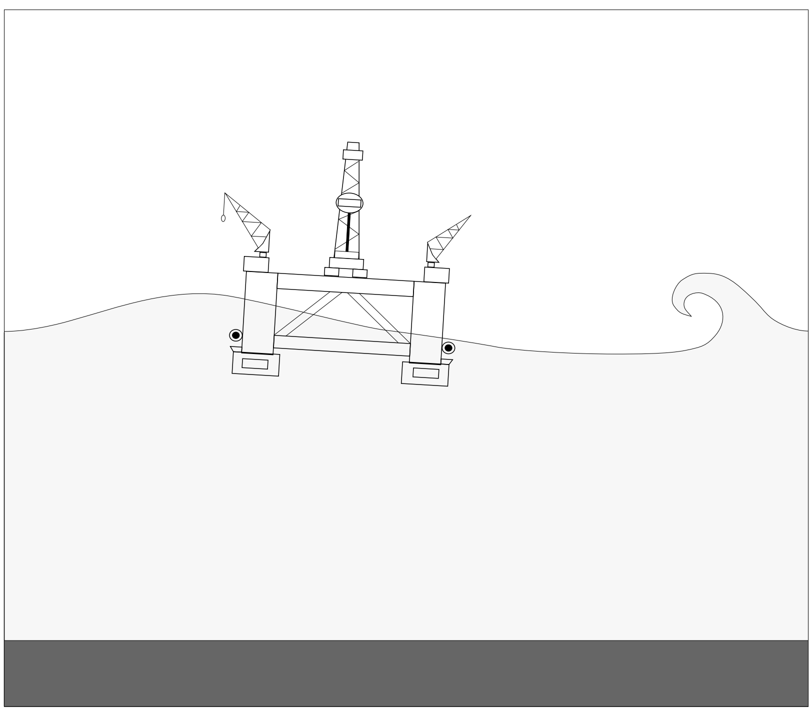
Semisim®

Comprehensive Wave-Frequency
Semisubmersible Simulation Software
From SeaSoft® Systems

User Manual

April, 2005



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Notice

About the SeaSoft Library

The SeaSoft family of software products for the offshore industry has been developed in response to a need for high quality, easy to use analytical tools for numerical simulation of the dynamic and static characteristics of a wide variety of offshore vessels and mooring structures.

The variety of computing platforms now used in engineering and naval architectural environments requires that offshore engineering software be easily transportable to a wide variety of computers (Macintosh, Unix, Windows, etc.) so that software tools can easily be moved to new computing facilities as the need arises. The SeaSoft program library was developed with these considerations in mind.

SeaSoft's products are capable, in most circumstances, of exceeding the physical modeling capabilities of older, operationally more complex codes while far surpassing them in terms of versatility and ease of use. Benchmark efforts by the DeepStar Committee (http://www.deepstar.org), using high-quality model test data as simulation quality arbiter, have shown unequivocally that the quality of the SeaSoft simulations surpasses all other available mooring tools, be they time-domain, frequency-domain or hybrid.

In the development of this suite of programs, the principal objectives have been (1) to deliver state of the art computational abilities to the offshore industry in packages that would permit their utilization by any technically trained individual with a need for the information, and (2) to insure that the quality and robustness of the underlying physical and analytical modeling are second to none.

The software is oriented specifically towards the practicing marine/offshore engineer and naval architect. In order to be of maximum utility to this audience, the software has been designed so that first-time or infrequent users can produce meaningful results.

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Chapter 1

Introduction

Background

Semisim is a member of the SeaSoft family of software packages for the offshore industry. These programs have been developed to provide high quality, easy to use analytical tools for simulation of dynamic and static characteristics of a wide variety of offshore vessels and structures.

Purpose

Semisim is a general-purpose simulation program for estimating wave-frequency loads and motions of semisubmersibles of all types in the hulls-submerged, non-transit configuration.

Objectives

In the development of Semisim, the principal objective has been to produce a state of the art computational tool usable by any individual with training in ocean engineering methods. The package is thus directed specifically towards the *practicing* system designer, marine/offshore engineer and naval architect. In order to be of maximum utility to this audience, the software has been designed so that even a first-time user can produce meaningful results.

Batch Processing Capabilities

The stand-alone versions of all SeaSoft applications can be scripted using standard scripting tools available on all platforms. This provides a repetitive execution mechanism that can provide simulation output for any collection of environmental or mooring system data (the latter being used in mooring optimization analyses). Because of short simulation execution times, Semisim is capable of completing many tens of thousands of simulations in a single overnight batch run even on consumer-class computers.

Support of Related Simulations

Apart from its central role of semisubmersible wave-frequency motion analysis, Semisim plays an important auxiliary role in supplying vessel and fairlead motion characteristics for other simulations in the SeaSoft library, including CALMsim, Moorsim, SALMsim, Sparsim, SPMsim, TLPsim and Towsim.

Frequently Asked Questions (FAQ)

A database of "Frequently Asked Questions", or "FAQ", is maintained at the SeaSoft web site (http://www.seasoftsys.com) which contains a wealth of detailed real-life explanations and problem resolutions that supplements the User Manual, particularly for advanced users. In addition, the FAQ is updated more frequently than the user manuals and therefore may contain information pertinent to recent changes or additions that have not yet migrated into the manuals. The FAQ can be freely downloaded and searched by keyword(s); it is an invaluable resource for obtaining quick guidance on a wide range of issues from the mundane to the highly technical.

Chapter 2

Program Package Contents

The Semisim package comprises the user manual, the machine-executable program units, and support services provided by SeaSoft. The latter include bug reports, corrections and support of possible bug-related problems encountered during program execution.

Program Files

The disk files involved in the execution of the Semisim package are of three generic types: executable binary program files, binary data files and formatted data files.

The sole executable program file is Semisim (the "Simulator"), which interacts dynamically (without user intervention) with a suite of overlay modules that in general are operating-system specific.

In addition to these executable modules, which are supplied with the package and which must not be altered in any way by the user, a number of data files are created during the simulation process. These data files comprise two types, binary data files usable as input to the Simulator (SEMIDAT, SEMIBAK and LASTBAK) and formatted output data files (SEMISUM.stxt, SEMIRAO.stxt, SEMIRAN.stxt, SEMIN,.stxt) containing simulation results. Management and recommended archival procedures for these files are discussed in Appendix D.

The User Interface

The User Interface, an integral part of the Simulator, is used to create the input data file (the "SEMIDAT" file) required for execution of the Simulator. This input file contains physical information necessary for the simulation such as water depths, vessel physical characteristics, and so on. The file is the result of an interactive session between the user and the Simulator (see Appendix B for a sample session and Chapter 5 for discussion of the Interface). The Interface is also used to modify previously created data files when vessel characteristics, site or environmental conditions require change. Note that the input file is in machine-readable format and cannot be viewed or modified without the Simulation.

User Manual Overview

The Semisim user manual constitutes the major tutorial tool provided with the program package. To derive maximum benefit from the package, the manual should be thoroughly reviewed on two occasions: Upon initial package acquisition (before and during the first few simulation executions), and again after perhaps eight to ten weeks of use. The second review of the manual, if carried out after practical experience has been gained in the use of the program, is of inestimable value in sharpening the user's understanding of the program, its workings and its capabilities. The manual includes a reasonably extensive glossary and an index, which, along with the table of contents and internal cross-references should permit quick location of specific topics. Further, the manual is available in PDF format for easy keyword searches using any compatible PDF reader program. The most recent PDF version can always be obtained at the SeaSoft web site (http://www.seasoftsys.com).

Chapter 3 discusses the various classes of input data required and provides some details regarding special features and limitations of the simulation. It complements Chapter 5 by providing additional information on items of special importance and is therefore a valuable cross-reference point for the material in Chapter 5.

Chapter 4 discusses in detail the use of and options for output control in Semisim. It, too, is an important cross-reference point for Chapter 5, complementing the physical description of the output selection process given there.

Chapter 5 gives a Screen-by-Screen description of all input items required for Semisim and serves as a "super index" which can be used to answer most of the day-to-day operational questions that arise during Semisim execution. Cross-references to other portions of the user manual are given at appropriate points in Chapter 5 .

The most important appendices are Appendix A, which contains an extensive glossary of terms used in the user manual and program input/output materials, and Appendix B, Appendix C and Appendix Z which contain a sample problem useful in interpreting procedures and output materials associated with Semisim.

Program Capabilities

Semisim will perform well on virtually any semisubmersible vessel in the non-transit, hulls-submerged configuration at low or zero speed. The program has been designed to require an absolute minimum of vessel information for its execution. It is *not* necessary to be in possession of lines drawings or other detailed information to perform a simulation, although details of the shape, position and volume of all submerged portions of the vessel must be provided (See pages 8 and 30). In addition, it is necessary to assemble the following hydrostatic and mass distribution information: Displacement, transverse and longitudinal metacentric heights, vertical centers of gravity and buoyancy, waterplane area, pitch, roll and yaw gyradii. (See also page 27.) The gyradii are only required for those degrees of freedom for which motion response estimates are desired. Of course, pitch and roll natural periods, which are always reported by Semisim, will only be correct if meaningful gyradii have been supplied.

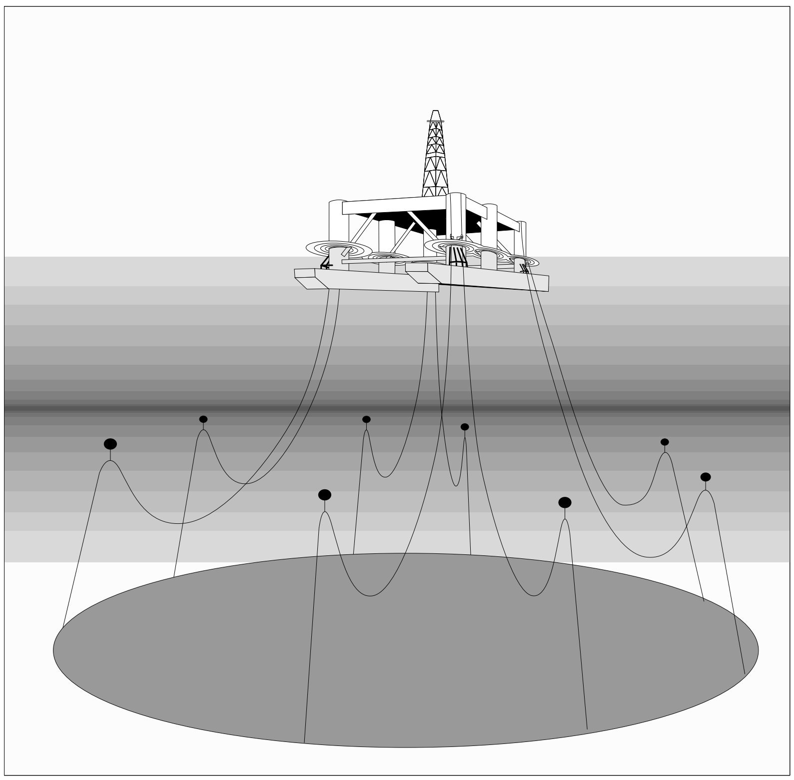
Automatic Backup of Input Files

When the Simulation is executed, it first inspects the local directory to see if any file with the name SEMIDAT is resident there. If so, a backup file named SEMIBAK is produced from the pre-existing SEMIDAT file while any pre-existing SEMIBAK file is renamed to LASTBAK. Any pre-existing LASTBAK file is lost. In this way, two generations of data files are maintained to protect against inadvertent data loss. This is discussed further under "file management" in Appendix D.

Chapter 3

Input File Preparation

For its execution, Semisim requires data of three distinct generic types: (1) site data consisting of water depth and water density, (2) physical data on the mass and geometrical properties of the vessel and (3) environmental data comprising principally regular and irregular wave conditions desired for the simulation. The ordering of topics in this chapter for the most part matches ordering of input data requested during an interactive session with Semisim. Refer to Appendix B for an example of data assembled in preparation for a simulation run. Refer to Chapter 5 for printed images of Screen presentations produced by Semisim and a detailed discussion of required input parameters.



Site Data

The characteristics of the site chosen for the simulation must be available to the program, and are requested as input on the first Screen "page" presented by Semisim. These are site water depth and water density. Fluid density is completely specifiable so that unusual conditions, such as very high salinity (and hence high density) water can be easily simulated. The water depth is required so that correct shallow-water wave characteristics will be used in the simulation. Semisim accounts automatically for all shallow water effects, including wavelength foreshortening and wave speed reduction. The choice of units to be used in the simulation, which may be either English or metric, is made on this Screen as well.

General Vessel Data

For purposes of a dynamic simulation of vessel performance, it is unnecessary to define vessel geometry with the great precision normally associated with evaluation of hydrostatic characteristics. This state of affairs arises because even the most sophisticated dynamic simulations can generally not produce better than ten or fifteen percent accuracy across the entire range of vessel and wave conditions of interest. This is a natural consequence of the immense difficulty of the full dynamic problem which at its simplest *approximate* level is one of a coupled, infinite degree of freedom linear dynamic system comprising vessel and surrounding fluid. The system is further complicated by inherent hydrodynamic nonlinearities. In addition, meaningful model tests required to provide baseline data are themselves extremely difficult to carry out. Indeed, model test data is rarely of better quality than the ten to fifteen percent quoted above for analytical results. Therefore a highly precise definition of vessel geometrical characteristics for the purpose of a dynamic simulation is unjustified, although it is nonetheless a routine prerequisite for utilization of "three-dimensional diffraction analysis"-based dynamics codes. Hydrostatic analysis, by contrast, is essentially an exact science, being simply an exercise in solid geometry. One is therefore justified in requiring input data to a *hydrostatics* program to be of high precision.

The vessel data required by Semisim is the minimum information necessary to permit faithful simulation of the vessel's dynamic characteristics. This minimum data comprises (see also page 8 ff, 27 ff and 29 ff):

1. Total vessel displacement.

2. Longitudinal and transverse metacenter locations. These are input relative to vessel baseline (i.e. as KML and KMT).

3. Vertical center of buoyancy from baseline (KB).

4. Vertical center of gravity from baseline (KG).

5. Vessel water-plane area at the required displacement.

6. Radii of gyration in Pitch, Roll and Yaw.

7. Vessel speed for simulation.

8. Sufficient dimensional information on submerged members to enable calculation of wave forces and moments.

Notes:

• As a cross check against erroneous input of member dimensions or hydrostatic values, Semisim estimates metacentric heights, displacement, water plane area and vertical center of buoyancy during simulation based on the supplied submerged member characteristics. Any discrepancy is reported at runtime with appropriate warning messages.

• The coordinate system in which all vessel physical properties are specified is a right-handed system with x positive forward, y positive to port (left when facing forward), z positive upwards; origin at vessel baseline directly below the center of gravity.

Decomposition into Members

In preparation for the simulation, the semisubmersible must be decomposed into a number of uniform members whose dimensions, shapes, locations and endpoint "termination types" must be provided. A discussion of the required data can be found, along with images of the relevant data Screens, on page 29 ff.

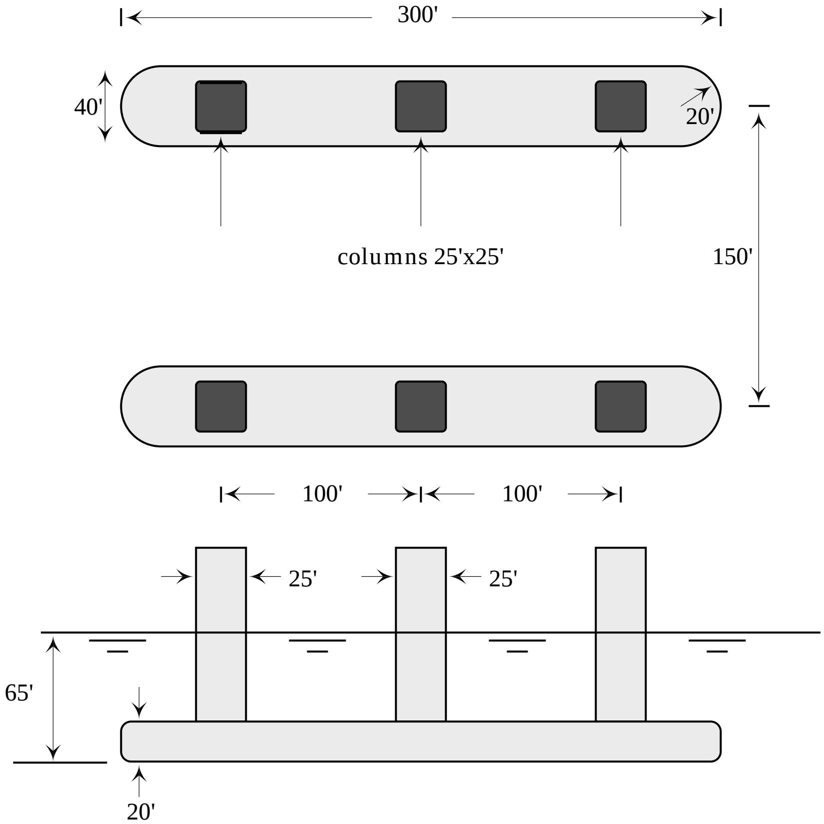
Member Specification Procedure

Decomposition of the submerged portion of the vessel into members is a rather subjective procedure which can be carried out in a number of approximately equivalent ways. We discuss here three of the most important decompositions, in order of increasing complexity and increasing precision of simulation. The accompanying figure and sample vessel illustrate the concepts introduced.

>>> ***Note*****:** The example in this chapter, though qualitatively similar to the sample problem illustrated in Chapter 5, Appendix B and Appendix Z, is distinct and should not be confused with the input Screens in Chapter 5 or the sample problem input (Appendix B) or output (Appendix Z).

The guiding principal in decomposing the semisubmersible into uniform "members" is that the member selection process should preserve without compromise the distribution of displaced volume of the simulated vessel and preserve, to the extent possible, the shape of the volume elements. This will insure that the important added mass and damping properties of the vessel as a whole will be faithfully simulated. Of primary concern is the added mass associated with vertical motions of the vessel or portions thereof (heave, pitch and roll); the heave degree of freedom, which produces motions of particular interest, is especially important. The added mass and damping associated with pure lateral motions (surge, sway and yaw) are far less critical; almost any reasonable member decomposition will produce a satisfactory simulation of the lateral degrees of freedom. In large part this inequality arises because vertical motions are associated with natural periods of vessel motion, which periods are sensitive to the virtual mass and moments of inertia of the vessel which include added mass contributions. Many important features of vessel response are tied to the natural periods and therefore indirectly to the added masses associated with "restored" degrees of freedom possessing resonance periods.

A central goal of the decomposition process should be to produce the fewest (and, therefore, volumetrically largest) members consistent with any geometrical constraints on the simulated vessel. For example, a long slender pontoon could in principal be modeled as a single monolithic member or as a series of adjacent "wall terminated" sub-members bracketed at the ends by "free, submerged" sub-members. The latter choice, aside from being unnecessarily complicated to implement, will also result in a degradation in simulation performance.



Pontoon-Dominant Decomposition

The "pontoon-dominant" decomposition is the simplest and fastest to implement because it requires the fewest number of distinct members and no adjustment of internally-computed added mass coefficients. This method, which is most applicable to vessels whose columns cover or "blanket" only a small percentage of the underlying pontoons, treats each pontoon as a single member whose breadth/depth ratio and volume is the same as the pontoon to be simulated. End effects, such as tapered or ship-shaped fore or aft sections, are simply accommodated by adjusting either the effective length or the average cross-sectional area of the simulated member to produce the correct total volume. Column members in this approximate decomposition scheme are considered to be sitting atop the pontoon members and to have no influence on hydrodynamic flows about the pontoon (which flows are characterized by the added mass coefficients of the pontoons). This is clearly not a perfect model because the presence of columns does in fact influence the flow about the pontoons in the vicinity of the column-pontoon interface, although the influence will be slight provided that the volume of affected pontoon is small compared to the overall pontoon volume. This neglect of flow disruption at the column-pontoon interfacial points generally results in an overestimate of heave added mass which produces a slight (typically 5%) overestimate in the natural periods of heave and roll. The pitch period error is usually considerably less and often completely negligible because most of the added (hydrodynamic) pitch moment results from fluid motions in the vicinity of pontoon ends, which are generally free of column interference. An easily implemented first-order correction to the pontoon-dominant approximation, which will normally eliminate the heave and roll period estimation error, is outlined in the next subsection. The included table illustrates the 4 members associated with each symmetric half of our simplified semisubmersible using the uncorrected pontoon-dominant decomposition. Refer to the figure above.

The following definitions are used in the accompanying example:

$V_{p\text{-}e} = 20x(\pi x20^2)/2 = 12{,}566.37$ -- Volume of pontoon semicircular end segments

$V_{p\text{-}c} = 20x25^2 = 12{,}500$ -- Volume of pontoon-column intersection region

$V_E = 20x[30x40 + \pi x20^2/2] = 36{,}566.37$ -- Volume of last 50' of pontoon (each end)

$A_{pp} = [40x(300 - 40) + \pi x20^2] = 11{,}656.64$ -- Pontoon area, projected onto waterplane

$V_p = 20xA_{pp} = 233{,}132.74$ -- Total pontoon volume

Member	***Description***	***Cross-Sectional Area***	***Effective Length***
1	Pontoon	$A_{p\text{-}x} = 20x40 = 800$	$V_p/A_{p\text{-}x} = 291.42$
2, 3, 4	Columns	$A_c = 25^2 = 625$	65 - 20 = 45

```
                    +++ Member Specification +++

  1) Member number:  3 of  8
  3) Axial cross-section profile: Rectangular

  4) Member dimensions (Mx,My,Mz) ..........     25.00     25.00     50.00
  5) Cross-sectional area ............................    625.00 square feet

 10) (Vx,Vy,Vz) coordinate of member base:     -100.00     75.00     20.00
 11) Base end termination type: Wall terminated

 12) (Vx,Vy,Vz) coordinate of member top:      -100.00     75.00     70.00
 13) Top end termination type:  Water-piercing

 15) Added mass/moment coefficients: Computed (deep water assumption)
 16) (Mx,My,Mz) Added mass coefficients:          1.22      1.22       .00
 17) (Mx,My,Mz) Added moment coefficients:        1.22      1.22       .00

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00
```

One of the 6 equivalent column specification Screens.

Note that vertical members always use the "deep water assumption" for internal calculation of added mass coefficients; "surface corrected" calculations apply only to horizontal members. Note also that the columns, because they are assumed to lie atop the underlying pontoon, have a "wall terminated" base termination type. The vertical extent of the column (50') has been chosen to insure that the column top (at 70' above baseline) lies above the waterline, which is 65' above baseline in the present example. See page 29 ff.

The following member specification Screen for the present example illustrates a pontoon member following internal calculation of the added mass coefficient assuming no column-pontoon interaction (see items 15 and 16).

```
                      +++ Member Specification +++

  1) Member number:  1 of  8
  3) Axial cross-section profile: Rectangular

  4) Member dimensions (Mx,My,Mz) ..........     20.00     40.00    291.42
  5) Cross-sectional area ............................    800.00 square feet

 10) (Vx,Vy,Vz) coordinate of member base:     -145.71     75.00     10.00
 11) Base end termination type: Free, submerged

 12) (Vx,Vy,Vz) coordinate of member top:       145.71     75.00     10.00
 13) Top end termination type:  Free, submerged

 15) Added mass/moment coefficients: Computed (with surface correction)
 16) (Mx,My,Mz) Added mass coefficients:          2.19       .65       .02
 17) (Mx,My,Mz) Added moment coefficients:         .58      2.03       .46

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00
```

Note that the length of the simulated member has been chosen so that total pontoon volume is correctly modeled.

Corrected Pontoon-Dominant Decomposition

An easily implemented correction to the pontoon-dominant decomposition can be accomplished by eliminating one-half of the vertical-motion related pontoon added mass associated with the region of the pontoon blanketed by column structures. Thus if the added mass coefficient computed for vertical motions of the bare pontoon were 2.2, and the total column coverage atop the pontoon amounted to 25% (that is, 25% of the total projected area of the pontoon were blanketed by column bases), one would specify an added mass coefficient of (1.1 + 0.75*1.1) = 1.93. This correction is usually sufficient to bring the natural periods of heave and roll to within a percent or two of the correct values, which is normally more than adequate. Similar adjustments to the pitch-relevant added moment coefficients (My in this case) are not usually necessary since most of the added pitch moment results from fluid motions in the vicinity of pontoon ends, which are generally free of column interference. Added moment corrections about other axes (roll and yaw) are almost always unnecessary. Adjustment of lateral added mass and moment coefficients are also normally unnecessary to obtain satisfactory results.

In the simplest implementation of this procedure, one first allows the editor to compute the vertical added mass coefficient for the full pontoon in the absence of column interference. The pontoon added mass coefficient is then manually adjusted according to the "half-blanketing" rule described above. In the present case, the corrected coefficient is given by

$$\text{corrected coefficient} = [1 + (A_{pp} - 3xA_c)/A_{pp}]\ x2.19/2 = 2.01$$

The added mass coefficient for vertical motions is then changed manually to the corrected value using items 15 and 16 as indicated on the following member specification Screen:

```
                    +++ Member Specification +++

  1) Member number:  1 of  8
  3) Axial cross-section profile: Rectangular

  4) Member dimensions (Mx,My,Mz) ..........     20.00     40.00    291.42
  5) Cross-sectional area ............................    800.00 square feet

 10) (Vx,Vy,Vz) coordinate of member base:     -145.71     75.00     10.00
 11) Base end termination type: Free, submerged

 12) (Vx,Vy,Vz) coordinate of member top:       145.71     75.00     10.00
 13) Top end termination type:  Free, submerged

 15) Added mass/moment coefficients: User-Specified
 16) (Mx,My,Mz) Added mass coefficients:          2.01       .65       .02
 17) (Mx,My,Mz) Added moment coefficients:         .58      2.03       .46

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00
```

The corrected data can now be copied using the "C" command to the remaining pontoon.

Column-Dominant Decomposition

The "column-dominant" member decomposition is a less subjective but more labor-intensive procedure that requires each pontoon be broken into a number of smaller members, with each inter-column pontoon segment comprising a distinct member. In this scheme, columns are treated as extending from the keel of the vessel upwards rather than sitting atop the pontoons; pontoon members are viewed as abutting up against the column structures rather than passing, without interruption, beneath. This procedure is most naturally adapted to designs in which the column structures blanket a substantial portion (one third or more) of the underlying pontoon. In general, the simplest possible physically reasonable decomposition with the fewest possible members should be adopted; the only rigid rule is that the total submerged volume and volume distribution be correctly simulated.

The column-dominant decomposition can be used in circumstances (small column blanketing) which would be candidates for a pontoon-dominant decomposition. This is largely a matter of individual preference. Simulation speed, data file debugging and data file creation all depend rather sensitively on total member number, so that the number of members chosen for vessel decomposition should usually be as small as possible, consistent with the requirements of simulation. A column-dominant decomposition for the illustrated vessel is given below. Each pontoon is divided into four members in this scheme, two identical end pieces and two identical inter-column segments. The column member specification is identical, except for member length, to that presented above for the pontoon-dominant decomposition; the columns now extend to keel level instead of to the pontoon tops as before.

Member	*Description*	*Cross-Sectional Area*	*Effective Length*
1, 2	Pontoon ends	$A_{p-x} = 20*40 = 800$	$[V_E - V_{p-c}/2]/A_{p-x} = 37.90$
3, 4	Pontoon center sections	$A_{p-x} = 20*40 = 800$	$100 - V_{p-c}/A_{p-x} = 84.38$
5, 6, 7	Columns	$A_c = 25^2 = 625$	65

```
                    +++ Member Specification +++

  1) Member number:  5 of  14
  3) Axial cross-section profile: Rectangular

  4) Member dimensions (Mx,My,Mz) ..........     25.00     25.00     70.00
  5) Cross-sectional area ...........................    625.00 square feet

 10) (Vx,Vy,Vz) coordinate of member base:     -100.00     75.00       .00
 11) Base end termination type: Free, submerged

 12) (Vx,Vy,Vz) coordinate of member top:      -100.00     75.00     70.00
 13) Top end termination type:  Water-piercing

 15) Added mass/moment coefficients: Computed (deep water assumption)
 16) (Mx,My,Mz) Added mass coefficients:          1.10      1.10       .05
 17) (Mx,My,Mz) Added moment coefficients:         .90       .90       .00

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00
```

One of the six equivalent columns, now assumed to reach from baseline to above the waterline, is specified above (note in particular items 1, 4, and 10-13).

```
                     +++ Member Specification +++

  1) Member number:  1 of  14
  3) Axial cross-section profile: Rectangular

  4) Member dimensions (Mx,My,Mz) ..........     20.00     40.00     37.90
  5) Cross-sectional area ............................    800.00 square feet

 10) (Vx,Vy,Vz) coordinate of member base:      107.81    100.00     10.00
 11) Base end termination type: Wall terminated

 12) (Vx,Vy,Vz) coordinate of member top:       145.71    100.00     10.00
 13) Top end termination type:  Free, submerged

 15) Added mass/moment coefficients: Computed (with surface correction)
 16) (Mx,My,Mz) Added mass coefficients:          1.69       .53       .14
 17) (Mx,My,Mz) Added moment coefficients:         .17      1.06       .41

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00
```

The first pontoon "end member" specification Screen.

Note in particular items 11 and 13 which now indicate the wall-terminated base of this member (which abuts up against a column member in this decomposition). The computed added mass coefficients reflect these member endpoint boundary conditions. The position of the member base and top have been chosen so that the *center* of the simulated member lies at the same point as the center of the simulated volume, although other approximately equivalent placements can be justified and will produce only negligible differences in simulation output.

The remaining 3 pontoon end members, which are equivalent to the above by suitable reflections through he origin, can be produced by "C"opying the data from the above page using the appropriate reflection option.

```
                      +++ Member Specification +++

  1) Member number:  2 of  14
  3) Axial cross-section profile: Rectangular

  4) Member dimensions (Mx,My,Mz) ..........     20.00     40.00     84.38
  5) Cross-sectional area ............................   800.00 square feet

 10) (Vx,Vy,Vz) coordinate of member base:        7.81    100.00     10.00
 11) Base end termination type: Wall terminated

 12) (Vx,Vy,Vz) coordinate of member top:        92.19    100.00     10.00
 13) Top end termination type:  Wall terminated

 15) Added mass/moment coefficients: Computed (with surface correction)
 16) (Mx,My,Mz) Added mass coefficients:          2.29       .67       .00
 17) (Mx,My,Mz) Added moment coefficients:         .67      2.29       .45

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00
```

One of the four central inter-column pontoon members is specified above.

Note again items 11 and 13, which indicate that both ends of the inter-column pontoon members abut up against column structures in this decomposition scheme. Again, the added mass coefficients reflect this endpoint boundary condition. The position of the member base and top have been chosen so that the *center* of the simulated member is at the center of the inter-column gap (50 feet from vessel centerline in this example); there is no need for the specified members to form a closed, contacting set of structures for the purpose of the simulation. Only the total member volume and the approximate positions of the volume elements need to be faithfully recreated.

The remaining 3 pontoon inter-column members, which are equivalent to the above by appropriate reflections thought he origin, can be produced by "C"opying the data from the above page using the appropriate reflections.

Description of Wave Types Supported

Environmental conditions that can be specified for the simulation comprise three classes of wave data: regular waves, irregular waves and swell. Additional details regarding environmental input data can be found in Chapter 5 .

Regular Wave Characteristics

Regular waves are simply long-crested surface waves of well-defined period. Waves of this type are commonly used in wave basin measurements to determine the RAOs ("Response Amplitude Operators") of a vessel. Semisim begins all simulation runs by calculating a user-specified collection of regular wave force, torque and motion response characteristics. The choice of regular wave periods to be used in RAO calculations will depend on whether or not irregular wave performance is to be estimated (see also page 33 ff):

1. If no irregular wave or swell response is required, any wave periods whatever may be selected for regular wave response data. This allows complete freedom in exploring details of the heave resonant peak, for example. In addition, exact wave periods determined in model basin tests or in full-scale measurements can be specified for response estimation. The maximum number of wave periods that can be specified in any given simulation is 40.

