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# SWATM2: A COMPUTER PROGRAM FOR THE PREDICTION OF SWATH SHIP MOTIONS IN REGULAR AND IRREGULAR WAVES

W.C.E. Nethercote - S.D. Piggott
M.W. Savory



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# SWATM2: A COMPUTER PROGRAM FOR THE PREDICTION OF SWATH SHIP MOTIONS IN REGULAR AND IRREGULAR WAVES


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**ABSTRACT**

The FORTRAN computer program SWATM2 enables calculation of five degree-of-freedom motions for SWATH ships. It is a development of an earlier DREA computer program with the added capability of predicting performance in long or short irregular crested seas with a variety of sea spectra. A worked example demonstrates satisfactory agreement between calculated and experimental results.

**RESUME**

Le programme d'ordinateur en FORTRAN SWATM2 permet de calculer les mouvements des navires SWATH à cinq degrés de liberté. Il s'agit d'un perfectionnement d'un programme d'ordinateur existant du CRDA dont la nouvelle caractéristique est la possibilité de prévision du rendement dans des mers à crêtes irrégulières longues ou courtes pour une diversité d'états de la mer. Un exemple auquel le programme a été appliqué démontre qu'il y a concordance satisfaisante entre les résultats calculés et expérimentaux.

## TABLE OF CONTENTS

## NOTATION

| | |
|---|---|
| A | constant in ITTC Spectrum |
| $A_{kj}(\omega')$ | (k,j) coefficient of $S_R'(\omega')$ |
| $A_{ij}$ | added mass coefficient in the ith mode due to motion in the jth mode. |
| B | constant in ITTC Spectrum |
| $B_{Ci}$ | box clearance of ship at station i |
| $B_{ij}$ | damping coefficient in the ith mode due to motion in the jth mode. |
| E | area under the wave energy spectrum |
| $F_i$ | freeboard of ship at station i |
| H | significant wave height |
| $H_o$ | average wave height of Gospodenetic - Miles wave sample |
| $H_x(\omega)$ | frequency response of a linear ship response, x, in unidirectional seas |
| $H_x(\omega,\nu_i)$ | frequency response of a linear ship response, x, in short-crested seas |
| h | period of operation, hours |
| k | slamming pressure form factor |
| $m_n$ | $n^{th}$ spectral moment $= \int_o^\infty \omega^n S(\omega)d\omega$ |
| $N_{BI}$ | number of box impacts per hour |
| $N_{DW}$ | number of deck wetnesses per hour |
| $N_{KE}$ | number of keel emergences per hour |
| P(BI) | probability of box impact |
| P(DW) | probability of deck wetness |
| P(KE) | probability of keel emergence |

| | |
|---|---|
| $P_h$ | most probable slamming pressure in h hours |
| $P_h(\alpha)$ | extreme slamming pressure in h hours with probability of exceedence, $\alpha$. |
| $S_\zeta(\omega)$ | wave displacement power spectral density function |
| $S(\omega,\nu)$ | short-crested sea spectrum |
| $S_B(\omega,T,H)$ | Bretschneider sea spectrum |
| $S_I(\omega,T,H)$ | ITTC sea spectrum |
| $S_R'(\omega,T,H)$ | normalized polynominal regression spectrum (Gospodnetic-Miles) |
| T | average wave period = T(-1) or T(1) |
| $T_o$ | average wave period of Gospodnetic - Miles wave sample |
| T(-1) | $2\pi(m_{-1}/m_o)$, energy averaged period |
| T(1) | $2\pi(m_o/m_1)$, modal period |
| $T_D$ | draft |
| $t_f$ | human tolerance weighting factor |
| $W(\nu)$ | wave energy spreading function |
| $\alpha$ | angular spacing between discrete wave directions, $\nu_i$, or probability of exceedence, depending on context. |
| $\beta$ | predominant wave direction |
| $\rho$ | mass density |
| $\sigma$ | root mean squared (RMS) value of a wave record |
| $\sigma_A$ | RMS vertical acceleration |
| $\sigma_{RMi}$ | RMS relative motion at station i |
| $\sigma_{RV}$ | RMS relative velocity |
| $\sigma_{sx}$ | RMS value of a linear ship response, x, in short-crested seas |

| | |
|---|---|
| $\sigma_x$ | RMS value of a linear ship response, x, in unidirectional seas |
| $\nu$ | wave direction |
| $\nu_i$ | $i^{th}$ wave direction |
| $\nu_S$ | one-half the total angular spread between the minimum and maximum values of $\nu_i$ |
| $\omega$ | wave circular frequency |
| $\omega'$ | normalized frequency = $\omega T/2\pi$ |
| $\omega_e$ | circular frequency of encounter |

## 1. INTRODUCTION

This report describes the computer program SWATM2, (SWATH Ship Motions, Modification 2). A user's manual is included together with sample input and output, and a description of an input data preparation program, OFFSET.

A theoretical model of SWATH ship motions, proposed by C.M. Lee[1] was incorporated in two computer programs[2] at the David W. Taylor Naval Research and Development Center (DTNSRDC). One program, MOT35, predicted heave and pitch motions while the other, MOT246, predicted sway, roll and yaw motions. At DREA, the two DTNSRDC programs, MOT35 and MOT246, were modified and combined to form the program SWATMO, predicting five degree of freedom motions in regular waves. The version of the program reported herein, SWATM2, is essentially an extension of the earlier DTNSRDC and DREA work, with the added capability of irregular seas calculations.

The theoretical basis of the computer program is adequately described in Reference 1 and will not be referred to here except where warranted by alterations or extensions of program capability. Details of alterations are described in Sections 2 and 3 and the user's manual is given in Appendix B. Section 4 describes the offset data preparation program, OFFSET. Section 5 presents a number of correlations of SWATM2 with model experiment results and with results obtained by use of the original DTNSRDC programs, MOT35 and MOT246. The agreement is satisfactory.

Users manuals, together with sample input and output cases, are given for SWATM2 and OFFSET in the Appendices.

## 2. BASES FOR CURRENT WORK

In its first form, SWATMO, the program predicted the vertical motion responses, heave and pitch; and the lateral motion responses, sway, roll, and yaw, for a SWATH ship moving in a regular wave train of arbitrary heading. These motions were obtained by solving the equations of motion which were formulated as linear second-order differential equations. The hydrodynamic coefficients in the equations of motion were divided into three categories:

(1) The coefficients which could be obtained under the potential-flow assumption for a non-lifting body. These coefficients were obtained by strip theory based on the solution of the two-dimensional hydrodynamic problem of cylinders oscillating on the free surface where the wave exciting coefficients were obtained by the Haskind relation[3].

(2) The hydrodynamic coefficients associated with the viscous nature of the fluid. These were obtained by the cross-flow approach for slender bodies with moderate angle of attack.

(3) The hydrodynamic coefficients contributed by the control surfaces. These were obtained by slender body theory for low-aspect ratio wing-body combinations.

Motions in irregular seaways are calculated by linear superposition of the regular wave response and the wave energy spectrum in the conventional manner, viz:

$$\sigma_x^2 = \int_0^\infty |H_x(\omega)|^2 S_\zeta(\omega)\, d\omega \tag{1}$$

$$H_{x_{RMS}} = \left(\int_0^\infty |H_x(\omega)|^2 S_\zeta(\omega)\, d\omega\right)^{1/2} \tag{2}$$

$$\simeq \left(\sum_{\omega_1}^{\omega_n} |H_x(\omega)|^2 S_\zeta(\omega)\Delta\omega\right)^{1/2} \tag{3}$$

where $\sigma_x^2$ is the variance of a response

$H_x$ is a response

$S(\omega)$ is the wave energy spectral density.

## 2.1 Sea State Descriptions

A number of wave energy spectrum formulations are in common use for irregular wave calculations:

(1) The Gospodnetic-Miles quadratic regression spectrum[4] is a two-parameter spectrum derived from data obtained at Station India in the North Atlantic. The parameters are significant wave height, H, and energy-averaged wave period, T. The normalized regression spectrum takes on the form

$$S_R'(\omega',T,H) = \sum_{k=0}^{M} \sum_{j=0}^{M-k} A_{kj}(\omega')(H - H_o)^k (T - T_o)^j \tag{4}$$

where $H_o$ and $T_o$ are the average H and T values of the measured spectra used to compute the regression. It has been determined[4] that $H_o$ = 4.016 m and $T_o$ = 9.159 s. Thus, the polynominal coefficients, $A_{kj}$, are functions of $\omega'$. These coefficients, $A_{kj}$, can be found in SUBROUTINE REGRES of the program. The energy-averaged period, T, based on spectral moments is defined by the formula

$$T = T(-1) = 2\pi(m_{-1}/m_o) \qquad (5)$$

where $m_n = n^{th}$ spectral moment $= \int_o^\infty \omega^n S_\zeta(\omega)\,d\omega$

(2) The Bretschneider two-parameter spectrum, with the parameters significant wave height and modal wave period as extracted from program PHHS5[5], is represented by the equation

$$S_B(\omega,T,H) = \alpha H^2/[\omega^5 T^4 \exp(\beta/(\omega T)^4)] \qquad (6)$$

where $\alpha$ = 487.0626 and $\beta$ = 1948.2444 with significant wave height, H, being in feet. The modal wave period, T, is defined as

$$T = T(1) = 2\pi(m_o/m_1). \qquad (7)$$

The modal wave period used with the Bretschneider spectrum is different from the energy-averaged period used with the quadratic regression spectrum. The two periods are not interchangeable.

(3) The ITTC spectrum[6], in which the parameters are significant wave height and modal wave period (or average zero-crossing period), is defined by

$$S_I(\omega,T,H) = \frac{A}{\omega^5}\ \exp\,(-B/\omega^4) \qquad (8)$$

where A and B are constants as given by

$$A = \frac{4\pi^3 H^2}{T^4} \text{ and } B = \frac{16\pi^3}{T^4}.$$

Note that the wave period, T, in this case is the modal wave period.

$$T = T(1) = 2\pi(m_o/m_1)$$

The ITTC spectrum differs trivially from the preceding Bretschneider formulation; the two have been included in the present program to offer the option of agreement with existing DREA programs or with the widely used ITTC spectrum.

(4) Where correlation of theory and experiment is undertaken there is often a need to predict responses from measured spectra which often differ markedly from the formulations just described; therefore, SWATM2 also accepts ordinates to arbitrary spectra as inputs.

## 2.2 Short-Crested Seas

The spectral formulations and root mean squared responses just described refer to one-dimension (long-crested) waves. In considering the short-crested (multi-directional) sea case the application of a cosine-squared spreading function is most common:

$$S(\omega,\nu) = W(\nu)S(\omega) \qquad (9)$$

where $S(\omega)$ is the point spectrum and $W(\nu)$ the spreading function.

$$W(\nu) = (\alpha/\nu_S)(\cos[90(\nu - \beta)/\nu_S])^2 \qquad (10)$$

where $\alpha$ is the angular spacing between the discrete wave directions $\nu$, and $\nu_S$ is half the total angular spread. $\alpha$, $\beta$, $\nu$, $\nu i$ and $\nu_S$ are all expressed in degrees. Typically, in numerical analysis (and as adopted as in the default valve in SWATM2) angular spread might be 120°, so $\nu_S$ = 60°, with

$$\beta-\nu_S \leq \nu \leq \beta+\nu_S$$

divided in n discrete wave directions spaced $\alpha$ degrees apart,

$$n = 2\nu_S/\alpha + 1$$

Expanding equation (1) for variance of response in long-crested waves to short-crested seas gives

$$\sigma^2_{sx} = \sum_{i=1}^{n} W(\nu_i)\sum_{\omega} |H_x(\omega,\nu_i)|^2 S_\zeta(\omega)\Delta\omega \qquad (11)$$

$$= \sum_{i=1}^{n} W(\nu_i)\sigma^2_{xi} \qquad (12)$$

where $\sigma^2_{xi}$ is the variance at heading $\nu_i$ in unidirectional seas. Again,

$$H_{sx_{RMS}} = \left(\sum_{i=1}^{n} W(\nu_i)\sigma^2{}_{xi}\right)^{1/2} \qquad (13)$$

## 2.3 Secondary Ship Responses

There are other seakeeping data of interest besides absolute body motions.

(1) The vibration ride quality index (VRQI):

The vibration ride quality index proposed by Payne[7] is used to quantify human tolerance to vertical ship motions and is defined as

$$VRQI = \sigma_A t_f^{1/2} \qquad (14)$$

where $\sigma_A$ is RMS vertical acceleration and $t_f$ is a "tolerance weighting factor". Payne's proposed VRQI limits are:

| Limit | Description | VRQI Must Be Less Than |
|---|---|---|
| A | Severe, less than one hour | 0.5 |
| B | Tolerable, less than one hour | 0.2 |
| C | Long-term, severe | 0.2 |
| D | Long-term, tolerable | 0.1 |

At low frequencies (below 0.2 Hz) tolerance to vertical accelerations increases significantly with decreasing frequency; however, Payne's low frequency model does not reflect this trend. To account for this increased tolerance at very low frequencies, Mackay and Schmitke[5] have proposed multiplying the root mean square vertical acceleration by a "tolerance weighting factor" such that the long term severe limit of VRQI follows the 50% motion sickness incidence curve. This "tolerance weighting factor" represented by $t_F$ in the VRQI formula, is defined as

$$t_F = \frac{\left\{1 + \left(\frac{2\omega_e}{1.571}\right)^2\right\}}{\left\{1 - \frac{\omega_e}{1.571}\right\}^2 + \left\{\frac{2\omega_e}{1.571}\right\}^2} \qquad (15)$$

where $\omega_e$ is encounter frequency.

(2) Deck wetness:

The probability of deck wetness, that is the probability of bow down relative motion being greater than the freeboard, at station i is given by

$$P(DW) = \exp - \frac{F_i^2}{2\sigma^2_{RM_i}} \qquad (16)$$

where F is freeboard, and $\sigma_{RM}$ is root mean square relative motion. The number of deck wetnesses per hour is simply

$$N_{DW} = \frac{3600}{T} P(DW) \qquad (17)$$

where T is the average wave period in seconds.

(3) Keel emergence:

The probability of keel emergence at station i may be determined by

$$P(KE) = \exp\left(- \frac{T_D{}^2 i}{2\sigma^2_{RM_i}}\right) \qquad (18)$$

where $T_D$ is draft. Again, keel emergences per hour may be calculated by

$$N_{KE} = \frac{3600}{T} P(KE) \qquad (19)$$

(4) Box impacts:

Similarly, if box impact occurs when relative motion, bow down, exceeds box clearance, then the probability of its occurrence at station i will be given by

$$P(BI) = \exp\left(- \frac{B_{Ci}^2}{2\sigma^2_{RM_i}}\right) \qquad (20)$$

where $B_C$ is box clearance above the still waterline. Box impacts per hour may be determined from

$$N_{BI} = \frac{3600}{T} P(BI) \qquad (21)$$

(5) Box slamming pressures:

Box slamming is of greater importance than hull bottom slamming for SWATH ships because typically draft is significantly greater than box clearance; but fortunately, the usual monohull algorithms for bottom slam pressure prediction can be used for the box bottom. Schmitke[8] outlines various methods for monohull slam pressure prediction and defines algorithms suitable for the frequency domain.

The most probable slam pressure in a period of h hours (in SWATM2, h = 20) is given by

$$P_h = \rho k \sigma_{RV}^2 \ln \left\{ \frac{3600h\, \sigma_{RV}}{2\pi \sigma_{RM}} P(BI) \right\} \qquad (22)$$

where $\rho$ is water mass density, k is slam pressure form factor, $\sigma_{RM}$ is rms relative motion, and $\sigma_{RV}$ is rms relative velocity.

In practice, the most probable pressure is unsuitable for design purposes because of its high probability of exceedence. A better measure of design slam pressure, is the extreme pressure, $P_h(\alpha)$, whose probability of exceedence in h hours is $\alpha$.

$$P_h(\alpha) = \rho k\, \sigma_{RV}^2 \ln \left\{ \frac{3600h\, \sigma_{RV}}{2\pi\alpha\sigma_{RM}} P(BI) \right\} \qquad (23)$$

A commonly used measure[8], $P_{20}$ (0.01), is adopted by SWATM2.

The specification of form factor, k, presents the greatest difficulty in calculating slam pressures. Experimental data for slamming of flat plates in waves show considerable scatter due to varying air entrapment and impact angle (the angle between the plate and the plane tangential to the wave surface at the impact point). Unfortunately neither of these parameters can be modelled in a linear frequency domain program. For present purposes, a default value of form factor, k=20, has been derived by an analysis of Reference 9; however, given the limited data in Reference 9, pressure predictions should be used with caution.

## 3. MODIFICATIONS TO PROGRAM

The most significant modification made to program SWATMO was the addition of irregular sea calculations; however, this addition required further changes in the basic program structure.

SWATMO calculated motions of a SWATH ship in regular waves. The amplitudes and phases of these motions were given as functions of encounter frequency, with encounter frequency ranges being specified in the program input. It is generally more convenient to prepare input data for seakeeping programs in terms of wavelength or absolute wave frequency. Thus, the input specifications of SWATMO were changed such that the range of wavelengths was required instead of the individual encounter frequencies. This form of input is consistent with other seakeeping programs at DREA.

SWATMO originally calculated added mass and damping coefficients at the encounter frequencies specified in input, these frequencies being the same for all headings, in one computer run. With the alteration of input to wavelength a difficulty arose: each of the different headings and speeds specified in the input would generate new encounter frequencies with the consequential increase in execution time being proportional to number of headings and speeds. In addition, the added mass and damping coefficient calculations are the most time-consuming part of the program.

Thus, an interpolation method was adopted to circumvent the problem. SWATM2 calculates the extreme encounter frequency values for each speed-heading combination input, and from these selects the overall range of encounter frequency required for calculations. The input parameter NWE (less than or equal to 30) then specifies the number of evenly spaced encounter frequencies at which added wave and damping coefficients will be calculated. The results of the calculation are stored in an array. For each speed-heading combination, the required coefficients are derived by quadratic interpolation from the stored array. Comparisons of the results of calculations both before and after incorporation of the interpolation routine suggests that no appreciable errors are introduced by interpolation.

In extending the program to irregular sea predictions, subroutines employed in the monohull program SHIPMO[10] were used where possible in order to ensure the consistency of predictions. The methods employed correspond to those given in Section 2.

## 4. PROGRAM "OFFSET"

The preparation of geometric input data for SWATM2 is laborious, particularly with respect to section offsets. A preparative program, OFFSET, was written to ease preparation of offset data.

### 4.1 Capabilities and Method

This program is capable of computing offsets for three hull configurations:

(1) hull section with strut,

(2) hull section without strut, and

(3) hull section with strut of zero thickness (i.e. stations 0 and 20).

Figure B2, Appendix B, illustrates the three section types.

Trignometric relations are used to calculate offsets as x and y coordinates. For hull sections with struts, 13 offset points are generated; for bare hull sections and hull sections with strut thickness equal to zero, 9 offset points are generated.

The OFFSET User's Guide is given in Appendix E.

## 5. DISCUSSION

With the alterations inherent in the development of SWATM2 from SWATM0 it was necessary to test the results against the "parent" programs, MOT35 and MOT246[2]. Additionally, comparisons were made with experimental data included in Reference 1. The computer program comparison was quite extensive and only extracts will be given herein.

Figures 1 to 4 illustrate comparable non-dimensional added mass and damping coefficients, where the subscripts refer to motions as follows:

| Index | Motion |
|---|---|
| 2 | sway |
| 3 | heave |
| 4 | roll |
| 5 | pitch |
| 6 | yaw |

While there are differences between the results for the parent program and SWATM2, they are not considered significant. For example, whereas the added mass coefficient, $A_{33}$, shows the largest discrepancy between SWATM2 and MOT 35; the result is only a three percent difference in total mass in the vertical plane, with an even smaller impact on predicted motions (also note Figure 6).

Motions predictions for both the parent program and SWATM2 are compared to experimental results[1] in Figures 5, 6, 7 and 8. Only for roll is there notable difference between programs, but in this case SWATM2 is more conservative.

Predicted motions correlate well with experimental results in the vertical plane for heave and relative bow motion, Figure 9, but only reasonably for pitch (Figure 5). Lateral motions, roll and yaw, are not modelled as well, a situation typical of many seakeeping programs. Fortunately vertical motions are generally of greatest importance in the early stages of ship design, and for SWATH ships at least, lateral motions are of small enough magnitude to present no serious risk to performance.

## 6. CONCLUDING REMARKS

A SWATH ship seakeeping performance prediction program, SWATM2, has been described. SWATM2 allows prediction of the performance of single or tandem strut SWATH ships in either regular or irregular seas. In irregular seas, either long- or short-crested spectral formulations may be employed.

It has been demonstrated that the results of use of SWATM2 correspond to results obtained from use of the two programs, MOT35 and MOT246, from which it was derived. A limited comparison with experimental data indicated that vertical plane motions are predicted satisfactorily, but that there are greater discrepancies between prediction and experiment for lateral motions. Fortunately, vertical plane motions are of most importance in the early design stages and SWATH ship lateral motions are generally of small enough magnitude to represent no serious risk to ship operation.

Nonetheless, future developments of SWATH seakeeping programs should address the improvement of lateral motions predictions. The addition of an active motion control fin modelling capability also would be valuable. Finally, SWATH box slamming experiments should be used to obtain more reliable form factor estimates than given herein.

## 7. ACKNOWLEDGEMENT

The box slamming algorithms were incorporated in the program by Dr. R.W. Graham and F.R. Crummey.

