

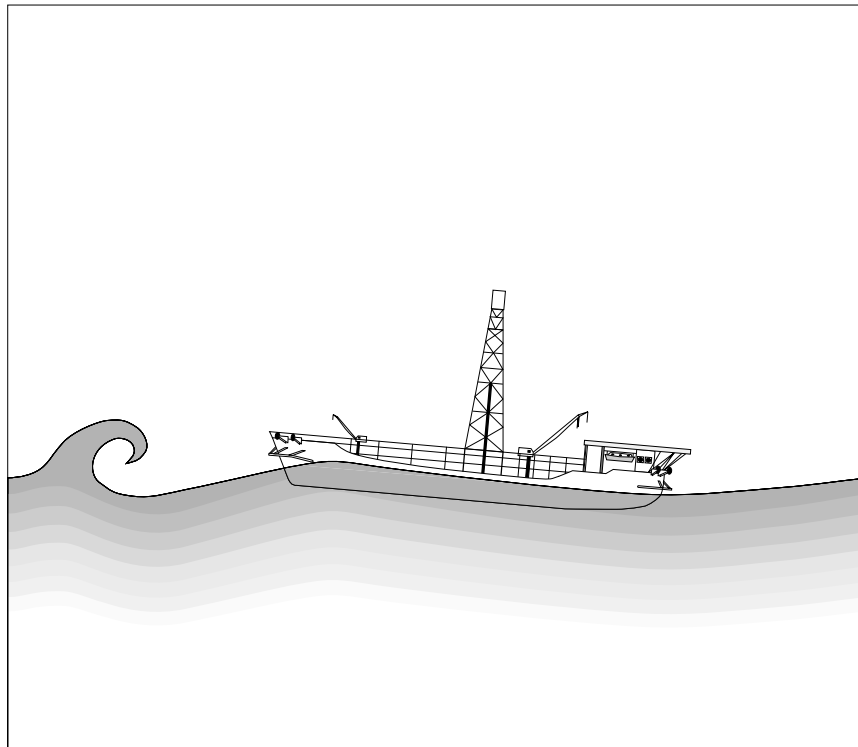
Shipsim[®]

Discsim[®]

Comprehensive Wave-Frequency
Displacement-Hull Simulation Software
From SeaSoft[®] Systems

User Manual

April, 2005



Shipsim

Discsim

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Displacement-Hull Simulation Software
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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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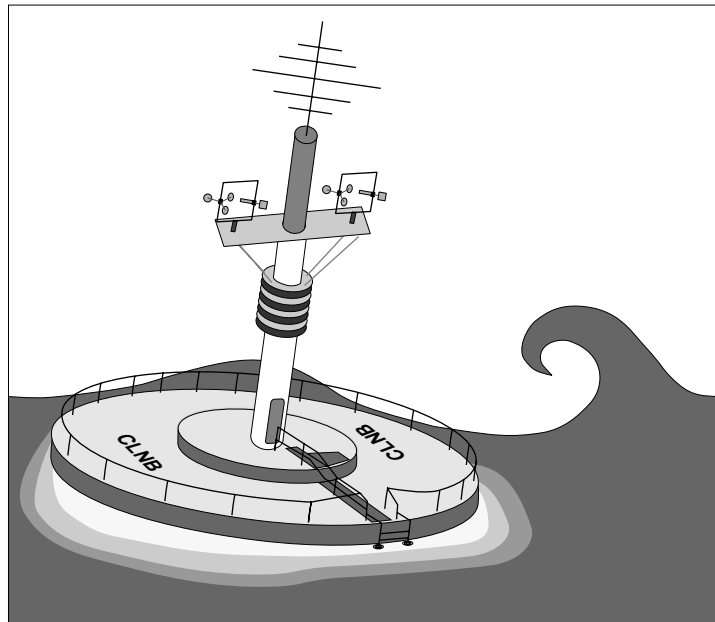
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Chapter 1

Introduction

Background

Shipsim and Discsim are two members 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. Shipsim relates to vessels with a conventional oblong waterplane (length/beam ratio of 3 or more), while Discsim relates to buoy-shaped vessels possessing azimuthally symmetric underwater forms. Although the wave forcing algorithms are very different for these two classes of vessel, the user-supplied data stream required for both simulations is identical. Therefore the same user interface and same user manual apply to both. With only a few exceptions, in the following pages the generic term "Shipsim" will be used to refer to *both* programs.



Purpose

Shipsim and Discsim are general-purpose simulation programs for estimating wave-frequency loads and motions of displacement-hull vessels of all types. Although designed primarily to accommodate full vessels with large block and prismatic coefficients common to the offshore industry, they are sufficiently versatile to be used for simulation of seagoing vessels with finer lines, such as container ships and liners, and cone-shaped vessels associated with Arctic operations in the presence of persistent ice.

Objectives

In the development of these programs, the principal objective has been to produce state of the art computational tools usable by any individual with training in ocean engineering methods. The packages are 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 in vessel motion analysis, Shipsim plays an important auxiliary role in producing data files containing vessel and fairlead motion characteristics for other simulations in the SeaSoft library, including Towsim, SALMsim, Moorsim, CALMsim and SPMsim.

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 Shipsim package comprises the user's 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 Shipsim package are of three generic types: executable binary program files, binary data files and formatted data files.

The sole executable program file is Shipsim (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 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 (SHIPDAT, SHIPBAK and LASTBAK) and formatted output data files (SHIPSUM.stxt, SHIPRAO.stxt, SHIPRAN.stxt, SHIPIN.stxt) containing simulation results. Management and recommended archival procedures for these files are discussed in Appendix D. The corresponding Discsim files are identified by the replacement of "SHIP" with "DISC" in each file name (DISCDAT, DISCBAK, DISCRAO.stxt, DISCRAN.stxt, DISCIN.stxt).

The User Interface

The User Interface, an integral part of the Simulator, is used to create the input data file (the "SHIPDAT" 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 problem and Chapter 5 for discussion of the Interface using screen images related to the sample problem). 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's Manual Overview

The Shipsim user's manual constitutes the major tutorial tool provided with the program package. To derive maximum benefit, 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 Shipsim. 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 Shipsim and serves as a "super index" which can be used to answer most of the day-to-day operational questions that arise during Shipsim execution. Cross-references to other portions of the user's 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's 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 Shipsim.

Program Capabilities

Shipsim will perform well on virtually any monohull vessel 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 vessel simulation. It is necessary, however, to assemble the following minimum hydrostatic and mass distribution information in order to complete a meaningful simulation run: Displacement, transverse and longitudinal metacentric heights, vertical centers of gravity and buoyancy, waterplane area, pitch, roll and yaw gyradii, and details of bilge radii and bilge keels, if available. (See also page 18 ff.) Note that both metacentric heights are required regardless of whether or not pitch information is desired, as this information is needed to infer the dimensions of the "dynamically similar box" for use in simulation calculations (See Appendix E). The gyradii are, however, 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 Shipsim, will only be correct if the correct gyradii have been supplied. A built-in database of VLCC tanker characteristics is available on-line which can be used to obtain reasonable and physically consistent data values for vessels with large block coefficients. (See Appendix G.)

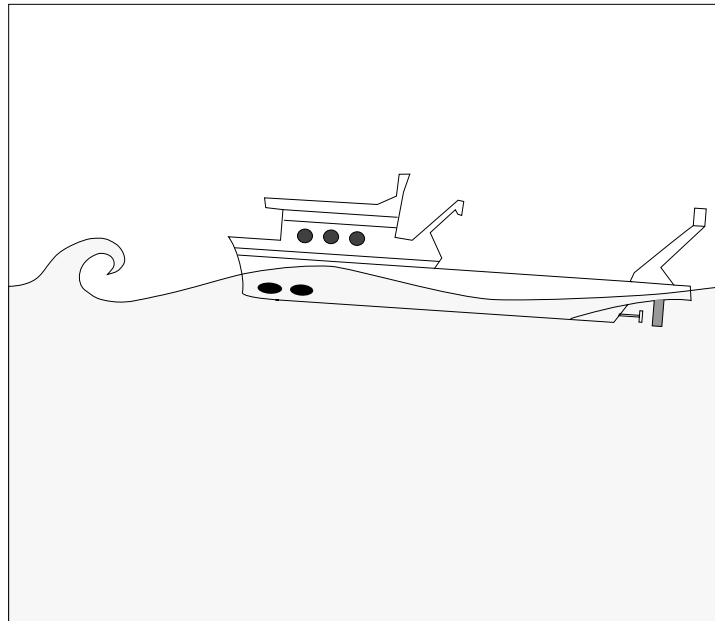
Automatic Backup of Input Files

When the Simulation is executed, it first inspects the local directory to see if any file with the name SHIPDAT (or DISCDAT) is resident there. If so, a backup file named SHIPBAK/DISCBAK is produced from the pre-existing SHIPDAT/DISCDAT file while any pre-existing SHIPBAK/DISCBAK 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, Shipsim 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 Shipsim. Refer to Appendix B for data required to simulate a Series 60 vessel of .7 block coefficient. Refer to Chapter 5 for images of Screen presentations produced by Shipsim 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 Shipsim (see also page 16). 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. Shipsim 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.

Vessel Data

For 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 routinely carried out during execution of almost all mainframe vessel 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.

In view of these considerations it is generally sufficient, for bodies of simple shape, to simulate a surrogate body of perfectly prismatic proportions (i.e. block coefficient equal to 1.0) whose mass distribution and crucial resonance periods of heave, pitch and roll accurately match those of the vessel to be modeled. This construct will be called the "dynamically similar box". Naturally, the greater the departure of the body to be simulated from a box, the greater are the errors arising from this simplifying procedure. However, the discussion of Appendix E shows that this procedure can successfully model dynamic characteristics of relatively high speed ocean-going transport vessels as well as the utility vessels with large block coefficients for which it was designed.

The vessel data required by Shipsim is the absolute minimum necessary to permit faithful simulation of the vessel's dynamic characteristics. This minimum data comprises (see also page 18 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 (VKB).
4. Vertical center of gravity from baseline (VKG).
5. Vessel water-plane area at the required displacement.
6. Radii of gyration in Pitch, Roll and Yaw.
7. Bilge characteristics at maximum beam station; radii and details of bilge keel, if any.
8. Vessel speed for simulation.

Notes:

- The water-plane area for each condition need only be approximate. It is used in a qualitative way to begin an iterative search for the dynamically similar box dimensions. This search can have multiple solutions. The water-plane characteristics are necessary to identify the solution which most closely matches pitch, roll and heave characteristics of the actual vessel.
- 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.

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. Shipsim 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 22 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 roll resonance 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 100.
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 Shipsim uses the computed regular wave RAOs in the determination of irregular wave response. Shipsim, 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 23.
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 Shipsim 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, in particular roll, and the influence of wave amplitude on the peak of the resonant response curves can be explored by executing Shipsim 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 irregular wave significant roll amplitudes computed in Shipsim (and on significant roll, pitch *and* heave amplitudes in Discsim). This is because the effects of nonlinear response in these RAOs have been incorporated. (Although Discsim differs somewhat from Shipsim in this respect, treating all three restored degrees of freedom with a nonlinear model, the remainder of this discussion will nonetheless be specific to Shipsim; the extension to the additional nonlinear degrees of freedom in Discsim should be self-evident.)

When irregular wave responses are desired, it is worthwhile for inexperienced users to execute Shipsim with two or three different choices for the regular wave heights or slopes in order to obtain a feeling for the influence on the significant roll 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 roll response of modest changes in wave amplitude used for RAO calculations is generally quite small. Whenever a large range of irregular wave heights is of interest, however, the effect of wave height on roll RAO can be important. In these cases a conservative approach is sometimes helpful: Because the roll RAO at roll resonance increases as regular wave height is reduced, one may always obtain an upper bound on significant roll response 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 roll 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. Shipsim 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 25 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 Shipsim, including Bretschneider, Pierson-Moskowitz, and several implementations of the JONSWAP spectrum (including the full 5-parameter representation; see page 35 ff). In addition, there are two ways to input a user-defined spectrum. (See page 22 and Appendix H) The individual spectral densities required as input for the user-supplied frequency spectrum must:

The individual spectral densities required as input for the *user-supplied* (or "custom") frequency spectrum must:

1. Be in a set of units consistent with those of the vessel properties, for example meters²/(radian/second) in metric units.
2. Represent a wave *amplitude* spectrum $S(\omega)$, where ω is the angular frequency variable. The integral of $S(\omega)$ from $\omega = 0$ to $\omega = \infty$ is equal to the variance of the wave amplitude spectrum. 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, whose spectral values are four times greater than the associated wave *amplitude* spectral values.
3. Be given at exactly the same wave *periods* as those specified for regular wave RAO determinations, which periods must possess equal period-to-period intervals as discussed above. This may require some interpolation of spectral data since spectra are normally reported at equal *frequency* intervals and not equal *period* intervals.

