Carderock Division, Naval Surface Warfare Center

West Bethesda, Maryland 20817-5700

CRDKNSWC/HD-1461-01 September 1998
Hydromechanics Directorate
Research and Development Report

Documentation for Program SHIPMO: a Database for Ship Motions

by
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and
Terry Applebee

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CRDKNSWC/HD-1461-01 Documentation for Program SHIPMO: A Ship Motions Database

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NDW-DTRC 5602/51 (Rev. 7-93)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1998	FINAL

4. TITLE AND SUBTITLE

Documentation for Program SHIPMO: a Database for Ship Motions

5. FUNDING NUMBERS

WU: 1-5610-446

6. AUTHOR(S)

Paul J. Kopp and Terry Applebee

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Surface Warfare Center, Carderock Division
Code 5500, Seakeeping Department
West Bethesda, Maryland
20817-5700

8. PERFORMING ORGANIZATION REPORT NUMBER

CDRKNSWC/HD-1461-01

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Air Systems Command
Joint Advanced Strike Technology (JAST) Program Office
1421 Jefferson Davis Highway
Arlington, Virginia 2243-5120

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLIMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Public Release: Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Joint Strike Force (JSF) Office at the Naval Air Systems Command (NAVAIR) tasked the Naval Surface Warfare Center, Carderock Division, to develop a ship motion database. The purpose of this database is to provide readily accessible ship motion data for air-capable ships to support design and development of JSF aircraft and to support shipboard operations. This report provides a description of the application and content of the database computer program as well as other supporting programs

14. SUBJECT TERMS

Ship Motions

15. NUMBER OF PAGES

39

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unclassified/Unlimited

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)

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ABSTRACT

The Joint Strike Force (JSF) Office at the Naval Air Systems Command (NAVAIR) tasked the Naval Surface Warfare Center, Carderock Division, to develop a ship motion database. The purpose of this database is to provide readily accessible ship motion data for air-capable ships to support design and development of JSF aircraft and to support shipboard operations. This report provides a description of the initial version (1.1) of the application and the content of the database computer program as well as other supporting programs.

ADMINISTRATIVE INFORMATION

This work was funded by the Joint Strike Fighter (JSF) Office, formerly the Joint Advanced Strike Technology (JAST) Office, of the Naval Air Systems Command (NAVAIR). It was performed by the Seakeeping Department, Code 5500, Naval Surface Warfare Center, Carderock Division, under Work Unit Number 1-5610-446.

INTRODUCTION

Knowledge of the motion responses of an air capable ship can be useful in the design of aircraft. Having ship motion data readily available can facilitate the design and development of JSF aircraft. The goal of the effort described here was to develop a computer program to allow access to a database of various motion responses for a range of sea and ship operational conditions for a selection of air capable ships. After considering various options for implementing this task from the points of view of user accessibility as well as maintainability, a series of programs, written in the C++ programming language, were developed to manage, access, and display information from the database. The primary advantages of using C++ for this task were the ability to encapsulate specific related groups of functions and related data into individual objects, and the ability to easily create user interface elements.

In this report, a description of the various options related to accessing this database are given. The database is structured to include three types of data: frequency domain, analytic time domain, and full-scale time domain. Only the frequency domain branch of the program has been implemented in this version of the program. The frequency domain data is generated using the U. S. Navy's Standard Ship Motions Program (SMP)[1,2,3] which is routinely used in the evaluation and design of ships. It is intended that this database will be expanded over time to include numerous classes of air capable ships.

The database computer program is written in C++ for a WIN32 capable operating system (either Windows 95, Windows 98 or Windows NT). Minimum recommended system requirements are: 100MHz Pentium processor, Windows 95 operating system, 16MB RAM, 500MB hard disk drive, CD-ROM, and super VGA display capable of 800 by 600 resolution in 256 colors. A more capable suggested system is: 166MHz Pentium processor, Windows NT Workstation operating system, 24MB RAM, 1.2GB hard disk drive, CD-ROM, laser printer, Iomega zip disk drive (to facilitate easy future updates to the database and/or programs), super VGA display capable of 1024 by 768 resolution at 256 colors. This more capable system configuration closely approximates the platform used for the development of the programs.

PROGRAM INSTALLATION

The initial release of the ship motions database and related programs is supplied on CD-ROM. In the root directory of the disk is an executable program named "SETUP.EXE". This program automates the task of installation and allows the user to select the disk drive and parent directory for all the files associated with this release of the ship motions database. If you experience problems with the automatic installation, consult the "README.TXT" file, also in the root directory of the distribution CD-ROM.

PROGRAM USAGE

The C++ program that accesses the ship motions database is called SHIPMO. SHIPMO in turn executes the program POLAR when speed-polar plots are requested, as will be described later. Complete documentation of the POLAR program is given in Appendix A. It is assumed that the user is familiar with the basic terminology used to describe and operate Microsoft Windows programs. In the discussion below, buttons with obvious uses such as "Help", "Exit", "Close" will not be discussed. Note that the data shown in any and all screen images here should not necessarily be considered representative of any particular ship or ship loading condition.

To access the database, execute the program SHIPMO. The "Ship Motions Database Application Manager" dialog box will appear on the screen, as shown in Figure 1. The "Analytic Time Domain Database" and "Full Scale Time Domain Database" are future options. The other two options, "Frequency Domain Database" and "Administrative Tasks" will be discussed below. Note that if the program is unable to find the frequency domain ship motions database file, a dialog box will appear to inform the user that they will not be able to view or administer the database.

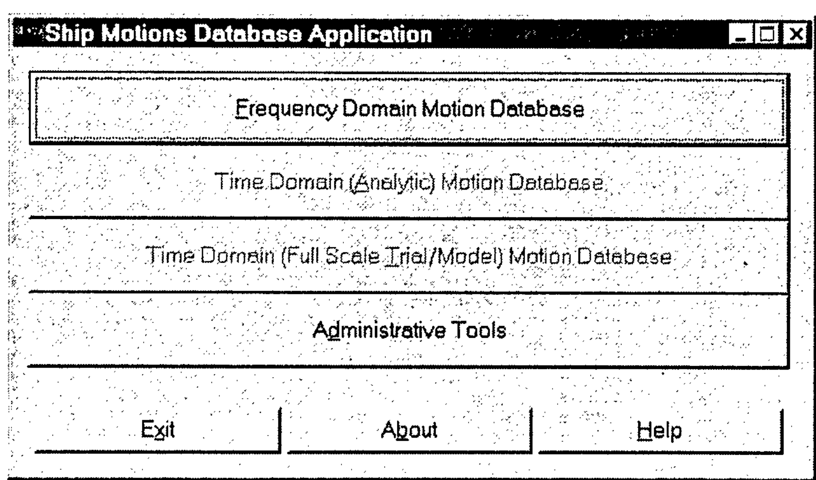


Figure 1. Ship Motions Database Application Manager Dialog Box

FREQUENCY DOMAIN DATABASE

In the dialog box shown in Figure 1, select "Frequency Domain Database". The dialog box "Frequency Domain Database: Ships and Loading Conditions" will appear, as shown in Figure 2. Choosing a ship in the list box on the side of the dialog box will display the list of associated ship loading conditions shown in the grid control on the right side of the dialog. Note that there may be more than one loading condition for each ship. Use the horizontal scroll bar at the bottom of the grid control to view additional values of attributes of the ship loading variants. These attributes are listed in Table 1.