2. If irregular wave or swell data is required, the regular wave periods chosen must be equally spaced. This is because numerical integration routines used in irregular wave computations require equally spaced periods for proper functioning, and Semisim uses the computed regular wave RAOs in the determination of irregular wave response. Semisim, which will not permit input of unequal regular-wave period intervals when irregular waves or swell are selected, provides an automatic mechanism to achieve the required equal spacing. This mechanism is described in Chapter 5, on page 34.

3. If irregular wave data is requested, the regular wave periods chosen should span a sufficiently wide band of periods to completely bracket important periods present in the irregular wave spectrum to be employed. The adequacy of the bracketing can be established by the simulation itself, but this requires that it be executed at least twice. To accomplish this check, a range of equally-spaced periods is selected and the simulation executed with the desired irregular wave spectra. The irregular wave output will indicate irregular wave heights as computed from numerical integration of each wave spectrum. If this value is not within 10 or 15 percent of the requested value, the range of wave periods was inadequate, and should be expanded by either increasing the largest wave period, reducing the smallest, or both. This procedure can be repeated as often as required to achieve the required range of regular waves.

4. In order to incorporate into the simulation nonlinear effects associated with hydrodynamic damping of the "square law" type, specification of the magnitude of incident waves must be made. In Semisim this is accomplished by specifying either the constant wave height or constant wave slope for which RAOs will be computed. Incorporation of nonlinear effects results in RAOs which are wave amplitude dependent, in contrast to the properties of a linear system.

Nonlinear effects are normally only noticeable for wave periods near vessel resonances and the influence of wave amplitude on the peak of the resonant response curves can be explored by executing Semisim for several different regular wave height values and comparing the results.

It should be noted that regular wave RAOs are used in the computation of irregular wave response, so the choice of regular wave height or slope will have some bearing on significant motion amplitudes computed in irregular wave calculations. When irregular wave response is desired, it is worthwhile for inexperienced users to execute Semisim with two or three different choices for the regular wave heights or slopes in order to obtain a feeling for the influence on significant response of variations in the regular wave amplitude used.

In principle, one should prepare a separate RAO for each irregular wave case of interest, with the wave height used in the RAO calculation dependent on significant wave height and spectral distribution of the desired irregular waves. In practice, however, this is seldom necessary. This is because the effect on significant responses of modest changes in wave amplitude used for RAO calculations is generally quite small. Note, however, that whenever a large range of irregular wave heights whose spectral content contains substantial energy near vessel resonant periods is of interest, the effect of wave height on response RAOs can be important. In these cases a conservative approach is sometimes helpful: Because RAOs at vessel natural periods increase as regular wave height is reduced, one may generally obtain an upper bound on significant responses by choosing the regular wave height to be .707 times the significant height of the smallest irregular waves of interest (this factor, equal to $1/\sqrt{2}$, insures that both regular and irregular waves have the same r.m.s. amplitude). In this way vessel response computed for larger irregular waves will be somewhat greater than the true response, resulting in a conservative estimate of the response.

Irregular Wave Characteristics

Irregular waves in nature comprise a superposition of regular waves of differing periods and directions. In test facilities, however, it is not always possible to obtain a spread in wave directions due to the need to generate waves with a single monolithic wavemaker, although some testing facilities do have limited capabilities for generating multi-directional waves. Semisim permits analysis of both types of irregular waves (i.e. short and long crested) so that both model basin tests and open ocean conditions may easily be simulated (see also page 36 ff). The degree of wave-crest shortening due to azimuthal spreading of wave energy is under complete user control through the choice of a "spreading index", which is more fully discussed in Chapter 5.

User-Specified Spectra

Many standard irregular wave spectra are built into Semisim, including Bretschneider, Pierson-Moskowitz, and several implementations of the JONSWAP spectrum (including the full 5-parameter representation; see page 36 ff). In addition, there are two ways to input a user-defined spectrum. (See page 40 and Appendix H.) The individual spectral densities required as input for the user-supplied frequency spectrum must:

- Be in a set of units consistent with those of the vessel properties; metric example: [meter^{2}sec] or, equivalently, [meter^2/(rad/sec)].

- Represent a wave *variance* spectrum $S(\omega)$, where ω is the circular frequency variable (in radians/sec). The integral of $S(\omega)$ from $\omega = 0$ to ω = infinity is equal to the variance of the sea surface elevation about the still water point. For spectra of interest in offshore applications, the square root of this variance is very close to one-fourth of the significant wave height associated with the spectrum. The significant height is defined as the average height of the one-third largest waves. Some care must be exercised here as spectra are sometimes reported as wave *height* spectra or wave *amplitude* spectra, whose spectral values are, respectively, eight or two times greater than the associated wave variance spectral values. Also, if the supplied spectrum is given in terms of hertz (cycles/second) rather than circular frequency (radians/second), each spectral value must be divided by $2\pi = 6.2832...$ before input.

• For the mechanism described on page 40, the spectral values must be given at exactly the same wave *periods* as those specified for regular wave RAO determinations (see page 40), which periods must possess equal period-to-period intervals as discussed above. This may require some interpolation of experimental or tabular spectral data since spectra are normally reported at equal frequency intervals and not equal period intervals. Note that the WAVESPEC.txt mechanism (Appendix H) does not share this requirement and is now the preferred mechanism for user-specification of wave spectral data.

• The spectral values, to reiterate, are those associated with a *frequency* spectrum and not a *period* spectrum; these differ from one another by a factor proportional to the square of the frequency. Since the significant height associated with a measured spectrum is usually known, the output significant wave height given by Semisim can be compared with the known value. This comparison will alert the user to any errors in spectrum scaling.

Swell Characteristics

Swell is a special class of irregular wave which is important in nature and therefore has been incorporated into Semisim (see also page 17 ff). Swell is by definition a superposition of regular waves of differing, but nearly equal, wave periods all of the same direction (i.e. the frequency spectrum is very narrow banded and the swell is long crested). This type of irregular wave is characterized by the phenomenon of "beats" or "groups" in which one observes clusters of larger waves, separated by quiet periods with much smaller waves. Swell is generally associated with relatively long waves propagating away from the site of distant weather systems. Irregular seas, by contrast, are normally considered to have developed locally and recently by action of local winds. They therefore have a relatively high content of short-period waves which have not had sufficient time to decay due to dissipative or nonlinear energy cascade mechanisms.

The swell spectrum utilized in Semisim is a narrow-banded spectrum with a Gaussian shape and user-specified bandwidth. The direction, height and period of the swell are also user-specifiable. Because the swell spectrum is narrow, simulations incorporating swell may require a smaller wave period interval for the RAO calculations than would be required in the absence of swell. The need for smaller intervals can be established by comparing the computed swell height, as reported by Semisim, with the requested value and reducing the size of the wave period interval as necessary. Equal wave period intervals are required for swell calculations, as for all irregular wave calculations.

Because one often finds "crossed seas" in which irregular waves from a local disturbance are superimposed upon an unrelated distant swell, Semisim permits simultaneous specification of irregular waves and background swell; swell can also be simulated alone, in the absence of other wave systems. Note that when irregular waves and swell are present simultaneously, they are assumed to be uncorrelated. This means, for example, that the significant wave height of the combination is equal to the square root of the sum of the squares of the wave heights taken independently. Note that when irregular waves and swell are present simultaneously, Semisim reports significant heights of the irregular wave and swell contributions separately and independently, although contributions to vessel dynamic characteristics from irregular waves and swell are combined into a single value according to the rule, mentioned above, for uncorrelated variables.

Chapter 4

Output Control And Description

Output Control

Semisim provides extensive controls which can be used to select data of specific interest for output. This keeps printout volume to a manageable level and provides some control over disk space. The output options should be carefully studied so that an intelligent selection of output can be made. Semisim is capable of generating considerably in excess of ten thousand pages of data in a single run if complete output for a maximum number of regular and irregular wave directions is requested.

Wave Parameter Control

At the highest level, output control consists of the selection of the number of regular wave periods, the number of regular and irregular wave directions, and the number of irregular wave conditions (heights and spectral peak periods) for each direction specified. The maximum values allowed in Semisim for these parameters are given below (see also pages 33 ff):

- Maximum number of regular wave periods = 100
- Maximum number of regular wave directions = 12
- Maximum number of irregular wave directions = 37
- Maximum number of irregular wave heights per direction = 6
- Maximum "spread sea" wave directions per irregular wave case = 36

RAO Output Control Options

At the secondary level of control, one may select or de-select the various possible RAO output streams according to the following hierarchy (see also page 43):

- Degrees of freedom output control - any of the six degrees of freedom may be selected for output.
- Force/torque output control - for any selected degree of freedom the net wave force or torque RAO corresponding to that degree of freedom may be selected for output.
- Motion output control - for any selected degree of freedom the corresponding motion RAO can be selected for output.

- Special location output control - up to 49 special locations rigidly affixed to the simulated vessel can be selected for analysis.

Acceleration output control - acceleration RAOs for all three components of acceleration at each selected point can be selected for output.

Velocity output control - velocity RAOs for all three components of velocity at each selected point can be selected for output.

Displacement output control - displacement RAOs or "relative motion" RAOs for all three components of displacement at each selected point can be selected for output.

Irregular Wave Output Options

The irregular wave output is not as voluminous as the RAO data, since only a few statistical parameters are computed for each irregular wave condition requested. Therefore both irregular wave force/torque and motion data are output for each requested degree of freedom whenever irregular waves are specified. Statistical summaries for the special location displacements, velocities and accelerations are also given.

Chapter 5

User Interface Description

This chapter is devoted to a description of the user interface to the Simulation (the "Editor") which is used for creation of new data files and editing of existing files. The following pages contain images of most console Screens produced by the Editor, along with annotated comments regarding the meaning of selected items on the Screen. Since all options for execution of the Simulation are represented by Editor selections, this chapter comprises an itemization of capabilities, input/output cross-reference and tutorial for the Simulation as well. All responses typed by the user at the console are in ***bold*** typeset, both on Screen images and in the text of this chapter. User-typed carriage returns are indicated by ***<c/r>***. Note that a carriage return (designated as "***Return***" on most keyboards but as "***Enter***" on some) is required as the last keystroke of *any* input to the console; thus, when we speak of "Entering the value 3", we in fact mean the keystroke combination "***3<c/r>***". (Quotation marks are included here and below only for readability; they are *never* to be used for data entry in the Editor.)

Screens are numbered sequentially according to the order of their appearance; unnumbered SubScreens that are subordinate to the main Screen but overlay it are designated by letter. Thus SubScreen 3a would be the first SubScreen of Screen 3.

General Editing Information

The editing session is largely self-explanatory; the editing alternatives consist of several simple, fundamental types:

1. The "toggle": Many editing items are configured as toggles between two possible values; selection of these items will require no further data input from the user. For example, selection of "units of measure" on Screen 1 below will cause the selected units to toggle between "English" and "metric". All items displaying a value of "yes" or "no" are of the toggle type.

2. Single datum input: Most of the selections in the Editor require input or modification of a single item on a Screen. To change a particular item, input the item number followed by a carriage return (***<c/r>***) at the "Enter number of selection:" prompt, and an appropriate prompt line requesting the new input value will appear at the Screen bottom. It is not necessary to input decimal points for floating point numbers without fractional parts (i.e. 10.0 can be input as 10). When more that one input value is required on an input line, the values should be separated by commas. A carriage return in response to a request for data will leave the current value of the data unchanged.

3. Expanded data input: For situations in which many numbers must be entered, or a choice more complicated than a simple datum input is involved, the Editor will produce a "SubScreen" subordinate to the active Screen to accomplish the input operation.

For example, a SubScreen is used to permit semi-automatic input of regular wave periods for RAO evaluation, the input of which one period at a time would be laborious.

4. Screen access "Help" menu: Entering "H" (*without* quotation marks) at any "Enter number of selection:" prompt will produce the Help menu displayed after console Screen 1 below. These paging options, which, like the "H" command, can be given at any "Enter number of selection:" prompt, are designed to permit ease of access to any Screen of the Editor from any other Screen. Both upper and lower case letters can be used.

5. Help with specific items: As illustrated further below, concise descriptions of many required input items can be obtained on-line by entering "***?n<c/r>***" at any "Enter selection number" prompt; n is the item number of interest on the current Editor Screen. Entering "***?<c/r>***" will cause all help text associated with the Screen presently in view to scroll by.

The following mechanisms for paging through the Editor should be noted: To page forward to the next sequential Screen, press the carriage return at the "Enter selection number" prompt; to page ***B***ackwards to the previous Screen, enter "***B<c/r>***"; the ***F***irst and ***L***ast input Screens can be accessed from any numbered Screen in the Editor by entering, respectively, "***F<c/r>***" or "***L<c/r>***"; one can ***S***kip a Screen by entering "***S<c/r>***" or ***J***ump to Screen "n" by entering "***Jn<c/r>***" (for example, ***J5<c/r>*** will produce a jump to Screen 5 from any numbered Screen in the Editor).

Editor Screen Images

Note that not all possible Screen images are displayed in this chapter; the images are intended only as aids to discussion and do not portray a realistic session in its entirety. The images correspond to the sample problem of Appendix B where a sketch of the sample vessel can be found.

```
          +=========================================================+
          |                                                         |
          |               **   Welcome to SemiSim   **              |
          |                                                         |
          |                                                         |
          |                   SemiSim  Version 5.05                 |
          |                                                         |
          |         Copyright (C) 2004 by SeaSoft Systems           |
          |                                                         |
          +=========================================================+


 (M) Modify existing data file, (C) Create a new file, (E) Execute simulation
 Enter letter of selection: M<c/r>
```

Title page: This Screen presents options to Modify (***M***) an existing Data file, Create (***C***) a wholly new one or Execute (***E***) the Simulation using an existing Data file. No response but "***M***", "***m***", "***C***", "***c***", "***E***" or "***e***" will be accepted. If either (***M***) or (***C***) are entered, any first or second generation Data files in the current directory will be copied to backup files to avoid inadvertent loss of data. Thus, the two most recent generations of data files are automatically preserved. At the end of the Editor session, a Data file with the new or modified data will be created in the current directory in addition to the two generations of backup files. Appendix D discusses file management procedures.

```
                    ****  Screen 1: Site conditions  ****

    Two-line Identification for this simulation:

1) [Semisim Sample Problem                                                   ]
2) [Six-Column semi; uniform pontoons                                        ]

3) Units of measure: Metric

4) Site water depth:           40.00 meters
5) Water density:            1025.18 kgw/cubic meter

Enter number of selection: H<c/r>
```

See Also: pp 5

Screen 1: This Screen contains necessary site data and other miscellaneous information. The units of measure can be toggled between English and metric by selecting item 3. Input of new numerical data (e.g., item 4) or character string data (e.g., item 1) is accomplished by selecting the relevant numbered item and responding appropriately to the ensuing prompts. In this example, we have requested "Navigational Help" by entering "***H***" at the "Enter number of selection:" prompt; the Screen response to this action follows:

```
(F)  First page
(L)  Last page
(S)  Skip ahead a page
(E)  Execute program
(B)  Back a page
(Jn) Jump to page "n"
(?)  Help summary for current page
(?n) Help on current page for selection "n"

Press <RETURN> to continue: <c/r>
```

Help Screen: This Screen contains instructions for access to various interface Screens and on-line help. The described actions are accomplished by entering the appropriate letter (uppercase or lowercase), followed by a carriage return, at an "Enter number of selection:" prompt on any numbered Screen.

```
                    ****  Screen 1: Site conditions  ****

    Two-line Identification for this simulation:

1) [Semisim Sample Problem                                                    ]
2) [Six-Column semi; uniform pontoons                                         ]

3) Units of measure: Metric

4) Site water depth:           40.00 meters
5) Water density:            1025.18 kgw/cubic meter

Enter number of selection: H<c/r>
```

Screen 1: Site conditions

Items 1-2: Two text records for documentation purposes.

Item 3: The units of measure can be toggled between English and metric by selecting item 3. Selection of this item produces the following SubScreen:

```
     >>> Units Conversion Options <<<

1) Convert only water density and unit labels to metric units
2) Convert ALL data values and units labels to metric units

Enter number of selection ("H" for help):
```

SubScreen 1a: This SubScreen permits two types of units conversions; it appears upon selection of item 3 on Screen 1.

Item 1 With a single exception (the water density value), this item alters *only* the *displayed* dimensional units (ft <=> meters, etc.). This is generally of use only during original creation of a data file (to change to metric from the English default); this action is always perfectly reversible. That is, two invocations of this option will return an existing data file to its unaltered original state regardless of the contents of the data file.

Note: To convert an *existing* data file between English and metric units, use Item 2.

Item 2 This item will convert all dimensional *values* in an existing data file between English and metric units. This option should be exercised with care; several things to consider:

- Executing this option twice will not in general reproduce *exactly* the original data file due to floating-point roundoff errors. Thus, two "equivalent" data files (original and twice-converted) may produce slightly differing output streams.

- Using this option may compromise the usefulness of inter-simulation data file transfers. Conversions to an existing data file should in general be carried out in the originating simulation. For example, to transfer a data file from Moorsim (English) to Shipsim (metric), you should do the conversion to metric in Moorsim, then use the *converted* MOORDAT file as input to Shipsim.

  Note: The problem arises because the converted variable sets differ between simulations; for example, mooring data 'hidden" in a SHIPDAT file imported from Moorsim will *not* be properly converted within Shipsim, resulting in a data file with mixed data types. A re-import of that converted SHIPDAT file back into Moorsim will therefore be problematic, with mooring data in one set of units and vessel data in the other.

- Any user-supplied external data files (see Appendix H) that are *dimensional* must be converted separately by hand. For example, WAVESPEC.txt files contain dimensional data; if they are to be used after a units conversion, they must also be converted by the user to the correct new set of units. Coefficient-type data files (i.e., USERRAOS.txt) are dimensionless and are independent of the system of units employed.

```
-- Water density --

1) Seawater
2) Freshwater
3) User-specified fluid density in lbs/cubic foot

Enter number of selection: <c/r>
```

See Also: pp 5 SubScreen 1b: This SubScreen permits water density specification; it appears upon selection of item 5 on Screen 1.

```
**************  Screen 2: Vessel Hydrostatic Characteristics  **************

 1) Vessel displacement ...............................   35925.00 m.ton
 2) Transverse metacentric height (KMT) ...............      26.20 m
 3) Longitudinal metacentric height (KML) .............      28.00 m
 4) Vertical center of buoyancy (VKB) .................       6.60 m
 5) Vertical center of gravity (VKG) ..................       8.64 m
 6) Vessel water plane area ...........................     748.20 m^2
 7) Length of vessel at waterline .....................      92.60 m
 8) Beam of vessel at waterline .......................      60.00 m
 9) Mean vessel draft .................................      20.00 m

Enter number of selection: <c/r>
```

See Also: pp 6 Screen 2: This Screen contains vessel hydrostatic data and dimensional data.

Notes:

- Displacement comprises total simulated vessel weight

- The metacentric height data required is "Keel-to-Metacenter" ("KM") rather than "CG-to-Metacenter" ("GM").

- KM (transverse or longitudinal), GM, VKG, VKB and IWP (waterplane moment of inertia) are related by:

  GM = KM - VKG
  GM = IWP/(Displacement Volume) - (VKG - VKB)

- For a *rectangular* waterplane of width B and length L,

  IWP (transverse) = $L*B^3/12$
  IWP (longitudinal) = $B*L^3/12$

- For a circular waterplane of radius R,

  IWP = $\pi*R^4/4$

- VKB should be obtained from hydrostatics, but is generally in the range of 1.5-2.0 times (pontoon height/2) for semisubmersibles

- VKG should include free-surface corrections, if any.

- Water plane area can be obtained from:

  (a) Calculation or estimation,

  (b) Hydrostatic immersion curves by dividing the curve value at the required draft (e.g., in tons/foot) by the water density (e.g., in tons/cubic foot) used for the curve preparation.

- Vessel Length and Beam comprise total waterline lengths projected on a vertical plane. This applies to all types of vessels including semisubmersibles.

- Draft comprises mean draft in the simulated condition.

```
***********  Screen 3: Vessel Gyradii and Bilge Specifications  ***********

 1) Pitch Gyradius ....................................     30.89 m
 2) Roll Gyradius .....................................     30.55 m
 3) Yaw Gyradius ......................................     41.74 m

 4) Bilge radius at maximum beam station ...............       .00 m
 5) Is there a bilge keel ..............................   No

 9) Vessel speed (knots) ..............................       .00

11) Trim angle (deg; bow down positive) ................       .00
12) Heel angle (deg; starboard down positive) ..........       .00

13) Utilize user-supplied vessel RAO data .............   No

Enter number of selection: <c/r>
```

See Also: pp 5

Screen 3: This Screen permits user specification of the remaining vessel mass properties; specifically the three independent gyradii, and the simulated vessel trim and heel. The bilge information is not used by Semisim; therefore items 4-5 will have no effect on simulation output.

Items 1 - 3: Generally, Gyradii must be estimated from first principles for Semisim.

Items 4 - 5: Bilge information is not used in Semisim**.**

Item 9: Mean motion of the vessel relative to the surrounding fluid affects the frequency versus wavelength relationship of waves as viewed from the vessel frame of reference; that is, for a specified wave length, the encounter frequency depends on vessel motion according to:

Shifted frequency = unshifted frequency - **VFWD•K**

Here, **VFWD** is the vessel velocity (whose *magnitude* is supplied by item 9 and *direction* by item 10, which will display only if item 9 is nonzero), **K** is the wave vector (2π/wavelength in the direction of wave advance) and **VFWD•K** is the wave vector magnitude times the projection of the vessel velocity vector on the wave vector direction.

In unusual cases (for example, when vessel motion is in the direction of wave propagation) the encounter period versus wavelength dependency can become multi-valued (i.e., two different wavelengths can be associated with a single encounter period). This makes the definition of the wave spectrum in irregular wave simulations problematic since the spectrum is defined in a vessel-fixed frame and there is no way of knowing how to apportion the wave energy in a given frequency band between the two associated wavelengths. The vessel speed option should therefore be used with special caution and particular attention given to its effect on irregular wave vessel responses.

The vessel speed option permits specification of a direction of motion in the global coordinate system; the usual right-handed coordinate system applies with 0 degrees corresponding to a forward speed condition. Note that vessel motion in the 90 degree direction equates physically to a "current" with a 270 degree "heading".

Items 11 -12: Trim and heel angles can be specified in degrees with positive angles corresponding to "right-hand rule" positive rotations about the pitch (Vy) and roll (Vx) axes, respectively. Note that response in all six degrees of vessel freedom are reported in an earth-relative coordinate system with vertical axis perpendicular to the waterplane *regardless* of trim and/or heel values (e.g., heave values are reported as c.g. motions perpendicular to the waterplane whether or not heel/trim are specified). The corrections produced by heel or trim specification are correct in the small angle limit (heel and/or trim < 10 degrees).

Item 13: User specification of vessel RAOs requires preparation of a formatted input file containing, for all six degrees of freedom, complex *dimensionless* RAOs for a two-dimensional array of circular wave frequencies and wave headings. RAOs for arbitrary frequencies and headings are obtained by interpolation within the array. The description and format of this data file is discussed in Appendix H.

```
***********  Screen 4: Vessel Period and Damping Specifications  ***********

  1) Heave damping is .................................. Computed
  3) Pitch damping is .................................. Specified
  4) Pitch damping (percent of critical) ...............     8.40

  5) Roll damping is ................................... Computed

  7) Heave period is ................................... Computed
  9) Pitch period is ................................... Computed
 11) Roll period is .................................... Specified
 12) Roll period (sec) ................................     23.70
```

Screen 4: User specification of natural periods and quasi-linear damping.

Items 1, 3, 5: Activation of these toggles produces a prompt for a user-specified damping value. Pitch, roll and heave damping will be computed internally unless specified by the user in percent of critical. User-supplied values become simple linear damping coefficients which do not depend on wave conditions. On the other hand, in many cases internal damping estimates produce an "equivalent linear damping" coefficient which depends on wave conditions, with larger waves resulting in larger damping coefficients.

Items 7, 9, 11: Pitch, roll and heave periods are normally computed internally. They can, however, be set by the user in special circumstances. Toggling of these items to "Specified" produces a prompt for a user-supplied value.

```
                 ****  Screen 5: Member Particulars  ****

  1) Number of members (Max 50):  8
  2) Default member Mx-damping coefficient ...........      2.00
  3) Default member My-damping coefficient ...........      2.00
  4) Default member Mz-damping coefficient ...........      2.00

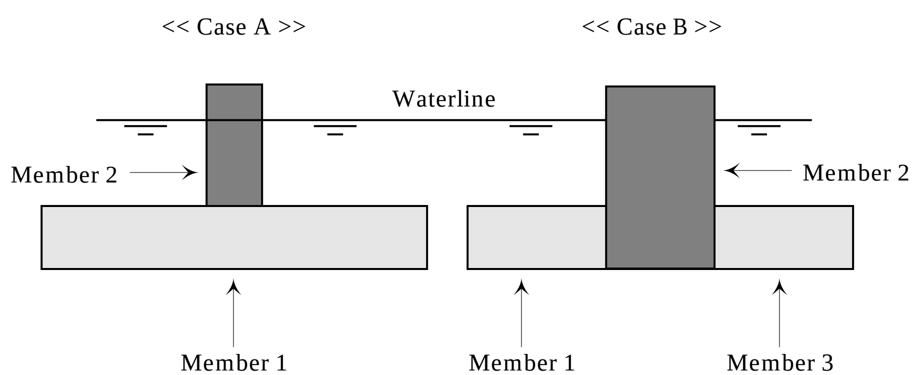
  5) Suppress hydrostatic warning messages ........... No

 Note: the next  8 sub-pages consist of individual member information.

 Enter number of selection: <c/r>
```

See Also: pp 8 ff

Screen 5: The vessel must be logically decomposed into "members" for simulation. These will comprise surface-piercing "columns" and wholly submerged "pontoons". Generally, if a column is much smaller than the pontoon it joins, the combination should comprise 2 members as in Case A below. Otherwise, the column should be defined as ending at the base of the pontoon and the pontoon divided into two members each abutting up against the intervening column as in Case B. In most cases, the two methods will not produce greatly differing results, especially if the case "A" treatment is supplemented with the column blanketing correction discussed on page 10.



Items 2-4: When changed, the new square-law damping coefficient(s) will be applied to all submerged portions of the vessel; damping coefficients for each member can later be individually set, if necessary, on the appropriate member page. Typically, these values should be near 1.0 although in special circumstances, for example the low Reynolds numbers of wave basin testing conditions, values as high as 2 or 3 may be appropriate.

Item 5: To aid in troubleshooting, Semisim uses member data to compute vessel hydrostatic characteristics such as displacement, VKB, VKM, waterplane area, etc. If the computed values are not consistent with values specified on page 27, warnings will be issued at run-time; these can be suppressed using this option. The warnings should be disabled with caution.

```
                    +++ Member Specification +++

  1) Member number:  1 of  8
  3) Axial cross-section profile: Circular/elliptic

  4) Member dimensions (Mx,My,Mz) ..........     12.60     12.60     12.10
  5) Cross-sectional area ............................    124.70 square meters


 10) (Vx,Vy,Vz) coordinate of member base:       38.33     30.00      8.00
 11) Base end termination type: Wall terminated

 12) (Vx,Vy,Vz) coordinate of member top:        38.33     30.00     20.10
 13) Top end termination type:  Water-piercing

 15) Added mass/moment coefficients: Computed (deep water assumption)
 16) (Mx,My,Mz) Added mass coefficients:          1.00      1.00      0.00
 17) (Mx,My,Mz) Added moment coefficients:        1.00      1.00      0.00

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 2.00      2.00      2.00
 20) (Mx,My,Mz) Drag moment coefficients:         2.00      2.00      2.00

 ("C", "D", "I" to Copy, Delete, Insert)
```

See Also: pp 8 ff

This sub-page describes a vertical, column-type member as can be seen from the identical plan-view locations (Vx,Vy) of the member base and top. The decomposition is according to the "pontoon-dominant" scheme described on pp 8 ff, as can be seen from the member base-end termination type and the vertical location of the member base atop the pontoon. (See the figure accompanying Appendix B).

Item 1: For purposes of identification, each member is given a unique member number. To access a particular member, select item 1 and input the desired number.

Item 3: Members normally have a well-defined long (or symmetry) axis (the member "Mz" axis). A cross-sectional slice perpendicular to that axis reveals a "rectangular", "circular/elliptic" or "rectangular/elliptic" cross section. "Rectangular" members have relatively sharp corners, "circular/elliptic" members have no corners and "rectangular/elliptic" members comprise an intermediate rectangular form with highly rounded corners.

Item 4: Two coordinate systems are needed to supply the information required on this page; a "Vessel" system (Vx,Vy,Vz) and a "Member" system (Mx,My,Mz). Member *dimensions* are given in the Member system (Mx,My,Mz).

The "Member System" is a Member-fixed right-handed system with origin at member centroid and Mz pointing along *either* the largest member dimension (the "member axis") *or* along an axis of symmetry; (Mx,My) are perpendicular to Mz. There are two cases of importance:

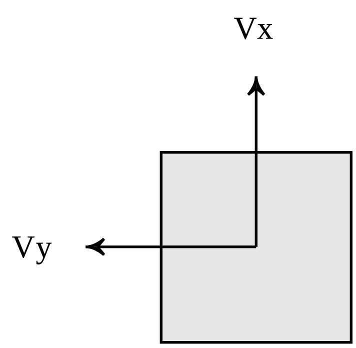
1. If Mz is *vertical* the (Mx,My,Mz) and (Vx,Vy,Vz) directions are *identical*.

2. If Mz is *not* vertical, then Mx lies orthogonal to Mz in a vertical plane containing Mz. My is defined by Mx, Mz, and the requirement that the coordinate system conform to the right-hand rule.

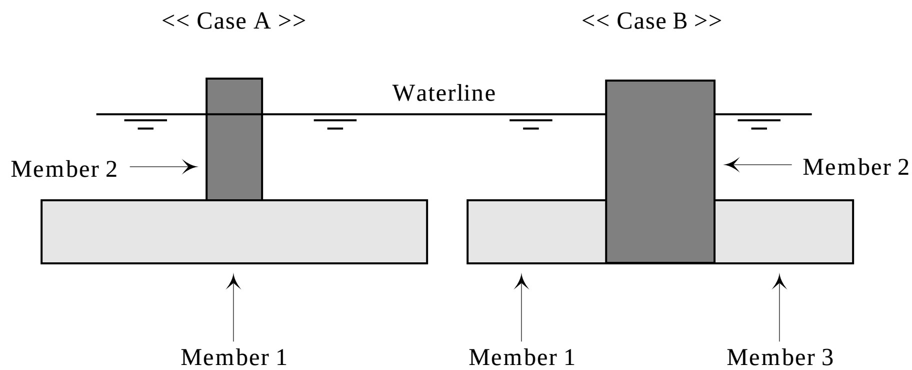
Item 5: The member area intercepted by a member-slicing plane perpendicular to the Mz axis.

Items 10-12: Two coordinate systems are needed to supply the information required on this page; a "Vessel" system (Vx,Vy,Vz) and a "Member" system (Mx,My,Mz). Member base and top *coordinates* are given in the Vessel system (Vx,Vy,Vz).

The "Vessel System" is a right-handed coordinate system with center at baseline (usually keel level) directly above or below vessel waterplane centroid. Vx is positive forward (towards the bow), Vz positive upwards and Vy positive to port (left when facing forwards). The Vessel system is the same for all members.