User-supplied spectral values, to reiterate, are those associated with a *frequency* spectrum $S(\omega)$ and not a *period* spectrum $S'(t)$ even though the $S(\omega)$ values are given on an equally spaced period grid ($S(\omega)$, $S'(t)$ 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 Shipsim can be compared with the known value. This comparison will alert the user to any errors in spectrum scaling or type of spectrum used.

Swell Characteristics

Swell is a special class of irregular wave which is important in nature and therefore has been incorporated into Shipsim (see also page 31 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 mechanisms.

The swell spectrum utilized in Shipsim is a narrow-banded Gaussian spectrum with 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 Shipsim, 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.

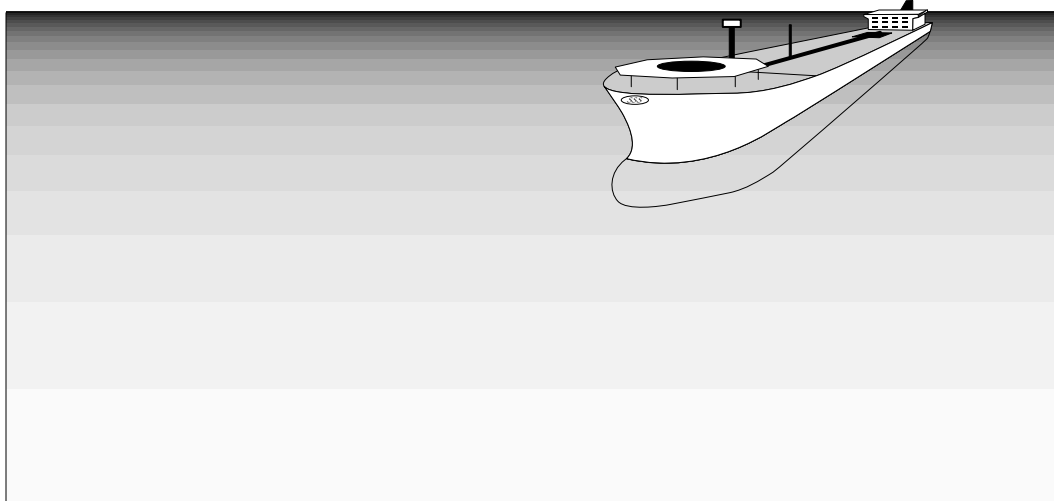
Because one often finds "crossed seas" in which irregular waves from a local disturbance are superimposed upon an unrelated distant swell, Shipsim permits simultaneous specification of irregular waves and background swell; swell can also be simulated alone, in the absence of other wave systems. Note 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, Shipsim 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

Shipsim 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. Shipsim is capable of generating over ten *thousand* pages of data in a single run if complete output for the 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 Shipsim for these parameters are given below (see also pages 22 - 30):

- 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 32):

- 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 than 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 *Backwards* to the previous Screen, enter "**B**<c/r>"; the *First* and *Last* input Screens can be accessed from any numbered Screen in the Editor by entering, "**F**<c/r>" or "**L**<c/r>"; one can *Skip* a Screen by entering "**S**<c/r>" or *Jump* 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.

```

+-----+
|                                             |
|                                             |
|               **  Welcome to Shipsim  **   |
|                                             |
|               ShipSim 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) [Series 60 Vessel                                     ]
2) [Shipsim Sample Simulation                           ]

3) Units of measure: English

4) Site water depth:           4000.00 feet
5) Water density:              64.00 lbs/cubic foot

Enter number of selection: H<c/r>

```

See Also: pp 6

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) [Series 60 Vessel ]
2) [Shipsim Sample Simulation ]

3) Units of measure: English

4) Site water depth:      4000.00 feet
5) Water density:        64.00 lbs/cubic foot

Enter number of selection: H<c/r>

```

Screen 1: Site conditions

Item 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 6 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 ..... 9256.00 k.lbs
2) Transverse metacentric height (KMT) ..... 17.60 ft
3) Longitudinal metacentric height (KML) ..... 485.00 ft
4) Vertical center of buoyancy (VKB) ..... 8.00 ft
5) Vertical center of gravity (VKG) ..... 9.00 ft
6) Vessel water plane area ..... 11700.00 ft^2
7) Length of vessel at waterline ..... 285.00 ft
8) Beam of vessel at waterline ..... 44.00 ft
9) Mean vessel draft ..... 14.00 ft

11) Help for Tanker-Type Physical Characteristics

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

See Also: pp 7 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:

$$\begin{aligned} GM &= KM - VKG \\ GM &= IWP/(\text{Displacement Volume}) - (VKG - VKB) \end{aligned}$$

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

$$\begin{aligned} IWP \text{ (transverse)} &= L*B^3/12 \\ IWP \text{ (longitudinal)} &= B*L^3/12 \end{aligned}$$

- For a circular waterplane of radius R,

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

- For Discsim applications, KMT and KML should be *equal* or unexpected results may occur.
- VKB should be obtained from hydrostatics, but is generally in the range of 1.0-1.2 times (Draft/2) for displacement-hull offshore vessels
- VKG should include free-surface corrections, if any.
- Water plane area can be obtained from:
 - (a) Calculation or estimation,
 - (b) The product of beam, length and published waterplane coefficient at the desired draft
 - (c) 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. For Discsim application, these values should be *equal*.
- Draft comprises mean draft in the simulated condition.
- The SeaSoft Tanker Model (Item 11) is described in Appendix G.

```

***** Screen 3: Vessel Gyradii and Bilge Specifications *****
1) Pitch Gyradius ..... 79.00 ft
2) Roll Gyradius ..... 15.30 ft
3) Yaw Gyradius ..... 81.00 ft

4) Bilge radius at maximum beam station ..... 1.50 ft
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 6 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. Bilge keel and bilge radius data are used in the computation of nonlinear roll damping characteristics.

Items 1-3: Pitch gyradii for slender displacement-hull vessels are usually between .24*Length and .30*Length.

Roll gyradii for displacement-hull vessels of conventional form are usually between .28*Beam and .40*Beam, with most vessels falling in a narrower range { .32*Beam < roll gyradius < .36*Beam }. For Discsim, pitch/roll gyradii generally will range from .25 to .35 of vessel *diameter*. Loaded wing tanks or especially deep hulls tend to produce gyradii near the indicated upper limits.

Yaw gyradii for slender displacement-hull vessels are usually comparable to, but slightly larger than, pitch gyradii. A useful *approximate* rule, valid for offshore vessels whose *thickness* is much less than their beam or length, is

$$\text{Yaw gyradius} \approx \sqrt{(P_g^2 + R_g^2)}$$

where P_g and R_g are, respectively, pitch and roll gyradii. For Discsim, this approximation becomes

$$\text{Yaw gyradius} \approx \sqrt{2}xP_g$$

Items 4-5: The bilge radius and presence or absence of a bilge keel determines the level of square-law roll damping. If a bilge keel is present, the bilge radius information is not used.

- 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:

$$\text{Shifted frequency} = \text{unshifted frequency} - \text{VFWD} \cdot \mathbf{K}$$

Here, VFWD is the vessel speed (in any user-specified direction), \mathbf{K} is the wave vector ($2\pi/\text{wavelength}$ in the direction of wave advance) and $\text{VFWD} \cdot \mathbf{K}$ 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 (V_y) and roll (V_x) 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 ..... Computed
5) Roll damping is ..... Computed

7) Heave period is ..... Computed
9) Pitch period is ..... Computed
11) Roll period is ..... Specified
12) Roll period (sec) ..... 7.10

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

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: Regular Wave Characteristics ****

1) Number of different periods (Max 100): 30
2) Periods (seconds) --
   4.00      4.50      5.00      5.50      6.00      6.50
   7.00      7.50      8.00      8.50      9.00      9.50
  10.00     10.50     11.00     11.50     12.00     12.50
  13.00     13.50     14.00     14.50     15.00     15.50
  16.00     16.50     17.00     17.50     18.00     18.50

3) Use constant wave height or wave slope: slope
4) Wave slope      3.00 degrees

5) Number of wave headings (Max 12): 2
6) Wave headings (degrees) --
   90.00      180.00

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

See Also: pp 8 ff Screen 5: 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. Specification

of wave height/slope only affects computation of roll response (Shipsim) or roll, pitch and heave (Discsim), as nonlinear hydrodynamic effects can be safely neglected for other degrees of freedom. 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 the symmetry of the "dynamically similar box" any 180 degree ambiguity in wave direction 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)    4.00    16)   11.50
2)    4.50    17)   12.00
3)    5.00    18)   12.50
4)    5.50    19)   13.00
5)    6.00    20)   13.50
6)    6.50    21)   14.00
7)    7.00    22)   14.50
8)    7.50    23)   15.00
9)    8.00    24)   15.50
10)   8.50    25)   16.00
11)   9.00    26)   16.50
12)   9.50    27)   17.00
13)  10.00    28)   17.50
14)  10.50    29)   18.00
15)  11.00    30)   18.50

31) Auto repeat

32) Delete a row & collapse array
33) Insert a row & expand array

Enter number of selection: <c/r>

```

```

-- Table of wave headings (degrees) --

1)    90.00
2)   180.00

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)

```

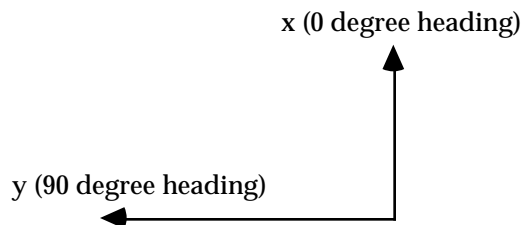
See Also: pp 8 ff

SubScreens 5a & 5b: These SubScreens display the "Auto Repeat" feature of the Editor applied to the input of regular wave periods and directions 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 6: Irregular wave specifications ****

1) Simulate irregular waves?   Yes
2) Wave type:   Bretschneider
3) Number of wave headings (Max 37):   2
4) Wave headings (degrees) --
    90.00      180.00

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

6) Significant height in feet
    7.00      10.00
7) Spectrum peak period (seconds)
    6.50      8.50

20) Use azimuthal spreading of irregular wave energy
21) Wave spreading index ..... 2.00
22) Sector size containing wave energy ..... 180.00 deg
23) Number of angular wedges (Max 36) ..... 6

Enter number of selection: <c/r>

```

See Also: pp 10 ff Screen 6: If irregular waves are required for the simulation, the irregular wave toggle must be set to "yes", which action will call up Screen 6 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 5); and (5) the WAVSPEC.txt spectral option, which has no restrictions as to the period values used for spectral data (see Appendix H).

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

$$\begin{aligned} S'(\omega, \theta) &= S(\omega) \cdot K \cdot \cos^p(\pi \cdot \theta / \theta_c) & -\theta_c/2 < \theta < +\theta_c/2 \\ S'(\omega, \theta) &= 0. & \text{abs}(\theta) > \theta_c/2 \end{aligned}$$

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 $\theta_c = 180$. 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 10 ff SubScreen 6a: 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** spectrum¹ 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-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 --> $\gamma = 3.3, \quad \sigma_a = .07, \quad \sigma_b = .09$

Sharp JONSWAP --> $\gamma = 4.2, \quad \sigma_a = .05, \quad \sigma_b = .07$

Squat JONSWAP --> $\gamma = 7.0, \quad \sigma_a = .68, \quad \sigma_b = .123$

General JONSWAP --> $\gamma, \sigma_a, \sigma_b$ 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.