Table 1. Description of Loading Condition Attributes

ATTRIBUTE	DESCRIPTION
Description	Title identifying the ship variant
Units	Assumed units for attributes, english (feet, LTSW) or metric (meters, tonnes)
Lpp	Length between perpendiculars
B	Beam
T	Draft
Trim	Trim, positive bow down
Disp	Displacement
GM	Nominal value of the transverse metacentric height
Del GM	Correction to the nominal transverse metacentric height to account for free surface effects
KG	Vertical center of gravity above the baseline
K Pitch	Mass radius of gyration in pitch normalized by Lpp
K Roll	Mass radius of gyration in roll normalized by B
K Yaw	Mass radius of gyration in yaw normalized by Lpp
# Bilge Keel Sets	Number of port/starboard pairs of bilge keels
# Skeg Sets	Number of port/starboard pairs of, or centerline skegs
# Rudder Sets	Number of port/starboard pairs of, or centerline rudders
# Shaft Brk Sets	Number of port/starboard pairs of, or centerline propeller shaft brackets
# Fin Sets	Number of port/starboard pairs of active or passive anti roll fins

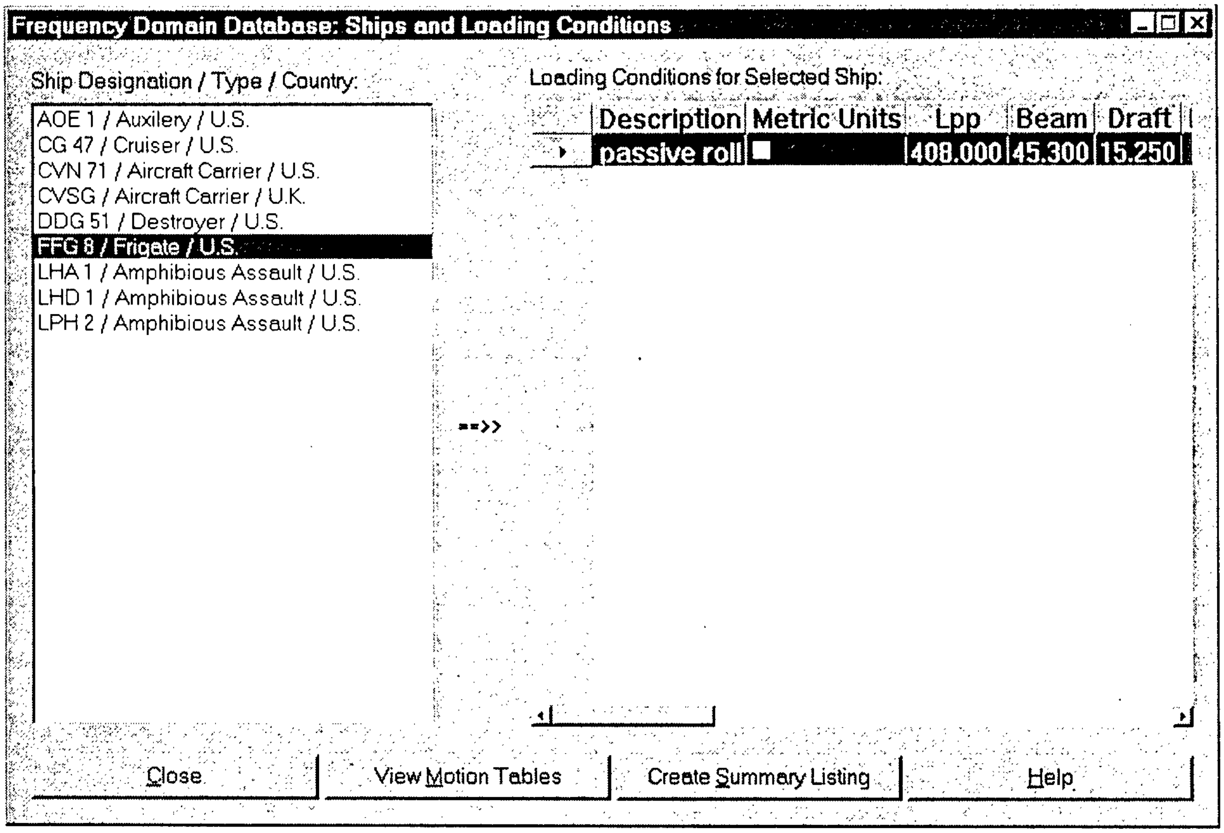


Figure 2. Frequency Domain Database: Ships and Loading Conditions Dialog Box

The "Create Summary Listing" button may be used to generate a document that describes the contents of the database. When selected, the program will indicate that a summary file has been created and then display the contents of the summary, as in Figure 3 below.

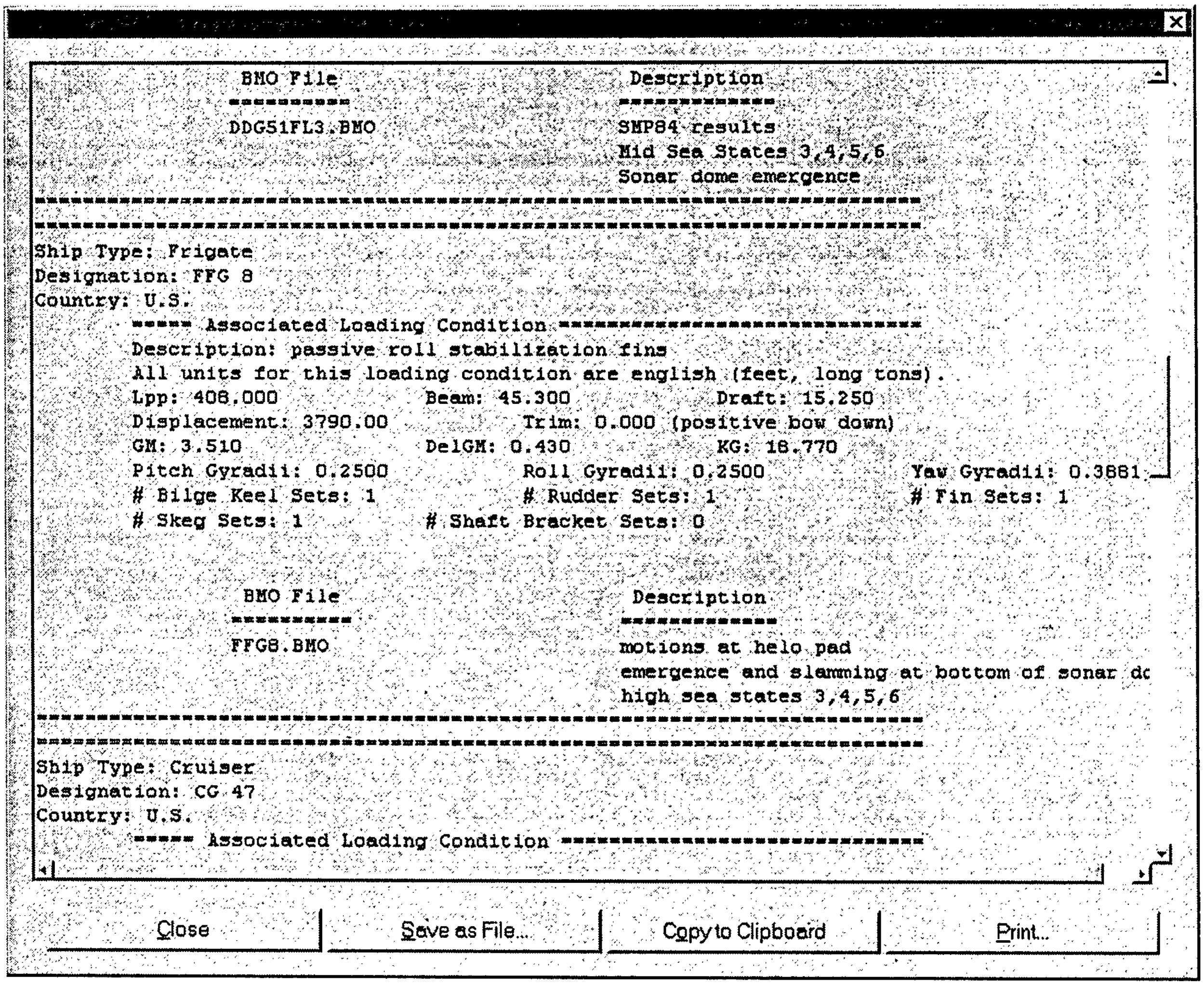


Figure 3. Database Summary View Window

The user has the option of returning to the previous menu, saving the summary to a separate text file, copying the information to the Windows clipboard (for instance, to paste into another document), or printing the information via the Windows print manager.

When "View Motion Tables" at the bottom of the "Frequency Domain Database: Ships and Loading Conditions" dialog box is selected (Figure 2), the motions data for the selected loading condition is read into memory from the binary motions output file. A message box is displayed while this occurs, as shown in Figure 4. Note that if there are no motion data files associated with the currently highlighted loading condition, the "View Motion Tables" button will be inactive and grayed out.

