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SHIPMO5: AN UPDATED USER'S MANUAL INCORPORATING NEW WAVE SPECTRA AND SHIP-REFERENCED FORCES

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Abstract

The ship motion computer program SHIPMO has been revised to increase its capabilities in several different areas. The new version of the program can compute forces relative to local ship axes and the resulting incidence of motion-induced interruptions or sliding events. Seakeeping positions may now be offset from the ship centreline. The program now includes expanded wave spectra capabilities, including multi-directional spectra. Motion computations may include hydrodynamic end-effect terms, which can be important for transom stern ships at forward speeds. SHIPMO5 also has an option for predicting propeller emergence, which can influence added power requirements.

Résumé

SHIPMO, le logiciel de simulation des mouvements d'un navire, a été révisé de manière à accroître ses possibilités sur divers plans. La nouvelle version du logiciel peut calculer les forces par rapport aux axes locaux du navire, ainsi que la fréquence résultante des événements de glissement ou des interruptions dues au mouvement. Les positions de tenue en mer peuvent maintenant être décalées par rapport à l'axe longitudinal du navire. Le programme comporte maintenant des fonctions étendues de calcul des spectres d'ondes, y compris les spectres multi-directionnels. Les calculs du mouvement peuvent tenir compte des effets hydrodynamiques finals, qui sont parfois importants dans le cas des navires à tableau arrière en marche avant. SHIPMO5 comporte aussi une option de prédiction de l'émergence de l'hélice, un événement qui peut accroître la consommation d'énergie du navire.

Contents

Notation

$A(P_i)$	spectral normalization factor
A_x	sectional area
A_{44}	added moment of inertia
a	wave amplitude
a_1, a_2, a_3	accelerations in global axes at position on ship
B	beam
C_B	block coefficient
CG	centre of gravity
F_i	excitation force for mode i
F_{lat}	lateral force estimator
F_{long}	longitudinal force estimator
F_v	vertical force estimator
f_i	sectional excitation force for mode i
$\overline{GM}$	metacentric height
g	gravitational acceleration
H_s	significant wave height
h	height above deck of CG of person
k_w	wave number
k_{xx}	roll radius of gyration
L	ship length between perpendiculars
LCG	longitudinal centre of gravity
$l(\delta)$	horizontal distance from CG of person to tipping point
$M_i(\nu)$	spectral directional spreading function
M_p	number of slides per second in port direction
MII	number of motion-induced interruptions during task
m_n	spectral moment
n_i	component of normal pointing outward from hull
$\vec{0}_\delta$	tipping point
P_i	spectral directional spreading parameter
S_{port}	port sliding force estimator
S_{stbd}	starboard sliding force estimator
$S(T), S(\omega_w)$	unidirectional wave spectral energy density
$S(\omega_w, \nu)$	directional wave spectral energy density
$S_S(\omega)$	spectral density of sliding estimator
s	half stance width of person on deck
T	draft or wave period
T_{aft}	aft tipping estimator
T_{fore}	forward tipping estimator
T_p	peak wave period
T_{port}	port tipping estimator
T_T	task duration
T_x	sectional draft
T_1	period corresponding to energy averaged wave frequency

T_{-1}	energy averaged wave period
U_k	ship speed in knots
V	effective flow velocity
x, y, z	coordinate system
α	exponent for JONSWAP spectrum
β_s	direction of wave propagation relative to ship velocity; $\beta_s = 180°$ for head seas
χ	compass bearing of ship forward velocity
δ	azimuth angle of tipping point $\vec{O}_\delta$
η_4, η_5, η_6	ship angular displacements
$\Gamma()$	gamma function
λ_i	spectral shape parameter
λ_s	tank valve resistance coefficient
μ_s	static coefficient of friction
ν	compass bearing from which wave component is approaching
ν_{mi}	mean compass direction (from) of spectral energy for component i
ρ	water density
σ	JONSWAP spectrum coefficient
ω	wave encounter frequency
ω_p	peak wave frequency
ω_w	wave frequency
ω_{-1}	frequency corresponding to energy averaged wave period
ζ_i	spectral amplitude parameter
$\triangle$	ship mass

1 Introduction

The ship motion computer program SHIPMO [1, 2, 3, 4] has been revised to increase its capabilities in ship seakeeping analysis. The changes have been implemented in a number of different aspects of the program.

To provide improved estimates of ship operability, SHIPMO5 can predict vertical, lateral, and longitudinal motions at off-centre seakeeping positions. These motions can subsequently be used to compute lateral and longitudinal force estimators and the resulting incidence of motion-induced interruptions (MII's) or sliding events at seakeeping positions using the theory described by Graham [5]. Computed lateral and longitudinal force estimators which result from accelerations relative to the local ship axes can also be used in ship systems design as described by Beck et al. [6].

Several new wave spectra have been added to SHIPMO. The JONSWAP spectrum [7] is suitable for fetch-limited conditions. The Ochi and Hubble 6 parameter spectrum [8] is a uni-directional spectrum having separate swell and sea components. The 10 parameter spectrum [9, 10, 11], which was originally proposed by Hogben and Cobb [12] as a multi-directional extension of the Ochi and Hubble 6 parameter spectrum, is also available. The new program can also use multi-directional hindcast spectra given by the user or from the Offshore Data Gathering Program (ODGP) hindcast model [9, 10]. Hydrodynamic end-effect terms [13] on transom sterns are available as optional computations. Incorporating end-effect terms gives improved motion predictions in many cases for transom stern ships at high forward speed [14]. A revised method for computing surge excitation should give improved force predictions along the hull and includes forces on the transom. SHIPMO5 can also predict propeller emergence frequency, which can influence added power requirements.

To simplify program input for the new version of SHIPMO, vertical coordinates of the centre of gravity, deck edge, anti-rolling tank, and seakeeping positions are input relative to the baseline; however, input files for older versions do not need to be modified to run with version 5 because the new version is capable of recognizing earlier version files and making the required adjustments to the input data.

SHIPMO5, like SHIPMO4 [4], does not have a wave load capability; thus, SHIPMO2 [2] must be used if wave loads are required.

2 General Discussion

This section discusses several important areas to note before running SHIPMO. The user may also wish to consult the theoretical basis of the program, given in References 1, 3, 5, and 13.

2.1 Coordinate Systems for Ship and Waves

The coordinate system used for the motion calculations is illustrated in Figure 1. Its origin is located at the equilibrium position of the ship centre of gravity (CG). The x axis points to the bow and y axis extends to port, and both axes are parallel to the undisturbed free surface. The z axis points vertically upward. The coordinate system translates with the mean velocity of the ship, maintaining a fixed orientation with respect to the free surface.

The sea direction β_s is defined in Figure 2 as the angle between the mean velocity vector of the ship and the direction of propagation of the wave train, which is normal to the crests of the waves. Thus, $\beta_s = 0°$ for following seas, $\beta_s = 90°$ for beam seas from port, and $\beta_s = 180°$ for head seas.

For the 10 parameter and hindcast directional spectra, an energy component is dependent on the compass bearing ν from which the component is approaching as defined in Figure 3. If the ship forward velocity has a compass bearing of χ, then the relative sea direction β_s of the energy component can be determined as follows:

$$\beta_s = \nu + 180° - \chi \tag{2.1}$$

For the input hindcast spectrum, the energy in each directional bin is the wave energy going to that direction. This convention is changed within SHIPMO such that the energy in each directional bin is the wave energy coming from that direction.

2.2 Accuracy of Hull Form Definition

Hull form input for SHIPMO can be in the form of sectional offsets, or sectional beam, draft and area coefficient. Good roll predictions require accurate offset data, since roll damping *is very sensitive to section geometry*. Therefore, it is recommended that the user use offsets to describe the section geometry whenever the lateral plane responses are required.

Sectional hydrodynamic properties can be computed using either the conformal mapping method or the close-fit method. It is possible to input offsets and still use the conformal mapping method to take advantage of faster computation times. When the conformal method is used outside the range indicated in Figure 4, which has been adapted from Reference 15, an error message will indicate which stations are outside the appropriate range. In general, the close-fit method is recommended whenever this is the case; however, if only bow stations having very small area coefficients (such as those occurring on some warships) are involved, the added mass of a station will be a small fraction of the total added mass and the error introduced by using the conformal method will be small. On the other hand, the added mass of a bulbous bow station may be significant; thus, when stations of this type lie outside the indicated range, the close-fit method should be used.

2.3 Wave Frequencies for Response Computations

Ship response is computed at wave frequencies specified in the program input. If motions in irregular seas are to be computed, care must be taken to cover the frequency range of interest adequately. Physically realistic limits on the frequency interval at full scale are:

$$0.2 \leq \omega_w \leq 2.0$$

where ω_w is the wave frequency.[1] SHIPMO is capable of computing responses for a maximum of 40 frequencies.

2.4 Encounter Frequencies for Added Mass, Damping, and Potentials

Hull sectional added mass, damping, and potentials are calculated at encounter frequencies specified by the user. A maximum number of 40 encounter frequencies can be specified.

The tables of sectional potentials, added mass, and damping as functions of encounter frequency are generated (or read from disk) before ship motions are computed. Particular values are interpolated from the tables as necessary, since a given wave frequency, sea direction, and ship speed will define the frequency of encounter. Care must be taken that the tables adequately cover the necessary encounter frequency range. In general, the relationship between frequency of encounter and the wave frequency is:

$$\omega = \omega_w - k_w U \cos\beta_s \tag{2.2}$$

where ω is the wave encounter frequency and U is the ship speed. For water of infinite depth, as assumed in SHIPMO, Equation (2.2) can be expressed as:

$$\omega = \omega_w - 0.0524\, U_k\, \omega_w^2 \cos\beta_s \tag{2.3}$$

where U_k is the ship speed in knots. It can be seen, particularly for a multi-directional analysis, that a large encounter frequency range may exist. In practice, the added mass, damping, and potentials will assymptotically approach limiting values at higher frequencies. A reasonable limit on the maximum frequency of encounter WEMAX for computations is WEMAX $\leq 20(g/L)^{1/2}$. It is recommended that the user check the output to ensure that no significant motions occur at encounter frequencies greater than WEMAX.

In solving the equations of motion, a lower limit WEMIN given as input is set on the frequency of encounter ω. This step is taken because the linear mathematical model of ship motions breaks down when $\omega = 0$ for $\omega_w > 0$. In practice, it is recommended that WEMIN be set such that WEMIN $\geq (g/L)^{1/2}$.

2.5 Option to Store Sectional Added Mass, Damping, and Potentials

For each ship hull section, SHIPMO generates tables of potentials, added masses, and damping over the range of encounter frequencies specified. These calculations are quite time-consuming and need not be repeated in subsequent runs if the hull form and CG location remain unchanged. Thus, provision is made that these tables may be stored on disk and merely read into the program for subsequent runs. This is most useful when examining the positions, types and sizes of stabilizing devices for a single hull.

[1] Although ω and ω_e are commonly used to denote wave frequency and wave encounter frequency respectively, this manual uses ω_w for wave frequency and ω for encounter frequency to maintain consistency with Reference 1.

3 Overview of Modifications

This section summarizes the changes made for version 5 of SHIPMO.

3.1 Units for Internal Computations

For previous SHIPMO versions, internal computations are conducted in FPS units. Internal computations for version 5 are done in metric or FPS units, depending on the unit system requested for program output. If the input unit system differs from the output unit system, then input values are converted to output units after echoing of user input.

3.2 Wave Spectra

A complete list of wave spectra available in SHIPMO5 is given here for reference.

Quadratic Regression Spectrum

The quadratic regression spectrum is based on observed wave records at station India in the North Atlantic [16]. Input parameters are significant wave height H_s and energy-averaged wave period T_{-1}, defined as:

$$T_{-1} = \frac{\int_0^\infty S(T)\, T \,\mathrm{d}\, T}{\int_0^\infty S(T) \,\mathrm{d}\, T} \tag{3.1}$$

where T is wave period and S(T) is spectral energy density. The spectral energy $S(\omega_u)$ is evaluated from a non-dimensional database as follows:

$$S(\omega_u) = \begin{cases} 0 & \text{for } \omega_u < 0.05\,\omega_{-1} \\ f(H_s, T_{-1}) & \text{for } 0.05\,\omega_{-1} \le \omega_u \le 4\,\omega_{-1} \\ 0 & \text{for } \omega_u > 4\,\omega_{-1} \end{cases} \tag{3.2}$$

where $\omega_{-1} = 2\pi/T_{-1}$. For fully-developed seas, the peak wave period T_p used as input for the Bretschneider and JONSWAP spectra can be related to the energy averaged period as follows:

$$T_p = 1.166\, T_{-1} \tag{3.3}$$

Bretschneider Spectrum

SHIPMO uses the Bretschneider spectrum taken from the 15th International Towing Tank Conference (ITTC) [7] as follows:

$$S(\omega_u) = \frac{487\, H_s^2}{T_p^4\, \omega_u^5} \exp\left[\frac{-1948}{T_p^4\, \omega_u^4}\right] \tag{3.4}$$

JONSWAP Spectrum

The JONSWAP spectrum models relatively high-peaked spectra typically encountered in fetch-limited regions [7]. The JONSWAP spectrum is obtained by multiplying the Bretschneider spectrum by a peak enhancement factor accounting for fetch limited conditions. The following JONSWAP formulation is used:

$$S(\omega_w) = \frac{320\ H_s^2}{T_p^4\ \omega_w^5}\ \exp\left[\frac{-1948}{T_p^4\ \omega_w^4}\right]\ 3.3^{\alpha} \tag{3.5}$$

$$\alpha = \exp\left[-\left(\frac{0.159\ \omega\ T_p - 1}{\sigma\sqrt{2}}\right)^2\right] \tag{3.6}$$

$$\sigma = \begin{cases} 0.07 & \text{for } \omega_w \leq 6.64/T_p \\ 0.09 & \text{for } \omega_w > 6.64/T_p \end{cases} \tag{3.7}$$

The Bretschneider and JONSWAP spectra can also be expressed in terms of the period T_1 corresponding to the average frequency using the following relationship for fully developed seas:

$$T_1 = 0.773\ T_p \tag{3.8}$$

where T_1 is evaluated as follows:

$$T_1 = 2\pi\ \frac{\int_0^{\infty} S(\omega_w)\ \mathrm{d}\ \omega_w}{\int_0^{\infty} S(\omega_w)\ \omega_w \mathrm{d}\ \omega_w} \tag{3.9}$$

Ochi and Hubble Six Parameter Spectrum

The Ochi and Hubble 6 parameter spectrum models collinear swell and sea components as follows:

$$S(\omega_w) = \frac{1}{4}\sum_{i=1}^{2} \frac{\left[\left(\frac{4\lambda_i+1}{4}\right)\ \omega_{p_i}^4\right]^{\lambda_i}\ \zeta_i^2\ \exp\left[-\left(\frac{4\lambda_i+1}{4}\right)\left(\frac{\omega_{p_i}}{\omega_w}\right)^4\right]}{\Gamma(\lambda_i)\ \omega_w^{(4\lambda_i+1)}} \tag{3.10}$$

where λ_i, ζ_i, and ω_{p_i} are the spectra shape parameter, significant wave height, and peak frequency for component i. If only one of the two components is considered and the shape parameter λ_i is equals one, then the six parameter spectrum is equivalent to the Bretschneider spectrum.

Ten Parameter Directional Spectrum

The ten parameter spectrum is a directional extension of the Ochi and Hubble six parameter spectrum. Each of the swell and sea components is multiplied by its own directional spreading function as follows:

$$M_i(\nu) = A(P_i)\ \cos^{2P_i}\left(\frac{\nu - \nu_{m_i}}{2}\right) \qquad i = 1,2 \tag{3.11}$$

where ν is the compass direction (from) of the directional contribution, and P_i and ν_{m_i} are the directional spread parameter and mean compass direction (from) for component i. The normalization factor $A(P_i)$ is expressed as:

$$A(P_i) \;=\; \frac{2^{(2P_i-1)}\,\Gamma^2(P_i+1)}{\pi\,\Gamma(2P_i+1)} \qquad i = 1,2 \tag{3.12}$$

Hindcast Spectra

Directional spectra from the Offshore Data Gathering Program (ODGP) hindcast model [10] can be used by SHIPMO5. A complete description of hindcast spectra data files is given in Appendix A.4.

User Input Directional Spectra

User input directional spectra can be read by SHIPMO5 based on the format given in Appendix A.6.

3.3 Seakeeping Calculations

Several new features have been incorporated into the seakeeping calculations at positions on the ship.

Zero-Crossing Periods

To give the user some information on the frequency content of the responses in irregular seas, zero-crossing periods, T_o, are now computed and output. The zero-crossing period is given by:

$$T_o \;=\; 2\,\pi\,\sqrt{\frac{m_o}{m_2}} \tag{3.13}$$

where m_i is the ith moment of the response spectrum.

Force Estimators and Motion-Induced Interruptions

The new version of SHIPMO includes an option for computing force estimators and the resulting incidence of motion-induced interruptions (MII's) [5]. The lateral and longitudinal force estimators indicate the force due to ship motion acting on a person or object relative to the local ship axes. Retaining linear terms and expressing as force per unit mass, the longitudinal. lateral. and vertical force estimators are as follows:

$$F_{long} \;=\; -a_1 \;+\; g\,\eta_5 \tag{3.14}$$

$$F_{lat} \;=\; -a_2 \;-\; g\,\eta_4 \tag{3.15}$$

$$F_v \;=\; -a_3 \;-\; g \tag{3.16}$$

where a_1, a_2 and a_3 are the local accelerations in the x, y and z directions, and η_4 and η_5 are the ship roll and pitch angles respectively.

In order to determine the effects of the above forces on equipment or people aboard ship, Graham [5] introduced a frequency-domain method for estimating the incidence of equipment sliding, or of personnel loss-of-balance events, termed motion-induced interruptions.

First consider an object on deck and suppose that the object has a static coefficient of friction given by μ_s. In this case, slides can only occur in the port or starboard directions. A slide to port will occur whenever:

$$F_{lat} \;>\; -\mu_s F_v \tag{3.17}$$

or

$$-a_2 - g\,\eta_4 - \mu_s a_3 \;>\; \mu_s g \tag{3.18}$$

The quantity on the left hand sides of Equation (3.18) was called a generalized lateral force estimator in Reference 5. In the present work, this quantity will be called the port sliding estimator function, and denoted by S_{port}. Tipping estimator functions will be considered below.

In Reference 5, the number of slides per unit time was derived, under the assumption that $S_{port}(t)$ followed the Rayleigh distribution. In fact, the result holds provided that $S_{port}(t)$ is a zero-mean Gaussian process, and is not restricted to narrow-band processes. Let $S_{S_{port}}(\omega)$ denote the (one-sided) power spectral density of $S_{port}(t)$ as a function of encounter frequency ω, and denote by m_n the spectral moments of $S_{S_{port}}(\omega)$:

$$m_n = \int_0^\infty \omega^n S_{S_{port}}(\omega) d\omega \tag{3.19}$$

Rice [17] (see also [18]) showed that the number of upcrossings (or downcrossings) per unit time of a threshold at level $\mu_s g$ is given by:

$$M_{port} \;=\; \frac{1}{2\pi}\sqrt{\frac{m_2}{m_0}}\,\exp\left[-\frac{(\mu_s\,g)^2}{2\,m_0}\right] \tag{3.20}$$

The quantity M_{port} is the number of slides per second in the port direction. For a shipboard task requiring T_T seconds to complete, the expected number of port sliding incidents during the duration of the task is obtained by multiplying Equation (3.20) by T_T.

Similarly, the number of sliding incidents that occur in the starboard direction can be determined from the number of upcrossings of the following sliding estimator function:

$$S_{stbd} \;=\; a_2 + g\,\eta_4 - \mu_s a_3 \tag{3.21}$$

Now consider the problem of motion-induced interruptions. First consider a person facing in the fore-and-aft direction, and assume that his centre of gravity is located at a height h above the deck, and that his stance width is $2s$, as shown in Figure 5. By taking moments about the lef' 'oot position, it can be seen that the person will tip to port if:

$$-a_2 - g\,\eta_4 - \frac{s}{h} a_3 \;>\; \frac{s}{h} g \tag{3.22}$$

The quantity on the left hand side of Equation (3.22) will be called the port tipping estimator function, and will be denoted by T_{port}. As in Reference 5, the quantity s/h is referred to as the tipping coefficient. The number of port tipping incidents can be determined as in Equation (3.20). From typical personnel stance geometries, representative values for s/h would be 0.25 and 0.17 for a person facing forward and sideways, respectively. On the other hand, a typical static coefficient for dry deck conditions is 0.7. Comparing Equations 3.18 and 3.22, it is clear that for dry deck conditions and non-skid surfaces, people will tip over before they slide.

Now consider tipping in the presence of combined vertical, lateral, and longitudinal accelerations. Suppose that a person is facing forward, and that at a given instant in time the resultant force parallel to the deck (the vector sum of F_{lat} and F_{long}) is in the direction δ shown in Figure 6. The corners of the rectangle shown in this figure are defined by the location of the feet of the crew member. The resultant force will result in a tip in the direction δ provided that

$$F_{long} \cos\delta + F_{lat} \sin\delta - \frac{l(\delta)}{h} a_3 > \frac{l(\delta)}{h} g \tag{3.23}$$

For a tip to occur at some point $\vec{O}_\delta$ on the top of the rectangle, it is necessary and sufficient that

$$F_{long} - \frac{l(0)}{h} a_3 > \frac{l(0)}{h} g \tag{3.24}$$

To see this, note that Equation 3.23 is equivalent to

$$\sqrt{F_{long}^2 + F_{lat}^2} - \frac{l(\delta)}{h} a_3 > \frac{l(\delta)}{h} g \tag{3.25}$$

Multiplying this result by $\cos\delta = F_{long}/\sqrt{F_{long}^2 + F_{lat}^2}$ we obtain

$$F_{long} - \frac{l(\delta)\cos\delta}{h} a_3 > \frac{l(\delta)\cos\delta}{h} g \tag{3.26}$$

which is equivalent to Equation 3.24.