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.

```

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      26)     .00
12)     .00      27)     .00
13)     .00      28)     .00
14)     .00      29)     .00
15)     .00      30)     .00

31) Auto repeat

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

```

See Also: pp 10 ff

SubScreen 6aa: This "Sub-SubScreen", which is accessed by selection of item 8 on SubScreen 6a, 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 ($\text{ft}^2\text{sec/radian}$ for English units; $\text{m}^2\text{sec/radian}$ for metric) must be specified at each of the periods in the regular wave period array on page 22. 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.

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) 180.00

- 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)

--- Irregular wave significant heights ---

- 1) 7.00
- 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)

--- Irregular wave spectrum peak periods ---

- 1) 6.50
- 2) 8.50

- 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)

SubScreens 6b-6c: These are completely analogous to one another and to the regular wave SubScreen 5b.

```

**** Screen 7: Background swell characteristics ***

1) Specify background swell? ..... Yes
2) Swell significant height ..... 3.00 feet
3) Swell significant period ..... 11.00 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 11

Screen 7: 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 headings, or it can be locked with a "relative" angle to each requested irregular wave direction. In the latter case, when a *relative* swell heading is requested, the angle specified in this item is **added** to each requested irregular wave direction to produce the swell direction applying to that particular irregular wave request.

```

          **** Screen 8: 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 feet

11) Output accelerations at selected points on vessel?  No
12) Output velocities at selected points on vessel?      No
13) Output displacements at selected points on vessel?  Yes

14) Number of points of interest (Max 49):  2
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 8: This is the output options Screen discussed on page 11 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, the 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)   150.00      .00      17.00
2)  -150.00      .00      17.00

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

Enter number of selection: <c/r>

```

See Also: pp 12 SubScreen 8a-8c: This SubScreen is activated by selection of item 15 on Screen 8; 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 9: More output options ****

1) Output force/torque RAOs ..... Yes
2) Output motion RAOs ..... Yes
3) Output RAOs for all spread sea angles .... No
8) Output goes to Disk, on logged drive
9) Debug option is off

Enter number of selection: <c/r>

```

See Also: pp 13 ff Screen 9: 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: When 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.

Item 8: Output can be directed to disk, Screen or printer; see below.

- Item 9: 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.

```
>>> Output Device Selection: <<<
1) Console
2) Disc
Enter number of selection: <c/r>
```

- See Also: pp 3 ff SubScreen 9b: This SubScreen permits selection of the device to receive the 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 10: 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 3 Screen 10: 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 SHIPIN.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 vessel data from a prehistoric "legacy" Moorsim project, you must first update the legacy MOORDAT (or SHIPDAT) file using the *current* version of Moorsim (or Shipsim).

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\SHIPDAT	(Windows OS)
HD3:SeaSoft:SPM:Proj_1:SHIPDAT	(Classic Macintosh)
\SeaSoft\SPM\Proj_1\SHIPDAT	(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 C_b).

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 than 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.
ULCC	"Ultra Large Crude Carrier".
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.

VLCC	"Very Large Crude Carrier".
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 C_{wp}).
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 $f(\alpha)S(w)$ where α is the angle relative to the direction of maximum seas, $f(\alpha)$ 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

Sample Problem

As a tutorial aid in the use of Shipsim, this appendix includes the data required to carry out a complete simulation for a Series 60 vessel of .7 block coefficient. The output generated by Shipsim corresponding to input data presented here is given in Appendix Z.

Input Data

We assume a vessel with the following physical characteristics:

1. Displacement.....	9256 kips
2. Length	315.0 ft
3. Beam	45.0 ft
4. Draft	15.0 ft
5. KMT.....	17.6 ft
6. KML.....	485.0 ft
7. VKB	8.0 ft
8. VKG.....	9.0 ft
9. Water plane area.....	11700 square feet
10. Pitch gyradius.....	79.0 ft
11. Roll gyradius	15.3 ft
12. Yaw gyradius	81.0 ft
13. Bilge radius	1.5 ft
14. Vessel speed.....	0.0 kts
15. Natural period of Roll	7.1 seconds

Environmental Conditions

The environmental conditions to be simulated are:

Regular waves:

- Periods from 4 to 18 seconds; constant wave slope of 3 degrees
- One-half second period intervals

- Regular wave directions of 180 and 90 degrees

Irregular waves:

- Bretschneider spectrum with height/period combinations of (7 ft, 6.5 seconds), (10 ft, 8.5 seconds)
- Irregular wave headings of 180 and 90 degrees
- Azimuthal spreading of wave energy according to a cosine-squared distribution (wave spreading index = 2)
- Background swell of 3 foot height, 11 second period and 30 degree heading

Output options

The output is to include all vessel force, torque and motion RAOs for the requested wave directions, and acceleration RAOs at the bow and stern 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 Editor Screens which would be displayed upon the successful completion of input of the above data. The output from Shipsim for this sample case is presented in Appendix Z.

Execution Messages

During execution of Shipsim, 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 34). 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 Shipsim 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 "dynamically similar box" data appearing on page two of the output should always be checked to see that the values are reasonable. The discussion of Appendix F should be noted in this regard.
2. The natural damping coefficients are given in percent of critical damping. The roll damping coefficient reflects the highly nonlinear nature of the roll degree of freedom, and will vary with the value for wave height or wave slope chosen for the simulation.
3. 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.
4. 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 at long periods, as contrasted with 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.
5. 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.
6. The period reported in column one is *wave encounter* period when a non-zero vessel 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 and is in the same direction as the vessel motion. That is, the vessel is overtaking the wave.

7. 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, as occurs for roll in beam seas, for example.

8. 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 *time-dependent* part of any 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, 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 simple measure of the most important periods involved in the motion.

Appendix D

File Management

File Requirements

As discussed earlier, Shipsim produces an unformatted input file called SHIPDAT containing the particulars of a given simulation including the vessel, site and environmental characteristics. Once a satisfactory SHIPDAT file has been produced, as determined by satisfactory output from Shipsim, 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 Shipsim work area on the disk, renamed to SHIPDAT, 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 SHIPIN.stxt

It is *essential* to archive, along with the binary SHIPDAT file, the formatted SHIPIN.stxt data file (produced automatically upon execution or by using the "Produce diskfile of input data" option on the last editor screen; see page 35 ff). 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 SHIPDAT files problematic. In such cases it may be advantageous to create a new data file manually from a SHIPIN archive.

Appendix E

Theoretical Considerations

This chapter is intended to give a brief overview of the theoretical basis underlying Shipsim 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 Shipsim. The general approach to the development of Shipsim has been to emphasize simulation performance in the cases of principal interest to the offshore industry. This choice has led to particularizations which favor relatively large block and prismatic coefficients and beam-to-draft ratios.

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 for extremely blocky vessels with blunt bow and stern profiles and, unless corrected, produces highly erroneous hydrodynamic coefficients in the long-wave limit. 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. In our view, 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 and a significant amount of effort must be devoted to the defense of unconventional theoretical approaches such as that adopted for use in Shipsim.

Wave Period Considerations

Shipsim was designed to give reliable estimates of loads and motions for a wide range of displacement-hull vessels 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 Shipsim 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 fine bow or stern lines or large bilge radii, whose geometrical 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 bilge forces, which are not considered by *any* ships 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 bilge radius and bilge keel characteristics in Shipsim are used in a nonlinear calculation of this type.)

To capitalize on the simplifications arising from the long-wave analytical approach, Shipsim determines the dimensions of a "dynamically similar box" whose beam, length, draft and mass properties (gyradii and centers of gravity) are chosen to insure that the dynamical properties of the box, especially the important natural periods of roll, pitch and heave, are (practically speaking) the same as the simulated vessel's. This procedure evidently is more justifiable for vessels of large block coefficient involved in typical offshore operations than for vessels with very fine lines of the type used in high-speed ocean transport. However, the procedure results in surprisingly good performance estimates even for vessels with block coefficients of .6 and less.

The use of an equivalent box for the purpose of determining the hydrodynamic properties of a vessel is 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 limit. This ability eliminates one of the most objectionable features of strip theories for the analysis of the very blocky vessels common to the offshore industry; namely the unrealistic logarithmic divergence of the sectional heave and pitch added mass coefficients with increasing period of motion.
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/draft characteristics as the vessel to be simulated.

Wave Period Limitations

Because of the emphasis on longer wave periods it is reasonable to suppose that Shipsim 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. (In particular, two-dimensional strip theories are best suited to the short period regime; for example, their calculation of sectional added masses, as noted above, are highly inaccurate in the long-wave limit.) For a number of reasons, however, the superiority of two- and three-dimensional diffraction theories in the short wave regime is of little practical consequence:

1. 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.
2. 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 ship 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 roll amplitudes is extremely sensitive to the nonlinear roll model employed, and is almost wholly independent of the sophistication of the potential-flow analysis used to compute the roll torque and potential damping.
3. The commonly accepted "standard" for vessel motion calculations, chronically under-used because of irritatingly long computation times, is the three-dimensional diffraction theory. To limit computation time, seldom are more than ten to fifteen wave periods chosen at which to compute the hydrodynamic coefficients and vessel 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 economics on the three-dimensional diffraction theory limits, to a large 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.

4. The facet size selected for diffraction-based programs is typically rather large, again to save on computing time and costs; large facets compromise the potential superiority of diffraction models for simulating short-period vessel response; 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 Shipsim 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, Shipsim's approximate results should be reliable for speeds of up to fifteen knots.

Caveats

Because Shipsim 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 Shipsim 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 Shipsim would give a good qualitative estimate of these motions, it should not be used uncritically for quantitative estimates.

Precision

The calculations in Shipsim 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 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 Shipsim 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 roll motions in much the same way as a conventional anti-roll tank. This situation is beyond the current capabilities of Shipsim, although the use of information provided by Shipsim, when combined with additional theoretical analysis that is beyond the scope of this manual, can produce meaningful motion estimates for this condition.

Shallow Water

Shipsim 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 (depth comparable to the half-beam of the vessel) 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 & Troubleshooting

Runtime Problems

The amount of input error checking done by Shipsim 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. Since the metacentric height data plays an important role in the determination of the dynamically similar box, these parameters should be checked and double checked for accuracy. The longitudinal metacenter (KML), in particular, is not as intuitively familiar to many people as is, for example, the KG. Therefore an input error related to the KML is likely to be overlooked, which would most likely lead to invalid simulation results. In this regard, the dynamically similar box dimensions which appear in the output stream are extremely useful diagnostic tools. This is because these dimensions, if the input data has been properly determined and entered, are always intuitively quite reasonable, indicating in general a vessel which is slightly shorter in length, slightly narrower in beam, and of somewhat shallower draft than the actual vessel. Any departure from what appears reasonable should result in a critical reappraisal of input data. The sample problem laid out in this manual should be consulted for guidance.

True code-related runtime problems with Shipsim 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.

Tanker Properties Facility

A built-in on-line "Help" facility is available to provide assistance in obtaining physical properties for VLCC tanker-type vessels. It can sometimes be useful in providing physically reasonable and consistent vessel properties when sufficient information is unavailable to permit simulation. Use of this facility should be limited to conventional vessels of large (greater than .7 or so) block coefficient. See Appendix G.

Error Messages

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

1. Error messages generated by the operating system arising from a failure to find Shipsim'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 Shipsim. These messages are system-dependent

and are beyond the scope of this manual.

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

Examples--

- RATIONALIZATION ERROR... SPECIFY VESSEL DRAFT AND RETRY: This message may appear if Shipsim is unable to find an appropriate dynamically similar box and will cause execution to cease. One or more of the water plane area, vessel displacement, KML and KMT values passed to Shipsim are suspect if this message occurs. If problems persist after carefully debugging the input data file, paying particular attention to the waterplane area, contact SeaSoft.

- BAD EQUIVALENT BOX...CHECK INPUT STREAM AND RETRY: This message can occur if the solution for the dynamically similar box dimensions appear to be unrealistic. The quality of the simulation then becomes suspect. Because this is a matter of judgement, Shipsim continues execution after issuing this message. If the box dimensions appearing in the output stream following the appearance of this message seem unreasonable, and no errors can be found in the input file, contact SeaSoft.