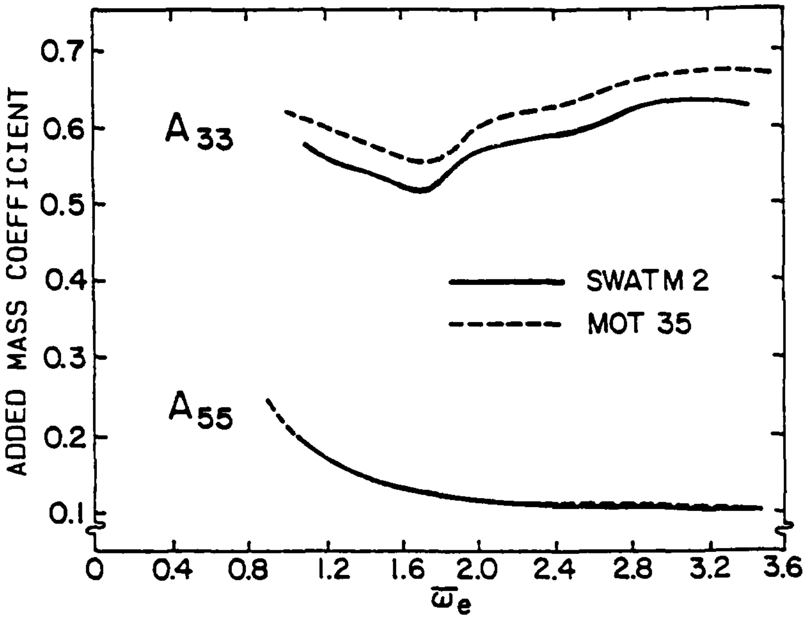


FIGURE 1: COMPARISON OF PITCH ($A_{55}$) AND HEAVE ($A_{33}$), ADDED MASS COEFFICIENT PREDICTIONS FROM SWATM2 AND MOT 35

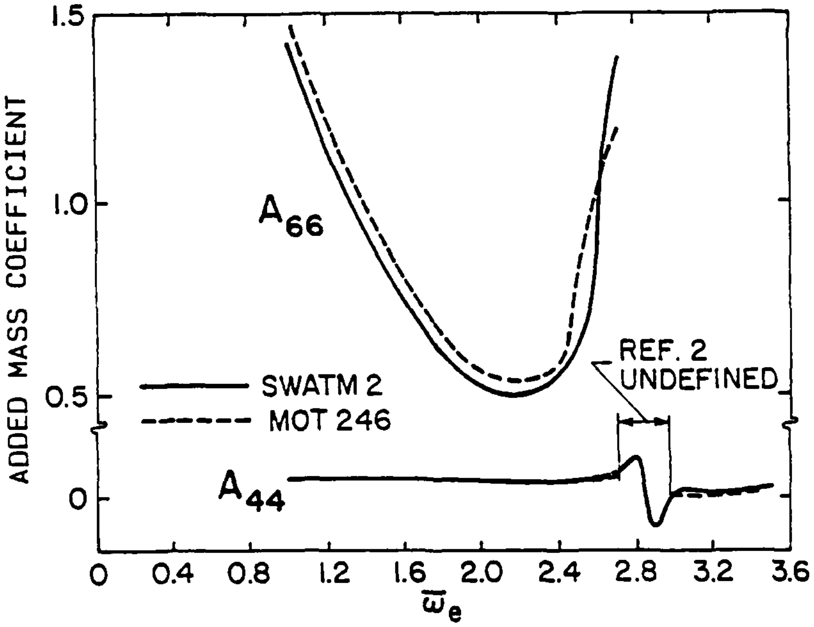


FIGURE 2: COMPARISON OF ROLL ($A_{44}$) AND YAW ($A_{66}$), ADDED MASS COEFFICIENT PREDICTIONS FROM SWATM2 AND MOT 246

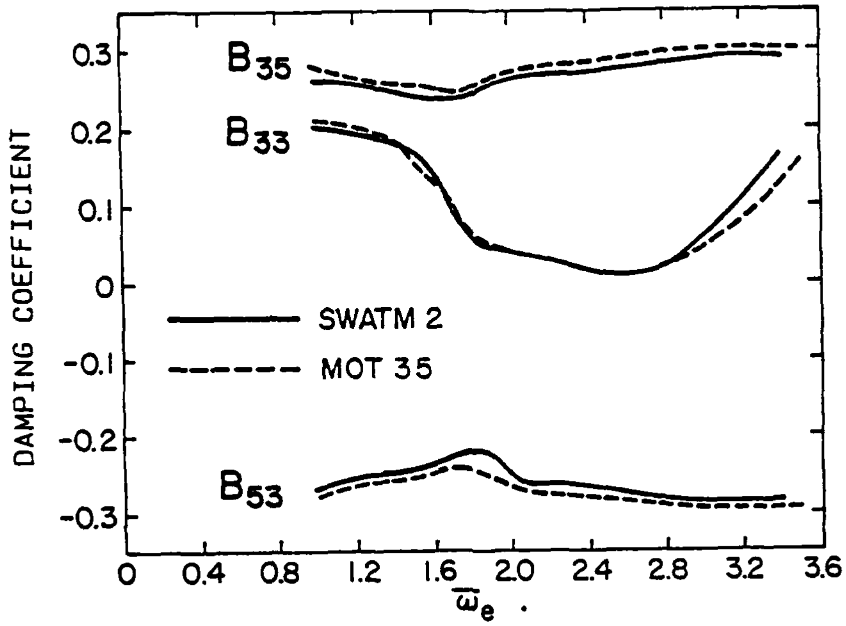


FIGURE 3: COMPARISON OF HEAVE ($B_{33}$), HEAVE-PITCH ($B_{35}$), AND PITCH-ROLL ($B_{53}$) DAMPING COEFFICIENT PREDICTIONS FROM SWATM2 AND MOT 35

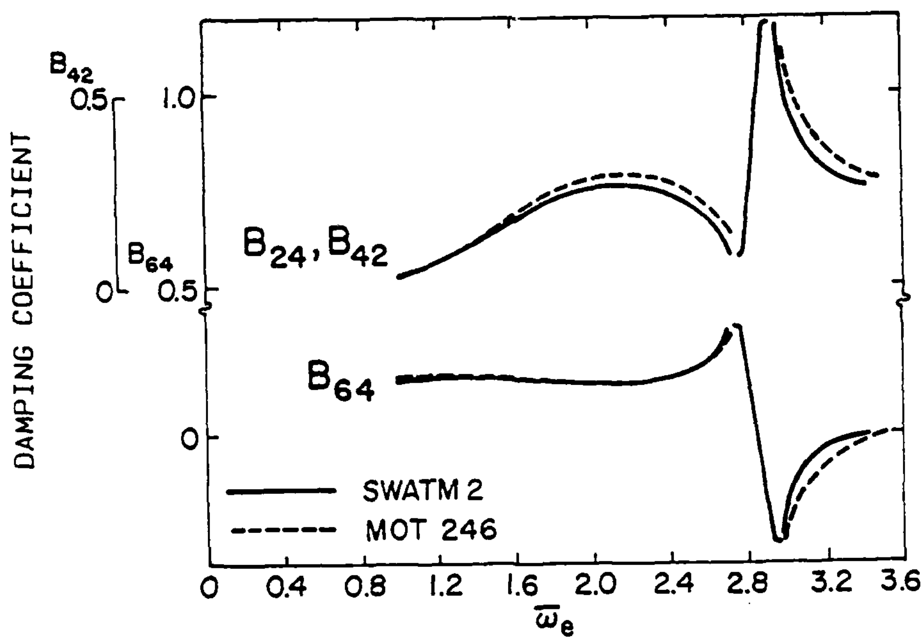


FIGURE 4: COMPARISON OF YAW-ROLL ($B_{64}$), SWAY-ROLL ($B_{24}$), AND ROLL SWAY ($B_{42}$) DAMPING COEFFICIENT PREDICTIONS FROM SWATM2 AND MOT 246

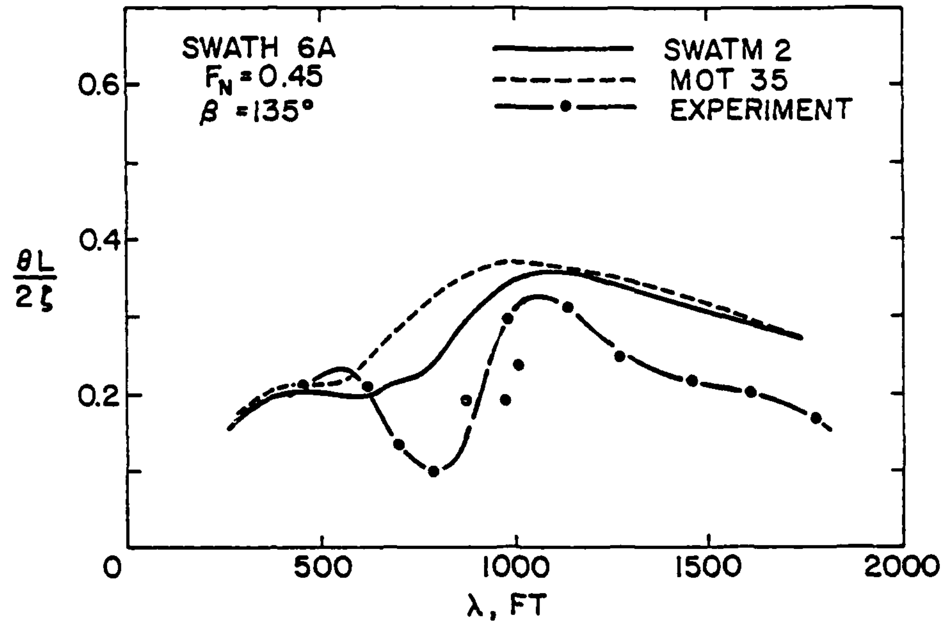


FIGURE 5: COMPARISON OF PITCH TRANSFER FUNCTIONS FROM SWATM2 AND MOT 35 WITH EXPERIMENTS

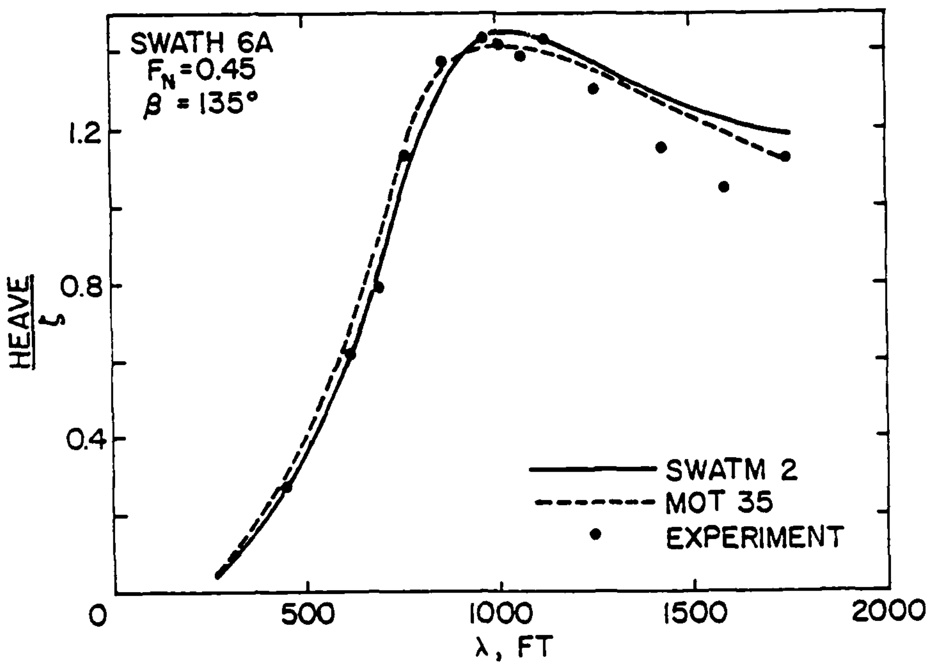


FIGURE 6: COMPARISON OF HEAVE TRANSFER FUNCTIONS FROM SWATM2 AND MOT 35 WITH EXPERIMENTS

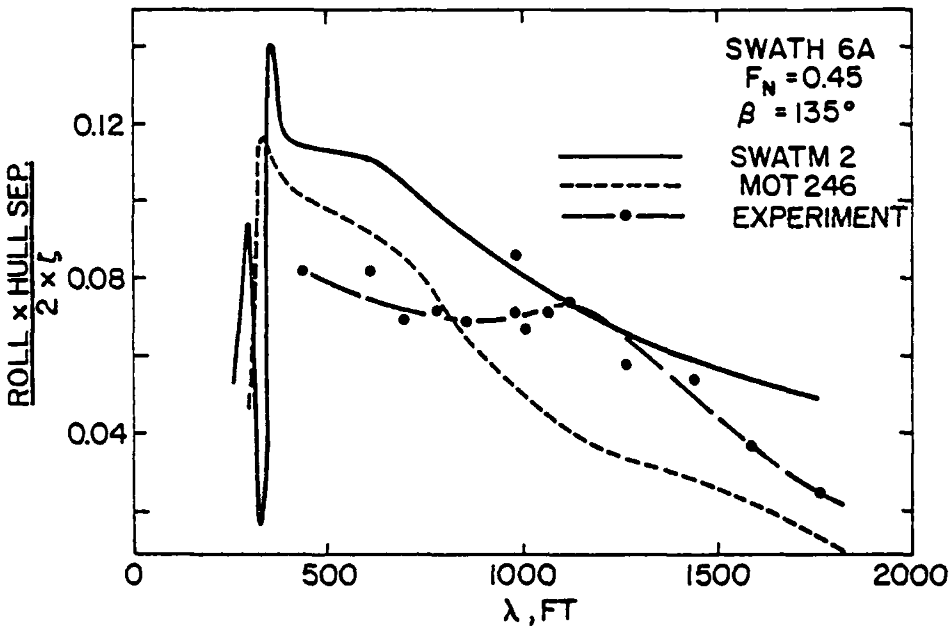


FIGURE 7: COMPARISON OF ROLL TRANSFER FROM SWATM2 AND MOT 246 WITH EXPERIMENTS

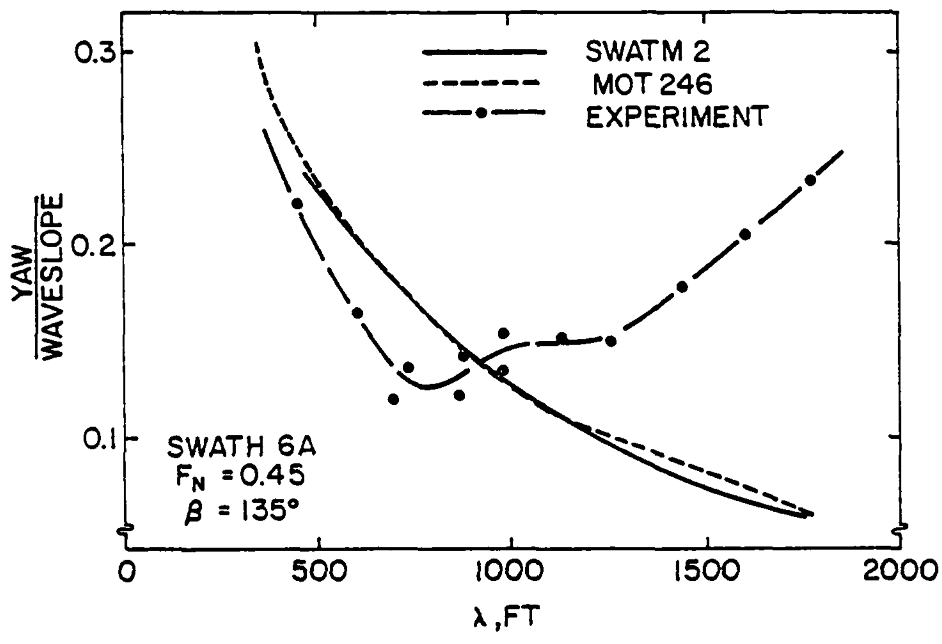


FIGURE 8: COMPARISON OF YAW TRANSFER FUNCTIONS FROM SWATM2 AND MOT 246 WITH EXPERIMENTS

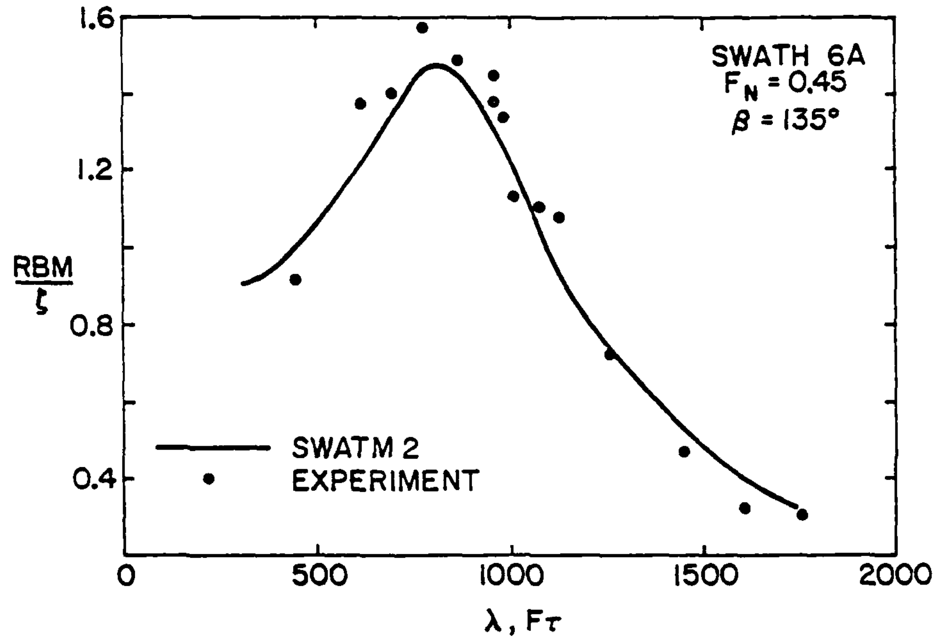


FIGURE 9: COMPARISON OF RELATIVE BOW MOTION TRANSFER FUNCTION FROM SWATM2 WITH EXPERIMENTS

## APPENDIX A

## LIST OF PROGRAM UNITS

| NAME | FUNCTION |
|---|---|
| BRETS | calculates the Bretschneider two-parameter wave elevation spectrum |
| CFTRP | performs a quadratic interpolation |
| DAVID | returns the two-dimensional frequency-dependent velocity potential and its normal derivatives on the body due to a pulsating source of unit strength |
| FINIT | returns the logarithmic terms in the expression of a pulsating source of unit strength |
| FRANK | returns the added mass, damping, and complex amplitudes of exciting forces and moments for each specific hull section |
| GAUSS | solves a set of complex matrix equations using Gaussian elimination |
| PAGE | writes the heading and page number on each page of output |
| PGM1 | returns the geometric and hydrostatic properties of the ship |
| PGM1B | returns absolute and relative motions, velocity, and acceleration as a result of the ship's motions in both regular and irregular seas |
| PGM2 | returns the added mass and damping coefficients |
| PGM2B | returns the cross-flow viscous damping contributions to the damping coefficients and wave exciting forces |
| PRESS | returns the pressures on the cross-section contours |
| REGRES | calculates Gospodnetic-Miles quadratic regression spectrum |
| SEAOUT | returns the probabilities of deck wetness, keel emergence, and box impact in irregular seas and outputs irregular sea calculations |
| SHORT | returns root mean square motions in short-crested seas |
| SIMPUN | evaluates an integral of a nonequidistant function by Simpson's rule |
| SITTC | calculates the ITTC wave spectrum |

| NAME | FUNCTION |
| --- | --- |
| SOLVE | sets up equations of motion and solves them by applying Cramer's rule to complex matrices |
| SPLINE | performs spline curve-fitting calculation used in short-crested sea calculations |
| SWATM2 | main program: reads in input and, as a check, writes out input for verification; sets constants to be used in later calculations according to the system of units specified; initiates execution |
| TAN | returns the tangent of an angle |
| XMAX | returns the maximum value of a specified array |
| XMIN | returns the minimum value of a specified array |

## APPENDIX B

## SWATM2 USER GUIDE

SWATM2 is structured for operation on a DEC-20 computer and may require modification for use on other machines. For example, the DEC-20 does not require initialization of arrays, unlike CDC computers.

The fundamental structure of SWATM2 is illustrated by the block diagram given in Figure B1. There are four main computational blocks:

- hydrostatic calculations;

- hull added mass, damping and exciting force calculations: done for each station over a sufficiently wide frequency range and stored in large arrays;

- frequency response calculations: computation of viscous damping terms, setting up of system matrix, solution of the equations of motion;

- irregular sea calculations: computation of root mean square values of pitch, heave, sway, roll, and yaw in specified seaway spectra.

The computer code for program SWATM2 consists of a main program plus a number of subroutines. The main program handles input and initiates execution while the subroutines are each called to perform appropriate calculations. A description of the computations performed by the individual program units is contained in Appendix A.

### B.1 Input

Program input consists of an alphanumeric title and records of numerical data, the records being in free format. The program reads the input from the disk file SWATM2.DAT. A sample input is given in Appendix B.

Detailed descriptions of the input records are given below.

Record (1), 1 alphanumeric string (FORMAT 10A5)

TITLE alphanumeric title of any length up to a maximum of 100 characters.

Record (2), 6 integers

IFIN indicates whether or not the ship has fins.
IFIN = 0 = > no fins
IFIN = 1 = > fins present

NUN      specifies the system of units used for input/output data.
         NUN = 1 = > British units
         NUN = 2 = > Metric units

ICO      control integer for program output of added mass coefficients.
         ICO = 0 = > suppress output of added mass coefficients
         ICO = 1 = > allow output of added mass coefficients

IEQ      control integer for program output of equations of motion solved, excited forces, and damping coefficients.
         IEQ = 0 = > suppress output of equations of motion solved solved, exciting forces, and damping coefficients
         IEQ = 1 = > allow output of equations of motion solved, exciting forces, and damping coefficients

IREG     control integer for program output of regular wave responses.
         IREG = 0 = > suppress output of regular wave responses
         IREG = 1 = > allow output of regular wave responses

ICHECK   control integer governing program execution with respect to verifying input data.
         ICHECK = 0 = > allow program to execute
         ICHECK = 1 = > suppress execution of program such that the output consists solely of input data. The purpose of this is to permit the user to verify the input data before the program is actually run.

Note: (1) If IFIN = 0, Records (11) and (12) are not read.