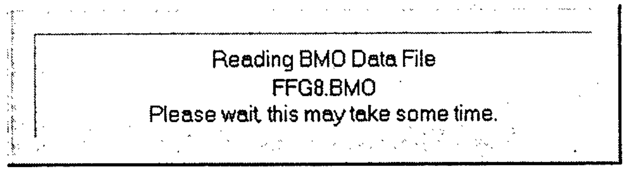


Figure 4. Message Box Displayed During Motions Data Read Operation

If there is an error reading the motions data file, or the motions data file can not be found, a message box will be displayed giving an indication of the nature of the error. Once the motions data have been read into memory, the dialog box "Frequency Domain Database: Listing of Motions" will appear, as shown in Figure 5. Note that if there was a problem reading the data file, the dialog box in Figure 5 will still be displayed, but there will be no motions data file information displayed. At the top of the screen, a number of informative descriptors appear: "Ship Designation", "Ship Type", "Country", and "Loading Description". These are echoes of the selected ship and loading condition from the previous dialog box of Figure 2. Next are two fields titled "SMP Run Description" and "BMO File Name". SMP Run Description lists the textual description of the nature of the SMP run which is being displayed. This information is entered into the database when the record for the ship motion data file is created. Normally, this information would include a list of the ship speeds and wave heights used in the original SMP run, but there is no requirement or control over what is placed in this field by the database administrator when the field is created. The "BMO File Name" field is the actual name of the motions data file that is currently being displayed. In the middle of the screen, in the grid control, there is a listing of available seaway-motion cases. Definitions of the terms used here are given in the Glossary section. The first column indicates the type of seaway. A check in the box indicates that the seaway has longcrested waves while a blank indicates shortcrested seas. Also given is the seaway's (significant wave height) "Wave Ht." in feet, the type of "Statistic" for the motion responses, the "Motion Name", and the motion "Units". The scroll bars facilitate viewing the available data and conditions. In addition, the grid control used supports the Microsoft Intellipoint mouse wheel to facilitate scrolling the data.

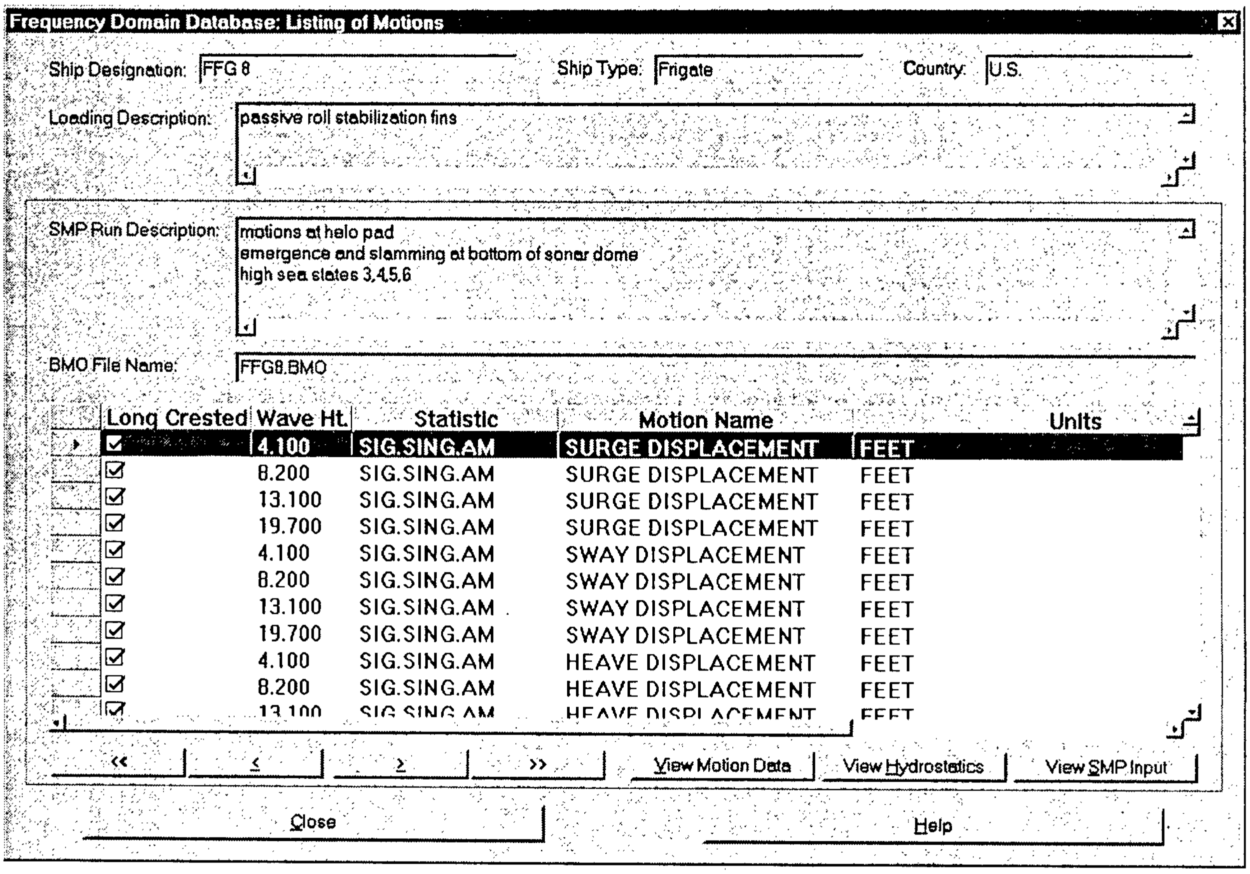


Figure 5. Frequency Domain Database: Listing of Motions Dialog Box

At the bottom of this dialog box there are several options and controls which can be selected. The VCR control style buttons (<< < > >>) can be used to step through different sets of data corresponding to the different SMP Run Descriptions. A mouse click on << accesses the first case (motions output for the current loading condition), >> the last case, < accesses the previous case, and > the next case. Note that selecting a new set of SMP output will force the entire data file to be read and display the message box show in Figure 4.

View Hydrostatics

If the user selects "View Hydrostatics", the SMP calculated hydrostatics are displayed, as shown in Figure 6. This is identical to the information the SMP writes to the output file. With the hydrostatics displayed, the user has the option of saving the information to a separate text file, copying the information to the Windows clipboard , or printing the information via the Windows print manager.