- INVALID SPREADING INDEX...: This message can occur if a 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 Shipsim 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 Shipsim 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 Shipsim may have trouble digesting them on some computer installations. Also, two second waves have no influence on vessel motions, and Shipsim 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

On-line Tanker Model

An implementation of the SeaSoft Tanker Model is available, on-line, within the user interface of all relevant SeaSoft mooring and motion simulations. This implementation is analytically identical to the SeaSoft Minimal Data Tanker Model and produces a subset of Minimal Model properties corresponding to the supplied deadweight (as usual, in Long Tons of 2240 pounds) and Simulation Draft. Note that SeaSoft simulation requirements for vessel properties are simulation-dependent; Moorsim, for example, needs wind and current areas for execution while Shipsim does not. Because the same tanker help routine is shared by all simulations, not all displayed variables are relevant for every simulation.

Operation of the on-line model is largely self-explanatory; in addition it has an internal on-line help facility. There are only two user-specifiable variables (DWT in Long Tons and Simulation Draft in appropriate simulation units) from which the remaining vessel physical properties are inferred. The on-line window (shown below), which is updated with every change in either input variable, only *displays* estimates; it *does not* transfer data into the simulation data file until specifically so instructed by the user.

```
.>>> Independent variables for      1. Deadweight (DWT).... 100000. Long Tons
      tanker property estimates:    2. Simulation Draft ... 22.00 feet

A. Vessel Displacement      123121. Kips      L. Freeboard-based load... 37.6%
B. Displacement-based load   44.1%        M. Draft-based load..... 46.6%

C. Length (LPP) .....      799.76        N. Transverse KM .....    80.72
D. Beam .....              135.81        O. Longitudinal KM ..... 2030.93
E. Draft .....             22.00        P. VKB.....              11.97
F. Roll Gyradius.....       56.93        Q. VKG .....             36.53
G. Pitch Gyradius .....    205.92        R. Bilge radius .....     6.24
H. Yaw Gyradius .....      213.64

I. Water Plane Area .....   96876.        W. Deadweight (DWT)..... 100000.
J. Head-on Current Area ..  2988.         T. Head-on Wind Area ..... 11157.
K. Beam-on Current Area ..  17595.        U. Beam-on Wind Area ..... 37922.

>>> Change items 1 or 2 for new estimates or input letter(s) ("ACD...")
      to select individual replacements (or "Z" to replace all);
      "?" for help, <Return> to continue WITHOUT replacement:
```

On-Line Tanker Model Work Window

Data Replacement Options:

Options for selecting subsets of the displayed data for simulation use include (i) any single property, (ii) any subset of displayed properties or (iii) all estimated properties. To select a single property for inclusion in the simulation data file, supply the appropriate letter designator at the Screen-bottom prompt (e.g., "A", without the quotation marks). To select all properties input "Z" at the prompt. A subset of displayed properties is selected by supplying the desired letter designators with or without a non-letter separator; for example, to transfer to the simulation data file a subset comprising items "A", "C" and "Q" from the displayed estimates, any of the following are acceptable input strings: "ACQ", "A,C,Q", "A-C-Q". Input of letter values to the editor (as always, without quotation marks) is case insensitive; "Z" and "z" achieve the same result. A <return> is required at the end of any input string to activate the input process.

On first-time entry to the on-line tanker model facility during a given program execution, the tanker properties initially displayed depend on the value assigned to DWT and draft prior to first-time entry. If either DWT or draft are zero on entry, displayed variables take on values contained in the data file, if any. Otherwise, the displayed variables take on values associated with the entry [DWT, draft] combination. In this regard, it should be noted that since DWT is not required for Shipsim execution (or indeed anywhere displayed outside the tanker properties facility), DWT will generally be zero on first entry from within Shipsim (unless, perhaps, the data file in use was imported from a simulation, like Moorsim, which may contain a nonzero deadweight value).

Full Load and Lightship Data:

For a given DWT, the properties of either the fully-loaded vessel or the lightship can be obtained from the help facility in the following way:

To obtain vessel properties associated with the fully loaded vessel, input a draft which is unrealistically large (e.g., 1000 feet or meters). After issuing a nonfatal error message, the facility will, if requested, return properties associated with the full load condition.

To obtain vessel properties associated with the lightship (zero cargo) condition, input a draft which is unrealistically small (e.g., 1 foot or meter). Again, after issuing an error message the facility will, if requested, return properties associated with the lightship condition.

The minimum size vessel that can be accommodated by the on-line model is 2000 DWT. There is no maximum vessel size, although no tanker larger than about 600,000 DWT has been constructed at this writing.

The "freeboard-based load percentage" is defined as 100 times the ratio [(fully loaded freeboard)/(simulation freeboard)]; other load measures are simple ratios of the simulated quantities to their full load counterparts (e.g., [simulation draft]/[fully loaded draft]).

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 27 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 22 ff). This is because response is always evaluated at each of these endpoint periods. Thus, if the period array on pp 22 has endpoints of 6 and 20 seconds, then WARRAY should extend on either end beyond the values ($2\pi/6 \approx 1.047\dots$ and $2\pi/20 \approx 0.314\dots$). 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 22 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 headings. 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:

$$\begin{aligned}\text{Real}[\text{CURSG}] &= \text{amplitude} * \cos(\text{phase}) \\ \text{Imaginary}[\text{CURSG}] &= \text{amplitude} * \sin(\text{phase})\end{aligned}$$

- 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: $\text{ft}^2/(\text{radian}/\text{sec})$ for English units; $\text{m}^2/(\text{radian}/\text{sec})$ 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 22), 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 $2*\pi = 6.2832\dots$ 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 Shipsim 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 1

Displacement-Hull Offshore Vessels

Shipsim Version 5.11

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By SeaSoft Systems

Series 60 Vessel
Shipsim Sample Simulation

Executed at 20:58 on 4/4/05

**
***** I. PHYSICAL CHARACTERISTICS SUMMARY *****
**

---- SITE CHARACTERISTICS ----

WATER DEPTH 4000.00 FEET
WATER DENSITY 64.00 LBS/CUBIC FOOT

---- VESSEL CHARACTERISTICS ----

DISPLACEMENT 9256.00 K.LBS
WATER PLANE AREA 11700.00 SQUARE FEET
VERTICAL (Z) KB 8.00 FEET
DRAFT 14.00 FEET

VERTICAL (Z) KG 9.00 FEET
NATURAL ROLL CENTER (VKR) 7.88 FEET
NATURAL PITCH CENTER (VKP) 8.88 FEET

PITCH GYRADIUS 79.00 FEET
ROLL GYRADIUS 15.30 FEET
YAW GYRADIUS 81.00 FEET

LONGITUDINAL KM (KML) 485.00 FEET
LONGITUDINAL GM (GML) 476.00 FEET
LONGITUDINAL IWP/DELTA 477.00 FEET

TRANSVERSE KM (KMT) 17.60 FEET
TRANSVERSE GM (GMT) 8.60 FEET
TRANSVERSE IWP/DELTA 9.60 FEET

---- DYNAMICALLY SIMILAR BOX CHARACTERISTICS ----

BOX LENGTH 271.50 FEET
BOX WIDTH 41.50 FEET
BOX DRAFT 12.84 FEET

TRIM ANGLE00 DEG
HEEL ANGLE00 DEG

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

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

NATURAL ROLL PERIOD 7.1 SECONDS
 NATURAL PITCH PERIOD 5.7 SECONDS
 NATURAL HEAVE PERIOD 5.8 SECONDS

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

NATURAL ROLL DAMPING IN BEAM WAVES 4.8 PERCENT
 Damping conversion: 1% = 0.160E+04 ft*kip/(rad/sec)
 NATURAL PITCH DAMPING IN HEAD WAVES 11.1 PERCENT
 Damping conversion: 1% = 0.799E+05 ft*kip/(rad/sec)
 NATURAL HEAVE DAMPING 16.8 PERCENT
 Damping conversion: 1% = 0.138E+02 k.lb/(ft/sec)

REGULAR WAVE SLOPE 3.0 DEGREES
 WATER DEPTH4000.0 FEET

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

---- REGULAR WAVE DATA: WAVE HEADING = 90.0 DEG
 WAVE SLOPE = 3.0 DEG
 VESSEL SPEED = .0 FT/SEC

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	SURGE AM/PHASE	SWAY AM/PHASE	HEAVE AM/PHASE
4.00	81.9	1.36	0.000/ -90.0	.705/ 90.5	.116/ 32.2
4.50	103.6	1.73	0.000/ -90.0	.930/ 85.6	.188/ 29.4
5.00	127.9	2.13	0.000/ -90.1	1.097/ 85.4	.261/ 26.2
5.50	154.8	2.58	0.000/ -90.3	1.221/ 86.4	.330/ 23.2
6.00	184.2	3.07	0.000/ -90.6	1.314/ 87.4	.392/ 20.6
6.50	216.2	3.60	0.000/ -91.0	1.386/ 88.2	.447/ 18.3
7.00	250.7	4.18	0.000/ -91.4	1.442/ 88.8	.495/ 16.3
7.50	287.8	4.80	0.000/ -91.7	1.487/ 89.2	.536/ 14.6
8.00	327.5	5.46	0.000/ -91.9	1.523/ 89.4	.571/ 13.1
8.50	369.7	6.16	0.000/ -92.0	1.553/ 89.6	.601/ 11.8
9.00	414.5	6.91	0.000/ -91.9	1.577/ 89.7	.627/ 10.6
9.50	461.8	7.70	0.000/ -91.8	1.598/ 89.8	.651/ 9.6
10.00	511.7	8.53	0.000/ -91.7	1.615/ 89.9	.671/ 8.7
10.50	564.2	9.40	0.000/ -91.5	1.630/ 89.9	.690/ 7.8
11.00	619.2	10.32	0.000/ -91.3	1.642/ 89.9	.706/ 7.1
11.50	676.7	11.28	0.000/ -91.1	1.653/ 89.9	.722/ 6.4
12.00	736.9	12.28	0.000/ -91.0	1.663/ 90.0	.736/ 5.8
12.50	799.6	13.33	0.000/ -90.8	1.671/ 90.0	.749/ 5.3
13.00	864.8	14.41	0.000/ -90.7	1.678/ 90.0	.761/ 4.8
13.50	932.6	15.54	0.000/ -90.6	1.685/ 90.0	.773/ 4.3
14.00	1003.0	16.72	0.000/ -90.5	1.691/ 90.0	.783/ 4.0
14.50	1075.9	17.93	0.000/ -90.4	1.696/ 90.0	.793/ 3.6
15.00	1151.4	19.19	0.000/ -90.4	1.700/ 90.0	.803/ 3.3
15.50	1229.4	20.49	0.000/ -90.3	1.705/ 90.0	.811/ 3.0
16.00	1310.0	21.83	0.000/ -90.3	1.708/ 90.0	.820/ 2.7
16.50	1393.1	23.22	0.000/ -90.2	1.712/ 90.0	.828/ 2.5
17.00	1478.9	24.65	0.000/ -90.2	1.715/ 90.0	.835/ 2.3
17.50	1567.1	26.12	0.000/ -90.2	1.718/ 90.0	.842/ 2.1
18.00	1658.0	27.63	0.000/ -90.1	1.720/ 90.0	.848/ 1.9
18.50	1751.3	29.19	0.000/ -90.1	1.723/ 90.0	.855/ 1.8

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

SURGE 167.7 KIPS/DEG
 SWAY 167.7 KIPS/DEG
 HEAVE 748.8 KIPS/FT
 ROLL 1442.6 FT-KIPS/DEG
 PITCH 79847.1 FT-KIPS/DEG
 YAW 79847.1 FT-KIPS/DEG

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 90.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOs +++

Table with 6 columns: WAVE PERIOD (SEC), WAVE LENGTH (FT), WAVE HEIGHT (FT), ROLL AM/PHASE, PITCH AM/PHASE, YAW AM/PHASE. Rows 4.00 to 18.50.

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

Table with 2 columns: Parameter (SURGE, SWAY, HEAVE, ROLL, PITCH, YAW) and Value (167.7, 167.7, 748.8, 1442.6, 79847.1, 79847.1).

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 90.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC

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

Table with 6 columns: WAVE PERIOD (SEC), WAVE LENGTH (FT), WAVE HEIGHT (FT), SURGE (FT./FT.), SWAY (FT./FT.), HEAVE (FT./FT.). Rows 4.00 to 18.50.

