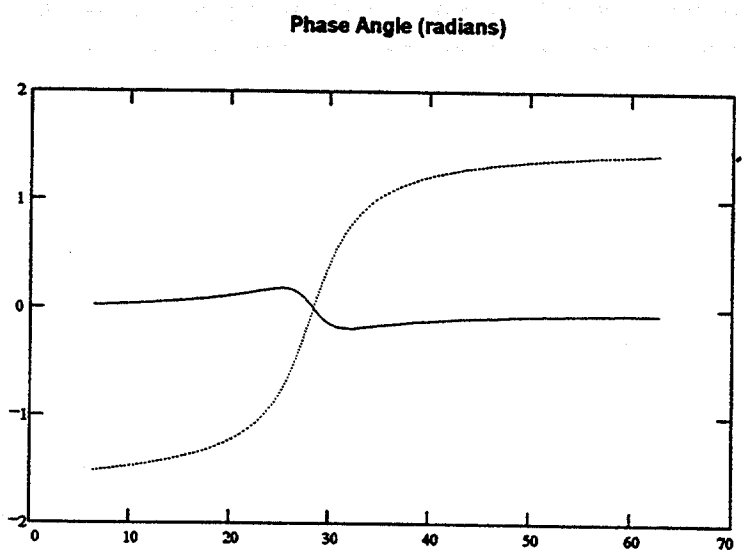


Figure 4-44 Centerwell Water Model Results: C1 Moderate, C2 High, Cx Low

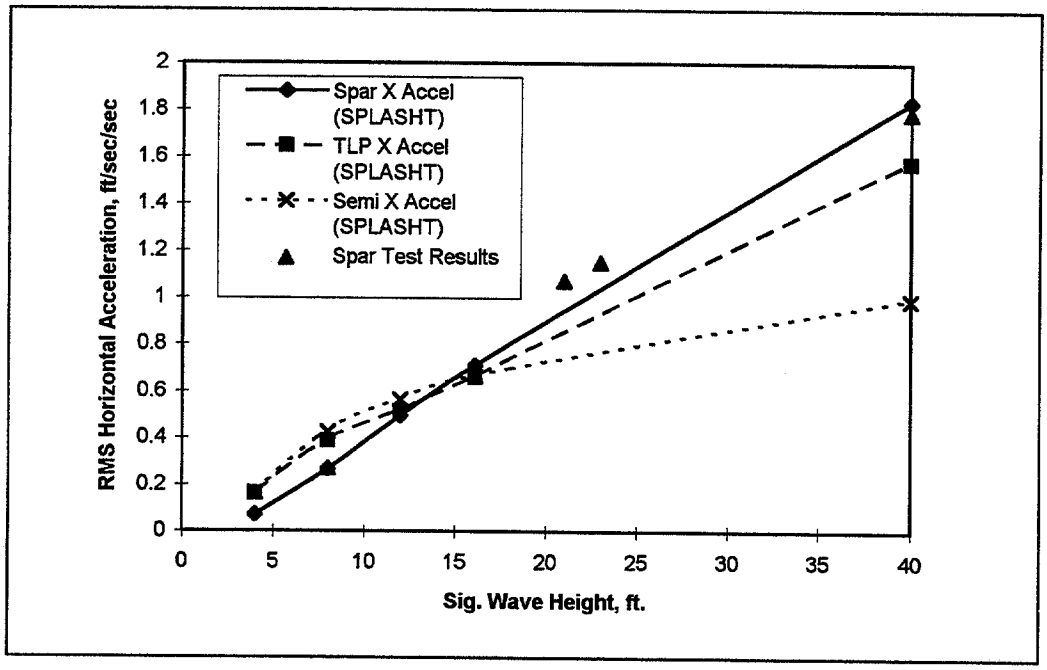


Figure 4-45 Deck Accelerations

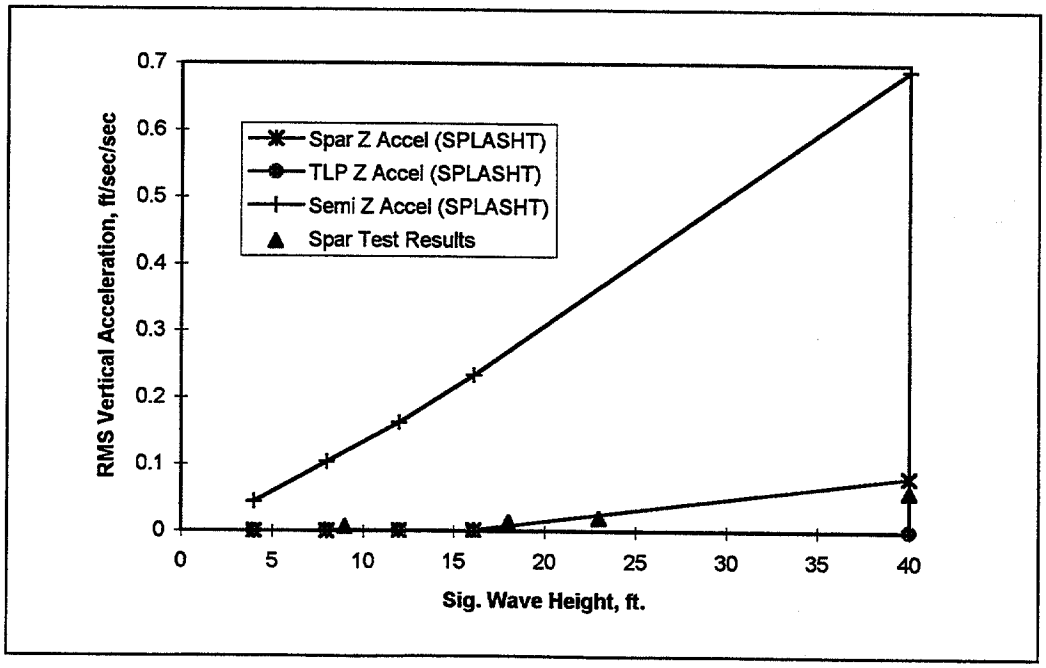


Figure 4-46 RMS Vertical Acceleration Comparisons

5. Measurement of Slowly Varying Drift Forces

5.1. *Objectives and design*

Constraint lines were introduced in order to directly measure the first and second order surge and sway forces. For this purpose, a similar experimental setup as the one used by J. A. Pinkster was used[1]. The main issue here was to design lines which would provide as little restraint on the platform's 1st order motions as possible, yet restraining the 2nd order motons (surge & pitch resonant motions), so that meaningful force measurements would be obtained.

The key parameter to design the constraint lines was their axial stiffness and the resulting resonant frequency. The introduction of constraint lines increases the natural frequency of the structure in the direction of the lines.

If the frequency response of the platform looks like Figure 5-1, then it is desirable to have the platform natural frequency f away from either peak. If f is too close to f_2, then it will resist large 1st order wave forces and shadow the second order effect. On the other hand, if f is too close to f_1, then there would be some magnification in low frequency force. So f should fall between f_1 and f_2. The springs used in the actual tests were designed to meet these design criteria.

[1] J. A. Pinkster, 1979. Mean and Low Frequency Wave Drifting Forces on Floating Structures, *Ocean Engng.* Vol. 6, pp. 593-615

5.2. *Description of the instrumentation involved*

The 133 ft diameter Spar was equipped with inline and lateral restraints lines. Tests in Configuration C were conducted with both inline and lateral restraints, while Configuration B had lateral restraints only and Configuration D inline restraints only. The 52.5 ft diameter Spar had just lateral restraints in Configuration M.

In the case of the large Spar, there were a total of eight constraint lines. Four lines were connected to the top of the hull, 5 ft below the water surface (model scale), each connection being made via underwater tension cells measuring axial loads T_1, T_2, T_3 and T_4 in the direction of the lines (see Figure 5-2). The four other lines were pulled at the bottom of the hull, 8.24 inches below the keel (model scale). These lines were connected to a ring which was mounted on two underwater shear load cells measuring X and Y loads in the direction of the cells axis, as shown in the picture. In Figure 5-2, waves are coming from the right, corresponding to the inline direction.

The small Spar was tested with lateral constraints only. The two top lines were connected to an X-Y shear load cell package similar to the one used at the keel of the large Spar. The lines were running 6.5 inches (model scale) above the deck. The two bottom lines were each connected to an O-ring located 1.25 inches above the keel. The connection was made with underwater tension cells, measuring tension in the direction of the lines. Figure 5-3 illustrates the setup. Waves are now coming towards the reader.

5.3. *Data processing*

The data processing was different according to the type of instrumentation used to measure loads (tension cells or shear load cells.)

5.3.1. Tension cell data processing

The primary goal was to obtain the X, Y and Z components of the tension, which was initially measured in the direction of the line. This direction changes as the platform moves. That is why it is necessary to know the X, Y, Z motion at the point of connection between the line and the Spar. The other extremity of the lines, the anchor point, was fixed. The derivation of the X and Y components of tension is shown in 2-Dimensions first, for one line. It is then extented to 3-D and the same procedure applies for each line.

Figure 5-4 illustrates an arbitrary displacement of the Spar in the X-Y plane. Here, (x,y) are the coordinates of the hull-line connecting point, derived from the optical tracking system and inclinometers, T_{XY} is the vector component in the X-Y plane of total tension T , T_X and T_Y are the X and Y components of T, and (x_A, y_A) are the fixed coordinates of the anchor point.

We can write (triangle relationships)

$$\frac{T_{XY}}{\sqrt{(x_A - x)^2 + (y_A - y)^2}} = \frac{T_X}{x_A - x} \tag{1}$$

and

$$\frac{T_{XY}}{\sqrt{(x_A - x)^2 + (y_A - y)^2}} = \frac{T_Y}{y_A - y} \tag{2}$$

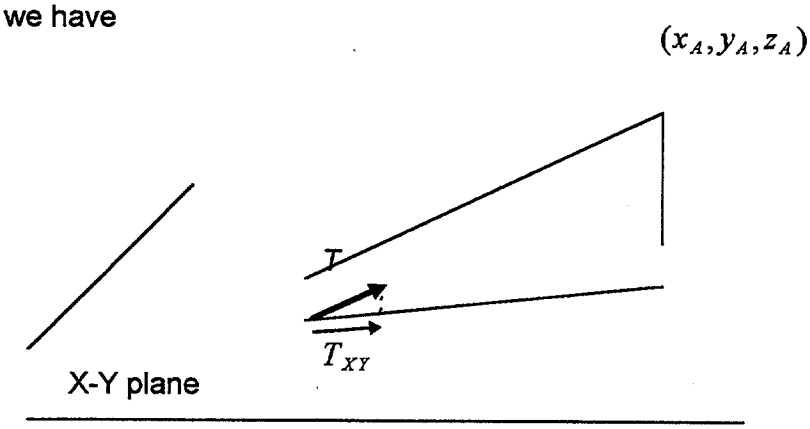
which gives

$$T_X = \frac{T_{XY}(x_A - x)}{\sqrt{(x_A - x)^2 + (y_A - y)^2}} \tag{3}$$

and

$$T_Y = \frac{T_{XY}(y_A - y)}{\sqrt{(x_A - x)^2 + (y_A - y)^2}} \tag{4}$$

Extending to 3-D, we have



$$\frac{T_{XY}}{\sqrt{(x_A - x)^2 + (y_A - y)^2}} = \frac{T}{\sqrt{(x_A - x)^2 + (y_A - y)^2 + (z_A - z)^2}} \tag{5}$$

Substituting equations (3) and (4) into (5), we obtain

$$T_X = \frac{T(x_A - x)}{\sqrt{(x_A - x)^2 + (y_A - y)^2 + (z_A - z)^2}} \tag{6}$$

$$T_Y = \frac{T(y_A - y)}{\sqrt{(x_A - x)^2 + (y_A - y)^2 + (z_A - z)^2}} \tag{7}$$

Similarly, we may write

$$T_Z = \frac{T(z_A - z)}{\sqrt{(x_A - x)^2 + (y_A - y)^2 + (z_A - z)^2}} \tag{8}$$

Note that $\sqrt{(x_A - x)^2 + (y_A - y)^2 + (z_A - z)^2}$ represents the total length of the constraint line as the Spar moves, T being the tension as it is given by the tension cells.

5.3.2. Shear load cells data processing

The procedure used here is different, because the cells are rigidly mounted on the Spar and measure X and Y force components in the direction of the cells axis (which are moving with the Spar). Therefore, in order to retrieve force components in the fixed coordinate system, one just needs to perform a transformation of coordinate system, going from the spar local coordinates to the basin global coordinates. The local coordinates differ from the global coordinates only by pitch, roll and yaw motion of the Spar. Therefore, pitch, roll and yaw angles were derived at the shear load cells location and the 3-D rotation matrix was applied to the data to perform the transformation of the coordinate system.

5.4. *Final results*

The total inline and lateral forces in the X and Y directions of the fixed basin coordinates were computed by adding the X forces at the top (resp. Y forces) to the X forces at the bottom (resp. Y forces), i.e.

$$F_{Xtotal} = F_{Xtop} + F_{Xbottom} \tag{9}$$

$$F_{Ytotal} = F_{Ytop} + F_{Ybottom} \tag{10}$$

Couples were obtained using the arm length *d* between top and bottom lines as follows

$$X_{couple} = (F_{Xtop} - F_{Xbottom}).d \tag{11}$$

$$Y_{couple} = (F_{Ytop} - F_{Ybottom}).d \tag{12}$$

5.5. *STEADY AND SLOWLY VARYING DRIFT FORCES AND MOMENTS*

5.5.1. Steady (or mean) drift force

The mean drift force was computed from regular waves tests obtained with Configuration C, i.e. no strakes, no moorings, but inline and lateral constraints. The 4 mooring lines were disconnected so that each constraint line could pick up all the first and second order loads experienced by the 133 ft diameter Spar. It was not possible to do a similar analysis for the 52.5 ft diameter Spar, because there was no test in regular waves with constraint lines performed in this case.

The mean drift force in the direction of the waves was directly obtained by taking the statistical mean of the total inline force (F_{Xtotal} above). This gives a mean drift force *F* in kips, which is then non-dimensionalized to yield the mean drift coefficient, as follows

$$Mean_Drift_Coeff = \frac{F}{\rho g R A^2} \tag{13}$$

where F is the mean drift force in kips, ρg is the water density times the gravitational acceleration ($\rho g = 0.064 kips / ft^3$), R is the radius of the Spar (*66.5 ft*) and A^2 is the square of the amplitude of the incident regular wave (A = wave height / 2).

Table 5-1 gives all the mean drift coefficients obtained for the different regular wave cases. The mean drift coefficients are plotted in Figure 5-9 as a function of the wave period. The potential drift computed with Hydro3 is also represented on Figure 5-9 and shows good agreement with the experiments, except for the peak part which is higher in the simulation. This confirms that the wave drift force on the Spar is dominated by potential effects, like it is for a barge (Pinkster, 1979).

5.5.2. Slowly varying drift force

The slowly varying wave drift forces were computed from bichromatic tests obtained with Configuration C. Again, this analysis was not possible for the 52.5 ft diameter Spar.

Frequency pairs ω_1 and ω_2 of bichromatic waves have been chosen so that the difference frequency $\omega_1 - \omega_2$ of the incident waves would be close to the natural periods in surge and pitch of the Spar.

The purpose of these bichromatic tests was to evaluate the Quadratic Transfer Function (QTF) of the structure and compare experimental results with analytical models. Since many models are based on the Newman's approximation, this study will give some insight as to how good this approximation is, when it comes to computing QTFs.

To derive the QTF coefficients, the following procedure was used. First, the Fourier Transform (FFT) of the total inline force measured in the constraint lines was taken for all bichromatic wave tests (see Figures 5-6, 5-7 and 5-8). The peaks at the difference frequency, resonance and wave frequencies were located and the data was then filtered at the observed difference frequency. This frequency was either 0.01333 Hz (closer to

pitch) or 0.005263 Hz (closer to surge), and the bandwidth used for filtering was 0.005 Hz. The choice of the bandwidth was very important as it influenced the final results. The value of 0.005 Hz was selected because it gave the cleanest, sharpest peaks after performing Power Spectral Densities on the filtered data.

Basic statistics were then run on the filtered data and the amplitude corresponding to the difference frequency loads was evaluated by taking the rms of the filtered surge data multiplied by $\sqrt{2}$. This gives the resulting force amplitude due to waves on the structure ($F_{measured}$ in Figure 5-5). In order to evaluate the wave force itself acting on the structure (F_{waves}), a magnification factor was applied to correct for amplification of the measured force, due to the possible proximity of the difference frequency peak to the resonance peak of the system.

The magnification factor is given in equation (14), and corresponds to the common amplitude response function obtained for a linear floating mooring system. In his thesis "Low Frequency Second Order Wave Exciting Forces on Floating Structures", Pinkster used the same formula

$$F_{wave} = \sqrt{(1-(\frac{T_n}{T})^2)^2 + \varsigma^2(\frac{T_n}{T})^2} \cdot F_{measured} \tag{14}$$

where T_n is the natural period of the restrained Spar, T is the period corresponding to the difference frequency (either 75 or 190 sec), ς being the damping factor of the system.

The natural periods and damping factors in surge and pitch of the system were derived from the free decay tests conducted in configuration C. The free decay time series showed some coupling between surge and pitch. So the signals were filtered at the peak

frequency. A damping analysis on the filtered data was then performed and yielded the following results

	Natural Period (sec) T_n	Damping Factor ς
Surge	36.93	0.0038
Pitch	30.51	0.0078

The corrected force was finally non-dimensionalized as follows

$$QTF_Coeff = \frac{F_{wave}}{\rho g R A_1 A_2} \tag{15}$$

where F_{wave} is the amplitude of drift force at the difference frequency in kips from Equation (14), ρg is the water density times the gravitational acceleration ($\rho g = 0.064 kips / ft^3$), R is the radius of the Spar (*66.5 ft*), A_1 and A_2 the amplitudes of the two waves forming the bichromatic train.

Table 5-2 and Figure 5-9 summarize the results of this exercise. In Fig 5-9 , QTF coefficients are plotted against the period of mean frequency. Figure 5-10 tabuates the QTF against the corresponding period pairs. The HYDRO3 mean drift coefficients are plotted along the diagonal.

From Figures 5-9 and 5-10 it appears that Newman's approximation is better for surge than it is for pitch, and that it is better at mean frequencies coresponding to periods below about 14 seconds than lower mean frequencies.

This is consistent with Pinkster's results for semis and tankers, namely that Newman's approxiation is valid for very low natural periods and for mean wave frequencies where first order diffraction dominates the drift force value.

5.5.3. Second order moments

The second order moments were computed about the center of gravity of the wetted Spar. The wet CG of the whole structure is located 307.3 ft above the keel (full scale), which is close to the fairlead position (300 ft above the keel).

The analysis was the same as the one used to derive QTF coefficients for the surge drift force. The moment was defined as follows

$$M_X = F_{Xtop}.d_1 - F_{Xbottom}.d_2 \tag{16}$$

where the notations are described in the Figure 5-11.

The data was non dimensionalized as follows

$$QTF_Coeff = \frac{M_X}{\rho g R A_1 A_2 Draft} \tag{17}$$

The results are shown in Table 5-3 and Figure 5-12. Table 5-3 also shows the centroid of the force based on the computed moments and forces (From Table 5-3). The results are with reference to the mean water line. Most values are well above the free surface suggesting an error in the moment calculation. Equation (16) involves subtraction of two large numbers and hence is prone to inaccuracy.

Equation (16) was applied in the frequency domain. Better results might be achieved if the moment were computed in the time domain prior to the FFT computation.

Test	Period (sec)	Height (ft)	Mean drift force (kips)	Mean drift force (non dim)
crg1	6	6	20.21	0.5276
crg2	7	12	74.54	0.4865
crg3	8	15	107.5	0.4490
crg4	9	18	107.1	0.3107
crg5	10	20	78.54	0.1845
crg6	12	20	40.75	0.0957
crg7	14	20	30.63	0.0720
crg8	16	20	23.7	0.0557
crg9	17	20	10.68	0.0251
crg10	21	20	-5.13	-0.0121

Table 5-1 Mean Drift Coefficients

Test	Wave1 (sec)	Height 1 (ft)	Wave 2 (sec)	Height 2 (ft)	df (Hz)	df (sec)	f ave (Hz)	f ave (sec)	Tn (sec)	Damp coeff	Surge force rms (kips)	Surge force ampl (kips)	Correcting Coeff	Adjusted force (kips)	coef (non dim)
cbc2	12	20	12.81	20	0.00526	190.01	0.081	12.41	36.93	0.0038	45.33	64.11	0.93	59.35	0.1395
cbc3	14	20	15.11	20	0.00526	190.01	0.069	14.56	36.93	0.0038	28.85	40.80	0.93	37.78	0.0888
cbc4	14	10	15.11	10	0.00526	190.01	0.069	14.56	36.93	0.0038	10.21	14.44	0.93	13.37	0.1256
cbc5	16	20	17.47	20	0.00526	190.01	0.060	16.74	36.93	0.0038	19.71	27.87	0.93	25.81	0.0606
cbc6	17	20	18.67	20	0.00526	190.01	0.056	17.84	36.93	0.0038	27.03	38.23	0.93	35.39	0.0832
cbc7	10	20	11.54	20	0.01333	75.00	0.093	10.77	30.51	0.0078	144.00	203.65	0.70	141.83	0.3332
cbc8	12	20	14.29	20	0.01333	75.00	0.076	13.15	30.51	0.0078		0.00	0.70	0.00	
cbc9	13	20	15.73	20	0.01333	75.00	0.070	14.37	30.51	0.0078	28.49	40.29	0.70	28.06	0.0659
cbc10	14	20	17.21	20	0.01333	75.00	0.064	15.61	30.51	0.0078	58.58	82.84	0.70	57.70	0.1356
cbc11	14	10	17.21	10	0.01333	75.00	0.064	15.61	30.51	0.0078	20.18	28.54	0.70	19.88	0.1868
cbc12	16	20	20.34	20	0.01333	75.00	0.055	18.17	30.51	0.0078	65.54	92.69	0.70	64.55	0.1517
cbc13	17	20	21.98	20	0.01333	75.00	0.051	19.49	30.51	0.0078	77.67	109.84	0.70	76.50	0.1797

Table 5-2 Quadratic Transfer Functions

Test	Wave1 (sec)	Height 1 (ft)	Wave 2 (sec)	Height 2 (ft)	df (Hz)	df (sec)	f ave (Hz)	f ave (sec)	Tn (sec)	Damp coeff	Moment Ampl (kips.ft)	Correcting coeff	Adjusted moment (kips.ft)	Centroid AMWL (ft)	coef (non dim)
cbc2	12	20	12.81	20	0.00526	190.01	0.081	12.41	36.93	0.0038	32612	0.93	30194	166	0.1091
cbc3	14	20	15.11	20	0.00526	190.01	0.069	14.56	36.93	0.0038	25710	0.93	23805	287	0.0860
cbc4	14	10	15.11	10	0.00526	190.01	0.069	14.56	36.93	0.0038	8589	0.93	7952	252	0.1150
cbc5	16	20	17.47	20	0.00526	190.01	0.060	16.74	36.93	0.0038	15570	0.93	14416	216	0.0521
cbc6	17	20	18.67 -	20	0.00526	190.01	0.056	17.84	36.93	0.0038	20930	0.93	19379	205	0.0701
cbc7	10	20	11.54	20	0.01333	75.00	0.093	10.77	30.51	0.0078	66270	0.70	46153	-17	0.1668
cbc8	12	20	14.29	20	0.01333	75.00	0.076	13.15	30.51	0.0078	0	0.70	0		
cbc9	13	20	15.73	20	0.01333	75.00	0.070	14.37	30.51	0.0078	41521	0.70	28917	688	0.1045
cbc10	14	20	17.21	20	0.01333	75.00	0.064	15.61	30.51	0.0078	51803	0.70	36077	282	0.1304
cbc11	14	10	17.21	10	0.01333	75.00	0.064	15.61	30.51	0.0078	15514	0.70	10804	201	0.1562
cbc12	16	20	20.34	20	0.01333	75.00	0.055	18.17	30.51	0.0078	47008	0.70	32738	164	0.1183
cbc13	17	20	21.98	20	0.01333	75.00	0.051	19.49	30.51	0.0078	40447	0.70	28168	25	0.1018

Table 5-3 2nd Order Moment Quadratic Transfer Functions

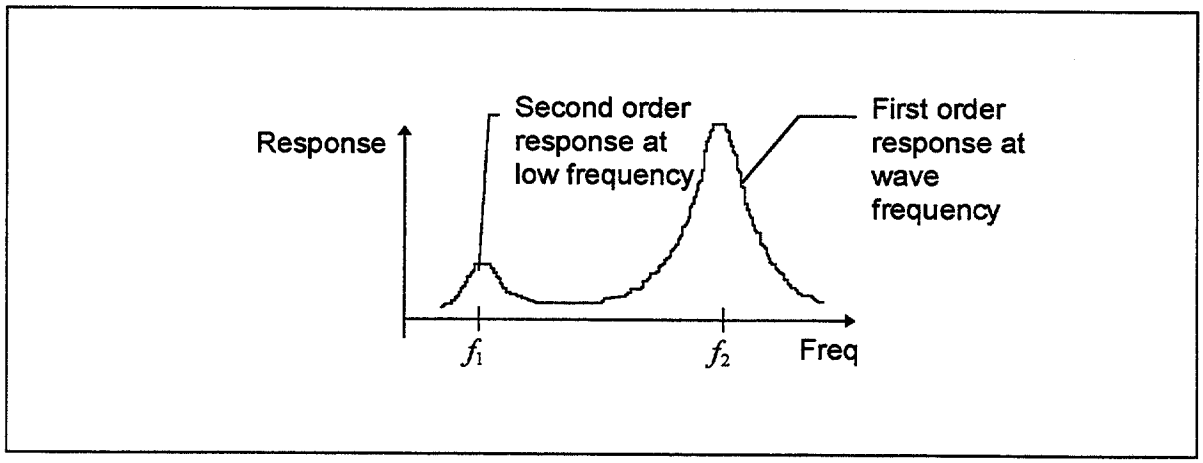


Figure 5-1 Response of Moored Body

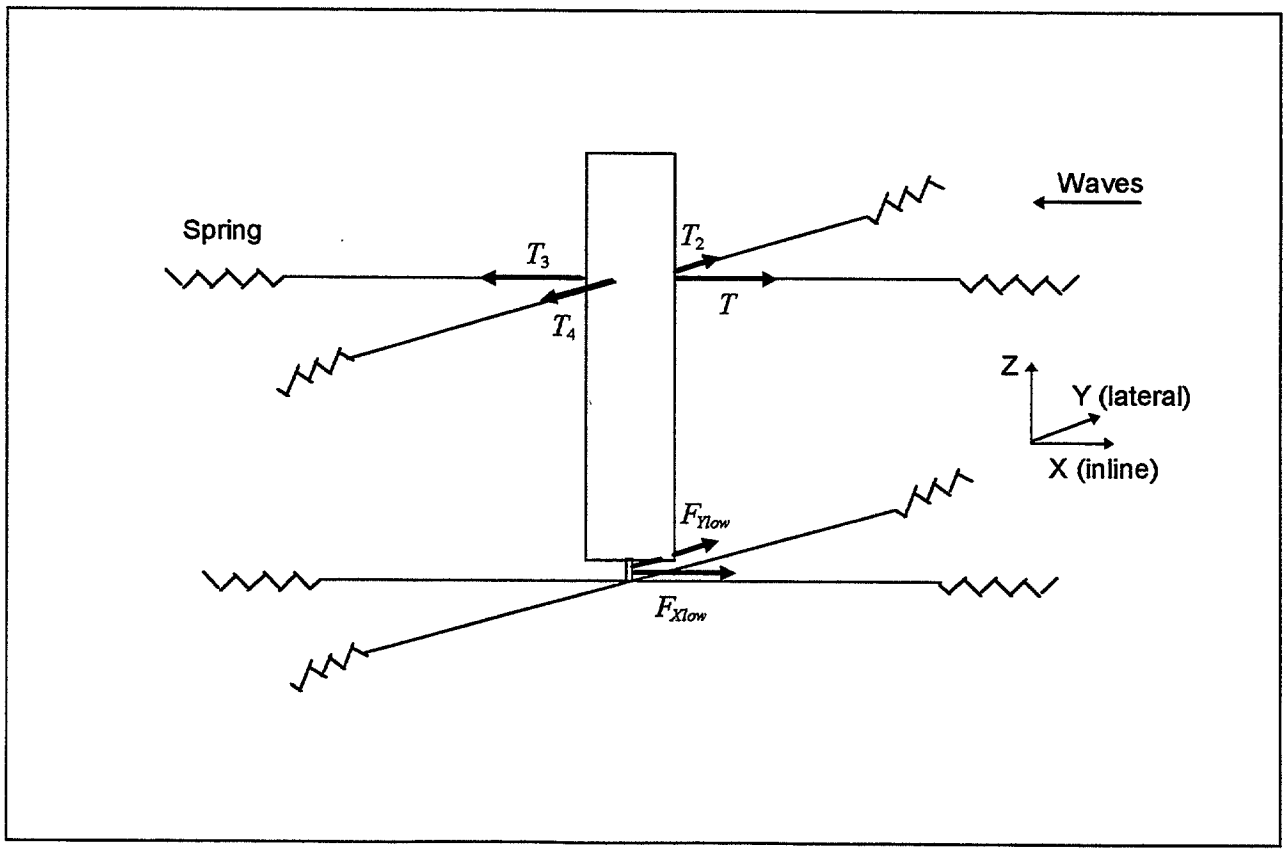


Figure 5-2 Constraint lines setup for the 133 ft diameter Spar

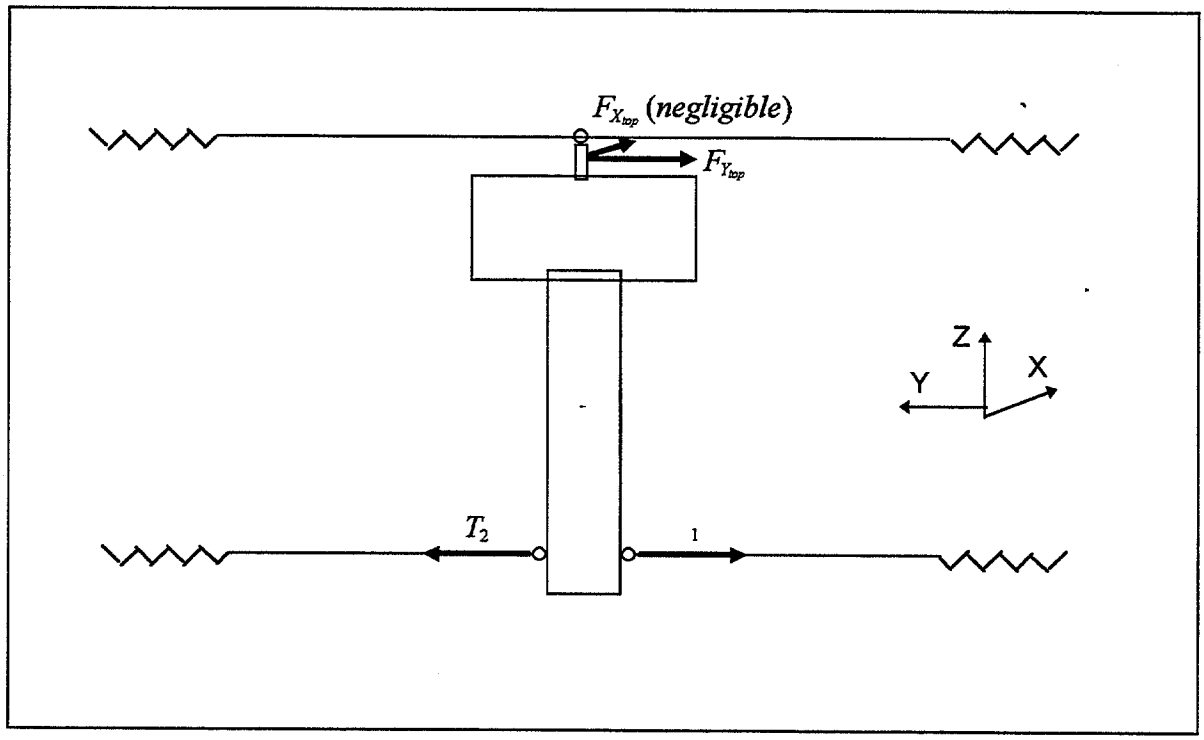


Figure 5-3 Constraint lines setup for the 52.5 ft diameter Spar

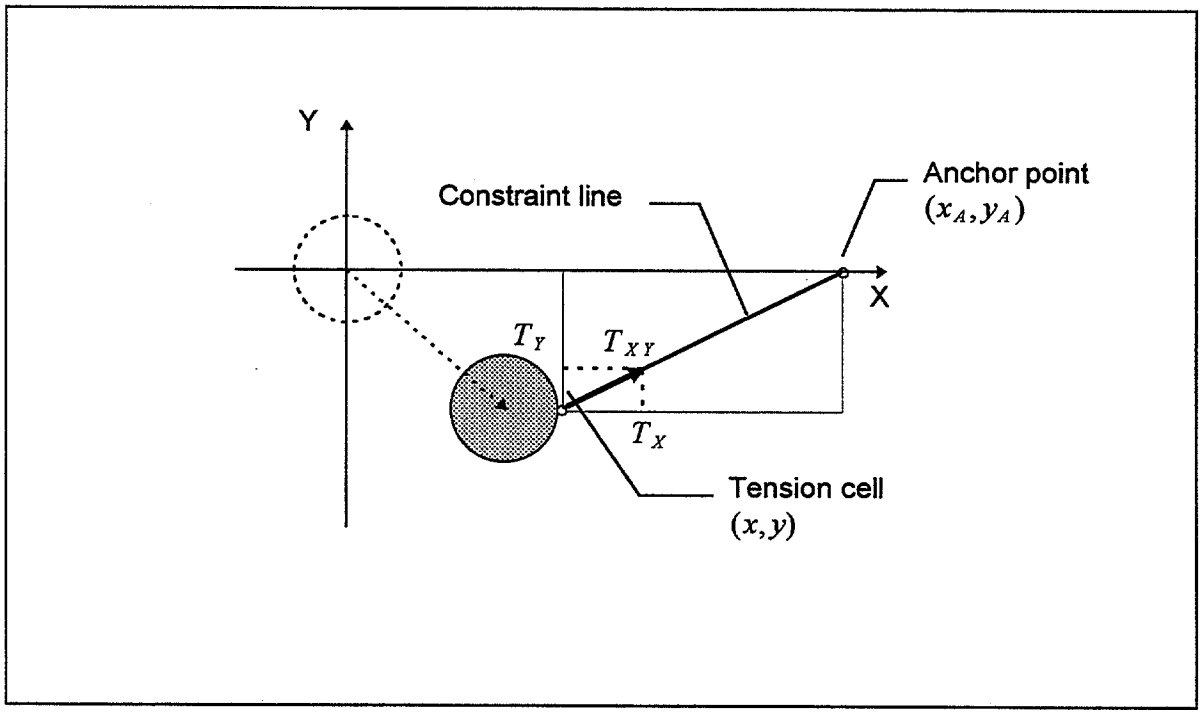


Figure 5-4 Geometry of Constraint Line

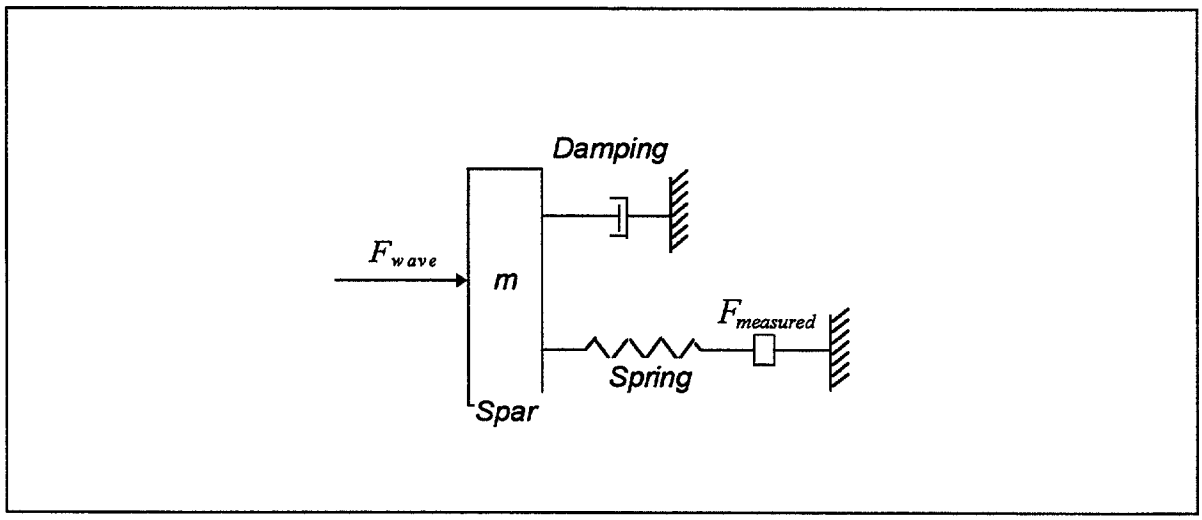


Figure 5-5 Schematic of the mooring system used in 2nd order force analysis

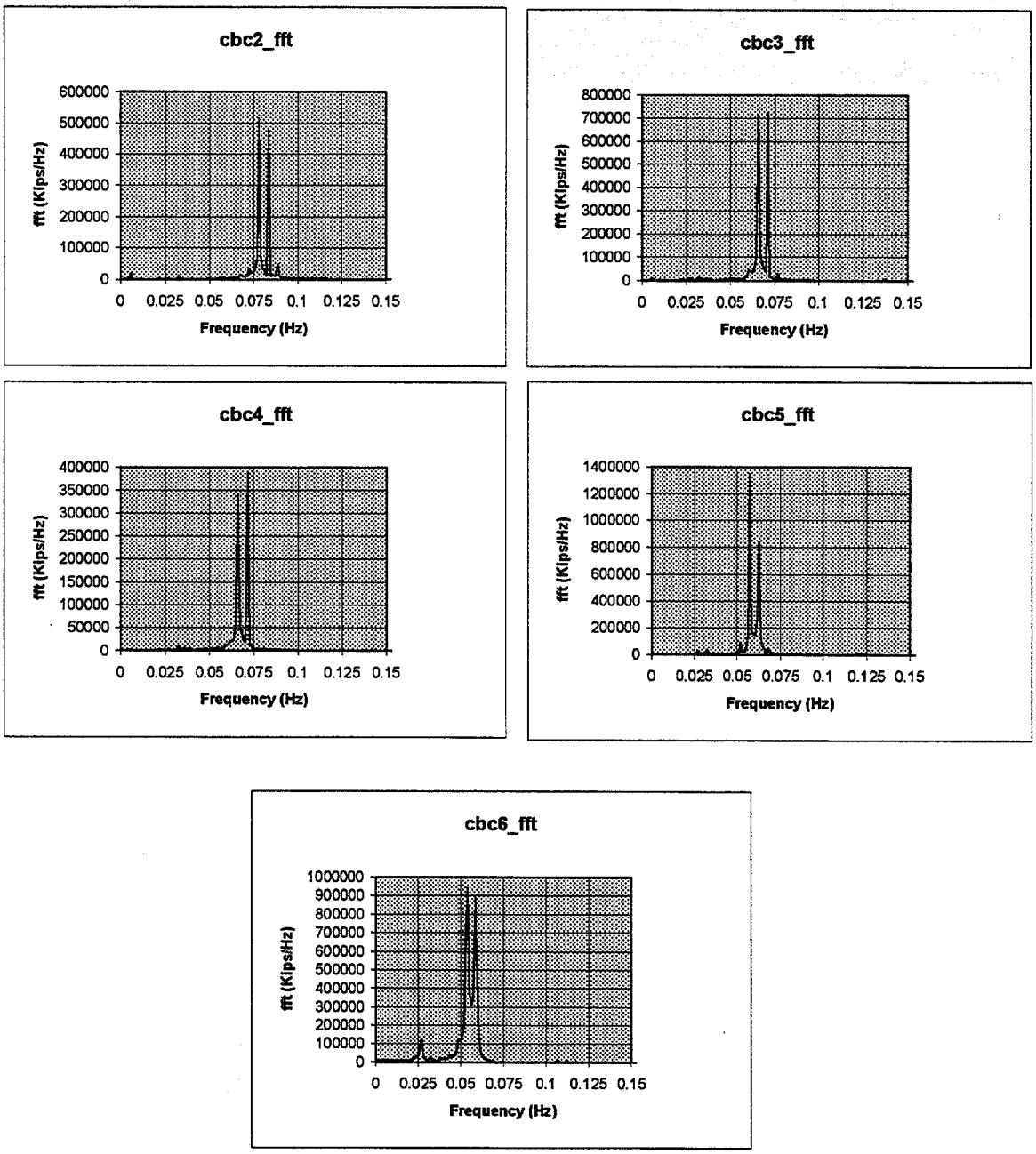


Figure 5-6 FFT Of Bichromatic Wave Tests CBC2 - CBC6

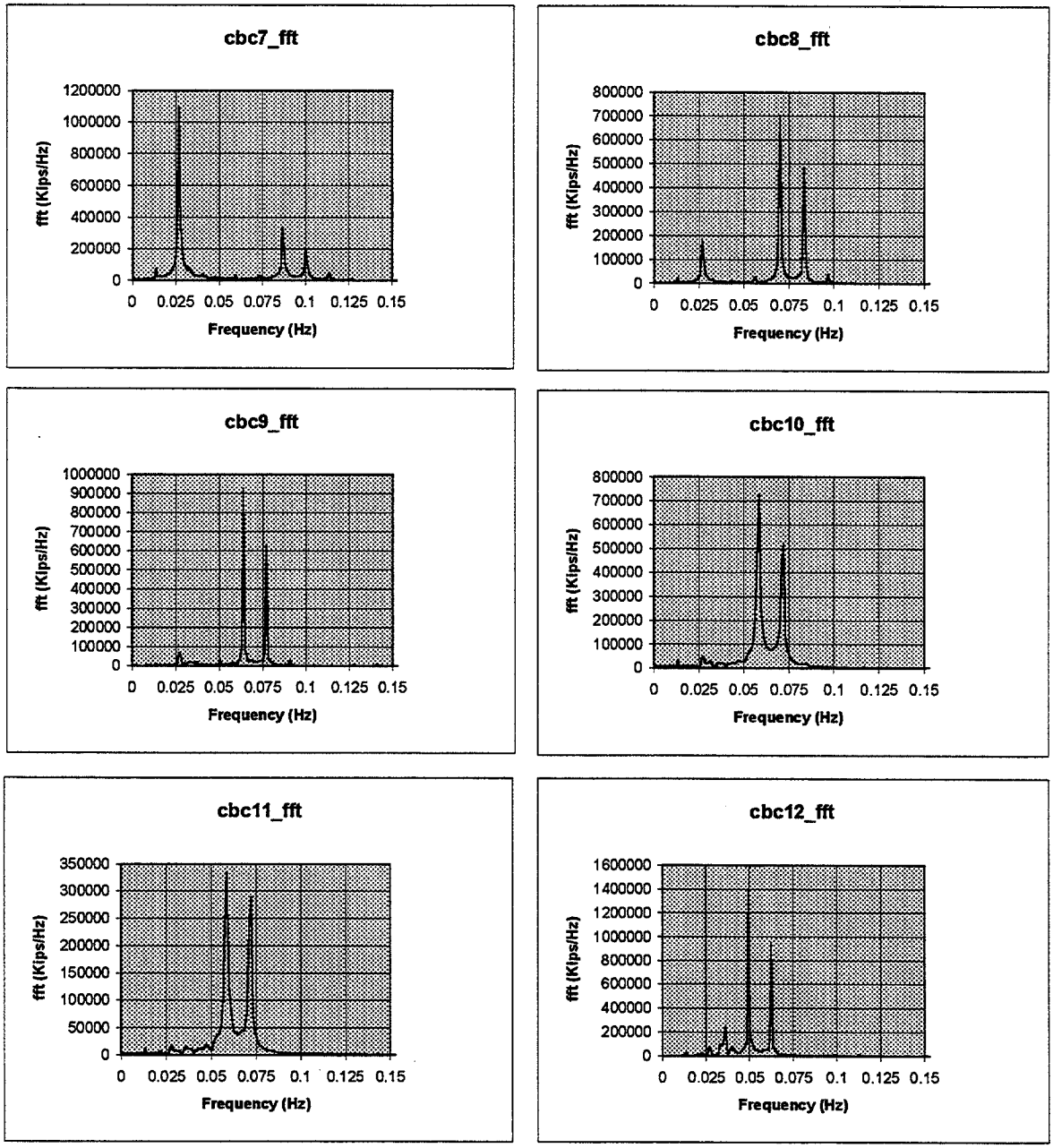


Figure 5-7 FFT of Bichromatic Wave Tests CBC7 - CBC12

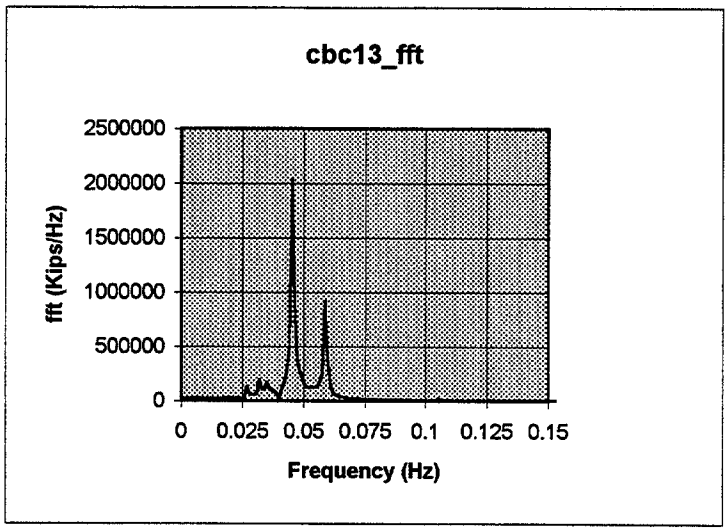


Figure 5-8 FFT of Bichromatic Wave Test CBC13

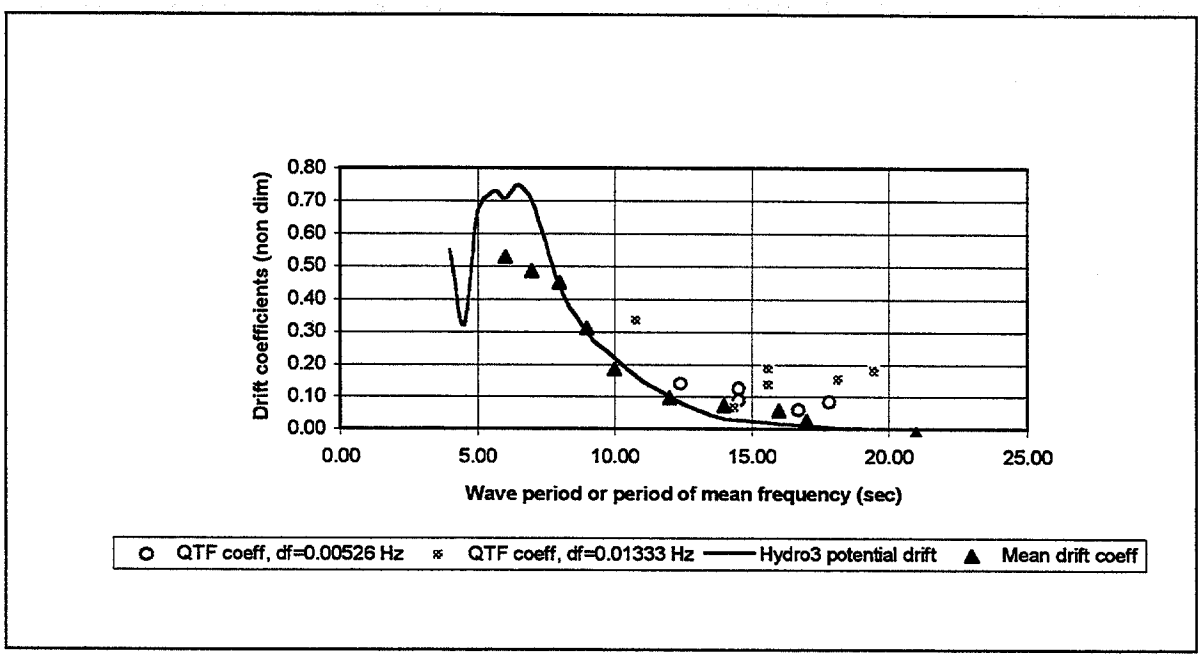


Figure 5-9 Mean Drift and Quadratic Transfer Coefficients

Period	4	4.5	5	5.6	6	6.5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
4	0.55																					
4.5		0.32																				
5			0.67																			
5.6				0.73																		
6					0.71																	
6.5						0.75																
7							0.7															
8								0.44														
9									0.3													
10										0.22	0.3332											
11											0.15											
12												0.1	0.14	0.1								
13													0.06		0.0659							
14														0.033	0.0888/.1256		.1356/1868					
15															0.023							
16																0.017	0.0606			0.152		
17																	0.01	0.0832				0.18
18																		0.006				
19																			0.002			
20																				5E-04		
21																					0	
22																						0

Figure 5-10 Quadratic Transfer Functions

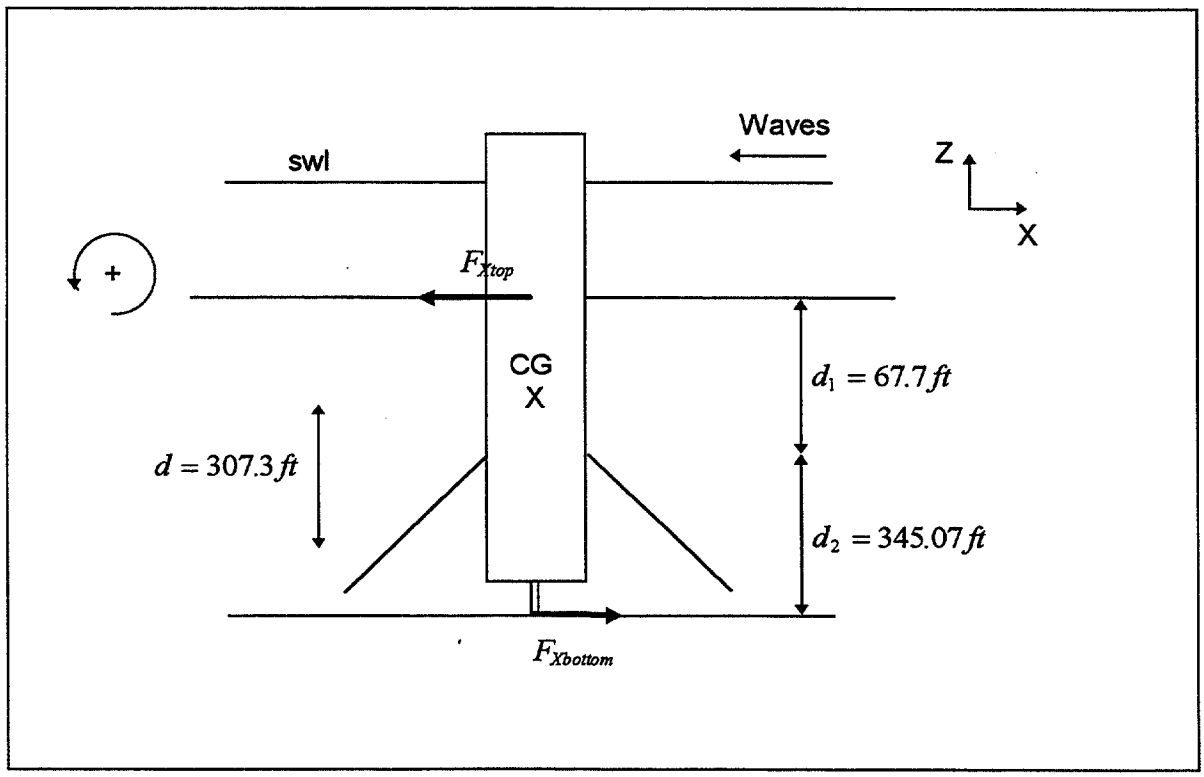


Figure 5-11 Drift Moment Reference Schematic

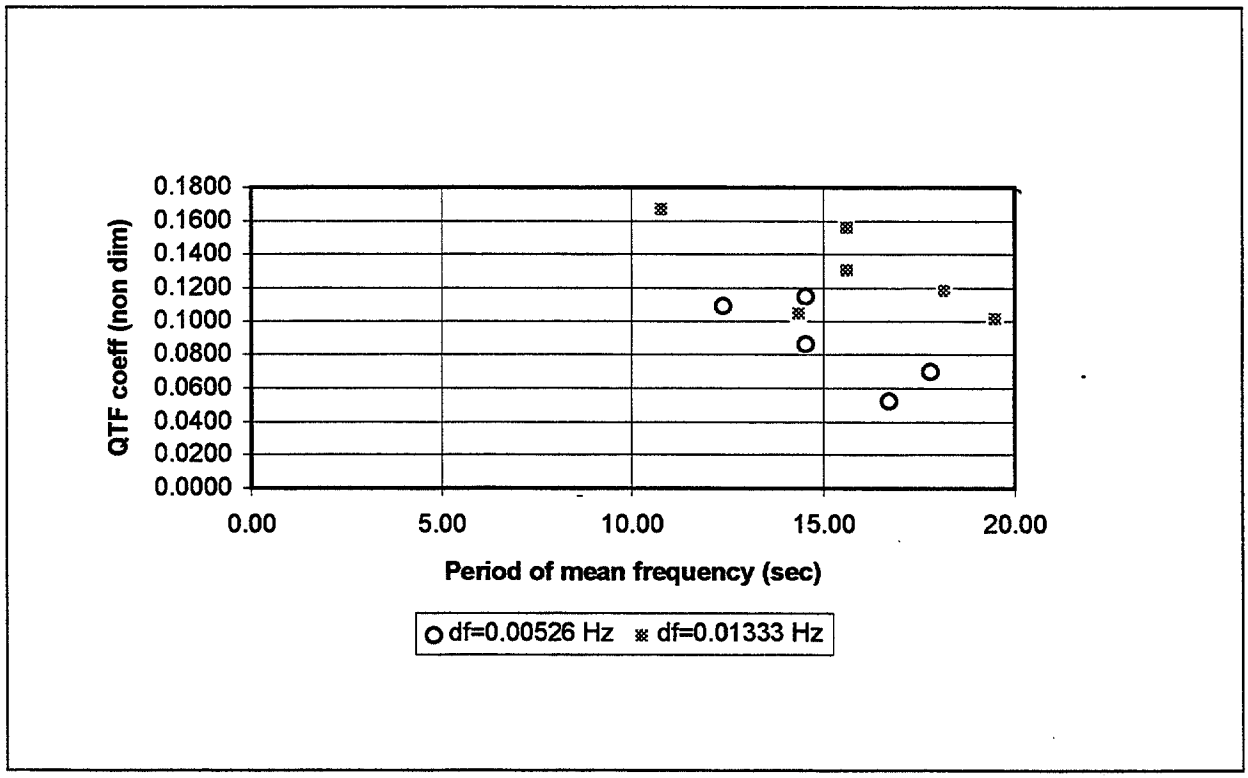


Figure 5-12 QTF Moment About CG

Appendix A

Test Listing

Test	Test Type	Configuration	Hs	Tp	Wave DSIG	Current	Pump Setting	Wind	Wind DSIG	
AINC	Inclining	A	-	-	-	-	-	-	-	
ASO	Static Offset	A	-	-	-	-	-	-	-	
AD1	Surge Damping	A	-	-	-	-	-	-	-	
AD2	Sway Damping	A	-	-	-	-	-	-	-	
AD3	Heave Damping	A	-	-	-	-	-	-	-	
AD4	Roll Damping	A	-	-	-	-	-	-	-	
AD5	Pitch Damping	A	-	-	-	-	-	-	-	
AD6	Yaw Damping	A	-	-	-	-	-	-	-	
ARAN1	Random Sea	A	8.0	7.7	OP_4	-	-	-	-	Operating Long-Crested
ARAN2	Random Sea	A	21.0	10.5	10YR_2	-	-	-	-	10 Year Storm
ARAN3	Random Sea	A	43.0	14.0	GOM1_3	-	-	-	-	GOM1
ARAN4	Random Sea	A	43.0	14.0	GOM2_3	-	-	-	-	GOM2
ARAN5	Random Sea	A	45.9	16.3	NS_3	-	-	-	-	North Sea
ARAN6	Random Sea	A	8.0	7.7	OP_2_MDS	-	-	-	-	Operating Short_Creste
AWIN2	Wind	A	-	-	-	-	-	43	43KT_3	10 Year Storm
AWIN5	Wind	A	-	-	-	-	-	59	59KT_3	North Sea
AWIN3	Wind	A	-	-	-	-	-	85	85KT_4	GOM1
AWIN4	Wind	A	-	-	-	-	-	85	85KT_4	GOM2
ACUR3	Current	A	-	-	-	4.3	1	-	-	GOM
ARC3	Random Sea	A	43.0	14.0		4.3	1	-	-	GOM1
ARC4	Random Sea	A	43.0	14.0		4.3	1	-	-	GOM2
ARCW3	Random Sea	A	43.0	14.0		4.3	1	85	85KT_4	GOM1
ARCW4	Random Sea	A	43.0	14.0		4.3	1	85	85KT_4	GOM2
ACUR5	Current	A	-	-	-	5.3	2	-	-	North Sea
ARC5	Random Sea	A	45.9	16.3		5.3	2	-	-	North Sea
ARCW5	Random Sea	A	45.9	16.3		5.3	2	58.7	59KT_3	North Sea
ACUR2	Current	A	-	-	-	6.3	3	-	-	10 Year Storm
ARC2	Random Sea	A	21.0	10.5	10YRC_6	6.3	3	-	-	10 Year Storm
ARCW2	Random Sea	A	21.0	10.5	10YRCW_4	6.3	3	43	43KT_3	10 Year Storm

Test	Test Type	Configuration	Hs	Tp	Wave DSIG	Current	Pump Setting	Wind	Wind DSIG	
BSO	Static Offset	B	-	-	-	-	-	-	-	
BD1	Surge Damping	B	-	-	-	-	-	-	-	
BD2	Sway Damping	B	-	-	-	-	-	-	-	
BD3	Heave Damping	B	-	-	-	-	-	-	-	
BD4	Roll Damping	B	-	-	-	-	-	-	-	
BD5	Pitch Damping	B	-	-	-	-	-	-	-	
BRG2	Regular Wave	B	12.0	7.0	RG4_1	-	-	-	-	
BRG4	Regular Wave	B	18.0	9.0	RG6_1	-	-	-	-	
BRG6	Regular Wave	B	20.0	12.0	RG8_1	-	-	-	-	
BRG8	Regular Wave	B	20.0	16.0	RG10_1	-	-	-	-	
BBC3	Bi-Chromatic Wave	B	20/20	14/15.11	BC3_2	-	-	-	-	
BBC5	Bi-Chromatic Wave	B	20/20	16/17.47	BC5_2	-	-	-	-	
BBC8	Bi-Chromatic Wave	B	20/20	12/14.29	BC8_2	-	-	-	-	
BBC10	Bi-Chromatic Wave	B	20/20	14/17.21	BC10_2	-	-	-	-	
BBC12	Bi-Chromatic Wave	B	20/20	16/20.34	BC12_2	-	-	-	-	
BRAN2	Random Sea	B	21.0	10.5	10YR_2	-	-	-	-	10 Year Storm
BRAN3	Random Sea	B	43.0	14.0	GOM1_3	-	-	-	-	GOM1
BRAN4	Random Sea	B	43.0	14.0	GOM2_3	-	-	-	-	GOM2
BRAN5	Random Sea	B	45.9	16.3	NS_3	-	-	-	-	North Sea
BWIN2	Wind	B	-	-	-	-	-	43	43KT_3	10 Year Storm
BWIN5	Wind	B	-	-	-	-	-	58.7	59KT_3	North Sea
BWIN3	Wind	B	-	-	-	-	-	85	85KT_4	GOM1
BWIN4	Wind	B	-	-	-	-	-	85	85KT_7	GOM2
BCUR3	Current	B	-	-	-	4.3	1	-	-	GOM
BRW3	Random Sea	B	43.0	14.0	GOM1_3	4.3	1	-	-	GOM1
BRW4	Random Sea	B	43.0	14.0	GOMC2_2	4.3	1	-	-	GOM2
BRWC3	Random Sea	B	43.0	14.0	GOM1_3	4.3	1	85	85KT_4	GOM1
BRWC4	Random Sea	B	43.0	14.0	GOMC2_2	4.3	1	85	85KT_7	GOM2
BCUR5	Current	B	-	-	-	5.3	2	-	-	North Sea
BRW5	Random Sea	B	45.9	16.3	NSC_2	5.3	2	-	-	North Sea
BRWC5	Random Sea	B	45.9	16.3	NSC_2	5.3	2	58.7	59KT_3	North Sea
BCUR2	Current	B	-	-	-	6.3	3	-	-	10 Year Storm
BRW2	Random Sea	B	21.0	10.5	10YRC_7	6.3	3	-	-	10 Year Storm
BRWC2	Random Sea	B	21.0	10.5	10YRCW_5	6.3	3	43	43KT_3	10 Year Storm

Test	Test Type	Configuration	Hs	Tp	Wave DSIG	Current	Pump Setting	Wind	Wind DSIG	
CD1	Surge Damping	C	-	-	-	-	-	-	-	
CD2	Sway Damping	C	-	-	-	-	-	-	-	
CD3	Heave Damping	C	-	-	-	-	-	-	-	
CD4	Roll Damping	C	-	-	-	-	-	-	-	
CD5	Pitch Damping	C	-	-	-	-	-	-	-	
CRG1	Regular Wave	C	6.0	6.0	RG3_3	-	-	-	-	
CRG2	Regular Wave	C	12.0	7.0	RG4_1	-	-	-	-	
CRG3	Regular Wave	C	15.0	8.0	RG5-1	-	-	-	-	
CRG4	Regular Wave	C	18.0	9.0	RG6_1	-	-	-	-	
CRG5	Regular Wave	C	20.0	10.0	RG7_1	-	-	-	-	
CRG6	Regular Wave	C	20.0	12.0	RG8_1	-	-	-	-	
CRG7	Regular Wave	C	20.0	14.0	RG9_2	-	-	-	-	
CRG8	Regular Wave	C	20.0	16.0	RG10_1	-	-	-	-	
CRG9	Regular Wave	C	20.0	17.0	RG11_3	-	-	-	-	
CRG10	Regular Wave	C	20.0	21.0	RG12_1	-	-	-	-	
CBC2	Bi-Chromatic Wave	C	20/20	12/12.81	BC2_2	-	-	-	-	
CBC3	Bi-Chromatic Wave	C	20/20	14/15.11	BC3_2	-	-	-	-	
CBC4	Bi-Chromatic Wave	C	10/10	14/15.11	BC4_2	-	-	-	-	
CBC5	Bi-Chromatic Wave	C	20/20	16/17.47	BC5_2	-	-	-	-	
CBC6	Bi-Chromatic Wave	C	20/20	17/18.67	BC6_2	-	-	-	-	
CBC7	Bi-Chromatic Wave	C	20/20	10/11.54	BC7_2	-	-	-	-	
CBC8	Bi-Chromatic Wave	C	20/20	12/14.29	BC8_2	-	-	-	-	
CBC9	Bi-Chromatic Wave	C	20/20	13/15.73	BC9_2	-	-	-	-	
CBC10	Bi-Chromatic Wave	C	20/20	14/17.21	BC10_2	-	-	-	-	
CBC11	Bi-Chromatic Wave	C	10/10	14/17.21	BC11_2	-	-	-	-	
CBC12	Bi-Chromatic Wave	C	20/20	16/20.34	BC12_2	-	-	-	-	
CBC13	Bi-Chromatic Wave	C	20/20	17/21.98	BC13_2	-	-	-	-	
CBC14	Bi-Chromatic Wave	C	20/15	13/8.96	BC14_2					
CRAN2	Random Sea	C	21.0	10.5	10YR_2	-	-	-	-	10 Year Storm

Test	Test Type	Configuration	Hs	Tp	Wave DSIG	Current	Pump Setting	Wind	Wind DSIG	
DD1	Surge Damping	D	-	-	-	-	-	-	-	
DD2	Sway Damping	D	-	-	-	-	-	-	-	
DD3	Heave Damping	D	-	-	-	-	-	-	-	
DD4	Roll Damping	D	-	-	-	-	-	-	-	
DD5	Pitch Damping	D	-	-	-	-	-	-	-	
DCUR3	Current	D	-	-	-	4.3	1	-	-	GOM
DRC3	Random Sea	D	43.0	14.0	GOM1_3	4.3	1	-	-	GOM1
DRC4	Random Sea	D	43.0	14.0	GOMC2_2	4.3	1	-	-	GOM2
DCUR5	Current	D	-	-	-	5.3	2	-	-	North Sea
DRC5	Random Sea	D	45.9	16.3	NSC_2	5.3	2	-	-	North Sea
DCUR2	Current	D	-	-	-	6.3	3	-	-	10 Year Storm
DRC2	Random Sea	D	21.0	10.5	10YRC_7	6.3	3	-	-	10 Year Storm
HD1	Surge Damping	A	-	-	-	-	-	-	-	
HD2	Sway Damping	A	-	-	-	-	-	-	-	
HD3	Heave Damping	A	-	-	-	-	-	-	-	
HD4	Roll Damping	A	-	-	-	-	-	-	-	
HD5	Pitch Damping	A	-	-	-	-	-	-	-	
HD6	Yaw Damping	A	-	-	-	-	-	-	-	
HWIN2	Wind	A	-	-	-	-	-	43	43KT_3	10 Year Storm
HWIN5	Wind	A	-	-	-	-	-	59	59KT_3	North Sea
HWIN3	Wind	A	-	-	-	-	-	85	85KT_4	GOM1
HWIN4	Wind	A	-	-	-	-	-	85	85KT_4	GOM2
HRAN1	Random Sea	A	8.0	7.7	OP_4	-	-	-	-	Operating Long-Crested
HRAN2	Random Sea	A	21.0	10.5	10YR_2	-	-	-	-	10 Year Storm
HRAN3	Random Sea	A	43.0	14.0	GOM1_3	-	-	-	-	GOM1
HRAN4	Random Sea	A	43.0	14.0	GOM2_3	-	-	-	-	GOM2
HRAN5	Random Sea	A	45.9	16.3	NS_3	-	-	-	-	North Sea
HRAN6	Random Sea	A	8.0	7.7	OP_2_MDS	-	-	-	-	Operating Short_Creste
HCUR3	Current	A	-	-	-	4.3	1	-	-	GOM
HRC3	Random Sea	A	43.0	14.0		4.3	1	-	-	GOM1
HRC4	Random Sea	A	43.0	14.0		4.3	1	-	-	GOM2
HRCW3	Random Sea	A	43.0	14.0		4.3	1	85	85KT_4	GOM1
HRCW4	Random Sea	A	43.0	14.0		4.3	1	85	85KT_4	GOM2
HCUR5	Current	A	-	-	-	5.3	2	-	-	North Sea
HRC5	Random Sea	A	45.9	16.3		5.3	2	-	-	North Sea
HRCW5	Random Sea	A	45.9	16.3		5.3	2	58.7	59KT_3	North Sea
HCUR2	Current	A	-	-	-	6.3	3	-	-	10 Year Storm

Test	Test Type	Configuration	Hs	Tp	Wave DSIG	Current	Pump Setting	Wind	Wind DSIG	
HRC2	Random Sea	A	21.0	10.5	10YRC_6	6.3	3	-	-	10 Year Storm
HRCW2	Random Sea	A	21.0	10.5	10YRCW_4	6.3	3	43	43KT_3	10 Year Storm
LSO	Static Offset	L	-	-	-	-	-	-	-	
LD1	Surge Damping	L	-	-	-	-	-	-	-	
LD2	Sway Damping	L	-	-	-	-	-	-	-	
LD3	Heave Damping	L	-	-	-	-	-	-	-	
LD4	Roll Damping	L	-	-	-	-	-	-	-	
LD5	Pitch Damping	L	-	-	-	-	-	-	-	
LD6	Yaw Damping	L	-	-	-	-	-	-	-	
LRAN1	Random Sea	L	8.0	7.7	OP_4	-	-	-	-	Operating Long-Crested
LRAN2	Random Sea	L	21.0	10.5	10YR_2	-	-	-	-	10 Year Storm
LRAN3	Random Sea	L	43.0	14.0	GOM1_3	-	-	-	-	GOM1
LRAN4	Random Sea	L	43.0	14.0	GOM2_3	-	-	-	-	GOM2
LRAN6	Random Sea	L	8.0	7.7	OP_2_MDS	-	-	-	-	Operating Short_Creste
LWIN2	Wind	L	-	-	-	-	-	43	43KT_3	10 Year Storm
LWIN3	Wind	L	-	-	-	-	-	85	85KT_4	GOM1
LWIN4	Wind	L	-	-	-	-	-	85	85KT_7	GOM2
LRG1	Regular Wave	C	6.0	6.0	RG3_3	-	-	-	-	
LRG2	Regular Wave	C	12.0	7.0	RG4_1	-	-	-	-	
LRG4	Regular Wave	C	18.0	9.0	RG6_1	-	-	-	-	
LRG5	Regular Wave	C	20.0	10.0	RG7_1	-	-	-	-	
LRG6	Regular Wave	C	20.0	12.0	RG8_1	-	-	-	-	
LRG7	Regular Wave	C	20.0	14.0	RG9_2	-	-	-	-	
LRG8	Regular Wave	C	20.0	16.0	RG10_1	-	-	-	-	
LCUR3	Current	L	-	-	-	4.3	1	-	-	GOM
LRC3	Random Sea	L	43.0	14.0		4.3	1	-	-	GOM1
LRC4	Random Sea	L	43.0	14.0		4.3	1	-	-	GOM2
LRCW3	Random Sea	L	43.0	14.0		4.3	1	85	85KT_4	GOM1
LRCW4	Random Sea	L	43.0	14.0		4.3	1	85	85KT_7	GOM2
LCUR2	Current	L	-	-	-	6.3	3	-	-	10 Year Storm
LRC2	Random Sea	L	21.0	10.5	10YRC_7	6.3	3	-	-	10 Year Storm
LRCW2	Random Sea	L	21.0	10.5	10YRCW_5	6.3	3	43	43KT_3	10 Year Storm
MSO	Static Offset	L	-	-	-	-	-	-	-	
MD1	Surge Damping	L	-	-	-	-	-	-	-	
MD2	Sway Damping	L	-	-	-	-	-	-	-	
MD3	Heave Damping	L	-	-	-	-	-	-	-	
MD4	Roll Damping	L	-	-	-	-	-	-	-	
MD5	Pitch Damping	L	-	-	-	-	-	-	-	

Test	Test Type	Configuration	Hs	Tp	Wave DSIG	Current	Pump Setting	Wind	Wind DSIG	
MWIN3	Wind	L	-	-	-	-	-	85	85KT_4	GOM1
MWIN4	Wind	L	-	-	-	-	-	85	85KT_7	GOM2
MCUR3	Current	L	-	-	-	4.3	1	-	-	GOM
MRC3	Random Sea	L	43.0	14.0		4.3	1	-	-	GOM1
MRC4	Random Sea	L	43.0	14.0		4.3	1	-	-	GOM2
MRCW3	Random Sea	L	43.0	14.0		4.3	1	85	85KT_4	GOM1
MRCW4	Random Sea	L	43.0	14.0		4.3	1	85	85KT_7	GOM2
MCUR2	Current	L	-	-	-	6.3	3	-	-	10 Year Storm
MRC2	Random Sea	L	21.0	10.5	10YRC_7	6.3	3	-	-	10 Year Storm
FD1	Surge Damping	F	-	-	-	-	-	-	-	w/o catenary riser
FD2	Sway Damping	F	-	-	-	-	-	-	-	w/o catenary riser
FD3	Heave Damping	F	-	-	-	-	-	-	-	w/o catenary riser
FD4	Roll Damping	F	-	-	-	-	-	-	-	w/o catenary riser
FD5	Pitch Damping	F	-	-	-	-	-	-	-	w/o catenary riser
FD6	Yaw Damping	F	-	-	-	-	-	-	-	w/o catenary riser
FRG9	Regular Wave	F	20.0	17.0	RG11_3	-	-	-	-	
FRG10	Regular Wave	F	20.0	21.0	RG12_1	-	-	-	-	
FRAN1	Random Sea	F	8.0	7.7	OP_4	-	-	-	-	Operating Long-Crested
FRAN2	Random Sea	F	21.0	10.5	10YR_2	-	-	-	-	10 Year Storm
FRAN3	Random Sea	F	43.0	14.0	GOM1_3	-	-	-	-	GOM1
FRAN6	Random Sea	F	12.1	16.0		-	-	-	-	GOM1
FCUR3	Current	F	-	-	-	4.3	1	-	-	GOM
FRC3	Random Sea	F	43.0	14.0	GOM1_3	4.3	1	-	-	GOM1
FRC6	Random Sea	F	12.1	16.0		4.3	1	-	-	W. AFRICA
FRCW3	Random Sea	F	43.0	14.0	GOM1_C	4.3	1	85	85KT_4	GOM1
FRCW6	Random Sea	F	12.1	16.0		4.3	1			W. AFRICA
FCUR2	Current	F	-	-	-	6.3	3	-	-	10 Year Storm
FRC2	Random Sea	F	21.0	10.5	10YRC_7	6.3	3	-	-	10 Year Storm
FRCW2	Random Sea	F	21.0	10.5	10YRCW_5	6.3	3	43	43KT_3	10 Year Storm
FSO	Static Offset	F	-	-	-	-	-	-	-	w/o catenary riser
F1D2	Sway Damping	F	-	-	-	-	-	-	-	w/o catenary riser
F1D3	Heave Damping	F	-	-	-	-	-	-	-	w/o catenary riser
F1D4	Roll Damping	F	-	-	-	-	-	-	-	w/o catenary riser
F1D5	Pitch Damping	F	-	-	-	-	-	-	-	w/o catenary riser
F1D6	Yaw Damping	F	-	-	-	-	-	-	-	w/o catenary riser
F1RAN3	Random Sea	F1	43.0	14.0	GOM1_3	-	-	-	-	GOM1
F1RAN5	Random Sea	F1	45.9	16.3	NS_3	-	-	-	-	North Sea

Test	Test Type	Configuration	Hs	Tp	Wave DSIG	Current	Pump Setting	Wind	Wind DSIG	
F2RAN3	Random Sea	F2	43.0	14.0	GOM1_3	-	-	-	-	GOM1
F1CUR3	Current	F1	-	-	-	4.3	1	-	-	GOM
F1RC3	Random Sea	F1	43.0	14.0		4.3	1	-	-	GOM1
F1RCW3	Random Sea	F1	43.0	14.0		4.3	1	85	85KT_4	GOM1
F1CUR5	Current	F1	-	-	-	5.3	2	-	-	North Sea
F1RC5	Random Sea	F1	45.9	16.3		5.3	2	-	-	North Sea
F1RCW5	Random Sea	F1	45.9	16.3		5.3	2	58.7	59KT_3	North Sea
F2CUR3	Current	F2	-	-	-	4.3	1	-	-	GOM
F2RC3	Random Sea	F2	43.0	14.0		4.3	1	-	-	GOM1
F2RCW3	Random Sea	F2	43.0	14.0		4.3	1	85	85KT_4	GOM1
ARG3	Regular Wave	A	15.0	8.0		-	-	-	-	
ARG5	Regular Wave	A	20.0	10.0	RG7_1	-	-	-	-	
ARG6	Regular Wave	A	20.0	12.0	RG8_1	-	-	-	-	
ARG7	Regular Wave	A	20.0	14.0	RG9_2	-	-	-	-	
ARG8	Regular Wave	A	20.0	16.0	RG10_1	-	-	-	-	
ARAN6	Random Sea	A	12.1	16.0	AFR_2	-	-	-	-	W. Africa
ACUR3	Current	A	-	-	-	4.3	1	-	-	W. Africa
ARC6	Random Sea	A	12.1	16.0	AFRC_2	4.3	1	-	-	W. Africa
ARCW6	Random Sea	A	12.1	16.0	AFRC_2	4.3	1	38	38KT_1	W. Africa

Appendix B

Tabulated Statistics

CONFIGURATION A - BARE CYLINDER UNRESTRAINED
TEST RESULTS SUMMARY

		Current only															
		acur2			acur3			acur5			acur7			awin2			awin3
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3													0.45	0.14	0.42	1.74
Ft	Std. Dev.													0.11	0.03	0.11	0.44
	Max													-0.2	0.1	0.35	1.05
	Min													-1.1	-0.1	-0.52	-2.06
WIND	Mean													40.33			84.62
Knots	Std. Dev.													4.67	3.99	2.38	9.22
	Max													59.94	14.09	7.95	119.35
	Min													26.74	-12.88	-7.49	53.11
CUR 1	Mean	4.64			3.31			3.91			3.74						
Ft/Sec	Std. Dev.	1.25	1.1	0.58	0.77	0.67	0.37	0.97	0.84	0.47	1.1	0.99	0.43				
	Max	8.37	2.58	2.52	5.66	1.78	1.89	7.52	2.34	1.88	7.09	2.1	1.61				
	Min	-0.09	-3.55	-2.55	0.56	-2.03	-1.84	0.85	-2.2	-1.87	0.56	-3.01	-1.83				
CUR 2	Mean	0.57			0.14			0.28			-0.01						
Ft/Sec	Std. Dev.	0.36	0.34	0.11	0.09	0.08	0.02	0.31	0.3	0.05	0.32	0.29	0.1				
	Max	1.74	0.96	0.66	0.43	0.24	0.14	0.98	0.5	0.32	0.92	0.52	0.42				
	Min	-0.87	-0.88	-0.68	-0.19	-0.28	-0.09	-0.65	-0.88	-0.3	-1.25	-1.06	-0.43				
SURGE_CG	Mean	-38.55			-20.85			-29			-20.16			-20.54			-57.29
Ft	Std. Dev.	7.32	7.32	0.12	5.67	5.67	0.08	7.68	7.68	0.18	6.87	6.85	0.43	13.1	13.1	0.11	9.64
	Max	-20.33	18.22	4.66	-7.41	13.36	1.52	-10.23	18.73	5.5	-4.51	15.55	10.48	6.76	27.26	3.49	-33.27
	Min	-56.92	-18.26	-1.15	-37.66	-16.83	-1.38	-44.43	-15.4	-4.38	-36.1	-15.87	-11.08	-46.79	-26.11	-1.63	-82.32
HEAVE_CG	Mean	-0.03			-0.02			-0.13			0.02			0			0.52
Ft	Std. Dev.	0.31	0.19	0.25	0.07	0.06	0.04	0.13	0.12	0.07	0.07	0.06	0.03	0.64	0.09	0.63	3.11
	Max	1.35	0.94	0.99	0.24	0.22	0.12	0.49	0.44	0.28	0.27	0.19	0.1	1.72	0.27	1.59	9.54
	Min	-1.16	-0.57	-0.99	-0.21	-0.16	-0.13	-0.56	-0.36	-0.31	-0.25	-0.2	-0.1	-1.64	-0.23	-1.6	-7.5
SWAY_CG	Mean	-0.33			3.47			-5.04			-3.53			5.9			2.83
Ft	Std. Dev.	15.12	15.11	0.4	10.76	10.76	0.12	20.75	20.71	1.11	11.17	11.17	0.13	1.72	1.71	0.08	2.19
	Max	33.58	33.78	9.41	27.21	23.75	2.22	50.81	55.92	28.01	31.58	35.09	2.78	9.3	3.3	1.47	8.79
	Min	-39.12	-38.8	-10.56	-24.24	-27.74	-3.3	-49.27	-44.16	-27.09	-29.4	-25.86	-3.43	2.18	-3.65	-1.34	-2.16
ROLL	Mean	0.01			0.01			0.06			-0.03			0.07			0.01
deg	Std. Dev.	1.16	1.16	0.04	0.32	0.32	0.01	0.57	0.57	0.03	0.25	0.25	0.01	0.14	0.14	0.01	0.84
	Max	2.84	2.83	0.73	0.88	0.86	0.24	2.02	1.9	0.21	0.86	0.88	0.34	0.35	0.28	0.03	2.12
	Min	-3.13	-3.16	-1.07	-0.77	-0.78	-0.13	-1.76	-1.85	-0.65	-0.8	-0.78	-0.3	-0.21	-0.27	-0.02	-2.21
YAW	Mean	-0.06			-0.15			-0.19			-0.05			-0.29			-1.3
deg	Std. Dev.	0.48	0.48	0.04	0.21	0.2	0.03	0.39	0.39	0.04	0.23	0.22	0.02	0.47	0.47	0.04	1.3
	Max	1.37	1.41	0.16	0.4	0.49	0.14	1.19	1.31	0.51	0.56	0.58	0.07	0.9	1.11	0.26	2.66
	Min	-1.43	-1.2	-0.51	-0.75	-0.53	-0.15	-1.4	-1.17	-0.53	-0.78	-0.68	-0.12	-1.66	-1.19	-0.45	-5.43
PITCH	Mean	-0.42			-0.24			-0.34			-0.23			-0.53			-2.24
deg	Std. Dev.	0.44	0.44	0.02	0.29	0.29	0.01	0.41	0.41	0.01	0.15	0.15	0	0.48	0.48	0.01	1.38
	Max	0.75	1.17	0.3	0.39	0.63	0.17	0.54	0.88	0.09	0.18	0.41	0.01	0.83	1.35	0.06	0.96
	Min	-1.9	-1.49	-0.33	-0.82	-0.58	-0.09	-1.14	-0.8	-0.09	-0.6	-0.37	-0.01	-1.83	-1.29	-0.1	-5.72
TENS-1	Mean	1433			1249			1298			1265			1256			1839
Kips	Std. Dev.	107.2	107	5.36	35.26	35.23	1.25	50.97	50.96	1.13	42.28	42.18	2.8	73.91	73.85	2.92	264.5
	Max	1806	369.4	97.09	1362	113.3	19.86	1419	120.1	14.07	1374	109	70.62	1409	148.4	8.86	2725
	Min	1271	-160	-105.4	1168	-80.91	-26.37	1183	-111	-18.76	1173	-91.06	-66.37	1097	-156.7	-12.01	1333
TENS-2	Mean	1129			1100			1150			1169			1206			1122
Kips	Std. Dev.	80.19	80.13	2.91	57.14	57.13	0.82	119.9	119.7	6.11	60.75	60.74	0.95	11.36	10.79	3.16	18.76
	Max	1352	218	68.77	1251	149	15.62	1527	380.7	144	1317	146.2	20.59	1238	23.15	11.35	1188
	Min	943.9	-183.1	-59.84	977.8	-121.8	-11.71	850.1	-299.5	-152.8	980.1	-188	-15.55	1177	-21.72	-15.43	1064
TENS-3	Mean	902.8			1031			989.8			1025			1012			844.8
Kips	Std. Dev.	39.49	39.48	1.1	30.15	30.13	0.82	40.56	40.55	0.78	37.36	37.27	2.45	70.2	70.15	2.68	51.39
	Max	999.6	97.36	10.67	1103	71.76	21.31	1087	96.65	16.62	1111	85.02	57.89	1164	149.6	9.83	972.6
	Min	804.5	-98.52	-11.55	943.9	-86.88	-15.88	910.9	-79.72	-18.01	940.1	-83.62	-61.12	873.5	-136.1	-9.88	710.9
TENS-4	Mean	1128			1152			1111			1171			1180			1173
Kips	Std. Dev.	79.33	79.27	2.9	53.99	53.98	0.92	107.7	107.5	5.85	60.05	60.04	0.76	9.06	8.73	2.43	20.83
	Max	1331	202.4	62.28	1271	119.2	13.82	1496	387.3	153.4	1363	189.7	9.36	1196	16.53	6.51	1234
	Min	907.3	-205.4	-66.1	1017	-134	-21.78	882.2	-225.3	-138.4	1031	-138.5	-12.81	1160	-17.37	-8.25	1098
REL. MOT.	Mean	-0.69			-0.82			-0.69			1.1			-0.96			-4.08
Ft	Std. Dev.	1.1	1.08	0.23	0.69	0.69	0.04	0.99	0.98	0.15	0.36	0.36	0.05	1.37	1.23	0.6	4.56
	Max	2.12	2.83	1.13	0.61	1.43	0.73	1.32	1.88	0.75	1.86	0.81	0.17	3.13	3.29	1.61	9.41
	Min	-4.41	-3.56	-1.16	-2.28	-1.41	-0.31	-3.09	-2.14	-0.58	-0.22	-1.06	-0.21	-6	-3.51	-1.61	-17.92
RUNUP	Mean	-2			-0.14			-5.22			0.55						
Ft	Std. Dev.	0.55	0.52	0.18	0.3	0.3	0.04	0.54	0.53	0.12	0.16	0.15	0.03				
	Max	-0.29	1.65	0.88	0.59	0.76	0.44	-3.95	1.26	0.91	1.08	0.51	0.13				
	Min	-3.79	-1.41	-0.82	-0.82	-0.61	-0.17	-6.95	-1.45	-0.8	0.02	-0.38	-0.14				
MOONPOOL	Mean	0.16			0.12			0.44						-0.02			0.56
Ft	Std. Dev.	0.03	0.03	0.01	0.01	0.01	0	0.02	0.02	0.01				0.05	0.04	0.03	0.45
	Max	0.26	0.08	0.02	0.15	0.03	0.01	0.64	0.2	0.03				0.19	0.13	0.17	2.09
	Min	0.08	-0.08	-0.03	0.08	-0.03	-0.02	0.39	-0.05	-0.03				-0.24	-0.13	-0.19	-0.97

CONFIGURATION A - BARE CYLINDER UNRESTRAINED
TEST RESULTS SUMMARY

		Wind only															
				awin4			awin5			aran1			aran2			aran3	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
WAVE	H1/3	0.6	1.44	1.63	0.47	1.37	1.02	0.23	0.91	8.97	0.24	8.96	22.28	0.9	22.24	44.88	1.63
Ft	Std. Dev.	0.15	0.36	0.41	0.12	0.34	0.25	0.06	0.23	2.24	0.06	2.24	5.57	0.23	5.56	11.22	0.41
	Max	0.35	1.15	0.05	0.39	1.34	0.43	0.13	0.7	9.26	0.16	9.08	24.3	0.77	22.87	48.37	2.21
	Min	-0.35	-1.25	-2.91	-0.38	-1.27	-1.52	-0.15	-0.94	-7.47	-0.19	-7.66	-17.69	-0.52	-17.8	-30.64	-1.03
WIND	Mean			83.31			57.38										
Knots	Std. Dev.	7.31	5.6	8.6	6.99	4.98	6.38	5.26	3.58								
	Max	26.03	19.89	111.18	19.7	19.02	78.34	16.16	12.5								
	Min	-21.12	-21.05	58.39	-20.9	-15.22	36.11	-20.32	-11.51								
CUR 1	Mean																
Ft/Sec	Std. Dev.																
	Max																
	Min																
CUR 2	Mean																
Ft/Sec	Std. Dev.																
	Max																
	Min																
SURGE_CG	Mean			-56.19			-38.01			-1.9			-6.99			-13.75	
Ft	Std. Dev.	9.63	0.22	9.68	9.68	0.28	16.36	16.35	0.46	1.8	1.79	0.2	9.09	9.05	0.89	11.96	11.59
	Max	23.91	2.03	-32.89	22.99	4.66	9.21	46.87	11.59	2.64	3.77	3.3	15.06	20.68	3.16	16.65	24.01
	Min	-25.01	-4.18	-76.93	-20.84	-5.88	-80.18	-41.57	-10.4	-5.97	-3.84	-2.84	-29.83	-21.46	-3.01	-46.88	-25.53
HEAVE_CG	Mean			0.51			0.14			0.01			-0.03			0.03	
Ft	Std. Dev.	0.63	3.05	2.03	0.53	1.96	0.73	0.18	0.71	0.37	0.04	0.37	0.47	0.06	0.47	1.67	0.34
	Max	2.85	7.78	5.35	1.97	4.73	2.14	0.66	1.75	0.95	0.12	0.9	1.18	0.19	1.12	5.11	1.3
	Min	-1.64	-7.85	-5.19	-1.14	-4.77	-1.69	-0.74	-1.69	-0.95	-0.13	-0.92	-1.19	-0.19	-1.09	-4.5	-1.57
SWAY_CG	Mean			3.26			6.32			0.04			0.09			0.3	
Ft	Std. Dev.	2.18	0.17	2.32	2.31	0.16	3.45	3.45	0.08	0.29	0.28	0.07	0.63	0.61	0.16	2.51	2.44
	Max	4.55	1.81	8.84	5.45	1.83	13.41	6.97	0.59	0.78	0.58	0.37	1.71	1.33	0.52	6.01	4.96
	Min	-4.93	-1.63	-1.4	-4.45	-1.54	-0.76	-7.03	-0.44	-1.22	-0.63	-0.59	-1.85	-1.61	-0.7	-8.36	-7.37
ROLL	Mean			0.11			0.03			0			-0.01			0.01	
deg	Std. Dev.	0.84	0.03	0.87	0.87	0.02	0.22	0.22	0.01	0.02	0.01	0.01	0.07	0.06	0.03	0.32	0.31
	Max	2.08	0.14	1.67	1.57	0.09	0.53	0.49	0.12	0.05	0.04	0.03	0.19	0.17	0.09	0.82	0.64
	Min	-2.23	-0.33	-1.59	-1.68	-0.07	-0.49	-0.51	-0.14	-0.06	-0.04	-0.04	-0.25	-0.17	-0.1	-0.8	-0.66
YAW	Mean			-1.51			-0.59			-0.35			-0.24			-0.06	
deg	Std. Dev.	1.29	0.1	1.32	1.32	0.1	0.75	0.75	0.06	0.04	0.03	0.02	0.1	0.08	0.05	0.69	0.67
	Max	3.88	0.7	2.56	4	0.52	1.62	2.2	0.43	-0.22	0.07	0.09	0.12	0.27	0.19	2.02	1.9
	Min	-3.91	-0.35	-6.22	-4.67	-0.34	-3.29	-2.57	-0.46	-0.5	-0.07	-0.1	-0.61	-0.24	-0.37	-2.09	-1.97
PITCH	Mean			-2.25			-1.09			-0.04			-0.14			-0.27	
deg	Std. Dev.	1.37	0.06	1.26	1.26	0.04	0.7	0.7	0.02	0.1	0.1	0.04	0.58	0.54	0.22	1.39	1.25
	Max	3.15	0.23	1.07	3.27	0.12	0.65	1.72	0.06	0.24	0.23	0.13	1.73	1.54	0.76	3.43	3.21
	Min	-3.43	-0.18	-5.4	-3.18	-0.11	-2.78	-1.68	-0.06	-0.35	-0.21	-0.14	-1.9	-1.53	-0.71	-4.29	-2.97
TENS-1	Mean			1818			1409			1156			1178			1240	
Kips	Std. Dev.	257.1	61.99	254.1	250.9	40.14	194.7	194.3	12.94	10.49	10.32	1.76	49.68	49.58	2.98	70.81	68.56
	Max	827.5	232.2	2468	591.4	144.2	2264	858.7	218.5	1182	23.84	13.59	1299	116.2	10.23	1495	163.3
	Min	-495.8	-177.2	1329	-474.7	-200.7	1092	-316.7	-289.2	1136	-19.09	-10.31	1053	-116.7	-9.86	1085	-123.3
TENS-2	Mean			1123			1208			1141			1132			1119	
Kips	Std. Dev.	13.54	12.93	16.04	13.63	8.38	19.18	18.85	3.28	2.75	1.76	1.87	4.16	3.38	2.24	15.64	13.7
	Max	39.23	37.28	1169	28.93	22.6	1254	39.13	9.85	1150	4.03	6.1	1146	9.93	6.94	1172	45.28
	Min	-31.62	-35.68	1074	-32.62	-23.47	1158	-42.92	-13.1	1132	-3.31	-5.33	1118	-7.18	-6.6	1074	-37.31
TENS-3	Mean			848.1			919.7			1108			1042			1014	
Kips	Std. Dev.	49.68	13.16	50.98	50.3	8.27	87.38	87.29	3.85	9.83	9.68	1.66	48.59	48.46	3.57	63.87	61.94
	Max	118.8	33.78	975	117.5	20.87	1174	254.6	56.92	1130	19.89	14.02	1162	111.6	11.44	1169	126.4
	Min	-116.2	-34.03	736.8	-110.6	-36.8	693.8	-221.9	-61.14	1085	-21.61	-11.27	923.8	-112.6	-13.47	851.7	-129
TENS-4	Mean			1171			1187			1136			1135			1121	
Kips	Std. Dev.	15.64	13.76	18.28	16.05	8.75	20.22	20.04	2.72	1.98	1.44	1.34	3.79	3.35	1.77	16.32	13.65
	Max	34.7	36.67	1224	48.3	21.04	1227	35.81	7.58	1143	3.29	3.53	1146	7.97	4.4	1163	33.3
	Min	-40.74	-36.13	1115	-43.1	-21.49	1147	-39.15	-6.92	1131	-3.1	-3.44	1123	-8.21	-4.64	1066	-38.75
REL. MOT.	Mean			-4.93			-2.4			-0.13			-0.4			-0.72	
Ft	Std. Dev.	3.47	2.95	3.74	3.19	1.95	1.97	1.84	0.69	2.45	0.27	2.44	7.11	1.41	6.96	14.13	2.99
	Max	7.63	8.22	6.01	7.63	5.26	2.92	4.25	1.83	11.44	0.7	10.94	32.84	3.93	30.03	48.27	6.51
	Min	-9.34	-8.09	-14.53	-8.45	-5.01	-8.56	-4.78	-2.06	-8.53	-0.64	-8.44	-23.3	-4.34	-23.85	-39.65	-7.56
RUNUP	Mean																
Ft	Std. Dev.																
	Max																
	Min																
MOONPOOL	Mean			0.31			-0.16			0.04			0.09			0.2	
Ft	Std. Dev.	0.36	0.27	0.4	0.34	0.22	0.17	0.15	0.09	0.04	0.01	0.04	0.13	0.06	0.11	0.18	0.09
	Max	1.39	0.77	1.39	0.96	0.74	0.43	0.48	0.27	0.17	0.04	0.13	1.06	0.28	0.74	1.24	0.26
	Min	-1.01	-0.88	-0.92	-0.93	-0.66	-0.69	-0.37	-0.32	-0.17	-0.04	-0.21	-0.23	-0.16	-0.42	-0.49	-0.18