If the forward tipping estimator function is defined as

$$T_{fore} = -a_1 + g\,\eta_5 - \frac{l(0)}{h} a_3 \tag{3.27}$$

then the forward tips can be counted by determining the upcrossings of T_{fore}. Similarly, the aft tipping estimator function can be defined via

$$T_{aft} = a_1 - g\,\eta_5 - \frac{l(0)}{h} a_3 \tag{3.28}$$

The total number of motion-induced interruptions is determined by summing the upcrossings of the four tipping estimator functions.

SHIPMO5 requires the user to input the duration of the task of interest, T_T, plus values for the lateral and longitudinal tipping coefficients. Representative values for these coefficients

Table 1: *Representative Tipping Coefficients*

Tipping forward	0.17
Tipping sideways	0.25
Sliding	0.7

Table 2: *MII Risk Levels*

Risk Level	MII's per Minute
1. possible	0.1
2. probable	0.5
3. serious	1.5
4. severe	3.0
5. extreme	5.0

given above are also given again in Table 1. As a guide to the user in interpreting the incidence of MII events, Table 2 reproduces information from Reference 5.

In the case of negligible longitudinal acceleration, which is usual on frigates and destroyers, the user can determine the sliding incidence by inputting the static coefficient of friction for both the lateral and longitudinal tipping coefficients. The user is cautioned that in the presence of significant longitudinal acceleration it is not true that the total number of slides is the sum of the upcrossings of the sliding estimator functions in the forward, port, aft, and starboard directions. The reason for this is that the coefficient of friction is the same in all directions, which implies that slides can occur in oblique directions without an associated upcrossing by any of the sliding estimator functions in the four primary directions.

Off-Centre Seakeeping Positions

Version 5 of SHIPMO reads y coordinates for seakeeping positions in addition to x and z coordinates. If a seakeeping position is located off the ship centreline, then responses for headings 180-360 degrees are not symmetrical to responses for headings 0-180 degrees. Consequently, input sea directions should range from 0 to at least 315 degrees if any seakeeping position is located off-centre.

Propeller Emergence Calculations

SHIPMO5 includes an option for predicting propeller motions and emergence, which can influence added power in waves. The theory described in Reference 19 for predicting keel emergence is used for predicting propeller emergence. The propeller emergence calculations can include the effects of the dynamic waterline due to ship forward motion and wave diffraction by the hull; however, the empirical methods for predicting the dynamic waterline may give inaccurate results at the stern.

3.4 Hydrodynamic End-Effect Terms

The new version of SHIPMO has an option for computing hydrodynamic end-effect terms [13] for transom stern ships at forward speed. End-effect terms are expected to give somewhat improved motion predictions at higher forward speed ($Fn > 0.2$) [14].

3.5 Surge Excitation Forces

A new method has been implemented for computing surge excitation force. An average surge normal for a finite length ship section is determined by considering the hull area projected onto the $y - z$ plane. Adopting the notation of Reference 1 and assuming that wavelength is large relative to draft and beam, the sectional and total surge excitation force are:

$$f_1(x) = g \exp(-i\, k_w\, x \cos\beta_s) \frac{\mathrm{d}A_x}{\mathrm{d}x} \qquad (3.29)$$

$$F_1 = \rho\, a \int_L f_1(x)\, \mathrm{d}x \qquad (3.30)$$

where A_x is sectional area, ρ is water density, and a is wave amplitude. The contribution from the transom to the total excitation force is done by taking the limit $\mathrm{d}x \rightarrow 0$ in Equations 3.29 and 3.30. The transom contribution to surge excitation is included regardless of whether the end-effect terms of the previous section are requested.

4 Input Description

This section describes the main features of input for SHIPMO5. Detailed record descriptions and a sample input file are given in Appendix A.

4.1 General Input Format

Program input consists of an alphanumeric title and records of free-format numerical data.

Two systems of units are available in SHIPMO5, either metric or British, as shown in Table 3. Most internal computations are carried out in British units; however, some RMS computations are carried out in the system of units selected for output.

Table 3: *Units for Metric and British Systems*

	Metric	British
Length	metres	feet
Displacement	tonnes	long tons
Force	Newtons	pounds
Speed	knots	knots

A sample input file is given in Appendix A.3 for a frigate. The principal particulars of the vessel are listed in Table 4. A body plan is shown in Figure 7. The vessel has twin screws, twin rudders, and a pair of bilge keels.

Table 4: *Ship Particulars for Sample Input File*

Displacement, Δ	2932 tonnes
Length between perpendiculars, L	108.5 m
Block coefficient, C_B	0.50
Length/beam, L/B	8.52
Length/draft, L/T	26.0
Metacentric height/beam, $\overline{GM}/B$	0.05
Roll radius of gyration/beam (in water), k_{xx}/B	0.35

4.2 Changes to Input from Previous SHIPMO Versions

When creating new input files for Version 5 of SHIPMO, attention should be given to changes in input due to new program features. The reader should also note that most vertical coordinates are now referenced to the baseline to make input files more consistent. A complete list of input changes is given in Appendix A.2.

4.3 Running Input Files for Previous Versions of SHIPMO

Although the above subsection indicates that input for SHIPMO5 differs from previous versions of SHIPMO, version 5 is capable of reading input files for old versions without modification. If the new variable IEND is not present in Record (d) of an input file, then the input file is assumed to be for earlier versions of SHIPMO. Modification of input variables is subsequently done within SHIPMO5. The only possible source of incompatibility in old input files is the sea direction PSDIR(I) for short-crested sea computations, for which a consistency check has been added to SHIPMO5.

5 Output Description

This section gives a brief summary of program output. A complete description of program output and sample output is given in Appendix B.

5.1 Printer Output

Main output for SHIPMO is written to an ASCII file suitable for printing on a line printer. A description of program output is given in Appendix B.1. A sample output file is given in Appendix B.3.

5.2 Post-Processor File

If post-processing output is requested from SHIPMO5 for use in other programs, an unformatted file is written to disk. Post-processing output has been updated from the previous output described in Reference 1, and is given in Appendix B.2.

6 Concluding Remarks

This user's manual has described the improvements implemented in the latest version of ship motion program SHIPMO, which has been designated SHIPMO5. These improvements are primarily in three areas. First, an enhanced capability for wave modelling has been incorporated in the program with the addition of JONSWAP, 10-parameter, and hindcast and user input directional wave spectra. Second, the program now computes forces relative to local ship axes and the resulting incidence of motion-induced interruptions or sliding events at user-specified seakeeping positions, which are no longer restricted to the centreline of the ship. Finally, motion computations may now include hydrodynamic end-effects.

All input vertical coordinates are referenced to the ship baseline in the new version of the program. Post-processor output has also been updated.

Example input and output files are presented for the updated program. Details of the input and output record structures are presented in the appendices.

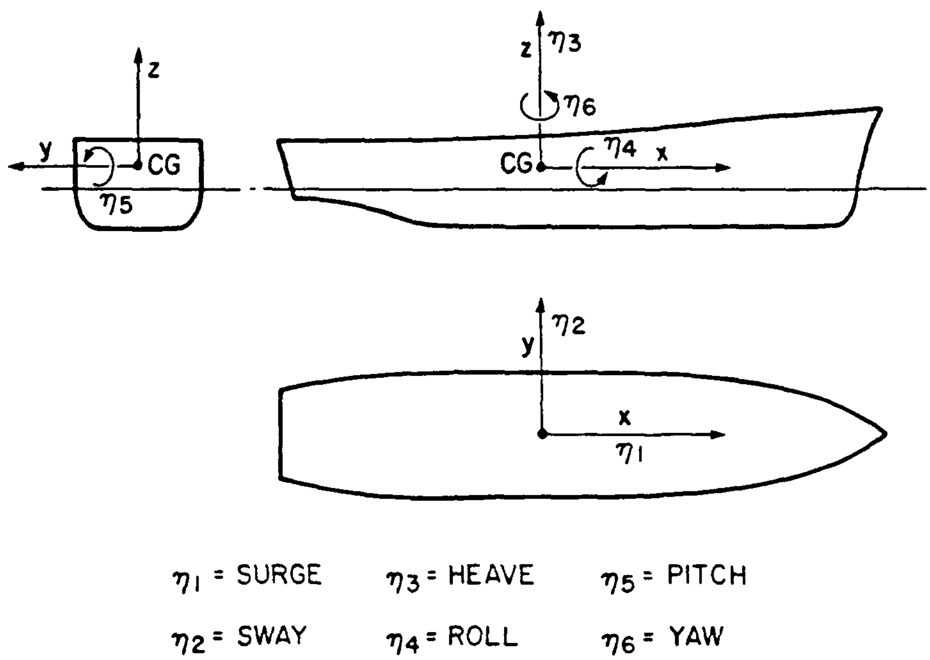


Figure 1: *Axis System (Arrows Indicate Senses of Motion)*

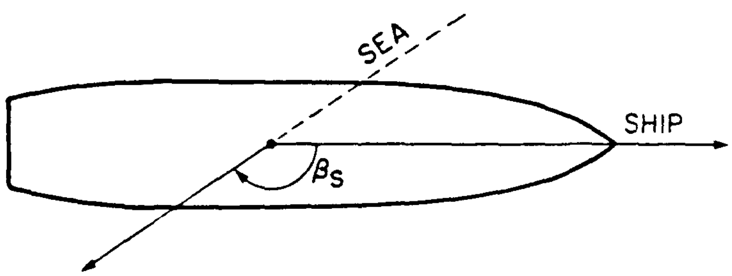


Figure 2: *Definition of Sea Direction Relative to Ship Heading*

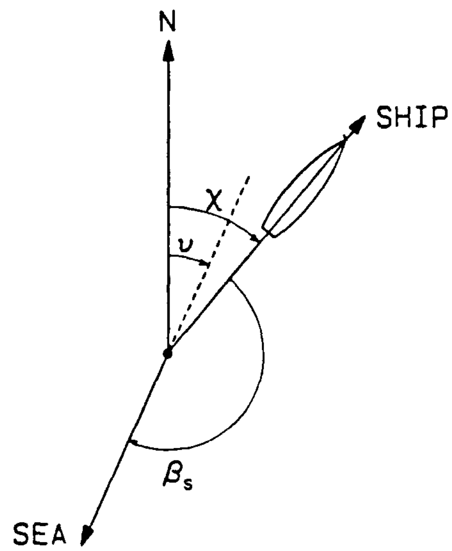


Figure 3: *Definition of Sea Direction and Ship Heading Relative to Compass*

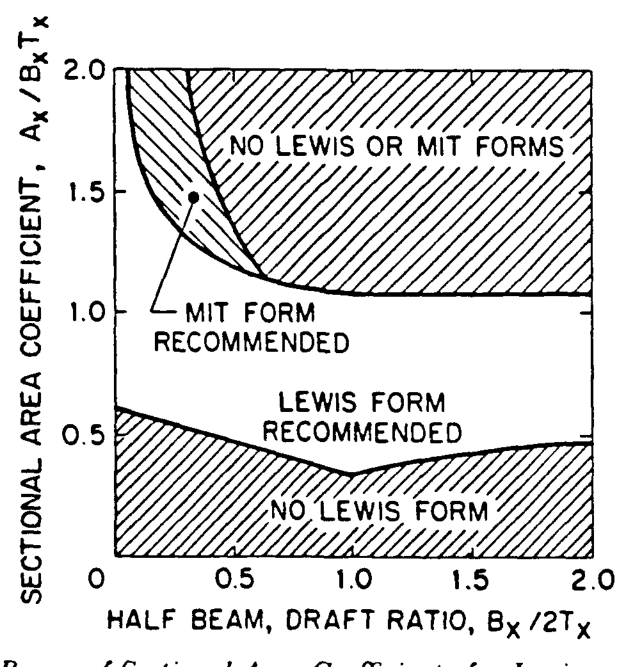


Figure 4: *Range of Sectional Area Coefficients for Lewis and MIT Forms*

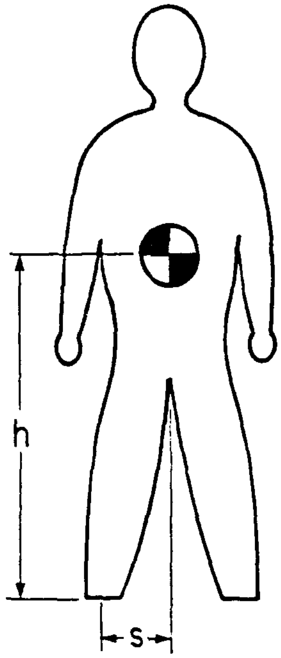


Figure 5: *Model for Person Standing on Deck*

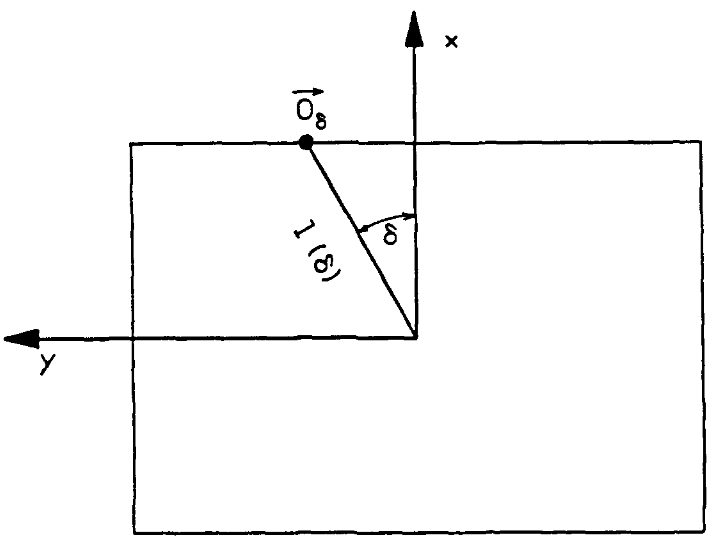


Figure 6: *Tipping Geometry in the Presence of Combined Vertical, Lateral, and Longitudinal Forces*

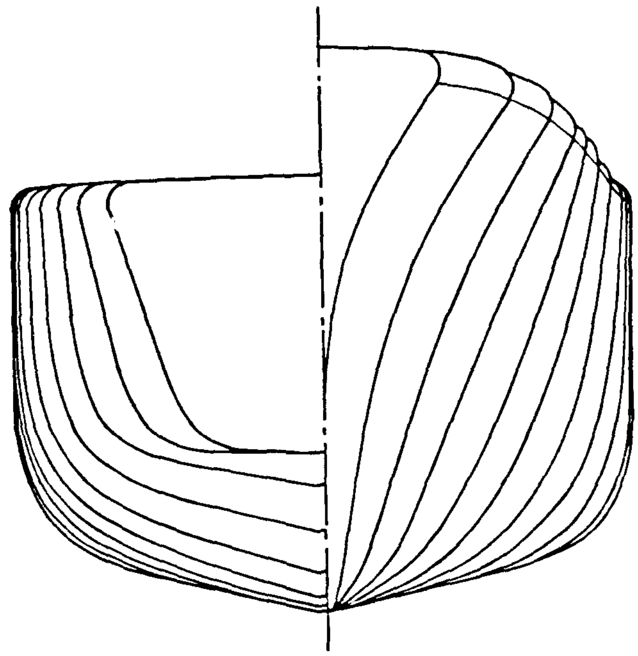


Figure 7: *Frigate Body Plan*

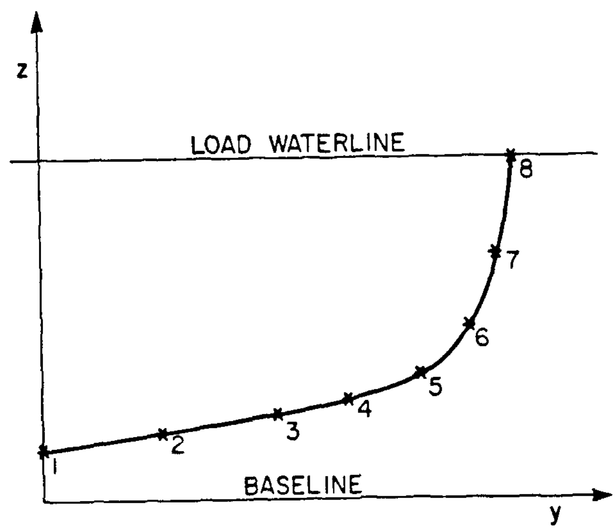


Figure 8: *Station Offsets up to the Load Waterline*

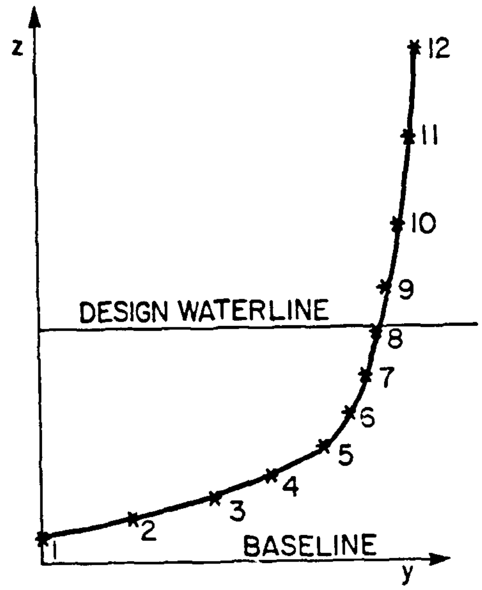


Figure 9: *Station Offsets up to the Deck Edge*

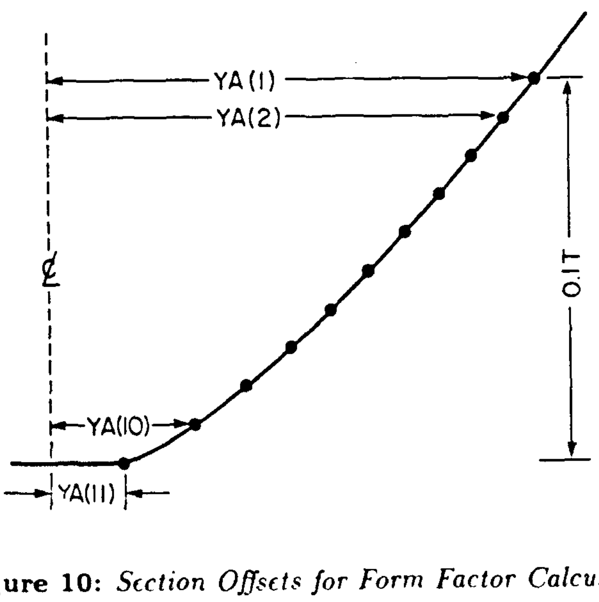


Figure 10: *Section Offsets for Form Factor Calculation*

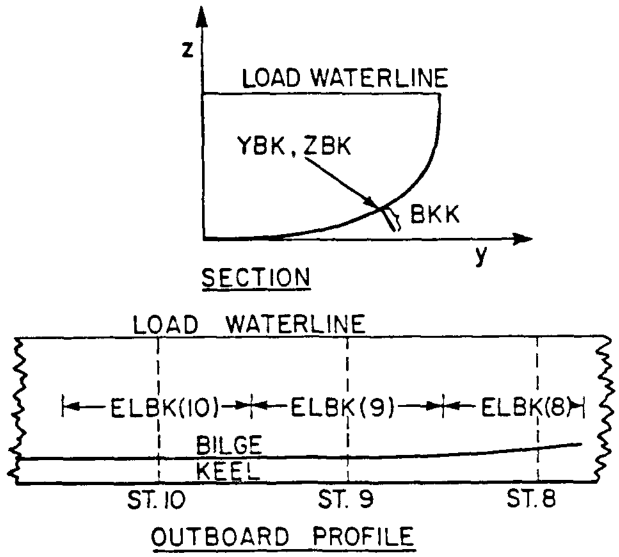


Figure 11: *Bilge Keel Inputs*

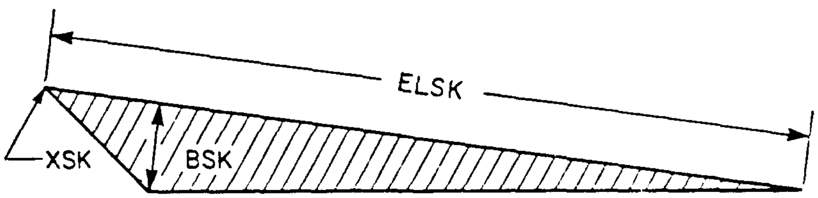


Figure 12: *Skeg Inputs*

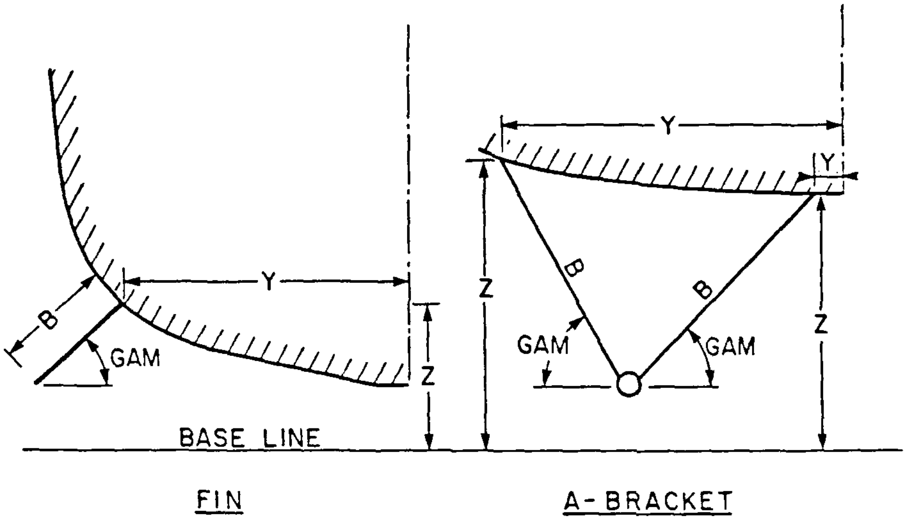


Figure 13: *Foil Inputs*

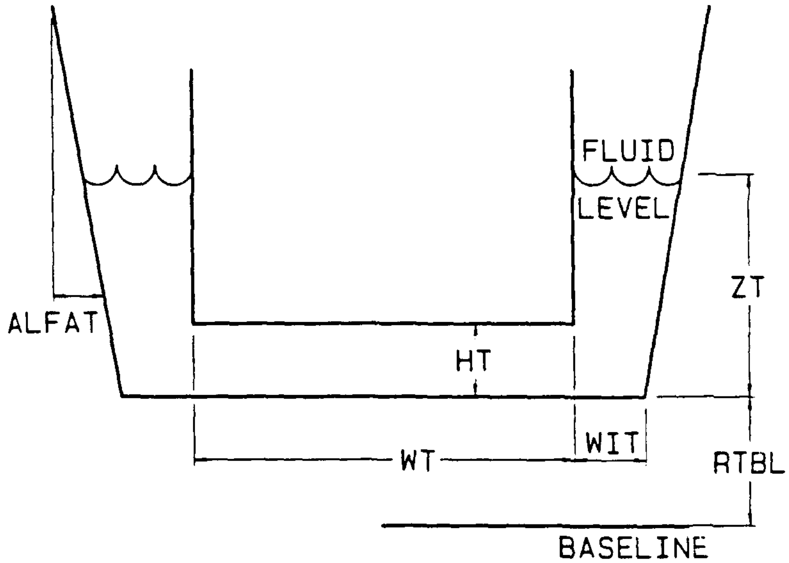


Figure 14: *Tank Inputs*

Appendix

A Program Input

A.1 Input Records

Detailed descriptions of SHIPMO5 input records are given below. Each new input record or sub-record corresponds to a new file line. The format of the input file may be adjusted by inserting extra blanks between any numerical data, and by placing data from within any particular record on separate lines; however, separate records cannot be combined on a single line.