Items 11-13: "Termination type" determines how hydrodynamic added masses and driving forces are calculated near member ends. A "wall terminated" end abuts against another submerged member of comparable or larger size, a "Water-piercing" end is out of the water, and a "Free, submerged" end allows circulation of water without interference from nearby members. Cases A and B (below) illustrate a common ambiguity. In Case A, both ends of Member 1 are "Free" while Member 2 has a "Piercing" and a "Terminated" end. In Case B Members 1 and 3 both have "Free" and "Terminated" ends while Member 2 has a "Free" and a "Piercing" end.



Item 15: Member added mass coefficients can be specified by the user or computed internally. The internal computation will proceed according to a deep-water assumption or with a free-surface correction to account for the proximity of a submerged member (usually a pontoon) to the waterline. The surface correction formally applies *only* to horizontal members.

Items 16-17: The Mx added mass coefficient relates to member accelerations in the Mx direction. The Mx added moment coefficient relates to member angular accelerations about the Mx axis. Deep-water added mass and moment coefficients for member accelerations perpendicular to the axis of a very long circular cylinder are 1.0.

Items 18 - 20: Member drag coefficients are used for calculation of resonant damping and hydrodynamic driving forces associated with square-law drag effects. They must be specified by the user. The Mx drag coefficient relates to member motions in the Mx direction. The Mx drag moment coefficient relates to member angular motions about the Mx axis. Typically, the drag coefficients will be approximately 1, although larger values are sometimes useful to simulate the sub-critical Reynolds numbers and incomplete flow separation associated with model test conditions.

```
                    +++ Member Specification +++

  1) Member number:  8 of  8
  3) Axial cross-section profile: Rectangular

  4) Member dimensions (Mx,My,Mz) ..........      8.00     16.00    100.00
  5) Cross-sectional area ............................    128.00 square meters

 10) (Vx,Vy,Vz) coordinate of member base:      -50.00     30.00      4.00
 11) Base end termination type: Free, submerged

 12) (Vx,Vy,Vz) coordinate of member top:        50.00     30.00      4.00
 13) Top end termination type:  Free, submerged

 15) Added mass/moment coefficients: Computed (with surface correction)
 16) (Mx,My,Mz) Added mass coefficients:          2.25       .64       .02
 17) (Mx,My,Mz) Added moment coefficients:         .56      2.05       .46

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 2.00      2.00      2.00
 20) (Mx,My,Mz) Drag moment coefficients:         2.00      2.00      2.00

 ("C", "D", "I" to Copy, Delete, Insert)
```

Notes: This sub-page describes a horizontal, pontoon-type member as can be seen from the constant vertical coordinate (Vz) of the member base and top. The decomposition is according to the "pontoon-dominant" scheme described on pp 8 ff, as can be seen from the member end termination types and the single-member pontoon. (See the figure accompanying Appendix B).

```
       ****  Screen 6: Regular Wave Characteristics  ****


 1) Number of different periods (Max 100): 25
 2) Periods (seconds) --
          6.00         7.00         8.00         9.00        10.00        11.00
         12.00        13.00        14.00        15.00        16.00        17.00
         18.00        19.00        20.00        21.00        22.00        23.00
         24.00        25.00        26.00        27.00        28.00        29.00
         30.00

 3) Use constant wave height or wave slope:  height
 4) Wave height       7.00  meters

 5) Number of wave headings (Max  12):  2
 6) Wave headings (degrees) --
         90.00       135.00
```

See Also: pp 14 ff Screen 6: This regular wave period array establishes which periods will be used for RAO evaluations; the value of wave height or wave slope chosen here is used in calculation of nonlinear responses. The wave slope/height selection is a toggle. Note the discussion in Chapter 3 regarding use of the regular wave height/slope parameter. Selection of items 2 or 5 will result in appearance of a SubScreen which facilitates the required data input. Note that the wave direction convention used here and elsewhere is that of wave "heading"; a wave heading of 180 degrees corresponds to waves coming *from* 0 degrees ("on the bow"; this differs from the normal meteorological convention for which a "North" wind is a wind blowing from, and not to, the North). Because of symmetry, any 180 degree ambiguity in wave heading has no effect on RAO magnitudes for the six primary degrees of freedom, although it does affect the sign of their phases and the RAO magnitudes and phases of composite variables, such as accelerations or displacements at selected points on the vessel.

```
  -- Table of wave periods (seconds) --

 1)    6.00      16)   21.00
 2)    7.00      17)   22.00
 3)    8.00      18)   23.00
 4)    9.00      19)   24.00
 5)   10.00      20)   25.00
 6)   11.00      21)   26.00
 7)   12.00      22)   27.00
 8)   13.00      23)   28.00
 9)   14.00      24)   29.00
10)   15.00      25)   30.00
11)   16.00
12)   17.00
13)   18.00
14)   19.00
15)   20.00

31) Auto repeat

32) Delete a row & collapse array
33) Insert a null row & expand array
34) Add a constant value to each array element
35) Add a constant value to each array element (modulo 360)
```

```
  -- Table of wave headings (degrees) --

 1)   90.00
 2)  135.00

 3) Auto repeat

 4) Delete a row & collapse array
 5) Insert a null row & expand array
 6) Add a constant value to each array element
 7) Add a constant value to each array element (modulo 360)

Enter number of selection: <c/r>
```

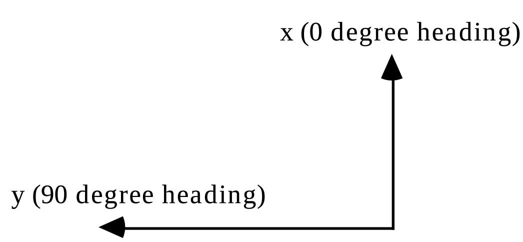
SubScreens 6a & 6b: These SubScreens display the "Auto Repeat" feature of the Editor applied to the input of regular wave periods and headings required for simulation. By selecting the "Auto Repeat" item number, prompts will be issued to permit automatic input of multiple values beginning at a user-specified first value and separated by a fixed user-specified interval. The prompts for the required user input are self-explanatory. If equally spaced periods are not desired, the values for each wave period can be entered individually. The "Delete a row" and "Insert a row" options are self explanatory and are normally used when a nonuniform array of values has been input and one or more has been left out or repeated by accident.

Notes:

- The regular wave period array specified here is used for computation of RAOs and for spectral integrations required to characterize motion and load response to random seas. The array should span all wave periods at which substantial irregular wave or swell energy exists. Whenever irregular wave computations are to be done, the wave periods *must* be equally spaced; use the "Auto Repeat" feature to assure equal spacing.

- Regular wave RAOs can be computed at each wave period using either uniform wave height or slope. The value of height or slope chosen should reflect the irregular waves of primary interest, if any, in the following way: For uniform regular wave heights, the regular wave height chosen should approximately equal the irregular wave height of interest divided by the square root of two. For uniform regular wave slopes, the height of the regular wave whose period matches the spectrum peak period should approximately equal the irregular wave height divided by the square root of two.

- Angles are defined in a "right-handed" earth-fixed global coordinate system with z positive upwards. The zero of angle is in the positive x direction; angles increase in a counter-clockwise direction. Thus, 90 degrees lies along the positive y axis. "Heading" is the direction towards which waves are headed, so 180 degree waves progress towards negative x and 90 degree waves progress towards positive y. With a vessel heading of zero degrees, the global coordinate system coincides with the vessel coordinate system.



```
       ****  Screen 7: Irregular wave specifications  ****

  1) Simulate irregular waves?   Yes
  2) Wave type:  Mean JONSWAP
  3) Number of wave headings (Max  37):   2
  4) Wave headings (degrees) --
        90.00       135.00

                        -- Wave parameters --
  5) Number of irregular wave cases for each heading (Max  6):  2

  6) Significant height in meters
         7.50        10.00
  7) Spectrum peak period (seconds)
        12.00        15.00

 20) Use long-crested irregular wave model
```

See Also: pp 16 ff

Screen 7: If irregular waves are required for the simulation, the irregular wave toggle must be set to "yes", which action will call up Screen 7 in its entirety.

Item 2: Available built-in wave spectra fall into five categories: (1) One-parameter spectra (i.e., Pierson-Moskowitz, which requires significant wave height specification only); (2) Two-parameter spectra (Bretschneider and the specialized two-parameter JONSWAP spectra, which require specification of significant wave height and spectral peak period); (3) Five-parameter spectra (i.e., a full JONSWAP implementation); (4) The Legacy Custom Spectrum (which requires user-supplied spectral values at each period of the specified regular wave period array of Screen 6); and (5) the WAVSPEC.txt spectral option, which has no restrictions as to the period values used for spectral data.

To change to a different spectrum choice, select Item 2 and a SubScreen will appear to accomplish the spectrum type selection.

Items 3-4: The selection procedure for irregular wave heading(s) is the same as for regular waves, and there is no connection between the regular and irregular wave headings chosen; they are independently specifiable. As in the case of regular waves, "wave direction" means the direction that the biggest waves are heading, which is normally the direction of the mean wind velocity vector. Note that this differs from the normal meteorological convention for which a North wind is a wind blowing from, and not to, the North.

Item 5: This selects the number of identifiable irregular wave conditions which will be run for each irregular wave heading specified. Some care should be exercised here to guard against exponential explosion in output volume. Note that 37 directions times 6 wave cases is 222 individual irregular wave conditions, which would generate a considerable volume of RAO data.

Items 6-7: Depending on whether a single-parameter wave spectrum (i.e. Pierson-

Moskowitz) or a two-parameter spectrum (e.g., Bretschneider) has been selected, one must specify the irregular wave height (one-parameter case) or wave height and spectral peak period (two-parameter case).

Item 20: To simulate short-crested irregular waves representing an azimuthally spread distribution of irregular wave energy, Item 20 must be toggled to "Use azimuthal spreading of irregular wave energy". In this case items 21-23 will appear for the specification of wave spreading parameters. The peak of the wave spectrum, when considered a function of azimuthal angle for fixed wave frequency, is presumed to occur at the "wave heading" specified in item 4. Wave crest shortening is accomplished in the Simulation by assuming that the azimuthal distribution of wave energy can be approximated by a power of the cosine of the angle away from the direction of maximum seas.

Note: Items 21-23 only display if item 20 is toggled to the "azimuthal spreading" option.

Item 21: The wave spreading index is the power "p" of cosine in a "$\cos^p$" wave energy distribution with azimuthal angle. The wave energy spectrum is thus

$$S'(\omega,\theta) = S(\omega)\bullet K\bullet\cos^p(\pi\bullet\theta/\theta_c) \qquad -\theta_c/2 < \theta < +\theta_c/2$$
$$S'(\omega,\theta) = 0. \qquad \mathrm{abs}(\theta) > \theta_c/2$$

where S represents the direction-*independent* wave energy spectrum, ω is wave frequency and θ is azimuthal angle, with $\theta = 0$ corresponding to the direction associated with the maximum seas. K is a normalization constant. Wave energy is evidently limited to an angular sector within $\theta_c/2$ degrees on either side of zero. θ_c must be > 0 but is otherwise not restricted.

Exponents ("p") in the range 2-4, and θ_c values near 180 degrees, have been found useful to match the azimuthal distribution of wave energy in many cases of naturally occurring wind-driven waves. Note that in principle the use of a very large spreading index in the Simulation should cause all measures of dynamical response to approach those obtained using the long-crested irregular wave model since long crested waves represent the limiting case of an extremely peaked azimuthal distribution. This can, in fact, be used as a test of the proper functioning of the azimuthal spreading feature. It should, however, be noted that the two methods of simulating long-crested waves, although theoretically equivalent in the limit of large spreading index, will in practice only lead to approximately the same results because of the built-in maximum spreading index (p = 67) and the limited fineness of the angular integration interval (Item 23).

Item 22: This is the size (in degrees) of the angular sector encompassing all approaching wave energy ("θ_c"). θ_c must be positive but is otherwise not restricted. Historically, a value θ_c of 180 degrees has been used, simulating waves coming from one-half of the azimuthal circle, with zero energy at and beyond +/- 90 degrees from the direction of maximum wave energy. In most practical cases θ_c will be equal (or close to) 180 degrees; however, θ_c can have any positive value and can be adjusted to simulate conditions, such as the eye of a hurricane, in which wave energy approaches from *all* directions. Specifically, for values of θ_c greater than 360, the distribution of wave energy with angle will possess components from all directions. In particular, a very large value of θ_c will produce a wave field which is nearly azimuthally symmetric (equal wave energy in all sectors), as quantified in the expression for $S'(\omega,\theta)$ above.

Item 23: The specified wave-energy sector "θ_c" must be broken into a user-specified number of angular wedges; this grid of wedges is used in the integration over angles required to characterize motion and load response to seas containing azimuthally-spread wave energy. The number must be an even integer, which requirement is enforced by the program. The default value is 6, which means the angular spacing will be 30 degrees for θ_c = 180. Although this seems rather coarse, the smoothness of the cosine function and the relatively slow variation in vessel RAOs with wave heading angle means that only a small number of angular intervals need be utilized in the integrations. The maximum assignable number is 12. The computer time required for simulation is a sensitive function of this number because vessel RAOs at all angular integration points must be computed whether or not their output has been requested by the user (only specifically user-requested RAOs are output--the rest are used in statistical calculations and then discarded).

```
-- Irregular wave types --

1)  Pierson-Moskowitz
2)  Mean JONSWAP
3)  Sharp JONSWAP
4)  Squat JONSWAP
5)  General JONSWAP
6)  Bretschneider
7)  WAVSPEC.txt input file
8)  Legacy Custom Spectrum

Enter number of selection:
```

See Also: pp 16 ff SubScreen 7a: This is the spectral type option SubScreen, which results from the selection of item 2 on Screen 6. The detailed features of the spectra provided are beyond the scope of this manual, but the following items should be noted:

Item 1: The **Pierson-Moskowitz** spectrum is a widely used single-parameter spectrum comprising a specific representation of a "fully developed" wind-driven sea condition. Only the significant wave height is specified for this spectrum.

Items 2-5: The **JONSWAP** spectrum[1] resulted from a synthesis of data compiled in the North Sea and is a five-parameter spectrum whose most notable characteristic is a somewhat narrower spectral bandwidth (i.e. a more peaked spectrum) than other widely-used spectra. Three special two-

[1] Rye, H., Byrd, R.C., and Torum, A., "Sharply Peaked Wave Energy Spectra in the North Sea", Offshore Technology Conference Proceedings paper #2107, pp 739, 1974.

parameter cases of this five-parameter spectrum are incorporated into the Simulation in addition to the full five-parameter spectrum. The JONSWAP parameters for each of these cases follow:

Mean JONSWAP -->	$\gamma = 3.3$,	$\sigma_a = .07$,	$\sigma_b = .09$
Sharp JONSWAP -->	$\gamma = 4.2$,	$\sigma_a = .05$,	$\sigma_b = .07$
Squat JONSWAP -->	$\gamma = 7.0$,	$\sigma_a = .68$,	$\sigma_b = .123$
General JONSWAP -->	γ, σ_a, σ_b user-specified		

The "Mean" incarnation is the one normally identified with JONSWAP; the "Sharp" spectrum is somewhat higher and more narrow (i.e., slightly more swell-like) while the "Squat" spectrum has a lower spectral peak and is rich in long-period wave components and poor in short-period components.

"γ" above corresponds to the Greek letter gamma occurring in the referenced paper while "σ" above corresponds to the Greek letter sigma occurring in that paper. The elimination of three parameters of the five-parameter JONSWAP spectrum in the first three choices above reduces each of the three derived JONSWAP spectral types to a two-parameter spectrum. They therefore become completely defined once the significant wave height and spectral peak period have been selected by the user.

Item 6: The **Bretschneider** spectrum is a widely used and convenient two-parameter spectrum which also requires specification of both significant wave height and spectral peak period. It has a somewhat greater bandwidth than commonly used JONSWAP spectra (although it can be represented by the full JONSWAP implementation with appropriate parameter values). It is equivalent to the so-called ISSC two-parameter spectrum except that one specifies the peak spectral period for the Bretschneider spectrum, while the ISSC spectrum is usually specified in terms of the mean period. The distinction is not important because either (mean or peak) can be derived from the other. The spectrum peak period has a much clearer physical significance and a much greater bearing on vessel motions than the mean period.

Item 7: This item permits user specification of a wave height spectrum via a textfile input mechanism; see "WAVSPEC.txt" in Appendix H.

Item 8: The **Legacy Custom Spectrum** is discussed below.

```
  Specify spectral densities at regular wave periods

  1)     .00      16)     .00
  2)     .00      17)     .00
  3)     .00      18)     .00
  4)     .00      19)     .00
  5)     .00      20)     .00
  6)     .00      21)     .00
  7)     .00      22)     .00
  8)     .00      23)     .00
  9)     .00      24)     .00
 10)     .00      25)     .00
 11)     .00
 12)     .00
 13)     .00
 14)     .00
 15)     .00

 26) Auto repeat

 27) Delete a row & collapse array
 28) Insert a null row & expand array
 29) Add a constant value to each array element
 30) Add a constant value to each array element (modulo 360)
```

SubScreen 7aa: This "Sub-SubScreen", which is accessed by selection of item 8 on SubScreen 7a, allows input of a user-specified wave spectrum. Although "Auto repeat" input is allowed, it is of limited value here since the spectral densities at each wave period are not in general simply related to one another. No checking is done to see that values have actually been provided. If all values are zero, it is likely that the simulation will crash due to divide by zero errors in the statistical routines. To use the custom wave spectrum, wave spectral energy in appropriate units (ft^2sec/radian for English units; m^2sec/radian for metric) must be specified at each of the periods in the regular wave period array on page 33. The wave spectrum must be defined so that the total area under the spectral curve between angular frequencies of (0,infinity) is equal to the variance {"sigma squared", $(r.m.s.)^2$ or (standard deviation)^2} of the sea surface elevation. See also page 16.

Note: If the supplied spectrum is given in terms of Hertz (cycles/second) rather than angular frequency (radians/second), each spectral value must first be divided by 2π to convert to angular frequency values.

```
--- Irregular wave headings ---

 1)   90.00
 2)  135.00

 3) Auto repeat

 4) Delete a row & collapse array
 5) Insert a null row & expand array
 6) Add a constant value to each array element
 7) Add a constant value to each array element (modulo 360)

Enter number of selection: <c/r>
```

```
--- Irregular wave significant heights ---

 1)    7.50
 2)   10.00

 3) Auto repeat

 4) Delete a row & collapse array
 5) Insert a null row & expand array
 6) Add a constant value to each array element
 7) Add a constant value to each array element (modulo 360)

Enter number of selection: <c/r>
```

```
--- Irregular wave spectrum peak periods ---

 1)   12.00
 2)   15.00

 3) Auto repeat

 4) Delete a row & collapse array
 5) Insert a null row & expand array
 6) Add a constant value to each array element
 7) Add a constant value to each array element (modulo 360)

Enter number of selection: <c/r>
```

SubScreens 7b-7d: These are analogous to one another and to the regular wave SubScreen 6b.

```
              ****  Screen 8: Background swell characteristics  ***

 1) Specify background swell? .......................   Yes


 2) Swell significant height ........................       3.00 meters
 3) Swell significant period ........................      18.00 seconds
 4) Swell spectral bandwidth ........................        .10

 5) Lock swell heading to irregular waves? ........   No
 6) Global swell heading ............................      30.00 degrees

Enter number of selection: <c/r>
```

See Also: pp 17

Screen 8: This is the swell selection Screen. It is fully displayed only if the swell request toggle shows "yes". Swell period, significant height and direction are required. Zero values for the swell period or height when the swell toggle shows "yes" will cause the Simulation to crash. The internal swell spectrum used is a Gaussian function of wave frequency, with spectral peak at the specified significant period and user-specified bandwidth (i.e., spectrum width at half maximum divided by peak frequency). The total area under the Gaussian curve is proportional to the ocean surface level variance. Because swell is assumed to be extremely narrow-banded, the swell spectrum peak period, swell significant period, average swell period, etc., are all assumed to be equal to each other. Angles are defined as for regular waves.

Note: A reasonable spectral bandwidth value, in the absence of better information, is the SeaSoft default value of 1/10.

Item 5: The swell heading can have a single fixed value (in the global coordinate system) for all irregular wave directions or can be locked with a "relative" angle to each requested irregular wave direction. Thus, when a relative swell direction is requested, the angle specified here is *added* to each specified irregular wave direction to produce the swell direction applying to that particular irregular wave request.

```
****  Screen 9: Output options  ****

 1) Surge  2) Sway   3) Heave  4) Roll   5) Pitch  6) Yaw
    Yes       Yes       Yes       Yes       Yes       Yes

 7) RAO units for angular motions: degrees/ degrees
 8) Report motions & loads at "natural" rotation centers

Note ---> Coordinates for the following are in meters

11) Output accelerations at selected points on vessel?   No
12) Output velocities at selected points onvessel?       No
13) Output relative motion at selected points on vessel? Yes

14) Number of points of interest (Max 49):  4
15) Enter point coordinates
16) Substitute relative motion for displacement data?    Yes
17) Motion is relative to free surface

Enter number of selection: <c/r>
```

Screen 9: This is the output options Screen discussed on page 17 ff.

Items 1-6: The degree of freedom selections are yes/no toggles.

Item 7: The RAOs for angular motions are commonly given in either dimensionless units (e.g., degrees of motion/degree of wave slope) or dimensional units (e.g., degrees of motion/foot of wave amplitude). Item 7 toggles between these two common angular RAO conventions.

Item 8: For a "free body" (e.g., a vessel in empty space, free of hydrodynamic influence), the center of gravity (or more accurately, center of mass) is that point to which an arbitrary force can be applied without producing *any* angular motions of the body. Due to coupling between fluid and vessel motions, the central role of the center of gravity in dynamical evaluations for floating vessels is compromised. For example, the "natural" roll center for a floating object lies at that point above the keel through which a transverse (sway-directed) force will produce *no* roll moment and hence no roll motion. Due to the presence of the enveloping fluid, this "natural" roll center lies in general somewhat below the vessel center of gravity; its position can be roughly described as the center of the combined vessel mass and hydrodynamic "sway added mass". Note that in general, the "natural" roll and pitch centers will lie at different levels above the keel, resulting from the inequality in sway and surge hydrodynamic added mass. Vessel forces and motions will be reported relative to the vessel center of gravity or the appropriate "natural" centers depending on the state of this toggle.

Items 11, 12, 13: Specification of vessel-fixed points chosen for special treatment is accomplished by toggling these items from "No" to "Yes", which will cause additional menu items to appear. There is no check that non-zero data has, in fact been entered into the point coordinate arrays. Neglecting to input the coordinate data will not cause the Simulation to crash, but may produce uninteresting data. Accelerations are those which would be measured by an accelerometer fixed to the vessel at the specified location. This differs in general from the second time derivative of the displacement vector at that location by the variable direction of gravity (in vessel-fixed coordinates) arising from angular motions. Velocities are computed as the first time derivative of the corresponding displacements.

Item 14: Specification of the number of points at which acceleration, velocity or displacement motion data is desired. These items are visible *only* if one of the items 11, 12, 13 is toggled to "Yes".

Item 15: See the SubScreen description below. This item is visible *only* if one of the items 11, 12, 13 is toggled to "Yes".

Item 16: This toggle substitutes the "relative motion" (between points on the vessel and water particle motions in the undisturbed wave field) for the absolute motion (i.e., displacement) of those points. (See item 17 below.) This is useful, for example, in estimating "air gap" statistics; that is, the amount of green water impinging on various overhanging structures or on the degree of bow immersion, if any. Interpretation of "air gap" data is complicated slightly by the fact that the variations reported may, depending on the state of the item 17 flag (below), occur about a nonzero mean value, unlike the variations for all other dynamical variables in the Simulation. (As noted above, he water surface is assumed to be undisturbed by the presence of the vessel in this calculation, which will usually result in a slight underestimate of air gap variation.) Thus an r.m.s. single amplitude air gap variation of 10 feet (significant variation of 20 feet) for a point whose mean position was 20 feet above mean water line would produce wave impingement by approximately one-third of the incident wave crests since the two r.m.s. (two sigma) level is exceeded in one-third of the wave cycles (Ref: the definition of Significant Wave Height).

Item 17: This item selects the fluid source points to be used in the relative motion RAOs, when requested. Available options are:

(1) a point on the water *surface* directly above or below the specified point(s) (useful for "air gap" evaluations) or

(2) a point *beneath* the mean surface at the precise location (including depth) of the specified vessel point(s).

In the latter case, depth attenuation of the wave field is taken into account in the relative motion evaluation; also the mean value of a "relative displacement" RAO variable is evidently zero in this case, unlike the "air gap" situation (case 1 above) where the mean value is commonly nonzero.

```
>>> Enter coordinates for motions evaluation
           x          y          z
 1)      30.00      30.00      40.00
 2)      30.00     -30.00      40.00
 3)     -30.00      30.00      40.00
 4)     -30.00     -30.00      40.00

 5) Copy a row to all others
 6) Delete a row & collapse array
 7) Insert a null row & expand array
 8) Rotate ALL coordinates counter-clockwise about z axis
 9) Translate ALL coordinates by a constant vector (dx,dy,dz)
10) Fill array with incremental rotations of row 1

Enter number of selection: <c/r>
```

SubScreen 9a-9c: This SubScreen is activated by selection of item 15 on Screen 9; it provides for input of specific coordinate values at which acceleration, velocity or displacement data is desired. The operation of this Screen is self-explanatory. Note that this is an instance in which all three coordinate values are entered on a single line, separated by commas, in response to the prompt (not shown above) produced by selecting one of the coordinate item numbers for modification. Note also the coordinate convention: x positive forward, y positive to port (left when facing forward), z positive upwards; origin at vessel baseline directly below the center of gravity.

Note:

The extensive "coordinate manipulation" options available on this page exist for manipulating and processing large amounts of coordinate data. To compute the locations of fairleads situated on a turret table, for example, input the first & rotate that value into all the remaining locations.

```
                  ****  Screen 10: More output options  ****


 1) Output force/torque RAOs ................. Yes
 2) Output motion RAOs ....................... Yes

 4) Square-law driving force treatment:

    <<Resonant damping ONLY, no square-law driving forces>>

 5) Utilize ONLY square law driving forces .................... No
 6) Simulate TLP mooring ("phantom weight") ................... No

 9) Output goes to Disk, on logged drive
10) Debug option is off

Enter number of selection: <c/r>
```

See Also: pp 20 ff

Screen 10: This is a second output options Screen.

Items 1-2: Permit selection or de-selection of RAO output; RAO output might be disabled, for example, if only statistical output were needed.

Item 3: If azimuthal spreading of wave energy has been specified, RAO data for intermediate angles on either side of the direction of maximum seas can be included or excluded from program output, as desired. Here item 3 is invisible because long-crested irregular waves were requested on Screen 7.

Item 4 : Semisim offers several options for the treatment of the square-law hydrodynamic driving and damping forces acting on submerged members. See this item's SubScreen for additional details.

Item 5 : The wave-related driving force acting on a submerged member comprises three components, classified by their phase relationship relative to the water particle acceleration which would exist at the location of interest in the absence of the member: (1) a "reactive" component in phase, (2) a "restorative" component 180 degrees out of phase, and (3) a "dissipative" component 90 degrees out of phase. The dissipative contribution for semisubmersibles is overwhelmingly dominated by square-law drag forces in most situations. This flag permits isolation of the cumulative vessel-wide dissipative contributions to the net vessel driving forces.

This is a rather specialized feature and is primarily used by SeaSoft for debugging the square-law driving force model. It is unlikely to be of wide use to the average analyst.

Items 6-7: In order to obtain approximate RAOs for TLPs, the net vertical mooring load (tendons plus risers, etc.) must be specified. (The displacement should reflect the true hydrostatic displacement, while the vessel gyradii should reflect the "in air" values.) In addition, the natural periods of heave, pitch and roll must be "hardwired" on the vessel specification page, taking into consideration the restoring effects (i.e., the elastic properties) of the tendons and risers.

Item 9: Output can be directed to disk or Screen; see below.

Item 10: The "debug" option, when activated ("on") causes rather unintelligible output to be sent to the Screen during program execution. The principal use of this feature is to aid SeaSoft in determining the cause of program failures. Its activation has no effect on program operation, other than a marked reduction in execution speed.

```
+++ Square-Law Driving Force Treatment Options +++

 1) <<Resonant damping ONLY, no square-law driving forces>>

 2) <<Full square-law driving force calculation at all wave periods>

 3) <<Resonant damping PLUS square-law driving forces on fixed vessel>>

  Enter number of selection: <c/r>
```

SubScreen 10a: Semisim offers several options for the treatment of the square-law hydrodynamic driving and damping forces acting on submerged members. This SubScreen permits selection of the desired treatment.

Item 1: Selection of this item will cause Semisim to ignore altogether hydrodynamic square-law wave forces acting on submerged members. Hydrodynamic damping near vessel resonance periods is computed using an approximate nonlinear procedure producing quasi-linear damping coefficients. The linear damping coefficients thus determined are applied at all wave periods, although because of the lightly-damped nature of these vessels' motions, the influence of damping forces is negligible except very near resonances. The quick turnaround provided by this option is useful for preliminary debugging of new data files and other "quick-look" requirements.

Item 2: Selection of this item will cause Semisim to formally accommodate square-law wave forces acting on all submerged members with a fully nonlinear response calculation. The treatment requires an iterative procedure at each RAO period specified and can result in long execution times. Because of the formal iterative determination of resonant motion amplitudes, the quoted quasi-linear resonant damping coefficients, which characterize the height of resonance response RAOs near resonance, are for guidance only; in a fully nonlinear calculation, linear damping coefficients are, strictly speaking, meaningless. This option represents the most comprehensive and formally exact treatment of wave excitation forces and hydrodynamic damping.

Item 3: Selection of this item will cause Semisim to *approximately* accommodate square-law wave forces acting on all submerged members at each regular wave period specified. This treatment, which does *not* require an iterative procedure, assumes that the vessel remains fixed in space for the purpose of computing square-law forces only. Hydrodynamic damping near vessel resonance periods is computed using an approximate nonlinear procedure producing a quasi-linear damping coefficient which is then applied at all wave periods. This approximate driving force/damping procedure results in greatly reduced execution times while retaining, in a semi-quantitative way, the effects of square-law wave driving forces and accurate response estimation near vessel resonance. Under normal circumstances, this option will produce results comparable to those of the full square-law driving force calculation

```
>>> Output Device Selection: <<<

1) Console
2) Disc

Enter number of selection: <c/r>
```

See Also: pp 3 ff

SubScreen 10b: This SubScreen permits selection of the device to receive output from the Simulation. The normal choice will be the disk, since at the end of execution, the various output disk files produced can be viewed at leisure, inspected for errors and omissions and later sent to the printer if desired. Output vectored to the Screen will be lost once it scrolls by.

```
****  Screen 11: End of Session  ****

1) Exit to operating system and update data file
2) Exit to operating system WITHOUT updating data file

3) Execute simulation in interactive mode
4) Execute simulation in silent mode

5) Produce diskfile of input data
6) Produce "WAVEOUT" file containing regular wave kinematics data

7) Import vessel and environment data from an external file

 (Press <RETURN> to review data.)

Enter number of selection:
```

See Also: pp 74

Screen 11: This is the final Screen of the Editor.

Item 1: This option will save the current *DAT data file (and, if necessary, produce appropriate *BAK and/or LASTBAK backup files) and exit to the operating system. It is used to "save" an incomplete *DAT data file prior to completion of data entry (to avoid data loss from unexpected power outages, for example).

No error checking is involved in this operation; a save and exit will always be accomplished without further ado.

Be warned, however, that repeated invocations of this option will cause the *original* data file to be lost "off the end" of the backup process as repeated [*DAT -> *BAK -> LASTBAK -> deletion] cascades take place. You should therefore always work on a copy of important data files lest you lose valuable data.