CONFIGURATION A - BARE CYLINDER UNRESTRAINED
TEST RESULTS SUMMARY

		Waves only															
			aran4			aran3-4			aran5			aran6			aran7		
		f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	44.84	45	1.62	44.92	44.92	1.8	44.88	48.52	1.14	48.52	8.5	0.3	8.48	12.76	0.22	12.76
Ft	Std. Dev.	11.21	11.25	0.41	11.23	11.23	0.45	11.22	12.13	0.29	12.13	2.12	0.08	2.12	3.19	0.06	3.19
	Max	45.34	48.1	1.86	47.4	48.37	3.14	47.16	57.49	1.18	55.84	9.93	0.49	9.47	11.66	0.21	11.87
	Min	-32.62	-32.12	-3.25	-32.46	-32.12	-4.54	-32.68	-36.47	-2.24	-37.49	-7.13	-0.22	-7.44	-9.76	-0.17	-9.68
WIND	Mean																
Knots	Std. Dev.																
	Max																
	Min																
CUR 1	Mean																
Ft/Sec	Std. Dev.																
	Max																
	Min																
CUR 2	Mean																
Ft/Sec	Std. Dev.																
	Max																
	Min																
SURGE_CG	Mean		-14.13			-13.94			-9.36			-1.63			-0.59		
Ft	Std. Dev.	2.94	13.65	13.32	2.97	12.83	12.49	2.95	15.62	15.1	3.97	3	2.99	0.17	1.55	1.13	1.07
	Max	8.95	21.29	31.48	9.4	21.3	31.28	9.4	39.66	33.97	18.49	4.2	5.59	1.39	4.37	2.78	4.01
	Min	-8.63	-58.07	-37.11	-9.68	-58.06	-37.34	-9.66	-48.2	-33.09	-14.98	-6.78	-4.82	-1.51	-5.41	-2.82	-3.85
HEAVE_CG	Mean		0.04			0.03			0.17			-0.02			0		
Ft	Std. Dev.	1.64	2.06	0.27	2.04	1.88	0.33	1.85	3.24	0.64	3.21	0.14	0.03	0.14	0.65	0.08	0.65
	Max	5.64	5.84	0.93	5.22	5.84	1.55	5.23	10.85	2.91	10.29	0.47	0.1	0.45	1.68	0.49	1.69
	Min	-4.87	-5.97	-0.73	-5.4	-5.97	-2.44	-5.4	-11	-2.33	-10.14	-0.46	-0.11	-0.45	-1.8	-0.31	-1.77
SWAY_CG	Mean		-0.98			-0.41			0.49			-0.23			0.23		
Ft	Std. Dev.	0.56	3.45	3.4	0.58	3.09	3.03	0.59	2.23	2.14	0.63	0.54	0.49	0.21	0.19	0.14	0.13
	Max	2.34	11.8	12.17	4.34	11.77	11.52	3.3	8.68	6.14	3.6	1.31	0.97	0.77	0.86	0.32	0.44
	Min	-2.13	-13.99	-12.68	-4.1	-14.05	-13.27	-3.3	-5.38	-5.99	-2.57	-1.77	-1.16	-0.77	-0.51	-0.48	-0.45
ROLL	Mean		0.03			0.02			0.03			0			0		
deg	Std. Dev.	0.08	0.43	0.42	0.08	0.38	0.37	0.08	0.61	0.61	0.09	0.05	0.04	0.03	0.06	0.05	0.02
	Max	0.3	1.64	1.41	0.29	1.64	1.42	0.31	1.94	1.52	0.46	0.17	0.09	0.11	0.18	0.15	0.07
	Min	-0.34	-1.44	-1.41	-0.31	-1.44	-1.4	-0.32	-1.3	-1.31	-0.38	-0.15	-0.08	-0.11	-0.17	-0.14	-0.08
YAW	Mean		0.02			-0.02			-0.06			-0.36			-0.05		
deg	Std. Dev.	0.17	0.81	0.79	0.16	0.75	0.73	0.17	0.91	0.9	0.18	0.06	0.03	0.05	0.1	0.1	0.04
	Max	0.63	2.33	1.91	0.51	2.33	1.95	0.59	2.98	2.55	0.69	-0.15	0.07	0.18	0.33	0.27	0.12
	Min	-0.57	-1.99	-1.78	-0.58	-2.09	-2.01	-0.58	-2.71	-2.54	-0.72	-0.6	-0.07	-0.2	-0.36	-0.26	-0.12
PITCH	Mean		-0.3			-0.28			-0.2			-0.04			-0.02		
deg	Std. Dev.	0.61	1.41	1.27	0.62	1.4	1.26	0.62	1.95	1.81	0.73	0.11	0.11	0.04	0.26	0.16	0.2
	Max	1.95	3.44	3.06	1.97	3.44	3.24	2.37	6.13	5.89	2.4	0.26	0.26	0.13	0.72	0.41	0.78
	Min	-1.75	-4.52	-3.14	-1.81	-4.52	-3.16	-1.83	-6.25	-4.97	-2.52	-0.36	-0.26	-0.12	-0.85	-0.44	-0.68
TENS-1	Mean		1245			1243			1217			1156			1152		
Kips	Std. Dev.	17.69	94.57	91.64	23.33	83.57	80.97	20.64	91.73	87.07	29	16.81	16.76	1.07	8.57	6.25	5.84
	Max	97.7	1787	380	175.1	1787	382.6	174.8	1685	238.1	238.7	1183	25.12	15.24	1182	16.51	16.2
	Min	-56.54	1047	-172.8	-162.8	1047	-170.6	-163.1	1016	-169.4	-118.2	1123	-31.57	-15.31	1123	-14.54	-16.61
TENS-2	Mean		1125			1122			1119			1139			1139		
Kips	Std. Dev.	7.5	20.71	18.6	9.07	18.57	16.57	8.33	18.94	13.09	13.78	3.3	2.98	1	3.26	0.92	3.06
	Max	32.89	1197	66.45	25.39	1197	69.58	31.92	1192	46.97	42.72	1149	6.46	3.98	1150	2.8	8.5
	Min	-24.28	1046	-70.92	-28.61	1046	-69.29	-29.26	1051	-34.98	-43.19	1130	-5.94	-3.42	1129	-2.23	-9.92
TENS-3	Mean		1008			1011			1033			1106			1130		
Kips	Std. Dev.	15.56	73.19	71.28	16.62	68.75	66.83	16.11	83.69	80.24	23.93	16.22	16.2	0.9	8.55	6.14	5.94
	Max	58.51	1199	167.4	52.64	1199	164.3	58.87	1235	175	73.15	1137	30.82	14.56	1160	14.11	22.42
	Min	-53.93	780.9	-192.9	-53.51	780.9	-196.2	-53.48	825.2	-165.3	-86.38	1079	-25.03	-13.45	1100	-15.69	-19.75
TENS-4	Mean		1114			1118			1123			1136			1157		
Kips	Std. Dev.	8.93	21.63	18.85	10.58	19.42	16.8	9.73	21.1	14.4	15.56	2.69	2.62	0.55	3.52	1.49	3.12
	Max	27.97	1186	63.63	30.34	1186	61.15	42.93	1194	50.09	54.82	1142	5.2	1.98	1167	3.59	9.43
	Min	-30.71	1032	-76.52	-31.1	1032	-79.86	-30.98	1056	-38.33	-46.08	1129	-5.95	-1.97	1144	-4.14	-9.88
REL. MOT.	Mean		-0.49			-0.6			-0.07			-0.28			-0.13		
Ft	Std. Dev.	13.81	14.44	3.05	14.11	14.29	3.03	13.96	15.16	4.41	14.5	2.38	0.3	2.36	3.99	0.39	3.97
	Max	45.98	52.11	6.96	50.55	52.11	7.11	50.55	84.05	15.22	76.87	8.95	0.64	9.3	13.97	1.11	14.1
	Min	-40.06	-42.86	-7.66	-45.53	-42.86	-7.66	-45.54	-50.71	-10.78	-46.14	-9.83	-0.88	-9.65	-12.66	-1.33	-11.91
RUNUP	Mean		1.46						1.31						0.27		
Ft	Std. Dev.		14.09	2.12	13.93				13.62	2.25	13.44				3.57	0.2	3.57
	Max		52.3	6.82	51.71				52.29	5.41	53.52				13.22	0.68	12.96
	Min		-42.74	-5.57	-46.44				-49.74	-7.19	-49.96				-10.89	-0.62	-11.27
MOONPOOL	Mean		0.19			0.19			0.08			0					
Ft	Std. Dev.	0.16	0.22	0.12	0.18	0.2	0.1	0.17	0.3	0.18	0.25	0.03	0.01	0.03		No value	
	Max	0.74	1.72	0.59	1.07	1.72	0.58	1.06	2.73	1.09	1.54	0.12	0.04	0.11			
	Min	-0.61	-0.54	-0.22	-0.9	-0.54	-0.23	-0.9	-0.73	-0.41	-1.1	-0.18	-0.04	-0.18			

CONFIGURATION A - BARE CYLINDER UNRESTRAINED
TEST RESULTS SUMMARY

		Waves & Current															
		arc2			arc3			arc4			arc3&4			arc5			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3	21.33	0.7	21.3	40.72	1.11	40.72	40.64	1.11	40.6	40.68	1.48	40.64	43.4	1.33	43.36	12.22
Ft	Std. Dev.	5.33	0.17	5.33	10.18	0.28	10.18	10.16	0.28	10.15	10.17	0.37	10.16	10.85	0.33	10.84	3.05
	Max	24.53	0.46	23.43	43.69	1.63	39.67	47.92	1.86	46.5	47.92	2.7	46.47	46.44	1.15	44.94	9.2
	Min	-16.9	-0.61	-17.22	-26.85	-0.75	-27.68	-28.9	-0.72	-29.74	-28.9	-1.27	-29.78	-35.79	-2.95	-36.09	-10.37
WIND	Mean																
Knots	Std. Dev.																
	Max																
	Min																
CUR 1	Mean	5.54			3.72			3.51			3.61			4.39			4.06
Ft/Sec	Std. Dev.	1.44	1.01	1.02	2.09	0.63	1.99	2.18	0.74	2.04	2.14	0.7	2.01	2.48	0.76	2.35	1.22
	Max	10.68	2.41	3.55	11.43	1.85	7.16	11.35	2.38	7.01	11.43	2.25	7.13	14.81	1.87	9.45	10.27
	Min	0.88	-2.43	-3.36	-3.76	-1.55	-7.57	-4.63	-2.25	-7.71	-4.63	-2.37	-7.75	-6.28	-2.3	-10.17	-0.02
CUR 2	Mean	-0.29			1.42			1.83			1.63			1.55			0.18
Ft/Sec	Std. Dev.	0.58	0.54	0.2	0.74	0.65	0.36	0.77	0.65	0.41	0.78	0.68	0.38	0.98	0.74	0.63	0.41
	Max	1.36	1.34	1.05	4.2	1.86	1.4	4.64	1.93	1.51	4.64	2.14	1.54	5.35	2.24	2.17	1.77
	Min	-6.77	-1.41	-3.58	-5.1	-1.96	-3.89	-5.56	-1.83	-3.39	-5.56	-2.15	-3.77	-6.37	-2.09	-4.18	-1.18
SURGE_CG	Mean	-40.64			-37.96			-40.82			-39.39			-44.82			-20.19
Ft	Std. Dev.	10.13	10.08	0.91	10.62	10.26	2.72	8.94	8.49	2.8	9.92	9.53	2.74	10.78	10.07	3.84	7.4
	Max	-6.01	33.38	6.28	-4.42	31.13	8.93	-14.61	23.54	11.84	-4.42	32.57	9.5	-19.98	22.35	15.68	-0.78
	Min	-63.1	-20.81	-8.49	-64.12	-22.19	-8.13	-66.46	-23.83	-8.86	-66.46	-24.86	-8.83	-77.18	-25.24	-14.93	-38.59
HEAVE_CG	Mean	-0.02			-0.03			-0.13			-0.08			-0.22			0.02
Ft	Std. Dev.	0.43	0.25	0.38	1.36	0.34	1.31	2.01	0.31	1.98	1.71	0.35	1.68	2.91	0.59	2.87	0.79
	Max	1.95	1.09	1.33	5.89	1.16	5.3	5.56	0.74	5.68	5.89	1.43	5.64	10.38	2.32	9.92	1.98
	Min	-1.52	-0.84	-1.28	-4.91	-1.27	-5.57	-5.91	-1.14	-5.73	-5.91	-2.42	-5.69	-9.32	-1.95	-9.45	-1.93
SWAY_CG	Mean	-7.02			-1.23			-3.47			-2.57			-6.03			-2.14
Ft	Std. Dev.	17.57	17.56	0.64	22.09	22.09	0.57	32.81	32.79	0.84	28.2	28.18	1.16	20.97	20.95	0.97	12.75
	Max	29.62	37.28	11.94	62.37	61.33	2.3	70.03	72.1	13.2	70.37	71.65	31.74	73.33	78.99	17.4	26.03
	Min	-59.13	-51.74	-13.09	-52.39	-50.25	-2.26	-69.33	-65.12	-14.69	-70.44	-66.98	-29.52	-85.93	-79.35	-21.04	-34.95
ROLL	Mean	-0.03			0.05			0.06			0.06			0.11			-0.02
deg	Std. Dev.	1.12	1.12	0.08	0.48	0.47	0.09	0.79	0.78	0.1	0.65	0.65	0.1	0.84	0.83	0.1	0.37
	Max	3.37	3.42	1.15	1.42	1.26	0.31	2.45	2.45	0.57	2.45	2.46	0.81	2.25	2.15	0.51	1.17
	Min	-3.53	-3.51	-1.22	-1.36	-1.35	-0.32	-2.32	-2.36	-0.53	-2.32	-2.36	-0.61	-2.04	-1.93	-0.44	-0.94
YAW	Mean	0.01			-0.09			-0.09			-0.09			-0.18			-0.2
deg	Std. Dev.	0.66	0.65	0.11	0.59	0.57	0.16	1.03	1.02	0.17	0.84	0.82	0.17	0.86	0.84	0.18	0.35
	Max	2.19	2.06	0.56	1.97	1.82	0.67	3.64	3.52	0.64	3.64	3.52	0.67	3.54	3.79	0.85	0.91
	Min	-1.86	-1.64	-0.41	-2.19	-1.92	-0.65	-3.44	-3.18	-0.7	-3.44	-3.18	-0.7	-3.72	-3.36	-0.62	-1.14
PITCH	Mean	-0.6			-0.5			-0.52			-0.51			-0.49			-0.23
deg	Std. Dev.	0.78	0.75	0.22	1.27	1.13	0.57	1.39	1.27	0.58	1.33	1.2	0.58	1.62	1.46	0.7	0.39
	Max	1.54	1.93	0.75	3.14	2.86	1.92	3.22	2.98	2.04	3.22	2.98	2.31	4.91	5.13	2.33	0.77
	Min	-2.84	-1.94	-0.71	-4.04	-2.57	-1.58	-4.66	-3.14	-1.68	-4.66	-3.17	-1.7	-5.92	-4.81	-2.5	-1.43
TENS-1	Mean	1484			1400			1432			1416			1508			1264
Kips	Std. Dev.	152.3	151.3	17.03	133.1	126	42.88	135.6	124.6	53.54	135.4	126.5	48.12	203.8	183.3	89.17	44.49
	Max	1978	455.8	204.7	1924	451.2	240.1	2003	500	213.1	2003	514.7	234.3	2557	557.5	508.5	1380
	Min	1203	-275.3	-167.7	1150	-241.8	-195.2	1205	-211.6	-228.1	1150	-258.4	-205.4	1238	-241.3	-364.7	1148
TENS-2	Mean	1168			1129			1166			1147			1170			1159
Kips	Std. Dev.	107.8	107.7	3.5	122.2	121.9	7.67	239.3	238.9	13.14	190.9	190.5	11.65	179.7	178.1	23.85	68.96
	Max	1737	575.1	61.77	1549	429.8	53.66	2032	856.4	77.53	2032	875.1	146.6	2692	1345	189.3	1342
	Min	970.6	-201	-53.98	804	-324.9	-30.31	751.6	-399.9	-66.55	751.6	-383.2	-156.2	725.8	-436.3	-164.5	1003
TENS-3	Mean	890.7			944.2			931.3			937.8			906.4			1025
Kips	Std. Dev.	54.01	53.83	4.46	55.37	53.4	14.64	46.08	43.13	16.2	51.35	48.97	15.44	56.15	51.29	22.92	40.57
	Max	1076	179.1	37.15	1128	168.2	64	1074	119.9	63.44	1128	174.5	65.17	1047	111.5	82.21	1132
	Min	779.8	-102.5	-40.85	814.8	-113.1	-51.32	805.4	-120.8	-47.89	805.4	-125.5	-49.47	727	-127.4	-84.34	928
TENS-4	Mean	1094			1139			1142			1140			1116			1161
Kips	Std. Dev.	90.3	90.25	2.98	136.8	136.6	7.93	225.8	225.3	14.99	186.7	186.2	13.61	148.5	147.4	17.52	68.89
	Max	1290	195.2	45.68	1798	632.7	36.75	2040	885.3	182.7	2040	867.2	272.6	2163	1031	126.2	1322
	Min	839.2	-251.5	-43.6	877.6	-257.4	-57.23	772.9	-370.3	-120.4	772.9	-367.2	-213	685.8	-407.5	-140.2	979.3
REL. MOT.	Mean	-0.71			-1.1			-1.92			-1.51			-0.43			-0.55
Ft	Std. Dev.	7.45	1.79	7.22	13.8	2.63	13.54	14.16	3.03	13.83	13.99	2.88	13.68	15.01	3.47	14.6	4.11
	Max	27.1	4.91	26.2	52.21	6.54	52.51	53.65	6.68	49.42	53.65	6.98	52.51	83.54	11.76	80.85	11.42
	Min	-24.51	-4.44	-24.15	-39.79	-6.32	-38.91	-44.28	-7.26	-46.87	-44.28	-7.65	-46.82	-53.89	-10.34	-50.57	-16.89
RUNUP	Mean	-1.04			0.91			0.04			0			-1.64			1.01
Ft	Std. Dev.	8.76	1.21	8.67	13.76	1.77	13.64	13.99	2	13.84	0	1.95	13.74	13.81	1.88	13.68	3.94
	Max	47.54	4.4	43.31	51.7	6.89	50.54	50.37	7.31	50.46	0	7.39	50.88	48.15	4.7	50.66	13.87
	Min	-28.94	-3.04	-29.71	-47.39	-5.04	-49.03	-45.22	-5.41	-48.74	0	-5.79	-48.94	-55.45	-6.01	-53.55	-14.11
MOONPOOL	Mean	0.36			0.34			0.42			0.38			0.66			
Ft	Std. Dev.	0.11	0.1	0.05	0.23	0.11	0.2	0.3	0.19	0.24	0.27	0.16	0.22	0.42	0.25	0.34	
	Max	1.13	0.4	0.38	2.55	0.47	1.16	2.35	0.68	1.47	2.55	0.74	1.46	2.73	1.13	1.56	
	Min	0.19	-0.16	-0.24	-0.69	-0.29	-1.13	-0.47	-0.47	-1.09	-0.69	-0.43	-1.13	-0.38	-0.46	-1.17	

CONFIGURATION A - BARE CYLINDER UNRESTRAINED
TEST RESULTS SUMMARY

				Waves, Wind & Current													
		arc7		arcw2			arcw3			arcw4			arcw3&4			arcw5	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
WAVE	H1/3	0.26	12.21	19.52	0.63	19.5	39.52	1.17	39.49	38.84	1.45	38.8	39.22	1.93	39.14	43.32	1.54
Ft	Std. Dev.	0.07	3.05	4.88	0.16	4.87	9.88	0.29	9.87	9.71	0.36	9.7	9.8	0.48	9.79	10.83	0.39
	Max	0.19	9.31	21.43	1.11	21.39	39.43	2.68	38.96	46.91	1.53	45.14	48.91	2.51	44.96	47.07	3.85
	Min	-0.17	-10.14	-16.55	-0.55	-16.96	-28.73	-0.72	-28.73	-30.81	-3.55	-29.84	-30.81	-2.51	-29.82	-35.27	-0.98
WIND	Mean			42.18			83.43			83.55			83.49			59.29	
Knots	Std. Dev.			4.79	4.09	2.45	9.38	6.64	6.63	9.61	6.91	6.67	9.5	6.75	6.66	7.47	5.12
	Max			61.66	11.84	9.33	116.33	23.75	22.25	116.15	17.24	23.64	116.33	23.3	23.78	83.79	15.3
	Min			26.4	-14.19	-7.33	57.05	-17.12	-21.07	56.71	-21.92	-23.08	58.71	-20.99	-22.94	39.17	-17.61
CUR 1	Mean			4.72			3.96			3.9			3.93			4.08	
Ft/Sec	Std. Dev.	0.84	0.86	1.44	1.02	1	2.15	0.71	1.99	2.21	0.81	2.01	2.18	0.76	2	2.51	0.87
	Max	2.18	2.89	10.38	3.01	3.85	11.14	1.7	6.96	12.98	1.68	7.41	12.98	1.72	7.41	13.17	2.53
	Min	-2.81	-3.18	-1.02	-2.7	-3.89	-4.65	-2.32	-8.14	-5.34	-2.27	-7.64	-5.34	-2.3	-8.1	-6.09	-2.53
CUR 2	Mean			-0.23			0.95			0.96			0.96			0.31	
Ft/Sec	Std. Dev.	0.35	0.2	1.55	0.51	1.17	1.93	0.84	1.41	1.89	0.77	1.4	1.91	0.8	1.4	2.29	0.86
	Max	0.93	0.87	1.93	1.46	3.13	4.63	2.42	3.97	4.4	2.02	3.94	4.63	2.42	4.15	4.51	2.66
	Min	-1.02	-0.69	-13.48	-1.49	-7.07	-12.94	-2.28	-7.48	-13.28	-2.33	-8.94	-13.28	-2.32	-9.03	-15.57	-2.19
SURGE_CG	Mean			-53.2			-75.47			-73.6			-74.53			-63.99	
Ft	Std. Dev.	7.32	1.1	9.12	9.07	0.91	7.81	7.31	2.73	12.03	11.7	2.8	10.18	9.8	2.77	9.6	8.81
	Max	18.44	8.2	-29.68	21.68	10.89	-46.42	25.48	10.47	-28.19	38.86	11.65	-28.19	39.8	11.33	-36.27	24.4
	Min	-16.77	-7.84	-82.91	-29.19	-7.44	-97	-17.68	-8.76	-110.4	-31.05	-9.2	-110.4	-30.04	-9.15	-96.89	-26.91
HEAVE_CG	Mean			-0.12			0.01			0.08			0.05			-0.25	
Ft	Std. Dev.	0.12	0.79	0.61	0.27	0.56	1.81	0.67	1.69	2	0.81	1.85	1.91	0.73	1.77	2.98	0.59
	Max	0.81	1.91	1.79	0.86	1.44	7.14	2.65	6.15	7.1	2.63	5.46	7.14	2.74	6.24	10.34	1.57
	Min	-0.44	-1.96	-1.91	-1.14	-1.49	-5.56	-1.79	-6.57	-5.18	-2.36	-4.59	-5.56	-2.3	-6.42	-11.3	-2.28
SWAY_CG	Mean			-4.19			1.65			-0.89			-0.06			-0.92	
Ft	Std. Dev.	12.75	0.21	24.82	24.81	0.42	35.23	35.22	0.58	29.88	29.87	0.56	33.25	33.24	0.84	34.85	34.81
	Max	28.03	2.63	71.91	75.58	3.11	79.84	77.93	4.54	69.94	70.16	2.5	80.38	80.3	17.45	75.98	81.72
	Min	-32.61	-2.56	-81.92	-57.15	-4.83	-78.48	-79.26	-2.67	-80.09	-58.08	-2.53	-80.45	-79.59	-17.44	-87.84	-86.4
ROLL	Mean			0.02			-0.05			0			-0.02			0.09	
deg	Std. Dev.	0.37	0.03	0.91	0.91	0.08	0.92	0.91	0.11	1.03	1.03	0.1	0.98	0.97	0.11	0.55	0.55
	Max	1.18	0.23	2.65	2.62	0.96	3.24	3.36	1.03	2.61	2.53	0.42	3.24	3.39	1.51	1.84	1.62
	Min	-0.9	-0.17	-2.49	-2.53	-1.28	-2.87	-2.42	-0.75	-2.82	-2.84	-0.36	-2.87	-2.81	-1.13	-1.41	-1.54
YAW	Mean			-0.58			-1.43			-1.55			-1.49			-1.05	
deg	Std. Dev.	0.35	0.05	0.73	0.72	0.11	1.24	1.23	0.19	1.54	1.52	0.18	1.4	1.38	0.19	1.13	1.12
	Max	1.02	0.31	1.72	2.19	0.71	3.84	4.99	0.77	2.88	4.3	1.09	3.84	5.04	1.06	2.64	3.26
	Min	-0.9	-0.28	-2.83	-2.14	-0.75	-4.75	-3.25	-1.24	-6.79	-4.9	-0.72	-6.79	-4.96	-2.12	-5.07	-4.07
PITCH	Mean			-1.06			-2.79			-2.78			-2.78			-1.57	
deg	Std. Dev.	0.34	0.2	0.71	0.68	0.21	1.48	1.35	0.57	1.72	1.62	0.58	1.6	1.49	0.58	1.7	1.56
	Max	0.79	0.75	1.13	1.87	0.71	1.41	3.44	2.14	1.78	3.81	1.99	1.78	3.83	2.14	4.3	5.7
	Min	-0.91	-0.63	-3.14	-1.75	-0.71	-7.63	-3.64	-1.67	-7.59	-4.16	-1.78	-7.63	-4.15	-1.75	-7	-4.91
TENS-1	Mean			1736			2388			2372			2380			1971	
Kips	Std. Dev.	43.89	7.27	232.3	231	23.7	358	327.5	144.5	550	529.4	149.7	464.1	440.2	147.1	304.2	270.2
	Max	105.1	27.12	2745	965.9	150	3737	1071	562.7	5151	2201	656.6	5151	2199	665.5	3826	1260
	Min	-110	-29.87	1325	-402.6	-181.5	1518	-790.4	-510.1	1317	-1051	-775.5	1317	-1064	-782.5	1336	-590.3
TENS-2	Mean			1162			1157			1158			1158			1176	
Kips	Std. Dev.	68.85	3.67	159	158.9	4.9	265.1	264.8	12.48	205.6	205.2	13.49	237.2	236.8	13.51	283.6	282.3
	Max	178	12.15	1864	690	38.74	2366	1190	64.74	1884	720.9	71	2366	1189	106.7	2757	1544
	Min	-151.6	-17.3	763.3	-397.2	-33.62	723.2	-428.9	-65.62	757.2	-389.8	-64.4	723.2	-429.1	-80.76	711.1	-460.9
TENS-3	Mean			823			745.7			753			749.3			807.2	
Kips	Std. Dev.	40.1	6.07	48.83	48.59	4.72	40.03	37.11	15.01	62.37	60.39	15.66	52.53	50.25	15.34	49.49	43.84
	Max	101.2	26.48	953.1	120.3	40.42	889.7	130.9	73.42	997.5	209.8	55.85	997.5	213.2	73.88	936.2	121.6
	Min	-89.25	-35.43	662.5	-159.1	-30.52	637.4	-82.5	-48.46	571.9	-159.6	-53.57	571.9	-155.1	-54.1	640.3	-139.3
TENS-4	Mean			1117			1205			1164			1184			1170	
Kips	Std. Dev.	68.79	3.63	155.3	155.3	4.44	279.3	279	12.32	200.5	200	13.19	243.9	243.5	13.13	251.7	249.9
	Max	155.4	16.08	2041	918.9	37.66	2289	1075	49.24	1994	813.3	75.98	2289	1096	94.61	2202	1016
	Min	-174.7	-22.06	807.2	-301.7	-50.76	737.7	-463.1	-54.63	834.9	-331.5	-59.55	737.7	-442.5	-87.63	683.5	-476.9
REL. MOT.	Mean			-1.31			-5.25			-5.83			-5.54			-2.42	
Ft	Std. Dev.	0.84	4.03	7.03	1.61	6.84	13.78	3.29	13.38	14.07	4.11	13.46	13.93	3.73	13.42	14.9	3.77
	Max	1.81	12.16	25.8	4.58	25.85	50.51	7.57	56.16	54.69	10.74	51.44	54.69	10.27	56.05	79.97	13.81
	Min	-2.28	-15.92	-24.63	-4.75	-25.1	-42.98	-8.92	-38.44	-48.05	-10.41	-48.86	-48.05	-10.56	-48.72	-52.59	-10.33
RUNUP	Mean			-4.76			-5.99			-6.16			0			-6.98	
Ft	Std. Dev.	0.43	3.92	7.86	1.33	7.74	13.81	2.54	13.57	13.49	2.7	13.21	0	2.61	13.39	13.43	2.13
	Max	1.24	12.86	33.04	4.84	33.09	47.07	8.68	50.26	46.82	7.14	52.41	0	8.97	52.17	43.07	6.12
	Min	-1.25	-14.91	-30.94	-3.76	-31.03	-55.8	-7.16	-53.56	-49.66	-7.64	-45.43	0	-8.02	-53.76	-58.83	-6.72
MOONPOOL	Mean			0.55			0.77			0.84			0.71			0.86	
Ft	Std. Dev.			0.12	0.11	0.05	0.5	0.36	0.35	0.62	0.5	0.37	0.57	0.44	0.36	0.55	0.32
	Max			1.8	0.7	0.62	2.65	1.06	1.5	3.77	2.41	1.45	3.77	2.35	1.5	4.29	1.45
	Min			0.38	-0.15	-0.46	-0.86	-0.81	-1.41	-0.77	-0.92	-1.62	-0.86	-0.98	-1.59	-0.74	-0.69

CONFIGURATION A - BARE CYLINDER UNRESTRAINED
TEST RESULTS SUMMARY

			arcw7		
		f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	43.28	12.13	0.55	12.12
Ft	Std. Dev.	10.82	3.03	0.14	3.03
	Max	48.34	9.4	0.36	9.35
	Min	-34.51	-10.66	-0.37	-10.58
WIND	Mean		47.11		
Knots	Std. Dev.	5.42	5.02	3.9	3.13
	Max	16.89	65.33	9.02	10.55
	Min	-15.3	32.14	-11.2	-9.21
CUR 1	Mean		3.92		
Ft/Sec	Std. Dev.	2.34	1.22	0.85	0.84
	Max	8.83	7.68	1.76	2.55
	Min	-8.51	-0.77	-2.81	-3.11
CUR 2	Mean		0.21		
Ft/Sec	Std. Dev.	1.73	0.33	0.26	0.18
	Max	5.25	1.76	0.9	0.85
	Min	-11.47	-0.86	-0.53	-0.74
SURGE_CG	Mean		-42.56		
Ft	Std. Dev.	3.82	6.58	6.5	1.04
	Max	11.82	-26.56	15.28	3.95
	Min	-18.15	-58.71	-14.67	-3.31
HEAVE_CG	Mean		0.14		
Ft	Std. Dev.	2.94	0.86	0.15	0.85
	Max	10.35	2.6	0.45	2.58
	Min	-10.7	-2.66	-0.45	-2.69
SWAY_CG	Mean		-3.31		
Ft	Std. Dev.	1.75	18.54	18.52	0.73
	Max	40.12	45.88	49.13	18.21
	Min	-42.21	-47.27	-43.75	-17.63
ROLL	Mean		-0.05		
deg	Std. Dev.	0.1	0.36	0.36	0.03
	Max	0.73	0.93	0.98	0.11
	Min	-1.01	-0.93	-0.89	-0.1
YAW	Mean		0.02		
deg	Std. Dev.	0.19	0.49	0.49	0.05
	Max	0.82	1.65	1.62	0.17
	Min	-0.76	-1.41	-1.34	-0.25
PITCH	Mean		-0.93		
deg	Std. Dev.	0.69	0.43	0.38	0.19
	Max	2.32	0.5	0.98	0.73
	Min	-2.53	-2.42	-1	-0.61
TENS-1	Mean		1472		
Kips	Std. Dev.	139.6	117	114.8	22.23
	Max	650.6	1871	352.7	93.44
	Min	-554.7	1296	-164.3	-82.1
TENS-2	Mean		1168		
Kips	Std. Dev.	27.33	104.4	104.2	6.07
	Max	230.3	1527	364.3	101.5
	Min	-166.4	904.3	-261	-104.6
TENS-3	Mean		901.9		
Kips	Std. Dev.	23.01	36	35.43	6.31
	Max	90.24	991	81.91	40.01
	Min	-88.11	812	-80.94	-23.03
TENS-4	Mean		1157		
Kips	Std. Dev.	29.67	99.6	99.46	5.1
	Max	632.1	1430	272	88.23
	Min	-439.4	914.6	-236.4	-85.61
REL. MOT.	Mean		-1.57		
Ft	Std. Dev.	14.42	4.18	0.98	4.06
	Max	77.28	9.9	2.16	11.54
	Min	-48.06	-16.96	-2.66	-14.51
RUNUP	Mean		-1.02		
Ft	Std. Dev.	13.25	3.76	0.58	3.71
	Max	50.2	10.94	1.49	11.7
	Min	-49.52	-14.81	-1.47	-13.18
MOONPOOL	Mean				
Ft	Std. Dev.	0.44			
	Max	1.84			
	Min	-1.69			

CONFIGURATION B - RESTRAINED
TEST RESULTS SUMMARY

		Current only											
		bcur2			bcur3			bcur5			bwin2		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3										0.34	0.15	0.3
Ft	Std. Dev.										0.09	0.04	0.08
	Max										0.54	0.11	0.34
	Min										-0.2	-0.08	-0.51
WIND	Mean										34.27		
Knots	Std. Dev.										3.62	3.09	1.83
	Max										48.53	9.07	7.02
	Min										24	-8.27	-5.74
CUR 1	Mean	4.68			4.02			4.35					
Ft/Sec	Std. Dev.	1.39	1.26	0.56	0.78	0.67	0.37	0.87	0.73	0.46			
	Max	8.57	2.94	2.16	6.77	1.87	1.49	7.15	1.83	1.9			
	Min	0.01	-3.95	-2.61	1.11	-2.08	-1.57	0.86	-3.6	-1.95			
CUR 2	Mean	-0.08			0.01			0.11					
Ft/Sec	Std. Dev.	0.29	0.26	0.13	0.26	0.24	0.08	0.36	0.34	0.12			
	Max	1.88	1.08	0.95	0.64	0.58	0.96	1.01	0.79	0.92			
	Min	-5.86	-0.59	-3.5	-6.82	-0.55	-3.36	-6.74	-0.83	-3.47			
SURGE_CG	Mean	-36.89			-18.1			-27.59			-21.59		
Ft	Std. Dev.	6.92	6.92	0.16	5.4	5.39	0.12	6.65	6.65	0.26	7.61	7.61	0.14
	Max	-17.72	19.06	5.1	-4.77	13.26	5.3	-12.17	15.32	4.87	-2.06	19.51	2.95
	Min	-50.84	-13.84	-3.76	-33.33	-15.15	-1.84	-45.43	-17.82	-6.59	-38.66	-16.98	-3.97
HEAVE_CG	Mean	-0.15			-0.02			-0.07			0.03		
Ft	Std. Dev.	0.04	0.03	0.03	0.04	0.03	0.03	0.06	0.04	0.05	0.39	0.07	0.38
	Max	0.06	0.07	0.17	0.25	0.06	0.21	0.12	0.11	0.17	1.02	0.24	0.89
	Min	-0.31	-0.12	-0.12	-0.17	-0.07	-0.13	-0.29	-0.1	-0.16	-0.95	-0.28	-0.92
SWAY_CG	Mean	0.44			-0.07			0.67			0.48		
Ft	Std. Dev.	0.31	0.3	0.06	0.15	0.15	0.04	0.22	0.21	0.05	0.15	0.13	0.05
	Max	1.33	0.88	0.3	0.46	0.49	0.15	1.33	0.56	0.3	0.98	0.4	0.26
	Min	-1.25	-1.02	-0.72	-0.58	-0.45	-0.35	-0.99	-0.62	-0.67	-0.8	-0.4	-0.59
ROLL	Mean	0.08			0			0.09			0.03		
deg	Std. Dev.	0.12	0.11	0.02	0.05	0.05	0.01	0.08	0.08	0.01	0.03	0.02	0.01
	Max	0.41	0.32	0.07	0.16	0.15	0.02	0.31	0.23	0.03	0.11	0.06	0.04
	Min	-0.3	-0.37	-0.14	-0.16	-0.17	-0.02	-0.15	-0.24	-0.1	-0.05	-0.06	-0.04
YAW	Mean	0.33			-0.11			-0.22			-0.07		
deg	Std. Dev.	0.25	0.25	0.04	0.07	0.06	0.03	0.13	0.13	0.02	0.37	0.36	0.04
	Max	1.21	0.85	0.6	0.12	0.21	0.21	0.22	0.38	0.23	0.89	0.9	0.23
	Min	-0.57	-0.9	-0.61	-0.64	-0.19	-0.54	-0.73	-0.47	-0.09	-1.38	-1.12	-0.27
PITCH	Mean	-0.46			-0.22			-0.29			-0.55		
deg	Std. Dev.	0.22	0.22	0.01	0.32	0.32	0.01	0.41	0.41	0.01	0.46	0.46	0.01
	Max	0.05	0.51	0.14	0.43	0.65	0.25	0.64	0.93	0.19	0.59	1.12	0.03
	Min	-1.11	-0.67	-0.2	-0.85	-0.62	-0.27	-1.23	-0.93	-0.14	-1.67	-1.13	-0.04
TENS-1	Mean	1387			1261			1315			1301		
Kips	Std. Dev.	52.45	52.44	0.67	32.79	32.76	0.98	42.71	42.64	2.35	48.41	48.34	2.42
	Max	1548	160.6	10.5	1359	97.62	12.81	1437	120.9	55.51	1430	122.8	23.57
	Min	1259	-128	-8.01	1185	-75.01	-10.03	1225	-89.77	-54.87	1183	-110.7	-19.2
TENS-2	Mean												
Kips	Std. Dev.												
	Max												
	Min												
TENS-3	Mean	894			1010			949.2			918.2		
Kips	Std. Dev.	35.89	35.88	0.41	28.04	28.03	0.35	34.5	34.44	1.82	40.42	40.38	1.75
	Max	993.7	99.17	6.9	1077	67.03	3.57	1027	78.21	45	1019	99.51	17.52
	Min	822.3	-71.59	-9.98	930	-79.49	-6.79	858.5	-90.6	-44.86	826.3	-88.42	-17.66
TENS-4	Mean												
Kips	Std. Dev.												
	Max												
	Min												
REL. MOT.	Mean	7.97			-0.41			0.33			-0.61		
Ft	Std. Dev.	0.54	0.53	0.07	0.76	0.75	0.09	1.01	1	0.14	1.17	1.11	0.38
	Max	8.94	1.03	0.54	0.94	1.34	1.26	2.2	1.97	1.21	2.55	2.75	1.13
	Min	6.41	-1.63	-0.79	-1.89	-1.56	-0.82	-2.09	-2.46	-0.87	-4.12	-2.83	-1.08
RUNUP	Mean												
Ft	Std. Dev.												
	Max												
	Min												
MOONPOOL	Mean	1.55			-0.56			1.12			0.06		
Ft	Std. Dev.	0.06	0.06	0	0.02	0.02	0	0.06	0.06	0.01	0.07	0.05	0.05
	Max	1.66	0.09	0.03	-0.51	0.04	0.02	1.17	0.05	0.08	0.34	0.17	0.19
	Min	1.42	-0.13	-0.04	-0.6	-0.04	-0.02	0.92	-0.16	-0.08	-0.22	-0.16	-0.25

CONFIGURATION B - RESTRAINED
TEST RESULTS SUMMARY

		Wind only											
		bwin3			bwin4			bwin5			bran2		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	0.45	0.17	0.38	0.67	0.28	0.58	0.68	0.44	0.49	20.92	0.89	20.88
Ft	Std. Dev.	0.11	0.04	0.09	0.17	0.07	0.14	0.17	0.11	0.12	5.23	0.22	5.22
	Max	0.37	0.14	0.75	0.2	0.18	0.51	0.37	0.24	0.43	21.92	0.98	20.67
	Min	-2.05	-0.19	-1.06	-2.1	-0.36	-1.24	-1.29	-0.22	-0.82	-16.25	-0.9	-16.31
WIND	Mean	67.34			66.51			48.2					
Knots	Std. Dev.	7.81	6.02	4.94	8.06	6.26	5.06	5.68	4.73	3.12			
	Max	97.4	18.53	17.57	100.65	16.25	19.14	70.47	14.38	10.65			
	Min	44.93	-17.76	-13.47	45.11	-17.9	-14.19	33.01	-14.92	-9.3			
CUR 1	Mean												
Ft/Sec	Std. Dev.												
	Max												
	Min												
CUR 2	Mean												
Ft/Sec	Std. Dev.												
	Max												
	Min												
SURGE_CG	Mean	-60.52			-59.22			-40.35			-6.87		
Ft	Std. Dev.	7.34	7.34	0.17	15.32	15.32	0.21	11.8	11.8	0.1	7.36	7.31	0.87
	Max	-40.75	19.56	3.24	-19.95	39.25	3.77	-10.76	29.57	0.97	13.3	18.5	5.39
	Min	-76.43	-15.95	-2.23	-92.41	-33.27	-4.59	-65.1	-24.74	-1.67	-26.32	-18.48	-3.14
HEAVE_CG	Mean	0.6			0.55			0.35			-0.01		
Ft	Std. Dev.	1.28	0.5	1.18	1.17	0.57	1.02	0.55	0.19	0.52	0.39	0.06	0.39
	Max	3.84	2.05	2.51	4.42	2.97	2.89	1.99	0.55	1.51	0.96	0.19	0.89
	Min	-2.45	-1	-2.46	-3.03	-1.95	-2.7	-1.39	-0.52	-1.49	-0.93	-0.17	-0.9
SWAY_CG	Mean	1.28			1.77			0.75			-0.1		
Ft	Std. Dev.	0.46	0.42	0.18	0.52	0.5	0.15	0.29	0.27	0.09	0.19	0.09	0.16
	Max	2.78	1.36	0.62	3.33	1.43	0.55	1.76	0.89	0.34	0.55	0.43	0.54
	Min	-0.67	-1.72	-0.64	-0.12	-1.72	-0.63	-0.9	-0.82	-0.67	-1.47	-0.25	-0.76
ROLL	Mean	0.14			0.21			0.06			0		
deg	Std. Dev.	0.07	0.04	0.05	0.06	0.05	0.04	0.04	0.04	0.02	0.03	0.02	0.03
	Max	0.43	0.16	0.14	0.38	0.15	0.11	0.19	0.1	0.05	0.11	0.06	0.1
	Min	-0.09	-0.15	-0.16	0	-0.15	-0.1	-0.08	-0.1	-0.05	-0.11	-0.05	-0.1
YAW	Mean	-1.3			-1.42			-0.61			-0.13		
deg	Std. Dev.	0.75	0.74	0.11	0.93	0.92	0.1	0.63	0.63	0.06	0.13	0.12	0.05
	Max	1.1	2.44	0.37	1.27	2.58	0.33	1.39	1.88	0.18	0.44	0.49	0.21
	Min	-3.49	-2.04	-0.5	-4.09	-2.55	-0.38	-2.57	-1.92	-0.25	-0.63	-0.4	-0.59
PITCH	Mean	-2.49			-2.49			-1.29			-0.14		
deg	Std. Dev.	1.24	1.24	0.04	1.17	1.17	0.03	0.7	0.7	0.02	0.52	0.48	0.22
	Max	0.71	3.13	0.1	0.65	3.13	0.1	0.41	1.7	0.06	1.58	1.4	0.75
	Min	-5.43	-2.98	-0.1	-5.87	-3.41	-0.1	-3.07	-1.8	-0.06	-1.86	-1.41	-0.73
TENS-1	Mean	1918			1928			1481			1193		
Kips	Std. Dev.	201.6	200.2	24.09	416.5	415.7	26.52	183.1	183	7.32	42.75	42.65	2.87
	Max	2409	447.1	60.29	3397	1466	136.7	2044	556.1	30.7	1303	105	12.78
	Min	1436	-456.8	-63.68	1276	-650.4	-110.1	1221	-257.6	-30.29	1082	-104	-14.53
TENS-2	Mean												
Kips	Std. Dev.												
	Max												
	Min												
TENS-3	Mean	732.5			739.1			837.7			1085		
Kips	Std. Dev.	38.11	37.77	5.08	80.42	80.3	4.44	62.53	62.49	2.23	38.9	38.77	3.12
	Max	826.8	89.24	11.03	940	198.4	18.13	986	150.1	12.49	1188	96.14	10.15
	Min	641.5	-82.75	-11.32	566.5	-172.5	-12.4	703.8	-134.6	-11.46	984.8	-95.23	-10.9
TENS-4	Mean												
Kips	Std. Dev.												
	Max												
	Min												
REL. MOT.	Mean	-6.74			-6.78			-3.38			-0.02		
Ft	Std. Dev.	3.26	3.06	1.13	3.08	2.91	0.99	1.8	1.73	0.52	6.99	1.18	6.88
	Max	1.14	7.09	3.25	1.62	7.67	2.96	0.91	4.05	1.51	31.24	3.48	29.12
	Min	-15.43	-8.02	-2.86	-18.1	-9.68	-3.11	-8.69	-4.69	-1.76	-22.8	-3.81	-24.01
RUNUP	Mean												
Ft	Std. Dev.												
	Max												
	Min												
MOONPOOL	Mean	0.05			0.08			0.32			0.04		
Ft	Std. Dev.	0.32	0.26	0.17	0.43	0.4	0.16	0.18	0.16	0.08	0.14	0.05	0.13
	Max	1.2	0.83	0.47	1.54	1.37	0.57	0.86	0.43	0.33	1.1	0.18	0.91
	Min	-0.99	-0.78	-0.59	-1.17	-1.22	-0.59	-0.19	-0.38	-0.44	-0.79	-0.18	-0.79

TION B - RESTRAINED
SULTS SUMMARY

Waves only							
bran4		bran3&4			bran5		
f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
2.53	42.6	43.48	2.29	43.36	45.08	2.19	45
0.63	10.65	10.87	0.57	10.84	11.27	0.55	11.25
2.88	47.45	51.51	2.47	47.65	59.88	1.85	56.65
-1.34	-30.75	-28.51	-1.2	-30.87	-32.74	-1.47	-35.39
		-14.39			-9.59		
12.72	2.97	12.45	12.09	2.98	13.59	13	3.96
29	9.45	20.12	28.58	9.48	24.1	27.71	12.21
-36.04	-9.7	-57.53	-36.47	-9.68	-45.06	-25.55	-14.73
		0.04			0.1		
0.3	1.97	1.84	0.4	1.8	3.06	0.55	3.03
1.32	5.08	5.97	1.67	5.07	10.59	2.21	9.52
-0.98	-5.01	-5.49	-2.29	-5	-10.92	-2.04	-9.54
		-0.07			0.03		
0.25	0.38	0.5	0.32	0.39	0.52	0.35	0.39
1.06	1.25	2.21	1.21	1.51	2.71	1.89	1.59
-0.7	-1.57	-1.68	-0.74	-1.67	-2.84	-1.24	-1.7
		0.01			0.01		
[illegible]	0.07	0.09	0.05	0.07	0.08	0.05	0.06
	0.22	0.32	0.18	0.28	0.4	0.29	0.23
	-0.27	-0.29	-0.16	-0.27	-0.23	-0.14	-0.19
		-0.16			-0.1		
0.31	0.12	0.31	0.29	0.13	0.56	0.54	0.15
0.85	0.56	1.09	0.86	0.54	2.42	2.1	0.64
-0.89	-0.45	-1.25	-0.88	-0.52	-2.41	-2.06	-0.56
		-0.3			-0.2		
1.24	0.62	1.47	1.34	0.62	1.76	1.6	0.73
3.41	1.97	4.04	3.88	2.24	5.59	5.26	2.39
-3.59	-1.82	-5.13	-3.61	-1.82	-5.74	-4.97	-2.57
		1240			1215		
81.98	19.67	76.45	74.39	17.6	77.22	73.44	23.95
316.4	169.7	1716	319.5	169.4	1548	167.5	168.7
-156.1	-131.1	1068	-153	-131.2	1033	-147.9	-77.16
		1042			1058		
66.09	14.33	64.28	62.71	14.11	70.19	67.03	20.89
144	44.91	1212	140.3	50.4	1233	138.2	66.75
-182.2	-49.15	839.4	-186.2	-49.08	874.1	-136.4	-79.31
		0.53			13.55		
3.03	13.45	13.83	3.28	13.42	27.15	23.42	13.74
7.09	48.97	50.79	8.53	48.88	86.47	66.26	51.41
-8.39	-43.13	-39.87	-9.49	-43.22	-44.83	-21.16	-45.33
		0.26			0.2		
0.17	0.33	0.37	0.17	0.33	0.46	0.23	0.4
0.76	1.82	2.27	0.77	1.88	2.09	1.06	1.46
-0.41	-1.34	-1.17	-0.4	-1.48	-1.57	-0.47	-1.79

ESTRAINED
IMMARY

Waves & Current						
	brc4			brc3&4		
03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
39.23	40.08	1.14	40.04	39.67	1.25	39.63
9.81	10.02	0.28	10.01	9.92	0.31	9.91
43.63	49.23	1.87	45.51	49.23	2.77	45.62
26.96	-30.14	-0.75	-30.48	-30.14	-0.87	-30.43
	4.1			4.11		
1.98	2.14	0.66	2.04	2.12	0.65	2.01
6.42	12.15	2.03	7.54	12.15	2.01	7.53
-7.85	-3.84	-1.51	-7.3	-4.4	-2.03	-7.87
	1.33			1.28		
0.37	0.67	0.54	0.4	0.74	0.64	0.38
1.31	3.6	1.87	1.47	4.16	2.21	1.47
-4.03	-1.3	-1.96	-1.75	-5.26	-1.92	-3.89
	-36.23			-37.8		
2.76	8.04	7.52	2.83	8.64	8.17	2.79
9.04	-12.27	20.44	9.41	-5.99	24.85	10.01
13.02	-64.02	-21.3	-9.09	-64.01	-21.74	-9.32
	-0.01			0		
1.37	2.04	0.24	2.02	1.76	0.37	1.72
5.29	5.17	0.64	5.05	5.78	1.75	5.05
-5.34	-5.47	-0.72	-5.19	-5.47	-3.38	-5.22
	0.16			-0.12		
0.56	0.6	0.29	0.52	0.64	0.34	0.54
2.34	2.53	0.77	1.85	2.39	1.22	2.37
-2.18	-2.05	-1.03	-1.73	-2.6	-1.01	-2.19
	0.03			0.03		
0.1	0.14	0.11	0.1	0.15	0.11	0.1
0.4	0.56	0.34	0.3	0.56	0.35	0.4
-0.36	-0.43	-0.3	-0.33	-0.51	-0.33	-0.36
	-0.05			-0.05		
0.16	0.28	0.24	0.14	0.3	0.26	0.15
0.79	0.96	0.72	0.62	0.98	0.8	0.94
-0.59	-1.24	-0.82	-0.52	-1.24	-0.82	-0.59
	-0.48			-0.5		
0.57	1.28	1.13	0.59	1.39	1.26	0.58
1.93	2.93	2.81	2.01	3.52	3.62	2.28
-1.59	-4.33	-2.85	-1.7	-4.96	-3.44	-1.7
	1376			1393		
31.56	73.95	67.81	29.51	84.98	79.36	30.36
187.1	1858	311.5	228.2	1858	326.3	226.1
169.2	1218	-134.2	-162.2	1201	-163.3	-169.4
	915.1			907.9		
13.12	40.79	37.99	14.85	43.43	41.1	14.01
56.8	1038	100.3	45.23	1062	126.2	56.3
48.99	788.1	-105.6	-43.88	785.5	-102.6	-46.98
	0.96			0.52		
12.89	13.41	2.78	13.12	13.36	3.05	13
48.43	50.7	6.55	47.72	50.7	7.73	48.42
37.19	-38.56	-6.99	-42.21	-38.56	-9.57	-42.28
	0.38			0.19		
0.34	0.41	0.23	0.34	0.45	0.29	0.34
2.13	2.24	0.65	1.46	2.42	0.85	2.18
-1.41	-1.04	-0.5	-1.3	-1.52	-0.73	-1.4

CONFIGURATION B - RESTRAINED
TEST RESULTS SUMMARY

											Waves, Wind & Current		
		brc5			brcw2			brcw3			brcw4		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	43.68	1.28	43.64	19.22	0.67	19.19	39.88	1.27	39.84	38.42	1.47	38.38
Ft	Std. Dev.	10.92	0.32	10.91	4.8	0.17	4.8	9.97	0.32	9.96	9.61	0.37	9.6
	Max	51.72	1.57	48.49	19	1.13	18.49	44.02	2.73	42.57	44.57	1.33	41.84
	Min	-33.53	-2.35	-33.75	-15.63	-0.5	-15.76	-28.98	-0.81	-29.18	-28.33	-3.9	-28.12
WIND	Mean				42.88			82.96			83.02		
Knots	Std. Dev.				4.13	3.42	2.27	9.84	7.27	6.63	9.7	6.91	6.79
	Max				54.5	8.04	7.62	120.06	23.16	24.95	118.17	20.34	25.15
	Min				29.29	-9.42	-6.66	54.66	-20.22	-20.43	53.99	-23.78	-20.38
CUR 1	Mean	4.65			4.97			4.11			4.18		
Ft/Sec	Std. Dev.	2.53	0.84	2.39	1.4	1.02	0.95	2.13	0.7	1.97	2.18	0.78	2
	Max	13	2.18	8.13	10.16	2.94	3.65	10.9	2.01	6.91	11.12	1.7	7.53
	Min	-5.98	-3.07	-9.18	-1.26	-3.63	-3.59	-3.72	-1.99	-7.34	-4.23	-2.38	-7.34
CUR 2	Mean	1.64			-0.14			1.05			0.66		
Ft/Sec	Std. Dev.	0.89	0.65	0.6	0.24	0.21	0.1	0.71	0.61	0.35	0.71	0.6	0.37
	Max	4.98	1.88	2.18	0.64	0.55	0.98	3.1	1.22	1.28	3.25	2.03	1.45
	Min	-5.98	-1.76	-4.26	-6.35	-0.67	-3.22	-5.84	-1.4	-4.11	-1.47	-1.42	-1.44
SURGE_CG	Mean	-38.76			-57.9			-77.05			-77.52		
Ft	Std. Dev.	11.31	10.61	3.92	10.25	10.21	0.95	9.14	8.7	2.81	7.96	7.43	2.87
	Max	-2.75	27.62	12.4	-30.27	26.26	11.17	-48.27	24.23	12.13	-52.26	20.93	16.63
	Min	-69.12	-24.22	-15.38	-91.89	-32.41	-13.19	-99.86	-17.88	-24.49	-100.3	-16.9	-9.7
HEAVE_CG	Mean	0.07			-0.18			0.29			0.31		
Ft	Std. Dev.	3.8	0.76	3.75	0.48	0.2	0.44	1.78	0.62	1.67	2.45	0.72	2.34
	Max	15.77	3.28	14.24	1.41	0.53	1.45	5.57	3.11	4.81	7.37	2.61	6.43
	Min	-15.41	-2.61	-14.42	-1.88	-0.91	-1.52	-5.13	-1.42	-5.54	-6.48	-1.74	-6.47
SWAY_CG	Mean	0.83			0.7			1.12			1.52		
Ft	Std. Dev.	0.75	0.45	0.6	0.63	0.39	0.5	0.74	0.51	0.53	0.85	0.64	0.55
	Max	4.3	1.65	2.54	3.43	1.25	2.03	4.17	1.63	3.55	4.19	1.81	1.96
	Min	-2.51	-1.42	-2.65	-1.74	-1.14	-1.93	-1.64	-1.7	-2.23	-1.6	-1.87	-2.17
ROLL	Mean	0.09			0.08			0.12			0.18		
deg	Std. Dev.	0.17	0.13	0.11	0.16	0.14	0.08	0.14	0.09	0.1	0.15	0.1	0.11
	Max	0.7	0.44	0.49	0.69	0.41	0.3	0.65	0.25	0.44	0.68	0.36	0.4
	Min	-0.55	-0.46	-0.45	-0.47	-0.38	-0.34	-0.35	-0.28	-0.37	-0.31	-0.29	-0.41
YAW	Mean	-0.09			0.17			-0.35			-0.47		
deg	Std. Dev.	0.48	0.44	0.17	0.61	0.6	0.13	0.83	0.81	0.21	0.96	0.94	0.2
	Max	1.78	1.68	0.8	2.09	1.75	0.45	2.03	2.32	2.89	2.21	2.5	1.37
	Min	-2.03	-1.59	-0.79	-1.9	-1.93	-0.48	-2.9	-2.4	-1.43	-3.61	-2.96	-1.38
PITCH	Mean	-0.43			-1.29			-2.87			-2.85		
deg	Std. Dev.	2.06	1.94	0.71	0.74	0.71	0.21	1.38	1.25	0.57	1.75	1.65	0.59
	Max	6.5	6.3	2.43	0.97	1.78	0.74	1.25	3.52	2.09	1.63	4.05	1.94
	Min	-6.89	-5.74	-2.56	-3.38	-1.89	-0.71	-7.89	-3.89	-1.65	-7.46	-3.98	-1.77
TENS-1	Mean	1415			1764			2353			2356		
Kips	Std. Dev.	124.9	107.9	62.94	255.7	254.7	22.79	354.6	330.4	128.9	310.3	275.5	143
	Max	2040	387.6	365.7	3083	1211	217.7	3739	1024	608.1	3750	981.2	641.5
	Min	1202	-165.1	-250.5	1345	-418.9	-222.9	1515	-748.3	-498.5	1556	-592.1	-685.1
TENS-2	Mean												
Kips	Std. Dev.												
	Max												
	Min												
TENS-3	Mean	894.6			784.1			703			698.8		
Kips	Std. Dev.	57.83	52.97	23.36	52.52	52.37	4	46.12	44.04	13.68	39.14	35.86	15.69
	Max	1067	126.2	79.07	923.3	133.9	51.95	846.8	125.9	60.48	825.3	106	47.77
	Min	743.7	-122.5	-88.31	610.5	-167.8	-45.36	597.2	-94.6	-40.86	580.9	-85.26	-45.86
TENS-4	Mean												
Kips	Std. Dev.												
	Max												
	Min												
REL. MOT.	Mean	4.21			5.96			-3.81			-4.11		
Ft	Std. Dev.	15.88	7.24	14.13	7.03	1.78	6.8	13.45	3.15	13.07	13.88	4.18	13.23
	Max	85.88	32.53	63.23	34.19	4.67	23.55	52.76	7.68	54.27	49.48	9.1	47.04
	Min	-45.7	-11	-55.19	-19.45	-4.39	-26.11	-38.92	-10.7	-37.45	-43.66	-10.99	-45.87
RUNUP	Mean												
Ft	Std. Dev.												
	Max												
	Min												
MOONPOOL	Mean	1.24			1.28			0.7			0.92		
Ft	Std. Dev.	0.52	0.25	0.46	0.3	0.19	0.23	0.57	0.35	0.45	0.62	0.36	0.5
	Max	3.4	1.08	1.84	2.48	0.85	0.99	3.77	1.06	2.37	3.32	1.19	2.05
	Min	-0.67	-0.5	-1.92	0.23	-0.42	-0.97	-0.98	-0.83	-1.56	-1.11	-1.17	-1.89

CONFIGURATION B - RESTRAINED
TEST RESULTS SUMMARY

		brcw3&4			brcw5		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	39.16	1.21	39.12	44.28	1.39	44.24
Ft	Std. Dev.	9.79	0.3	9.78	11.07	0.35	11.06
	Max	44.57	1.99	42.41	47.71	3.34	45.53
	Min	-28.98	-2.43	-29.15	-35.47	-1.06	-35.71
WIND	Mean	83.02			59.53		
Knots	Std. Dev.	9.77	7.09	6.7	7.33	5.12	5.23
	Max	120.06	23.29	25.25	84.97	13.26	15.06
	Min	53.99	-23.67	-20.51	39.47	-15.23	-15.58
CUR 1	Mean	4.14			4.67		
Ft/Sec	Std. Dev.	2.16	0.74	1.98	2.54	0.77	2.4
	Max	11.12	2	7.51	12.61	1.76	8.14
	Min	-4.23	-2.37	-7.36	-5.5	-2.71	-8.71
CUR 2	Mean	0.85			1.27		
Ft/Sec	Std. Dev.	0.73	0.63	0.36	0.78	0.57	0.53
	Max	3.25	1.82	1.54	4.15	2.17	1.64
	Min	-5.84	-1.6	-4.03	-5.09	-1.73	-2.88
SURGE_CG	Mean	-77.28			-64.28		
Ft	Std. Dev.	8.57	8.08	2.86	9.06	8.2	3.85
	Max	-48.27	24.41	17.12	-40.57	21.73	12.33
	Min	-100.3	-17.68	-14.89	-89.09	-18.56	-15.31
HEAVE_CG	Mean	0.3			0.14		
Ft	Std. Dev.	2.14	0.67	2.03	3.1	0.57	3.05
	Max	7.37	3.06	6.42	12.05	2.51	11.44
	Min	-6.48	-1.67	-6.49	-12.12	-1.55	-11.41
SWAY_CG	Mean	0.84			1.53		
Ft	Std. Dev.	0.82	0.62	0.54	0.69	0.43	0.54
	Max	3.72	1.94	2.18	4.34	1.75	2.05
	Min	-2.19	-1.88	-2.17	-1.3	-1.44	-1.92
ROLL	Mean	0.15			0.16		
deg	Std. Dev.	0.15	0.1	0.1	0.16	0.13	0.1
	Max	0.68	0.39	0.45	0.72	0.36	0.42
	Min	-0.35	-0.3	-0.41	-0.55	-0.38	-0.48
YAW	Mean	-0.41			-0.04		
deg	Std. Dev.	0.9	0.88	0.19	0.56	0.52	0.19
	Max	2.21	2.39	1	1.8	1.65	0.62
	Min	-3.61	-3.03	-0.68	-1.87	-1.5	-0.87
PITCH	Mean	-2.86			-1.67		
deg	Std. Dev.	1.57	1.46	0.58	1.69	1.54	0.69
	Max	1.63	4.05	2.08	4.46	5.61	2.25
	Min	-7.89	-3.99	-1.77	-7.42	-4.8	-2.52
TENS-1	Mean	2354			1916		
Kips	Std. Dev.	333.2	303.8	136.8	248.3	215.8	122.8
	Max	3750	1026	689	2959	562.3	809.5
	Min	1515	-746.6	-682.4	1391	-490	-370.2
TENS-2	Mean						
Kips	Std. Dev.						
	Max						
	Min						
TENS-3	Mean	700.9			760.6		
Kips	Std. Dev.	42.82	40.11	14.97	45.82	40.4	21.63
	Max	846.8	128.2	102	886.1	102.6	71.61
	Min	580.9	-92.38	-57.35	647.8	-89.73	-85.43
TENS-4	Mean						
Kips	Std. Dev.						
	Max						
	Min						
REL. MOT.	Mean	-3.96			5.51		
Ft	Std. Dev.	13.67	3.71	13.15	14.46	3.77	13.95
	Max	52.76	8.87	54.18	65.34	12.61	56.48
	Min	-43.66	-11.21	-45.65	-50.89	-13.16	-49.6
RUNUP	Mean						
Ft	Std. Dev.						
	Max						
	Min						
MOONPOOL	Mean	0.81			1.1		
Ft	Std. Dev.	0.6	0.37	0.47	0.66	0.27	0.6
	Max	3.77	1.31	2.38	3.22	0.93	2.23
	Min	-1.11	-1.05	-1.88	-1.15	-0.65	-2.2

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

		Current only												
		fcur2			fcur3			f1cur3			f1cur5			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3													
Ft	Std. Dev.													
	Max													
	Min													
WIND	Mean													
Knots	Std. Dev.													
	Max													
	Min													
CUR 1	Mean	4.81			3.26			3.87			4.01			3.58
Ft/Sec	Std. Dev.	1.47	1.32	0.62	0.99	0.88	0.41	0.91	0.79	0.4	1.21	1.06	0.55	0.93
	Max	9.02	2.87	2.57	6.9	2.07	1.91	6.51	2.1	1.54	8.01	2.84	2.83	7.06
	Min	0.76	-3.25	-2.97	-3.23	-2.13	-2.79	0.72	-2.24	-1.42	0.08	-2.76	-3.16	-3.84
CUR 2	Mean	0.43			0.13			0.49			0.54			0.11
Ft/Sec	Std. Dev.	0.49	0.45	0.16	0.25	0.21	0.11	0.24	0.2	0.1	0.35	0.31	0.15	0.24
	Max	1.92	1.02	0.7	0.94	0.4	0.45	1.94	0.59	0.73	1.87	0.99	0.79	2.7
	Min	-0.89	-0.78	-0.8	-0.77	-0.55	-0.46	-0.29	-0.57	-0.35	-5.24	-0.8	-2.69	-5.26
SURGE_CG	Mean	-30.59			-18.6			-38.07			-47.85			-42.37
Ft	Std. Dev.	11.33	11.33	0.11	7.11	7.11	0.06	3.41	3.41	0.05	4.48	0.11	0.06	4.12
	Max	-1.92	28.63	2.63	-2.63	15.94	1.3	-28.45	9.57	0.4	-36.23	0.27	0.38	-32.64
	Min	-60.95	-30.35	-2.88	-37.04	-18.41	-0.49	-47.25	-9.1	-0.16	-61.9	-0.46	-1.36	-54.4
HEAVE_CG	Mean	-0.16			-0.04			-0.04			-0.26			-0.04
Ft	Std. Dev.	0.1	0.1	0.03	0.06	0.06	0.02	0.05	0.05	0.02	0.12	4.48	0.02	0.06
	Max	0.14	0.25	0.1	0.18	0.14	0.13	0.12	0.11	0.09	0.03	11.59	0.09	0.16
	Min	-0.56	-0.35	-0.1	-0.27	-0.2	-0.1	-0.25	-0.17	-0.11	-0.8	-13.96	-0.1	-0.24
SWAY_CG	Mean	-12.58			-6.65			-11.16			-18.65			-13.25
Ft	Std. Dev.	13.26	13.26	0.18	11.82	11.82	0.31	7.23	7.22	0.38	14.54	0.45	0.07	9.79
	Max	20.54	33.11	4.07	23.65	30.22	7.52	7.53	18.67	9.33	16.02	1.37	1.83	7.03
	Min	-49.83	-37.21	-4.65	-31.68	-24.96	-7.84	-28.92	-17.7	-9.52	-45.76	-1.34	-0.8	-38.13
ROLL	Mean	0.01			-0.02			0.12			0.16			0.1
deg	Std. Dev.	0.57	0.57	0.01	0.17	0.17	0.01	0.14	0.14	0	0.22	0.22	0.01	0.16
	Max	1.63	1.62	0.07	0.66	0.68	0.22	0.58	0.46	0.03	0.81	0.65	0.18	0.6
	Min	-1.62	-1.63	-0.21	-0.51	-0.49	-0.19	-0.31	-0.42	-0.1	-0.42	-0.58	-0.22	-0.3
YAW	Mean	0.23			-0.1			0.7			1.13			0.93
deg	Std. Dev.	0.43	0.43	0.02	0.22	0.22	0.02	0.3	0.3	0.03	0.45	14.73	0.03	0.31
	Max	1.47	1.22	0.22	0.52	0.56	0.11	1.65	0.9	0.16	2.56	38.99	0.13	1.73
	Min	-0.79	-1	-0.1	-0.86	-0.71	-0.18	-0.25	-0.92	-0.21	-0.3	-29.39	-0.15	0.02
PITCH	Mean	-0.41			-0.23			-0.39			-0.57			-0.44
deg	Std. Dev.	0.14	0.14	0	0.08	0.08	0	0.08	0.08	0	0.13	0.13	0	0.09
	Max	-0.06	0.35	0.04	0.01	0.25	0.04	-0.17	0.22	0.01	-0.17	0.4	0.06	-0.17
	Min	-0.78	-0.37	-0.04	-0.53	-0.3	-0.05	-0.59	-0.21	-0.01	-0.93	-0.36	-0.07	-0.66
TENS-1	Mean	1343			1249			1400			1590			1358
Kips	Std. Dev.	111.1	111.1	0.88	43.54	43.53	0.58	38.81	38.81	0.55	112.3	112.3	0.66	36.31
	Max	1884	539.1	12.4	1368	118.8	2.12	1561	159.7	5.34	1939	347.3	8.91	1515
	Min	1149	-192.8	-15.07	1155	-93.57	-8.9	1316	-82.19	-6.71	1370	-218.1	-7.34	1288
TENS-2	Mean	1210			1170			1218			1269			1215
Kips	Std. Dev.	79.03	79.02	1.36	64.44	64.41	1.78	39.66	39.59	2.16	84.99	84.98	0.78	53.72
	Max	1532	325.8	25.29	1309	138.7	43.36	1316	97.02	53.13	1547	278.3	5.07	1359
	Min	1035	-173.5	-23.96	1006	-162.7	-41.84	1116	-101.8	-53.06	1078	-190.2	-11.58	1102
TENS-3	Mean	973			1037			924			872.3			939.6
Kips	Std. Dev.	61.45	61.45	0.68	39.02	39.01	0.51	18.81	18.8	0.45	24.4	24.39	0.5	22.97
	Max	1131	157.3	13.72	1125	86.05	7.54	978.3	53.28	1.87	937.7	64.29	2.04	997.9
	Min	808.2	-164	-10.89	933.2	-102.3	-2.9	872.5	-50.14	-2.03	792.1	-78.7	-3.35	869.8
TENS-4	Mean	1078			1116			1101			1076			1065
Kips	Std. Dev.	70.06	70.05	1.11	63.15	63.12	1.74	39.15	39.09	2.1	77.31	77.3	0.65	53.03
	Max	1247	168.2	22.72	1279	162.3	40.14	1199	97.27	48.91	1266	188.6	9.75	1175
	Min	885.8	-190.9	-25.35	980.3	-134.1	-42.93	1003	-96.18	-51.03	932.2	-142.9	-3.5	930.9
REL. MOT.	Mean	-2.21			-0.99			-0.88			-0.96			-0.71
Ft	Std. Dev.	0.36	0.36	0.06	0.2	0.2	0.02	0.18	0.18	0.02	0.31	0.31	0.04	0.2
	Max	-1.41	0.82	0.23	-0.47	0.56	0.16	-0.44	0.44	0.07	0.15	1.09	0.25	-0.07
	Min	-3.18	-0.89	-0.22	-1.73	-0.76	-0.17	-1.33	-0.45	-0.1	-1.86	-0.9	-0.31	-1.23
RUNUP	Mean	2.09			0.41			0.44			0.74			0.74
Ft	Std. Dev.	0.2	0.19	0.05	0.1	0.1	0.02	0.09	0.09	0.02	0.18	0	0.04	0.11
	Max	2.6	0.49	0.16	0.66	0.23	0.08	0.71	0.24	0.07	1.5	0	0.12	1.08
	Min	1.46	-0.52	-0.21	0.04	-0.36	-0.12	0.19	-0.21	-0.08	0.16	0	-0.13	0.41
MOONPOOL	Mean													
Ft	Std. Dev.													
	Max													
	Min													

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

		f2cur3		fran1			fran2			fran3			Waves on! fran6	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
WAVE	H1/3			8.6	0.23	8.58	21.8	0.43	21.79	46.12	1.39	46.12	12.73	0.22
Ft	Std. Dev.			2.15	0.06	2.15	5.45	0.11	5.45	11.53	0.35	11.53	3.18	0.06
	Max			9.12	0.45	8.21	21.68	0.51	21.57	42.9	1.97	41.22	11.61	0.33
	Min			-7.82	-0.17	-7.9	-18.8	-0.67	-18.86	-31.39	-0.87	-31.71	-9.82	-0.18
WIND	Mean													
Knots	Std. Dev.													
	Max													
	Min													
CUR 1	Mean													
Ft/Sec	Std. Dev.	0.81	0.42											
	Max	2.38	1.83											
	Min	-2.25	-3.16											
CUR 2	Mean													
Ft/Sec	Std. Dev.	0.19	0.13											
	Max	0.46	1.16											
	Min	-0.45	-2.38											
SURGE_CG	Mean			-2.05			-6.24			-13.7			-0.52	
Ft	Std. Dev.	4.11	0.26	1.32	1.31	0.16	6.24	6.18	0.89	11.89	11.49	3.04	1.65	1.25
	Max	9.96	6.24	1.29	3.16	0.62	11.54	16.64	2.92	18.14	27.78	9.15	4.81	3.09
	Min	-12.05	-7.03	-5.45	-3.13	-0.54	-22.62	-15.27	-2.89	-44.86	-26.36	-12.21	-5.34	-3.33
HEAVE_CG	Mean			-0.01			0			-0.01			-0.01	
Ft	Std. Dev.	0.05	0.02	0.03	0.02	0.02	0.08	0.05	0.06	0.46	0.19	0.42	0.14	0.04
	Max	0.16	0.07	0.09	0.04	0.08	0.37	0.12	0.26	1.91	0.5	2.02	0.5	0.13
	Min	-0.15	-0.08	-0.17	-0.07	-0.09	-0.32	-0.18	-0.24	-1.89	-0.62	-1.6	-0.49	-0.14
SWAY_CG	Mean			-1.34			0.26			0.02			0.17	
Ft	Std. Dev.	9.79	0.11	0.34	0.33	0.08	0.69	0.67	0.18	2.01	1.96	0.42	0.23	0.18
	Max	20.22	2.66	-0.49	0.63	0.49	2.61	2.03	0.61	4.61	3.8	1.52	0.89	0.39
	Min	-24.81	-2.63	-4.44	-0.71	-1.58	-2.03	-1.81	-0.7	-6.71	-6.21	-1.82	-0.57	-0.38
ROLL	Mean			0			0.01			-0.01			0	
deg	Std. Dev.	0.16	0.01	0.04	0.04	0.01	0.09	0.08	0.03	0.13	0.11	0.07	0.03	0.02
	Max	0.51	0.16	0.12	0.11	0.04	0.24	0.22	0.09	0.4	0.3	0.25	0.11	0.06
	Min	-0.4	-0.26	-0.12	-0.11	-0.04	-0.23	-0.19	-0.11	-0.45	-0.25	-0.29	-0.1	-0.06
YAW	Mean			-0.06			0.66			0.73			0.7	
deg	Std. Dev.	0.31	0.02	0.09	0.09	0.03	0.34	0.34	0.04	0.99	0.98	0.12	0.06	0.04
	Max	0.77	0.09	0.24	0.23	0.09	1.81	1.09	0.21	3.66	2.68	0.52	0.98	0.12
	Min	-0.89	-0.18	-0.35	-0.23	-0.09	-0.37	-0.92	-0.25	-2.27	-2.69	-0.53	0.51	-0.12
PITCH	Mean			-0.04			-0.13			-0.27			-0.03	
deg	Std. Dev.	0.09	0	0.08	0.07	0.04	0.42	0.36	0.22	1.01	0.79	0.63	0.21	0.06
	Max	0.27	0.03	0.25	0.22	0.13	1.14	0.95	0.74	2.84	2.35	2.02	0.73	0.19
	Min	-0.22	-0.02	-0.33	-0.2	-0.14	-1.52	-0.93	-0.71	-3.27	-2.13	-1.78	-0.78	-0.19
TENS-1	Mean			1153			1181			1225			1149	
Kips	Std. Dev.	36.25	1.93	7.82	7.76	0.76	35.57	35.37	3.68	68.34	66.57	15.4	9.01	7.16
	Max	157.3	47.98	1172	16.28	4.09	1275	87.06	23.68	1439	165.7	62.03	1174	18.8
	Min	-73.95	-44.51	1133	-18.19	-5.01	1086	-87.2	-20.92	1052	-154.7	-51.06	1121	-18.24
TENS-2	Mean			1141			1143			1143			1144	
Kips	Std. Dev.	53.72	0.65	2.19	2	0.59	3.8	3.59	1.07	10.83	10.51	2.55	1.69	1.11
	Max	142.6	11.81	1147	4.99	2.64	1156	9.78	3.55	1182	33.49	11.05	1151	2.82
	Min	-111.5	-11.65	1135	-3.95	-2.82	1130	-10.43	-3.55	1117	-22.37	-10.2	1138	-2.71
TENS-3	Mean			1124			1096			1058			1127	
Kips	Std. Dev.	22.92	1.47	7.44	7.4	0.63	34.1	33.96	3.06	64.01	62.7	12.83	8.4	6.93
	Max	57.39	34.02	1143	17.93	3.45	1187	85.97	19.58	1226	150.8	44.05	1154	16.69
	Min	-68.94	-36.78	1105	-16.85	-3.14	1007	-83.32	-22.57	900.1	-137.5	-42.01	1104	-17.99
TENS-4	Mean			1137			1169			1170			1171	
Kips	Std. Dev.	53.02	0.84	2	1.8	0.56	3.95	3.84	0.7	11.97	11.74	2.22	1.7	1.31
	Max	108.9	16.66	1144	4.93	2.85	1182	10.97	2.57	1200	23.14	9.71	1178	2.82
	Min	-132.8	-15.75	1130	-4.07	-3.55	1156	-11.08	-2.49	1134	-34.96	-8.23	1165	-3.11
REL MOT.	Mean			-0.37			-0.33			0.02			-0.15	
Ft	Std. Dev.	0.2	0.04	2.48	0.2	2.47	7.26	0.85	7.2	14.09	1.92	13.95	3.86	0.15
	Max	0.55	0.14	10.72	0.63	10.47	32.07	2.2	29.86	52.98	5.5	49.45	14.68	0.46
	Min	-0.48	-0.13	-8.78	-0.6	-8.54	-26	-2.21	-25.79	-37.76	-5.2	-41.6	-11.64	-0.42
RUNUP	Mean			0.43			1.13			2.57			0.26	
Ft	Std. Dev.	0.1	0.04	3.8	0.26	3.79	8.7	1.15	8.62	15.31	2.27	15.13	3.64	0.09
	Max	0.27	0.14	22.96	1.52	21.08	53.92	6.62	46.65	69.49	8.42	64.26	13.52	0.38
	Min	-0.26	-0.12	-11.94	-0.64	-13.39	-28.09	-3.15	-30	-38.58	-5.1	-44.83	-11.14	-0.42
MOONPOOL	Mean													
Ft	Std. Dev.													
	Max													
	Min													

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CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

			f1ran3			f1ran5			f2ran3			frc2		
		f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	12.73	46.08	1.29	46.04	48.72	1.45	48.68	46.52	1.24	46.48	21.46	0.53	21.44
Ft	Std. Dev.	3.18	11.52	0.32	11.51	12.18	0.36	12.17	11.63	0.31	11.62	5.36	0.13	5.36
	Max	11.69	43.09	1.74	41.4	57.03	2.04	56.16	41.55	1.69	40.17	22.91	0.67	21.93
	Min	-9.83	-31.84	-0.6	-32.19	-38.62	-1.62	-39.36	-31.6	-0.7	-31.81	-16.71	-0.39	-17.19
WIND	Mean													
Knots	Std. Dev.													
	Max													
	Min													
CUR 1	Mean											5.46		
Ft/Sec	Std. Dev.											1.51	1.02	1.1
	Max											10.52	2.43	4.38
	Min											-2.61	-3.11	-4.82
CUR 2	Mean											0.93		
Ft/Sec	Std. Dev.											0.51	0.47	0.21
	Max											3.32	1.3	1.21
	Min											-1.12	-1.24	-1.65
SURGE_CG	Mean		-15.27			-10.72			-15.03			-41.6		
Ft	Std. Dev.	1.08	9.11	8.57	3.1	11.24	10.47	4.1	9.12	8.56	3.12	6.84	6.78	0.88
	Max	4.24	11.55	20.54	9.81	19.89	22.14	12.93	12.47	23.03	9.63	-21.96	19.35	4.26
	Min	-3.89	-39.31	-19.32	-9.13	-46.6	-26.09	-14.91	-40.24	-20.43	-10.1	-58.61	-16.49	-7.97
HEAVE_CG	Mean		-0.08			0.1			0.03			-0.27		
Ft	Std. Dev.	0.13	0.47	0.21	0.42	0.75	0.26	0.71	0.49	0.21	0.44	0.13	0.1	0.08
	Max	0.5	2.1	0.59	1.79	2.69	0.91	2.32	2.41	0.57	1.87	0.15	0.26	0.29
	Min	-0.41	-2.13	-0.62	-1.92	-2.52	-0.92	-2.58	-1.91	-0.58	-1.87	-0.7	-0.29	-0.27
SWAY_CG	Mean		1.28			0.92			1.19			2.61		
Ft	Std. Dev.	0.14	2.56	2.52	0.43	1.41	1.3	0.55	1.98	1.94	0.39	14.43	14.43	0.48
	Max	0.47	10.8	8.52	2.03	6.63	3.88	2.49	8.41	6.06	1.75	29.35	25.98	2.5
	Min	-0.48	-4.17	-4.86	-1.76	-2.55	-3.3	-2.34	-2.85	-3.74	-1.71	-34.06	-35.83	-6.43
ROLL	Mean		0.01			0.02			0.01			0.06		
deg	Std. Dev.	0.02	0.15	0.12	0.09	0.13	0.09	0.09	0.13	0.11	0.07	0.64	0.64	0.07
	Max	0.08	0.55	0.52	0.34	0.53	0.28	0.48	0.52	0.45	0.29	2.32	2.1	0.3
	Min	-0.08	-0.55	-0.51	-0.36	-0.57	-0.32	-0.49	-0.5	-0.47	-0.35	-1.89	-1.9	-0.26
YAW	Mean		0.01			0.01			0.1			-0.03		
deg	Std. Dev.	0.04	0.8	0.71	0.36	0.99	0.83	0.54	0.76	0.66	0.37	0.63	0.62	0.1
	Max	0.14	2.49	1.99	1.27	3.84	2.3	2.37	3.04	1.84	1.29	1.87	1.75	0.69
	Min	-0.15	-2.48	-2.08	-1.3	-3.62	-2.33	-1.99	-2.27	-1.87	-1.26	-1.58	-1.49	-0.4
PITCH	Mean		-0.29			-0.21			-0.27			-0.52		
deg	Std. Dev.	0.2	0.99	0.76	0.63	1.08	0.79	0.74	0.96	0.73	0.63	0.44	0.38	0.22
	Max	0.81	2.71	2.17	2	3.19	2.89	2.44	2.62	2.11	1.99	0.89	1.13	0.68
	Min	-0.69	-3.23	-1.88	-1.8	-4.9	-2.51	-2.54	-3.2	-1.87	-1.79	-2.02	-1.06	-0.67
TENS-1	Mean		1239			1220			1192			1438		
Kips	Std. Dev.	5.43	51.63	49.42	14.93	64.58	60.81	21.75	50.37	48.15	14.77	100.4	99.66	12.35
	Max	18.02	1382	111.7	53.57	1519	172.1	132.7	1330	112.6	48.05	1790	345.7	56.35
	Min	-21.09	1102	-113.4	-46.92	1071	-126.6	-73.07	1051	-124.3	-47.54	1274	-162.2	-52.55
TENS-2	Mean		1144			1148			1134			1129		
Kips	Std. Dev.	1.12	14.27	14.03	2.5	8.34	7.52	3.56	10.83	10.49	2.62	78.34	78.32	1.33
	Max	3.65	1177	29.16	8.97	1174	18.75	13.45	1161	19.51	9.27	1329	197.3	31.92
	Min	-3.87	1094	-47.55	-9.21	1120	-23.44	-13.04	1092	-33.51	-10.75	985.3	-142.2	-18.65
TENS-3	Mean		1052			1073			1087			914		
Kips	Std. Dev.	4.72	47.92	46.29	12.37	59.39	56.72	17.58	48.34	46.73	12.39	37	36.85	3.29
	Max	17.33	1189	108	40.44	1214	120.6	58.81	1228	125	39.6	1021	104.2	17.05
	Min	-16.15	933.2	-101.3	-41.43	897.5	-147.3	-61.18	960.4	-106.6	-41.81	822.5	-90.95	-17.76
TENS-4	Mean		1147			1150			1131			1159		
Kips	Std. Dev.	0.85	13.95	13.8	1.96	7.61	6.84	3.29	11.18	10.98	1.99	77.41	77.39	1.28
	Max	3.56	1196	45.94	11.29	1173	20.78	11.88	1174	36.03	12.97	1303	142.4	18.5
	Min	-3.43	1116	-27.24	-8.73	1127	-19	-12.12	1109	-20.1	-8.99	969.9	-187.8	-31.72
REL. MOT.	Mean		0.21			0.33			0.07			-2.53		
Ft	Std. Dev.	3.86	13.93	1.85	13.8	14.09	1.96	13.95	13.87	1.82	13.75	6.97	0.94	6.9
	Max	14.9	48.98	4.99	48.21	86.95	8.42	82.71	51.4	5.57	47.14	28.89	2.88	29.83
	Min	-11.37	-36.51	-4.76	-41.16	-44.78	-5.04	-44.57	-36.71	-4.86	-40	-24.78	-2.87	-22.53
RUNUP	Mean		2.41			2.12			2.46			1.92		
Ft	Std. Dev.	3.64	14.52	2.15	14.35	13.61	1.6	13.51	14.75	2.12	14.59	8.49	0.87	8.44
	Max	13.25	64.11	7.98	59.17	67.34	6.79	61.54	65.48	8.1	60.43	45.61	3.09	42.47
	Min	-11.55	-36.2	-4.52	-42.08	-38.78	-3.71	-43.78	-37.5	-4.66	-44.58	-24.16	-2.03	-27.87
MOONPOOL	Mean													
Ft	Std. Dev.													
	Max													
	Min													

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

		Waves & Current												
		frc3			frc6			f1rc3			f1rc5			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3	40.88	1.31	40.84	12.23	0.25	12.23	40.76	1.04	40.76	45	1.43	44.96	42
Ft	Std. Dev.	10.22	0.33	10.21	3.06	0.06	3.06	10.19	0.26	10.19	11.25	0.36	11.24	10.5
	Max	46.43	1.54	42.86	9.63	0.21	9.63	43.89	2.05	41.2	51.75	1.76	50.97	52.48
	Min	-30.04	-0.88	-30.93	-10.11	-0.19	-10.01	-29.83	-0.7	-30.61	-36.4	-2.78	-36.71	-29.88
WIND	Mean													
Knots	Std. Dev.													
	Max													
	Min													
CUR 1	Mean	3.95			3.56			3.86			4.71			3.8
Ft/Sec	Std. Dev.	2.41	0.91	2.22	1.27	0.94	0.83	2.36	0.82	2.2	2.71	0.88	2.56	2.4
	Max	10.87	2.28	7.22	7.44	2.19	2.69	10.53	1.82	7.09	13.72	2.2	8.86	11.08
	Min	-5.92	-2.92	-7.43	-0.6	-2.86	-3.24	-5.75	-2.26	-7.79	-7.06	-3	-9.27	-5.87
CUR 2	Mean	2.16			0.64			1.85			1.96			1.82
Ft/Sec	Std. Dev.	0.81	0.65	0.48	0.41	0.36	0.17	0.84	0.72	0.42	1.19	0.96	0.69	0.84
	Max	4.65	1.53	1.86	2.09	0.57	0.8	9.05	2.6	4.05	6.42	3.48	2.32	9.63
	Min	-0.77	-1.77	-1.99	-0.88	-0.92	-0.66	-0.7	-1.84	-1.98	-1.93	-1.95	-2.86	-5.23
SURGE_CG	Mean	-38.13			-20.68			-46.34			-55.96			-55.95
Ft	Std. Dev.	9.71	9.29	2.82	8.07	8	1.07	8.13	7.59	2.9	8.58	7.59	4.01	8.37
	Max	-3.68	29.3	9.96	4.31	23.6	4.18	-14.43	24.51	10.52	-30.36	19.27	15.78	-31.02
	Min	-60.92	-18.5	-15.8	-44.83	-22.49	-6.58	-72.2	-20.55	-8.44	-81.1	-22.17	-15.11	-81.91
HEAVE_CG	Mean	-0.19			-0.08			-0.15			-0.72			-0.16
Ft	Std. Dev.	0.45	0.22	0.39	0.2	0.09	0.18	0.46	0.24	0.39	0.88	0.37	0.81	0.48
	Max	1.42	0.7	1.97	0.74	0.33	0.62	1.74	0.71	1.71	2.41	1.18	2.59	1.8
	Min	-1.99	-0.8	-1.45	-0.79	-0.25	-0.57	-1.86	-0.82	-1.64	-3.82	-1.51	-2.85	-1.74
SWAY_CG	Mean	-2.93			-3.83			-7.21			-8.24			-14.51
Ft	Std. Dev.	24.88	24.87	0.63	15.07	15.07	0.27	18.19	18.17	0.91	25.81	25.79	0.87	23.67
	Max	58.1	60.01	3.43	31.48	35.18	4.55	34.62	41.21	16.25	49.93	57.99	3.52	40.06
	Min	-56.32	-52.72	-5.99	-37.5	-33.34	-5.34	-47.4	-39.33	-17.1	-69.43	-60.07	-4.79	-65
ROLL	Mean	0.03			0.07			0.12			0.21			0.25
deg	Std. Dev.	0.28	0.26	0.1	0.21	0.21	0.03	0.24	0.22	0.1	0.38	0.36	0.14	0.3
	Max	1	0.92	0.41	0.83	0.67	0.25	0.85	0.65	0.37	1.67	1.32	0.64	1.58
	Min	-0.73	-0.63	-0.43	-0.48	-0.52	-0.22	-0.53	-0.55	-0.35	-1.09	-1.01	-0.9	-0.64
YAW	Mean	0.07			0.31			0.6			0.74			0.77
deg	Std. Dev.	1.11	1.1	0.15	0.28	0.27	0.05	0.73	0.63	0.36	1.08	0.93	0.55	0.8
	Max	3.47	3.28	0.69	1.2	0.78	0.21	3.44	1.8	1.53	5.66	3.13	2.33	3.49
	Min	-3.35	-3.37	-0.51	-0.46	-0.7	-0.18	-2.09	-2.25	-1.2	-3.16	-2.61	-2.56	-2.05
PITCH	Mean	-0.47			-0.24			-0.61			-0.66			-0.66
deg	Std. Dev.	0.91	0.69	0.59	0.23	0.11	0.2	0.9	0.67	0.6	1.03	0.73	0.72	0.88
	Max	2.57	2.24	1.86	0.57	0.35	0.74	2.31	2.12	1.98	2.38	2.76	2.37	2.21
	Min	-3.28	-1.91	-1.61	-1.06	-0.38	-0.65	-3.69	-1.94	-1.66	-5.54	-2.68	-2.57	-3.51
TENS-1	Mean	1410			1262			1570			1788			1583
Kips	Std. Dev.	114.5	107.5	39.3	50.68	50.31	6.13	170.6	159.3	61.16	230	204.8	104.6	176.4
	Max	1849	313	197.4	1456	170.3	31.06	2165	484.9	204.2	2769	768.2	371.4	2164
	Min	1172	-215.9	-161.3	1117	-136.5	-23.36	1248	-290.8	-201.2	1329	-418.8	-328.5	1299
TENS-2	Mean	1163			1160			1202			1248			1260
Kips	Std. Dev.	151.5	151.5	3.76	82	81.98	1.55	106.3	106.1	5.12	214.9	214.7	9.04	194
	Max	1719	562.3	25.46	1348	186.3	30.14	1590	374.7	99.1	2168	911.4	119.4	1977
	Min	829.2	-330.5	-25.14	970.6	-188.8	-26.89	974.3	-218.7	-95.86	901.8	-344.1	-51.39	938.7
TENS-3	Mean	935			1027			880.9			834.5			871.2
Kips	Std. Dev.	51.16	49.7	12.11	44.33	44.07	4.74	42.79	41.12	11.82	44.02	40.34	17.61	44.4
	Max	1114	154.5	54.06	1164	132.2	18.25	1046	133.3	45.88	964.5	108.5	58.86	1000
	Min	821.6	-96.86	-38.89	897.5	-123.5	-24.28	760	-105.5	-38.39	707.3	-115.2	-60.82	748.3
TENS-4	Mean	1132			1117			1124			1131			1061
Kips	Std. Dev.	143.7	143.6	3.33	80.49	80.47	1.46	97.48	97.4	3.76	136.9	136.8	4.15	126.8
	Max	1674	550.8	25.65	1308	189.4	24.08	1351	222	90.13	1477	333	17.46	1358
	Min	846.5	-283.5	-31.31	938.7	-176.6	-28.72	910.5	-210.3	-83.62	823.7	-305.3	-21.62	796.2
REL. MOT.	Mean	-2.01			-1.87			0.59			0.86			-0.7
Ft	Std. Dev.	13.84	1.73	13.73	3.87	0.28	3.86	13.76	1.66	13.66	14.05	1.76	13.93	13.65
	Max	53.23	6	53.67	10	0.81	11.71	54.49	5.51	51.79	87.77	8.64	84.4	52.76
	Min	-39.5	-4.55	-40.44	-15.07	-0.81	-13.26	-40.25	-4.64	-42.27	-46.28	-4.75	-48.7	-39.09
RUNUP	Mean	3.74			0.31			2.7			3.8			1.76
Ft	Std. Dev.	15.24	2.01	15.1	3.61	0.22	3.61	14.75	1.81	14.63	14.32	1.49	14.24	14.23
	Max	71.19	8.37	61.66	11.83	0.79	11.53	68.26	8.27	60.82	68.78	6.01	60.91	67.46
	Min	-38.38	-4.13	-48.42	-11.68	-0.59	-12.05	-39.82	-4.09	-46.54	-37.91	-3.76	-43.89	-39.63
MOONPOOL	Mean													
Ft	Std. Dev.													
	Max													
	Min													