Record (a), Fifty Character Title
TITLE (columns 1 - 80)

TITLE Alphanumeric title (maximum of 80 characters) which is written on output.

Record (b), Control Integers
IN, IOUT, IRHO, ISPEC, ICORR, IRESP, IPPF (7 integers)

IN Specifies the system of units used for input data.

IN = 0 British units.
IN = 1 Metric units.

IOUT Specifies the system of units used for output data.

IOUT = 0 British units.
IOUT = 1 Metric units.

IRHO Specifies whether ship is in salt or fresh water.

IRHO = 0 Salt water (ρ = 1.9906 slug/ft^3, 1026.08 kg/m^3).
IRHO = 1 Fresh water (ρ = 1.940 slug/ft^3, 1000.0 kg/m^3).

ISPEC Specifies the seaway spectrum to be used for motion calculations in irregular seaways.

ISPEC = 0 Quadratic regression spectrum.
ISPEC = 1 Bretschneider two parameter spectrum.
ISPEC = 2 Measured uni-directional spectrum.
ISPEC = 3 JONSWAP spectrum.
ISPEC = 4 Ochi and Hubble six parameter uni-directional spectrum.
ISPEC = 5 Ten parameter directional spectrum.

ISPEC = 6 ODGP hindcast directional spectrum.

ISPEC = 7 User input directional spectrum.

ICORR Specifies corrections to be made to the incoming wave train.

ICORR = 0 No corrections are applied.

ICORR = 1 Corrections are made for wave deformation by the hull (dynamic swell-up) and for wave profile generated from hull forward motion.

ICORR = 2 A correction is made only for wave profile generated from hull forward motion.

IRESP Control integer for program output of regular wave responses.

IRESP = 0 Suppress output of regular wave responses, and of roll damping coefficients.

IRESP = 1 Allow output of regular wave responses, but suppress output of roll damping coefficients.

IRESP = 2 Allow output of regular wave responses and of roll damping coefficients.

IPPF Control integer governing disk file storage of resulting frequency responses and RMS motions for post-processing.

IPPF = 0 Disk storage is not used.

IPPF = 1 Frequency responses and RMS motions are stored in a sequential disk file for post-processing. The name of the disk file must be specified in Record (b1). File format is given in Appendix B.2.

Note: If a measured seaway uni-directional spectrum is being used (ISPEC = 2) the units of the spectral density must be specified in Record (f2) below. The units of the spectral density may be chosen independently of the value of IN specified. In the case of a hindcast spectrum (ISPEC = 6) the input is always in metric units, as described in Appendix A.4.

Record (b1), File Name if Disk Storage Specified for Responses and Motions

Read only if IPPF = 1 in Record (b)

PPNAME (columns 1 - 20)

PPNAME The disk file name for storing frequency responses and RMS motions for post-processing (maximum 20 characters).

Record (c), Wave Frequencies for Response Calculations

WMIN, WMAX, DW (3 reals)
See discussion in Section 2.3

WMIN Lowest wave frequency for which ship motions are to be calculated (rad/sec).

WMAX Highest wave frequency for which ship motions are to be calculated (rad/sec).

DW Increment in wave frequency between WMIN and WMAX for which ship motions are to be calculated (rad/sec). Due to storage considerations, DW should be set such that DW $\geq$ (WMAX $-$ WMIN)/39.

Record (d), Encounter Frequencies for Added Mass and Damping Calculations

ISAVE, WEMIN, WEMAX, DWE, METHOD, IEND (1 integer, 3 reals, 2 integers)
See discussion in Sections 2.4 and 2.5.

ISAVE Control integer governing disk file storage of the two-dimensional section potentials, added mass and damping.

ISAVE = 0 Disk storage is not used.

ISAVE = 1 The hull sectional potentials, added mass and damping which are computed in the program are stored in a sequential disk file for future use. The name of the disk file must be specified in Record (d1).

ISAVE $\geq$ 2 The hull sectional potentials, added mass and damping for the ship are read from a sequential disk file which has already been created through a previous execution of the program. The disk file name must be specified in Record (d1).

WEMIN Lowest encounter frequency for which the hull sectional potentials, added mass and damping are calculated (rad/sec).

WEMAX Highest encounter frequency for which the hull sectional potentials, added mass and damping are calculated (rad/sec).

DWE Increment in encounter frequency between WEMIN and WEMAX for which the hull sectional properties are calculated (rad/sec). Due to storage considerations, DWE should be set such that DWE $\geq$ (WEMAX $-$ WEMIN)/39.

METHOD Control integer governing the computational method for the hull sectional properties. See discussion in Section 2.2.

METHOD = 0 Hull sectional properties are computed using section offsets and the close-fit method. No long wavelength approximations are made in computing exciting forces.

METHOD = 1 The close-fit method is used as for METHOD = 0; however, long wavelength approximations are made in computing exciting forces.

METHOD = 2 Hull sectional properties are computed using general section data (beam, draft, area coefficient) and the conformal mapping method. Long wavelength approximations are made in computing exciting forces. This method involves less computation time.

IEND Control integer for end-effect hydrodynamic terms.

IEND = 0 Hydrodynamic end-effect terms not included.

IEND = 1 Hydrodynamic end-effect terms included.

Record (d1), File Name for Storing Potentials, Added Mass and Damping

Read only if ISAVE > 0 in Record (d).

ADNAME (columns 1 - 20)

ADNAME The disk file name for hull sectional potentials, added mass and damping coefficients (maximum 20 characters).

Record (e), Number of Sea Directions and Short-Crested Analysis Spreading Angle

Read only if ISPEC $\leq$ 4 in Record (b).

NSD, ANGLE (1 integer, 1 real)

NSD Number of principal sea directions to be considered with respect to ship heading (maximum of 36). If NSD = 0, default headings from 0 to 180 degrees in 15 degree increments and a spreading angle of 90 degrees are used.

ANGLE The spreading angle (degrees) to be used in a short-crested sea spectrum analysis. If ANGLE $\leq$ 0.0 and NSD > 0, no short-crested analysis is carried out.

Record (e1), Principal Sea Directions

Read only if ISPEC $\leq$ 4 in Record (b) and NSD > 0 in Record (e).

PSDIR(I) (NSD reals)

PSDIR(I) The principal sea directions to be considered relative to the ship velocity vector (degrees). There must be NSD values.

Notes:

1. If ANGLE > 0.0 and NSD > 0 in Record (e), a sufficient range of sea directions must be given for short-crested calculations. For all seakeeping positions on the centreline (YPOS(I) = 0.0 for all I in Record (j1)), PSDIR must cover the range 0 - 180 degrees. If any seakeeping position is off centreline, PSDIR must cover the range from 0 to a minimum of 315.0 degrees.
2. If ANGLE > 0.0 and NSD > 0 in Record (e), PSDIR values must be given in ascending or descending order, with a maximum increment of 45.0 degrees between any 2 values.

Record (f), Sea State Definition

NSEA (1 integer)

NSEA Number of seaways for which motions are to be computed (maximum 10).

Notes:

1. If motions in irregular seas are not desired, set NSEA = 0. Record (f1) is required.
2. If a measured (ISPEC = 2), hindcast (ISPEC = 6), or user input directional (ISPEC = 7) spectrum is used, NSEA must be set equal to 1.

Record (f1), Wave Slope if no Sea States Specified

Read only if NSEA = 0 in Record (f).

WVSLP (1 real)

WVSLP A wave slope (in degrees) used to determine wave height in the estimation of viscous roll damping. A nominal slope of 3 degrees is recommended.

Record (f2), Significant Wave Height and Characteristic Period

Read only if ISPEC $\leq$ 3 in Record (b) and NSEA > 0 in Record (f).

HSW(I), TSW(I) (NSEA records, 2 reals/record)

HSW(I) Significant wave height of seaway I (ft or m).

TSW(I) Characteristic wave period (sec):

ISPEC = 0 energy-averaged period of seaway I.

ISPEC = 1 peak wave period of seaway I.

ISPEC = 2 any measure of the wave period may be used.

ISPEC = 3 peak wave period of seaway I.

Note: For ISPEC = 2, the significant wave height and period are used to label tables in the output, and HSW is also used to calculate the sea state number. HSW and TSW do not affect the response calculations. If HSW and TSW are not known exactly, estimates may be used.

Record (f3), Input of Measured Point Spectrum

Read only if ISPEC = 2 in Record (b) and NSEA = 1 in Record (f).

ITOP, ISEAIN, INDATA (3 integers, free format)

ITOP Number of frequencies for spectral density input (maximum 300).

ISEAIN System of units for spectral density:

ISEAIN = 0 British units

ISEAIN = 1 Metric units

The units of spectral density (m^2/(rad/s) or ft^2/(rad/s)) may be chosen independently of the value IN specified in Record (b).

INDATA Format of the spectral density input

INDATA = 0 Spectral data in the form of output from the DREA WAVE program. SHIPMO calls a file named WAVE.LST for the data, which is echoed in the SHIPMO5 output. A typical WAVE.LST file is shown in Appendix B of the SHIPMO4 manual [4].

INDATA = 1 Spectral data is stored in a file, the name of which must be specified in Record (f3a).

Record (f3a), File Name for Spectral Data from Disk File

Read only if INDATA = 1 in Record (f3).

SPECTR (columns 1 - 20)

SPECTR The disk file name for wave sea spectral data (maximum 20 characters). The spectral data file must contain 2 × ITOP entries in the following order:

$$\omega_{w1}, S(\omega_{w1}), \omega_{w2}, S(\omega_{w2}), \omega_{w3}, S(\omega_{w3}), ..., \omega_{wITOP}, S(\omega_{wITOP})$$

where $S(\omega_{wi})$ is the spectral density at frequency ω_{wi}. A sample input file is given in Appendix C of the SHIPMO4 manual [4].

Record (f4), Ochi and Hubble 6 Parameter Uni-Directional Spectrum

Read only if ISPEC = 4 in Record (b) and NSEA > 0 in Record (f).

ZETA1(I), OMEGA1(I), LAMB1(I), ZETA2(I), OMEGA2(I), LAMB2(I) (NSEA records, 6 reals/record)

ZETA1(I) Significant wave height of swell component (ft or m).

OMEGA1(I) Peak frequency of swell component (rad/s).

LAMB1(I) Spectral shape parameter of swell component.

ZETA2(I) Significant wave height of sea component (ft or m).

OMEGA2(I) Peak frequency of sea component (rad/s).

LAMB2(I) Spectral shape parameter of sea component.

Record (f5), 10 Parameter Directional Spectrum

Read only if ISPEC = 5 in Record (b) and NSEA > 0 in Record (f).
ZETA1(I), OMEGA1(I), LAMB1(I), KAPA1(I), EXPP1(I), ZETA2(I), OMEGA2(I), LAMB2(I), KAPA2(I), EXPP2(I) (NSEA records, 10 reals/record)

ZETA1(I) Significant wave height of swell component (ft or m).

OMEGA1(I) Peak frequency of swell component (rad/s).

LAMB1(I) Spectral shape parameter of swell component.

KAPA1(I) Mean compass direction (from) of swell component (degrees).

EXPP1(I) Spreading parameter of swell component.

ZETA2(I) Significant wave height of sea component (ft or m).

OMEGA2(I) Peak frequency of sea component (rad/s).

LAMB2(I) Spectral shape parameter of sea component.

KAPA2(I) Mean compass direction (from) of sea component (degrees).

EXPP2(I) Spreading parameter of sea component.

Record (f6), Hindcast Spectrum File Name

Read only if ISPEC = 6 in Record (b) and NSEA = 1 in Record (f).
HCFILE (columns 1 - 20)

HCFILE The disk file name from which hindcast data are read (maximum 20 characters). The format of hindcast spectral data files is described in Appendix A.4. The units for this input file are independent of the values chosen for IN and IOUT in Record (b).

Record (f7), User Input Directional Spectrum File Name

Read only if ISPEC = 7 in Record (b) and NSEA = 1 in Record (f).
SPDIRFILE (columns 1 - 20)

SPDIRFILE The disk file name from which the user input directional spectrum is read (maximum 20 characters). The format of the user input directional spectrum files is described in Appendix A.6. The units for this input file are independent of the values chosen for IN and IOUT in Record (b).

Record (g), Ship Speeds

UKMIN, UKMAX, DUK (3 reals)

UKMIN Lowest ship speed for which motions are to be calculated (knots).

UKMAX Highest ship speed for which motions are to be calculated (knots).

DUK Increment in ship speed between UKMIN and UKMAX for which ship motions are to be calculated (knots).

Record (h), Basic Ship Data
EL, KG, GMIN, ZWL, RNF, RRGB, YRGL, IRG (7 reals, 1 integer)

EL Length between perpendiculars (ft or m).

KG Height of CG (ft or m) above the baseline.

GMIN Metacentric height (ft or m). If input value is 0.0, GMIN will be computed from offset data and will not be corrected for internal free surfaces.

ZWL Vertical position (z coordinate, ft or m) of the waterplane with respect to the datum line used for hull and appendage offsets. Only used if offsets are being input up to the load waterline (i.e. NOFF $\leq$ 8 for all stations in Record (i1) below). Otherwise, input ZWL = 0.0.

RNF Roll natural frequency (rad/sec). Used if RRGB = 0.0.

RRGB Roll radius of gyration, non-dimensionalized with respect to beam. Used if RNF = 0.0.

YRGL Yaw radius of gyration, non-dimensionalized with respect to length (EL). Also used for pitch radius of gyration. If unknown, 0.25 can be used as a representative value.

IRG Control integer for roll radius of gyration calculation:

IRG = 0 $I4 = \Delta(RRGB \times B)^2 - A_{44}$. RRGB or RNF has been measured in water. RRGB lies between 0.35 and 0.40 for most small warships.

IRG = 1 $I4 = \Delta(RRGB \times B)^2$. RRGB or RNF has been measured in air.

Note: One of RNF or RRGB must be specified, with the other input as 0.0.

Record (i), Station Definition and Scaling Factors
NSTOT, NST, BMSF, DTSF (2 integers, 2 reals)

NSTOT Total number of equally spaced stations into which the ship hull has been divided for representation (maximum 21).

NST The number of stations for which offsets or beam, draft and area coefficient are input. NST can be less than NSTOT if the ship is lacking a bulbous bow or transom stern.

BMSF A beam-wise scaling factor, applied to the horizontal offsets, YA, given in Record (i2a), or to the station beam given in Record (i3). A default value of 1.0 is assigned if BMSF ≤ 0.

DTSF A draft-wise scaling factor, applied to the vertical offsets, ZA, given in Record (i2b), or to the station draft given in Record (i3). A default value of 1.0 is assigned if DTSF ≤ 0.

Note: NST should be sufficiently large to adequately describe the hull. For each of the NST stations, there must be one Record (i1) followed by either one each of Records (i2a) and (i2b), or one Record (i3).

Record (i1), Station Number, Number of Offsets and Eddy-Making Calculations
XA(I), NOFF(I) IEDDY(I) (1 real, 2 integers)

XA(I) Station number ($0 \leq XA \leq NSTOT - 1$). Station 0 is at the forward perpendicular, and station NSTOT − 1 is at the after perpendicular.

NOFF(I) Number of offsets to follow in Records (i2a) and (i2b) (maximum 12).

- NOFF(I) ≤ 1 Beam, draft, and area coefficient will be input (Record (i3)) to describe the hull section, which will be modelled using a Lewis or M.I.T. form. The range of section parameters for which Lewis and M.I.T. forms exist is shown in Figure 4 which has been adapted from Reference 15.
- NOFF(I) > 1 Offsets will be input (Records (i2a) and (i2b) up to the load waterline or deck edge. If NOFF(I) ≤ 8 for all I, offsets are input up to the load waterline. If NOFF(I) > 8 for some I, then offsets are input up to the deck edge for all stations, and the program will calculate the load waterline location. In this case, Records (i4), (i5) and (i6) below specify the loading conditions.

IEDDY(I) Control integer for eddy-making calculations.

- IEDDY = 0 The station has a shape unlikely to produce eddies as the ship rolls, such as a destroyer hull section with extremely rounded bilges.
- IEDDY = 1 For V or U-shaped stations such as normally occur far forward.
- IEDDY = 2 For stations triangular at the keel, or stations spanned by the skeg.
- IEDDY = 3 For stations with a shape likely to produce eddies at the bilges as the ship rolls. These consist of all stations for which the curvature is a maximum at the bilges. They range from full, almost rectangular merchant vessel midship sections to typical destroyer midship sections.

Note: See Section 2.2 for guidelines regarding accuracy of input offsets.

Record (i2a), Horizontal Offsets at Station XA(I)

Read only if NOFF(I) > 1 in Record (i1).
YA(I,J) (NOFF(I) reals)

YA(I,J) NOFF(I) horizontal offsets of station I (ft or m). The first offset point of each station must have a YA value of 0.

Record (i2b), Vertical Offsets at Station XA(I)

Read only if NOFF(I) > 1 in Record (i1).
ZA(I,J) (NOFF(I) reals)

ZA(I,J) NOFF(I) vertical offsets of station I (ft or m). Values are given as heights above the hull baseline.

Notes:

1. In the case NOFF(I) $\leq$ 8 for all I, the last point must be at the intersection of the load waterline with the station contour. See Figure 8.
2. In the case NOFF(I) > 8 for some I, the last offset point should be at the deck edge. Ideally, the user should input 8 offsets below the design waterline and 4 offsets above it. See Figure 9.

Record (i3), Beam, Draft and Area Coefficient at Station XA(I)

Read only if NOFF(I) $\leq$ 1 in Record (i1).
BEAM(I), DRAFT(I), ACOEF(I) (3 reals)

BEAM(I) Beam at station I (ft or m).

DRAFT(I) Draft at station I (ft or m).

ACOEF(I) Area coefficient at station I.

Note: Offsets are generated internally using either a Lewis form or, if the section is bulbous, an M.I.T. form.

Record (i4), Control Integer for Load Waterline Calculation

Read only if NOFF(I) > 8 for some I in Record (i1).
IBAL (1 integer)

IBAL Indicates the method used to specify the loading conditions.

IBAL = 0 Input displacement and LCG (Record (i5)).

IBAL = 1 Input midship draft and trim by stern (Record (i6)).

Record (i5), Waterline from Displacement and Longitudinal Centre of Gravity

Read only if NOFF(I) > 8 for some I in Record (i1) and IBAL = 0 in Record (i4).

DISP, RLCG (2 reals)

DISP Ship displacement (tonnes or tons).

RLCG Distance from the forward perpendicular to the LCG (ft or m).

Record (i6), Waterline from Midship Draft and Trim by the Stern

Read only if NOFF(I) > 8 for some I in Record (i1) and IBAL = 1 in Record (i4).

DMID, TRIM (2 reals)

DMID Draft at midships (ft or m).

TRIM Trim by the stern (positive for stern down) relative to bow (ft or m). This trim is the difference between the actual trim and the trim at the hydrostatic condition at which offsets were measured.

Record (j), Positions for Seakeeping Calculations and Slamming Parameters

NPOS, THR, SLAMEX, (1 integer, 2 reals)

NPOS Number of positions for irregular seas seakeeping calculations (maximum 10).

THR Time period (hours) for which number of slams, slamming pressures and slamming forces are computed for the stations specified in Records (j1). If THR = 0.0, a default value of 20 hours is used.

SLAMEX Exceedence parameter for calculating extreme slamming pressure for design consideration. If SLAMEX = 0.0, a default value of 0.01 is used.

Note: One Record (j1) is required for each of the NPOS positions.

Record (j1), Geometry and Options for Seakeeping Calculations

Read only if NPOS > 0 in Record (j).

XST(I), YPOS(I), ZPOS(I), DECKH(I), ISLAM(I), IMII(I) (NPOS records of 4 reals, 2 integers)

XST(I) Station number of position I where calculations are to be done ($0 \leq$ XST $\leq$ NSTOT − 1).

YPOS(I) Horizontal coordinate (y-coordinate) of position I relative to the centreline (ft or m). If YPOS(I) is not equal to zero, then see Note 1 for Record (e1).

ZPOS(I) Vertical coordinate (z-coordinate) of position I relative to the baseline (ft or m).

DECKH(I) Distance from the baseline to the deck edge at position I (ft or m). If the resulting freeboard is negative, deck wetness computations are omitted.

ISLAM(I) Control integer for slamming and deck wetness calculations at position I.

ISLAM = 0 No slamming or deck wetness calculations are performed at station I. Records (j2) or (j3) are not required.

ISLAM = 1 Slamming calculations are performed at station I using the truncated wedge approach. The form factor may be either given in Record (j2) or computed using the truncated wedge approach of Reference 20. Record (j2) is required. Deck wetness calculations are also performed.

ISLAM = 2 Slamming calculations are performed at station I using offsets given in Record (j3). Deck wetness calculations are also performed.

ISLAM = 3 Deck wetness calculations are performed at station I. No Records (j2) or (j3) are required.

ISLAM < 0 Propeller emergence calculations are performed at station I. No Records (j2) or (j3) are required.