Item 2: Permits exit of the Editor with *no changes* to the current data file; all data modifications made during the current editing session *will be lost.*

Item 3: This option causes simulation execution to proceed with a comprehensive information stream directed to the console. This stream is useful for troubleshooting purposes. This is the same as the "E"xecution item available from any editor page or from the opening screen.

Item 4: This option causes the normal console messages that accompany execution to be written instead to a text file ("Diagnostics.stxt"). Because console output is very CPU-intensive, executions will run to completion substantially faster with this option; batch operations in particular will enjoy a considerable speed increase.

The downside: Should unusual conditions be encountered during simulation, there is no mechanism for user control or intervention. Problematic simulations may therefore terminate prematurely in "silent" mode. These should be re-run in "interactive" mode because they can often be coaxed to completion with appropriate user response(s) to run-time error conditions.

Item 5: Produces a diskfile named SEMIN.stxt of all Editor session Screen images for documentation purposes.

Item 6: This option will produce a text file, "WAVEOUT.stxt", with comprehensive tables of regular wave properties applicable to the current simulation (including group and phase speeds, horizontal and vertical water particle accelerations, velocities and amplitudes, etc.) at each of the user-specified wave periods.

Item 7: This option permits importation of vessel and environmental data from any SeaSoft data file. The source file can be from any simulation, but should have been created by or updated to the same version number as the importing application or the imported data may be corrupted. For example, to import Semisubmersible vessel data from a prehistoric "legacy" Moorsim project, you must first update the legacy MOORDAT (or SEMIDAT) file using the *current* version of Moorsim (or Semisim).

Notes: The file selection mechanism is very rudimentary to preserve cross-platform independence: The editor will produce a prompt to which you must supply, in the notation of your operating system, a valid *absolute* or *relative* path to the target file. Some examples:

• *Absolute* path to a file in any directory

C:\SeaSoft\SPM\Proj_1\SEMIDAT	(Windows OS)
HD3:SeaSoft:SPM:Proj_1:SEMIDAT	(Classic Macintosh)
\SeaSoft\SPM\Proj_1\SEMIDAT	(Linux, Mac OS X)

The *relative* path method is simpler and is recommended, especially if the desired import file is in a deeply-buried directory. Place a copy of the target file in your working directory, give it a convenient short name (e.g., "ND" for New Data), and type that short name at the simulation prompt. Then, for a resident file "ND" in the *working* directory, the *relative* path is simply:

ND (All Operating Systems)

Appendix A

Glossary

acceleration RAOs	These are acceleration responses to wave action at selected points on the vessel. Note that these are accelerations that would be measured by a vessel-fixed accelerometer, and are not second order time derivatives of the displacement RAOs.
added mass	Refers to the enhancement of inertial properties of a body undergoing accelerated motion in a surrounding fluid.
angular wedge	The basic unit of angle used in numerical integrations involving angular-dependent quantities, such as wave amplitude spectra, for short-crested ("azimuthally spread") irregular waves.
Auto Repeat	A feature permitting rapid input of a long string of equally spaced input variables, such as regular wave periods.
azimuthal spreading	Refers to irregular sea conditions in which waves approach simultaneously from many directions; i.e., appear short-crested.
background swell	A long-period, long-crested wave underlying, and often obscured by, locally generated wind driven seas.
ballasted	Refers to a condition of partial load for a VLCC or ULCC which represents the smallest practical operational displacement. Normally definition is in terms of freeboard (with ballast condition freeboard typically defined as approximately three to four times full load freeboard); in this manual it refers to any tanker load condition, substantially less than full, which is more appropriately represented by characteristics of a lightly loaded vessel than a fully loaded one.
bilge	The area at the bottom of a vessel where the nearly flat bottom turns upwards to form the nearly vertical side.
bilge keel	A protuberance, situated near the bilge, whose function is to create turbulence in the surrounding fluid during rolling motions, thereby dissipating roll energy and reducing the magnitude of roll excursions.
block coefficient	The displacement of a vessel at a given waterline divided by the product of its molded beam, length, and draft; a measure of the "boxiness" of the hull form (symbolized by Cb).

bracketing	This refers to the procedure of selecting regular wave periods for a simulation of vessel performance in irregular waves; in particular the highest and lowest regular wave periods selected must "bracket" the periods in which the irregular waves, as characterized by the wave spectrum, possess substantial wave energy.
Bretschneider	A widely used two-parameter wave spectrum specified by the significant wave height and the spectral peak period.
Cargo Weight	The difference between "Displacement" and "Lightship Weight".
characteristic period	The ratio of the r.m.s. value to the r.m.s. rate of a particular dynamical variable; same as the zero-upcross period.
characteristic wind speed	The wind speed which would, if acting for an infinite period of time in deep water with no fetch limitations, create waves of the height specified in an irregular wave analysis request. It is a measure of severity of environmental conditions associated with specified sea conditions.
conventional bow	Refers to a conventional tanker bow design with prominent bulbous protrusion and a deeply notched profile; this bow is generally more sharply pointed in plan view than the contrasting "cylindrical" bow shape.
coordinate convention	In this document, x is positive forward, y positive to port (left when facing forward), z positive upwards; origin at vessel baseline directly below the center of gravity.
crossed sea	Simultaneous occurrence of two or more distinct and identifiable wave systems from different sources.
custom spectrum	A user-specified irregular wave spectrum for which values of wave spectral densities are individually specified at each wave period rather than computed from Simulation-resident formulas.
cylindrical bow	Refers to a tanker bow configuration which, viewed from the side, is indented to such a small degree that it appears almost cylindrical; when viewed from the top, this bow type is considerably more blunt and rounded that the contrasting "conventional" type.
Davenport	A widely used wind gust spectrum which is completely defined by the mean wind speed and a surface roughness factor.
deadweight (DWT)	Formally, the deadweight is simply cargo weight and comprises the difference between displacement and lightship weight; it is therefore a continuous function of mean vessel draft condition. However, for our purposes DWT refers to the design maximum deadweight, which corresponds to the maximum cargo carrying capacity of a VLCC and is

	commonly used as a standard measure of tanker size.
diffraction theory	A method for computing wave forces and torques on a body in waves which utilizes potential (ideal) fluid theory in conjunction with a finite lattice of fluid sources and sinks distributed about the body so that the boundary condition of zero velocity component normal to the body surface is approximately satisfied.
displacement RAOs	These characterize the motion of selected points on the vessel. They include contributions from all six degrees of freedom, combined with proper phase to produce three components (vertical, lateral and forward) of displacement at the indicated point. Coordinates are specified in the vessel-fixed frame, as are the components of motion.
double amplitude	See "single amplitude".
dry weight	Refers to the weight of an object out of water, in contrast to the submerged, or "wet" weight which is influenced by the buoyancy of the displaced fluid.
dynamic pressure	One-half of the mass density of a flowing fluid times the square of the flow speed.
dynamical variable	Any of the forces, torques, accelerations, velocities or motions that might be selected for dynamic analysis.
dynamically similar box	A special construct whose most important dynamical properties, including all mass, added mass and hydrostatic properties, are chosen to closely approximate those of the simulated vessel. The selection process insures, in particular, that the important natural periods of roll, pitch and heave are properly modeled.
enhancement factor	A multiplicative coefficient that can be assigned by the user to increase or decrease the relative importance of wind, wave and current forces on the vessel.
Epsilon	The "Fullness Parameter", or "Epsilon", is a measure of variation in waterplane area as draft is varied; an imaginary vessel whose waterplane area was independent of draft would have Epsilon = 1, while a "knife-keeled" vessel whose waterplane went to zero at zero draft would have Epsilon = 0. Epsilon is used internally to model variations of certain vessel hydrostatic properties with changes of draft.
floating point	Refers to a numerical variable in Fortran which is used and stored in memory in exponential format as opposed to simple integer ("fixed point") format.
frequency spectrum	A spectral density function whose independent variable is frequency, as opposed to period or wavelength or otherwise.
Froude-Krilov	Identifies the so-called "principal part" of the driving

	force/torque produced on a fixed structure in the presence of waves. It is the force that would be produced on a floating body were the pressure field due to the waves not affected by the presence of the body itself; a condition that is approximately realized in the long wavelength limit.
Full Load Draft	The design maximum draft of a vessel corresponding to the design maximum load for seagoing operations. This is sometimes known as Maximum Draft, Design Draft, Loaded Draft, Summer Draft, or in England as the Summer Draught.
fully-developed	The limiting sea condition associated with a given wind speed and fetch corresponding to an infinite duration of the specified wind conditions.
global coordinates	Any coordinate system fixed to the earth which provides a suitable reference system for definition of environmental forces and directions. The origin is at the mooring centroid.
GM	The vertical distance between the center of gravity and metacenter. Equal to KM minus KG. Transverse and longitudinal values are associated respectively with KMT and KML.
gyradius	The square root of the ratio between the mass moment of inertia of a body about its center of gravity and its mass. A measure of the angular inertia of a body.
high-frequency	Refers to frequencies contained within the bandwidth of naturally-occurring surface waves; for practical purposes, the range of periods indicated by this qualifier is three to twenty seconds.
high-speed	In this document, high-speed refers to speeds comparable to the phase speed of waves of primary interest to operations, namely six to sixteen seconds or so, which corresponds to deep water phase speeds of thirty to eighty feet per second.
Hull Area	The above- or below-water projected area of the hull, neglecting contribution from any superstructure such as deck houses or production equipment, subject to hydrodynamic forces of wind or current.
in-plane	Refers to points lying in a vertical aligned with the mean offset direction from the quiescent-condition mooring centroid to the displaced (environmentally-determined) mean mooring centroid.
input file	File produced by the Editor containing input data.
JONSWAP	The JOint North Sea WAve Project. A systematic study of North Sea wave conditions carried out in response to the high level of petroleum exploration and development activities there.

KB, KG, KML, KMT	The vertical positions of the center of buoyancy, center of gravity, and longitudinal and transverse metacenters, all measured from the keel baseline.
kgw	Kilogram weight; a unit of weight equal to 1/1000 of a metric ton.
kip	The unit of weight used when English units are selected. Equal to 1000 pounds.
Lightship Weight	The weight of vessel and machinery without crew, cargo or consumables such as stores or fuel.
long crested	Refers to naturally occurring waves, such as swell, which are highly unidirectional and possess long, unbroken wave crests and troughs.
low-frequency	In this manual this refers to oscillations whose period is much greater than periods associated with naturally occurring waves. In particular, the natural periods of oscillation of moored vessels fall in this category, these being typically from one to ten minutes.
Lpp, LBP	The "length between perpendiculars" is a common measure of vessel length that is generally quite close to the length of the waterline at maximum draft condition. It is usually about 5% less than the overall vessel length (LOA).
machine-readable	Data files which remain in machine-encoded format and which cannot be easily interpreted without a computer program equipped to display them, such as the Editor.
mainframe	A large data processing machine with special floating point mathematics processors, high speed circuitry and core addressing capabilities measured in hundreds of megabytes.
metric ton	The unit of weight used when metric units are selected. Equal to the weight of 1000 kilograms at a nominal gravitational acceleration of 9.8 meters/second**2, or roughly 2205 pounds.
moulded depth	For practical purposes, this is the profile height of the hull from keel to main deck level; it is by definition draft plus freeboard in this document.
N.A.	Not Applicable.
natural period	The period with which a vessel will oscillate in a particular degree of freedom, once displaced from equilibrium. For unmoored vessels, this only applies to degrees of freedom (roll, pitch, heave) which experience static restoring forces upon displacement from equilibrium. For highly asymmetric vessels, well-defined natural periods for roll, pitch and heave may not exist due to coupling between the degrees of freedom.

nonlinear damping	The damping associated with the finite viscosity of water is of the "square law" type for conditions of relevance. This means that response characteristics do not scale linearly with wave amplitude. For practical purposes, nonlinear effects can usually be ignored except near system resonances, where natural linear damping contributions, for instance those arising from wave radiation, are small.
paging	The facility in the Editor which permits progress through the input file in either the forward (with a "carriage return") or backward (by inputting a "B") directions.
period spectrum	A spectral density function using wave period as the independent variable, as opposed to wave frequency.
phase	The property of a dynamical variable such as the force or torque which, in the presence of a regular wave, indicates the timing of the maximum of that variable with respect to the occurrence of the wave crest at a prescribed datum, usually the waterplane centroid. A positive phase angle indicates that the maximum of the variable occurs in advance of ("leads") the arrival of the wave crest.
phase speed	The advance speed of a wave crest.
Pierson-Moskowitz	A widely used one-parameter wave spectrum which is completely specified by significant wave height and is characteristic of a fully-developed sea condition in deep water with an infinite fetch.
quasi-linear	This refers to a method of linearization of non-linear phenomenon, such as roll damping, which is accomplished by choosing a linear variable which behaves, in most important respects, like the nonlinear variable to be modeled. In the case of roll damping, this amounts to choosing a linear damping coefficient that produces the same dissipation per regular wave cycle at a given wave height as the true nonlinear roll damping. Unlike a linear damping coefficient, the "quasi-linear" coefficient will depend on the value of wave height selected.
quasi-static	This refers to dynamic phenomena which occur on a time scale which is so long that the system is at each instant very near to an equilibrium configuration; in particular acceleration, damping and other quantities which depend explicitly upon time derivatives of dynamical variables can be considered negligible.
RAO	The Response Amplitude Operator; in practical usage, this refers to the amplitude of the transfer function from wave height (or amplitude, or slope) to force, torque, or motion variables. Formally, however, the RAO includes both the amplitude and the phase of the transfer function.
S.A.	Single Amplitude. Also occurs in the form S.A./S.A. for

	"single amplitude over single amplitude" in the display of RAOs.
scale factor	The force and torque RAOs produced are presented in dimensionless form; except for yaw, these tend to a constant, non-zero value at long wavelengths in the deep water limit. (This constant value is 1 for heave, pitch and roll; for surge and sway the constant value may be greater than one.) The scale factors used to non-dimensionalize the force/torque RAOs are given in the force- and torque-specific printouts. For each degree of freedom, the physical force or torque is determined from the RAO value, the wave amplitude (or slope), and the scale factor by multiplying these three quantities together. The forces and torques for all degrees of freedom except heave scale with wave slope; heave scales with wave amplitude. The units of the scale factors indicate whether to use wave slope or amplitude as a multiplier in determining the dimensional force or torque.
shallow water	Shallow here refers to bottom influence on the phase speed and vertical pressure distribution of waves. For most practical purposes, water can be considered "deep" whenever its depth exceeds 1/4 of the wavelength. The effects of shallow water wave characteristics on vessel performance are taken into account.
sigma	The square root of the variance of a time history such as low-frequency surge motions or wave-frequency loads. It corresponds to the root-mean-square (r.m.s.) value (the standard deviation) of the variable. For many processes, the "significant" value is nearly equal to twice the sigma value.
significant	In most discussions of statistical properties of wave-excited motion or load variables, the significant value is defined as the average of the one-third highest occurrences of the variable in a particular record. For a narrow-banded process whose peaks are distributed according to a Rayleigh distribution, which for practical purposes includes most processes of interest to the offshore industry, the significant value is very nearly equal to twice the root-mean-square (r.m.s.) value of the variable.
significant rate	This is a slight misnomer; in this manual it is twice the r.m.s. value of the time derivative of a particular dynamical variable.
significant value	Formally, this is the average of the one-third largest excursions of a dynamical variable; in this manual it is taken to be twice the r.m.s. value of that variable.
significant wave height	The average of the one-third largest waves in a particular sample of water surface elevations. For spectra of interest in offshore operations, this is very closely equal to four times the square root of the variance of the wave amplitude spectrum, which is also four times the root-mean-square

	deviation of the water surface from the calm water level.
significant wave period	The average period of the one-third largest waves in a particular statistical sample.
Simulation Draft	The mean draft associated with the desired partial loading condition for the target vessel.
single amplitude	This refers to the use of "single amplitude" (S.A.), or mean-to-maximum of variables in quoting RAOs or statistical measures of motions and loads. This is to be compared with "double amplitude" (D.A.) measure which is a measure of peak-to-trough, or maximum to minimum, values of a motion or load variable. The former is exactly one-half the latter, except that S.A./S.A. RAOs are exactly the same as D.A./D.A. RAOs, because the factors of one-half cancel out of the ratio.
spectrum peak period	The period corresponding to the highest spectral density value of a particular frequency spectrum. For well-behaved spectra, this is very close to the "significant period"; or the average period of the significant waves. This contrasts with the "average" wave period which is generally considerably smaller than the significant period and is therefore of limited value in the practical characterization of wave periods.
strip theory	This is a theory of the "diffraction" type which is particularized to the case of long, slender vessels and short wave periods.
superstructure wind area	The projected areas (beam-on and head-on) of above-deck structures, primarily comprising the aft-end deckhouse in conventional VLCC designs.
toggle	This is a generic mechanism used to change an input variable having two possible values, such as metric versus English units specification.
variance	The total area under a spectral plot; it corresponds to the squared root-mean-square fluctuations of the spectral variable about its mean value.
velocity RAOs	These characterize the velocity of selected points on the vessel relative to an inertially fixed coordinate system. Note, however, that both point coordinates and velocity components are resolved in the vessel-fixed frame.
vessel-fixed	This refers, in particular, to a coordinate system fixed with respect to the vessel with x-axis forward, y-axis to port and z-axis vertical. The origin of this system is generally taken to be at keel level below the plan-view centroid of the waterplane area.
waterplane coefficient	The waterplane area of a vessel at a given waterline divided by the product of its waterline beam and length; a measure

of the rectangularity of the waterplane (symbolized by Cwp).

wave amplitude: Because waves are not symmetrical about the still water position, the "wave amplitude" as such is not a well defined quantity. This expression, where it occurs, refers to the vertical amplitude of water particle excursions at the surface. This value is equal to one-half of the wave height for waves satisfying the usual assumption of linearity (i.e. wave height "small" compared to wave length).

wave drift force: This "second order" force, acting on a floating body in the presence of waves, is proportional in strength to the square of the wave amplitude; in an irregular sea it has a frequency spectrum with significant components at zero frequency (static force) and very low frequency. The low-frequency components, sometimes called "slowly variable wave-drift forces" contribute to the excitation of long-period oscillations in moored systems.

wave heading: This is the direction which the waves are actually heading. Thus a 180 degree wave heading is associated with waves impinging on the bow; that is, they are "head waves".

wave height: The elevation as measured from a wave crest to the immediately adjacent trough.

wave slope: The tangent of the angle which a regular wave surface, viewed in profile, makes to the horizontal at the point of maximum slope (near the still-water line).

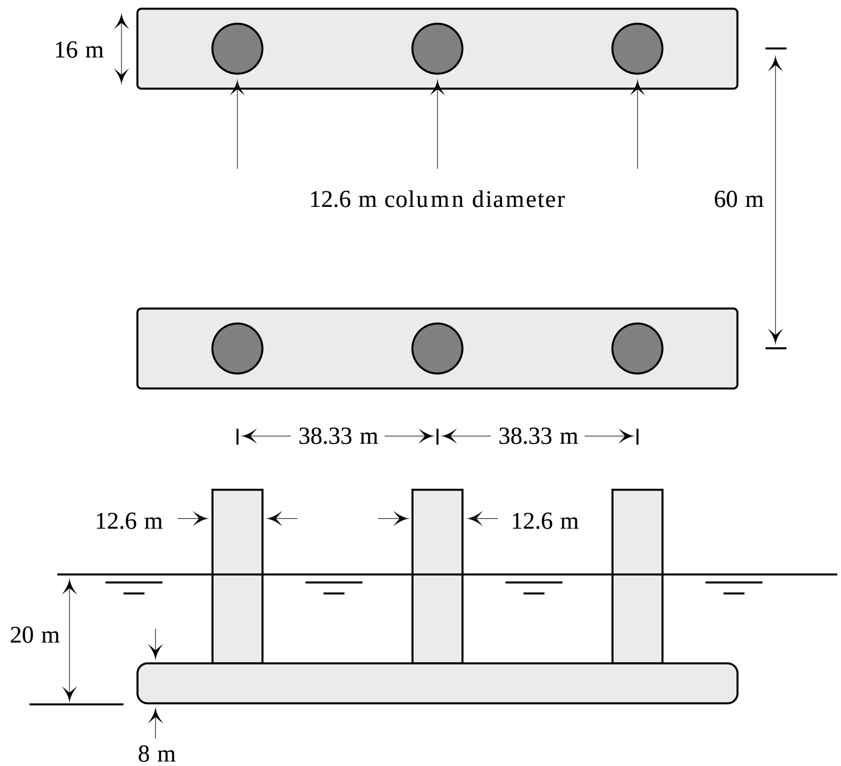
wave spreading index: The exponent of cosine in the analytical description of angular distribution of wave energy used in the Simulation. The short-crested sea spectrum is assumed to be representable in the form f(a)S(w) where a is the angle relative to the direction of maximum seas, f(a) is a power of the cosine of that angle, and S(w) is the frequency spectrum of the wave amplitudes.

zero-upcross period: The ratio of the r.m.s. value to the r.m.s. rate of a particular dynamical variable; same as the characteristic period.

Appendix B

Elementary Sample Problem

As a tutorial aid in the use of Semisim, this appendix includes the data required to carry out a complete semisubmersible motion simulation. The output generated by Semisim corresponding to the input data presented here is given in Appendix Z. The sketch below depicts the submerged dimensions of the vessel.



General Input Data

We assume a vessel with the following physical characteristics:

1. Displacement..35925.00 metric tons

2. Length at waterline..92.60 meters

3. Beam at waterline..60.00 meters

4. Draft ....20.00 meters

5. KMT...26.20 meters

6. KML...28.00 meters
7. VKB...6.60 meters
8. VKG...8.64 meters
9. Water plane area..748.20 square meters
10. Pitch gyradius...30.89 meters
11. Roll gyradius...30.55 meters
12. Yaw gyradius...41.74 meters
13. Bilge radius..00 meters
14. Vessel speed...0.0 kts
15. User-specified pitch damping.........................8.4 percent
16. User-specified roll period..............................23.7 seconds

Member Decomposition Data

We select the simplest member decomposition scheme described in Chapter 3, the "pontoon-dominant" decomposition. This requires for the present example eight distinct members of two generic types, namely 6 columns and 2 pontoons. The generic pontoon member is a right rectangular cylinder of length 100 meters, width 16 meters and depth 8 meters. The generic column member is a 12.6 meter diameter circular cylinder resting atop the pontoon and piercing the water surface. Refer to Chapter 5, page 29 ff for images of the member specification Screens. In order to implement the column-blanketing correction discussed in Chapter 3, note that the columns blanket an area of $3 \times \pi \times (12.6^2)/4$ square meters out of a total of 1600 square meters on each pontoon, or about 23%. The corrected pontoon vertical added mass coefficient, were it to be used, would therefore be (1 + .77)x2.25/2 = 1.99 (see page 33). This correction would be implemented by replacing the internally computed pontoon vertical added mass coefficient (2.25) by the corrected value (1.99), which has *not* been done for this sample problem and the sample output in Appendix Z.

Environmental Conditions

The environmental conditions to be simulated are:

Regular waves:

- Periods from 6 to 30 seconds
- One second period intervals
- Constant wave height of 7 meters

• Regular wave directions of 135 and 90 degrees

Irregular waves

•Mean JONSWAP spectrum with height/period combinations of (7 m, 12 seconds), (10 m, 15 seconds)

• Irregular wave headings of 135 and 90 degrees

• Long-crested irregular waves to simulate wave basin conditions

• Background swell of 3 meter height, 18 second period and 135 degree heading

Output options:

The output is to include all vessel force, torque and motion RAOs for the requested wave directions, and relative motion RAOs at the four corners at deck level. Output is also to include significant irregular wave forces, torques, motions and accelerations for the requested irregular wave conditions. The output should be vectored to the disk.

Screen Display

The Screen copies included in Chapter 5 are printed images of the Editor Screens which would be displayed upon the successful completion of input of the above data. The output from Semisim for this sample case is presented in Appendix Z.

Execution Messages

During execution of Semisim, Screen displays of two types are possible:

- The first type of Screen display occurring during program execution, which is not under the user's control, consists of simple messages indicating the program activity taking place at the moment of message generation. This facility is useful when computation time is slow, perhaps because of heavy CPU load.

- The second type of Screen output is associated with the "debug" flag that can be turned on by the user, as discussed in Chapter 5 (See pp 45). Setting this flag will cause a stream of more or less unintelligible numbers to appear on the Screen as various parts of the program are exercised. This will normally be of little value except to aid SeaSoft in determining causes of program failures.

Appendix C

Sample Problem Output Description

Appendix Z contains output generated by Semisim as a result of a simulation execution using input data presented in Appendix B . Note that the Screen images presented in Chapter 5 also correspond to the same sample problem. This Appendix describes the output in Appendix Z.

RAO Output Notes

The output is largely self-explanatory, but the following items should be noted:

1. The natural damping coefficients are given in percent of critical damping. The damping coefficients reflect the highly nonlinear nature of semisubmersible damping, and will vary with the value for wave height or wave slope chosen for the simulation.

2. The RAO phases are chosen so that zero phase angle corresponds to a wave elevation maximum at the center of the vessel. Thus the heave phase angle should approach zero for long waves, since the vessel behaves as a water particle in that limit and follows the water surface more or less completely. Furthermore, a positive phase angle corresponds to a phase lead in our convention, so that for waves advancing from fore to aft (180 degree wave heading) surge motion at long wavelengths, which leads the wave crest by 90 degrees, should exhibit a positive phase angle of approximately 90 degrees. The surge force in the same circumstance should exhibit a negative phase angle of approximately 90 degrees at long wavelengths, since it lags the wave crest by 90 degrees.

3. The force and torque scale factors given on the force/torque RAO page are chosen so that all forces and torques, with the exception of the yaw torque, scale to a constant value near unity at long wavelengths in the deep water limit. For heave, total force depends only upon wave height in the long wave limit, as can be inferred from the units of the heave force scale factor. The remaining degrees of freedom scale with wave slope rather than wave height. In order to compute the dimensional value of the regular wave torque for pitch, for example, one therefore must multiply the RAO value by the scale factor times the wave slope associated with the regular wave of interest. The force/torque RAOs themselves are totally dimensionless, in contrast to the motion RAOs, which have dimensions as indicated by the units posted above the motion RAO columns.

4. The wave length and wave slope reported in columns two and three of the RAO output tables fully reflect effects of shallow water on the wave.

5. The period reported in column one is *wave encounter* period when a non-zero speed is specified for the vessel. A negative period in this context means that the wave phase speed is less than the vessel's speed component along the wave direction. That is, the vessel is overtaking the wave.

6. The motion RAOs are labelled "quasi-linear". This refers to the way in

which nonlinear effects have been taken into consideration. Basically, an effective linear damping coefficient is used which results in the same dissipation per cycle of motion as the true nonlinear damping would provide. This results in RAOs that are wave-amplitude dependent, which dependence is generally only visible near weakly damped resonance peaks.

7. The following notations appearing on the RAO output pages should be noted:

- AM/PHASE: amplitude/phase of the complex RAO quantity.

- S.A./S.A.: refers to the fact that all RAOs are in terms of "single amplitude" motion divided by "single amplitude" wave elevation (or "wave amplitude"). This is, of course equivalent to "double amplitude" motion divided by "double amplitude" wave elevation (or "wave height"). Similar comments apply to those RAOs which are scaled by wave slope rather than wave elevation.

- X COMP: refers to the x (forward) component of acceleration, velocity or displacement for the locations on the vessel selected for special analysis. Similarly for Y and Z. Note that the components of acceleration reported are those which would be measured by vessel-fixed accelerometers. For example, the x component of acceleration reported includes contributions associated with the non-vanishing projection of the gravitational acceleration vector along the vessel-fixed x axis as a result of a non-zero pitch amplitude.

Irregular Wave Output Notes

Each irregular wave statistics summary reports spectral type, azimuthal spreading condition, wave height, direction and spectral peak period. In addition, a characteristic "fully-developed" wind speed associated with the given conditions is reported. In the case of Pierson-Moskowitz spectra, this is the unique wind speed associated with the 1-parameter spectrum. In other cases, it is the wind speed associated with a Pierson-Moskowitz spectrum of the same significant wave height. When swell has been requested, the swell parameters are reported on this page as well. The following items should be noted:

1. The wave heights reported, whether for one of the special spectral types or for swell, are the *computed* wave heights. They should be close to, but seldom exactly equal to, the *requested* wave heights. If computed values differ by more than 10 or 15 percent from requested values, the simulation should be rerun with a wider range of wave periods or, possibly, in the case of swell, with a finer wave period interval. In the case of irregular wave spectra, the most common cause of "lost wave height" is too large a minimum regular wave period. This specific circumstance is generally of little consequence to vessel motions or loads since short-period waves that are "lost" from the statistical analysis by this error contribute very little to vessel dynamics.

2. The "significant single amplitude value" reported on the statistics output pages is twice the square root of the variance of the amplitude spectrum of the motion or load. This may create some confusion since vessel motions are often reported as "double amplitude" or "peak-to-

peak". To obtain double amplitude values, simply double the significant single amplitude values given.

3. The "significant rate" reported is twice the square root of the amplitude time derivative spectrum, and is a statistical measure of the average rate of change of the variable.

4. The "zero-upcross period" reported is simply the ratio of the significant value to the significant rate and is thus a useful simple measure of the most important periods involved in the motion.

Appendix D

File Management

File Requirements

As discussed earlier, Semisim produces an unformatted input file called SEMIDAT containing the particulars of a given simulation including the vessel, site and environmental characteristics. Once a satisfactory SEMIDAT file has been produced, as determined by satisfactory output from Semisim, the input file should be archived for later use by giving it a more meaningful name and placing a copy of it in an archive area along with the date and purpose for its creation. A copy of the archived file can then, at any later time, be copied to the Semisim work area on the disk, renamed to SEMIDAT, and reworked as necessary for the new simulation. The same procedure should be used to archive a copy of each formatted output file for future reference.

Importance of Archiving SEMIN.stxt

It is *essential* to archive, along with the binary SEMIDAT file, the SEMIN.stxt formatted data file produced with the "Produce diskfile of input data" option on the last editor screen. This is important because it is impossible to view the data in binary files without the Editor. Although it is SeaSoft policy to provide upgrade paths for data files as the Simulation's data structures change over time, these changes may in unusual circumstances make reading very old SEMIDAT files problematic. In such cases it may be advantageous to create a new data file manually from a SEMIN archive.

Appendix E

Theoretical Considerations

This chapter is intended to give a brief overview of the theoretical basis underlying Semisim and an outline of the considerations involved in choosing which aspects of the physical system to emphasize, and which to de-emphasize, in the mathematical model which forms the underlying structure of Semisim. The general approach to the development of Semisim has been to emphasize simulation performance in the cases of principal interest to the offshore industry.

In the following material, extensive mention will be made of two- and three-dimensional "diffraction theories", which comprise the two most common methods for determining hydrodynamic driving forces required for vessel motions calculations. A detailed discussion of these methods goes beyond the scope of this manual, but it should be noted that the two-dimensional ("strip") theories make use of large length/beam and length/draft ratios and fine bow/stern profiles common to seagoing ship-shaped vessels in an approximate "slender-body" scheme that is compromised in particular in the calculation of wave forces on column members. The three-dimensional theories are based on a "brute force" calculation of the hydrodynamic coefficients using finite-element source-sink calculations that are extremely computer-intensive and unsuitable for day-to-day engineering applications. Calculations based on the three-dimensional model are often used in lieu of measurements; this because the theory represents an approximate solution of an "exact" set of governing equations. This use is not justifiable since the "exact" equations are not exact at all, ignoring as they do a wide variety of phenomena associated with fluid motions that are not adequately represented by the potential flow models on which the "exact" theory is based. Whatever their strengths and limitations, use of these analytical models is firmly established in the offshore industry.