>>> 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 SLOPE = 3.0 DEG
 VESSEL SPEED = .0 FT/SEC
 ROLL DAMPING = 4.8 PERCENT

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	ROLL (DEG/DEG)	PITCH (DEG/DEG)	YAW (DEG/DEG)
			AM/PHASE	AM/PHASE	AM/PHASE
4.00	81.9	1.36	.084/ 96.2	0.000/ 99.7	0.000/ 2.2
4.50	103.6	1.73	.163/ 99.3	0.000/ 114.2	0.000/ -1.9
5.00	127.9	2.13	.301/ 102.8	0.000/ 138.9	0.000/ -2.5
5.50	154.8	2.58	.551/ 106.6	0.000/ 178.3	0.000/ -7
6.00	184.2	3.07	1.043/ 112.1	0.000/-143.6	0.000/ 2.9
6.50	216.2	3.60	2.227/ 124.3	0.000/-121.8	0.000/ 7.3
7.00	250.7	4.18	5.311/ 168.7	0.000/-110.1	0.000/ 11.5
7.50	287.8	4.80	4.229/-126.7	0.000/-103.2	0.000/ 14.7
8.00	327.5	5.46	2.722/-108.1	0.000/-98.9	0.000/ 16.6
8.50	369.7	6.16	2.103/-101.7	0.000/-96.1	0.000/ 17.4
9.00	414.5	6.91	1.787/-98.8	0.000/-94.2	0.000/ 17.2
9.50	461.8	7.70	1.600/-97.1	0.000/-92.9	0.000/ 16.4
10.00	511.7	8.53	1.477/-96.1	0.000/-92.0	0.000/ 15.1
10.50	564.2	9.40	1.392/-95.4	0.000/-91.4	0.000/ 13.6
11.00	619.2	10.32	1.329/-94.9	0.000/-91.0	0.000/ 12.1
11.50	676.7	11.28	1.282/-94.5	0.000/-90.7	0.000/ 10.5
12.00	736.9	12.28	1.245/-94.2	0.000/-90.5	0.000/ 9.1
12.50	799.6	13.33	1.215/-94.0	0.000/-90.4	0.000/ 7.8
13.00	864.8	14.41	1.191/-93.7	0.000/-90.3	0.000/ 6.7
13.50	932.6	15.54	1.171/-93.6	0.000/-90.2	0.000/ 5.7
14.00	1003.0	16.72	1.154/-93.4	0.000/-90.2	0.000/ 4.8
14.50	1075.9	17.93	1.139/-93.2	0.000/-90.1	0.000/ 4.1
15.00	1151.4	19.19	1.127/-93.1	0.000/-90.1	0.000/ 3.4
15.50	1229.4	20.49	1.116/-93.0	0.000/-90.1	0.000/ 2.9
16.00	1310.0	21.83	1.107/-92.9	0.000/-90.1	0.000/ 2.5
16.50	1393.1	23.22	1.099/-92.7	0.000/-90.0	0.000/ 2.1
17.00	1478.9	24.65	1.092/-92.6	0.000/-90.0	0.000/ 1.8
17.50	1567.1	26.12	1.085/-92.6	0.000/-90.0	0.000/ 1.5
18.00	1658.0	27.63	1.080/-92.5	0.000/-90.0	0.000/ 1.3
18.50	1751.3	29.19	1.074/-92.4	0.000/-90.0	0.000/ 1.1

>>> 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 SLOPE = 3.0 DEG
 VESSEL SPEED = .0 FT/SEC

+++ DISPLACEMENT RAOs IN FT PER UNIT WAVE AMP. (S.A./S.A.) +++

WAVE PERIOD (SEC)	COORDINATES (150.0, .0, 17.0)			COORDINATES (-150.0, .0, 17.0)		
	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
4.00	0.000/ 91	.458/ -88	.097/-122	0.000/ 91	.458/ -88	.097/-122
4.50	0.000/ 95	.615/ -92	.239/-115	0.000/ 95	.615/ -92	.239/-115
5.00	0.000/ 104	.752/ -90	.503/-103	0.000/ 104	.752/ -90	.503/-103
5.50	0.000/ 122	.888/ -86	.899/ -83	0.000/ 122	.888/ -86	.899/ -83
6.00	0.000/ 125	1.053/ -80	1.227/ -57	0.000/ 125	1.053/ -80	1.227/ -57
6.50	0.000/ 110	1.329/ -70	1.308/ -36	0.000/ 110	1.329/ -70	1.308/ -36
7.00	0.000/ 99	1.696/ -36	1.269/ -23	0.000/ 99	1.696/ -36	1.269/ -23
7.50	0.000/ 94	.726/ -8	1.215/ -15	0.000/ 94	.726/ -8	1.215/ -15
8.00	0.000/ 92	.514/ -40	1.171/ -11	0.000/ 92	.514/ -40	1.171/ -11
8.50	0.000/ 91	.575/ -55	1.137/ -8	0.000/ 91	.575/ -55	1.137/ -8
9.00	0.000/ 90	.639/ -62	1.111/ -6	0.000/ 90	.639/ -62	1.111/ -6
9.50	0.000/ 90	.689/ -66	1.092/ -4	0.000/ 90	.689/ -66	1.092/ -4
10.00	0.000/ 90	.730/ -69	1.076/ -3	0.000/ 90	.730/ -69	1.076/ -3
10.50	0.000/ 90	.764/ -72	1.064/ -2	0.000/ 90	.764/ -72	1.064/ -2
11.00	0.000/ 90	.792/ -75	1.054/ -2	0.000/ 90	.792/ -75	1.054/ -2
11.50	0.000/ 90	.816/ -77	1.047/ -1	0.000/ 90	.816/ -77	1.047/ -1
12.00	0.000/ 90	.836/ -79	1.040/ -1	0.000/ 90	.836/ -79	1.040/ -1
12.50	0.000/ 90	.853/ -80	1.034/ -1	0.000/ 90	.853/ -80	1.034/ -1
13.00	0.000/ 90	.867/ -82	1.030/ -1	0.000/ 90	.867/ -82	1.030/ -1
13.50	0.000/ 90	.879/ -83	1.026/ 0	0.000/ 90	.879/ -83	1.026/ 0
14.00	0.000/ 90	.889/ -84	1.023/ 0	0.000/ 90	.889/ -84	1.023/ 0
14.50	0.000/ 90	.898/ -85	1.020/ 0	0.000/ 90	.898/ -85	1.020/ 0
15.00	0.000/ 90	.906/ -86	1.018/ 0	0.000/ 90	.906/ -86	1.018/ 0
15.50	0.000/ 90	.913/ -86	1.015/ 0	0.000/ 90	.913/ -86	1.015/ 0
16.00	0.000/ 90	.919/ -87	1.014/ 0	0.000/ 90	.919/ -87	1.014/ 0
16.50	0.000/ 90	.924/ -87	1.012/ 0	0.000/ 90	.924/ -87	1.012/ 0
17.00	0.000/ 90	.929/ -87	1.011/ 0	0.000/ 90	.929/ -87	1.011/ 0
17.50	0.000/ 90	.934/ -88	1.010/ 0	0.000/ 90	.934/ -88	1.010/ 0
18.00	0.000/ 90	.938/ -88	1.009/ 0	0.000/ 90	.938/ -88	1.009/ 0
18.50	0.000/ 90	.941/ -88	1.008/ 0	0.000/ 90	.941/ -88	1.008/ 0

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

---- REGULAR WAVE DATA: WAVE HEADING = 180.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	SURGE		SWAY		HEAVE	
			AM/PHASE		AM/PHASE		AM/PHASE	
4.00	81.9	1.36	.054/ 90.0		0.000/ 75.1		.015/-147.8	
4.50	103.6	1.73	.082/-89.9		0.000/-100.8		.028/ 29.4	
5.00	127.9	2.13	.044/-91.5		0.000/-97.3		.018/ 26.2	
5.50	154.8	2.58	.103/ 91.6		0.000/ 85.2		.047/-156.8	
6.00	184.2	3.07	.182/ 89.8		0.000/ 86.9		.092/-159.4	
6.50	216.2	3.60	.160/ 86.1		0.000/ 88.0		.087/-161.7	
7.00	250.7	4.18	.071/ 72.4		0.000/ 88.6		.039/-163.7	
7.50	287.8	4.80	.061/-63.6		0.000/-90.9		.033/ 14.6	
8.00	327.5	5.46	.184/-81.7		0.000/-90.6		.115/ 13.1	
8.50	369.7	6.16	.303/-85.9		0.000/-90.4		.197/ 11.8	
9.00	414.5	6.91	.409/-87.9		0.000/-90.3		.274/ 10.6	
9.50	461.8	7.70	.500/-89.1		0.000/-90.2		.343/ 9.6	
10.00	511.7	8.53	.578/-89.7		0.000/-90.1		.405/ 8.7	
10.50	564.2	9.40	.644/-90.1		0.000/-90.1		.459/ 7.8	
11.00	619.2	10.32	.699/-90.4		0.000/-90.1		.507/ 7.1	
11.50	676.7	11.28	.746/-90.5		0.000/-90.1		.549/ 6.4	
12.00	736.9	12.28	.785/-90.5		0.000/-90.0		.585/ 5.8	
12.50	799.6	13.33	.817/-90.5		0.000/-90.0		.618/ 5.3	
13.00	864.8	14.41	.845/-90.5		0.000/-90.0		.646/ 4.8	
13.50	932.6	15.54	.869/-90.4		0.000/-90.0		.671/ 4.3	
14.00	1003.0	16.72	.889/-90.4		0.000/-90.0		.694/ 4.0	
14.50	1075.9	17.93	.906/-90.3		0.000/-90.0		.714/ 3.6	
15.00	1151.4	19.19	.921/-90.3		0.000/-90.0		.733/ 3.3	
15.50	1229.4	20.49	.934/-90.3		0.000/-90.0		.749/ 3.0	
16.00	1310.0	21.83	.945/-90.2		0.000/-90.0		.764/ 2.7	
16.50	1393.1	23.22	.955/-90.2		0.000/-90.0		.778/ 2.5	
17.00	1478.9	24.65	.963/-90.2		0.000/-90.0		.790/ 2.3	
17.50	1567.1	26.12	.971/-90.1		0.000/-90.0		.802/ 2.1	
18.00	1658.0	27.63	.977/-90.1		0.000/-90.0		.812/ 1.9	
18.50	1751.3	29.19	.983/-90.1		0.000/-90.0		.822/ 1.8	

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

SURGE	167.7 KIPS/DEG
SWAY	167.7 KIPS/DEG
HEAVE	748.8 KIPS/FT
ROLL	1442.6 FT-KIPS/DEG
PITCH	79847.1 FT-KIPS/DEG
YAW	79847.1 FT-KIPS/DEG