IMII(I) Control integer for MII calculations at position I.

IMII = 0 No MII calculations are performed at position I. No Record (j4) is required.

IMII = 1 MII calculations are performed at position I. Record (j4) is required.

Note: For each seakeeping position, one Record (j1) is required followed by:

ISLAM ≤ 0 No Record.

ISLAM = 1 Record (j2).

ISLAM = 2 Record (j3).

In addition, an MII data record may be required as follows:

IMII = 0 No Record.

IMII = 1 Record (j4).

Record (j2), Geometry for Truncated Wedge Slamming Calculations

Read only if ISLAM = 1 in Record (j1).

DEADR, HWFB, FFACT (3 reals)

DEADR Deadrise angle at position I (degrees). For correct slamming force calculations, DEADR > 0 degrees. If DEADR < 5 degrees, the internal calculation of form factor may not be accurate and a warning will be issued. In this case, it is recommended that the form factor be input (FFACT > 0.0) or that offsets be used (ISLAM = 2) as described in Record (j3)

HWFB Half-width of flat bottom at position I (ft or m).

FFACT Form factor at position I. If FFACT $\leq$ 0.0, the form factor is computed internally using the truncated wedge approach.

Record (j3), Offsets Below 1/10th Draft for Slamming Calculations

Read only if ISLAM = 2 in Record (j1).

N, YSTA(J) (1 integer, N reals)

N Number of offsets input for station I in performing slamming calculations. Maximum value for N is 11.

YSTA(J) N-dimensional array whose elements are the horizontal offsets (distance from the centerline) read at equal vertical intervals, starting at 0.1 T_x and continuing down to the edge of the flat bottom (ft or m). See Figure 10.

Record (j4), Data for MII Calculations

Read only if IMII = 1 in Record (j1).

TCLAT(I), TCLONG(I), TIMEOP(I) (3 reals)

TCLAT(I) Lateral tipping coefficient at position I. If TCLAT < 0, a default value of 0.25 is used.

TCLONG(I) Longitudinal tipping coefficient at position I. If TCLONG < 0, a default value of 0.17 is used.

TIMEOP(I) Time of operation at position I (s). If TIMEOP < 0, a default value of 60 seconds is used.

Note: For sliding calculations, the user should input TCLAT(I) = TCLONG(I) = the static coefficient of friction.

Record (k), Number of Bilge Keel Pairs

NBKP (1 integer)

NBKP Number of bilge keel pairs (maximum value = 5).

Record (k1), First and Last Stations Spanned by Bilge Keel

Read only if NBKP > 0 in Record (k).

NFBK(I), NLBK(I) (NBKP records, 2 integers)

NFBK(I) First station spanned by bilge keel I.

NLBK(I) Last station spanned by bilge keel I

Record (k2), Bilge Keel Offsets, Breadths and Lengths

Read only if NBKP > 0 in Record (k).

YBK(J), ZBK(J), BKK(J), ELBK(J) (4 reals/record)

YBK(J) Horizontal bilge keel offset at station J (ft or m).

ZBK(J) Vertical bilge keel offset at station J (ft or m) relative to hull baseline.

BKK(J) Bilge keel breadth at station J (ft or m).

ELBK(J) Bilge keel length at station J (ft or m).

Notes:

1. One Record (k2) is required for each station spanned by bilge keel I. That is, following each Record (k1), there must be (NLBK(I) − NFBK(I) + 1) Records (k2).
2. See Figure 11 for clarification of bilge keel inputs.

Record (l), Skeg Data

XSK, BSK, ELSK (3 reals)

XSK Station number ($0 \leq XSK \leq NSTOT - 1$) of aftmost point where skeg meets hull.

BSK Skeg Breadth (ft or m), see Figure 12.

ELSK Skeg Length (ft or m), see Figure 12.

Record (m), Number of Fin Pairs and Propeller Shaft Brackets

NFP, NSH (2 integers)

NFP Number of fin pairs or tank stabilization indicator.

- NFP > 0 The ship has NFP fin pairs for roll stabilization but no tank. Maximum value of 4.
- NFP = 0 The ship has neither fins nor tank.
- NFP < 0 The ship uses a U-tank for roll stabilization but no fins.

NSH Number of propeller shaft brackets (maximum value = 4). A shaft bracket consists of 2 arms, as show in Figure 13.

Record (m1), Fin, Bracket and Rudder Data

X(I), Y(I), Z(I), B(I), CR(I), CE(I), CLA0(I), GAM(K), VEFF(I) (NFS records , 9 reals/record)

X(I) Station at whic[illegible] [illegible]il I is located ($0 \leq X \leq NSTOT - 1$).

Y(I) Horizontal coordinate of root of foil I (ft or m). For rudders, if Y(NFS) = 0, the ship is assumed to have a single rudder. If the rudder stock offset distance is positive (Y(NFS) > 0), it is assumed that there are twin rudders, each with the specified span and chord. The x, y, and z coordinates refer to the rudder stock.

Z(I) Vertical coordinate of root of foil I (ft or m) relative to hull baseline.

B(I) Span of foil I (ft or m).

CR(I) Root chord of foil I (ft or m).

CE(I) Tip chord of foil I (ft or m).

CLA0(I) Lift curve slope of foil I (rad^{-1}). If CLA0(I) is unknown, input zero and the program will calculate a value.

GAM(I) Dihedral angle of foil I (degrees). For rudders, the dihedral angle is always taken as 90 degrees, regardless of the value read for GAM(NFS). Hence, GAM(NFS) is used merely to specify whether or not the rudder is in the propeller slipstream, where:

GAM(NFS) = 0 Rudder not in propeller slipstream, and the rudder lift curve slope is corrected for boundary layer effects.

GAM(NFS) = 1 Rudder is in propeller slipstream, and no boundary layer correction is made.

VEFF(I) Correction factor applied to the ship forward speed U in determining the effective flow velocity V over foil I. $V = U \times$ VEFF(I). If foil is in wake, VEFF(I) < 1. If foil is in propeller slip-stream, VEFF(I) $\geq$ 1. If VEFF(I) $\leq$ 0.0, a default value is taken as VEFF(I) = 1.0. For warships, VEFF(I) is typically between 0.8 and 1.2, but it is difficult to estimate VEFF(I) accurately. It is recommended that the user input VEFF(I) = 1.0 in all cases, since this is sufficiently accurate for engineering purposes.

Notes:

1. Fins, propeller shaft brackets, and rudders are regarded as foils. One Record (m1) is necessary for each foil in the following order:
   NFP Records for the fin pairs (NFP $\geq$ 0),
   NSH records for the propeller shaft brackets,
   1 record for the rudder or rudders.
   That is, NFS = NFP + NSH + 1 Records (m1) are required.
2. For NFP fin pairs, coordinates are input for the port foil; it is assumed that a counterpart exists on the starboard side. Note that y and z coordinates apply to the foil root. The z coordinate is input as height above baseline. Foil inputs are illustrated in Figure 13.
3. A shaft bracket consists of 2 arms, each considered as a foil. For NSH = 1, input data only for the port arm of the bracket. For NSH = 2 or 4, input data for both arms of each port bracket, with the record for the outboard arm preceding that for the inboard arm. For NSH = 3, input data for the

outboard arm of the port bracket, followed by the inboard arm of the port bracket, followed by the port arm of the centre bracket.

Record (m2), Nominal Fin Angle and Flap Fractional Fin-Lift Increase

Read only if NFP > 0 in Record (m).

BETNOM, FLINC (2 reals)

BETNOM Nominal fin angle (degrees). BETNOM is used in estimating fin-fin and fin-bilge keel interference effects.

FLINC Fractional increase in fin lift due to flap deflection (for an unflapped fin FLINC = 0.0).

Record (m3), Rudder Roll Gains, Natural Frequency and Damping

QFDDR, QFDR, QFR, WR, ZETR, WLR, WHR (7 reals)

QFDDR Rudder roll acceleration gain (sec^2).

QFDR Rudder roll velocity gain (sec).

QFR Rudder roll gain.

WR Rudder control system natural frequency (rad/sec).

ZETR Rudder control system damping ratio.

WLR Low frequency cut-off for rudder roll stabilizer (rad/sec).

WHR High frequency cut-off for rudder roll stabilizer (rad/sec).

Note: If modelling of the steering system is not required, all parameters in Record (m3) should be set to zero.

Record (m4), Rudder Yaw Gains

QYDDR, QYDR, QYR (3 reals)

QYDDR Rudder yaw acceleration gain (sec^2).

QYDR Rudder yaw velocity gain (sec).

QYR Rudder yaw gain.

Note: If modelling of the steering system is not required, all parameters in Record (m4) should be set to zero.

Record (m5), Fin Roll Gains, Natural Frequency and Damping

Read only if NFP > 0 in Record (m).

QFDD, QFD, QF, WF, ZETF, WHF (6 reals)

QFDD Fin roll acceleration gain (sec^2).

QFD Fin roll velocity gain (sec).

QF Fin roll gain.

WF Fin control system natural frequency (rad/sec).

ZETF Fin control system damping ratio.

WHF High frequency cut-off for fin roll stabilizer (rad/sec).

Record (m6), Anti-Rolling Tank Data

Read only if NFP < 0 in Record (m).

TL, WT, W1T, ZT, ALFAT, HT, RTBL, XTST, RHOT, VS, VSO, WB (12 reals)

TL Longitudinal length of anti-rolling tank (ft or m).

WT Width of tank connecting duct (ft or m).

W1T Bottom width of tank vertical leg (ft or m).

ZT Average fluid depth in tank vertical leg (ft or m).

ALFAT Inclination of outside wall of tank vertical leg (degrees).

HT Height of tank connecting duct (ft or m).

RTBL Height above baseline of bottom of tank connecting duct (ft or m).

XTST Station number of tank location ($0 \leq XTST \leq NSTOT - 1$).

RHOT Specific gravity of tank fluid.

VS Tank valve resistance coefficient for frequencies $\omega > WB$.

VSO Tank valve resistance coefficient for $\omega = 0$. Set to 0.0 for a pure passive tank.

WB Break frequency (rad/sec). Set to 0.0 for a pure passive tank.

Notes:

1. Tank inputs are illustrated in Figure 14.
2. Tank valve resistance coefficient may be assigned any value between zero and infinity. The value used in computations is:

$$\lambda_s = \begin{cases} VS & \text{for } \omega \geq WB \\ VSO + (VS - VSO)\omega/WB & \text{for } \omega < WB \end{cases}$$

This scheme enables modelling of a controllable passive tank in which damping is effectively increased at low frequencies in order to avoid amplification of roll by the stabilizer in quartering seas. For example, satisfactory simulation of a controllable passive tank installed on a destroyer has been achieved by setting VS = 15, WB = 0.9 RNF, and VSO = 25 VS.

Record (n), Control Integer for Next Case
NEXT (1 integer)

NEXT Control integer to end program.

NEXT > 0 Input data for another case follows immediately (i.e. Records (a)-(n)).

NEXT ≤ 0 Terminate program following all calculations for the preceding data.

A.2 Changes to Input Records Since SHIPMO Version 4

The following is a list of changes made to input records between SHIPMO versions 4 and 5. Note that SHIPMO5 is capable of reading older input files without modification, as described in Section 4.3

Hydrodynamic End-Effect Control Integer IEND in Record (d)

Control integer IEND is included in Record (d).

Principal Sea Directions PSDIR(I) in Record (e1) for Short-Crested Seas

If responses in short-crested seas are requested (NSD = 0 or ANGLE > 0 in Record (e)), attention must be given to PSDIR(I). If all seakeeping positions are on the centreline (YPOS(I) = 0 for all I in Record (j1)), PSDIR must cover the range 0-180 degrees. If any seakeeping position is off centreline, PSDIR must cover the range from 0 to a minimum of 315 degrees. PSDIR can be in ascending or descending order, with a maximum increment of 45 degrees between values. SHIPMO5 checks to see if these criteria are satisfied, and terminates execution if the input sea directions need to be modified.

Centre of Gravity Location KG in Record (h)

The height of the CG is given relative to the baseline.

Y Offset of Seakeeping Position YPOS(I) in Record (j1)

The y offset YPOS(I) for a seakeeping position is included in Record (j1).

Vertical Coordinate of Seakeeping Position ZPOS(I) in Record (j1)

The vertical coordinate ZPOS(I) is be given relative to the ship baseline.

Vertical Coordinate of Deck Edge DECKH(I) in Record (j1)

The vertical coordinate of the deck edge DECKH(I) is given relative to the ship baseline.

Motion-Induced Interruption Control Integer MII(I) in Record (j1)

Control integer MII(I) is included in Record (j1).

Height of Bottom of Anti-Roll Tank RTBL in Record (m6)

The height of the bottom of the tank connecting duct RTBL is given relative to the ship baseline.

Longitudinal Location of Anti-Roll Tank XTST in Record (m6)

The longitudinal location of the anti-roll tank is input as station number XTST.

A.3 Sample Input File

```
Record (a)   :  FRIGATE EXAMPLE                                         <----- Title
Record (b)   :  0 1 0 1    2 2 0          <----- Control integers
Record (c)   :  .2 2.0 0.1               <----- Wave frequencies
Record (d)   :  0 0.1 5.8 0.2  0   0   <----- Encounter frequencies, Method, IEND
Record (e)   :  7, 90.0   <----- Number of sea directions, ANGLE
Record (e1)  :  0 30 60 90 120 150 180.0  <----- Sea directions
Record (f)   :  1  <----- Number of seaways
Record (f2)  :  10.66, 10.0  <----- Significant wave height, period
Record (g)   :  18 18 1  <----- Ship speeds
Record (h)   :  356.0 18.09 2.09 0.0 0.0 0.35 0.25 0  <----- Basic ship data
Record (i)   :  21 20 1. 1.            <----- Number of stations, scaling factors
Record (i1)  :   1 12  1      <----- Station number 1 data
Record (i2a) :    0.0  0.46  1.19  1.82  2.33  2.57  2.84  3.50  4.50  6.55  9.25 12.79
Record (i2b) :    0.0  0.00  2.77  6.60  9.93 11.21 12.61 15.53 18.84 23.84 28.78 34.01
Record (i1)  :   2 12  1
Record (i2a) :    0.0  0.49  1.60  2.76  3.61  4.49  5.04  6.56  8.32 11.19 13.65 15.57
Record (i2b) :    0.0  0.0  1.44  3.62  5.96  8.70 10.56 15.05 19.40 25.42 29.81 32.65
Record (i1)  :   3 12  1
Record (i2a) :    0.0  0.49  3.07  4.55  5.77  6.90  8.24  9.58 11.19 13.40 15.19 17.16
Record (i2b) :    0.0  0.0  2.01  3.69  6.06  8.49 11.76 14.97 18.87 23.68 27.30 31.40
Record (i1)  :   4 12  1
Record (i2a) :    0.0  0.49  3.79  6.43  8.75 10.19 11.53 12.72 14.00 15.38 16.92 18.09
Record (i2b) :    0.0  0.0  1.54  3.86  7.13  9.97 12.77 15.58 18.86 22.32 26.88 30.34
Record (i1)  :   5 12  1
Record (i2a) :    0.0  0.55  4.59  8.68 11.01 12.75 14.52 16.01 16.37 17.33 17.92 18.93
Record (i2b) :    0.0  0.0  1.30  4.18  6.86  9.76 13.47 17.34 18.82 22.12 25.01 29.30
Record (i1)  :   6 12  1
Record (i2a) :    0.0  0.52  7.18 11.60 14.70 15.80 16.62 17.90 18.25 18.81 19.24 19.65
Record (i2b) :    0.0  0.0  1.93  4.94  8.78 10.59 12.55 16.66 18.65 21.67 25.21 28.14
Record (i1)  :   7 12  0
Record (i2a) :    0.0  0.52  8.78 12.59 15.29 17.10 18.14 19.11 19.64 20.06 20.22 20.27
Record (i2b) :    0.0  0.0  2.10  4.01  6.39  9.04 11.22 14.52 18.60 23.83 26.69 27.53
Record (i1)  :   8 12  0
Record (i2a) :    0.0  0.49  8.87 13.40 16.23 18.61 19.71 20.40 20.47 20.65 20.66 20.74
Record (i2b) :    0.0  0.0  1.91  3.46  5.27  8.46 11.66 15.12 18.49 22.64 25.47 27.16
Record (i1)  :   9 12  3
Record (i2a) :    0.0  0.49  8.90 14.66 17.43 19.36 20.39 20.84 20.99 20.94 20.92 20.94
Record (i2b) :    0.0  0.0  1.91  3.49  5.16  7.53 10.58 13.75 19.04 22.18 24.92 27.04
Record (i1)  :  10 12  3
Record (i2a) :    0.0  0.46 12.67 16.51 18.66 19.73 20.51 20.87 21.00 20.97 20.92 20.94
Record (i2b) :    0.0  0.0  2.65  4.16  5.98  7.69 10.03 12.98 16.12 20.72 24.06 26.50
Record (i1)  :  11 12  3
Record (i2a) :    0.0  0.43 12.67 16.39 18.53 19.54 20.36 20.77 20.97 20.94 20.92 20.94
Record (i2b) :    0.0  0.0  2.71  4.32  6.16  7.66 10.15 13.01 16.12 20.72 24.06 26.50
Record (i1)  :  12 12  3
Record (i2a) :    0.0  0.43  9.90 14.33 17.40 18.87 20.08 20.62 20.91 20.91 20.92 20.91
Record (i2b) :    0.0  0.0  2.14  3.65  5.66  7.28  9.90 12.95 16.12 20.72 24.06 26.5
Record (i1)  :  13 12  3
Record (i2a) :    0.0  0.43 11.53 14.72 16.69 18.74 19.68 20.41 20.81 20.85 20.86 20.85
Record (i2b) :    0.0  0.0  2.99  4.34  5.66  7.90  9.87 12.64 16.12 20.72 24.09 26.50
Record (i1)  :  14 12  3
Record (i2a) :    0.0  0.40  9.56 13.95 17.48 18.76 19.68 20.28 20.60 20.76 20.77 20.75
Record (i2b) :    0.22  0.22  2.82  4.74  7.34  9.05 11.14 13.63 16.12 20.72 24.03 26.50
Record (i1)  :  15 12  2
Record (i2a) :    0.0  0.40  8.36 14.56 16.95 18.51 19.39 20.02 20.26 20.48 20.46 20.45
Record (i2b) :    0.96  0.96  3.40  6.17  7.99 10.14 12.41 14.93 16.15 20.72 24.06 26.5
Record (i1)  :  16 12  2
Record (i2a) :    0.0  0.51  8.41 11.21 14.58 16.45 17.89 19.16 19.40 19.68 19.75 19.80
Record (i2b) :    2.70  2.70  4.93  5.97  7.66  9.26 11.35 15.27 16.08 20.71 24.05 26.5
Record (i1)  :  17 12  2
Record (i2a) :    0.00  0.46  7.66 12.55 14.85 16.35 17.02 17.41 18.10 18.60 18.77 18.84
Record (i2b) :    5.41  5.41  7.06  8.55  9.99 11.56 12.86 13.86 16.08 20.64 24.02 26.5
```

```
Record (i1)    :   18 12  2
Record (i2a)   :     0.0  0.38 10.20 12.26 13.55 14.62 15.38 15.78 16.32 17.00 17.38 17.64
Record (i2b)   :     8.48  8.48 10.06 10.73 11.48 12.42 13.63 14.69 16.10 20.66 24.01 26.5
Record (i1)    :   19 12  0
Record (i2a)   :     0.0  6.56  8.93 10.22 11.33 11.97 12.61 13.25 13.82 14.88 15.59 16.10
Record (i2b)   :    10.66 10.75 10.89 11.37 12.02 12.65 13.59 14.83 16.08 20.65 24.00 26.5
Record (i1)    :   20 12  0
Record (i2a)   :     0.03  4.74  6.25  7.23  8.15  8.80  9.65 10.17 10.78 12.20 13.29 14.13
Record (i2b)   :    10.66 10.81 10.97 11.32 11.86 12.45 13.63 14.75 16.06 20.63 24.02 26.5
Record (i4)    :   1                        <----- Control integer for load waterline
Record (i6)    :   13.69  0.5       <----- Draft at midships, trim by stern
Record (j)     :   1  20.0 .01       <----- Number of positions
Record (j1)    :   3.0  0.0  29.27  33.29  1  1   <----- Position for seakeeping calculation
Record (j2)    :   34.5  .5  0.                   <----- Data for slamming calculation
Record (j4)    :   0.25  0.17   60.0              <----- Tipping coefficient, time of operation
Record (k)     :   1                        <----- Number of bilge keel pairs
Record (k1)    :   10 14                    <----- First and last stations spanned by bilge keel
Record (k2)    :   18.960 7.010 2.000 12.100 <----- Bilge keel offsets
Record (k2)    :   18.780 6.100 2.000 17.800
Record (k2)    :   18.470 6.000 2.000 17.800
Record (k2)    :   18.250 6.380 2.000 17.800
Record (k2)    :   18.210 7.130 2.000 21.900
Record (l)     :   17.87 3.900 60.000     <----- Skeg data
Record (m)     :   0 2      <----- Number of fin pairs, propeller shaft brackets
Record (m1)    :   19.30 10.200 10.500 7.400 2.625 2.625 0.000 79.000 1.000 <--- Outboard arm
Record (m1)    :   19.30 3.800 9.700 7.350 2.625 2.625 0.000 65.000 1.000   <--- Inboard arm
Record (m1)    :   19.16  6.500  5.850 9.920 7.5 6.017 0.0 1.0 1.000        <--- Rudder data
Record (m3)    :   0.000 0.000 0.000 0.000 0.000 0.000 0.000    <--- Rudder roll gains
Record (m4)    :   0.000 0.000 0.000       <--- Rudder yaw gains
Record (n)     :   0
```

A.4 Input Format for Hindcast Directional Spectrum

When a hindcast directional spectrum is selected by the user (ISPEC = 6 in Record (b)). spectral data is read from a formatted file specified in Record (f6). The contents of the file are as follows:

Record 1 - Labels for File Descriptors
Format (A89)

LABELS	Character*89	Labels for values on following line.