Wave Period Considerations

Semisim was designed to give reliable estimates of loads and motions for a wide range of semisubmersibles operating in a variety of sea conditions under those circumstances in which the loads and motions are most important. This choice dictates that performance estimates for long waves take precedence over those for short waves. (For our purposes the dividing line between 'long' and 'short' waves can be taken to be the vessel length.) The central role of longer waves is justified because of the physical connection between larger waves (and therefore greater motions and loads) and longer wave periods. Briefly, the connection results from the following facts: (1) big waves are generated by high wind speeds; (2) the phase speed of the largest waves produced is directly proportional to wind speed; (3) the phase speed of surface waves increases with wave period; hence higher winds give bigger waves of longer wave period and greater wavelength. For "fully developed" deep-water waves the wave period is proportional to the wind speed while the significant wave height is proportional to the square of the wind speed. Note that because of the monotonic relationship between wave period and wave length for surface gravity waves, "long period" and "long wavelength" are synonymous in this discussion.

Mathematical Model

The mathematical model used in the development of Semisim is based upon the usual assumption that the dynamical properties of a vessel are completely determined by its mass properties and underwater geometry. In order to simplify geometrical specification of the vessel, reduce user workload in simulation execution and reduce simulation execution time, the decision was made to develop a simulation which took maximum advantage of powerful simplifications arising naturally out of a long-wave asymptotic approach to vessel dynamics.

Intuitively, it is clear that waves of length comparable to or greater than the vessel length do not appreciably "feel" hull geometrical variations, such as the shape of columns or pontoons, whose dimensions are much less than the vessel length and hence very much less than the wavelength. However, these features can and do effect second-order forces, such as wave drift forces and square-law damping forces, which are not considered by *any* vessel motion program in the calculation of the first-order potential theory hydrodynamic loads under discussion. These second-order phenomena must be handled separately from the potential-flow analysis; for instance, the specification of member hydrodynamic drag characteristics in Semisim are used in nonlinear calculations of this type.

To capitalize on the simplifications arising from the long-wave analytical approach, Semisim treats the vessel as a disconnected collection of submerged members, the forces and moments on which are each analyzed more-or-less exactly, assuming that wave diffraction effects are negligible in the determination of the wave-frequency ("first-order") wave forces. Member-member interactions are accommodated by the simple expedient of categorizing a limited number of possible member end effects which cover the important cases such as pontoon-column interface regions where their plainly exists important interactions between the intersecting members. See also pages 29 ff and 8 ff.

These simplifications are of great utility, given the desired emphasis on long-period waves, for two reasons:

1. The ability to make use of limited, but extremely powerful, analytical results for the three-dimensional added mass and damping properties of simple geometrical shapes in the long period (no wave-diffraction) limit.

2. The ability to use analytically exact closed form expressions for the dominant long-wave contributions to the wave forces and torques acting on the body. In order to arrive at the overall driving forces, these dominant long-wave contributions (the so-called Froude-Krilov contributions) are supplemented by frequency-dependent contributions, related to wave diffraction phenomenon, which are associated with hydrodynamic added mass and damping effects. These frequency-dependent modifications to the long-wave contributions are taken from analytical results for simple underwater shapes, such as right rectangular parallelepipeds or ellipsoids,

with the same beam/length and beam/depth characteristics as the members to be simulated.

Wave Period Limitations

Because of the emphasis on longer wave periods it is reasonable to suppose that Semisim might be less successful at predicting motions and loads in the very short period regime, where wavelengths considerably smaller than the vessel length must be accommodated, than other widely-used vessel motions programs based on conventional diffraction methods. For a number of reasons, however, the superiority of two- and three-dimensional diffraction theories in the short wave regime is of no practical consequence:

1. Because of their fundamental design, semisubmersibles produce extremely small wave diffraction/scattering for waves of importance to vessel motions and exhibit negligible levels of potential damping (that is, wave radiation damping arising from vessel motions) compared to displacement-hull vessels.

2. The motions and loads associated with short periods are small (generally much less than one-tenth as large as motions associated with long-period waves of the same height or slope) and, for most practical purposes, uninteresting. In fact, the motions are so small that their experimental determination, and in particular the crucial determination of their phases, is extraordinarily difficult; for this reason the agreement between measurement and theory is virtually never very satisfying (for short-period waves), regardless of the type of vessel motion analysis used. The detailed calculation of vessel motions in period regimes where vessel motions are practically insignificant is an exercise which can only be justified for academic investigations, and not for engineering applications.

3. The various hydrodynamic nonlinearities associated with bilge damping, wave slap and wave breaking at the hull-sea interface become important in determining vessel motion performance in large waves; no theory based on potential flow analysis (including all frequency-domain vessel motion programs) can account for these effects without extensive nonlinear modifications unrelated to the sophistication of the (potential-theory based) driving force calculations. In particular, the prediction of resonant peak response amplitudes is extremely sensitive to the nonlinear damping model employed, and is almost wholly independent of the sophistication of the potential-flow analysis used to compute potential damping.

4. The commonly accepted "standard" for vessel motion calculations is the three-dimensional diffraction theory. To constrain computational resources, seldom are more than ten to fifteen wave periods (and even fewer wave approach angles) chosen at which to compute the hydrodynamic coefficients, and hence the motions. The calculation of "composite" quantities such as the displacement of a point somewhere on the vessel requires the superposition of all six degrees of freedom with correct phase interrelationships; because such superpositions often create amplitudes which, especially at short wave periods, are more strongly period dependent than the component motions (heave, pitch, etc.), the lack of period resolution enforced by computational expediency on the three-dimensional diffraction theory ruins, to a certain extent, its theoretical ability to give relatively precise motion estimates at each single period selected for simulation.

This shortcoming is especially acute when one requires irregular-wave related superposition integrals over a continuum of wave periods.

5. The facet size selected for diffraction-based programs is typically rather large, again to save on computing time; large facets compromise the potential superiority of diffraction models for simulating vessel response to very short waves; this is because when wavelengths become comparable to the source/sink facet size, computational precision is destroyed.

In summary, the calculation of vessel motions in a seaway is, and will remain for some time to come, an extremely inexact science for which investments to improve on long-wave calculations will, for the larger wave heights of primary interest, pay exceedingly skimpy dividends. One must be content with calculations which will seldom agree with measurements to better than 10 or 20 percent no matter how hard one works at improving any single aspect of the calculations.

Speed Limitation

A speed limitation occurs in the vessel speed feature of Semisim because it corrects only for variation in wave encounter *frequency* when calculating regular and irregular wave response, and *not* variation in pressure around the hull arising from terms in Bernoulli's equation which are proportional to the square of the fluid velocity. These terms, though of second order in the wave height to wavelength ratio for zero speed, become first order in that ratio at finite speed. As a practical matter, this neglect will have only a small influence on simulation performance for vessel speeds up to approximately one-half of the phase speed of the waves of primary interest. Thus, for deep-water waves of ten second period, Semisim's approximate results should be reliable for speeds of up to fifteen knots.

Caveats

Because Semisim has been optimized to perform well at longer wave periods, analyses which require high precision at short wave periods should be undertaken with care. In particular, the phasing of vessel motions at short periods becomes extremely difficult to model accurately with any analytical tool (and, as mentioned earlier, to measure). Because the relative phases between motions in several degrees of freedom are combined to compute motions, velocities and accelerations at specified points on the vessel, judgement must be exercised when utilizing Semisim for short-period applications requiring these features. An example of a questionable application would be the motions of a crane boom used in vessel-to-vessel transfer in light, short period seas. Although Semisim would give a good qualitative estimate of these motions, it should not be used uncritically for quantitative estimates.

Precision

The calculations in Semisim are all carried out in Fortran single precision. The number of significant digits associated with single precision variables varies widely among different Fortran compilers, ranging from only six significant decimal digits to as many as eighteen. For this reason, occasionally a large input value, such as a vessel displacement of

1,000,000.00 will appear in the output as a slightly different value, for instance 1,000,000.71.

Free Surface Effects

Accounting in a meaningful way for the presence of a significant free surface effect in estimating vessel dynamical characteristics requires careful thought and considerable judgment. Generally the effects will be small and therefore can often be ignored altogether. In some installations, however, ballast tanks are so large that their effects on vessel dynamics, in particular pitch and roll motions, can be considerable. In such circumstances, the method of handling the free surface will depend upon what range of wave frequencies are of greatest importance. The lowest "slosh" period of the fluid in the largest tanks should first be estimated. For example, the lowest period of a square tank with side A and fluid depth D is:

$$T = 2\sqrt{[(A\pi/g)/\tanh(\pi D/A)]}$$

Here g is the gravitational acceleration. If this period is short compared to wave frequencies of interest, as it normally will be, the free surface can be taken into account in a dynamic simulation exactly as it is in a static assessment, namely by reducing the vessel CG passed to Semisim by the waterplane moment of inertia of the tank divided by the vessel's displaced volume. If the lowest slosh period is comparable to wave periods of interest the tank, if large enough, can effect vessel motions, in particular pitch and roll, in much the same way as a conventional anti-roll tank. This situation is beyond the current capabilities of Semisim, although the use of information provided by Semisim, when combined with additional theoretical analysis that is beyond the scope of this manual, can produce meaningful motion estimates for this condition.

Shallow Water

Semisim uses the correct shallow-water wave properties in computing the quasi-static, or Froude-Krilov, component of wave forces and torques. However, the vessel added mass and damping characteristics are computed assuming that the vessel oscillates in deep water. Normally this will not have a significant effect on computed motions or loads. However, in extremely shallow water (keel-to-bottom distance comparable to the half-beam of the pontoon) the flow field due to the oscillating vessel will begin to interact with the sea bottom, and some degradation in simulation performance will occur.

Appendix F

Execution Errors

Runtime Problems

The amount of input error checking done by Semisim is extremely limited, in keeping with the necessity of maintaining the degree of flexibility required of programs used by highly trained individuals. By far the most common runtime errors are the result of physically unreasonable input data. This kind of problem can arise from typographical errors, transcription errors or simple omissions of data. When runtime problems of any kind occur, the first course of action is to carefully inspect and re-inspect the input file, especially vessel physical data, to be sure that the data is reasonable.

True code-related runtime problems with Semisim should be rare, although in any computer code of this complexity, programming errors may from time to time surface. When all reasonable measures fail to produce a meaningful simulation, a bug report should be made to SeaSoft.

Error Messages

Error messages which may be encountered during the execution of Semisim are of three types:

1. Error messages generated by the operating system arising from a failure to find Semisim's various executable or data files. Errors of this type may also be generated if the input file cannot be found by the operating system, or if there is inadequate disk space to store the output files generated by Semisim. These messages are system-dependent and are beyond the scope of this manual.

2. Error messages built into the Semisim Fortran code itself. Generally these will suggest a course of action to correct the fault leading to the problem. Examples--

- INVALID SPREADING INDEX...: This message can occur if value less than zero or greater than 67 has been input for the spreading index (see the discussion in Chapter 5). Note that a negative index results in a singularity in the wave spectrum at plus and minus 90 degrees from the maximum sea direction. When this error occurs, the simulation is terminated.

3. Fortran runtime errors. These are errors trapped by the Fortran runtime package. They are typically announced in rather opaque jargon, with references to floating overflows, divide by zero, attempted square roots of negative numbers, and the like. They normally result in immediate program termination. In a complex engineering-oriented analysis code such as Semisim the requirement of maximum flexibility of application is at odds with the highly protective programming practices normally associated with business software. As a result, Fortran runtime errors will from time to time occur. Some situations that may result in these errors include:

• Wave period too short. Wave periods less than four seconds or so can sometimes lead to runtime errors. To explore short period limitations for a particular computer and vessel type, simply execute Semisim repeatedly with shorter and shorter periods and note where the first sign of trouble appears.

• Wave period too long. Same type of problem as too short a wave period.

• Irregular waves or swell specified with zero significant height.

• Regular waves specified with zero height or slope.

Runtime problems will not normally develop if a physically reasonable range of wave periods is requested. Forty second waves, for instance, simply do not occur in nature, and Semisim may have trouble digesting them on some computer installations. Also, two second waves have no influence on vessel motions, and Semisim will not necessarily be able to deal with them. Note that, strictly speaking, the parameter of importance in these discussions is not the wave period, but a dimensionless quantity involving the wave period and the physical dimensions of the simulated body. The wave period values given here assume a body of typical offshore dimensions, that is one measured in hundreds of feet.

Appendix G

Complex Sample Problem

This appendix examines a semisubmersible of considerable underwater complexity in order to illustrate in a concrete way several of the more important options for decomposition of such a vessel into members. The vessel selected for this exercise is similar, *but by no means identical*, to the Ocean America and Ocean Valiant, well-known twin-sister semisubmersibles operated at one time by ODECO, Inc. In particular, the specifications given herein are for illustration purposes only and should *not* be used for simulation of either of the above-mentioned vessels.

All dimensions are in feet unless otherwise indicated. Vessel coordinate values [x,y] are measured in feet from the waterplane centroid, z from keel level, x positive forward, y positive to port (left when facing forwards) and z positive upwards. Sketches and other vessel data appear at the end of this appendix.

Our complex semisubmersible has 26 identifiable underwater members comprising 16 small structural support members which will be the same for all member decomposition options, and 10 principal members comprising 8 vertical columns and 2 horizontal pontoons.

General Observations

Lumped Member Simulations

It is possible to reduce the number of members in the simulation model by a procedure of "lumping" smaller support structures with larger column and pontoon members. In this way the total number of simulated members could fairly easily be reduced to 10; i.e., 8 column members and two pontoon members. To accomplish this, the column members would be simulated to be somewhat larger than they actually are to include both the waterplane areas and displacement of the eight water-piercing support members (see pp. 74), one for each column. The pontoon member volume would include the displacement associated with the 8 fully submerged horizontal cross-members (see pp. 74ff). This procedure would lead to a satisfactory simulation which would execute in a minimum amount of time. However, direct simulation of all support members requires less effort on the part of the user and is probably less prone to input errors although the resulting simulation (which would require a minimum of 26 members) would take more than twice as long to execute as a 10 member "lumped" model.

Minimal Simulations

It is possible to generate a "minimal" simulation, satisfactory for many applications, comprising only 6 members for most semisubmersibles, including the present example; 4 corner column members and two pontoon members. In the present example, this would require lumping not only the small vertically-disposed support members but also the small inboard vertical columns in with the larger corner columns. This procedure, which might be useful in special circumstances, should probably not be undertaken by the casual user since an optimum simulation would require moving the 4 simulated columns inboard slightly from the position of the existing large corner columns. This option will *not* be discussed further at this time.

Pontoon Simulation Procedures

The simplest pontoon simulation procedure is in all cases to construct a single, uniform, right cylindrical pontoon member of appropriate cross-sectional profile. There are two potential shortcomings of this simplification:

1. It is impossible with centrally disposed uniform pontoons to simulate a fore-aft pontoon asymmetry which, to a greater or lesser degree, exists in most vessels. Such a symmetrical model would be incapable, for example, of predicting pitching motions in regular, long-crested beam seas. Generally speaking, however, the fore-aft asymmetry is so slight, and its consequences on vessel motions so insignificant, that the uniform pontoon model is adequate for most simulation requirements. If, for special applications, a fore-aft asymmetry is to be modeled, each pontoon member must be broken into sub-members for modeling purposes.

2. The selection of a single pontoon member automatically produces what we have called a "pontoon-dominant" simulation, in which the column members are disposed atop the pontoons as opposed to passing through them as in a "column-dominant" simulation. For vessels with very large columns and relatively smallish pontoons, the pontoon-dominant procedure, though generally simpler to implement and modify, may produce a slightly inferior simulation.

Recommendations

Our vessel, due to its large pontoon members relative to its column members, is a natural candidate for a "pontoon-dominant" type of member decomposition. In the absence of a need for fore-aft asymmetry, the simplest possible decomposition (26 members in this case) should be used. In this appendix, in order to illustrate general procedures in a comprehensive way, we nonetheless discuss and analyze three distinct options, the "minimal" 26 member pontoon-dominant configuration, a 30 member pontoon-dominant configuration possessing fore-aft asymmetry, and a 30 member column-dominant configuration possessing fore-aft asymmetry.

Support Members

The invariant structural support members and their relevant Editor Screens are given below, with a single Screen devoted to each member family comprising members equivalent except for placement and orientation.

Quantifying Modeling Differences

In the final analysis, the only *quantitative* means to compare two modeling implementations (e.g., a "column-dominant" and "pontoon-dominant"), thereby improving on the admittedly subjective comments here and elsewhere in this manual, is to prepare *both* for simulation and compare the results.

```
                     +++ Member Specification +++

 1) Member number: 13 of 26
 3) Axial cross-section profile: Circular/elliptic

 4) Member dimensions (Mx,My,Mz) ..........     11.00     11.00    153.00
 5) Cross-sectional area ...........................     95.03 square feet

10) (Vx,Vy,Vz) coordinate of member base:      -32.00     76.50     38.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:       -32.00    -76.50     38.00
13) Top end termination type:  Wall terminated

15) Added mass/moment coefficients: Computed (with surface correction)
16) (Mx,My,Mz) Added mass coefficients:          1.01      1.00       .00
17) (Mx,My,Mz) Added moment coefficients:        1.00      1.01       .00

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 large port-to-starboard submerged circular support members lying in a horizontal plane (11' diameter, centers at [x,z] = [±32, 38])

```
                     +++ Member Specification +++

 1) Member number: 12 of 26
 3) Axial cross-section profile: Circular/elliptic

 4) Member dimensions (Mx,My,Mz) ..........      8.50      8.50    130.00
 5) Cross-sectional area ...........................     56.75 square feet

10) (Vx,Vy,Vz) coordinate of member base:      100.00     65.00     38.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:       100.00    -65.00     38.00
13) Top end termination type:  Wall terminated

15) Added mass/moment coefficients: Computed (with surface correction)
16) (Mx,My,Mz) Added mass coefficients:          1.01      1.00       .00
17) (Mx,My,Mz) Added moment coefficients:        1.00      1.01       .00

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 small port-to-starboard submerged circular support members lying in a horizontal plane (8.5' diameter, centers at [x,z] = [±100, 38])

```
                      +++ Member Specification +++

  1) Member number: 17 of 26
  3) Axial cross-section profile: Circular/elliptic

  4) Member dimensions (Mx,My,Mz) ..........      6.00      6.00     88.41
  5) Cross-sectional area ............................     28.27 square feet

 10) (Vx,Vy,Vz) coordinate of member base:       86.00     70.00     38.00
 11) Base end termination type: Wall terminated

 12) (Vx,Vy,Vz) coordinate of member top:        32.00       .00     38.00
 13) Top end termination type:  Wall terminated

 15) Added mass/moment coefficients: Computed (with surface correction)
 16) (Mx,My,Mz) Added mass coefficients:          1.00      1.00       .00
 17) (Mx,My,Mz) Added moment coefficients:        1.00      1.00       .00

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

 ("C", "D", "I" to Copy, Delete, Insert)
```

4 diagonal submerged circular support members lying in a horizontal plane
(6' diameter, endpoints at [x1,y1,z1] = [±86, ±70, 38], [x2,y2,z2] = [±32, 0, 38])

```
                      +++ Member Specification +++

  1) Member number: 23 of 26
  3) Axial cross-section profile: Circular/elliptic

  4) Member dimensions (Mx,My,Mz) ..........      6.00      6.00    128.76
  5) Cross-sectional area ............................     28.27 square feet

 10) (Vx,Vy,Vz) coordinate of member base:       32.00     88.00     38.00
 11) Base end termination type: Wall terminated

 12) (Vx,Vy,Vz) coordinate of member top:        32.00       .00    132.00
 13) Top end termination type:  Water-piercing

 15) Added mass/moment coefficients: Computed (deep water assumption)
 16) (Mx,My,Mz) Added mass coefficients:          1.00      1.00       .00
 17) (Mx,My,Mz) Added moment coefficients:        1.00      1.00       .00

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

 ("C", "D", "I" to Copy, Delete, Insert)
```

4 diagonal water-piercing circular support members lying in the small-columns' vertical plane (6' diameter, endpoints at [x1,y1,z1] = [±32, ±88, 38], [x2,y2,z2] = [±32, 0, 132], angle with vertical = 43.11 degrees)

```
                       +++ Member Specification +++

  1) Member number: 25 of 26
  3) Axial cross-section profile: Circular/elliptic

  4) Member dimensions (Mx,My,Mz) ..........      6.00      6.00    128.76
  5) Cross-sectional area ............................     28.27 square feet

 10) (Vx,Vy,Vz) coordinate of member base:      100.00     88.00     38.00
 11) Base end termination type: Wall terminated

 12) (Vx,Vy,Vz) coordinate of member top:       100.00       .00    132.00
 13) Top end termination type:  Water-piercing

 15) Added mass/moment coefficients: Computed (deep water assumption)
 16) (Mx,My,Mz) Added mass coefficients:          1.00      1.00       .00
 17) (Mx,My,Mz) Added moment coefficients:        1.00      1.00       .00

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

 ("C", "D", "I" to Copy, Delete, Insert)
```

4 diagonal water-piercing circular support members lying in the large-columns' vertical plane (6' diameter, endpoints at $[x_1,y_1,z_1]$ = [±100, ±88, 38], $[x_2,y_2,z_2]$ = [±100, 0, 132], angle with vertical = 43.11 degrees)

Principal Columns and Pontoon Members

4 large corner circular columns
(46' diameter, centers at [x,y] = [±100, ±88])

4 small intermediate columns
(23' diameter, centers at [x,y] = [±32, ±88])

2 submerged rectangular pontoons of nonuniform cross-section at y = ±88

Vessel Physical Data Notes

Published Vessel Data (80' Draft):

Displacement	95,940.00 kips
KMT	72.03 ft
KML	74.78 ft
Pitch Gyradius	103.32 ft
Roll Gyradius	102.76 ft
Yaw Gyradius	124.77 ft
VKG	60.71 ft

As is frequently the case, the physical data supplied for our vessel shows a slight inconsistency which required resolution before proceeding with the simulation. The discrepancy was discovered because internal hydrostatics checks in Semisim failed to confirm the supplied KML, KMT data. The discrepancy is easily demonstrated due to the fact that the *difference* between KML and KMT involves only the waterplane area moments of inertia Ixx, Iyy and not the center of buoyancy VKB, which cannot be known exactly without vessel hydrostatics data:

KML = Iyy/DELTA + VKB
KMT = Ixx/DELTA + VKB
KML - KMT = (Iyy - Ixx)/DELTA.

Here, Ixx, Iyy are waterplane area moments of inertia (with units of ft^4) and DELTA is the vessel displaced volume (1.499e6 ft^3).

Since all the waterplane elements for our vessel are circular or elliptical, their waterplane moment contributions can be computed easily and exactly, either by the simulation itself or by hand, which calculation leads to KML - KMT = 3.20 ft. The published value for this difference is 2.75 ft. Although the error is small, it was sufficient to cause Semisim's calculations of KML, KMT to be in conflict with supplied values, which conflict initiated investigation of the error. To resolve the discrepancy, it was assumed that the supplied KML value was correct and that the KMT value was in error (the calculation of KMT is slightly more prone to error because of the disposition of the oblique vertical-plane support members).

Derived Data:

Ixx/DELTA ....44.04 ft
Iyy/DELTA ....47.25 ft
VKB (= KML - Ixx/DELTA)..27.54 ft
KMT (= Iyy/DELTA + VKB; See note above)..................71.58 ft
Waterplane area ($4\pi[R_L^2 + R_s^2] + 8\pi R_o^2/\cos\{43.1\}$) ....8619.30 ft^2

Here, R_L = large column radius (23'), R_s = small column radius (11.5'), R_o = oblique water-piercing member radius (3').

Editor Screens Common to All Simulation Models

```
**************  Screen 2: Vessel Hydrostatic Characteristics  **************

 1) Vessel displacement ................................   95940.00 k.lbs
 2) Transverse metacentric height (KMT) ................      71.58 ft
 3) Longitudinal metacentric height (KML) ..............      74.78 ft
 4) Vertical center of buoyancy (VKB) ..................      27.54 ft
 5) Vertical center of gravity (VKG) ...................      60.71 ft
 6) Vessel water plane area ............................    8619.30 ft^2
 7) Length of vessel at waterline ......................     280.00 ft
 8) Beam of vessel at waterline ........................     280.00 ft
 9) Mean vessel draft ..................................      80.00 ft
```

```
***********  Screen 3: Vessel Gyradii and Bilge Specifications  ***********

 1) Pitch Gyradius ....................................    103.32 ft
 2) Roll Gyradius .....................................    102.76 ft
 3) Yaw Gyradius ......................................    124.77 ft

 4) Bilge radius at maximum beam station ...............       .00 ft
 5) Is there a bilge keel .............................   No

 9) Vessel speed (knots) ..............................       .00
10) Trim angle (deg; bow down positive) ................       .00
11) Heel angle (deg; starboard down positive) ..........       .00
```

```
***********  Screen 4: Vessel Period and Damping Specifications  ***********

 1) Heave damping is ................................... Computed
 3) Pitch damping is ................................... Computed
 5) Roll damping is .................................... Computed

 7) Heave period is .................................... Computed
 9) Pitch period is .................................... Computed
11) Roll period is ..................................... Computed
```

The submerged volumes required for the calculation of pontoon and column characteristics follow:

$$\Delta_{columns} = 4\pi[R_L^2 + R_s^2]\{80\text{-}28\}\ ft^3 = 4.32e5\ ft^3$$

$$\Delta_{horizontal\ xmembers} = 2\pi R_{Lx}^2\{176 - 23\} + 2\pi R_{sx}^2\{176 - 46\}\ ft^3 + 4\pi R_{ox}^2\sqrt{}\{68^2 + 88^2\} = 5.64e4\ ft^3$$

$$\Delta_{vertical\ xmembers} = 8\pi R_o^2\{80 - 38\}/\cos(43.1) = 1.30e4\ ft^3$$

$$\Delta_{pontoons} = \{DELTA - \Delta_{columns} - \Delta_{horizontal\ xmembers} - \Delta_{vertical\ xmembers}\} = 1.00e6\ ft^3$$

Here, R_{Lx}, R_{sx} and R_{ox} refer to the radii of the large (11' diameter), small (8.5' diameter) and oblique (6' diameter) cross members.

Pontoon-Dominant Simulation

The simplest pontoon-dominant simulation which includes all identifiable members comprises the 26 members identified below. The simplest pontoon-dominant simulation which, in addition, possesses a fore-aft asymmetry comprises 30 members total, with each pontoon member being subdivided into 3 submembers. We begin by modeling the 26 member configuration which under most circumstances would be the configuration of choice for this vessel.

26 Member Model

Because the pontoons are tapered port-to-starboard at the bow and top-to-bottom as well as port-to-starboard at the stern, a reasonable and easily determined "effective pontoon" can be derived by choosing a uniform scale factor f to multiply all pontoon dimensions equally. That is, if B_e, L_e, D_e are the "effective" beam, length and depth of the simulated pontoons then

$B_e = B•f$
$L_e = L•f$
$D_e = D•f$

where

$B_eL_eD_e = .5x\Delta_{pontoons} = f^3•[BLD]$

B = 57', L = 390', D = 28'.

This procedure yields f = .93 and

$B_e = 52.99'$
$L_e = 362.55'$
$D_e = 26.03'$

The pontoons' top is best placed so that the vertical center of buoyancy of the simulated pontoon matches that of the actual pontoon. As this information is not always available (as in the present example), a reasonable alternative is to place the pontoon *top* at the same height above baseline (28') as the top of the actual pontoon; in the present case this requires a simulated pontoon centerline vertical endpoint position of (28 - 26.03 + (26.03)/2) = 15'. This procedure will generally yield a satisfactorily close match between the desired and simulated center of buoyancy and produces as an added benefit the most reasonable estimates for hydrodynamic wave forces on the pontoons, which forces are at their greatest at the pontoon tops due to the decay of wave amplitude with increasing depth.

Pontoon Cross-Section Characterization

Because of the rounded corners of the pontoon cross-section, they are formally intermediate between a rectangle with square corners and an elliptical form with no straight sides. The cross-sectional form is nonetheless highly rectangular and choice of "rectangular" versus "rectangular/elliptic (intermediate)" is subjective; either choice will lead to a satisfactory simulation, although the "intermediate" option is most appropriate for the present example.

Water-Piercing Element Lengths

The lengths and endpoints of all water-piercing members should be selected so that they will in fact pierce the waterplane under all draft conditions to be investigated. The simulation will find the correct waterline on each piercing member and ignore portions of that member lying above the waterline.

Column Blanketing Correction

The column blanketing percentage is given by

$b.p. = 2\pi[R_L^2 + R_s^2]/B_eL_e = .22\ (22\%)$

The corrected pontoon added mass coefficient for vertical pontoon motions is therefore

.5x[1 + (1 -b.p.)]x2.14 = 1.91

where 2.14 is the Semisim-generated vertical added mass coefficient (with surface proximity correction) for the isolated "effective" pontoon, which coefficient *lacks* column-pontoon interfacial interference effects.

Fore-Aft Asymmetry Considerations: the 30 Member Model

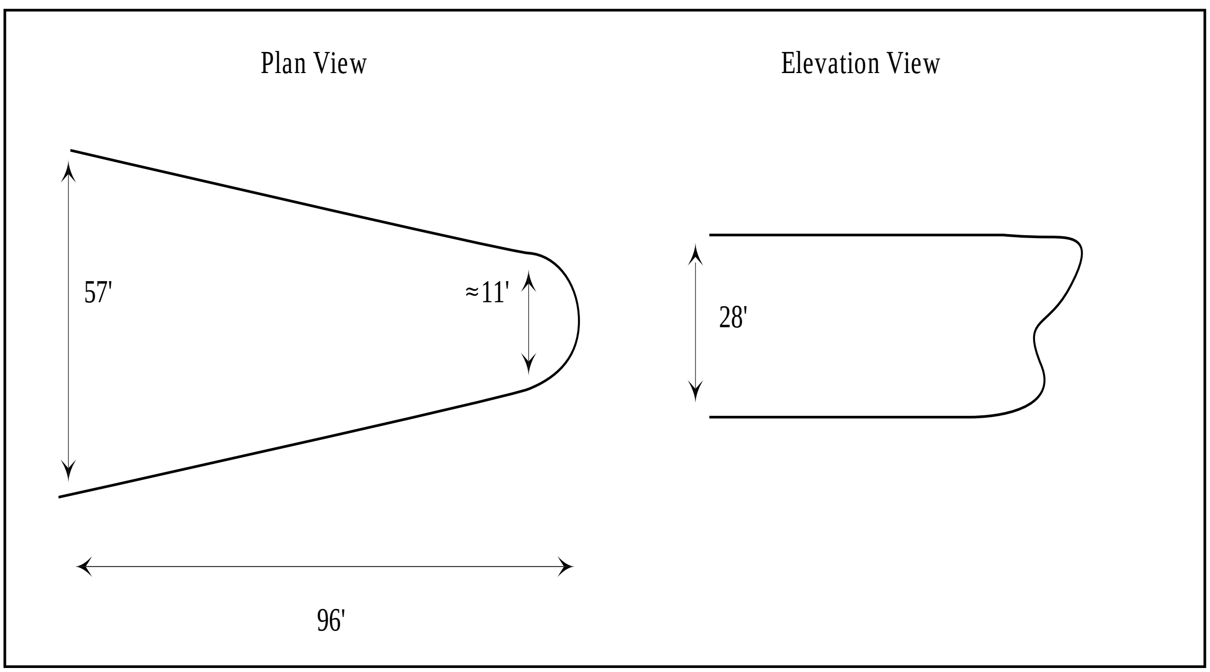
If it is necessary to simulate the fore-aft asymmetry of the pontoons, they must be divided into submembers. The simplest subdivision for the O.A. comprises three submembers for each pontoon (i.e., fore, aft and center submembers). This subdivision produces a simulation model comprising a total of 30 members. The specification of these members is subjective but should be volumetrically correct and at least qualitatively correct with regard to shape. *Slight variations in member dimensions and volumes arising from subjective choices in the specification will have no significant effect on simulation performance.*

Center Pontoon Submember

The center pontoon submembers are simply right rectangular parallelepipeds of dimension 28'x57'x200' and total volume

$\Delta_{\text{pontoon centers}}$ = 2x28x57x200 = 6.38e5 ft^3

Forward Pontoon Submember



The forward submembers' total volume can be estimated, in the absence of more detailed volumetric information, using a simple trapezoidal model with a plan-view base of 57', top of ≈ 11':

$$\Delta_{\text{pontoon bows}} = 2x[.5x(57 + 11)x28x96] = 1.83e5\ ft^3$$

while the total stern submember volume can be estimated by differencing

$$\Delta_{\text{pontoon sterns}} = \Delta_{\text{pontoons}} - \Delta_{\text{pontoon bows}} - \Delta_{\text{pontoon centers}} = 1.81e5\ ft^3$$

The forward submember (beginning at the center of the forward large column) is most simply simulated by a 28' deep x 96' long uniform member since it is approximately full *depth* along its length. The rectangular dimensions producing the required volume are thus

B_{ef} = 34'
L_{ef} = 96'
D_{ef} = 28'

The aft submember (ending at the center of the aft large column) is most simply simulated by a 57' wide x 94' long uniform member since it is nearly full *width* along its length. The rectangular dimensions producing the required volume are thus

B_{ea} = 57'
L_{ea} = 94'
D_{ea} = 16.87'

The vertical height of the centerline for the aft member is, from a theoretical perspective, best chosen so that the *top* of this member lies at the correct height (28' above baseline) which requires a simulated centerline vertical endpoint position of (28 - 16.87 + (16.87)/2) = 19.56'. (This choice, among the several possible *simple* alternatives, produces the best estimate of member vertical center of buoyancy since the member is larger near the top; in addition, the largest and most important water particle accelerations, which occur at the shallowest depth in a wave field, "see" the full pontoon top width at the correct depth with this procedure.)