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 180.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	ROLL		PITCH		YAW	
			AM/PHASE		AM/PHASE		AM/PHASE	
4.00	81.9	1.36	0.000/-88.2		.002/-85.3		0.000/-47.5	
4.50	103.6	1.73	0.000/ 93.7		.005/-79.7		0.000/-32.1	
5.00	127.9	2.13	0.000/ 95.4		.019/ 103.3		0.000/ 157.3	
5.50	154.8	2.58	0.000/-83.8		.032/ 105.4		0.000/ 166.6	
6.00	184.2	3.07	0.000/-83.7		.007/ 106.8		0.000/ 178.0	
6.50	216.2	3.60	0.000/-84.1		.049/-75.8		0.000/-6.7	
7.00	250.7	4.18	0.000/-84.8		.123/-77.1		0.000/-4.2	
7.50	287.8	4.80	0.000/ 94.5		.200/-78.8		0.000/-2.8	
8.00	327.5	5.46	0.000/ 93.8		.274/-80.4		0.000/-2.0	
8.50	369.7	6.16	0.000/ 93.1		.340/-81.9		0.000/-1.4	
9.00	414.5	6.91	0.000/ 92.6		.399/-83.3		0.000/-1.0	
9.50	461.8	7.70	0.000/ 92.1		.452/-84.5		0.000/-0.8	
10.00	511.7	8.53	0.000/ 91.7		.498/-85.5		0.000/-0.6	
10.50	564.2	9.40	0.000/ 91.4		.540/-86.3		0.000/-0.5	
11.00	619.2	10.32	0.000/ 91.1		.578/-87.0		0.000/-0.4	
11.50	676.7	11.28	0.000/ 90.9		.612/-87.5		0.000/-0.3	
12.00	736.9	12.28	0.000/ 90.8		.643/-88.0		0.000/-0.2	
12.50	799.6	13.33	0.000/ 90.6		.671/-88.3		0.000/-0.2	
13.00	864.8	14.41	0.000/ 90.5		.696/-88.6		0.000/-0.2	
13.50	932.6	15.54	0.000/ 90.4		.719/-88.9		0.000/-0.1	
14.00	1003.0	16.72	0.000/ 90.4		.740/-89.1		0.000/-0.1	
14.50	1075.9	17.93	0.000/ 90.3		.759/-89.2		0.000/-0.1	
15.00	1151.4	19.19	0.000/ 90.3		.776/-89.3		0.000/-0.1	
15.50	1229.4	20.49	0.000/ 90.2		.791/-89.5		0.000/-0.1	
16.00	1310.0	21.83	0.000/ 90.2		.805/-89.5		0.000/-0.1	
16.50	1393.1	23.22	0.000/ 90.2		.818/-89.6		0.000/ 0.0	
17.00	1478.9	24.65	0.000/ 90.1		.830/-89.7		0.000/ 0.0	
17.50	1567.1	26.12	0.000/ 90.1		.840/-89.7		0.000/ 0.0	
18.00	1658.0	27.63	0.000/ 90.1		.850/-89.8		0.000/ 0.0	
18.50	1751.3	29.19	0.000/ 90.1		.858/-89.8		0.000/ 0.0	

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

SURGE	167.7 KIPS/DEG
SWAY	167.7 KIPS/DEG
HEAVE	748.8 KIPS/FT
ROLL	1442.6 FT-KIPS/DEG
PITCH	79847.1 FT-KIPS/DEG
YAW	79847.1 FT-KIPS/DEG

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 180.0 DEG
 WAVE SLOPE = 3.0 DEG
 VESSEL SPEED = .0 FT/SEC

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	SURGE (FT./FT.)		SWAY (FT./FT.)		HEAVE (FT./FT.)	
			AM/PHASE		AM/PHASE		AM/PHASE	
4.00	81.9	1.36	.051/ -90.0		0.000/ -104.9		.012/ 57.7	
4.50	103.6	1.73	.078/ 90.1		0.000/ 79.4		.036/ -115.6	
5.00	127.9	2.13	.042/ 88.6		0.000/ 83.6		.034/ -103.8	
5.50	154.8	2.58	.099/ -88.1		0.000/ -92.1		.129/ 96.6	
6.00	184.2	3.07	.174/ -89.6		0.000/ -87.2		.287/ 122.6	
6.50	216.2	3.60	.153/ -92.9		0.000/ -82.2		.254/ 143.6	
7.00	250.7	4.18	.068/ -106.2		0.000/ -77.9		.100/ 156.5	
7.50	287.8	4.80	.058/ 118.1		0.000/ 105.4		.075/ -15.9	
8.00	327.5	5.46	.176/ 100.2		0.000/ 107.3		.236/ -11.2	
8.50	369.7	6.16	.289/ 96.1		0.000/ 108.0		.373/ -8.2	
9.00	414.5	6.91	.390/ 94.0		0.000/ 107.7		.485/ -6.2	
9.50	461.8	7.70	.478/ 92.8		0.000/ 106.8		.576/ -4.7	
10.00	511.7	8.53	.552/ 91.9		0.000/ 105.5		.650/ -3.7	
10.50	564.2	9.40	.615/ 91.3		0.000/ 103.9		.709/ -2.9	
11.00	619.2	10.32	.668/ 91.0		0.000/ 102.3		.757/ -2.3	
11.50	676.7	11.28	.712/ 90.7		0.000/ 100.7		.796/ -1.8	
12.00	736.9	12.28	.749/ 90.5		0.000/ 99.3		.827/ -1.5	
12.50	799.6	13.33	.781/ 90.3		0.000/ 98.0		.853/ -1.2	
13.00	864.8	14.41	.807/ 90.2		0.000/ 96.8		.874/ -1.0	
13.50	932.6	15.54	.830/ 90.2		0.000/ 95.8		.892/ -.8	
14.00	1003.0	16.72	.849/ 90.1		0.000/ 94.9		.906/ -.7	
14.50	1075.9	17.93	.866/ 90.1		0.000/ 94.1		.919/ -.6	
15.00	1151.4	19.19	.880/ 90.1		0.000/ 93.5		.929/ -.5	
15.50	1229.4	20.49	.892/ 90.1		0.000/ 93.0		.938/ -.4	
16.00	1310.0	21.83	.903/ 90.0		0.000/ 92.5		.945/ -.3	
16.50	1393.1	23.22	.912/ 90.0		0.000/ 92.1		.951/ -.3	
17.00	1478.9	24.65	.920/ 90.0		0.000/ 91.8		.957/ -.3	
17.50	1567.1	26.12	.927/ 90.0		0.000/ 91.5		.962/ -.2	
18.00	1658.0	27.63	.934/ 90.0		0.000/ 91.3		.966/ -.2	
18.50	1751.3	29.19	.939/ 90.0		0.000/ 91.1		.969/ -.2	

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 180.0 DEG
 WAVE SLOPE = 3.0 DEG
 VESSEL SPEED = .0 FT/SEC
 ROLL DAMPING = 1.2 PERCENT

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	ROLL (DEG/DEG)		PITCH (DEG/DEG)		YAW (DEG/DEG)	
			AM/PHASE		AM/PHASE		AM/PHASE	
4.00	81.9	1.36	0.000/ 93.0		.002/ 99.3		0.000/ 132.5	
4.50	103.6	1.73	0.000/ -84.8		.008/ 114.7		0.000/ 148.0	
5.00	127.9	2.13	0.000/ -82.6		.052/ -41.3		0.000/ -21.9	
5.50	154.8	2.58	0.000/ 99.0		.126/ -1.7		0.000/ -10.7	
6.00	184.2	3.07	0.000/ 100.5		.029/ 37.8		0.000/ 4.0	
6.50	216.2	3.60	0.000/ 103.9		.157/ -122.1		0.000/ -176.9	
7.00	250.7	4.18	0.000/ 136.5		.332/ -110.2		0.000/ -170.7	
7.50	287.8	4.80	0.000/ 81.7		.477/ -103.3		0.000/ -166.6	
8.00	327.5	5.46	0.000/ 87.8		.592/ -98.9		0.000/ -164.1	
8.50	369.7	6.16	0.000/ 89.2		.681/ -96.1		0.000/ -163.0	
9.00	414.5	6.91	0.000/ 89.6		.748/ -94.2		0.000/ -163.0	
9.50	461.8	7.70	0.000/ 89.7		.799/ -92.9		0.000/ -163.8	
10.00	511.7	8.53	0.000/ 89.7		.837/ -92.0		0.000/ -165.0	
10.50	564.2	9.40	0.000/ 89.6		.867/ -91.4		0.000/ -166.4	
11.00	619.2	10.32	0.000/ 89.6		.890/ -91.0		0.000/ -168.0	
11.50	676.7	11.28	0.000/ 89.5		.907/ -90.7		0.000/ -169.5	
12.00	736.9	12.28	0.000/ 89.5		.922/ -90.5		0.000/ -170.9	
12.50	799.6	13.33	0.000/ 89.4		.933/ -90.4		0.000/ -172.2	
13.00	864.8	14.41	0.000/ 89.4		.943/ -90.3		0.000/ -173.3	
13.50	932.6	15.54	0.000/ 89.4		.950/ -90.2		0.000/ -174.3	
14.00	1003.0	16.72	0.000/ 89.4		.957/ -90.2		0.000/ -175.2	
14.50	1075.9	17.93	0.000/ 89.4		.962/ -90.1		0.000/ -175.9	
15.00	1151.4	19.19	0.000/ 89.4		.967/ -90.1		0.000/ -176.6	
15.50	1229.4	20.49	0.000/ 89.4		.971/ -90.1		0.000/ -177.1	
16.00	1310.0	21.83	0.000/ 89.4		.974/ -90.1		0.000/ -177.5	
16.50	1393.1	23.22	0.000/ 89.4		.977/ -90.0		0.000/ -177.9	
17.00	1478.9	24.65	0.000/ 89.4		.979/ -90.0		0.000/ -178.2	
17.50	1567.1	26.12	0.000/ 89.4		.982/ -90.0		0.000/ -178.5	
18.00	1658.0	27.63	0.000/ 89.4		.984/ -90.0		0.000/ -178.7	
18.50	1751.3	29.19	0.000/ 89.4		.985/ -90.0		0.000/ -178.9	

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 180.0 DEG
 WAVE SLOPE = 3.0 DEG
 VESSEL SPEED = .0 FT/SEC

+++ DISPLACEMENT RAOs IN FT PER UNIT WAVE AMP. (S.A./S.A.) +++

COORDINATES				COORDINATES		
(150.0, .0, 17.0)				(-150.0, .0, 17.0)		
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
4.00	.050/ -90	0.000/ 154	.020/ -56	.050/ -90	0.000/ -62	.038/ 86
4.50	.082/ 91	0.000/ 121	.100/ -81	.082/ 91	0.000/ 9	.057/ 143
5.00	.033/ 59	0.000/ -13	.366/ 143	.033/ 59	0.000/ 150	.397/ -45
5.50	.110/ -65	0.000/ -28	.796/ 169	.110/ -65	0.000/ -170	.759/ 7
6.00	.170/ -87	0.000/ -72	.311/ 150	.170/ -87	0.000/ -96	.335/ 96
6.50	.186/ -98	0.000/ -135	.746/ 77	.186/ -98	0.000/ -32	.711/ -142
7.00	.135/ -108	0.000/ -144	1.256/ 74	.135/ -108	0.000/ -8	1.245/ -114
7.50	.056/ -146	0.000/ -165	1.560/ 73	.056/ -146	0.000/ 12	1.567/ -100
8.00	.094/ 119	0.000/ -167	1.710/ 73	.094/ 119	0.000/ 19	1.729/ -91
8.50	.198/ 101	0.000/ -171	1.761/ 71	.198/ 101	0.000/ 25	1.788/ -84
9.00	.300/ 96	0.000/ -175	1.752/ 69	.300/ 96	0.000/ 30	1.784/ -78
9.50	.390/ 94	0.000/ 179	1.712/ 67	.390/ 94	0.000/ 33	1.746/ -73
10.00	.469/ 92	0.000/ 174	1.656/ 64	.469/ 92	0.000/ 36	1.690/ -69
10.50	.537/ 91	0.000/ 169	1.596/ 62	.537/ 91	0.000/ 38	1.628/ -65
11.00	.595/ 91	0.000/ 164	1.536/ 59	.595/ 91	0.000/ 40	1.566/ -62
11.50	.644/ 90	0.000/ 159	1.480/ 56	.644/ 90	0.000/ 42	1.506/ -58
12.00	.686/ 90	0.000/ 154	1.429/ 54	.686/ 90	0.000/ 44	1.451/ -55
12.50	.721/ 90	0.000/ 150	1.382/ 51	.721/ 90	0.000/ 45	1.402/ -52
13.00	.752/ 90	0.000/ 146	1.340/ 49	.752/ 90	0.000/ 47	1.357/ -50
13.50	.778/ 90	0.000/ 142	1.303/ 46	.778/ 90	0.000/ 49	1.317/ -47
14.00	.800/ 90	0.000/ 139	1.271/ 44	.800/ 90	0.000/ 50	1.282/ -45
14.50	.820/ 90	0.000/ 136	1.242/ 42	.820/ 90	0.000/ 52	1.252/ -42
15.00	.837/ 90	0.000/ 133	1.216/ 40	.837/ 90	0.000/ 54	1.224/ -40
15.50	.852/ 90	0.000/ 130	1.194/ 38	.852/ 90	0.000/ 55	1.200/ -38
16.00	.865/ 90	0.000/ 128	1.174/ 36	.865/ 90	0.000/ 57	1.179/ -36
16.50	.876/ 90	0.000/ 125	1.156/ 34	.876/ 90	0.000/ 58	1.161/ -34
17.00	.886/ 90	0.000/ 123	1.141/ 32	.886/ 90	0.000/ 59	1.144/ -33
17.50	.895/ 90	0.000/ 121	1.127/ 31	.895/ 90	0.000/ 61	1.130/ -31
18.00	.903/ 90	0.000/ 120	1.114/ 29	.903/ 90	0.000/ 62	1.117/ -30
18.50	.910/ 90	0.000/ 118	1.104/ 28	.910/ 90	0.000/ 63	1.106/ -28