Record 2 - File Descriptors
Format (I2, I2, 1X, I2, I2, 1X, I6. 1X, F8.3, F8.2, 2X, F6.2, 2X, F6.2, 2X, F6.3, 4F8.2)

IYR	Integer	Last two digits of year.
IMON	Integer	Month.
IDAY	Integer	Day of month.
IHR	Integer	Hour (GMT).
IGRP	Integer	Grid point number.
LAT	Real	Latitude (degrees).
LONG	Real	Longitude (degrees).
WSPD	Real	Wind speed (m/s).
WDIR	Real	Wind direction (degrees) from which wind is approaching.
USHEAR	Real	Wind shear velocity (m/s).
HS	Real	Significant wave height (m).
TS	Real	Significant wave period (m).
VMD	Real	Mean direction (to) of energy propagation (degrees).
TP	Real	Peak wave period (s).

Record 3 - Blank

Record 4 - Wave Frequencies
Format (A9, 3X, 15F8.5)

LABEL	Character*9	Line label "FREQUENCY".
FREQ(15)	Real	Array of circular frequencies for energy components (Hz).

Record 5 - Direction Label
Format (A9)

LABEL	Character*9	Line label "DIRECTION".

Remaining Records - Directional Spectral Energies (Maximum 24 Records)
Format (F7.1, 4X, 15F8.5)

DIR	Real	Compass direction (to) for energy components on line (degrees).
E(15)	Real	Total energy for given direction and frequency (m^2).

Note: Each spectral energy record covers a directional range of 15 degrees; however, no records are given for directions with very low energies.

A.5 Sample Input Hindcast Directional Spectrum

YM DH	GP	LAT	LONG	M/SEC	FROM	U*	HSIG	TSIG	VMD	TPEAK
8403.1100.	1106.	46.250	-48.75	22.37	228.03	1.068	7.63	10.09	42.16	13.05

FREQUENCY	0.04047	0.04440	0.05000	0.05556	0.06111	0.06670	0.07222	0.08056	0.09167	0.10278	0.11667	0.13333	0.15833	0.20833	0.30833
DIRECTION															
7.5	0.00000	0.00001	0.00003	0.00008	0.00031	0.00158	0.00811	0.05596	0.05837	0.04476	0.04073	0.02203	0.01928	0.01060	0.00629
22.5	0.00001	0.00006	0.00023	0.00089	0.00466	0.02797	0.05777	0.11450	0.07939	0.04986	0.04366	0.02221	0.01972	0.01195	0.00766
37.5	0.00002	0.00025	0.00120	0.00856	0.04990	0.09320	0.09619	0.15493	0.09624	0.05620	0.04526	0.02335	0.02095	0.01334	0.00854
52.5	0.00016	0.00142	0.00888	0.05356	0.10226	0.11426	0.11143	0.17233	0.10130	0.05803	0.04656	0.02396	0.02159	0.01394	0.00870
67.5	0.00041	0.00221	0.00810	0.03030	0.05973	0.06665	0.07662	0.14635	0.09045	0.05231	0.04349	0.02267	0.02050	0.01332	0.00809
82.5	0.00029	0.00091	0.00190	0.00574	0.01212	0.01479	0.02060	0.07937	0.05429	0.03432	0.03395	0.01663	0.01774	0.01168	0.00688
97.5	0.00006	0.00016	0.00034	0.00076	0.00185	0.00119	0.00148	0.01006	0.00648	0.00404	0.00788	0.00565	0.00882	0.00911	0.00540
112.5	0.00001	0.00003	0.00002	0.00002	0.00002	0.00003	0.00006	0.00039	0.00035	0.00035	0.00078	0.00063	0.00208	0.00451	0.00403
127.5	0.00000	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00001	0.00001	0.00002	0.00003	0.00004	0.00017	0.00037	0.00315
247.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00014	0.00011	0.00001	0.00000	0.00000	0.00000
262.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00027	0.00149	0.00108	0.00015	0.00000	0.00000	0.00000
277.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00006	0.00133	0.00439	0.00258	0.00048	0.00002	0.00000	0.00000
292.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00011	0.00117	0.00518	0.00430	0.00102	0.00008	0.00000	0.00000
307.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00013	0.00121	0.00649	0.00820	0.00292	0.00075	0.00001
322.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00017	0.00192	0.01268	0.02098	0.01694	0.01644	0.00831	0.00299
337.5	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00005	0.00052	0.00626	0.01868	0.02533	0.01903	0.01764	0.00848	0.00360
352.5	0.00000	0.00000	0.00001	0.00001	0.00004	0.00014	0.00067	0.01539	0.03537	0.03097	0.03378	0.02158	0.01889	0.00958	0.00481

A.6 Input Format for User Input Directional Spectrum

When a user input directional spectrum is selected (ISPEC = 7 in Record (b)), spectral data is read from a formatted file specified in Record (f7). The contents of the file are as follows:

Record 1 - Spectrum Title
SPTITLE (Columns 1-80)

SPTITLE Alphanumeric title (maximum of 80 characters) which is written on output.

Record 2 - Spectrum Parameters
ISEAIN, ITOP, HS, TP (2 integers, 2 reals)

ISEAIN System of units for significant wave height and spectral density:

ISEAIN = 0 British units

ISEAIN = 1 Metric units

The units of wave height (ft or m) and spectral density ($ft^2/(rad/s)/rad$ or $m^2/(rad/s)/rad$) may be chosen independently of the value IN specified in Record (b) of the main input file.

ITOP Number of frequencies for spectral density input (maximum 30).

HS Significant wave height (ft or m).

TP Characteristic wave period (ft or m).

Record 3 - Spectrum Frequencies
AW(I) (ITOP reals)

AW(I) Frequencies for spectral energy densities (rad/s).

Records 4-39 - Sea Direction and Spectral Energy Densities
DIR, (ENSP(IDIR, J), J = 1, ITOP) (36 records, 1+ITOP reals/record)

DIR Sea direction (from) for spectral energy densities (degrees).

ENSP(IDIR, J) Spectral energy densities ($m^2/(rad/s)/rad$ or $ft^2/(rad/s)/rad$).

Note: Sea directions DIR must begin at 0 degrees and increase in 10 degree increments to a maximum of 350 degrees. The program will terminate if this convention is not followed.

B Program Output

This Appendix gives a detailed description of line printer and post-processor output from SHIPMO.

B.1 Printer Output Description

Appendix B.3 contains the program output which results from the sample input of Appendix A.3. Since the output is self-explanatory, only a brief description is required.

The first eight pages are devoted to listing input data and results of hydrostatic calculations. This is necessary for checking purposes. On the first page, information is given about Records (a) to (h). If a measured or hindcast spectrum was used, the spectral data would have been listed on page two of the output. Pages two and three list hull offsets and the fourth and fifth pages are line printer plots of the body plan. These provide a valuable visual check of the offset data. The program always outputs the offsets up to the load waterline, even when the input file contains offsets up to the deck edge. The output offsets are also adjusted to account for any trim. Note that the offset data are not output when ISAVE = 2. The sixth page contains hydrostatic quantities computed from the offsets, as well as data on specified positions for seakeeping calculations. On the seventh page, bilge keel, skeg, fin, A-bracket, rudder, and control inputs are listed. Anti-rolling tank inputs would also be listed on this page, if applicable, as well as certain tank parameters such as tank natural frequency. Also on this page are the roll radius of gyration and roll natural frequency (rad/s).

The next fourteen pages contain the motions and roll damping coefficients in regular waves at the seven sea directions specified. To minimize unnecessary output, regular wave responses for headings greater than 180 degrees are not output because of symmetry. For each heading, the motion responses are followed by roll damping coefficients if they have been requested. On the output, W is wave frequency and WE is frequency of encounter, both in rad/s. W.L./L is wavelength divided by ship length. Phases are expressed relative to wave elevation at the CG: e.g., sway phase = 90 degrees means sway achieves its maximum positive value at a point on the wave cycle 90 degrees before wave elevation at the CG achieves its maximum positive value. Note that SHIPMO phase angles can be converted to the ITTC convention [7] as follows:

ITTC		SHIPMO
Surge phase	=	Surge phase + 180 degrees
Sway phase	=	Sway phase
Heave phase	=	Heave phase
Roll phase	=	Roll phase + 180 degrees
Pitch phase	=	Pitch phase
Yaw phase	=	Yaw phase

ROLANG is the roll angle at which the roll damping coefficients were computed. If the program is computing the motions in irregular waves, then for each sea state and heading, ROLANG is the average roll amplitude, which equals 1.25 times the RMS roll. If only regular wave computations are being performed, then for each heading and wave frequency, ROLANG equals the wave slope (specified in Record (f1)) times the roll response per unit wave slope.

The translational and angular amplitudes of the motions are non-dimensionalized by wave amplitude and maximum wave slope, respectively.

The output of motions and roll damping coefficients in regular waves is optional, and may be deleted by setting IRESP = 0 in Record (b). This option would be exercised when only motions in irregular seas are of interest, as is often the case. Note further that although frequency response is computed for each seaway specified in Records (f2), (f4), or (f5), frequency response is output only for the first seaway when NSEA > 1. This eliminates unnecessary output, since frequency responses computed for different seaways would have noticeable differences only in roll, where peak response is inversely proportional to roll damping which is directly proportional to root mean square (RMS) roll. The reader is reminded that in the case of a measured seaway spectrum (ISPEC = 2), hindcast spectrum (ISPEC = 6), or user input directional spectrum (ISPEC = 7), NSEA must equal 1.

The remainder of the output presents the results of irregular sea calculations. In addition to the RMS responses, zero-crossing periods are now output. If a non-directional spectrum has been selected (quadratic regression, Bretschneider, JONSWAP, measured point, or Ochi and Hubble 6 parameter, ISPEC = 0-4), seakeeping data are given for unidirectional and short-crested seas at each of the principal sea directions (headings) specified in Record (e1). If symmetry exists (i.e. a point lies on the ship centreline), output is not given for headings greater than 180 degrees. For the directional spectra (10 parameter, hindcast, or user input directional, ISPEC = 5, 6 or 7), the motion responses are not symmetric even for positions on the centreline, and seakeeping data are given only for short-crested seas for default ship compass headings of 0-360 degrees.

The output RMS values begin with the ship translational and rotational motions at the CG, as well as RMS rudder, fin, or tank angles due to stabilizer activity. Next, the results of seakeeping calculations for the positions specified in Record (j1) are listed. Vertical, lateral, and longitudinal motions are given for all seakeeping positions. Motion-induced interruption (or sliding) statistics and forces relative to local ship axes are given for positions with MII(I) = 1. Finally deck wetness and slamming computations (ISLAM(I) $\geq$ 1) or propeller emergence computations (ISLAM(I) < 0), and or deck wetness calculations (freeboard > 0) may be given for seakeeping positions. Slamming computations are performed as described in Reference 20. The output is as follows:

- RMS relative vertical displacement and velocity.
- vibration ride quality index (see Reference 19).
- probability of deck wetness at any instant.
- expected number of deck wetnesses per hour.
- probability of keel emergence at any instant.

- expected keel emergences per hour,
- most probable maximum slam pressure during THR hours,
- slam pressure with SLAMEX probability of exceedence during THR hours,
- most probable maximum slam force/unit length during THR hours,
- slam force/unit length with SLAMEX probability of exceedence during THR hours.

The following output values are given for propeller emergence computations:

- RMS relative vertical displacement and velocity,
- probability of propeller emergence at any instant,
- expected number of propeller emergences per hour.

In the regular sea case, the responses are output in nondimensional form, but in the irregular sea case most of the output is dimensional. Hence, when running SHIPMO5 with model data, care must be taken to interpret the irregular sea results correctly.

B.2 Post-Processor Output

In program SHIPMO, frequency responses and RMS motions may be stored on disk for post-processing. This is accomplished by specifying IPPF = 1 in Record (b), and giving the disk file a name in Record (b1). Data will then be written into a sequential, unformatted binary file.

Contents of the post-processing file are given below. Variables with numbers in parentheses beside them (e.g. TITLE(10)) represent arrays.

Record 1 - General Specifications from Program Input

TITLE(10)	Char*10	Alphanumeric title with time and date appended.
NSP	Integer	Number of ship speeds.
UKMIN	Real	Lowest ship speed (knots).
DUK	Real	Ship speed increment (knots).
NSEA	Integer	Number of seaways.
ISEA(10)	Integer	NATO sea-states for seaways.
HSW(10)	Real	Significant wave heights (ft or m).
TSW(10)	Real	Representative periods (s).
NSD	Integer	Number of sea directions.

PSDIR(36)	Real	Sea directions.
ANGLE	Real	Spreading angle (degrees).
ISPEC	Integer	Spectrum control integer.

Record 2 - General Specifications (Continued)

NW	Integer	Number of wave frequencies.
WMIN	Real	Lowest wave frequency (rad/s).
DW	Real	Wave frequency increment (rad/s).
IOUT	Integer	Output units control integer (IOUT = 0 for FPS, IOUT = 1 for SI). IOUT determines units of all post-processing output.

Record 3 - Data for Seakeeping Positions

NPOS	Integer	Number of positions.
XST(10)	Real	Position station numbers.
YPOS(10)	Real	Position y-coordinates (ft or m).
ZPOS(10)	Real	Position z-coordinates relative to CG (ft or m).
DRST(10)	Real	Draft at positions (ft or m).
FORM(10)	Real	Position slamming form factors. The slamming pressure at a position is obtained as follows: $$P(I) = 0.5\rho \times FORM(I) \times V_r^2$$ where V_r is the relative velocity (ft/s or m/s) between the water surface and the keel.
FREEB(10)	Real	Freeboard without correction for dynamic waterline (ft or m).
SLFF(10)	Real	Dimensional position slamming force factor (ft or m). The sectional force (i.e. force/unit length) is obtained from the slamming pressure as follows: $$F(I) = SLFF(I) \times P(I)$$
SLAMEX	Real	Exceedence probability for extreme slamming pressures and forces.
THR	Real	Time period for slamming (hours).

The remaining records are repeated for each of the NSP ship speeds.

Next NSD Records - Regular Response Data for NSD Sea Directions

AMPHAS(40, 8)	Complex	Regular wave response of CG. The real component is the dimensionless amplitude (normalized by wave amplitude or maximum wave slope) and the imaginary component is the phase angle (degrees). Array components are AMPHAS(IW, JMODE), where IW is the frequency and JMODE is the mode. The 8 modes are as follows:

1. Surge
2. Sway
3. Heave
4. Roll
5. Pitch
6. Yaw
7. Rudder
8. Stabilizer

Note: If there is more than 1 seaway, AMPHAS is written only for the first seaway.

Next NSEA Records - RMS Motions for NSEA Seaways

RMS(36,8,3)	Real	RMS motions at the CG. Array components are RMS(JSD, KMODE, LDVA), JSD is the sea direction, KMODE is the mode as given for AMPHAS, and LDVA is the type of motion. The 3 motion types are as follows:

1. Displacement (ft or m)
2. Velocity (ft/s or m/s)
3. Acceleration (g's)

RMSX(36,10,22)	Real	RMS motions at seakeeping positions. Array components are RMS(JSD, KPOS, LMODE), where KPOS is the seakeeping position and LMODE is the mode. The modes for seakeeping positions are as follows:

1. Vertical displacement (ft or m)
2. Vertical velocity (ft/s or m/s)
3. Vertical acceleration (g's)
4. Relative displacement (ft or m)
5. Relative velocity (ft/s or m/s)
6. Vibration ride quality index
7. Lateral displacement (ft or m)
8. Lateral velocity (ft/s or m/s)
9. Lateral acceleration (g's)
10. Lateral force estimator (g's)
11. Port tipping estimator function (g's)
12. Time derivative of 11 (g's/s)
13. Starboard tipping estimator function (g's)

14. Time derivative of 13 (g's/s)
15. Longitudinal displacement (ft or m)
16. Longitudinal velocity (ft/s or m/s)
17. Longitudinal acceleration (g's)
18. Longitudinal force estimator (g's)
19. Aft tipping estimator function (g's)
20. Time derivative of 19 (g's/s)
21. Forward tipping estimator function (g's)
22. Time derivative of 21 (g's/s)

Note: For unidirectional spectra (ISPEC = 0-4), RMS and RMSX are only written for long-crested seas. For the 10 parameter and hindcast spectra (ISPEC = 5,6), RMS and RMSX are written only for directional seas, with PSDIR(JSD) being the ship compass heading for RMS and RMSX.

In summary, the post-processing file contains a total of 3 + NSP×(NSD + NSEA) records.

B.3 Sample Printer Output

```
 SHIPMO5 --- SHIP MOTIONS IN OBLIQUE SEAS      PROGRAM VERSION 5.0, DECEMBER 1991

FRIGATE EXAMPLE                                        <----- Title      10:43:14   3-APR-92


DIMENSIONS REQUESTED :  INPUT - FPS    OUTPUT - SI
MOTIONS COMPUTED FOR : < SALT> WATER
     SEAWAY SPECTRUM : BRETSCHNEIDER

DYNAMIC SWELL-UP CORRECTION : NO
    WAVE PROFILE CORRECTION : YES

 REGULAR RESPONSE PRINT-OUT : YES
     ROLL DAMPING PRINT-OUT : YES
  OUTPUT DATA SAVED ON FILE : NO

WAVE FREQUENCY RANGE FOR REGULAR RESPONSE :  0.200 TO 2.000  IN STEPS OF 0.100

    HULL SECTIONAL ADDED MASS & DAMPING COMPUTATIONS
ENCOUNTER FREQUENCY RANGE :  0.100 TO 5.900  IN STEPS OF 0.200
              METHOD USED : CLOSE-FIT
END EFFECT HYDRODYNAMIC TERMS USED :  NO

    7 SEA DIRECTIONS FOR MOTION CALCULATIONS

     0.0      30.0      60.0      90.0     120.0     150.0     180.0

SPREADING ANGLE FOR SHORT-CRESTED SEA SPECTRUM = 90.00

     NO OF SEAWAYS CONSIDERED = 1

 SIG WAVE HT    WAVE PERIOD    SEA STATE
     FT            SEC
  10.6600        10.0000          5

 1 SHIP SPEEDS : 18.00 TO 18.00  IN STEPS OF 1.00 KNOTS


             SHIP LENGTH = 356.00 FT
 HT OF CG ABOVE BASELINE =  18.09 FT
          METACENTRIC HT =   2.09 FT

         ROLL NATURAL FREQUENCY = 0.000
 ROLL RADIUS OF GYRATION / BEAM = 0.350
YAW RADIUS OF GYRATION / LENGTH = 0.250
                            IRG = 0

               MIDSHIPS DRAFT = 13.690 FT
            TRIM BY THE STERN =  0.500 FT
```