Column Blanketing Correction

If a pontoon-dominant simulation is desired, the vertical added mass coefficients of all three pontoon submembers should be adjusted for column blanketing. (Alternatively, a column-dominant simulation, described below, may be used. The latter procedure requires slightly more effort in determining pontoon submember dimensions but avoids the necessity of a blanketing correction.)

For a pontoon-dominant simulation, the usual rule should be applied to each submember:

Center Submember

A_{pon} = 200x57
$A_{\text{mid col}}$ = 2x415.48
$A_{\text{end col}}$ = 1x1661.9
$[A_{\text{mid col}} + A_{\text{end col}}]/A_{pon}$ = .219

corrected added mass coefficient = 2.27x[1 + (1 -.219)]/2 = 2.02

Forward Submember

A_{pon} = 96x34
A_{col} = 1661.9/2
A_{col}/A_{pon} = .255
corrected added mass coefficient = 1.26x[1 + (1 -.255)]/2 = 1.10

Aft Submember

A_{pon} = 57x94
A_{col} = 1661.9/2
A_{col}/A_{pon} = .155
corrected added mass coefficient = 3.16x[1 + (1 -.155)]/2 = 2.92

Note that the uncorrected added mass coefficients (2.27, 1.26, 3.16) were simulation-produced values for the specified member dimensions using the water surface-corrected formulation. Also note that the column blanket area for the large corner columns has been divided equally between its surrounding submembers in each case.

26 Member Pontoon-Dominant Simulation: Member Definitions

```
                  ****  Screen 5: Member Particulars  ****

 1) Number of members (Max 50): 26
 2) Default member Mx-damping coefficient ...........      1.00
 3) Default member My-damping coefficient ...........      1.00
 4) Default member Mz-damping coefficient ...........      1.00

 5) Suppress hydrostatic warning messages ........... No

Note: the next 26 sub-pages consist of individual member information.
```

```
                     +++ Member Specification +++

 1) Member number:  1 of 26
 3) Axial cross-section profile: Circular/elliptic

 4) Member dimensions (Mx,My,Mz) ..........     46.00     46.00     80.00
 5) Cross-sectional area ............................   1661.90 square feet

10) (Vx,Vy,Vz) coordinate of member base:      100.00     88.00     28.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:       100.00     88.00    108.00
13) Top end termination type:  Water-piercing

15) Added mass/moment coefficients: Computed (deep water assumption)
16) (Mx,My,Mz) Added mass coefficients:          1.00      1.00       .00
17) (Mx,My,Mz) Added moment coefficients:        1.00      1.00       .00

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

4 large corner circular columns (46' diameter, centers at [x,y] = [±100, ±88], base at z = 28')

```
                     +++ Member Specification +++

 1) Member number:  5 of 26
 3) Axial cross-section profile: Circular/elliptic

 4) Member dimensions (Mx,My,Mz) ..........     23.00     23.00     80.00
 5) Cross-sectional area ............................    415.48 square feet

10) (Vx,Vy,Vz) coordinate of member base:       32.00     88.00     28.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:        32.00     88.00    108.00
13) Top end termination type:  Water-piercing

15) Added mass/moment coefficients: Computed (deep water assumption)
16) (Mx,My,Mz) Added mass coefficients:          1.00      1.00       .00
17) (Mx,My,Mz) Added moment coefficients:        1.00      1.00       .00

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

4 small intermediate columns (23' diameter, centers at [x,y] = [±32, ±88], base at z = 28')

```
                      +++ Member Specification +++

  1) Member number:  9 of 26
  3) Axial cross-section profile: Rectangular/elliptic (intermediate)

  4) Member dimensions (Mx,My,Mz) ..........     26.03     52.99    362.55
  5) Cross-sectional area ............................   1379.33 square feet

 10) (Vx,Vy,Vz) coordinate of member base:     -181.28     88.00     15.00
 11) Base end termination type: Free, submerged

 12) (Vx,Vy,Vz) coordinate of member top:       181.28     88.00     15.00
 13) Top end termination type:  Free, submerged

 15) Added mass/moment coefficients: User-specified
 16) (Mx,My,Mz) Added mass coefficients:          1.91       .55       .02
 17) (Mx,My,Mz) Added moment coefficients:         .49      1.98       .49

 18) Drag/drag moment coefficients: User-specified
 19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
 20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

 ("C", "D", "I" to Copy, Delete, Insert)
```

2 submerged rectangular pontoons of uniform cross-section at y = ±88

30 Member Pontoon-Dominant Simulation: Member Definitions

```
                  ****  Screen 5: Member Particulars  ****

  1) Number of members (Max 50): 30
  2) Default member Mx-damping coefficient ...........      1.00
  3) Default member My-damping coefficient ...........      1.00
  4) Default member Mz-damping coefficient ...........      1.00

  5) Suppress hydrostatic warning messages ........... No

 Note: the next 30 sub-pages consist of individual member information.
```

```
                      +++ Member Specification +++

 1) Member number:  9 of 30
 3) Axial cross-section profile: Rectangular/elliptic (intermediate)

 4) Member dimensions (Mx,My,Mz) ..........     16.87     57.00     94.00
 5) Cross-sectional area ............................    961.59 square feet

10) (Vx,Vy,Vz) coordinate of member base:     -194.00     88.00     19.56
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:      -100.00     88.00     19.56
13) Top end termination type:  Free, submerged

15) Added mass/moment coefficients: User-specified
16) (Mx,My,Mz) Added mass coefficients:          2.92       .33       .04
17) (Mx,My,Mz) Added moment coefficients:         .22      2.69      1.29

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 submerged rectangular pontoons of nonuniform cross-section at y = ±88; Aft Submember

```
                      +++ Member Specification +++

 1) Member number: 11 of 30
 3) Axial cross-section profile: Rectangular/elliptic (intermediate)

 4) Member dimensions (Mx,My,Mz) ..........     28.00     57.00    200.00
 5) Cross-sectional area ............................   1596.00 square feet

10) (Vx,Vy,Vz) coordinate of member base:     -100.00     88.00     14.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:       100.00     88.00     14.00
13) Top end termination type:  Wall terminated

15) Added mass/moment coefficients: User-specified
16) (Mx,My,Mz) Added mass coefficients:          2.02       .58       .00
17) (Mx,My,Mz) Added moment coefficients:         .58      2.27       .47

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 submerged rectangular pontoons of nonuniform cross-section at y = ±88; Center Submember

```
                      +++ Member Specification +++

 1) Member number: 13 of 30
 3) Axial cross-section profile: Rectangular/elliptic (intermediate)

 4) Member dimensions (Mx,My,Mz) ..........     28.00     34.00     96.00
 5) Cross-sectional area ............................    952.00 square feet

10) (Vx,Vy,Vz) coordinate of member base:      100.00     88.00     14.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:       196.00     88.00     14.00
13) Top end termination type:  Free, submerged

15) Added mass/moment coefficients: User-specified
16) (Mx,My,Mz) Added mass coefficients:          1.10       .85       .04
17) (Mx,My,Mz) Added moment coefficients:         .71      1.07       .04

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 submerged rectangular pontoons of nonuniform cross-section at y = ±88; Forward Submember

Column-Dominant Simulation

From a strictly logical perspective, all eight columns would be taken to near keel depth in a column-dominant simulation. This would evidently require that each pontoon be divided into five submembers. This would produce an eminently satisfactory simulation but the smallness of the inboard columns suggests in this case a somewhat simpler alternative, namely that only the four large corner columns be considered for full-depth column-dominant treatment, while the smaller inboard columns be treated in the "pontoon-dominant" fashion. We will adopt this strategy in the present discussion, although it must be noted that any of these procedures will produce satisfactory simulation results; the choice is largely one of personal preference.

The four large columns are considered to project downwards to near keel level rather than terminating at the 28' pontoon top level. The volume associated with this increased column depth must be removed from the pontoon submembers. This is most simply carried out by shortening the length of each pontoon submember by an appropriate amount. The forward column, which is surrounded by full depth (28') pontoon submembers, should project to baseline. Because the aft pontoon submember is *not* full depth, the aft column draft can be most reasonably be made equal to the average of the pontoon submember drafts on either side, namely .5x[28 + 16.87] = 22.44'

Central Submember

Corrected length = 200 - [.5x(28 + 22.44)x1661.9]/[28x57] = 173.74

Forward Submember

Corrected length = 96 - .5x[28x1661.9]/[28x34] = 71.56

Aft Submember

Corrected length = 94 - .5x[28x1661.9]/[16.87x57] = 69.80

Note that in the transfer of volume from pontoon submembers to the large column members, each pontoon submember surrounding a particular large column has shared in the volume transfer in an equitable way.

Strictly speaking, the central pontoon submember added mass coefficient should have a blanketing correction applied for the small inboard columns, although the smallness of these columns is such that this correction could easily be neglected in this example. We include it for completeness.

A_{pon} = 173.74x57
A_{col} = 2x415.48
A_{col}/A_{pon} = .084
corrected added mass coefficient = 2.27x[1 + (1 -.084)]/2 = 2.17

Note that the unmodified pontoon added mass coefficient, 2.27, is independent of the central pontoon length because of its "wall terminated" end conditions (see the pontoon-dominant decomposition with 200 ft long pontoon central submember above.)

30 Member Column-Dominant Simulation: Member Definition Screens

```
                 ****  Screen 5: Member Particulars  ****

 1) Number of members (Max 50): 30
 2) Default member Mx-damping coefficient ...........      1.00
 3) Default member My-damping coefficient ...........      1.00
 4) Default member Mz-damping coefficient ...........      1.00

5) Suppress hydrostatic warning messages ........... No

Note: the next 30 sub-pages consist of individual member information.
```

```
                      +++ Member Specification +++

 1) Member number:  1 of 30
 3) Axial cross-section profile: Circular/elliptic

 4) Member dimensions (Mx,My,Mz) ..........     46.00     46.00    110.00
 5) Cross-sectional area ............................   1661.90 square feet

10) (Vx,Vy,Vz) coordinate of member base:      100.00     88.00       .00
11) Base end termination type: Free, submerged

12) (Vx,Vy,Vz) coordinate of member top:       100.00     88.00    110.00
13) Top end termination type:  Water-piercing

15) Added mass/moment coefficients: Computed (deep water assumption)
16) (Mx,My,Mz) Added mass coefficients:           .88       .88       .06
17) (Mx,My,Mz) Added moment coefficients:         .68       .68       .00

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 large forward corner circular columns (46' diameter, centers at [x,y] = [±100, ±88], base at z = 0')

```
                      +++ Member Specification +++

 1) Member number:  3 of 30
 3) Axial cross-section profile: Circular/elliptic

 4) Member dimensions (Mx,My,Mz) ..........     46.00     46.00    110.00
 5) Cross-sectional area ............................   1661.90 square feet

10) (Vx,Vy,Vz) coordinate of member base:     -100.00     88.00      5.56
11) Base end termination type: Free, submerged

12) (Vx,Vy,Vz) coordinate of member top:      -100.00     88.00    115.56
13) Top end termination type:  Water-piercing

15) Added mass/moment coefficients: Computed (deep water assumption)
16) (Mx,My,Mz) Added mass coefficients:           .88       .88       .06
17) (Mx,My,Mz) Added moment coefficients:         .68       .68       .00

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 large aft corner circular columns (46' diameter, centers at [x,y] = [±100, ±88], base at z = 5.56')

```
                    +++ Member Specification +++

 1) Member number:  5 of 30
 3) Axial cross-section profile: Circular/elliptic

 4) Member dimensions (Mx,My,Mz) ..........     23.00     23.00    110.00
 5) Cross-sectional area ............................    415.48 square feet

10) (Vx,Vy,Vz) coordinate of member base:       32.00     88.00     28.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:        32.00     88.00    138.00
13) Top end termination type:  Water-piercing

15) Added mass/moment coefficients: Computed (deep water assumption)
16) (Mx,My,Mz) Added mass coefficients:          1.00      1.00       .00
17) (Mx,My,Mz) Added moment coefficients:        1.00      1.00       .00

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

4 small intermediate columns (23' diameter, centers at [x,y] = [±32, ±88], base at z = 28')

```
                    +++ Member Specification +++

 1) Member number:  9 of 30
 3) Axial cross-section profile: Rectangular/elliptic (intermediate)

 4) Member dimensions (Mx,My,Mz) ..........     16.87     57.00     74.61
 5) Cross-sectional area ............................    961.59 square feet

10) (Vx,Vy,Vz) coordinate of member base:     -194.00     88.00     19.56
11) Base end termination type: Free, submerged

12) (Vx,Vy,Vz) coordinate of member top:      -119.39     88.00     19.56
13) Top end termination type:  Wall terminated

15) Added mass/moment coefficients: Computed (with surface correction)
16) (Mx,My,Mz) Added mass coefficients:          3.01       .32       .06
17) (Mx,My,Mz) Added moment coefficients:         .18      2.43      1.27

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 submerged rectangular pontoons of nonuniform cross-section at y = ±88; Aft Submember

```
                      +++ Member Specification +++

 1) Member number: 11 of 30
 3) Axial cross-section profile: Rectangular/elliptic (intermediate)

 4) Member dimensions (Mx,My,Mz) ..........     28.00     57.00    173.74
 5) Cross-sectional area ............................   1596.00 square feet

10) (Vx,Vy,Vz) coordinate of member base:      -86.87     88.00     14.00
11) Base end termination type: Wall terminated

12) (Vx,Vy,Vz) coordinate of member top:        86.87     88.00     14.00
13) Top end termination type:  Wall terminated

15) Added mass/moment coefficients: User-specified
16) (Mx,My,Mz) Added mass coefficients:          2.17       .58       .00
17) (Mx,My,Mz) Added moment coefficients:         .58      2.27       .47

18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

2 submerged rectangular pontoons of nonuniform cross-section at y = ±88; Center Submember

```
                      +++ Member Specification +++

 1) Member number: 13 of 30
 3) Axial cross-section profile: Rectangular/elliptic (intermediate)

 4) Member dimensions (Mx,My,Mz) ..........     28.00     34.00     71.56
 5) Cross-sectional area ............................    952.00 square feet

10) (Vx,Vy,Vz) coordinate of member base:      124.44     88.00     14.00
11) Base end termination type: Wall terminated

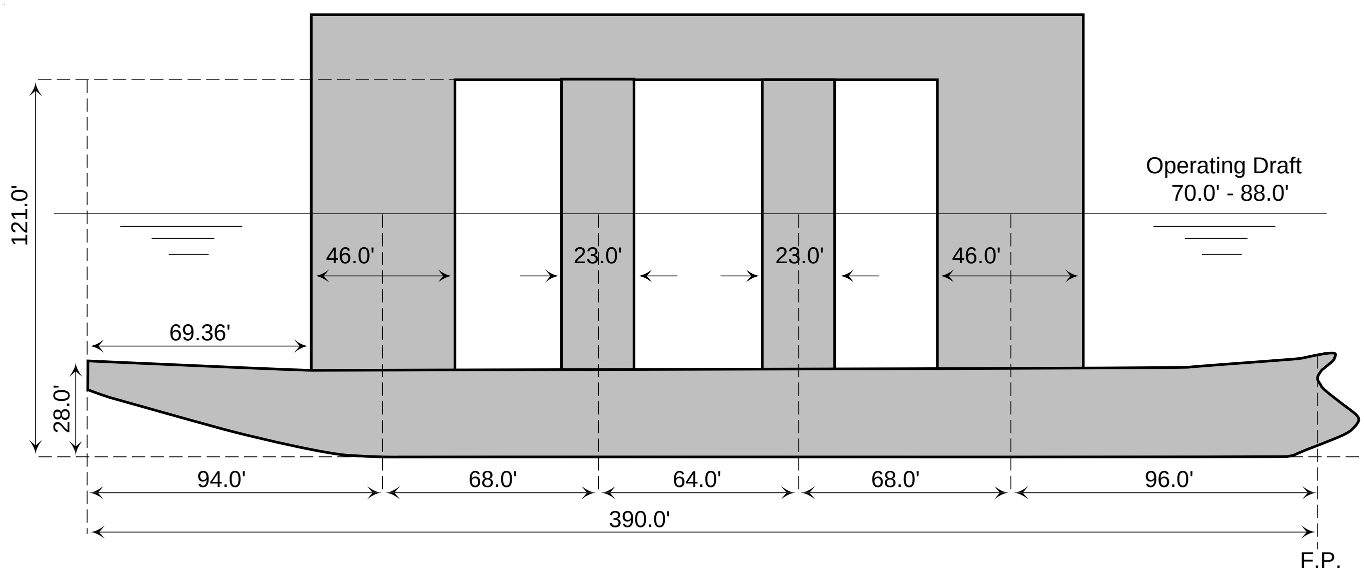
12) (Vx,Vy,Vz) coordinate of member top:       196.00     88.00     14.00
13) Top end termination type:  Free, submerged

15) Added mass/moment coefficients: Computed (with surface correction)
16) (Mx,My,Mz) Added mass coefficients:          1.20       .82       .07
17) (Mx,My,Mz) Added moment coefficients:         .61       .94       .04

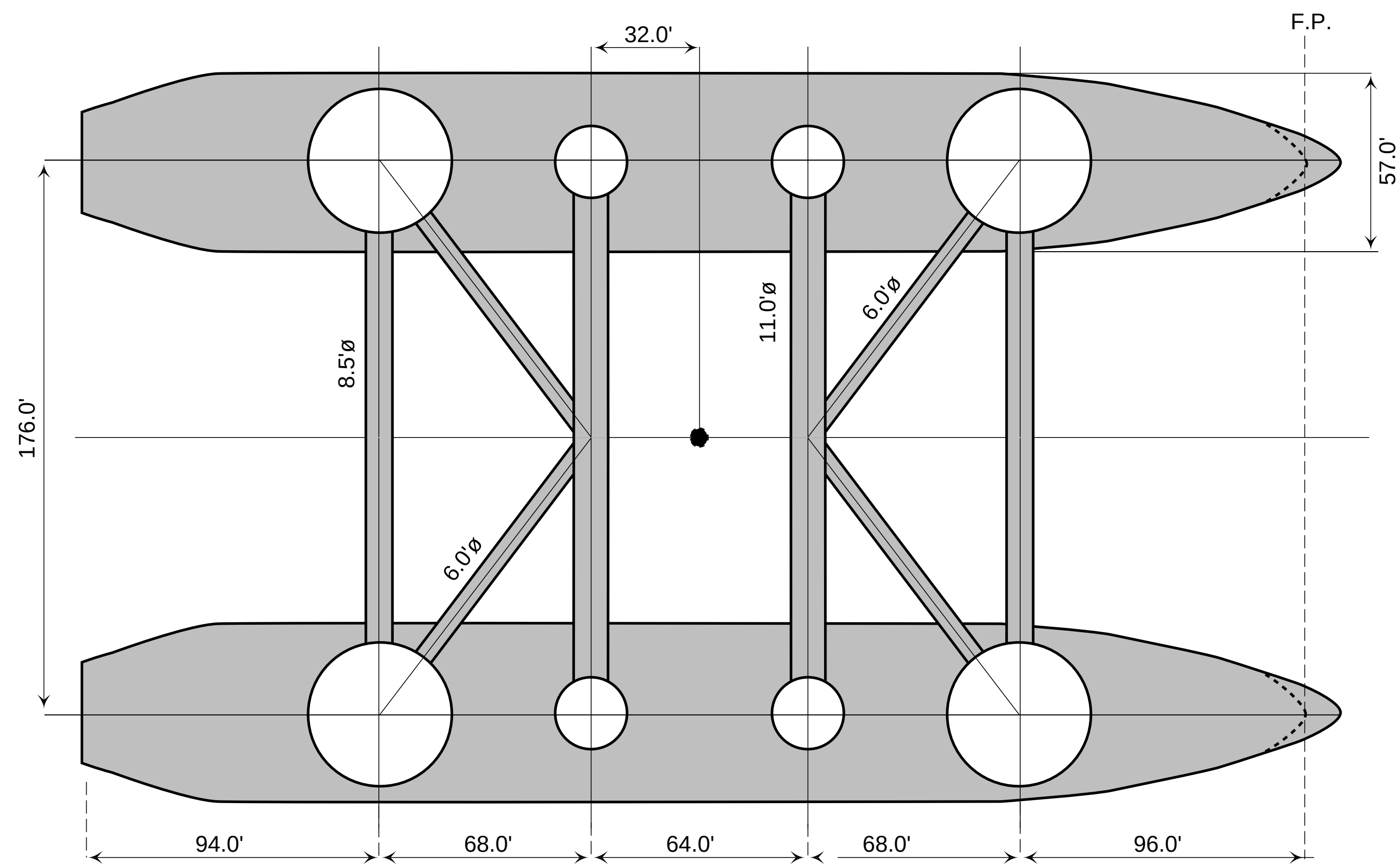
18) Drag/drag moment coefficients: User-specified
19) (Mx,My,Mz) Drag coefficients                 1.00      1.00      1.00
20) (Mx,My,Mz) Drag moment coefficients:         1.00      1.00      1.00

("C", "D", "I" to Copy, Delete, Insert)
```

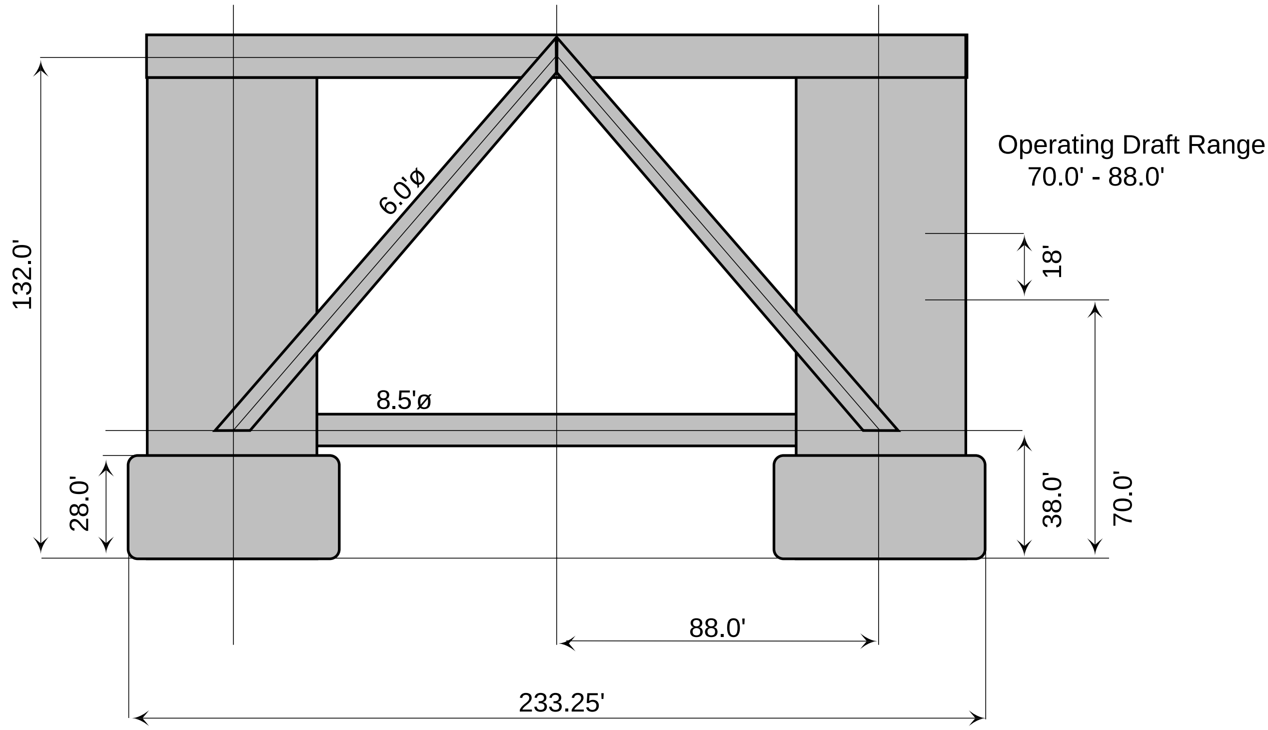
2 submerged rectangular pontoons of nonuniform cross-section at y = ±88; Forward Submember



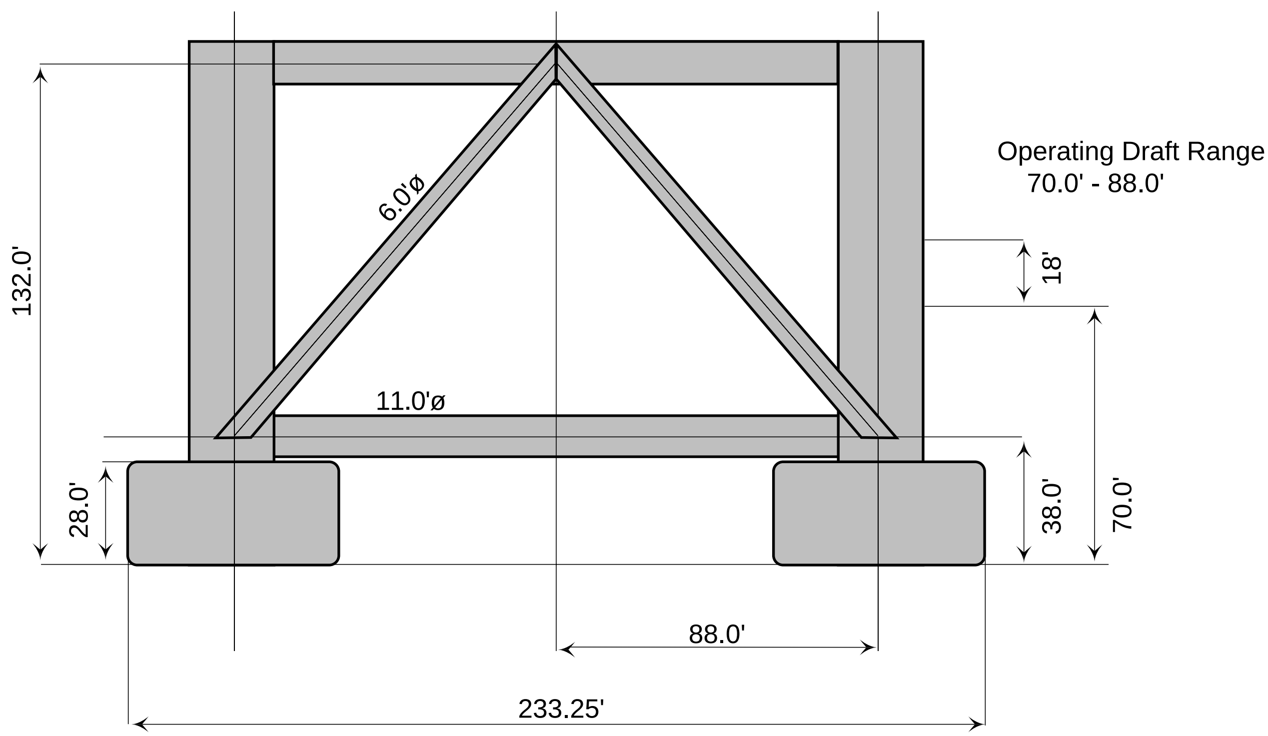
Starboard Elevation



Plan



Large Column Section



Small Column Section

Appendix H

User-Supplied Data Formats

The following documentation provides information necessary to interface Semisim with externally-produced first-order wave-frequency motion data ("USERRAOS.txt), thus bypassing Semisim's internal RAO calculations, and user-supplied wave spectral data (WAVESPEC.txt), to substitute for the built-in models described on page 38 ff.

"USERRAOS.txt"

The required RAO data can be developed from any suitable source, most commonly from a suitable three-dimensional diffraction program. Before this option is activated, the user must prepare a formatted data file called "USERRAOS.txt", documented below, containing all required first-order wave-frequency vessel RAO information. One anticipated use of this facility is in conjunction with the comprehensive SeaSoft simulations (for example, Moorsim) to permit cross-checking of user-supplied vessel RAO formats and data against the SeaSoft model. In this regard, it is useful to note that the Moorsim manual has additional information regarding this capability.

"USERRAOS" data files can be produced with any text editor by hand or from electronically copied tabular output from any source. The data can be in any Fortran-compatible floating-point format, for example ".123E-2" or ".00123", with any number of significant figures. Refer to the sample data file below, deliberately chosen to be unrealistically small for demonstration purposes.

User data is provided at NAZ user-specified azimuthal wave headings (in degrees) for a one-dimensional array WARRAY of NFREQ wave frequencies. This produces a two-dimensional array, one for each (frequency, angle) combination. The specific format of these files is reflected in the Fortran code snippet used to read the file (see below). Data for arbitrary frequencies and headings are obtained at runtime by interpolation within the user-specified array. The maximum values of NFREQ and NAZ are currently 51 and 37 respectively; any changes in these values can be found on-line in the relevant help item.

General Notes:

- The frequencies in WARRAY should extend beyond the wave period limits specified for RAO evaluation (see pp 33 ff). This is because response is always evaluated at each of these endpoint periods. Thus, if the period array on pp 33 has endpoints of 6 and 20 seconds, then WARRAY should extend on either end beyond the values (2pi/6 ≈ 1.047... and 2pi/20 ≈ 0.314...). In the event this condition is not met, a runtime warning will be issued and a linear extrapolation will be performed using endpoint data. Note that the use of the above frequency endpoint values (i.e., 1.047 and 0.314) will likely produce the mentioned runtime warning for the RAO array of pp 33 due to floating-point round-off error, while WARRAY endpoints of (1.048, 0.313) would eliminate the runtime warning.

- For consistency with usage throughout this documentation, wave "directions" are specified as wave *heading*s. That is, 0 degrees corresponds to stern-on waves, 90 degrees to waves approaching from starboard (propagating in the positive y direction), etc.

- To insure proper handling of circular symmetry in all conditions, the supplied angular array, containing NAZ elements, must comprise the *closed* interval [0, 360]; i.e., should contain data for both 0 degrees and 360 degrees, even though these are physically the same angle. Normally, this array will comprise equally-spaced angle points (for example 10 degree increments giving 37 angles in the closed interval [0, 360]), although equal angle increments are not a requirement.