TABLE OF SHIP PARTICULARS

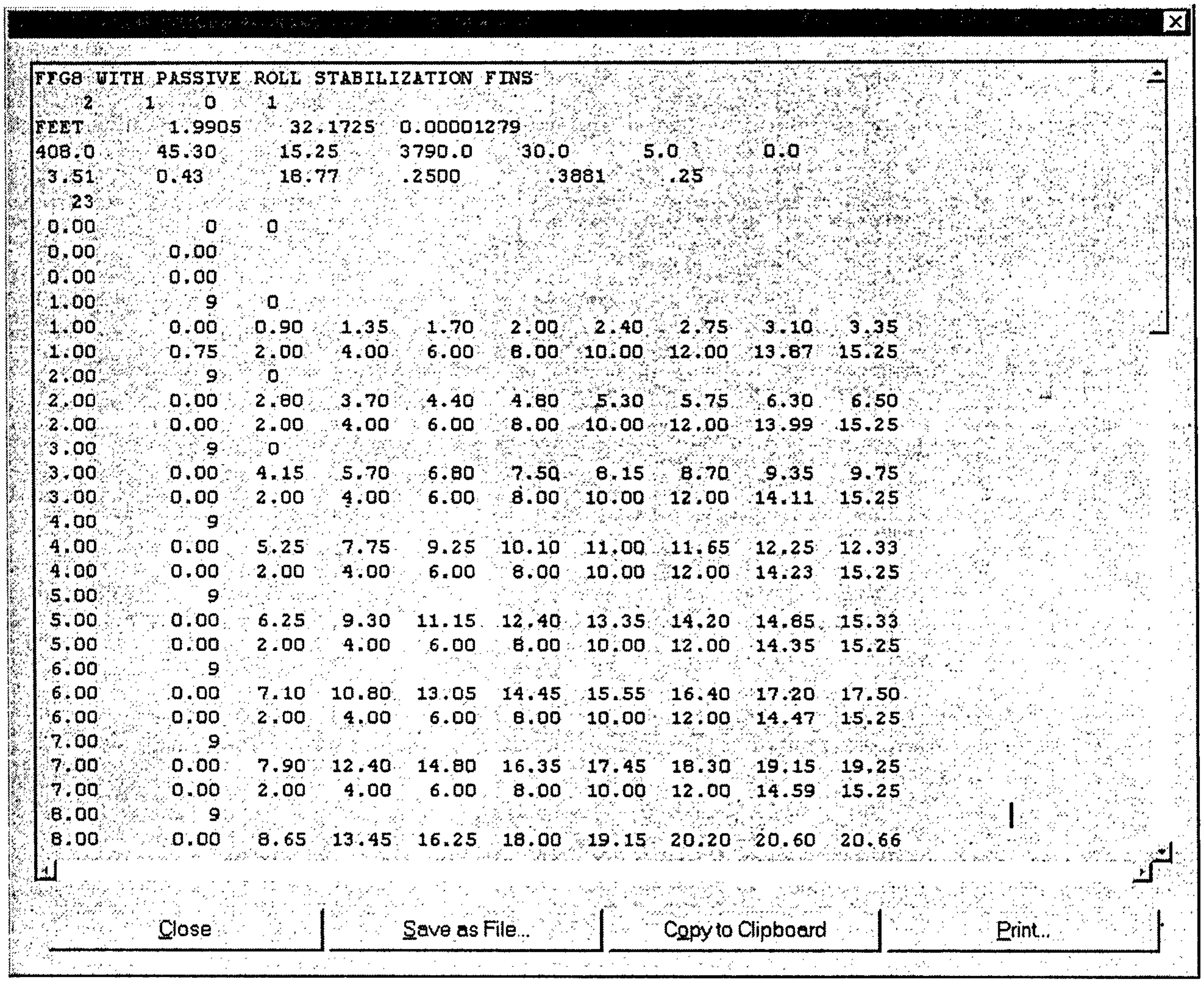
SHIP CHARACTERISTICS -			
SHIP LENGTH (LPP)	408.00 FEET	LENGTH/BEAM	9.007
BEAM AT MIDSHIPS	45.30 FEET	BEAM/DRAFT	2.970
DRAFT AT MIDSHIPS	15.25 FEET	DRAFT/BEAM	0.337
DISPLACEMENT (S.W.)	3701.0 L. TONS	DISPL/(.01LPP)**3	54.493
DESIGN SHIP SPEED	30.00 KNOTS	FROUDE NUMBER	0.442
VERTICAL LOCATIONS -			
C. OF GRAVITY (VCG)*	3.95 FEET	VCG/BEAM	0.087
C. OF GRAVITY (KG)**	19.20 FEET	KG/BEAM	0.424
METACENTRIC HT. (GM)	3.39 FEET	GM/BEAM	0.075
METACENTER (KM)**	22.59 FEET	KM/BEAM	0.499
C. OF BUOYANCY (KB)**	9.52 FEET	KB/BEAM	0.210
LONGITUDINAL LOCATIONS* -**			
C. OF GRAVITY (LCG)	206.70 FEET	LCG/LENGTH	0.507
C. OF BUOYANCY (LCB)	206.70 FEET	LCB/LENGTH	0.507
C. OF FLOTATION (LCF)	227.55 FEET	LCF/LENGTH	0.558
MOTION CHARACTERISTICS -			
ROLL GYRADIUS	17.58 FEET	RG/BEAM	0.388
PITCH GYRADIUS	102.00 FEET	PG/LPP	0.250

Close | Save as File... | Copy to Clipboard | Print...

Figure 6. Display of Calculated Hydrostatics

View SMP Input

If the user selects "View SMP Input", a listing of the SMP input file is displayed, as shown in Figure 7. While the SMP input is displayed, the user has the option of saving the information to a separate text file, copying the information to the Windows clipboard, or printing the information via the Windows print manager.

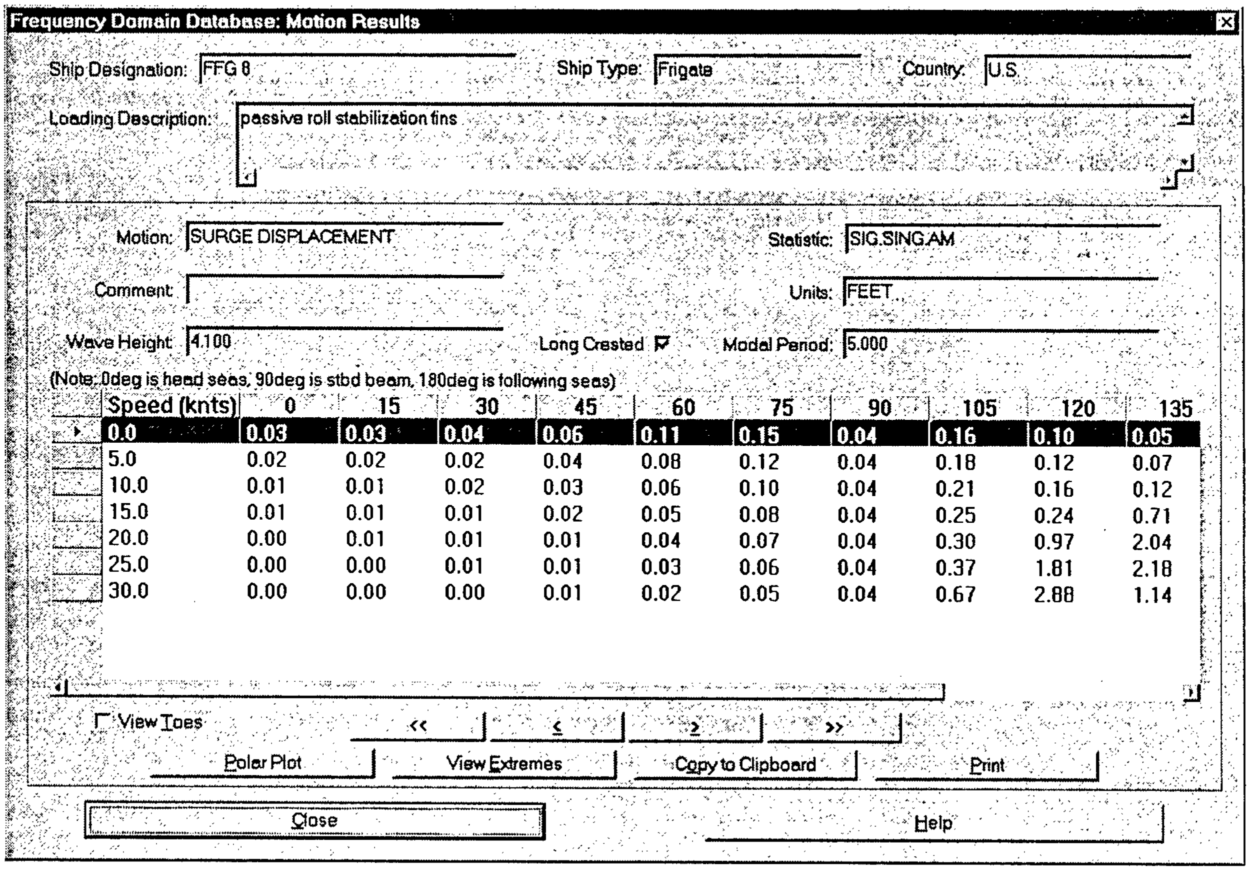


```
FFG8 WITH PASSIVE ROLL STABILIZATION FINS
  2   1   0   1
FEET     1.9905     32.1725   0.00001279
408.0    45.30      15.25     3790.0     30.0     5.0     0.0
 3.51    0.43       18.77     .2500      .3881    .25
  23
 0.00      0      0
 0.00    0.00
 0.00    0.00
 1.00      9      0
 1.00    0.00   0.90   1.35   1.70   2.00   2.40   2.75   3.10   3.35
 1.00    0.75   2.00   4.00   6.00   8.00  10.00  12.00  13.87  15.25
 2.00      9      0
 2.00    0.00   2.80   3.70   4.40   4.80   5.30   5.75   6.30   6.50
 2.00    0.00   2.00   4.00   6.00   8.00  10.00  12.00  13.99  15.25
 3.00      9      0
 3.00    0.00   4.15   5.70   6.80   7.50   8.15   8.70   9.35   9.75
 3.00    0.00   2.00   4.00   6.00   8.00  10.00  12.00  14.11  15.25
 4.00      9
 4.00    0.00   5.25   7.75   9.25  10.10  11.00  11.65  12.25  12.33
 4.00    0.00   2.00   4.00   6.00   8.00  10.00  12.00  14.23  15.25
 5.00      9
 5.00    0.00   6.25   9.30  11.15  12.40  13.35  14.20  14.85  15.33
 5.00    0.00   2.00   4.00   6.00   8.00  10.00  12.00  14.35  15.25
 6.00      9
 6.00    0.00   7.10  10.80  13.05  14.45  15.55  16.40  17.20  17.50
 6.00    0.00   2.00   4.00   6.00   8.00  10.00  12.00  14.47  15.25
 7.00      9
 7.00    0.00   7.90  12.40  14.80  16.35  17.45  18.30  19.15  19.25
 7.00    0.00   2.00   4.00   6.00   8.00  10.00  12.00  14.59  15.25
 8.00      9
 8.00    0.00   8.65  13.45  16.25  18.00  19.15  20.20  20.60  20.66
```


Figure 7. Display of SMP Input File

View Motion Data

This button gives access to the calculated responses for the selected ship and seaway-motion cases. At the top of the dialog box "Frequency Domain Database: Listing of Motion Data," shown in Figure 8, three descriptors from the previous dialog box are repeated. The "Units" specified are those of the motion response. Significant "Wave Height" is always given in the units shown (feet or meters) and "Modal Period" is given in seconds. The motion responses are listed for different combinations of ship speed (given in knots) and relative wave headings (in degrees).