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

---- REGULAR WAVE DATA: WAVE HEADING = 30.0 DEG
 WAVE SLOPE = 3.0 DEG
 VESSEL SPEED = .0 FT/SEC

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOs +++

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	SURGE AM/PHASE	SWAY AM/PHASE	HEAVE AM/PHASE
4.00	81.9	1.36	.022/ 90.0	.022/ 78.3	.007/ 32.2
4.50	103.6	1.73	.062/ 89.9	.061/ 80.7	.024/ 29.4
5.00	127.9	2.13	.054/ -89.1	.053/ -96.7	.025/ -153.8
5.50	154.8	2.58	.143/ -89.9	.140/ -94.5	.076/ -156.8
6.00	184.2	3.07	.137/ -92.1	.133/ -93.0	.080/ -159.4
6.50	216.2	3.60	.061/ -102.2	.058/ -92.0	.037/ -161.7
7.00	250.7	4.18	.054/ 110.3	.049/ 88.7	.034/ 16.3
7.50	287.8	4.80	.167/ 96.8	.162/ 89.1	.117/ 14.6
8.00	327.5	5.46	.275/ 93.5	.267/ 89.4	.200/ 13.1
8.50	369.7	6.16	.369/ 91.8	.359/ 89.6	.278/ 11.8
9.00	414.5	6.91	.450/ 90.7	.438/ 89.7	.349/ 10.6
9.50	461.8	7.70	.518/ 90.1	.504/ 89.8	.411/ 9.6
10.00	511.7	8.53	.575/ 89.7	.559/ 89.9	.465/ 8.7
10.50	564.2	9.40	.622/ 89.5	.605/ 89.9	.512/ 7.8
11.00	619.2	10.32	.661/ 89.4	.643/ 89.9	.553/ 7.1
11.50	676.7	11.28	.694/ 89.4	.675/ 89.9	.589/ 6.4
12.00	736.9	12.28	.721/ 89.4	.702/ 90.0	.621/ 5.8
12.50	799.6	13.33	.744/ 89.4	.724/ 90.0	.649/ 5.3
13.00	864.8	14.41	.763/ 89.5	.743/ 90.0	.674/ 4.8
13.50	932.6	15.54	.780/ 89.5	.759/ 90.0	.696/ 4.3
14.00	1003.0	16.72	.794/ 89.6	.773/ 90.0	.716/ 4.0
14.50	1075.9	17.93	.806/ 89.6	.784/ 90.0	.734/ 3.6
15.00	1151.4	19.19	.816/ 89.7	.794/ 90.0	.750/ 3.3
15.50	1229.4	20.49	.825/ 89.7	.803/ 90.0	.765/ 3.0
16.00	1310.0	21.83	.833/ 89.8	.811/ 90.0	.778/ 2.7
16.50	1393.1	23.22	.840/ 89.8	.817/ 90.0	.790/ 2.5
17.00	1478.9	24.65	.846/ 89.8	.823/ 90.0	.801/ 2.3
17.50	1567.1	26.12	.851/ 89.9	.828/ 90.0	.812/ 2.1
18.00	1658.0	27.63	.856/ 89.9	.833/ 90.0	.821/ 1.9
18.50	1751.3	29.19	.860/ 89.9	.837/ 90.0	.830/ 1.8

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

SURGE	167.7 KIPS/DEG
SWAY	167.7 KIPS/DEG
HEAVE	748.8 KIPS/FT
ROLL	1442.6 FT-KIPS/DEG
PITCH	79847.1 FT-KIPS/DEG
YAW	79847.1 FT-KIPS/DEG

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 30.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC

+++ DIMENSIONLESS DRIVING FORCE/TORQUE RAOs +++

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	ROLL		PITCH		YAW	
			AM/PHASE		AM/PHASE		AM/PHASE	
4.00	81.9	1.36	.004/ -88.2		.005/ 95.1		.019/ -40.2	
4.50	103.6	1.73	.014/ -86.3		.007/ -80.5		.016/ 150.5	
5.00	127.9	2.13	.014/ 95.3		.022/ -76.5		.030/ 162.3	
5.50	154.8	2.58	.041/ 96.2		.011/ -74.0		.009/ 172.1	
6.00	184.2	3.07	.042/ 96.3		.032/ 105.0		.024/ -8.9	
6.50	216.2	3.60	.020/ 95.9		.095/ 104.3		.054/ -5.4	
7.00	250.7	4.18	.018/ -84.8		.164/ 102.9		.075/ -3.6	
7.50	287.8	4.80	.063/ -85.5		.230/ 101.3		.088/ -2.5	
8.00	327.5	5.46	.108/ -86.2		.290/ 99.6		.095/ -1.8	
8.50	369.7	6.16	.151/ -86.9		.342/ 98.1		.096/ -1.3	
9.00	414.5	6.91	.190/ -87.4		.388/ 96.7		.095/ -1.0	
9.50	461.8	7.70	.225/ -87.9		.428/ 95.5		.092/ -.7	
10.00	511.7	8.53	.255/ -88.3		.464/ 94.5		.088/ -.6	
10.50	564.2	9.40	.282/ -88.6		.496/ 93.7		.084/ -.4	
11.00	619.2	10.32	.305/ -88.9		.525/ 93.0		.079/ -.4	
11.50	676.7	11.28	.325/ -89.1		.552/ 92.5		.075/ -.3	
12.00	736.9	12.28	.342/ -89.2		.576/ 92.0		.070/ -.2	
12.50	799.6	13.33	.357/ -89.4		.598/ 91.7		.066/ -.2	
13.00	864.8	14.41	.370/ -89.5		.618/ 91.4		.062/ -.1	
13.50	932.6	15.54	.382/ -89.6		.636/ 91.1		.058/ -.1	
14.00	1003.0	16.72	.392/ -89.6		.652/ 90.9		.055/ -.1	
14.50	1075.9	17.93	.401/ -89.7		.667/ 90.8		.052/ -.1	
15.00	1151.4	19.19	.409/ -89.7		.681/ 90.7		.049/ -.1	
15.50	1229.4	20.49	.416/ -89.8		.693/ 90.5		.046/ -.1	
16.00	1310.0	21.83	.422/ -89.8		.705/ 90.5		.043/ -.1	
16.50	1393.1	23.22	.428/ -89.8		.715/ 90.4		.041/ 0.0	
17.00	1478.9	24.65	.433/ -89.9		.724/ 90.3		.039/ 0.0	
17.50	1567.1	26.12	.437/ -89.9		.733/ 90.3		.037/ 0.0	
18.00	1658.0	27.63	.442/ -89.9		.741/ 90.2		.035/ 0.0	
18.50	1751.3	29.19	.445/ -89.9		.748/ 90.2		.033/ 0.0	

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

SURGE	167.7	KIPS/DEG
SWAY	167.7	KIPS/DEG
HEAVE	748.8	KIPS/FT
ROLL	1442.6	FT-KIPS/DEG
PITCH	79847.1	FT-KIPS/DEG
YAW	79847.1	FT-KIPS/DEG

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 30.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	SURGE (FT./FT.)		SWAY (FT./FT.)		HEAVE (FT./FT.)	
			AM/PHASE		AM/PHASE		AM/PHASE	
4.00	81.9	1.36	.021/ -90.0		.013/ -101.7		.006/ -122.3	
4.50	103.6	1.73	.059/ -90.1		.035/ -99.2		.031/ -115.6	
5.00	127.9	2.13	.052/ 91.0		.030/ 84.2		.049/ 76.2	
5.50	154.8	2.58	.137/ 90.4		.079/ 88.2		.206/ 96.6	
6.00	184.2	3.07	.131/ 88.5		.075/ 92.9		.249/ 122.6	
6.50	216.2	3.60	.058/ 78.8		.032/ 97.8		.109/ 143.6	
7.00	250.7	4.18	.051/ -68.3		.027/ -77.8		.087/ -23.5	
7.50	287.8	4.80	.160/ -81.5		.088/ -74.6		.264/ -15.9	
8.00	327.5	5.46	.262/ -84.6		.144/ -72.7		.410/ -11.2	
8.50	369.7	6.16	.353/ -86.2		.193/ -72.0		.526/ -8.2	
9.00	414.5	6.91	.430/ -87.3		.236/ -72.3		.617/ -6.2	
9.50	461.8	7.70	.495/ -88.1		.273/ -73.2		.689/ -4.7	
10.00	511.7	8.53	.549/ -88.7		.305/ -74.5		.746/ -3.7	
10.50	564.2	9.40	.594/ -89.0		.333/ -76.1		.790/ -2.9	
11.00	619.2	10.32	.631/ -89.3		.356/ -77.7		.826/ -2.3	
11.50	676.7	11.28	.663/ -89.5		.376/ -79.3		.855/ -1.8	
12.00	736.9	12.28	.689/ -89.6		.392/ -80.7		.878/ -1.5	
12.50	799.6	13.33	.711/ -89.7		.406/ -82.0		.896/ -1.2	
13.00	864.8	14.41	.729/ -89.8		.418/ -83.2		.912/ -1.0	
13.50	932.6	15.54	.745/ -89.9		.428/ -84.2		.924/ -.8	
14.00	1003.0	16.72	.758/ -89.9		.436/ -85.1		.935/ -.7	
14.50	1075.9	17.93	.770/ -89.9		.443/ -85.9		.943/ -.6	
15.00	1151.4	19.19	.780/ -89.9		.449/ -86.5		.951/ -.5	
15.50	1229.4	20.49	.788/ -90.0		.455/ -87.0		.957/ -.4	
16.00	1310.0	21.83	.796/ -90.0		.459/ -87.5		.962/ -.3	
16.50	1393.1	23.22	.802/ -90.0		.463/ -87.9		.966/ -.3	
17.00	1478.9	24.65	.808/ -90.0		.466/ -88.2		.970/ -.3	
17.50	1567.1	26.12	.813/ -90.0		.469/ -88.5		.973/ -.2	
18.00	1658.0	27.63	.817/ -90.0		.472/ -88.7		.976/ -.2	
18.50	1751.3	29.19	.821/ -90.0		.474/ -88.9		.979/ -.2	

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 30.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC
ROLL DAMPING = 3.6 PERCENT

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

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE HEIGHT (FT)	ROLL (DEG/DEG)	PITCH (DEG/DEG)	YAW (DEG/DEG)
			AM/PHASE	AM/PHASE	AM/PHASE
4.00	81.9	1.36	.002/ 95.2	.005/ -80.2	.010/ 139.8
4.50	103.6	1.73	.009/ 98.1	.011/ 113.8	.011/ -29.3
5.00	127.9	2.13	.013/ -78.9	.062/ 138.9	.025/ -16.9
5.50	154.8	2.58	.060/ -75.8	.043/ 178.9	.009/ -5.2
6.00	184.2	3.07	.104/ -71.6	.125/ 36.0	.029/ 177.0
6.50	216.2	3.60	.095/ -61.8	.304/ 58.1	.075/-175.6
7.00	250.7	4.18	.229/ 163.9	.443/ 69.9	.120/-170.1
7.50	287.8	4.80	.503/-119.0	.549/ 76.8	.160/-166.3
8.00	327.5	5.46	.486/-103.1	.627/ 81.1	.193/-163.9
8.50	369.7	6.16	.489/ -98.2	.684/ 83.9	.221/-162.9
9.00	414.5	6.91	.497/ -96.1	.726/ 85.8	.246/-163.0
9.50	461.8	7.70	.505/ -94.9	.757/ 87.1	.267/-163.7
10.00	511.7	8.53	.512/ -94.2	.779/ 88.0	.285/-165.0
10.50	564.2	9.40	.517/ -93.8	.796/ 88.6	.300/-166.4
11.00	619.2	10.32	.520/ -93.4	.808/ 89.0	.314/-168.0
11.50	676.7	11.28	.523/ -93.2	.818/ 89.3	.325/-169.5
12.00	736.9	12.28	.525/ -93.0	.825/ 89.5	.334/-170.9
12.50	799.6	13.33	.526/ -92.8	.831/ 89.6	.342/-172.2
13.00	864.8	14.41	.527/ -92.7	.836/ 89.7	.349/-173.3
13.50	932.6	15.54	.527/ -92.6	.840/ 89.8	.354/-174.3
14.00	1003.0	16.72	.527/ -92.5	.843/ 89.8	.359/-175.2
14.50	1075.9	17.93	.527/ -92.4	.846/ 89.9	.363/-175.9
15.00	1151.4	19.19	.526/ -92.3	.848/ 89.9	.366/-176.6
15.50	1229.4	20.49	.526/ -92.2	.850/ 89.9	.369/-177.1
16.00	1310.0	21.83	.525/ -92.1	.852/ 89.9	.372/-177.5
16.50	1393.1	23.22	.525/ -92.0	.854/ 90.0	.374/-177.9
17.00	1478.9	24.65	.524/ -92.0	.855/ 90.0	.376/-178.2
17.50	1567.1	26.12	.523/ -91.9	.856/ 90.0	.377/-178.5
18.00	1658.0	27.63	.523/ -91.8	.857/ 90.0	.379/-178.7
18.50	1751.3	29.19	.522/ -91.8	.858/ 90.0	.380/-178.9