<u>Record (3), 7 integers</u>

NFR      number of wave frequencies for which ship motions are to be calculated (rad/sec).
         maximum = 30

NBTA     number of principal sea directions to be considered with respect to ship heading (degrees).
         maximum = 8

NFN      number of Froude numbers for which motions are to be calculated.
         maximum = 4

NWE      number of encounter frequencies for which the hull sectional potentials, added mass, and damping are calculated (rad/sec)
         maximum = 30

NSTR     number of positions at which relative and absolute motions are to be computed for seakeeping calculations.
         maximum = 10

NOS      number of stations for which hull/strut offset information is input.
         maximum = 30

NLOOP    maximum number of iterations for determination of non-linear viscous damping effects. A value of 3 should be adequate.

<u>Notes</u>: (1) A principal sea direction is meant to be the principal direction of wave advance relative to the ship velocity vector.

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(2) For each principal sea direction, the ship responses for regular and irregular seas are determined.

(3) For a short-crested sea spectrum, the spreading function is centered about this angle. A curve-fitting routine (SPLINE) is used to allow motions to be computed over the range determined by the spreading function by interpolation. Thus, for irregular sea calculations, NBTA must be at least 3.

(4) The tables of sectional potentials, added mass, and damping are generated, as a function of encounter frequency, before ship motions are computed. From these tables, particular values are interpolated as necessary, since a given wave frequency, sea direction, and ship speed will define the frequency of encounter. Thus, it is necessary to ensure that the tables adequately cover the required encounter frequency range.

(5) The hull and submerged portion of the strut are represented by stations such that Station 0 occurs at the leading edge of the strut and Station 20 at the trailing edge of the strut. The distance between these stations, which is exactly EL, is divided into even intervals. The hull section forward of Station 0 is divided into evenly spaced stations having negative station numbers while the hull section aft of Station 20 is represented by evenly spaced stations having station numbers of value greater than 20.

(6) One record (19) must be input for each of the NOS stations.

<u>Record (4), 2 reals</u>

WLMIN lowest value of wavelength non dimensionalized by ship length.
WLMAX highest value of wavelength non-dimensionalized by ship length.

<u>Notes:</u> (1) The frequency range for which ship motions are to be calculated is determined by the equation:

$$\omega = \frac{2\pi g}{\lambda} \text{ where } \omega \text{ has units rad/sec}$$

Thus, the lowest wave frequency for which ship motions are to be calculated will occur at WLMAX while the highest wave frequency will occur at WLMIN.

(2) The increment in wave frequency between the minimum and maximum wave frequency is determined in the program by dividing the frequency range by the number of wave frequencies at which ship motions are to be calculated less one (NFR - 1).

(3) Wave encounter frequencies are calculated for each ship speed, heading angle, and wave frequency. The range of wave encounter frequencies is computed by determining the minimum and maximum of all the encounter frequencies with the increment being determined by dividing the difference by the number of wave encounter frequencies less one for which the hull sectional potentials, added mass, and damping are to be calculated (NWE-1).

<u>Record (5), NBTA reals</u>

WANG(I) principle sea directions to be considered relative to the ship velocity vector (degrees). There must be NBTA values.

<u>Note</u>: (1) WANG(I) = 0° for following seas.
WANG(I) = 180° for head seas.

<u>Record (6), NFN reals</u>

FN(I) Froude numbers for which calculations are desired. There must be NFN values.

<u>Note</u>: (1) $F_n = CV/\sqrt{gEL}$ where EL = strut length (station 0 to 20)
V = forward velocity of ship (knots)
C = conversion factor
if British units used: C = 1.689
if Metric units used: C = 0.5144

<u>Record (7), 1 real</u>

SD one-half the distance between the centerlines of the two hulls (i.e. one-half the hull spacing) (m or ft).

<u>Record (8), NSTR reals</u>

RBMST(I) station number of position I where calculations are to be done. There must be NSTR values.

<u>Note</u>: (1) The station numbering convention for RBMST(I) must be consistent with the numbering of the hull; i.e. Station 0.0 is at the leading edge of the strut and Station 20.0 is at the trailing edge of the strut.

<u>Record (9), NSTR reals</u>

RBMHT(I) vertical coordinate (z-coordinate) of position I relative to the calm waterline (m or ft). There must be NSTR values.

Note: (1) The value of RBMHT(I) must be given as the distance from the calm waterline to the point of interest (in the same dimensional unit as EL), with a positive sign indicating a point below. In the program, this vertical coordinate system is changed to become relative to CG.

Record (10), 7 reals

| | |
|---|---|
| EL | strut length (i.e. distance between Station 0.0 and Station 20.0) (m or ft). |
| GYR | pitch and yaw radius of gyration (non-dimensionalized by EL). |
| GYRT | roll radius of gyration (non-dimensionalized by EL). |
| GCB | longitudinal center of bouyancy given in terms of station numbers as measured from Station 0.0. |
| VCG | vertical center of gravity referenced to the waterline, with a positive sign indicating below the waterline and a negative sign indicating above (m or ft). |
| GMT | transverse metacentric height (m or ft). |
| DEPCAT | vertical distance (a positive number) between waterline and maximum breadth point of hull (m or ft). |

Notes: (1) The value of EL is used for non-dimensionalization in the program and should be used in defining the input variables GYR, GYRT, RN(I).

(2) By defining GCB = 0, GCB will be calculated in the program.

(3) By defining GMT = 0, GMT will be calculated in the program.

Records (11) and (12) are not to be input if IFIN = 0. Records (11) and (12) describe the geometry of the allowable arrangement of fins, one pair, A in Record 11, with the second pair, B, in Record 12.

Record (11), 8 reals

| | |
|---|---|
| FAL | longitudinal distance from Station 0.0 to quarter chord of the fin (m or ft). |
| FAY | transverse distance between centerline of the ship and the centroid of the fin (m or ft). |
| DEPA | vertical distance between waterline and mean depth of the fin (m or ft). |
| CHRDA | chord of the fin (m or ft). |
| SPNA | geometric span of the fin (m or ft). |
| THKA | maximum thickness of the fin (m or ft). |
| CLFA | lift-curve slope of the fin ($rad^{-1}$). |
| XZFA | drag coefficient of the fin. |

Notes: (1) If the fin is full-span (i.e. spans the entire distance between hulls), then SPNA is defined as one-half that distance.

(2) XZFA may be approximated by 1.2, the value for a flat plate attached to a wall in a uniform flow normal to the plate.

(3) CLFA can be calculated as follows:

Lift Curve Slope for Fins[11]

$$\text{CLFA} = \text{lift curve slope} = \frac{1.8\pi A_e}{1.8 + \sqrt{(A_e)^2 + 4}} \text{ per radian}$$

$$\text{where } A_e = \frac{r_o - r^2/r^2{}_o}{\text{avg. chord}}$$

where r - radius of submerged hull cross-section at which the fin is attached.

$r_o$ - is the transverse distance from the centre line of the hull to the tip of the fin.

$A_e$ - effective aspect ratio.

Record (12), 8 reals

FBL
FBY
DEPB
CHRDB
SPNB
THKB
CLFB
XZFB

Notes: (1) These are the data for Fin B.

(2) The descriptions are the same as for the input of Record (11).

Record (13), 2 reals

XZFO hull cross-flow drag coefficient.
XZVL hull viscous-lift coefficient.

Note: (1) For a SWATH with circular hull cross sections, XZFO is defined as 0.5 and XZVL is defined as 0.07.

Record (14), 1 integer

ISPEC — control integer specifying the seaway spectrum to be used for motion calculations in irregular seaways.
ISPEC = 0 = > no irregular sea calculations desired
ISPEC = 1 = > Quadratic regression spectrum (Gospodnetic-Miles)
ISPEC = 2 = > Bretschneider two parameter spectrum
ISPEC = 3 = > ITTC sea spectrum
ISPEC = 4 = > seaway spectrum must be input

Notes: (1) If motions in irregular seas are not desired, set ISPEC = 0. If ISPEC = 0, no Records (15) - (19) are read.

(2) If unique spectrum is desired (i.e. ISPEC = 4), the wave energy spectrum values (S(ω)) must be read in for each corresponding wave frequency (ω). These are input as Record 16.

Records (15), (16), (17), (18), (19) are not input if ISPEC = 0

Record (15), 1 integer

NSEA — number of seaways for which motions are to be computed maximum = 10.

Note: (1) For NSEA > 0, one record (18) is required for each seaway.

Record (16) is input only if ISPEC = 4.

Record (16), NFR reals

SW(N,I) — wave energy value obtained from the unique sea spectrum corresponding to the $i^{th}$ wave frequency used in the program. There must be NFR values.

Note: (1) Record (16) is repeated NSEA times, once for each seaway.

Record (17), 1 real

ANGLE — spreading angle to be used in a short-crested sea spectrum analysis (degrees). If ANGLE ≤ 0.0, no short-crested analysis is carried out.

Note: (1) If ANGLE > 0.0, a short-crested sea spectrum is considered by applying a spreading function about the principal sea direction, with motions computed over a range of angles, in 5° steps, from WANG - ANGLE to WANG + ANGLE.

where WANG = principal sea direction (read from Record (5)).

ANGLE = specified spreading angle.

For example, by specifying WANG = 90° and ANGLE = 15°, a spreading function is applied to responses computed at sea directions of 75°, 80°, 85°, 90°, 95°, 100°, 105°. Naturally, as the value of ANGLE is increased, computation time will increase.

<u>Record (18), 2 reals</u>

HSW(I) significant wave height of seaway I (m or ft).
TSW(I) average wave period of seaway I (sec).
ISPEC = 1: energy-averaged period of seaway I (sec)
ISPEC = 2: modal wave period of seaway I (sec)
ISPEC = 3: average zero-crossing period of seaway I (sec)
ISPEC = 4: energy-averaged period of seaway I (sec)

<u>Notes</u>: (1) If guidance is required in selecting modal wave period, Table B1 provides the probability distribution of seastate parameters for the North Atlantic. Alternatively, standard TSW/HSW formulations may be used, such as the following:
ISPEC = 1, 2, 4 = > $TSW = 6.17 + 5(HSW/g)^{1/2}$
ISPEC = 3 = > $TSW = 1.96\ HSW^{1/2}$

(2) For the ITTC spectrum only, the following relationships may be used:

$T_o = 1.406\ T_Z$
$T_1 = 1.087\ T_Z$
$T_o = 1.166\ T_{-1}$

(3) Record (18) is repeated NSEA times, once for each seaway.

<u>Record (19), 3 reals</u>

FREEB(I) freeboard at position I (m or ft).
BXCL(I) box clearance at position I (m or ft).
FFACT (I) box slam pressure form factor at position I.

<u>Note</u>: (1) Record (19) is repeated NSTR times, once for each desired position.
(2) The default value of form factor, k= 20.0, is set if FFACT(I) = 0.0

<u>Record (20), 1 real, 2 integers</u>

ST(I) station number of the $I^{th}$ displacement station of the ship.
MN(I) number of offset points used to describe the $I^{th}$ station.
$3 \leq NM(I) \leq 20$.

MPS(I) indicates location of parallel middle body.
MPS(I) = 2 => first station of parallel middle body
MPS(I) = 1 => each station, following the first station of parallel middle body, that is part of the parallel middle body
MPS(I) = 0 => station is not part of the parallel middle body

Notes: (1) The stations corresponding to ST(1), ST(I) = 0., ST(I) = 10., ST(I) = 20., and ST(NOS) must be given.

(2) ST(I) = 0. is located at the leading edge of the strut while ST(I) - 20. is located at the trailing edge of the strut. Thus, the distance between ST(I) = 0. and ST(I) = 20. corresponds to the distance EL (i.e. the strut length). The value of ST(I) will be negative if the station is forward of Station 0 and greater than 20.0 if the station is aft of Station 20.

(3) The stations should be evenly spaced between Station 0 and Station 20. The stations at the nose (forward of Station 0) and at the tail (aft of Station 20) need not have the same spacing as between Station 0 and Station 20. They should be given as, at least, pairs of even intervals.

(4) MPS(I) is used to avoid costly repetition of the calculation of added mass and damping coefficients.

(5) Record (20) is repeated NOS times, once for each station.

Record (21), NM reals

X(I,J) values of the X-coordinates of the offsets of the immersed cross-sectional contour (i.e. horizontal offsets) at Station (I) (m or ft).
$1 \leq I \leq NOS$
$1 \leq J \leq NM$

Record (22), NM reals

Y(I,J) values of the Y-coordinates of the points corresponding to X(I,J) (i.e. vertical offsets of Station (I)) (m or ft). Refer to Figures B2 to B4 in reading the following notes.
$1 \leq I \leq NOS$
$1 \leq J \leq NM$

Notes: (1) The origin of the X-Y coordinate system is at the point of maximum draft at the longitudinal centerplane of one hull.

(2) The vertical offsets are input as heights above the hull baseline.

(3) All offsets must be input in a counter-clockwise direction. There are basically three different transverse section configurations: (1) completely submerged hull cross-section; (2) hull cross-section with attached strut; and (3) hull cross-section with overhanging strut.

Configuration 1: Completely submerged hull cross-section (no strut present). The first offset point must be at the intersection of the longitudinal plane of symmetry of the hull with the station contour closest to the surface (i.e. at the point where the y-coordinate is maximum). The last offset point must also be this point in order to close out the curve.

Configuration 2: Hull cross-section with attached strut. The first offset point must be at the intersection of the station contour at starboard with the design waterline, while the last offset point must be at the intersection of the design waterline with the station contour at port. Note that the program will close out the curve so that the areas can be determined.

Configuration 3: Hull cross-section with overhanging strut (i.e. strut not attached to the hull at the station). The first offset point must be at the intersection of the overhanging strut contour at starboard with the design waterline. Offsets are then read in counter-clockwise around the strut contour until it intersects with the longitudinal centerplane of the strut. Next, offsets are input down the longitudinal centerplane until it intersects with the hull contour. Offsets are then input counter-clockwise around the hull contour until the first offset on the hull is reached again. Next, offsets are read up the longitudinal centerplane (i.e. the same points as before) until it intersects with the overhanging strut contour. Finally, the strut offsets are input counter-clockwise around the strut up to the point where it intersects the design waterline on port. This is the last offset point.

Refer to Figure 2 and to Section 5.

(4) Records (21) and (22) are repeated NOS times once for each station. Note that all the x-coordinates for Station (I) are input followed by all the corresponding y-coordinates for Station (I); that is, the offsets are not read in coordinate pairs.

## B.2 Output

This section describes the output in order of appearance on the printout. This may be compared with the sample output given in Appendix C.

(a) Input data. First, information is given regarding input records (1) to (20). Following this, the hull offsets are listed according to each station. These input data are printed for checking purposes.

(b) Hydrostatic calculations. Beam, draft, area coefficient, and critical encounter frequency are given for each station followed by the hydrostatic data for one hull. These data include the ship's strut length, beam and draft at midships, displacement, block coefficient, longitudinal and vertical center of buoyancy, longitudinal center of flotation, radius of gyration, and the transverse metacentric height. Also calculated and displayed here are the heave/pitch restoring coefficients, the moment of inertia, and the projected area of the submerged hull.

(c) Regular Wave Calculations. This portion of the output begins with a reference table which describes scaling factors used by the program. If the control variable ICO is set equal to 1, the added mass coefficients are listed along with the corresponding encounter frequencies. For each specified ship speed (i.e. Froude number), the appropriate table of added mass coefficients is output. This output may be suppressed by setting ICO = 0. If the control variable IEQ is set equal to 1, the equations of motion solved are given for each ship speed and heading angle. This is followed by the damping coefficients and then the exciting forces, moments and phases for each ship speed and heading angle. Also listed are wave frequency, encounter frequency, and the ratios ship length divided by wavelength and the inverse, wavelength divided by ship length. This allows the user greater flexibility in choosing the appropriate base values for making plots. This section of output may be suppressed by setting IEQ = 0. If the control variable IREG is set equal to 1, the regular frequency responses (i.e. motion amplitudes and phases) are output for each ship speed and wave heading angle. Again, the same selection of base values are given to facilitate comparisons. Also output are the relative and absolute displacements, velocities, and accelerations at a specified height above the waterline for each desired station along the ship. This is repeated for each ship speed and for each heading angle. By setting IREG = 0, the output of the regular responses is suppressed.

(d) Irregular Sea Calculations. The remainder of the output presents the results of irregular sea calculations. For each of the seaways specified and for each ship speed and principal heading angle, seakeeping data are given for unidirectional and short-crested seas. First, RMS values of ship translational and rotational motions are given; specifically sway acceleration, heave displacement and acceleration, roll, pitch, and yaw. Next are listed the results of seakeeping calculations for each specified position along the ship at a particular height above the waterline. These include

- RMS absolute heave motion, velocity, and acceleration;
- RMS relative heave motion and velocity;
- vibration ride quality index;
- probability of deck wetness and number of deck wetnesses per hour;
- probability of keel emergence and number of keel emergences per hour;
- probability of box impact and number of box impacts per hour.
- most probable slam pressure in a 20 hour period of operation.
- extreme slam pressure with 1 percent probability of exceedence in a 20 hour period of operation.

| SIGNIFICANT WAVEHEIGHT (H) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13.0 | | | | | | | | | | | | .1 | |
| 11.0 | | | | | | | | | | | .2 | .2 | |
| 9.5 | | | | | | | | | | .1 | .2 | .1 | |
| 8.5 | | | | | | | | | .2 | .5 | .2 | .2 | |
| 7.5 | | | | | | | | .2 | .6 | .6 | .3 | .2 | |
| 6.5 | | | | | | | | 1.0 | .8 | .7 | .3 | .2 | |
| 5.5 | | | | | | | .5 | 2.3 | 1.0 | .8 | .4 | .2 | |
| 4.5 | | | | | | .5 | 2.4 | 2.6 | 1.0 | .8 | .4 | .2 | .1 |
| 3.5 | | | | | .6 | 3.5 | 3.0 | 2.6 | 1.1 | .8 | .5 | .3 | .1 |
| 2.5 | | | | 1.7 | 4.2 | 4.4 | 2.9 | 2.3 | 1.2 | 1.0 | .6 | .3 | .1 |
| 1.5 | | .2 | 3.0 | 5.1 | 4.2 | 4.1 | 2.8 | 2.6 | 1.2 | 1.3 | .7 | .4 | .1 |
| 0.5 | .4 | .3 | 4.2 | 4.3 | 3.0 | 3.7 | 2.0 | 2.0 | .9 | 1.0 | .5 | .2 | |
| | 3.2 | 4.8 | 6.3 | 7.5 | 8.8 | 9.7 | 10.9 | 12.4 | 13.8 | 15.0 | 16.4 | 18.0 | 20.0 |

MODAL WAVE PERIOD (SEC)

TABLE B1: SIGNIFICANT WAVE HEIGHT BY MODEL WAVE PERIOD - ANNUAL PERCENTAGE OCCURRENCE IN THE NORTH ATLANTIC (FROM REFERENCE 12)