Frequency Domain Database: Motion Results

Ship Designation: FFG 8 Ship Type: Frigate Country: U.S.

Loading Description: passive roll stabilization fins

Motion: SURGE DISPLACEMENT Statistic: SIG.SING.AM

Comment: Units: FEET

Wave Height: 4.100 Long Crested Modal Period: 5.000

(Note: 0deg is head seas, 90deg is stbd beam, 180deg is following seas)

Speed (knts)	0	15	30	45	60	75	90	105	120	135
0.0	0.03	0.03	0.04	0.06	0.11	0.15	0.04	0.16	0.10	0.05
5.0	0.02	0.02	0.02	0.04	0.08	0.12	0.04	0.18	0.12	0.07
10.0	0.01	0.01	0.02	0.03	0.06	0.10	0.04	0.21	0.16	0.12
15.0	0.01	0.01	0.01	0.02	0.05	0.08	0.04	0.25	0.24	0.71
20.0	0.00	0.01	0.01	0.01	0.04	0.07	0.04	0.30	0.97	2.04
25.0	0.00	0.00	0.01	0.01	0.03	0.06	0.04	0.37	1.81	2.18
30.0	0.00	0.00	0.00	0.01	0.02	0.05	0.04	0.67	2.88	1.14

View Toes << < > >>

Polar Plot View Extremes Copy to Clipboard Print

Close Help

Figure 8. Frequency Domain Database: Listing of Motions Dialog Box

Several choices are given at the bottom of the box:

<< < > >> can be used to step through different modal periods for the selected significant wave height and motion response. Note that the number appearing in the "Modal Period" box will change as the user scrolls through them. As before, a mouse click on << accesses the first modal period, >> the last, < accesses the previous modal period, and > the next. Note that since all motions data for the displayed file have been read, there is no delay in showing the data for other modal periods.

The "Print" button will send a copy of the motions data in the table to the system printer. The "Copy to Clipboard" button placed the motion table and extreme value table on the Windows clipboard in plain text for transfer to another program.

View Toes

This check box allows the user to toggle between viewing the response "Statistic" and the encountered modal period (T_{oe}) as shown in Figure 9.

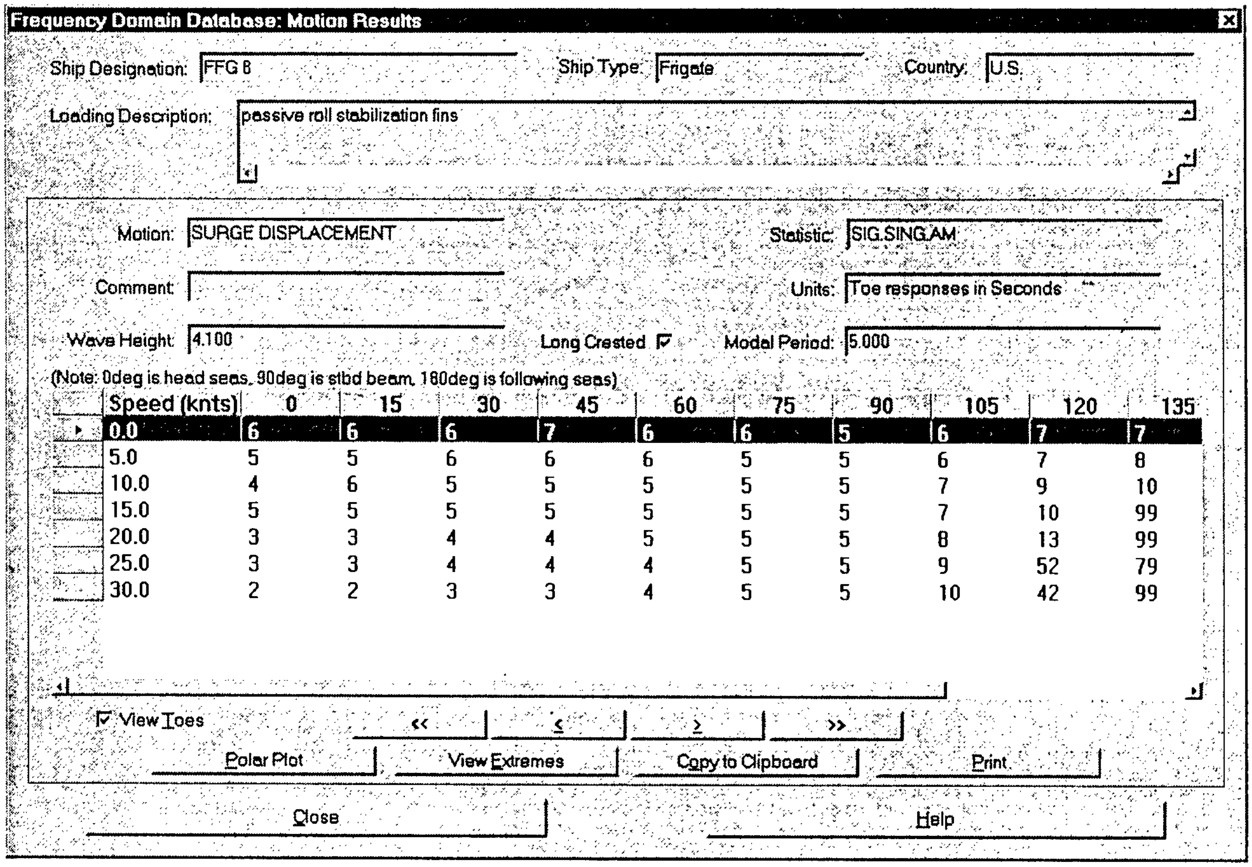


Figure 9. Frequency Domain Database: Listing of Motions Dialog Box with Toes Shown

Polar Plot

Selecting this option executes the program POLAR. A window titled "Motion Response Polar Plot" will appear with a plot of the selected response. A sample plot is shown in Figure 10. In the polar plot, speed is the radial coordinate and the relative wave heading is the angular coordinate. In interpreting these plots, note that the area for a range of headings varies with speed squared and that details at zero speed are essentially lost. Contour plots of responses are presented. The menu bar (at the top) includes various options relating to the presentation of the plot, etc, which are self-explanatory. Note that each polar plot is displayed in a separate instance of the POLAR program. This program is essentially independent of the SHIPMO program, and thus the user can have many polar plots open at one time, as long as there are sufficient system resources (memory) available. Full documentation of the POLAR program is given in Appendix A.