SHIP OFFSETS (IN FT) AT 21 STATIONS
SCALING FACTORS : Y => 1.000 Z => 1.000
TRIMMED OFFSETS FROM MIDSHIPS DRAFT AND TRIM

STATION 0 X = 0.00 IEDDY = 0

Y-	0.000
Z-	13.690

STATION 1 X = 17.80 IEDDY = 1

Y-	0.000	0.460	1.190	1.820	2.330	2.570	2.840	3.033
Z-	0.225	0.225	2.995	6.825	10.155	11.435	12.835	13.690

STATION 2 X = 35.60 IEDDY = 1

Y-	0.000	0.490	1.600	2.760	3.610	4.490	5.040	6.032
Z-	0.200	0.200	1.640	3.820	6.160	8.900	10.760	13.690

STATION 3 X = 53.40 IEDDY = 1

Y-	0.000	0.490	3.070	4.550	5.770	6.900	8.240	8.973
Z-	0.175	0.175	2.185	3.865	6.235	8.665	11.935	13.690

STATION 4 X = 71.20 IEDDY = 1

Y-	0.000	0.490	3.790	6.430	8.750	10.190	11.530	11.856
Z-	0.150	0.150	1.690	4.010	7.280	10.120	12.920	13.690

STATION 5 X = 89.00 IEDDY = 1

Y-	0.000	0.550	4.590	8.680	11.010	12.750	14.520	14.557
Z-	0.125	0.125	1.425	4.305	6.985	9.885	13.595	13.690

STATION 6 X = 106.80 IEDDY = 1

Y-	0.000	0.520	7.180	11.600	14.700	15.800	16.620	16.944
Z-	0.100	0.100	2.030	5.040	8.880	10.690	12.650	13.690

STATION 7 X = 124.60 IEDDY = 0

Y-	0.000	0.520	8.780	12.590	15.290	17.100	18.140	18.844
Z-	0.075	0.075	2.175	4.085	6.465	9.115	11.295	13.690

STATION 8 X = 142.40 IEDDY = 0

Y-	0.000	0.490	8.870	13.400	16.230	18.610	19.710	20.105
Z-	0.050	0.050	1.960	3.510	5.320	8.510	11.710	13.690

STATION 9 X = 160.20 IEDDY = 3

Y-	0.000	0.490	8.900	14.660	17.430	19.360	20.390	20.828
Z-	0.025	0.025	1.935	3.515	5.185	7.555	10.605	13.690

STATION 10 X = 178.00 IEDDY = 3

Y-	0.000	0.460	12.670	16.510	18.660	19.730	20.510	20.899
Z-	0.000	0.000	2.650	4.160	5.980	7.690	10.030	13.690

SHIP OFFSETS (IN FT) AT 21 STATIONS
SCALING FACTORS : Y => 1.000 Z => 1.000
TRIMMED OFFSETS FROM MIDSHIPS DRAFT AND TRIM

STATION 11 X = 195.80 IEDDY = 3

Y-	0.000	0.430	12.670	16.390	18.530	19.540	20.360	20.815
Z-	-0.025	-0.025	2.685	4.295	6.135	7.635	10.125	13.690

STATION 12 X = 213.60 IEDDY = 3

Y-	0.000	0.430	9.900	14.330	17.400	18.870	20.080	20.692
Z-	-0.050	-0.050	2.090	3.600	5.610	7.230	9.850	13.690

STATION 13 X = 231.40 IEDDY = 3

Y-	0.000	0.430	11.530	14.720	16.690	18.740	19.680	20.539
Z-	-0.075	-0.075	2.915	4.265	5.585	7.825	9.795	13.690

STATION 14 X = 249.20 IEDDY = 3

Y-	0.000	0.400	9.560	13.950	17.480	18.760	19.680	20.301
Z-	0.120	0.120	2.720	4.640	7.240	8.950	11.040	13.690

STATION 15 X = 267.00 IEDDY = 2

Y-	0.000	0.400	8.360	14.560	16.950	18.510	19.390	19.741
Z-	0.835	0.835	3.275	6.045	7.865	10.015	12.285	13.690

STATION 16 X = 284.80 IEDDY = 2

Y-	0.000	0.510	8.410	11.210	14.580	16.450	17.890	18.697
Z-	2.550	2.550	4.780	5.820	7.510	9.110	11.200	13.690

STATION 17 X = 302.60 IEDDY = 2

Y-	0.000	0.460	7.660	12.550	14.850	16.350	17.020	17.412
Z-	5.235	5.235	6.885	8.375	9.815	11.385	12.685	13.690

STATION 18 X = 320.40 IEDDY = 2

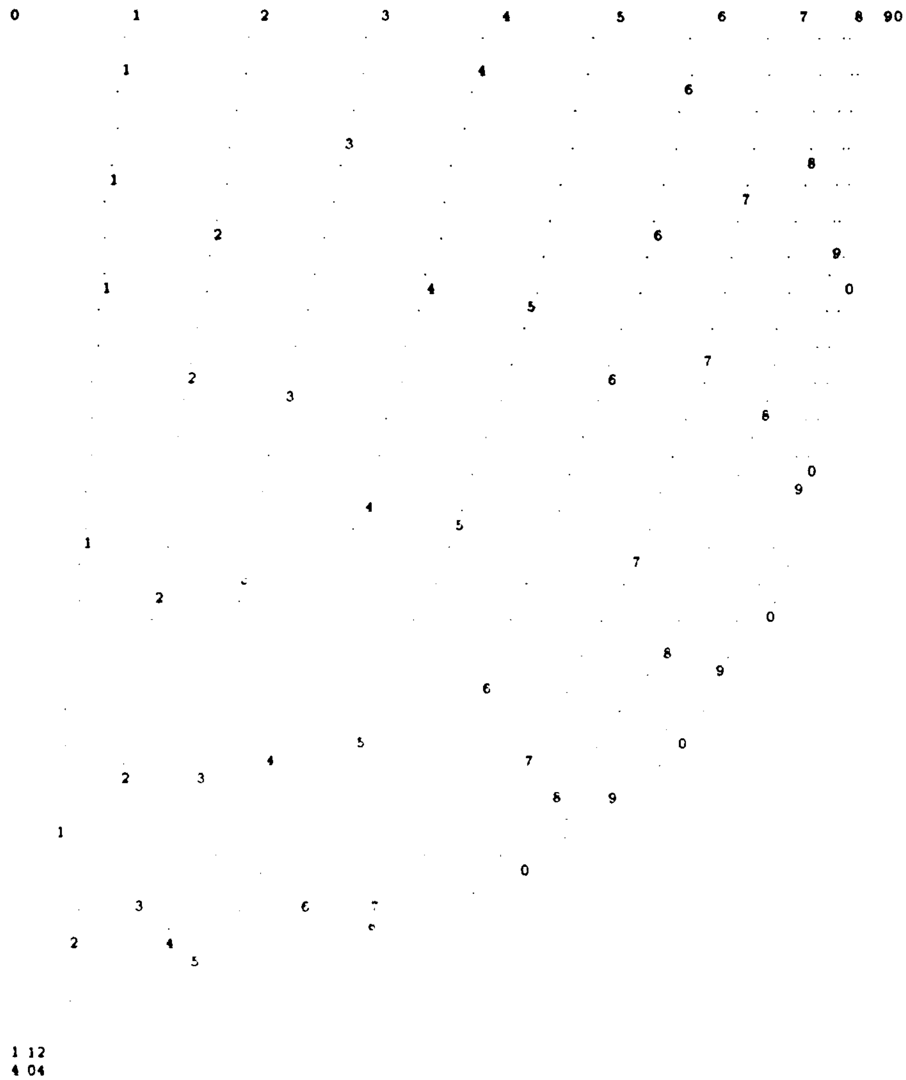
Y-	0.000	0.380	10.200	12.260	13.550	14.620	15.380	15.478
Z-	8.280	8.280	9.860	10.530	11.280	12.220	13.430	13.690

STATION 19 X = 338.20 IEDDY = 0

Y-	0.000	6.560	8.930	10.220	11.330	11.970	12.610	12.778
Z-	10.435	10.525	10.665	11.145	11.795	12.425	13.365	13.690

STATION 20 X = 356.00 IEDDY = 0

Y-	0.030	4.740	6.250	7.230	8.150	8.800	9.650	9.794
Z-	10.410	10.560	10.720	11.070	11.600	12.200	13.380	13.690



GENERAL HULL PARAMETERS

LENGTH = 108.51 M METACENTRIC HT = 0.64 M (COMPUTED VALUE = 0.80 M)

BEAM = 12.74 M KG = 5.51 M (CG 1.34 M ABOVE W.L.)

DRAFT = 4.17 M XCG = 56.60 M FROM F.P. (ST 10.432) (COMPUTED)

DISPLACEMENT = 2931.92 TONNES BLOCK = 0.4953

STATION	X(CG) M	BEAM M	DRAFT M	AREA COEF	HULL FORM
0	56.60	0.000	0.000	0.000	
1	51.17	1.849	4.104	0.601	OFFSETS
2	45.75	3.677	4.112	0.615	OFFSETS
3	40.32	5.470	4.119	0.641	OFFSETS
4	34.90	7.227	4.127	0.669	OFFSETS
5	29.47	8.874	4.135	0.696	OFFSETS
6	24.05	10.329	4.142	0.720	OFFSETS
7	18.62	11.487	4.150	0.744	OFFSETS
8	13.19	12.256	4.157	0.771	OFFSETS
9	7.77	12.697	4.165	0.785	OFFSETS
10	2.34	12.740	4.173	0.803	OFFSETS
11	-3.08	12.689	4.180	0.797	OFFSETS
12	-8.51	12.614	4.188	0.780	OFFSETS
13	-13.93	12.521	4.196	0.759	OFFSETS
14	-19.36	12.375	4.136	0.735	OFFSETS
15	-24.78	12.034	3.918	0.715	OFFSETS
16	-30.21	11.398	3.395	0.717	OFFSETS
17	-35.63	10.614	2.577	0.718	OFFSETS
18	[illegible]1.06	9.435	1.649	0.741	OFFSETS
19	-46.49	7.789	0.992	0.865	OFFSETS
20	-51.91	5.970	1.000	0.836	OFFSETS

1 SPECIFIED POSITIONS FOR SEAKEEPING CALCULATIONS
ZPOS AND DECK HEIGHT GIVEN RELATIVE TO BASELINE

STATION	YPOS FT	ZPOS FT	DRAFT FT	DECK HEIGHT FT	DEADRISE ANGLE-DEG	HWFB FT	FORM FACTOR	LAT TIP COEFF	LONG TIP COEFF	TIME FOR OPERATION (S)
3.00	0.00	29.27	13.51	33.29	34.50	0.50	4.78	0.25	0.17	60.00

SLAMMING TIME PERIOD = 20.00 HOURS
EXCEEDENCE PROBABILITY = 0.010

************ BILGE KEEL DATA (IN FT) ************

NO OF BILGE KEEL PAIRS = 1

BK	STATION	YBK	ZBK	BREADTH	LENGTH
1	10	18.960	7.010	2.000	12.100
1	11	18.780	6.100	2.000	17.800
1	12	18.470	6.000	2.000	17.800
1	13	18.250	6.380	2.000	17.800
1	14	18.210	7.130	2.000	21.900

****************** SKEG DATA (IN FT) ******************

STATION = 17.87   BREADTH = 3.900   LENGTH = 60.000

********************************* FOIL DATA (FPS UNITS) *********************************

NO OF FIN PAIRS = 0
NO OF SHAFT BRACKET PAIRS = 2

FOIL	STATION	YF	ZF	SPAN	RT CHORD	TP CHORD	CLA	DI ANGLE	VEFF
1 = BRACKET	19.30	10.200	10.500	7.400	2.625	2.625	0.000	79.000	1.000
2 = BRACKET	19.30	3.800	9.700	7.350	2.625	2.625	0.000	65.000	1.000
3 = RUDDER	19.16	6.500	5.850	9.920	7.500	6.017	0.000	90.000	1.000

NO OF RUDDERS = 2 / IN PROP SLIPSTREAM : YES

CONTROLS	ACCEL GAIN	VEL GAIN	GAIN	NATURAL FREQ	DAMPING RATIO	HIFREQ CUTOFF	LOFREQ CUTOFF
RUDDER ROLL :	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
RUDDER YAW :	0.000	0.000	0.000				

ROLL RADIUS OF GYRATION = 4.04 M
RRG/BEAM = 0.3169
RRG/R = 0.4793   WHERE R=SQRT((B/2)**2+T**2)
ROLL NATURAL FREQUENCY = 0.5605

C.G. FREQUENCY RESPONSE IN REGULAR WAVES

SEA DIRECTION = 0.0 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

VISCOUS ROLL DAMPING FOR :

SEA STATE = 5 , SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

TRANSLATION & ANGULAR AMPLITUDES NON-DIMENSIONALIZED BY WAVE AMP & WAVE SLOPE RESPECTIVELY

		SURGE		SWAY		HEAVE		ROLL		PITCH		YAW		W.L./L
W	WE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	
0.200	0.162	1.414	-90.62	0.000	0.00	0.993	-0.14	0.000	0.00	1.076	88.57	0.000	0.00	14.196
0.300	0.215	1.764	-86.53	0.000	0.00	0.964	-0.16	0.000	0.00	0.997	90.55	0.000	0.00	6.309
0.400	0.249	2.232	-84.89	0.000	0.00	0.892	-0.03	0.000	0.00	0.905	93.09	0.000	0.00	3.549
0.500	0.264	2.805	-83.59	0.000	0.00	0.761	0.28	0.000	0.00	0.784	96.24	0.000	0.00	2.271
0.600	0.260	3.439	-82.04	0.000	0.00	0.566	0.73	0.000	0.00	0.623	100.07	0.000	0.00	1.577
0.700	0.237	4.008	-79.70	0.000	0.00	0.329	0.76	0.000	0.00	0.433	104.67	0.000	0.00	1.159
0.800	0.195	4.213	-75.28	0.000	0.00	0.102	-5.26	0.000	0.00	0.243	110.51	0.000	0.00	0.887
0.900	0.135	3.119	-60.40	0.000	0.00	0.057	-149.17	0.000	0.00	0.092	121.22	0.000	0.00	0.701
1.000	0.055	3.954	90.94	0.000	0.00	0.087	-153.69	0.000	0.00	0.021	-157.77	0.000	0.00	0.568
1.100	0.043	6.481	105.38	0.000	0.00	0.032	-127.10	0.000	0.00	0.031	-88.77	0.000	0.00	0.469
1.200	0.161	1.081	119.13	0.000	0.00	0.034	-6.08	0.000	0.00	0.014	-34.04	0.000	0.00	0.394
1.300	0.297	0.274	-133.39	0.000	0.00	0.024	15.49	0.000	0.00	0.014	74.46	0.000	0.00	0.336
1.400	0.452	0.114	-153.57	0.000	0.00	0.018	163.01	0.000	0.00	0.008	135.24	0.000	0.00	0.290
1.500	0.626	0.034	142.95	0.000	0.00	0.019	178.75	0.000	0.00	0.008	-109.26	0.000	0.00	0.252
1.600	0.819	0.020	-42.92	0.000	0.00	0.012	-38.37	0.000	0.00	0.006	-37.93	0.000	0.00	0.222
1.700	1.031	0.015	-47.79	0.000	0.00	0.007	-58.72	0.000	0.00	0.007	60.05	0.000	0.00	0.196
1.800	1.262	0.013	117.73	0.000	0.00	0.009	108.77	0.000	0.00	0.004	143.68	0.000	0.00	0.175
1.900	1.511	0.003	-173.41	0.000	0.00	0.014	-95.16	0.000	0.00	0.004	-164.37	0.000	0.00	0.157
2.000	1.780	0.007	-62.37	0.000	0.00	0.041	-10.50	0.000	0.00	0.003	-45.46	0.000	0.00	0.142

ROLL DAMPING COEFFICIENTS IN REGULAR WAVES

DAMPING COEFFICIENTS NON-DIMENSIONALIZED BY MULTIPLYING BY RNF/(2.*C44)
(i.e. roll damping given as fraction of critical)

ADDED ROLL INERTIA NON-DIMENSIONALIZED BY ROLL INERTIA

RNF = 0.561 RAD/SEC   C44 = 0.1832E+08 N-M   I44 = 0.4778E+08 KG-M**2

ROLANG IS THE ROLL ANGLE IN DEGREES AT WHICH THE ROLL DAMPING HAS BEEN COMPUTED

SEA DIRECTION = 0.0 DEG

U = 18.0 KNOTS   FROUDE NO = 0.284

SEA STATE = 5, SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

WW	WE	ROLANG	B44TOTAL	BLIFT	BWAVE	BBK	BEDDY	BVHULL	BVAPPEND	A44TOTAL
0.200	0.162	1.3	0.137	0.119	0.000	0.018	0.000	0.001	0.000	0.205
0.300	0.215	1.3	0.140	0.119	0.000	0.020	0.000	0.001	0.000	0.206
0.400	0.249	1.3	0.141	0.119	0.000	0.022	0.000	0.001	0.000	0.207
0.500	0.264	1.3	0.141	0.119	0.000	0.022	0.000	0.001	0.000	0.207
0.600	0.260	1.3	0.141	0.119	0.000	0.022	0.000	0.001	0.000	0.207
0.700	0.237	1.3	0.140	0.119	0.000	0.021	0.000	0.001	0.000	0.206
0.800	0.195	1.3	0.139	0.119	0.000	0.019	0.000	0.001	0.000	0.206
0.900	0.135	1.3	0.136	0.119	0.000	0.017	0.000	0.001	0.000	0.205
1.000	0.055	1.3	0.134	0.119	0.000	0.015	0.000	0.001	0.000	0.204
1.100	0.043	1.3	0.134	0.119	0.000	0.015	0.000	0.001	0.000	0.204
1.200	0.161	1.3	0.137	0.119	0.000	0.018	0.000	0.001	0.000	0.205
1.300	0.297	1.3	0.143	0.119	0.000	0.023	0.000	0.001	0.000	0.208
1.400	0.452	1.3	0.148	0.119	0.001	0.028	0.000	0.001	0.000	0.214
1.500	0.626	1.3	0.156	0.118	0.006	0.032	0.000	0.001	0.000	0.223
1.600	0.819	1.3	0.174	0.117	0.020	0.035	0.000	0.001	0.000	0.228
1.700	1.031	1.3	0.204	0.116	0.047	0.039	0.000	0.001	0.001	0.217
1.800	1.262	1.3	0.232	0.115	0.072	0.042	0.000	0.001	0.001	0.186
1.900	1.511	1.3	0.238	0.114	0.077	0.046	0.000	0.001	0.001	0.154
2.000	1.780	1.3	0.230	0.112	0.066	0.049	0.000	0.001	0.002	0.139

C.G. FREQUENCY RESPONSE IN REGULAR WAVES

SEA DIRECTION = 30.0 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

VISCOUS ROLL DAMPING FOR :

SEA STATE = 5 , SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

TRANSLATION & ANGULAR AMPLITUDES NON-DIMENSIONALIZED BY WAVE AMP & WAVE SLOPE RESPECTIVELY

		SURGE		SWAY		HEAVE		ROLL		PITCH		YAW		W.L./L
W	WE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	
0.200	0.167	1.161	-92.67	0.565	98.07	0.995	-0.13	0.858	61.88	0.944	88.30	0.517	-12.46	14.196
0.300	0.226	1.388	-87.79	0.614	101.34	0.972	-0.13	0.944	57.22	0.870	90.36	0.561	-7.52	6.309
0.400	0.269	1.684	-85.99	0.638	105.93	0.913	0.05	1.091	56.02	0.795	92.92	0.627	-3.36	3.549
0.500	0.295	2.025	-84.81	0.607	114.41	0.806	0.47	1.322	56.81	0.705	96.08	0.703	0.64	2.271
0.600	0.305	2.371	-83.62	0.502	133.27	0.645	1.17	1.593	59.29	0.589	99.93	0.772	5.25	1.577
0.700	0.299	2.637	-82.09	0.414	-178.19	0.436	2.28	1.767	64.46	0.442	104.89	0.802	11.84	1.159
0.800	0.276	2.673	-79.71	0.700	-118.49	0.213	3.15	1.682	73.16	0.285	111.19	0.760	22.33	0.887
0.900	0.237	2.217	-74.77	1.326	-83.03	0.029	-11.27	1.262	87.19	0.143	120.55	0.625	41.17	0.701
1.000	0.182	0.814	-45.23	2.118	-43.40	0.074	-158.53	0.627	114.21	0.044	144.44	0.447	82.03	0.568
1.100	0.110	4.354	95.46	4.885	32.63	0.074	-150.55	0.250	-138.64	0.020	-121.51	0.536	158.38	0.469
1.200	0.022	6.179	106.72	6.058	96.64	0.022	-97.35	0.389	-72.15	0.023	-82.05	0.519	-146.21	0.394
1.300	0.083	2.292	131.46	5.040	151.93	0.038	1.71	0.316	-39.64	0.009	-30.06	0.333	-87.05	0.336
1.400	0.204	0.592	-130.84	0.688	-158.69	0.024	25.90	0.145	-17.93	0.012	74.92	0.118	-20.13	0.290
1.500	0.341	0.206	-149.80	0.325	-115.55	0.017	160.73	0.169	40.64	0.006	132.13	0.048	11.71	0.252
1.600	0.495	0.058	149.78	0.048	-101.46	0.019	-172.12	0.159	30.43	0.006	-110.28	0.009	144.13	0.222
1.70[illegible]	0.66[illegible]	0.019	-31.55	0.046	56.79	0.010	-45.80	0.108	79.80	0.005	-43.88	0.007	169.20	0.196
1.800	0.851	0.028	-49.74	0.019	100.13	0.012	-21.65	0.042	83.70	0.005	58.44	0.005	-34.65	0.175
1.900	1.054	0.009	112.26	0.026	-134.51	0.008	120.98	0.024	-148.71	0.004	132.39	0.003	-37.06	0.157
2.000	1.273	0.011	129.93	0.005	-72.26	0.007	21.90	0.006	-128.86	0.004	-143.43	0.003	131.12	0.142

ROLL DAMPING COEFFICIENTS IN REGULAR WAVES

DAMPING COEFFICIENTS NON-DIMENSIONALIZED BY MULTIPLYING BY RNF/(2.*C44)
(i.e. roll damping given as fraction of critical)

ADDED ROLL INERTIA NON-DIMENSIONALIZED BY ROLL INERTIA

RNF = 0.561 RAD/SEC C44 = 0.1832E+08 N-M I44 = 0.4778E+08 KG-M**2

ROLANG IS THE ROLL ANGLE IN DEGREES AT WHICH THE ROLL DAMPING HAS BEEN COMPUTED

SEA DIRECTION = 30.0 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

SEA STATE = 5, SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

WW	WE	ROLANG	B44TOTAL	BLIFT	BWAVE	BBK	BEDDY	BVHULL	BVAPPEND	A44TOTAL
0.200	0.167	4.4	0.150	0.119	0.000	0.031	0.000	0.001	0.000	0.184
0.300	0.226	4.4	0.155	0.119	0.000	0.035	0.000	0.001	0.000	0.184
0.400	0.269	4.4	0.157	0.119	0.000	0.038	0.000	0.001	0.000	0.184
0.500	0.295	4.4	0.159	0.119	0.000	0.039	0.000	0.001	0.000	0.184
0.600	0.305	4.4	0.159	0.119	0.000	0.040	0.000	0.001	0.000	0.184
0.700	0.299	4.4	0.159	0.119	0.000	0.039	0.000	0.001	0.000	0.184
0.800	0.276	4.4	0.158	0.119	0.000	0.038	0.000	0.001	0.000	0.184
0.900	0.237	4.4	0.155	0.119	0.000	0.036	0.000	0.001	0.000	0.184
1.000	0.182	4.4	0.152	0.119	0.000	0.032	0.000	0.001	0.000	0.184
1.100	0.110	4.4	0.146	0.119	0.000	0.026	0.000	0.001	0.000	0.184
1.200	0.022	4.4	0.145	0.119	0.000	0.025	0.000	0.001	0.000	0.184
1.300	0.083	4.4	0.145	0.119	0.000	0.025	0.000	0.001	0.000	0.184
1.400	0.204	4.4	0.153	0.119	0.000	0.034	0.000	0.001	0.000	0.184
1.500	0.341	4.4	0.161	0.119	0.000	0.042	0.000	0.001	0.000	0.184
1.600	0.495	4.4	0.170	0.118	0.002	0.049	0.000	0.001	0.000	0.184
1.700	0.665	4.4	0.182	0.118	0.008	0.055	0.000	0.001	0.001	0.184
1.800	0.851	4.4	0.204	0.117	0.023	0.061	0.000	0.001	0.001	0.184
1.900	1.054	4.4	0.236	0.116	0.050	0.067	0.000	0.001	0.002	0.184
2.000	1.273	4.4	0.265	0.115	0.073	0.072	0.001	0.001	0.003	0.184

C.G. FREQUENCY RESPONSE IN REGULAR WAVES

SEA DIRECTION = 60.0 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

VISCOUS ROLL DAMPING FOR :