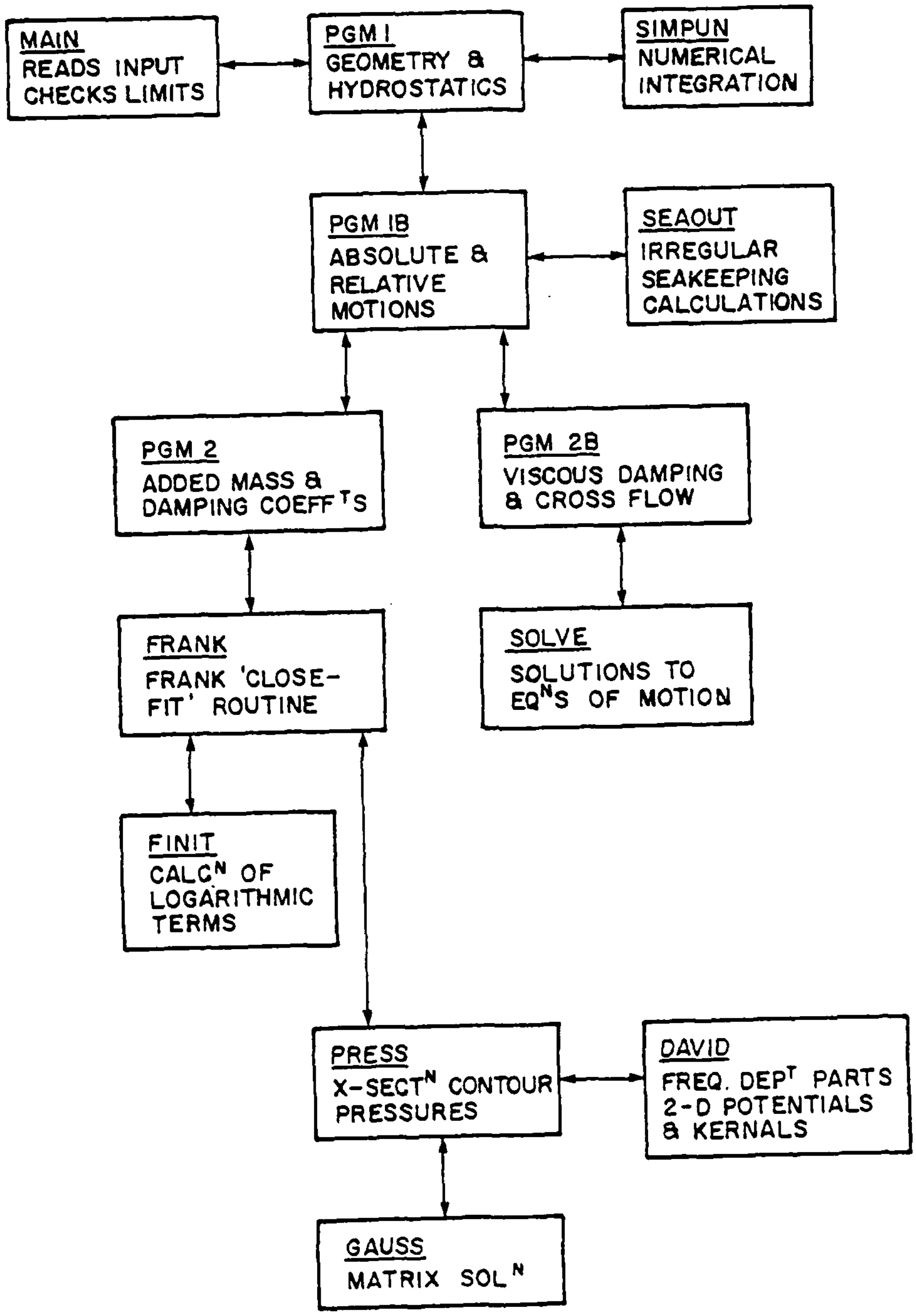


FIGURE B1: SWATM2 BLOCK DIAGRAM

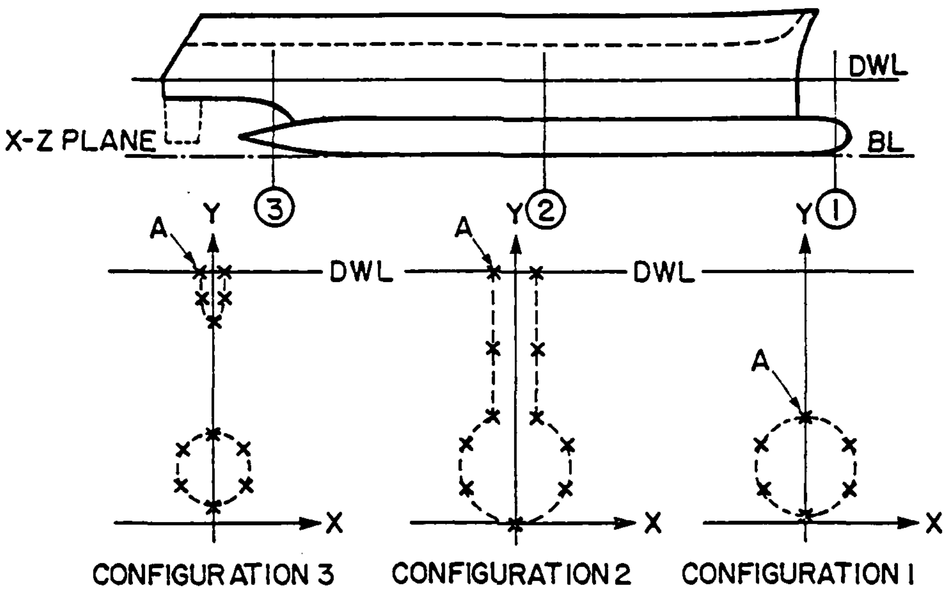


FIGURE B2: SWATM2 OFFSET DESCRIPTION

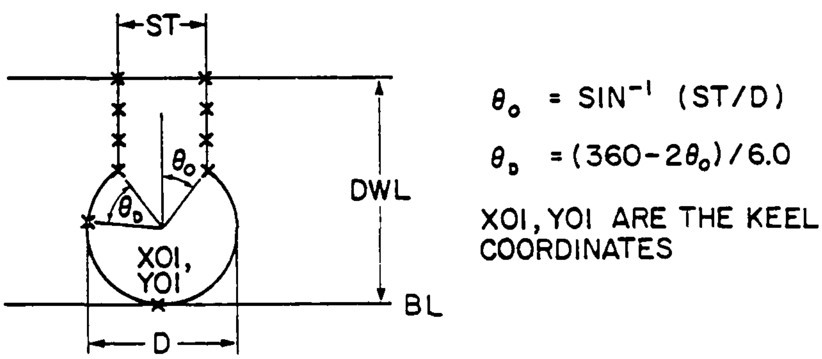


FIGURE B3: OFFSET TRIGONOMETRIC RELATIONSHIPS

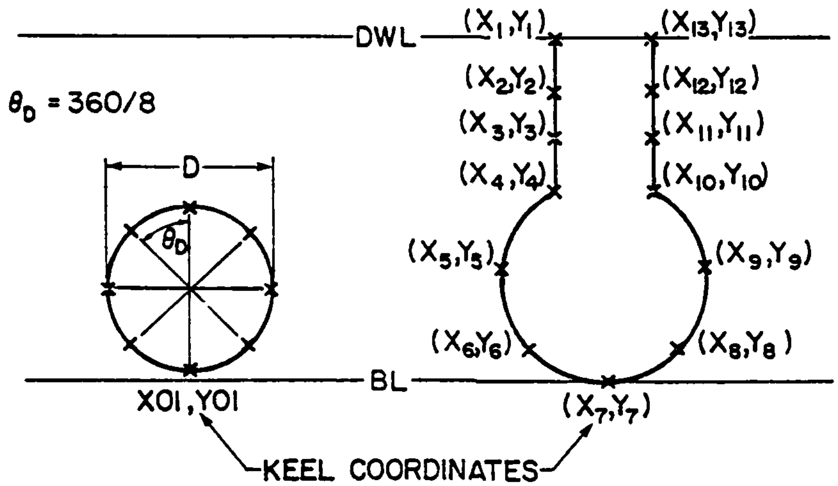


FIGURE B4: ARRANGEMENT OF OFFSET COORDINATES

## APPENDIX C

## SAMPLE INPUT FOR SWATM 2

This input represents SWATH 6A in bow seas. For directional seas, it is necessary to specify a range of unidirectional headings, typically 0 to 180 degrees in steps of 30 degrees. This has not been done here to save space.

```
SWATH 6A REGULAR WAVE TEST CASE
  1  1  1  1  1  0
  25   1   1  25   1   22   3
  1.5  10.0
  135.
  0.4537
  37.5
10.27278
7.330
 172.3      0.315   0.223     0.0         7.44       15.00      19.17
  40.44      25.75     19.17     8.5       10.2        1.28       4.38       1.2
 188.12      23.55     19.17    14.7       17.6        2.2        3.43       1.2
   0.5       0.07
   0
  -2.4         9         0
  -1.6         9         0
   -.8         9         0
   0.0         9         0
   1.0        15         0
   2.0        15         0
   3.0        15         0
   4.0        15         0
   6.0        15         2
   8.0        15         1
  10.0        15         1
  12.0        15         1
  14.0        15         1
  16.0        15         0
  17.0        15         0
  18.0        15         0
  19.0        15         0
  20.0         9         0
  21.5         9         0
  23.0         9         0
  23.8         9         0
  24.6         9         0
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0. | -3.44 | -4.87 | -3.44 | 0. | 3.44 | 4.87 | 3.44 |
| 0. | | | | | | | |
| 12.37 | 10.94 | 7.50 | 4.06 | 2.63 | 4.06 | 7.50 | 10.94 |
| 12.37 | | | | | | | |
| 0. | -4.23 | -5.98 | -4.23 | 0. | 4.23 | 5.98 | 4.23 |
| 0. | | | | | | | |
| 13.48 | 11.73 | 7.50 | 3.27 | 1.52 | 3.27 | 7.50 | 11.73 |
| 13.48 | | | | | | | |
| 0. | -4.70 | -6.65 | -4.70 | 0. | 4.70 | 6.65 | 4.70 |
| 0. | | | | | | | |
| 14.15 | 12.20 | 7.50 | 2.80 | 0.85 | 2.80 | 7.50 | 12.20 |
| 14.15 | | | | | | | |
| 0. | -5.06 | -7.16 | -5.06 | 0. | 5.06 | 7.16 | 5.06 |
| 0. | | | | | | | |
| 14.66 | 12.56 | 7.50 | 2.44 | 0.34 | 2.44 | 7.50 | 12.56 |
| 14.66 | | | | | | | |
| -1.06 | -1.06 | -1.06 | -1.06 | -4.89 | -7.47 | -5.28 | 0. |
| 5.28 | 7.47 | 4.89 | 1.06 | 1.06 | 1.06 | 1.06 | |
| 26.67 | 22.74 | 18.82 | 14.89 | 13.14 | 7.50 | 2.22 | 0.03 |
| 2.22 | 7.50 | 13.14 | 14.89 | 18.82 | 22.74 | 26.67 | |
| -2.17 | -2.17 | -2.17 | -2.17 | -4.47 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 4.47 | 2.17 | 2.17 | 2.17 | 2.17 | |
| 26.67 | 22.67 | 18.68 | 14.68 | 13.52 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.52 | 14.68 | 18.68 | 22.67 | 26.67 | |
| -3.01 | -3.01 | -3.01 | -3.01 | -4.11 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 4.11 | 3.01 | 3.01 | 3.01 | 3.01 | |
| 26.67 | 22.57 | 18.47 | 14.37 | 13.78 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.78 | 14.37 | 18.47 | 22.57 | 26.67 | |
| -3.41 | -3.41 | -3.41 | -3.41 | -3.92 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.92 | 3.41 | 3.41 | 3.41 | 3.41 | |
| 26.67 | 22.51 | 18.34 | 14.18 | 13.90 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.90 | 14.18 | 18.34 | 22.51 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |

```
  2.20     7.50    13.96    14.07    18.27    22.47    26.67
 -3.48    -3.48    -3.48    -3.48    -3.88    -7.50    -5.30     0.
  5.30     7.50     3.88     3.48     3.48     3.48     3.48
 26.67    22.49    18.32    14.14    13.92     7.50     2.20     0.
  2.20     7.50    13.92    14.14    18.32    22.49    26.67
 -3.12    -3.12    -3.12    -3.12    -4.05    -7.50    -5.30     0.
  5.30     7.50     4.05     3.12     3.12     3.12     3.12
 26.67    22.55    18.43    14.32    13.81     7.50     2.20     0.
  2.20     7.50    13.81    14.32    18.43    22.55    22.67
 -2.43    -2.43    -2.43    -2.43    -4.31    -7.42    -5.25     0.
  5.25     7.42     4.31     2.43     2.43     2.43     2.43
 26.67    22.62    18.57    14.52    13.55     7.50     2.25     0.08
  2.25     7.50    13.55    14.52    18.57    22.62    26.67
 -1.43    -1.43    -1.43    -1.43    -4.56    -7.21    -5.10     0.
  5.10     7.21     4.56     1.43     1.43     1.43     1.43
 26.67    22.63    18.60    14.56    13.08     7.50     2.40     0.29
  2.40     7.50    13.08    14.56    18.60    22.63    26.67
  0.      -4.81    -6.80    -4.81     0.       4.81     6.80     4.81
  0.
 14.30    12.31     7.50     2.69     0.70     2.69     7.50    12.31
 14.30
  0.      -4.22    -5.97    -4.22     0.       4.22     5.97     4.22
  0.
 13.47    11.72     7.50     3.28     1.53     3.28     7.50    11.72
 13.47
  0.      -3.33    -4.71    -3.33     0.       3.33     4.71     3.33
  0.
 12.21    10.83     7.50     4.17     2.79     4.17     7.50    10.83
 12.21
  0.      -2.32    -3.28    -2.32     0.       2.32     3.28     2.32
  0.
 10.78     9.82     7.50     5.18     4.22     5.18     7.50     9.82
 10.78
  0.      -1.06    -1.50    -1.06     0.       1.06     1.50     1.06
  0.
  9.00     8.56     7.50     6.44     6.00     6.44     7.50     8.56
  9.00
@
```

## APPENDIX D

## SAMPLE OUTPUT FOR SWATM2

This output was generated using the input file in Appendix C, on a DEC 20-60 computer.

THE FOLLOWING



PAGES

```
SWATMO   SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE                                  PAGE    1

SYSTEM OF UNITS USED : BRITISH

 SWATH 6A IRREGULAR WAVE TEST CASE
     1     1     1     1     1     0
    25     1     1    25     1    22     3
    1.50000  10.00000
  135.00000
    0.45370
   37.50000
    4.00000
   50.00000
  172.30000    0.31500    0.22300    0.00000    7.44000   15.00000   19.17000
   40.44000   25.75000   19.17000    8.50000   10.20000    1.28000    4.38000    1.20000
  188.12000   23.55000   19.17000   14.70000   17.60000    2.20000    3.43000    1.20000
    0.50000    0.07000
    2
    1
  0.0000
 18.0000    9.9100
   34.00000  20.00000    0.00000
   -2.4000         9         0
   -1.6000         9         0
   -0.8000         9         0
    0.0000         9         0
    1.0000        15         0
    2.0000        15         0
    3.0000        15         0
    4.0000        15         0
    6.0000        15         2
    8.0000        15         1
   10.0000        15         1
   12.0000        15         1
   14.0000        15         1
   16.0000        15         0
   17.0000        15         0
   18.0000        15         0
   19.0000        15         0
   20.0000         9         0
   21.5000         9         0
   23.0000         9         0
   23.8000         9         0
   24.6000         9         0


SWATMO   SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE                                  PAGE    2

                                          STATION    -2.4000
  0.0000   -3.4400   -4.8700   -3.4400    0.0000    3.4400    4.8700    3.4400    0.0000
 12.3700   10.9400    7.5000    4.0600    2.6300    4.0600    7.5000   10.9400   12.3700

                                          STATION    -1.6000
  0.0000   -4.2300   -5.9800   -4.2300    0.0000    4.2300    5.9800    4.2300    0.0000
 13.4800   11.7300    7.5000    3.2700    1.5200    3.2700    7.5000   11.7300   13.4800

                                          STATION    -0.8000
  0.0000   -4.7000   -6.6500   -4.7000    0.0000    4.7000    6.6500    4.7000    0.0000
 14.1500   12.2000    7.5000    2.8000    0.8500    2.8000    7.5000   12.2000   14.1500

                                          STATION     0.0000
  0.0000   -5.0600   -7.1600   -5.0600    0.0000    5.0600    7.1600    5.0600    0.0000
 14.6600   12.5600    7.5000    2.4400    0.3400    2.4400    7.5000   12.5600   14.6600

                                          STATION     1.0000
 -1.0600   -1.0600   -1.0600   -1.0600   -4.8900   -7.4700   -5.2800    0.0000    5.2800    7.4700
  4.8900    1.0600    1.0600    1.0600    1.0600
 26.6700   22.7400   18.8200   14.8900   13.1400    7.5000    2.2200    0.0300    2.2200    7.5000
 13.1400   14.8900   18.8200   22.7400   26.6700

                                          STATION     2.0000
 -2.1700   -2.1700   -2.1700   -2.1700   -4.4700   -7.5000   -5.3000    0.0000    5.3000    7.5000
  4.4700    2.1700    2.1700    2.1700    2.1700
 26.6700   22.6700   18.6800   14.6800   13.5200    7.5000    2.2000    0.0000    2.2000    7.5000
 13.5200   14.6800   18.6800   22.6700   26.6700

                                          STATION     3.0000
 -3.0100   -3.0100   -3.0100   -3.0100   -4.1100   -7.5000   -5.3000    0.0000    5.3000    7.5000
  4.1100    3.0100    3.0100    3.0100    3.0100
 26.6700   22.5700   18.4700   14.3700   13.7800    7.5000    2.2000    0.0000    2.2000    7.5000
 13.7800   14.3700   18.4700   22.5700   26.6700

                                          STATION     4.0000
 -3.4100   -3.4100   -3.4100   -3.4100   -3.9200   -7.5000   -5.3000    0.0000    5.3000    7.5000
  3.9200    3.4100    3.4100    3.4100    3.4100
 26.6700   22.5100   18.3400   14.1800   13.9000    7.5000    2.2000    0.0000    2.2000    7.5000
 13.9000   14.1800   18.3400   22.5100   26.6700

                                          STATION     6.0000
 -3.6300   -3.6300   -3.6300   -3.6300   -3.8100   -7.5000   -5.3000    0.0000    5.3000    7.5000
  3.8100    3.6300    3.6300    3.6300    3.6300
 26.6700   22.4700   18.2700   14.0700   13.9600    7.5000    2.2000    0.0000    2.2000    7.5000
 13.9600   14.0700   18.2700   22.4700   26.6700