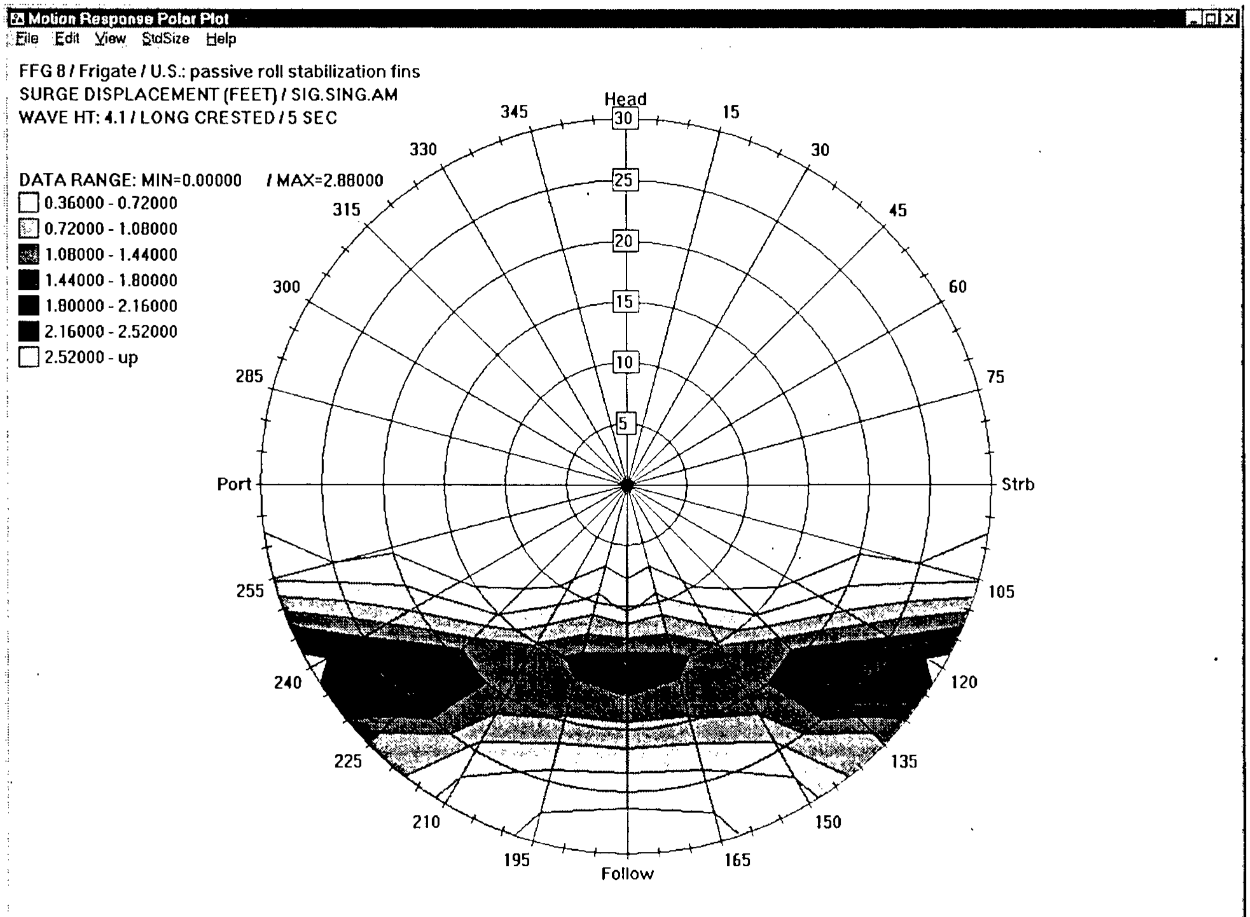
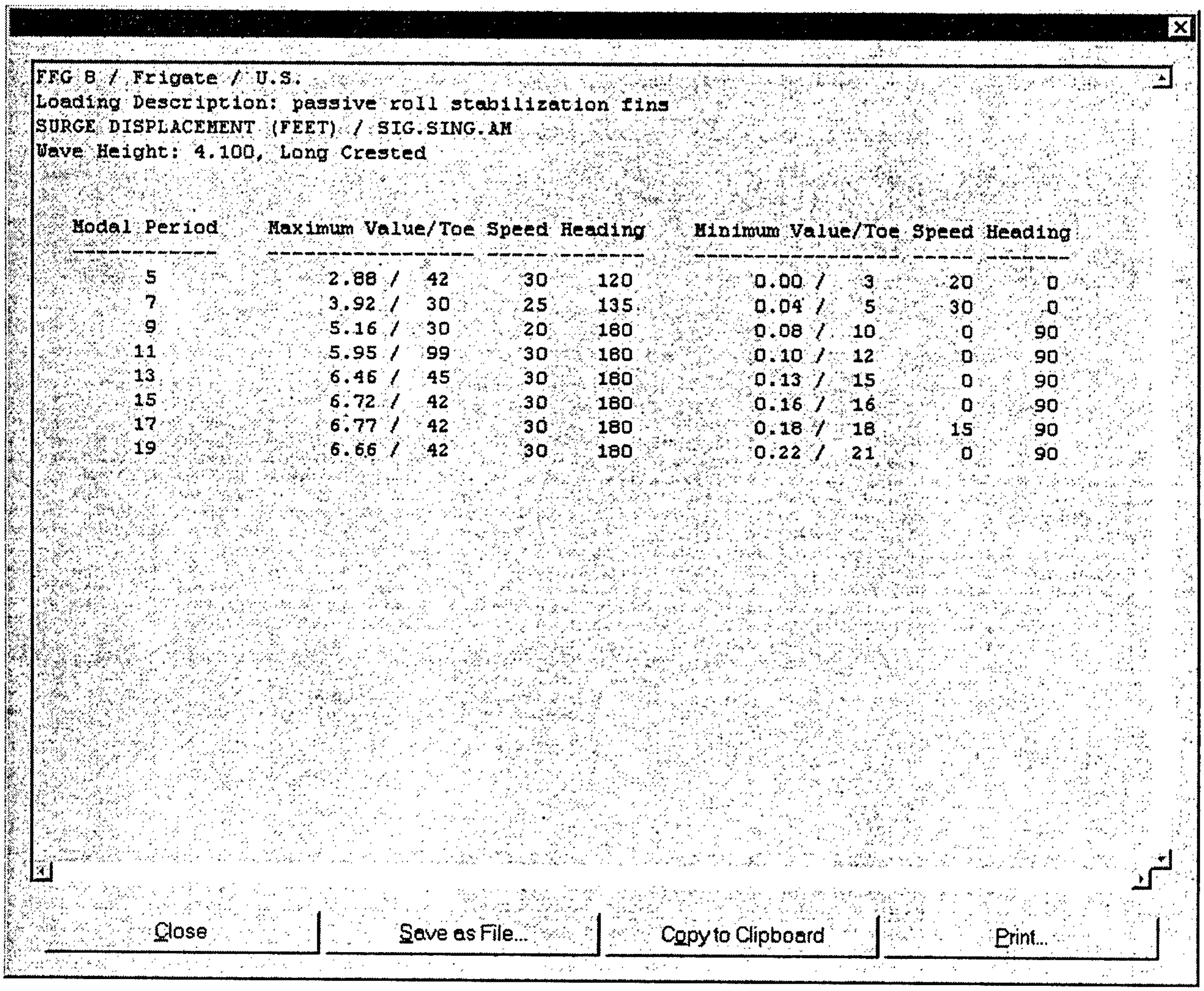


Figure 10. Sample Polar Plot

View Extremes

For each significant wave height and family of spectral modal periods, the largest value for the selected response along with the corresponding speed and relative wave heading are displayed. The associated T_{oe} is also given, as shown in Figure 11. While viewing the extreme motions, the user has the option of saving the information to a separate text file, copying the information to the Windows clipboard, or printing the information via the Windows print manager.



FFG 8 / Frigate / U.S.
Loading Description: passive roll stabilization fins
SURGE DISPLACEMENT (FEET) / SIG.SING.AM
Wave Height: 4.100, Long Crested

Modal Period	Maximum Value/Toe	Speed	Heading	Minimum Value/Toe	Speed	Heading
5	2.88 / 42	30	120	0.00 / 3	20	0
7	3.92 / 30	25	135	0.04 / 5	30	0
9	5.16 / 30	20	180	0.08 / 10	0	90
11	5.95 / 99	30	180	0.10 / 12	0	90
13	6.46 / 45	30	180	0.13 / 15	0	90
15	6.72 / 42	30	180	0.16 / 16	0	90
17	6.77 / 42	30	180	0.18 / 18	15	90
19	6.66 / 42	30	180	0.22 / 21	0	90

Figure 11. Display of Extreme Motions

BASIC SHIP MOTION THEORY

Details of the ship motion prediction theory used to generate the contents of the motion data files used by the SHIPMO database program can be found in the bibliography. However, an abbreviated introduction into the process is provided here in order that the database can be used correctly and effectively. A summary of terms is also presented to aid the user.

The U.S. Navy Standard Ship Motion Program (SMP) is used to produce the translational and angular ship statistical responses in irregular seas that make up the SHIPMO database. These predictions are obtained from the product of Ship Response Amplitude Operators (RAOs) × Sea Spectra × Frequency Mapping. Predictions of ship responses in regular waves provide the basis from which the RAOs are obtained.