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

										Waves, Wind & Current				
		f2rc3		frcw2			frcw3			frcw6			f1rcw3	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
WAVE	H1/3	1.61	41.96	20.1	0.56	20.08	39.57	1.2	39.54	12.32	0.38	12.31	39.97	1.81
Ft	Std. Dev.	0.4	10.49	5.03	0.14	5.02	9.89	0.3	9.88	3.08	0.09	3.08	9.99	0.45
	Max	1.57	48.94	23.15	0.62	22.55	48.6	2.3	44.41	9.99	0.26	9.82	42.29	2.85
	Min	-0.74	-30.19	-17.7	-0.48	-18.31	-28.74	-0.69	-28.2	-9.94	-0.34	-9.94	-30.02	-0.86
WIND	Mean			41.52			84.91			46.24			85.33	
Knots	Std. Dev.			4.9	4.07	2.69	10.67	7.77	7.31	4.8	3.77	2.93	9.87	6.94
	Max			64.73	15.64	9.52	120.06	20.86	26.27	61.42	9.67	11.63	115.56	21.17
	Min			27.43	-11.5	-8.37	54.99	-22.39	-22.82	32.82	-9.31	-9.8	51.16	-23.77
CUR 1	Mean			5.09			3.84			3.7			4.35	
Ft/Sec	Std. Dev.	1.1	2.13	1.54	1.11	1.05	2.41	0.86	2.21	1.13	0.73	0.82	2.33	0.68
	Max	2.04	8.34	9.64	3.09	3.96	11.95	2.03	7.01	7.6	1.81	2.83	13	1.96
	Min	-3.57	-7.19	-0.87	-2.83	-4.62	-4.64	-2.66	-8.4	-0.59	-2.51	-3.22	-3.8	-2.19
CUR 2	Mean			0.22			2.34			0.75			1.64	
Ft/Sec	Std. Dev.	0.7	0.45	0.44	0.4	0.16	1.04	0.92	0.48	0.32	0.23	0.2	0.75	0.62
	Max	2.22	4.22	1.76	0.89	0.82	5.47	1.93	1.96	1.8	0.55	0.75	4.25	1.63
	Min	-1.61	-3.97	-1.13	-0.87	-0.57	-1.38	-2.66	-2.64	-0.3	-0.61	-0.68	-1.1	-1.44
SURGE_CG	Mean			-49.39			-72.98			-40.57			-78.83	
Ft	Std. Dev.	7.86	2.87	9.77	9.73	0.86	8.43	7.95	2.81	9.81	9.75	1.06	6.14	5.44
	Max	19.47	11.35	-12.57	36.19	2.84	-41.83	27.99	10.69	-10.21	28.46	3.93	-60.84	14.8
	Min	-19.18	-8.4	-74.55	-23.1	-3.1	-95.28	-16.94	-16.89	-64.94	-22.94	-3.35	-96.17	-12.35
HEAVE_CG	Mean			-0.18			0.05			-0.02			-0.19	
Ft	Std. Dev.	0.27	0.4	0.23	0.18	0.14	0.71	0.44	0.56	0.25	0.15	0.21	0.67	0.45
	Max	0.74	1.86	0.7	0.43	0.47	3.17	1.51	3.01	0.82	0.4	0.78	2.62	1.63
	Min	-0.8	-1.6	-0.89	-0.65	-0.49	-2.39	-1.39	-2.14	-1.06	-0.53	-0.89	-2.64	-1.34
SWAY_CG	Mean			-6.46			-1.27			3.07			-1.97	
Ft	Std. Dev.	23.66	0.69	21.79	21.79	0.52	25.44	25.43	0.55	16.38	16.38	0.34	25.07	25.06
	Max	53.65	5.59	49	55	5.49	65.39	65.51	2.47	42.55	39.3	7.11	56.82	57.87
	Min	-49.27	-5.25	-52.5	-45.49	-6.19	-60.25	-58.06	-2.53	-40.12	-42.92	-7.05	-52.36	-48.76
ROLL	Mean			-0.04			-0.1			0.02			-0.04	
deg	Std. Dev.	0.28	0.11	0.63	0.63	0.08	0.27	0.26	0.09	0.25	0.25	0.03	0.29	0.27
	Max	1.06	0.39	1.65	1.61	0.55	0.84	0.84	0.45	0.8	0.79	0.21	0.82	0.71
	Min	-0.75	-0.45	-1.9	-1.69	-0.31	-0.95	-0.71	-0.4	-0.72	-0.71	-0.16	-0.92	-0.69
YAW	Mean			0.31			0.9			0.39			1.15	
deg	Std. Dev.	0.72	0.36	0.96	0.95	0.11	1.03	1.02	0.17	0.45	0.45	0.06	0.79	0.71
	Max	2.2	1.55	2.84	2.41	0.39	3.78	2.96	0.66	1.81	1.41	0.41	3.9	2.04
	Min	-2.38	-1.36	-2.23	-2.39	-0.42	-1.7	-2.4	-0.67	-0.81	-1.14	-0.5	-1.04	-1.86
PITCH	Mean			-1.01			-2.31			-0.85			-2.47	
deg	Std. Dev.	0.65	0.59	0.6	0.56	0.22	1.14	0.98	0.59	0.32	0.25	0.2	0.98	0.78
	Max	2.04	2.01	0.68	1.4	0.74	1.17	3.04	2.08	0.26	0.79	0.78	0.31	2.1
	Min	-1.88	-1.64	-2.9	-1.43	-0.72	-6.39	-2.74	-1.72	-1.98	-0.82	-0.65	-5.79	-2.54
TENS-1	Mean			1611			2299			1443			2658	
Kips	Std. Dev.	166.5	58.31	208.8	208.2	16.53	347.3	324	125	140.8	139.7	17.3	383	338.2
	Max	454.4	214	2216	553.8	79.13	3679	991.5	594.6	1966	487	74.67	4021	866.7
	Min	-256.7	-252.2	1218	-387	-64.41	1419	-813.2	-553.1	1193	-236.6	-65.39	1964	-613.9
TENS-2	Mean			1181			1165			1123			1191	
Kips	Std. Dev.	193.9	4.59	128.9	128.9	2.14	166.9	166.8	4.48	88.48	88.44	2.04	155.5	155.4
	Max	704	31.1	1593	417.6	29.35	1853	668	25.5	1366	240.9	39.25	1742	534
	Min	-321	-33.55	890.3	-288.4	-23.92	807.6	-353.5	-30.67	912.8	-207.8	-42.62	871.5	-313.9
TENS-3	Mean			869.5			741.3			916.8			699.9	
Kips	Std. Dev.	42.7	12.14	52.29	52.19	3.23	43.57	41.85	12.08	53.82	53.6	4.87	31.5	29.3
	Max	101.8	50.08	1058	186.5	10.65	906.4	149.8	47.58	1085	158	18.42	796.6	80.88
	Min	-106.5	-38.96	739	-123	-13.57	631	-86.92	-43.63	784.5	-124.3	-16.04	615.8	-66.55
TENS-4	Mean			1114			1150			1155			1170	
Kips	Std. Dev.	126.7	2.06	116.6	116.5	1.47	157.6	157.5	4.88	88.43	88.4	1.95	139.1	139
	Max	293.9	28.97	1436	316.1	22.21	1913	760.7	37.39	1375	218.4	34.63	1673	483.9
	Min	-261.1	-19.62	882.6	-228.8	-28.23	837.9	-313	-39.88	927.4	-226	-38.4	910.5	-255.4
REL. MOT.	Mean			-2.84			-3.9			-2.25			-2.99	
Ft	Std. Dev.	1.59	13.55	7.24	1.42	7.09	13.62	2.44	13.4	4	0.64	3.95	13.45	1.9
	Max	4.87	51.63	25.84	3.87	26.15	47.57	6.67	48.67	9.62	1.9	11.65	52.84	4.99
	Min	-4.55	-41.47	-27.07	-3.5	-27.62	-41.57	-7.51	-38.7	-15.74	-2.73	-12.74	-43.35	-5.23
RUNUP	Mean			0.89			-0.84			-1.75			-0.18	
Ft	Std. Dev.	1.61	14.13	9.13	1.36	9.03	14.35	2.39	14.14	3.63	0.44	3.6	14.89	2.39
	Max	6.97	60.06	54.81	5.77	50.31	61.39	8.72	57.44	10.29	1.5	11.34	65.15	9.26
	Min	-3.61	-44.23	-25.29	-3.69	-28.44	-38.55	-5.76	-43.74	-13.74	-2.09	-11.91	-37.78	-5.63
MOONPOOL	Mean													
Ft	Std. Dev.													
	Max													
	Min													

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

			f1rcw5			f2rcw3		
		f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	39.91	43.88	1.49	43.84	39.95	1.27	39.92
Ft	Std. Dev.	9.98	10.97	0.37	10.96	9.99	0.32	9.98
	Max	41.39	53.73	3.51	51.49	44.91	2.69	42.85
	Min	-31.07	-38.36	-0.99	-39.75	-29.68	-0.91	-29.94
WIND	Mean		59.94			86.63		
Knots	Std. Dev.	6.99	7.57	4.95	5.7	10.51	7.63	7.25
	Max	22.25	84.91	13.21	17.98	124.02	27.09	23.93
	Min	-21.36	38.06	-14.18	-15.6	57.28	-18.66	-24.47
CUR 1	Mean		5.04			4.41		
Ft/Sec	Std. Dev.	2.19	2.76	0.92	2.58	2.32	0.78	2.15
	Max	6.55	14.09	2.17	9.67	12.52	2.27	7.08
	Min	-7.86	-4.79	-2.95	-8.92	-4.48	-1.94	-8.25
CUR 2	Mean		1.73			1.38		
Ft/Sec	Std. Dev.	0.41	1	0.74	0.66	0.98	0.87	0.43
	Max	2.17	4.91	2.32	2.16	9.58	1.71	4.1
	Min	-2.01	-1.86	-1.89	-2.49	-2.08	-2.37	-1.95
SURGE_CG	Mean		-73.22			-85.74		
Ft	Std. Dev.	2.84	7.01	5.76	3.99	6.65	5.99	2.88
	Max	10.74	-52.89	16.18	12.32	-58.96	21.92	10.77
	Min	-9.83	-112.7	-17.19	-26.13	-102.6	-13.04	-12.87
HEAVE_CG	Mean		-0.54			0.02		
Ft	Std. Dev.	0.49	0.84	0.41	0.73	0.71	0.46	0.54
	Max	1.87	2.19	1.53	2.57	2.98	1.59	2.13
	Min	-2.07	-3.39	-1.49	-2.75	-2.51	-1.35	-2.26
SWAY_CG	Mean		-4.68			1.2		
Ft	Std. Dev.	0.65	27.88	27.81	1.8	22.86	22.85	0.58
	Max	4.66	69.6	66.21	43.02	44.59	42.98	3.62
	Min	-4.43	-71.74	-67.2	-40.14	-49.37	-49.89	-1.94
ROLL	Mean		0			-0.04		
deg	Std. Dev.	0.1	0.35	0.33	0.12	0.31	0.29	0.1
	Max	0.37	1.05	0.91	0.42	0.96	1.01	0.36
	Min	-0.37	-1.12	-0.92	-0.47	-0.94	-0.76	-0.39
YAW	Mean		1.12			1.36		
deg	Std. Dev.	0.34	1.15	1.03	0.52	0.75	0.66	0.35
	Max	1.45	6.13	4.35	2.31	4.22	1.95	1.79
	Min	-1.24	-4.15	-3.88	-2.01	-1.07	-2.16	-1.27
PITCH	Mean		-1.6			-2.48		
deg	Std. Dev.	0.58	0.99	0.7	0.71	1.02	0.84	0.59
	Max	2.1	1.43	2.96	2.41	0.75	2.67	2.07
	Min	-1.66	-6.08	-2.68	-2.6	-6.31	-2.73	-1.71
TENS-1	Mean		2345			2460		
Kips	Std. Dev.	179.7	303.3	236.6	189.4	321.8	276.2	164.6
	Max	629.1	4307	987.5	1454	3576	856.2	623.4
	Min	-604.7	1758	-496.9	-776.6	1600	-731.7	-522.4
TENS-2	Mean		1225			1115		
Kips	Std. Dev.	4.19	215.4	215.1	11.33	138.8	137.2	16.48
	Max	30.19	2242	1008	203.1	1615	492	59.16
	Min	-28.21	820.1	-384.1	-220.6	735.8	-267.9	-95.22
TENS-3	Mean		733.3			674.5		
Kips	Std. Dev.	11.56	35.58	31.06	17.33	38.74	34.45	15.72
	Max	46.24	841.7	91.98	56.5	825.6	115.9	61.72
	Min	-39.84	612.2	-76.74	-86.32	546.6	-67.69	-72.98
TENS-4	Mean		1165			1129		
Kips	Std. Dev.	3.16	164	162.7	19.94	124.9	124.3	10.22
	Max	26.2	2006	614.9	503.6	1391	240	36.33
	Min	-27.92	798.8	-370.6	-419.8	815.6	-272.1	-59.68
REL. MOT.	Mean		-0.51			-3.43		
Ft	Std. Dev.	13.31	14.06	1.67	13.96	13.51	2.07	13.35
	Max	52.44	78.29	7.61	73.62	48.55	6.4	50.97
	Min	-40.01	-48.84	-5.28	-48.76	-39.82	-6.7	-36.99
RUNUP	Mean		0.46			-0.85		
Ft	Std. Dev.	14.69	13.85	1.5	13.77	14.56	2.33	14.37
	Max	61.74	64.8	6.98	58.52	62.17	8.96	58.7
	Min	-45.87	-39.14	-4.12	-41.19	-40.26	-5.65	-43.94
MOONPOOL	Mean							
Ft	Std. Dev.							
	Max							
	Min							

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

		Current only												
		fcur2			fcur3			f1cur3			f1cur5			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
TENSION	H1/3	205.7			208.1			222			207.1			196.2
AT RISER 1	Std. Dev.	1.73	1.59	0.65	1.38	1.3	0.41	5.09	5.05	0.62	2.89	2.85	0.44	1.16
Kips	Max	210.7	4.3	2.97	212.7	3.44	1.7	237.4	14.68	3.86	217.8	9.94	1.93	200.9
	Min	200.2	-4.5	-3.66	203.5	-4.09	-2.12	210.6	-10.46	-6.93	200.6	-5.29	-1.74	192.8
TENSION	Mean	217.2			216.6			216.2			229			214
AT RISER 2	Std. Dev.	1.32	1.06	0.75	1.36	1.27	0.44	12.86	12.76	1.53	26.1	25.94	2.92	1.27
Kips	Max	221.4	2.57	3.26	220.8	3.54	1.59	273.4	54.52	22.43	313.2	85.48	21.58	218
	Min	210.9	-3.23	-4.38	212	-4.21	-1.89	195.1	-22.62	-19.39	197	-32.38	-21.68	210.1
TENSION	Mean	-0.25			-0.17			0.77			0.71			323.1
AT CATENARY	Std. Dev.	0.09	0.07	0.04	0.13	0.1	0.05	0.09	0.07	0.04	0.1	0.07	0.04	1.95
RISER	Max	0.09	0.21	0.17	0.22	0.2	0.2	1.09	0.26	0.16	1.09	0.11	0.19	329
Kips	Min	-0.5	-0.13	-0.16	-0.5	-0.15	-0.2	0.44	-0.19	-0.21	0.38	-0.26	-0.24	318.7
RISER 1 - KEEL	Mean	15.4			6.63			16.64			22.95			15.03
LOADS X DIR	Std. Dev.	1.17	1.05	0.38	0.92	0.78	0.33	0.94	0.77	0.37	1.2	1.07	0.39	0.79
Kips	Max	19.47	2.85	1.61	10.17	2.58	1.16	19.74	2.16	1.29	27.4	3.39	1.34	18.61
	Min	11.29	-3.02	-1.34	3.32	-2.24	-1.19	12.89	-2.17	-1.64	18.61	-2.85	-1.55	8.49
RISER 1 - KEEL	Mean	9.46			8.38			16.96			18.3			12.13
LOADS Y DIR	Std. Dev.	2.21	2.08	0.6	1.4	1.19	0.58	1.38	1.14	0.6	1.96	1.74	0.77	1.36
Kips	Max	17.08	6.63	2.87	12.84	2.81	2.74	21.19	2.63	2.66	27.13	5.48	4.73	19.43
	Min	-0.42	-7.63	-2.77	2.23	-3.74	-2.56	10.05	-4.05	-3.24	7.93	-4.84	-3.91	-3.06
RISER 1	Mean	-0.24			-0.11			-0.56			-1.47			-0.22
HEAVE	Std. Dev.	0.12	0.12	0.01	0.04	0.04	0	0	0	0	0	0	0	0.07
Ft	Max	-0.04	0.21	0.05	-0.01	0.1	0.05	-0.55	0	0.01	-1.45	0	0.01	-0.06
	Min	-0.73	-0.5	-0.05	-0.22	-0.12	-0.05	-0.57	-0.01	-0.01	-1.48	0	-0.01	-0.53
RISER 19	Mean	0.08			0.06			-0.11			-0.04			0.16
HEAVE	Std. Dev.	0.19	0.19	0.02	0.06	0.06	0.01	0	0	0	0.05	0.18	0	0.08
Ft	Max	0.53	0.47	0.1	0.27	0.24	0.06	-0.1	0	0.01	0.11	0.72	0.05	0.39
	Min	-0.57	-0.68	-0.08	-0.06	-0.13	-0.06	-0.12	-0.01	-0.01	-0.17	-0.52	-0.04	-0.17

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

		f2cur3		fran1			fran2			fran3			Waves only fran6	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
TENSION	H1/3			204.3			205.5			206.9			204.7	
AT RISER 1	Std. Dev.	1.09	0.33	1.11	0.74	0.79	2.01	1.21	1.5	5.03	2.3	4.31	1.96	0.63
Kips	Max	4.22	1.68	207.8	2.16	1.96	217.9	4.01	5.7	242	7.15	24.78	212.1	1.96
	Min	-3.03	-1.27	201.2	-1.86	-2	195	-2.44	-6	185	-6.15	-16.27	195.1	-1.92
TENSION	Mean			214.6			205			205.9			205.1	
AT RISER 2	Std. Dev.	1.19	0.41	1.12	0.7	0.84	1.28	0.77	0.88	3.07	0.71	2.78	1.62	0.61
Kips	Max	2.88	1.72	218.8	1.76	2.5	215.1	2.16	5.16	224.7	1.84	13.86	215.5	1.98
	Min	-3.4	-1.76	211.3	-1.99	-2.12	196.7	-2.07	-4.79	186.6	-2.15	-11.36	198	-1.8
TENSION	Mean			-0.07			-0.03			-0.27			-0.03	
AT CATENARY	Std. Dev.	1.93	0.23	0.13	0.1	0.05	0.09	0.07	0.04	0.1	0.08	0.04	0.12	0.1
RISER	Max	5.41	2.2	0.35	0.18	0.21	0.36	0.25	0.16	0.03	0.2	0.15	0.36	0.29
Kips	Min	-4.08	-1.78	-0.37	-0.19	-0.19	-0.36	-0.18	-0.15	-0.62	-0.21	-0.15	-0.36	-0.18
RISER 1 - KEEL	Mean			0.99			7.62			6.96			9.07	
LOADS X DIR	Std. Dev.	0.64	0.34	0.89	0.56	0.58	2.08	1.31	1.54	4.55	3.92	2.23	1.3	0.56
Kips	Max	2.47	1.32	3.94	1.56	2.1	12.5	3	5.4	24.76	13.11	9.37	12.91	1.23
	Min	-1.72	-2.89	-2.91	-1.91	-2.43	-2.41	-4.12	-6.77	-11.1	-11.69	-11.96	3.41	-1.33
RISER 1 - KEEL	Mean			1.55			-12.91			-10.62			-13.39	
LOADS Y DIR	Std. Dev.	1.15	0.59	1.18	0.5	0.94	3.25	0.85	3.06	7.74	5.59	5.26	3.05	0.7
Kips	Max	2.57	3.2	5.63	1.65	3.32	-4.2	2.77	8.57	7.15	12.97	16.14	-6.32	1.96
	Min	-4.1	-6.45	-4.66	-1.16	-5.21	-27.97	-2.79	-11.95	-30.73	-6.45	-19.79	-28.92	-2.37
RISER 1	Mean			0.02			-0.1			-0.31			0	
HEAVE	Std. Dev.	0.07	0.01	0.02	0.02	0.01	0.17	0.15	0.08	0.67	0.44	0.5	0.16	0.05
Ft	Max	0.17	0.09	0.09	0.08	0.04	0.31	0.37	0.3	1.87	1.12	1.95	0.55	0.17
	Min	-0.32	-0.09	-0.05	-0.06	-0.04	-0.73	-0.46	-0.31	-3.27	-1.42	-2.35	-0.57	-0.19
RISER 19	Mean			0.03			-0.01			-0.05			0	
HEAVE	Std. Dev.	0.08	0.01	0.04	0.03	0.01	0.22	0.2	0.09	0.63	0.44	0.45	0.13	0.05
Ft	Max	0.22	0.05	0.16	0.1	0.06	0.6	0.49	0.34	2.26	1.08	1.89	0.48	0.14
	Min	-0.34	-0.05	-0.07	-0.1	-0.05	-0.79	-0.62	-0.33	-2.07	-1.48	-1.95	-0.52	-0.15

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

			f1ran3			f1ran5			f2ran3			frc2		
		f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
TENSION	H1/3		224.1			228.3			195.8			205.1		
AT RISER 1	Std. Dev.	1.82	19.81	9.33	17.43	20.68	6.53	19.61	4.59	1.32	4.33	2.38	1.5	1.75
Kips	Max	6.08	294	31.89	60.27	294.8	16.96	60.52	218.4	4.43	20.63	220.8	5.13	9.85
	Min	-6.1	182	-24.97	-41.33	201.8	-23.66	-35.27	183	-3.85	-13.82	194.1	-4.53	-7.54
TENSION	Mean		239.6			238.1			212.6			216.7		
AT RISER 2	Std. Dev.	1.44	49.1	22.32	43.68	50.71	20.33	46.53	3.49	0.84	3.3	1.61	0.84	1.22
Kips	Max	4.63	333.7	77.04	108.1	332	49.58	104.8	235.2	2.32	18.56	226.2	2.23	6.45
	Min	-4.66	183.4	-62.04	-100.8	178.1	-59.83	-90.06	198.5	-2.54	-12.83	208	-2.26	-4.99
TENSION	Mean		0.87			0.7			323.4			-0.33		
AT CATENARY	Std. Dev.	0.04	0.08	0.05	0.04	0.13	0.09	0.07	2.67	2.13	1.58	0.08	0.06	0.03
RISER	Max	0.15	1.09	0.18	0.15	1.09	0.23	0.25	332.1	5.11	5.27	0.02	0.2	0.16
Kips	Min	-0.14	0.44	-0.14	-0.26	0.44	-0.21	-0.27	314.9	-4.89	-6.13	-0.7	-0.19	-0.17
RISER 1 - KEEL	Mean		1.42			6.21			8.06			15.68		
LOADS X DIR	Std. Dev.	1.1	4.75	3.98	2.52	5.51	4.27	3.43	4.39	3.94	1.86	1.84	1.56	0.89
Kips	Max	3.2	17.7	10.23	9.75	35.68	17.85	20.84	19.73	9.21	8.18	20.9	3.61	3.67
	Min	-4.8	-16.43	-12.51	-9.17	-23.99	-14.89	-17.34	-8.98	-13.83	-8.99	6.59	-5.87	-7.15
RISER 1 - KEEL	Mean		6.21			9.28			5.35			7.54		
LOADS Y DIR	Std. Dev.	2.9	6.43	2.3	5.89	6.64	2.78	5.95	6.24	4.92	3.77	2.77	2.5	1.11
Kips	Max	9.02	23.74	7.72	12.74	33.39	8.6	17.76	15.93	4.82	18.62	17.72	8.02	4.7
	Min	-12.02	-11.81	-5.27	-19.31	-9.47	-5.63	-20.69	-20.57	-13.49	-25.8	-2.22	-7.87	-8.44
RISER 1	Mean		3.12			4.6			-0.17			-0.42		
HEAVE	Std. Dev.	0.16	1.59	1.55	0.32	0.87	0.59	0.65	0.71	0.48	0.52	0.22	0.2	0.09
Ft	Max	0.54	6.82	2.42	1.61	7.27	1.15	2.94	2.3	1.25	1.84	0.23	0.68	0.45
	Min	-0.57	-2.08	-4.46	-3.21	1.1	-2.49	-1.83	-3.28	-1.53	-2.32	-1.15	-0.58	-0.3
RISER 19	Mean		0.15			0.15			0.05			0.03		
HEAVE	Std. Dev.	0.12	0.51	0.37	0.35	0.75	0.44	0.61	0.59	0.38	0.45	0.3	0.28	0.1
Ft	Max	0.44	2.01	1.14	1.7	2.57	1.22	2.36	2.27	1.1	2	0.87	0.71	0.39
	Min	-0.41	-1.67	-1.21	-1.46	-3.83	-2.34	-1.94	-2.01	-1.19	-1.68	-1.04	-0.97	-0.34

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

		Waves & Current												
		frc3			frc6			f1rc3			f1rc5			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
TENSION	H1/3	206			205.2			225.5			222.6			199.1
AT RISER 1	Std. Dev.	4.72	1.87	4.18	2.32	1.01	2.04	19.12	7.35	17.63	21.58	7.13	20.38	4.52
Kips	Max	239.8	7.08	18.68	215.7	2.82	6.97	277.6	22.16	49.81	299.9	20.83	67.64	223.6
	Min	182.1	-5.65	-16.77	188	-2.62	-9.34	202.8	-18.57	-37.11	197.5	-25.13	-33.71	184.9
TENSION	Mean	216.1			216.9			239.8			243.3			213.7
AT RISER 2	Std. Dev.	3.21	0.98	2.86	1.9	0.87	1.63	46.27	20.8	41.28	48.71	19.66	44.68	3.27
Kips	Max	235.2	3.13	15.56	224.8	2.35	5.84	327.4	66.64	106.3	337.4	51.72	100.3	235.7
	Min	198.4	-2.87	-12.82	208.1	-2.28	-5.57	186.7	-61.03	-89.65	184.7	-72.25	-97.28	200.8
TENSION	Mean	-0.38			-0.37			0.6			0.69			321.8
AT CATENARY	Std. Dev.	0.08	0.06	0.04	0.08	0.06	0.03	0.15	0.13	0.05	0.14	0.12	0.05	2.82
RISER	Max	0.09	0.15	0.2	-0.04	0.13	0.16	1.03	0.27	0.23	1.09	0.19	0.33	331
Kips	Min	-0.7	-0.16	-0.17	-0.76	-0.18	-0.12	0.24	-0.21	-0.23	0.31	-0.27	-0.22	313
RISER 1 - KEEL	Mean	12.07			12.57			14.47			20.44			14.84
LOADS X DIR	Std. Dev.	3.73	3.24	1.79	1.15	0.93	0.56	4.69	4.09	2.22	5.9	4.77	3.42	3.58
Kips	Max	24.47	9.71	7.4	16.3	2.54	1.99	28.22	10.81	9.53	40.79	16.16	13.87	28.32
	Min	-2.4	-10.75	-10.11	8.23	-2.43	-2.2	-3.56	-12.68	-9.69	-17.45	-21.42	-17.63	-1.41
RISER 1 - KEEL	Mean	3.21			7.56			11.47			12.42			10.02
LOADS Y DIR	Std. Dev.	3.89	2.7	2.72	1.66	1.39	0.8	5.01	3.22	3.76	5.39	3.93	3.6	3.35
Kips	Max	13.58	6.8	11.08	12.73	4.07	3.25	22.04	6.84	11.96	26.39	9.72	14.17	19.75
	Min	-22.38	-8.34	-20.28	-0.42	-4.71	-5.56	-19.97	-14.83	-21.66	-21.78	-14.08	-19.51	-13.99
RISER 1	Mean	-0.51			-0.15			-0.94			3.69			-0.64
HEAVE	Std. Dev.	0.62	0.41	0.47	0.21	0.11	0.19	0.51	0.41	0.3	0.82	0.6	0.56	0.63
Ft	Max	1.57	1.24	1.86	0.57	0.33	0.64	0.95	1.1	1.29	6.2	1.5	2.84	1.35
	Min	-2.87	-1.59	-2.3	-0.91	-0.47	-0.72	-3.15	-1.42	-1.58	0.43	-2.32	-1.64	-3.23
RISER 19	Mean	-0.12			0.04			-0.18			0.19			-0.02
HEAVE	Std. Dev.	0.61	0.44	0.43	0.19	0.12	0.16	0.44	0.33	0.29	0.78	0.47	0.63	0.54
Ft	Max	2.08	1.3	1.63	0.76	0.29	0.56	1.56	0.91	1.38	2.81	1.42	2.29	1.9
	Min	-2.13	-1.66	-1.81	-0.72	-0.49	-0.59	-1.72	-1.39	-1.24	-3.62	-2.24	-2.27	-2.13

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

				Waves, Wind & Current										
		f2rc3		frcw2			frcw3			frcw6			f1rcw3	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
TENSION	H1/3			206.3			209.1			205.2			223.7	
AT RISER 1	Std. Dev.	1.35	4.26	3.01	2.06	2.1	7.78	4.12	6.47	2.71	1.13	2.42	22.32	11.5
Kips	Max	4.42	20.38	223.1	7.58	7.32	256.5	16.75	30.26	221.1	2.88	9.11	292.2	43.13
	Min	-3.29	-13.21	194.9	-5.02	-6.75	185.3	-9.72	-21.43	196.3	-3.23	-7.88	198.5	-27.11
TENSION	Mean			216.6			217.5			215.9			241.4	
AT RISER 2	Std. Dev.	1.09	3	1.86	1.02	1.42	4.75	1.92	4.24	1.92	0.91	1.62	44.56	15.19
Kips	Max	3.95	15.21	227.8	3.15	6.4	242.7	8.45	19.36	224.6	2.24	5.15	325.9	53.99
	Min	-2.98	-11.25	206.3	-2.95	-7.58	202.4	-4.25	-15.35	208.8	-2.23	-4.99	188.2	-50.14
TENSION	Mean			-0.33			-0.16			-0.25			0.83	
AT CATENARY	Std. Dev.	2.28	1.65	0.09	0.07	0.04	0.14	0.12	0.05	0.1	0.07	0.05	0.08	0.05
RISER	Max	6.14	5.33	0.09	0.16	0.18	0.22	0.27	0.25	0.15	0.18	0.2	1.09	0.12
Kips	Min	-5.03	-5.99	-0.63	-0.19	-0.15	-0.63	-0.22	-0.22	-0.57	-0.16	-0.19	0.44	-0.13
RISER 1 - KEEL	Mean			8.53			-5.41			4.14			2.88	
LOADS X DIR	Std. Dev.	3.18	1.6	3.16	2.62	1.51	6.01	5.39	2.51	2.15	1.63	1.14	6.34	5.54
Kips	Max	10.56	8.58	17.63	6	5.22	13.75	15.21	9.89	11.91	6.12	4.22	20.66	14.47
	Min	-10.87	-11.2	-16.7	-6.58	-11.63	-33.97	-15.49	-17.53	-15.48	-5.02	-7.28	-26.24	-20.87
RISER 1 - KEEL	Mean			-12.85			-13.82			-11.68			-6.54	
LOADS Y DIR	Std. Dev.	2.43	2.22	6.19	3.33	4.26	8.34	5.65	5.45	5.93	4.01	3.52	9.94	7.01
Kips	Max	4.71	11.29	6.16	10.77	14.52	8.49	17.87	23.75	7.85	16.19	11.75	18.54	18.61
	Min	-11.89	-20.6	-93.57	-13.43	-41.22	-107.3	-18.48	-66.08	-84.34	-7.38	-28.28	-93.6	-17.82
RISER 1	Mean			-0.8			-2.19			-0.65			-2.82	
HEAVE	Std. Dev.	0.43	0.46	0.36	0.34	0.13	1.13	0.95	0.62	0.28	0.19	0.2	0.6	0.54
Ft	Max	1.08	1.55	0.11	0.82	0.4	1.72	2.39	2.47	0.23	0.54	0.83	-1.14	1.37
	Min	-1.61	-2.02	-2.25	-1.13	-0.52	-7.24	-3.61	-3.4	-1.6	-0.62	-0.82	-5.47	-2.57
RISER 19	Mean			0.03			-0.25			0.04			-0.3	
HEAVE	Std. Dev.	0.38	0.39	0.37	0.34	0.15	0.66	0.33	0.57	0.26	0.17	0.2	0.41	0.27
Ft	Max	1.09	1.66	0.92	0.85	0.59	2.27	0.88	2.6	1.02	0.45	0.85	1.19	0.85
	Min	-1.65	-1.55	-1.6	-1.44	-0.55	-3.73	-1.25	-2.62	-0.95	-0.44	-0.78	-2.12	-0.95

CONFIGURATION F - RISERS
TEST RESULTS SUMMARY

			f1rcw5			f2rcw3		
		f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
TENSION	H1/3		222.2			198.9		
AT RISER 1	Std. Dev.	19.11	22.63	8.38	21.03	7.1	2.71	6.49
Kips	Max	69.77	307.8	20.44	71.49	235.4	9.05	28.07
	Min	-45.19	198.8	-25.01	-37.65	182.4	-6.92	-19.96
TENSION	Mean		246.8			212.3		
AT RISER 2	Std. Dev.	41.88	48.07	18.8	44.42	4.29	1.58	3.93
Kips	Max	97.86	340.1	83.5	99.92	237.4	6.85	21.41
	Min	-74.81	187.9	-53.51	-83.35	195.6	-3.93	-17.27
TENSION	Mean		0.67			321.3		
AT CATENARY	Std. Dev.	0.04	0.13	0.1	0.05	2.56	1.89	1.7
RISER	Max	0.22	1.09	0.29	0.31	330.1	5.17	5.51
Kips	Min	-0.31	0.31	-0.23	-0.22	312.9	-5.04	-6.01
RISER 1 - KEEL	Mean		13.71			-44.27		
LOADS X DIR	Std. Dev.	2.9	6.03	4.68	3.74	25.33	13.79	16.72
Kips	Max	10.08	31.59	13.71	16.44	4.51	37.2	55.11
	Min	-21.87	-23.99	-20.3	-19.65	-193.4	-38.2	-90.77
RISER 1 - KEEL	Mean		0.74			-176.1		
LOADS Y DIR	Std. Dev.	6.16	7.26	5.37	4.48	91	48.18	60.57
Kips	Max	21.87	19.7	15.82	17.72	-17.07	126	209.6
	Min	-82.93	-33.98	-17.91	-20.79	-743.6	-124.8	-321.8
RISER 1	Mean		-2.43			-2.25		
HEAVE	Std. Dev.	0.27	0.78	0.65	0.44	1.03	0.86	0.58
Ft	Max	1.23	0.03	1.74	2.14	1.72	2.45	2.71
	Min	-1.16	-6.24	-3.4	-1.8	-7.49	-3.55	-2.45
RISER 19	Mean		-0.26			-0.13		
HEAVE	Std. Dev.	0.3	0.67	0.41	0.52	0.58	0.31	0.5
Ft	Max	1.3	2.18	1.01	1.96	2	1.01	2.14
	Min	-1.16	-2.59	-1.58	-2.3	-2.71	-1.06	-2.17

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		Current only								
		hcur2			hcur3			hcur5		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3									
Ft	Std. Dev.									
	Max									
	Min									
WIND	Mean									
Knots	Std. Dev.									
	Max									
	Min									
CUR 1	Mean	1.11			3.35			4.24		
Ft/Sec	Std. Dev.	1.14	0.72	0.85	0.86	0.76	0.37	0.96	0.83	0.46
	Max	4.59	1.67	3.23	6.06	2.06	1.68	7.42	2.07	1.7
	Min	-2.85	-1.95	-4.02	-0.7	-2.28	-2.62	0.69	-2.58	-2.04
CUR 2	Mean	-1.86			2.16			2.76		
Ft/Sec	Std. Dev.	1.07	0.84	0.64	0.82	0.75	0.31	1.02	0.91	0.46
	Max	1.4	1.74	2.76	4.25	1.61	1.51	5.89	2.15	1.76
	Min	-5.31	-2.15	-2.41	-0.51	-1.92	-1.45	-4.54	-2.49	-3.98
SURGE_CG	Mean	-58.25			-37.52			-49.68		
Ft	Std. Dev.	6.72	6.72	0.12	4.65	4.65	0.23	3.47	3.47	0.16
	Max	-37.59	20.62	2.72	-26.07	11.43	5.7	-37.7	11.93	3.6
	Min	-72.18	-13.85	-3.54	-48.71	-11.17	-5.64	-62.2	-12.53	-3.88
HEAVE_CG	Mean	-0.28			0.15			-0.01		
Ft	Std. Dev.	0.19	0.16	0.11	0.06	0.05	0.04	0.1	0.09	0.05
	Max	0.45	0.53	0.4	0.39	0.13	0.14	0.27	0.22	0.16
	Min	-0.88	-0.4	-0.39	-0.07	-0.13	-0.11	-0.46	-0.36	-0.22
SWAY_CG	Mean	-18.17			-10.87			-18.57		
Ft	Std. Dev.	16.45	16.45	0.09	9.6	9.6	0.05	13.25	13.24	0.65
	Max	19.17	37.32	1.95	13.04	23.87	0.75	10.62	29.11	15.9
	Min	-60.78	-42.5	-2.08	-46.59	-35.65	-1.16	-47.08	-28.41	-16.67
ROLL	Mean	0.19			0.11			0.17		
deg	Std. Dev.	0.51	0.51	0.02	0.23	0.23	0.01	0.27	0.27	0
	Max	1.83	1.65	0.57	0.8	0.69	0.17	0.93	0.76	0.01
	Min	-1.44	-1.63	-0.24	-0.43	-0.54	-0.27	-0.55	-0.72	-0.02
YAW	Mean	1.3			0.51			0.77		
deg	Std. Dev.	0.73	0.73	0.05	0.35	0.35	0.03	0.37	0.37	0.05
	Max	3.49	2.11	0.18	1.44	0.95	0.3	1.89	1.05	0.72
	Min	-0.75	-1.87	-0.42	-0.93	-1.31	-0.3	-0.38	-1.12	-0.79
PITCH	Mean	-0.75			-0.4			-0.57		
deg	Std. Dev.	0.23	0.23	0.01	0.14	0.14	0	0.14	0.14	0
	Max	-0.04	0.71	0.13	-0.03	0.37	0.01	-0.17	0.4	0.05
	Min	-1.51	-0.76	-0.11	-0.76	-0.36	0	-0.98	-0.41	-0.02
TENS-1	Mean	1809			1353			1553		
Kips	Std. Dev.	177.4	177.4	3	47.3	47.25	1.95	83.22	83.14	3.47
	Max	2187	377.7	23.17	1528	172.2	44.33	1885	330.6	84.92
	Min	1378	-428.9	-45.5	1274	-78	-44.21	1352	-198.1	-82.22
TENS-2	Mean	1282			1196			1230		
Kips	Std. Dev.	121.9	121.9	2.07	57.55	57.54	0.93	81.82	81.73	3.55
	Max	1948	658.3	13.13	1510	315.1	9.18	1522	291.7	86.92
	Min	1074	-203.3	-21.78	1064	-129.2	-9.38	1071	-157.7	-84.6
TENS-3	Mean	840.4			962.2			890.8		
Kips	Std. Dev.	36.3	36.28	0.97	24.48	24.44	1.27	19.61	19.58	1.03
	Max	951.1	109.5	8.4	1020	56.3	30.26	959.9	68.08	21.11
	Min	762.2	-76.71	-4.92	907.9	-54.03	-27.69	818.9	-70.66	-22
TENS-4	Mean	1050			1094			1051		
Kips	Std. Dev.	84.19	84.18	0.97	48.68	48.68	0.69	66.44	66.36	3.14
	Max	1231	179.3	5.01	1216	120	7.56	1197	145	74.83
	Min	814.5	-235	-12.93	913.7	-179.3	-9.66	909	-141	-80.17
REL. MOT.	Mean	-0.85			-0.85			-0.58		
Ft	Std. Dev.	0.52	0.51	0.11	0.33	0.33	0.03	0.32	0.32	0.05
	Max	0.7	1.55	0.43	0.02	0.91	0.1	0.54	1.1	0.18
	Min	-2.64	-1.67	-0.43	-1.83	-0.9	-0.12	-1.43	-0.9	-0.16
RUNUP	Mean	0.22			-0.13			-0.44		
Ft	Std. Dev.	0.29	0.27	0.09	0.16	0.16	0.03	0.17	0.17	0.04
	Max	0.99	0.86	0.3	0.37	0.45	0.1	0.32	0.72	0.14
	Min	-0.92	-0.97	-0.32	-0.61	-0.41	-0.1	-0.98	-0.48	-0.14
MOONPOOL	Mean	0.64			-0.09			0.21		
Ft	Std. Dev.	0.08	0.08	0.01	0.04	0.04	0	0.02	0.02	0
	Max	0.92	0.3	0.12	-0.01	0.09	0.07	0.26	0.04	0.01
	Min	0.41	-0.23	-0.11	-0.17	-0.08	-0.07	0.17	-0.03	-0.01

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		Wind only									
		hwin2			hwin3			hwin4			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3	0.64	0.47	0.41	1.62	0.52	1.36	1.54	0.4	1.33	1.02
Ft	Std. Dev.	0.16	0.12	0.1	0.4	0.13	0.34	0.39	0.1	0.33	0.26
	Max	0.57	0.19	0.38	0.26	0.38	1.11	-0.15	0.23	1.19	0.28
	Min	-0.53	-0.27	-0.36	-2.79	-0.29	-1.33	-3.13	-0.29	-1.2	-1.58
WIND	Mean	42.09			82.31			82.25			58.67
Knots	Std. Dev.	4.69	3.92	2.55	8.75	6.86	5.39	8.43	6.71	5.07	6.28
	Max	55.99	10.5	8.15	113.02	18.37	21.55	112.54	19.57	20.11	80.53
	Min	27.72	-11.34	-9.28	54.12	-21.56	-19.29	58.38	-18.05	-16.36	37.94
CUR 1	Mean										
Ft/Sec	Std. Dev.										
	Max										
	Min										
CUR 2	Mean										
Ft/Sec	Std. Dev.										
	Max										
	Min										
SURGE_CG	Mean	-21.22			-57.8			-57.34			-38.17
Ft	Std. Dev.	6.6	6.59	0.15	7.76	7.75	0.2	9.12	9.11	0.23	9.1
	Max	-5.02	16.15	4.65	-38.33	19.13	2.07	-37.27	19.91	2.66	-14.49
	Min	-36.55	-15.29	-3.26	-74.19	-16.32	-2.93	-79.19	-21.73	-4.18	-61.1
HEAVE_CG	Mean	0.09			0.48			0.44			0.19
Ft	Std. Dev.	0.39	0.08	0.39	1.21	0.49	1.11	1.12	0.43	1.04	0.78
	Max	1.03	0.26	0.87	4.05	1.81	2.81	3.86	1.64	2.7	2.26
	Min	-0.94	-0.26	-0.87	-2.57	-1.06	-2.77	-2.97	-1.12	-2.76	-1.81
SWAY_CG	Mean	0.47			3.29			3.58			1.06
Ft	Std. Dev.	0.4	0.4	0.04	1.47	1.46	0.13	2.08	2.07	0.13	0.73
	Max	1.47	0.95	0.15	7.1	3.81	0.69	8.64	4.88	0.71	3.04
	Min	-0.56	-0.98	-0.19	-0.46	-3.57	-0.78	-1.26	-4.66	-0.43	-0.87
ROLL	Mean	0.01			0.03			0.11			0.01
deg	Std. Dev.	0.13	0.13	0.01	0.81	0.81	0.02	0.56	0.56	0.02	0.25
	Max	0.33	0.31	0.02	1.74	1.74	0.34	1.32	1.21	0.06	0.64
	Min	-0.3	-0.31	-0.02	-1.69	-1.67	-0.29	-1.16	-1.24	-0.07	-0.63
YAW	Mean	-0.6			-1.6			-1.79			-0.9
deg	Std. Dev.	0.33	0.33	0.04	1.2	1.19	0.11	1.01	1	0.1	0.49
	Max	0.46	1.01	0.14	1.84	3.3	0.66	0.92	2.58	0.41	0.51
	Min	-1.62	-0.99	-0.17	-4.89	-3.39	-0.87	-5.22	-3.22	-0.31	-2.2
PITCH	Mean	-0.51			-2.17			-2.15			-1.09
deg	Std. Dev.	0.36	0.36	0.01	1.11	1.11	0.04	1.05	1.05	0.04	0.63
	Max	0.4	0.91	0.08	0.93	3.05	0.11	0.62	2.8	0.11	0.49
	Min	-1.52	-1.01	-0.09	-5.03	-2.87	-0.15	-4.6	-2.42	-0.13	-2.55
TENS-1	Mean	1271			1843			1833			1426
Kips	Std. Dev.	40.76	40.67	2.46	211.2	209.9	23.56	242.3	241.3	21.67	123.4
	Max	1374	97.33	13.02	2298	443.8	65.06	2419	575.9	132.9	1913
	Min	1170	-97.84	-17.71	1419	-424.5	-61.92	1377	-452.4	-172.9	1229
TENS-2	Mean	1119			1123			1125			1124
Kips	Std. Dev.	4.93	4.52	1.67	11.63	10.71	4.41	14.01	13.36	4.07	7.05
	Max	1135	12.57	6.63	1162	29	12.39	1166	30.3	12.45	1149
	Min	1105	-10.43	-5.2	1092	-29.66	-12.4	1091	-28.72	-12.72	1103
TENS-3	Mean	1057			861			863.1			965.9
Kips	Std. Dev.	35.33	35.27	1.96	41.01	40.67	5.23	48.26	47.99	5.08	48.68
	Max	1149	87.76	14.17	948.6	84.42	13.62	969.9	103.5	23.93	1091
	Min	973	-80.43	-16.3	768.6	-84.6	-14.24	745.1	-110.9	-35.04	841.8
TENS-4	Mean	1143			1171			1171			1151
Kips	Std. Dev.	5.73	5.3	2.09	16	14.96	5.69	17.31	16.47	5.34	9.46
	Max	1159	15.46	6.25	1211	39.91	14.72	1217	45.95	14.32	1176
	Min	1126	-13.24	-5.37	1137	-29.84	-15.55	1120	-41.34	-15.66	1130
REL. MOT.	Mean	-0.55			-5.02			-5.1			-2.23
Ft	Std. Dev.	0.95	0.87	0.38	3.02	2.81	1.12	2.82	2.62	1.05	1.71
	Max	2.02	2.11	1.05	2.83	7.12	3.33	2.82	6.71	2.9	2.2
	Min	-3.56	-2.49	-1.03	-14.24	-7.54	-3.49	-12.79	-6.5	-3.4	-7.03
RUNUP	Mean	-1.87			-5.82			-6.08			-3.88
Ft	Std. Dev.	0.62	0.51	0.34	1.81	1.48	1.05	1.7	1.38	0.98	1.06
	Max	-0.08	1.23	0.89	-1.08	3.59	3.53	-0.3	3.39	3.01	-0.92
	Min	-3.96	-1.34	-1.16	-12.07	-4.05	-3.06	-11.38	-3.77	-3.14	-7.04
MOONPOOL	Mean	-0.01			-0.52			-0.55			-0.26
Ft	Std. Dev.	0.05	0.03	0.04	0.25	0.2	0.15	0.25	0.21	0.13	0.13
	Max	0.23	0.11	0.23	0.41	0.54	0.63	0.24	0.64	0.49	0.22
	Min	-0.21	-0.14	-0.2	-1.26	-0.56	-0.68	-1.33	-0.67	-0.4	-0.65

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		hwin5	
		f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	0.49	0.79
Ft	Std. Dev.	0.12	0.2
	Max	0.26	0.68
	Min	-0.28	-0.69
WIND	Mean		
Knots	Std. Dev.	5.15	3.58
	Max	15.44	13.1
	Min	-19.4	-11.12
CUR 1	Mean		
Ft/Sec	Std. Dev.		
	Max		
	Min		
CUR 2	Mean		
Ft/Sec	Std. Dev.		
	Max		
	Min		
SURGE_CG	Mean		
Ft	Std. Dev.	9.1	0.08
	Max	23.68	0.34
	Min	-22.84	-0.48
HEAVE_CG	Mean		
Ft	Std. Dev.	0.17	0.76
	Max	0.49	1.82
	Min	-0.53	-1.85
SWAY_CG	Mean		
Ft	Std. Dev.	0.72	0.07
	Max	1.82	0.23
	Min	-1.87	-0.32
ROLL	Mean		
deg	Std. Dev.	0.25	0.01
	Max	0.63	0.09
	Min	-0.64	-0.13
YAW	Mean		
deg	Std. Dev.	0.48	0.07
	Max	1.37	0.24
	Min	-1.26	-0.34
PITCH	Mean		
deg	Std. Dev.	0.63	0.02
	Max	1.59	0.07
	Min	-1.48	-0.06
TENS-1	Mean		
Kips	Std. Dev.	123	9.31
	Max	469.5	32.84
	Min	-193.1	-30.47
TENS-2	Mean		
Kips	Std. Dev.	6.32	2.94
	Max	19.09	8.85
	Min	-16.16	-8.85
TENS-3	Mean		
Kips	Std. Dev.	48.54	3.46
	Max	123	9
	Min	-119.2	-9.19
TENS-4	Mean		
Kips	Std. Dev.	8.55	4.02
	Max	22.21	11.76
	Min	-18.14	-10.66
REL. MOT.	Mean		
Ft	Std. Dev.	1.53	0.75
	Max	3.95	2.37
	Min	-3.49	-2.17
RUNUP	Mean		
Ft	Std. Dev.	0.79	0.69
	Max	2.03	1.98
	Min	-1.84	-2
MOONPOOL	Mean		
Ft	Std. Dev.	0.09	0.09
	Max	0.31	0.3
	Min	-0.25	-0.3

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		hran1			hran2			hran3			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3	8.59	0.32	8.58	21.74	0.47	21.72	45.8	1.06	45.8	46.72
Ft	Std. Dev.	2.15	0.08	2.14	5.43	0.12	5.43	11.45	0.26	11.45	11.68
	Max	10.4	0.19	8.96	22.89	0.38	22.3	44.47	1.2	41.79	52.37
	Min	-6.93	-0.23	-7.14	-16.76	-0.84	-17.11	-30.14	-0.77	-30.23	-31.98
WIND	Mean										
Knots	Std. Dev.										
	Max										
	Min										
CUR 1	Mean										
Ft/Sec	Std. Dev.										
	Max										
	Min										
CUR 2	Mean										
Ft/Sec	Std. Dev.										
	Max										
	Min										
SURGE_CG	Mean	-0.17			-7.06			-15.01			-15.94
Ft	Std. Dev.	1.57	1.55	0.18	6.52	6.46	0.88	9.59	9.1	3.02	11.86
	Max	3.14	3.08	1.69	12.82	18.13	2.98	12.91	21.59	9.3	16.12
	Min	-3.62	-3.34	-1.53	-25.92	-17.94	-3.13	-40.11	-21.25	-8.95	-49.73
HEAVE_CG	Mean	-0.01			-0.01			0.07			0.08
Ft	Std. Dev.	0.24	0.04	0.23	0.27	0.06	0.26	1.12	0.3	1.08	1.16
	Max	0.61	0.15	0.54	0.91	0.2	0.84	4.53	1.05	4.53	3.25
	Min	-0.61	-0.19	-0.54	-0.87	-0.18	-0.8	-3.6	-1.17	-3.67	-2.97
SWAY_CG	Mean	-0.39			-0.43			0.15			0.51
Ft	Std. Dev.	0.47	0.45	0.1	0.58	0.53	0.22	1.79	1.68	0.62	2.66
	Max	0.75	1.05	0.58	1.37	1.44	0.89	6.68	5.15	2.68	9.68
	Min	-2.09	-0.81	-0.6	-2.24	-1.39	-0.87	-4.49	-4.2	-2.24	-8.38
ROLL	Mean	-0.02			-0.01			0			0.01
deg	Std. Dev.	0.03	0.03	0.01	0.11	0.11	0.03	0.19	0.16	0.11	0.24
	Max	0.07	0.06	0.07	0.28	0.24	0.13	0.56	0.41	0.45	0.99
	Min	-0.11	-0.07	-0.05	-0.3	-0.22	-0.14	-0.47	-0.38	-0.4	-0.89
YAW	Mean	-0.29			-0.28			-0.34			-0.17
deg	Std. Dev.	0.04	0.03	0.03	0.18	0.14	0.11	0.69	0.54	0.43	0.76
	Max	-0.13	0.08	0.13	0.3	0.35	0.52	1.98	1.98	1.69	2.98
	Min	-0.45	-0.08	-0.13	-1.09	-0.5	-0.53	-2.67	-1.94	-1.72	-2.25
PITCH	Mean	0			-0.14			-0.29			-0.31
deg	Std. Dev.	0.09	0.08	0.04	0.52	0.48	0.22	1.2	1.03	0.62	1.31
	Max	0.28	0.24	0.14	1.74	1.44	0.72	3.03	2.82	1.98	3.3
	Min	-0.29	-0.2	-0.14	-1.83	-1.45	-0.73	-4.09	-2.68	-1.77	-4.13
TENS-1	Mean	1165			1194			1244			1248
Kips	Std. Dev.	9.32	9.16	1.62	37.11	36.89	3.93	54.9	52.54	15.9	71.34
	Max	1186	17.55	10.98	1302	102	12.68	1402	117.3	59.82	1551
	Min	1143	-18.76	-10.41	1088	-100.6	-13.29	1107	-124	-50.39	1070
TENS-2	Mean	1125			1129			1129			1127
Kips	Std. Dev.	3.23	2.91	1.15	5.14	4.78	1.7	11.65	10.34	5.29	15.97
	Max	1134	5.95	4.59	1145	13.61	6.72	1166	24.32	23	1184
	Min	1115	-6.99	-4.5	1115	-11.98	-4.84	1090	-33.62	-18.08	1071
TENS-3	Mean	1161			1135			1092			1087
Kips	Std. Dev.	8.48	8.37	1.21	34.8	34.62	3.43	49.85	47.94	13.63	62.1
	Max	1180	16.07	11.23	1237	94.36	13.35	1232	110.6	49.51	1247
	Min	1142	-16.22	-9.93	1036	-93.05	-11.22	971.2	-109.8	-53.14	915.4
TENS-4	Mean	1148			1146			1149			1148
Kips	Std. Dev.	2.46	1.96	1.39	5.12	4.48	2.42	13.05	10.4	7.86	16.96
	Max	1157	5.76	4.51	1166	12.79	8.48	1186	30.96	26.76	1204
	Min	1141	-4.45	-4.49	1131	-11.78	-7.7	1112	-30.46	-25.51	1090
REL. MOT.	Mean	0.11			-0.14			0.02			-0.02
Ft	Std. Dev.	2.49	0.21	2.48	7.18	1.13	7.09	13.81	2.43	13.59	14.26
	Max	12.58	0.61	11.98	34.67	3.49	32.66	49.26	5.78	46.66	51.05
	Min	-8.13	-0.53	-8.49	-25	-3.51	-24.49	-39.46	-6.35	-38.12	-42.1
RUNUP	Mean	0.69			0.83			1.63			1.56
Ft	Std. Dev.	3.89	0.24	3.88	8.49	1.01	8.42	14.57	1.84	14.44	14.95
	Max	21.07	0.98	19.38	47.49	5.4	42.52	54.07	6.21	54.1	53.88
	Min	-12.8	-0.6	-13.94	-29.37	-2.8	-32.03	-38.16	-4.93	-42.75	-40.29
MOONPOOL	Mean	0.05			0.08			0.14			0.18
Ft	Std. Dev.	0.02	0.02	0.01	0.11	0.03	0.1	0.36	0.06	0.35	0.37
	Max	0.14	0.04	0.06	0.96	0.08	0.81	1.4	0.15	1.3	2.2
	Min	-0.08	-0.04	-0.09	-0.62	-0.06	-0.7	-1.03	-0.19	-1.16	-1.05

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		Waves only									
		hran4		hran3-4			hran5			hran6	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
WAVE	H1/3	1.43	46.68	46.28	1.21	46.24	48.36	1.13	48.32	8.6	0.2
Ft	Std. Dev.	0.36	11.67	11.57	0.3	11.56	12.09	0.28	12.08	2.15	0.05
	Max	3.2	49.73	52.37	2.04	49.4	52.78	1.05	53.63	10.23	0.15
	Min	-0.9	-32.8	-31.98	-0.94	-32.8	-35.42	-2.47	-36.2	-6.79	-0.12
WIND	Mean										
Knots	Std. Dev.										
	Max										
	Min										
CUR 1	Mean										
Ft/Sec	Std. Dev.										
	Max										
	Min										
CUR 2	Mean										
Ft/Sec	Std. Dev.										
	Max										
	Min										
SURGE_CG	Mean			0.25			-11.34			-1.7	
Ft	Std. Dev.	11.46	3.06	2.32	10.36	3.04	11.79	11.07	4.04	2.56	2.56
	Max	27.59	9.57	9.68	27.13	9.63	24.26	26.19	13.68	2.92	4.39
	Min	-29.74	-9.71	-8.62	-30.2	-14.97	-45.78	-27.24	-14.97	-6.2	-4.32
HEAVE_CG	Mean			1.59			0.15			0	
Ft	Std. Dev.	0.27	1.13	14.76	0.3	1.1	1.57	0.46	1.53	0.12	0.03
	Max	0.91	3.37	54.07	1.32	3.55	4.93	1.85	5.09	0.45	0.08
	Min	-0.74	-3.21	-40.29	-1.64	-3.21	-5.39	-1.8	-5.62	-0.37	-0.09
SWAY_CG	Mean			0.07			0.9			-0.1	
Ft	Std. Dev.	2.57	0.69	1.14	2.21	0.69	2.39	2.26	0.76	0.47	0.41
	Max	7.97	3.79	4.53	8.29	3.89	8.85	5.61	3.36	1.41	0.87
	Min	-7.48	-2.73	-3.6	-7.54	-3.28	-5.18	-5.82	-2.5	-1.49	-1
ROLL	Mean			0.01			0.02			0	
deg	Std. Dev.	0.21	0.11	0.22	0.19	0.11	0.29	0.27	0.12	0.08	0.07
	Max	0.76	0.49	0.99	0.77	0.49	1.22	0.87	0.57	0.24	0.16
	Min	-0.7	-0.46	-0.89	-0.69	-0.46	-0.79	-0.68	-0.6	-0.23	-0.16
YAW	Mean			-15.47			-0.3			-0.24	
deg	Std. Dev.	0.61	0.45	10.79	0.58	0.44	1	0.8	0.6	0.09	0.06
	Max	1.62	2.02	16.13	1.9	2.18	3.16	3.71	2.38	0.07	0.12
	Min	-1.8	-1.64	-49.72	-2.03	-1.72	-4.29	-3.82	-2.53	-0.58	-0.16
PITCH	Mean			-0.3			-0.22			-0.03	
deg	Std. Dev.	1.15	0.62	1.26	1.09	0.62	1.59	1.41	0.73	0.1	0.09
	Max	2.87	1.95	3.3	2.87	2.31	4.95	4.81	2.4	0.22	0.21
	Min	-2.52	-1.81	-4.13	-2.66	-1.87	-5.26	-4.18	-2.59	-0.33	-0.21
TENS-1	Mean			1246			1221			1160	
Kips	Std. Dev.	69.1	17.69	63.69	61.41	16.84	67.63	63.64	22.95	14.84	14.78
	Max	213.9	130	1551	216.4	130	1496	169.7	109.2	1186	23.64
	Min	-152.8	-74.02	1070	-150.5	-73.71	1053	-139.2	-70.43	1132	-26.22
TENS-2	Mean			1128			1125			1121	
Kips	Std. Dev.	15	5.41	14.01	12.9	5.36	14.6	13	6.61	3.18	2.94
	Max	46	18.61	1184	44.85	34.37	1169	37.01	25.79	1131	7.57
	Min	-47.06	-17.42	1071	-48.08	-27.86	1085	-33.83	-26.46	1111	-6.58
TENS-3	Mean			1089			1111			1160	
Kips	Std. Dev.	60.57	13.69	56.36	54.66	13.69	61.26	58.13	19.39	13.94	13.89
	Max	140.1	42.04	1247	137.5	47.54	1274	128.6	63.76	1187	24.47
	Min	-157.4	-46.34	915.4	-159.5	-51.96	944.2	-137.6	-74.68	1135	-24.01
TENS-4	Mean			1148			1145			1140	
Kips	Std. Dev.	14.86	8.17	15.14	12.82	8.04	17.28	14	10.3	3.09	2.92
	Max	41.49	24.72	1204	41.36	31.29	1192	34.86	35.09	1149	6.7
	Min	-42.96	-27.8	1090	-42.87	-27.51	1094	-31.11	-32.13	1129	-9.39
REL. MOT.	Mean			0			0.45			0.02	
Ft	Std. Dev.	2.76	13.99	14.04	2.6	13.79	14.45	3.46	14.03	2.37	0.24
	Max	6.11	50.9	51.05	6.14	50.98	84.61	11.8	81.2	8.95	0.54
	Min	-6.64	-42.51	-42.1	-6.58	-42.51	-47.6	-8.18	-43.58	-9.04	-0.57
RUNUP	Mean			-18.21			1.11			0.19	
Ft	Std. Dev.	2.19	14.78	17.23	2.02	14.61	13.88	1.86	13.76	3.68	0.2
	Max	7.41	53.4	40.06	7.22	55.01	54.11	4.5	54.02	18.07	1.1
	Min	-5.61	-45.39	-81.36	-5.46	-45.55	-40.65	-5.46	-42.7	-11.67	-0.44
MOONPOOL	Mean			0.16			0.12			0	
Ft	Std. Dev.	0.08	0.36	0.36	0.07	0.35	0.49	0.12	0.48	0.01	0.01
	Max	0.32	1.44	2.2	0.35	1.44	2.77	0.52	2.06	0.08	0.02
	Min	-0.19	-1.46	-1.05	-0.21	-1.46	-1.39	-0.23	-1.83	-0.05	-0.02

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		f > 0.03 Hz
WAVE	H1/3	8.58
Ft	Std. Dev.	2.15
	Max	9.22
	Min	-6.95
WIND	Mean	
Knots	Std. Dev.	
	Max	
	Min	
CUR 1	Mean	
Ft/Sec	Std. Dev.	
	Max	
	Min	
CUR 2	Mean	
Ft/Sec	Std. Dev.	
	Max	
	Min	
SURGE_CG	Mean	
Ft	Std. Dev.	0.17
	Max	1.91
	Min	-1.68
HEAVE_CG	Mean	
Ft	Std. Dev.	0.12
	Max	0.36
	Min	-0.37
SWAY_CG	Mean	
Ft	Std. Dev.	0.22
	Max	0.72
	Min	-0.68
ROLL	Mean	
deg	Std. Dev.	0.03
	Max	0.11
	Min	-0.1
YAW	Mean	
deg	Std. Dev.	0.06
	Max	0.19
	Min	-0.2
PITCH	Mean	
deg	Std. Dev.	0.04
	Max	0.13
	Min	-0.12
TENS-1	Mean	
Kips	Std. Dev.	1.12
	Max	10.23
	Min	-9.42
TENS-2	Mean	
Kips	Std. Dev.	0.88
	Max	2.83
	Min	-3.29
TENS-3	Mean	
Kips	Std. Dev.	0.92
	Max	10.99
	Min	-10.21
TENS-4	Mean	
Kips	Std. Dev.	0.87
	Max	3.3
	Min	-3.25
REL. MOT.	Mean	
Ft	Std. Dev.	2.36
	Max	8.58
	Min	-9.64
RUNUP	Mean	
Ft	Std. Dev.	3.67
	Max	17.45
	Min	-12.09
MOONPOOL	Mean	
Ft	Std. Dev.	0.01
	Max	0.06
	Min	-0.06

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		Waves & Current									
		hrc2			hrc3			hrc4			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3	19.86	0.52	19.84	40.52	1.4	40.48	41.16	1.04	41.12	40.84
Ft	Std. Dev.	4.96	0.13	4.96	10.13	0.35	10.12	10.29	0.26	10.28	10.21
	Max	17.94	0.43	17.33	43.81	2.22	41.56	45.21	1.8	44.47	45.21
	Min	-14.84	-0.36	-14.66	-28.38	-0.86	-28.87	-30.86	-0.59	-31.4	-30.86
WIND	Mean										
Knots	Std. Dev.										
	Max										
	Min										
CUR 1	Mean	0.98			4.18			3.86			4.02
Ft/Sec	Std. Dev.	1.34	0.58	1.18	2.33	0.78	2.19	2.45	0.83	2.3	2.4
	Max	4.96	1.48	3.64	11.84	1.99	7.53	12.17	2.23	8.45	12.17
	Min	-3.65	-1.99	-4.26	-6.57	-4.26	-8.97	-6.65	-2.29	-9.23	-6.65
CUR 2	Mean	-1.49			1.92			2			1.96
Ft/Sec	Std. Dev.	1.15	0.76	0.85	1.82	0.72	1.66	1.82	0.68	1.69	1.82
	Max	2.13	2	3.16	8.81	2.43	5.74	7.93	1.78	5.51	8.81
	Min	-5.48	-2.25	-3.1	-4.61	-1.98	-5.21	-4.99	-1.88	-6.26	-4.99
SURGE_CG	Mean	-66.52			-51.84			-51.1			-6.88
Ft	Std. Dev.	5.86	5.79	0.87	8.41	7.93	2.82	10.15	9.73	2.9	26.96
	Max	-50.81	14.85	2.8	-22.44	23.87	11.07	-21.39	26.68	10.26	64.46
	Min	-84.79	-17.44	-2.71	-79.29	-21.86	-8.38	-80.15	-23.14	-9.3	-77.04
HEAVE_CG	Mean	-0.44			-0.02			-0.09			1.81
Ft	Std. Dev.	0.24	0.17	0.18	0.98	0.34	0.92	1.08	0.3	1.04	14.77
	Max	0.27	0.41	0.55	4.27	1.04	4.57	3.19	1.1	2.96	53.01
	Min	-1.48	-0.86	-0.46	-4.39	-1.6	-3.93	-3.3	-0.9	-2.54	-40.2
SWAY_CG	Mean	-17.19			-6.79			-6.3			-0.05
Ft	Std. Dev.	21.13	21.11	0.81	25.99	25.98	0.71	27.36	27.33	1.25	1.03
	Max	43.3	60.48	16.36	64.12	69.95	2.86	62.42	67.99	25.21	4.27
	Min	-74.09	-56.93	-15.29	-75.69	-68.18	-2.57	-69.25	-62.14	-25.1	-4.39
ROLL	Mean	0.11			0.1			0.13			0.11
deg	Std. Dev.	0.53	0.52	0.08	0.37	0.35	0.11	0.36	0.34	0.12	0.36
	Max	1.92	1.78	0.33	1.24	1.06	0.4	1.54	1.15	0.5	1.54
	Min	-1.28	-1.25	-0.34	-0.95	-0.94	-0.38	-0.92	-0.87	-0.5	-0.95
YAW	Mean	1.34			0.31			0.44			-51.47
deg	Std. Dev.	0.92	0.9	0.18	0.82	0.73	0.38	0.95	0.84	0.43	9.33
	Max	4.22	2.46	0.67	3.1	2.24	1.45	3.9	2.37	1.87	-21.39
	Min	-2.42	-3.62	-0.62	-2.28	-2.33	-1.45	-2.82	-2.78	-1.56	-80.15
PITCH	Mean	-0.96			-0.68			-0.69			-0.69
deg	Std. Dev.	0.46	0.41	0.21	1.03	0.85	0.58	1.22	1.06	0.59	1.13
	Max	0.43	1.25	0.7	2.3	2.4	2.04	2.76	2.66	2.07	2.76
	Min	-2.43	-1.06	-0.65	-3.87	-2.18	-1.66	-4.43	-2.86	-1.71	-4.43
TENS-1	Mean	2035			1627			1627			1627
Kips	Std. Dev.	171.5	169.9	23.06	187.2	175	66.26	224.2	214.2	66.27	206.5
	Max	2903	783.4	104.7	2426	620.4	240.2	2352	550.5	252.3	2426
	Min	1601	-418.7	-99.58	1255	-340.9	-230.2	1255	-354.5	-226.1	1255
TENS-2	Mean	1300			1195			1203			1199
Kips	Std. Dev.	191.4	191.3	6.56	197.8	197.7	7.04	227.4	227	13.26	213.2
	Max	2300	983.4	121.6	2279	1072	47.34	2124	883.2	235.4	2279
	Min	951.4	-348.4	-143.3	814.9	-377.9	-47.32	806.7	-383.2	-195.2	806.7
TENS-3	Mean	797.1			882			884.5			883.2
Kips	Std. Dev.	30.17	29.98	3.32	43.15	41.31	12.46	52.09	50.51	12.73	47.85
	Max	877.5	78.22	10.55	1028	120.9	57.4	1036	135.6	40.59	1036
	Min	714.3	-78.48	-11.06	744.3	-112.5	-47.93	743.4	-111.9	-41.13	743.4
TENS-4	Mean	1059			1131			1129			1130
Kips	Std. Dev.	107.2	107.1	3.96	168	167.8	6.61	163.4	163	10.03	165.7
	Max	1394	327.1	85.07	1907	765.3	35.09	1882	708.5	133.7	1907
	Min	777	-282.7	-79.61	773.3	-353.7	-30.74	796.9	-322.4	-130.4	773.3
REL. MOT.	Mean	-1.12			-1.22			-0.6			-0.91
Ft	Std. Dev.	6.95	0.97	6.88	13.75	2.01	13.59	13.76	2.5	13.53	13.76
	Max	25.46	2.81	25.05	56.09	5.5	54.07	54.1	6.11	52.79	56.09
	Min	-23.01	-2.65	-23.55	-39.27	-5.55	-41.35	-43.36	-6.49	-45.1	-43.36
RUNUP	Mean	0.9			1.83			1.79			-57.72
Ft	Std. Dev.	8.85	1.01	8.79	14.93	1.74	14.82	14.62	1.82	14.5	15.26
	Max	51.17	8.25	43.12	52.87	6.13	51.59	53.01	6.41	52.49	-11.87
	Min	-26.63	-3.05	-32.61	-40.13	-4.87	-47.15	-40.2	-4.29	-46.04	-112
MOONPOOL	Mean	1.05			0.07			0.3			0.19
Ft	Std. Dev.	0.19	0.16	0.11	0.34	0.16	0.3	0.36	0.19	0.3	0.37
	Max	2.08	0.82	0.43	2.06	0.63	1.41	4.99	0.61	3.27	4.99
	Min	0.36	-0.45	-0.4	-1.19	-0.26	-1.1	-1.18	-0.32	-1.23	-1.19

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		hrc3&4		hrc5		
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	1.36	40.8	43.04	1.41	43
Ft	Std. Dev.	0.34	10.2	10.76	0.35	10.75
	Max	2.71	44.43	47.01	1.65	46.15
	Min	-0.94	-31.39	-34.65	-2.59	-34.77
WIND	Mean					
Knots	Std. Dev.					
	Max					
	Min					
CUR 1	Mean			5.15		
Ft/Sec	Std. Dev.	0.82	2.25	2.69	0.88	2.53
	Max	2.15	8.38	14.28	2.55	8.91
	Min	-4.14	-9.18	-4.78	-2.21	-9.38
CUR 2	Mean			2.88		
Ft/Sec	Std. Dev.	0.7	1.68	2.09	0.83	1.92
	Max	2.38	5.67	9.48	2.13	6.14
	Min	-2.03	-6.25	-6.93	-2.33	-8.79
SURGE_CG	Mean			-64.04		
Ft	Std. Dev.	8.87	2.88	9.67	8.83	3.93
	Max	27.06	10.34	-37.07	22.87	12.35
	Min	-22.81	-9.82	-95.21	-25.94	-15.61
HEAVE_CG	Mean			-0.32		
Ft	Std. Dev.	0.33	0.98	1.43	0.52	1.34
	Max	1.2	3.84	5.01	1.55	4.73
	Min	-1.76	-4.09	-6.43	-2.96	-4.76
SWAY_CG	Mean			-15.35		
Ft	Std. Dev.	26.94	0.94	34.28	34.25	1.33
	Max	70.41	15.5	71.32	85.56	24.69
	Min	-69.6	-14.06	-94.29	-78.23	-27.91
ROLL	Mean			0.07		
deg	Std. Dev.	0.34	0.12	0.56	0.55	0.14
	Max	1.17	0.5	2.19	1.94	0.56
	Min	-0.96	-0.5	-1.66	-1.52	-0.52
YAW	Mean			0.74		
deg	Std. Dev.	0.79	0.41	1.19	1.04	0.59
	Max	2.44	1.88	5.37	4.04	2.69
	Min	-2.7	-1.54	-4.28	-3.29	-2.42
PITCH	Mean			-0.75		
deg	Std. Dev.	0.96	0.59	1.18	0.95	0.7
	Max	2.67	2.4	3.17	3.62	2.29
	Min	-2.84	-1.73	-5.47	-3.17	-2.53
TENS-1	Mean			1955		
Kips	Std. Dev.	195.2	67.24	310.8	285.1	123.6
	Max	620	295.5	3748	1436	629.3
	Min	-355.4	-326.2	1343	-597.6	-623.8
TENS-2	Mean			1310		
Kips	Std. Dev.	212.9	9.65	386.3	383.5	45
	Max	1068	163.4	3365	1995	884.3
	Min	-382.3	-113	765.9	-539	-972.1
TENS-3	Mean			819.8		
Kips	Std. Dev.	46.11	12.76	48.89	45.31	18.35
	Max	136.7	81.91	978.1	123.8	63.32
	Min	-114	-65.14	673	-123.9	-65.63
TENS-4	Mean			1092		
Kips	Std. Dev.	165.5	8.35	227.1	226.7	13
	Max	766.2	91.15	2130	994.4	139.7
	Min	-352.8	-82.26	654.2	-443.6	-128.8
REL. MOT.	Mean			0		
Ft	Std. Dev.	2.29	13.56	14.13	2.24	13.95
	Max	6.44	54.07	69.3	8.62	65.27
	Min	-6.15	-45.13	-47.45	-5.85	-45.44
RUNUP	Mean			1.08		
Ft	Std. Dev.	1.78	14.66	14.42	1.43	14.35
	Max	6.49	52.61	52.6	4.8	52.99
	Min	-4.87	-47.24	-42.05	-3.7	-44.34
MOONPOOL	Mean			0.67		
Ft	Std. Dev.	0.21	0.3	0.54	0.33	0.42
	Max	0.72	3.34	3.71	2.12	1.93
	Min	-0.37	-1.21	-1.17	-0.48	-1.7

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		Waves, Wind & Current									
		hrcw2			hrcw3			hrcw4			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3	19.97	0.63	19.95	39.58	1.52	39.54	38.98	1.67	38.93	39.28
Ft	Std. Dev.	4.99	0.16	4.99	9.9	0.38	9.89	9.74	0.42	9.73	9.82
	Max	25.34	0.96	24.42	43.06	2.6	40.05	43.02	1.16	40.31	43.06
	Min	-16.21	-0.58	-16.38	-29.06	-0.83	-29.13	-29.28	-4.43	-29.59	-29.28
WIND	Mean	41.67			82.07			81.95			82.01
Knots	Std. Dev.	4.7	4.02	2.4	9.16	6.69	6.27	9.64	7.1	6.5	9.4
	Max	60.47	11.07	7.7	113.25	19.14	19.31	119.23	24.22	27.89	119.23
	Min	25.89	-14.79	-7.41	58.25	-16.57	-20.4	54.67	-20.01	-22.29	54.67
CUR 1	Mean	1.13			4.21			1.3			2.75
Ft/Sec	Std. Dev.	1.23	0.55	1.02	2.33	0.74	2.13	2.44	0.85	2.21	2.8
	Max	5.42	1.48	3.68	12.39	1.85	7.2	9.32	1.62	7.13	12.39
	Min	-3.45	-1.67	-3.89	-5.32	-2.14	-8.05	-8.5	-3.22	-7.89	-8.5
CUR 2	Mean	-1.46			1.57			1.46			1.51
Ft/Sec	Std. Dev.	1.4	0.77	1.05	1.93	0.65	1.77	1.96	0.74	1.77	1.94
	Max	2.61	2.33	3.86	7.04	1.66	5.28	8.24	2.13	5.97	8.24
	Min	-10.85	-2.34	-5.83	-8.62	-1.98	-8.01	-10.18	-1.63	-8.85	-10.18
SURGE_CG	Mean	-70.4			-79.83			-81.95			-80.88
Ft	Std. Dev.	5.95	5.88	0.89	6.58	5.92	2.87	6.49	5.82	2.89	6.62
	Max	-55.88	13.05	3.67	-53.95	22.32	10.29	-58.96	19.25	10.22	-53.95
	Min	-85.12	-13.87	-8.24	-100.8	-16.33	-14.7	-103.2	-14.86	-9.34	-103.2
HEAVE_CG	Mean	-0.36			0.23			0.12			0.18
Ft	Std. Dev.	0.42	0.2	0.37	1.1	0.59	0.93	1.4	0.6	1.27	1.26
	Max	0.81	0.59	0.94	4.7	2.28	3.64	5.91	2.23	4.07	5.91
	Min	-1.78	-0.75	-1.02	-3.86	-1.75	-4.11	-4.26	-1.76	-4.12	-4.26
SWAY_CG	Mean	-9.72			1.52			2.15			1.38
Ft	Std. Dev.	18.1	18.09	0.53	28.02	28.01	0.73	26.77	26.75	0.91	27.9
	Max	42.46	52.06	6.7	59.13	57.54	9.8	64.28	61.89	16.17	64.79
	Min	-55.86	-45.03	-5.91	-61.95	-62.34	-9.3	-61.7	-62.9	-17.49	-63.49
ROLL	Mean	0.12			-0.02			0.01			-0.01
deg	Std. Dev.	0.5	0.49	0.08	0.59	0.58	0.1	0.57	0.56	0.1	0.58
	Max	1.43	1.19	0.34	1.89	1.8	0.37	1.38	1.39	0.35	1.89
	Min	-1.24	-1.36	-0.34	-1.68	-1.6	-0.38	-1.74	-1.48	-0.34	-1.74
YAW	Mean	0.94			-0.7			-0.83			-0.77
deg	Std. Dev.	0.84	0.82	0.18	1.02	0.96	0.35	1.2	1.15	0.37	1.12
	Max	3.81	2.49	0.81	2.5	2.88	1.55	3.49	3.67	1.94	3.49
	Min	-1.58	-2.19	-0.64	-3.82	-2.59	-1.32	-4.39	-3.39	-1.49	-4.39
PITCH	Mean	-1.41			-2.8			-2.76			-2.78
deg	Std. Dev.	0.44	0.39	0.22	1.23	1.08	0.58	1.33	1.2	0.59	1.28
	Max	0.13	1.15	0.75	0.89	3.16	2.14	1.5	3.22	2.05	1.5
	Min	-2.84	-0.95	-0.69	-6.93	-3.6	-1.73	-7.07	-3.56	-1.74	-7.07
TENS-1	Mean	2140			2556			2687			2621
Kips	Std. Dev.	183	181	27.03	355.4	311.1	172	408.7	359.5	194.4	388.6
	Max	2816	635.1	161.1	4069	1147	724.9	4326	1186	691.1	4326
	Min	1720	-380.5	-132.6	1703	-776.9	-592.2	1823	-714	-678.9	1703
TENS-2	Mean	1236			1164			1158			1161
Kips	Std. Dev.	118.9	118.8	2.94	199.2	199	8.3	185.8	185.5	10.87	192.7
	Max	1795	542	39.6	1962	780.3	36.66	1999	808	89.45	1999
	Min	957	-276.1	-38.26	838.1	-318.6	-53.68	817.9	-338.1	-85.8	817.9
TENS-3	Mean	774.8			731.3			719.7			725.5
Kips	Std. Dev.	31.66	31.42	3.85	32.69	30.24	12.41	32.41	29.5	13.41	33.07
	Max	858.9	74.53	14.61	869.8	126.7	57.27	828.5	87.87	42.22	869.8
	Min	697.9	-71.59	-14.06	637.9	-70.54	-42.3	632.1	-68.16	-44.51	632.1
TENS-4	Mean	1097			1188			1202			1195
Kips	Std. Dev.	93.57	93.51	3.06	174.1	173.8	10.24	182.8	182.6	9.93	178.6
	Max	1400	297.9	29.89	1813	624.9	82.58	1929	724.2	82.18	1929
	Min	853.9	-244.2	-29.77	840.9	-347.9	-59.69	853	-351.7	-95.37	840.9
REL. MOT.	Mean	-1.58			-4.32			-4.23			-4.27
Ft	Std. Dev.	6.92	0.92	6.86	13.56	2.67	13.29	13.59	3.01	13.25	13.57
	Max	22.23	2.99	23.99	44.56	7.92	48.49	51.47	8.71	49.82	51.47
	Min	-25.48	-2.41	-25.24	-40.89	-9.36	-38.54	-43.77	-9.15	-46.68	-43.77
RUNUP	Mean	-1.24			-2.4			-2.54			-2.47
Ft	Std. Dev.	8.38	0.79	8.34	14.63	2.19	14.47	14.17	2.19	14	14.41
	Max	33.48	2.98	33.48	52.47	8.13	54.22	52.63	8.31	55.35	52.63
	Min	-27.27	-2.29	-28.05	-41.4	-7.41	-43.71	-40.77	-6.26	-43.42	-41.4
MOONPOOL	Mean	1.56			-0.1			-0.09			-0.09
Ft	Std. Dev.	0.16	0.13	0.1	0.47	0.28	0.38	0.5	0.3	0.41	0.49
	Max	2.09	0.28	0.48	2.02	1.14	1.5	2.13	0.83	1.48	2.13
	Min	0.89	-0.34	-0.37	-1.59	-0.8	-1.35	-1.81	-0.77	-1.54	-1.81

CONFIGURATION H - STRAKES
TEST RESULTS SUMMARY

		hrcw3&4		hrcw5		
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	1.4	39.24	43.76	1.64	43.72
Ft	Std. Dev.	0.35	9.81	10.94	0.41	10.93
	Max	1.6	40.16	51.48	3.54	50.29
	Min	-2.57	-29.5	-35.56	-1.04	-35.11
WIND	Mean			59.59		
Knots	Std. Dev.	6.89	6.39	7.26	5.07	5.2
	Max	24.05	27.86	82.72	12.3	16.44
	Min	-19.92	-22.3	37.24	-16.07	-12.91
CUR 1	Mean			4.9		
Ft/Sec	Std. Dev.	1.66	2.18	2.73	0.97	2.53
	Max	3.28	7.21	15.35	2.35	10.53
	Min	-4.61	-7.98	-4.66	-2.62	-8.98
CUR 2	Mean			2.32		
Ft/Sec	Std. Dev.	0.7	1.77	2.3	0.9	2.06
	Max	2.04	5.95	8.91	2.04	6.65
	Min	-1.91	-8.85	-12.56	-2.4	-9.94
SURGE_CG	Mean			-73		
Ft	Std. Dev.	5.96	2.89	7.64	6.54	3.94
	Max	23.4	10.27	-52.02	17.23	12.55
	Min	-15.86	-10.74	-105.2	-16.56	-23.59
HEAVE_CG	Mean			-0.15		
Ft	Std. Dev.	0.59	1.12	1.44	0.53	1.34
	Max	2.33	4.04	4.17	1.57	3.74
	Min	-1.77	-4.07	-4.67	-2.06	-4.12
SWAY_CG	Mean			-0.81		
Ft	Std. Dev.	27.89	0.91	32.05	32	1.8
	Max	63.15	22.53	72.27	72.94	40.67
	Min	-63.84	-22.14	-68.04	-66.13	-40.62
ROLL	Mean			0.05		
deg	Std. Dev.	0.57	0.1	0.5	0.49	0.12
	Max	1.79	0.45	1.58	1.47	0.43
	Min	-1.61	-0.58	-1.51	-1.42	-0.51
YAW	Mean			-0.09		
deg	Std. Dev.	1.06	0.36	1.2	1.06	0.55
	Max	3.64	2.09	6.19	6.06	2.67
	Min	-3.41	-1.47	-5.23	-3.55	-2.14
PITCH	Mean			-1.74		
deg	Std. Dev.	1.14	0.59	1.25	1.04	0.69
	Max	3.25	2.14	2.35	3.53	2.32
	Min	-3.63	-1.77	-6.23	-3.58	-2.55
TENS-1	Mean			2233		
Kips	Std. Dev.	342.4	183.8	310.5	259.9	169.6
	Max	1251	717.6	4308	1002	1292
	Min	-841.6	-681.8	1588	-501.1	-856.5
TENS-2	Mean			1179		
Kips	Std. Dev.	192.4	9.73	246.3	245.9	13.98
	Max	804.5	96.87	2079	871.7	200.7
	Min	-341.5	-112.4	746.5	-425.6	-208
TENS-3	Mean			770.2		
Kips	Std. Dev.	30.4	12.99	37.77	32.92	18.51
	Max	132.6	57.8	883.6	86.46	62.02
	Min	-73.67	-51	645.5	-92.58	-85.95
TENS-4	Mean			1186		
Kips	Std. Dev.	178.3	10.2	231.8	231.1	18.2
	Max	730.4	109.5	2245	1008	391
	Min	-354.2	-123.6	819.1	-356.8	-268.3
REL. MOT.	Mean			-1.5		
Ft	Std. Dev.	2.84	13.27	14.05	2.51	13.82
	Max	8.62	49.75	84.13	9.53	77.32
	Min	-9.47	-46.56	-50.16	-6.59	-46.23
RUNUP	Mean			-1.58		
Ft	Std. Dev.	2.18	14.23	13.76	1.5	13.68
	Max	8.12	55.19	52.12	5.35	54.95
	Min	-7.53	-43.98	-42.19	-4.63	-40.42
MOONPOOL	Mean			0.62		
Ft	Std. Dev.	0.29	0.39	0.46	0.25	0.39
	Max	1.14	1.49	3.55	1.22	1.77
	Min	-0.8	-1.45	-1.4	-0.49	-1.82