                                          STATION     8.0000
 -3.6300   -3.6300   -3.6300   -3.6300   -3.8100   -7.5000   -5.3000    0.0000    5.3000    7.5000
  3.8100    3.6300    3.6300    3.6300    3.6300
 26.6700   22.4700   18.2700   14.0700   13.9600    7.5000    2.2000    0.0000    2.2000    7.5000
 13.9600   14.0700   18.2700   22.4700   26.6700
```

STATION 10.0000

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -3.6300 | -3.6300 | -3.6300 | -3.6300 | -3.8100 | -7.5000 | -5.3000 | 0.0000 | 5.3000 | 7.5000 |
| 3.8100 | 3.6300 | 3.6300 | 3.6300 | 3.6300 | | | | | |
| 26.6700 | 22.4700 | 18.2700 | 14.0700 | 13.9600 | 7.5000 | 2.2000 | 0.0000 | 2.2000 | 7.5000 |
| 13.9600 | 14.0700 | 18.2700 | 22.4700 | 26.6700 | | | | | |

STATION 12.0000

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -3.6300 | -3.6300 | -3.6300 | -3.6300 | -3.8100 | -7.5000 | -5.3000 | 0.0000 | 5.3000 | 7.5000 |
| 3.8100 | 3.6300 | 3.6300 | 3.6300 | 3.6300 | | | | | |
| 26.6700 | 22.4700 | 18.2700 | 14.0700 | 13.9600 | 7.5000 | 2.2000 | 0.0000 | 2.2000 | 7.5000 |
| 13.9600 | 14.0700 | 18.2700 | 22.4700 | 26.6700 | | | | | |

STATION 14.0000

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -3.6300 | -3.6300 | -3.6300 | -3.6300 | -3.8100 | -7.5000 | -5.3000 | 0.0000 | 5.3000 | 7.5000 |
| 3.8100 | 3.6300 | 3.6300 | 3.6300 | 3.6300 | | | | | |
| 26.6700 | 22.4700 | 18.2700 | 14.0700 | 13.9600 | 7.5000 | 2.2000 | 0.0000 | 2.2000 | 7.5000 |
| 13.9600 | 14.0700 | 18.2700 | 22.4700 | 26.6700 | | | | | |

STATION 16.0000

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -3.4800 | -3.4800 | -3.4800 | -3.4800 | -3.8800 | -7.5000 | -5.3000 | 0.0000 | 5.3000 | 7.5000 |
| 3.8800 | 3.4800 | 3.4800 | 3.4800 | 3.4800 | | | | | |
| 26.6700 | 22.4900 | 18.3200 | 14.1400 | 13.9200 | 7.5000 | 2.2000 | 0.0000 | 2.2000 | 7.5000 |
| 13.9200 | 14.1400 | 18.3200 | 22.4900 | 26.6700 | | | | | |

STATION 17.0000

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -3.1200 | -3.1200 | -3.1200 | -3.1200 | -4.0500 | -7.5000 | -5.3000 | 0.0000 | 5.3000 | 7.5000 |
| 4.0500 | 3.1200 | 3.1200 | 3.1200 | 3.1200 | | | | | |
| 26.6700 | 22.5500 | 18.4300 | 14.3200 | 13.8100 | 7.5000 | 2.2000 | 0.0000 | 2.2000 | 7.5000 |
| 13.8100 | 14.3200 | 18.4300 | 22.5500 | 22.6700 | | | | | |

STATION 18.0000

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -2.4300 | -2.4300 | -2.4300 | -2.4300 | -4.3100 | -7.4200 | -5.2500 | 0.0000 | 5.2500 | 7.4200 |
| 4.3100 | 2.4300 | 2.4300 | 2.4300 | 2.4300 | | | | | |
| 26.6700 | 22.6200 | 18.5700 | 14.5200 | 13.5500 | 7.5000 | 2.2500 | 0.0800 | 2.2500 | 7.5000 |
| 13.5500 | 14.5200 | 18.5700 | 22.6200 | 26.6700 | | | | | |

STATION 19.0000

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| -1.4300 | -1.4300 | -1.4300 | -1.4300 | -4.5600 | -7.2100 | -5.1000 | 0.0000 | 5.1000 | 7.2100 |
| 4.5600 | 1.4300 | 1.4300 | 1.4300 | 1.4300 | | | | | |
| 26.6700 | 22.6300 | 18.6000 | 14.5600 | 13.0800 | 7.5000 | 2.4000 | 0.2900 | 2.4000 | 7.5000 |
| 13.0800 | 14.5600 | 18.6000 | 22.6300 | 26.6700 | | | | | |

STATION 20.0000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.0000 | -4.8100 | -6.8000 | -4.8100 | 0.0000 | 4.8100 | 6.8000 | 4.8100 | 0.0000 |
| 14.3000 | 12.3100 | 7.5000 | 2.6900 | 0.7000 | 2.6900 | 7.5000 | 12.3100 | 14.3000 |

STATION 21.5000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.0000 | -4.2200 | -5.9700 | -4.2200 | 0.0000 | 4.2200 | 5.9700 | 4.2200 | 0.0000 |
| 13.4700 | 11.7200 | 7.5000 | 3.2800 | 1.5300 | 3.2800 | 7.5000 | 11.7200 | 13.4700 |

STATION 23.0000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.0000 | -3.3300 | -4.7100 | -3.3300 | 0.0000 | 3.3300 | 4.7100 | 3.3300 | 0.0000 |
| 12.2100 | 10.8300 | 7.5000 | 4.1700 | 2.7900 | 4.1700 | 7.5000 | 10.8300 | 12.2100 |

SWATMO SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE PAGE 4

STATION 23.8000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.0000 | -2.3200 | -3.2800 | -2.3200 | 0.0000 | 2.3200 | 3.2800 | 2.3200 | 0.0000 |
| [illegible] | 9.8200 | 7.5000 | 5.1800 | 4.2200 | 5.1800 | 7.5000 | 9.8200 | 10.7800 |

STATION 24.6000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.0000 | -1.0600 | -1.5000 | -1.0600 | 0.0000 | 1.0600 | 1.5000 | 1.0600 | 0.0000 |
| 9.0000 | 8.5600 | 7.5000 | 6.4400 | 6.0000 | 6.4400 | 7.5000 | 8.5600 | 9.0000 |

| STATION | BEAM | DRAFT | AREA COEFFICIENT |
|---|---|---|---|
| -2.4000 | 0.0000 | 9.7400 | 0.8316 |
| -1.6000 | 0.0000 | 11.9600 | 0.8339 |
| -0.8000 | 0.0000 | 13.3000 | 0.8326 |
| 0.0000 | 0.0000 | 14.3200 | 0.8324 |
| 1.0000 | 2.1200 | 26.6400 | 3.5199 |
| 2.0000 | 4.3400 | 26.6700 | 1.9624 |
| 3.0000 | 6.0200 | 26.6700 | 1.5386 |
| 4.0000 | 6.8200 | 26.6700 | 1.3572 |
| 6.0000 | 7.2600 | 26.6700 | 1.3532 |
| 8.0000 | 7.2600 | 26.6700 | 1.3532 |
| 10.0000 | 7.2600 | 26.6700 | 1.3532 |
| 12.0000 | 7.2600 | 26.6700 | 1.3532 |
| 14.0000 | 7.2600 | 26.6700 | 1.3532 |
| 16.0000 | 6.9600 | 26.6700 | 1.3919 |
| 17.0000 | 6.2400 | 26.6700 | 1.4238 |
| 18.0000 | 4.8600 | 26.5900 | 1.7806 |
| 19.0000 | 2.8600 | 26.3800 | 2.6034 |
| 20.0000 | 0.0000 | 13.6000 | 0.8339 |
| 21.5000 | 0.0000 | 11.9400 | 0.8328 |
| 23.0000 | 0.0000 | 9.4200 | 0.8331 |
| 23.8000 | 0.0000 | 6.5600 | 0.8338 |
| 24.6000 | 0.0000 | 3.0000 | 0.8323 |

CRITICAL ENC. FREQ. FOR STATION -2.4000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION -1.6000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION -0.8000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION 0.0000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION 1.0000 = 15.9790
CRITICAL ENC. FREQ. FOR STATION 2.0000 = 11.1679
CRITICAL ENC. FREQ. FOR STATION 3.0000 = 9.4824
CRITICAL ENC. FREQ. FOR STATION 4.0000 = 8.9089
CRITICAL ENC. FREQ. FOR STATION 6.0000 = 8.6347
CRITICAL ENC. FREQ. FOR STATION 8.0000 = 8.6347
CRITICAL ENC. FREQ. FOR STATION 10.0000 = 8.6347
CRITICAL ENC. FREQ. FOR STATION 12.0000 = 8.6347
CRITICAL ENC. FREQ. FOR STATION 14.0000 = 8.6347
CRITICAL ENC. FREQ. FOR STATION 16.0000 = 8.8189
CRITICAL ENC. FREQ. FOR STATION 17.0000 = 9.3138
CRITICAL ENC. FREQ. FOR STATION 18.0000 = 10.5536
CRITICAL ENC. FREQ. FOR STATION 19.0000 = 13.7573
CRITICAL ENC. FREQ. FOR STATION 20.0000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION 21.5000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION 23.0000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION 23.8000 = 0.0000
CRITICAL ENC. FREQ. FOR STATION 24.6000 = 0.0000

MINIMUM CRITICAL ENC. FREQ. = 0.0000 DUE TO STATION 24.6000



***DATA FOR ONE HULL***

LENGTH BETWEEN PERPENDICULARS = 172.30000 FEET
BEAM AT MIDSHIP = 7.26000 FEET
DRAFT AT MIDSHIP = 26.67000 FEET
DISPLACEMENT = 1347.067 LONG TONS
BLOCK COEFFICIENT = 1.44947
LONGITUDINAL CENTER OF BUOYANCY = 88.26141 FEET AFT OF F.P.
LONGITUDINAL CENTER OF BUOYANCY = 10.24509 STATIONS ' LEADING EDGE OF STRUT
LONGITUDINAL CENTER OF FLOTATION = 86.77538 FEET AFT OF F.P.
LONGITUDINAL CENTER OF FLOTATION = 10.07259 STATIONS ' LEADING EDGE OF STRUT
VERTICAL CENTER OF BUOYANCY = 16.03670 FEET FROM THE DESIGNED LOAD WATERLINE
RADIUS OF GYRATION/L.B.P. = 0.31500
TRANSVERSE METACENTRIC HEIGHT = 15.00000 FEET
BEAM/DRAFT = 0.27222
LENGTH/BEAM = 23.73278

THE HEAVE-HEAVE RESTORING COEFFICIENT IS 3.66354
THE HEAVE-PITCH RESTORING COEFFICIENT IS -0.03160
THE PITCH-PITCH RESTORING COEFFICIENT IS 0.16751

PROJECTED AREA OF THE SUBMERGED HULL/L**2 = 0.108621E+00
MOMENT/L**3 = 0.166009E-02    MOMENT OF INERTIA/L**4 = 0.146022E-01

HULL SEPARATION/BEAM = 9.3306

SWATMO   SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE   PAGE 7

DYNAMIC COEFFICIENTS OF THE EQUATIONS OF MOTION

A22 AND A33 ARE SCALED BY M.
A24,A26,A62,A35,AND A53 ARE SCALED BY M*L.
A44,A46,A64,A66,AND A55 ARE SCALED BY M*L*L.
B22 AND B33 ARE SCALED BY M*SQRT(G/L).
B24,B26,B62,B35,AND B53 ARE SCALED BY M*SQRT(G*L).
B44,B46,B64,B66,AND B55 ARE SCALED BY M*L*SQRT(G*L).
(B44* IS B44 EXCLUDING CROSS-FLOW DRAG CONTRIBUTIONS.)

EXCITING FORCE,MOMENTS AND PHASES

THE SWAY FORCE IS SCALED BY M*G*A.
THE ROLL AND YAW MOMENTS ARE SCALED BY M*G*A.
(*MOMENT DENOTES THE MOMENT SCALED BY M*G*A*(WAVE NUMBER).)
THE FORCE AMPLITUDE IS SCALED BY THE HEAVE RESTORING FORCE
C33 = RHO*G*A*(WATERPLANE AREA).
THE MOMENT AMPLITUDE IS SCALED BY THE PITCH RESTORING MOMENT
C55 = RHO*G*A*(MOMENT OF INERTIA OF WATERPLANE)/L.
(*MOMENT DENOTES THE MOMENT AMPLITUDE SCALED BY L*(WAVE NUMBER)*C55.)

MOTION AMPLITUDES AND PHASES

THE SWAY AMPLITUDE AND THE HEAVE AMPLITUDE ARE SCALED BY A.
THE ROLL AMPLITUDE IS SCALED BY 2*A/B.
THE YAW AMPLITUDE AND THE PITCH AMPLITUDE ARE SCALED BY 2*A/L.
(*ROLL DENOTES ROLL AMPLITUDE SCALED BY A*(WAVE NUMBER).)
(*YAW DENOTES YAW AMPLITUDE SCALED BY A*(WAVE NUMBER).)
(*PITCH DENOTES PITCH AMPLITUDE SCALED BY A*(WAVE NUMBER).)

M IS THE DISPLACED MASS.
G IS THE ACCELERATION DUE TO GRAVITY.
L IS THE DISTANCE BETWEEN PERPENDICULARS.
A IS THE WAVE AMPLITUDE.
B IS THE TOTAL HULL SEPARATION.
RHO IS THE WATER DENSITY.
FN IS THE FROUDE NUMBER = (FORWARD SPEED)/SQRT(G*L).
BETA IS THE WAVEHEADING ANGLE IN DEGREES.
(BETA=180.0 FOR HEAD SEAS.)
OMEGA IS THE ENCOUNTER FREQUENCY NON-DIMENSIONALIZED BY SQRT(G/L).
THE HULL SEPARATION/BEAM RATIO IS THE DISTANCE BETWEEN
THE HULLS DIVIDED BY THE BEAM OF ONE HULL.
THE PHASE ANGLE IS MEASURED IN DEGREES WITH RESPECT TO THE WAVE AT CG.
L/LAM = L/(WAVE LENGTH).

SWATMO   SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE   PAGE 8

BARE HULL POTENTIAL FLOW ADDED MASS AND DAMPING COEFFICIENTS
FN = .454

| OMEGA | A33 | A35 | A53 | A55 | B33 | B35 | B53 | B55 |
|---|---|---|---|---|---|---|---|---|
| 0.9942 | 0.428175 | -0.092825 | 0.091015 | 0.176001 | 0.200272 | 0.193394 | -0.195132 | 0.052716 |
| 1.0941 | 0.419735 | -0.075889 | 0.074362 | 0.158537 | 0.198207 | 0.189627 | -0.191240 | 0.045408 |
| 1.1939 | 0.413678 | -0.062306 | 0.060964 | 0.145709 | 0.193647 | 0.186921 | -0.188450 | 0.039636 |
| 1.2938 | 0.409256 | -0.051374 | 0.050164 | 0.135931 | 0.187304 | 0.184913 | -0.186446 | 0.035126 |
| 1.3936 | 0.405649 | -0.042481 | 0.041423 | 0.128164 | 0.179585 | 0.183209 | -0.184877 | 0.031610 |
| 1.4935 | 0.401920 | -0.034912 | 0.034150 | 0.121687 | 0.169756 | 0.181380 | -0.183322 | 0.028704 |
| 1.5933 | 0.397164 | -0.027367 | 0.027218 | 0.116006 | 0.152709 | 0.179086 | -0.182283 | 0.025558 |
| 1.6931 | 0.393021 | -0.017337 | 0.017997 | 0.111181 | 0.111629 | 0.177408 | -0.179219 | 0.020219 |
| 1.7930 | 0.398735 | -0.007181 | 0.007503 | 0.108368 | 0.052024 | 0.180666 | -0.181146 | 0.013637 |
| 1.8928 | 0.408230 | -0.004693 | 0.003770 | 0.106480 | 0.033414 | 0.185369 | -0.185059 | 0.011535 |
| 1.9927 | 0.412909 | -0.004777 | 0.003007 | 0.104333 | 0.034064 | 0.187558 | -0.187115 | 0.010932 |
| 2.0925 | 0.575365 | -0.000870 | 0.005859 | 0.111930 | 0.032469 | 0.261204 | -0.260881 | 0.009679 |
| 2.1924 | 0.580977 | -0.000194 | 0.004938 | 0.109908 | 0.027181 | 0.263623 | -0.263556 | 0.007757 |
| 2.2922 | 0.586792 | 0.000553 | 0.004006 | 0.108481 | 0.019998 | 0.266075 | -0.266380 | 0.005516 |
| 2.3920 | 0.593342 | 0.001198 | 0.003235 | 0.107665 | 0.012842 | 0.268805 | -0.269593 | 0.003380 |
| 2.4919 | 0.600662 | 0.001635 | 0.002734 | 0.107398 | 0.007517 | 0.271839 | -0.273202 | 0.001808 |
| 2.5917 | 0.434256 | -0.002165 | -0.001399 | 0.099969 | 0.005671 | 0.196025 | -0.198019 | 0.001260 |
| 2.6916 | -0.423950 | -0.022039 | -0.020951 | 0.064988 | 0.008686 | -0.193659 | 0.191034 | 0.002137 |
| 2.7914 | -0.108687 | -0.015429 | -0.013390 | 0.079632 | 0.017508 | -0.050905 | 0.047718 | 0.004718 |
| 2.8913 | 0.118933 | -0.011038 | -0.007513 | 0.089554 | 0.032474 | 0.052157 | -0.055763 | 0.009107 |
| 2.9911 | 0.169744 | -0.010822 | -0.005428 | 0.091984 | 0.053186 | 0.075106 | -0.078920 | 0.015183 |
| 3.0909 | 0.291501 | -0.009042 | -0.001589 | 0.096204 | 0.078465 | 0.130372 | -0.134136 | 0.022594 |
| 3.1908 | 0.769419 | 0.000899 | 0.010383 | 0.111309 | 0.106407 | 0.347364 | -0.350808 | 0.030769 |
| 3.2906 | 0.955689 | 0.004316 | 0.015592 | 0.115364 | 0.134562 | 0.432154 | -0.435038 | 0.038973 |
| 3.3905 | 0.630836 | -0.003732 | 0.008914 | 0.102786 | 0.160206 | 0.285129 | -0.287292 | 0.046389 |

BARE HULL POTENTIAL FLOW ADDED MASS COEFFICIENTS
FN = .454

| OMEGA | A22 | A24=A42 | A26 | A62 | A44 | A46 | A64 | A66 |
|---|---|---|---|---|---|---|---|---|
| 0.9942 | 5.600134 | 0.316563 | 0.294221 | -0.171648 | 0.038973 | -3.749510 | 3.758366 | 1.571242 |
| 1.0941 | 5.486244 | 0.317702 | 0.377519 | -0.239849 | 0.039480 | -2.007013 | 2.016564 | 1.353912 |
| 1.1939 | 5.310254 | 0.315216 | 0.465960 | -0.314815 | 0.039841 | 0.022446 | -0.012232 | 1.178916 |
| 1.2938 | 5.079117 | 0.309102 | 0.549798 | -0.389349 | 0.040029 | 0.027133 | -0.016444 | 1.035135 |
| 1.3936 | 4.799450 | 0.299358 | 0.617[illegible]63 | -0.453693 | 0.040015 | 0.031380 | -0.020525 | 0.907709 |
| 1.4935 | 4.482878 | 0.286278 | 0.660[illegible]0 | -0.498544 | 0.039780 | 0.034625 | -0.023950 | 0.797893 |
| 1.5933 | 4.147444 | 0.270603 | 0.674822 | -0.518468 | 0.039327 | 0.036515 | -0.026303 | 0.702161 |
| 1.6931 | 3.813101 | 0.253335 | 0.662850 | -0.513419 | 0.038679 | 0.037011 | -0.027406 | 0.620577 |
| 1.7930 | 3.493859 | 0.235[illegible]01 | 0.631671 | -0.487520 | 0.037858 | 0.036337 | -0.027313 | 0.553162 |
| 1.8928 | 3.188816 | 0.216563 | 0.589548 | -0.446412 | 0.036851 | 0.034865 | -0.026210 | 0.498901 |
| 1.9927 | 2.861624 | 0.195059 | 0.544359 | -0.394597 | 0.035530 | 0.032928 | -0.024272 | 0.454695 |
| 2.0925 | 2.360476 | 0.160719 | 0.504707 | -0.332417 | 0.033322 | 0.031096 | -0.021455, | 0.411525 |
| 2.1924 | 9.425164 | 0.569187 | 0.297659 | -0.438164 | 0.057563 | 0.019166 | -0.028263 | 0.803184 |
| 2.2922 | 4.189337 | 0.262287 | 0.378814 | -0.258565 | 0.038568 | 0.023703 | -0.018309 | 0.513578 |
| 2.3920 | 3.955677 | 0.242498 | 0.356899 | -0.184562 | 0.036807 | 0.022012 | -0.014326 | 0.520872 |
| 2.4919 | 4.231367 | 0.250307 | 0.341019 | -0.103592 | 0.036589 | 0.020267 | -0.009973 | 0.581560 |
| 2.5917 | 5.111566 | 0.287497 | 0.352010 | 0.014638 | 0.037942 | 0.019174 | -0.003889 | 0.734510 |
| 2.6916 | 8.135425 | 0.419861 | 0.541965 | 0.333286 | 0.044095 | 0.023004 | 0.010618 | 1.271130 |
| 2.7914 | 20.106456 | 1.226431 | -0.827983 | -12.832919 | 0.105920 | -0.045242 | -0.596934 | 1.659617 |
| 2.8913 | -30.846266 | -1.634373 | 0.828915 | -1.431489 | -0.067729 | 0.051435 | -0.082846 | -2.149843 |
| 2.9911 | -7.345828 | -0.350296 | 0.232663 | -0.450777 | 0.009371 | 0.016197 | -0.026875 | -0.565301 |
| 3.0909 | -3.755988 | -0.158165 | 0.175797 | -0.313700 | 0.020673 | 0.012225 | -0.019079 | -0.275395 |
| 3.1908 | -2.267791 | -0.079060 | 0.149290 | -0.249541 | 0.025368 | 0.010254 | -0.015473 | -0.149655 |
| 3.2906 | -1.448932 | -0.035706 | 0.131325 | -0.209123 | 0.028057 | 0.008935 | -0.013250 | -0.079828 |
| 3.3905 | -0.928642 | -0.008385 | 0.117271 | -0.179860 | 0.029877 | 0.007951 | -0.011691 | -0.035971 |



BARE HULL POTENTIAL FLOW DAMPING COEFFICIENTS
FN = .454

| OMEGA | B22 | B24=B42 | B26 | B62 | B44 | B46 | B64 | B66 |
|---|---|---|---|---|---|---|---|---|
| 0.9942 | 0.507512 | -8.178995 | -2.529944 | 2.551617 | -0.319383 | 0.043922 | 0.331171 | 0.142825 |
| 1.0941 | 0.814414 | -5.307789 | -2.471565 | 2.506653 | -0.169632 | -0.021315 | 0.266967 | 0.199742 |
| 1.1939 | 1.226539 | 0.054478 | -2.382610 | 2.435914 | 0.002302 | -0.141387 | 0.144639 | 0.267197 |
| 1.2938 | 1.732400 | 0.080384 | -2.266463 | 2.342328 | 0.003592 | -0.137842 | 0.142637 | 0.340559 |
| 1.3936 | 2.293293 | 0.111095 | -2.127016 | 2.228005 | 0.005261 | -0.132514 | 0.139123 | 0.412197 |
| 1.4935 | 2.849373 | 0.143978 | -1.970972 | 2.096792 | 0.007240 | -0.125625 | 0.134144 | 0.473389 |
| 1.5933 | 3.338426 | 0.175743 | -1.808024 | 1.955367 | 0.009406 | -0.117618 | 0.127927 | 0.517272 |
| 1.6931 | 3.716162 | 0.203511 | -1.648272 | 1.811736 | 0.011620 | -0.109039 | 0.120838 | 0.540967 |
| 1.7930 | 3.965142 | 0.225503 | -1.498422 | 1.671906 | 0.013766 | -0.100308 | 0.113204 | 0.545568 |
| 1.8928 | 4.090408 | 0.241072 | -1.357835 | 1.535697 | 0.015759 | -0.091460 | 0.105050 | 0.534549 |
| 1.9927 | 4.108828 | 0.250307 | -1.209503 | 1.387135 | 0.017533 | -0.081534 | 0.095463 | 0.511954 |
| 2.0925 | 4.039503 | 0.253583 | -0.984005 | 1.157891 | 0.019028 | -0.065928 | 0.079908 | 0.481231 |
| 2.1924 | 3.897604 | 0.251223 | -4.192463 | 4.359932 | 0.020170 | -0.251340 | 0.265141 | 0.444730 |
| 2.2922 | 3.690665 | 0.243263 | -1.821311 | 1.980094 | 0.020865 | -0.112283 | 0.125716 | 0.403522 |
| 2.3920 | 3.414344 | 0.229140 | -1.720915 | 1.868465 | 0.020988 | -0.103586 | 0.116457 | 0.357067 |
| 2.4919 | 3.042554 | 0.206936 | -1.853689 | 1.985854 | 0.020345 | -0.107563 | 0.119566 | 0.302072 |
| 2.5917 | 2.497416 | 0.170727 | -2.265008 | 2.373228 | 0.018519 | -0.125290 | 0.135585 | 0.228789 |
| 2.6916 | 1.666068 | 0.098886 | -3.619702 | 3.762383 | 0.014012 | -0.187779 | 0.193203 | 0.137803 |
| 2.7914 | 103.088629 | 4.737478 | -42.610390 | -24.365792 | 0.246514 | -2.062523 | -0.949660 | 18.444156 |
| 2.8913 | 20.823890 | 1.237062 | 13.995854 | -13.994048 | 0.080883 | 0.743468 | -0.739563 | 1.568136 |
| 2.9911 | 6.738519 | 0.424683 | 3.384457 | -3.281147 | 0.031195 | 0.163283 | -0.154576 | 0.629553 |
| 3.0909 | 5.153888 | 0.329598 | 1.763191 | -1.644992 | 0.024441 | 0.076717 | -0.066802 | 0.491787 |
| 3.1908 | 4.474937 | 0.288655 | 1.087541 | -0.970253 | 0.020902 | 0.040889 | -0.030850 | 0.430179 |
| 3.2906 | 4.062657 | 0.264748 | 0.713747 | -0.601013 | 0.014511 | 0.021105 | -0.011294 | 0.393076 |
| 3.3905 | 3.764183 | 0.248830 | 0.474894 | -0.367755 | 0.016855 | 0.008508 | 0.000909 | 0.366616 |

ADDED MASS COEFFICIENTS AND DAMPING COEFFICIENTS EXCLUDING CROSS-FLOW DRAG
FN = .454

| OMEGA | A33 | A35 | A53 | A55 | B33 | B35 | B53 | B55 |
|---|---|---|---|---|---|---|---|---|
| 0.9942 | 0.512963 | -0.055489 | 0.128350 | 0.218572 | 1.406966 | 0.565173 | 0.099711 | 0.341821 |
| 1.0941 | 0.504522 | -0.038553 | 0.111698 | 0.198032 | 1.404901 | 0.561406 | 0.103603 | 0.334514 |
| 1.1939 | 0.498465 | -0.024970 | 0.098299 | 0.182867 | 1.400341 | 0.558730 | 0.106393 | 0.328742 |
| 1.2938 | 0.494044 | -0.014039 | 0.087500 | 0.171273 | 1.393997 | 0.556692 | 0.108397 | 0.324232 |
| 1.3936 | 0.490436 | -0.005145 | 0.078759 | 0.162065 | 1.386279 | 0.554988 | 0.109966 | 0.320716 |
| 1.4935 | 0.486708 | 0.002424 | 0.071486 | 0.154427 | 1.376450 | 0.553159 | 0.111521 | 0.317810 |
| 1.5933 | 0.481931 | 0.009969 | 0.064553 | 0.147796 | 1.359403 | 0.550865 | 0.113560 | 0.314663 |
| 1.6931 | 0.477809 | 0.019999 | 0.055332 | 0.142184 | 1.318323 | 0.549187 | 0.115624 | 0.309325 |
| 1.7930 | 0.483523 | 0.030154 | 0.044839 | 0.138712 | 1.258718 | 0.552445 | 0.113697 | 0.302742 |
| 1.8928 | 0.493018 | 0.032643 | 0.041106 | 0.136266 | 1.240108 | 0.557148 | 0.109784 | 0.300640 |
| 1.9927 | 0.497697 | 0.032559 | 0.040343 | 0.133643 | 1.240757 | 0.559137 | 0.107727 | 0.300038 |
| 2.0925 | 0.660152 | 0.036466 | 0.043195 | 0.140830 | 1.239163 | 0.612983 | 0.033961 | 0.298785 |
| 2.1924 | 0.665765 | 0.037142 | 0.042274 | 0.138454 | 1.231875 | 0.635402 | 0.031287 | 0.296863 |
| 2.2922 | 0.671580 | 0.037888 | 0.041342 | 0.136717 | 1.226692 | 0.637854 | 0.028463 | 0.294622 |
| 2.3920 | 0.678130 | 0.038534 | 0.040570 | 0.135630 | 1.219536 | 0.640584 | 0.025250 | 0.292485 |
| 2.4919 | 0.685450 | 0.038971 | 0.040069 | 0.135123 | 1.214210 | 0.643618 | 0.021641 | 0.290914 |
| 2.5917 | 0.519044 | 0.035170 | 0.035936 | 0.127481 | 1.212365 | 0.567804 | 0.096824 | 0.290366 |
| 2.6916 | -0.339163 | 0.015297 | 0.016385 | 0.092311 | 1.215380 | 0.178120 | 0.485877 | 0.291242 |
| 2.7914 | -0.023899 | 0.021906 | 0.023945 | 0.106786 | 1.224202 | 0.320874 | 0.342560 | 0.293824 |
| 2.8913 | 0.203721 | 0.026297 | 0.029822 | 0.116556 | 1.239166 | 0.423936 | 0.239080 | 0.296212 |
| 2.9911 | 0.254531 | 0.026514 | 0.031908 | 0.118850 | 1.259880 | 0.446885 | 0.215923 | 0.304288 |
| 3.0909 | 0.376288 | 0.028294 | 0.035746 | 0.122945 | 1.285158 | 0.502151 | 0.160707 | 0.311700 |
| 3.1908 | 0.854207 | 0.038235 | 0.047718 | 0.137938 | 1.313101 | 0.719143 | -0.055965 | 0.319875 |
| 3.2906 | 1.040477 | 0.041652 | 0.052928 | 0.141890 | 1.341256 | 0.803933 | -0.140196 | 0.328079 |
| 3.3905 | 0.715624 | 0.033603 | 0.046249 | 0.129219 | 1.366899 | 0.656908 | 0.307550 | 0.335494 |



ADDED MASS COEFFICIENTS
FN = .454

| OMEGA | A22 | A24=A42 | A26 | A62 | A44 | A46 | A64 | A66 |
|---|---|---|---|---|---|---|---|---|
| 0.9942 | 5.600134 | 0.316563 | 0.426506 | -0.171648 | 0.040608 | -3.738547 | 3.758366 | 1.570712 |
| 1.0941 | 5.486244 | 0.317702 | 0.486761 | -0.239849 | 0.041114 | -1.997960 | 2.016564 | 1.353474 |
| 1.1939 | 5.310254 | 0.315216 | 0.557695 | -0.314815 | 0.041475 | 0.030049 | -0.012232 | 1.178548 |
| 1.2938 | 5.079117 | 0.309102 | 0.627921 | -0.389349 | 0.041664 | 0.033608 | -0.016444 | 1.032822 |
| 1.3936 | 4.799450 | 0.299358 | 0.685093 | -0.453693 | 0.041649 | 0.036960 | -0.020525 | 0.907439 |
| 1.4935 | 4.482878 | 0.286278 | 0.719299 | -0.498544 | 0.041414 | 0.039484 | -0.023950 | 0.797658 |
| 1.5933 | 4.147444 | 0.270603 | 0.726333 | -0.518468 | 0.040961 | 0.040784 | -0.026303 | 0.701955 |
| 1.6931 | 3.813101 | 0.253335 | 0.708465 | -0.513419 | 0.040313 | 0.040792 | -0.027406 | 0.620394 |
| 1.7930 | 3.493859 | 0.235301 | 0.672347 | -0.487520 | 0.039492 | 0.039708 | -0.027313 | 0.552999 |
| 1.8928 | 3.188816 | 0.216563 | 0.626046 | -0.446412 | 0.038485 | 0.037870 | -0.026210 | 0.498755 |
| 1.9927 | 2.861624 | 0.195059 | 0.577291 | -0.394597 | 0.037164 | 0.035658 | -0.024272 | 0.454563 |
| 2.0925 | 2.360476 | 0.160719 | 0.534571 | -0.332417 | 0.034956 | 0.033571 | -0.021455 | 0.411405 |
| 2.1924 | 9.425164 | 0.569187 | 0.324865 | -0.438164 | 0.059197 | 0.021420 | -0.028263 | 0.803075 |
| 2.2922 | 4.189337 | 0.252287 | 0.403701 | -0.258565 | 0.040202 | 0.025765 | -0.018309 | 0.513478 |
| 2.3920 | 3.955677 | 0.242498 | 0.379753 | -0.184562 | 0.038441 | 0.023906 | -0.014326 | 0.520780 |
| 2.4919 | 4.231367 | 0.250307 | 0.362077 | -0.103592 | 0.038223 | 0.022012 | -0.009973 | 0.581475 |
| 2.5917 | 5.111566 | 0.287497 | 0.371478 | 0.014638 | 0.039576 | 0.020787 | -0.003889 | 0.734432 |
| 2.6916 | 8.135425 | 0.419861 | 0.560015 | 0.333286 | 0.045730 | 0.024500 | 0.010619 | 1.271054 |
| 2.7914 | 20.106456 | 1.226431 | -0.811201 | -12.832919 | 0.107554 | -0.043851 | -0.596934 | 1.659550 |
| 2.8913 | -30.846266 | -1.634373 | 0.844558 | -1.431489 | -0.066094 | 0.052731 | -0.082846 | -2.149906 |
| 2.9911 | -7.345828 | -0.350296 | 0.247279 | -0.450777 | 0.011005 | 0.017409 | -0.026875 | -0.565360 |
| 3.0909 | -3.755988 | -0.158165 | 0.189484 | -0.313700 | 0.022307 | 0.013359 | -0.019079 | -0.275450 |
| 3.1908 | -2.267791 | -0.079060 | 0.162134 | -0.249541 | 0.027003 | 0.011318 | -0.015673 | -0.149707 |
| 3.2906 | -1.448932 | -0.035706 | 0.143401 | -0.209123 | 0.029691 | 0.009936 | -0.013250 | -0.079876 |
| 3.3905 | -0.928642 | -0.008385 | 0.128647 | -0.179860 | 0.031511 | 0.008893 | -0.011691 | -0.036016 |

SWATMO SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE PAGE 13

EQUATIONS OF MOTION SOLVED EXCITING FORCE INCLUDING FIN AND BODY LIFT CONTRIBUTIONS.

FN = .454
BETA = 135.0

| WW | WE | HEAVE | PHASE | PITCH | PHASE | LAM/L |
|---|---|---|---|---|---|---|
| 0.343 | 0.430 | 1.19725 | -3.040 | 0.32268 | -123.063 | 10.0000 |
| 0.365 | 0.464 | 1.25936 | -5.577 | 0.35496 | -128.406 | 8.8014 |
| 0.388 | 0.499 | 1.33316 | -9.431 | 0.38309 | -134.951 | 7.8061 |
| 0.410 | 0.535 | 1.41197 | -15.107 | 0.40212 | -142.887 | 6.9706 |
| 0.433 | 0.572 | 1.47729 | -23.083 | 0.40409 | -152.243 | 6.2623 |
| 0.455 | 0.609 | 1.49509 | -33.469 | 0.37933 | -162.426 | 5.6568 |
| 0.478 | 0.648 | 1.42900 | -45.530 | 0.32412 | -171.460 | 5.1350 |
| 0.501 | 0.687 | 1.27296 | -57.692 | 0.25105 | -175.362 | 4.6822 |
| 0.523 | 0.726 | 1.05819 | -68.047 | 0.19158 | -169.010 | 4.2868 |
| 0.546 | 0.767 | 0.85521 | -73.868 | 0.16733 | -159.030 | 3.9394 |
| 0.568 | 0.808 | 0.71054 | -76.931 | 0.15301 | -150.334 | 3.6326 |
| 0.591 | 0.850 | 0.59974 | -79.294 | 0.14666 | -140.933 | 3.3603 |
| 0.613 | 0.893 | 0.45036 | -83.804 | 0.18852 | -132.718 | 3.1175 |
| 0.636 | 0.936 | 0.36611 | -85.058 | 0.19734 | -130.102 | 2.9001 |
| 0.659 | 0.981 | 0.30236 | -85.409 | 0.20028 | -128.449 | 2.7047 |
| 0.681 | 1.026 | 0.24937 | -85.253 | 0.20097 | -127.555 | 2.5284 |
| 0.704 | 1.072 | 0.20409 | -84.630 | 0.19978 | -127.038 | 2.3688 |
| 0.726 | 1.118 | 0.18417 | -83.746 | 0.18942 | -124.439 | 2.2238 |
| 0.749 | 1.165 | 0.32995 | -61.640 | 0.07764 | -129.156 | 2.0917 |
| 0.772 | 1.213 | 0.18564 | -79.541 | 0.15629 | -116.169 | 1.9711 |
| 0.794 | 1.262 | 0.12525 | -81.160 | 0.16960 | -118.933 | 1.8606 |
| 0.817 | 1.312 | 0.09552 | -80.498 | 0.16860 | -119.379 | 1.7591 |
| 0.839 | 1.362 | 0.05880 | -73.596 | 0.16599 | -122.527 | 1.6658 |
| 0.862 | 1.413 | 0.04210 | -65.287 | 0.15749 | -123.761 | 1.5796 |
| 0.884 | 1.465 | 0.03441 | -68.317 | 0.15246 | -122.325 | 1.5000 |

SWATMO SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE PAGE 14

EQUATIONS OF MOTION SOLVED USING B44 EXCLUDING VISCOUS EFFECTS

FN = .454
BETA = 135.0

| WW | WE | SWAY | PHASE | ROLL | PHASE | YAW | PHASE | LAM/L |
|---|---|---|---|---|---|---|---|---|
| 0.343 | 0.430 | 0.23167 | 56.740 | 0.07376 | -5.849 | 0.25251 | 145.564 | 10.0000 |
| 0.365 | 0.464 | 0.21629 | 56.863 | 0.10729 | -5.744 | 0.25147 | 147.281 | 8.8014 |
| 0.388 | 0.499 | 0.35224 | 65.225 | 0.42057 | 15.726 | 0.32460 | 168.958 | 7.8061 |
| 0.410 | 0.535 | 0.51144 | 84.937 | 0.11868 | 151.610 | 0.09687 | 169.251 | 6.9706 |
| 0.433 | 0.572 | 0.51161 | 85.362 | 0.12694 | 144.792 | 0.10940 | 171.417 | 6.2623 |
| 0.455 | 0.609 | 0.50925 | 85.742 | 0.13452 | 139.090 | 0.12267 | 172.591 | 5.6568 |
| 0.478 | 0.648 | 0.50424 | 86.091 | 0.14153 | 134.241 | 0.13634 | 173.178 | 5.1350 |
| 0.501 | 0.687 | 0.49699 | 86.438 | 0.14783 | 130.072 | 0.14993 | 173.505 | 4.6822 |
| 0.523 | 0.726 | 0.48833 | 86.825 | 0.15316 | 126.473 | 0.16300 | 173.734 | 4.2868 |
| 0.546 | 0.767 | 0.47961 | 87.322 | 0.15746 | 123.421 | 0.17519 | 173.947 | 3.9394 |
| 0.568 | 0.808 | 0.47252 | 88.044 | 0.16109 | 120.972 | 0.18604 | 174.249 | 3.6326 |
| 0.591 | 0.850 | 0.47013 | 89.214 | 0.16491 | 119.299 | 0.19486 | 174.762 | 3.3603 |
| 0.613 | 0.893 | 0.55127 | -261.729 | 0.19074 | 124.808 | 0.17601 | 175.161 | 3.1175 |
| 0.636 | 0.936 | 0.24142 | 75.261 | 0.11199 | 103.461 | 0.23548 | 166.290 | 2.9001 |
| 0.659 | 0.981 | 0.33243 | 83.327 | 0.13737 | 107.627 | 0.24003 | 173.642 | 2.7047 |
| 0.681 | 1.026 | 0.38332 | 87.749 | 0.15398 | 110.153 | 0.24316 | 177.437 | 2.5284 |
| 0.704 | 1.072 | 0.39630 | 89.318 | 0.16276 | 110.191 | 0.25264 | -179.774 | 2.3688 |
| 0.726 | 1.118 | 0.40757 | -269.947 | 0.17652 | 109.502 | 0.26895 | -176.532 | 2.2238 |
| 0.749 | 1.165 | 0.37449 | -269.530 | 0.19218 | 100.361 | 0.28084 | 174.726 | 2.0917 |
| 0.772 | 1.213 | 0.30275 | -262.578 | 0.12270 | 25.271 | 0.33934 | -178.610 | 1.9711 |
| 0.794 | 1.262 | 0.41319 | 89.387 | 0.08864 | 58.176 | 0.39379 | -179.796 | 1.8606 |
| 0.817 | 1.312 | 0.43529 | 79.590 | 0.08939 | 94.124 | 0.51139 | 167.413 | 1.7591 |
| 0.839 | 1.362 | 0.40562 | 60.158 | 0.09286 | 75.677 | 0.50848 | 136.559 | 1.6658 |
| 0.862 | 1.413 | 0.30904 | 49.912 | 0.07229 | 67.839 | 0.31310 | 118.310 | 1.5796 |
| 0.884 | 1.465 | 0.24474 | 44.276 | 0.05875 | 65.260 | 0.19386 | 125.001 | 1.5000 |

EQUATIONS OF MOTION SOLVED WITH VISCOUS CROSS-FLOW DAMPING EFFECTS.