To develop a ship's RAOs, the six-degrees-of-freedom (6DOF) responses (i.e., surge, sway, heave, roll, pitch, and yaw) are calculated at the origin, which lies in the undisturbed free surface at the longitudinal center of gravity of the ship. The ship is assumed to move at constant speed at arbitrary headings with respect to regular sinusoidal waves of unit amplitude. Furthermore, the motions are assumed to be small, linear, and harmonic with respect to the wave, except for roll which exhibits nonlinear behavior. [Nonlinear roll response, which results from the nonlinear behavior of the roll damping components with increasing speed and roll angle, also influences the roll-coupled motions of sway and yaw.] The 6DOF transfer functions (response per unit wave amplitude) are computed for various ship speeds, heading angles, wave frequencies, and roll angles. Likewise, transfer functions of the translational displacements of any point on the ship can also be computed. Squaring of the amplitude of the regular wave transfer function for a given response at each frequency develops the RAO for that ship motion. RAOs are computed for the 6DOF displacements, velocities, and accelerations as well as the motions at any defined point(s). RAOs are calculated for headings around the clock in 15-degree increments. Zero degrees represents head seas, 90 degrees is starboard beam seas, 180 degrees is following seas, etc.

Prediction of a ship's irregular sea motion responses utilizes the RAO computations and a family of Bretschneider, two-parameter wave spectral formulations. The two parameters are significant wave height, $(\zeta_W)_{1/3}$, and modal wave period, T_O. Using eight different modal periods, the cross product of the RAO and wave spectrum, frequency by frequency, produces eight response spectra for a given ship motion and ship speed. The area under each spectrum represents the standard deviation (σ), or sometimes referred to as the RMS value, and has statistical (Rayleigh) relationships as defined in Table 2. For instance, a common statistic used in ship design is the "significant" value (2σ) which is average of the one-third highest amplitudes. The peak of each response spectrum is associated with an encountered modal period, designated T_{oe}. For each motion and significant wave height, both the statistical response and the T_{oe} are computed for each modal wave period, ship speed, and relative heading combination.

Table 2. Constants for Single Amplitude Rayleigh Statistics.

Statistic	Conversion Factor	Probability of Exceedance*
Root mean square amplitude, RMS	1.00 σ	60.653%
Average amplitude	1.25 σ	45.783%
Average highest of 1/3 amplitudes, significant value	2.00 σ	13.534%
Highest expected amplitude in 10 successive amplitudes	2.15 σ	9.914%
Average of highest 1/10 amplitude	2.55 σ	3.873%
Highest expected amplitude in 30 successive amplitudes	2.61 σ	3.317%
Highest expected amplitude in 50 successive amplitudes	2.80 σ	1.984%
Highest expected amplitude in 100 successive amplitudes	3.03 σ	1.015%
Highest expected amplitude in 200 successive amplitudes	3.25 σ	0.509%
Highest expected amplitude in 1000 successive amplitudes	3.72 σ	0.099%
Highest expected amplitude in 3000 successive amplitudes	4.00 σ	0.045%

NOTES:

σ^2 is the statistical variance of a time history.

*Rayleigh probability distribution assumed.

(Note: to obtain wave height or double amplitude statistics from RMS values, multiply the single amplitude constants by 2.0)

Since the Bretschneider wave spectra formulation is only two-parameter (significant wave height and modal period), all the spectral energy is assumed to be unidirectional. This is referred to as long crested seas and may more typically be equated to a pure swell condition. In the real world, this is a rare event. Therefore, a distributed energy function is used in SMP to provide a more realistic dispersion of wave energy, and this condition is referred to as short crested. Both long crested and short crested motion values are included in the motion data files used by the database.

It should be noted that the linear characteristics of the motions not coupled to roll angle (e.g., surge, pitch, vertical acceleration at a point, etc.) allows the user to estimate motion values at a different statistic or different wave height than those directly reported in the database. For instance, an RMS pitch value of two degrees in a six-foot significant wave height can be used to predict a significant pitch angle in a ten-foot significant wave height by multiplying the rms value by two (2σ = significant) and again by 10/6 (the ratio of significant wave heights). The answer in this case is that the predicted significant pitch angle in a ten-foot significant wave height (2×2×1.67) equals 6.68 degrees. This type of operation, however, is not valid for "lateral" type motions, such as roll or lateral acceleration at a point, because of their inherent nonlinear behavior.

The user is referred to the Glossary for useful definitions and explanations of terms used.

SUMMARY

A program to display and manage a database of ship motions has been developed using the C++ programming language to run under a WIN32 operating system. The use and operation of the program, and associated utility programs, has been described. The capability to further enhance the program with database access to full scale and analytic time domain data has been included. It is intended that these enhancements will be addressed in a future release of the program. Other future enhancements could include a query and search capability, and the ability to access the database information through the Internet via a web browser. That capability will also require that some form of access control to the database be implemented.

GLOSSARY

Longitudinal, lateral, and vertical displacements, velocities, and accelerations	These denote the motions of the ship at a ship location specified in the comment. Sometimes referred to as "motions at a point".
Loading condition	In the context of the SHIPMO program, a loading condition specifies a specific combination of ship length, beam, draft, displacement, trim, GM, KG, pitch, roll, and yaw radii of gyration, and number and type of appendages. As such, loading conditions could also indicate different design variants.
Long crested waves	Long crested waves are uni-directional waves. That is, the wave crests (or troughs) are all parallel to one another and all cuts which are perpendicular to the crests is identical. Typical of a swell-type of sea condition.
Modal Period (T_o)	Wave period associated with the peak of the wave spectrum.
Relative Motion, Relative Velocity	The displacement or velocity of the ship, relative to the wave elevation, where it is assumed that the ship does not alter the wave train. That is, the relative motion is the difference between the wave elevation and the ship's response. The location on the ship where response is calculated is specified in the comment.
Relative Wave Heading	The heading of the ship, relative to the wave heading. Specifically, 0°=head seas; 45°=starboard bow quartering seas; 90°=starboard beam seas, etc.
Short crested seas	Short crested seas are confused seas, composed of waves from many direction. In the calculated motion responses, the cosine-squared spreading function is applied to the long crested responses.
Significant Wave Height $(\zeta_w)_{1/3}$	The average of the highest 1/3 of the wave heights in a time history. This is generally said to be close to the value observers estimate as the wave height. It is calculated by taking the square root of the integral with respect to wave frequency of the wave spectrum and multiplying by 4.
Statistic	This identifies the statistical quantity of the motion responses which is presented. It is defined in the input to run SMP and in the database will typically be the significant single amplitude (SIG.SING.AM). The significant single amplitude is the average of the highest 1/3 of the amplitudes of the motion response in a time history, and is calculated by taking the square root of the integral of the wave spectrum with respect to wave frequency and multiplying by 2.
Surge, Sway, Heave, Roll, Pitch and Yaw	Responses of the ship in six degrees of freedom, relative to a coordinate system which has its origin in the calm water.
T_{oe}	Wave encounter period associated with the peak of the response spectrum. The response spectrum is the cross product of the wave spectrum and the square of the motion transfer function per unit wave amplitude (i.e. the RAO).
Wave Spectrum	The energy distribution of the seaway at a point, given as a function of wave frequency with units ft^2-sec. The Bretschneider wave spectral formulation is used in the calculations.

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APPENDIX A: OPERATION OF PROGRAM POLAR

Overview

The POLAR program is a separate, self contained executable program that can be used to generate general speed-polar contour plots from a user supplied data file in a specific format. The SHIPMO database program, when requested to render a speed-polar plot of motion responses, will automatically generate an appropriate data file formatted for the POLAR program and then execute the POLAR program with that generated data file. This process is transparent to the user. This Appendix is meant to provide documentation for the use of the POLAR program, either when run by the SHIPMO database program or when run separately by the user with their own data files.

The POLAR program is a WIN32 executable program, meaning that is can be run on either the Windows 95 operating system or Windows NT operating system. The program can be initiated from a command prompt, shortcut, or directly, with or without a single command argument (the name of a data file).

Menu Commands

There are five main menu options for the polar plotting program; File, Edit, View, StdSize, and Help. Under the File menu option, there are four sub-options; Open, Print, Print setup, and Exit. The File:Open option will invoke the standard Windows file open dialog box and is used to load a new data file. Note that the polar plotting program is a single document interface (SDI) application and can only have one data file loaded at a time and one plot displayed at a time. However, there is no restriction on having multiple instances of the program operating. The File:Print option will render a copy of the plot currently displayed to the Windows printer. Note that there is a known problem with printing under Windows 95, due to internal differences between the Windows 95 and Windows NT GDI graphics functions. Printing does, however, function properly under Windows NT. The File:Print Setup option will invoke the standard Windows printer properties dialog. The File:Exit option will immediately terminate the application.