SEA STATE = 5 , SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

TRANSLATION & ANGULAR AMPLITUDES NON-DIMENSIONALIZED BY WAVE AMP & WAVE SLOPE RESPECTIVELY

		SURGE		SWAY		HEAVE		ROLL		PITCH		YAW		W.L./L
W	WE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	
0.200	0.181	0.603	-102.37	0.923	93.91	0.999	-0.13	1.244	69.99	0.580	87.03	0.455	-12.69	14.196
0.300	0.257	0.634	-93.14	0.963	95.23	0.988	-0.06	1.359	64.79	0.510	89.70	0.480	-8.10	6.309
0.400	0.324	0.696	-89.86	0.989	96.84	0.962	0.09	1.536	59.43	0.482	91.86	0.509	-6.71	3.549
0.500	0.382	0.764	-88.28	0.992	99.23	0.920	0.29	1.801	51.98	0.463	93.87	0.537	-6.70	2.271
0.600	0.430	0.829	-87.28	0.968	102.95	0.848	0.87	2.151	41.26	0.431	96.86	0.554	-7.46	1.577
0.700	0.468	0.880	-86.48	0.918	108.13	0.745	2.01	2.510	27.57	0.387	100.82	0.550	-8.73	1.159
0.800	0.498	0.905	-85.69	0.831	114.83	0.610	4.00	2.783	13.66	0.332	105.92	0.517	-9.65	0.887
0.900	0.517	0.885	-84.79	0.697	124.48	0.454	7.26	2.936	2.30	0.268	112.37	0.461	-9.86	0.701
1.000	0.528	0.804	-83.62	0.539	140.96	0.291	12.98	2.939	-5.11	0.199	120.98	0.383	-9.44	0.568
1.100	0.528	0.649	-81.82	0.420	169.26	0.142	24.87	2.741	-8.11	0.131	133.03	0.287	-8.41	0.469
1.200	0.520	0.423	-78.11	0.392	-155.74	0.040	71.06	2.266	-6.62	0.074	151.54	0.180	-5.78	0.394
1.300	0.502	0.153	-61.96	0.385	-125.36	0.047	173.62	1.485	-1.35	0.036	-174.95	0.073	6.09	0.336
1.400	0.474	0.151	71.99	0.289	-87.11	0.055	-152.29	0.557	-0.36	0.019	-115.21	0.038	133.65	0.290
1.500	0.437	0.348	88.01	0.279	2.05	0.041	-108.32	0.290	-109.82	0.016	-59.69	0.102	166.87	0.252
1.600	0.390	0.398	94.79	0.607	55.12	0.039	-46.09	0.536	-112.45	0.012	-14.84	0.115	-174.92	0.222
1.700	0.335	0.257	113.03	0.783	85.61	0.040	-4.59	0.382	-95.24	0.008	35.50	0.070	-142.20	0.196
1.800	0.269	0.258	-152.17	0.524	141.84	0.025	34.57	0.101	-59.51	0.005	83.32	0.053	-36.71	0.175
1.900	0.194	0.788	-132.07	1.298	-104.43	0.015	120.48	0.099	98.71	0.003	119.73	0.108	18.87	0.157
2.000	0.110	1.855	-145.07	4.551	-45.29	0.021	-178.82	0.120	150.14	0.001	138.29	0.131	73.07	0.142

ROLL DAMPING COEFFICIENTS IN REGULAR WAVES

DAMPING COEFFICIENTS NON-DIMENSIONALIZED BY MULTIPLYING BY RNF/(2.*C44)
(i.e. roll damping given as fraction of critical)

ADDED ROLL INERTIA NON-DIMENSIONALIZED BY ROLL INERTIA

RNF = 0.561 RAD/SEC   C44 = 0.1832E+08 N-M   I44 = 0.4778E+08 KG-M**2

ROLANG IS THE ROLL ANGLE IN DEGREES AT WHICH THE ROLL DAMPING HAS BEEN COMPUTED

SEA DIRECTION = 60.0 DEG

U = 18.0 KNOTS   FROUDE NO = 0.284

SEA STATE = 5, SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

WW	WE	ROLANG	B44TOTAL	BLIFT	BWAVE	BBK	BEDDY	BVHULL	BVAPPEND	A44TOTAL
0.200	0.181	10.2	0.165	0.119	0.000	0.045	0.000	0.001	0.000	0.204
0.300	0.257	10.2	0.172	0.119	0.000	0.052	0.000	0.001	0.000	0.204
0.400	0.324	10.2	0.178	0.119	0.000	0.058	0.000	0.001	0.000	0.204
0.500	0.382	10.2	0.182	0.119	0.000	0.062	0.000	0.001	0.000	0.204
0.600	0.430	10.2	0.186	0.119	0.001	0.065	0.000	0.001	0.000	0.204
0.700	0.468	10.2	0.189	0.119	0.001	0.067	0.000	0.001	0.001	0.204
0.800	0.498	10.2	0.191	0.118	0.002	0.069	0.000	0.001	0.001	0.204
0.900	0.517	10.2	0.193	0.118	0.002	0.070	0.000	0.001	0.001	0.204
1.000	0.528	10.2	0.193	0.118	0.002	0.071	0.000	0.001	0.001	0.204
1.100	0.528	10.2	0.193	0.118	0.003	0.071	0.000	0.001	0.001	0.204
1.200	0.520	10.2	0.193	0.118	0.002	0.070	0.000	0.001	0.001	0.204
1.300	0.502	10.2	0.191	0.118	0.002	0.069	0.000	0.001	0.001	0.204
1.400	0.474	10.2	0.189	0.118	0.001	0.068	0.000	0.001	0.001	0.204
1.500	0.437	10.2	0.186	0.119	0.001	0.065	0.000	0.001	0.000	0.204
1.600	0.390	10.2	0.183	0.119	0.000	0.062	0.000	0.001	0.000	0.204
1.700	0.335	10.2	0.178	0.119	0.000	0.058	0.000	0.001	0.000	0.204
1.800	0.269	10.2	0.173	0.119	0.000	0.053	0.000	0.001	0.000	0.204
1.900	0.194	10.2	0.166	0.119	0.000	0.047	0.000	0.001	0.000	0.204
2.000	0.110	10.2	0.157	0.119	0.000	0.037	0.000	0.001	0.000	0.204

C.G. FREQUENCY RESPONSE IN REGULAR WAVES

SEA DIRECTION = 90.0 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

VISCOUS ROLL DAMPING FOR :

SEA STATE = 5 , SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

TRANSLATION & ANGULAR AMPLITUDES NON-DIMENSIONALIZED BY WAVE AMP & WAVE SLOPE RESPECTIVELY

		SURGE		SWAY		HEAVE		ROLL		PITCH		YAW		W.L./L
W	WE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	
0.200	0.200	0.185	-171.45	0.975	89.63	1.002	-0.12	1.277	87.14	0.079	67.97	0.033	113.18	14.196
0.300	0.300	0.082	-174.28	0.951	90.26	0.998	0.00	1.593	78.59	0.003	7.88	0.046	33.80	6.309
0.400	0.400	0.046	-175.70	0.931	91.74	1.002	-0.08	2.103	61.30	0.009	60.01	0.060	-19.93	3.549
0.500	0.500	0.029	-176.56	0.943	92.84	1.001	-0.04	2.557	23.81	0.003	75.26	0.079	-80.86	2.271
0.600	0.600	0.020	-177.13	0.931	90.27	1.007	-0.20	1.766	-20.44	0.006	68.81	0.063	-141.98	1.577
0.700	0.700	0.015	-177.54	0.866	89.19	1.012	-0.36	0.958	-39.48	0.005	72.35	0.041	-175.48	1.159
0.800	0.800	0.011	-177.85	0.805	89.48	1.024	-0.90	0.573	-45.29	0.007	60.37	0.029	163.05	0.887
0.900	0.900	0.008	-178.09	0.739	90.15	1.040	-1.80	0.371	-45.38	0.007	49.89	0.023	149.88	0.701
1.000	1.000	0.007	-178.28	0.675	91.40	1.065	-3.69	0.260	-42.34	0.008	29.82	0.019	136.72	0.568
1.100	1.100	0.005	-178.43	0.609	93.12	1.092	-6.86	0.193	-38.32	0.007	1.75	0.016	126.38	0.469
1.200	1.200	0.004	-178.56	0.543	95.42	1.118	-12.43	0.149	-34.31	0.007	-47.92	0.014	116.64	0.394
1.300	1.300	0.003	-178.67	0.479	98.50	1.113	-21.18	0.118	-30.28	0.008	-121.00	0.012	108.42	0.336
1.400	1.400	0.003	-178.77	0.417	102.26	1.023	-33.75	0.094	-26.93	0.013	175.69	0.011	101.97	0.290
1.500	1.500	0.002	-178.85	0.360	107.04	0.815	-46.24	0.076	-23.46	0.016	126.40	0.010	97.00	0.252
1.600	1.600	0.002	-178.92	0.306	112.71	0.569	-53.26	0.060	-20.01	0.016	91.03	0.009	93.57	0.222
1.700	1.700	0.002	-178.98	0.258	119.62	0.401	-52.63	0.048	-16.33	0.013	64.85	0.008	91.26	0.196
1.800	1.800	0.001	-179.04	0.215	127.70	0.307	-50.10	0.038	-12.18	0.009	43.41	0.007	89.87	0.175
1.900	1.900	0.001	-179.09	0.178	137.24	0.225	-43.43	0.030	-7.68	0.008	31.14	0.007	89.22	0.157
2.000	2.000	0.001	-179.13	0.146	149.41	0.159	-30.79	0.023	-1.33	0.007	22.56	0.006	89.21	0.142

ROLL DAMPING COEFFICIENTS IN REGULAR WAVES

DAMPING COEFFICIENTS NON-DIMENSIONALIZED BY MULTIPLYING BY RNF/(2.*C44)
(i.e. roll damping given as fraction of critical)

ADDED ROLL INERTIA NON-DIMENSIONALIZED BY ROLL INERTIA

RNF = 0.561 RAD/SEC   C44 = 0.1832E+08 N-M   I44 = 0.4778E+08 KG-M**2

ROLANG IS THE ROLL ANGLE IN DEGREES AT WHICH THE ROLL DAMPING HAS BEEN COMPUTED

SEA DIRECTION = 90.0 DEG

U = 18.0 KNOTS   FROUDE NO = 0.284

SEA STATE = 5, SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

WW	WE	ROLANG	B44TOTAL	BLIFT	BWAVE	BBK	BEDDY	BVHULL	BVAPPEND	A44TOTAL
0.200	0.200	2.8	0.147	0.119	0.000	0.027	0.000	0.001	0.000	0.135
0.300	0.300	2.8	0.152	0.119	0.000	0.032	0.000	0.001	0.000	0.135
0.400	0.400	2.8	0.156	0.119	0.000	0.037	0.000	0.001	0.000	0.135
0.500	0.500	2.8	0.161	0.118	0.002	0.040	0.000	0.001	0.000	0.135
0.600	0.600	2.8	0.167	0.118	0.005	0.043	0.000	0.001	0.000	0.135
0.700	0.700	2.8	0.175	0.118	0.010	0.046	0.000	0.001	0.000	0.135
0.800	0.800	2.8	0.186	0.117	0.018	0.049	0.000	0.001	0.001	0.135
0.900	0.900	2.8	0.199	0.117	0.029	0.051	0.000	0.001	0.001	0.135
1.000	1.000	2.8	0.215	0.117	0.043	0.054	0.000	0.001	0.001	0.135
1.100	1.100	2.8	0.230	0.116	0.055	0.056	0.000	0.001	0.001	0.135
1.200	1.200	2.8	0.243	0.116	0.067	0.058	0.000	0.001	0.002	0.135
1.300	1.300	2.8	0.253	0.115	0.075	0.060	0.000	0.001	0.002	0.135
1.400	1.400	2.8	0.257	0.114	0.077	0.062	0.001	0.001	0.003	0.135
1.500	1.500	2.8	0.259	0.114	0.077	0.063	0.001	0.001	0.003	0.135
1.600	1.600	2.8	0.257	0.113	0.074	0.065	0.001	0.001	0.004	0.135
1.700	1.700	2.8	0.255	0.113	0.070	0.067	0.001	0.001	0.004	0.135
1.800	1.800	2.8	0.252	0.112	0.065	0.068	0.001	0.001	0.005	0.135
1.900	1.900	2.8	0.249	0.111	0.061	0.070	0.001	0.001	0.005	0.135
2.000	2.000	2.8	0.246	0.111	0.056	0.071	0.001	0.001	0.006	0.135

C.G. FREQUENCY RESPONSE IN REGULAR WAVES

SEA DIRECTION = 120.0 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

VISCOUS ROLL DAMPING FOR :

SEA STATE = 5 , SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

TRANSLATION & ANGULAR AMPLITUDES NON-DIMENSIONALIZED BY WAVE AMP & WAVE SLOPE RESPECTIVELY

		SURGE		SWAY		HEAVE		ROLL		PITCH		YAW		W.L./L
W	WE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	
0.200	0.219	0.415	119.61	0.767	86.49	1.003	0.12	1.174	101.83	0.441	-86.92	0.375	157.87	14.196
0.300	0.343	0.359	104.81	0.695	88.00	1.002	-0.10	1.772	78.72	0.499	-90.65	0.245	159.99	6.309
0.400	0.476	0.324	98.77	0.664	91.48	1.001	-0.16	2.907	26.27	0.513	-92.89	0.220	-167.21	3.549
0.500	0.618	0.292	95.56	0.624	87.29	0.999	-0.27	2.246	-55.06	0.526	-95.99	0.296	179.72	2.271
0.600	0.770	0.259	93.52	0.517	86.82	0.994	-0.40	1.241	-96.32	0.540	-100.82	0.229	172.48	1.577
0.700	0.932	0.223	92.00	0.416	88.00	0.997	-0.89	0.827	-118.72	0.550	-108.22	0.176	174.22	1.159
0.800	1.102	0.185	90.71	0.314	90.00	1.037	-3.91	0.597	-133.05	0.551	-120.01	0.136	178.42	0.887
0.900	1.283	0.144	89.46	0.213	94.11	1.108	-18.43	0.427	-143.09	0.522	-140.26	0.102	-176.13	0.701
1.000	1.472	0.103	88.05	0.126	102.70	0.812	-55.46	0.284	-150.44	0.372	-174.19	0.072	-169.01	0.568
1.100	1.672	0.065	86.11	0.063	120.02	0.219	-76.20	0.165	-156.18	0.149	159.46	0.047	-158.58	0.469
1.200	1.880	0.032	82.34	0.025	158.72	0.061	-63.23	0.072	-162.18	0.053	156.12	0.028	-142.34	0.394
1.300	2.098	0.009	66.20	0.016	-117.81	0.075	6.38	0.011	166.40	0.016	-167.75	0.015	-117.60	0.336
1.400	2.326	0.006	-67.62	0.021	-68.49	0.058	37.50	0.025	34.27	0.011	-99.70	0.008	-82.78	0.290
1.500	2.563	0.010	-83.41	0.022	-35.00	0.019	47.05	0.031	29.27	0.011	-83.90	0.004	-34.23	0.252
1.600	2.810	0.008	-89.78	0.016	-8.01	0.013	128.29	0.021	32.29	0.003	-63.88	0.003	24.06	0.222
1.700	3.065	0.003	-107.33	0.010	34.40	0.011	141.36	0.007	42.81	0.002	11.22	0.002	72.82	0.196
1.800	3.331	0.002	159.06	0.005	100.32	0.014	128.72	0.004	164.93	0.004	91.33	0.002	114.51	0.175
1.900	3.606	0.002	141.34	0.005	169.52	0.007	-97.67	0.005	-159.08	0.001	-139.06	0.001	162.69	0.157
2.000	3.890	0.002	160.77	0.002	-177.06	0.003	-122.02	0.003	-155.02	0.001	-174.11	0.001	-117.45	0.142

ROLL DAMPING COEFFICIENTS IN REGULAR WAVES

DAMPING COEFFICIENTS NON-DIMENSIONALIZED BY MULTIPLYING BY RNF/(2.*C44)
(i.e. roll damping given as fraction of critical)

ADDED ROLL INERTIA NON-DIMENSIONALIZED BY ROLL INERTIA

RNF = 0.561 RAD/SEC   C44 = 0.1832E+08 N-M   I44 = 0.4778E+08 KG-M**2

ROLANG IS THE ROLL ANGLE IN DEGREES AT WHICH THE ROLL DAMPING HAS BEEN COMPUTED

SEA DIRECTION = 120.0 DEG

U = 18.0 KNOTS   FROUDE NO = 0.284

SEA STATE = 5, SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

WW	WE	ROLANG	B44TOTAL	BLIFT	BWAVE	BBK	BEDDY	BVHULL	BVAPPEND	A44TOTAL
0.200	0.219	2.3	0.146	0.119	0.000	0.026	0.000	0.001	0.000	0.143
0.300	0.343	2.3	0.151	0.119	0.000	0.032	0.000	0.001	0.000	0.143
0.400	0.476	2.3	0.157	0.118	0.001	0.037	0.000	0.001	0.000	0.143
0.500	0.618	2.3	0.165	0.118	0.005	0.041	0.000	0.001	0.000	0.143
0.600	0.770	2.3	0.179	0.118	0.016	0.045	0.000	0.001	0.000	0.143
0.700	0.932	2.3	0.200	0.117	0.033	0.048	0.000	0.001	0.001	0.143
0.800	1.102	2.3	0.226	0.116	0.056	0.052	0.000	0.001	0.001	0.143
0.900	1.283	2.3	0.247	0.115	0.074	0.055	0.000	0.001	0.002	0.143
1.000	1.472	2.3	0.254	0.114	0.077	0.059	0.000	0.001	0.003	0.143
1.100	1.672	2.3	0.251	0.113	0.071	0.062	0.001	0.001	0.003	0.143
1.200	1.880	2.3	0.244	0.112	0.062	0.065	0.001	0.001	0.004	0.143
1.300	2.098	2.3	0.238	0.110	0.052	0.068	0.001	0.001	0.006	0.143
1.400	2.326	2.3	0.232	0.109	0.044	0.071	0.001	0.001	0.007	0.143
1.500	2.563	2.3	0.225	0.107	0.034	0.074	0.002	0.001	0.008	0.143
1.600	2.810	2.3	0.224	0.106	0.029	0.077	0.002	0.001	0.010	0.143
1.700	3.065	2.3	0.220	0.104	0.022	0.079	0.002	0.001	0.011	0.143
1.800	3.331	2.3	0.222	0.103	0.021	0.082	0.002	0.001	0.013	0.143
1.900	3.606	2.3	0.225	0.101	0.021	0.085	0.003	0.001	0.014	0.143
2.000	3.890	2.3	0.218	0.100	0.011	0.088	0.003	0.001	0.016	0.143

C.G. FREQUENCY RESPONSE IN REGULAR WAVES

SEA DIRECTION = 150.0 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

VISCOUS ROLL DAMPING FOR :

SEA STATE = 5 , SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

TRANSLATION & ANGULAR AMPLITUDES NON-DIMENSIONALIZED BY WAVE AMP & WAVE SLOPE RESPECTIVELY

		SURGE		SWAY		HEAVE		ROLL		PITCH		YAW		W.L./L
W	WE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	
0.200	0.233	0.604	110.21	0.412	84.73	1.002	-0.13	0.758	108.49	0.819	-88.96	0.333	157.93	14.196
0.300	0.374	0.512	99.95	0.353	87.73	0.996	-0.16	1.313	71.17	0.874	-92.00	0.207	163.43	6.309
0.400	0.531	0.435	95.60	0.342	90.29	0.978	-0.14	2.324	-15.79	0.897	-95.79	0.238	-169.53	3.549
0.500	0.705	0.357	93.06	0.267	85.80	0.943	0.15	1.298	-92.57	0.904	-101.75	0.201	173.04	2.271
0.600	0.895	0.277	91.17	0.192	87.72	0.897	0.83	0.776	-122.87	0.886	-111.25	0.135	175.75	1.577
0.700	1.101	0.195	89.39	0.119	90.62	0.879	-1.06	0.491	-139.11	0.815	-127.07	0.090	-175.76	1.159
0.800	1.324	0.117	87.22	0.055	98.49	0.814	-23.07	0.277	-149.63	0.634	-155.91	0.056	-163.76	0.887
0.900	1.563	0.051	83.10	0.014	130.65	0.193	-60.11	0.112	-157.80	0.238	159.25	0.030	-144.85	0.701
1.000	1.818	0.008	55.57	0.008	-96.79	0.082	33.41	0.007	165.34	0.029	147.70	0.015	-112.56	0.568
1.100	2.090	0.012	-79.33	0.013	-44.73	0.083	25.22	0.038	22.59	0.022	-86.87	0.007	-68.72	0.469
1.200	2.378	0.011	-89.27	0.012	-20.66	0.026	51.85	0.035	20.33	0.015	-70.06	0.003	8.17	0.394
1.300	2.683	0.003	-114.09	0.005	5.84	0.022	173.46	0.012	17.88	0.005	-151.79	0.003	79.29	0.336
1.400	3.004	0.003	139.79	0.003	179.35	0.005	179.89	0.005	-160.51	0.001	47.86	0.002	111.51	0.290
1.500	3.341	0.002	155.35	0.004	-170.78	0.011	32.57	0.006	-168.79	0.004	30.54	0.001	-87.26	0.252
1.600	3.695	0.001	-145.84	0.001	50.14	0.003	92.55	0.001	102.41	0.001	158.86	0.001	-63.67	0.222
1.700	4.065	0.001	34.56	0.002	36.62	0.006	86.89	0.002	41.35	0.002	72.78	0.000	86.49	0.196
1.800	4.451	0.001	52.15	0.000	19.24	0.002	-70.91	0.001	-116.87	0.000	-62.67	0.000	145.64	0.175
1.900	4.854	0.000	-110.28	0.001	-123.76	0.007	-138.54	0.001	-128.24	0.002	-148.57	0.000	-60.64	0.157
2.000	5.273	0.001	-128.25	0.001	61.80	0.001	-112.43	0.000	55.17	0.000	-119.87	0.000	-20.21	0.142

ROLL DAMPING COEFFICIENTS IN REGULAR WAVES

DAMPING COEFFICIENTS NON-DIMENSIONALIZED BY MULTIPLYING BY RNF/(2.*C44)
(i.e. roll damping given as fraction of critical)