FN = .454
BETA = 135.0

| WW | WE | HEAVE | PHASE | PITCH | PHASE | LAM/L |
|---|---|---|---|---|---|---|
| 0.343 | 0.430 | 1.19725 | -3.040 | 0.32268 | -123.063 | 10.0000 |
| 0.365 | 0.464 | 1.25936 | -5.577 | 0.35496 | -128.406 | 8.8014 |
| 0.388 | 0.499 | 1.33316 | -9.431 | 0.38309 | -134.951 | 7.8061 |
| 0.410 | 0.535 | 1.41197 | -15.107 | 0.40212 | -142.487 | 6.9706 |
| 0.433 | 0.572 | 1.47729 | -23.083 | 0.40409 | -152.243 | 6.2623 |
| 0.455 | 0.609 | 1.49509 | -33.469 | 0.37933 | -162.426 | 5.6568 |
| 0.478 | 0.648 | 1.42900 | -45.530 | 0.32412 | -171.460 | 5.1350 |
| 0.501 | 0.687 | 1.27296 | -57.692 | 0.25105 | -175.362 | 4.6822 |
| 0.523 | 0.726 | 1.05819 | -68.047 | 0.19158 | -169.010 | 4.2868 |
| 0.546 | 0.767 | 0.85521 | -73.868 | 0.16733 | -159.030 | 3.9394 |
| 0.568 | 0.808 | 0.71054 | -76.931 | 0.15301 | -150.334 | 3.6326 |
| 0.591 | 0.850 | 0.59974 | -79.294 | 0.14666 | -140.933 | 3.3603 |
| 0.613 | 0.893 | 0.45036 | -83.004 | 0.18852 | -132.713 | 3.1175 |
| 0.636 | 0.936 | 0.36611 | -85.058 | 0.19734 | -130.112 | 2.9001 |
| 0.659 | 0.981 | 0.30236 | -85.409 | 0.20028 | -128.449 | 2.7047 |
| 0.681 | 1.026 | 0.24937 | -85.253 | 0.20097 | -127.555 | 2.5284 |
| 0.704 | 1.072 | 0.20409 | -84.630 | 0.19978 | -127.038 | 2.3688 |
| 0.726 | 1.118 | 0.18417 | -83.746 | 0.18942 | -124.439 | 2.2238 |
| 0.749 | 1.165 | 0.32995 | -61.640 | 0.07764 | -129.156 | 2.0917 |
| 0.772 | 1.213 | 0.18564 | -79.541 | 0.15629 | -116.169 | 1.9711 |
| 0.794 | 1.262 | 0.12525 | -81.160 | 0.16960 | -118.933 | 1.8606 |
| 0.817 | 1.312 | 0.09552 | -80.498 | 0.16860 | -119.379 | 1.7591 |
| 0.839 | 1.362 | 0.05880 | -73.596 | 0.16599 | -122.527 | 1.6658 |
| 0.862 | 1.413 | 0.04210 | -65.287 | 0.15749 | -123.761 | 1.5796 |
| 0.884 | 1.465 | 0.03441 | -68.317 | 0.15246 | -122.325 | 1.5000 |



EQUATIONS OF MOTION SOLVED WITH CROSS-FLOW VISCOUS DAMPING AND ROLL WAVE EXCITING MOMENT INCLUDED

FN = .454
BETA = 135.0

| WW | WE | SWAY | PHASE | ROLL | PHASE | YAW | PHASE | LAM/L |
|---|---|---|---|---|---|---|---|---|
| 0.343 | 0.430 | 0.23124 | 56.645 | 0.07390 | -5.859 | 0.25283 | 145.556 | 10.0000 |
| 0.365 | 0.464 | 0.21560 | 56.714 | 0.10757 | -5.762 | 0.25191 | 147.265 | 8.8014 |
| 0.388 | 0.499 | 0.35022 | 64.906 | 0.42579 | 15.598 | 0.32759 | 168.903 | 7.8061 |
| 0.410 | 0.535 | 0.50824 | 85.303 | 0.11701 | 134.851 | 0.10084 | 168.833 | 6.9706 |
| 0.433 | 0.572 | 0.50898 | 85.802 | 0.12252 | 129.671 | 0.11290 | 170.703 | 6.2623 |
| 0.455 | 0.609 | 0.50726 | 86.228 | 0.12822 | 125.618 | 0.12569 | 171.791 | 5.6568 |
| 0.478 | 0.648 | 0.50286 | 86.603 | 0.13407 | 122.254 | 0.13894 | 172.346 | 5.1350 |
| 0.501 | 0.687 | 0.49618 | 86.963 | 0.13967 | 119.349 | 0.15218 | 172.754 | 4.6822 |
| 0.523 | 0.726 | 0.48804 | 87.352 | 0.14460 | 116.798 | 0.16494 | 173.030 | 4.2868 |
| 0.546 | 0.767 | 0.47977 | 87.843 | 0.14865 | 114.617 | 0.17684 | 173.289 | 3.9394 |
| 0.568 | 0.808 | 0.47310 | 88.547 | 0.15205 | 112.925 | 0.18741 | 173.634 | 3.6326 |
| 0.591 | 0.850 | 0.47112 | 89.685 | 0.15555 | 111.974 | 0.19595 | 174.187 | 3.3603 |
| 0.613 | 0.893 | 0.55342 | -261.408 | 0.17884 | 119.329 | 0.17680 | 174.582 | 3.1175 |
| 0.636 | 0.936 | 0.24136 | 77.216 | 0.10689 | 93.367 | 0.23609 | 167.887 | 2.9001 |
| 0.659 | 0.981 | 0.33321 | 83.926 | 0.12991 | 100.101 | 0.24035 | 173.263 | 2.7047 |
| 0.681 | 1.026 | 0.38455 | 88.192 | 0.14511 | 104.120 | 0.24323 | 177.113 | 2.5284 |
| 0.704 | 1.072 | 0.39761 | 89.702 | 0.15340 | 105.034 | 0.25253 | 179.978 | 2.3688 |
| 0.726 | 1.118 | 0.40884 | -269.600 | 0.16692 | 105.247 | 0.26873 | -176.693 | 2.2238 |
| 0.749 | 1.165 | 0.37577 | -269.145 | 0.18456 | 96.350 | 0.28075 | 174.652 | 2.0917 |
| 0.772 | 1.213 | 0.30395 | -262.121 | 0.13056 | 21.172 | 0.33952 | -178.559 | 1.9711 |
| 0.794 | 1.262 | 0.41506 | 89.778 | 0.01476 | 1.758 | 0.39414 | -179.748 | 1.8606 |
| 0.817 | 1.312 | 0.43748 | 79.962 | 0.08242 | 88.951 | 0.51299 | 167.497 | 1.7591 |
| 0.839 | 1.362 | 0.40785 | 60.502 | 0.08842 | 70.487 | 0.51141 | 136.573 | 1.6658 |
| 0.862 | 1.413 | 0.31093 | 50.241 | 0.06847 | 61.706 | 0.31543 | 118.106 | 1.5796 |
| 0.884 | 1.465 | 0.24653 | 44.568 | 0.05475 | 58.815 | 0.19471 | 124.493 | 1.5000 |

EQUATIONS OF MOTION SOLVED WITH VISCOUS CROSS-FLOW DAMPING EFFECTS.

FN = .454
BETA = 135.0

| WW | WE | HEAVE | PHASE | PITCH | PHASE | LAM/L |
|---|---|---|---|---|---|---|
| 0.343 | 0.430 | 1.19636 | -3.116 | 0.32180 | -123.088 | 10.0000 |
| 0.365 | 0.464 | 1.25627 | -5.727 | 0.35155 | -128.276 | 8.8014 |
| 0.388 | 0.499 | 1.32643 | -9.649 | 0.37729 | -134.666 | 7.8061 |
| 0.410 | 0.535 | 1.39939 | -15.360 | 0.39404 | -142.393 | 6.9706 |
| 0.433 | 0.572 | 1.43621 | -23.279 | 0.39404 | -151.391 | 6.2623 |
| 0.455 | 0.609 | 1.46619 | -33.441 | 0.36843 | -160.923 | 5.6568 |
| 0.478 | 0.648 | 1.39034 | -45.073 | 0.31477 | -168.847 | 5.1350 |
| 0.501 | 0.687 | 1.22985 | -56.639 | 0.24641 | -171.095 | 4.6822 |
| 0.523 | 0.726 | 1.00691 | -66.143 | 0.19426 | -163.052 | 4.2868 |
| 0.546 | 0.767 | 0.80662 | -71.297 | 0.17217 | -154.837 | 3.9394 |
| 0.568 | 0.808 | 0.69206 | -75.200 | 0.15450 | -149.286 | 3.6326 |
| 0.591 | 0.850 | 0.59836 | -77.782 | 0.15298 | -140.451 | 3.3603 |
| 0.613 | 0.893 | 0.43635 | -86.931 | 0.15188 | -130.458 | 3.1175 |
| 0.636 | 0.936 | 0.36214 | -85.588 | 0.18753 | -129.066 | 2.9001 |
| 0.659 | 0.981 | 0.30226 | -84.745 | 0.19944 | -127.970 | 2.7047 |
| 0.681 | 1.026 | 0.24976 | -84.567 | 0.20073 | -127.114 | 2.5284 |
| 0.704 | 1.072 | 0.20430 | -84.298 | 0.19887 | -126.609 | 2.3688 |
| 0.726 | 1.118 | 0.19291 | -79.080 | 0.20253 | -125.661 | 2.2238 |
| 0.749 | 1.165 | 0.37886 | -37.545 | 0.20559 | -126.430 | 2.0917 |
| 0.772 | 1.213 | 0.18378 | -85.713 | 0.14153 | -110.316 | 1.9711 |
| 0.794 | 1.262 | 0.12463 | -84.218 | 0.16625 | -118.008 | 1.8606 |
| 0.817 | 1.312 | 0.09556 | -82.724 | 0.16747 | -119.145 | 1.7591 |
| 0.839 | 1.362 | 0.05649 | -78.552 | 0.16399 | -122.329 | 1.6658 |
| 0.862 | 1.413 | 0.04255 | -65.679 | 0.15813 | -123.936 | 1.5796 |
| 0.884 | 1.465 | 0.03504 | -68.098 | 0.15307 | -122.385 | 1.5000 |



EQUATIONS OF MOTION SOLVED WITH CROSS-FLOW VISCOUS DAMPING AND ROLL WAVE EXCITING MOMENT INCLUDED

FN = .454
BETA = 135.0

| WW | WE | SWAY | PHASE | ROLL | PHASE | YAW | PHASE | LAM/L |
|---|---|---|---|---|---|---|---|---|
| 0.343 | 0.430 | 0.23121 | 56.627 | 0.07391 | -5.854 | 0.25287 | 145.560 | 10.0000 |
| 0.365 | 0.464 | 0.21448 | 57.008 | 0.10757 | -6.029 | 0.25187 | 147.084 | 8.8014 |
| 0.388 | 0.499 | 0.32131 | 67.712 | 0.43823 | 7.446 | 0.33655 | 162.975 | 7.8061 |
| 0.410 | 0.535 | 0.50027 | 85.414 | 0.16498 | 119.692 | 0.10710 | 170.649 | 6.9706 |
| 0.433 | 0.572 | 0.50879 | 85.833 | 0.12264 | 128.585 | 0.11315 | 170.660 | 6.2623 |
| 0.455 | 0.609 | 0.50700 | 86.265 | 0.12870 | 124.420 | 0.12598 | 171.754 | 5.6568 |
| 0.478 | 0.648 | 0.50256 | 86.648 | 0.13479 | 120.942 | 0.13927 | 172.350 | 5.1350 |
| 0.501 | 0.687 | 0.49585 | 87.018 | 0.14052 | 117.964 | 0.15254 | 172.715 | 4.6822 |
| 0.523 | 0.726 | 0.48773 | 87.415 | 0.14545 | 115.407 | 0.16530 | 172.987 | 4.2868 |
| 0.546 | 0.767 | 0.47951 | 87.909 | 0.14943 | 113.286 | 0.17718 | 173.244 | 3.9394 |
| 0.568 | 0.808 | 0.47290 | 88.513 | 0.15268 | 111.709 | 0.15771 | 173.588 | 3.6326 |
| 0.591 | 0.850 | 0.47099 | 89.746 | 0.15600 | 110.915 | 0.19619 | 174.143 | 3.3603 |
| 0.613 | 0.893 | 0.55346 | -261.361 | 0.17881 | 118.500 | 0.17699 | 174.537 | 3.1175 |
| 0.636 | 0.936 | 0.24119 | 77.298 | 0.10745 | 92.396 | 0.23621 | 167.459 | 2.9001 |
| 0.659 | 0.981 | 0.33316 | 83.965 | 0.13004 | 99.556 | 0.24041 | 173.242 | 2.7047 |
| 0.681 | 1.026 | 0.38458 | 88.206 | 0.14447 | 133.417 | 0.24323 | 177.103 | 2.5284 |
| 0.704 | 1.072 | 0.39771 | 89.694 | 0.15244 | 135.172 | 0.25248 | 179.980 | 2.3688 |
| 0.726 | 1.118 | 0.40905 | -269.637 | 0.16594 | 105.430 | 0.26866 | -176.680 | 2.2238 |
| 0.749 | 1.165 | 0.37486 | -268.576 | 0.14926 | 90.547 | 0.28099 | 174.561 | 2.0917 |
| 0.772 | 1.213 | 0.32002 | -261.697 | 0.13527 | -10.258 | 0.34162 | -179.533 | 1.9711 |
| 0.794 | 1.262 | 0.41379 | 89.671 | 0.01300 | 23.097 | 0.39394 | -179.755 | 1.8606 |
| 0.817 | 1.312 | 0.43801 | 79.749 | 0.08116 | 92.324 | 0.51285 | 167.404 | 1.7591 |
| 0.839 | 1.362 | 0.40771 | 60.473 | 0.08860 | 70.927 | 0.51120 | 136.567 | 1.6658 |
| 0.862 | 1.413 | 0.31080 | 50.241 | 0.06885 | 61.842 | 0.31538 | 118.127 | 1.5796 |
| 0.884 | 1.465 | 0.24644 | 44.380 | 0.05512 | 58.791 | 0.19477 | 124.519 | 1.5000 |

NUMBER OF ITERATIONS = 1

DAMPING COEFFICIENTS INCLUDING CROSS-FLOW DRAG
FN = .456

BETA = 135.0

| OMEGA | B33 | B35 | B53 | B55 |
|---|---|---|---|---|
| 0.9942 | 1.414205 | 0.565163 | 0.099701 | 0.342957 |
| 1.0941 | 1.414722 | 0.562033 | 0.102859 | 0.337301 |
| 1.1939 | 1.414015 | 0.559577 | 0.105324 | 0.332640 |
| 1.2938 | 1.412478 | 0.557657 | 0.107236 | 0.328898 |
| 1.3936 | 1.410325 | 0.556106 | 0.108775 | 0.325974 |
| 1.4935 | 1.407190 | 0.554705 | 0.110181 | 0.323671 |
| 1.5933 | 1.401016 | 0.553171 | 0.111776 | 0.321567 |
| 1.6931 | 1.386767 | 0.551325 | 0.113863 | 0.318921 |
| 1.7930 | 1.349964 | 0.549746 | 0.116204 | 0.316055 |
| 1.8928 | 1.290499 | 0.552413 | 0.114878 | 0.307352 |
| 1.9927 | 1.265079 | 0.554493 | 0.111109 | 0.304467 |
| 2.0925 | 1.262127 | 0.552522 | 0.115570 | 0.303527 |
| 2.1924 | 1.260075 | 0.621518 | 0.047492 | 0.302307 |
| 2.2922 | 1.254639 | 0.615831 | 0.033029 | 0.300349 |
| 2.3920 | 1.246822 | 0.638284 | 0.030155 | 0.297943 |
| 2.4919 | 1.238576 | 0.641031 | 0.026844 | 0.295525 |
| 2.5917 | 1.232004 | 0.648430 | 0.018777 | 0.293629 |
| 2.6916 | 1.229254 | 0.578401 | 0.087431 | 0.292813 |
| 2.7914 | 1.231296 | 0.135161 | 0.476081 | 0.293546 |
| 2.8913 | 1.242464 | 0.343507 | 0.319630 | 0.296655 |
| 2.9911 | 1.261016 | 0.427768 | 0.235899 | 0.302137 |
| 3.0909 | 1.286990 | 0.452148 | 0.211711 | 0.309775 |
| 3.1908 | 1.318513 | 0.651906 | 0.012419 | 0.319052 |
| 3.2906 | 1.352149 | 0.806463 | -0.140911 | 0.328881 |
| 3.3905 | 1.383377 | 0.657861 | 0.008503 | 0.337899 |



DAMPING COEFFICIENTS
FN = .456

| OMEGA | B22 | B24=B42 | B44 BETA = 135.0 | B66 | B26 | B62 | B46 | B64 | B44* |
|---|---|---|---|---|---|---|---|---|---|
| 0.9942 | 0.795731 | -8.155108 | -0.269710 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 1.0941 | 1.102633 | -5.283902 | -0.151924 | 0.231886 | -2.472720 | 2.505499 | -0.021572 | 0.266710 | -0.120516 |
| 1.1939 | 1.514758 | 0.078364 | 0.005884 | 0.299341 | -2.383765 | 2.434759 | -0.141644 | 0.144383 | 0.051417 |
| 1.2938 | 2.020619 | 0.104270 | 0.052536 | 0.372703 | -2.267618 | 2.341173 | -0.138099 | 0.142380 | 0.052708 |
| 1.3936 | 2.581512 | 0.134981 | 0.053784 | 0.444341 | -2.128170 | 2.226850 | -0.132771 | 0.138867 | 0.054376 |
| 1.4935 | 3.137592 | 0.167864 | 0.055328 | 0.505533 | -1.972127 | 2.095637 | -0.125881 | 0.133888 | 0.056355 |
| 1.5933 | 3.626645 | 0.199629 | 0.057125 | 0.549416 | -1.809179 | 1.954212 | -0.117874 | 0.127671 | 0.058521 |
| 1.6931 | 4.004381 | 0.227397 | 0.059104 | 0.573111 | -1.649427 | 1.810581 | -0.109295 | 0.120581 | 0.060736 |
| 1.7930 | 4.253361 | 0.249389 | 0.061167 | 0.577712 | -1.499577 | 1.670751 | -0.100565 | 0.112947 | 0.062882 |
| 1.8928 | 4.378627 | 0.264958 | 0.063217 | 0.566693 | -1.358989 | 1.534342 | -0.091716 | 0.104793 | 0.064874 |
| 1.9927 | 4.397047 | 0.274193 | 0.065177 | 0.544098 | -1.210658 | 1.385980 | -0.081790 | 0.095206 | 0.066649 |
| 2.0925 | 4.327722 | 0.277469 | 0.066980 | 0.513375 | -0.985160 | 1.156736 | -0.066185 | 0.079651 | 0.068144 |
| 2.1924 | 4.185823 | 0.275110 | 0.068571 | 0.476874 | -4.193617 | 4.358777 | -0.251597 | 0.264884 | 0.069285 |
| 2.2922 | 3.978884 | 0.267150 | 0.069854 | 0.435666 | -1.822466 | 1.978939 | -0.112540 | 0.125459 | 0.069981 |
| 2.3920 | 3.702563 | 0.253026 | 0.070644 | 0.389211 | -1.722070 | 1.867311 | -0.103842 | 0.116200 | 0.070104 |
| 2.4919 | 3.330773 | 0.230822 | 0.070958 | 0.334216 | -1.854844 | 1.984699 | -0.107819 | 0.119309 | 0.069460 |
| 2.5917 | 2.785635 | 0.194613 | 0.070435 | 0.260933 | -2.266163 | 2.372073 | -0.125546 | 0.135328 | 0.067635 |
| 2.6916 | 1.954287 | 0.122772 | 0.068615 | 0.169947 | -3.620857 | 3.761228 | -0.188036 | 0.192946 | 0.063127 |
| 2.7914 | 103.376848 | 4.761365 | 0.086136 | 18.476300 | -42.611545 | -24.366947 | -2.062780 | -0.949916 | 0.295629 |
| 2.8913 | 21.112109 | 1.260948 | 0.260880 | 1.600280 | 13.994699 | -13.995203 | 0.743211 | -0.739819 | 0.129998 |
| 2.9911 | 7.026738 | 0.448570 | 0.111616 | 0.661697 | 3.383302 | -3.282302 | 0.163027 | -0.154832 | 0.080310 |
| 3.0909 | 5.442107 | 0.353484 | 0.077804 | 0.523931 | 1.762036 | -1.646147 | 0.076461 | -0.067058 | 0.073556 |
| 3.1908 | 4.763156 | 0.312542 | 0.072186 | 0.462323 | 1.086386 | -0.971408 | 0.040633 | -0.031107 | 0.070017 |
| 3.2906 | 4.350876 | 0.288635 | 0.069013 | 0.425220 | 0.712592 | -0.602168 | 0.020849 | -0.011551 | 0.067627 |
| 3.3905 | 4.052402 | 0.272716 | 0.066947 | 0.398760 | 0.473739 | -0.368910 | 0.008251 | 0.000643 | 0.065970 |

EXCITING FORCE, MOMENTS AND PHASES
FN = .454
BETA = 135.0

| WW | WE | L/LAM | FORCE | PHASE | MOMENT | PHASE | *MOMENT | LAM/L |
|---|---|---|---|---|---|---|---|---|
| 0.3425 | 0.4296 | 0.1000 | 0.81052 | 20.368 | 0.02974 | 95.400 | 0.04733 | 10.0000 |
| 0.3651 | 0.4641 | 0.1136 | 0.79068 | 21.959 | 0.12205 | 35.111 | 0.17097 | 8.8014 |
| 0.3877 | 0.4993 | 0.1281 | 0.77019 | 23.520 | 0.24692 | 28.318 | 0.30677 | 7.8061 |
| 0.4103 | 0.5352 | 0.1435 | 0.74900 | 25.020 | 0.39000 | 26.022 | 0.43267 | 6.9706 |
| 0.4328 | 0.5719 | 0.1597 | 0.72692 | 26.402 | 0.55193 | 24.943 | 0.55009 | 6.2623 |
| 0.4554 | 0.6096 | 0.1768 | 0.70139 | 27.562 | [illegible] | [illegible] | [illegible] | [illegible] |
| 0.4780 | 0.6475 | 0.1947 | 0.67631 | 28.318 | 0.94173 | 23.453 | 0.77128 | 5.1350 |
| 0.5006 | 0.6866 | 0.2136 | 0.64065 | 28.529 | [illegible] | [illegible] | [illegible] | [illegible] |
| 0.5232 | 0.7266 | 0.2333 | 0.58353 | 28.669 | 1.42362 | 18.022 | 0.97129 | 4.2868 |
| 0.5457 | 0.7668 | 0.2538 | 0.51686 | 32.754 | 1.55092 | 13.333 | 0.97240 | 3.9394 |
| 0.5683 | 0.8081 | 0.2753 | 0.49322 | 38.737 | [illegible] | [illegible] | [illegible] | [illegible] |
| 0.5909 | 0.8501 | 0.2976 | 0.48538 | 42.107 | 1.72300 | 16.899 | 0.92148 | 3.3603 |
| 0.6135 | 0.8929 | 0.3208 | 0.47189 | 43.737 | 1.89296 | 19.562 | 0.93923 | 3.1175 |
| 0.6360 | 0.9364 | 0.3448 | 0.45123 | 44.732 | 2.07712 | 21.429 | 0.95874 | 2.9001 |
| 0.6586 | 0.9807 | 0.3697 | 0.42578 | 45.436 | 2.25889 | 22.890 | 0.97238 | 2.7047 |
| 0.6812 | 1.0257 | 0.3955 | 0.39723 | 45.934 | 2.43222 | 24.214 | 0.97874 | 2.5284 |
| 0.7038 | 1.0715 | 0.4222 | 0.36678 | 46.232 | 2.59591 | 25.549 | 0.97366 | 2.3688 |
| 0.7264 | 1.1181 | 0.4497 | 0.33533 | 46.307 | 2.75097 | 26.943 | 0.97364 | 2.2238 |
| 0.7489 | 1.1654 | 0.4781 | 0.30275 | 46.156 | 2.89777 | 28.315 | 0.96469 | 2.0917 |
| 0.7715 | 1.2136 | 0.5073 | 0.27267 | 45.336 | 3.04751 | 29.808 | 0.95603 | 1.9711 |
| 0.7941 | 1.2623 | 0.5375 | 0.24328 | 43.752 | 3.19498 | 31.095 | 0.94611 | 1.8606 |
| 0.8167 | 1.3118 | 0.5685 | 0.21534 | 41.046 | 3.33710 | 32.081 | 0.93431 | 1.7591 |
| 0.8393 | 1.3622 | 0.6003 | 0.18941 | 36.641 | 3.46769 | 32.668 | 0.91933 | 1.6658 |
| 0.8618 | 1.4133 | 0.6331 | 0.16572 | 29.964 | 3.57505 | 32.818 | 0.89878 | 1.5796 |
| 0.8844 | 1.4651 | 0.6667 | 0.14492 | 20.300 | 3.64777 | 32.605 | 0.87084 | 1.5000 |



EXCITING FORCE, MOMENTS AND PHASES
FN = .454
BETA = 135.0

| WW | WE | L/LAM | SFORCE | PHASE | RMOMENT | PHASE | *MOMENT | YMOMENT | PHASE | *MOMENT | LAM/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.3425 | 0.4296 | 0.1000 | 2.99535 | -98.816 | 0.13895 | -103.607 | 0.22114 | 1.07420 | 177.310 | 1.70964 | 10.0000 |
| 0.3651 | 0.4641 | 0.1136 | 3.48017 | -100.069 | 0.16518 | -103.996 | 0.23138 | 1.13491 | 175.726 | 1.58977 | 8.8014 |
| 0.3877 | 0.4993 | 0.1281 | 3.99717 | -101.729 | 0.19514 | -106.712 | 0.24243 | 1.18687 | 173.753 | 1.47206 | 7.8061 |
| 0.4103 | 0.5352 | 0.1435 | 4.53144 | -103.759 | 0.22554 | -105.934 | 0.25022 | 1.21904 | 171.422 | 1.35240 | 6.9706 |
| 0.4328 | 0.5719 | 0.1597 | 5.06277 | -106.061 | 0.25921 | -107.516 | 0.25835 | 1.23246 | 168.832 | 1.22837 | 6.2623 |
| 0.4554 | 0.6094 | 0.1768 | 5.56935 | -108.486 | 0.29376 | -109.325 | 0.26447 | 1.22154 | 166.136 | 1.09976 | 5.6568 |
| 0.4780 | 0.6476 | 0.1947 | 6.03201 | -110.853 | 0.32811 | -111.206 | 0.26815 | 1.18485 | 163.522 | 0.96833 | 5.1350 |
| 0.5006 | 0.6866 | 0.2136 | 6.43795 | -112.978 | 0.36136 | -113.002 | 0.26927 | 1.12336 | 161.190 | 0.83712 | 4.6822 |
| 0.5232 | 0.7264 | 0.2333 | 6.78469 | -114.666 | 0.39282 | -114.548 | 0.26801 | 1.04028 | 159.362 | 0.70975 | 4.2868 |
| 0.5457 | 0.7668 | 0.2538 | 7.08407 | -115.756 | 0.42250 | -115.699 | 0.26490 | 0.94091 | 158.260 | 0.58993 | 3.9394 |
| 0.5683 | 0.8081 | 0.2753 | 7.35831 | -116.147 | 0.45090 | -116.354 | 0.26069 | 0.83066 | 158.078 | 0.48025 | 3.6326 |
| 0.5909 | 0.8501 | 0.2976 | 7.63807 | -115.784 | 0.47901 | -116.445 | 0.25618 | 0.71418 | 159.333 | 0.38196 | 3.3603 |
| 0.6135 | 0.8929 | 0.3208 | 7.96315 | -114.946 | 0.50822 | -115.937 | 0.25216 | 0.59478 | 161.453 | 0.29511 | 3.1175 |
| 0.6360 | 0.9364 | 0.3448 | 8.38802 | -112.727 | 0.54220 | -114.725 | 0.25026 | 0.47421 | 165.988 | 0.21888 | 2.9001 |
| 0.6586 | 0.9807 | 0.3697 | 8.99688 | -110.226 | 0.58333 | -112.714 | 0.25110 | 0.35284 | 174.321 | 0.15189 | 2.7047 |
| 0.6812 | 1.0257 | 0.3955 | 9.94133 | -106.531 | 0.64090 | -109.828 | 0.25790 | 0.23258 | -167.514 | 0.09359 | 2.5284 |
| 0.7038 | 1.0715 | 0.4222 | 11.54962 | -102.208 | 0.73321 | -105.884 | 0.27642 | 0.15885 | -113.418 | 0.05989 | 2.3688 |
| 0.7264 | 1.1181 | 0.4497 | 14.75112 | -96.909 | 0.91156 | -100.590 | 0.32262 | 0.36146 | -50.080 | 0.12793 | 2.2238 |
| 0.7489 | 1.1654 | 0.4781 | 24.44217 | -113.378 | 1.50058 | -112.046 | 0.49955 | 4.21340 | -9.377 | 1.40334 | 2.0917 |
| 0.7715 | 1.2136 | 0.5073 | 43.50293 | -202.709 | 4.22923 | 161.153 | 1.32674 | 23.26679 | -3.496 | 7.29208 | 1.9711 |
| 0.7941 | 1.2623 | 0.5375 | 52.84926 | -254.917 | 3.13552 | 106.021 | 0.92850 | 2.40455 | 16.533 | 0.71204 | 1.8606 |
| 0.8167 | 1.3118 | 0.5685 | 13.11992 | -247.068 | 0.75444 | 117.419 | 0.21123 | 0.28574 | -25.689 | 0.08000 | 1.7591 |
| 0.8393 | 1.3622 | 0.6003 | 7.00258 | -236.125 | 0.40645 | 132.324 | 0.10776 | 0.31322 | -50.030 | 0.08304 | 1.6658 |
| 0.8618 | 1.4133 | 0.6331 | 4.55073 | -223.901 | 0.27726 | 147.361 | 0.06970 | 0.40042 | -50.732 | 0.10067 | 1.5796 |
| 0.8844 | 1.4651 | 0.6667 | 3.29828 | -210.830 | 0.21508 | 160.387 | 0.05135 | 0.48667 | -48.440 | 0.11619 | 1.5000 |

MOTION AMPLITUDES AND PHASES
FN = .454
BETA = 135.0

| WW | WE | L/LAM | HEAVE | PHASE | PITCH | PHASE | *PITCH | LAM/L |
|---|---|---|---|---|---|---|---|---|
| 0.3425 | 0.4296 | 0.1000 | 1.19636 | -3.116 | 0.32180 | -123.088 | 1.02633 | 10.0000 |
| 0.3651 | 0.4641 | 0.1136 | 1.25738 | -5.691 | 0.35348 | -128.415 | 0.99030 | 8.8014 |
| 0.3877 | 0.4993 | 0.1281 | 1.32894 | -9.591 | 0.38063 | -134.915 | 0.94577 | 7.8061 |
| 0.4103 | 0.5352 | 0.1435 | 1.40346 | -15.301 | 0.39818 | -142.738 | 0.88347 | 6.9706 |
| 0.4328 | 0.5719 | 0.1597 | 1.45186 | -23.244 | 0.39834 | -151.863 | 0.79604 | 6.2623 |
| 0.4554 | 0.6094 | 0.1768 | 1.47169 | -33.450 | 0.37249 | -161.562 | 0.67071 | 5.6568 |
| 0.4780 | 0.6476 | 0.1967 | 1.40166 | -45.156 | 0.31858 | -169.857 | 0.52073 | 5.1350 |
| 0.5006 | 0.6866 | 0.2136 | 1.24923 | [illegible] | [illegible] | [illegible] | 0.3714[illegible] | 4.6822 |
| 0.5232 | 0.7264 | 0.2333 | 1.04276 | -66.993 | 0.19436 | -166.333 | 0.26521 | 4.2868 |
| 0.5457 | 0.7668 | 0.2538 | 0.84792 | -72.691 | [illegible] | [illegible] | [illegible] | 3.9394 |
| 0.5683 | 0.8081 | 0.2753 | 0.70811 | -75.799 | 0.15662 | -149.809 | 0.18110 | 3.6326 |
| 0.5909 | 0.8501 | 0.2976 | 0.59960 | -78.246 | 0.14966 | -140.454 | 0.16008 | 3.3603 |
| 0.6135 | 0.8929 | 0.3208 | 0.45167 | [illegible] | [illegible] | [illegible] | [illegible] | 3.1175 |
| 0.6360 | 0.9364 | 0.3448 | 0.36780 | -84.239 | 0.19886 | -129.961 | 0.18357 | 2.9001 |
| 0.6586 | 0.9807 | 0.3697 | 0.30416 | -84.658 | 0.20165 | -128.371 | 0.17361 | 2.7047 |
| 0.6812 | 1.0257 | 0.3955 | 0.25114 | -84.561 | 0.20222 | -127.469 | 0.16275 | 2.5284 |
| 0.7038 | 1.0715 | 0.4222 | 0.20576 | -83.994 | 0.20094 | -126.973 | 0.15151 | 2.3688 |
| 0.7264 | 1.1181 | 0.4497 | 0.18578 | -83.114 | 0.19039 | -124.454 | 0.13476 | 2.2238 |
| 0.7489 | 1.1654 | 0.4781 | 0.32948 | -60.818 | 0.08043 | -130.831 | 0.05355 | 2.0917 |
| 0.7715 | 1.2134 | 0.5073 | 0.18698 | -78.767 | 0.15671 | -116.508 | 0.09832 | 1.9711 |
| 0.7941 | 1.2623 | 0.5375 | 0.12655 | -80.505 | 0.17013 | -119.063 | 0.10076 | 1.8606 |
| 0.8167 | 1.3118 | 0.5685 | 0.09667 | -79.897 | 0.16915 | -119.474 | 0.09471 | 1.7591 |
| 0.8393 | 1.3622 | 0.6003 | 0.05967 | -73.255 | 0.16670 | -122.575 | 0.08839 | 1.6658 |
| 0.8618 | 1.4133 | 0.6331 | 0.04275 | -65.144 | 0.15821 | -123.812 | 0.07955 | 1.5796 |
| 0.8844 | 1.4651 | 0.6667 | 0.03504 | -68.098 | 0.15307 | -122.385 | 0.07308 | 1.5000 |



MOTION AMPLITUDES AND PHASES
FN = .454
BETA = 135.0

| WW | WE | L/LAM | SWAY | PHASE | ROLL | PHASE | *ROLL | YAW | PHASE | *YAW | LAM/L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.3425 | 0.4296 | 0.1000 | 0.23121 | 56.627 | 0.07391 | -5.854 | 0.54050 | 0.25287 | 145.560 | 0.80491 | 10.0000 |
| 0.3651 | 0.4641 | 0.1136 | 0.21557 | 56.680 | 0.10761 | -5.751 | 0.69259 | 0.25197 | 147.272 | 0.70592 | 8.8014 |
| 0.3877 | 0.4993 | 0.1281 | 0.35071 | 64.812 | 0.42614 | 15.784 | 2.43253 | 0.32773 | 169.042 | 0.81432 | 7.8061 |
| 0.4103 | 0.5352 | 0.1435 | 0.50825 | 85.334 | 0.11568 | 134.098 | 0.58968 | 0.10097 | 168.720 | 0.22402 | 6.9706 |
| 0.4328 | 0.5719 | 0.1597 | 0.50906 | 85.830 | 0.12122 | 129.110 | 0.55516 | 0.11297 | 170.509 | 0.22520 | 6.2623 |
| 0.4554 | 0.6094 | 0.1768 | 0.50735 | 86.252 | 0.12701 | 125.198 | 0.52540 | 0.12573 | 171.715 | 0.22638 | 5.6568 |
| 0.4780 | 0.6476 | 0.1947 | 0.50297 | 86.624 | 0.13296 | 121.934 | 0.49927 | 0.13895 | 172.327 | 0.22713 | 5.1350 |
| 0.5006 | 0.6866 | 0.2136 | 0.49630 | 86.981 | 0.13866 | 119.101 | 0.47477 | 0.15218 | 172.707 | 0.22681 | 4.6822 |
| 0.5232 | 0.7264 | 0.2333 | 0.48816 | 87.367 | 0.14369 | 116.600 | 0.45044 | 0.16493 | 172.992 | 0.22506 | 4.2868 |
| 0.5457 | 0.7668 | 0.2538 | 0.47989 | 87.855 | 0.14783 | 114.456 | 0.42588 | 0.17683 | 173.258 | 0.22173 | 3.9394 |
| 0.5683 | 0.8081 | 0.2753 | 0.47322 | 88.557 | 0.15130 | 112.794 | 0.40193 | 0.18739 | 173.608 | 0.21668 | 3.6326 |
| 0.5909 | 0.8501 | 0.2976 | 0.47124 | 89.692 | 0.15484 | 111.871 | 0.38049 | 0.19592 | 174.166 | 0.20956 | 3.3603 |
| 0.6135 | 0.8929 | 0.3208 | 0.55361 | -261.407 | 0.17775 | 119.298 | 0.40523 | 0.17675 | 174.553 | 0.17539 | 3.1175 |
| 0.6360 | 0.9364 | 0.3448 | 0.24132 | 77.248 | 0.10701 | 93.002 | 0.22695 | 0.23613 | 167.876 | 0.21798 | 2.9001 |
| 0.6586 | 0.9807 | 0.3697 | 0.33324 | 83.939 | 0.12972 | 99.932 | 0.25657 | 0.24035 | 173.254 | 0.20693 | 2.7047 |
| 0.6812 | 1.0257 | 0.3955 | 0.38461 | 88.197 | 0.14475 | 104.344 | 0.26764 | 0.24321 | 177.107 | 0.19574 | 2.5284 |
| 0.7038 | 1.0715 | 0.4222 | 0.39768 | 89.705 | 0.15300 | 105.005 | 0.26502 | 0.25250 | 179.975 | 0.19039 | 2.3688 |
| 0.7264 | 1.1181 | 0.4497 | 0.40892 | -269.600 | 0.16649 | 105.271 | 0.27074 | 0.26871 | -176.694 | 0.19021 | 2.2238 |
| 0.7489 | 1.1654 | 0.4781 | 0.37582 | -259.151 | 0.18629 | 96.419 | 0.28188 | 0.28074 | 174.653 | 0.14692 | 2.0917 |
| 0.7715 | 1.2134 | 0.5073 | 0.30378 | -262.109 | 0.13109 | 21.441 | 0.18895 | 0.33949 | -178.558 | 0.11300 | 1.9711 |
| 0.7941 | 1.2623 | 0.5375 | 0.41501 | 89.804 | 0.01544 | 2.436 | 0.02101 | 0.39413 | -179.743 | 0.23342 | 1.8606 |
| 0.8167 | 1.3118 | 0.5685 | 0.43746 | 79.968 | 0.08247 | 88.855 | 0.10609 | 0.51299 | 147.500 | 0.28725 | 1.7591 |
| 0.8393 | 1.3622 | 0.6003 | 0.40773 | 60.505 | 0.08876 | 70.515 | 0.10812 | 0.51135 | 136.583 | 0.27113 | 1.6658 |
| 0.8618 | 1.4133 | 0.6331 | 0.31081 | 50.249 | 0.06888 | 61.725 | 0.07956 | 0.31543 | 118.129 | 0.15860 | 1.5796 |
| 0.8844 | 1.4651 | 0.6667 | 0.24644 | 44.580 | 0.05512 | 58.793 | 0.06046 | 0.19477 | 124.516 | 0.09300 | 1.5000 |

SWATMO SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE PAGE 25

RELATIVE AND ABSOLUTE DISPLACEMENT,VELOCITY,AND ACCELERATION AT STATION 4.0000 AND HEIGHT 50.0000 FEET

SPEED = 20.0 KNOTS
WAVE HEADING = 135.0 DEGREES

| | ******************HEAVE-PITCH****************** | | | | ***********SWAY-ROLL-YAW********** | | | |
|---|---|---|---|---|---|---|---|---|
| ENC PER SEC | REL DISPL | ABS DISPL | VEL | ACCEL/G | ABS DISPL | VEL | ACCEL/G | WAVE L/L |
| 14.62 | 0.316 | 1.308 | 0.562 | 0.008 | 3.738 | 1.606 | 0.021 | 10.0000 |
| 13.54 | 0.415 | 1.389 | 0.645 | 0.009 | 5.427 | 2.519 | 0.036 | 8.8014 |
| 12.58 | 0.545 | 1.479 | 0.738 | 0.011 | 21.263 | 10.616 | 0.165 | 7.8061 |
| 11.74 | 0.708 | 1.567 | 0.839 | 0.014 | 5.408 | 2.895 | 0.048 | 6.9706 |
| 10.99 | 0.898 | 1.629 | 0.932 | 0.017 | 5.646 | 3.229 | 0.057 | 6.2623 |
| 10. . | 1.091 | 1.626 | 0.991 | 0.019 | 5.908 | 3.600 | 0.068 | 5.6568 |
| 9.70 | 1.245 | 1.524 | 0.987 | 0.020 | 6.186 | 4.006 | 0.081 | 5.1350 |
| 9.15 | 1.325 | 1.325 | 0.910 | 0.019 | 6.459 | 4.435 | 0.095 | 4.6822 |
| 8.65 | 1.319 | 1.070 | 0.777 | 0.018 | 6.703 | 4.869 | 0.110 | 4.2868 |
| 8.19 | 1.259 | 0.846 | 0.648 | 0.015 | 6.906 | 5.296 | 0.126 | 3.9394 |
| 7.78 | 1.212 | 0.688 | 0.556 | 0.014 | 7.077 | 5.719 | 0.144 | 3.6326 |
| 7.39 | 1.176 | 0.563 | 0.478 | 0.013 | 7.249 | 6.163 | 0.163 | 3.3603 |
| 7.04 | 1.101 | 0.385 | 0.344 | 0.010 | 8.307 | 7.418 | 0.206 | 3.1175 |
| 6.71 | 1.063 | 0.295 | 0.276 | 0.008 | 5.080 | 4.757 | 0.138 | 2.9001 |
| 6.41 | 1.033 | 0.230 | 0.226 | 0.007 | 6.123 | 6.005 | 0.183 | 2.7047 |
| 6.13 | 1.009 | 0.180 | 0.185 | 0.006 | 6.824 | 6.999 | 0.223 | 2.5284 |
| 5.86 | 0.987 | 0.142 | 0.153 | 0.005 | 7.225 | 7.742 | 0.258 | 2.3688 |
| 5.62 | 0.985 | 0.124 | 0.139 | 0.005 | 7.895 | 8.827 | 0.307 | 2.2238 |
| 5.39 | 1.050 | 0.316 | 0.368 | 0.013 | 8.806 | 10.262 | 0.372 | 2.0917 |
| 5.18 | 1.009 | 0.125 | 0.152 | 0.006 | 6.693 | 8.121 | 0.306 | 1.9711 |
| 4.98 | 0.971 | 0.079 | 0.100 | 0.004 | 1.085 | 1.370 | 0.054 | 1.8606 |
| 4.79 | 0.955 | 0.069 | 0.091 | 0.004 | 3.637 | 4.771 | 0.195 | 1.7591 |
| 4.61 | 0.929 | 0.079 | 0.108 | 0.005 | 3.913 | 5.330 | 0.226 | 1.6658 |
| 4.45 | 0.921 | 0.085 | 0.120 | 0.005 | 3.032 | 4.285 | 0.188 | 1.5796 |
| 4.29 | 0.923 | 0.080 | 0.118 | 0.005 | 2.468 | 3.615 | 0.165 | 1.5000 |

SWATMO SHIP MOTIONS OF SWATH 6A IRREGULAR WAVE TEST CASE PAGE 26

RMS MOTIONS IN UNIDIRECTIONAL SEAS

SPEED = 20.0 KNOTS FROUDE NO = 0.454

SEA STATE = 6 SIG WAVE HT = 18.0000 FEET WAVE PERIOD = 9.9100 SEC

| HEADING (DEG) | SWAY ACC (G) | HEAVE (F) | HEAVE ACC (G) | ROLL (DEG) | PITCH (DEG) | YAW (DEG) |
|---|---|---|---|---|---|---|
| 135.0 | 0.053 | 2.170 | 0.063 | 0.416 | 0.575 | 1.076 |

STATION = 4.0000 Z = 57.4400 F

| HEADING | *************VERTICAL************** | | | | | FREQ | SWAY | PROB | DW PER | PROB | KE PER | PROB | SI PER | SLAM PRESSURE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MOT | VEL | ACC | REL.MOT | REL.VEL | | ACC | (DW) | HOUR | (KE) | HOUR | (SI) | HOUR | MOST PROB | EXTREME |
| DEG | F | F/SEC | G | F | F/SEC | | G | | | | | | | PSI | PSI |
| 135.0 | 2.311 | 1.910 | 0.054 | 4.953 | 5.053 | 0.062 | 0.068 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0003 | 0.1 | 8.577 | 41.091 |