- Each record in the data files, *including the last*, must be terminated by an end-of-record identifier (normally, a "carriage return" or "newline" character) or a runtime error will result.

- No testing is done to assure that the arrays are complete or logically consistent.

Format of the USERRAOS Data File

The format of the "USERRAOS.txt" file is reflected in the following code snippet.

```
C  Begin Snippet

      IMPLICIT NONE
      INTEGER NFREQ, NAZ, IA, IW, UNIT
      REAL HEAD(NAZ), WARRAY(NFREQ)
      COMPLEX CUSRG(NFREQ,NAZ),CUSWY(NFREQ,NAZ),CUHEV(NFREQ,NAZ)
      COMPLEX CUROL(NFREQ,NAZ),CUPIT(NFREQ,NAZ),CUYAW(NFREQ,NAZ)
C
C  NFREQ    - Number of wave frequencies
C  NAZ      - Number of wave headings
C  HEAD     - Wave heading in degrees, [0,360] inclusive
C  WARRAY   - Array of frequencies (radians/second)
C  CUSRG,CUSWY,CUHEV - Complex Dimensionless RAO data at each frequency & angle
C  CUROL,CUPIT,CUYAW - Complex Dimensionless RAO data at each frequency & angle
C
C  Read "USERRAOS"
C
       READ (UNIT,*) NFREQ,NAZ    !Number of frequencies & headings
       DO 50 IA = 1,NAZ           !Outer, angle loop
           READ (UNIT,*) HEAD(IA) !Wave heading in degrees
       DO 50 IW = 1,NFREQ         !Inner, frequency loop
           READ (UNIT,*) WARRAY(IW),
      1                  CUSRG(IW,IA),CUSWY(IW,IA),CUHEV(IW,IA),
      1                  CUROL(IW,IA),CUPIT(IW,IA),CUYAW(IW,IA)
50     CONTINUE

C  End Snippet
```

USERRAOS Notes:

- The relationship between RAO amplitude and phase output by the various SeaSoft simulations (see Appendix Z for an example) and the complex quantities required for USERRAOS can be deduced from the following discussion for surge, which applies equally to all degrees of freedom:

- Vessel surge RAOs reported by Semisim, Moorsim, or any other SeaSoft application is quoted in terms of the amplitude and phase angle of the complex surge RAO. That is, at each required wave period and wave heading, the surge RAO is reported as an "amplitude/phase" combination (for example, .75/ -95.1 for an RAO amplitude of 0.75 and phase angle of -95.1 degrees). The corresponding real and imaginary parts of CURSG for that amplitude/phase pair are given by:

  Real[CUSRG] = amplitude*cos(phase)
  Imaginary[CUSRG] = amplitude*sin(phase)

- When importing RAO data from non-SeaSoft applications, keep in mind the SeaSoft phase angle convention in which a positive phase angle corresponds to a phase lead. If the imported RAO data is taken from an application with a different phase convention, the data will need to be adjusted to comply with the SeaSoft convention before creating USERRAOS.

- Angular RAOs (roll, pitch, yaw) must be supplied in *dimensionless* form; i.e. degrees/degree.

- A file with RAO data for three frequencies at each of 5 headings might look like this:

>>> Begin USERRAOS.txt example (data should be tab, comma or space delimited)

```
3      5
0.0
0.698  0.000  -0.070 0.000  0.000  0.001  -0.010 0.000  0.000  0.000  0.000  0.000  0.000
0.419  0.011  0.240  0.000  0.000  -0.266 0.159  0.000  0.000  0.034  0.115  0.000  0.000
0.299  0.081  -0.237 0.000  0.000  0.160  -0.010 0.000  0.000  0.017  0.480  0.000  0.000
90.0
0.698  0.000  0.000  -0.008 -0.450 0.007  -0.090 -0.020 0.004  0.000  0.000  0.000  0.000
0.419  0.000  0.000  0.210  -0.896 1.245  -0.742 -1.324 -2.891 0.000  0.000  0.000  0.000
0.299  0.000  0.000  0.468  -1.457 1.118  -0.072 -0.008 -1.180 0.000  0.000  0.000  0.000
180.0
0.698  0.000  0.070  0.000  0.000  0.001  -0.010 0.000  0.000  0.000  0.000  0.000  0.000
0.419  -0.011 -0.240 0.000  0.000  -0.266 0.159  0.000  0.000  -0.034 -0.115 0.000  0.000
0.299  -0.081 0.237  0.000  0.000  0.160  -0.010 0.000  0.000  -0.017 -0.480 0.000  0.000
270.0
0.698  0.000  0.000  0.008  0.450  0.007  -0.090 0.020  -0.004 0.000  0.000  0.000  0.000
0.419  0.000  0.000  -0.210 0.896  1.245  -0.742 1.324  2.891  0.000  0.000  0.000  0.000
0.299  0.000  0.000  -0.468 1.457  1.118  -0.072 0.008  1.180  0.000  0.000  0.000  0.000
360.0
0.698  0.000  -0.070 0.000  0.000  0.001  -0.010 0.000  0.000  0.000  0.000  0.000  0.000
0.419  0.011  0.240  0.000  0.000  -0.266 0.159  0.000  0.000  0.034  0.115  0.000  0.000
0.299  0.081  -0.237 0.000  0.000  0.160  -0.010 0.000  0.000  0.017  0.480  0.000  0.000
```

>>> End USERRAOS example

Format of *WAVESPEC.txt* Data Files

File structure: The first line (or record) of the text file is the number of [Frequency, Spectrum] data records present in the file, followed by the data records themselves, with one record per line.

The format of both these files is reflected in the following descriptive code snippet.

```
C  Begin Snippet

      IMPLICIT NONE
      INTEGER NFREQ, IW, UNIT
      REAL WARRAY(NFREQ), SPECTRUM(NFREQ)
C
C  NFREQ    - Number of wave frequencies
C  WARRAY   - Array of frequencies [radians/second]
C  SPECTRUM - Array of spectral values [see comments below for units]
C
C  Read SPECTRUM
C
       READ (UNIT,*) NFREQ       !Number of frequencies
       DO 50 IW = 1,NFREQ        !Frequencies loop
          READ (UNIT,*) WARRAY(IW),SPECTRUM(IW)
50     CONTINUE

C  End Snippet
```

User Spectral Files: General Usage Notes:

- The maximum number of (frequency, spectral value) pairs = 61
- You must use circular frequencies (radians/second).
- The (frequency, spectral value) pairs must be ordered monotonically in the frequencies, with either ascending or descending values of frequency.
- The frequency and spectral value on each line should be separated by any standard value separator, typically a comma or tab character.
- The file must terminate with at least one empty line; text appended below that empty termination line will be ignored.

Wavespec Usage Notes:

- You must use wave height spectral values in units appropriate to the simulation: ft^2/(radian/sec) for English units; m^2/(radian/sec) for metric.
- The frequency span must include the frequencies associated with the endpoint periods in the wave period array specified on the "regular wave" data page (see page 33), but the frequency values themselves need not match the wave period array. (Note that in this regard, the WAVESPEC.txt implementation differs from the "Legacy Custom Spectrum" implementation, which is less flexible.)

- The wave spectrum must be defined so that the total area under the spectral curve between angular frequencies of (0,infinity) is equal to the variance {AKA "sigma squared", (RMS)^2 or (standard deviation)^2} of the sea surface elevation. Note: If the originating spectral data is given in terms of hertz (cycles/second) rather than angular frequency (radians/second), each spectral value must be divided by 2*pi = 6.2832... to obtain the correct variance upon integration.

  A WAVESPEC.txt file representing a narrow rectangular spectrum (RMS = 10, peak at 10 seconds) using 11 frequencies might look like:

```
>>> Begin WAVESPEC.txt example (data should be tab, comma or space delimited)
11
10.         0.
0.70        0.
0.69999     769.2
0.6981317   769.2
0.66138793  769.2
0.62831853  769.2
0.5983986   769.2
0.57119866  769.2
0.570       769.2
0.569999    0.
0.01        0.

Comment: This Spectrum has a sigma of 10.
>>> End WAVESPEC.txt example (note blank line terminates data)
```

Appendix Z

Sample Problem Output

This appendix contains output generated by Semisim as a result of a simulation execution using input data presented in Appendix B . Note that the Screen images presented in Chapter 5 also correspond to the same sample problem.

```
SeaSoft Systems Simulation Library




Volume  3

Semi-Submersible Offshore Vessels




-----------------------------

Semisim Version 5.11

Copyright (C) 2005
By SeaSoft Systems

-----------------------------



Semisim Sample Problem
Six-Column semi; uniform pontoons


Executed at 20:29 on 4/4/05
```

```
**                                                                        **
************   I.  PHYSICAL CHARACTERISTICS SUMMARY (AS INPUT)  ***********
**                                                                        **


  ----  SITE CHARACTERISTICS  ----


          WATER DEPTH ...........................     40.00 METERS
          WATER DENSITY .........................   1025.18 KGW/CUBIC METER


  ----  VESSEL CHARACTERISTICS  ----


          DISPLACEMENT ..........................  35925.00 M.TONS
          WATER PLANE AREA ......................    748.20 SQUARE METERS
          VERTICAL KB ...........................      6.60 METERS
          DRAFT .................................     20.00 METERS

          VERTICAL KG ...........................      8.64 METERS
          LONGITUDINAL (X) CG ...................       .00 METERS
          TRANSVERSE (Y) CG .....................       .00 METERS

          PITCH GYRADIUS ........................     30.89 METERS
          ROLL GYRADIUS .........................     30.55 METERS
          YAW GYRADIUS ..........................     41.74 METERS

          LONGITUDINAL GM (GML) .................     19.36 METERS
          LONGITUDINAL KM (KML) .................     28.00 METERS
          LONGITUDINAL IWP/DELTA ................     21.40 METERS

          TRANSVERSE GM (GMT) ...................     17.56 METERS
          TRANSVERSE KM (KMT) ...................     26.20 METERS
          TRANSVERSE IWP/DELTA ..................     19.60 METERS

          TRIM ANGLE ............................       .00 DEG
          HEEL ANGLE ............................       .00 DEG
```

```
**                                                                           **
***********   I.  PHYSICAL CHARACTERISTICS SUMMARY (AS ESTIMATED)  *********
**                                                                           **

  ----  VESSEL CHARACTERISTICS  ----

            DISPLACEMENT ..........................  35925.00 M.TONS
            WATER PLANE AREA ......................    748.20 SQUARE METERS
            VERTICAL KB ...........................      6.60 METERS
            DRAFT .................................     20.00 METERS

            EQUIVALENT VERTICAL KG ................      8.64 METERS
            FORWARD (X) KB ........................       .00 METERS
            LATERAL (Y) KB ........................       .00 METERS

            FORWARD (X) WATERPLANE CENTROID  ......       .00 METERS
            LATERAL (Y) WATERPLANE CENTROID  ......       .00 METERS

            LONGITUDINAL GM (GML) .................     19.36 METERS
            LONGITUDINAL KM (KML) .................     28.00 METERS
            LONGITUDINAL IWP/DELTA ................     21.41 METERS
            PITCH CENTER OF ROTATION ..............      9.65 METERS

            TRANSVERSE GM (GMT) ...................     17.65 METERS
            TRANSVERSE KM (KMT) ...................     26.29 METERS
            TRANSVERSE IWP/DELTA ..................     19.69 METERS
            ROLL CENTER OF ROTATION ...............      8.18 METERS
```

```
**                                                                           **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  *************
**                                                                           **


  ----  NATURAL PERIODS AT ZERO SPEED  ----


            NATURAL ROLL PERIOD ....................   23.7 SECONDS
            NATURAL PITCH PERIOD ...................   21.5 SECONDS
            NATURAL HEAVE PERIOD ...................   22.3 SECONDS


  ----  QUASI-LINEAR ZERO SPEED DAMPING COEFFICIENTS  ----


            NATURAL ROLL DAMPING ...................    9.5 PERCENT
            Damping conversion: 1% =  0.475E+05 m.ton*m./(rad/sec)

            NATURAL PITCH DAMPING ..................    8.4 PERCENT
            Damping conversion: 1% =  0.476E+05 m.ton*m./(rad/sec)

            NATURAL HEAVE DAMPING ..................   13.5 PERCENT
            Damping conversion: 1% =  0.545E+02 m.ton/(m/sec)



            REGULAR WAVE HEIGHT.....................    7.0 METERS
            WATER DEPTH ............................   40.0 METERS
```

```
**                                                                          **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                          **
```

```
----  REGULAR WAVE DATA:  WAVE HEADING        =  90.0 DEG
                          WAVE HEIGHT         =   7.0 M.
                          VESSEL SPEED        =    .0 M./SEC
```

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOS +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	SURGE AM/PHASE	SWAY AM/PHASE	HEAVE AM/PHASE
6.00	56.1	22.45	0.000/ 56.5	.472/ -90.0	1.761/ 0.0
7.00	76.2	16.53	0.000/ 51.2	.512/ -90.0	1.588/ 0.0
8.00	98.6	12.78	0.000/ 49.1	.271/ -90.0	.650/ 0.0
9.00	122.3	10.31	0.000/-131.0	.028/ 90.0	.049/ 180.0
10.00	146.3	8.62	0.000/-130.1	.297/ 90.0	.389/ 180.0
11.00	170.1	7.41	0.000/-128.7	.519/ 90.0	.494/ 180.0
12.00	193.5	6.51	0.000/-127.1	.697/ 90.0	.474/ 180.0
13.00	216.5	5.82	0.000/-125.4	.841/ 90.0	.398/ 180.0
14.00	239.1	5.27	0.000/-123.8	.957/ 90.0	.300/ 180.0
15.00	261.4	4.82	0.000/-122.2	1.052/ 90.0	.197/ 180.0
16.00	283.4	4.45	0.000/-120.7	1.130/ 90.0	.097/ 180.0
17.00	305.2	4.13	0.000/-119.3	1.195/ 90.0	.004/ 180.0
18.00	326.7	3.86	0.000/-118.1	1.250/ 90.0	.081/ .0
19.00	348.1	3.62	0.000/-116.9	1.297/ 90.0	.158/ 0.0
20.00	369.3	3.41	0.000/-115.8	1.337/ 90.0	.226/ 0.0
21.00	390.4	3.23	0.000/-114.7	1.371/ 90.0	.288/ .0
22.00	411.3	3.06	0.000/-113.8	1.401/ 90.0	.343/ 0.0
23.00	432.2	2.92	0.000/-112.9	1.428/ 90.0	.393/ 0.0
24.00	452.9	2.78	0.000/-112.0	1.451/ 90.0	.437/ 0.0
25.00	473.6	2.66	0.000/-111.2	1.471/ 90.0	.477/ 0.0
26.00	494.3	2.55	0.000/-110.5	1.489/ 90.0	.514/ 0.0
27.00	514.8	2.45	0.000/-109.8	1.505/ 90.0	.546/ 0.0
28.00	535.3	2.35	0.000/-109.2	1.519/ 90.0	.576/ 0.0
29.00	555.8	2.27	0.000/-108.6	1.532/ 90.0	.603/ 0.0
30.00	576.2	2.19	0.000/-108.0	1.544/ 90.0	.627/ 0.0

```
----  REGULAR WAVE FORCE/TORQUE SCALE FACTORS  ----

  SURGE ..................................      627.0 M.TON/DEG
  SWAY  ..................................      627.0 M.TON/DEG
  HEAVE ..................................      767.0 M.TON/METER
  ROLL  ..................................    11010.3 M.TON-METER/DEG
  PITCH ..................................    12138.9 M.TON-METER/DEG
  YAW   ..................................    12138.9 M.TON-METER/DEG
```

++> Note: Moments evaluated about "natural" roll and pitch centers


```
**                                                                          **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                          **
```

```
----  REGULAR WAVE DATA:  WAVE HEADING        =  90.0 DEG
                          WAVE HEIGHT         =   7.0 M.
                          VESSEL SPEED        =    .0 M./SEC
```

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOS +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	ROLL AM/PHASE	PITCH AM/PHASE	YAW AM/PHASE
6.00	56.1	22.45	.049/ -90.0	0.000/ 16.9	0.000/ .0
7.00	76.2	16.53	.603/ 90.0	0.000/-150.6	0.000/ 33.7
8.00	98.6	12.78	1.062/ 90.0	0.000/-116.6	0.000/ -63.4
9.00	122.3	10.31	1.204/ 90.0	0.000/ 180.0	0.000/ -90.0
10.00	146.3	8.62	1.141/ 90.0	0.000/ 180.0	0.000/ -26.6
11.00	170.1	7.41	.984/ 90.0	0.000/ 90.0	0.000/-164.1
12.00	193.5	6.51	.799/ 90.0	0.000/ 45.0	0.000/ 180.0
13.00	216.5	5.82	.617/ 90.0	0.000/ -48.4	0.000/ -45.0
14.00	239.1	5.27	.450/ 90.0	0.000/ -90.0	0.000/-108.4
15.00	261.4	4.82	.301/ 90.0	0.000/ 90.0	0.000/ -90.0
16.00	283.4	4.45	.170/ 90.0	0.000/ -14.0	0.000/ 144.0
17.00	305.2	4.13	.056/ 90.0	0.000/-138.8	0.000/ 180.0
18.00	326.7	3.86	.044/ -90.0	0.000/ -90.0	0.000/ -90.0
19.00	348.1	3.62	.131/ -90.0	0.000/ -36.9	0.000/ 82.9
20.00	369.3	3.41	.208/ -90.0	0.000/ .0	0.000/ .0
21.00	390.4	3.23	.275/ -90.0	0.000/-153.4	0.000/ -36.0
22.00	411.3	3.06	.334/ -90.0	0.000/ -51.3	0.000/ .0
23.00	432.2	2.92	.387/ -90.0	0.000/ -14.0	0.000/ .0
24.00	452.9	2.78	.433/ -90.0	0.000/-159.4	0.000/ -97.1
25.00	473.6	2.66	.475/ -90.0	0.000/ -26.6	0.000/ -97.1
26.00	494.3	2.55	.512/ -90.0	0.000/-149.7	0.000/ -76.0
27.00	514.8	2.45	.545/ -90.0	0.000/ -90.0	0.000/ .0
28.00	535.3	2.35	.575/ -90.0	0.000/ .0	0.000/ 79.4
29.00	555.8	2.27	.602/ -90.0	0.000/-143.1	0.000/ -72.6
30.00	576.2	2.19	.627/ -90.0	0.000/-140.2	0.000/ .0


```
----  REGULAR WAVE FORCE/TORQUE SCALE FACTORS  ----

  SURGE ..................................      627.0 M.TON/DEG
  SWAY  ..................................      627.0 M.TON/DEG
  HEAVE ..................................      767.0 M.TON/METER
  ROLL  ..................................    11010.3 M.TON-METER/DEG
  PITCH ..................................    12138.9 M.TON-METER/DEG
  YAW   ..................................    12138.9 M.TON-METER/DEG
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++> Note: Moments evaluated about "natural" roll and pitch centers

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**                                                                          **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                          **
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---- REGULAR WAVE DATA: WAVE HEADING = 90.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC

+++ QUASI-LINEAR RESPONSE RAOS (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	SURGE (M./ M.) AM/PHASE	SWAY (M./ M.) AM/PHASE	HEAVE (M./ M.) AM/PHASE
6.00	56.1	22.45	0.000/-123.5	.274/ 90.0	.137/-175.5
7.00	76.2	16.53	0.000/-128.8	.298/ 90.0	.172/-174.7
8.00	98.6	12.78	0.000/-130.9	.159/ 90.0	.095/-173.7
9.00	122.3	10.31	0.000/ 49.0	.017/ -90.0	.010/ 7.4
10.00	146.3	8.62	0.000/ 49.9	.184/ -90.0	.097/ 8.6
11.00	170.1	7.41	0.000/ 51.3	.334/ -90.0	.156/ 9.9
12.00	193.5	6.51	0.000/ 52.9	.470/ -90.0	.189/ 11.5
13.00	216.5	5.82	0.000/ 54.6	.594/ -90.0	.199/ 13.3
14.00	239.1	5.27	0.000/ 56.2	.710/ -90.0	.187/ 15.5
15.00	261.4	4.82	0.000/ 57.8	.819/ -90.0	.154/ 18.2
16.00	283.4	4.45	0.000/ 59.3	.924/ -90.0	.095/ 21.6
17.00	305.2	4.13	0.000/ 60.7	1.024/ -90.0	.005/ 26.0
18.00	326.7	3.86	0.000/ 61.9	1.122/ -90.0	.128/-148.2
19.00	348.1	3.62	0.000/ 63.1	1.217/ -90.0	.319/-140.3
20.00	369.3	3.41	0.000/ 64.2	1.310/ -90.0	.583/-129.3
21.00	390.4	3.23	0.000/ 65.3	1.402/ -90.0	.916/-114.5
22.00	411.3	3.06	0.000/ 66.2	1.492/ -90.0	1.250/ -96.2
23.00	432.2	2.92	0.000/ 67.1	1.581/ -90.0	1.468/ -77.5
24.00	452.9	2.78	0.000/ 68.0	1.669/ -90.0	1.538/ -61.7
25.00	473.6	2.66	0.000/ 68.8	1.756/ -90.0	1.519/ -49.9
26.00	494.3	2.55	0.000/ 69.5	1.842/ -90.0	1.468/ -41.3
27.00	514.8	2.45	0.000/ 70.2	1.928/ -90.0	1.412/ -35.1
28.00	535.3	2.35	0.000/ 70.8	2.013/ -90.0	1.362/ -30.5
29.00	555.8	2.27	0.000/ 71.4	2.098/ -90.0	1.319/ -27.0
30.00	576.2	2.19	0.000/ 72.0	2.182/ -90.0	1.282/ -24.2

>>> Note: Surge and sway RAOs evaluated at "natural" pitch and roll centers


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**                                                                          **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                          **
```


---- REGULAR WAVE DATA: WAVE HEADING = 90.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC
ROLL DAMPING = .0 PERCENT

+++ QUASI-LINEAR RESPONSE RAOS (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	ROLL (DEG/DEG) AM/PHASE	PITCH (DEG/DEG) AM/PHASE	YAW (DEG/DEG) AM/PHASE
6.00	56.1	22.45	.003/ 92.9	0.000/-160.1	0.000/ 180.0
7.00	76.2	16.53	.058/ -86.5	0.000/ 32.9	0.000/-146.3
8.00	98.6	12.78	.136/ -85.9	0.000/ 67.6	0.000/ 116.6
9.00	122.3	10.31	.203/ -85.2	0.000/ 4.9	0.000/ 90.0
10.00	146.3	8.62	.246/ -84.5	0.000/ 5.7	0.000/ 153.4
11.00	170.1	7.41	.269/ -83.6	0.000/ -83.4	0.000/ 15.9
12.00	193.5	6.51	.274/ -82.7	0.000/-127.2	0.000/ .0
13.00	216.5	5.82	.263/ -81.6	0.000/ 140.7	0.000/ 135.0
14.00	239.1	5.27	.238/ -80.3	0.000/ 100.7	0.000/ 71.6
15.00	261.4	4.82	.198/ -78.7	0.000/ -77.1	0.000/ 90.0
16.00	283.4	4.45	.139/ -76.8	0.000/-178.4	0.000/ -36.0
17.00	305.2	4.13	.057/ -74.4	0.000/ 60.7	0.000/ .0
18.00	326.7	3.86	.057/ 108.7	0.000/ 115.2	0.000/ 90.0
19.00	348.1	3.62	.218/ 113.0	0.000/ 177.2	0.000/ -97.1
20.00	369.3	3.41	.451/ 119.0	0.000/-130.8	0.000/ 180.0
21.00	390.4	3.23	.794/ 127.9	0.000/ 100.8	0.000/ 144.0
22.00	411.3	3.06	1.291/ 141.8	0.000/-126.2	0.000/ 180.0
23.00	432.2	2.92	1.895/ 162.4	0.000/ -65.4	0.000/ 180.0
24.00	452.9	2.78	2.304/-172.4	0.000/ 163.2	0.000/ 82.9
25.00	473.6	2.66	2.310/-150.5	0.000/ -55.6	0.000/ 82.9
26.00	494.3	2.55	2.124/-135.5	0.000/-173.5	0.000/ 104.0
27.00	514.8	2.45	1.929/-125.9	0.000/-110.1	0.000/ 180.0
28.00	535.3	2.35	1.770/-119.4	0.000/ -17.5	0.000/-100.6
29.00	555.8	2.27	1.648/-114.9	0.000/-158.6	0.000/ 107.4
30.00	576.2	2.19	1.553/-111.7	0.000/-154.1	0.000/ 180.0

>>> Note: Surge and sway RAOs evaluated at "natural" pitch and roll centers

** **
*************** II. UNMOORED VESSEL MOTION CHARACTERISTICS **************
** **

---- REGULAR WAVE DATA: WAVE HEADING = 90.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC

+++ RELATIVE MOTION RAOS IN M. PER UNIT WAVE AMP. (S.A./S.A.) +++

	---- COORDINATES (30.0, 30.0, 40.0) ----			---- COORDINATES (30.0, -30.0, 40.0) ----		
WAVE PERIOD (SEC)	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
6.00	0.000/ 118	.747/-106	.867/ -14	0.000/ 163	.747/ -73	.863/ 12
7.00	0.000/ 85	.700/ -28	.774/ 36	0.000/ 55	.716/-151	.780/ -39
8.00	0.000/ 140	.939/ 5	.720/ 68	0.000/ 47	.979/ 174	.727/ -72
9.00	0.000/-164	1.062/ 18	.689/ 89	0.000/ 12	1.115/ 162	.689/ -93
10.00	0.000/-158	1.088/ 24	.676/ 102	0.000/ 0	1.148/ 157	.665/-108
11.00	0.000/-138	1.070/ 26	.677/ 112	0.000/ -20	1.133/ 155	.658/-119
12.00	0.000/-141	1.034/ 26	.691/ 119	0.000/ -58	1.099/ 155	.667/-128
13.00	0.000/ 149	.994/ 25	.718/ 125	0.000/ 124	1.059/ 155	.691/-134
14.00	0.000/ 171	.955/ 23	.757/ 130	0.000/ 56	1.017/ 157	.731/-139
15.00	0.000/ -96	.921/ 21	.810/ 135	0.000/ -22	.976/ 159	.790/-143
16.00	0.000/ 170	.892/ 18	.880/ 140	0.000/ -76	.935/ 162	.872/-145
17.00	0.000/ 62	.873/ 14	.971/ 145	0.000/ 51	.892/ 165	.984/-146
18.00	0.000/ 168	.867/ 9	1.085/ 151	0.000/ 88	.844/ 170	1.137/-145
19.00	0.000/ 168	.884/ 3	1.223/ 159	0.000/-169	.787/ 176	1.342/-141
20.00	0.000/-129	.945/ -3	1.374/ 170	0.000/-128	.709/-175	1.606/-134
21.00	0.000/ 92	1.080/ -8	1.502/-177	0.000/ 96	.591/-164	1.903/-122
22.00	0.000/-121	1.326/ -10	1.558/-163	0.000/-122	.396/-143	2.128/-105
23.00	0.000/ -65	1.646/ -4	1.573/-151	0.000/ -59	.119/ -75	2.115/ -84
24.00	0.000/ 171	1.831/ 8	1.566/-136	0.000/ 152	.347/ 53	1.803/ -64
25.00	0.000/ -67	1.760/ 20	1.434/-121	0.000/ -28	.623/ 85	1.392/ -51
26.00	0.000/-144	1.590/ 27	1.233/-109	0.000/ 159	.761/ 103	1.079/ -45
27.00	0.000/-108	1.436/ 31	1.045/-100	0.000/ -89	.820/ 115	.873/ -43
28.00	0.000/ 4	1.318/ 32	.892/ -94	0.000/ -29	.845/ 123	.732/ -42
29.00	0.000/-110	1.231/ 32	.772/ -90	0.000/ 134	.854/ 128	.631/ -42
30.00	0.000/-152	1.164/ 32	.677/ -87	0.000/-138	.856/ 133	.555/ -42

** **
*************** II. UNMOORED VESSEL MOTION CHARACTERISTICS **************
** **

---- REGULAR WAVE DATA: WAVE HEADING = 90.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC

+++ RELATIVE MOTION RAOS IN M. PER UNIT WAVE AMP. (S.A./S.A.) +++

	---- COORDINATES (-30.0, 30.0, 40.0) ----			---- COORDINATES (-30.0, -30.0, 40.0) ----		
WAVE PERIOD (SEC)	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
6.00	0.000/ 118	.747/-106	.867/ -14	0.000/ 163	.747/ -73	.863/ 12
7.00	0.000/ 85	.700/ -28	.774/ 36	0.000/ 55	.716/-151	.780/ -39
8.00	0.000/ 140	.939/ 5	.720/ 68	0.000/ 47	.979/ 174	.727/ -72
9.00	0.000/-164	1.062/ 18	.689/ 89	0.000/ 12	1.115/ 162	.689/ -93
10.00	0.000/-158	1.088/ 24	.676/ 102	0.000/ 0	1.148/ 157	.665/-108
11.00	0.000/-138	1.070/ 26	.677/ 112	0.000/ -20	1.133/ 155	.658/-119
12.00	0.000/-141	1.034/ 26	.691/ 119	0.000/ -58	1.099/ 155	.667/-128
13.00	0.000/ 149	.994/ 25	.718/ 125	0.000/ 124	1.059/ 155	.691/-134
14.00	0.000/ 171	.955/ 23	.757/ 130	0.000/ 56	1.017/ 157	.731/-139
15.00	0.000/ -96	.921/ 21	.810/ 135	0.000/ -22	.976/ 159	.790/-143
16.00	0.000/ 170	.892/ 18	.880/ 140	0.000/ -76	.935/ 162	.872/-145
17.00	0.000/ 62	.873/ 14	.971/ 145	0.000/ 51	.892/ 165	.984/-146
18.00	0.000/ 168	.867/ 9	1.085/ 151	0.000/ 88	.844/ 170	1.137/-145
19.00	0.000/ 168	.884/ 3	1.223/ 159	0.000/-169	.787/ 176	1.342/-141
20.00	0.000/-129	.945/ -3	1.374/ 170	0.000/-128	.709/-175	1.606/-134
21.00	0.000/ 92	1.080/ -8	1.502/-177	0.000/ 96	.591/-164	1.903/-122
22.00	0.000/-121	1.326/ -10	1.558/-163	0.000/-122	.396/-143	2.128/-105
23.00	0.000/ -65	1.646/ -4	1.573/-151	0.000/ -59	.119/ -75	2.115/ -84
24.00	0.000/ 171	1.831/ 8	1.566/-136	0.000/ 152	.347/ 53	1.803/ -64
25.00	0.000/ -67	1.760/ 20	1.434/-121	0.000/ -28	.623/ 85	1.392/ -51
26.00	0.000/-144	1.590/ 27	1.233/-109	0.000/ 159	.761/ 103	1.079/ -45
27.00	0.000/-108	1.436/ 31	1.045/-100	0.000/ -89	.820/ 115	.873/ -43
28.00	0.000/ 4	1.318/ 32	.892/ -94	0.000/ -29	.845/ 123	.732/ -42
29.00	0.000/-110	1.231/ 32	.772/ -90	0.000/ 134	.854/ 128	.631/ -42
30.00	0.000/-152	1.164/ 32	.677/ -87	0.000/-138	.856/ 133	.555/ -42