ADDED ROLL INERTIA NON-DIMENSIONALIZED BY ROLL INERTIA

RNF = 0.561 RAD/SEC   C44 = 0.1832E+08 N-M   I44 = 0.4778E+08 KG-M**2

ROLANG IS THE ROLL ANGLE IN DEGREES AT WHICH THE ROLL DAMPING HAS BEEN COMPUTED

SEA DIRECTION = 150.0 DEG

U = 18.0 KNOTS   FROUDE NO = 0.284

SEA STATE = 5, SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

WW	WE	ROLANG	B44TOTAL	BLIFT	BWAVE	BBK	BEDDY	BVHULL	BVAPPEND	A44TOTAL
0.200	0.233	1.3	0.141	0.119	0.000	0.021	0.000	0.001	0.000	0.150
0.300	0.374	1.3	0.145	0.119	0.000	0.026	0.000	0.001	0.000	0.150
0.400	0.531	1.3	0.151	0.118	0.003	0.030	0.000	0.001	0.000	0.150
0.500	0.705	1.3	0.163	0.118	0.010	0.034	0.000	0.001	0.000	0.150
0.600	0.895	1.3	0.183	0.117	0.028	0.037	0.000	0.001	0.000	0.150
0.700	1.101	1.3	0.214	0.116	0.055	0.040	0.000	0.001	0.001	0.150
0.800	1.324	1.3	0.236	0.115	0.075	0.044	0.000	0.001	0.001	0.150
0.900	1.563	1.3	0.238	0.114	0.075	0.047	0.000	0.001	0.002	0.150
1.000	1.818	1.3	0.230	0.112	0.064	0.050	0.000	0.001	0.002	0.150
1.100	2.090	1.3	0.220	0.110	0.052	0.053	0.001	0.001	0.003	0.150
1.200	2.378	1.3	0.211	0.108	0.042	0.056	0.001	0.001	0.004	0.150
1.300	2.683	1.3	0.202	0.106	0.030	0.059	0.001	0.001	0.005	0.150
1.400	3.004	1.3	0.198	0.104	0.024	0.062	0.001	0.001	0.006	0.150
1.500	3.341	1.3	0.197	0.103	0.021	0.064	0.001	0.001	0.007	0.150
1.600	3.695	1.3	0.199	0.101	0.020	0.067	0.002	0.001	0.008	0.150
1.700	4.065	1.3	0.193	0.099	0.012	0.070	0.002	0.001	0.009	0.150
1.800	4.451	1.3	0.190	0.097	0.006	0.072	0.002	0.001	0.011	0.150
1.900	4.854	1.3	0.193	0.096	0.006	0.075	0.002	0.001	0.012	0.150
2.000	5.273	1.3	0.197	0.094	0.008	0.078	0.003	0.001	0.013	0.150

C.G. FREQUENCY RESPONSE IN REGULAR WAVES

SEA DIRECTION = 180.0 DEG

U = 18.0 KNOTS   FROUDE NO = 0.284

VISCOUS ROLL DAMPING FOR :

SEA STATE = 5 , SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

TRANSLATION & ANGULAR AMPLITUDES NON-DIMENSIONALIZED BY WAVE AMP & WAVE SLOPE RESPECTIVELY

		SURGE		SWAY		HEAVE		ROLL		PITCH		YAW		W.L./L
W	WE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE	
0.200	0.238	0.664	108.32	0.000	0.00	1.001	-0.13	0.000	0.00	0.958	-89.37	0.000	0.00	14.196
0.300	0.385	0.553	98.95	0.000	0.00	0.992	-0.17	0.000	0.00	1.012	-92.51	0.000	0.00	6.309
0.400	0.551	0.458	94.89	0.000	0.00	0.966	-0.11	0.000	0.00	1.034	-96.92	0.000	0.00	3.549
0.500	0.736	0.362	92.43	0.000	0.00	0.915	0.45	0.000	0.00	1.031	-104.06	0.000	0.00	2.271
0.600	0.940	0.264	90.46	0.000	0.00	0.853	1.55	0.000	0.00	0.980	-115.70	0.000	0.00	1.577
0.700	1.163	0.168	88.41	0.000	0.00	0.823	-3.00	0.000	0.00	0.841	-135.80	0.000	0.00	1.159
0.800	1.405	0.082	85.26	0.000	0.00	0.559	-38.25	0.000	0.00	0.518	-174.17	0.000	0.00	0.887
0.900	1.665	0.021	74.02	0.000	0.00	0.100	25.57	0.000	0.00	0.087	142.37	0.000	0.00	0.701
1.000	1.945	0.011	-73.33	0.000	0.00	0.102	31.17	0.000	0.00	0.019	-77.75	0.000	0.00	0.568
1.100	2.243	0.013	-87.89	0.000	0.00	0.041	34.45	0.000	0.00	0.027	-72.24	0.000	0.00	0.469
1.200	2.561	0.004	-107.87	0.000	0.00	0.013	164.28	0.000	0.00	0.006	-110.56	0.000	0.00	0.394
1.300	2.897	0.003	139.76	0.000	0.00	0.005	165.79	0.000	0.00	0.002	77.24	0.000	0.00	0.336
1.400	3.252	0.002	157.90	0.000	0.00	0.020	31.28	0.000	0.00	0.009	25.43	0.000	0.00	0.290
1.500	3.626	0.001	-139.73	0.000	0.00	0.003	90.29	0.000	0.00	0.001	149.06	0.000	0.00	0.252
1.600	4.019	0.001	45.45	0.000	0.00	0.005	74.07	0.000	0.00	0.002	57.80	0.000	0.00	0.222
1.700	4.431	0.001	49.85	0.000	0.00	0.002	-95.52	0.000	0.00	0.001	-98.89	0.000	0.00	0.196
1.800	4.862	0.001	-116.01	0.000	0.00	0.007	-169.42	0.000	0.00	0.002	-173.77	0.000	0.00	0.175
1.900	5.311	0.000	174.87	0.000	0.00	0.001	-169.48	0.000	0.00	0.000	-161.75	0.000	0.00	0.157
2.000	5.780	0.001	63.63	0.000	0.00	0.001	16.30	0.000	0.00	0.000	10.97	0.000	0.00	0.142

ROLL DAMPING COEFFICIENTS IN REGULAR WAVES

DAMPING COEFFICIENTS NON-DIMENSIONALIZED BY MULTIPLYING BY RNF/(2.*C44)
(i.e. roll damping given as fraction of critical)

ADDED ROLL INERTIA NON-DIMENSIONALIZED BY ROLL INERTIA

RNF = 0.561 RAD/SEC   C44 = 0.1832E+08 N-M   I44 = 0.4778E+08 KG-M**2

ROLANG IS THE ROLL ANGLE IN DEGREES AT WHICH THE ROLL DAMPING HAS BEEN COMPUTED

SEA DIRECTION = 180.0 DEG

U = 18.0 KNOTS   FROUDE NO = 0.284

SEA STATE = 5, SIG WAVE HT = 3.249 M , WAVE PERIOD = 10.000 SEC , SPECTRUM = BRETSCHNEIDER

WW	WE	ROLANG	B44TOTAL	BLIFT	BWAVE	BBK	BEDDY	BVHULL	BVAPPEND	A44TOTAL
0.200	0.238	1.3	0.140	0.119	0.000	0.021	0.000	0.001	0.000	0.206
0.300	0.385	1.3	0.145	0.119	0.000	0.026	0.000	0.001	0.000	0.212
0.400	0.551	1.3	0.152	0.118	0.003	0.030	0.000	0.001	0.000	0.220
0.500	0.736	1.3	0.165	0.118	0.013	0.034	0.000	0.001	0.000	0.227
0.600	0.940	1.3	0.190	0.117	0.035	0.037	0.000	0.001	0.000	0.224
0.700	1.163	1.3	0.221	0.116	0.063	0.041	0.000	0.001	0.001	0.200
0.800	1.405	1.3	0.238	0.114	0.077	0.044	0.000	0.001	0.001	0.166
0.900	1.665	1.3	0.235	0.113	0.071	0.048	0.000	0.001	0.002	0.144
1.000	1.945	1.3	0.224	0.111	0.059	0.051	0.000	0.001	0.003	0.136
1.100	2.243	1.3	0.215	0.109	0.047	0.054	0.001	0.001	0.003	0.134
1.200	2.561	1.3	0.204	0.107	0.034	0.057	0.001	0.001	0.004	0.136
1.300	2.897	1.3	0.200	0.105	0.028	0.060	0.001	0.001	0.005	0.139
1.400	3.252	1.3	0.197	0.103	0.022	0.063	0.001	0.001	0.007	0.142
1.500	3.626	1.3	0.198	0.101	0.021	0.066	0.001	0.001	0.008	0.146
1.600	4.019	1.3	0.192	0.099	0.013	0.069	0.002	0.001	0.009	0.145
1.700	4.431	1.3	0.188	0.097	0.005	0.071	0.002	0.001	0.010	0.145
1.800	4.862	1.3	0.191	0.096	0.006	0.074	0.002	0.001	0.012	0.148
1.900	5.311	1.3	0.195	0.094	0.008	0.077	0.002	0.001	0.013	0.150
2.000	5.780	1.3	0.194	0.092	0.003	0.080	0.003	0.001	0.015	0.151

RMS MOTIONS IN UNIDIRECTIONAL SEAS

U = 18.0 KNOTS FROUDE NO = 0.284

SEA STATE = 5 SIG WAVE HT = 3.2492 M WAVE PERIOD = 10.0000 SEC SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

MOTIONS AT SHIP CG

HEADING	SURGE	SWAY	TO	SWAY ACC	HEAVE	TO	HEAVE ACC	ROLL	TO	PITCH	TO	YAW	TO	RUDDER	FIN/TANK
DEG	M	M	SEC	G	M	SEC	G	DEG	SEC	DEG	SEC	DEG	SEC	DEG	DEG
0.0	2.954	0.00	0.0	0.000	0.33	24.4	0.002	0.00	0.0	0.81	25.7	0.00	0.0	0.000	0.000
30.0	2.107	1.46	48.9	0.004	0.38	21.0	0.003	3.56	22.9	0.82	21.4	1.93	26.2	0.000	0.000
60.0	0.657	0.70	14.4	0.014	0.55	14.1	0.011	8.19	12.4	0.82	13.1	1.30	12.9	0.000	0.000
90.0	0.013	0.66	8.6	0.042	0.82	7.7	0.066	2.22	9.4	0.04	4.3	0.10	7.5	0.000	0.000
120.0	0.168	0.33	7.5	0.025	0.75	6.4	0.084	1.87	6.8	1.27	5.5	0.37	6.1	0.000	0.000
150.0	0.167	0.11	7.2	0.010	0.60	6.1	0.070	1.03	6.4	1.42	5.6	0.18	6.1	0.000	0.000
180.0	0.158	0.00	0.0	0.000	0.54	6.1	0.065	0.00	0.0	1.40	5.6	0.00	0.0	0.000	0.000

STATION = 3.00 Y = 0.00 M Z = 3.46 M (referenced to CG)

MOTIONS AT STATION

HEADING	**********VERTICAL****************				********LATERAL*********			******LONGITUDINAL******		
	DISP	TO	VEL	ACC	DISP	TO	ACC	DISP	TO	ACC
DEG	M	SEC	M /SEC	G	M	SEC	G	M	SEC	G
0.0	0.700	25.4	0.173	0.005	0.000	0.0	0.000	2.912	31.0	0.014
30.0	0.734	21.2	0.217	0.007	1.454	36.6	0.007	2.066	25.8	0.015
60.0	0.846	13.5	0.394	0.019	0.543	14.9	0.011	0.611	13.5	0.014
90.0	0.817	7.7	0.669	0.067	0.722	8.2	0.050	0.013	9.6	0.001
120.0	1.351	5.7	1.486	0.183	0.488	7.3	0.042	0.127	6.9	0.013
150.0	1.392	5.7	1.544	0.187	0.192	7.0	0.018	0.123	6.6	0.013
180.0	1.354	5.6	1.507	0.182	0.000	0.0	0.000	0.116	6.5	0.013

FORCES RELATIVE TO LOCAL AXES AND MOTION-INDUCED INTERRUPTIONS
LAT TIP COEFF = 0.250 , LONG TIP COEFF = 0.170 , TIME FOR OPERATION = 60.0 s

HEADING	***LATERAL***		**LONGITUDINAL**		TOTAL
	LFE	MII	LFE	MII	MII
DEG	G		G		
0.0	0.000	0.000	0.001	0.000	0.000
30.0	0.061	0.001	0.002	0.000	0.001
60.0	0.139	1.938	0.004	0.000	1.938
90.0	0.077	0.150	0.001	0.000	0.150
120.0	0.063	0.138	0.025	0.130	0.267
150.0	0.028	0.003	0.028	0.214	0.217
180.0	0.000	0.000	0.028	0.189	0.189

SLAMMING AND DECK WETNESS CALCULATIONS - FREEBOARD AT STATION IS 6.03 M
FREEBOARD AFTER WAVE PROFILE CORRECTION IS 5.75 M

HEADING	****VERTICAL******		VRQI	PROB	DW PER	PROB	KE PER	SLAM PRESSURE		SLAM FORCE	
	REL DISP	REL VEL		(DW)	HOUR	(KE)	HOUR	MOSTPROB	EXTREME	MOSTPROB	EXTREME
DEG	M	M /SEC						KPA	KPA	N / M	N / M
0.0	0.748	0.215	0.003	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
30.0	0.712	0.203	0.004	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
60.0	0.559	0.281	0.016	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
90.0	0.154	0.245	0.076	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
120.0	1.129	1.587	0.211	0.0000	0.0	0.0013	1.0	37.41	94.25	33828.9	85221.0
150.0	1.427	1.984	0.217	0.0003	0.2	0.0155	12.3	106.41	195.29	96217.4	176578.5
180.0	1.475	2.078	0.212	0.0005	0.4	0.0203	16.3	122.68	220.14	110925.0	199044.9

RMS MOTIONS IN SHORT-CRESTED SEAS - SPREADING ANGLE = 90.00 DEG

U = 18.0 KNOTS FROUDE NO = 0.284

SEA STATE = 5 SIG WAVE HT = 3.2492 M WAVE PERIOD = 10.0000 SEC SPECTRUM = BRETSCHNEIDER

HEADING OF 180 DEGREES CORRESPONDS TO HEAD SEAS

MOTIONS AT SHIP CG

HEADING DEG	SURGE M	SWAY M	TO SEC	SWAY ACC G	HEAVE M	TO SEC	HEAVE ACC G	ROLL DEG	TO SEC	PITCH DEG	TO SEC	YAW DEG	TO SEC	RUDDER DEG	FIN/TANK DEG
0.0	2.281	1.00	34.8	0.007	0.40	17.6	0.007	4.20	14.4	0.82	19.5	1.40	21.2	0.000	0.000
30.0	2.035	0.97	25.5	0.014	0.47	12.1	0.020	4.68	13.6	0.78	17.7	1.36	19.8	0.000	0.000
60.0	1.407	0.88	17.2	0.023	0.60	8.9	0.041	5.10	12.7	0.74	9.8	1.22	17.4	0.000	0.000
90.0	0.699	0.69	12.4	0.028	0.69	7.6	0.060	4.42	11.7	0.86	6.3	0.88	14.4	0.000	0.000
120.0	0.245	0.44	9.0	0.026	0.70	6.8	0.071	2.83	10.0	1.11	5.6	0.43	9.4	0.000	0.000
150.0	0.159	C.26	8.0	0.019	0.65	6.4	0.072	1.38	7.4	1.31	5.6	0.22	6.3	0.000	0.000
180.0	0.165	0.16	7.5	0.012	0.61	6.2	0.071	1.06	6.6	1.39	5.6	0.20	6.1	0.000	0.000

STATION = 3.00 Y = 0.00 M Z = 3.46 M (referenced to CG)

MOTIONS AT STATION

HEADING	***********VERTICAL***************				********LATERAL*********			******LONGITUDINAL******		
	DISP	TO	VEL	ACC	DISP	TO	ACC	DISP	TO	ACC
DEG	M	SEC	M /SEC	G	M	SEC	G	M	SEC	G
0.0	0.742	19.1	0.244	0.010	0.969	31.8	0.007	2.242	27.8	0.014
30.0	0.762	14.7	0.326	0.023	0.932	23.8	0.015	1.998	27.2	0.014
60.0	0.855	8.9	0.600	0.063	0.850	15.4	0.028	1.377	25.0	0.012
90.0	1.029	6.7	0.968	0.113	0.693	10.8	0.036	0.675	20.1	0.011
120.0	1.211	5.9	1.280	0.154	0.498	8.2	0.036	0.218	11.2	0.011
150.0	1.332	5.7	1.464	0.177	0.346	7.6	0.028	0.118	6.7	0.013
180.0	1.372	5.7	1.522	0.185	0.242	7.2	0.021	0.122	6.6	0.013

FORCES RELATIVE TO LOCAL AXES AND MOTION-INDUCED INTERRUPTIONS
LAT TIP COEFF = 0.250 , LONG TIP COEFF = 0.170 , TIME FOR OPERATION = 60.0 s

HEADING	***LATERAL***		**LONGITUDINAL**		TOTAL
	LFE	MII	LFE	MII	MII
DEG	G		G		
0.0	0.071	0.017	0.003	0.000	0.017
30.0	0.082	0.100	0.003	0.000	0.100
60.0	0.095	0.411	0.007	0.000	0.411
90.0	0.090	0.427	0.015	0.000	0.427
120.0	0.068	0.104	0.022	0.020	0.124
150.0	0.043	0.008	0.026	0.123	0.131
180.0	0.033	0.003	0.028	0.191	0.193

SLAMMING AND DECK WETNESS CALCULATIONS - FREEBOARD AT STATION IS 6.03 M
FREEBOARD AFTER WAVE PROFILE CORRECTION IS 5.75 M

HEADING	****VERTICAL******		VRQI	PROB	DW PER	PROB	KE PER	SLAM PRESSURE		SLAM FORCE	
	REL DISP	REL VEL		(DW)	HOUR	(KE)	HOUR	MOSTPROB	EXTREME	MOSTPROB	EXTREME
DEG	M	M /SEC						KPA	KPA	N / M	N / M
0.0	0.703	0.222	0.008	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
30.0	0.658	0.242	0.025	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
60.0	0.616	0.506	0.072	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
90.0	0.773	0.990	0.130	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
120.0	1.064	1.478	0.178	0.0000	0.0	0.0006	0.4	23.33	72.65	21094.3	65684.1
150.0	1.307	1.828	0.206	0.0001	0.1	0.0069	5.6	77.32	152.79	69910.1	138152.3
180.0	1.400	1.958	0.214	0.0002	0.2	0.0132	10.6	100.74	187.29	91084.1	169342.0

References

1. R.T. Schmitke and B.W. Whitten, "SHIPMO - A FORTRAN Program to Predict Ship Motions in Waves," DREA Technical Memorandum 81/C, October 1981.

2. R. Graham and G. Miller, "SHIPMO2 - An Updated User's Manual for the SHIPMO Computer Program Incorporating Measured Sea Spectra and Wave Loads," DREA Technical Memorandum 84/G, May 1984.

3. R. Graham, "SHIPMO3: Improved Viscous Roll Damping Predictions for the SHIPMO Computer Program," DREA Technical Memorandum 86/212, May 1986.

4. R. Graham and C. Trudelle, "SHIPMO4 - An Updated User's Manual for the SHIPMO Computer Program Incorporating an Extended Hydrostatics Capability and an Improved Viscous Roll Damping Model," DREA Technical Communication 87/304, March 1987.

5. R. Graham, "Motion-Induced Interruptions as Ship Operability Criteria," *Naval Engineers Journal* **102**(2), 65–71 (1990).

6. R.F. Beck, W.E. Cummins, J.F. Dalzell, P. Mandel, and W.C. Webster, "Motions in Waves," in *Principles of Naval Architecture* (Society of Naval Architects and Marine Engineers, 1989), Vol. 3, Ch. 8.

7. ITTC Seakeeping Committee Report, in *15'th International Towing Tank Conference* (The Hague, September 1978), Vol. 1, pp. 55–114.

8. M.K. Ochi and E.N. Hubble, "Six-Parameter Wave Spectra," in *15'th Coastal Engineering Conference* (Honolulu, 1976), Vol. 1, pp. 301–328.

9. B.-A. Juszko, "Parameterization of Directional Wave Spectra - Part 2, Volume I: Final Report," DREA Contractor Report CR/89/445, Volume I, Juszko Scientific Services, December 1989.

10. B.-A. Juszko, "Parameterization of Directional Wave Spectra - Part 2, Volume II: User's Manual for the Programs RMODEL, FITHM and FITDM," DREA Contractor Report CR/89/445, Volume II, Juszko Scientific Services, December 1989.

11. R. Graham and B.-A. Juszko, "Parameterization of Directional Spectra and Its Influence on Ship Motion Predictions," *submitted to Marine Technology* (1991).

12. N. Hogben and F.C. Cobb, "Parametric Modelling of Directional Wave Spectra," in *Offshore Technology Conference* (Paper OTC 5212, Houston, 1986).

13. N. Salvesen, E.O. Tuck, and O. Faltinsen, "Ship Motions and Sea Loads," *Transactions, Society of Naval Architects and Marine Engineers* **78**, 250–287 (1970).

14. K.A. McTaggart, "Influence of End Effect Terms on Predictions by Ship Motion Program SHIPMO," DREA Technical Memorandum 90/205, December 1990. Limited Distribution.

15. W. Frank and N. Salvesen, "The Frank Close-Fit Ship-Motion Computer Program," NSRDC Report 3289, June 1970.

16. D. Gospodnetic and M. Miles, "Some Aspects of the Average Shape of Wave Spectra at Station 'India' (59° N, 19° W)," in *International Symposium on the Dynamics of Marine Vehicles and Structures in Waves* (London, 1974).

17. S.O. Rice, "Mathematical Analysis of Random Noise," *Bell Systems Technical Journal* **23,24** (1944,1945).

18. W.G. Price and R.E.D. Bishop, *Probabilistic Theory of Ship Dynamics* (John Wiley & Sons, New York, 1974).

19. M. Mackay and R.T. Schmitke, "PHHS - A FORTRAN Program for Ship Pitch, Heave, and Seakeeping Prediction," DREA Technical Memorandum 78/B, April 1978.

20. R.T. Schmitke, "Improved Slamming Predictions for the PHHS Computer Program," DREA Technical Memorandum 79/A, February 1979.

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The ship motion computer program SHIPMO has been revised to increase its capabilities in several different areas. The new version of the program can compute forces relative to local ship axes and the resulting incidence of motion-induced interruptions or sliding events. Seakeeping positions may now be offset from the ship centreline. The program now includes expanded wave spectra capabilities, including multi-directional spectra. Motion computations may include hydrodynamic end effect terms, which can be important for transom stern ships at forward speeds. SHIPMO5 also has an option for predicting propeller emergence, which can influence added power requirements.

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ship motion computer program

seakeeping

surge, sway, heave, roll, pitch, yaw

wave spectra