```
SWATH 6A REGULAR WAVE TEST CASE
  1  1  1  1  1  0
  25  1  1  25  1  22  3
  1.5  10.0
  135.
  0.4537
  37.5
10.27278
7.330
 172.3      0.315   0.223     0.0       7.44     15.00    19.17
  40.44      25.75     19.17     8.5      10.2      1.28      4.38     1.2
 188.12      23.55     19.17    14.7      17.6      2.2       3.43     1.2
   0.5        0.07
   0
  -2.4        9        0
  -1.6        9        0
   -.8        9        0
   0.0        9        0
   1.0       15        0
   2.0       15        0
   3.0       15        0
   4.0       15        0
   6.0       15        2
   8.0       15        1
  10.0       15        1
  12.0       15        1
  14.0       15        1
  16.0       15        0
  17.0       15        0
  18.0       15        0
  19.0       15        0
  20.0        9        0
  21.5        9        0
  23.0        9        0
  23.8        9        0
  24.6        9        0
 0.       -3.44    -4.87    -3.44     0.       3.44     4.87     3.44
 0.
12.37     10.94     7.50     4.06     2.63     4.06     7.50    10.94
12.37
 0.       -4.23    -5.98    -4.23     0.       4.23     5.98     4.23
 0.
13.48     11.73     7.50     3.27     1.52     3.27     7.50    11.73
13.48
 0.       -4.70    -6.65    -4.70     0.       4.70     6.65     4.70
 0.
14.15     12.20     7.50     2.80     0.85     2.80     7.50    12.20
14.15
 0.       -5.06    -7.16    -5.06     0.       5.06     7.16     5.06
 0.
14.66     12.56     7.50     2.44     0.34     2.44     7.50    12.56
14.66
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| -1.06 | -1.06 | -1.06 | -1.06 | -4.89 | -7.47 | -5.28 | 0. |
| 5.28 | 7.47 | 4.89 | 1.06 | 1.06 | 1.06 | 1.06 | |
| 26.67 | 22.74 | 18.82 | 14.89 | 13.14 | 7.50 | 2.22 | 0.03 |
| 2.22 | 7.50 | 13.14 | 14.89 | 18.82 | 22.74 | 26.67 | |
| -2.17 | -2.17 | -2.17 | -2.17 | -4.47 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 4.47 | 2.17 | 2.17 | 2.17 | 2.17 | |
| 26.67 | 22.67 | 18.68 | 14.68 | 13.52 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.52 | 14.68 | 18.68 | 22.67 | 26.67 | |
| -3.01 | -3.01 | -3.01 | -3.01 | -4.11 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 4.11 | 3.01 | 3.01 | 3.01 | 3.01 | |
| 26.67 | 22.57 | 18.47 | 14.37 | 13.78 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.78 | 14.37 | 18.47 | 22.57 | 26.67 | |
| -3.41 | -3.41 | -3.41 | -3.41 | -3.92 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.92 | 3.41 | 3.41 | 3.41 | 3.41 | |
| 26.67 | 22.51 | 18.34 | 14.18 | 13.90 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.90 | 14.18 | 18.34 | 22.51 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.63 | -3.63 | -3.63 | -3.63 | -3.81 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.81 | 3.63 | 3.63 | 3.63 | 3.63 | |
| 26.67 | 22.47 | 18.27 | 14.07 | 13.96 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.96 | 14.07 | 18.27 | 22.47 | 26.67 | |
| -3.48 | -3.48 | -3.48 | -3.48 | -3.88 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 3.88 | 3.48 | 3.48 | 3.48 | 3.48 | |
| 26.67 | 22.49 | 18.32 | 14.14 | 13.92 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.92 | 14.14 | 18.32 | 22.49 | 26.67 | |
| -3.12 | -3.12 | -3.12 | -3.12 | -4.05 | -7.50 | -5.30 | 0. |
| 5.30 | 7.50 | 4.05 | 3.12 | 3.12 | 3.12 | 3.12 | |
| 26.67 | 22.55 | 18.43 | 14.32 | 13.81 | 7.50 | 2.20 | 0. |
| 2.20 | 7.50 | 13.81 | 14.32 | 18.43 | 22.55 | 22.67 | |
| -2.43 | -2.43 | -2.43 | -2.43 | -4.31 | -7.42 | -5.25 | 0. |
| 5.25 | 7.42 | 4.31 | 2.43 | 2.43 | 2.43 | 2.43 | |
| 26.67 | 22.62 | 18.57 | 14.52 | 13.55 | 7.50 | 2.25 | 0.08 |
| 2.25 | 7.50 | 13.55 | 14.52 | 18.57 | 22.62 | 26.67 | |
| -1.43 | -1.43 | -1.43 | -1.43 | -4.56 | -7.21 | -5.10 | 0. |
| 5.10 | 7.21 | 4.56 | 1.43 | 1.43 | 1.43 | 1.43 | |
| 26.67 | 22.63 | 18.60 | 14.56 | 13.08 | 7.50 | 2.40 | 0.29 |
| 2.40 | 7.50 | 13.08 | 14.56 | 18.60 | 22.63 | 26.67 | |

```
 0.     -4.81   -6.80   -4.81   0.      4.81    6.80    4.81
 0.
14.30   12.31    7.50    2.69   0.70    2.69    7.50   12.31
14.30
 0.     -4.22   -5.97   -4.22   0.      4.22    5.97    4.22
 0.
13.47   11.72    7.50    3.28   1.53    3.28    7.50   11.72
13.47
 0.     -3.33   -4.71   -3.33   0.      3.33    4.71    3.33
 0.
12.21   10.83    7.50    4.17   2.79    4.17    7.50   10.83
12.21
 0.     -2.32   -3.28   -2.32   0.      2.32    3.28    2.32
 0.
10.78    9.82    7.50    5.18   4.22    5.18    7.50    9.82
10.78
 0.     -1.06   -1.50   -1.06   0.      1.06    1.50    1.06
 0.
 9.00    8.56    7.50    6.44   6.00    6.44    7.50    8.56
 9.00
@
```