CONFIGURATION L - ALL MOORING LINES INTACT
TEST RESULTS SUMMARY

		Current only						Wind only						
		Icur3			Iwin2			Iwin3			Iwin4			
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f
WAVE	H1/3	0.21	0.17	0.12	0.17	0.15	0.06	0.4	0.39	0.07	0.27	0.26	0.06	8.44
Ft	Std. Dev.	0.05	0.04	0.03	0.04	0.04	0.02	0.1	0.1	0.02	0.07	0.06	0.02	2.11
	Max	-0.28	0.12	0.12	0.09	0.08	0.09	-0.26	0.21	0.16	-0.85	0.16	0.14	8.76
	Min	-0.67	-0.1	-0.13	-0.2	-0.11	-0.1	-0.76	-0.22	-0.2	-1.23	-0.1	-0.13	-7.87
WIND	Mean	-0.05			43.27			86.33			85.33			0.08
Knots	Std. Dev.	0.06	0.04	0.03	5.01	4.29	2.54	8.97	7.08	5.48	8.83	7.02	5.34	0.16
	Max	0.31	0.07	0.29	58.14	12.02	8.59	120.47	22.54	20.57	120.12	18.56	19.22	0.24
	Min	-0.2	-0.12	-0.16	27.83	-14.08	-7.91	61.89	-18.9	-17.17	59.82	-21.15	-19.4	-0.27
CUR 1	Mean	3.45			0.04			-0.04			0.06			0.07
Ft/Sec	Std. Dev.	0.91	0.81	0.4	0.27	0.03	0.14	0.88	0.05	0.53	0.84	0.08	0.51	0.27
	Max	6.38	2.37	1.62	1.08	0.09	0.62	3.06	0.2	2	3.3	0.3	1.8	1.07
	Min	0.37	-2.51	-2.06	-1.15	-0.07	-0.72	-3.73	-0.15	-1.83	-3.04	-0.23	-1.81	-0.94
CUR 2	Mean	0.52			-0.04			-0.03			-0.08			-0.11
Ft/Sec	Std. Dev.	0.21	0.18	0.07	0.12	0.03	0.1	0.11	0.05	0.08	0.1	0.03	0.08	0.09
	Max	1.17	0.35	0.27	0.58	0.09	0.36	0.43	0.12	0.33	0.32	0.09	0.3	0.35
	Min	-0.14	-0.46	-0.44	-0.48	-0.1	-0.36	-0.47	-0.11	-0.32	-0.48	-0.1	-0.27	-0.48
SURGE_CG	Mean	-24.39			-11.73			-46.33			-44.7			-0.73
Ft	Std. Dev.	4.62	4.61	0.23	5.45	5.45	0.19	9.72	9.7	0.63	12.52	12.51	0.5	1.19
	Max	-10.22	13.87	5.3	2.18	13.76	0.65	-22.88	22.47	5.53	-15.88	28.77	4.93	2.56
	Min	-34.76	-10.43	-5.28	-26.35	-14.38	-1.38	-72.13	-25.73	-9.97	-81.31	-36.24	-1.96	-4.13
HEAVE_CG	Mean	-0.42			0.17			0.22			0.17			0
Ft	Std. Dev.	0.21	0.2	0.04	0.25	0.22	0.12	0.57	0.48	0.3	0.68	0.6	0.32	0.07
	Max	0.15	0.54	0.21	0.85	0.47	0.42	1.62	0.88	1.13	1.76	1.02	1.49	0.28
	Min	-1.12	-0.58	-0.18	-0.97	-0.76	-0.42	-2.62	-1.82	-1.18	-3.89	-2.6	-1.51	-0.34
SWAY_CG	Mean	-0.39			2.03			8.1			7.93			-0.06
Ft	Std. Dev.	8.55	8.55	0.1	1.52	1.46	0.41	2.77	2.69	0.71	2.31	2.16	0.88	0.26
	Max	25.51	25.96	1.86	5.65	3.43	1.19	15.97	7.87	1.86	13.94	6.14	2.87	0.77
	Min	-21.43	-21.1	-0.64	-2.1	-3.54	-1.17	0.33	-7.65	-2.19	0.63	-6.42	-2.65	-0.77
ROLL	Mean	-0.07			0.02			-0.11			0.02			-0.02
deg	Std. Dev.	1.77	1.76	0.05	0.23	0.23	0.02	0.57	0.56	0.06	0.65	0.65	0.08	0.06
	Max	4.99	5.05	1.09	0.72	0.67	0.08	1.85	1.96	0.27	2.43	2.37	0.39	0.15
	Min	-4.9	-4.86	-1.02	-0.68	-0.69	-0.1	-1.66	-1.54	-0.25	-2.1	-2.21	-0.31	-0.19
YAW	Mean	-0.04			0.04			0.22			-0.4			0.14
deg	Std. Dev.	0.63	0.62	0.1	0.99	0.57	0.8	2.34	2.11	1.07	2.39	2.08	1.25	0.05
	Max	1.45	1.39	0.29	3.21	2.18	2.34	7.71	6.52	6.08	6.95	6.43	3.57	0.34
	Min	-1.9	-1.75	-0.38	-2.86	-1.87	-2.08	-6.37	-6.4	-4.66	-8.24	-5.38	-4	-0.02
PITCH	Mean	0.53			-0.61			-2.32			-2.24			0
deg	Std. Dev.	0.25	0.25	0.02	0.72	0.72	0.04	1.59	1.59	0.14	1.83	1.83	0.13	0.14
	Max	1.18	0.66	0.08	1.37	1.99	0.13	1.96	4.44	0.71	3.49	5.44	0.5	0.5
	Min	-0.13	-0.66	-0.07	-2.83	-2.19	-0.12	-6.73	-4.4	-0.65	-8.36	-6.05	-0.58	-0.44
TENS-1	Mean	499.8			455			565.3			560.4			460.6
Kips	Std. Dev.	8.6	8.56	0.73	14.65	11.65	7.11	22.47	22.34	2.41	27.56	27.36	3.08	2.37
	Max	523.7	22.31	8.18	500	32.48	23.55	636.8	68.97	7.03	652.9	89.74	19.61	467.3
	Min	473.2	-25.29	-8.76	381.5	-32.38	-41.43	506.3	-56.86	-8.58	485.7	-70.05	-23.93	453.4
TENS-2	Mean	457.8			422.4			476.8			474.6			443.7
Kips	Std. Dev.	15	14.96	0.84	10.8	7.19	6.59	15.54	15.24	3.02	17.07	16.66	3.68	1.78
	Max	498.2	38.48	9.24	454.5	21.17	21.37	531	50.3	9.69	525.2	47.2	17.06	449.9
	Min	411.3	-45.2	-9.9	356.4	-19.94	-35.76	433.8	-39.26	-10.88	418.5	-44.51	-23.23	438.2
TENS-3	Mean	414.4			404.5			367.7			368.8			435.4
Kips	Std. Dev.	16.61	16.59	0.58	8.77	7.21	3.98	12.69	12.61	1.39	15.94	15.81	1.8	1.38
	Max	454.7	38.84	3.1	433.3	20.46	13.2	403.5	35.22	4.69	409.4	39.97	9.26	440.2
	Min	364.6	-48.4	-2.65	365	-18.9	-21.3	328.1	-34.97	-5.26	317.6	-48.8	-16.82	429.3
TENS-4	Mean	385.2			401.5			314			317.7			432.3
Kips	Std. Dev.	8.65	8.63	0.59	11.76	11.74	0.68	23.65	23.57	2.06	28.6	28.55	1.77	2.26
	Max	410	24.16	11.86	436.5	34.34	2.16	375.7	61.81	10.52	392.5	76.3	6.43	439.7
	Min	363.7	-20.43	-11.35	367.1	-33.4	-2.49	243.8	-67.8	-6.47	222.2	-92.98	-6.35	424.9
TENS-5	Mean	414.7			427.1			396.9			397.2			440.1
Kips	Std. Dev.	17.2	17.17	0.81	4.99	4.93	0.67	11.86	11.79	1.43	13.03	12.95	1.43	1.66
	Max	468	53.58	12	442.6	15.56	2.13	426.5	29.22	11.46	434.8	36.61	4.61	445.8
	Min	370.9	-43.01	-12.17	413.3	-13.9	-2.35	353.8	-43.3	-10.25	360.8	-36.36	-4.68	435.3
TENS-6	Mean	477.4			466.7			527.3			524.5			452.3
Kips	Std. Dev.	18.66	18.65	0.55	7.94	7.67	2.01	14.58	14.33	2.78	17.89	17.64	3.23	1.55
	Max	532.1	54.41	2.97	490.7	22.91	7.01	573.5	46.12	9.25	578.1	52.52	10.69	458.1
	Min	435.2	-42.63	-2.48	441.5	-21.09	-5.81	484.3	-39.52	-9.52	474.3	-44.92	-9.94	445.8
TETHER	Mean	1822			1826			2031			2038			1798
Kips	Std. Dev.	31.53	27.9	14.69	102.4	13.3	101.6	250	97.74	230.1	232	117.5	200.1	45.06
	Max	1972	98.31	73.99	2166	56.86	339.7	2943	422.2	705.7	2923	660.4	706.3	1939
	Min	1770	-52.02	-70.94	1494	-39.52	-336.8	1336	-190.3	-622.3	1318	-244.1	-706.9	1665
REL. MOT.	Mean	0.57												-0.01
Ft	Std. Dev.	0.53	0.52	0.11										2.27
	Max	2.4	1.54	0.48										10.42
	Min	-0.72	-1.23	-0.51										-7.55
RUNUP	Mean	2.6			-1.78			-3.02			-2.76			0.28
Ft	Std. Dev.	0.27			0.37			0.78			0.87			3.11
	Max	3.61			-0.17			0.98			2.49			17.95
	Min	1.93			-2.77			-5.22			-5.42			-11.57
OFFSET FORCE	Mean	3.84			-0.8			-0.85			-0.41			-0.24
Kips	Std. Dev.	0.19			0.14			0.12			0.16			0.13
	Max	4.38			-0.3			-0.47			0.03			0.07
	Min	3.38			-0.97			-0.97			-0.8			-0.6

CONFIGURATION L - ALL MOORING LINES INTACT
TEST RESULTS SUMMARY

							Waves only							
		Iran1		Iran3			Iran4			Iran3&4			Iran6	
		f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz
WAVE	H1/3	0.21	8.43	44.88	1.19	44.88	44.64	1.3	44.6	44.76	1.19	44.72	8.69	0.14
Ft	Std. Dev.	0.05	2.11	11.22	0.3	11.22	11.16	0.33	11.15	11.19	0.3	11.18	2.17	0.03
	Max	0.18	7.97	40.37	1.39	38.94	52.19	2.63	49.99	52.19	1.36	49.8	10.08	0.14
	Min	-0.17	-8.31	-28.59	-0.73	-30.14	-30.76	-0.83	-31.64	-30.76	-0.79	-31.66	-6.98	-0.1
WIND	Mean			0.06			-0.05			0			-0.02	
Knots	Std. Dev.	0.08	0.09	0.16	0.09	0.1	0.24	0.2	0.1	0.21	0.16	0.1	0.16	0.09
	Max	0.15	0.29	0.85	0.49	0.43	2.92	2.54	0.6	2.92	2.46	0.6	0.29	0.15
	Min	-0.17	-0.34	-0.34	-0.2	-0.4	-0.49	-0.3	-0.88	-0.49	-0.25	-0.87	-0.39	-0.18
CUR 1	Mean			0.06			0.13			0.1			0.01	
Ft/Sec	Std. Dev.	0.03	0.26	2.41	0.26	2.39	2.41	0.33	2.38	2.41	0.3	2.38	0.25	0.03
	Max	0.08	0.92	7.74	0.74	7.77	8.87	1.27	8.22	8.87	1.25	8.2	0.98	0.11
	Min	-0.11	-0.96	-7.6	-0.68	-7.18	-8.01	-0.73	-7.82	-8.01	-0.72	-7.85	-0.92	-0.08
CUR 2	Mean			0.05			-0.17			-0.06			0.01	
Ft/Sec	Std. Dev.	0.04	0.07	0.38	0.26	0.27	0.29	0.09	0.27	0.35	0.22	0.27	0.09	0.03
	Max	0.1	0.26	1.4	0.83	0.98	0.79	0.2	1.09	1.4	0.94	1.08	0.45	0.09
	Min	-0.13	-0.24	-1.14	-0.3	-1	-1.21	-0.26	-0.79	-1.21	-0.37	-1.01	-0.34	-0.06
SURGE_CG	Mean			-86.19			-86.24			-86.22			-0.64	
Ft	Std. Dev.	1.15	0.32	6.03	4.55	3.95	6.75	5.45	3.98	6.4	5.01	3.97	1.47	1.44
	Max	2.91	1.09	-64.09	16.4	13.47	-65.99	13.78	12.95	-64.09	16.43	13.08	2.98	3.12
	Min	-3.02	-1.06	-110.2	-15.39	-12.17	-108.8	-14.67	-15.03	-110.2	-15.64	-20.42	-4.56	-3.55
HEAVE_CG	Mean			-0.47			-0.51			-0.49			0	
Ft	Std. Dev.	0.05	0.06	0.34	0.25	0.24	0.39	0.29	0.25	0.37	0.27	0.25	0.07	0.05
	Max	0.12	0.21	0.58	0.6	0.9	0.86	0.62	1.08	0.86	0.6	1.08	0.28	0.15
	Min	-0.15	-0.21	-1.95	-0.97	-0.94	-2.14	-1.11	-1.19	-2.14	-1.12	-1.27	-0.22	-0.14
SWAY_CG	Mean			-0.55			-0.9			-0.73			-0.05	
Ft	Std. Dev.	0.24	0.1	1.15	1.1	0.34	1.39	1.35	0.36	1.29	1.24	0.35	0.63	0.56
	Max	0.53	0.36	3.76	3.31	1.23	2.9	3.32	1.23	3.76	3.47	1.23	2.17	1.39
	Min	-0.49	-0.38	-4.91	-3.94	-1.32	-5.47	-4.12	-1.53	-5.47	-4.3	-1.54	-2	-1.36
ROLL	Mean			-0.15			-0.16			-0.15			-0.01	
deg	Std. Dev.	0.06	0.02	0.15	0.13	0.07	0.17	0.15	0.07	0.16	0.14	0.07	0.08	0.06
	Max	0.14	0.07	0.45	0.36	0.25	0.37	0.43	0.29	0.45	0.43	0.29	0.25	0.17
	Min	-0.16	-0.06	-0.61	-0.39	-0.23	-0.65	-0.38	-0.27	-0.65	-0.39	-0.33	-0.3	-0.18
YAW	Mean			0.35			0.29			0.32			0.15	
deg	Std. Dev.	0.03	0.04	0.24	0.17	0.17	0.29	0.22	0.19	0.27	0.2	0.18	0.09	0.03
	Max	0.07	0.14	1.4	0.57	0.69	1.38	0.71	1.08	1.4	0.68	0.97	0.48	0.09
	Min	-0.1	-0.15	-0.86	-0.6	-0.64	-0.97	-0.6	-0.76	-0.97	-0.63	-0.76	-0.17	-0.09
PITCH	Mean			-2.75			-2.77			-2.76			0	
deg	Std. Dev.	0.12	0.06	0.97	0.72	0.66	1.12	0.91	0.66	1.05	0.82	0.66	0.14	0.13
	Max	0.39	0.23	0.44	2.82	2.16	0.31	2.87	2.21	0.44	2.85	2.62	0.5	0.39
	Min	-0.34	-0.21	-6.93	-2.37	-1.93	-6.88	-2.22	-1.94	-6.93	-2.34	-1.95	-0.56	-0.45
TENS-1	Mean			650.7			651.5			651.1			460.9	
Kips	Std. Dev.	2.29	0.49	14.4	10.2	10.15	16.09	12.51	10.12	15.27	11.42	10.13	2.8	2.73
	Max	6.2	1.89	708.5	37.87	30.52	704.5	32.86	29.98	708.5	37.2	29.8	469.1	6.47
	Min	-6.45	-1.93	600.3	-37.05	-37.8	603.4	-34.12	-33.14	600.3	-37.17	-37.52	453.4	-7.3
TENS-2	Mean			538.4			539.8			539.1			444.6	
Kips	Std. Dev.	1.54	0.64	10.67	7.49	7.58	11.82	9.12	7.5	11.28	8.37	7.54	2.01	1.79
	Max	3.78	2.44	580.2	27.49	22.42	582.4	25.8	21.88	582.4	27	22.54	451.3	5.28
	Min	-4.82	-2.7	504.5	-24.07	-26.27	505.4	-24.67	-24.25	504.5	-24.5	-27.1	438.2	-4.05
TENS-3	Mean			339.9			339.9			339.9			435.7	
Kips	Std. Dev.	1.17	0.61	7.16	4.24	5.75	8.21	5.82	5.77	7.7	5.09	5.76	1.55	1.35
	Max	3.14	2.21	362.1	15.02	18.52	364.6	16.44	19.54	364.6	16.5	19.64	441.5	4.08
	Min	-3.44	-2.17	314.3	-14.88	-19.17	313.1	-14.77	-18.06	313.1	-14.8	-19.07	429.8	-3.96
TENS-4	Mean			225.6			225.6			225.6			432.5	
Kips	Std. Dev.	2.18	0.57	14.63	10.38	10.31	16.56	12.93	10.35	15.62	11.72	10.32	2.63	2.57
	Max	6.9	2.1	275.9	38.11	37.56	273.8	36.09	34.99	275.9	37.79	37.29	440.4	6.67
	Min	-6.64	-1.98	167	-39.65	-32.06	169	-34.1	-30.61	167	-39.41	-31.87	424.3	-7.74
TENS-5	Mean			342.8			341			341.9			441	
Kips	Std. Dev.	1.54	0.55	7.45	5.45	5.08	7.98	6.1	5.14	7.77	5.85	5.11	2.09	1.99
	Max	4.76	1.78	368.5	19.97	17.26	365.9	18.39	18.31	368.5	20.69	18.45	446.7	4.37
	Min	-3.39	-1.91	316	-18.51	-17.61	309.9	-15.99	-16.51	309.9	-17.48	-17.56	434.5	-4.87
TENS-6	Mean			559.7			558.7			559.2			452.4	
Kips	Std. Dev.	1.46	0.44	8.03	5.26	6.06	9.41	7.1	6.16	8.76	6.27	6.11	1.83	1.73
	Max	3.45	1.59	590.1	18.5	17.78	590.1	17.33	18.73	590.1	18.75	18.63	458.1	5.04
	Min	-4.51	-1.79	531.4	-18.57	-21.52	532.8	-17.9	-19.19	531.4	-18.41	-21.09	445.8	-4.68
TETHER	Mean			2037			2038			2038			1799	
Kips	Std. Dev.	2.3	44.99	153.9	33.01	150.3	160.3	39.93	155.2	157.1	36.66	152.7	41.64	1.97
	Max	8.4	138.3	2561	158.3	550.2	2603	159.7	526.3	2603	158.4	548.3	1937	8.44
	Min	-7.01	-135.7	1564	-96.64	-470.6	1512	-94.17	-570.2	1512	-92.97	-568.9	1664	-5.02
REL. MOT.	Mean			-2.49			-2.7			-2.59			-0.09	
Ft	Std. Dev.	0.22	2.25	11.89	1.17	11.83	12	1.45	11.91	11.94	1.31	11.87	2.21	0.22
	Max	0.69	9.68	42.51	4.24	44.44	46.53	5.05	49.51	46.53	4.39	49.34	11.64	0.75
	Min	-0.61	-7.48	-35.52	-3.41	-32.41	-37.33	-3.18	-36.06	-37.33	-3.34	-36.01	-7.42	-0.68
RUNUP	Mean			2.55			2.91			2.73			0.23	
Ft	Std. Dev.			12.02			12.32			12.17	1.3	12.09	2.94	
	Max			59.31			60.76			60.76	5.65	56.71	15.13	
	Min			-28.17			-27.42			-28.17	-2.79	-33.35	-9.74	
OFFSET FORCE	Mean			578.7			578.1						0.16	
Kips	Std. Dev.			15.25			15.6						0.1	
	Max			641.6			657						0.47	
	Min			516.6			518.3						-0.19	

CONFIGURATION L - ALL MOORING LINES INTACT
TEST RESULTS SUMMARY

			Waves & Current											
			Irc2			Irc3			Irc4			Irc3&4		
		f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	8.68	19.38	0.75	19.36	39.24	1.2	39.2	39.2	0.98	39.18	39.29	2.59	39.18
Ft	Std. Dev.	2.17	4.85	0.19	4.84	9.81	0.3	9.8	9.8	0.24	9.79	9.82	0.65	9.79
	Max	9.6	19.55	1.48	18.75	48.83	1.78	42.99	38.99	1.91	38.74	48.83	3.13	42.86
	Min	-7.19	-15.76	-0.42	-16.14	-28.55	-0.62	-29.4	-31.43	-0.57	-31.07	-31.43	-1.6	-31.17
WIND	Mean		0			0.06			0.19			0.13		
Knots	Std. Dev.	0.08	0.07	0.03	0.04	0.13	0.09	0.07	0.17	0.09	0.1	0.16	0.11	0.09
	Max	0.31	0.35	0.08	0.29	1.74	1.02	0.76	0.72	0.21	0.35	1.74	0.96	0.75
	Min	-0.31	-0.16	-0.1	-0.18	-0.13	-0.27	-0.61	-0.13	-0.18	-0.36	-0.13	-0.33	-0.61
CUR 1	Mean		5.16			3.81			3.85			3.83		
Ft/Sec	Std. Dev.	0.24	1.56	1.15	1.04	2.33	0.8	2.18	2.33	0.65	2.23	2.33	0.73	2.2
	Max	0.89	11.53	2.73	3.79	11.65	2.53	8.3	12.27	1.58	8.45	12.27	2.49	8.44
	Min	-0.86	0.49	-2.69	-3.59	-5.38	-2.06	-7.49	-4.06	-1.74	-7.79	-5.38	-2.11	-7.81
CUR 2	Mean		-0.35			1.66			1.33			1.5		
Ft/Sec	Std. Dev.	0.07	0.4	0.35	0.19	0.89	0.78	0.42	0.73	0.63	0.36	0.83	0.73	0.39
	Max	0.28	1.3	1.16	0.97	5.64	3.15	1.83	4.04	2.18	1.77	5.64	3.32	1.85
	Min	-0.3	-1.69	-0.84	-0.89	-1.3	-1.97	-1.83	-0.91	-1.28	-1.81	-1.3	-1.8	-1.8
SURGE_CG	Mean		-39.81			-28.58			-28.44			-28.51		
Ft	Std. Dev.	0.31	8.24	8.14	1.27	7.78	6.88	3.63	8.45	7.59	3.72	8.12	7.25	3.67
	Max	1.07	-19.13	19.48	4.34	-8.64	16.6	13.97	-5.72	18.38	13.04	-5.72	18.51	14.05
	Min	-0.96	-61.35	-20.69	-3.97	-57.83	-23.49	-9.94	-62	-26.66	-11.88	-62	-26.61	-11.84
HEAVE_CG	Mean		-0.61			-0.56			-0.63			-0.59		
Ft	Std. Dev.	0.05	0.42	0.4	0.13	0.44	0.36	0.25	0.5	0.43	0.26	0.48	0.4	0.26
	Max	0.22	0.44	1.05	0.89	0.58	0.76	0.96	0.73	0.96	0.93	0.73	0.93	0.97
	Min	-0.22	-2.59	-1.59	-0.51	-2.53	-1.6	-0.9	-2.8	-1.77	-0.99	-2.8	-1.81	-0.98
SWAY_CG	Mean		-6.07			0.51			2.43			1.47		
Ft	Std. Dev.	0.3	13	12.98	0.7	11.08	11.06	0.65	12	11.98	0.6	11.59	11.57	0.66
	Max	1.08	41.8	46.61	9.78	38	37.53	6.4	40.04	37.25	4.31	40.04	38.21	12.05
	Min	-0.95	-49.15	-40.95	-12.43	-27.56	-27.57	-10.63	-28.61	-30.02	-4.73	-28.61	-29.05	-10.56
ROLL	Mean		-0.25			-0.01			0.18			0.08		
deg	Std. Dev.	0.05	2.39	2.39	0.14	1.2	1.2	0.11	1.11	1.1	0.11	1.16	1.16	0.11
	Max	0.19	6.63	6.04	0.87	3.77	3.8	0.44	3.33	3.1	0.75	3.77	3.7	0.67
	Min	-0.19	-6.77	-6.44	-2.1	-4.44	-4.19	-0.44	-2.81	-2.92	-0.46	-4.44	-4.28	-0.46
YAW	Mean		-0.33			-0.22			-0.56			-0.39		
deg	Std. Dev.	0.08	0.81	0.79	0.18	0.52	0.49	0.17	0.58	0.55	0.19	0.57	0.54	0.18
	Max	0.29	2.32	2.28	0.7	1.67	1.35	0.93	1.06	1.43	1.58	1.67	1.51	1.56
	Min	-0.3	-3.34	-2.63	-0.69	-2.22	-1.56	-0.79	-2.63	-1.82	-0.75	-2.63	-2.01	-0.75
PITCH	Mean		0.56			0.64			0.74			0.69		
deg	Std. Dev.	0.06	0.6	0.55	0.25	0.96	0.75	0.61	1.06	0.86	0.62	1.01	0.8	0.61
	Max	0.21	2.49	1.73	0.87	3.62	2.02	1.86	4.24	2.91	2.19	4.24	2.96	2.2
	Min	-0.18	-1.14	-1.36	-0.8	-3.34	-2.58	-1.7	-3.37	-2.68	-1.84	-3.37	-2.64	-1.83
TENS-1	Mean		525.6			508.1			510.2			509.1		
Kips	Std. Dev.	0.52	15.36	15	3.26	16.82	13.85	9.53	18.24	15.37	9.81	17.58	14.67	9.67
	Max	2.33	566.1	36.22	11.47	574.2	48.16	26.18	585.9	60.52	30.48	585.9	61.61	30.39
	Min	-1.93	485.2	-37.7	-12.12	465.1	-34.29	-33.63	464.7	-37.4	-33.81	464.7	-36.45	-34.15
TENS-2	Mean		479.2			461.3			464.1			462.7		
Kips	Std. Dev.	0.67	23.33	23.13	2.96	18.58	17.19	7.03	20.81	19.58	7.04	19.78	18.46	7.05
	Max	3.47	547.6	66.8	11.76	526.5	51.47	19.76	536.4	62.96	21.39	536.4	64.4	21.66
	Min	-2.68	410.8	-68.18	-13.54	393.3	-66.64	-25.62	404.5	-49.29	-23.78	393.3	-68	-23.87
TENS-3	Mean		406.1			409.5			407.5			408.5		
Kips	Std. Dev.	0.64	23.65	23.57	1.88	17.69	16.97	4.98	18.71	18.01	5.05	18.23	17.53	5.01
	Max	2.31	475	69.48	10.48	456.8	39.82	18.52	461	47.62	20.81	461	46.67	20.97
	Min	-2.43	329.6	-72.71	-23.78	346.1	-52.42	-14.39	336.1	-67.96	-17.49	336.1	-68.98	-17.32
TENS-4	Mean		353.9			377.9			379.9			378.9		
Kips	Std. Dev.	0.54	15.23	14.91	3.09	17.29	14.3	9.71	18.59	15.63	10.07	17.98	15.01	9.89
	Max	2.05	392	32.94	10.29	420	34.08	34.19	428.9	35.26	34.85	428.9	36.5	35.04
	Min	-1.95	312.6	-38.83	-10.35	313.2	-52.28	-27.14	311.1	-60.4	-33.14	311.1	-59.47	-33.02
TENS-5	Mean		391.9			411.7			413.4			412.6		
Kips	Std. Dev.	0.56	26.13	26.04	2.12	19.39	18.65	5.28	21.07	20.37	5.38	20.27	19.55	5.34
	Max	1.94	473.8	82.6	12.68	475.9	64.49	21.58	468.5	50.42	19.98	475.9	63.47	23.67
	Min	-2.03	320.3	-70.83	-6.89	348.1	-52.02	-16.22	346.4	-61.8	-18.07	346.4	-61.01	-21.35
TENS-6	Mean		482			481.8			487			484.4		
Kips	Std. Dev.	0.49	25.41	25.32	2.08	19.59	18.74	5.67	20.66	19.87	5.64	20.3	19.5	5.64
	Max	1.98	564.6	80.57	21.43	550.7	55.37	19.21	564.9	75.08	17.08	564.9	77.78	20.18
	Min	-2.14	409.9	-68.9	-6.87	427.9	-42	-18.95	430.1	-52.68	-21.17	427.9	-50.11	-20.7
TETHER	Mean		1913			1837			1834			1836		
Kips	Std. Dev.	41.58	117.7	64.9	98.17	188.6	39.11	184.5	194.1	41.08	189.7	191.4	40.1	187.1
	Max	138.2	2449	341.9	388.8	2600	203	729.5	2826	196.8	911.3	2826	206	905.8
	Min	-133.5	1493	-102.6	-372.5	1257	-64.46	-599.4	1246	-75.93	-644.2	1246	-76.26	-645.4
REL. MOT.	Mean		2.48			1.22			1			1.11		
Ft	Std. Dev.	2.19	5.84	1.15	5.73	11.46	1.44	11.36	11.73	1.58	11.62	11.6	1.51	11.49
	Max	11.07	30.68	4.38	24.74	48.44	5.34	45.48	47.1	5.62	44.41	48.44	5.52	45.39
	Min	-7.37	-17.17	-2.77	-18.42	-30.14	-3.77	-32.44	-36.43	-4.56	-37.52	-36.43	-4.81	-37.52
RUNUP	Mean		2.26			4.4			3.91			4.16		
Ft	Std. Dev.		6.24			12.28			12.42			12.35	1.23	12.28
	Max		33.05			63.82			62.84			63.82	5.38	56.38
	Min		-17.21			-28.4			-28.72			-28.72	-2.87	-36.29
OFFSET FORCE	Mean		44.74			5.13			86.46					
Kips	Std. Dev.		0.09			0.35			0.05					
	Max		45.16			5.55			86.77					
	Min		44.32			4.38			86.27					

CONFIGURATION L - ALL MOORING LINES INTACT
TEST RESULTS SUMMARY

		Waves, Wind & Current											
		lrcw2			lrcw3			lrcw4			lrcw3&4		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	18.95	0.84	18.92	39.01	1.24	38.98	37.98	1.39	37.94	38.53	1.82	38.46
Ft	Std. Dev.	4.74	0.21	4.73	9.75	0.31	9.74	9.5	0.35	9.49	9.63	0.46	9.62
	Max	19.71	1.17	18.94	42.07	2.85	40.95	42.93	1.06	42.82	42.93	2.36	42.62
	Min	-15.55	-0.56	-16.16	-29.99	-0.9	-29.71	-30.66	-3.91	-29.67	-30.66	-2.87	-29.62
WIND	Mean	41.6			84.79			85.21			84.97		
Knots	Std. Dev.	4.91	4.15	2.58	9.5	6.8	6.62	9.67	7.18	6.47	9.59	6.99	6.54
	Max	59.76	14.51	8.02	120.59	21.56	22.35	120.12	19.18	25.27	120.59	21.31	25.33
	Min	26.07	-11.72	-9.04	58.79	-15.34	-26.27	51.64	-24.72	-23.24	51.64	-24.57	-26.11
CUR 1	Mean	5.36			4			4.03			4.02		
Ft/Sec	Std. Dev.	1.54	1.08	1.08	2.38	0.8	2.2	2.38	0.74	2.23	2.38	0.77	2.21
	Max	11.06	2.79	3.7	11.73	2.19	8.26	12.79	1.87	7.81	12.79	2.17	8.23
	Min	-0.06	-3.57	-4.15	-5.71	-2.14	-7.82	-4.87	-2.41	-8.68	-5.71	-2.38	-8.68
CUR 2	Mean	-0.29			1.96			1.78			1.87		
Ft/Sec	Std. Dev.	0.49	0.44	0.2	1.01	0.9	0.44	0.95	0.84	0.44	0.98	0.88	0.44
	Max	1.53	1.01	1.11	5.34	2.65	1.98	5.07	2.54	2.27	5.34	2.72	2.27
	Min	-2.07	-1.27	-1.37	-1.2	-2.09	-1.89	-1.45	-2.04	-2.22	-1.45	-2.13	-2.21
SURGE_CG	Mean	-55.25			-77.99			-76.61			-77.3		
Ft	Std. Dev.	10.1	10	1.44	9.98	9.25	3.73	10.65	9.97	3.74	10.34	9.64	3.73
	Max	-17.12	36.85	15.58	-45.91	27.5	18.75	-45.59	26.65	14	-45.59	27.38	17.63
	Min	-84.97	-27.82	-16.48	-108	-25.11	-20.98	-107.8	-24.11	-12.93	-108	-25.88	-16.9
HEAVE_CG	Mean	-0.63			-0.84			-0.74			-0.79		
Ft	Std. Dev.	0.5	0.48	0.14	0.78	0.69	0.36	0.73	0.63	0.38	0.76	0.66	0.37
	Max	0.7	1.24	0.48	1.13	1.22	1.41	1.07	1.27	1.78	1.13	1.32	1.77
	Min	-2.47	-1.71	-0.49	-4.72	-2.97	-1.31	-4.43	-2.38	-1.74	-4.72	-3.02	-1.75
SWAY_CG	Mean	-6.28			3.43			6.21			4.82		
Ft	Std. Dev.	12.87	12.85	0.78	14.08	14.04	1.02	12.6	12.57	0.89	13.43	13.4	0.95
	Max	30.38	36.45	13.14	39.09	34.97	9.62	48.03	40.92	5.13	48.03	42.26	10.47
	Min	-39.91	-32.94	-14.05	-32.99	-35.72	-7.06	-26.04	-32.9	-4.57	-32.99	-37.09	-9.24
ROLL	Mean	-0.38			-0.02			-0.16			-0.09		
deg	Std. Dev.	1.79	1.79	0.12	1.14	1.13	0.15	0.99	0.98	0.14	1.07	1.06	0.15
	Max	4.28	4.63	1.32	3.05	3.17	1.17	3.51	3.7	0.6	3.51	3.64	0.98
	Min	-5.32	-4.87	-1.54	-3.87	-3.55	-0.68	-3.4	-3.22	-0.69	-3.87	-3.48	-1.62
YAW	Mean	0.37			-0.12			0.25			0.07		
deg	Std. Dev.	0.95	0.74	0.63	1.92	1.57	1.13	1.94	1.69	1.07	1.94	1.64	1.09
	Max	3.45	1.99	1.86	6.43	5.84	3.77	6.72	5.83	4.23	6.72	5.97	4.3
	Min	-2.67	-2.18	-1.95	-5.44	-4.26	-3.57	-5.4	-5.12	-3.44	-5.44	-4.95	-3.71
PITCH	Mean	-0.08			-1.43			-1.72			-1.58		
deg	Std. Dev.	0.78	0.74	0.26	1.69	1.57	0.63	1.7	1.57	0.64	1.7	1.57	0.64
	Max	2.26	1.93	0.94	3.52	4.11	2.14	3.34	4.72	2.38	3.52	4.57	2.35
	Min	-2.9	-2.29	-0.79	-6.2	-3.99	-1.93	-7.44	-4.86	-2.16	-7.44	-4.97	-2.25
TENS-1	Mean	560.2			626.8			626.2			626.5		
Kips	Std. Dev.	18.61	18.2	3.8	24.8	22.57	10.27	25.75	23.64	10.22	25.28	23.09	10.28
	Max	618	54.86	33.05	719.5	64.66	30.31	715.5	75.25	34.46	719.5	74.65	45.65
	Min	490.1	-66.74	-32.52	543.8	-62.4	-50.71	552.3	-63.66	-36.11	543.8	-63.72	-60.39
TENS-2	Mean	495.8			518.8			515			516.9		
Kips	Std. Dev.	23.85	23.54	3.77	27.62	26.33	8.33	25.61	24.28	8.19	26.7	25.39	8.28
	Max	565.2	63.59	15.52	608.9	69.12	23.71	590.9	68.96	29.88	608.9	71.07	36.7
	Min	428.3	-63.17	-15.42	442.3	-70.39	-43.66	445.5	-59.26	-27.42	442.3	-68.43	-55.17
TENS-3	Mean	386.3			349.3			343.3			346.3		
Kips	Std. Dev.	21.31	21.18	2.16	22.29	21.8	4.66	21.35	20.81	4.75	22.03	21.52	4.71
	Max	440.7	52.66	26.07	408.6	54.06	15.16	410.2	68.5	19.67	410.2	65.66	19.71
	Min	313.2	-69.05	-27.01	275.7	-63.34	-15.43	258.5	-73.91	-17.26	258.5	-76.85	-18.43
TENS-4	Mean	315.5			255.9			256.4			256.2		
Kips	Std. Dev.	18.97	18.66	3.38	24.48	22.4	9.89	26.18	24.17	10.05	25.35	23.29	10.01
	Max	385.4	67.76	32.19	334.8	65.27	42.96	332.1	64.34	33.52	334.8	65.24	52.28
	Min	259.7	-53.97	-35.54	170.6	-65.81	-30.28	165.5	-81.76	-32.96	165.5	-81.01	-43.85
TENS-5	Mean	375			360.6			365.5			363.1		
Kips	Std. Dev.	24.76	24.68	1.94	25.19	24.62	5.3	22.99	22.34	5.42	24.24	23.63	5.37
	Max	453.3	77.55	8.58	425.1	61.58	23.15	428.6	56.31	18.22	428.6	59.3	29.39
	Min	306.3	-63.45	-6.44	288.2	-62.97	-16.93	304	-55.98	-18.45	288.2	-65.59	-19.92
TENS-6	Mean	501.6			555.9			561.9			558.9		
Kips	Std. Dev.	22.62	22.45	2.79	23.85	22.84	6.87	23.4	22.5	6.53	23.82	22.87	6.71
	Max	576	71.76	35.39	634.9	72.99	20.76	645.9	74.8	23.26	645.9	77.85	29.19
	Min	443.1	-55.94	-36.83	484.8	-60.3	-32.73	490.7	-72.57	-22.15	484.8	-69.64	-35.02
TETHER	Mean	1926			2088			2078			2083		
Kips	Std. Dev.	118.5	51.35	106.8	257.9	80.16	245.1	265.1	88.03	250	261.5	84.32	247.5
	Max	2332	200.5	400.1	3141	329.7	864.2	3116	407.5	770.2	3141	400.7	863.9
	Min	1566	-108.1	-370.9	1303	-178.7	-798.9	1330	-231.5	-772.3	1303	-238.3	-802.9
REL. MOT.	Mean	1.99			0.21			-0.31			-0.05		
Ft	Std. Dev.	5.98	1.44	5.8	11.81	2.75	11.48	11.72	2.62	11.42	11.77	2.69	11.45
	Max	24.65	4.41	21.25	51.37	8.07	45.11	42.7	9.34	45.3	51.37	9.04	45.43
	Min	-17.54	-4.08	-19.06	-34.61	-6.66	-32.23	-36.46	-7	-35.67	-36.46	-7.11	-35.92
RUNUP	Mean	1.22			3.04			2.4			2.72		
Ft	Std. Dev.	6.49			12.22			11.98			12.1	1.44	12
	Max	36.47			58.5			58.49			58.5	6.61	54.44
	Min	-19.02			-28.3			-28.65			-28.65	-3.3	-37.4
OFFSET FORCE	Mean	44.89			85.24			85.94					
Kips	Std. Dev.	0.16			0.24			0.05					
	Max	45.33			85.44			86.27					
	Min	44.66			84.77			85.77					

CONFIGURATION M - LATERAL RESTRAINT
TEST RESULTS SUMMARY

		Current only						Wind only					
		mcur2			mcur3			mwin3			mwin4		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	0.27	0.21	0.16	0.22	0.19	0.1	1.79	0.59	1.5	1.79	0.57	1.5
Ft	Std. Dev.	0.07	0.05	0.04	0.05	0.05	0.03	0.45	0.15	0.38	0.45	0.14	0.37
	Max	0.26	0.13	0.18	-0.08	0.1	0.11	1.78	0.39	1.27	1.5	0.4	1.21
	Min	-0.28	-0.14	-0.18	-0.41	-0.12	-0.1	-1.28	-0.36	-1.36	-1.85	-0.32	-1.19
WIND	Mean	0.03			0.03			86.09			84.91		
Knots	Std. Dev.	0.13	0.08	0.07	0.15	0.07	0.08	9.25	7.28	5.72	9.04	7.31	5.29
	Max	0.27	0.09	0.31	0.26	0.18	0.29	120	21.36	19.41	114.38	19.96	17.72
	Min	-0.41	-0.22	-0.29	-0.25	-0.14	-0.3	55.12	-17.22	-18.18	56.66	-20.38	-18.48
CUR 1	Mean	5.75			3.35			-0.08			-0.09		
Ft/Sec	Std. Dev.	1.1	0.85	0.65	0.91	0.79	0.42	0.78	0.05	0.48	0.77	0.06	0.49
	Max	9.59	2.43	2.63	6.63	2.79	1.66	2.7	0.15	1.71	2.53	0.15	2.05
	Min	1.5	-2.55	-2.84	0.53	-2.2	-1.78	-2.94	-0.16	-1.73	-2.82	-0.14	-1.79
CUR 2	Mean	0.2			0.32			0.09			0.13		
Ft/Sec	Std. Dev.	0.63	0.59	0.21	0.48	0.46	0.12	0.14	0.05	0.11	0.14	0.06	0.1
	Max	3.18	2.2	1.08	2.47	1.57	0.92	0.66	0.14	0.38	0.79	0.2	0.5
	Min	-2.4	-1.78	-1.46	-0.8	-0.89	-0.77	-0.38	-0.12	-0.37	-0.52	-0.17	-0.43
SURGE_CG	Mean	-29.55			-17.76			-43.3			-40.8		
Ft	Std. Dev.	6.17	6.17	0.13	3.64	3.64	0.07	12.54	12.53	0.66	11.26	11.24	0.65
	Max	-9.16	20.33	2.58	-8.44	9.25	1.32	-11.55	31.37	2.97	-11.47	28.74	2.13
	Min	-43.59	-14.01	-1.59	-26.21	-8.45	-0.84	-75.63	-32.8	-9.04	-71.27	-30.73	-10.94
HEAVE_CG	Mean	-0.33			-0.15			0.27			0.3		
Ft	Std. Dev.	0.21	0.21	0.02	0.11	0.11	0.02	0.64	0.56	0.31	0.64	0.55	0.33
	Max	0.29	0.56	0.1	0.14	0.27	0.09	1.75	0.99	1.34	1.64	1.04	1.07
	Min	-1.11	-0.75	-0.09	-0.52	-0.35	-0.07	-2.94	-2.37	-1.49	-2.91	-2.17	-1.22
SWAY_CG	Mean	-1.12			-0.98			-0.01			0.47		
Ft	Std. Dev.	0.52	0.28	0.44	0.28	0.16	0.18	1.38	0.63	1.23	1.63	0.64	1.49
	Max	0.91	0.77	1.39	2.63	0.49	1.66	9.48	2.97	4.68	6.62	4.2	5.16
	Min	-3.11	-0.82	-1.47	-4.66	-0.62	-2.24	-5.95	-1.54	-4.27	-5.28	-1.72	-4.9
ROLL	Mean	-0.12			-0.13			0.02			0.12		
deg	Std. Dev.	0.04	0.02	0.04	0.01	0.01	0.01	0.13	0.09	0.09	0.13	0.09	0.09
	Max	0.02	0.07	0.12	-0.08	0.03	0.04	0.65	0.38	0.43	0.9	0.45	0.33
	Min	-0.26	-0.05	-0.12	-0.19	-0.05	-0.03	-0.43	-0.23	-0.37	-0.31	-0.22	-0.32
YAW	Mean	-0.07			-0.11			-0.49			-0.95		
deg	Std. Dev.	0.17	0.07	0.15	0.07	0.03	0.06	1.59	0.74	1.41	1.87	0.69	1.74
	Max	0.47	0.17	0.45	0.14	0.13	0.19	3.98	1.92	4.16	4.7	2.28	5.92
	Min	-0.62	-0.28	-0.43	-0.33	-0.09	-0.19	-5.54	-2.62	-4	-7.9	-2.04	-6.17
PITCH	Mean	0.29			0.23			-2.3			-2.21		
deg	Std. Dev.	0.36	0.36	0.02	0.19	0.19	0.01	1.78	1.77	0.15	1.78	1.77	0.15
	Max	1.46	1.17	0.07	0.92	0.69	0.04	3.25	5.57	0.45	2.71	5.07	0.4
	Min	-0.88	-1.16	-0.08	-0.3	-0.53	-0.04	-7.63	-5.06	-0.55	-7.99	-5.5	-0.69
TENS-1	Mean	511.1			481.7			555.7			549.5		
Kips	Std. Dev.	10.8	10.76	0.84	6.79	6.77	0.48	26.74	26.56	3.07	25.12	24.88	3.46
	Max	538.5	23.8	3.8	498.3	15.16	3.11	626.2	71.98	9.57	619.5	70.07	13.37
	Min	475.5	-35.23	-3.51	466.1	-14.48	-3.08	497.4	-60.15	-9.55	474.2	-75.07	-12.64
TENS-2	Mean	476.3			459.3			495.5			492.4		
Kips	Std. Dev.	4.45	4.19	1.31	2.63	2.49	0.62	16.92	16.26	4.66	16.52	15.56	5.49
	Max	490.3	11.17	5.06	467.4	7.21	3.47	544.4	50.81	13.38	539.4	47.53	18.04
	Min	460.2	-14.53	-4.17	452.1	-5.54	-2.54	452.1	-42.36	-13.34	446.2	-51.89	-17.52
TENS-3	Mean	413.3			425.5			391.3			392.4		
Kips	Std. Dev.	5.18	5.09	0.78	3.26	3.17	0.54	12.45	12.31	1.77	12.06	11.91	1.85
	Max	431.9	16.91	3.36	435.2	7.88	2.28	423.5	31.02	5.94	428.9	35.65	5.31
	Min	400.8	-11.44	-3.42	416.8	-7.66	-2.17	354.7	-32.68	-7.16	353.5	-34.92	-11.3
TENS-4	Mean	377.6			401.8			322			327.7		
Kips	Std. Dev.	10.94	10.94	0.33	6.74	6.73	0.22	27.97	27.89	2.17	26.66	26.58	2.02
	Max	414.7	36.81	3.6	417.8	15.56	2.85	386.2	65.23	6.51	406.5	80.53	5.73
	Min	352.9	-24.54	-3.27	386.9	-14.55	-1.66	242	-78.06	-11.2	246.8	-78.21	-12.82
TENS-5	Mean	404.9			416.5			381			382.9		
Kips	Std. Dev.	6.09	6.04	0.73	3.9	3.86	0.41	12.7	12.63	1.33	12.15	12.07	1.43
	Max	424.2	18.64	2.45	427.2	9.63	1.6	411.9	31	4.18	419.8	37.59	4.26
	Min	390	-12.96	-2.39	406.7	-8.48	-1.58	342.4	-36.18	-4.6	345	-36.07	-4.76
TENS-6	Mean	476.3			459.4			497.1			494.9		
Kips	Std. Dev.	6.39	6.36	0.52	3.9	3.87	0.35	15.14	14.82	3.11	14.15	13.67	3.64
	Max	491.5	14.47	2	469.2	9.1	1.26	537.5	42.09	9.32	533.4	39.74	13.21
	Min	454.6	-20.93	-1.81	450.1	-8.19	-1.52	463.3	-32.39	-8.28	457.4	-39.55	-11.58
TETHER	Mean	1806			1795			2015			2009		
Kips	Std. Dev.	18.19	18.06	2.13	6.26	6.11	1.31	232.4	106.4	206.7	245.9	111.6	219.2
	Max	1888	75.71	8.49	1820	22.08	5.61	2886	446.5	845.2	2877	590	711.3
	Min	1773	-30.19	-9.54	1780	-13.54	-4.68	1284	-213	-689.6	1298	-238.8	-625.9
REL. MOT.	Mean	-0.26			0.03			-1.42			-1.84		
Ft	Std. Dev.	0.65	0.65	0.08	0.33	0.32	0.04	2.85	2.8	0.54	2.87	2.82	0.53
	Max	1.9	2.18	0.37	1.22	1.17	0.19	9.55	9.98	2.02	8.74	9.54	2.24
	Min	-2.45	-1.93	-0.36	-0.97	-0.93	-0.19	-7.74	-6.74	-2	-8.11	-7.27	-1.77
RUNUP	Mean	4.36			3.42			-1.85			-3.23		
Ft	Std. Dev.	0.24			0.1			0.91			0.82		
	Max	5.09			3.81			2.81			1.25		
	Min	3.66			3.13			-4.61			-5.69		
OFFSET FORCE	Mean	-3.26			-0.9			-0.11			-0.37		
Kips	Std. Dev.	0.16			0.11			0.13			0.15		
	Max	-2.68			-0.51			0.47			-0.03		
	Min	-3.68			-1.34			-0.7			-1.03		

CONFIGURATION M - LATERAL RESTRAINT
TEST RESULTS SUMMARY

		Waves & Current											
		mrc2			mrc3			mrc4			mrc3&4		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	18.84	0.48	18.82	38.96	1.52	38.92	39.36	1.46	39.32	39.16	1.57	39.11
Ft	Std. Dev.	4.71	0.12	4.71	9.74	0.38	9.73	9.84	0.37	9.83	9.79	0.39	9.78
	Max	20.18	0.51	19.81	41.87	2.05	38.58	44.56	1.83	42.32	44.56	3.07	42.35
	Min	-14.54	-0.41	-14.65	-28.08	-0.75	-28.36	-30.04	-0.91	-30.55	-30.04	-1.12	-30.6
WIND	Mean	-0.11			0.16			0.2			0.18		
Knots	Std. Dev.	0.16	0.1	0.08	0.15	0.07	0.08	0.14	0.07	0.08	0.14	0.08	0.08
	Max	0.04	0.15	0.29	1.09	0.27	0.59	0.95	0.52	0.3	1.09	0.54	0.6
	Min	-0.47	-0.19	-0.31	-0.27	-0.22	-0.41	-0.25	-0.26	-0.44	-0.27	-0.25	-0.44
CUR 1	Mean	4.65			4.22			4.05			4.13		
Ft/Sec	Std. Dev.	1.66	1.25	1.08	2.35	0.77	2.21	2.41	0.76	2.29	2.38	0.77	2.25
	Max	9.98	4.06	3.64	11.88	1.96	6.89	12	1.96	7.82	12	2.06	7.79
	Min	-0.91	-3.53	-4.74	-4.87	-2.42	-8.09	-5.76	-2.48	-8.36	-5.76	-2.52	-8.35
CUR 2	Mean	0.92			2.89			3.17			3.03		
Ft/Sec	Std. Dev.	0.91	0.86	0.28	0.96	0.86	0.42	1.04	0.92	0.49	1.01	0.9	0.46
	Max	4.26	2.44	1.5	6.66	2.86	1.67	6.7	2.08	2	6.7	2.72	2
	Min	-1.09	-1.5	-1.37	-0.38	-2.16	-1.74	-1.86	-2.95	-3	-1.86	-2.81	-2.97
SURGE_CG	Mean	-37.6			-27.37			-26.61			-26.99		
Ft	Std. Dev.	7.67	7.55	1.34	5.74	4.41	3.67	6.26	5.03	3.72	6.02	4.74	3.7
	Max	-17.34	18.52	4.63	-9.6	11.95	12.54	-10.26	11.5	12.56	-9.6	11.89	12.66
	Min	-61.47	-21.4	-4.88	-46.41	-13.09	-9.85	-48.72	-17.65	-11.95	-48.72	-17.27	-11.86
HEAVE_CG	Mean	-0.54			-0.41			-0.36			-0.38		
Ft	Std. Dev.	0.34	0.31	0.12	0.39	0.29	0.26	0.41	0.31	0.27	0.4	0.3	0.27
	Max	0.4	0.78	0.4	0.75	0.74	1.04	0.82	0.85	0.95	0.82	0.87	1.04
	Min	-1.82	-1.1	-0.44	-2.02	-1.14	-0.95	-2.59	-1.55	-1.07	-2.59	-1.52	-1.06
SWAY_CG	Mean	-1.35			-1.43			-1.48			-1.45		
Ft	Std. Dev.	1.45	0.37	1.4	1.7	0.27	1.67	1.7	0.28	1.67	1.7	0.28	1.67
	Max	4.32	1.37	5.82	4.94	0.85	5.99	4.7	0.92	5.8	4.94	0.89	5.97
	Min	-5.9	-1.23	-4.55	-7.78	-0.79	-6.25	-6.78	-0.93	-5.75	-7.78	-1.03	-6.25
ROLL	Mean	-0.16			-0.19			-0.19			-0.19		
deg	Std. Dev.	0.31	0.03	0.31	0.42	0.02	0.42	0.42	0.02	0.42	0.42	0.02	0.42
	Max	1.01	0.07	1.13	1.42	0.1	1.61	1.31	0.09	1.46	1.42	0.1	1.61
	Min	-1.27	-0.11	-1.14	-1.74	-0.13	-1.55	-1.59	-0.09	-1.39	-1.74	-0.15	-1.55
YAW	Mean	0.04			-0.04			-0.13			-0.08		
deg	Std. Dev.	0.35	0.07	0.34	0.44	0.09	0.43	0.45	0.1	0.44	0.45	0.1	0.43
	Max	1.25	0.21	1.26	1.63	0.29	1.79	1.44	0.39	1.58	1.63	0.34	1.73
	Min	-1.12	-0.24	-1.1	-1.72	-0.25	-1.52	-1.83	-0.36	-1.75	-1.83	-0.41	-1.74
PITCH	Mean	0.49			0.51			0.41			0.46		
deg	Std. Dev.	0.64	0.58	0.26	0.9	0.66	0.61	0.94	0.71	0.62	0.92	0.68	0.61
	Max	2.42	1.67	0.95	3.44	2.01	1.9	3.86	2.88	2.08	3.86	2.82	2.09
	Min	-1.77	-2.03	-0.92	-2.88	-2.08	-1.67	-3.2	-2.33	-1.88	-3.2	-2.38	-1.87
TENS-1	Mean	525.8			499.5			500			499.7		
Kips	Std. Dev.	13.99	13.62	3.17	13.64	9.86	9.4	14.61	11.05	9.55	14.14	10.47	9.48
	Max	568.9	38.8	12.13	547.9	35.2	25.6	551.5	42.62	28.39	551.5	42.93	28.16
	Min	480	-41.9	-11.69	457.2	-30.34	-31.71	461.6	-27.42	-31.46	457.2	-30.71	-31.33
TENS-2	Mean	482.3			468.2			469.9			469		
Kips	Std. Dev.	7.4	6.75	2.94	9.3	6.45	6.67	9.79	7.13	6.66	9.59	6.84	6.67
	Max	507.9	22.8	9.93	500.2	23.41	18.87	505.6	25.2	21.12	505.6	26.07	21.09
	Min	455.7	-22.93	-11.5	439	-19.12	-25.27	444.4	-18.09	-22.77	439	-19.99	-24.31
TENS-3	Mean	406.7			417.2			417.6			417.4		
Kips	Std. Dev.	6.84	6.45	2.2	6.84	4.47	5.15	7.51	5.05	5.54	7.18	4.77	5.34
	Max	428.1	18.91	8.19	442.3	14.6	18.65	438.6	12.91	20.37	442.3	14.45	20.28
	Min	383.2	-19.3	-8.53	393.7	-15.29	-17.79	390.4	-19.52	-17.65	390.4	-19.32	-17.79
TENS-4	Mean	362.1			384.6			385.5			385		
Kips	Std. Dev.	14.62	14.28	3.13	14.09	10.1	9.82	15.35	11.56	10.09	14.74	10.86	9.96
	Max	409.2	43.45	10.63	430.5	31.74	31.71	426.7	30.26	32.66	430.5	31.31	32.49
	Min	316.1	-40.36	-11.63	335.4	-36.89	-27.49	332.3	-44.05	-32.14	332.3	-43.64	-31.9
TENS-5	Mean	397.9			407.7			407.9			407.8		
Kips	Std. Dev.	7.24	6.93	2.07	6.69	4.64	4.81	7.06	5.24	4.73	6.88	4.95	4.77
	Max	420.2	18.76	7.32	427.7	13.49	18.66	427.7	12.38	18.98	427.7	13.37	18.87
	Min	373	-20	-7.45	383.9	-17.9	-15.49	380.4	-19.97	-16.64	380.4	-19.93	-16.87
TENS-6	Mean	485.2			469.4			469.9			469.6		
Kips	Std. Dev.	8.51	8.11	2.58	8.3	5.3	6.38	8.9	6.02	6.54	8.6	5.67	6.46
	Max	510.6	23.71	10.25	496.1	17.63	21.08	497.9	23.68	19.9	497.9	23.94	21.06
	Min	459.6	-23.56	-9.6	442.8	-17.4	-20.49	446.4	-15.34	-21.25	442.8	-17.65	-21.13
TETHER	Mean	1836			1825			1827			1826		
Kips	Std. Dev.	105.9	28.9	101.9	193.3	22.99	192	196.1	25.61	194.5	194.7	24.31	193.2
	Max	2231	108.6	378.7	2530	93.38	697.3	2805	135.6	915.7	2805	137.5	908.6
	Min	1484	-52.99	-354.3	1252	-52.44	-589.6	1252	-71.61	-625.2	1252	-70.6	-628
REL. MOT.	Mean	-0.29			0.85			0.64			0.74		
Ft	Std. Dev.	6.37	1.12	6.26	11.51	1.25	11.44	11.45	1.27	11.37	11.48	1.25	11.41
	Max	27.52	3.34	26.65	53.3	4.8	45.54	46.13	5.39	45.08	53.3	5.27	45.62
	Min	-21.46	-3.8	-21.05	-32.61	-2.99	-32.26	-34.48	-4.05	-35.43	-34.48	-4.13	-35.53
RUNUP	Mean	5.57			5.19			5.39			5.29		
Ft	Std. Dev.	7.83			12.03			12.03			12.03		
	Max	49.11			63.22			63.75			63.75		
	Min	-17.25			-26.27			-26.53			-26.53		
OFFSET FORCE	Mean	-3.42			-1.28			-1.83					
Kips	Std. Dev.	0.14			0.14			0.15					
	Max	-3.02			-0.84			-1.18					
	Min	-3.85			-1.85			-2.35					

CONFIGURATION M - LATERAL RESTRAINT
TEST RESULTS SUMMARY

		Waves, Wind & Current								
		mrcw3			mrcw4			mrcw3&4		
		all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz	all f	f < 0.03 Hz	f > 0.03 Hz
WAVE	H1/3	38.48	1.2	38.44	38.51	1.65	38.46	38.5	1.65	38.45
Ft	Std. Dev.	9.62	0.3	9.61	9.63	0.41	9.61	9.63	0.41	9.61
	Max	44.46	2.28	40.43	41.22	1.19	39.54	44.46	1.43	40.39
	Min	-29.62	-0.81	-29.18	-29	-4.03	-29.55	-29.82	-2.59	-29.54
WIND	Mean	84.67			83.31			84.02		
Knots	Std. Dev.	9.49	6.91	6.53	9.72	7.33	6.37	9.63	7.15	6.44
	Max	114.44	20.49	22.48	117.22	17.65	26.02	117.22	20.86	25.9
	Min	56.18	-17.35	-19.72	52.33	-23.29	-20.29	52.33	-23.39	-22.28
CUR 1	Mean	4.02			3.88			3.95		
Ft/Sec	Std. Dev.	2.37	0.71	2.22	2.51	0.98	2.27	2.44	0.86	2.24
	Max	12.03	1.88	8.83	12.01	2.14	7.87	12.03	2.06	7.81
	Min	-4.63	-2.43	-8.28	-6.53	-3.17	-7.9	-6.53	-3.23	-8.28
CUR 2	Mean	2.27			2.7			2.48		
Ft/Sec	Std. Dev.	1.14	1.05	0.42	1.32	1.25	0.41	1.25	1.18	0.42
	Max	5.59	2.44	2.08	5.75	2.22	1.82	5.75	2.41	2.02
	Min	-0.85	-2.55	-2.4	-0.86	-2.8	-1.98	-0.86	-2.61	-2.32
SURGE_CG	Mean	-70.43			-67.28			-68.86		
Ft	Std. Dev.	8.79	7.96	3.72	8.49	7.6	3.79	8.78	7.94	3.76
	Max	-43.35	24.46	13.92	-42.03	20.97	17.65	-42.03	22.85	15.29
	Min	-110	-28.54	-11.72	-90.81	-18.54	-13.41	-110	-30.1	-14.5
HEAVE_CG	Mean	-0.29			-0.21			-0.25		
Ft	Std. Dev.	0.69	0.58	0.37	0.65	0.51	0.39	0.67	0.55	0.38
	Max	1.42	1.09	1.26	1.45	1.04	1.67	1.45	1.06	1.67
	Min	-4.3	-2.59	-1.57	-3.4	-1.93	-1.38	-4.3	-2.64	-1.56
SWAY_CG	Mean	-0.89			-0.87			-0.88		
Ft	Std. Dev.	1.82	0.58	1.72	1.84	0.65	1.72	1.83	0.62	1.72
	Max	7.09	1.94	6.97	6.81	2.31	7.26	7.09	2.27	7.2
	Min	-9.03	-1.95	-6.19	-6.42	-1.68	-5.37	-9.03	-2.01	-6.2
ROLL	Mean	-0.06			-0.05			-0.06		
deg	Std. Dev.	0.41	0.06	0.41	0.4	0.07	0.4	0.41	0.06	0.4
	Max	1.29	0.26	1.33	1.67	0.26	1.68	1.67	0.27	1.72
	Min	-1.48	-0.23	-1.36	-1.25	-0.17	-1.28	-1.48	-0.24	-1.36
YAW	Mean	-0.86			-0.85			-0.85		
deg	Std. Dev.	1.26	0.58	1.12	1.3	0.63	1.14	1.28	0.6	1.13
	Max	3.96	2.29	4.64	3.67	2	4.05	3.96	2.27	4.61
	Min	-4.92	-1.99	-3.85	-5.29	-1.95	-3.5	-5.29	-2	-3.82
PITCH	Mean	-1.78			-1.84			-1.81		
deg	Std. Dev.	1.59	1.45	0.65	1.58	1.44	0.65	1.58	1.45	0.65
	Max	3.23	4.44	2.04	2.66	4.41	2.31	3.23	4.48	2.28
	Min	-6.34	-3.83	-1.9	-7.05	-4.28	-2.12	-7.05	-4.32	-2.1
TENS-1	Mean	610.1			604.9			607.5		
Kips	Std. Dev.	22.14	19.77	9.97	21.94	19.34	10.34	22.19	19.73	10.17
	Max	712	74.4	32.79	669.1	54.29	34.91	712	77.24	36.23
	Min	540.8	-66.84	-34.67	534.1	-51.47	-36.64	534.1	-63.67	-35.38
TENS-2	Mean	527.5			526.1			526.8		
Kips	Std. Dev.	15.75	13.67	7.81	15.48	13.29	7.92	15.63	13.49	7.88
	Max	597.5	50.99	25.07	576.8	38.27	28.29	597.5	51.96	27.98
	Min	480.9	-43.79	-26.47	479.1	-37.41	-28.4	479.1	-42.32	-28.29
TENS-3	Mean	367.8			370.6			369.2		
Kips	Std. Dev.	10.29	8.82	5.29	10.17	8.54	5.49	10.33	8.8	5.39
	Max	401.3	28.25	18.52	402.5	22.6	18.52	402.5	26.71	18.65
	Min	322	-30.11	-18.17	332.5	-28.95	-21.71	322	-31.47	-23.91
TENS-4	Mean	273.9			280.2			277		
Kips	Std. Dev.	22.75	20.41	10.09	22.3	19.77	10.31	22.74	20.32	10.22
	Max	343.6	67.89	34.1	350.8	52.85	33.93	350.8	64.27	34.06
	Min	169.1	-75.8	-32.73	199.7	-62.26	-33.24	169.1	-78.91	-39.15
TENS-5	Mean	358.2			359.8			359		
Kips	Std. Dev.	10.36	8.98	5.17	10.09	8.66	5.17	10.26	8.85	5.17
	Max	391.4	29.87	19.25	390.9	23.61	20.52	391.4	28.85	20.62
	Min	311.3	-33.93	-15.85	318.7	-27.18	-18.8	311.3	-34.65	-18.72
TENS-6	Mean	532.3			528.9			530.6		
Kips	Std. Dev.	12.65	10.56	6.97	12.44	10.24	7.05	12.66	10.54	7.01
	Max	586.6	38.25	26.1	564.8	27	23.03	586.6	40.15	26.4
	Min	492	-35.07	-25.34	485.1	-26.41	-27.53	485.1	-32.95	-26.93
TETHER	Mean	2047			2036			2042		
Kips	Std. Dev.	258.5	70.65	248.6	287.6	74.68	277.7	273.5	72.94	263.5
	Max	3157	297.1	884.4	2977	320.1	979.2	3157	312.9	977.2
	Min	1289	-146.7	-789.8	1242	-142.1	-836	1242	-153.5	-839.7
REL. MOT.	Mean	-1.06			-1.25			-1.16		
Ft	Std. Dev.	11.5	2.47	11.23	11.54	2.35	11.3	11.52	2.4	11.26
	Max	42.35	8.52	41.39	43	7.93	46.21	43	8.67	46.29
	Min	-34.42	-5.79	-32.53	-36.66	-6.79	-37.25	-36.66	-6.57	-37.49
RUNUP	Mean	2.9			2.88			2.89		
Ft	Std. Dev.	11.57			11.3			11.44		
	Max	55.96			57.39			57.39		
	Min	-26.09			-25.42			-26.09		
OFFSET FORCE	Mean	-2.3			-2.62					
Kips	Std. Dev.	0.13			0.16					
	Max	-1.68			-2.01					
	Min	-2.85			-3.35					

Appendix C

Pre-Test Simulation Statistics

CONFIDENTIAL

		100 Year Storm Gulf of Mexico					100 Year Storm North Sea					10 Year Storm					Oprtns
TDSIM File		A1	A2	A3	A4	A5	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
OTRC DSIG		ARAN3	ACUR3	ARW3	AWIN3	ARWC3	ARAN5	ACUR5	ARW5	AWIN5	ARWC5	ARAN2	ACUR2	ARW2	AWIN2	ARWC2	ARAN1
Hs	Significant	43.4	0.0	43.9	0.0	43.9	46.6	0.0	46.1	0.0	4E1	21.3	0.0	21.4	0.0	21.4	8.4
(ft)	max H	67.8	0.0	78.6	0.0	78.6	72.3	0.0	96.2	0.0	8E2	36.1	0.0	34.8	0.0	34.8	13.0
Tp (sec)	W Period	14.1	0.0	14.1	0.0	14.1	16.2	0.0	16.2	0.0	1E2	10.8	0.0	10.8	0.0	10.8	7.6
Wind vel	mean	0.0	0.0	0.0	85.1	85.1	0.0	0.0	0.0	58.8	5E8	0.0	0.0	0.0	42.9	42.9	0.0
(kts) @755'	max	0.0	0.0	0.0	141.2	141.2	0.0	0.0	0.0	93.5	9E5	0.0	0.0	0.0	68.6	68.6	0.0
Current (ft/sec)	Surface	0.0	4.3	4.3	0.0	4.3	0.0	5.7	5.7	0.0	E7	0.0	6.3	6.3	0.0	6.3	0.0
Surge	mean	24.2	27.8	48.7	65.3	82.5	19.1	43.8	53.6	43.4	72.2	9.5	48.9	53.2	26.0	63.1	3.5
(ft)	rms	10.4	0.0	8.6	10.1	7.0	7.5	0.0	4.8	8.3	E0	3.4	0.0	2.3	7.8	3.2	1.1
	max	52.7	27.8	68.8	86.5	102.8	37.7	43.8	36.5	59.6	93.7	16.8	48.9	58.3	42.7	70.7	6.3
	min	-1.9	27.8	25.2	44.9	61.8	-0.4	43.8	38.3	25.7	53.7	2.0	48.9	47.4	13.4	55.4	1.0
Heave	mean	0.2	0.0	0.1	0.2	0.0	0.2	0.0	0.0	0.1	-C1	0.0	-0.1	-0.1	0.0	-0.1	0.0
(ft)	rms	1.6	0.0	0.9	0.8	1.0	3.7	0.0	1.3	0.2	11	0.2	0.0	0.3	0.1	0.2	0.0
	max	4.0	0.0	4.3	2.9	3.7	9.3	0.0	4.0	0.8	33	0.5	-0.1	0.6	0.3	0.5	0.1
	min	-4.0	0.0	-1.9	-1.7	-2.3	-9.2	0.0	-3.3	-0.6	-28	-0.4	-0.1	-0.8	-0.2	-0.7	-0.1
Pitch	mean	-0.4	-0.4	-0.9	-2.4	-3.2	-0.3	-0.6	-1.0	-1.2	-21	-0.2	-0.7	-0.9	-0.6	-1.5	-0.1
(deg)	rms	1.4	0.0	1.1	2.0	1.7	1.5	0.0	0.9	0.9	10	0.6	0.0	0.4	0.5	0.5	0.2
	max	4.0	-0.4	3.3	2.1	0.8	3.8	-0.6	1.6	1.0	C5	1.7	-0.7	0.3	0.4	-0.1	0.4
	min	-5.0	-0.4	-6.2	-6.5	-7.7	-6.0	-0.6	-5.2	-3.4	-E5	-1.6	-0.7	-2.0	-1.8	-3.0	-0.5
Air Gap	mean	59.3	59.6	58.7	56.9	55.3	59.3	59.3	58.5	58.6	5E9	59.8	59.1	58.8	59.3	57.9	59.9
(ft)	rms	11.6	0.0	11.6	2.3	11.8	13.1	0.0	12.3	1.0	12.4	5.6	0.0	5.6	0.6	5.6	2.2
@710' x -66.5'	max	98.2	59.6	98.1	61.9	96.2	98.2	59.3	99.2	61.2	93.6	77.0	59.1	80.6	60.6	77.1	67.6
	min	18.9	59.6	16.5	51.9	12.8	17.5	59.3	15.5	56.0	13.2	40.1	59.1	40.6	58.0	38.8	53.0
Air Gap	mean	60.2	60.4	60.6	62.3	62.4	60.0	60.7	30.6	61.3	616	60.1	60.8	60.8	60.7	61.3	60.1
(ft)	rms	11.4	0.0	11.4	2.2	11.3	12.9	0.0	12.1	1.0	120	5.5	0.0	5.5	0.6	5.5	2.1
@710' x +66.5'	max	96.8	60.4	104.7	67.6	103.5	99.9	60.7	107.3	63.8	10E1	78.6	60.8	77.9	62.2	78.7	67.4
	min	26.2	60.4	21.0	57.1	20.8	19.5	60.7	18.0	59.0	1E3	40.5	60.8	41.5	59.5	43.9	52.7
Mooring line 1	mean	1,021	1,001	890	799	706	1,048	916	865	916	763	1,098	889	866	1,010	812	1,130
(kips)	rms	56	0	46	53	38	44	0	27	43	33	18	0	12	41	17	6
@ fairlead,	max	1,175	1,001	1,017	906	827	1,181	916	950	1,012	869	1,142	889	899	1,079	854	1,145
downstream	min	867	1,001	780	679	586	930	916	784	832	638	1,056	889	838	919	770	1,116
Mooring line 2&4	mean	1,152	1,151	1,157	1,163	1,169	1,151	1,155	1,158	1,155	1,164	1,149	1,156	1,157	1,151	1,160	1,149
(kips)	rms	6	0	2	4	5	15	0	5	2	4	3	0	4	1	4	3
@ fairlead,	max	1,170	1,151	1,174	1,176	1,183	1,189	1,155	1,174	1,160	1,141	1,151	1,156	1,160	1,155	1,163	1,149
abeam	min	1,133	1,151	1,146	1,152	1,158	1,112	1,155	1,143	1,150	1,150	1,147	1,156	1,154	1,149	1,157	1,149
Mooring line 3	mean	1,284	1,299	1,552	2,010	2,693	1,254	1,395	1,648	1,457	2,190	1,201	1,511	1,634	1,291	1,916	1,168
(kips)	rms	67	0	185	294	441	44	0	135	134	196	19	0	64	42	88	6
@ fairlead,	max	1,637	1,299	2,060	2,979	4,487	1,364	1,395	2,106	1,804	3,740	1,243	1,511	1,777	1,398	2,144	1,182
upstream	min	1,137	1,299	1,279	1,438	1,849	1,135	1,395	1,353	1,290	1,642	1,155	1,511	1,464	1,220	1,703	1,153

		100 Year Storm Gulf of Mexico					100 Year Storm North Sea					10 Year Storm				
TDSIM File		B1	B2	B3	B4	B5	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19
OTRC DSIG		BRAN3	BCUR3	BRW3	BWIN3	BRWC3	BRAN5	BCUR5	BRW5	BWIN5	BRWC5	BRAN2	BCUR2	BRW2	BWIN2	BRWC2
Hs	Significant	43.4	0.0	43.9	0.0	43.9	46.6	0.0	46.1	0.0	46.1	21.3	0.0	21.4	0.0	21.4
(ft)	max H	67.8	0.0	78.6	0.0	78.6	72.3	0.0	86.2	0.0	86.2	36.1	0.0	34.8	0.0	34.8
Tp (sec)	W Period	14.1	0.0	14.1	0.0	14.1	16.2	0.0	16.2	0.0	16.2	10.8	0.0	10.8	0.0	10.8
Wind vel	mean	0.0	0.0	0.0	85.1	85.1	0.0	0.0	0.0	58.8	58.8	0.0	0.0	0.0	42.9	42.9
(kts) @755'	max	0.0	0.0	0.0	141.2	141.2	0.0	0.0	0.0	93.5	93.5	0.0	0.0	0.0	68.6	68.6
Current (ft/sec)	Surface	0.0	4.3	4.3	0.0	4.3	0.0	5.3	5.3	0.0	5.3	0.0	6.3	6.3	0.0	6.3
Surge	mean	24.7	28.6	49.0	65.1	82.1	19.5	44.4	53.7	43.7	71.8	9.8	49.1	53.4	26.7	63.0
(ft)	rms	10.4	0.1	8.4	9.9	7.0	7.5	0.2	4.7	8.5	5.9	3.4	0.2	2.3	7.7	3.2
	max	53.0	28.9	68.3	86.5	102.4	37.8	45.3	66.6	60.0	93.0	17.1	49.6	58.5	43.1	70.5
	min	-1.1	28.4	26.1	45.3	61.4	1.1	44.0	38.7	25.2	53.5	2.2	48.9	47.5	14.2	55.3
Heave	mean	0.2	0.0	0.1	0.2	0.1	0.3	0.0	0.1	0.1	0.0	0.0	0.0	-0.1	0.0	-0.1
(ft)	rms	1.3	0.0	0.9	0.8	1.0	3.1	0.2	1.3	0.2	1.2	0.2	0.0	0.3	0.1	0.2
	max	3.8	0.0	4.3	2.9	3.7	8.4	0.3	4.3	0.7	3.8	0.5	0.1	0.6	0.3	0.5
	min	-2.8	0.0	-2.1	-1.7	-2.3	-7.8	-0.3	-3.3	-0.5	-3.2	-0.4	-0.1	-0.7	-0.2	-0.6
Pitch	mean	-0.4	-0.4	-0.9	-2.4	-3.2	-0.3	-0.6	-1.0	-1.2	-2.1	-0.2	-0.7	-0.9	-0.6	-1.5
(deg)	rms	1.4	0.0	1.1	2.0	1.7	1.5	0.0	0.9	0.8	1.0	0.6	0.0	0.4	0.5	0.5
	max	4.0	-0.4	3.2	2.1	0.8	3.8	-0.5	1.6	1.0	0.5	1.7	-0.7	0.3	0.5	-0.1
	min	-4.9	-0.4	-6.1	-6.4	-7.7	-5.6	-0.6	-5.2	-3.4	-5.5	-1.6	-0.7	-2.0	-1.8	-3.0
Air Gap	mean	59.3	59.6	58.7	56.9	55.3	59.3	59.3	58.5	58.6	56.9	59.8	59.1	58.8	59.3	57.9
(ft)	rms	11.6	0.3	11.6	2.4	11.9	13.0	0.2	12.3	1.0	12.4	5.6	0.2	5.6	0.6	5.6
@710' x -66.5'	max	98.7	59.6	97.8	62.4	96.2	97.5	59.7	100.1	61.2	94.2	76.9	59.2	80.6	60.6	76.7
	min	17.1	59.6	16.3	51.8	12.5	17.5	59.0	15.5	56.0	13.2	40.3	59.0	40.9	57.9	39.1
Air Gap	mean	60.2	60.4	60.6	62.3	62.6	60.0	60.7	60.7	61.3	61.7	60.1	60.8	60.9	60.7	61.4
(ft)	rms	11.4	0.3	11.4	2.3	11.3	12.8	0.1	12.1	1.0	12.0	5.5	0.2	5.5	0.6	5.5
@710' x +66.5'	max	97.3	60.4	104.3	67.6	103.6	98.3	61.0	108.4	63.9	107.2	78.6	60.9	78.1	62.2	79.0
	min	26.7	60.4	21.0	57.4	20.8	21.0	60.3	17.9	59.0	16.3	40.4	60.7	41.2	59.5	43.9
Restraint line 2&4	mean	1,675	1,685	1,859	2,075	2,348	1,647	1,805	1,905	1,812	2,160	1,611	1,852	1,900	1,682	2,024
(kips)	rms	59	6	87	140	126	33	5	57	76	94	8	4	26	44	42
@ 375' above keel	max	1,879	1,686	2,104	2,443	2,797	1,782	1,813	2,132	1,975	2,597	1,635	1,856	1,957	1,801	2,140
abeam	min	1,600	1,682	1,665	1,828	1,976	1,600	1,801	1,748	1,666	1,891	1,600	1,849	1,832	1,620	1,925
Restraint line 6&8	mean	417	417	450	471	503	411	442	458	436	489	403	450	457	415	473
(kips)	rms	17	2	24	41	39	11	3	16	19	22	3	3	7	10	12
@ 36.7' below keel	max	502	419	575	611	627	462	444	531	503	553	412	451	483	447	506
abeam	min	400	415	407	403	429	400	441	427	403	437	400	449	441	401	446
Mooring line 1	mean	1,019	997	889	800	708	1,046	913	864	915	765	1,097	888	865	1,006	812
(kips)	rms	55	2	45	52	38	43	3	27	44	33	18	2	12	41	17
@ fairlead,	max	1,164	1,003	1,013	904	831	1,164	916	953	1,015	874	1,140	890	898	1,075	854
downstream	min	870	993	780	681	588	932	907	783	830	642	1,054	885	838	917	771
Mooring line 3	mean	1,288	1,304	1,557	2,006	2,667	1,256	1,399	1,652	1,464	2,180	1,202	1,518	1,639	1,295	1,916
(kips)	rms	67	4	184	288	433	43	1	135	139	192	19	3	65	42	88
@ fairlead,	max	1,624	1,308	2,047	2,986	4,457	1,367	1,416	2,115	1,809	3,697	1,245	1,529	1,778	1,403	2,139
upstream	min	1,136	1,299	1,281	1,444	1,844	1,148	1,391	1,360	1,286	1,633	1,158	1,509	1,472	1,225	1,700

		Regular Waves				Bichromatic Waves				
TDSIM File		B24	B26	B28	B30	B35	B37	B40	B42	B44
OTRC DSIG		BG2	BG4	BG6	BG8	BBC2	BBC3	BBC8	BBC10	BBC12
Hs	Significant	11.9	17.8	19.5	20.6	20.0/19.5	20.6/20.3	19.5/19.5	20.0/20.4	20.6/20.3
(ft)	max H	11.9	17.8	19.5	20.6	39.4	40.7	38.7	40.3	40.8
Tp (sec)	W Period	7.0	9.0	12.0	16.0	14.0/15.1	16.0/17.5	12.0/14.3	14.0/17.2	16.0/20.3
Wind vel	mean									
(kts) @755'	max									
Current (ft/sec)	Surface									
Surge	mean	-0.2	0.1	0.4	0.3	7.6	4.4	12.5	7.5	10.2
(ft)	rms	0.3	0.6	1.2	2.2	3.1	3.5	2.1	2.8	5.6
	max	0.2	1.0	2.1	3.3	11.5	10.7	15.5	12.2	23.3
	min	-0.6	-0.8	-1.3	-2.8	-0.1	-3.5	7.6	1.5	-2.4
Heave	mean	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.3	1.2
(ft)	rms	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.5	18.9
	max	0.0	0.0	0.1	0.3	0.4	0.9	1.5	1.6	33.6
	min	0.0	0.0	0.1	-0.1	-0.1	-0.3	-0.5	-0.8	-30.5
Pitch	mean	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.1	-0.1
(deg)	rms	0.1	0.3	0.4	0.6	0.6	0.7	2.1	1.8	4.7
	max	0.2	0.4	0.6	0.8	1.0	1.3	2.8	2.6	10.1
	min	-0.2	-0.4	-0.6	-0.8	-1.5	-1.6	-4.2	-3.8	-10.3
Air Gap	mean	60.0	59.9	59.8	59.9	59.6	59.7	59.5	59.6	59.4
(ft)	rms	4.4	6.6	7.2	7.6	10.2	10.9	10.5	10.8	22.8
@710' x -66.5'	max	66.2	69.3	70.1	70.8	80.5	81.7	77.7	79.2	106.8
	min	53.9	50.7	49.9	49.3	39.4	38.6	36.4	36.2	-3.1
Air Gap	mean	60.0	59.9	59.8	59.9	59.8	59.8	59.8	59.8	59.7
(ft)	rms	4.4	6.6	7.2	7.6	10.0	10.8	10.2	10.6	22.8
@710' x +66.5'	max	66.2	69.3	69.9	70.8	80.8	81.6	83.6	83.7	118.8
	min	53.9	50.7	50.1	49.3	40.2	39.1	43.3	42.5	18.2
Restraint line 2&4	mean	1,600	1,600	1,600	1,601	1,607	1,604	1,617	1,607	1,651
(kips)	rms	0	0	3	5	6	6	9	8	33
@ 375' above keel	max	1,600	1,600	1,601	1,602	1,615	1,615	1,642	1,628	1,775
abeam	min	1,600	1,600	1,600	1,600	1,600	1,600	1,607	1,601	1,600
Restraint line 6&8	mean	400	400	400	400	401	401	407	404	433
(kips)	rms	0	1	1	1	1	1	8	4	28
@ 36.7' below keel	max	400	400	400	400	403	402	422	413	572
abeam	min	400	400	400	400	400	400	400	400	400
Mooring line 1	mean	1,150	1,149	1,147	1,148	1,109	1,126	1,084	1,110	1,099
(kips)	rms	2	3	8	14	18	21	14	18	57
@ fairlead,	max	1,153	1,155	1,158	1,167	1,155	1,174	1,107	1,143	1,223
downstream	min	1,147	1,142	1,136	1,128	1,086	1,088	1,052	1,070	963
Mooring line 3	mean	1,148	1,149	1,151	1,151	1,190	1,173	1,218	1,191	1,208
(kips)	rms	3	4	8	14	18	21	14	18	61
@ fairlead,	max	1,151	1,156	1,163	1,170	1,213	1,211	1,253	1,230	1,325
upstream	min	1,145	1,143	1,140	1,131	1,145	1,127	1,194	1,162	1,081

		10 Year	Regular Waves									
File/Config		C15	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32
OTRC DSIG		CRAN2	CRG1	CRG2	CRG3	CRG4	CRG5	CRG6	CRG7	CRG8	CRG9	CRG10
Hs	Significant	21.3	6.0	11.9	15.3	17.8	20.6	19.5	20.0	20.6	20.9	19.9
(ft)	max H	36.1	6.0	11.9	15.3	17.8	20.6	19.5	20.0	20.6	20.9	19.9
Tp (sec)	W Period	10.8	6.0	7.0	8.0	9.0	10.0	12.0	14.0	16.0	17.0	21.0
Wind vel	mean	0.0										
(kts) @755'	max	0.0										
Current (ft/sec)	Surface	0.0										
Surge	mean	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(ft)	rms	1.1	0.1	0.3	0.5	0.7	1.0	1.3	1.9	2.7	3.2	5.0
	max	4.6	0.2	0.4	0.7	1.0	1.4	1.9	2.8	3.8	4.5	7.1
	min	-3.3	-0.2	-0.4	-0.7	-1.0	-1.4	-1.9	-2.7	-3.8	-4.4	-7.1
Heave	mean	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0
(ft)	rms	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	1.4
	max	0.4	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.5	2.1
	min	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.3	-2.0
Pitch	mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(deg)	rms	0.4	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.7
	max	1.2	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.0
	min	-1.7	-0.1	-0.2	-0.3	-0.4	-0.6	-0.7	-0.8	-0.9	-1.0	-1.0
Air Gap	mean	59.9	60.0	60.0	60.0	59.9	59.8	59.8	59.8	59.8	59.8	59.8
(ft)	rms	5.6	2.2	4.4	5.7	6.6	7.6	7.2	7.4	7.7	7.9	8.6
@710' x -66.5'	max	77.2	63.1	66.2	68.0	69.4	70.8	70.2	70.5	70.9	71.2	72.1
	min	38.9	56.9	53.8	52.0	50.7	49.2	49.8	49.5	49.2	48.9	47.9
Air Gap	mean	60.0	60.0	60.0	60.0	59.9	59.8	59.8	59.8	59.8	59.8	59.8
(ft)	rms	5.5	2.2	4.4	5.7	6.6	7.6	7.2	7.4	7.7	7.9	8.6
@710' x +66.5'	max	79.3	63.1	66.2	68.0	69.4	70.8	70.0	70.5	70.9	71.2	72.2
	min	42.2	56.9	53.8	52.0	50.7	49.2	50.0	49.5	49.2	49.0	47.9
Restraint line 1	mean	9,928	10,000	10,001	10,001	10,000	9,997	9,998	9,999	10,001	10,006	10,014
(kips)	rms	743	91	219	353	501	697	926	1,272	1,684	1,932	2,840
@ 375' above keel	max	12,340	10,120	10,310	10,500	10,710	10,990	11,290	11,800	12,390	12,720	14,020
downstream	min	6,813	9,877	9,691	9,503	9,292	9,012	8,707	8,200	7,619	7,273	6,019
Restraint line 2&4	mean	1,600	1,600	1,600	1,600	1,600	1,600	1,601	1,601	1,601	1,602	1,604
(kips)	rms	2	0	0	0	0	3	4	4	5	6	6
@ 375' above keel	max	1,604	1,600	1,600	1,600	1,600	1,601	1,601	1,601	1,603	1,603	1,607
abeam	min	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Restraint line 3	mean	10,074	10,000	9,999	9,999	10,001	10,004	10,003	10,005	10,004	10,000	9,994
(kips)	rms	744	91	219	353	501	698	926	1,272	1,685	1,932	2,840
@ 375' above keel	max	13,220	10,120	10,310	10,500	10,710	10,990	11,300	11,810	12,390	12,740	13,990
upstream	min	7,673	9,877	9,688	9,501	9,293	9,018	8,720	8,207	7,624	7,294	5,991
Restraint line 5	mean	2,521	2,500	2,500	2,500	2,500	2,501	2,501	2,501	2,500	2,500	2,501
(kips)	rms	155	29	68	103	137	176	186	184	150	120	107
@ 36.7' below keel	max	3,202	2,540	2,596	2,646	2,695	2,750	2,763	2,762	2,713	2,670	2,653
downstream	min	1,994	2,460	2,404	2,354	2,306	2,252	2,239	2,240	2,288	2,332	2,347
Restraint line 6&8	mean	400	400	400	400	400	400	400	400	400	400	400
(kips)	rms	1	0	0	0	1	1	1	1	1	1	1
@ 36.7' below keel	max	401	400	400	400	400	400	400	400	400	400	400
abeam	min	400	400	400	400	400	400	400	400	400	400	400
Restraint line 7	mean	2,479	2,500	2,500	2,500	2,500	2,499	2,499	2,499	2,500	2,500	2,499
(kips)	rms	155	29	68	103	137	176	187	184	150	120	107
@ 36.7' below keel	max	3,006	2,540	2,596	2,646	2,694	2,748	2,761	2,760	2,712	2,668	2,653
upstream	min	1,798	2,460	2,404	2,354	2,305	2,250	2,237	2,238	2,287	2,330	2,347

		Bichromatic Waves													
		C33	C34	C35	C36	C37	C38	C39	C40	C41	C42	C43	C44	C45	C52
		CBC1	CBC2	CBC3	CBC4	CBC5	CBC6	CBC7	CBC8	CBC9	CBC10	CBC11	CBC12	CBC13	????
	Significant	15.3/14.7	19.5/20.4	20.0/19.5	11.0/9.9	20.6/20.3	20.9/20.9	20.6/19.7	19.5/19.5	20.6/20.9	20.0/20.4	11.0/10.2	20.6/20.3	20.9/20.5	20.6/14.7
	max H	30.0	39.6	39.4	20.8	40.7	41.7	40.2	38.7	41.4	40.3	21.2	40.8	41.3	35.3
	W Period	8.0/9.0	12.0/12.8	14.0/15.1	14.0/15.1	16.0/17.5	17.0/18.6	10.0/11.5	12.0/14.3	13.0/15.8	14.0/17.2	14.0/17.2	16.0/20.3	17.0/22.1	13.0/9.0
	mean														
	max														
	Surface														
Surge	mean	0.3	0.2	0.1	0.0	0.1	0.1	0.3	0.1	0.1	0.1	0.0	0.1	0.0	0.2
	rms	0.8	2.0	2.8	1.5	3.8	6.9	1.6	2.2	2.9	3.4	1.7	4.8	5.9	1.7
	max	2.2	4.3	5.7	2.9	7.7	17.8	3.8	4.7	5.9	6.8	3.5	9.6	11.4	3.3
	min	-0.9	-3.6	-5.3	-2.8	-7.4	-13.0	-2.4	-4.0	-5.3	-6.3	-3.4	-9.1	-11.2	-3.3
Heave	mean	0.0	0.1	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1
	rms	0.0	0.1	0.2	0.0	0.3	1.0	0.1	0.1	0.2	0.3	0.1	1.3	2.3	0.9
	max	0.1	0.3	0.6	0.2	0.9	2.6	0.3	0.3	0.5	0.7	0.3	2.6	3.8	1.9
	min	0.0	-0.1	-0.3	-0.1	-0.4	-2.5	-0.1	-0.1	-0.2	-0.4	-0.2	-2.4	-3.4	-1.7
Pitch	mean	-0.1	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1
	rms	0.4	0.6	0.7	0.4	0.8	2.1	0.6	0.6	0.7	0.8	0.4	0.8	0.9	0.6
	max	0.4	1.1	1.3	0.7	1.5	3.8	0.8	1.1	1.3	1.4	0.8	1.6	1.7	1.1
	min	-1.0	-1.4	-1.5	-0.8	-1.6	-4.8	-1.4	-1.4	-1.6	-1.6	-0.8	-1.7	-1.8	-1.1
Air Gap	mean	59.8	59.6	59.6	59.9	59.6	59.5	59.6	59.6	59.6	59.6	59.9	59.7	59.7	59.7
	rms	7.9	10.4	10.4	5.5	10.9	11.5	10.6	10.2	10.9	10.6	5.6	11.4	12.5	9.4
	max	75.5	80.7	80.9	70.9	81.5	84.6	80.9	80.3	81.8	81.4	71.2	82.7	85.0	79.9
	min	43.9	39.0	39.2	49.1	38.5	36.6	38.5	39.5	38.3	38.8	48.8	37.6	35.4	42.0
Air Gap	mean	60.0	59.7	59.7	59.9	59.7	59.5	59.7	59.7	59.6	59.7	59.9	59.7	59.7	59.8
	rms	7.8	10.2	10.3	5.5	10.8	11.3	10.4	10.1	10.8	10.5	5.5	11.3	12.4	9.3
	max	76.0	80.6	80.8	70.8	81.7	86.2	81.3	80.2	81.8	81.4	71.1	82.5	84.9	79.5
	min	44.8	39.9	39.6	49.3	38.8	35.6	39.7	40.4	38.8	39.3	49.0	38.1	35.7	42.1
Line 1	mean	9,808	9,889	9,939	9,982	9,964	9,990	9,812	9,909	9,923	9,947	9,985	9,965	9,984	9,877
	rms	592	1,326	1,747	922	2,320	4,514	1,087	1,457	1,832	2,062	1,068	2,819	3,364	1,164
	max	10,690	12,380	13,320	11,780	14,510	18,500	11,640	12,600	13,370	13,890	12,080	15,350	16,380	12,230
	min	8,385	7,170	6,419	8,151	5,340	0	7,357	6,927	6,220	5,792	7,852	4,398	3,493	7,772
Line 2	mean	1,600	1,601	1,601	1,600	1,602	1,609	1,601	1,601	1,601	1,602	1,600	1,604	1,605	1,601
	rms	2	4	4	3	5	12	4	4	5	5	4	6	7	4
	max	1,601	1,604	1,606	1,602	1,609	1,655	1,603	1,604	1,606	1,608	1,602	1,614	1,618	1,602
	min	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,601	1,600
Line 3	mean	10,193	10,115	10,066	10,019	10,043	10,074	10,192	10,096	10,083	10,059	10,016	10,045	10,030	10,128
	rms	594	1,327	1,748	922	2,320	4,566	1,090	1,459	1,833	2,063	1,068	2,820	3,364	1,164
	max	11,630	12,850	13,600	11,860	14,690	21,480	12,670	13,100	13,810	14,240	12,160	15,630	16,540	12,240
	min	9,317	7,632	6,697	8,222	5,520	1,651	8,366	7,417	6,649	6,137	7,931	4,677	3,654	7,784
Line 5	mean	2,556	2,529	2,515	2,504	2,508	2,511	2,552	2,524	2,519	2,513	2,503	2,508	2,506	2,534
	rms	166	211	184	97	125	827	227	201	194	160	84	135	213	210
	max	2,955	2,982	2,921	2,700	2,760	3,926	3,082	2,965	2,939	2,849	2,671	2,802	2,924	2,925
	min	2,311	2,148	2,157	2,317	2,277	1,124	2,181	2,166	2,170	2,224	2,351	2,216	2,087	2,059
Line Bus	mean	400	400	400	400	400	401	400	400	400	400	400	400	400	400
	rms	0	0	0	0	1	1	0	1	1	1	0	1	1	0
	max	400	400	400	400	400	404	401	400	400	400	400	400	400	400
	min	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Line 7	mean	2,444	2,471	2,485	2,496	2,492	2,490	2,448	2,476	2,481	2,487	2,497	2,493	2,496	2,466
	rms	166	211	184	98	125	827	227	201	194	160	84	135	213	210
	max	2,689	2,852	2,843	2,683	2,723	3,877	2,819	2,834	2,830	2,776	2,649	2,784	2,913	2,941
	min	2,045	2,018	2,079	2,300	2,240	1,076	1,918	2,035	2,061	2,151	2,329	2,199	2,076	2,075

		100 Year GOM		100 Year NS		10 Year GOM	
TDSIM File		D2	D3	D11	D12	D16	D17
OTRC DSIG		DCUR3	DRC3	DCUR5	DRC5	DCUR2	DRC2
Hs	Significant	0.0	43.9	0.0	46.1	0.0	21.4
(ft)	max H	0.0	78.6	0.0	86.2	0.0	34.8
Tp (sec)	W Period	0.0	14.1	0.0	16.2	0.0	10.8
Wind vel	mean	0.0	0.0	0.0	0.0	0.0	0.0
(kts) @755'	max	0.0	0.0	0.0	0.0	0.0	0.0
Current (ft/sec)	Surface	4.3	4.3	5.3	5.3	6.3	6.3
Surge	mean	0.3	0.6	0.5	0.7	0.6	0.7
(ft)	rms	0.0	2.5	0.0	3.4	0.0	0.7
	max	0.3	13.6	0.5	15.9	0.6	3.2
	min	0.3	-8.2	0.5	-11.7	0.6	-1.3
Heave	mean	0.0	0.1	0.0	0.1	0.0	0.0
(ft)	rms	0.0	0.7	0.0	1.8	0.0	0.2
	max	0.0	2.7	0.0	6.5	0.0	0.4
	min	0.0	-2.1	0.0	-4.9	0.0	-0.4
Pitch	mean	-0.1	-0.3	-0.2	-0.3	-0.2	-0.3
(deg)	rms	0.0	0.7	0.0	0.8	0.0	0.2
	max	-0.1	2.4	-0.2	1.8	-0.2	0.4
	min	-0.1	-4.2	-0.2	-3.8	-0.2	-1.3
Air Gap	mean	59.9	59.4	59.8	59.4	59.8	59.6
(ft)	rms	0.5	11.5	0.0	12.3	0.0	5.6
@710' x -66.5'	max	59.9	98.7	59.8	107.9	59.8	79.0
	min	59.9	16.8	59.8	14.4	59.8	42.0
Air Gap	mean	60.1	59.9	60.2	59.9	60.2	60.3
(ft)	rms	0.4	11.4	0.0	12.2	0.0	5.5
@710' x +66.5'	max	60.1	100.8	60.2	108.4	60.2	76.4
	min	60.1	21.8	60.2	15.2	60.2	37.8
Restraint line 1	mean	9,801	9,562	9,685	9,502	9,601	9,500
(kips)	rms	55	1,614	0	2,043	0	444
@ 375' above keel	max	9,801	15,390	9,685	16,540	9,601	10,860
downstream	min	9,800	1,081	9,685	202	9,601	7,758
Restraint line 3	mean	10,200	10,445	10,316	10,509	10,400	10,501
(kips)	rms	36	1,621	0	2,050	0	446
@ 375' above keel	max	10,200	19,110	10,316	19,960	10,400	12,260
upstream	min	10,200	4,678	10,316	3,496	10,400	9,145
Restraint line 5	mean	2,544	2,610	2,569	2,617	2,588	2,616
(kips)	rms	13	272	0	262	0	94
@ 36.7' below keel	max	2,545	3,878	2,569	3,390	2,588	3,027
downstream	min	2,543	1,584	2,569	1,548	2,588	2,317
Restraint line 7	mean	2,456	2,390	2,431	2,384	2,412	2,384
(kips)	rms	10	272	0	262	0	94
@ 36.7' below keel	max	2,457	3,417	2,431	3,457	2,412	2,683
upstream	min	2,455	1,123	2,431	1,612	2,412	1,973
Mooring line 2&4	mean	1,149	1,149	1,149	1,149	1,149	1,149
(kips)	rms	3	1	0	7	0	3
@ fairlead,	max	1,149	1,160	1,149	1,176	1,149	1,151
abeam	min	1,149	1,140	1,149	1,129	1,149	1,147

Free Oscillation Simulations

TDSIM File	A46	A47	A48	A49	A50	A51	A51a
OTRC DSIG	AD1	AD2	AD3	AD4	AD5	AD6	AD6
Response	Surge	Sway	Heave	Roll	Pitch	Yaw	Yaw
Sample - sec	1844	1844	1998	2162	2162	2263	2303
Cycles k	5	5	70	30	30	29	30
T cycle - sec	368.8	368.8	28.5	72.1	72.1	78.0	76.8
Amplitude A(0) - ft/deg	35.33	35.33	11.62	5.37	5.37	59.0	9.95
Amplitude A(k) - ft/deg	1.65	1.65	2.87	0.04	0.04	50.2	8.48
Avg Decay, A(n+1)/A(n)	0.54	0.54	0.98	0.85	0.85	0.994	0.995
Damping C/Ccrit	0.097	0.097	0.003	0.026	0.026	0.001	0.001

TDSIM File	B46	B47	B48	B49	B50
OTRC DSIG	BD1	BD2	BD3	BD4	BD5
Response	Surge	Sway	Heave	Roll*	Pitch
Sample - sec	1874	1936	2292	1865	2308
Cycles k	5	54	80	53	32
T cycle - sec	374.8	35.9	28.7	35.2	72.1
Amplitude A(0) - ft/deg	35.94	20.01	17.49	1.55	6.77
Amplitude A(k) - ft/deg	1.61	0.07	2.91	0.04	0.05
Avg Decay, A(n+1)/A(n)	0.54	0.90	0.98	0.93	0.86
Damping C/Ccrit	0.098	0.017	0.004	0.011	0.025

TDSIM File	C46	C47	C48	C49	C50
OTRC DSIG	CD1	CD2	CD3	CD4	CD5
Response	Surge	Sway	Heave	Roll*	Pitch*
Sample - sec	2121	1980	2235	1589	1858
Cycles k	62	53	80	44	49
T cycle - sec	34.2	37.4	27.9	36.1	37.9
Amplitude A(0) - ft/deg	8.71	20.01	18.29	2.93	2.22
Amplitude A(k) - ft/deg	0.03	0.07	3.03	0.01	0.02
Avg Decay, A(n+1)/A(n)	0.91	0.90	0.98	0.87	0.91
Damping C/Ccrit	0.015	0.017	0.004	0.022	0.015

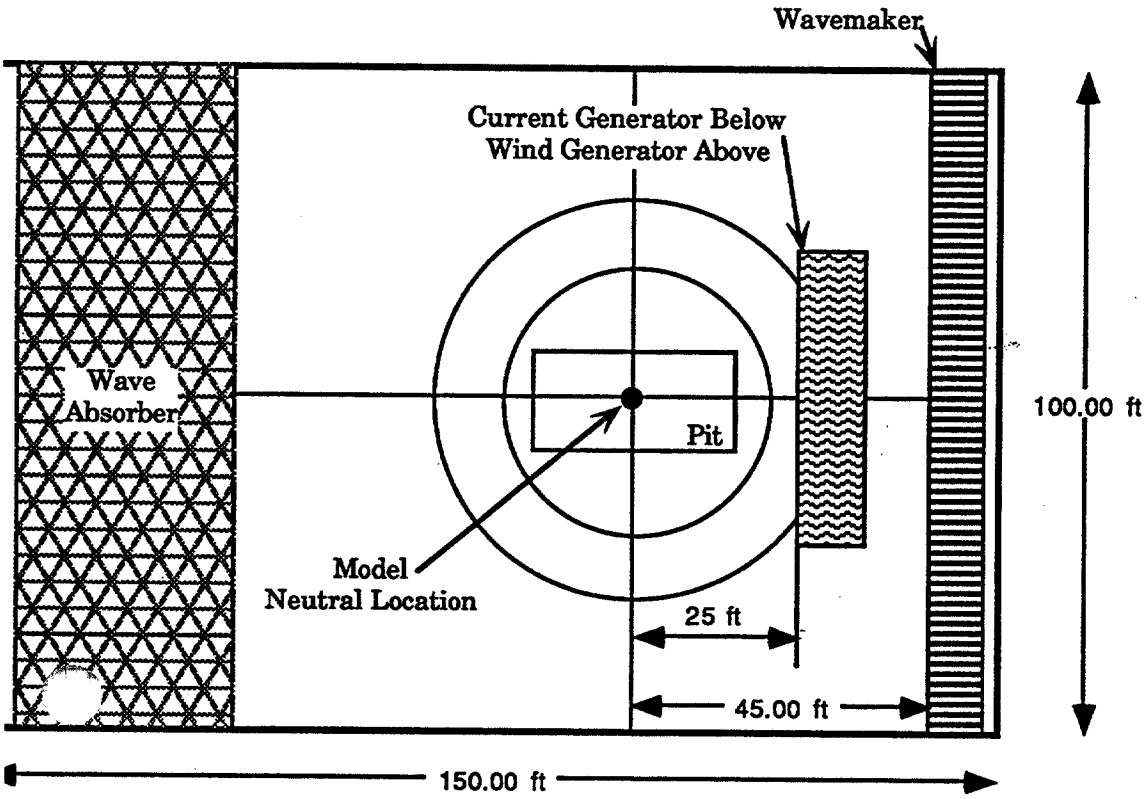
TDSIM File	D46	D47	D48	D49	D50
OTRC DSIG	DD1	DD2	DD3	DD4	DD5
Response	Surge	Sway	Heave	Roll	Pitch*
Sample - sec	2119	2137	2226	2249	1857
Cycles k	62	14	80	33	49
T cycle - sec	34.2	152.6	27.8	68.2	37.9
Amplitude A(0) - ft/deg	8.90	46.57	17.41	7.99	2.29
Amplitude A(k) - ft/deg	0.03	0.83	3.01	0.04	0.02
Avg Decay, A(n+1)/A(n)	0.91	0.75	0.98	0.85	0.91
Damping C/Ccrit	0.015	0.046	0.003	0.025	0.015

* Cross-coupled with Surge/Sway, Pitch/Roll period approx 39 sec.