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**                                                                          **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                          **
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---- REGULAR WAVE DATA: WAVE HEADING = 135.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOS +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	SURGE AM/PHASE	SWAY AM/PHASE	HEAVE AM/PHASE
6.00	56.1	22.45	.059/ -90.0	.066/ 90.0	.211/-180.0
7.00	76.2	16.53	.001/ -90.0	0.000/ 90.0	.038/ .0
8.00	98.6	12.78	.028/ -90.0	.037/ 90.0	.157/ 180.0
9.00	122.3	10.31	.118/ -90.0	.155/ 90.0	.441/-180.0
10.00	146.3	8.62	.223/ -90.0	.293/ 90.0	.587/ 180.0
11.00	170.1	7.41	.318/ -90.0	.421/ 90.0	.602/-180.0
12.00	193.5	6.51	.399/ -90.0	.529/ 90.0	.538/-180.0
13.00	216.5	5.82	.466/ -90.0	.620/ 90.0	.439/-180.0
14.00	239.1	5.27	.521/ -90.0	.696/ 90.0	.328/ 180.0
15.00	261.4	4.82	.566/ -90.0	.758/ 90.0	.217/-180.0
16.00	283.4	4.45	.604/ -90.0	.810/ 90.0	.112/-180.0
17.00	305.2	4.13	.636/ -90.0	.854/ 90.0	.016/-180.0
18.00	326.7	3.86	.663/ -90.0	.891/ 90.0	.072/ 0.0
19.00	348.1	3.62	.686/ -90.0	.923/ 90.0	.150/ 0.0
20.00	369.3	3.41	.706/ -90.0	.950/ 90.0	.220/ 0.0
21.00	390.4	3.23	.723/ -90.0	.974/ 90.0	.282/ .0
22.00	411.3	3.06	.737/ -90.0	.994/ 90.0	.338/ 0.0
23.00	432.2	2.92	.750/ -90.0	1.012/ 90.0	.388/ 0.0
24.00	452.9	2.78	.762/ -90.0	1.028/ 90.0	.433/ 0.0
25.00	473.6	2.66	.772/ -90.0	1.042/ 90.0	.474/ 0.0
26.00	494.3	2.55	.781/ -90.0	1.055/ 90.0	.510/ 0.0
27.00	514.8	2.45	.789/ -90.0	1.066/ 90.0	.543/ 0.0
28.00	535.3	2.35	.796/ -90.0	1.076/ 90.0	.573/ 0.0
29.00	555.8	2.27	.802/ -90.0	1.085/ 90.0	.600/ 0.0
30.00	576.2	2.19	.808/ -90.0	1.093/ 90.0	.625/ 0.0

---- REGULAR WAVE FORCE/TORQUE SCALE FACTORS ----

SURGE .... 627.0 M.TON/DEG
SWAY .... 627.0 M.TON/DEG
HEAVE .... 767.0 M.TON/METER
ROLL .... 11010.3 M.TON-METER/DEG
PITCH .... 12138.9 M.TON-METER/DEG
YAW .... 12138.9 M.TON-METER/DEG

++> Note: Moments evaluated about "natural" roll and pitch centers


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**                                                                          **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                          **
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---- REGULAR WAVE DATA: WAVE HEADING = 135.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOS +++

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	ROLL AM/PHASE	PITCH AM/PHASE	YAW AM/PHASE
6.00	56.1	22.45	.083/ -90.0	.094/ -90.0	.036/ 180.0
7.00	76.2	16.53	.091/ 90.0	.080/ -90.0	.068/ .0
8.00	98.6	12.78	.405/ 90.0	.140/ 90.0	.046/ 0.0
9.00	122.3	10.31	.600/ 90.0	.312/ 90.0	.005/-180.0
10.00	146.3	8.62	.647/ 90.0	.370/ 90.0	.048/-180.0
11.00	170.1	7.41	.601/ 90.0	.348/ 90.0	.077/-180.0
12.00	193.5	6.51	.512/ 90.0	.286/ 90.0	.094/-180.0
13.00	216.5	5.82	.410/ 90.0	.210/ 90.0	.104/ 180.0
14.00	239.1	5.27	.309/ 90.0	.131/ 90.0	.110/ 180.0
15.00	261.4	4.82	.214/ 90.0	.056/ 90.0	.112/ 180.0
16.00	283.4	4.45	.128/ 90.0	.014/ -90.0	.112/-180.0
17.00	305.2	4.13	.051/ 90.0	.076/ -90.0	.111/-180.0
18.00	326.7	3.86	.017/ -90.0	.131/ -90.0	.109/ 180.0
19.00	348.1	3.62	.077/ -90.0	.181/ -90.0	.107/ 180.0
20.00	369.3	3.41	.131/ -90.0	.224/ -90.0	.104/ 180.0
21.00	390.4	3.23	.178/ -90.0	.263/ -90.0	.102/ 180.0
22.00	411.3	3.06	.220/ -90.0	.298/ -90.0	.099/ 180.0
23.00	432.2	2.92	.258/ -90.0	.329/ -90.0	.096/-180.0
24.00	452.9	2.78	.291/ -90.0	.357/ -90.0	.093/ 180.0
25.00	473.6	2.66	.321/ -90.0	.381/ -90.0	.091/-180.0
26.00	494.3	2.55	.348/ -90.0	.404/ -90.0	.088/ 180.0
27.00	514.8	2.45	.372/ -90.0	.424/ -90.0	.086/ 180.0
28.00	535.3	2.35	.394/ -90.0	.442/ -90.0	.083/-180.0
29.00	555.8	2.27	.414/ -90.0	.458/ -90.0	.081/ 180.0
30.00	576.2	2.19	.431/ -90.0	.473/ -90.0	.079/ 180.0

---- REGULAR WAVE FORCE/TORQUE SCALE FACTORS ----

SURGE .... 627.0 M.TON/DEG
SWAY .... 627.0 M.TON/DEG
HEAVE .... 767.0 M.TON/METER
ROLL .... 11010.3 M.TON-METER/DEG
PITCH .... 12138.9 M.TON-METER/DEG
YAW .... 12138.9 M.TON-METER/DEG

++> Note: Moments evaluated about "natural" roll and pitch centers

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**                                                                        **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                        **

  ----  REGULAR WAVE DATA:  WAVE HEADING        = 135.0 DEG
                            WAVE HEIGHT         =   7.0 M.
                            VESSEL SPEED        =    .0 M./SEC

                          +++  QUASI-LINEAR RESPONSE RAOS (S.A./S.A.)  +++
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WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	SURGE (M./ M.) AM/PHASE	SWAY (M./ M.) AM/PHASE	HEAVE (M./ M.) AM/PHASE
6.00	56.1	22.45	.046/ 90.0	.038/ -90.0	.016/ 4.5
7.00	76.2	16.53	.001/ 90.0	0.000/ -90.0	.004/-174.7
8.00	98.6	12.78	.022/ 90.0	.021/ -90.0	.023/ 6.3
9.00	122.3	10.31	.096/ 90.0	.093/ -90.0	.085/ 7.4
10.00	146.3	8.62	.186/ 90.0	.181/ -90.0	.146/ 8.6
11.00	170.1	7.41	.277/ 90.0	.271/ -90.0	.190/ 9.9
12.00	193.5	6.51	.363/ 90.0	.357/ -90.0	.214/ 11.5
13.00	216.5	5.82	.445/ 90.0	.438/ -90.0	.219/ 13.3
14.00	239.1	5.27	.523/ 90.0	.516/ -90.0	.205/ 15.5
15.00	261.4	4.82	.597/ 90.0	.590/ -90.0	.169/ 18.2
16.00	283.4	4.45	.668/ 90.0	.662/ -90.0	.110/ 21.6
17.00	305.2	4.13	.737/ 90.0	.732/ -90.0	.019/ 26.0
18.00	326.7	3.86	.805/ 90.0	.800/ -90.0	.113/-148.2
19.00	348.1	3.62	.871/ 90.0	.866/ -90.0	.303/-140.3
20.00	369.3	3.41	.936/ 90.0	.931/ -90.0	.566/-129.3
21.00	390.4	3.23	.999/ 90.0	.996/ -90.0	.898/-114.5
22.00	411.3	3.06	1.062/ 90.0	1.059/ -90.0	1.231/ -96.2
23.00	432.2	2.92	1.124/ 90.0	1.121/ -90.0	1.451/ -77.5
24.00	452.9	2.78	1.186/ 90.0	1.183/ -90.0	1.524/ -61.7
25.00	473.6	2.66	1.247/ 90.0	1.245/ -90.0	1.507/ -49.9
26.00	494.3	2.55	1.307/ 90.0	1.305/ -90.0	1.458/ -41.3
27.00	514.8	2.45	1.367/ 90.0	1.366/ -90.0	1.404/ -35.1
28.00	535.3	2.35	1.427/ 90.0	1.426/ -90.0	1.355/ -30.5
29.00	555.8	2.27	1.486/ 90.0	1.485/ -90.0	1.313/ -27.0
30.00	576.2	2.19	1.545/ 90.0	1.545/ -90.0	1.277/ -24.2

>>> Note: Surge and sway RAOs evaluated at "natural" pitch and roll centers

```
**                                                                        **
***************  II.  UNMOORED VESSEL MOTION CHARACTERISTICS  **************
**                                                                        **

  ----  REGULAR WAVE DATA:  WAVE HEADING        = 135.0 DEG
                            WAVE HEIGHT         =   7.0 M.
                            VESSEL SPEED        =    .0 M./SEC
                            ROLL DAMPING        =    .0 PERCENT

                          +++  QUASI-LINEAR RESPONSE RAOS (S.A./S.A.)  +++
```

WAVE PERIOD (SEC)	WAVE LENGTH (M.)	WAVE SLOPE (DEG)	ROLL (DEG/DEG) AM/PHASE	PITCH (DEG/DEG) AM/PHASE	YAW (DEG/DEG) AM/PHASE
6.00	56.1	22.45	.006/ 92.9	.008/ 92.9	.002/ 0.0
7.00	76.2	16.53	.009/ -86.5	.009/ 93.5	.006/ 180.0
8.00	98.6	12.78	.052/ -85.9	.022/ -85.9	.006/ 180.0
9.00	122.3	10.31	.101/ -85.2	.066/ -85.1	.001/ 0.0
10.00	146.3	8.62	.140/ -84.5	.102/ -84.3	.009/ 0.0
11.00	170.1	7.41	.164/ -83.6	.123/ -83.4	.017/ 0.0
12.00	193.5	6.51	.176/ -82.7	.128/ -82.2	.025/ 0.0
13.00	216.5	5.82	.175/ -81.6	.119/ -80.9	.033/ 0.0
14.00	239.1	5.27	.164/ -80.3	.094/ -79.3	.040/ 0.0
15.00	261.4	4.82	.141/ -78.7	.051/ -77.1	.047/ 0.0
16.00	283.4	4.45	.105/ -76.8	.016/ 105.6	.053/ 0.0
17.00	305.2	4.13	.052/ -74.4	.119/ 109.5	.060/ 0.0
18.00	326.7	3.86	.022/ 108.7	.278/ 115.2	.066/ 0.0
19.00	348.1	3.62	.129/ 113.0	.532/ 124.1	.072/ 0.0
20.00	369.3	3.41	.284/ 119.0	.940/ 139.2	.077/ 0.0
21.00	390.4	3.23	.515/ 127.9	1.473/ 164.2	.083/ 0.0
22.00	411.3	3.06	.851/ 141.8	1.752/-164.8	.089/ 0.0
23.00	432.2	2.92	1.263/ 162.4	1.634/-141.3	.094/ 0.0
24.00	452.9	2.78	1.548/-172.4	1.437/-127.4	.100/ .0
25.00	473.6	2.66	1.562/-150.5	1.282/-119.1	.105/ 0.0
26.00	494.3	2.55	1.443/-135.5	1.169/-113.7	.111/ 0.0
27.00	514.8	2.45	1.316/-125.9	1.088/-110.1	.116/ 0.0
28.00	535.3	2.35	1.212/-119.4	1.027/-107.5	.121/ 0.0
29.00	555.8	2.27	1.131/-114.9	.981/-105.5	.127/ 0.0
30.00	576.2	2.19	1.069/-111.7	.945/-103.9	.132/ .0

>>> Note: Surge and sway RAOs evaluated at "natural" pitch and roll centers

**
*************** II. UNMOORED VESSEL MOTION CHARACTERISTICS **************
**

---- REGULAR WAVE DATA: WAVE HEADING = 135.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC

+++ RELATIVE MOTION RAOS IN M. PER UNIT WAVE AMP. (S.A./S.A.) +++

	---- COORDINATES ---- (30.0, 30.0, 40.0)			---- COORDINATES ---- (30.0, -30.0, 40.0)		
WAVE PERIOD (SEC)	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
6.00	.634/ -90	.649/ 89	.983/-179	.702/ 176	.717/ -2	.955/ 91
7.00	.685/ -88	.732/ 91	1.002/-177	.738/ 110	.682/ -70	.995/ 20
8.00	.737/ -88	.800/ 91	.975/-176	.693/ 64	.650/-119	.960/ -16
9.00	.737/ -89	.802/ 90	.913/-177	.735/ 34	.703/-150	.842/ -41
10.00	.699/ -89	.763/ 90	.852/-178	.793/ 17	.759/-166	.733/ -60
11.00	.644/ -90	.706/ 90	.808/-179	.831/ 9	.791/-174	.668/ -77
12.00	.583/ -90	.644/ 89	.785/-179	.851/ 5	.804/-178	.645/ -91
13.00	.520/ -91	.583/ 89	.781/ 179	.859/ 3	.807/ 179	.658/-103
14.00	.456/ -92	.523/ 89	.795/ 179	.859/ 3	.803/ 178	.701/-113
15.00	.390/ -93	.465/ 88	.828/-179	.853/ 4	.796/ 179	.770/-120
16.00	.320/ -96	.406/ 87	.880/-177	.842/ 6	.786/-179	.869/-125
17.00	.245/-104	.347/ 85	.954/-174	.824/ 9	.774/-177	1.002/-127
18.00	.178/-126	.284/ 81	1.050/-169	.792/ 14	.757/-175	1.181/-126
19.00	.205/-171	.220/ 72	1.158/-161	.728/ 23	.733/-171	1.414/-122
20.00	.411/ 171	.172/ 48	1.235/-149	.583/ 37	.696/-165	1.681/-113
21.00	.734/-176	.207/ 11	1.170/-135	.265/ 59	.630/-157	1.864/ -99
22.00	.938/-151	.366/ -2	1.019/-130	.189/ -77	.503/-146	1.865/ -85
23.00	.907/-131	.600/ 4	1.038/-129	.500/ -58	.269/-132	1.812/ -71
24.00	.809/-120	.783/ 23	1.101/-120	.647/ -45	.095/ 129	1.607/ -56
25.00	.721/-113	.816/ 40	1.063/-107	.715/ -37	.350/ 117	1.307/ -45
26.00	.654/-110	.765/ 53	.948/ -97	.751/ -32	.508/ 128	1.059/ -40
27.00	.601/-107	.699/ 60	.824/ -89	.771/ -28	.592/ 136	.882/ -37
28.00	.559/-105	.641/ 65	.718/ -84	.783/ -25	.638/ 142	.755/ -36
29.00	.524/-104	.593/ 68	.630/ -81	.790/ -23	.664/ 146	.660/ -36
30.00	.495/-103	.553/ 70	.559/ -78	.795/ -22	.681/ 149	.586/ -36

**
*************** II. UNMOORED VESSEL MOTION CHARACTERISTICS **************
**

---- REGULAR WAVE DATA: WAVE HEADING = 135.0 DEG
WAVE HEIGHT = 7.0 M.
VESSEL SPEED = .0 M./SEC

+++ RELATIVE MOTION RAOS IN M. PER UNIT WAVE AMP. (S.A./S.A.) +++

	---- COORDINATES ---- (-30.0, 30.0, 40.0)			---- COORDINATES ---- (-30.0, -30.0, 40.0)		
WAVE PERIOD (SEC)	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
6.00	.699/ 3	.715/-177	.953/ -91	.634/ -89	.649/ 90	.984/ 179
7.00	.737/ 69	.683/-109	.996/ -20	.685/ -91	.732/ 88	1.008/ 177
8.00	.691/ 114	.642/ -61	.981/ 16	.737/ -90	.800/ 89	.983/ 176
9.00	.721/ 145	.679/ -30	.889/ 40	.737/ -89	.802/ 91	.923/ 175
10.00	.768/ 161	.723/ -14	.802/ 58	.700/ -87	.763/ 92	.863/ 175
11.00	.800/ 170	.748/ -5	.750/ 72	.645/ -86	.707/ 93	.821/ 174
12.00	.817/ 174	.758/ -1	.733/ 85	.584/ -85	.646/ 94	.800/ 173
13.00	.825/ 176	.760/ 0	.745/ 96	.522/ -85	.585/ 95	.799/ 172
14.00	.831/ 176	.757/ 1	.781/ 105	.458/ -84	.526/ 95	.818/ 172
15.00	.836/ 175	.754/ 0	.839/ 113	.391/ -83	.468/ 96	.859/ 172
16.00	.848/ 173	.753/ 0	.922/ 120	.319/ -84	.409/ 97	.924/ 172
17.00	.873/ 170	.755/ -2	1.035/ 128	.237/ -87	.349/ 97	1.022/ 173
18.00	.926/ 167	.766/ -4	1.188/ 135	.145/-102	.283/ 96	1.162/ 176
19.00	1.036/ 163	.791/ -7	1.396/ 144	.128/-165	.210/ 92	1.367/-179
20.00	1.248/ 163	.842/ -11	1.679/ 156	.333/ 169	.134/ 74	1.670/-171
21.00	1.536/ 171	.939/ -14	1.995/ 174	.654/-175	.129/ 19	2.072/-156
22.00	1.618/-173	1.104/ -14	2.096/-163	.868/-148	.285/ -3	2.318/-133
23.00	1.449/-162	1.312/ -8	1.938/-144	.854/-127	.518/ 5	2.152/-109
24.00	1.274/-158	1.416/ 2	1.747/-129	.770/-115	.707/ 25	1.733/ -90
25.00	1.154/-157	1.345/ 13	1.523/-115	.692/-107	.755/ 45	1.319/ -78
26.00	1.076/-158	1.216/ 19	1.288/-105	.630/-102	.717/ 58	1.033/ -72
27.00	1.023/-158	1.107/ 21	1.087/ -97	.581/ -99	.662/ 67	.845/ -69
28.00	.985/-159	1.027/ 22	.928/ -91	.541/ -97	.611/ 72	.714/ -67
29.00	.957/-160	.970/ 22	.803/ -87	.509/ -95	.567/ 76	.618/ -66
30.00	.936/-161	.928/ 21	.705/ -84	.482/ -93	.531/ 79	.545/ -66
30.00	1.25/ 95	1.18/ -86	.67/ -75	1.24/ 91	1.18/ -86	.48/ -57

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**                                                                        **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                        **


  ----  ENVIRONMENTAL CHARACTERISTICS  ----


  WAVE SPECTRAL TYPE -- MEAN JONSWAP
                      : LONG-CRESTED SEAS


            CALCULATED SIGNIFICANT WAVE HEIGHT .....   7.26 M.
            SPECTRUM PEAK PERIOD ..................  12.00 SECONDS
            SPECTRUM ZERO UPCROSS PERIOD ..........  10.41 SECONDS
            CHARACTERISTIC WIND SPEED .............  16.41 M./SECOND
            DIRECTION OF MAXIMUM SEAS .............  90.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

            CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
            GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
            SWELL PERIOD ..........................  18.00 SECONDS


  ----  VESSEL DYNAMICS SUMMARY  ----

>>> Note: Moments evaluated about "natural" roll and pitch centers

                    +++ SIGNIFICANT SINGLE AMPLITUDE FORCES/TORQUES +++

                         SIGNIFICANT     SIGNIFICANT    ZERO UPCROSS
                            VALUE           RATE        PERIOD (SEC)

  SURGE (M.TONS)           682.512         241.721         17.741
  SWAY  (M.TONS)          3112.836        2016.791          9.698
  HEAVE (M.TONS)          1699.001        1332.779          8.010
  ROLL  (M.TON-MTR)      88096.900       60106.292          9.209
  PITCH (M.TON-MTR)       2893.975         940.191         19.340
  YAW   (M.TON-MTR)       2205.689         795.686         17.417

>>> Note: Surge and sway motions evaluated at "natural" pitch and roll centers


                        +++ SIGNIFICANT SINGLE AMPLITUDE MOTIONS +++


                         SIGNIFICANT     SIGNIFICANT    ZERO UPCROSS
                            VALUE           RATE        PERIOD (SEC)

  SURGE (M. )                1.236            .421         18.464
  SWAY  (M. )                2.033            .928         13.768
  HEAVE (M. )                 .876            .382         14.414
  ROLL  (DEG)                1.862           1.089         10.742
  PITCH (DEG)                 .924            .283         20.504
  YAW   (DEG)                 .108            .038         18.084
```


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**                                                                        **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                        **


  ----  ENVIRONMENTAL CHARACTERISTICS  ----


  WAVE SPECTRAL TYPE -- MEAN JONSWAP
                      : LONG-CRESTED SEAS


            CALCULATED SIGNIFICANT WAVE HEIGHT .....   7.26 M.
            SPECTRUM PEAK PERIOD ..................  12.00 SECONDS
            SPECTRUM ZERO UPCROSS PERIOD ..........  10.41 SECONDS
            CHARACTERISTIC WIND SPEED .............  16.41 M./SECOND
            DIRECTION OF MAXIMUM SEAS .............  90.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

            CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
            GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
            SWELL PERIOD ..........................  18.00 SECONDS
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  ----  LOCAL MOTION SUMMARIES: SELECTED POINTS  ----


                      +++  SIGNIFICANT SINGLE AMP. RELATIVE MOTION +++

 POINT COORDINATES          X COMP          Y COMP          Z COMP
    ( X, Y, Z)

(   30.0,   30.0,   40.0)      .559           3.691           3.027
(   30.0,  -30.0,   40.0)     1.112           4.022           3.186
(  -30.0,   30.0,   40.0)     1.563           3.857           3.262
(  -30.0,  -30.0,   40.0)      .505           3.896           3.226
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**                                                                            **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                            **
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---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- MEAN JONSWAP
: LONG-CRESTED SEAS

```
CALCULATED SIGNIFICANT WAVE HEIGHT .....   9.93 M.
SPECTRUM PEAK PERIOD ..................  15.00 SECONDS
SPECTRUM ZERO UPCROSS PERIOD ..........  12.58 SECONDS
CHARACTERISTIC WIND SPEED .............  20.52 M./SECOND
DIRECTION OF MAXIMUM SEAS .............  90.00 DEGREES
```

+++ BACKGROUND SWELL DATA +++

```
CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
SWELL PERIOD ..........................  18.00 SECONDS
```

---- VESSEL DYNAMICS SUMMARY ----

>>> Note: Moments evaluated about "natural" roll and pitch centers

+++ SIGNIFICANT SINGLE AMPLITUDE FORCES/TORQUES +++

	SIGNIFICANT VALUE	SIGNIFICANT RATE	ZERO UPCROSS PERIOD (SEC)
SURGE (M.TONS)	682.512	241.721	17.741
SWAY (M.TONS)	4390.775	2259.750	12.208
HEAVE (M.TONS)	1596.167	1198.168	8.370
ROLL (M.TON-MTR)	80724.312	54838.382	9.249
PITCH (M.TON-MTR)	2893.975	940.191	19.340
YAW (M.TON-MTR)	2205.689	795.686	17.417

>>> Note: Surge and sway motions evaluated at "natural" pitch and roll centers

+++ SIGNIFICANT SINGLE AMPLITUDE MOTIONS +++

	SIGNIFICANT VALUE	SIGNIFICANT RATE	ZERO UPCROSS PERIOD (SEC)
SURGE (M.)	1.236	.421	18.464
SWAY (M.)	3.880	1.581	15.418
HEAVE (M.)	1.163	.453	16.135
ROLL (DEG)	1.971	1.056	11.725
PITCH (DEG)	.924	.283	20.504
YAW (DEG)	.108	.038	18.084


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**                                                                            **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                            **
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---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- MEAN JONSWAP
: LONG-CRESTED SEAS

```
CALCULATED SIGNIFICANT WAVE HEIGHT .....   9.93 M.
SPECTRUM PEAK PERIOD ..................  15.00 SECONDS
SPECTRUM ZERO UPCROSS PERIOD ..........  12.58 SECONDS
CHARACTERISTIC WIND SPEED .............  20.52 M./SECOND
DIRECTION OF MAXIMUM SEAS .............  90.00 DEGREES
```

+++ BACKGROUND SWELL DATA +++

```
CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
SWELL PERIOD ..........................  18.00 SECONDS
```


---- LOCAL MOTION SUMMARIES: SELECTED POINTS ----

+++ SIGNIFICANT SINGLE AMP. RELATIVE MOTION +++

POINT COORDINATES (X, Y, Z)	X COMP	Y COMP	Z COMP
(30.0, 30.0, 40.0)	.559	4.773	4.356
(30.0, -30.0, 40.0)	1.112	5.074	4.520
(-30.0, 30.0, 40.0)	1.563	4.902	4.522
(-30.0, -30.0, 40.0)	.505	4.974	4.548

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**                                                                          **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                          **


  ----  ENVIRONMENTAL CHARACTERISTICS  ----


  WAVE SPECTRAL TYPE -- MEAN JONSWAP
                      : LONG-CRESTED SEAS


            CALCULATED SIGNIFICANT WAVE HEIGHT .....   7.26 M.
            SPECTRUM PEAK PERIOD ..................  12.00 SECONDS
            SPECTRUM ZERO UPCROSS PERIOD ..........  10.41 SECONDS
            CHARACTERISTIC WIND SPEED .............  16.41 M./SECOND
            DIRECTION OF MAXIMUM SEAS ............. 135.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

            CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
            GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
            SWELL PERIOD ..........................  18.00 SECONDS


  ----  VESSEL DYNAMICS SUMMARY  ----

>>> Note: Moments evaluated about "natural" roll and pitch centers

                    +++ SIGNIFICANT SINGLE AMPLITUDE FORCES/TORQUES +++

                         SIGNIFICANT     SIGNIFICANT    ZERO UPCROSS
                            VALUE           RATE        PERIOD (SEC)

 SURGE (M.TONS)           1606.652         810.511         12.455
 SWAY  (M.TONS)           2136.588        1073.735         12.503
 HEAVE (M.TONS)           1348.833         761.644         11.127
 ROLL  (M.TON-MTR)       45619.382       28586.890         10.027
 PITCH (M.TON-MTR)       27588.660       17188.521         10.085
 YAW   (M.TON-MTR)        7877.990        5044.683          9.812

>>> Note: Surge and sway motions evaluated at "natural" pitch and roll centers


                        +++ SIGNIFICANT SINGLE AMPLITUDE MOTIONS +++


                         SIGNIFICANT     SIGNIFICANT    ZERO UPCROSS
                            VALUE           RATE        PERIOD (SEC)

 SURGE (M. )                 1.736            .738         14.785
 SWAY  (M. )                 1.717            .727         14.829
 HEAVE (M. )                  .919            .391         14.748
 ROLL  (DEG)                 1.150            .625         11.573
 PITCH (DEG)                 1.201            .518         14.559
 YAW   (DEG)                  .185            .088         13.281
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**                                                                          **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                          **


  ----  ENVIRONMENTAL CHARACTERISTICS  ----


  WAVE SPECTRAL TYPE -- MEAN JONSWAP
                      : LONG-CRESTED SEAS


            CALCULATED SIGNIFICANT WAVE HEIGHT .....   7.26 M.
            SPECTRUM PEAK PERIOD ..................  12.00 SECONDS
            SPECTRUM ZERO UPCROSS PERIOD ..........  10.41 SECONDS
            CHARACTERISTIC WIND SPEED .............  16.41 M./SECOND
            DIRECTION OF MAXIMUM SEAS ............. 135.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

            CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
            GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
            SWELL PERIOD ..........................  18.00 SECONDS
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```
  ----  LOCAL MOTION SUMMARIES: SELECTED POINTS  ----


                       +++  SIGNIFICANT SINGLE AMP. RELATIVE MOTION +++

 POINT COORDINATES         X COMP          Y COMP          Z COMP
    ( X, Y, Z)

(   30.0,   30.0,   40.0)     2.311           2.511           3.436
(   30.0,  -30.0,   40.0)     3.162           3.009           3.320
(  -30.0,   30.0,   40.0)     3.269           2.931           3.542
(  -30.0,  -30.0,   40.0)     2.302           2.512           3.696
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**                                                                         **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                         **


  ----  ENVIRONMENTAL CHARACTERISTICS  ----


  WAVE SPECTRAL TYPE -- MEAN JONSWAP
                      : LONG-CRESTED SEAS


            CALCULATED SIGNIFICANT WAVE HEIGHT .....   9.93 M.
            SPECTRUM PEAK PERIOD ..................  15.00 SECONDS
            SPECTRUM ZERO UPCROSS PERIOD ..........  12.58 SECONDS
            CHARACTERISTIC WIND SPEED .............  20.52 M./SECOND
            DIRECTION OF MAXIMUM SEAS ............. 135.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

            CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
            GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
            SWELL PERIOD ..........................  18.00 SECONDS


  ----  VESSEL DYNAMICS SUMMARY  ----

>>> Note: Moments evaluated about "natural" roll and pitch centers

                     +++ SIGNIFICANT SINGLE AMPLITUDE FORCES/TORQUES +++

                          SIGNIFICANT     SIGNIFICANT     ZERO UPCROSS
                             VALUE            RATE        PERIOD (SEC)

  SURGE (M.TONS)           2330.181        1035.049          14.145
  SWAY  (M.TONS)           3113.446        1379.286          14.183
  HEAVE (M.TONS)           1321.961         708.293          11.727
  ROLL  (M.TON-MTR)       42068.350       26091.830          10.130
  PITCH (M.TON-MTR)       24768.290       15390.000          10.112
  YAW   (M.TON-MTR)        9755.204        5261.478          11.650

>>> Note: Surge and sway motions evaluated at "natural" pitch and roll centers


                         +++ SIGNIFICANT SINGLE AMPLITUDE MOTIONS +++


                          SIGNIFICANT     SIGNIFICANT     ZERO UPCROSS
                             VALUE            RATE        PERIOD (SEC)

  SURGE (M. )                 2.953           1.185          15.654
  SWAY  (M. )                 2.925           1.172          15.674
  HEAVE (M. )                 1.203            .467          16.184
  ROLL  (DEG)                 1.270            .627          12.733
  PITCH (DEG)                 1.491            .565          16.579
  YAW   (DEG)                  .303            .128          14.866
```



```
**                                                                         **
****************   III.  IRREGULAR WAVE STATISTICS SUMMARY   ***************
**                                                                         **


  ----  ENVIRONMENTAL CHARACTERISTICS  ----


  WAVE SPECTRAL TYPE -- MEAN JONSWAP
                      : LONG-CRESTED SEAS


            CALCULATED SIGNIFICANT WAVE HEIGHT .....   9.93 M.
            SPECTRUM PEAK PERIOD ..................  15.00 SECONDS
            SPECTRUM ZERO UPCROSS PERIOD ..........  12.58 SECONDS
            CHARACTERISTIC WIND SPEED .............  20.52 M./SECOND
            DIRECTION OF MAXIMUM SEAS ............. 135.00 DEGREES

       +++ BACKGROUND SWELL DATA +++

            CALCULATED SIGNIFICANT SWELL HEIGHT ....   3.00 M.
            GLOBAL SWELL DIRECTION ................ 135.00 DEGREES
            SWELL PERIOD ..........................  18.00 SECONDS
```



```
  ----  LOCAL MOTION SUMMARIES: SELECTED POINTS  ----


                        +++  SIGNIFICANT SINGLE AMP. RELATIVE MOTION +++

POINT COORDINATES          X COMP          Y COMP          Z COMP
   ( X, Y, Z)

(   30.0,   30.0,   40.0)     2.509           2.780           4.573
(   30.0,  -30.0,   40.0)     4.245           4.021           4.583
(  -30.0,   30.0,   40.0)     4.454           3.919           4.867
(  -30.0,  -30.0,   40.0)     2.489           2.784           4.990
```

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