## APPENDIX E

## OFFSET USER GUIDE

Record (1), 1 integer

NOS the number of stations to be analyzed.

Note: (1) Non-integer stations should be given arbitrary integer station numbers, later to be corrected by editing the output file with the computer system editor.

Record (2), 2 reals

D(I) diameter of hull at $I^{th}$ station.

ST(I) strut thickness at $I^{th}$ station.

Note: (1) Record (2) must be repeated NOS times. D(I) and ST(I) must be entered as a pair.

Record (3), 1 real

DWL the draft of the SWATH ship.

Note: (1) DWL is given as distance from baseline to free surface.

Record (4), 2 reals

X01(I) x-keel coordinate of $I^{th}$ station.
Y01(I) y-keel coordinate of $I^{th}$ station.

Note: (1) X01(I) and Y01(I) must be entered as a pair.
Record (4) must be repeated NOS times.

### 5.3 Listings

Samples of input and output are given in Appendices F and G.

## APPENDIX F

## SAMPLE INPUT FOR OFFSET

This input represents a trivial case of two SWATH sections. The first section has a hull diameter of 15 feet with a strut 5 ft thick. The keel is on the baseline. The second section is forward of the strut, with a reduced diameter of 13 feet and the keel 1 foot above the baseline.

```
  2
15.0        9.0
13.0        0.0
28.0
 0.0       30.0
 1.0       30.0
```

## APPENDIX G

## SAMPLE OUTPUT FOR OFFSET

This output was generated using the input file in Appendix D

```
-4.5000  -4.5000  -4.5000  -4.5000  -7.4665  -5.5481   0.0000   5.5481   7.4665
 4.5000   4.5000   4.5000   4.5000
28.0000  33.1667  38.3333  43.5000  38.2084  32.4534  30.0000  32.4534  38.2084
43.5000  38.3333  33.1667  28.0000
 0.0000  -4.5962  -6.5000  -4.5962   0.0000   4.5962   6.5000   4.5962   0.0000
43.0000  41.0962  36.5000  31.9038  30.0000  31.9038  36.5000  41.0962  43.0000
```

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