Appendix D

Selected Data from OTRC Report

;ure 2.1 OTRC Model Basin Plan and Profile



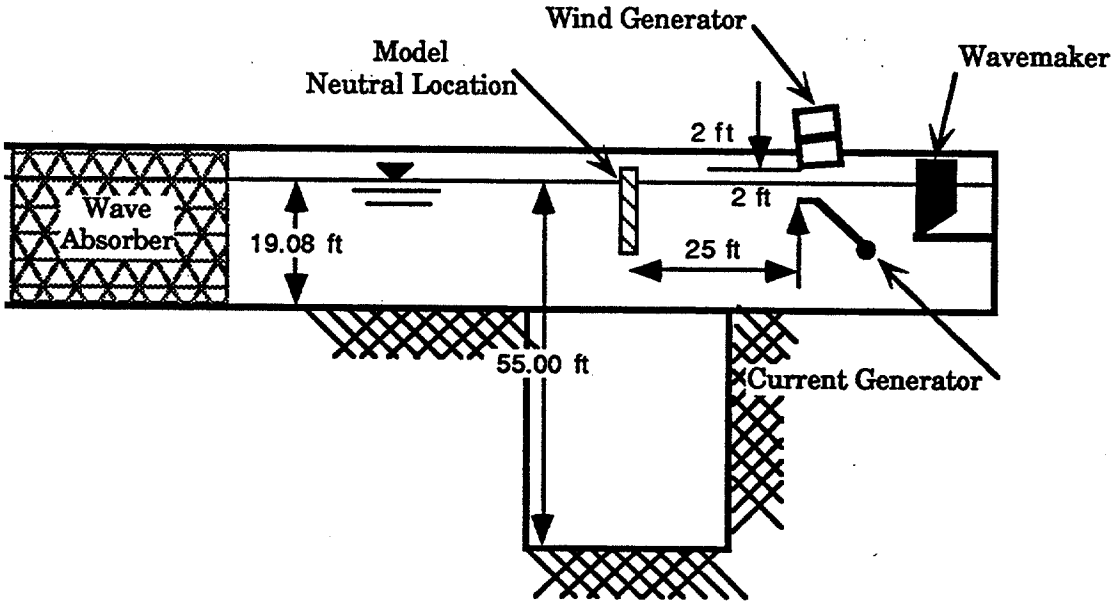


Table 2.1 Regular Waves

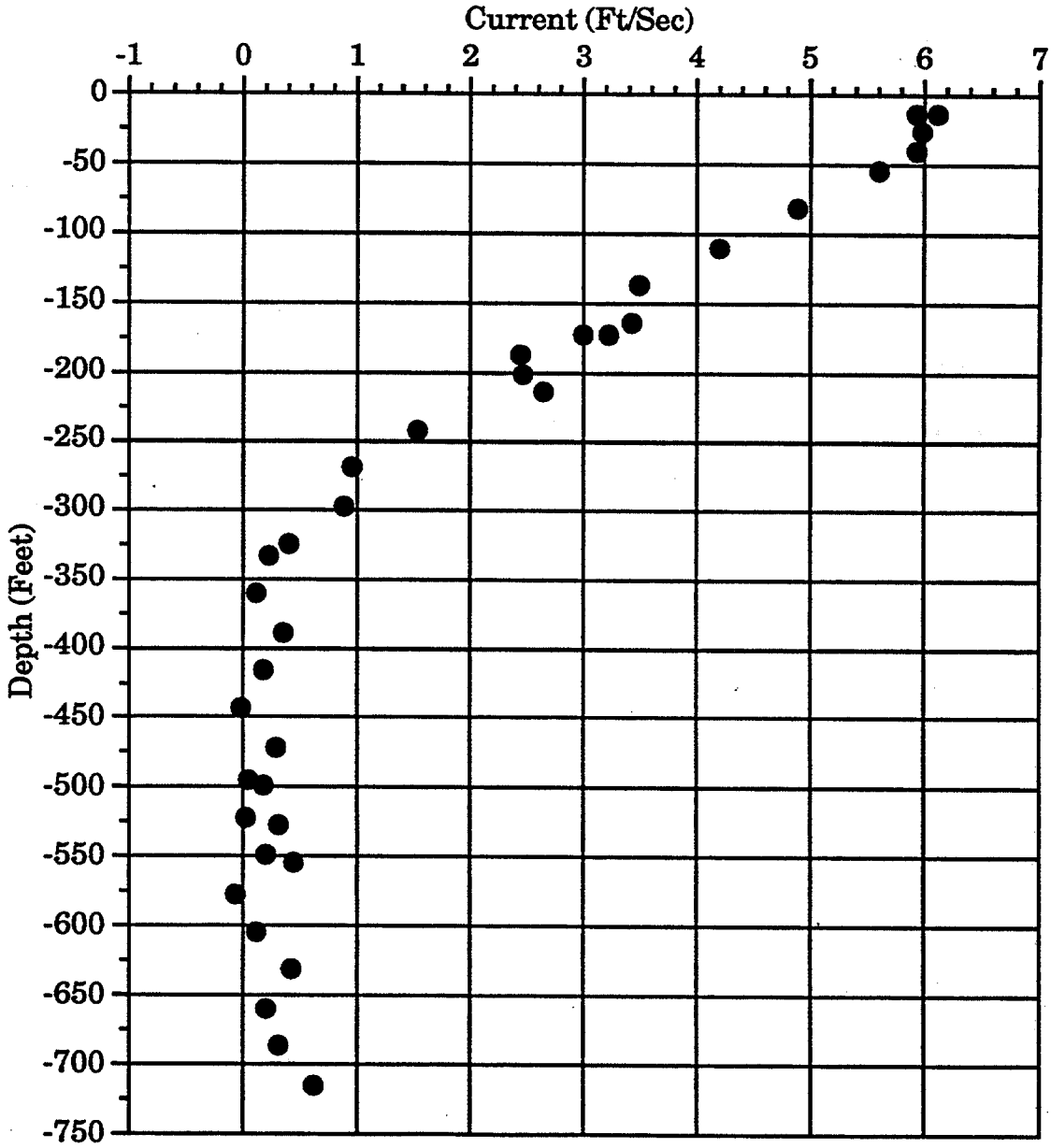
Drive Signal	H Target (Feet)	T Target (Seconds)	H Measured (Feet)	T Measured (Seconds)
RG3	6	6	6.03	6.00
RG4	12	7	11.85	7.01
RG5	15	8	15.32	8.01
RG6	18	9	17.80	9.00
RG7	20	10	20.57	10.00
RG8	20	12	19.47	12.00
RG9	20	14	19.98	14.01
RG10	20	16	20.55	15.99
RG11	20	17	20.94	17.00
RG12	20	21	19.86	21.00
RG13	10	14	10.95	14.00
RG14	20	13	20.59	13.00
BCL1	15	8.96	14.69	8.95
BCL2	20	12.81	20.38	12.82
BCL3	20	15.11	19.51	15.10
BCL4	10	15.11	9.86	15.10
BCL5	20	17.47	20.28	17.47
BCL6	20	18.67	20.94	18.62
BCL7	20	11.54	19.72	11.52
BCL8	20	14.29	19.53	14.29
BCL9	20	15.73	20.87	15.76
BCL10	20	17.21	20.37	17.21
BCL11	10	17.21	10.24	17.20
BCL12	20	20.34	20.29	20.33
BCL13	20	21.98	20.51	22.06

Table 2.2 Bi-Chromatic Waves

Drive Signal	H Target (Feet)	T Target (Seconds)	H Measured (Feet)	T Measured (Seconds)
BC1	15 / 15	8.0 / 8.96	15.32 / 14.69	8.009 / 8.95
BC2	20 / 20	12.0 / 12.81	19.47 / 20.38	12.00 / 12.82
BC3	20 / 20	14.0 / 15.11	19.98 / 19.51	14.01 / 15.10
BC4	10 / 10	14.0 / 15.11	10.95 / 9.86	14.01 / 15.11
BC5	20 / 20	16.0 / 17.47	20.55 / 20.28	15.99 / 17.46
BC6	20 / 20	17.0 / 18.67	20.94 / 20.94	17.00 / 18.62
BC7	20 / 20	10.0 / 11.54	20.57 / 19.72	9.995 / 11.52
BC8	20 / 20	12.0 / 14.29	19.47 / 19.53	12.00 / 14.29
BC9	20 / 20	13.0 / 15.73	20.59 / 20.87	13.01 / 15.76
BC10	20 / 20	14.0 / 17.21	19.98 / 20.37	14.01 / 17.21
BC11	10 / 10	14.0 / 17.21	10.95 / 10.24	14.01 / 17.20
BC12	20 / 20	16.0 / 20.34	20.55 / 20.29	15.99 / 20.33
BC13	20 / 20	17.0 / 21.98	20.94 / 20.51	17.00 / 22.06
BC14	20 / 15	13.0 / 8.96	20.59 / 14.69	13.01 / 8.95

Figure 2.2 10 Year Storm Current Profile

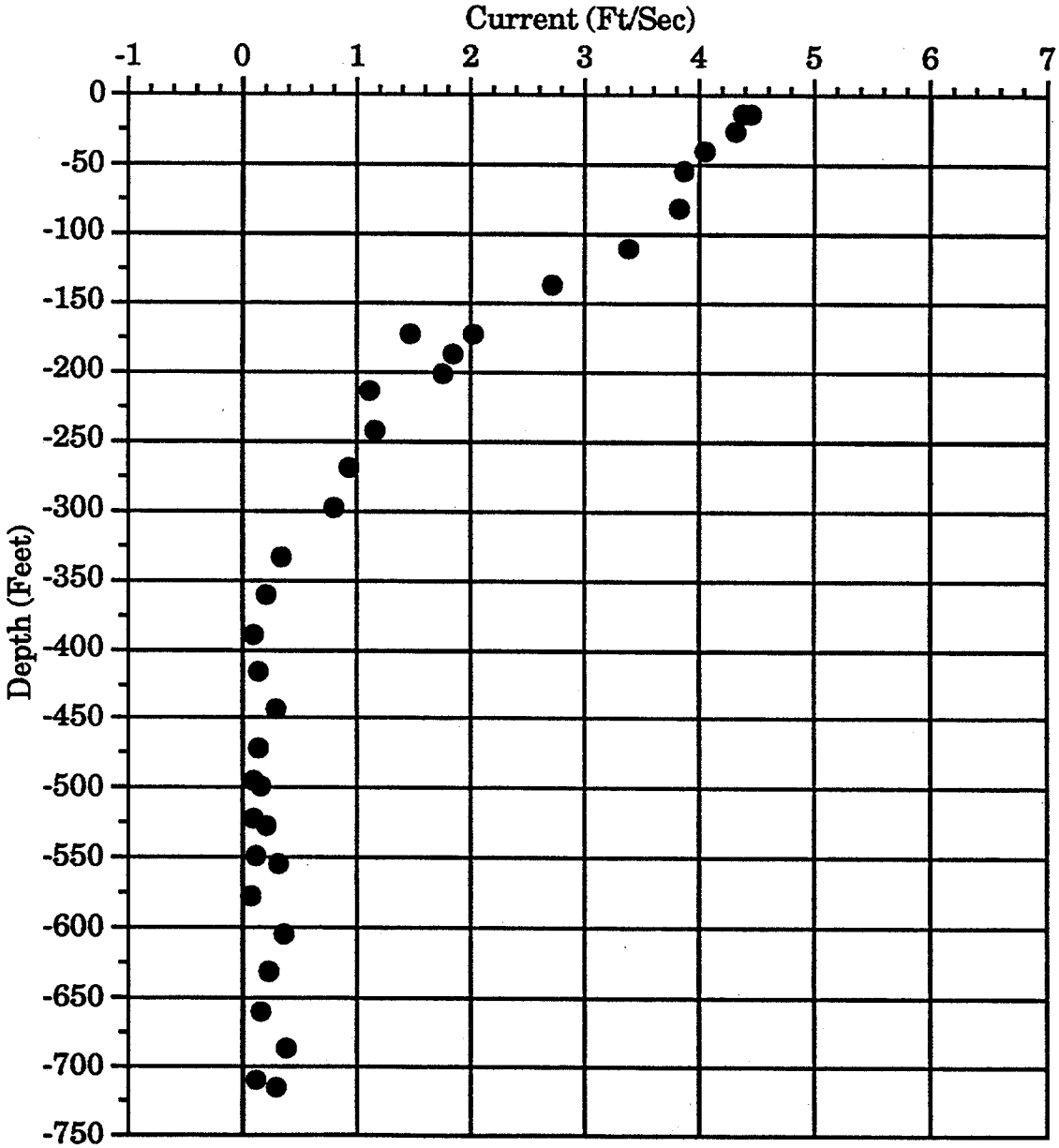
Target = 6.3 Ft/Sec Surface Current



Note: Values are prototype scale.

Figure 2.3 Gulf Of Mexico 100 Year Hurricane & West Africa Current Profile

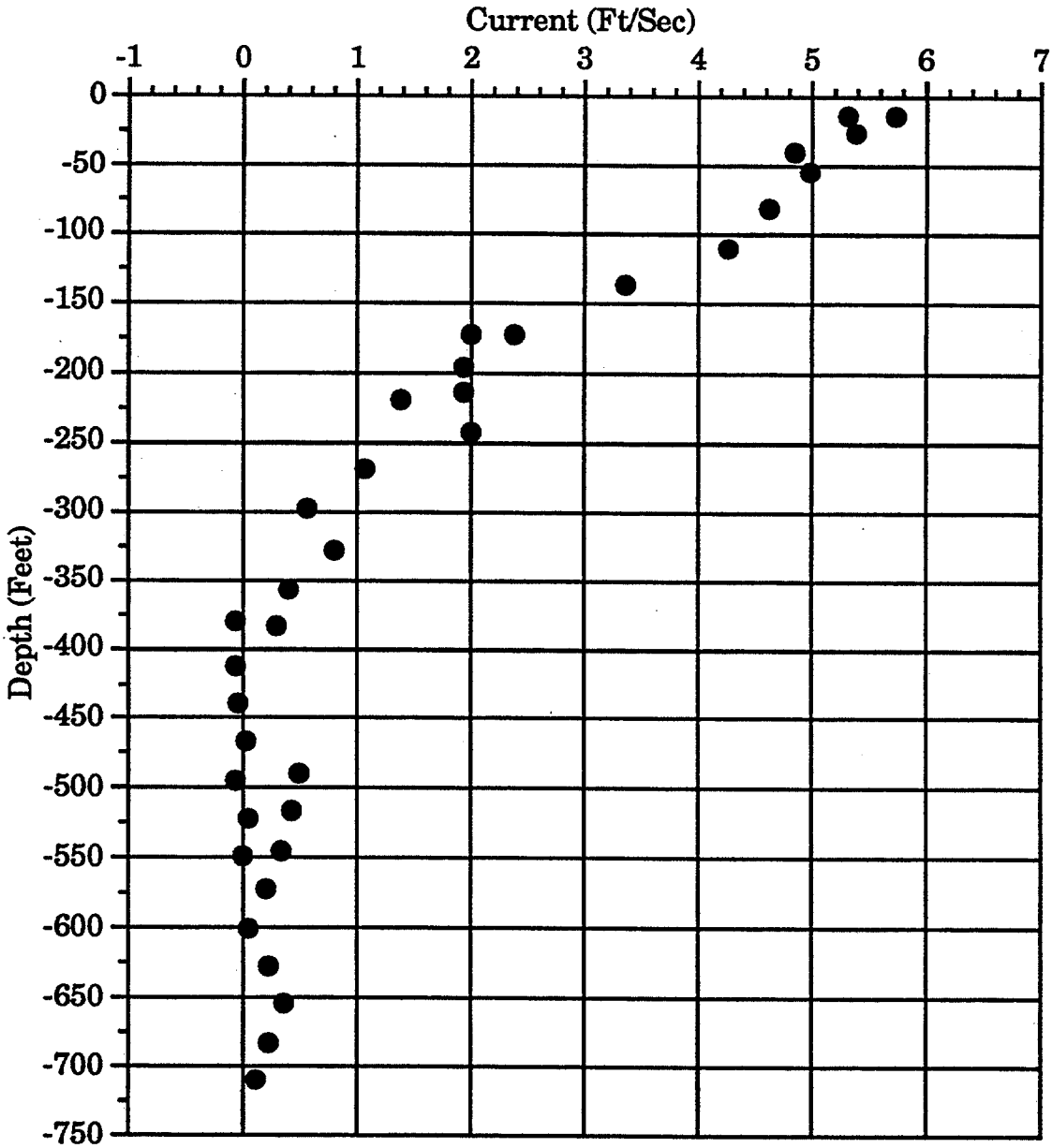
Target = 4.3 Ft/Sec Surface Current



Note: Values are prototype scale.

Figure 2.4 North Atlantic Current Profile

Target = 5.3 Ft/Sec Surface Current



Note: Values are prototype scale.

FIGURE 2.5 Typical Current Time Series

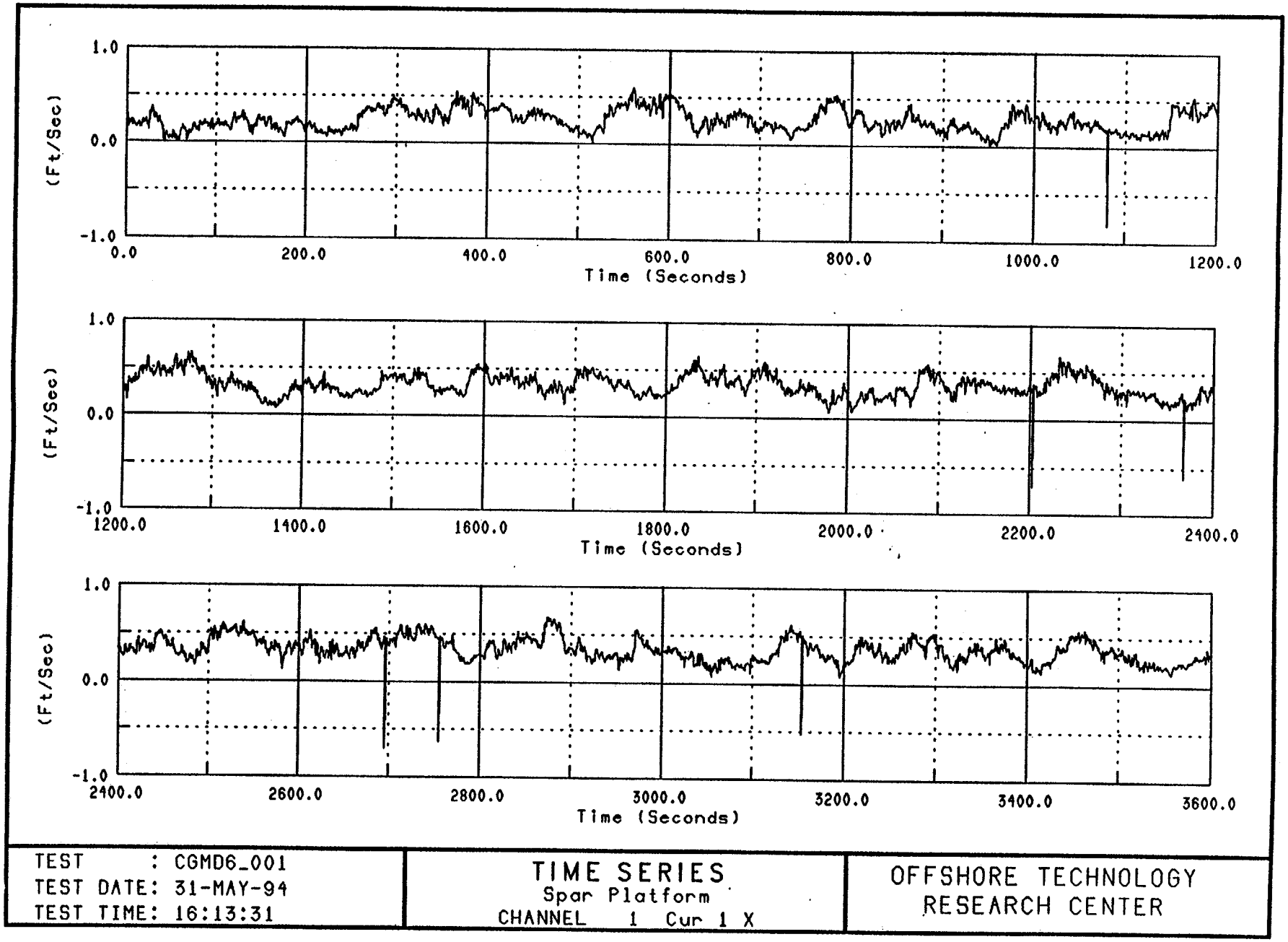
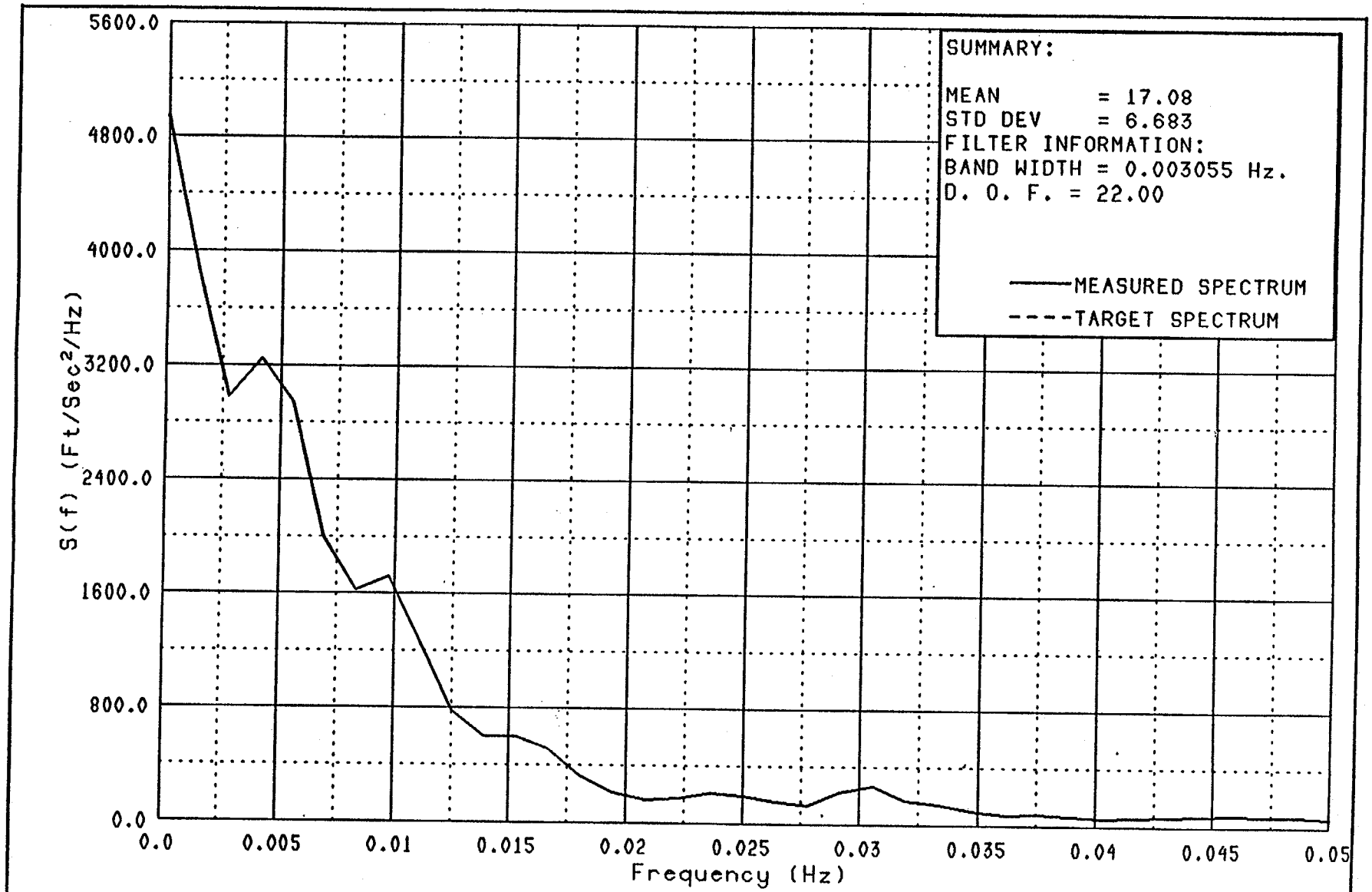


FIGURE 2.6 Typical Current Power Spectrum



TEST : CGMD6_001 TEST DATE: 31-MAY-94 TEST TIME: 16:13:31	POWER SPECTRAL DENSITY Spar Platform CHANNEL 1 Cur 1 X	OFFSHORE TECHNOLOGY RESEARCH CENTER

Table 2.5 Nominal Wind Conditions

Test Name	Mean Wind Speed	Environment
43Kt1	43	10 Year Storm
59Kt1	59	North Atlantic Storm
85Kt1	85	10 Year Gulf of Mexico Hurricane
85Kt2	85	10 Year Gulf of Mexico Hurricane
38Kt1	38	West Africa Storm

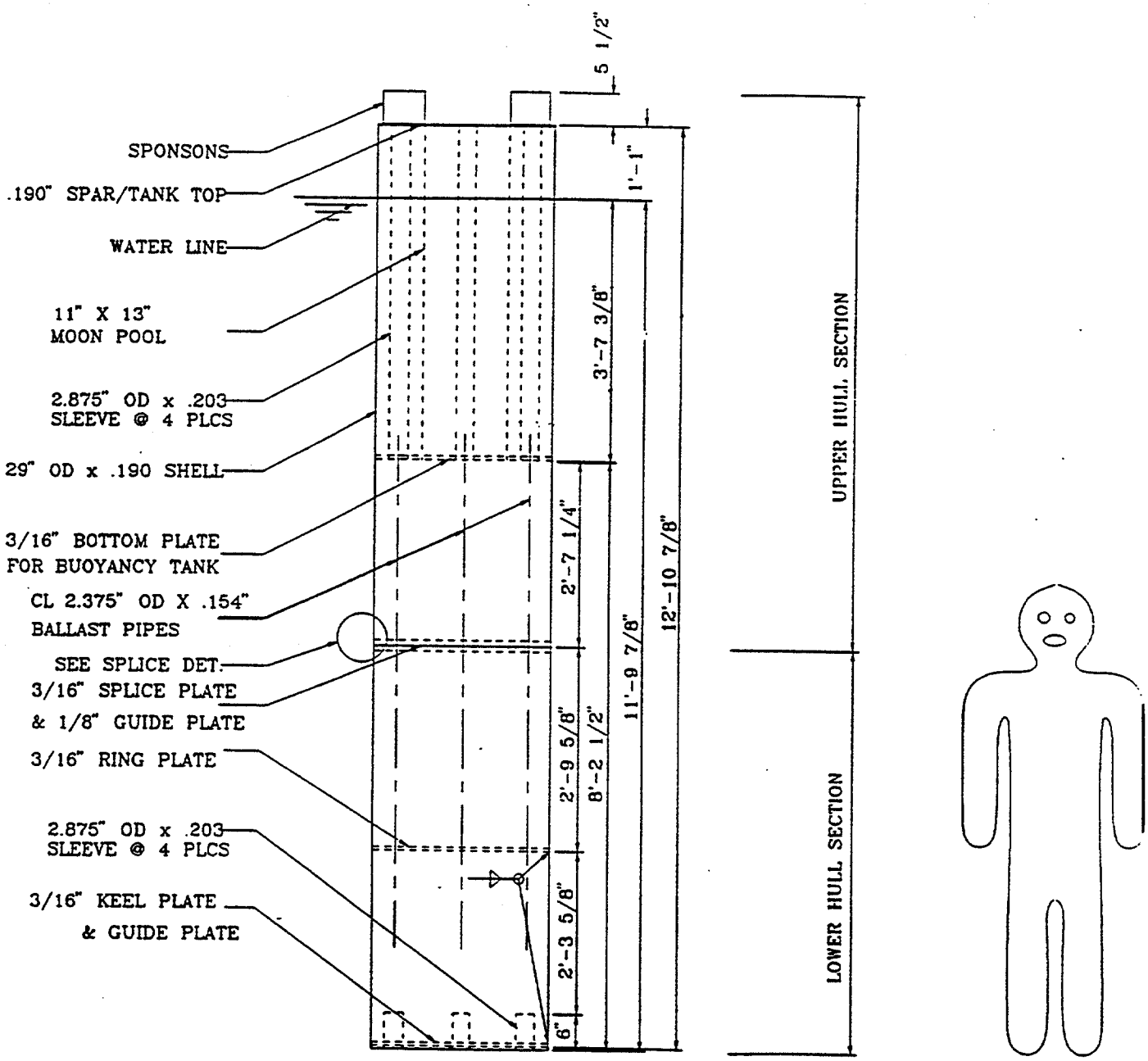
Note: Reference wind speed is at 66 feet above still water level.

Table 3.1 Froude Scale Relationships

Quantity	Scale Relationship	Scale Value
Length	λ	55.000
Time	$\lambda^{1/2}$	7.416
Velocity	$\lambda^{1/2}$	7.416
Acceleration	1.0	1.000
Rotation	1.0	1.000
Force	$(\rho_s/\rho_f)\lambda^3$	170,641.026
Weight	$(\rho_s/\rho_f)\lambda^3$	170,641.026

Modification Factors for North Atlantic Test Results

Quantity	Modifier Relationship	Modifier Value
Length	63.46/55	1.1538
Time	$(63.46/55)^{1/2}$	1.0742
Velocity	$(63.46/55)^{1/2}$	1.0742
Acceleration	1.0	1.000
Rotation	1.0	1.000
Force	$(63.46/55)^3$	1.5361
Weight	$(63.46/55)^3$	1.5361



Note: Dimensions are model scale

FIGURE 3.1 Large Spar Hull Drawing

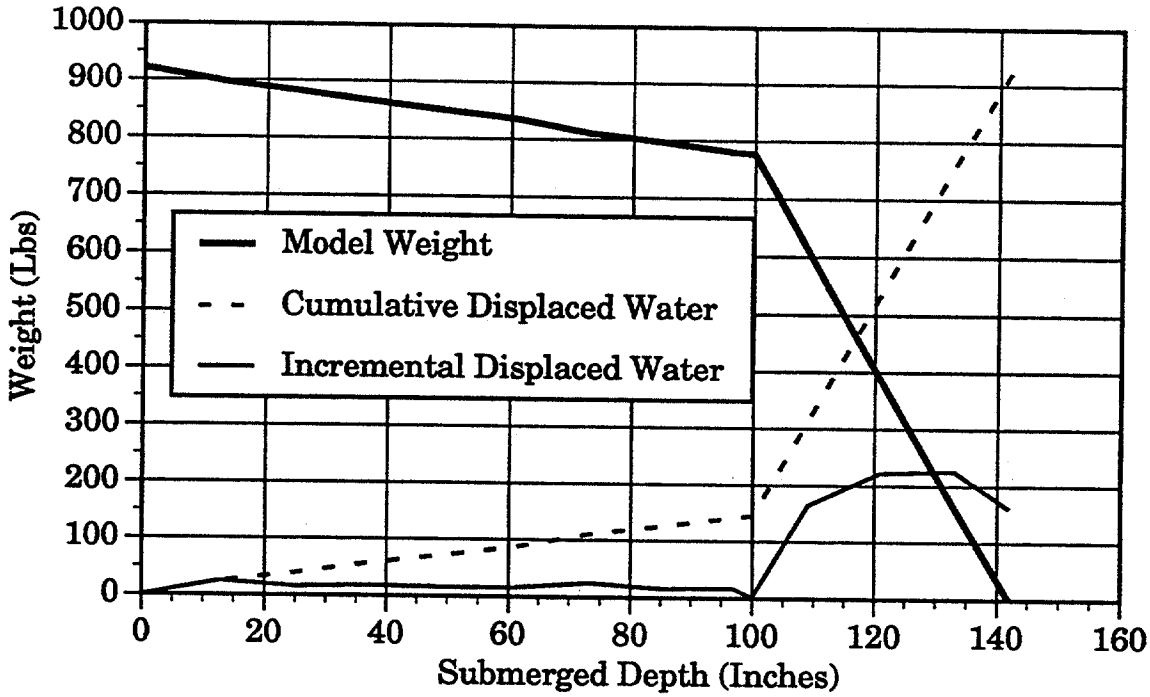
Table 3.2 Large Spar Principal Particulars

	Prototype	Model
Hull		
Diameter	133.0 ft	2.42 ft
Draft	650.0 ft	11.83 ft
Length	710.0 ft	12.91 ft
Hard Tank Depth	192.5 ft	3.50 ft
Fairlead Depth	350.0 ft	6.36 ft
Moonpool Width	50.0 ft	0.91 ft
Moonpool Length	60.0 ft	1.09 ft
Sponson Length	29.79 ft	0.54 ft
Sponson Width	36.67 ft	0.67 ft
Sponson Height	25.21 ft	0.46 ft
Deck		
Length	232.00 ft	4.22 ft
Width	232.00 ft	4.22 ft
Height	1.00 ft	55.00 ft
Slot Length	177.42 ft	3.23 ft
Slot Width	50.42 ft	0.92 ft

Table 3.3 Large Spar Mass Properties in Air

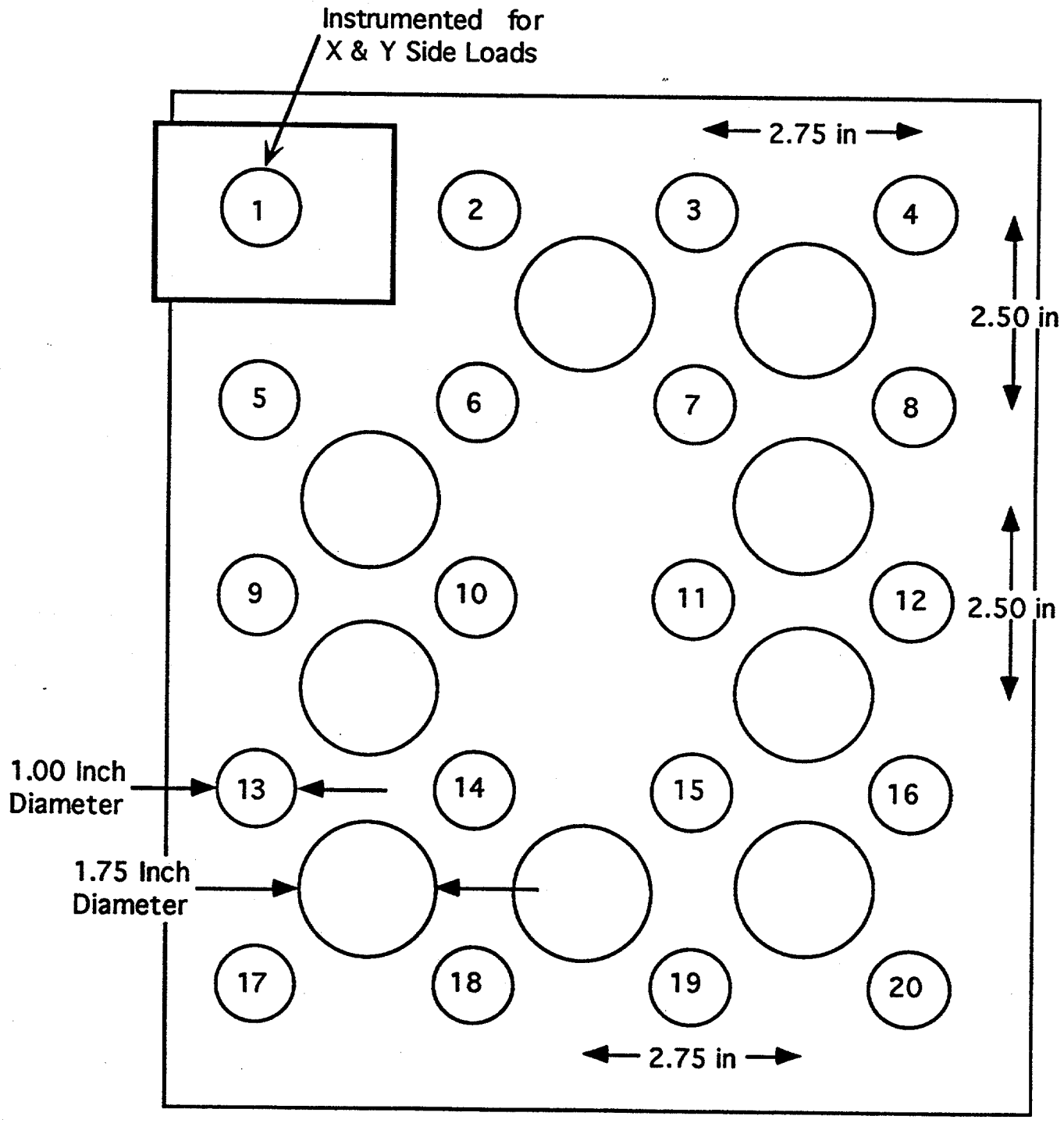
	Prototype Target	Model Achieved (Prototype Units)	Model Achieved (Model Units)
Hull			
Weight	127,277 kips	127,298 kips	764.00 lbs
KG	375.67 ft	375.56 ft	81.94 in
Pitch Gyradius	231.99 ft	226.69 ft	49.46 in
Roll Gyradius	231.99 ft	226.69 ft	49.46 in
Deck			
Weight	27,041 kips	27,047 kips	158.50 lbs
KG	749.74 ft	749.74 ft	163.58 in
Pitch Gyradius	–	92.90 ft	20.27 in
Roll Gyradius	–	87.73 ft	19.14 in

Figure 3.2 Large Spar Displacement



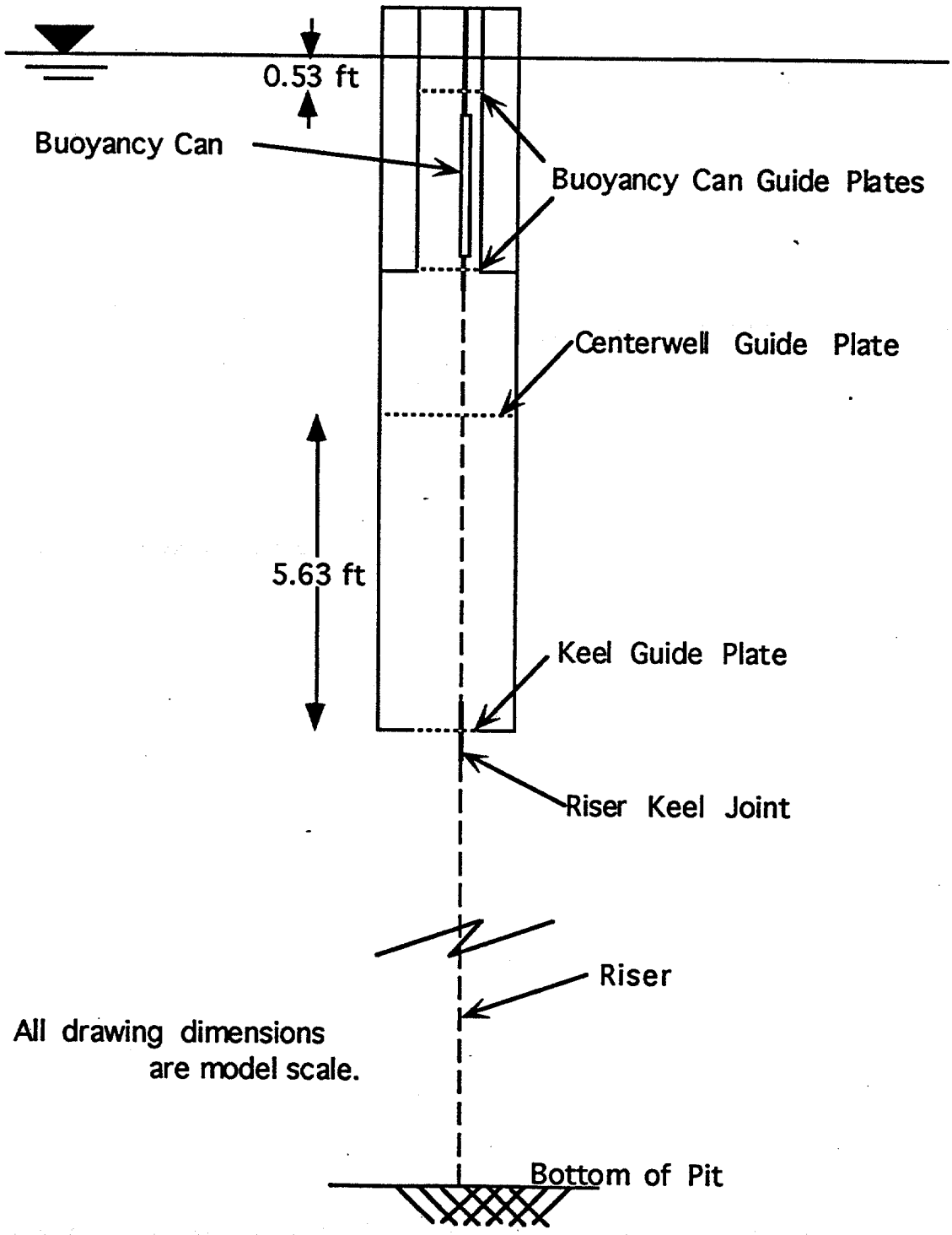
Draft (Inches)	Weight Displaced Water (Lbs)	Cumulative Displaced Water (Lbs)	Incremental Displaced Water (Lbs)
141.81	0	921	161
132.94	161	760	225
120.94	386	535	222
108.94	608	313	164
100.25	772	149	5
99.88	777	144	0
99.56	777	144	3
96.94	780	141	16
84.94	796	125	15
73.00	811	110	24
60.88	835	86	15
48.88	850	71	15
36.88	865	56	17
24.88	882	39	15
12.88	897	24	24
0.00	921	0	0

Figure 3.4 Keel Guide Plate



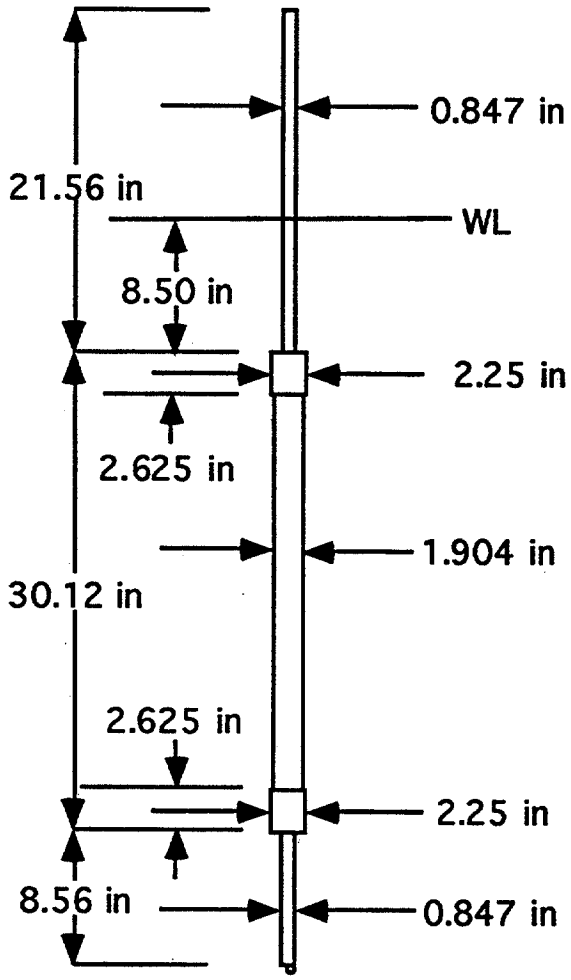
Note: All drawing dimensions are model scale.

Figure 3.5 Buoyancy Can, Riser and Guide Plate Layout



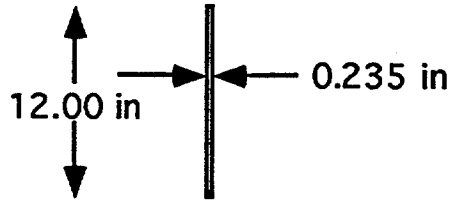
Note: All drawing dimensions are model scale.

Figure 3.6 Buoyancy Can and Riser Joint Dimensions



Buoyancy Can

Material: PVC Pipe



Riser Keel Joint

Material: Copper Tubing

Figure 3.7 Large Spar Target Stiffness Curve for Individual Mooring Lines

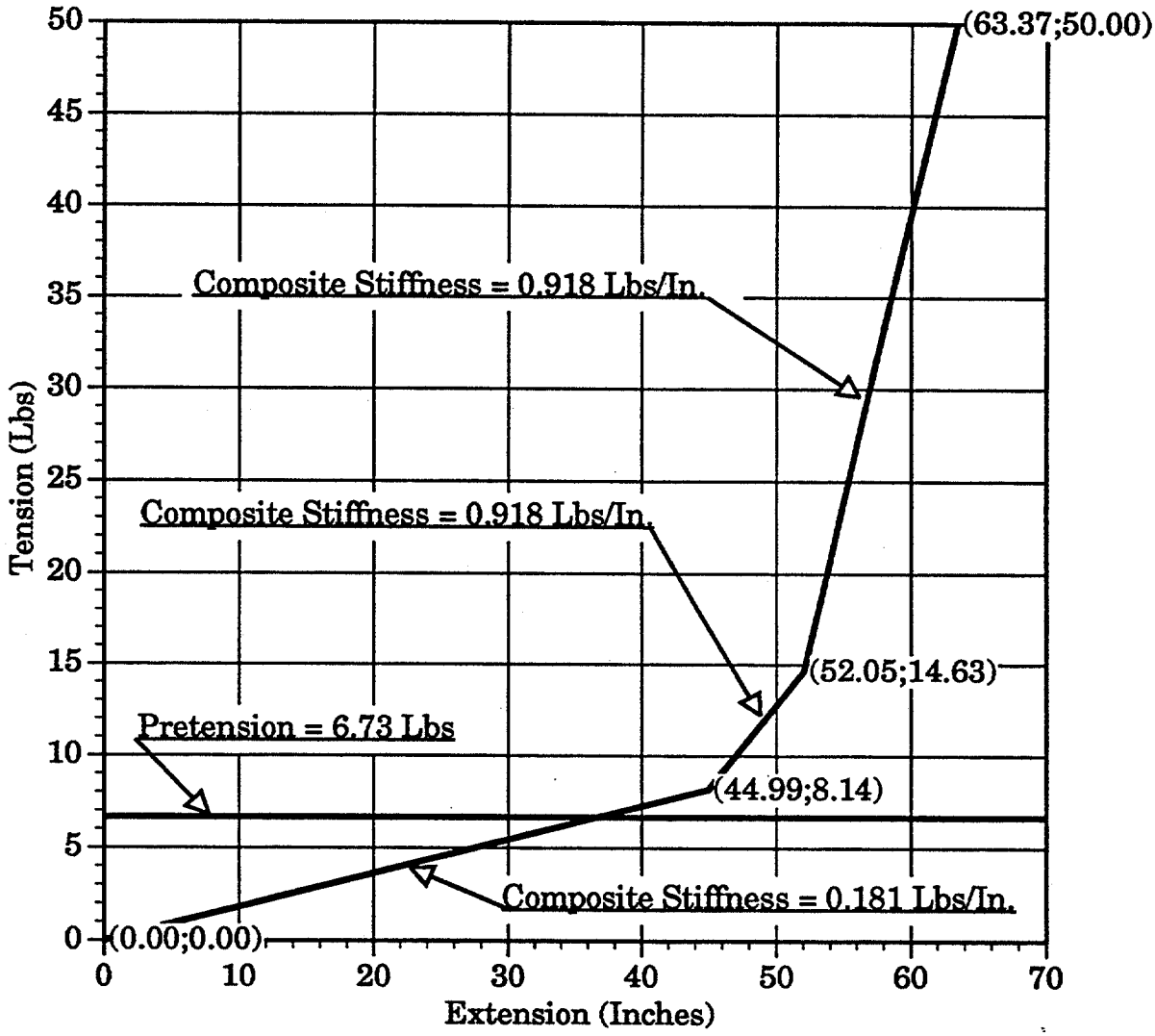


Figure 3.8 Large Spar Mooring Plan

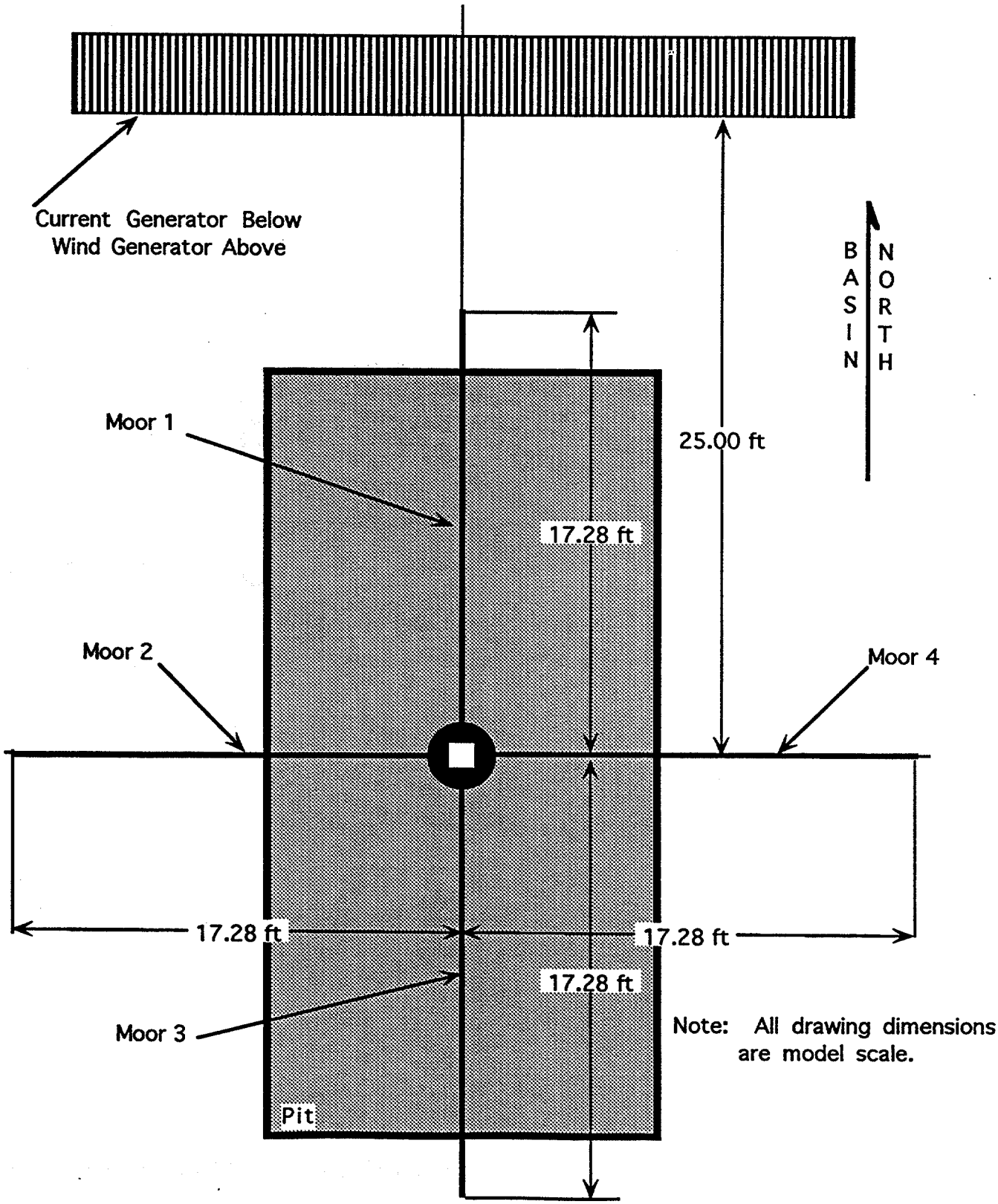
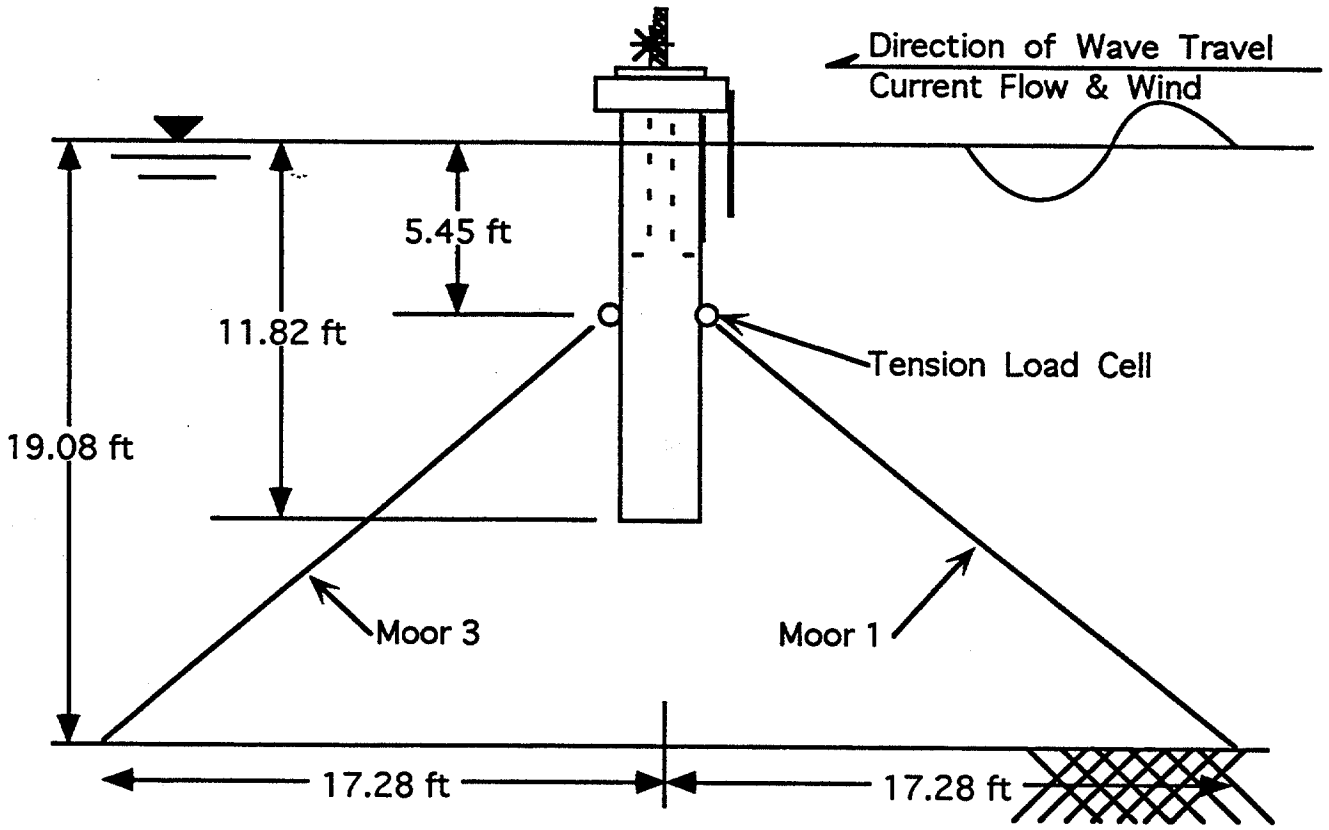


Figure 3.9 Large Spar Mooring Profile

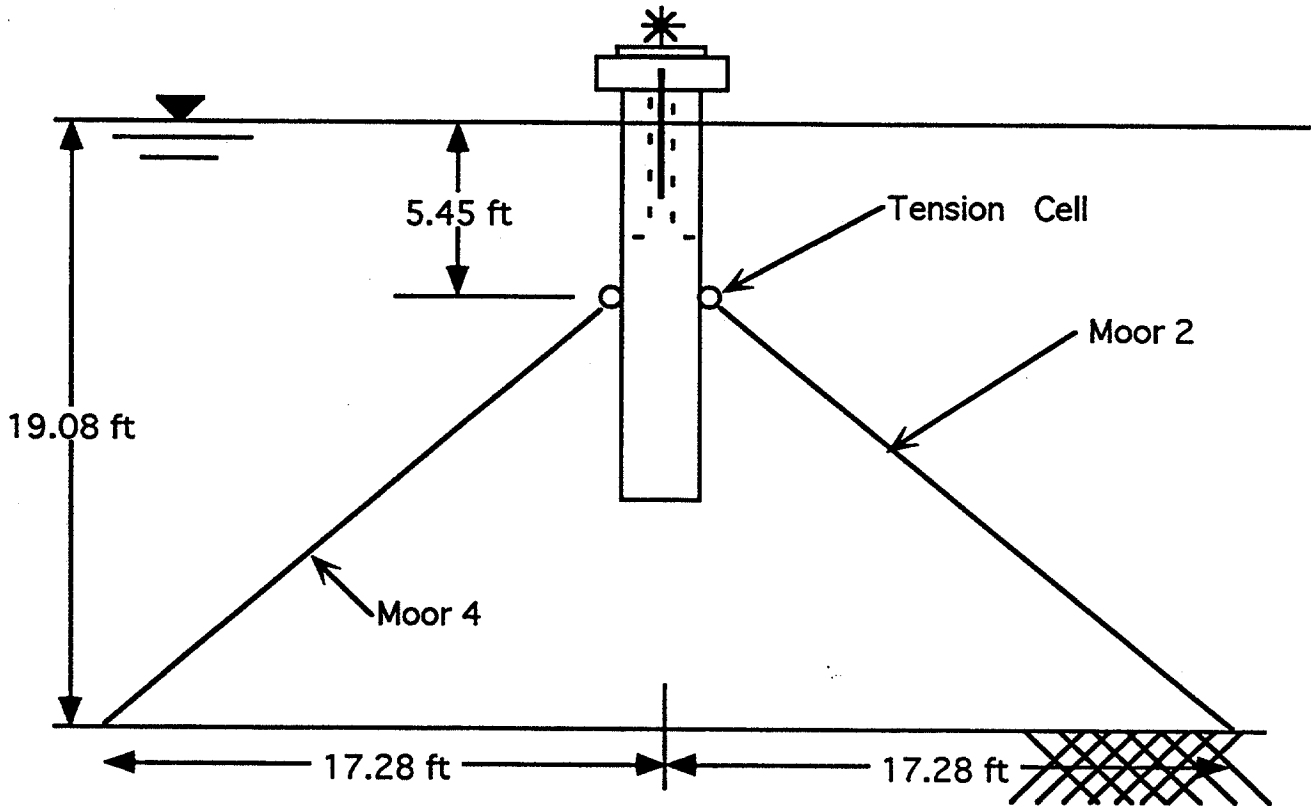


Note: All drawing dimensions are model scale.

Applicable to :

- Configuration A
- Configuration B
- Configuration F
- Configuration F1
- Configuration F2
- Configuration H
- Configuration J
- Configuration O

Figure 3.10 Large Spar Mooring Front Elevation



Note: All drawing dimensions are model scale.

Applicable to :

- Configuration A
- Configuration D
- Configuration F
- Configuration F1
- Configuration F2
- Configuration H
- Configuration J
- Configuration O

Table 3.4 Small Spar Principal Particulars

	Prototype	Model
	Hull	
Diameter	52.5 ft	0.95 ft
Draft	443 ft	8.05 ft
Length	506 ft	9.20 ft
Fairlead Depth	41.8 ft	0.76 ft
	Deck	
Length	165.0 ft	3.0 ft
Width	165 .0 ft	3.0 ft
Height	64.2 ft	1.17 ft

Table 3.5 Small Spar Model Mass Properties

	Prototype Target	Model Achieved (Prototype Units)	Model Achieved (Model Units)
Weight	58,492 kips	58,530 kips	343.00 lbs
KG	203.51 ft	203.50 ft	44.40 in
Pitch Gyradius	201.70 ft	201.07 ft	43.87 in
Roll Gyradius	201.70 ft	196.17 ft	42.80 in

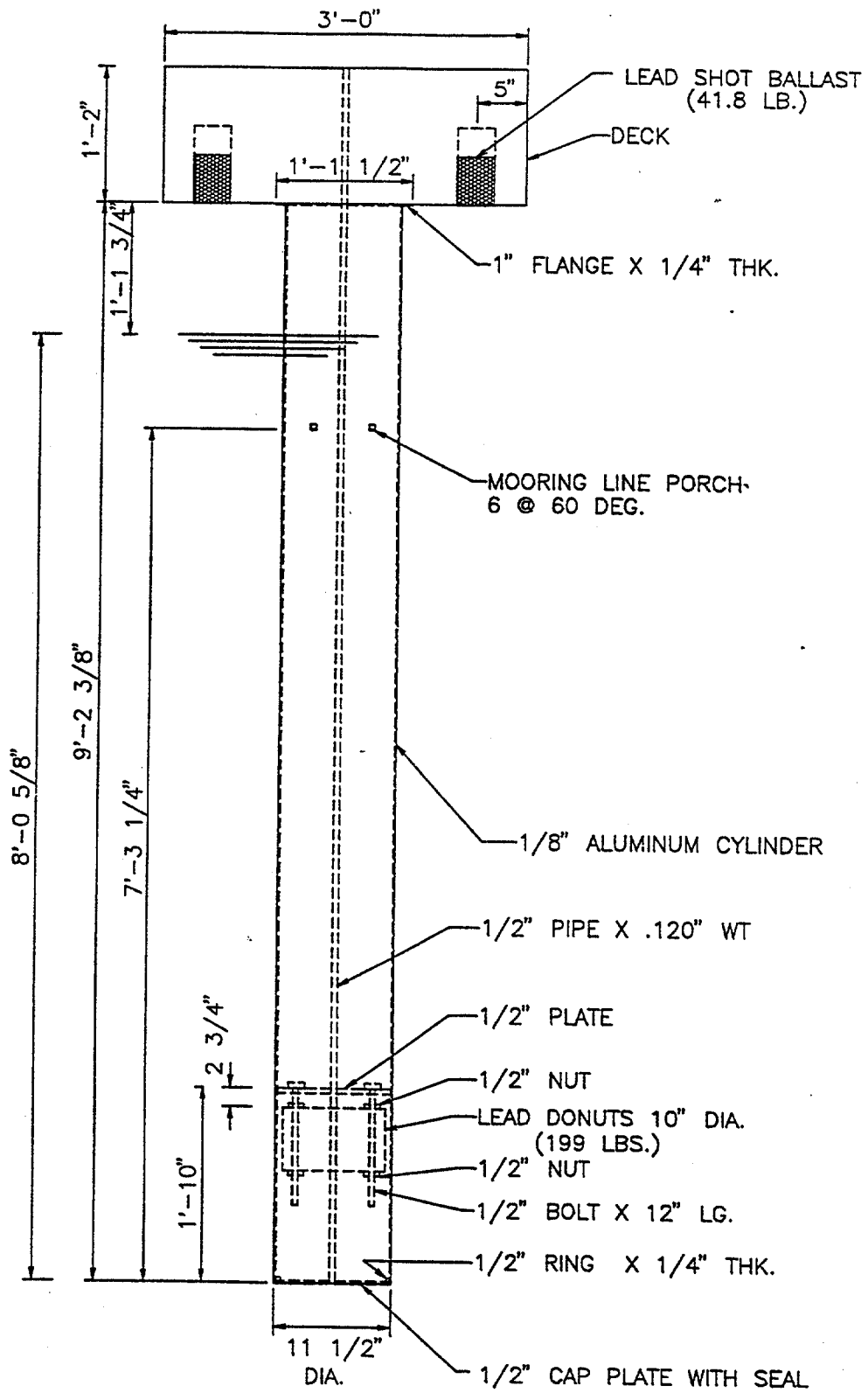


FIGURE 3.11 Small Spar Model Profile Sketch

Table 3.6 Small Spar Mooring System Summary

Target Properties

Tether

	Prototype		Model	
O.D.	0.25	in	13.75	in
Stiffness	27.5	lbs/in.	1025.1	kips/ft
Pretension @ Keel	10.63	lbs	1814	kips
Pretension @ Bottom	3.44	lbs	587	kips

Mooring

	Prototype		Model	
O.D.	0.0625	in	3.44	in
Stiffness	0.0726	lbs/in.	2.7	kips/ft
Pretension	2.60	lbs	444.4	kips

Figure 3.12 Small Spar Mooring Plan

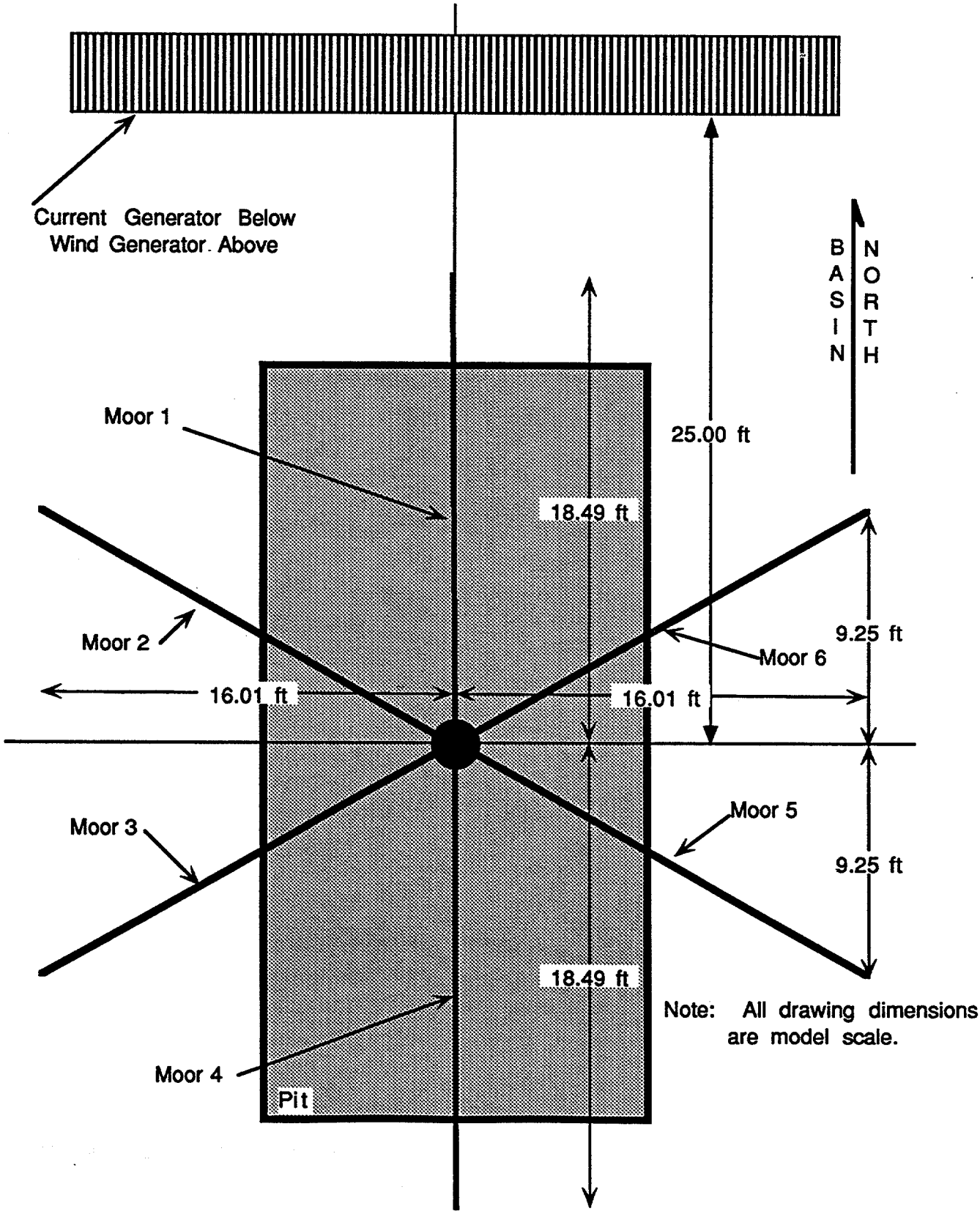
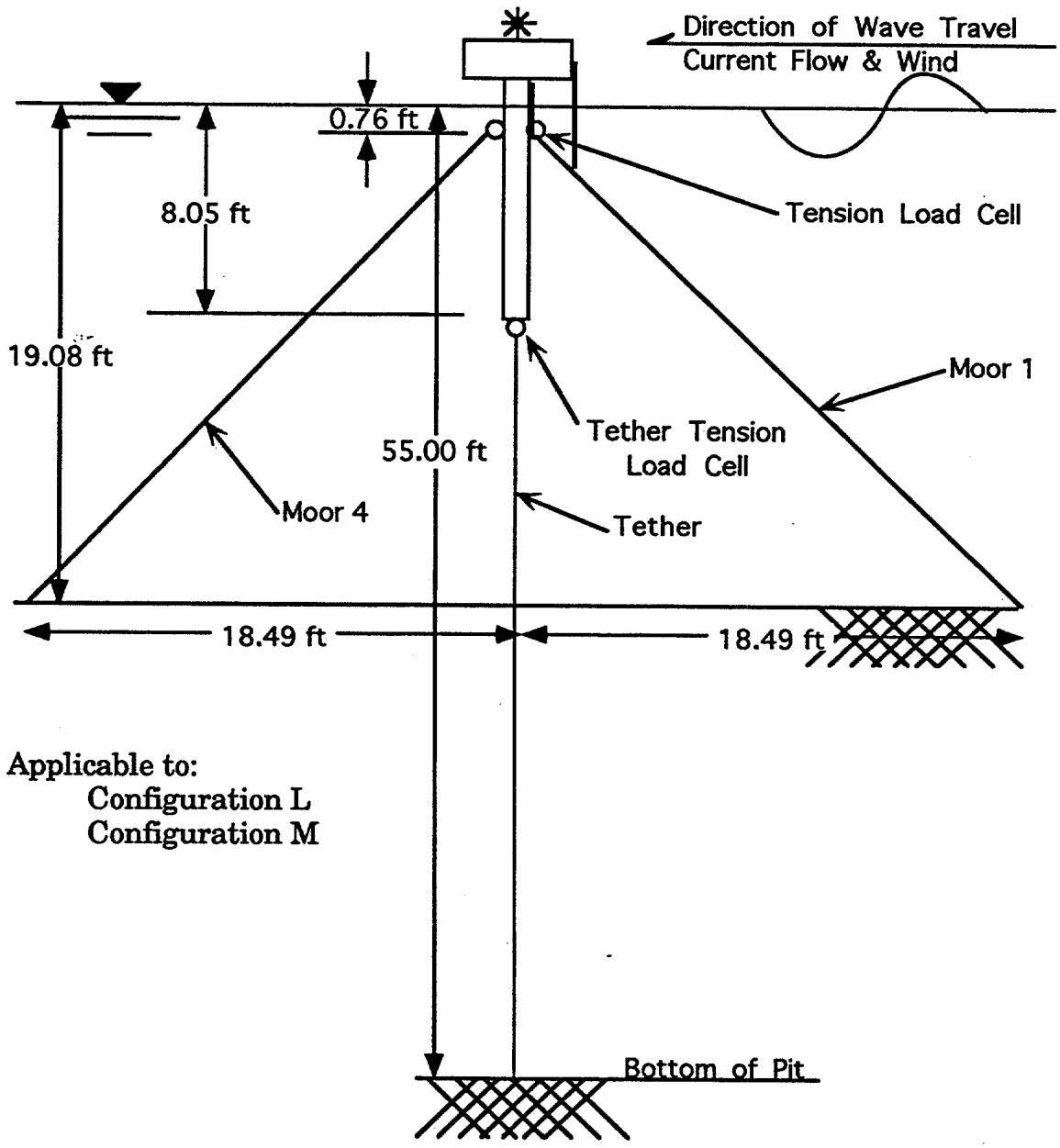


Figure 3.13 Small Spar Mooring Profile



Applicable to:
Configuration L
Configuration M

Note: All drawing dimensions are model scale.

Table 3.7 Tanker Principal Particulars

	Prototype	Model
Length Overall	669.2 ft	12.2 ft
Length Between Perpendiculars	627.9 ft	11.4 ft
Beam	91.7 ft	1.7 ft
Depth	48.4 ft	0.9 ft
Weight	106,650. kips	625.0 lbs
LCG	318.5 ft	5.8 ft from bow
Gyradius	131.1 ft	2.4 ft

Table 3.8 Principal Particulars for Barge in Slide-On Tests

	Prototype	Model
Length Overall	542.0 ft	9.8 ft
Length Between Perpendiculars	375.8 ft	6.8 ft
Beam	183.3 ft	3.3 ft
Depth	28.6 ft	0.5 ft
Weight	36,346.5 kips	213.0 lbs

Appendx E

References

MARINE PHYSICAL LABORATORY

COPY

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UNIVERSITY OF CALIFORNIA, SAN DIEGO
MARINE PHYSICAL LABORATORY OF THE
SCRIPPS INSTITUTION OF OCEANOGRAPHY
SAN DIEGO 52, CALIFORNIA

Flip-Floating Instrument Platform

F. H. Fisher and F. N. Spiess

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Flip-Floating Instrument Platform

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(Received 11 June 1963)

A stable platform from which to perform experiments at sea has been a long-sought goal of sea-going scientists. In order to perform fine-scale experiments on fluctuations of acoustic signals in the ocean the manned buoy FLIP has been built to provide the needed stable platform for such work.

The 355-ft-long, 600-ton craft is towed to station in the horizontal position, and operates in the vertical position at a draft of 300 ft with its electronics laboratory about 30 ft above the water line.

A description is given of its development, stability, and operating characteristics, including the unique flipping operation.

GENERAL NEED

THE desirability and need for a stable platform from which to perform experiments at sea are brought home forcefully to oceanographers on virtually every sea trip aboard conventional craft. On a ship buffeted by waves, not only do personnel and equipment fail to perform as well as on land or calm water, but sometimes the effects to be measured are masked by the action of the sea.

The stability of long, narrow, buoyant objects floating with the long dimension vertical is well known and made use of, for example, in the form of wave poles. Dr. Allyn Vine of the Woods Hole Oceanographic Institution has long advocated taking advantage of the stability of such objects to provide a stable platform for sea-going scientists by up-ending a modified conventional submarine hull. Many approaches to the problem of providing a stable platform at sea have been suggested. The purpose of this paper is to describe a solution to this problem which was made at this laboratory.

In March 1960, the authors decided a specific need existed for a stable platform based on experimental work which showed that wave-action effects even at a few hundred feet below the surface caused enough motion of a submarine to limit measurements of fluctuations in acoustic propagation. To measure fine-scale fluctuations in phase and amplitude of sound waves due to inhomogeneities in the ocean such as thermal microstructure,[1] it is necessary to have a stable platform. Without it the problem would be similar to attempting the study of optical twinkling or radio scintillation of stars from a mobile observatory being driven on a bumpy road.

BASIC REQUIREMENTS

In discussing requirements of a platform to satisfy the primary need for stability, the following additional requirements were established:

1. It should have a draft of 300 ft to mount hydrophones at this depth for the acoustic fluctuation measurements in order to separate multipath effects due to surface reflections.
2. It should be an acoustically quiet platform, and acoustic reflections from the hull should be minimized. This led to the requirement that the hull be flooded completely in the region near the hydrophones to avoid acoustic reflections.
3. It should have a high degree of torsional rigidity so that the position of hydrophones at the 300-ft depth would be accurately known.
4. It should have an electronics laboratory above the surface from which visual, radio, and radar contact could be maintained with a surface ship from which a source could be lowered to transmit sound waves for making the fluctuation measurements.

[1] See, for example, (a) L. N. Liebermann, J. Acoust. Soc. Am. 23, 563 (1951). (b) D. Mintzer, J. Acoust. Soc. Am. Part I, 25, 922 (1953); Part II, 25, 1107 (1953); Part III, 26, 186 (1954). (c) E. Skudrzyk, J. Acoust. Soc. Am. 29, 50 (1957). (d) V. N. Karavainikov, Soviet Phys.—Acoust. 3, 175 (1957).

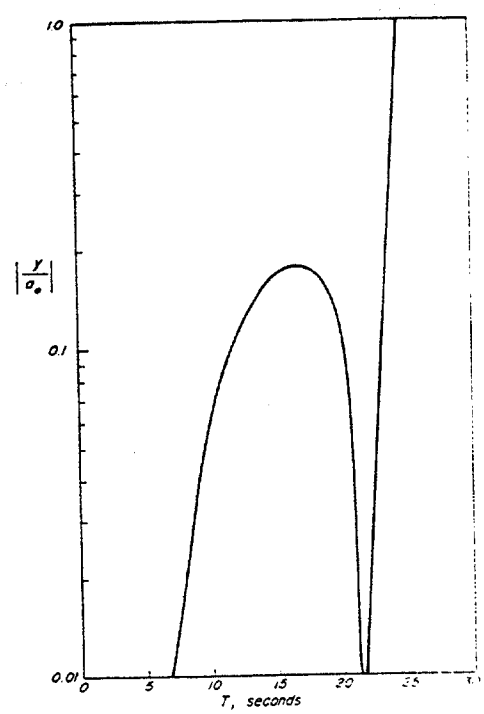


FIG. 1. Vertical motion response of FLIP as a function of wave period; y represents the motion of FLIP, and a_0 is the wave amplitude at the surface. The resonant period is 27 sec, and a null occurs at about 21.5 sec due to cancellation of the downward forces on the conical section and the upward forces on the bottom of FLIP.

5. It should be capable of being berthed at a pier or dock where the draft might be as shallow as 15 ft.

To meet the primary requirement for stability, the authors finally chose a configuration based on theoretical work by Rudnick,[2] which would have a 300-ft draft in the operating position with a reduction in cross-sectional area of 60% at the 150-ft draft. Such a configuration would have a vertical motion response which would be 10% or less than the surface motion; it would have a resonant period of about 25 sec, which is well out of the region 5 to 18 sec to which most of the wave-motion energy is confined. For example, a simple cylinder would have a natural period of 18 sec with a consequently greater response. The shallow draft in port dictated that the maximum draft of the hull be about 10 ft, which meant a maximum dimension of about 20 ft perpendicular to the longitudinal axis. Since the electronics laboratory was to be above the surface, it was decided that space for power-generating equipment, living quarters, and an oceanographic wet laboratory also be above the surface, with sufficient clearance for the upper section to withstand 30-ft waves. This added up to an over-all length of approximately 350 ft in the vertical position.

[2] P. Rudnick, "The Motion of a Spar Buoy is Swell," Internal Memorandums, Part I, MPL-U-17/60 (14 June 1960), and Part II, MPL-U-21/60 (7 July 1960), Univ. Calif., San Diego, Marine Phys. Lab. Scripps Inst. Oceanog. (to be published).

For the acoustic work a 50-ft hydrophone boom was to be mounted at the 300-ft depth. In order to know the location of hydrophones on this boom, it was necessary to provide a way of measuring the relative twist between the electronics laboratory above the surface and the hydrophone boom 331 ft below the electronics-deck level. An unobstructed light path with a minimum diameter of 12 in. was provided so that polarized light could be used to measure torsional changes of the hull.

DEVELOPMENT AND DESCRIPTION

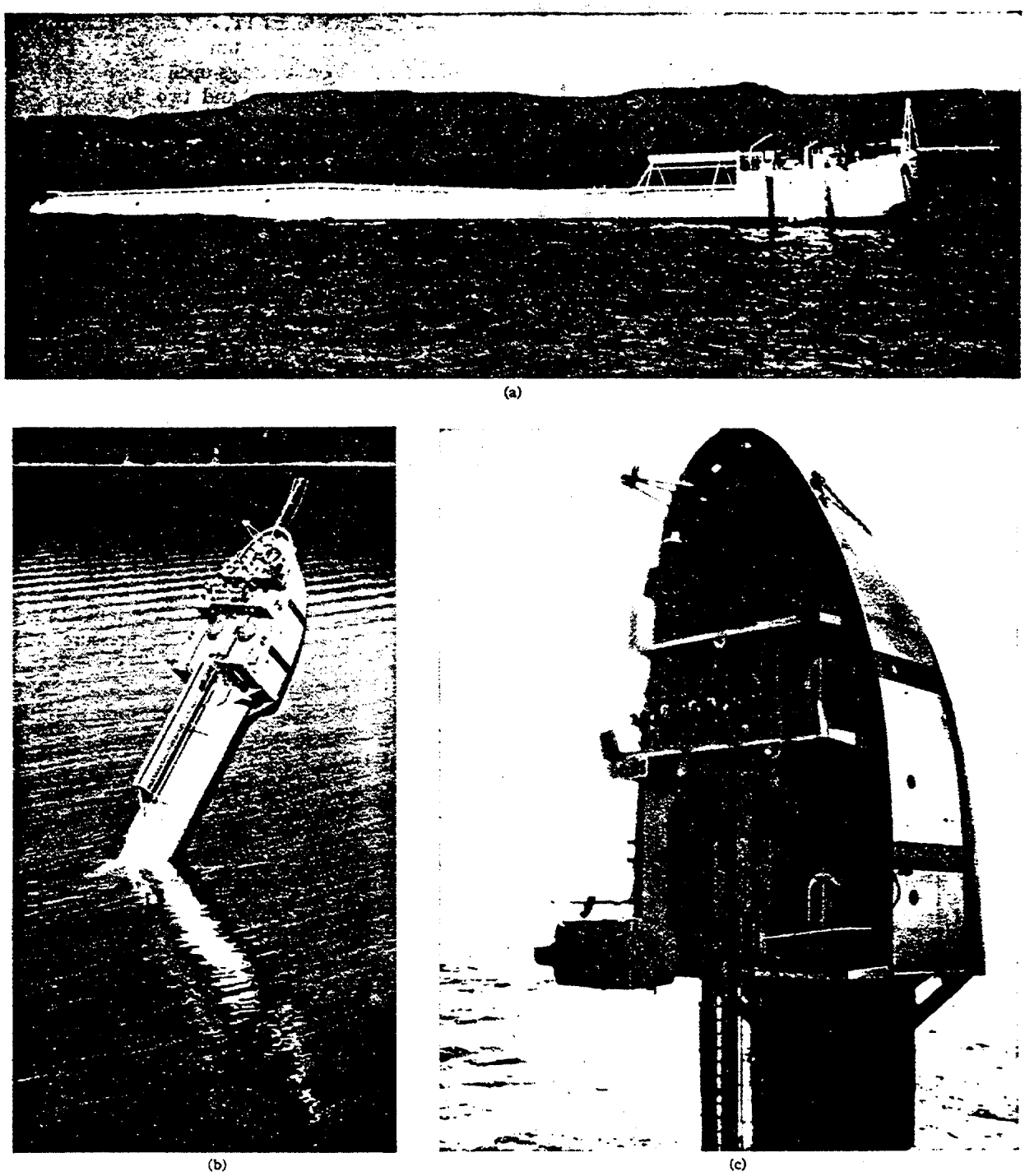
Although many configurations were considered, including the up-ended submarine, it was finally decided the craft should be a single welded unit which could be towed to station in the horizontal position and brought to the vertical position by flooding ballast tanks. Upon completion of an experiment, it would be brought back to the horizontal position for towing to home port or another station. In addition, it was to be capable of staying on station for up to two weeks with a scientific party and a crew of 4 to 6.