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

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

---- REGULAR WAVE DATA: WAVE HEADING = 30.0 DEG
WAVE SLOPE = 3.0 DEG
VESSEL SPEED = .0 FT/SEC

+++ DISPLACEMENT RAOs IN FT PER UNIT WAVE AMP. (S.A./S.A.) +++

WAVE PERIOD (SEC)	COORDINATES (150.0, .0, 17.0)			COORDINATES (-150.0, .0, 17.0)		
	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE	X COMP AM/PHASE	Y COMP AM/PHASE	Z COMP AM/PHASE
4.00	.024/ -88	.114/ 145	.051/ 104	.024/ -88	.128/ -45	.059/ -84
4.50	.054/ -92	.118/ -47	.122/ -77	.054/ -92	.090/ 174	.083/ 130
5.00	.071/ 105	.182/ -5	.434/ -35	.071/ 105	.199/ 153	.478/ 133
5.50	.138/ 96	.110/ 60	.312/ 39	.138/ 96	.122/ 119	.356/ 143
6.00	.154/ 78	.198/ 145	.674/-165	.154/ 78	.166/ 36	.702/ 56
6.50	.128/ 67	.346/ 175	1.321/-126	.128/ 67	.322/ 14	1.338/ 62
7.00	.062/ 36	.407/-163	1.674/-107	.062/ 36	.503/ 4	1.664/ 66
7.50	.078/ -54	.452/-164	1.828/ -94	.078/ -54	.593/ 12	1.803/ 68
8.00	.169/ -76	.515/-156	1.866/ -86	.169/ -76	.604/ 9	1.834/ 68
8.50	.260/ -82	.543/-149	1.841/ -79	.260/ -82	.612/ 5	1.803/ 66
9.00	.341/ -85	.556/-144	1.783/ -73	.341/ -85	.613/ 0	1.743/ 65
9.50	.411/ -87	.562/-141	1.711/ -69	.411/ -87	.608/ -4	1.671/ 62
10.00	.471/ -88	.563/-138	1.636/ -64	.471/ -88	.601/ -9	1.598/ 60
10.50	.522/ -88	.561/-136	1.564/ -61	.522/ -88	.591/ -14	1.529/ 57
11.00	.565/ -89	.557/-134	1.497/ -57	.565/ -89	.581/ -20	1.466/ 54
11.50	.601/ -89	.552/-132	1.437/ -54	.601/ -89	.571/ -25	1.411/ 51
12.00	.632/ -89	.547/-130	1.384/ -51	.632/ -89	.562/ -29	1.361/ 49
12.50	.658/ -89	.541/-129	1.338/ -48	.658/ -89	.553/ -34	1.318/ 46
13.00	.680/ -89	.535/-127	1.297/ -45	.680/ -89	.545/ -38	1.281/ 44
13.50	.699/ -89	.530/-126	1.262/ -43	.699/ -89	.537/ -41	1.248/ 42
14.00	.715/ -89	.525/-124	1.231/ -40	.715/ -89	.531/ -45	1.220/ 39
14.50	.730/ -89	.521/-123	1.204/ -38	.730/ -89	.525/ -48	1.195/ 37
15.00	.742/ -89	.517/-121	1.181/ -36	.742/ -89	.520/ -50	1.174/ 35
15.50	.753/ -89	.513/-120	1.161/ -34	.753/ -89	.516/ -53	1.155/ 33
16.00	.763/ -89	.510/-118	1.143/ -32	.763/ -89	.513/ -55	1.138/ 32
16.50	.771/ -89	.508/-117	1.128/ -31	.771/ -89	.510/ -57	1.124/ 30
17.00	.778/ -89	.505/-116	1.115/ -29	.778/ -89	.507/ -59	1.111/ 29
17.50	.785/ -89	.503/-115	1.103/ -28	.785/ -89	.505/ -61	1.100/ 27
18.00	.791/ -89	.502/-113	1.092/ -26	.791/ -89	.503/ -63	1.090/ 26
18.50	.796/ -89	.500/-112	1.083/ -25	.796/ -89	.501/ -64	1.081/ 25

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY *****
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 6.40 FT
 SPECTRUM PEAK PERIOD 6.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 5.70 SECONDS
 CHARACTERISTIC WIND SPEED 29.17 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 90.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 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 (K.LBS)	138.318	116.388	7.467
SWAY (K.LBS)	966.548	1126.059	5.393
HEAVE (K.LBS)	951.763	760.974	7.858
ROLL (K.LBS-FT.)	2645.527	2914.552	5.703
PITCH (K.LBS-FT.)	51006.490	39414.511	8.131
YAW (K.LBS-FT.)	33891.253	35680.650	5.968

>>> 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 (FT)	1.020	.630	10.172
SWAY (FT)	1.702	1.676	6.381
HEAVE (FT)	2.671	2.375	7.065
ROLL (DEG)	7.693	6.974	6.931
PITCH (DEG)	1.496	1.352	6.950
YAW (DEG)	.606	.556	6.849

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY *****
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 6.40 FT
 SPECTRUM PEAK PERIOD 6.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 5.70 SECONDS
 CHARACTERISTIC WIND SPEED 29.17 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 90.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 SECONDS

---- LOCAL MOTION SUMMARIES: SELECTED POINTS ----

+++ SIGNIFICANT SINGLE AMP. DISPLACEMENTS +++

POINT COORDINATES (X, Y, Z)	X COMP	Y COMP	Z COMP
(150.0, .0, 17.0)	.904	2.771	4.751
(-150.0, .0, 17.0)	.904	2.783	4.729

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY *****
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 9.70 FT
 SPECTRUM PEAK PERIOD 8.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 6.87 SECONDS
 CHARACTERISTIC WIND SPEED 38.15 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 90.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 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 (K.LBS)	205.645	161.643	7.994
SWAY (K.LBS)	1210.384	1248.769	6.090
HEAVE (K.LBS)	1698.250	1254.534	8.505
ROLL (K.LBS-FT.)	3707.292	3520.125	6.617
PITCH (K.LBS-FT.)	77928.874	59319.300	8.254
YAW (K.LBS-FT.)	43734.930	42605.920	6.450

>>> 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 (FT)	1.428	.929	9.651
SWAY (FT)	2.956	2.433	7.635
HEAVE (FT)	4.421	3.567	7.788
ROLL (DEG)	11.983	10.467	7.193
PITCH (DEG)	2.173	1.851	7.376
YAW (DEG)	.920	.776	7.445

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY *****
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 9.70 FT
 SPECTRUM PEAK PERIOD 8.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 6.87 SECONDS
 CHARACTERISTIC WIND SPEED 38.15 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 90.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 SECONDS

---- LOCAL MOTION SUMMARIES: SELECTED POINTS ----

+++ SIGNIFICANT SINGLE AMP. DISPLACEMENTS +++

POINT COORDINATES (X, Y, Z)	X COMP	Y COMP	Z COMP
(150.0, .0, 17.0)	1.224	4.065	7.211
(-150.0, .0, 17.0)	1.224	4.074	7.197

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY *****
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 6.40 FT
 SPECTRUM PEAK PERIOD 6.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 5.70 SECONDS
 CHARACTERISTIC WIND SPEED 29.17 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 180.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 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 (K.LBS)	162.222	151.987	6.706
SWAY (K.LBS)	226.736	212.519	6.704
HEAVE (K.LBS)	698.522	437.906	10.023
ROLL (K.LBS-FT.)	735.649	630.622	7.330
PITCH (K.LBS-FT.)	55474.863	42806.130	8.143
YAW (K.LBS-FT.)	29138.242	30455.390	6.011

>>> 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 (FT)	1.053	.679	9.745
SWAY (FT)	.710	.509	8.761
HEAVE (FT)	1.560	1.102	8.897
ROLL (DEG)	2.655	2.316	7.203
PITCH (DEG)	1.590	1.402	7.124
YAW (DEG)	.544	.485	7.043

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY *****
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 6.40 FT
 SPECTRUM PEAK PERIOD 6.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 5.70 SECONDS
 CHARACTERISTIC WIND SPEED 29.17 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 180.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 SECONDS

---- LOCAL MOTION SUMMARIES: SELECTED POINTS ----

+++ SIGNIFICANT SINGLE AMP. DISPLACEMENTS +++

POINT COORDINATES (X, Y, Z)	X COMP	Y COMP	Z COMP
(150.0, .0, 17.0)	.947	1.761	4.441
(-150.0, .0, 17.0)	.947	1.462	4.451

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY ***** **
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 9.70 FT
 SPECTRUM PEAK PERIOD 8.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 6.87 SECONDS
 CHARACTERISTIC WIND SPEED 38.15 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 180.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 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 (K.LBS)	254.195	205.581	7.769
SWAY (K.LBS)	380.543	313.380	7.630
HEAVE (K.LBS)	1188.133	773.872	9.647
ROLL (K.LBS-FT.)	1326.204	1031.940	8.075
PITCH (K.LBS-FT.)	101405.200	75055.610	8.489
YAW (K.LBS-FT.)	38452.281	36897.820	6.548

>>> 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 (FT)	1.740	1.138	9.603
SWAY (FT)	1.306	.919	8.929
HEAVE (FT)	2.709	1.893	8.994
ROLL (DEG)	4.387	3.709	7.432
PITCH (DEG)	2.673	2.161	7.770
YAW (DEG)	.843	.695	7.620

**
 ***** III. IRREGULAR WAVE STATISTICS SUMMARY ***** **
 **

---- ENVIRONMENTAL CHARACTERISTICS ----

WAVE SPECTRAL TYPE -- BRETSCHNEIDER
 : SHORT-CRESTED SEAS

ANGULAR SECTOR CONTAINING WAVE ENERGY .. 180.00 DEGREES
 POWER OF COSINE IN SPREADING FACTOR 2.00
 CALCULATED SIGNIFICANT WAVE HEIGHT 9.70 FT
 SPECTRUM PEAK PERIOD 8.50 SECONDS
 SPECTRUM ZERO UPCROSS PERIOD 6.87 SECONDS
 CHARACTERISTIC WIND SPEED 38.15 FT/SECOND
 DIRECTION OF MAXIMUM SEAS 180.00 DEGREES

+++ BACKGROUND SWELL DATA +++

CALCULATED SIGNIFICANT SWELL HEIGHT 3.00 FT
 GLOBAL SWELL DIRECTION 30.00 DEGREES
 SWELL PERIOD 11.00 SECONDS

---- LOCAL MOTION SUMMARIES: SELECTED POINTS ----

+++ SIGNIFICANT SINGLE AMP. DISPLACEMENTS +++

POINT COORDINATES (X, Y, Z)	X COMP	Y COMP	Z COMP
(150.0, .0, 17.0)	1.495	2.803	7.453
(-150.0, .0, 17.0)	1.495	2.225	7.553

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