Once the general concept had been worked out, consultation with naval architects resulted in feasibility studies by M. Rosenblatt and Sons, San Francisco, California, which indicated that it was possible to build such a craft and that the cost appeared to be reasonable. From studies conducted on 1/100-, 1/25-, and 1/10-scale models, the towing, heave and pitch response,[3] and flipping characteristics were determined and undesirable features eliminated. Upon obtaining satisfactory performance with the model, Rosenblatt and Sons prepared contract plans and specifications for a full-scale prototype. Gundersqn Brothers Engineering Company of Portland, Oregon, with the lowest bid, was awarded the contract to build the buoy.

Larry Glosten, naval architect, served as design agent and prepared the final design of FLIP, which involved reduction of stress discontinuities. As a result, the abrupt transition at 150 ft from the bottom was changed into a 90-ft-long conical transition. This change also altered the response of FLIP to wave motion; its resonant period was increased from about 25 to 27 sec, and its predicted response is shown in Fig. 1.

FLIP is 355 ft long and is made up of about 530 tons of steel and 70 tons of concrete located in the horizontal keel. It is shown in the horizontal and vertical positions, as well as during the flipping operation in Fig. 2. The flipping operation can be readily understood with the aid of Fig. 3. The numbers appearing above the words "inboard profile" refer to the distance in feet from the stern of FLIP, which is the bottom of FLIP in the vertical position. All the ballast tanks have pipes which begin at the upper right-hand corner of the tanks in the upper part of Fig. 3. This means that the openings

[3] N. Vytlacil, TM 81-73-6, Lockheed Missiles and Space Divilon (February 1961).



(a) (b) (c)

FIG. 2. Photographs of FLIP (a) in the horizontal position, (b) during flipping operation, and (c) in the vertical position.

to the pipes are always at the top of the tanks. The pipes extend outside the hull all the way up to the control station in the bow section where valves can be operated to let air out of the tanks or to force compressed air into them, thereby controlling the flipping operation.

Tanks 2 and 4 are 40-ft-long, free-flooding tanks and are not controlled in any manner. Four large free-flooding holes are located at the top of these tanks in the vertical position. Tank 1B is also free-flooding Tanks 1T, 3B, and 3T are 30 ft long and open directly to the sea with the openings located at the lower left-hand corner of the tanks so that they are at the bottom of the tanks in either position. These last three tanks are the principal tanks as far as the flipping operation is concerned. Tank 3 is divided by a partition across the middle into 3T and 3B. There are separate, heavy-duty,

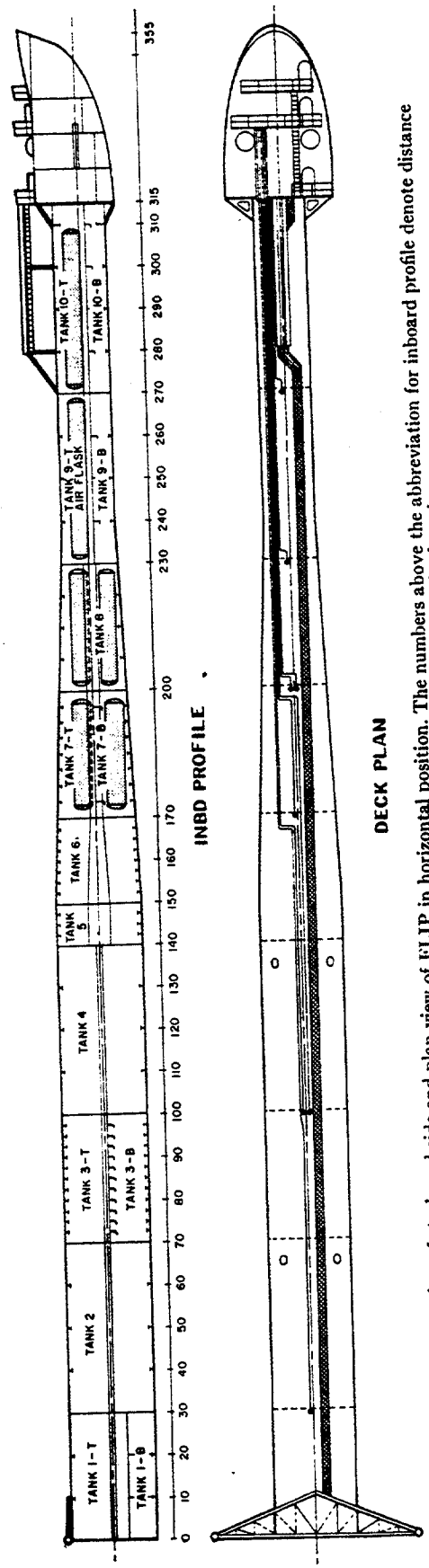


FIG. 3. Cut-away view of starboard side and plan view of FLIP in horizontal position. The numbers above the abbreviation for inboard profile denote distance in feet from the stern. The 50-ft hydrophone boom appears at the stern in the deck plan view.

4-in. pipes going to tanks 1T, 3T, and 3B. Two 10-in.-diam flood openings go to tank 1T from the bottom of FLIP. Large flood openings open into tank 3B, but only two 2-in.-diam holes and two 3-in.-diam holes allow water to go from 3B into 3T. These orifice holes, which make possible a smooth transition to the vertical position, resulted from model studies of the flipping process, which showed that if air were allowed to vent freely out of ballast tanks as they were flooded the model acquired an undesirable diving action which indicated the full scale behavior would show a surge of 30 to 40 ft as it went to the vertical position. The surge occurred as the model flipped to the vertical position because there was a significant decrease in buoyancy as the air in the ballast tanks was compressed due to the increase in hydrostatic pressure. Once sufficient water is in the ballast tanks to initiate the flipping process, any further decrease in buoyancy is unnecessary. This surge was reduced by closing the vent valve after flipping had commenced; however, this meant that the model would ride on a compliant bubble of air when it finally reached the vertical position, which was not a desirable feature from the stability aspect. It also meant that by allowing water to flood freely into the tanks it was not necessary to require the tanks to withstand the hydrostatic pressure since pressure would be equalized.

By restricting the flow of water through orifices, the flipping operation could not only be made smoother, but the undesirable effect of riding on a very compliant bubble could be avoided. Although this necessitated additional expense to insure that the ballast tank with the restricted orifice could withstand the complete hydrostatic pressure differential to which it might be subjected, it was felt worthwhile to secure the advantage of greater control and smoothness of the operation.

The 70 tons of concrete in the horizontal keel was another result of the model studies. In early models the structures did not have cylindrical symmetry, and at the beginning of the flipping procedure models rolled over 180° and 90° about their longitudinal axis. This catastrophic behavior was eliminated by going to approximately the present configuration of concentric cylinders and by using ballast in the horizontal keel to assure a reliable procedure.

Tank 5 is a permanent hard tank and does not open to the sea. Tanks 6, 7T, 7B, 8, and 9B all serve as ballast tanks and are fitted with 10-in., hydraulically operated, flood valves which can seal off the tanks from the sea. All these tanks can withstand the hydrostatic pressure corresponding to their depth and serve as hard tanks. Smaller pipes go from these tanks to the control station.

Four thousand cubic feet of compressed air for forcing water out of the ballast tanks is stored in ten large air bottles, shown in Fig. 3, with two air bottles each in tanks 9 and 10 and three each in tanks 7 and 8.

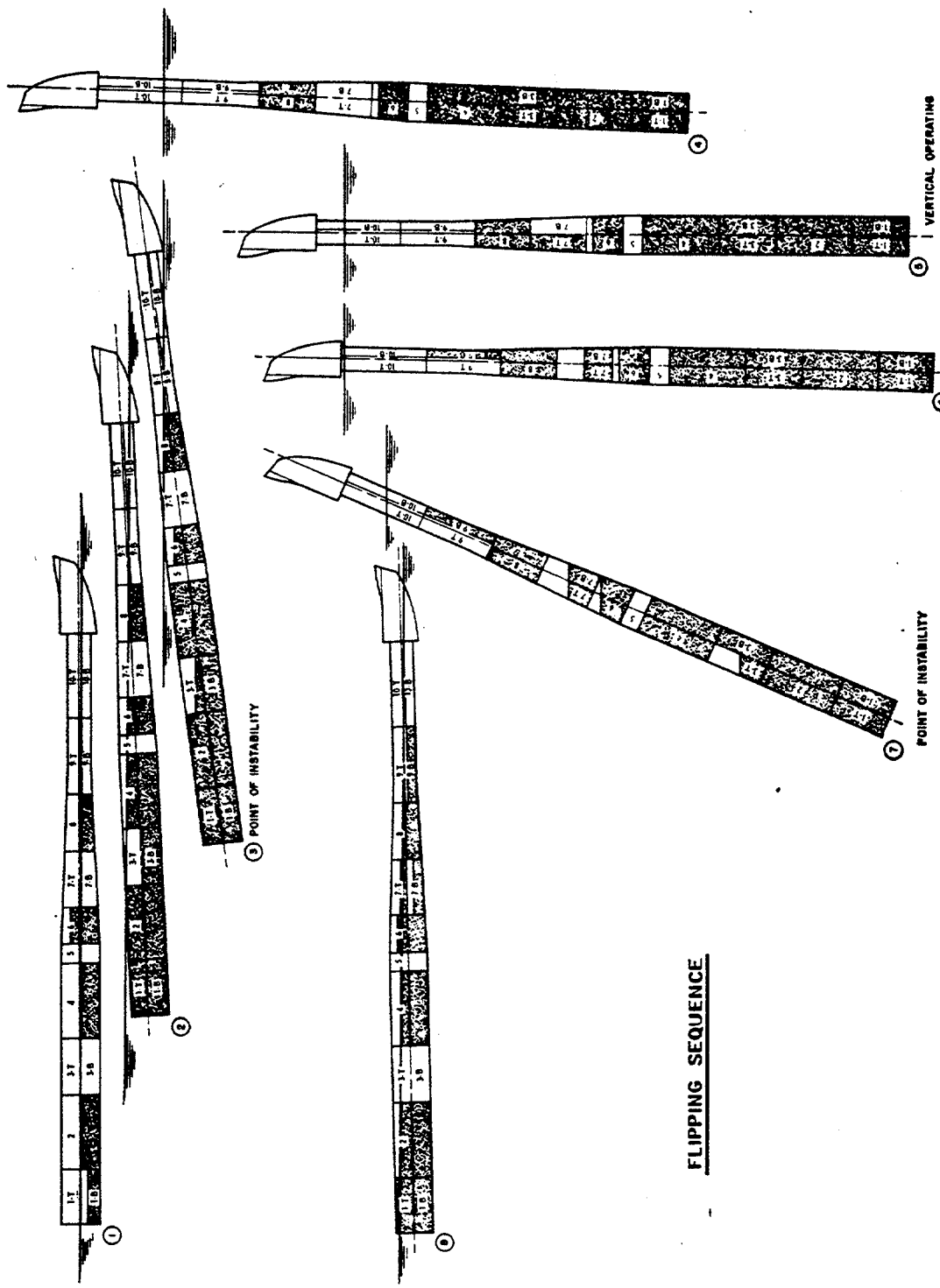


FIG. 4. Distribution of water ballast (shaded areas) in tanks as FLIP goes through transition from horizontal to vertical and back again. (1) Distribution for towing and prior to flipping to vertical. (2) Approximately 15 min after commencing, flipping operation tanks 1T and 3B are flooded. (3) Approximately 20 min after commencing flipping operation, the point of instability is reached with about 50 tons of water in tank 3T. Free-flooding tanks 2 and 4 are filled, and tanks 6 and 8 are allowed to free-flood. (4) About 2 min after reaching the point of instability, FLIP comes to equilibrium in this position. (5) It is trimmed to the vertical position and the 300-ft draft. Flooding tank 7T compensates for the concrete ballast along the horizontal keel. (6) To go back to the horizontal position, water is simultaneously flooded into tanks 7B and 9B as compressed air is forced into tank 3T. This gives a righting moment which brings FLIP back to the horizontal right side up. (7) About 8 min after commencing the transition back to horizontal, the point of instability is reached. At this point it is unnecessary to force any more air into tank 3T since the decreasing hydrostatic pressure will allow the air to expand. (8) FLIP broaches the surface about 2 min later, and more air is now required to remove water from ballast tanks to trim FLIP to the regular towing position.

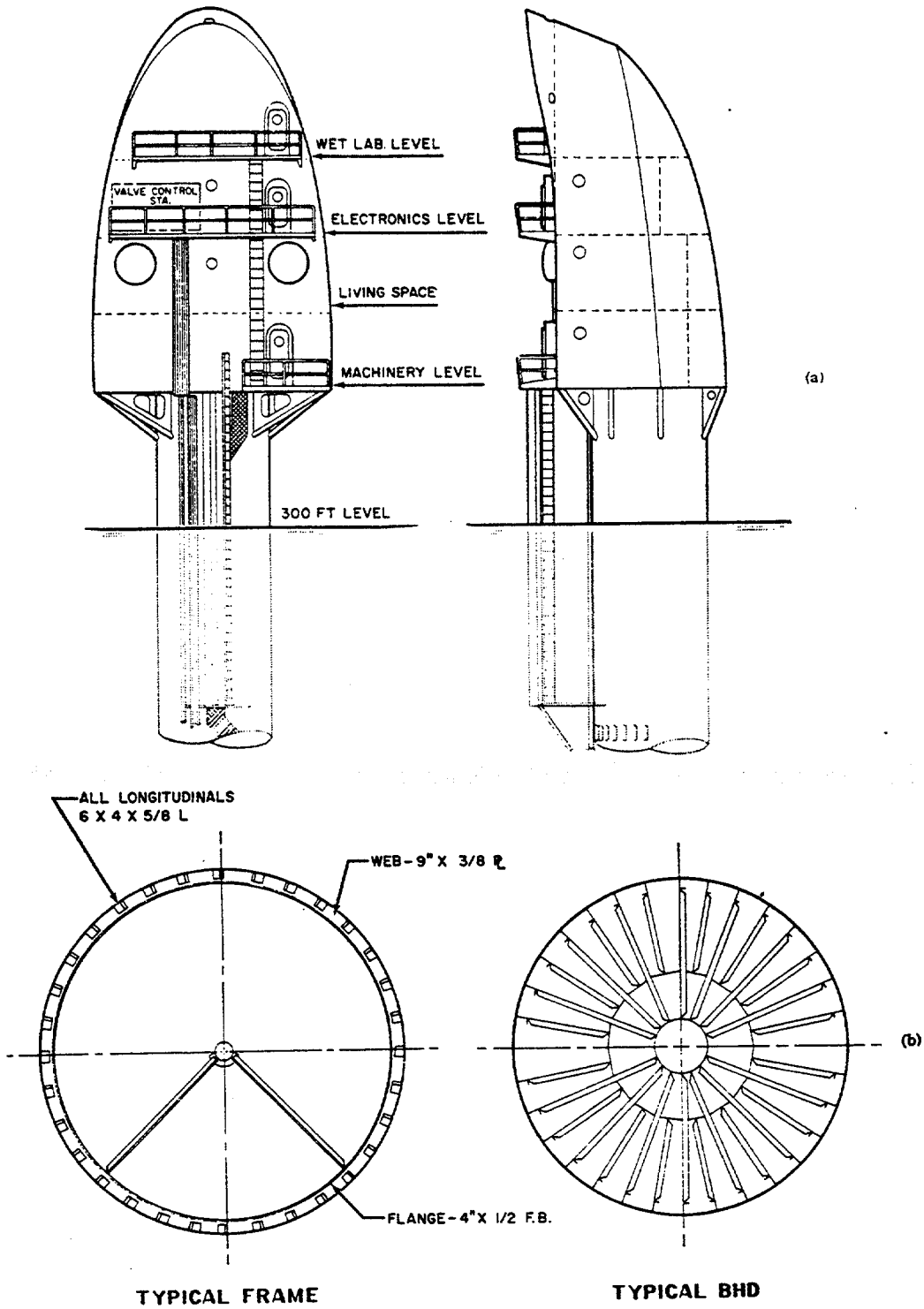
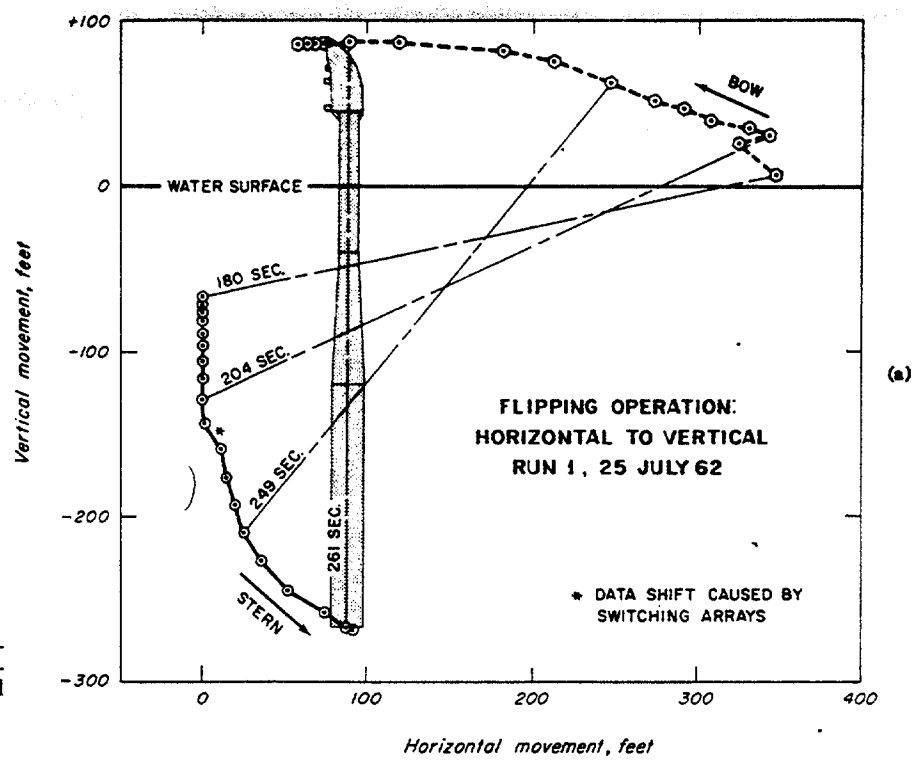


FIG. 5. Front and side schematic views of FLIP in the vertical position at the normal operating draft of 300 ft. The diameter of the cylindrical section is 12.5 ft; the width of the bow section is 25 ft. Spacing between decks is about 8.5 ft. The engine room and living spaces are 14.5 ft deep, while the electronics level is 12.5 ft deep.

At the beginning of a flipping operation, the buoy has water distributed in it, as shown by the dark areas in sequence 1 of Fig. 4; this corresponds very nearly to the normal towing position. Valves are opened to let air out of tanks 1T, 3B, and 3T so that 3T is the last tank to be flooded. Tanks 3B and 3T each hold 150 tons of water. About 20 min is required to reach sequence 3 in which approximately 50 tons of water in tank 3T



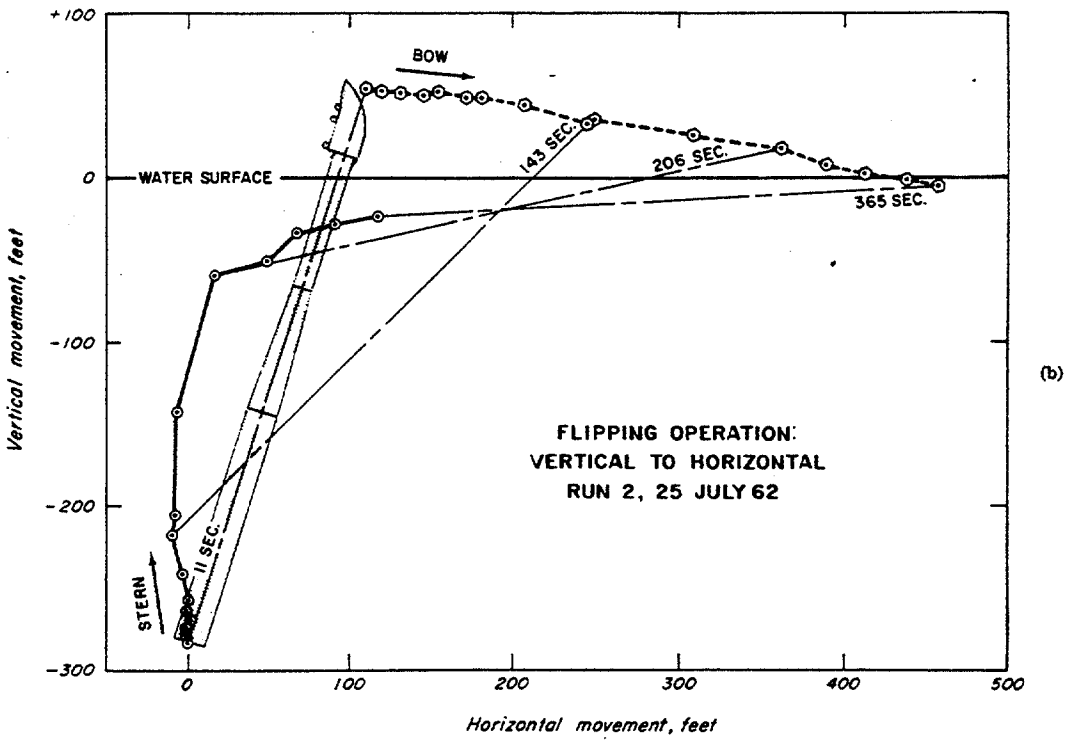


FIG. 6. Position of FLIP as a function of time in going (a) from horizontal to vertical and (b) from vertical to horizontal positions.

brings the operation to the point of instability, after which FLIP goes to the vertical position shown in sequence 4 in a little less than 2 min. By trimming the ballast in upper tanks, it is brought to the 300-ft draft, and with tank 7T full and 7B empty the concrete ballast is compensated so that FLIP will be vertical.

To go back again to the horizontal position, compressed air is forced into tank 3T. This, coupled with the 70 tons of concrete ballast, gives a righting moment so that FLIP returns to the horizontal right side up. Simultaneous flooding of tanks 9B and 7B assists in providing a righting moment as well as minimizing the

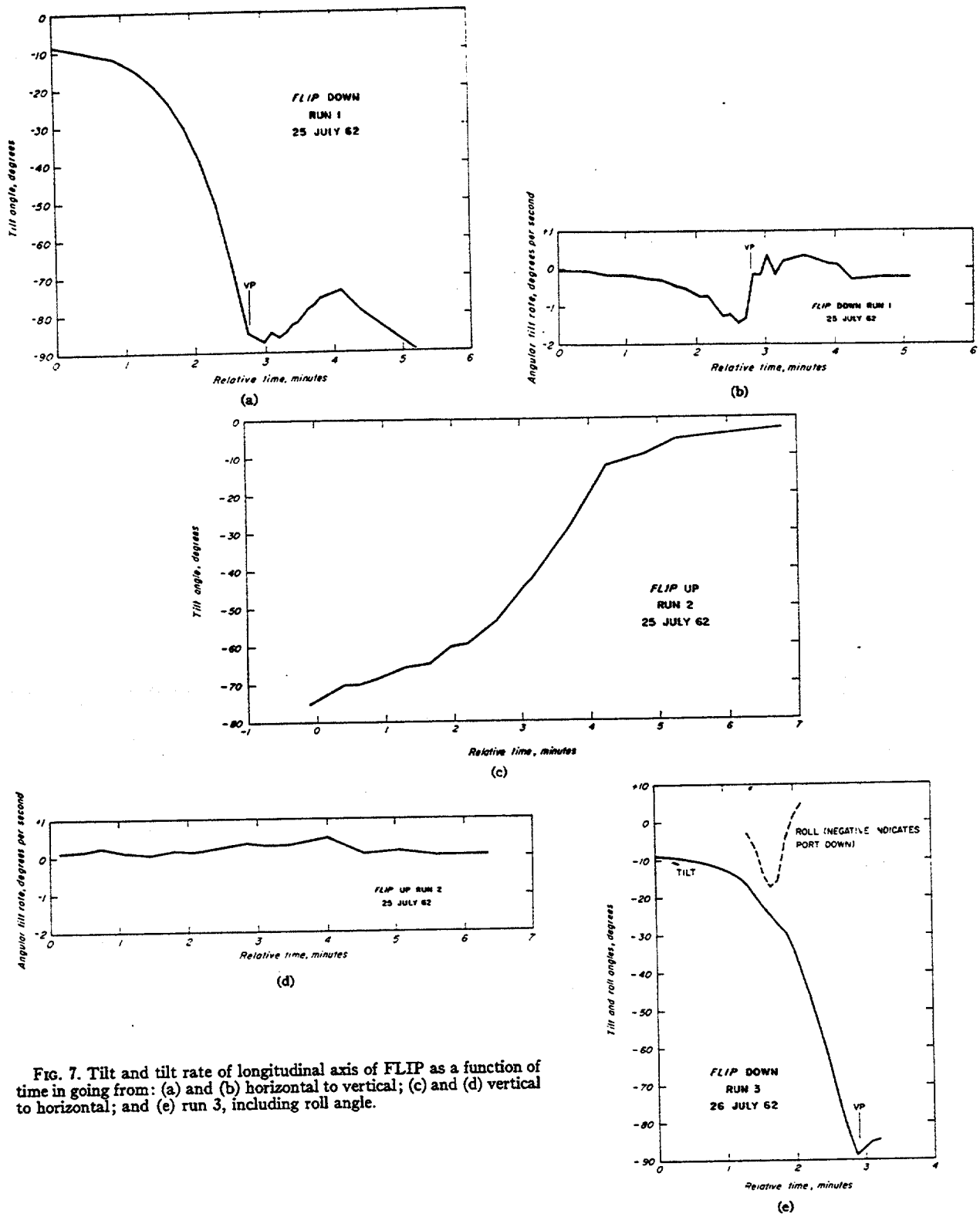
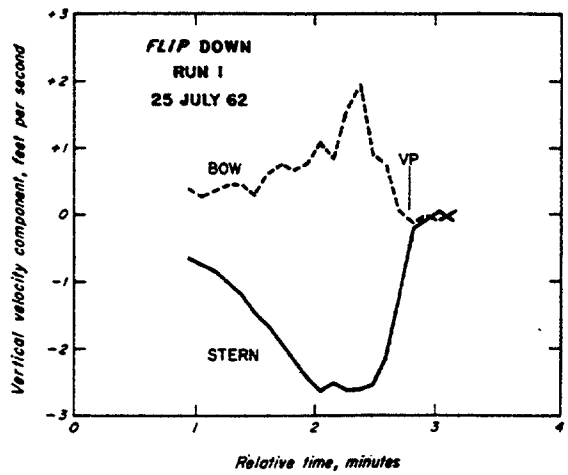


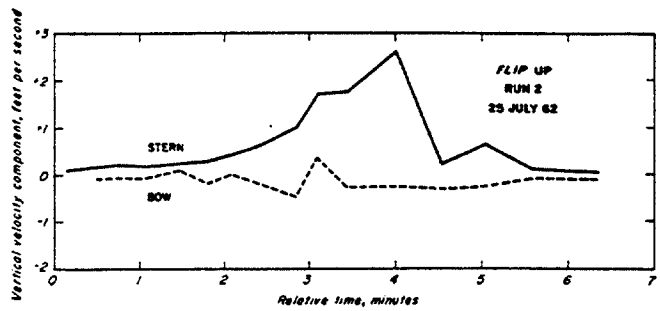
FIG. 7. Tilt and tilt rate of longitudinal axis of FLIP as a function of time in going from: (a) and (b) horizontal to vertical; (c) and (d) vertical to horizontal; and (e) run 3, including roll angle.

vertical height of FLIP above the water. It takes only about 8 min to reach the point of instability shown in sequence 7, and another 2 min to reach the position shown in sequence 8.

The general above-water features of FLIP are shown in Fig. 5. At a normal draft of 300 ft, the lowest deck—the machinery level—is 15 ft above the mean water line. This space, about 25 ft wide, 14½ ft deep, and 8½ ft



(a)



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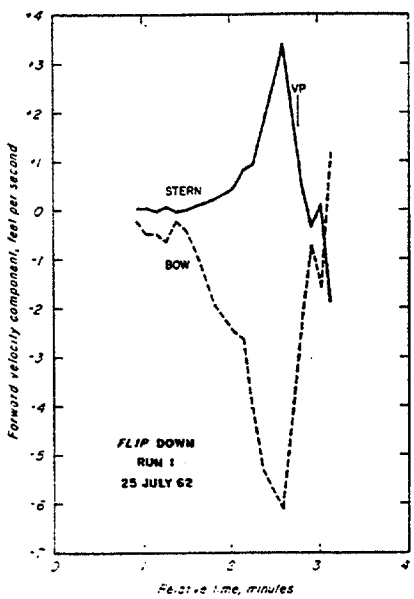

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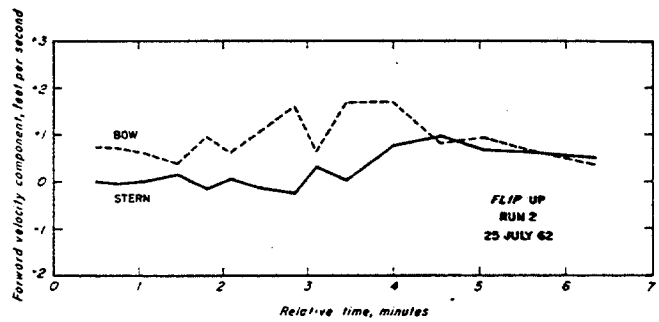


(d)

FIG. 8. Vertical and horizontal velocities of the bow and stern of FLIP as a function of time in going from: (a) and (b) horizontal to vertical; (c) and (d) vertical to horizontal.

high, contains power-generating equipment, two 60-kW, and one 7½-kW electric generators which are driven by diesel engines. These units are mounted in trunnions so that they will always be vertical and capable of operating in both the vertical and horizontal positions or even during flipping, as is done with the small unit.

The next deck, approximately the same size as the lower deck, contains living quarters in which the range, refrigerator, freezer, kitchen sink, bunks, and table all rotate so they are functional in both the vertical and horizontal positions.

The electronics laboratory, somewhat smaller, contains twelve relay racks mounted on their sides in four bays of three each so that equipment can be mounted sideways and tested in the horizontal position with complete access to front and rear of each rack. In the vertical position all the equipment is then in a normal position.

The wet laboratory contains two air compressors for charging up the 4000 cu ft of 250-psi air stored in ten air bottles in the upper tanks of FLIP.

The flipping operation is effected from the valve control station just outside the electronics level. The platforms shown extend out 4 ft from FLIP and, as shown, run approximately the full width of the bow section.

FLIPPING PERFORMANCE

The buoy was built at the Gunderson Brothers Engineering Company in Portland, Oregon, and launched 22 June 1962. Initial trials were conducted at Dabob Bay in the Hood Canal, Washington. This site was selected not only for the calm water, appropriate depth, and weak currents, but also because the facilities of the Keyport Naval Torpedo Station were made available to us. In particular, the three-dimensional tracking

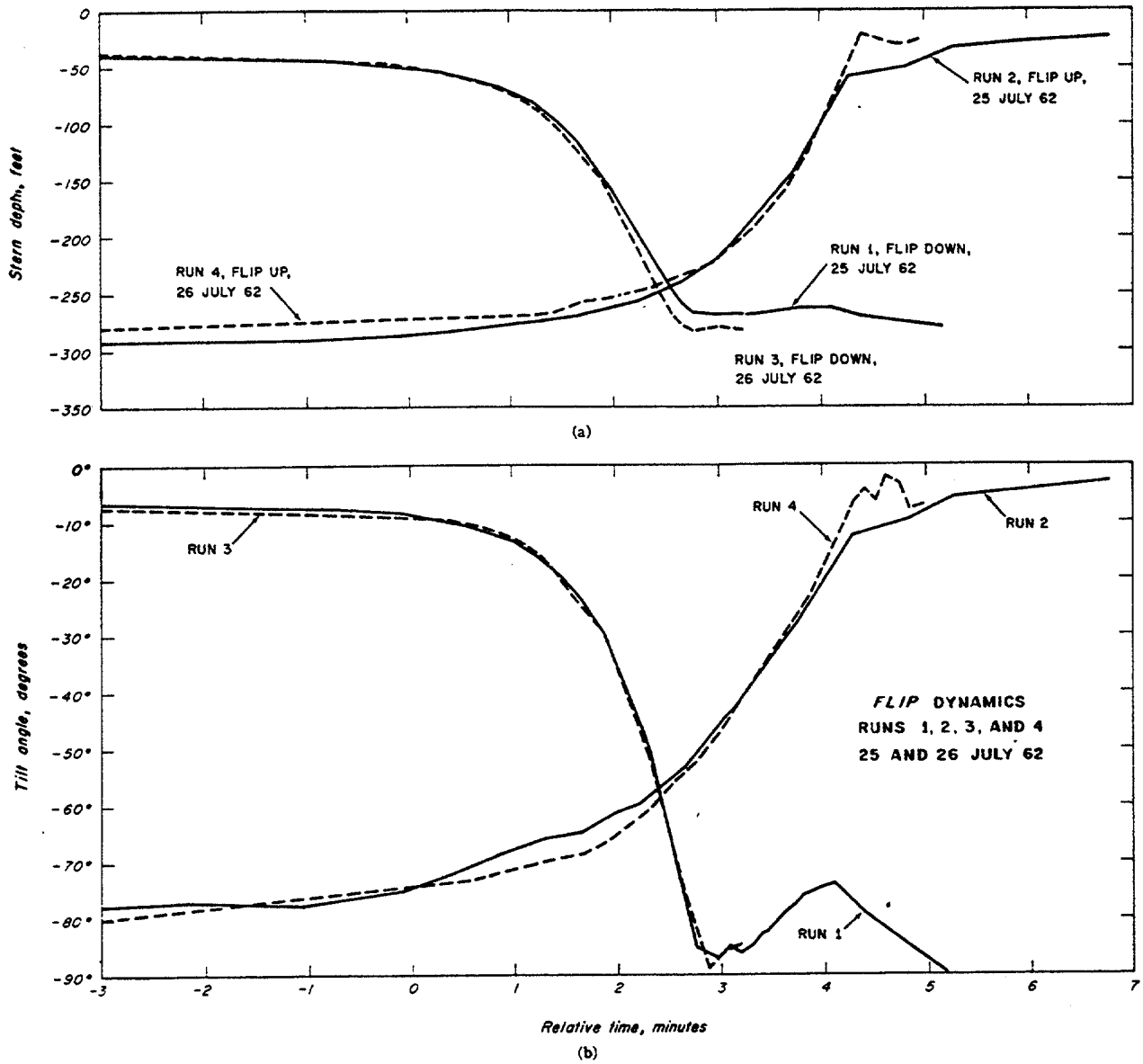


FIG. 9. Comparison of two successive flipping operations: (a) position of stern, and (b) tilt angle as a function of time. The time coordinates in 8(b) apply to 9(a).

range offered the opportunity to record absolute motion during the flipping operation.

After the buoy was outfitted, it was towed to Dabob Bay, and on 23 July 1962 it made its first flip in the afternoon. The motion of the buoy was measured during two of the four subsequent flips later in the week. Acoustic transponders were mounted as follows for the measurements:

1. For measuring tilt two hydrophones were mounted along the horizontal keel at positions 17.7 ft and 140 ft from the stern. To measure roll another hydrophone was mounted on the end of the port hydrophone boom, 25 ft from the center of FLIP and 20.1 ft above the keel. The accuracy in measuring position varied since the hull sometimes interfered with the acoustic paths. The errors in measurement were equal to or less than ± 4.33 ft in coordinate resultants, $\pm 2.0°$ in tilt angle, and $\pm 10°$ in roll angle.

Figure 6 shows the position of FLIP as a function of time in making the transitions from horizontal to vertical and back again. Figure 7 shows the tilt angle and tilt rate as a function of time. Figure 8 shows the vertical and horizontal velocity components at the bow and the stern. A superposition of the stern position and the tilt angle for two different runs shown in Fig. 9 demonstrates the reproducibility of the flipping operation.

ACOUSTICS RESEARCH PROGRAM

Initially FLIP will be used for experimental investigation of acoustic fluctuations in amplitude and phase

difference. Hydrophones will be mounted along the hydrophone boom to study fluctuations as a function of hydrophone spacing. Comparison of the direction of arrival of acoustic and electromagnetic signals from the source ship will be possible with the aid of the uhf equipment. Direct optical sightings on the source will provide bore sight alignment of the uhf equipment.

Reference between acoustic and electromagnetic signals will be made using polarized light, as mentioned earlier. Using the Perkin-Elmer model 707 twist polarimeter, the torsional rigidity of FLIP has been measured. The principles of operation have been described by Falconi.[4] On FLIP a polarized light transmitter is mounted at the stern in the 12-in. optical tube which is 150 ft long and located in the center of FLIP. The light continues through the various upper tanks until it reaches a 12-in. tube passing through the engine room, living quarters, and up about 2 ft into the electronics laboratory where the analyzer is mounted. By using a Faraday cell to modulate the plane of polarization, it is possible to measure torsional deflections of 0.001° over the 333-ft path. There appears to be about a 3-min rotational shift as FLIP goes from the horizontal to the vertical position. In the vertical position in modest seas of height 5 to 7 ft, the twist motion is less than ±0.005°, as shown in Fig. 10.

Using standard optical techniques and a Wild T-2 theodolite, it is possible to transfer the direction normal to the hydrophone boom mounts via the polarized light up to the polarimeter analyzer in the electronics laboratory. Accurately aligned mirrors mounted on both the polarimeter transmitter at the bottom of FLIP and on the analyzer are provided so that autocollimation techniques can be used for referencing the uhf equipment to the hydrophones.

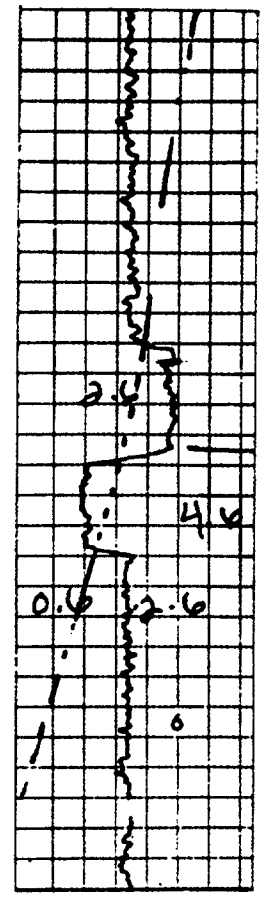


FIG. 10. Twist polarimeter recording of torsional oscillations of FLIP, 4 April 1963. The large deflections are 1-min calibration steps made with a mechanical tangent arm. The twist in seas of height 5 to 7 ft is less than ±15 sec of arc (±0.005°).

SUMMARY

The performance of FLIP has been highly satisfactory thus far. The towing and flipping operations in seas up to 8 ft have become routine, and the stability in the vertical position, according to preliminary measurements,[5] is as expected. Orientation motors have been installed so that in the vertical position FLIP can be steered to any given direction. A more detailed description of the structure and arrangements of FLIP has been made by Bronson and Glosten.[6]

Facilities for personnel on board FLIP have been increased so that twelve people including a crew of six can stay on board for a week to two weeks at a time without reprovisioning. Transfers of personnel can be made at sea in the vertical position, but FLIP's stability makes small-boat transfers dangerous. Usually transfers are now made in the horizontal position.

It appears that not only will FLIP be a highly useful stable platform from which to conduct acoustic research, but it will find much use in the following areas: seismic waves, ocean-wave spectra, and directions of arrival of storm-generated waves, ambient noise, and marine biology.

In addition, the general concept of stable platforms similar to FLIP may be useful in other applications such as navigation or tracking stations, and drill platforms.

ACKNOWLEDGMENTS

The entire program which led to the construction of this novel platform was a result of the interest of Dr. F. N. Spiess, Director of the Marine Physical Laboratory, in the acoustic phase fluctuation properties of the ocean. He persuaded Dr. Fisher to take an active interest in experimental work on these properties which began in June 1959. By March 1960 it was clear that platform motion was a problem limiting the work.

The concept of FLIP received an enthusiastic and ready response from Captain C. B. Momsen, Jr., Head of Office of Naval Research, Code 466. With the strong

[4] O. Falconi, "The Alignment Polarimeter," presentation, Automatic Optical Alignment Symposium, 1961, Perkin-Elmer Corporation, Norwalk, Connecticut.

[5] P. Rudnick and E. Squier, "Accelerations of FLIP, Preliminary Data," MPL Tech. Memo. 134, Univ. Calif., San Diego, Marine Phys. Lab. Scripps Inst. Oceanog. (18 Feb. 1963).

[6] E. D. Bronson and L. R. Glosten, "FLIP—Floating Instrument Platform," SIO Ref. 62-24, Univ. Calif., San Diego, Marine Phys. Lab. Scripps Inst. Oceanog. (1 Nov. 1962).

support of Dr. Benjamin Snavely of the Naval Ordnance Laboratory, funds were obtained to proceed with studies and eventually the construction of FLIP.

The model work on the flipping process was performed at the Marine Physical Laboratory (MPL) by Dr. Fisher, with the help principally of C. S. Mundy, as well as several other members of MPL.

The Marine Physical Laboratory was fortunate in having Professor Henry Schade, University of California, Berkeley, and Admiral Charles D. Wheelock, USN (Ret), as consultants.

With the contract awarded to Gunderson Brothers Engineering Company, Earl D. Bronson, Cdr., USN (Ret), became the resident inspector for MPL and is now Officer-in-Charge of FLIP with a regular operating crew of 6.

Finn Outler, Technical Superintendent at MPL, surmounted many financial and administrative problems in obtaining much of the equipment as Government Furnished Equipment through our ONR contract officer, Lt. Cdr. John C. Bajus, USN.

The five acceptance test flips in Dabob Bay were conducted by Dr. Spiess with Dr. Fisher, E. D. Bronson, and C. S. Mundy of MPL, and with Bill Gilmore of Gunderson Brothers Engineering Company.

The facilities of the Keyport Naval Torpedo Station were made available through the cooperation of the Bureau of Weapons. Captain H. C. Maynard, USN, Commanding Officer, J. E. Mason, Engineering Division Head, K. Willey, Project Engineer, Lt. (j.g.) O. Kohl, Diving Officer and Liaison Officer for FLIP, and many others were most generous and ready in their cooperation with the FLIP staff. It is through their efforts that it was possible to take advantage of the unique opportunity for obtaining the absolute motion of FLIP in its operations.

The launching on 22 June 1962 was highlighted by the principal speaker, The Honorable Warren G. Magnuson, United States Senator, who has long had a keen and active interest in the future of oceanography.

This work represents one of the results of research sponsored by the U. S. Office of Naval Research.

Motion of a Large Spar Buoy in Sea Waves[1]

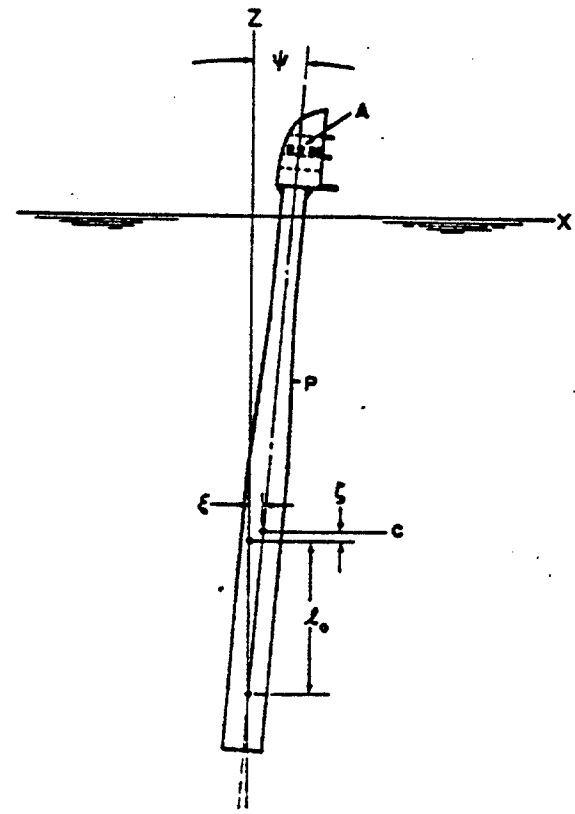
By Philip Rudnick[2]

Measurements and first-order calculations are given for the motion of the large spar buoy FLIP in response to ocean waves. Wave pressure and three components of acceleration were recorded over a one-month period. Within substantial tolerances, observed and calculated frequency-response ratios are in agreement. Observations of the damping of transient motions are also reported.

A. Introduction

FLIP (floating instrument platform) is a manned spar buoy used by Scripps Institution of Oceanography as a stable support for oceanographic instrumentation. The vessel is towed to and from station in a horizontal attitude. For use, it is brought, by reballasting, to a vertical position in which a bow section becomes a superstructure which contains working and living space. A rough indication of the configuration is shown in Fig. 1. Normal draft is 300 ft and the superstructure extends 55 ft above the waterline. Some further numerical information is given in Section C, Table 3. More extensive descriptions of the buoy and its operation have appeared [1, 2].[3]

During the month of September, 1963, FLIP was maintained continuously on station at 39° 20′N, 148° 30′W, about midway between Hawaii and the Alaskan coast, serving as one of a wide-spread group of observation points in a study of ocean swell [3]. As a secondary project, using nonoptimized instrumentation, components of buoy acceleration were measured simultaneously with wave pressure. Based on these data, this report presents first, for this season and geographic location, a quantitative description of the stability and motions of the buoy, and second, a comparison of the observations with calculated frequency-response ratios of buoy acceleration to wave pressure. Some observations on the damping of transient motions are also described.



A = accelerometers
P = pressure sensor

Fig. 1 Configuration of FLIP, showing coordinates employed (refer to notation list, Section C, and caption to Fig. 4), and location of sensors

B. Description of Observations and Summary of Results

One vertical (V) and two horizontal accelerometers were mounted rigidly in the buoy, one of the latter (H_1) in a "fore-and-aft" azimuth and the other (H_2) at right angles. (The azimuth of the keel is taken as the "heading" of the buoy when vertical.) The output of each horizontal instrument, which we call apparent horizontal acceleration, contains a substantial contribution from angular motion of pitch or roll, as well as the effect of horizontal acceleration of the buoy center. No experimental basis was provided for separating these two parts; reliance for this is wholly on theory. Readings of wave pressure were obtained from one of the sensors (P) installed by Snodgrass, *et al.* [3] at 100 ft depth. The

[1] This report represents the results of research sponsored by the Office of Naval Research. Contribution of the Scripps Institution of Oceanography, University of California, San Diego, Calif.

[2] University of California, San Diego, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, Calif.

[3] Numbers in brackets designate References at end of paper.

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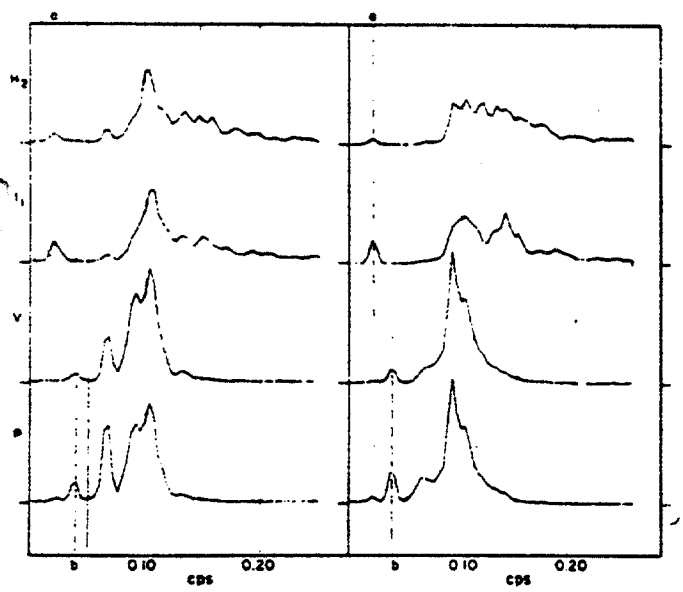
Table 1 Cumulative Distribution Among Records of Power and RMS Values

Fraction of cases, f	Vertical acceleration (42 cases): total power, cm²/sec⁴	total rms, cm/sec²	at resonance, rms: acceleration, cm/sec²	at resonance, rms: displacement, cm	Wave pressure[a] (50 cases): total power, cm²	total rms, cm
1.00	4.0	2.0	0.22	4.1	637	25
0.90	2.4	1.6	0.17	3.2	290	17
0.75	1.6	1.3	0.11	2.1	187	14
0.50	0.70	0.84	0.078	1.5	105	10
0.25	0.41	0.64	0.067	1.3	58	7.6
0.10	0.28	0.53	0.045	0.8	40	6.3

Apparent horizontal acceleration (52 cases), H_1 fore-and-aft, H_2 transverse

f	total power, cm²/sec⁴: H_1	H_2	combined H_1 and H_2	total combined, rms, cm/sec²	ratio of total power H_2 to H_1	at resonance total power cm²/sec⁴: H_1	H_2	combined rms angle, deg
1.00	649	450	910	30	5.85	69	13	0.53
0.90	500	360	800	28	2.33	14	5.3	0.26
0.75	320	240	570	24	1.40	6.6	3.3	0.18
0.50	175	140	353	19	0.68	3.7	1.6	0.13
0.25	95	83	210	15	0.49	1.5	0.8	0.09
0.10	59	64	161	13	0.34	0.4	0.4	0.05
least					0.23			

The table gives cumulative distributions in the usual sense; each entry is a least value which exceeds a fraction f of all values observed.
[a] Wave pressure measured at 100 ft depth, expressed in cm of sea-water column, not corrected for vertical motion of the sensor.



H_1, H_2 = apparent horizontal acceleration, fore-and-aft and transverse components, respectively
V = vertical acceleration
P = wave pressure
a, b = resonant frequencies, for pitch-roll and heave, respectively

Fig. 2 Examples of power spectra. Ordinates are proportional to power. Spectra are normalized to constant area. September 5 (left) and September 26 (right), both 18:00 local time

minor contribution to this measurement arising from vertical displacement of the buoy, mainly at the lowest frequencies, was not removed. Fifty-two simultaneous record-sets from the four instruments (V, H_1, H_2, P), of half-hour duration at 12-hour intervals over a 26-day period, were taken. In 12 cases one instrument (V or P) was lacking.

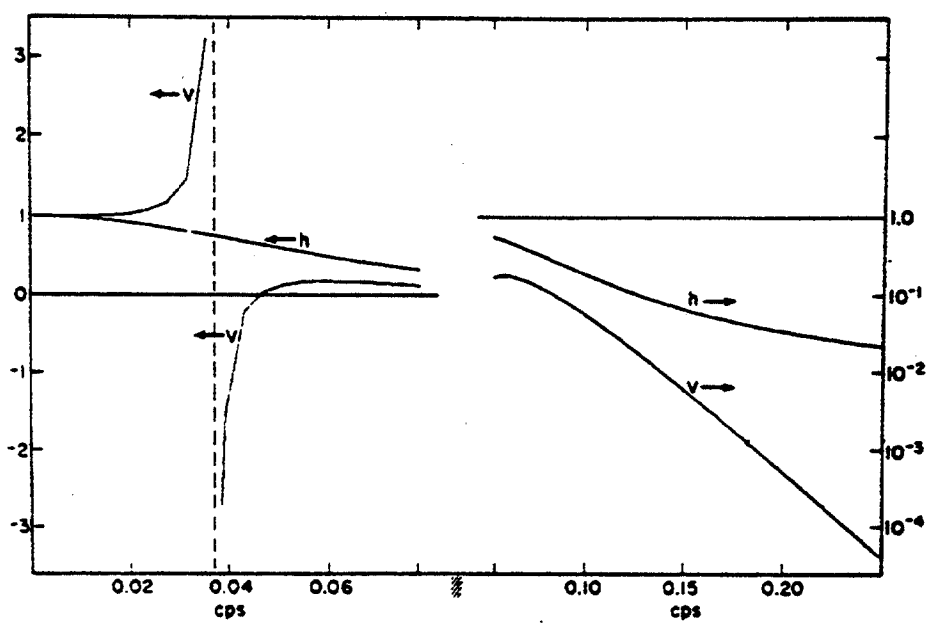
Further description of the instrumentation and treatment of data, and a critical discussion of results, are given in Sections D and E. Here we summarize the main findings.

Each record from each instrument, after reduction to zero mean, yielded a mean squared value (variance), called a total power, and a power spectrum, indicating the distribution of this power with respect to frequency. Table 1 shows the range of total-power values observed and corresponding root-mean-square values of the accelerations and pressure. Median values of the latter are of the order of 1 cm/sec² for vertical acceleration, 20 cm/sec² for apparent horizontal acceleration, and 10 cm of water for wave pressure at 100 ft depth. Estimated median rms displacements at the position of the accelerometers, in the laboratory in the superstructure, are 3 cm vertical and 50 cm horizontal. Observed extremes of total power had ratios of the order of 10 or 20.

Examples of the power spectra are shown in Fig. 2. Pitch-roll resonance is indicated by a peak at 0.021 cps (48-sec period) in the spectra of apparent horizontal acceleration, and heave resonance at 0.037 cps (27-sec period) in the vertical acceleration spectra. A peak at the latter frequency in the pressure spectra arises wholly from vertical displacement of the buoy. Ranges of power values at these resonances are also shown in Table 1. These are of the order of 1 to 10 percent of the total power for the horizontal and of 10 percent for the vertical case. Except for these resonances, power in all the spectra lies almost wholly above a natural low frequency limit for waves of about 0.06 cps. Vertical acceleration and pressure show a high frequency limit around 0.14 cps which is set by strongly rising attenuation of wave mo-

Table 2 Spectral Power Response Ratios

frequency, cps	quartile values lower	quartile values upper	estimated median	relative spread of quartiles, percent	calculated value	ratio, observed median to calculated
Ratio, vertical acceleration to wave pressure, unit (0.01 cm²/sec⁴)/cm² (sea water)						
0.037 (resonant)	0.33	0.46	0.38	−13, +21	0.286	1.33
0.062	0.44	0.50	0.47	±7	0.366	1.28
0.078	0.74	0.85	0.795	±7	0.743	1.07
0.094	0.93	1.06	0.995	±7	0.921	1.08
0.109	0.97	1.11	1.04	±7	0.967	1.08
0.125	0.95	1.12	1.035	±8	0.967	1.07
0.141	0.97	1.31	1.14	±15	0.977	1.17
Ratio, sum of two components of apparent horizontal acceleration to wave pressure, unit (cm²/sec⁴)/cm² (sea water)						
0.051	0.49	1.95	0.98	−50, +99	0.12	8.2
0.062	0.35	0.60	0.47	±27	0.33	1.4
0.078	0.71	1.00	0.85	±17	0.81	0.95
0.094	1.5	2.0	1.73	±14	1.74	0.99
0.109	3.2	4.4	3.8	±16	3.80	1.00
0.125	7.4	10.7	8.9	±16	8.94	0.99
0.141	19	25	22	±14	23.5	0.94
0.156	40	68	52	−23, +30	69.8	0.76
0.172	66	148	99	−33, +50	239	0.41



v = vertical displacement ratio, buoy to sea surface (ζ/z_0^*)
h = horizontal displacement ratio, buoy center, c, to sea surface (ξ/x_0^*)

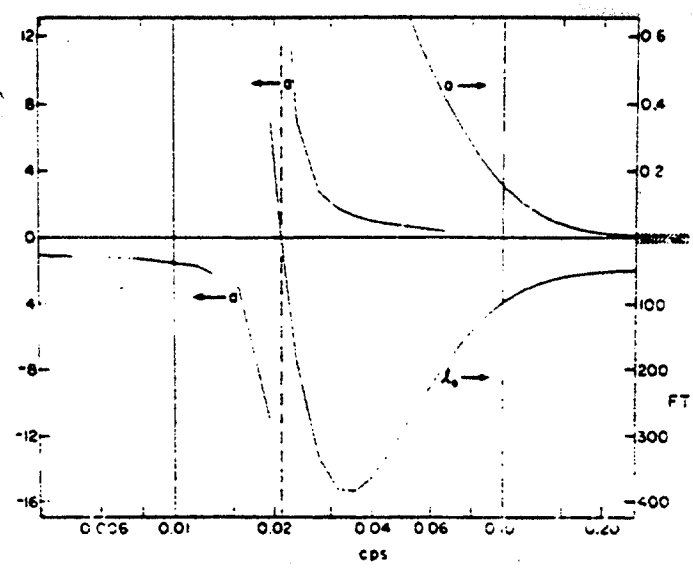
Fig. 3 Response of buoy to waves, as function of frequency

tion with depth at higher frequencies. (At 0.14 cps there is a 16-fold attenuation of power from the surface to 100 ft depth.) The pressure and vertical acceleration spectra are always closely similar because the pressure sensor was located near the effective center for the predominant vertical accelerating force arising from wave pressure on the expanding conical section of the hull. The apparent horizontal acceleration is also influenced by waves at lesser depths, and these spectra fall off more gradually toward high frequency.

Cross spectra, expressed as coherence and phase, were also computed, and are discussed in Section E.

In the pitch-roll resonance, about 0.9 of the apparent horizontal acceleration is attributable to the static effect of (oscillatory) angular displacement. At the higher frequencies of prominent wave motion, the effective fraction is smaller, in the range 0.25 to 0.10, depending on the specific shape of the spectrum. A typical near-median record might show a total rms angular displacement of 0.25 deg, made up of independent contributions of 0.13 deg from the pitch-roll resonance and 0.21 deg from the wave-frequency region.

Section C presents a calculation of the linear relations which are expected between wave pressure forces and the



a = ratio of pitch-roll angle to sea-surface slope ($\psi/kz_0°$)
L_0 = distance to stationary axis, measured downward from buoy center, c, (ξ/ψ)

Fig. 4 Angular response of buoy to waves, as function of frequency

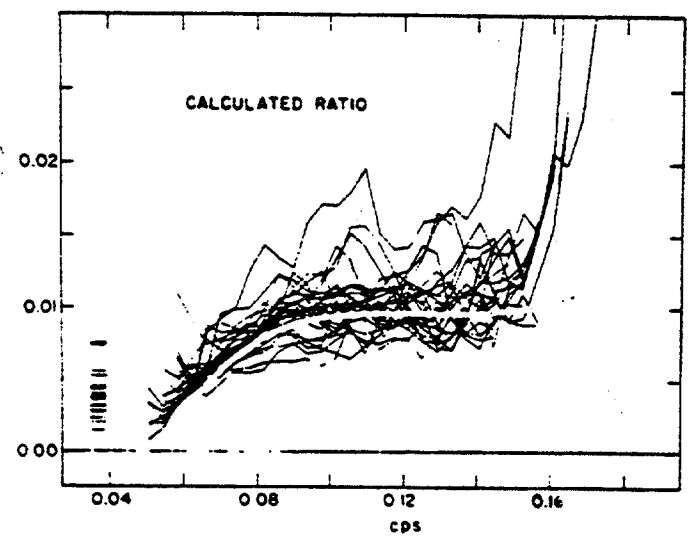


Fig. 5 Ratios of observed power spectra, vertical acceleration to wave pressure. Unit (cm²/sec⁴)/cm² of sea water. Plot includes the most disparate, and over half of all, observations. Bars at left represent single numbers referring to heave resonant frequency. Only regions where the two spectra have coherence of at least 0.71 are plotted (aside from resonant frequency)

consequent buoy motion. Figs. 3 and 4 show the results applied to FLIP. Effects of wind and other possible sources of oscillatory motion are estimated to be minor. Using this analysis, predicted frequency-dependent ratios were calculated, (*a*) between the power spectra of vertical acceleration and measured wave pressure, and (*b*) between the spectrum of total power in both components of apparent horizontal acceleration and the wave

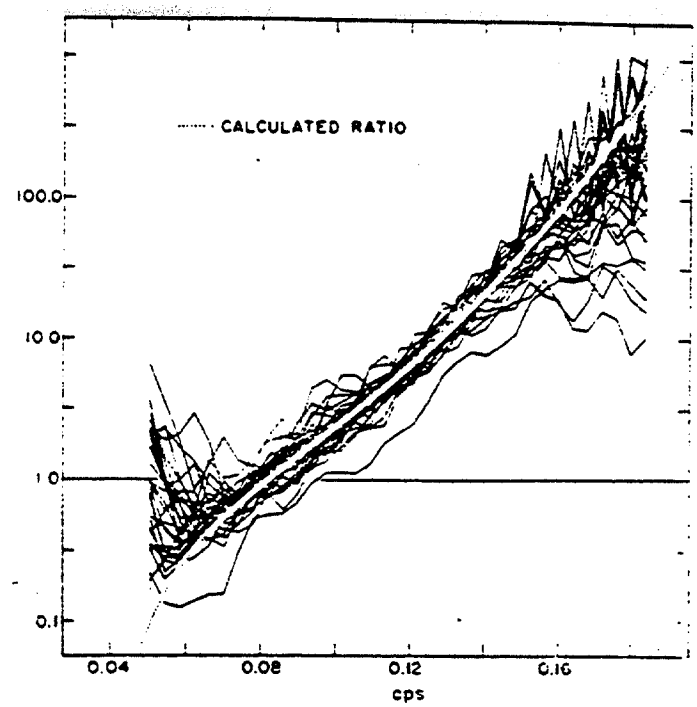


Fig. 6 Ratio of observed power spectra, apparent horizontal acceleration (two components combined) to wave pressure. Plot includes the most disparate, and over half of all, observations

pressure spectrum. These calculations recognized the depth of the pressure sensor and its vertical motion with the buoy (the latter contributing 15 to 25 percent of the apparent pressure amplitude in the region of the main spectral peak), and the combined effects of translation and rotation in the apparent horizontal acceleration. Values of these same two ratios were taken from all sets of observed power spectra.

It is to be expected that these observed ratios would be constant from case to case at a given frequency, and would agree with the predicted values. The expected constancy is to a surprising degree lacking. Figs. 5 and 6 and Table 2 indicate the range of values obtained for the observed ratios, and their relation to calculated values. The large scatter, discussed further in Section E, is not understood. The agreement between median observed ratios and the calculated values is considered significant and it is concluded that the linear mechanism considered in Section C is reflected by the data, subject to tolerances of about 10 to 30 percent representing uninterpreted scattering in the data.

The wave pressure spectra obtained by Snodgrass, *et al.* [3], had three times the resolution of those reported here. These were made available to me and provided the best observed values of the resonant frequencies. That found for the heave resonance is 0.0368 cps, in agreement with the calculated value to well within the estimated 1-percent uncertainty of the latter. The observed pitch-roll resonance, at 0.0210 cps, is 5 percent below the calculated value, but is considered in agreement within the larger uncertainty of the latter. A fre-

quency of null vertical response, predicted by theory, is clearly marked by a phase reversal in the (V, P) cross spectra (low resolution) at the calculated position, 0.0458 cps, within the limit of resolution of the spectra (Section D).

Evidence on damping comes from two sources. The high-resolution spectra of Snodgrass, *et al.* [3], indicate that both resonances are very sharp indeed at the observed amplitudes. Some observations on the decay of transients have given the best information on damping. These and all numerical results are discussed in Section F.

C. Calculation of Peformance

The buoy is considered to be a long, slender, rigid body floating in a near-vertical attitude, with its submerged surface a figure of revolution. We compute the major features of its response to a train of surface gravity waves having a single frequency and amplitude in the linear range, propagating in a single direction. The only forces considered are gravity and the effect of pressure on the submerged surface; friction is neglected.

We follow Newman [4] in restricting horizontal buoy dimensions and displacements both of buoy and waves (ξ, ζ, ψd, A) to be small when compared either to the vertical buoy dimension or the scale of waves (d, $1/k$); we retain only first powers of the small quantities. Sea slope and buoy inclination ψ are thus small angles; buoy and wave accelerations are small compared to g; variations in wave acceleration over the horizontal buoy dimensions are second order, and neglected. Products of inertia are likewise negligible, and moments of inertia about all axes in a horizontal plane are taken equal.

In considering this analysis, a second coordinate system fixed in the buoy is conceptually important, and for convenience may be so chosen that it coincides with the stationary (x, y, z) system when the buoy is undisplaced. In what follows, only the (x, y, z) system is referred to explicitly, but some such references may best be understood as relating to a buoy-fixed system with negligible displacement.

Three forces are considered to act on the buoy. The first is the weight of the buoy, represented by the first integral on the left in equation (1). In this and all succeeding expressions involving the mass element dM, the region of integration is the entire structure of the

Nomenclature

x, y, z = right-hand rectangular position coordinates with respect to fixed axes. The z-axis, positive upward, is vertical and coincides with the undisturbed position of the buoy axis. The positive x-axis is in the direction of wave propagation. The origin is at the undisturbed sea surface.

t = time

ρ = fluid density

$\mathbf{g}$ (or g) = vector (or scalar) acceleration of gravity

Wave properties:

x^* (or z^*) = x-component (or z-component) of particle displacement

z_s^* (or x_s^*) = value of z^* (or x^*) at the intersection of the sea surface and the undisturbed buoy axis

$\mathbf{a}^*$ = particle acceleration vector

$\mathbf{a}_x^*$ = vector component of $\mathbf{a}^*$ in x-direction

a_x^* (or a_z^*) = scalar x-component (or z-component) of $\mathbf{a}^*$

A = amplitude

ω = radian frequency

k = radian wave number, vertical decay constant

h (or l_w) = expressions related to wave force (or torque) defined by equation (5) or (16)

Identifiers of certain points fixed in the buoy, used as arguments of position-dependent variables:

m = center of mass, on the axis of the buoy

b = undisturbed center of buoyancy, a point above m on the axis of the buoy and fixed in it

c = midpoint between m and b

Properties of buoy:

M = total mass

B = instantaneous mass of displaced fluid

S = constant reference value of area of cross section normal to the axis, formally arbitrary but presumed chosen to be generally representative of submerged portion

$s(z)$ = relative cross-sectional area, a function of axial position, so defined that $Ss(z)$ is the actual area

L = length parameter expressing M through equation (4), presumed to be of the order of the draft of the buoy as a result of a suitable choice of S

d = draft

l = distance between b and m

γ (or β) = radius of gyration of the buoy (or of the displaced fluid) about an axis in the y-direction through c

Coordinates of buoy:

ξ (or $\ddot{\xi}$) = x-component of displacement from its undisturbed position (or of acceleration) of point c

ζ (or $\ddot{\zeta}$) = z-component of displacement (or of acceleration) of point c

ψ (or $\ddot{\psi}$) = angular displacement of the upwardly directed buoy axis from the positive z-axis (or angular acceleration), positive when the sense is from positive z-axis toward positive x-axis.

$\mathbf{r}$ = position vector of any point in the buoy relative to c as origin

$\mathbf{a}$ (or $\boldsymbol{\alpha}$) = acceleration vector of any point in the buoy relative to a fixed origin (or to c as origin)

$\mathbf{a}_x$ (or α_x) = vector component of $\mathbf{a}$ (or $\boldsymbol{\alpha}$) in x-direction

buoy, above as well as below the surface, and the integral embodies the actual mass distribution.

The second force considered is the resultant transmitted to the submerged surface of the buoy by those hydrostatic and wave pressures which would exist at the positions in question in the absence of the buoy. This system of surface forces is equivalent (both as to resultant force and moment) to the system of supporting and accelerating forces which, again, act on the fluid particles within the enclosed volume in the absence of the buoy. This result is expressed in the second integral and first part of the third on the left in equation (1). Here and at succeeding occurrences of the mass element dB, the region of integration is the submerged portion of the buoy, and the mass distribution involved is that of the displaced fluid.

The third force considered is a hydrodynamic response to transverse acceleration of the buoy, also communicated to the buoy by pressure. Lamb [5] treats a uniform two-dimensional flow across a long circular cylinder and shows that transverse acceleration of the cylinder relative to the unperturbed flow is opposed, at any portion of the cylinder, by a force equal to the product of the relative acceleration and the mass of displaced fluid. This result is applied as an approximation at each transverse section of the buoy despite the nonuniformity of the cross section and of the transverse flow. At each section, the transverse acceleration of the buoy is referred to the transverse wave acceleration corresponding to the axial position. This result is separated into two terms, a virtual wave force which completes the left member of equation (1), and a virtual transverse inertial term which is the second integral on the right. The first integral on the right is the actual unbalanced force which accelerates the buoy.

$$\int \mathbf{g}\,dM - \int \mathbf{g}\,dB + \int (\mathbf{a}^* + \mathbf{a}_z^*)\,dB = \int \mathbf{a}\,dM + \int \mathbf{a}_z\,dB \quad (1)$$

The two terms involving g are large and nearly canceling. Here the integral over B must involve the disturbed position of the buoy. The remaining terms are small; in them the integrals over B will be evaluated over the undisturbed region, and the integrands will be considered to vary in the axial direction only.

The first-order equations derived by Newman [4] from a more sophisticated formulation are consistent with the results obtained here, and thus reflect the action of the same forces which are considered in the foregoing.

Taking horizontal components from equation (1) gives

$$2\int \mathbf{a}_z^*\,dB = M\mathbf{a}_z(m) + M\mathbf{a}_z(b) = 2M\mathbf{a}_z(c) \quad (2)$$

or

$$\ddot{\xi} = \int a_z^*\,dB/M \quad (3)$$

The buoy mass M will be represented by a length L defined by

$$M = \rho SL, \qquad L = \int s(z)\,dz \quad (4)$$

The following definition will also be used.

$$h = \int \exp(kz)\, s(z) k\, dz \quad (5)$$

In both (4) and (5), the range of integration is the submerged vertical extent of the undisturbed buoy.

The wave motion is described by the following expressions for particle displacement.

$$x^* = A \exp(kz) \cos(\omega t - kx) \quad (6)$$

$$z^* = -A \exp(kz) \sin(\omega t - kx) \quad (7)$$

together with

$$\omega^2 = gk \quad (8)$$

Equations (6) and (7) will be used only for $x = 0$.

Equation (3) can be restated, using (4), (5), and (8), following a double differentiation of (6).

$$\ddot{\xi} = -(gAh/L) \cos \omega t \quad (9)$$

A similar treatment of the vertical components of equation (1) requires use of the relation

$$B - M = \rho S s(0)(z_0^* - \zeta) \quad (10)$$

and leads to

$$\ddot{\zeta} + (gs(0)/L)\zeta = \int a_z^*\,dB/M + gs(0)z_0^*/L \quad (11)$$

$$= (gA/L) \sin \omega t\,[h - s(0)] \quad (12)$$

Next, we write a moment equation corresponding to (1)

$$\int \mathbf{r} \times \mathbf{g}\,dM - \int \mathbf{r} \times \mathbf{g}\,dB + \int \mathbf{r} \times (\mathbf{a}^* + \mathbf{a}_z^*)\,dB = \int \mathbf{r} \times \mathbf{a}\,dM + \int \mathbf{r} \times \mathbf{a}_z\,dB \quad (13)$$

It is to be noted that this equation is independent of the origin of the position vector $\mathbf{r}$ because of equation (1) and hence true for the present choice of the moving point c as origin. Here again the first two integrals on the left are the large ones and in them the inclination of the buoy must be recognized, but in the second integral the difference between B and M will be neglected. As before, the other two integrals over B will be evaluated over the undisturbed region, and variations in acceleration over each horizontal section neglected. Hence, in the third integral on the left, the mean $\mathbf{r}$ over each horizontal section is vertical and only horizontal components of acceleration contribute to the value of the integral. On the right, $\mathbf{a}$ and $\mathbf{a}_z$ are separated into two terms each, involving respectively acceleration of point c, and acceleration with respect to it. With these steps we obtain

$$M[\mathbf{r}(m) - \mathbf{r}(b)] \times \mathbf{g} + 2\int \mathbf{r} \times \mathbf{a}_z^*\,dB = M[\mathbf{r}(m) + \mathbf{r}(b)] \times \mathbf{a}(c) + \int \mathbf{r} \times \mathbf{a}\,dM + \int \mathbf{r} \times \mathbf{a}_z\,dB \quad (14)$$

The first term on the left represents gravitational torque components about x- and y-axis. The second term is the wave torque, about the y-axis only. The first term on the right vanishes because of the particular location chosen for the origin c. The second and third terms on the right represent general rigid-body rotational reactions with an inertial tensor referred to point c, and will not be discussed in detail.

Under the hypotheses of vanishing products of inertia, equal moments of inertia about all transverse

axes through c, and no torque about the longitudinal axis, a solution exists in which there is no rotation about the longitudinal axis, and small rotations occur about the x- and y-axes, independently. For this case we take y-components from (14) and with rearrangement obtain

$$\ddot{\psi} + [gl/(\gamma^2 + \beta^2)]\psi = -2g\Delta l_w h \cos \omega t/[I_c(\gamma^2 + \beta^2)] \quad (15)$$

using the abbreviation

$$l_w h = \int [z - z(c)] \exp (kz) s(z) k dz \quad (16)$$

As in (5), the integration is over the submerged vertical extent of the undisturbed buoy. In γ, the higher-order part contributed by transverse mass distribution, while not necessary, may with some reason be included; β, however, by reason of the approximation which introduced it, refers to longitudinal mass distribution only.

Equations (9), (12), and (15) may be integrated to give the following steady-state frequency-response ratios, referring the displacements ξ and ζ to those of the sea surface, and ψ to the sea-surface slope.

$$\xi/x_0^* = h/kL \quad (17)$$

$$\zeta/z_0^* = [h - s(0)]/[kL - s(0)] \quad (18)$$

$$\psi/kx_0^* = -(h/kL)2l_w/[l - k(\gamma^2 + \beta^2)] \quad (19)$$

In view of the independence of the angular equation (19) and its counterpart about the x-axis, corresponding to the fact that small angular displacements from the z-axis may be represented by vectors in the x-y plane, solutions like the foregoing may be superposed to represent the effect of waves with any spectrum of frequency and direction.

At very low frequencies, $h \to kL$ and $2l_w \to l$, giving response ratios from (17), (18), and (19) of 1, 1, and -1. The frequencies of heave and pitch resonance are fixed by the zeros of the denominators on the right of (18) and (19).

It is useful to integrate (5) and (16) by parts. Allowing a finite cross section at the bottom of the buoy,

$$h - s(0) = -s(-d) \exp (-kd) + \int_{s(0)}^{s(-d)} \exp (kz) ds(z) \quad (5')$$

$$l_w h = [-z(c) - 1/k]h + ds(-d) \exp (-kd) + \int_{s(0)}^{s(-d)} z \exp (kz) ds(z) \quad (16')$$

The right member of (5′) displays the numerator on the right of (18) in an informative manner. We see that the vertical response ratio decreases exponentially toward high frequencies, whereas the horizontal ratio is of order k^{-1}. It further appears that if the buoy has any expansion of cross section below the waterline, the vertical response ratio will be positive at high frequencies and pass through a null to negative values in a region above the heave resonance, becoming again positive below resonance. The null frequency is always above the resonance because h is less than kL for all finite frequencies, as can be seen from (4) and (5).

Table 3 Numerical Information for FLIP

Displacement, tons	2104
Hull diameter, ft	
above cone	12.5
below cone	20.0
Depth below normal waterline, ft, to:	
bottom of buoy (d)	300
bottom of cone ($d_1 + \delta$)	150
top of cone ($d_1 - \delta$)	60
effective center (point c)	180
Mass-equivalent length L, based on S = maximum cross section, ft	234
Relative cross section at waterline, $s(0)$	0.391
Separation of centers of mass and buoyancy, l, ft	7.7[a]
or	6.9[b]
Radius of gyration, actual mass, γ, ft	82.1
Radius of gyration, displaced mass, β, ft	78.4

[a] The least value determinable from information on structure and equipment.
[b] Determined by observation of pitch-roll resonance.

The hydrodynamic inertial effect influences only the angular motion. The presence of β^2 on the left in (15) is the chief consequence; it lowers the resonant frequency by roughly a factor $2^{1/2}$. On the right, 2 in the numerator and β^2 in the denominator largely offset one another.

Response ratios for FLIP have been calculated numerically. The hull shape, except for minor appendages, consists of two cylindrical sections joined by a truncated cone, as shown in Fig. 1. For such a configuration, with arbitrary dimensions, one finds:

$$L = d - [1 - s(0)](d_1 + \epsilon)$$

$$-z(b)L = \tfrac{1}{2}d^2 - \tfrac{1}{2}[1 - s(0)][d_1^2 + 2\epsilon d_1 + \tfrac{1}{3}\delta^2]$$

$$[\beta^2 - (l/2)^2 + z(b)^2]L = \tfrac{1}{3}d^3 - [1 - s(0)][\tfrac{1}{3}d_1^3 + \epsilon d_1^2 + \tfrac{1}{3}\delta^2 d_1 + \tfrac{1}{3}\epsilon\delta^2]$$

the integral appearing on the right of (5′),

$$I_0 = \int \exp (kz) ds(z) = [1 - s(0)] \exp (-kd_1) \times [\sinh (k\delta)/(k\delta) - \{\cosh k\delta - \sinh (k\delta)/(k\delta)\} 3k\epsilon/(k\delta)^2]$$

and the integral on the right of (16′),

$$\int_{s(0)}^{s(-d)} z \exp (kz) ds(z) = -d_1 I_0 + [1 - s(0)] \exp (-kd_1) [\{(1/k) + 6\epsilon/(k\delta)^2\} \{\cosh k\delta - \sinh (k\delta)/(k\delta)\} - 3\epsilon \sinh (k\delta)/(k\delta)]$$

where the conical section has a mid depth d_1 and length 2δ, the lower cylinder has cross section S, and

$$\epsilon = (\delta/3)[1 - s(0)^{1/2}]/[1 + s(0)^{1/2}]$$

Numerical response ratios for FLIP, based on the foregoing and Table 3, are given in Figs. 3 and 4, and Table 4. There is also shown the ratio ξ/ψ, which relates the horizontal translation to the angular motion, and can be interpreted as the depth of an effective axis of rotation, measured downward from point c. Calcu-

Table 4 Calculated Response Ratios for FLIP

frequency f in cps	vertical buoy displacement, to that of sea surface ζ/z_0*	horizontal displacement of buoy center, c, to that of sea surface ξ/z_0*	inclination of buoy axis to sea surface slope ψ/kz_0*	depth below center c of effective axis of rotation (ξ/ψ) in ft
0.035				384.0 (max)
0.0460	0.0			
0.05	0.122	0.600	0.683	287.0
0.059	0.177 (max)			
0.10	0.0582	0.186	0.156	97.5
0.20	$5.61 \cdot 10^{-4}$	0.0346	0.0136	51.7

lated critical frequencies are: 0.0221 cps for pitch-roll resonance, 0.0369 cps for heave resonance, and 0.0460 cps for null heave response.

D. Data Acquisition and Treatment

Each component of horizontal acceleration (H_1, H_2) was sensed by a pair of Convectron tubes in a dc bridge circuit. These elements, a product of Bendix Aviation Corp., operate on the basis of convective cooling of heated filaments. Vertical acceleration (V) was indicated by a leaf-spring instrument of a type described by Spiess [8]. Wave pressure data (P) were obtained as a parallel output from one of the Vibrotron pressure transducers installed by Snodgrass, *et al.* [3], but these data were handled quite independently of the other experiment. The accelerometers were located 35 ft above the waterline, the pressure sensor 100 ft below.

The latter two instruments (V and P) yielded frequency-coded outputs which were reduced to analog voltages with Hewlett-Packard Model 500 B frequency meters. Such voltages from all four sensors were amplified, digitized, and punched on paper tape as 8-bit numbers. The rms deviations from the mean for these records would usually occupy 4 or 5 bits on the same scale. Each instrument was sampled at 2-sec intervals; for the successive instruments, sampling instants were separated by 0.16 sec. The length of the normal record was 864 sample-sets.

Data reduction was done with a small computer, Bendix G15 D. All records were plotted for inspection and editing. Four autocorrelation functions and four cross correlation functions (between H_1 and H_2, and between P and each of H_1, H_2, and V) were computed to a maximum of 64 lags. Fourier transformation and smoothing with weights 0.23, 0.54, 0.23 yielded power spectra [6] and cross spectra to a maximum frequency 0.25 cps with 64 ordinates spaced 0.0039 cps, and resolution indicated by a separation of 0.0072 cps between half-power points of the single frequency pattern.

Coherence and phase (polar coordinates in the complex plane for the cross spectral density when normalized to be a complex correlation coefficient) were computed for each cross spectrum. Computed ratios of power spectra already have been mentioned. The V-to-P ratios shown in Fig. 5 are limited in each case of those frequencies for which the coherence is greater than 0.71.

E. Evaluation of Results

Overall accuracy of 5 to 10 percent was desired for these measurements. In a number of aspects, choice of instrumentation was governed by availability rather than superior suitability, but it was hoped that the chosen tolerances were preserved. Both the Vibration pressure transducer [7] and the Spiess accelerometer [8] are considered instruments of more than adequate quality. The use of frequency meters for decoding their outputs was judged to be adequate without quantitative investigation. The pressure spectra obtained correspond reasonably, though not closely, with those obtained by Snodgrass, *et al.* [3], from the same instrument (and made available to me) from overlapping but much longer sampling intervals. Use of the Convectrons as linear dynamic transducers is easily open to question. However, one subsequent comparison with a Spiess accelerometer showed a satisfactory zero-lag correlation of 0.95 between the simultaneous wave records. The calibration constants for the accelerometers showed long-term and warm-up drifts of several percent.

Rejection of frequencies above the Nyquist limit at the point of sampling and digitizing is well accomplished for the pressure and vertical acceleration by the natural attenuation of wave motion with depth. No corresponding attenuation was provided for the horizontal accelerations, and these spectra suffer some contamination by high frequencies.

Comparison of coherence and phase shown in the cross spectra with expected values gives some indication of amount of experimental errors and of contamination of linearly wave-induced motion by any other real effects. The highest coherences are expected and found between the pressure and vertical acceleration, where the wave-related components are expected to have unit coherence, independent of direction of wave arrival. In the spectral region of major power, observed coherences are generally above 0.90 and frequently above 0.95. The values drop rapidly in the skirts of the spectrum and may fall below 0.5 when the spectrum drops below roughly 10 percent of peak intensity, suggesting minor real contamination, as well as an instrumental background, in the spectra.

One quite plausible kind of such contamination is clearly indicated by inspection of spectra, and the ratios in Fig. 5. In the operation of the buoy no precise indication is used for verticality of the axis, and it is to be pre-

[2 - 1/2Q]

Table 5 Damping of Resonant Motions

resonant motion	amplitude decay fraction, per 100 sec	range of rms velocity	Q (δ)	drag coefficient
heave	0.13 ± 17%	3.6 to 2.5 cm/sec	89 (.006)	10.3 referred to maximum horizontal area
heave	0.10 ± 25%	2.5 to 1.0 cm/sec	115 (.004)	
heave	(steady-state spectra)	0.95 to 0.35 cm/sec	50 to 80 (.006-.01)	
pitch-roll	0.45 ± 10%	0.0027 to 0.0016 rad/sec	14 (.035)	1.54 referred to area projected on vertical plane
pitch-roll	0.25 ± 16%	0.0016 to 0.0006 rad/sec	26 (.019)	
pitch-roll	(steady-state spectra)	0.0011 to 0.0003 rad/sec	25 to 40 (.02)	

sumed that from time to time the mean position of the axis may deviate from vertical by some fraction of a degree. This will result in a corresponding small fraction of the horizontal acceleration appearing in the output of the vertical instrument, being there relatively conspicuous because of the higher sensitivity and lower total signal. Peaks in the horizontal spectra at relatively high frequency sometimes have minor counterparts in the vertical acceleration spectrum, and these cases account for at least some of the abnormally high ratios at high frequency seen in Fig. 5.

Even if the mean position of the axis is vertical, a peak in the horizontal spectrum is expected to give a second-order contribution at double frequency in the vertical spectrum. No instances of this kind have been found.

Coherence between wave pressure and a component of horizontal acceleration is expected only to the extent that wave propagation in one sense along the axis in question predominates over that in the reverse direction. The observations are consistent with this. Instances of coherence as high as 0.8 to 0.9 are quite frequent, but usually occur in a more limited region of the spectrum, and the day-to-day variability of coherence is higher, for the horizontal as compared with the vertical case. Coherence between the two components of horizontal acceleration is expected only when there is a direction of predominant wave propagation oblique to the horizontal axes. Again the observations are consistent. Coherence is often completely absent, but often occurs in a more or less limited spectral region; the maximum amount is usually less than 0.9.

Indicated phase relations are approximately as expected, 0 or 180 deg between V and P and between H_1 and H_2, 90 or 270 deg between H_1 or H_2 and P. There is usually, but not invariably, predominant wave propagation in the down-wind rather than the up-wind direction. Departures from the expected phase angles are sufficiently variable from case to case to suggest that drag forces are not the predominant influence. In the region of the peak of the V and P spectra, the phase relation is usually within 10 deg, one side or the other, of the expected coincidence between maximum pressure and maximum downward acceleration. It seems probable that these departures should be ascribed mainly to traces of horizontal acceleration in the vertical spectrum.

The spread among the response-ratio curves as shown in Figs. 5 and 6 has been studied for indications as to its possible causes with little conclusion. With respect to the H-to-P ratios, the increased scatter shown in Fig. 6 at both extremes of frequency is understandable as related to low spectral power level, but the minimum scatter in the mid-frequency region (Table 2) is surprisingly large. No allocation between experimental errors and real effects, such as those of wind or turbulence in the water flow, is attempted.

The V-to-P comparison presents the additional feature of high coherence between the two spectra, expected and to a considerable extent realized.

The agreement of the median with the expected value, and the quartile deviations, shown in Table 2 for the central frequency region, seem consistent with the experimental uncertainties, including indicated intrusion of horizontal accelerations into the vertical record. However, the more deviant ratios are frequently associated with high coherence, suggesting random variations in the transfer ratio, not strongly correlated from one frequency region to another. To some extent, at least, this may be attributable to the admixture of horizontal accelerations. However, the same situation appears at the frequency of vertical resonance, when the high Q-value indicated in Section F gives a clear reason for expecting the peak in the pressure spectrum to arise almost wholly from vertical buoy displacement, and hence to be tightly related to the vertical acceleration peak. Yet, while 19 out of 40 cases show coherence of 0.92 or above at the resonant frequency, 8 of these show V-to-P ratios departing from the median by from 1 to 3 times a limit suggested by the coherence values. The median ratio is considerably further from the expected value here than at higher frequencies. Again, no interpretation of these features is offered.

Of the three critical frequencies in the spectra, the resonant peak and the null in vertical response offer no difficulty in calculation from buoy mass and dimensions. The pitch-roll resonant frequency, however, depends on the relatively small separation between centers of buoyancy and mass, and is difficult to predict with accuracy for this reason. The mass of the buoy as determined from nominal submerged dimensions and given in Table 3 exceeds by 11 tons a sum of total structural and equipment mass (known to be not quite complete), calculated capacity of flooded tanks, and observed final content of a trim tank. This unaccounted mass was assigned to the superstructure in determining the first value of l

Table 6 Velocity Differences Between Motion of Water and of FLIP at the Same Depth, for Waves of Frequency 0.094 CPS. Velocity Differences Are Expressed as a Ratio to One Component of Wave Velocity at the Sea Surface

Depth, ft:	0	81	105 (center of conical hull section)	156	242	257	300
Component:							
vertical	+0.93	—	+0.25	—	0	—	−0.03
horizontal	+0.42	0	—	−0.08 (max)	—	0	+0.06

given in Table 3. The observed resonant frequency corresponds to the second, smaller value, which is taken as correct, implying only a small error in the accepted mass distribution. It is believed that the theoretical approximation used in Section C to fix the hydrodynamic moment of inertia would not understate this quantity and hence would not contribute to the present discrepancy.

F. Damping

The spectra might show frictional effects in two ways: (1) phase shifts in response relative to the wave pressure, and (2) the form of the resonance peaks in the spectra. As already indicated in Section E, the first possibility appears to fail.

The high-resolution pressure spectra obtained and made available by Snodgrass, *et al.* [3], showed both resonance peaks; a sample of eight spectra, including both high- and low-power cases, was studied. Three ways were tried for estimating the conventional sharpness parameter Q (the reciprocal of the fractional power dissipation per radian phase advance in the transient oscillation).

First, the total area under the heave resonance peak (which does not depend in first order on the resolution) was compared to an estimate of the spectrum level of the exciting wave motion, taken from a minimum point at a nearby frequency in the same spectrum. This latter was evidently precarious; the extremes among the eight values of Q were 5 and 310, but four of them lay in the range 57 to 72. This method was not available for the pitch-roll resonance. The other two approaches rested on the fact that the heave and pitch-roll peaks were, respectively, about 25 and 50 percent wider than the calculated single-frequency pattern, enabling estimates of the true spectral width, or Q. The observed widths were estimated, case by case, by comparing either the total area under the peak, or a second difference among the three greatest ordinates, indicating curvature at the peak, to the height of the peak. For the heave resonance, extreme values of Q from both these alternatives were 42 and 120; half the results from the first fell in the range 57 to 82, from the second 48 to 60. A summary of the foregoing is entered in Table 5. The pitch-roll Q appeared to be about half the heave value. No dependence of Q on power level was indicated

These conclusions are inferences from quite minute features of the spectra, and have been supplemented by other experiments conducted in December, 1964. Transient motions of the buoy were excited in one of two ways, the decay being observed by means of horizontal accelerometer or deep-pressure records. In one method, the draft of the buoy was reduced about 7 ft by partially blowing the deepest ballast tank. Then rapid flooding of the tank caused return to normal draft, accompanied by a transient vertical oscillation.

In another method, horizontal tow-line tension was suddenly released, producing a transient roll and also, it was found, a larger vertical oscillation than by the other method. This was done both at normal and reduced draft, as a second purpose of the experiment was to observe the change in roll frequency with change of draft.

Numerical values of decay in vertical motion were taken from five records of deep (300 ft) pressure, when as many as 30 oscillations could be followed with seemingly good signal-to-noise ratio, but still with substantial case-to-case differences. For the roll motions, four records from each of two horizontal accelerometers were used. About 15 oscillations usually could be followed, but because of higher noise level (motion forced by waves), numerical values for decay were taken from not more than the first eight. Results are summarized in Table 5, including the corresponding values of Q and, for the largest amplitudes, equivalent values of drag coefficient, assuming frictional force proportional to square of velocity. There is more indication of such nonlinearity in the pitch-roll motion than in the heave.

The damping indicated in Table 5, small though it is, is still amply large to include values of the order of those calculated by Newman [4] as arising from the reradiation of surface waves.

With respect to frictional effects in the forced motion of the buoy, we will make only a qualitative observation. The motion of the buoy tends to be some sort of mean of that of the displaced water, were the buoy removed. Hence local wave velocity relative to an immediately neighboring surface of the buoy is in opposite senses in different places, and frictional forces will to some extent oppose one another in producing phase shifts, both in linear and angular motion. Table 6 shows some of these relative velocities calculated for a single-frequency motion corresponding to a usual position of the peak in the acceleration spectra.

In the transient experiments, the frequency for roll was apparently about 4 percent lower than that for pitch, and both were multiplied by 0.763 ± 0.005 when the separation l between centers of mass and buoyancy was reduced by a calculated 2.96 ft. Allowing for a 2-percent

reduction in effective moment of inertia, the indicated value of l is 6.9 ft, in agreement with the observed pitch-roll frequency in the steady-state spectra.

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RESPONSES OF A SPAR PLATFORM IN RANDOM WAVES AND CURRENTS (EXPERIMENT vs. THEORY)

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ABSTRACT

The response characteristics of a large slack-moored floating spar in regular waves, bichromatic waves, and unidirectional irregular waves with or without sheared currents are investigated by experiment and numerical method. The experiment with 1:55 scale model was conducted in the Offshore Technology Research Center (OTRC) three-dimensional wave basin located at Texas A&M University. A time-domain nonlinear motion analysis computer program was developed to numerically simulate the performance of the spar for various wave and current conditions. It was found that the linear wave-body interaction theory alone was not adequate and the second-order wave-body interaction theory including the effects of viscous and wave drift dampings had to be used for the reliable motion prediction of a spar. The complete first- and second-order diffraction/radiation programs for bichromatic, bi-directional waves were developed using the higher-order boundary element method (HOBEM), and the viscous drag forces were computed from the Morison drag formula based on the relative velocity squared. The wave drift damping was computed using the modified drift gradient method. The two-term Volterra series were used to calculate the time series of nonlinear potential excitations in random seas. The resulting numerical results agreed well with our measured data. It was seen that the low-frequency surge and pitch responses were in general greater than the wave-frequency responses and the slowly-varying responses were appreciably reduced in the presence of currents. The total response amplitudes were found to be practically acceptable in the survival condition characterized by an 100-year storm sea.

1. INTRODUCTION

Numerous oil and gas discoveries have recently been made in water depths ranging from 2000 ft to 6,000 ft. Those deep water reserves, however, have not been actively developed yet mainly due to the high development cost and technological uncertainties. In this regard, an innovative, reliable, and cost-effective platform concept needs to be explored to justify such investment and risk involved in the ultra-deepwater development.

The spar (see Figure 1) is a new, reliable, and cost-effective platform concept which seems economically feasible to the depth as deep as 10,000 ft (Perryman & Beynet, 1994). It is a deep draft, large diameter straight sided hollow-cylindrical vessel which can support drilling and production equipment and store plenty of oil in its hull (Glanville et al. 1991). Its deep draft gives it excellent motion characteristics in the most severe sea states, which has already been proved through the successful operation of a similar floating instrument platform, FLIP, located in the North Pacific. The spar also has a number of other attractive features compared to existing platforms, such as low cost construction, installation, and relocation, insensitivity to water depth, higher riser protection, and early cash flow and so on.

The natural frequencies of all the compliant modes of the spar are typically smaller than the frequencies of appreciable wave energy. This implies that the linear wave-body interaction theory alone *cannot* adequately predict the resonance phenomena (Kim & Yue, 1990). The second-order difference-frequency wave loads in this case are likely to be the most important contribution to the low-frequency large-amplitude resonant motions (Kim & Ran, 1993). Furthermore, in this low frequency region, the wave damping is in general smaller than the viscous and higher-order wave-drift dampings. Therefore, it is very important to include those nonlinear effects for the reliable motion prediction and optimum design of a spar.

In this paper, the motion charactersitics of this new platform concept in storm waves and currents are investigated. Recently, a number of oil companies formed a Joint Industry Project (JIP) for the experimental study of a spar in the three dimensional wave basin of the Offshore Technology Research Center (OTRC) located at Texas A&M University. A series of experiments were conducted for various wave and current conditions with the 1:55 scale model of a slack-moored floating spar whose particulars are summarized in Table 1. Contrary to its name, the present spar has large (40-m) diameter which is about 1/5 of its draft. In paralell with this kind of experimental program, we also developed a reliable numerical method to be able to predict the responses of the platform in random waves and currents.

From the JIP experiment, it was seen that the measured motion amplitudes of the spar in the survival condition were in general acceptable. The slowly-varying surge and pitch responses turned out to be much greater than wave-frequency responses. Our numerical prediction agreed well with measured responses when the second-order diffraction method was used with viscous and wave-drift dampings. In this paper, the effects of wave directional spreading are not considered, and only the results for uni-directional waves with or without sheared currents are presented.

For our time-domain analysis, the first-order wave forces, added mass, wave damping, and the second-order difference-frequency forces are computed from the higher-order boundary element method (HOBEM) (Liu et al., 1993). As far as the potential theory is concerned,

our computation is complete up to the second order. The two-term Volterra series model (Neal, 1974) is adopted for the time-series generation of the second-order wave excitations and wave-drift damping in irregular waves. The iterative Newmark-beta method is used for the direct time integration of the nonlinear equation of motion, and a convolution integral technique is used to account for the frequency-dependent wave damping. The possible vortex induced vibration (VIV) was not considered in our numerical modelling.

2. NUMERICAL METHOD

In this section, we consider the computation of wave loads on and responses of a spar platform in random waves and currents. For analysis, the right-handed Cartesian coordinate system with the origin on the quiescent free surface and z-axis positive upward is chosen. Then, the equations of the heave and surge-pitch coupling motions are

$$\begin{pmatrix} m+m_{11} & mz_g+m_{15} \\ mz_g+m_{51} & I+m_{55} \end{pmatrix} \begin{pmatrix} \ddot{x} \\ \ddot{\theta} \end{pmatrix} + \begin{pmatrix} B+b_{11} & b_{15} \\ b_{51} & b_{55} \end{pmatrix} \begin{pmatrix} \dot{x} \\ \dot{\theta} \end{pmatrix} + \begin{pmatrix} K_{11} & K_{15} \\ K_{51} & K_{55}+\tilde{K}_{55} \end{pmatrix} \begin{pmatrix} x \\ \theta \end{pmatrix} = \begin{pmatrix} F_x(t) \\ M_y(t) \end{pmatrix}$$

$$(m+m_{33})\ddot{z} + b_{33}\dot{z} + (K_{33}+\tilde{K}_{33})z = F_z(t) \tag{1}$$

in which m and I are the mass and moment of inertia of the spar including the entrapped water inside. It is assumed that the bottom of the hollow cylinder is closed to restrict the fluid flow through it and the sloshing motion of the inside water little affects the response of the spar. The symbols m_{ij}, b_{ij}, $\tilde{K}_{ij}$ are the added mass, wave damping, and hydrostatic restoring coefficients of the i-th mode due to j-th-mode motion. The symbol K represents the restoring coefficient caused by mooring lines, B the wave drift damping, and z_g the vertical coordinate of the center of gravity. The mooring stiffness K generally varies with motion amplitudes and this effect is accounted for in our nonlinear time-domain analysis. The right-hand side F and M are exciting forces and moments which consist of potential and viscous forces:

$$\begin{pmatrix} F_x(t) \\ M_y(t) \end{pmatrix} = \frac{1}{2} C_D \rho D \int_{-h}^{\zeta} (U+u-\dot{x}-z\dot{\theta}) \left| U+u-\dot{x}-z\dot{\theta} \right| \begin{pmatrix} 1 \\ z \end{pmatrix} dz + \begin{pmatrix} F_x^{(1)}(t) \\ M_y^{(1)}(t) \end{pmatrix} + \begin{pmatrix} F_x^{(2)}(t) \\ M_y^{(2)}(t) \end{pmatrix}$$

$$F_z(t) = F_{vz}(t) + F_z^{(1)}(t) + F_z^{(2)}(t), \tag{2}$$

where ρ is the fluid density, ζ the free-surface elevation, h the water depth, D the diameter of the spar, and C_D the drag coefficient. In (2), the horizontal wave particle velocity u and current velocity U are functions of the vertical position z. The symbols $F^{(1)}, M^{(1)}$ and $F^{(2)}, M^{(2)}$ are the first- and second-order potential-induced wave exciting forces. Since all the natural frequencies of the spar are small, only second-order difference-frequency excitations need to be considered. They are calculated by using the complete second-order diffraction/radiation program based on the higher-order boundary element method. Instead of solving the second-order potential, the indirect approach employing the assisting radiation potential was used. It is well known that the second-order spatial derivatives of the first-order velocity potential on the body surface cannot be calculated accurately when conventional constant panel methods are used. Using high-order elements and interpolation functions, they can be calculated in a reliable manner. The details are given in Liu et al. (1993). The wave drift damping B in (1) was calculated using the following modified drift gradient method:

$$\begin{pmatrix} B_x \\ B_y \end{pmatrix} = \left(\frac{4\omega}{g} \begin{pmatrix} F_{dx} \\ F_{dy} \end{pmatrix} + \frac{\omega^2}{g} \begin{pmatrix} \frac{\partial F_{dx}}{\partial \omega} \\ \frac{\partial F_{dy}}{\partial \omega} \end{pmatrix} \right) \begin{pmatrix} \cos\beta \\ \sin\beta \end{pmatrix} \mp \frac{2\omega}{g} \begin{pmatrix} \frac{\partial F_{dx}}{\partial \beta} \\ \frac{\partial F_{dy}}{\partial \beta} \end{pmatrix} \begin{pmatrix} \sin\beta \\ \cos\beta \end{pmatrix}, \qquad (3)$$

where F_d is the second-order mean drift force and β is the wave heading of the incident wave.

As for the drag force in (2), it is assumed that the characteristic wavelength is sufficiently large to be able to use the above Morison drag formula. For simplicity, the incident wave elevation at the centerline of the spar was used for the upper bound ζ and the wave kinematics above the mean sea level is assumed to be uniform with the values at $z = 0$. The drag force is calculated at each time step with respect to the instantaneous position. The Keulegan-Carpenter (K-C) number for the present problem is typically small, hence we expect that the force is dominated by the potential term. However, the viscous damping plays an important role in the low frequency region near the natural frequencies. The drag coefficient C_D is a function of both K-C and Re numbers and surface roughness, and only limited experimental results are available in our small K-C and large Re number range (Sarpkaya & Issacson, 1981; Sarpkaya, 1986; Marthinsen, 1989). In this paper, we used $C_D = 0.6$ based on our free oscillation tests.

Noting that both added mass and wave damping are frequency dependent, the following time-domain equation valid for arbitrary excitations is used. For heave, for example,

$$(m + m_{33}(\infty))\ddot{z}(t) + \int_0^\infty R_{33}(t-\tau)\dot{z}(\tau)d\tau + (K_{33} + \tilde{K}_{33})z(t) = F_z(t), \qquad (4)$$

where $m_{33}(\infty)$ represents the heave added mass at infinite frequency and R_{33} is the heave retardation function which is a Fourier cosine transform of the heave wave damping:

$$R_{33}(t) = \frac{2}{\pi}\int_0^\infty b_{33}(\omega)\cos\omega t d\omega. \tag{5}$$

The added mass $m_{33}(\omega)$ and retardation function $R_{33}(t)$ are related through the so-called Kramers-Kronig relation:

$$m_{33}(\infty) = m_{33}(\omega) + \frac{1}{\omega}\int_0^\infty R_{33}(t)\sin\omega t dt. \tag{6}$$

The convolution integral in (4) is truncated according to the behavior of the retardation function. It is seen that $R(t)$ attenuates rapidly with time in an oscillatory manner. In order to effectively depress the transient response of (4), the force is gradually increased from zero to the actual magnitude using the following modulation function:

$$\Xi(t) = \frac{1}{2}[1 - \cos(\pi t/50)] \qquad (t \leq 50s). \tag{7}$$

As a numerical time integration scheme for (4) and more complicated coupled surge-pitch motions, the Newmark-beta method is used. For this, the convolution integral is first moved to the right-hand side, and then the response at time $t - \Delta t$ is used for the initial evaluation of the drag and convolution terms to solve the unknown response at time t through an iterative procedure until 0.1% relative error is reached.

The random free-surface elevation $\zeta(t)$ and the second-order slowly-varying excitations $F^{(2)}(t)$ are computed from

$$\zeta(t) = Re\sum_{i=1}^{N}\mathcal{A}_i e^{i\omega_i' t} \qquad (\mathcal{A}_i = A_i e^{i\epsilon_i}), \tag{8}$$

$$F^{(2)}(t) = Re\sum_{i=1}^{N}\sum_{j=1}^{N}\mathcal{A}_i\mathcal{A}_j^* \; f^-(\omega_i,\omega_j)\; e^{i(\omega_i'-\omega_j')t}, \tag{9}$$

where A_i is the amplitude of the ith component frequency ω_i; $A_i = \sqrt{2S(\omega_i)\Delta\omega}$ with $\Delta\omega$ being the regular frequency interval, and ω_i' is the randomly chosen frequency between $(\omega_i - \frac{\Delta\omega}{2})$ and $(\omega_i + \frac{\Delta\omega}{2})$. The random phase ϵ_i is uniformly distributed between 0 and 2π, and generated from a random number generator. In (9), $f^-(\omega_i,\omega_j)$ represents the diffrence-frequency force quadratic transfer function (QTF) due to a pair of unit-amplitude regular

waves of frequency ω_i and ω_j. The symbol N designates the total number of frequency components and (*) denotes the complex conjugate. If we use the equal frequency division, it is well known that the signal will repeat itself after $(\frac{2\pi}{\Delta\omega})$, and therefore $\Delta\omega$ should be very small in order to get a very long time series. In view of this, the above simulation technique utilizing randomly perturbed frequency ω' is used.

3. EXPERIMENT

The experiments were conducted at the Offshore Technology Research Center's (OTRC) three-dimensional wave basin equipped with wind and current generators. The wave basin is 45.7-m long, 30.5-m wide, and has a primary water depth of 5.8m. The multi-directional wave maker consists of 48 hydraulically-actuated single hinged boards along one end of the basin. Wave absorption is provided at the opposite end by a progressive absorber consisting of a series of expanded metal screens of decreasing porosity. In this wave basin, short-crested irregular waves as high as 1m can be generated. The current generator consists of three multi-port jet manifolds that can be placed in any direction at variable depths. The maximum current speed is about 0.4m/s.

Wave heights were measured using capacitance wave probes. The heave and surge motions were measured by an optical tracking system located 1.02m (model scale) above the mean sea level, while pitch motions were recorded by the inclinometer. The data were acquired at a sample rate of 40 Hz using a NEFF 620 data aquisition system with 10Hz anti-aliasing filters (Duggal & Niedzwecki, 1994). Wave generation, data aquisition, and basic analysis were accomplished using the GEDAP software package (Miles, 1990). Some tests were conducted with lateral constraints or vortex suppression devices in order to minimize possible vortex induced lateral vibration. The results presented here are those without them. Even in this case, the vortex induced motions were observed to be small.

Four taut springs were used to simulate a slack mooring system. They were attached to the spar at the points close to the center of gravity. The stiffness of the resulting mooring system was measured in the static-offset tests. The stiffness increased piecewise linearly with offset displacement i.e. it was 191 kN/m when the offset was less than 13.7m, and 206kN/m when the offset was between 13.7m and 29.5m.

The 1:55 scale model was made of 0.19-inch-thick steel plate hollow cylinder with four guide plates inside. The particulars of the JIP spar are summarized in Table 1. The profile of the platform is shown in Figure 1. The bottom of the hollow cylinder was closed by a keel plate which possesses a number of small holes to guide risers. Therefore, the entrapped water inside the hull can be regarded as the additional mass. The upper part of the hull provides required buoyancy and has a 13×11-inch^2 rectangular moonpool at the center. Several ballast tubes filled with lead cells were used in the model spar to lower the center of gravity.

The run time for each irregular wave test was one hour (prototype scale). It is found that the available dampings at surge, pitch, and heave natural frequencies are in general small, and therefore, transient motions persist for quite a long time, as shown in the time series (e.g. Figure 11). The heave responses are found to be very small (less than ± 1m) even for 100-year storm, and thus they are not presented in this paper. In the next section, all the results will be presented in the proto-type scale.

4. RESULTS AND DISCUSSION

All the first- and second-order hydrodynamic coefficients and forces, such as added mass, wave damping, and first- and second-order wave loads, were calculated using HOBEM (Liu et al., 1993). The wetted surface of the spar was discretized into 18 quadratic elements (82 nodal points) per quadrant. Smaller elements were placed near the free surface. For the second-order computation, the free surface excluding the waterplane area was divided into two regions by a partition circle. The inner free surface was numerically integrated using higher-order elements. The highly oscillatory outer free surface integral was evaluated by a moving average technique. The computed results were checked through comparison with those computed from the ring-source boundary integral equation method (Kim & Yue, 1989,1990). Using the computed values, the natural periods were estimated to be 316 seconds (0.02 rad/s) for surge, and 69 seconds (0.09 rad/s) for pitch, which is close to measured values, 325 seconds for surge and 67 seconds for pitch. All the response results presented here except for Table 2 are those with respect to the location of the optical tracking system (1.02m above mean sea level).

Figure 2 shows the surge added mass, wave damping, and the first-order wave exciting forces as function of dimensionless wavenumber ka (a=radius). It is seen that wave damping is very small in the low frequency range. It is also seen that the added mass is not sensitive to the change in frequency. The computed wave damping and exciting force satisfy the Haskind relation, $b_{11} = kF_x^2/8\rho g C_g A^2$, with C_g and g being the group velocity and gravitational acceleration.

Figures 3 show the surge and pitch excitation QTFs plotted in the bi-frequency domain. The first-order motion effects are included in this computation, as explained in Liu et al.(1993). The diagonals of the figures represent the second-order mean surge and pitch excitations. The magnitudes are significantly reduced when compared with the QTFs of the statinary spar. As can be seen in the figure, the magnitudes increase rapidly near the diagonal mainly due to the contribution of the second-order difference-frequency incident waves (Kim & Yue, 1990).

We expect from Figure 2 that the viscous and wave drift dampings are much greater than the wave damping in the low frequency region, while the opposite is true at wave frequencies. The drag coefficient C_D of (2) was determined after comparing our computation

with the results of our free-oscillation tests in calm water. For instance, Figures 4 show the measured transient pitch responses which closely match with our numerical simulation with C_D=0.6. Although C_D = 0.6 was obtained from the free-oscillation test in calm water, the same value was used throughout our computation under the assumption that the C_D value in waves is not quite different from 0.6. When the damping is assumed to be linear, the estimated damping ratio, 0.033 for surge and 0.012 for pitch, is very close to the measured damping ratio, 0.040 for surge and 0.011 for pitch.

The wave drift damping was calculated using the modified drift gradient method (Clark et al., 1993) which was proven to be quite accurate compared to more rigorous method of Emmerhof & Sclavounos (1992). The computed wave drift dampings of the stationary spar for three different wave headings are plotted in Figure 5. It is interesting to note that there exists non-zero surge wave-drift damping when $\beta = 90°$. The computer program for the wave drift damping of a moving spar is not developed yet. It is expected to be smaller than that of the stationary spar, and thus half of the values of Figure 5 were used, which correlates reasonably with experimental data. In irregular waves, the wave drift damping is a function of two frequencies and directions as the second-order wave loads. The wave drift damping results for bichromatic waves are not available yet in the open literature. Therefore, the off-diagonal components were approximated by their diagonal values, which is similar to the well-known Newman's (1974) approximation for slowly-varying forces. Since the relevant natural frequencies are small and the damping is important only near the natural frequency, this approximation is expected to be reasonable.

Figures 6 show the measured and numerically predicted surge and pitch responses in regular waves of 3-m height and 14-s period. The simulated mean and wave-frequency responses are in good agreement with measurement. We also see in both numerical and experimental results the transient surge and pitch responses at their natural periods.

We next present the pitch responses of the spar in two kinds of bichromatic waves. Figures 7 show the pitch-response time series in a pair of 6-m height regular waves of 16-s and 17.5-s periods (B1), and 12-s and 14.2-s periods (B2). Again in both cases, our simulated results agree well with experimental results. For case B1, we observe primarily the wave frequency response modulated at the period corresponding to $\omega_1 - \omega_2$. Whereas, for case B2, we see that the steady-state slowly-varying response at the difference frequency is greater than the wave-frequency response. Since the frequency difference of two waves (0.08 rad/s) is close to the pitch natural frequency (0.09 rad/s), there exists beat phenomenon with about 630-s period (or 0.01 rad/s), which can be seen in both experiment and numerical simulation.

We next present the results for an 100-year storm sea in the Gulf of Mexico characterized by the JONSWAP spectrum of significant wave height (H_s)=13.1m, peak period (T_p)=14 seconds, and over-shoot parameter γ=2. The measured wave spectrum is compared in

Figure 8 with a numerically simulated spectrum. The characteristic wavelength corresponding to T_p is about 306m (diameter/wavelength=0.13), and therefore it is assumed that the Morison drag formula can be used for the waves of significant energy. The measured and numerically predicted surge and pich response spectra are shown in Figures 9 and 10. We see excellent agreement in wave-frequency responses in both cases. The spectra of slowly-varying pitch responses also agree very well, while there exists some discrepancy in slowly-varying surge responses. This discrepancy can mainly be attributed to the insufficient simulation time compared to the natural period of slow surge motion. In other words, there are only about ten low-frequency oscillations including transient-dominant initial responses within our one-hour simulation time. Therefore, much longer time series (or experimental run time) is needed to have better agreement. In addition, the small reflection from the tank may contribute in a nontrivial manner to the increase of slowly-varying surge responses, as pointed out in Kim (1992). In Figures 9, we observe double peaks at surge and pitch natural frequencies because of the strong coupling between the two modes.

From Figures 9 and 10, we can conclude that the slowly-varying responses excited by the second-order difference-frequency wave loads are in general much greater than wave-frequency responses for these kinds of platforms. It was also found that the magnitude of the low-frequency drag-induced excitation is much smaller than that of the second-order potential-induced excitation. The time series corresponding to Figures 9 and 10 are presented in Figures 11 and 12. Since the expression (9) is based on the QTF instead of the quadratic impulse response function (Kim & Yue, 1991), the phase is not matched between the experimental and simulated time series. However, it seems that the overall trend and statistical characteristics of the two time series are analogous.

Finally, the surge and pitch responses of the spar in the same irregular waves (Figure 8) and sheared currents are investigated. The currents decay approximately linearly from the maximum velocity 1.3m/s at the free surface to zero at the depth of 106.7m. The theory which can handle the nonlinear wave-body interaction with sheared currents is not available yet in the open literature. However, it is well known that the wave-frequency excitations are not greatly affected by currents. Therefore, we assumed that the current primarily influences the drag force and the shift of the frequency through Doppler effect. Under this assumption, our numerical simulation was carried out and the predicted spectra are compared in Figures 13 and 14 with measured response spectra. In our experiments, it was found that our current generating system induced low-frequency excitations, and this effect was excluded after measuring the response by the current only. Figures 13 and 14 show that the present numerical method can adequately predict the appreciable reduction of slowly-varying responses as well as slight decrease of wave-frequency responses in the presense of currents.

Having confirmed that our numerical simulation is reliable, an extensive parametric study

can be carried out with varying main particulars of the spar to find an optimum design. We present in Table 2 the 6-hour-simulation results to compare important response statistics during the 100-year storm event. In this table, the surge responses of the center of gravity are presented. It can be seen that the surge amplitudes at the center of gravity are smaller than the values of Figure 11, which implies that the center of rotation is close to the center of gravity. Otherwise, the overall trend is similar to that of Figures 11 and 12. We also note that the mean surge offset in currents is about 7.3m, which is greatly increased compared to 3-m offset in the absence of currents.

5. CONCLUDING REMARKS

The response characteristics of a large floating spar in regular waves, bichromatic waves, and unidirectional irregular waves with or without sheared currents were investigated by experiment and numerical method. The experiment with 1:55 scale model was conducted in the OTRC three-dimensional wave basin for various wave and current conditions. A time-domain nonlinear motion analysis computer program was developed to numerically simulate the performance of the spar. It was found that the linear wave-body interaction theory alone was not adequate and second-order wave-body interaction theory including the effects of viscous and wave drift dampings had to be used for the reliable motion prediction of a spar. The first- and second-order wave diffraction/radiation problems were solved by the higher-order boundary element method. The viscous drag forces were computed from the Morison drag formula based on the relative velocity squared. The wave drift damping was computed using the modified drift gradient method. The two-term Volterra series were used to calculate the time series of nonlinear potential excitations in random seas. The resulting coupled, nonlinear equations of motions were integrated in the time domain by using an iterative Newmark-beta method.

Our estimated natural frequencies of the spar closely matched with measured values. The viscous drag coefficient was determined based on our free oscillation test in calm water. Our numerical simulation agreed well with the free-decay test when $C_D = 0.6$ was used. After this drag coefficient and wave drift damping were included, our numerical results for regular, bichromatic, and irregular waves agreed well with our measured data. It was seen in both numerical and experimental results that the low-frequency surge and pitch responses were in general greater than the wave-frequency responses. It was also seen that the slowly-varying responses were appreciably reduced but the mean offset was significantly increased in the presense of currents. The total response amplitudes were found to be acceptable in the survival condition. Since the mooring line was replaced by massless springs both in our experiment and numerical simulation, the actual surge response is expected to be smaller than the predicted values because of the additional mooring line damping. The developed computer program can be used for an extensive parametric study to find the optimum design of a spar.

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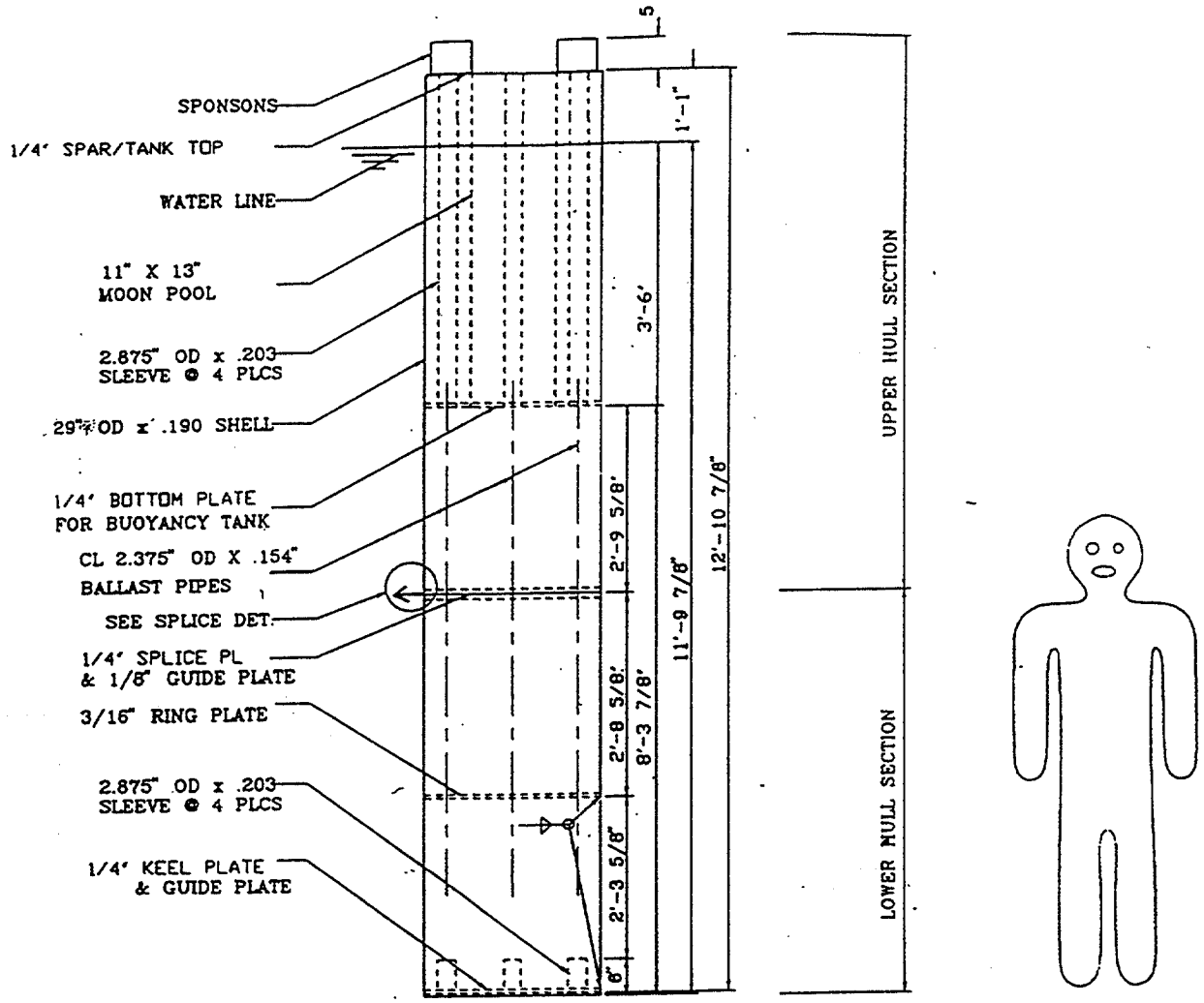
Table 1. Main particulars of the JIP Spar

Diameter	40.5140 m
Draft	198.1980 m
Mass(with entrapped water)	2.592*10e8 kg
Center of gravity(below waterline)	105.98 m
Pitch Gyradius	62.3315 m
Mooring Point(below waterline)	105.6495 m

Table 2. Summary of response statistics from 6-hour numerical simulation

	100 Year Storm	
	without current	with current
Mean value of surge	2.96 m	7.28 m
Mean value of pitch	0.0045 rad	0.0087 rad
Max. wave frequency surge amplitude	1.62 m	1.59 m
Max. wave frequency pitch amplitude	0.028 rad	0.022 rad
Max. slow varying surge amplitude	7.55 m	5.28 m
Max. slow varying pitch amplitude	0.064 rad	0.051 rad
Max. surge response	-5.62 to 11.91 m	1.85 to 13.52 m
Max. pitch response	-0.071 to 0.091 rad	-0.067 to 0.078 rad



SPAR HULL

1:55 SCALE

Figure 1. Particulars of the JIP spar platform in model scale

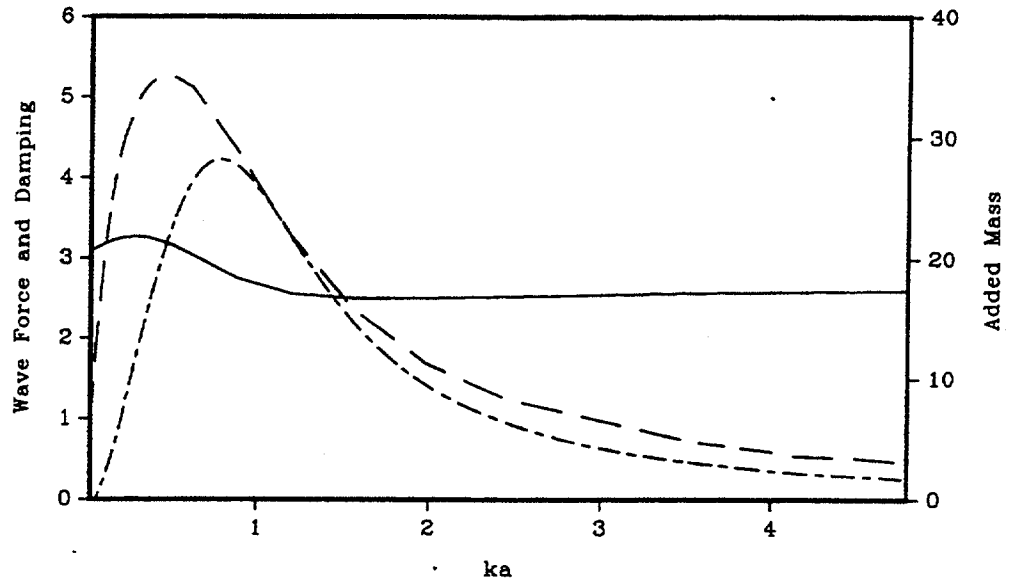


Figure 2. Dimensionless surge added mass ($m_{11}/\rho a^3$,——), wave damping ($b_{11}/\rho a^3\omega$,— - —), and first-order exciting force ($F_x/\rho g a^2 A$,- - - -)

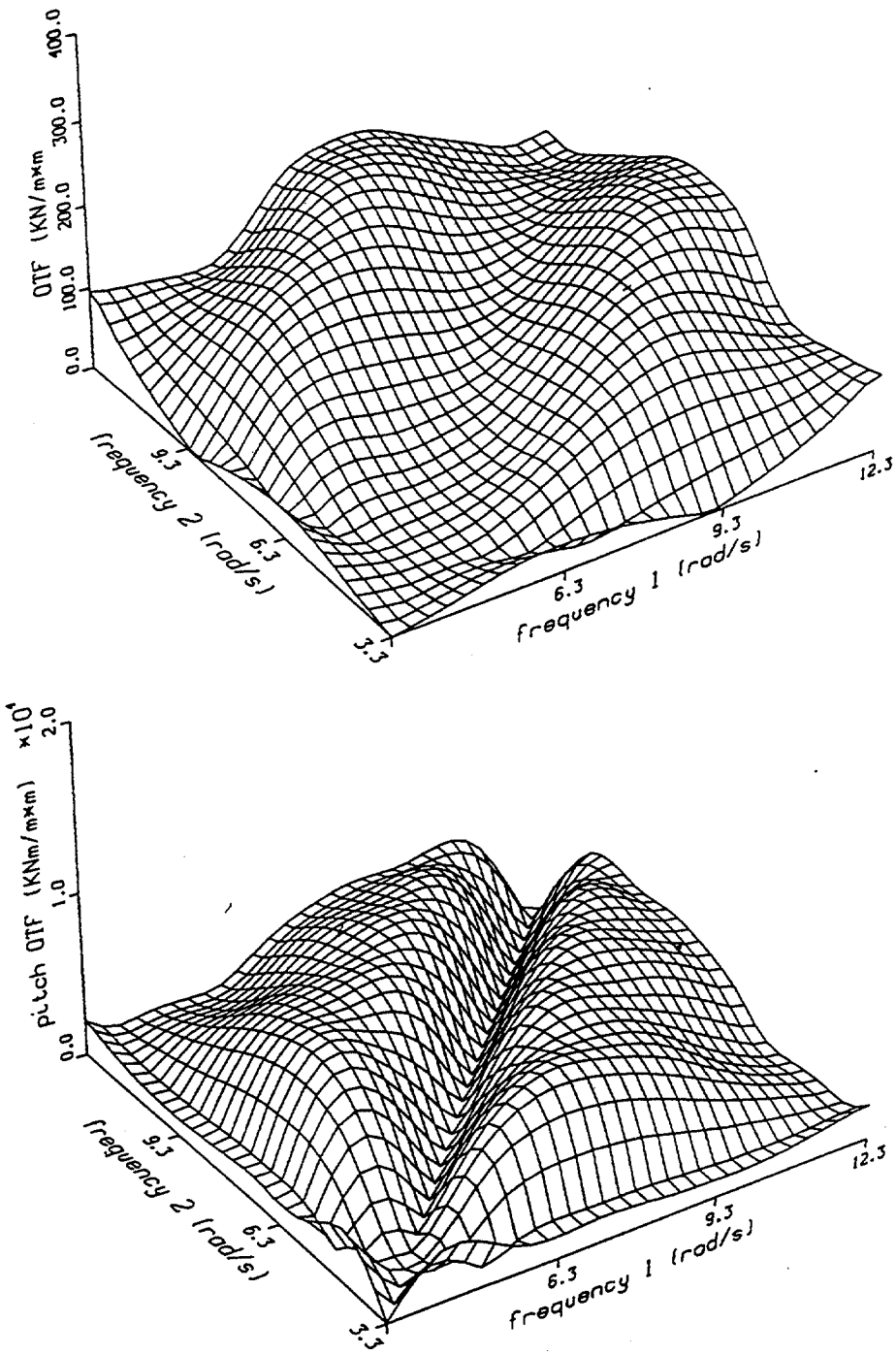


Figure 3. Surge (a) and pitch (b) difference-frequency excitation QTF

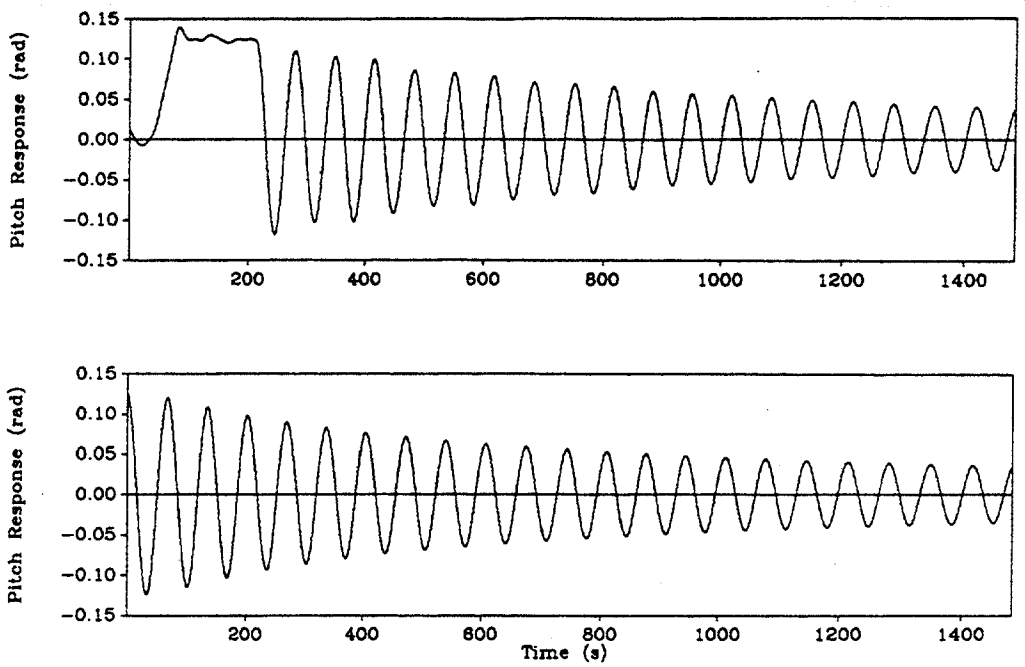


Figure 4. Pitch free-decay test in calm water; (a) experiment, (b) numerical simulation

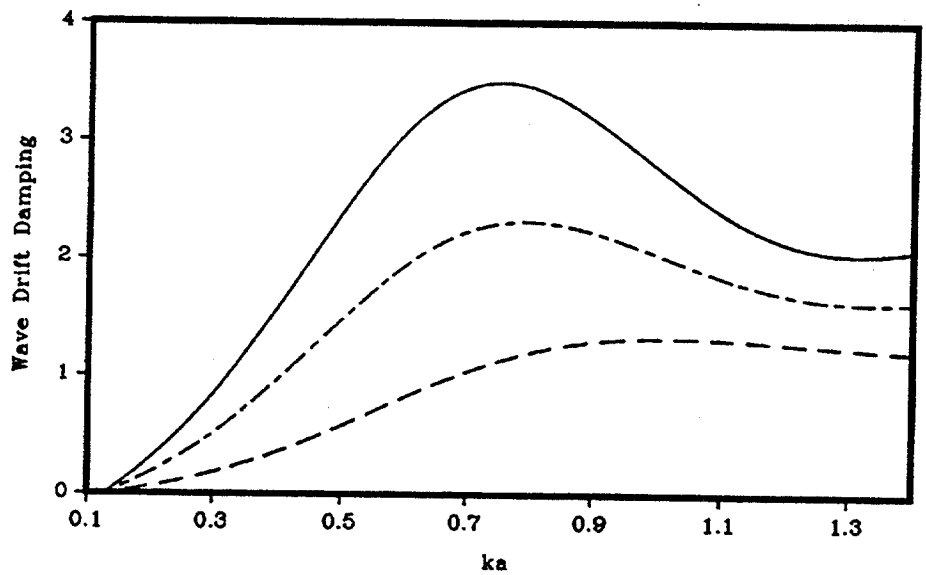


Figure 5. Wave drift damping ($B/\rho\omega a A^2$) of the stationary JIP spar as function of dimensionless wavenumber ka; 0° (——), 45° (— - —), 90° (- - - -).

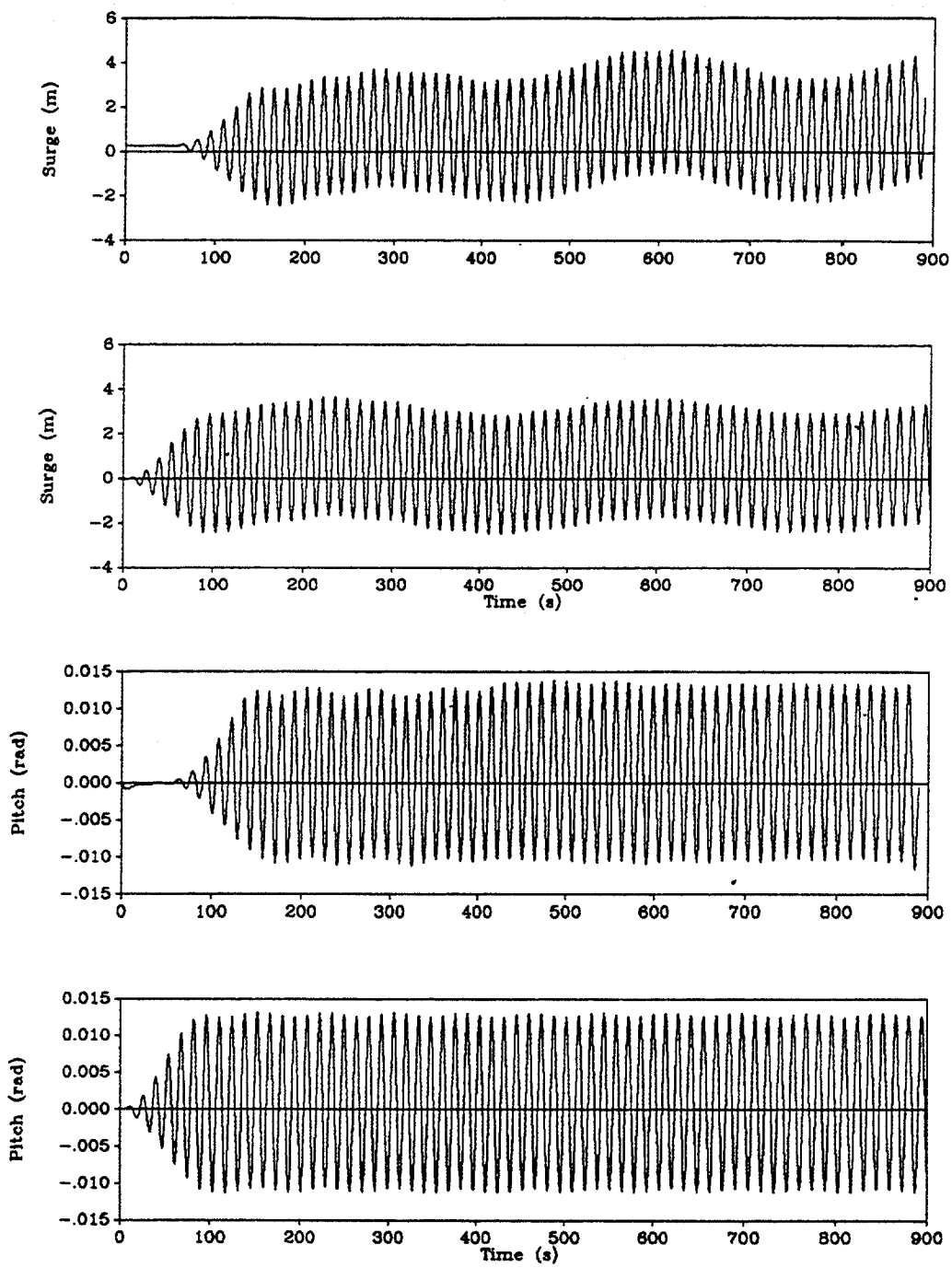


Figure 6. Spar responses in regular waves (H = 3m, T=14s); (a) experimental surge, (b) numerical surge, (c) experimental pitch, and (d) numerical pitch

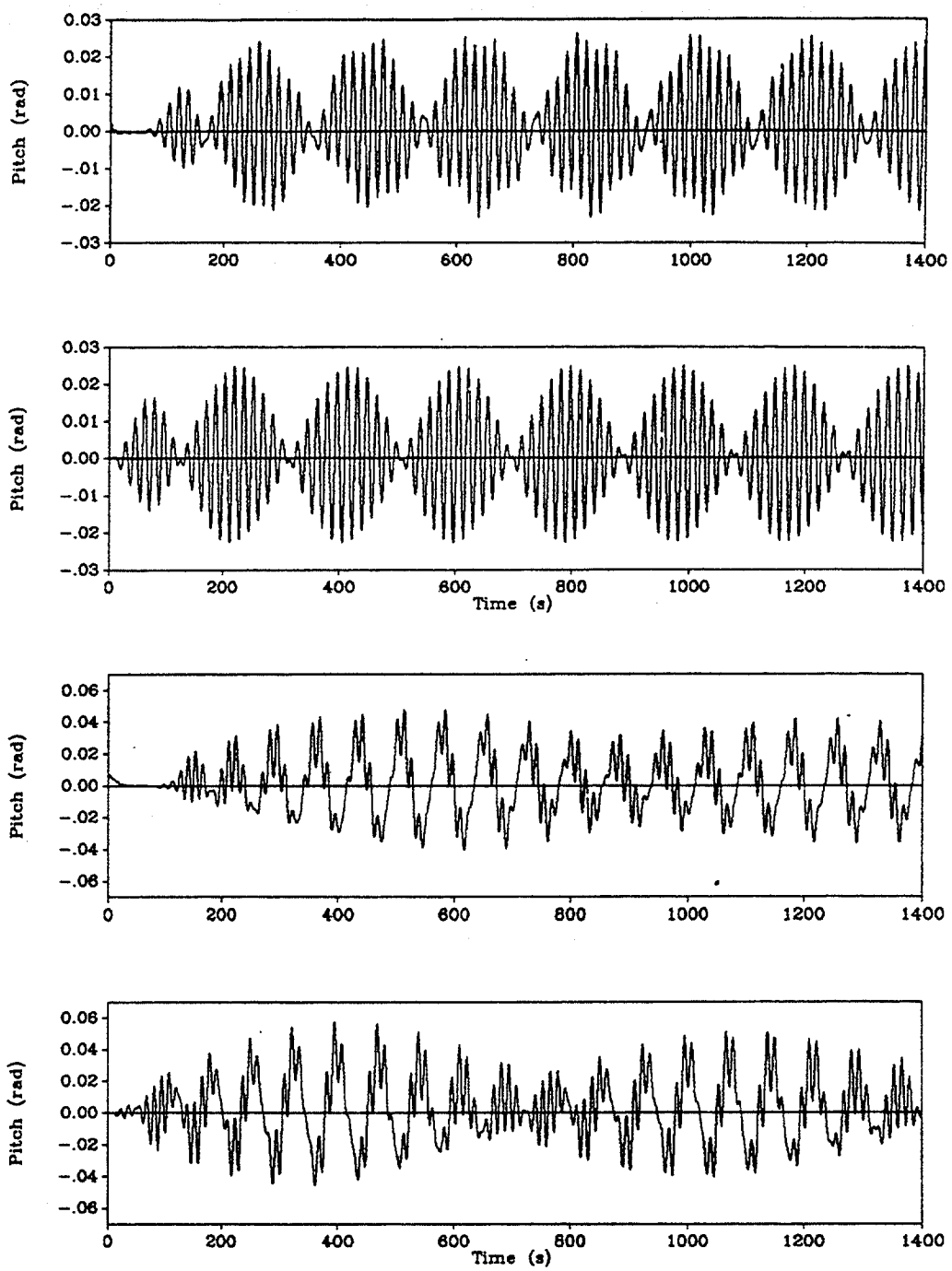


Figure 7. Pitch responses in bichromatic waves B1 (16s,6m and 17.5s,6m) and B2 (12s,6m and 14.2s,6m); (a) B1 experiment, (b) B1 numerical simulation, (c) B2 experiment, and (d) B2 numerical simulation.

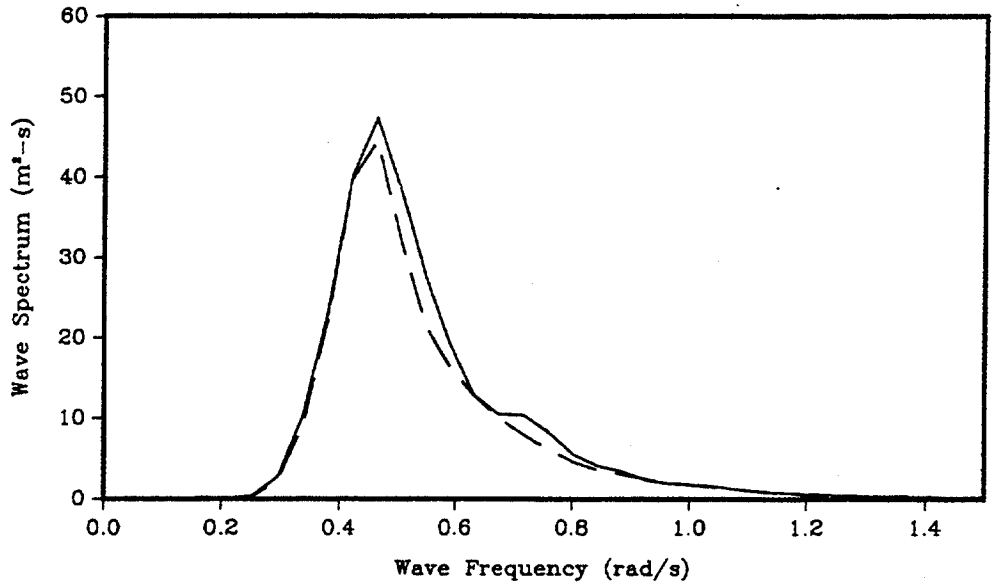


Figure 8. Measured (——) and simulated (- - - - -) JONSWAP input wave spectra.

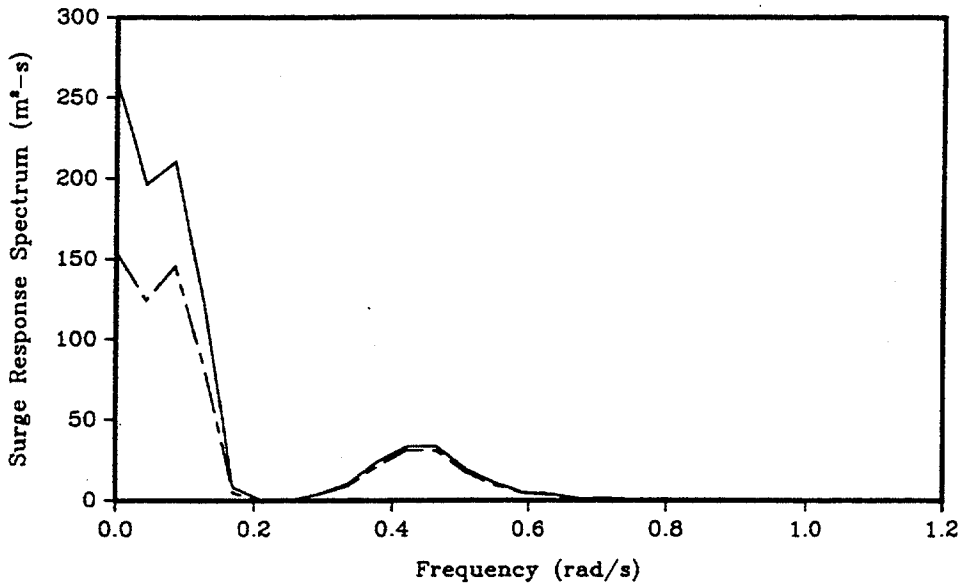


Figure 9. Measured (——) and numerically simulated (— - —) surge response spectra.

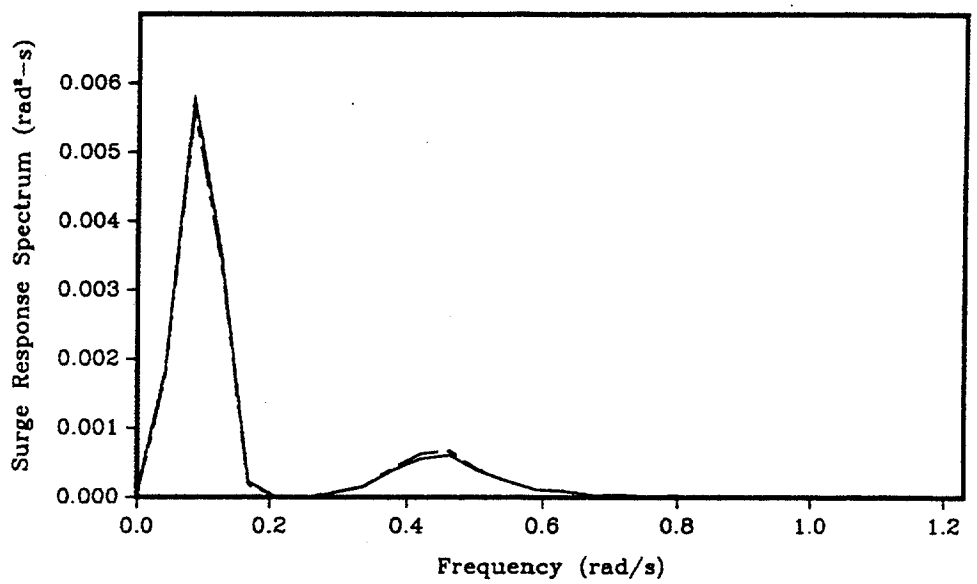


Figure 10. Measured (——) and numerically simulated (— - —) pitch response spectra.

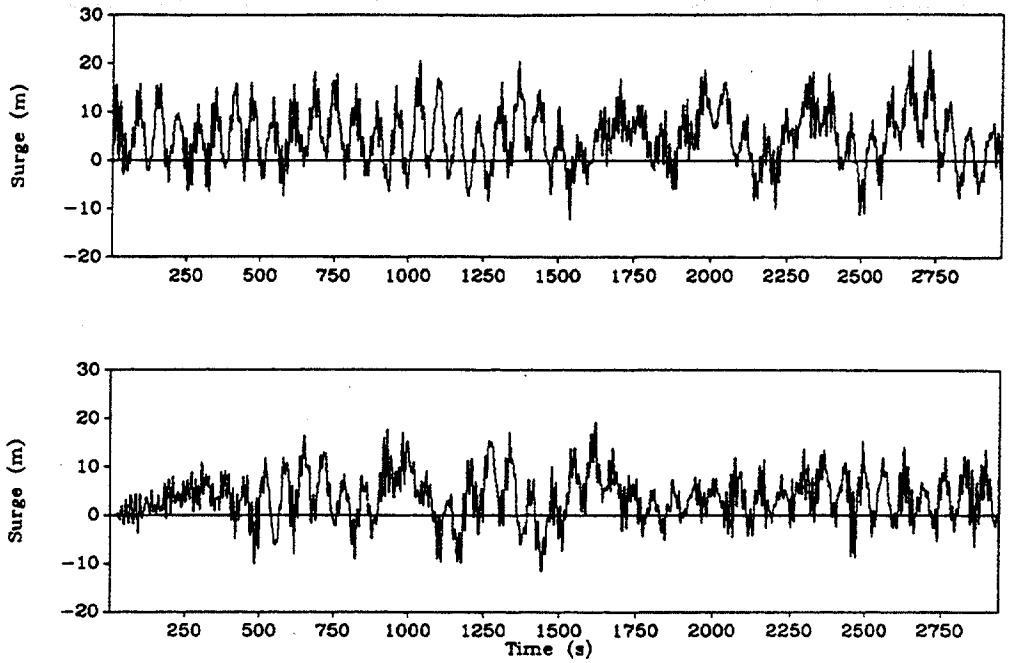


Figure 11. Surge-response time series in 100-year storm seas; (a) experiment, and (b) numerical simulation.

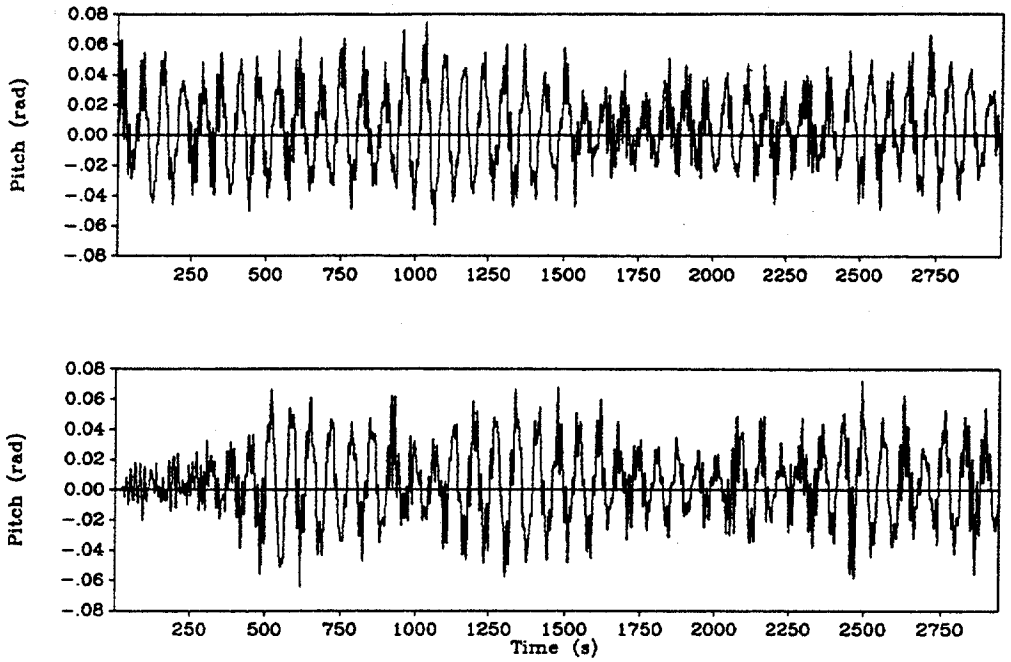


Figure 12. Pitch-response time series in 100-year storm seas; (a) experiment, and (b) numerical simulation.

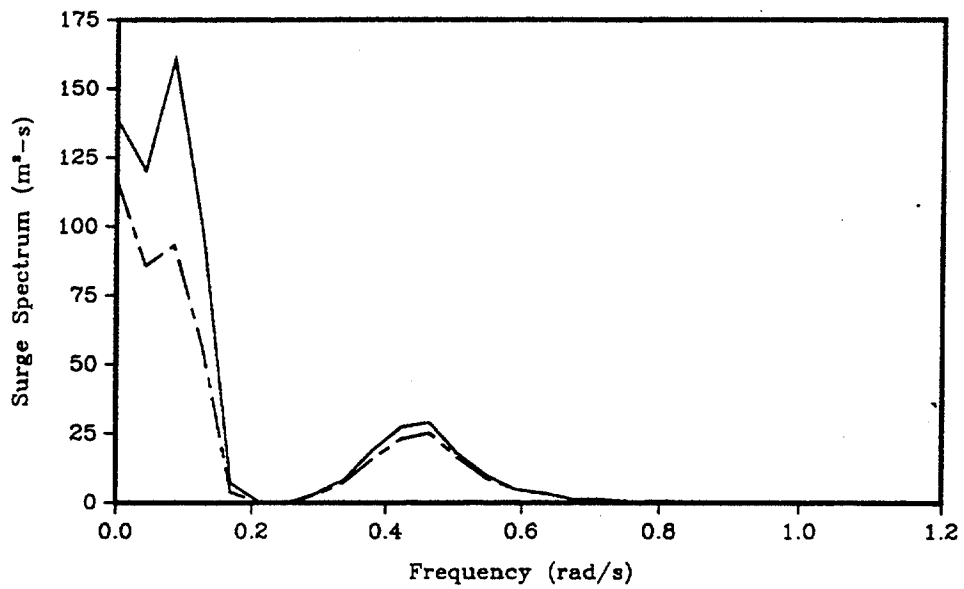


Figure 13. Measured (——) and numerically simulated (— - —) surge response spectra with currents.

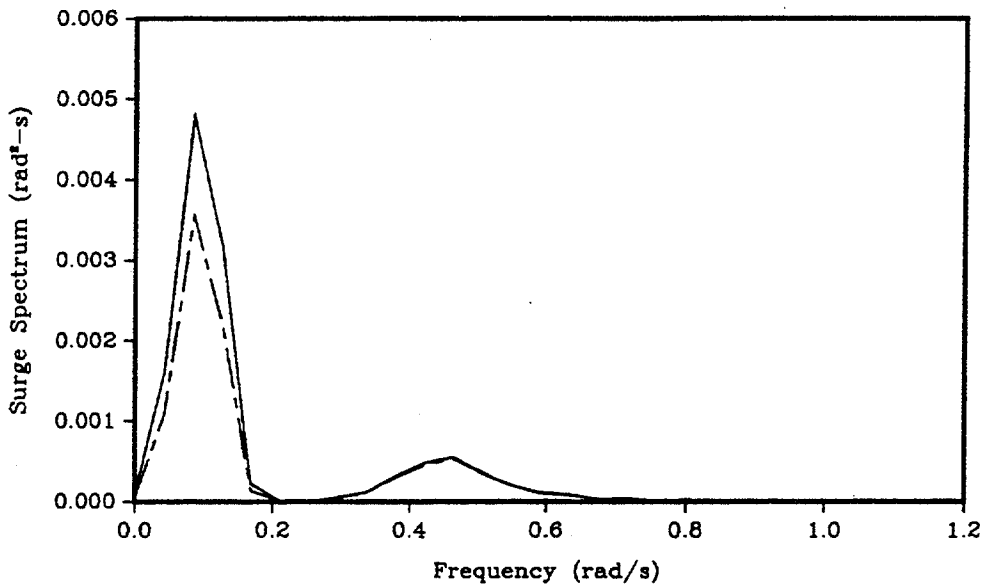


Figure 14. Measured (——) and numerically simulated (— - —) pitch response spectra with currents.

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On the Typical Qualities of SPAR Type Structures for Initial or Permanent Field Development

By

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ABSTRACT

The size of Spartype units - slender vertical floating bodies - may range between a float and the huge construction exceeding a length of 200 m. Two sizes between these extremes have been built by IHC Holland, namely the ELSBM and Shell-Esso-Brent Spar. Beaming on the use of Spar Units in offshore industry, not necessarily oil offshore industry, the general design philosophy with the influence of major parameters like draught, column and stability is shortly treated. Considerations regarding the strength during fabrication upending and use, as well as the fabrication, and upending itself are made. A large part of the paper gives attention to oscillatory and low frequency behaviour of the larger units in regular and irregular waves.

DESCRIPTION AND USE OF SPARTYPE STRUCTURES

Spartype structures in general are vertically floating constructions with an oblong shape. Their waterline is comparatively small, which classifies them as semi-submersibles. The floatation part and the ballast part are spaced appart to create stability. The construction between the two parts is either a space frame or closed structure, so that the three elements form one body (figure 1, 2)

References and illustrations at end of paper.

A column protruding through the watersurface connects the main body with the superstructure.

By changing the main dimensions the properties of the unit can be influenced. Thus it is possible to meet the requirements that follow from the different functions the Spar has to fulfil. Some of these functions with their specific requirements are:

1. Helicopter landing base
   Small shortperiodic motions
2. Offshore loading terminal (ELSBM-type)
   Small motion relative to tanker
   Small motion relative to bottom manifold
3. Oil storage terminal
   Storage volume
   Small motions relative to flowline connections
4. Emplacement for fixed equipment
   Large weight carrying capacity
   Small motions as required by the equipment

In practice a combination of these functions will be asked for. For example all functions are called upon by a Production/storage Spar that includes an offloading facility.

GENERAL DESIGN

The design of a light spar type heli-landing base, tanker loading terminal or light house is simply based on achieving adequate small motions as to guarantee satisfactory perfor-

mance. The design criteria can be imposed by equipment, personnel, underwater hoses, bow-hawser etc. A long slender body, with a small water line area and a relative high radius of gyration in pitch direction is ideally suited for this purpose, although minimum surge motions cannot be obtained in this way.

The design of larger units is more complicated as we have to deal with more factors when settling the dimensions. We will discuss some of the parameters.

a) Draught
As will be discussed later, such a unit is built horizontally. However, after upending and assembly of the superstructure in a calm bay, the last tow to the final site is in vertical position. So the minimum possible draught must be in accordance with the minimum waterdepth during tow out (towing draught). At design draught, the unit must have a bottom clearance allowing for a possible flow line layout and seabed constructions like a bottom manifold. Depending on the spar bottom motions this clearance may vary around 25-40 m.
For the motion behaviour a longer body is preferred. Up to a draught of 200 m, one will chose the draught as large as possible.

b) Protruding column
The diameter of the protruding column bears heavily on the motion behaviour of the unit. Not only the heave motion is influenced upon but the pitch and surge motion as well, by the fact that the column, is placed in the surface wave disturbance zone (small diameter is attractive).
The free space in the column is used for placing equipment like anchor handling, production etc. This brings up the wish for a certain minimum diameter. Finally, a minimum waterline area is required for safety reasons. When there is no need for increasing the diameter beyond this minimum value, this value is choosen.
The length of the column is such, that the superstructure is high enough above the water and that the main body is out of the wave zone.

c) Superstructure and tanker mooring
The wind effected area has to be kept as small as possible for keeping the anchor loads small. The tanker mooring system and the wind forces on the superstructure should not introduce a rotating moment on the Spar.

d) Stability
Minimum stability will result in minimum total motions of the superstructure. Yet the minimum horizontal motion of the bottom is not necessarily coupled to this minimum GM.
When the draught is kept constant, the weight of the unit is decreased by situating the shoulder level as high as possible.
This conflicts with the wish to reduce the volume in the relative largest wave motion zone. Usually preference is given to decreasing the motions above decreasing the weight.

A crude storage Spar knows several loading situations with different stabilities. Given the smallest stability, the highest stability is dependent on the arrangement. Sometimes it can be necessary to change the arrangement as to decrease the difference in stabilities. This results in more favourable motions of the superstructure.

CONSTANT DRAUGHT PRINCIPLE

A Spar is designed for one specific draught. So when different loading conditions occur, a system keeping the total weight constant is to be incorporated.
A system useful on all crude storage spar units is hereafter described.
Crude oil coming from a production platform or from the Spar's own production equipment must be stored temporary in the storage compartments. Offloading should be done by discharging oil and by taking in ballast weight simultaneously. Seawater fits this purpose excellent, except that its specific weight is about 20% higher than that of the crude.
In ballast condition the storage compartments should be filled 80% with water. The remaining volume could than be filled with an explosive air/gas mixture. This is not acceptable; the air volume needs to be separated at all times from the oil storage.
This separate space Buoyancy Control Room will be filled with air (ballasted condition) or water (loaded condition). The place of the BCR is not fixed; it can be choosen such that the stability difference between ballasted and loaded condition is acceptable.
The distance between the centres of gravity in loaded and ballast condition is approximately 16% of the distance of the centre of the BCR to the centre of gravity in loaded condition.
Bringing the buoyancy control room near the centre of gravity is favourable for the maximum operational conditions due to decreased motions in ballast conditions.
The disadvantages of a BCR in the storage compartments over a BCR on top of these compartments are the higher hydrostatic pressures on the shell of the buoyancy control room and the large amount of energy consumed by pumping the BCR empty against the head of seawater.
The main advantages of the low BCR, apart from motions, is that the last phase of the upending is not as critical any more.

BALLAST WATER AND OIL HANDLING ON STORAGE SPARS

The crude oil storage spar concept is based on the concept of the superseding of oil and water. The pressure communication between the storage compartments and the sea is in principle the same as that of a reversed glass with the crude oil trapped underneath. To prevent contamination of the sea with oil, the bottom is closed and the pressure communication between the storage compartment and the sea is achieved by a pipe, leading from the bottom to a seachest just under the still water level (figure 3). This arrangement ensures that seawater is loaded without additional pumping. All ballast water leaving the Spar is run through a water treatment plant to separate possible oil from the water.

STRENGTH

In calculating the strength of the spar, two main groups of conditions are distinguished:

- conditions on location
- conditions during construction, towing, upending and installation

The location conditions again may be divided into:

- Normal Operating Conditions
- Survival Condition

In case of a Spar with storage capacity, these conditions comprise all variations between fully loaded and fully ballasted.

In every single case the loads acting on the structure consists of the following elements:

steady loading - hydrostatic pressure and pressure differences
- equipment + structural weight

dynamic loading - hydrodynamic loads
- acceleration forces due to equipment and structural weight

local loading - anchoring forces
- mooring forces
- equipment foundations

Different parts of the construction will be determined by different loading cases.
The buoyancy control rooms undergo their maximum loading in fully ballasted condition with the inside at atmospheric pressure and a maximal hydrostatic head at the outside.
Of the main storage tank, the outside walls will be critically loaded during the upending procedure.

The main underwater body is divided by radial bulkheads. All subdivisions are treated as separate tanks. The condition with oil at one side and water at the other side (damaged) determines the strength of the bulkheads.

The strength calculation proper is executed with finite element computer programs.

FABRICATION

The long cylindrical shape of the Spar makes horizontal building imperative when no protected deep water construction site is available. If built in a horizontal position on a slipway or a drydock, ring or ring-segment sections can be added to the structure (fig. 4). The use of moulds for the fabrication assures a proper fit. Wall plating need not be rolled to a curved plate but bends under its own weight in a counter formed mould.
The building of the column and the superstructure with all equipment is very much facilitated if it is done in the upright position. This poses only a problem for the column because it must be mated to the main body in the dock. For the Brent spar this was effected by tilting the column with cranes and transporting it with a barge to the main cylinder that still rests on its blocks in the partially floaded dry dock. Ballasting the barge brings the column at the desired level.
The barge remains attached to the column during the towing out of the dock, till later on the unit is properly trimmed.

The fixed ballast that is installed next may come in any form. Ease of installation (pumpable), price and homogeneity make heavy concrete a clear fayorite.
During the installation of the fixed ballast, the buoyancy control rooms must be progressively filled with water to control the trim and draught.
After installation of the fixed ballast, the spar mainbody is prepared for towing to a sheltered deep water site for the upending, temporary mooring and the assembly with the superstructure. This superstructure is, like the column, built in a vertical position and transported to the assembly site on a barge.

THE UPENDING

This procedure is based on the controlled tilting of the mainbody by filling the storage compartments with seawater. The main controlling element is a fail-safe valve placed at the lowest point of the main cylinder wall near the fixed ballast. All compartments in the storage part are interconnected during the upending. The connections between the storage compartments can be closed in case of emergency by additional valves.

The most important aspect of the upending is the controlling of the pressure differences over

the outside wall of the storage compartments. So the level indicators must be accurate over a large range of levels.

ASSEMBLY

The draught of the unit can be increased after upending by filling the Buoyancy control rooms. This increased draught facilitates the lifting of the superstructure onto the column. This can be done by a large crane although alternative procedures are possible. Debal-lasting the BCR's will make the lower part take the weight of the super structure. The welding of the mating joint and the connect-ing of hydraulic and electric systems will finalize the construction of the Spar.

SPAR MOTION IN REGULAR WAVES

The steady and unsteady forces acting on a Spar are:

1. oscillating wave force
2. added mass, damping, hydrostatic and ancho-ring forces due to the spar motion
3. tanker mooring force
4. windforce
5. current force
6. wave drift force

For a medium size unit (Brent Spar type) the relation between the forces and moments acting on the centre of gravity are in survival conditions without a tanker ($H_{1/3}$=17m, $\overline{T}$=15sec, V_W=48m/s, V_C=0,6m/s)

Force due to:	Force in surge di-rection X	Vertical force Z	Moment θ
wave(amplitude)	1	1(0.1-X)	1
anchoring(ampli-tude)	0.01	0.08	0
no tanker	-	-	-
wind(constant)	0.005	-	0.01
current(con-stant)	0.005	-	0.005
constant drift "reflection"	0.0005	-	0

The relation between the forces in operational conditions with tanker are: ($H_{1/3}$=5m, $\overline{T}$=8-9sec).

Force due to:	X	Z	θ
wave(amplitude)	1	1(0.3xX)	1
tanker(amplitude)	0.05	0.05	0.05

The following relations between the restoring Forces are being expected.

Restoring force of:	X	Z	θ
Spar	0	1	1
anchoring	1	0.13	0
bowhawser(fixed tanker)	3-4.5	0.1-0.2	0.25-1

The natural frequency can be effected by the restoring forces, but it seems, that, for the purpose of calculating the exciting forces, only the wave forces have to be taken into account. Modeltest results show that ignoring the anchoring- and bowhawserforces is not always allowed, but for practical purpose, it is acceptable. When determining the maximum displacement, the excursions due to the steady wind current and bowhawser force have to be included.
Besides the static offsets, the wind force is capable of introducing large dynamic motions. The motions in waves of slender bodies, or a construction formed by slender bodies, can be calculated with good results with the strip theory. Good description of the striptheory as used in shipmotion calculations are found in literature (ref. 3). The principle of striptheory is to divide the ship in short prismatic bodies. It is assumed that, apart from a forward speed correction, the water moves in a vertical plane perpendicular to the longitudinal axis of the ship. The motions of offshore structures can be calculated by dividing the structure not only in longitu-dinal direction, but in a three dimensional way (4).
For Spar type structures it is only necessary to use a vertical division. In this way, the influence of stability, moment of inertia, waterdepth, ratio between the dimensions etc. can be established.

The normally predominant linear potential wave forces are pressure forces equal to the pressure forces in a undisturbed wave plus a force correcting for the presence of the body. The last force is normally split up in an added mass and a damping force. The damping force, varying linearly with the water velocity, is very small for these structures with a large draught (5).
Figure 5 shows these forces. The vertical force on shoulder and bottom are counter acting each other. Determined by the relation between the diameters of the column and main cylinder and by the relative draughts of shoulders and bottom, there will be one wave frequency giving no vertical force. For lower frequen-cies, the wave force is negative, higher fre-quencies give positive vertical wave forces. The heave motion will change phase at this specific frequency and will consequently be-come zero.
The surge motion is not submitted to such a phenomenon and will continuously decrease to zero for increasing frequency. The pitch motion would, if the moments resulting from

the forces on shoulder and bottom were large enough, also change phase at one specific frequency. Unfortunately, the moment resulting from the horizontal forces forms the major part of the total moment. It is clear, that the position of the centre of gravity and the magnitude of the horizontal wave force on the upperpart have a large influence on the pitch motion. Figure 5 shows also, that at increased wave frequencies, the total horizontal wave force is acting nearer to the water surface. This means, that the pitch motion becomes more important than the surge motion and that the horizontal motion of the bottom can be opposite to the horizontal motion of the superstructure.

INFLUENCE OF SOME PARAMETERS

1. Centre of gravity

It has been mentioned, that the position of the centre of gravity has a large influence on the pitch motion. As the centre of buoyancy is fixed by the outside dimensions, an increase of stability can only be achieved by lowering the centre of gravity. The unfavourable effect is that the pitchmoment increases together with the natural frequency. This will shift the response characteristic to higher frequencies and will increase the response operators.

In waves, point of application, magnitude and direction of the buoyancy force changes continuously and so does the metacentric height. This means that an unstable pitch motion can be induced by a heave motion having a frequency in the regions with centre frequencies 2,1,0.66 ..... times the natural pitch frequency (Ref. 6 Matthieu equations).
Increase of the stability alterations due to waves relative to the still water stability increases the frequency regions. Lessening of this non linear phenomenon can only be achieved by increasing the still-water stability.

2. Column diameter to main cylinder diameter.

The column - to main cylinder diameter ratio determines the ratio shoulder to bottom area which fixes the wave frequency for change of sign of the heave force. This ratio is used as a design parameter. Furthermore the column diameter is a direct measure for the natural heave frequency and has a large influence on the pitch angles in short waves. Figures 6-1, 6-2, 6-3 give the calculated uncoupled motion characteristics of the centre of gravity. Due to zero damping, the motion can only be in or out phase, so a change of phase is given by a change of sign.

The vertical dimensions of the spar determine the water pressure acting on the shell, so a nondimensional wave number $(T \cdot k/2\pi)$, occurring in the hydrodynamic wave pressure under water, can be a useful dimensionless frequency. Non dimensionalizing the pitch angle is not done by using the wave slope. Instead, the displacement at a distance T from the centre of gravity, due to pitch alone, is divided by the wave amplitude. The normal wave spectrum representation can now be used.

3. Influence of breadth

Increasing the diameter of the column and maincylinder in proportion with a factor α means increasing the section area with a factor α^2.
The horizontal wave forces and added mass forces increase with a factor α^2. So the surge motion will remain the same. The pitch motion changes slightly due to the increase of the surface inertia moment with a factor α^4. The moment on the shoulder and bottom and the metacentre above the centre of buoyancy (I_{wl}/∇) are small and do not change proportional to the section area.
The vertical forces, irrespective of the small added mass forces, also change with a factor α^2, as do the vertical reaction forces.

Conclusion

Summarizing, it can be concluded that
- not the absolute values of the dimensions of a Spar, but their relations to one another are important for the motion behaviour. It is possible to adjust the design to the expected seastates by selecting the diameters of the column and maincylinder and by adjusting the depth of the shoulder.
  Some restrictions like minimum column diameter and minimum stability are of interest to the designer. The minimum shoulder depth (collision damage) is in general not too interesting as a shoulder far under the watersurface is already favoured for the surge and pitch motion.

In the 1000.000 bbl proposal, a further lowering of the shoulder-resulting in larger ballast and total weight - was not necessary in the seastates the unit would meet.

SPAR MOTION BEHAVIOUR IN IRREGULAR WAVES

1. Survival condition (mean period 14-15 sec)
   Figure 6 shows, that a draught increase shifts the frequency characteristics to lower frequencies (see $\sqrt{T/\lambda}$). In general, a draught increase gives a decrease of the

motions. However, the draught can be restricted by the waterdepth and the allowable stresses during the upending procedure. Figure 7 gives a rough impression of the motion as calculated or measured during modeltests. The large influence of the stability on the pitch motions and on the coherent horizontal displacements of the top or bottom can clearly be seen by the broad surge and pitch ranges. The lower lines are minimum values (low stability).
The motions normally met in practice are between the lower and upper line, although higher pitch and deck motions are not unconceivable. The 1000.000 barrel proposal is given with dots; B - ballast; L - loaded. These graphs serve only as to give an indication of the motions of a production or storage Spar. Application of smaller and shorter spars can differ substantially from longer and heavier spars. The weights of a small spar (only serving as a mooring point) are concentrated near the ends, so the radius of gyration is relative large.
Due to absence of equipment, the column diameter can be kept small. So, although the stability is relatively large, small units designed with a fixed centre of gravity can exhibit less pitch- and horizontal deck motion than given in figure 7. A production Spar also has a relatively large radius of gyration due to the equipment and due to the fixed ballast increase. The minimum column diameter will not be as small as the minimum diameter for a storage spar. The place of the Buoyancy Control Room, where by ballasting the difference in specific gravity of seawater and oil is absorbed, is of great importance. A high BCR, with a minimum GM in loaded condition - oil in the storage compartment and seawater in the BCR - results in a high stability in the ballast condition. Lowering the BCR improves the pitch motion in ballast condition.
The superstructure has to be kept free from the wave action. With figure 7-2 it is possible to calculate for a given probability of exceedance during a certain time span, the maximum immersion in survival conditions. An improvement would be to deduce from the anticipated wave heights and periods a long term prediction of the immersion. However, it is well known, that using the linear operators in rough sea conditions defined by standard sea spectra may lead to wrong results. So, a certain airgap between the "maximum" wave and the superstructure remains necessary.
Due to its shape, the shoulder will not be exposed to slamming and consequently has not to be kept under the water surface by all means.

Operational conditions (mean period 8-9 seconds)
The highest sea state nowadays allowing a tanker to be moored is characterized by a significant wave height of about 5m, with a mean period of 8-9 seconds. The normal Spar motions in this irregular sea is given in figure 8. Reducing the horizontal motions of the mooring point is of great importance in reducing the peak forces in the bowhawser
Reducing these peaks, means that a tanker is able to remain moored in a higher seastate. So, the relative motion between tanker-bow and Spar mooring needs to be minimized.
Lowering the relative motions in the maximum operational conditions usually means lowering the relative motions in a lower seastate, so the tanker can be moored and connected in higher waves.

OPTIMIZING

We have to achieve minimum motions at several points. Not only the oscillating motion but the total motion; including the offsets must be considered.
In survival and maximum operational conditions we can try to minimize the horizontal and vertical "flow line entry point" motions (at keel level).
It can also be necessary to minimize the mooring point motions.
In all cases, the static excursions due to the mean wind- and current forces and the lowfrequency pitch and surge motion of the spar-tanker system must be taken into account. Stiffening the total spring characteritics leads to a reduced low frequency motion of the tanker. This means, that a short bowhawser, large spar stability and a stiff anchoring system with a high point of attachment would give favourable result
up will give high peak forces in the bowhawser because of the too stiff bowhawser in connection with the large motions of the too stable spar. Normally the Spar mooring point is situated at a high level. Lowering this point, till the bowhawser is horizontal reduces the peakforces as well by the lower horizontal spar motions as by the decreased influence of the vertical spar and tanker bow motions. As it is impossible to satisfy all these requirements at the same time, every design needs a careful analysis for obtaining the desired compromise between the survival and operational behaviour.

LOW FREQUENCY MOTIONS OF SPAR UNITS

References 7 and 8 discuss the origin of the low frequency motions of moored structures. A simple explanation is given here. The constant wave drift force exerted by regular waves on a floating object is by theory and

experiment proportional to the square of the wave amplitude. In an irregular sea. (superposed of regular waves) squaring the momentary amplitude yields a mean, a slowly oscillating and a fast oscillating value.
Infact, the sum of the oscillating part of the driftforces (distributed over the shell) in regular waves should be used instead of the sum of regular waves.
The drift force on a Spar is also proportional to the square of the wave amplitude but a few features prevent the unit from the large excursions that are normally observed with moored tankers.

-- A spar is tied with springs in all directions.
The spring constant in heave, pitch and roll direction is relatively large.
The spring constant in yaw directions is the lowest of all.
In all cases, the spring constants are such that negative elongations give negative forces; this is not the case with bowhawsers.

-- By his shape, the Spar is less exposed to the wave action than a surface ship.
The mean driftforce on a tanker with an equal volume is approximately ten times higher than on a spar. The slow variations will also differ to the same factor ten.

-- A Spar is symmetric around the vertical axis, consequently the coupled sway-yaw motion will not be introduced by the surge motion. The conclusion is that the low frequency surge and pitch motion of a spar is considerable less than the surge - sway - yaw motion of a single line moored tanker.
Modeltests confirm this.

LOW FREQUENCY MOTIONS OF A SPAR-TANKER SYSTEM

It has been explained that the low frequency drift force acting on the tanker is the primary source of the low frequency behaviour of the spar-tanker unit. A further simplification of the system should be possible when we could delete the Spar mass forces. This is not the case, as can seen by comparing the natural frequencies.

Tanker in the total system	surge	0.02 rad/sec
	sway/yaw	0.01 rad/sec
spar alone	heave	0.2 rad/sec
	pitch	0.2 rad/sec
	surge	0.025 rad/sec

For low frequencies (0.02) the spring force in heave and pitch directions are predominant to the mass forces in these directions. This is not the case with the surge direction .

So the double pendulum system cannot be symplified for analytical purposes and model testsare necessary to obtain numerical values. In general model tests last approximately 35 minutes. After this time, the characteristics of the distribution functions remain constant. Modeltests ,involving long periodic motions ought to be extended to 15 hours for obtaining good statistical information. The Brent Spar test duration was 2.5 hour which increased the reliability to a great extend as compared to 35 minutes test duration.
The designer is usually interested in maximum values like the maximum motion between spar and tanker. Although from a statistical point of view a maximum can be exceeded by waiting long enouch, in practice a short term maximum or a probable maximum is a kind of absolute maximum due to the finite time for stationary wind, current and wave conditions, (aprox. 3 hours).
As the total time a tanker is moored to the Spar is considerably more than the maximum time the environment remains constant, extrapolation of the model test is still necessary.
Analyzing possibilities of lowfrequency motions are quite restricted. The system is non-linear by the absence of pressure forces in the bowhawser and by the non linear strain elongation characteristics of the bowhawser.
Short term prediction of the relative motions can be made with the experiments and the theory for broad spectra. It is supposed and this is not exactly true, that the distribution of the momentary displacement is Gaussian (ref 9 and 10).
The width of the relative heave spectrum (between loading boom and tanker bow) is approximately 0.65. The widths of the relative surge and sway motion spectra are 0.92 and 0.99 respectively. Using the measured energy levels (m_o) predictions can be made of the expected extremes.
One can determine the energy levels of normal ship motions with the aid of linear response functions and wave spectra. It seems, that low frequency energy levels can also be found in this way except that the shape of the wave spectrum becomes very important (ref 7).
As far as we know, the energy levels of non-linear systems cannot be found by simple means.

Normal motions are not sensitive to wind, current, bowhawser etc.
The energy levels are only dependent on the seastate. Low frequency motions are very sensitive to wind, current, bowhawser, backpropulsion etc. This makes the number of variables too large for exhaustive modeltesting.
We need to limit the modeltests to those we expect to give the largest motions and forces.
It is clear, that because of the inaccuracy of the predictions as well as the unpredictable weather and the wear of the bowhawser, good safety measures are a necessity.

On the Brent Spar Unit, a large dial, clearly visible from the tanker shows the bowhawser force. Fracture of the hawser, characterized by a sudden force drop activates the safety system, cutting of the oil flow and uncoupling the hose tanker connection.

1000.000 bbl Storage Spar

To illustrate the possibilities of the Spar type system, a preliminary design of a 1000.000 bbl storage Spar has been made. The following approximate figures are from a storage unit operating in 210 m waterdepth in the Northern North Sea:

displacement	212000 t
oil storage	159000 m^3=134600 t
buoyancy control room capacity (seawater)	2800 t
total fixed ballast	16000 t
steelweight	25000 t
equipment, turntable anchoring accommodation etc	8400 t
columndiameter	20 m
shoulderdepth	30 m
main cylinder length	145 m
main cylinder diameter	42 m
GM loaded	2.3 m
GM ballast	12.3 m
radius of gyration (pitch and roll)	53 m loaded
radius of gyration (pitch and roll)	47 m ballast

The motion behaviour of such a unit is given in the figures 7 and 8. It can be concluded, that all important oscillatory motions are of the same order of magnitude as is found for the Shell-Esso Brent Spar. For loaded conditions (L) the motions are even better. Ballasted conditions (B) can possibly be improved by changing the location of the buoyancy control rooms (GM).
Due to the increased main cylinder diameter, the current drag becomes of more importance. This necessitates the use of a heavier anchoring system.
Preliminary calculations for the indicated waterdepth show that this unit can be anchored with 12 U3 quality chains with a diameter of 115 mm.
If such a unit is used in much the same way as the discussed storage terminal Spar, there will not be any need for having a bigger superstructure. Increasing the transfer pumpcapacity and watertreatment equipment can be realised inside the 20m diameter column. The construction of the protruding column will not change importantly as compared to the 17m diameter of the existing unit. However, the main cylinder shows a considerable increase of diameter. So an inner column of preferably 20 m diameter will be required in order to restrict the unsupported stiffened plate width of the outer barrel and the radial bulkheads. So, inside the inner 20 m barrel an hexagonal bulkheadsystem is adopted where a twelve bulkhead pattern is found between inner and outer barrel. This coincides with the choice of a twelve anchor stopper arrangement. The actual construction of the main cylinder will have to be done horizontally, seen the total length of 145 m. Dry docks of sufficient large dimensions and having adequate hoisting arrangement can be found all over the world nowadays.

CONCLUSION

The Spar concept has a wide field of applications. From very small loading terminals to the big 1000.000 bbl storage unit, they all have one thing in common: the motion behaviour can be easily influenced upon by the designer. The construction will tend to follow the described pattern and can be realised in shallow water sites. Transport and upending have proved not to pose any limitations.

Offshore designers are welcome to let their imagination go to find new areas of fruitful use for the Spar concept.

ACKNOWLEDGEMENT

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Nomenclature

DB -diameter of main cylinder
DC -diameter of column
GM -distance of centre of gravity to metacentre
$H_{1/3}$ -significant wave height
LB -length of main cylinder
LC -length of column (under water surface)
T -draught
$\bar{T}$ -mean wave period
V_c -current velocity
V_w -wind velocity
X -surge amplitude
Z -heave amplitude
$k=\frac{2\pi}{\lambda}$ - wave number
k_{zz} - radius of gyration in pitch direction
k'_{zz} - radius of gyration including added mass $(\sqrt{\frac{I}{\rho\nabla}})$
∇ - displacement (volume)
λ - wave length
θ - pitchangle (amplitude) (radians)
ζ - wave amplitude
ω - frequency (rad/sec)

Note : in figures 7,8 :

$\frac{X}{\zeta}, \frac{Z}{\zeta}, \frac{\theta}{\zeta}$: significant motion amplitude divided by significant wave amplitude (m/m or degr/m)

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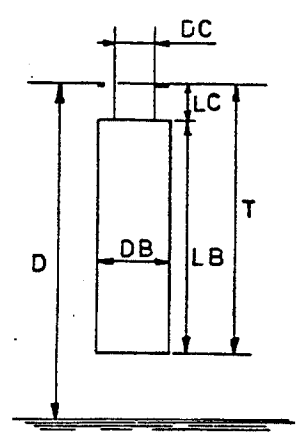
TABLE 1 - TABLE REFERRING TO FIG. 6

DB/LB = 0.52

LB/LC = 3.44

GM/T = 0.0313

	DC/DB	$\nabla^{1/3}/T$	k_{zz}/T	k'_{zz}/T	D/T
1	1.00	0.506	0.28	0.40	1.75
2	0.76	0.490	0.30	0.41	1.75
2b	0.76	0.490	0.30	0.41	12.5
3	0.52	0.477	0.31	0.40	1.75
3b	0.52	0.477	0.31	0.40	12.5
4	0.26	0.468	0.32	0.39	1.75
5	0	0.465	0.32	0.39	1.75



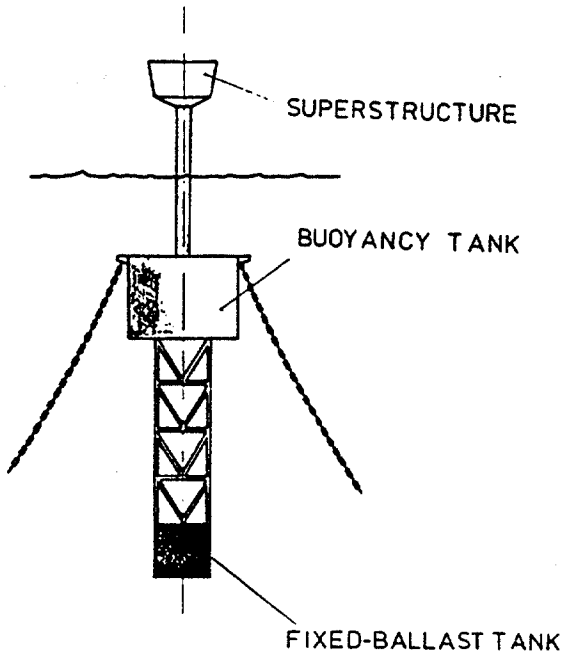


Fig. 1 - Basic spar concept.

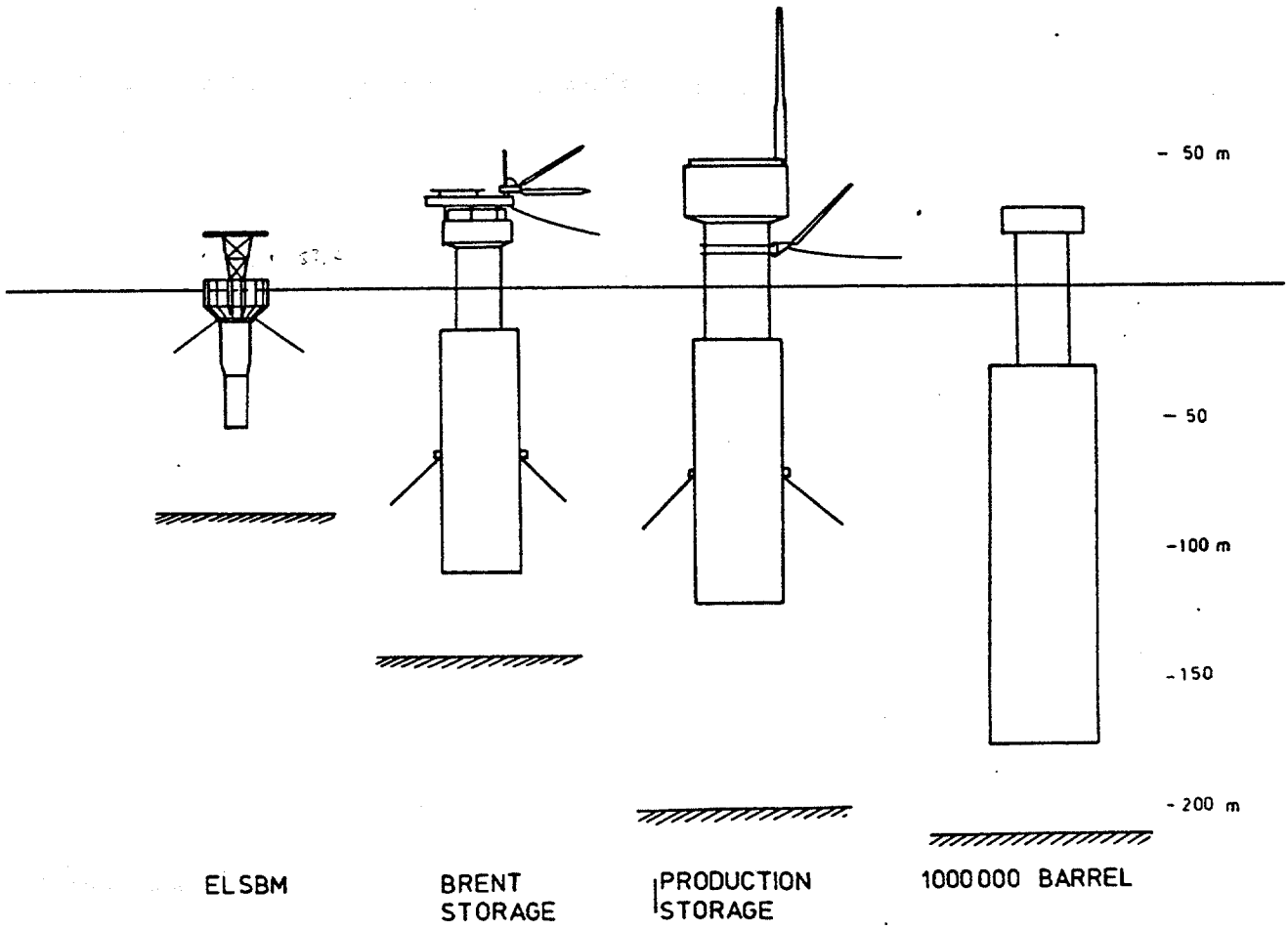


Fig. 2 - Several examples of spar designs.

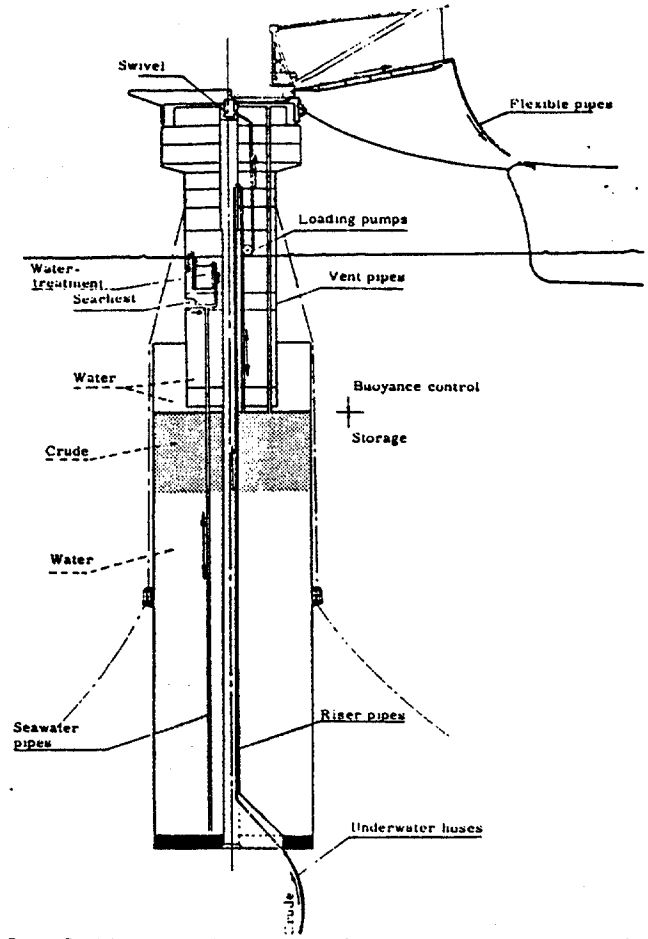


Fig. 3 - Ballast water and oil handling system.

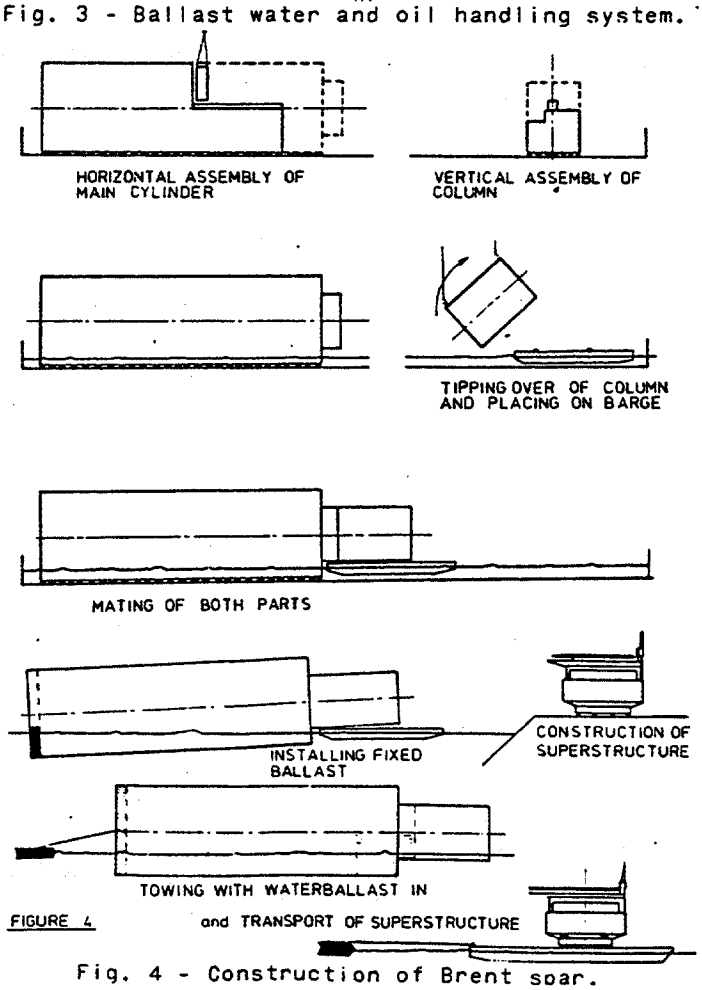
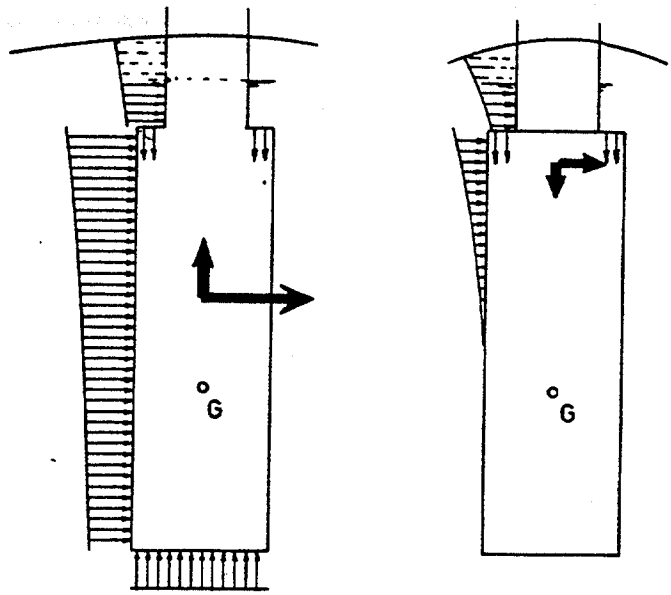


Fig. 4 - Construction of Brent spar.



LONG WAVES SHORT WAVES

Fig. 5 - Schematic representation of the oscillating wave forces.

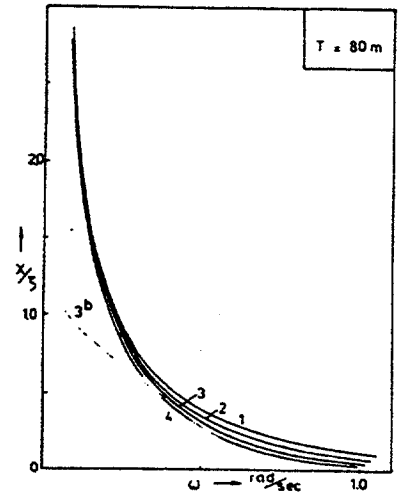


Fig. 6a- Surge motion in regular waves of C.G.

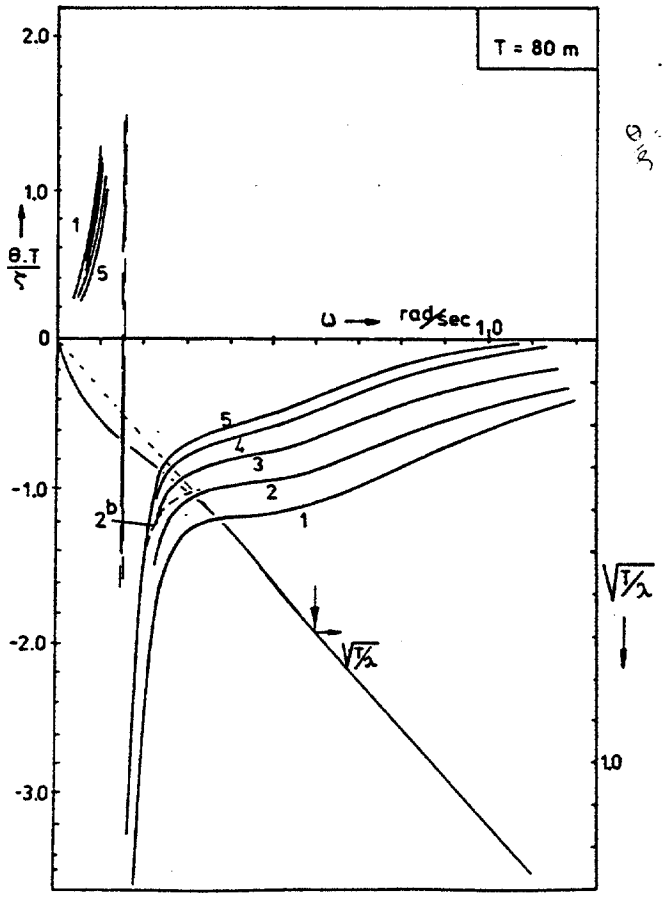


Fig. 6b- Motion due to pitch in regular waves.

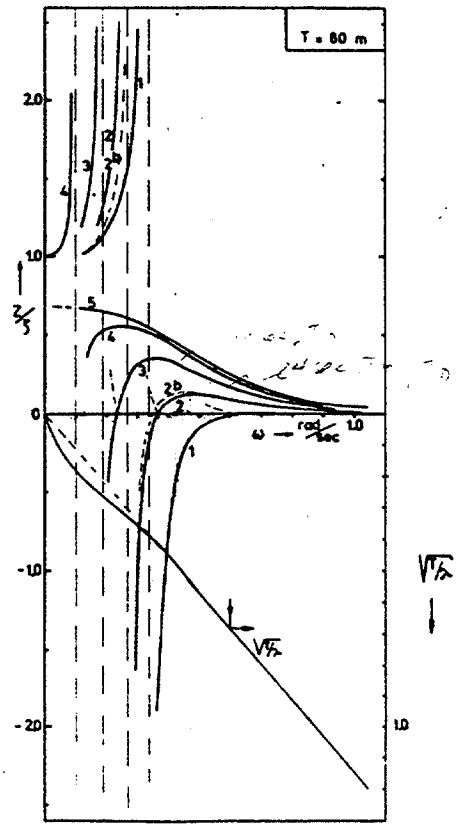


Fig. 6c- Heave motion in regular waves of C.G.

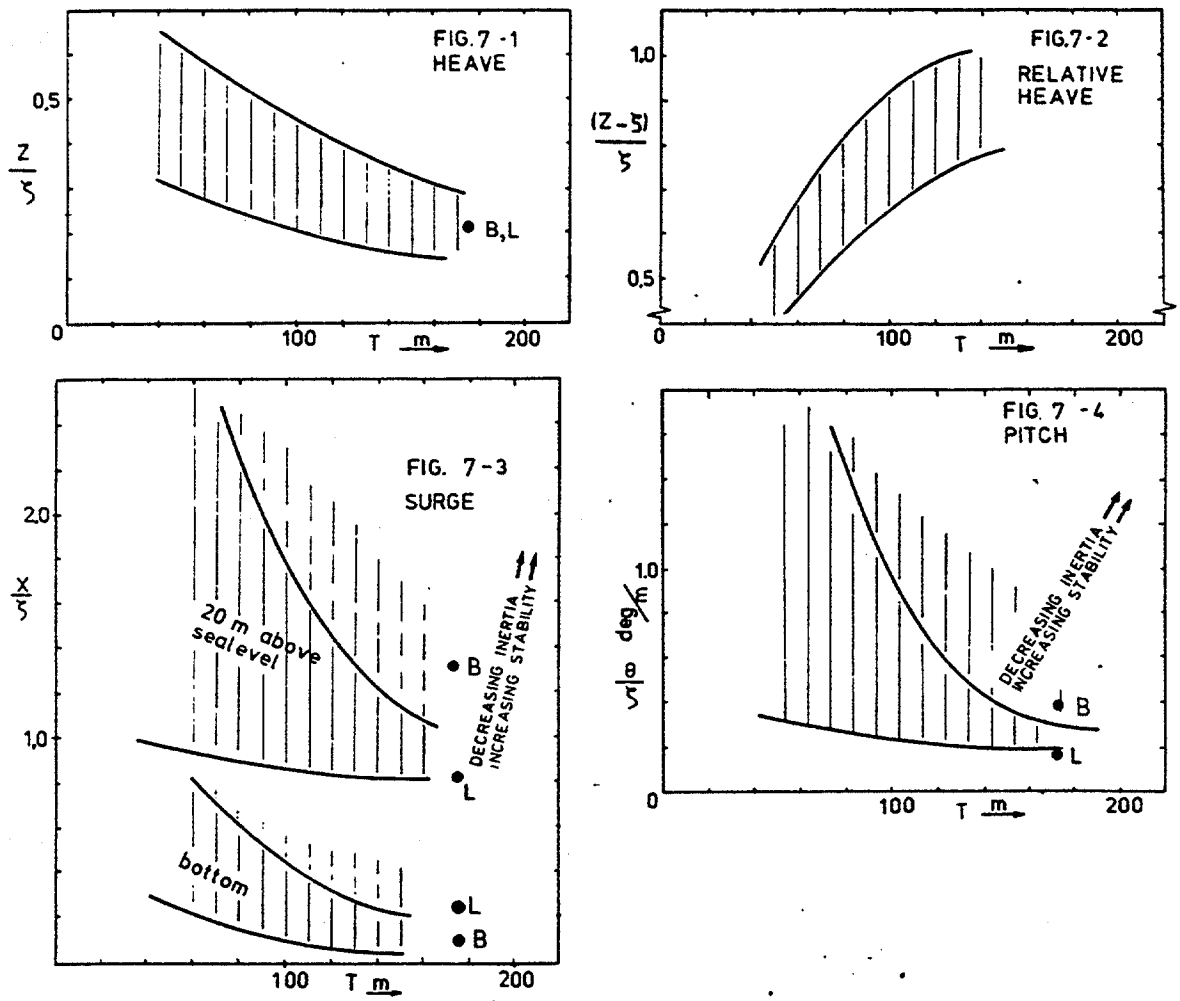


Fig. 7 - Indication of the significant motions in survival conditions.

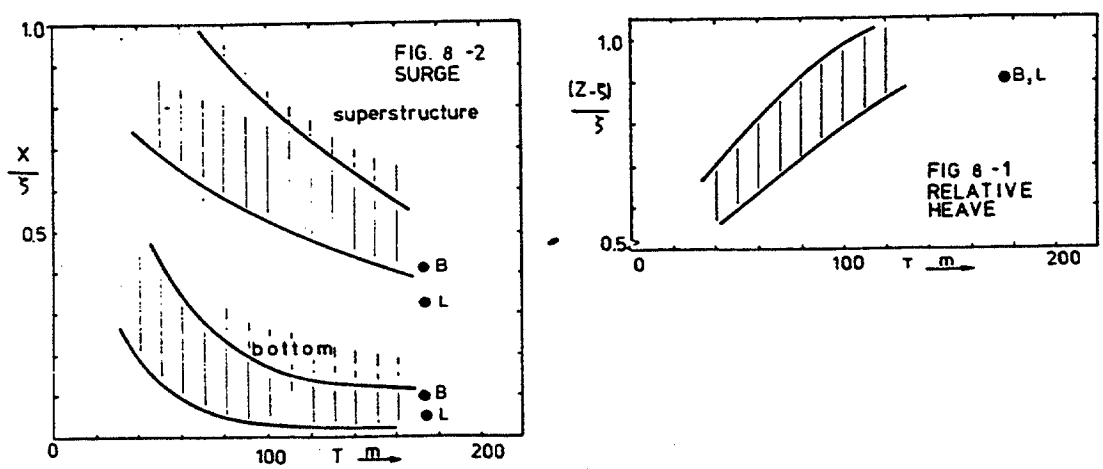


Fig. 8 - Indication of the significant motions in operational conditions.

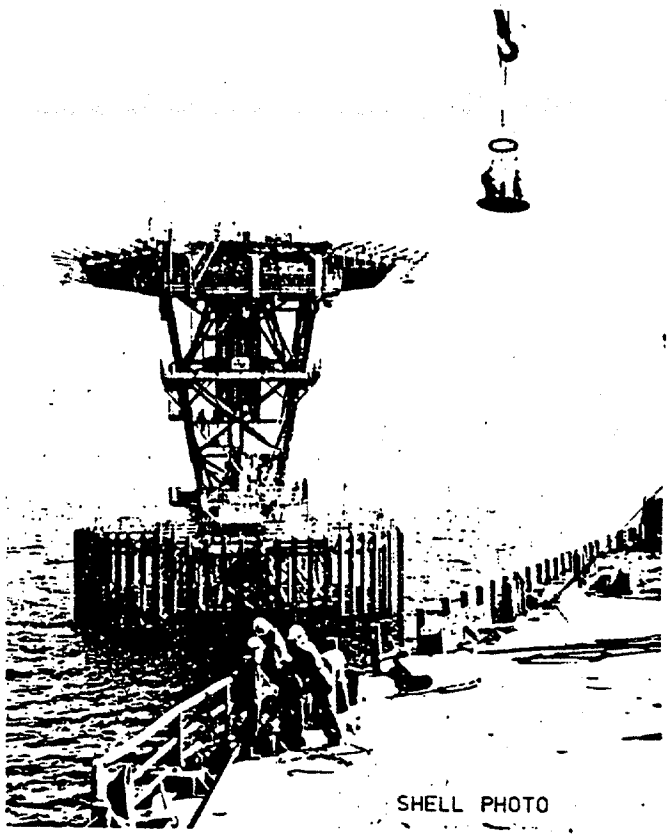


Fig. 9

Fig. 10

Incorporation of Potential Flow Effects (Drift and Damping) in TDSIM6

The proprietary program, TDSIM6, is a general purpose time domain simulation code for the wave induced motion of floating bodies. Fluid forces on slender cylindrical members of the body are computed directly in the program using a variation on the Morison formula. Additional forces may be computed externally to TDSIM6 and input to the computation. This is a brief description of the procedure used to input frequency-dependent potential flow forces that are supplied in the form of tables of damping and drift force coefficients versus frequency. For the present computations, these coefficients were computed by a 3-D panel code known as HYDRO3. An assumption of small wave- and body motion underlies the 3-D panel computation of these coefficients. This is not expected to be a severe restriction on their application to the present SPAR configuration since the motions are expected to be small and the assumption of small wave steepness has been found to be acceptable in a wide variety of wave-body problems including the present.

The frequency-dependent damping terms are included in the time domain simulation by means of the convolution integral technique. The drift effects are computed directly from the wave decomposition. These two procedures are described in the following.

Frequency-dependent Radiation Damping.

We first obtain the damping impulse response or "memory" function by evaluating the Fourier cosine transform of the damping coefficient.

$$L_{ij}(\tau) = \frac{2}{\pi} \int_0^\infty \lambda_{ij}(\omega) \cos \omega\tau \, d\omega \qquad (1)$$

The value of the damping force at the current time t, is then obtained as the convolution over the past history of the velocity.

$$F_{di}(t) = \int_0^\infty L_{ij}(\tau)\, \dot{x}_j(t-\tau)\, d\tau \qquad (2)$$

Here, $F_{di}(t)$, is the wave damping in direction i at time t. The surge damping for the 105x650 ft. SPAR is shown in Figure 1 and its Fourier cosine transform or impulse response function in Figure 2.

Slow Drift Effects.

Note that the total drift force is the combination of effects due to viscous drag acting on the surface piercing members of the platform and potential forces due to wave reflection effects. The viscous drift is inherently included by TDSIM6 since the forces on cylindrical members are computed over the exact wetted length of the member at each time step. The drift force due to wave reflection, however, must be computed separately and added at each time step.

Figure 3 gives a plot of the nondimensional drift force transfer function for the 105x650 SPAR, computed under the assumption that the spar is (a) free to surge, and (b) rigidly restrained in its mean position. The motion is seen to have a relatively small but nevertheless measurable effect. In regular waves, there will be only a steady force on the platform of magnitude given by the value plotted in Figure 3. In random waves, there will be a nonzero mean and a time varying force, the latter having frequency characteristics similar to those of the wave envelope.

Let the train of random waves be approximated as a sum of regular wave components given by equation (3)

$$\eta(t) = \sum_{i=1}^{N} a_i \cos(\omega_i t + \varepsilon_i) \tag{3}$$

where the ε_i are randomly distributed in $0, 2\pi$.

The steady force is given by,

$$F_o = \sum_{i=1}^{N} a_i^2 D_{ii} \tag{4}$$

where, D_{ii} is the regular wave drift force transfer function at wave frequency ω_i.

The low frequency part of the second order drift force is given by

$$F_s(t) = \sum_{i \neq j} \sum_{j \neq i} D_{ij} \frac{a_i a_j}{2} \cos[(\omega_i - \omega_j) t + (\varepsilon_i - \varepsilon_j)] \tag{5}$$

As an approximation, we take $D_{ij} \approx D_{kk}$, where D_{kk} is the regular wave drift force transfer function at the mean of frequencies ω_i and ω_j. Equation (5) then becomes,

$$F_s(t) = \sum_{i=1}^{N} \sum_{j=i+1}^{N} D_{kk} a_i a_j \cos[(\omega_i - \omega_j) t + (\varepsilon_i - \varepsilon_j)] \tag{6}$$

Equations (2), (4) and (6) are now in a form suitable for incorporating the wave damping and slow drift forces in the algorithm used by TDSIM6 in integrating the equations of motion.

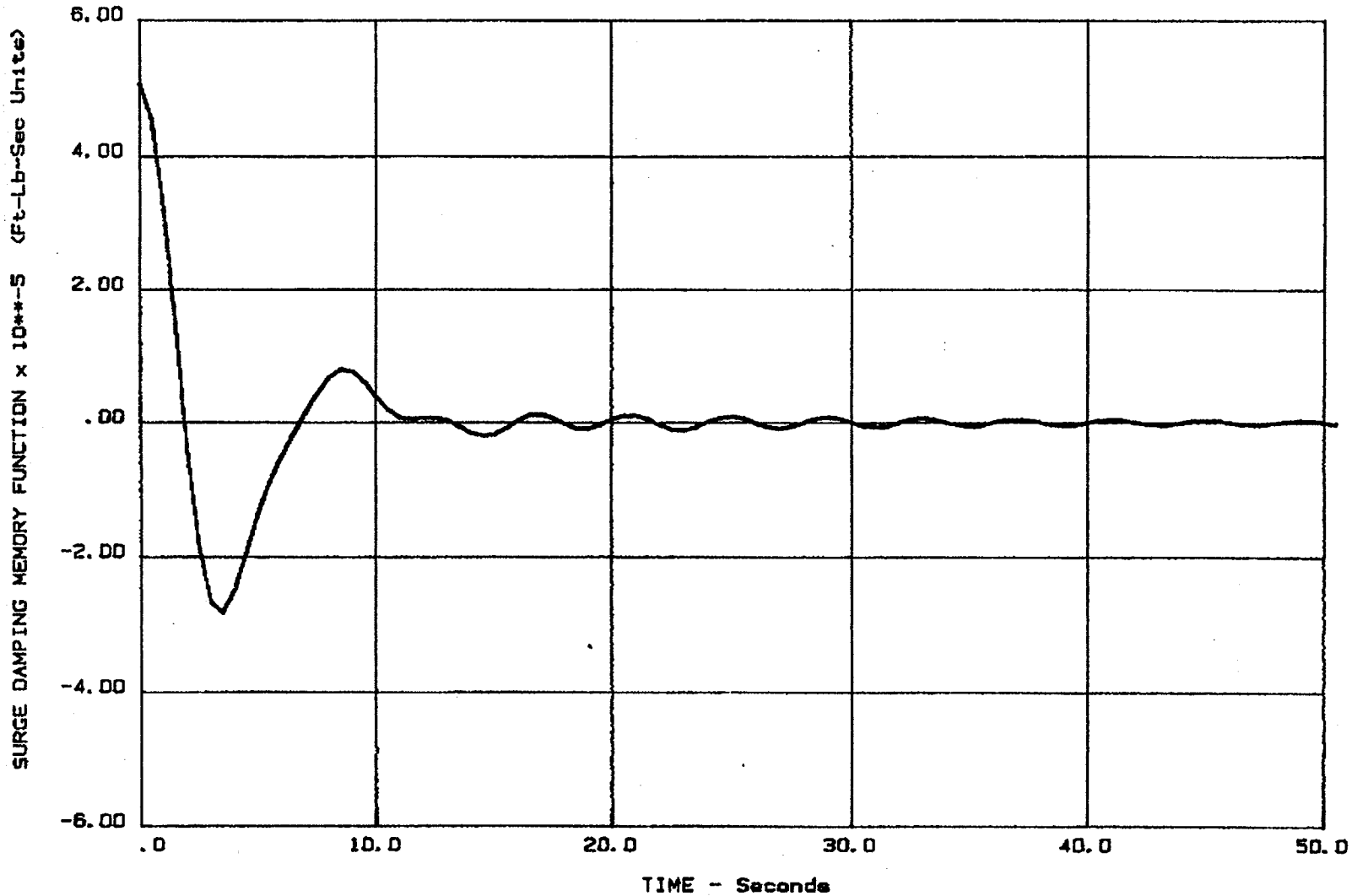


FIG 2 SHELL SPAR, 105x650, POTENTIAL SURGE DAMPING MEMORY FUNCTION

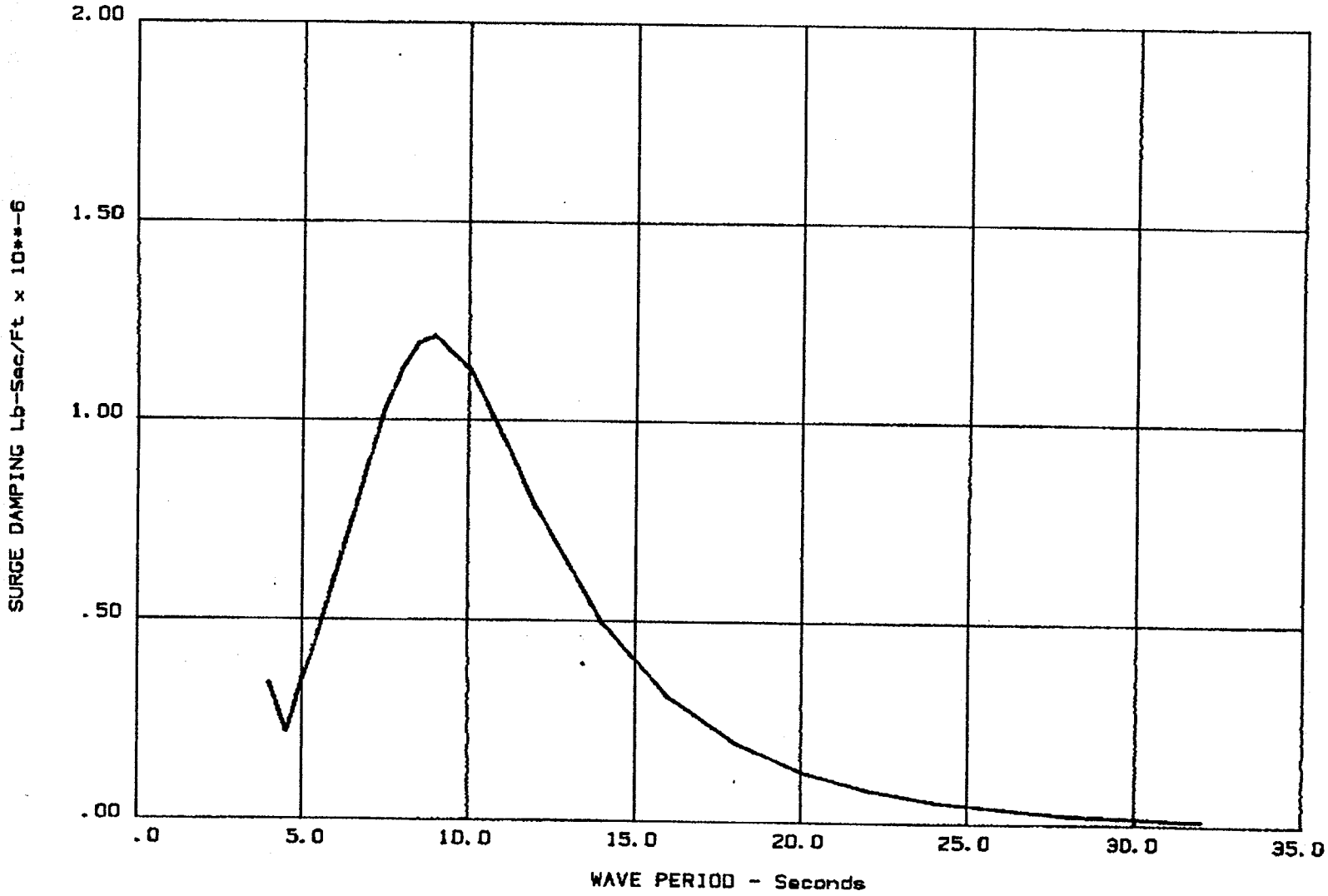


FIG 1 SHELL SPAR 105 Ft Dia x 650 Ft Draft 3000 FT DEPTH 16-SIDES

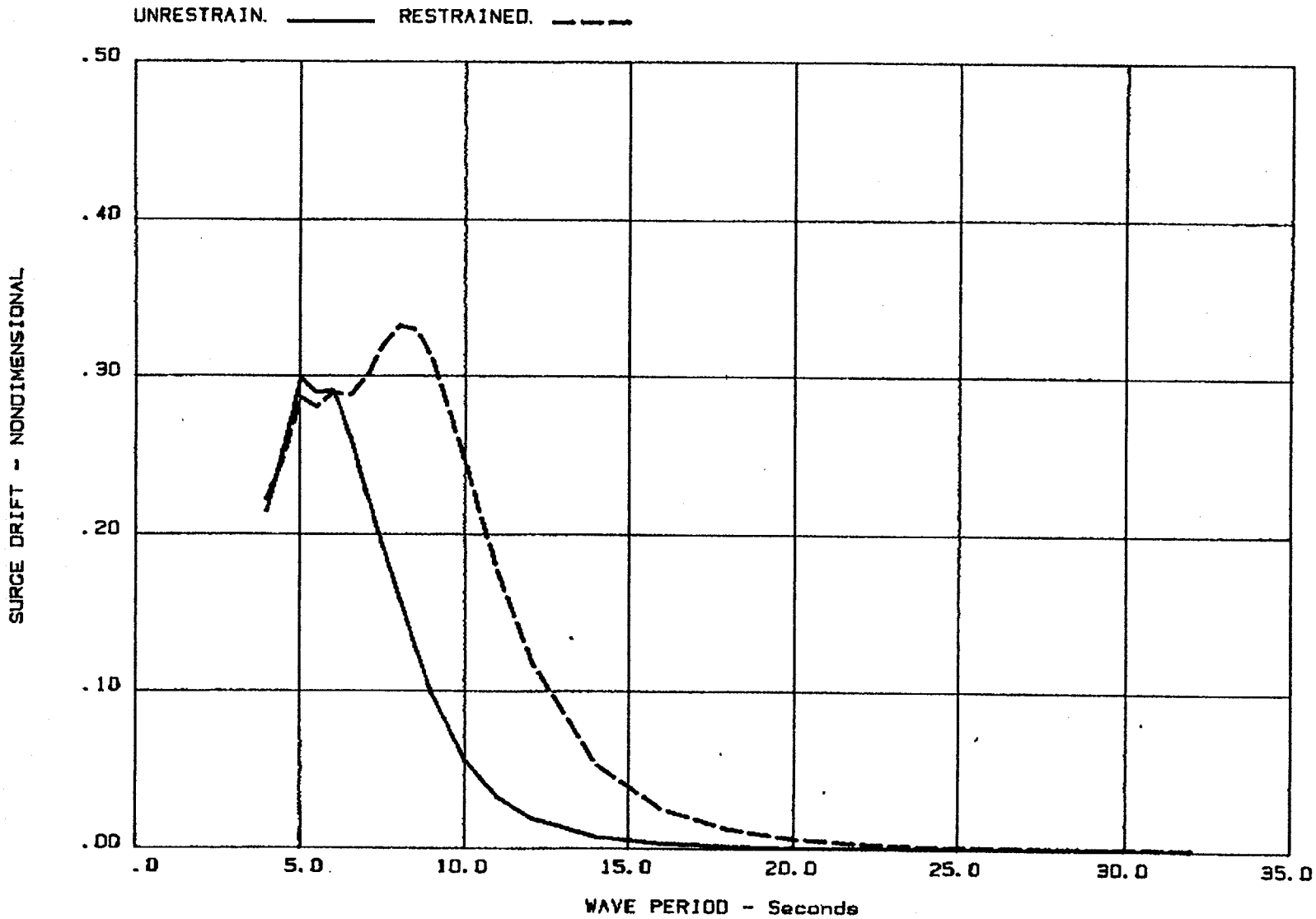
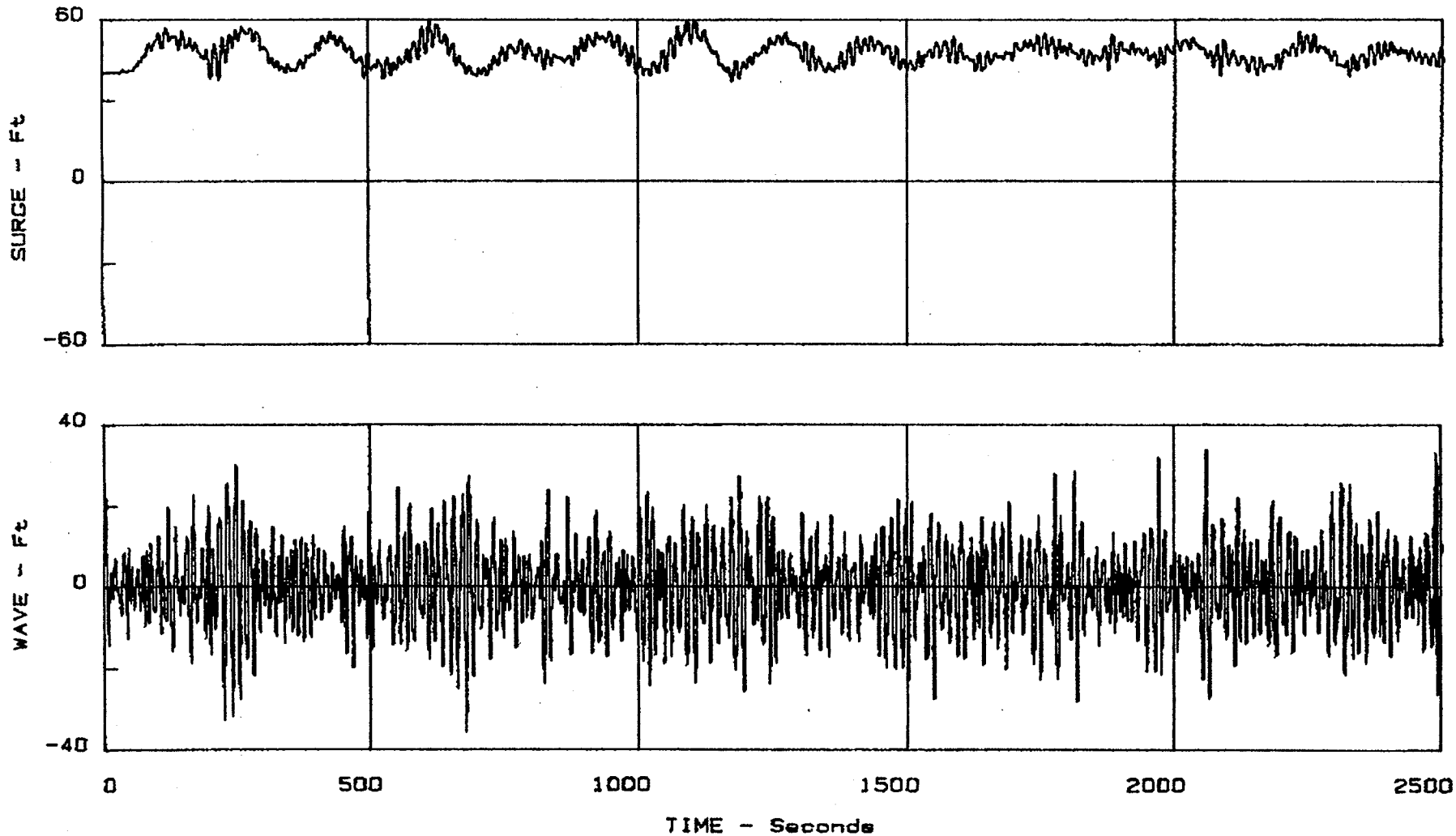
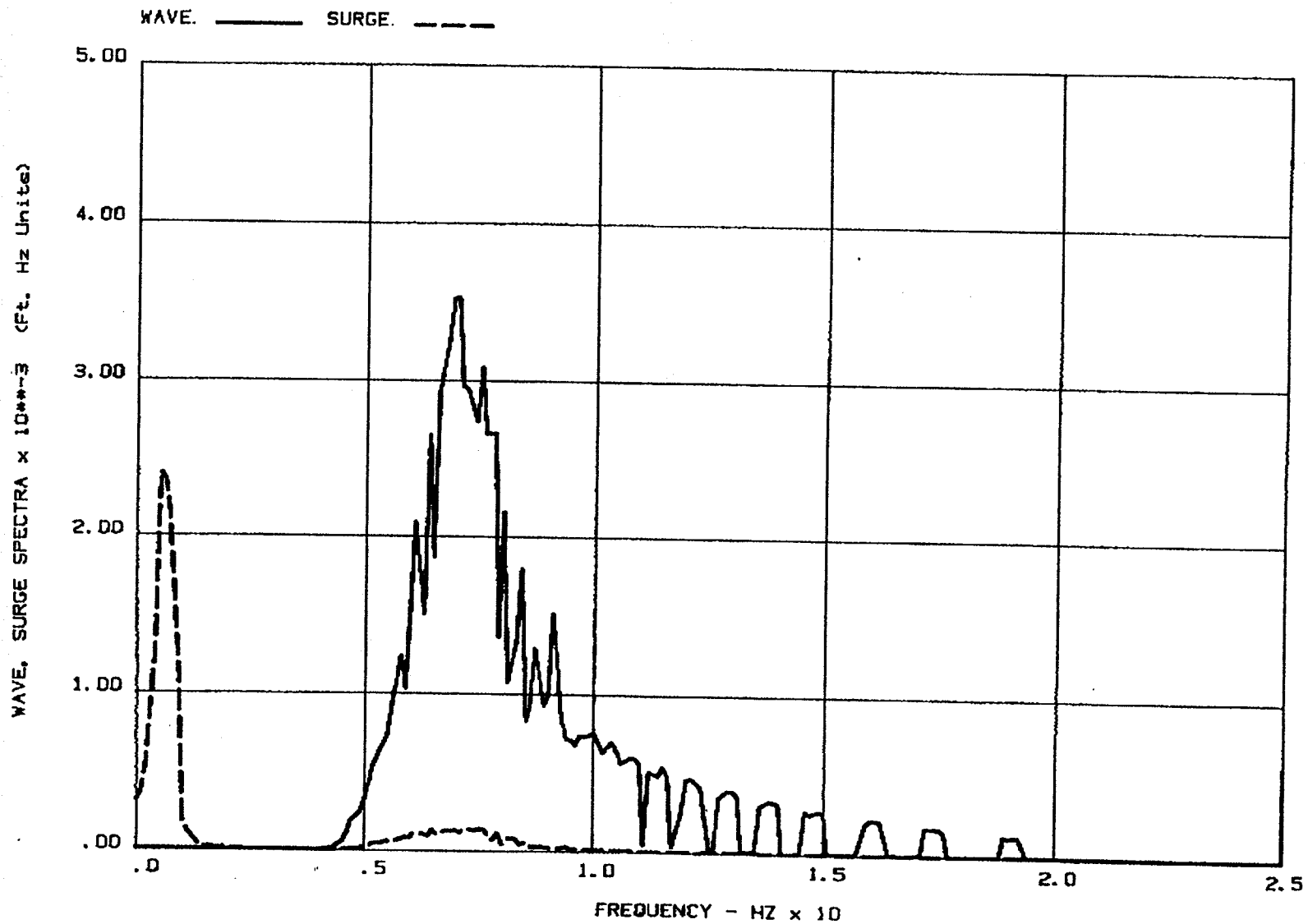


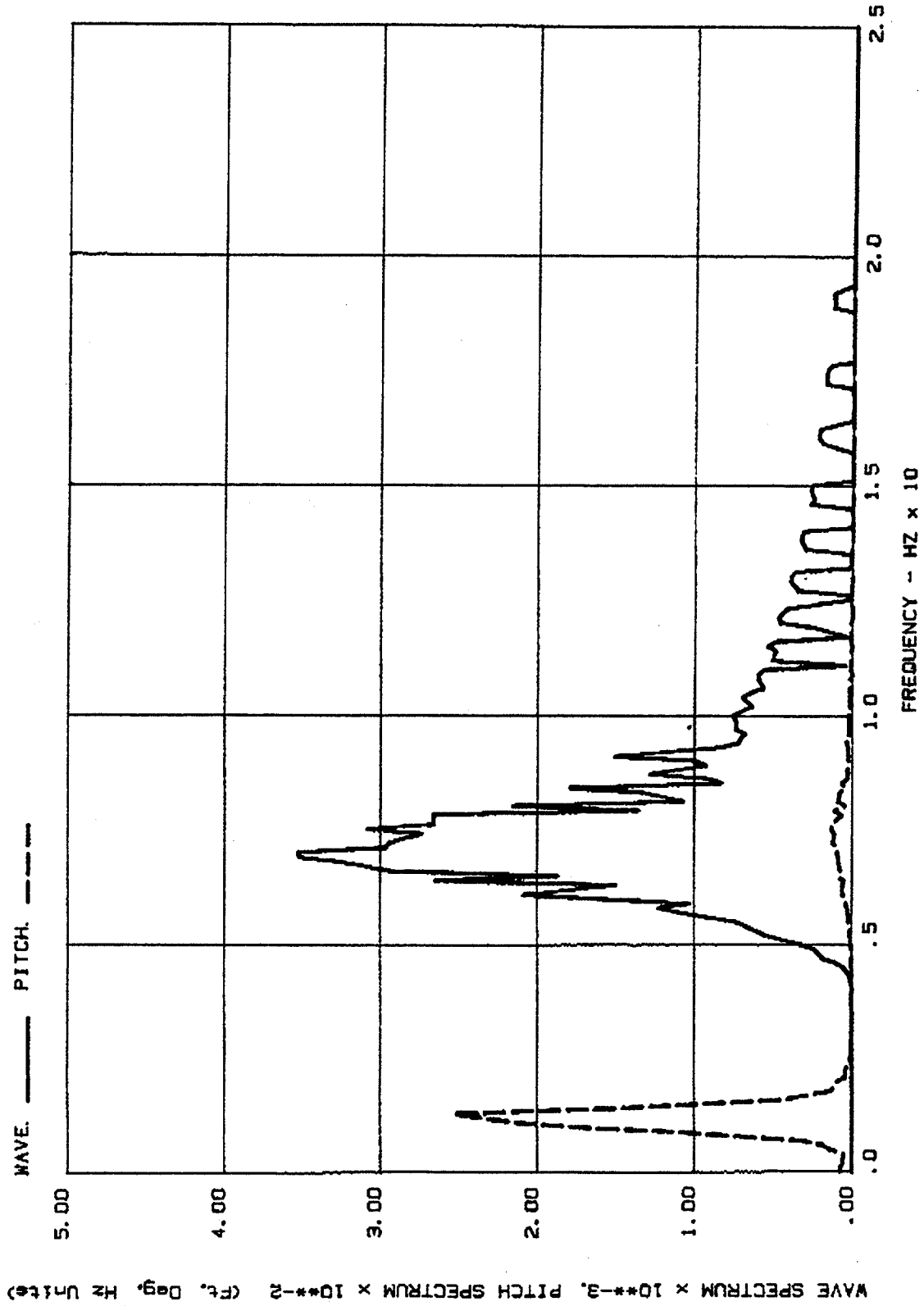
FIG 3 SHELL SPAR 105 Ft Dia x 650 Ft Draft 3000 FT DEPTH 16-SIDES



RUN2, SHELL SPAR, DIAM 105, DRAFT 650, 100 YEAR STORM W/POT DRFT, DAMP.



SHELL SPAR, 105x650, 100 YEAR STORM W/PDT DRFT, DAMP RMS: WV=10.04 SURGE=4.171



SHELL SPAR, 105x650, 100 YEAR STORM W/PDT DRFT, DAMP RMS: WV=10.04, PITCH=1.349

RUN2, SHELL SPAR, DIAM 105, DRAFT 650, 100 YEAR STORM W/POT DRFT, DAMP.

--- MOTION STATISTICS ---

	WAVE	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH
MEAN	0.0057	47.3169	-0.1608	0.0000	0.0000	0.0000	-3.8167
RMS	10.3144	4.1609	1.6221	0.0000	0.0000	0.0000	1.4303
NO. OF POS. PEAKS	243	198	93	28	53	41	206
MEAN OF POS. PEAKS	10.8641	49.4410	1.8572	0.0000	0.0000	0.0000	-3.0022
MAX. POS. PEAK	34.0155	59.7286	4.8911	0.0000	0.0000	0.0000	-0.0401
NO. OF NEG. PEAKS	243	197	93	29	53	41	207
MEAN OF NEG. PEAKS	-11.0175	44.9764	-2.0438	0.0000	0.0000	0.0000	-4.4334
MAX. NEG. PEAK	-35.5531	36.6895	-4.2585	0.0000	0.0000	0.0000	-8.9101

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RUN2, SHELL SPAR, DIAM 105, DRAFT 650, 100 YEAR STORM W/POT DRFT, DAMP.

--- TENSION STATISTICS ---

	WAVE	TEN-1	TEN-2	TEN-3	TEN-4	TEN-5	TEN-6
MEAN	5.7443E-03	3.4167E+05	3.5868E+05	3.9448E+05	4.7103E+05	5.9016E+05	7.2663E+05
RMS	1.0314E+01	4.8280E+03	4.5580E+03	3.3754E+03	7.1866E+03	2.4638E+04	5.7118E+04
NO. OF POS. PEAKS	243	193	189	169	160	186	193
MEAN OF POS. PEAKS	1.0864E+01	3.4478E+05	3.6155E+05	3.9719E+05	4.7568E+05	6.0443E+05	7.6124E+05
MAX. POS. PEAK	3.4015E+01	3.5603E+05	3.7241E+05	4.0526E+05	4.9920E+05	6.8433E+05	9.5350E+05
NO. OF NEG. PEAKS	243	193	189	169	159	185	192
MEAN OF NEG. PEAKS	-1.1018E+01	3.3882E+05	3.5596E+05	3.9201E+05	4.6634E+05	5.7625E+05	6.9450E+05
MAX. NEG. PEAK	-3.5553E+01	3.2799E+05	3.4520E+05	3.8435E+05	4.5036E+05	5.2763E+05	5.9256E+05

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Appendix F

SPLASHT Results

GENERIC 6-COL. SEMI. 77.31 FT. DRFT GM=15 FT 90 DEG. 675 FT DEPTH HS=4-40 ft

- - - WEIGHT AND OTHER PROPERTIES OF PLATFORM - - -

WEIGHT	=	58587600.00
X-COORDINATE OF C.G.	=	0.00
Y-COORDINATE OF C.G.	=	54.87
Z-COORDINATE OF C.G.	=	0.00
DISPLACEMENT	=	58609413.71
X-COORDINATE OF C.B.	=	0.00
Y-COORDINATE OF C.B.	=	25.58
Z-COORDINATE OF C.B.	=	0.00
DEPTH OF BASELINE	=	77.31
WATER DEPTH	=	675.00

- - - NATURAL UNDAMPED PERIODS OF MOTION - - -

SURGE	=	209.084
HEAVE	=	19.540
SWAY	=	255.228
ROLL	=	36.601
YAW	=	542.007
PITCH	=	34.096

Motion Comparisons for Semi and TLP

GENERIC 6-COL. SEMI. 77.31 FT. DRFT GM=15 FT 90 DEG. 675 FT DEPTH HS=4-40 ft

RMS MOTIONS		CENTER OF GRAVITY						POINT 1			POINT
HSIG	TPK	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH	X-	Y-	Z-	
4.000	5.400	0.000	0.039	0.116	0.020	0.000	0.000	0.000	0.039	0.141	
8.000	7.400	0.000	0.127	0.301	0.132	0.000	0.000	0.000	0.127	0.422	
12.000	9.200	0.000	0.354	0.633	0.293	0.000	0.000	0.000	0.354	0.586	
16.100	10.300	0.000	0.643	1.113	0.441	0.000	0.000	0.000	0.643	0.773	
40.000	14.400	0.000	4.045	5.158	1.179	0.000	0.000	0.000	4.045	3.279	

Motion Comparisons for Semi and TLP

GENERIC 6-COL. SEMI. 77.31 FT. DRFT GM=15 FT 90 DEG. 675 FT DEPTH HS=4-40 ft
RMS VELOCITY POINT 1 POINT

HSIG	TPK	X-	Y-	Z-
4.00	5.40	0.000	0.041	0.145
8.00	7.40	0.000	0.111	0.393
12.00	9.20	0.000	0.226	0.514
16.10	10.30	0.000	0.370	0.621
40.00	14.40	0.000	1.563	1.513

Motion Comparisons for Semi and TLP

GENERIC 6-COL. SEMI. 77.31 FT. DRFT GM=15 FT 90 DEG. 675 FT DEPTH HS=4-40 ft
RMS ACCEL. (INCL. G) POINT 1 POINT

HSIG	TPK	X-	Y-	Z-
4.00	5.40	0.000	0.044	0.164
8.00	7.40	0.000	0.104	0.424
12.00	9.20	0.000	0.163	0.563
16.10	10.30	0.000	0.235	0.666
40.00	14.40	0.000	0.690	0.993

Motion Comparisons for Semi and TLP

GENERIC 6-COL. SEMI. 77.31 FT. DRFT GM=15 FT 90 DEG. 675 FT DEPTH HS=4-40 ft

REL VERT MOTN		POINT 1 (YO =100.00)		POINT
HSIG	TPK	RMS	1/HOUR	1/10000
4.00	5.40	1.016	3.555	4.496
8.00	7.40	2.069	7.240	9.155
12.00	9.20	2.947	10.315	13.045
16.10	10.30	3.765	13.176	16.662
40.00	14.40	8.715	30.503	38.573

GENERIC 6-COL. SEMI. 77.31 FT. DRFT GM=15 FT 90 DEG. 675 FT DEPTH HS=4-40 ft
CGMOTIONS FOR WAVES AT ANGLE= 90.00 DEG

WAVE PER	FREQZ	FREQR	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH
32.000	0.0313	0.1963	0.00000	0.98191	1.31474	0.02030	0.00000	0.00000	0.00	0.12	89.89	-61.77	0.00	0.00
31.500	0.0317	0.1995	0.00000	1.00093	1.27399	0.01717	0.00000	0.00000	0.00	0.16	89.89	-57.64	0.00	0.00
31.000	0.0323	0.2027	0.00000	1.02169	1.23378	0.01472	0.00000	0.00000	0.00	0.21	89.90	-53.48	0.00	0.00
30.500	0.0328	0.2060	0.00000	1.04442	1.19414	0.01278	0.00000	0.00000	0.00	0.26	89.90	-49.26	0.00	0.00
30.000	0.0333	0.2094	0.00000	1.06941	1.15509	0.01124	0.00000	0.00000	0.00	0.31	89.90	-44.96	0.00	0.00
29.500	0.0339	0.2130	0.00000	1.07335	1.13922	0.01603	0.00000	0.00000	0.00	0.33	89.91	-64.62	0.00	0.00
29.000	0.0345	0.2167	0.00000	1.07812	1.12339	0.02090	0.00000	0.00000	0.00	0.36	89.92	-73.22	0.00	0.00
28.500	0.0351	0.2205	0.00000	1.08388	1.10757	0.02530	0.00000	0.00000	0.00	0.39	89.93	-77.70	0.00	0.00
28.000	0.0357	0.2244	0.00000	1.09082	1.09173	0.02915	0.00000	0.00000	0.00	0.42	89.93	-80.36	0.00	0.00
27.500	0.0364	0.2285	0.00000	1.09917	1.07582	0.03251	0.00000	0.00000	0.00	0.46	89.94	-82.08	0.00	0.00
27.000	0.0370	0.2327	0.00000	1.10923	1.05985	0.03542	0.00000	0.00000	0.00	0.51	89.94	-83.26	0.00	0.00
26.500	0.0377	0.2371	0.00000	1.12138	1.04379	0.03794	0.00000	0.00000	0.00	0.57	89.94	-84.09	0.00	0.00
26.000	0.0385	0.2417	0.00000	1.13613	1.02762	0.04012	0.00000	0.00000	0.00	0.64	89.94	-84.70	0.00	0.00
25.500	0.0392	0.2464	0.00000	1.15412	1.01134	0.04200	0.00000	0.00000	0.00	0.73	89.94	-85.16	0.00	0.00
25.000	0.0400	0.2513	0.00000	1.17627	0.99494	0.04362	0.00000	0.00000	0.00	0.84	89.94	-85.51	0.00	0.00
24.500	0.0408	0.2565	0.00000	1.20383	0.97842	0.04501	0.00000	0.00000	0.00	0.98	89.94	-85.77	0.00	0.00
24.000	0.0417	0.2618	0.00000	1.23861	0.96175	0.04618	0.00000	0.00000	0.00	1.16	89.94	-85.97	0.00	0.00
23.500	0.0426	0.2674	0.00000	1.27757	0.94709	0.04971	0.00000	0.00000	0.00	1.39	89.94	-86.44	0.00	0.00
23.000	0.0435	0.2732	0.00000	1.32875	0.93218	0.05282	0.00000	0.00000	0.00	1.69	89.94	-86.78	0.00	0.00
22.500	0.0444	0.2793	0.00000	1.39796	0.91703	0.05556	0.00000	0.00000	0.00	2.12	89.94	-87.02	0.00	0.00
22.000	0.0455	0.2856	0.00000	1.49528	0.90163	0.05795	0.00000	0.00000	0.00	2.75	89.94	-87.21	0.00	0.00
21.500	0.0465	0.2922	0.00000	1.64372	0.88718	0.06208	0.00000	0.00000	0.00	3.78	89.93	-87.48	0.00	0.00
21.000	0.0476	0.2992	0.00000	1.88929	0.87242	0.06572	0.00000	0.00000	0.00	5.59	89.93	-87.68	0.00	0.00
20.500	0.0488	0.3065	0.00000	2.35957	0.85736	0.06891	0.00000	0.00000	0.00	9.32	89.92	-87.82	0.00	0.00
20.000	0.0500	0.3142	0.00000	3.53685	0.84197	0.07169	0.00000	0.00000	0.00	19.78	89.92	-87.90	0.00	0.00
19.500	0.0513	0.3222	0.00000	6.76172	0.82687	0.07567	0.00000	0.00000	0.00	75.20	89.91	-87.91	0.00	0.00
19.000	0.0526	0.3307	0.00000	2.47928	0.81146	0.07905	0.00000	0.00000	0.00	144.26	89.90	-88.13	0.00	0.00
18.500	0.0541	0.3396	0.00000	0.92692	0.79575	0.08339	0.00000	0.00000	0.00	155.17	89.89	-88.28	0.00	0.00
18.000	0.0556	0.3491	0.00000	0.37549	0.77967	0.08713	0.00000	0.00000	0.00	153.55	89.88	-88.37	0.00	0.00
17.500	0.0571	0.3590	0.00000	0.14834	0.76316	0.09070	0.00000	0.00000	0.00	138.86	89.87	-88.47	0.00	0.00
17.000	0.0588	0.3696	0.00000	0.06922	0.74621	0.09385	0.00000	0.00000	0.00	64.20	89.86	-88.55	0.00	0.00
16.500	0.0606	0.3808	0.00000	0.15041	0.72675	0.09960	0.00000	0.00000	0.00	14.81	89.83	-88.60	0.00	0.00
16.000	0.0625	0.3927	0.00000	0.22255	0.70721	0.10451	0.00000	0.00000	0.00	6.39	89.79	-88.63	0.00	0.00
15.500	0.0645	0.4054	0.00000	0.26316	0.68523	0.10943	0.00000	0.00000	0.00	3.84	89.76	-88.71	0.00	0.00
15.000	0.0667	0.4189	0.00000	0.29265	0.66325	0.11363	0.00000	0.00000	0.00	2.45	89.71	-88.78	0.00	0.00
14.500	0.0690	0.4333	0.00000	0.30958	0.63702	0.11862	0.00000	0.00000	0.00	1.82	89.66	-88.88	0.00	0.00
14.000	0.0714	0.4488	0.00000	0.32117	0.61115	0.12278	0.00000	0.00000	0.00	1.36	89.60	-88.96	0.00	0.00
13.500	0.0741	0.4654	0.00000	0.32036	0.57920	0.12724	0.00000	0.00000	0.00	1.40	89.50	-89.10	0.00	0.00
13.000	0.0769	0.4833	0.00000	0.31815	0.54830	0.13090	0.00000	0.00000	0.00	1.41	89.40	-89.20	0.00	0.00
12.500	0.0800	0.5027	0.00000	0.30534	0.50863	0.13447	0.00000	0.00000	0.00	2.09	89.24	-89.42	0.00	0.00
12.000	0.0833	0.5236	0.00000	0.29329	0.47055	0.13717	0.00000	0.00000	0.00	2.68	89.08	-89.57	0.00	0.00
11.500	0.0870	0.5464	0.00000	0.26842	0.42278	0.13966	0.00000	0.00000	0.00	4.50	88.79	-89.95	0.00	0.00
11.000	0.0909	0.5712	0.00000	0.24650	0.37771	0.14100	0.00000	0.00000	0.00	6.27	88.46	-90.21	0.00	0.00
10.500	0.0952	0.5984	0.00000	0.20128	0.31989	0.13956	0.00000	0.00000	0.00	10.19	88.02	-90.87	0.00	0.00
10.000	0.1000	0.6283	0.00000	0.16268	0.26576	0.13732	0.00000	0.00000	0.00	15.28	87.34	-91.42	0.00	0.00
9.500	0.1053	0.6614	0.00000	0.09991	0.19773	0.13153	0.00000	0.00000	0.00	22.18	86.72	-92.45	0.00	0.00
9.000	0.1111	0.6981	0.00000	0.04879	0.13553	0.12480	0.00000	0.00000	0.00	40.91	84.83	-93.58	0.00	0.00
8.500	0.1176	0.7392	0.00000	0.01406	0.05691	0.11373	0.00000	0.00000	0.00	143.67	84.87	-94.44	0.00	0.00

8.000	0.1250	0.7854	0.00000	0.05240	0.01048	0.10184	0.00000	0.00000	0.00	-166.59	-77.41	-96.38	0.00	0.00
7.500	0.1333	0.8378	0.00000	0.07379	0.08877	0.08543	0.00000	0.00000	0.00	-160.85	-94.74	-96.83	0.00	0.00
7.000	0.1429	0.8976	0.00000	0.07963	0.16953	0.06440	0.00000	0.00000	0.00	-163.66	-94.19	-95.08	0.00	0.00
6.500	0.1538	0.9666	0.00000	0.07497	0.23726	0.03801	0.00000	0.00000	0.00	-172.78	-88.46	-88.54	0.00	0.00
6.000	0.1667	1.0472	0.00000	0.06662	0.23891	0.01014	0.00000	0.00000	0.00	173.71	-77.66	-76.02	0.00	0.00
5.500	0.1818	1.1424	0.00000	0.05618	0.15652	0.00505	0.00000	0.00000	0.00	166.95	-73.48	96.13	0.00	0.00
5.000	0.2000	1.2566	0.00000	0.02341	0.05253	0.00890	0.00000	0.00000	0.00	165.00	-67.27	96.52	0.00	0.00
4.500	0.2222	1.3963	0.00000	0.00754	0.02626	0.01016	0.00000	0.00000	0.00	20.12	106.06	90.61	0.00	0.00
4.000	0.2500	1.5708	0.00000	0.00588	0.02075	0.00799	0.00000	0.00000	0.00	20.04	106.30	90.44	0.00	0.00
3.500	0.2857	1.7952	0.00000	0.00445	0.01589	0.00610	0.00000	0.00000	0.00	19.84	106.57	90.64	0.00	0.00
3.000	0.3333	2.0944	0.00000	0.00324	0.01167	0.00447	0.00000	0.00000	0.00	19.91	106.84	90.84	0.00	0.00
2.500	0.4000	2.5133	0.00000	0.00223	0.00811	0.00309	0.00000	0.00000	0.00	19.96	107.10	91.02	0.00	0.00
2.000	0.5000	3.1416	0.00000	0.00142	0.00519	0.00198	0.00000	0.00000	0.00	20.00	107.36	91.20	0.00	0.00

GENERIC FOUR LEGGED TLP DEPTH = 1500 FT WAVE HS=4-40 FT

MEM	X1	Y1	Z1	X2	Y2	Z2	SEMI AXES HORIZ.	SEMI AXES VERT	CDH	CDV	CMH	CMV	CDX1	CDX2	CMX1	CMX2
1	100.00	0.00	100.00	100.00	0.01	100.00	27.500	27.500	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
2	100.00	0.00	-100.00	100.00	0.01	-100.00	27.500	27.500	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
3	-100.00	0.00	-100.00	-100.00	0.01	-100.00	27.500	27.500	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
4	-100.00	0.00	100.00	-100.00	0.01	100.00	27.500	27.500	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
5	100.00	15.00	73.56	100.00	15.00	-73.56	15.000	15.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
6	-73.56	15.00	-100.00	73.56	15.00	-100.00	15.000	15.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
7	-100.00	15.00	73.56	-100.00	15.00	-73.56	15.000	15.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
8	-73.56	15.00	100.00	73.56	15.00	100.00	15.000	15.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
10	100.00	51.97	72.61	100.00	150.00	0.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
11	100.00	51.97	-72.61	100.00	150.00	0.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
12	72.61	51.97	-100.00	0.00	150.00	-100.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
13	-72.61	51.97	-100.00	0.00	150.00	-100.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
14	-100.00	51.97	-72.61	-100.00	150.00	0.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
15	-100.00	51.97	72.61	-100.00	150.00	0.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
16	-72.61	51.97	100.00	0.00	150.00	100.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
17	72.61	51.97	100.00	0.00	150.00	100.00	5.000	5.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001

GENERIC FOUR LEGGED TLP DEPTH = 1500 FT WAVE HS=4-40 FT

- - - WEIGHT AND OTHER PROPERTIES OF PLATFORM - - -

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WEIGHT                  = 40068400.00
X-COORDINATE OF C.G.    =        0.00
Y-COORDINATE OF C.G.    =       62.50
Z-COORDINATE OF C.G.    =        0.00

DISPLACEMENT            = 80033669.53
X-COORDINATE OF C.B.    =        0.00
Y-COORDINATE OF C.B.    =       33.88
Z-COORDINATE OF C.B.    =        0.00

DEPTH OF BASELINE       =       85.00
WATER DEPTH             =     1500.00
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- - - NATURAL UNDAMPED PERIODS OF MOTION - - -

```
SURGE    =      65.178
HEAVE    =       0.828
SWAY     =      65.178
ROLL     =       0.814
YAW      =      57.798
PITCH    =       0.814
```

Motion Comparisons for Semi and TLP

GENERIC FOUR LEGGED TLP DEPTH = 1500 FT WAVE HS=4-40 FT

RMS MOTIONS			CENTER OF GRAVITY					POINT 1			POINT
HSIG	TPK	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH	X-	Y-	Z-	
4.000	5.400	0.000	0.000	0.147	0.000	0.000	0.000	0.000	0.000	0.147	
8.000	7.400	0.000	0.001	0.432	0.001	0.000	0.000	0.000	0.001	0.431	
12.000	9.200	0.000	0.002	0.851	0.001	0.000	0.000	0.000	0.002	0.850	
16.100	10.300	0.000	0.002	1.479	0.001	0.000	0.000	0.000	0.002	1.478	
40.000	14.400	0.000	0.008	7.116	0.002	0.000	0.000	0.000	0.008	7.114	

Motion Comparisons for Semi and TLP

GENERIC FOUR LEGGED TLP DEPTH = 1500 FT WAVE HS=4-40 FT

RMS VELOCITY POINT 1 POINT

HSIG	TPK	X-	Y-	Z-
4.00	5.40	0.000	0.000	0.151
8.00	7.40	0.000	0.001	0.400
12.00	9.20	0.000	0.001	0.617
16.10	10.30	0.000	0.001	0.909
40.00	14.40	0.000	0.004	3.153

GENERIC FOUR LEGGED TLP DEPTH = 1500 FT WAVE HS=4-40 FT
RMS ACCEL. (INCL. G) POINT 1 POINT

HSIG	TPK	X-	Y-	Z-
4.00	5.40	0.000	0.000	0.161
8.00	7.40	0.000	0.001	0.386
12.00	9.20	0.000	0.001	0.514
16.10	10.30	0.000	0.001	0.660
40.00	14.40	0.000	0.002	1.578

Motion Comparisons for Semi and TLP

GENERIC FOUR LEGGED TLP DEPTH = 1500 FT WAVE HS=4-40 FT
REL VERT MOTN POINT 1 (YO =100.00) POINT

HSIG	TPK	RMS	1/HOUR	1/10000
4.00	5.40	0.993	3.476	4.396
8.00	7.40	2.000	7.002	8.854
12.00	9.20	3.004	10.514	13.296
16.10	10.30	4.031	14.108	17.841
40.00	14.40	10.007	35.023	44.289

GENERIC FOUR LEGGED TLP DEPTH = 1500 FT WAVE HS=4-40 FT
CGMOTIONS FOR WAVES AT ANGLE= 90.00 DEG

WAVE	PER	FREQZ	FREQR	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH
32.000	0.0313	0.1963		0.00000	0.00316	1.87468	0.00009	0.00000	0.00000	0.00	-2.02	88.01	-85.66	0.00	0.00
31.500	0.0317	0.1995		0.00000	0.00314	1.81212	0.00009	0.00000	0.00000	0.00	-2.05	88.11	-86.19	0.00	0.00
31.000	0.0323	0.2027		0.00000	0.00313	1.75172	0.00009	0.00000	0.00000	0.00	-2.08	88.22	-86.69	0.00	0.00
30.500	0.0328	0.2060		0.00000	0.00312	1.69338	0.00009	0.00000	0.00000	0.00	-2.11	88.32	-87.16	0.00	0.00
30.000	0.0333	0.2094		0.00000	0.00310	1.63702	0.00009	0.00000	0.00000	0.00	-2.14	88.42	-87.60	0.00	0.00
29.500	0.0339	0.2130		0.00000	0.00307	1.61455	0.00009	0.00000	0.00000	0.00	-2.22	88.47	-87.94	0.00	0.00
29.000	0.0345	0.2167		0.00000	0.00303	1.59225	0.00010	0.00000	0.00000	0.00	-2.31	88.52	-88.24	0.00	0.00
28.500	0.0351	0.2205		0.00000	0.00299	1.57009	0.00011	0.00000	0.00000	0.00	-2.39	88.57	-88.53	0.00	0.00
28.000	0.0357	0.2244		0.00000	0.00296	1.54805	0.00011	0.00000	0.00000	0.00	-2.49	88.61	-88.79	0.00	0.00
27.500	0.0364	0.2285		0.00000	0.00292	1.52611	0.00012	0.00000	0.00000	0.00	-2.59	88.66	-89.03	0.00	0.00
27.000	0.0370	0.2327		0.00000	0.00287	1.50425	0.00012	0.00000	0.00000	0.00	-2.69	88.71	-89.26	0.00	0.00
26.500	0.0377	0.2371		0.00000	0.00283	1.48245	0.00013	0.00000	0.00000	0.00	-2.80	88.75	-89.48	0.00	0.00
26.000	0.0385	0.2417		0.00000	0.00278	1.46066	0.00013	0.00000	0.00000	0.00	-2.92	88.79	-89.68	0.00	0.00
25.500	0.0392	0.2464		0.00000	0.00274	1.43888	0.00014	0.00000	0.00000	0.00	-3.05	88.83	-89.88	0.00	0.00
25.000	0.0400	0.2513		0.00000	0.00269	1.41706	0.00014	0.00000	0.00000	0.00	-3.19	88.87	-90.07	0.00	0.00
24.500	0.0408	0.2565		0.00000	0.00263	1.39902	0.00015	0.00000	0.00000	0.00	-3.35	88.90	-90.27	0.00	0.00
24.000	0.0417	0.2618		0.00000	0.00258	1.38062	0.00015	0.00000	0.00000	0.00	-3.53	88.92	-90.47	0.00	0.00
23.500	0.0426	0.2674		0.00000	0.00251	1.36184	0.00016	0.00000	0.00000	0.00	-3.72	88.95	-90.66	0.00	0.00
23.000	0.0435	0.2732		0.00000	0.00245	1.34264	0.00017	0.00000	0.00000	0.00	-3.93	88.97	-90.86	0.00	0.00
22.500	0.0444	0.2793		0.00000	0.00239	1.32299	0.00017	0.00000	0.00000	0.00	-4.16	88.99	-91.06	0.00	0.00
22.000	0.0455	0.2856		0.00000	0.00232	1.30288	0.00018	0.00000	0.00000	0.00	-4.41	89.01	-91.26	0.00	0.00
21.500	0.0465	0.2922		0.00000	0.00225	1.28226	0.00018	0.00000	0.00000	0.00	-4.68	89.03	-91.47	0.00	0.00
21.000	0.0476	0.2992		0.00000	0.00217	1.26111	0.00019	0.00000	0.00000	0.00	-4.99	89.05	-91.68	0.00	0.00
20.500	0.0488	0.3065		0.00000	0.00209	1.23940	0.00019	0.00000	0.00000	0.00	-5.34	89.07	-91.90	0.00	0.00
20.000	0.0500	0.3142		0.00000	0.00201	1.21708	0.00020	0.00000	0.00000	0.00	-5.72	89.08	-92.12	0.00	0.00
19.500	0.0513	0.3222		0.00000	0.00192	1.19456	0.00020	0.00000	0.00000	0.00	-6.15	89.07	-92.43	0.00	0.00
19.000	0.0526	0.3307		0.00000	0.00183	1.17144	0.00021	0.00000	0.00000	0.00	-6.64	89.06	-92.77	0.00	0.00
18.500	0.0541	0.3396		0.00000	0.00173	1.14768	0.00021	0.00000	0.00000	0.00	-7.21	89.05	-93.12	0.00	0.00
18.000	0.0556	0.3491		0.00000	0.00163	1.12323	0.00021	0.00000	0.00000	0.00	-7.88	89.03	-93.50	0.00	0.00
17.500	0.0571	0.3590		0.00000	0.00151	1.09361	0.00021	0.00000	0.00000	0.00	-8.60	88.99	-94.10	0.00	0.00
17.000	0.0588	0.3696		0.00000	0.00140	1.06304	0.00021	0.00000	0.00000	0.00	-9.49	88.94	-94.77	0.00	0.00
16.500	0.0606	0.3808		0.00000	0.00128	1.03148	0.00021	0.00000	0.00000	0.00	-10.57	88.90	-95.50	0.00	0.00
16.000	0.0625	0.3927		0.00000	0.00115	0.99888	0.00020	0.00000	0.00000	0.00	-11.94	88.85	-96.32	0.00	0.00
15.500	0.0645	0.4054		0.00000	0.00102	0.96059	0.00019	0.00000	0.00000	0.00	-13.38	88.71	-97.77	0.00	0.00
15.000	0.0667	0.4189		0.00000	0.00088	0.92204	0.00018	0.00000	0.00000	0.00	-15.31	88.57	-99.48	0.00	0.00
14.500	0.0690	0.4333		0.00000	0.00074	0.88310	0.00017	0.00000	0.00000	0.00	-18.04	88.43	-101.54	0.00	0.00
14.000	0.0714	0.4488		0.00000	0.00060	0.84369	0.00016	0.00000	0.00000	0.00	-22.16	88.29	-104.05	0.00	0.00
13.500	0.0741	0.4654		0.00000	0.00045	0.78859	0.00014	0.00000	0.00000	0.00	-27.50	87.97	-109.51	0.00	0.00
13.000	0.0769	0.4833		0.00000	0.00030	0.73403	0.00011	0.00000	0.00000	0.00	-38.23	87.64	-117.63	0.00	0.00
12.500	0.0800	0.5027		0.00000	0.00017	0.67986	0.00009	0.00000	0.00000	0.00	-66.35	87.29	-130.21	0.00	0.00
12.000	0.0833	0.5236		0.00000	0.00016	0.62593	0.00008	0.00000	0.00000	0.00	-125.15	86.93	-149.18	0.00	0.00
11.500	0.0870	0.5464		0.00000	0.00028	0.55422	0.00008	0.00000	0.00000	0.00	-160.38	86.35	176.05	0.00	0.00
11.000	0.0909	0.5712		0.00000	0.00044	0.48408	0.00010	0.00000	0.00000	0.00	-173.24	85.65	149.33	0.00	0.00
10.500	0.0952	0.5984		0.00000	0.00059	0.39789	0.00015	0.00000	0.00000	0.00	-177.05	84.91	131.38	0.00	0.00
10.000	0.1000	0.6283		0.00000	0.00074	0.31513	0.00019	0.00000	0.00000	0.00	-179.49	83.70	122.90	0.00	0.00
9.500	0.1053	0.6614		0.00000	0.00082	0.21939	0.00025	0.00000	0.00000	0.00	-178.33	82.44	116.59	0.00	0.00
9.000	0.1111	0.6981		0.00000	0.00081	0.11494	0.00030	0.00000	0.00000	0.00	-176.04	80.97	111.52	0.00	0.00
8.500	0.1176	0.7392		0.00000	0.00070	0.00220	0.00035	0.00000	0.00000	0.00	-173.79	-3.52	106.51	0.00	0.00

8.000	0.1250	0.7854	0.00000	0.00048	0.12325	0.00039	0.00000	0.00000	0.00	-172.32	-96.03	101.56	0.00	0.00
7.500	0.1333	0.8378	0.00000	0.00018	0.23997	0.00044	0.00000	0.00000	0.00	-173.62	-88.37	99.48	0.00	0.00
7.000	0.1429	0.8976	0.00000	0.00011	0.33120	0.00044	0.00000	0.00000	0.00	13.44	-90.82	95.60	0.00	0.00
6.500	0.1538	0.9666	0.00000	0.00036	0.35188	0.00040	0.00000	0.00000	0.00	10.73	-86.62	96.40	0.00	0.00
6.000	0.1667	1.0472	0.00000	0.00045	0.27883	0.00028	0.00000	0.00000	0.00	9.00	-84.02	99.03	0.00	0.00
5.500	0.1818	1.1424	0.00000	0.00031	0.11382	0.00000	0.00000	0.00000	0.00	6.74	-84.36	0.00	0.00	0.00
5.000	0.2000	1.2566	0.00000	0.00005	0.03536	0.00025	0.00000	0.00000	0.00	0.34	127.10	-72.96	0.00	0.00
4.500	0.2222	1.3963	0.00000	0.00016	0.08714	0.00040	0.00000	0.00000	0.00	-178.94	93.53	-85.37	0.00	0.00
4.000	0.2500	1.5708	0.00000	0.00014	0.01347	0.00010	0.00000	0.00000	0.00	-179.72	-35.78	129.54	0.00	0.00
3.500	0.2857	1.7952	0.00000	0.00001	0.02297	0.00022	0.00000	0.00000	0.00	0.57	-113.33	68.08	0.00	0.00
3.000	0.3333	2.0944	0.00000	0.00008	0.00494	0.00003	0.00000	0.00000	0.00	0.10	84.95	0.00	0.00	0.00
2.500	0.4000	2.5133	0.00000	0.00014	0.00055	0.00005	0.00000	0.00000	0.00	-178.84	49.37	0.00	0.00	0.00
2.000	0.5000	3.1416	0.00000	0.00008	0.00064	0.00009	0.00000	0.00000	0.00	1.33	70.25	-107.23	0.00	0.00

MICRO-SPLASH - STABLE PLATFORM LOADS AND MOTIONS VERSION 2.1b 09/11/95 23:23:13 PAGE 4

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT

MEM	X1	Y1	Z1	X2	Y2	Z2	SEMI AXES HORIZ.	SEMI AXES VERT	CDH	CDV	CMH	CMV	CDX1	CDX2	CMX1	CMX2
100	0.00	750.00	0.00	0.00	740.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.001
200	0.00	740.00	0.00	0.00	710.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
300	0.00	710.00	0.00	0.00	695.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
400	0.00	695.00	0.00	0.00	662.50	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
500	0.00	662.50	0.00	0.00	650.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
600	0.00	650.00	0.00	0.00	627.50	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
700	0.00	627.50	0.00	0.00	610.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
800	0.00	610.00	0.00	0.00	590.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
900	0.00	590.00	0.00	0.00	545.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
1000	0.00	545.00	0.00	0.00	495.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
1100	0.00	495.00	0.00	0.00	470.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
1200	0.00	470.00	0.00	0.00	245.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
1300	0.00	245.00	0.00	0.00	20.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
1400	0.00	20.00	0.00	0.00	10.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	0.000	0.000	0.001	0.001
1500	0.00	10.00	0.00	0.00	0.00	0.00	65.000	65.000	1.000	1.000	1.000	1.000	1.000	0.000	0.001	1.000
20	0.00	750.00	0.00	1.00	750.00	0.00	0.010	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT

--- CATENARY ANCHOR LINES ---

LINE NO	X-COORD	Y-COORD	Z-COORD	DIRECTION	LENGTH	SP.WT.	TENSION	EA
1	0.000	245.000	0.000	180.000	10000.000	75.000	4.5000E+05	2.5000E+07
2	0.000	245.000	0.000	270.000	10000.000	75.000	4.5000E+05	2.5000E+07
3	0.000	245.000	0.000	90.000	10000.000	75.000	4.5000E+05	2.5000E+07
4	0.000	245.000	0.000	0.000	10000.000	75.000	4.5000E+05	2.5000E+07

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT

- - - WEIGHT AND OTHER PROPERTIES OF PLATFORM - - -

WEIGHT	=	551138077.01
X-COORDINATE OF C.G.	=	0.00
Y-COORDINATE OF C.G.	=	312.65
Z-COORDINATE OF C.G.	=	0.00
DISPLACEMENT	=	552531677.72
X-COORDINATE OF C.B.	=	0.00
Y-COORDINATE OF C.B.	=	325.00
Z-COORDINATE OF C.B.	=	0.00
DEPTH OF BASELINE	=	650.00
WATER DEPTH	=	2640.00

- - - NATURAL UNDAMPED PERIODS OF MOTION - - -

SURGE	=	990.877
HEAVE	=	28.794
SWAY	=	990.877
ROLL	=	87.484
YAW	=	99999.000
PITCH	=	87.484

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT

RMS MOTIONS		CENTER OF GRAVITY						POINT 1			POINT
HSIG	TPK	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH	X-	Y-	Z-	
4.000	5.400	0.000	0.000	0.015	0.007	0.001	0.000	0.000	0.000	0.068	
8.000	7.400	0.000	0.000	0.091	0.039	0.002	0.000	0.000	0.000	0.389	
12.000	9.200	0.000	0.001	0.246	0.095	0.004	0.000	0.000	0.001	0.968	
16.100	10.300	0.000	0.005	0.432	0.155	0.006	0.000	0.000	0.005	1.615	
40.000	14.400	0.000	0.259	2.141	0.576	0.014	0.000	0.000	0.259	6.503	

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT

RMS VELOCITY POINT 1 POINT

HSIG	TPK	X-	Y-	Z-
4.00	5.40	0.000	0.000	0.066
8.00	7.40	0.000	0.000	0.302
12.00	9.20	0.000	0.001	0.636
16.10	10.30	0.000	0.002	0.971
40.00	14.40	0.000	0.082	3.005

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT
RMS ACCEL. (INCL. G) POINT 1 POINT

HSIG	TPK	X-	Y-	Z-
4.00	5.40	0.000	0.000	0.070
8.00	7.40	0.000	0.000	0.268
12.00	9.20	0.000	0.000	0.497
16.10	10.30	0.000	0.001	0.711
40.00	14.40	0.000	0.027	1.837

Motion Comparisons for Semi and TLP

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT

REL VERT MOTN		POINT 1 (YO =100.00)		POINT
HSIG	TPK	RMS	1/HOUR	1/10000
4.00	5.40	0.993	3.476	4.396
8.00	7.40	2.000	7.001	8.853
12.00	9.20	3.003	10.511	13.292
16.10	10.30	4.030	14.106	17.838
40.00	14.40	10.103	35.360	44.716

130 FT DIA. SPAR, CAT ANCHORS, Hs = 4-40 FT
CGMOTIONS FOR WAVES AT ANGLE= 90.00 DEG

WAVE PER	FREQZ	FREQR	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH	SURGE	HEAVE	SWAY	ROLL	YAW	PITCH
32.000	0.0313	0.1963	0.00000	2.33647	0.69310	0.05717	0.00039	0.00000	0.00	0.37	90.00	89.94	-90.03	0.00
31.500	0.0317	0.1995	0.00000	2.63382	0.68497	0.05781	0.00040	0.00000	0.00	0.45	90.00	89.94	-90.02	0.00
31.000	0.0323	0.2027	0.00000	3.06878	0.67667	0.05847	0.00041	0.00000	0.00	0.57	90.00	89.94	-90.02	0.00
30.500	0.0328	0.2060	0.00000	3.76250	0.66818	0.05915	0.00042	0.00000	0.00	0.75	90.00	89.95	-90.02	0.00
30.000	0.0333	0.2094	0.00000	5.03693	0.65950	0.05984	0.00044	0.00000	0.00	1.09	90.00	89.95	-90.02	0.00
29.500	0.0339	0.2130	0.00000	8.12527	0.65061	0.06054	0.00045	0.00000	0.00	1.92	90.00	89.95	-90.02	0.00
29.000	0.0345	0.2167	0.00000	26.11624	0.64149	0.06126	0.00046	0.00000	0.00	6.74	90.00	89.96	-90.02	0.00
28.500	0.0351	0.2205	0.00000	17.20296	0.63212	0.06199	0.00048	0.00000	0.00	175.15	90.00	89.96	-90.02	0.00
28.000	0.0357	0.2244	0.00000	5.99913	0.62251	0.06273	0.00049	0.00000	0.00	178.15	90.00	89.96	-90.02	0.00
27.500	0.0364	0.2285	0.00000	3.44593	0.61262	0.06347	0.00051	0.00000	0.00	178.83	90.00	89.97	-90.02	0.00
27.000	0.0370	0.2327	0.00000	2.31957	0.60245	0.06423	0.00053	0.00000	0.00	179.13	90.00	89.97	-90.02	0.00
26.500	0.0377	0.2371	0.00000	1.68774	0.59199	0.06498	0.00054	0.00000	0.00	179.30	90.00	89.97	-90.02	0.00
26.000	0.0385	0.2417	0.00000	1.28514	0.58122	0.06573	0.00056	0.00000	0.00	179.41	90.00	89.97	-90.01	0.00
25.500	0.0392	0.2464	0.00000	1.00751	0.57014	0.06648	0.00058	0.00000	0.00	179.48	90.00	89.97	-90.01	0.00
25.000	0.0400	0.2513	0.00000	0.80554	0.55873	0.06723	0.00060	0.00000	0.00	179.53	90.00	89.98	-90.01	0.00
24.500	0.0408	0.2565	0.00000	0.65286	0.54700	0.06796	0.00062	0.00000	0.00	179.57	90.00	89.98	-90.01	0.00
24.000	0.0417	0.2618	0.00000	0.53412	0.53492	0.06868	0.00065	0.00000	0.00	179.61	90.00	89.98	-90.01	0.00
23.500	0.0426	0.2674	0.00000	0.43977	0.52250	0.06938	0.00067	0.00000	0.00	179.63	90.00	89.98	-90.01	0.00
23.000	0.0435	0.2732	0.00000	0.36353	0.50974	0.07006	0.00069	0.00000	0.00	179.65	90.00	89.98	-90.01	0.00
22.500	0.0444	0.2793	0.00000	0.30114	0.49663	0.07070	0.00072	0.00000	0.00	179.67	90.00	89.99	-90.01	0.00
22.000	0.0455	0.2856	0.00000	0.24957	0.48318	0.07131	0.00075	0.00000	0.00	179.68	90.00	89.99	-90.01	0.00
21.500	0.0465	0.2922	0.00000	0.20665	0.46938	0.07187	0.00077	0.00000	0.00	179.69	90.00	89.99	-90.01	0.00
21.000	0.0476	0.2992	0.00000	0.17072	0.45525	0.07238	0.00080	0.00000	0.00	179.70	90.00	89.99	-90.01	0.00
20.500	0.0488	0.3065	0.00000	0.14055	0.44080	0.07283	0.00083	0.00000	0.00	179.70	90.00	89.99	-90.01	0.00
20.000	0.0500	0.3142	0.00000	0.11516	0.42603	0.07320	0.00087	0.00000	0.00	179.71	90.00	89.99	-90.01	0.00
19.500	0.0513	0.3222	0.00000	0.09380	0.41096	0.07349	0.00090	0.00000	0.00	179.71	90.00	89.99	-90.01	0.00
19.000	0.0526	0.3307	0.00000	0.07585	0.39561	0.07369	0.00093	0.00000	0.00	179.71	90.00	89.99	-90.00	0.00
18.500	0.0541	0.3396	0.00000	0.06080	0.38001	0.07378	0.00097	0.00000	0.00	179.72	90.00	90.00	-90.00	0.00
18.000	0.0556	0.3491	0.00000	0.04824	0.36419	0.07374	0.00101	0.00000	0.00	179.72	90.00	90.00	-90.00	0.00
17.500	0.0571	0.3590	0.00000	0.03783	0.34818	0.07357	0.00104	0.00000	0.00	179.71	90.00	90.00	-90.00	0.00
17.000	0.0588	0.3696	0.00000	0.02925	0.33201	0.07325	0.00108	0.00000	0.00	179.71	90.00	90.00	-90.00	0.00
16.500	0.0606	0.3808	0.00000	0.02226	0.31574	0.07277	0.00112	0.00000	0.00	179.71	90.00	90.00	-90.00	0.00
16.000	0.0625	0.3927	0.00000	0.01662	0.29940	0.07211	0.00117	0.00000	0.00	179.70	89.99	90.00	-90.00	0.00
15.500	0.0645	0.4054	0.00000	0.01213	0.28306	0.07126	0.00121	0.00000	0.00	179.69	89.99	90.00	-90.00	0.00
15.000	0.0667	0.4189	0.00000	0.00863	0.26678	0.07020	0.00125	0.00000	0.00	179.68	89.99	90.00	-90.00	0.00
14.500	0.0690	0.4333	0.00000	0.00594	0.25060	0.06892	0.00130	0.00000	0.00	179.67	89.99	90.00	-90.00	0.00
14.000	0.0714	0.4488	0.00000	0.00393	0.23461	0.06741	0.00134	0.00000	0.00	179.65	89.99	90.00	-90.00	0.00
13.500	0.0741	0.4654	0.00000	0.00246	0.21886	0.06567	0.00139	0.00000	0.00	179.62	89.99	90.00	-90.00	0.00
13.000	0.0769	0.4833	0.00000	0.00143	0.20342	0.06368	0.00143	0.00000	0.00	179.57	89.99	90.00	-90.00	0.00
12.500	0.0800	0.5027	0.00000	0.00073	0.18835	0.06147	0.00148	0.00000	0.00	179.48	89.99	90.00	-90.00	0.00
12.000	0.0833	0.5236	0.00000	0.00028	0.17371	0.05902	0.00152	0.00000	0.00	179.19	89.99	90.00	-90.00	0.00
11.500	0.0870	0.5464	0.00000	0.00001	0.15956	0.05635	0.00157	0.00000	0.00	165.74	89.99	90.00	-90.00	0.00
11.000	0.0909	0.5712	0.00000	0.00013	0.13800	0.05057	0.00152	0.00000	0.00	0.43	89.99	90.00	-90.00	0.00
10.500	0.0952	0.5984	0.00000	0.00020	0.12423	0.04715	0.00154	0.00000	0.00	0.12	89.99	90.00	-90.00	0.00
10.000	0.1000	0.6283	0.00000	0.00022	0.11096	0.04352	0.00156	0.00000	0.00	0.02	89.99	90.00	-90.00	0.00
9.500	0.1053	0.6614	0.00000	0.00021	0.09818	0.03971	0.00156	0.00000	0.00	-0.01	89.99	90.00	-90.00	0.00
9.000	0.1111	0.6981	0.00000	0.00020	0.08589	0.03575	0.00156	0.00000	0.00	-0.02	89.99	90.00	-90.00	0.00
8.500	0.1176	0.7392	0.00000	0.00018	0.07406	0.03165	0.00154	0.00000	0.00	-0.03	89.99	90.00	-90.00	0.00
8.000	0.1250	0.7854	0.00000	0.00015	0.06268	0.02745	0.00150	0.00000	0.00	-0.03	89.99	90.00	-90.00	0.00

7.500	0.1333	0.8378	0.00000	0.00013	0.05172	0.02316	0.00143	0.00000	0.00	-0.03	89.99	90.00	-90.00	0.00
7.000	0.1429	0.8976	0.00000	0.00011	0.04118	0.01882	0.00133	0.00000	0.00	-0.03	90.00	90.00	-90.00	0.00
6.500	0.1538	0.9666	0.00000	0.00008	0.03106	0.01446	0.00118	0.00000	0.00	-0.02	90.00	90.00	-90.00	0.00
6.000	0.1667	1.0472	0.00000	0.00006	0.02145	0.01016	0.00097	0.00000	0.00	-0.02	90.00	90.00	-90.00	0.00
5.500	0.1818	1.1424	0.00000	0.00004	0.01257	0.00605	0.00068	0.00000	0.00	-0.02	90.00	90.00	-90.00	0.00
5.000	0.2000	1.2566	0.00000	0.00001	0.00493	0.00240	0.00033	0.00000	0.00	-0.02	90.00	90.00	-90.00	0.00
4.500	0.2222	1.3963	0.00000	0.00000	0.00054	0.00027	0.00005	0.00000	0.00	179.98	-90.00	-90.00	0.00	0.00
4.000	0.2500	1.5708	0.00000	0.00001	0.00251	0.00125	0.00027	0.00000	0.00	179.99	-90.00	-90.00	90.00	0.00
3.500	0.2857	1.7952	0.00000	0.00000	0.00069	0.00035	0.00010	0.00000	0.00	179.99	-90.00	-90.00	90.00	0.00
3.000	0.3333	2.0944	0.00000	0.00000	0.00062	0.00031	0.00012	0.00000	0.00	-0.01	90.00	90.00	-90.00	0.00
2.500	0.4000	2.5133	0.00000	0.00000	0.00015	0.00007	0.00004	0.00000	0.00	0.00	-90.00	-90.00	0.00	0.00
2.000	0.5000	3.1416	0.00000	0.00000	0.00002	0.00001	0.00001	0.00000	0.00	0.00	90.00	0.00	0.00	0.00