The Edit menu option has only one sub-option, copy. This may be used to render an image of the currently displayed plot to the Windows clipboard. This option is the normal method that should be used to include polar plots in documents composed using Microsoft Word, Corel Word Perfect, or the Windows WordPad application. Note that the image placed on the clipboard will be identical in size to the image on the screen. The StdSize menu option, which has no sub-options, may be used to resize the polar plotting program window to a constant, standard size. This, when used in conjunction with the Edit:Copy option, will always produce plot images on the Windows clipboard of the same size. Thus, reports containing multiple speed-polar plots will have a consistent look.

The View menu option contains six sub-options; Select Plot, Contour Levels, Color, Black&White, Filled Contours, and Non-Filled Contours. The View:Select Plot option is used to select which data set to display as a speed-polar plot. This option is applicable only in situations where the data file being used has more than one data set contained in it. This is not the case for polar plots generated automatically by the SHIPMO program. The View:Contour Levels option is used to add, change, or delete contour levels for the currently displayed plot. Use of this option only effects the plot being displayed and does not alter the contour levels specified in the data file nor does it alter the contour levels for the data set. Hence, if you change the contour levels to view a different data set, and then go back to the previous data set, the settings that you specified earlier are not retained. The last four sub-options for the View menu option, Color, Black&White, Filled Contours, and Non-Filled Contours, are toggles. Color speed-polar plots are visually pleasing on the screen, but do not print with the same clarity as black and white (actually shades of gray) plots, at least on monochrome laser printers. Also, filled contours are easier to understand than contour lines only.

The last menu option, Help, has one sub-option; About. This is used to display a dialog box that indicates the program version number.

Data File Format

The data file format used by the Polar Plotting Program is sufficiently general to accommodate a wide range of uses. The best way to describe the data format is to show a sample data file, as in Table A1 below.

Table A1. Sample Speed-Polar Data File

```
#
# Speed-Polar data file format description:
#
#  *all lines starting with # are ignored (comment lines)
#
#  title line
#  subtitle line
#  second subtitle line
#  x axis title (reserved for future use)
#  y axis title (reserved for future use)
#  heading angles (separated by commas and/or spaces)
#  *there are 1 or more following lines specifying speed and plot values
#  speed value1 value2 .... valueN  (N values corresponding to N heading angles)
#  CONTOURS (this word in uppercase signals the end of the data and the start of contour values)
#  *there are 1 or more following lines specifying contour levels to be plotted, or
#  * instead of specifying levels, use the work AUTO to perform automatic level picking
#  * (auto level just selects 5 contours within the range of the data, not pretty but it works)
#  level1 level2 .... levelM
#  END (this word in uppercase signals the end of the contour values)
#
#  *multiple data sets can be placed in a speed-polar data file
################################################################################
FFG8, PASSIVE FINS: HEAVE ACCELERATION, SIG.SING.AM (G)
FIRST TEST CASE FOR POLAR PROGRAM SAMPLE DATA
SHORTCRESTED, 4.1 (FEET, SIG.HT.), 7.5 (SEC)
XAXIS
YAXIS
0 15 30 45 60 75 90 105 120 135 150 165 180
0 1.1975 1.5425 2.2175 2.875 3.385 3.7 3.785 3.635 3.26 2.695 2.0025 1.3025 0.935
5 1.8425 2.135 2.74 3.335 3.78 4.02 4.015 3.77 3.3025 2.6375 1.875 1.115 0.7075
10 2.585 2.8525 3.4125 3.955 4.3325 4.485 4.38 4.0225 3.4325 2.665 1.8 0.9875 0.5425
15 3.46 3.7025 4.235 4.73 5.0475 5.1025 4.875 4.37 3.64 2.7375 1.7725 0.8975 0.4225
20 4.475 4.7 5.175 5.615 5.8375 5.785 5.4175 4.77 3.8775 2.8375 1.7675 0.8375 0.325
25 5.3775 5.5875 6.04 6.43 6.59 6.4325 5.9525 5.16 4.1275 2.9625 1.785 0.795 0.26
30 6.0575 6.2775 6.735 7.1225 7.25 7.025 6.4525 5.5425 4.3925 3.0925 1.8175 0.78 0.2325
CONTOURS
 2 3 4 5 6 7
END
#
FFG8, PASSIVE FINS: HEAVE ACCELERATION, SIG.SING.AM (G)
SECOND CASE FOR POLAR PROGRAM SAMPLE DATA
SHORTCRESTED, 8.2 (FEET, SIG.HT.), 8.8 (SEC)
XAXIS
YAXIS
0 15 30 45 60 75 90 105 120 135 150 165 180
0 2.537 3.047 4.119 5.204 6.078 6.621 6.773 6.525 5.896 4.948 3.81 2.722 2.208
5 3.811 4.236 5.169 6.116 6.842 7.208 7.164 6.708 5.88 4.752 3.454 2.248 1.671
10 5.517 5.883 6.682 7.476 8.011 8.164 7.885 7.173 6.088 4.722 3.245 1.91 1.264
```

```
15 7.804 8.104 8.755 9.365 9.665 9.541 8.952 7.909 6.491 4.838 3.141 1.679 0.953
20 10.693 10.908 11.374 11.724 11.715 11.24 10.25 8.812 7.024 5.047 3.106 1.515 0.72
25 13.602 13.754 14.056 14.169 13.864 13.026 11.649 9.8 7.619 5.313 3.127 1.409 0.564
30 16.271 16.381 16.565 16.494 15.947 14.805 13.064 10.83 8.277 5.626 3.197 1.352 0.469
CONTOURS
 2.5 5 7.5 10 12.5 15
END
#
```

In this file, the basic format is described in the first 20 lines. All lines that begin with the # character are treated as comments and ignored by the program. Note that comment lines may appear ONLY before or after the actual data and plot specification lines. The first line for a data set is a main title, which may be of any length. The following two lines are subtitles, which may also be of any length. Note that the main title and the two subtitles should be reasonably short so that they will be displayed properly on the plot. The next two lines are reserved for future use and may be blank. The next line specifies heading angles. Headings may be evenly or unevenly spaced, as long as they are increasing in value and they include 0 and 180 degrees as the first and last heading respectively. In this case, the plot will be assumed symmetric about the 0-180 degree axis. Alternatively, headings may be increasing with even or uneven spacing, as long as they include 0 and 360 degrees as the first and last heading respectively.

Following the heading angle line are two or more data lines. Each data line has a ship speed as the first number, followed by data values corresponding to the previously specified heading angle. For example, if the headings are given as 0, 15, 30, ... , 180 degrees (13 heading angles), then there must also be 13 corresponding data values. Data values, ship speed, and heading angles are separated by one or more spaces. The ship speed for each data line must be increasing from the previous data line, in any even or uneven increment. After the last data line must be the word CONTOURS in upper case. This tells the polar program that no more data values are to be read in and that the following line will specify the contour levels to be initially plotted for this data set. Contour levels are specified as floating point numbers, separated by commas. Any number of contour levels may be specified. Alternatively, the word AUTO, in upper case, may be used. This will instruct the polar plotting program to automatically select 5 even contour levels between the maximum and minimum values in the data set. The last line of the data set is the word END, in upper case. This indicates to the polar plotting program that this is the end of the data set. From this point, the user is free to add additional comment lines or more data sets. In the example of Table A1, two data sets are specified.

APPENDIX B: OPERATION OF PROGRAM BMOFILE

When the program BMOFILE is executed without command line arguments, the following output is displayed:

Table B1. BMOFILE Program Command Line Options

```
ERROR! - not enough command line arguments.

 Syntax:   BMOFILE -[cihnlxf] <bmofile> <otherfile>
   where <bmofile> is the fully qualified name of a BMO format file
   and <otherfile> is a fully qualified file name depending on the
   command option specified.

   Command options (not case sensitive):
        -c                create a BMO file from an SMP output file
                          where <otherfile> is the SMP output file name.
        -c95              create a BMO file from an SMP95 output file
                          where <otherfile> is the SMP95 output file base name.
                               (reads out and oot files)
        -i                extract the SMP input file from the BMO file
                          to the file specified by <otherfile>.
        -h                extract the hydrostaics output from the BMO file
                          to the file specified by <otherfile>.
        -n                show the number of output tables in the BMO file,
                          the <otherfile> is not used.
        -l                create summary listing of the output tables,
                          writting it to <otherfile>.
        -x                extract a motion table to <otherfile>,
                          for this option, there are additional required
                          parameters: [L|S] [WaveHt] [Motion]
                          where L|S is for long or short crested waves,
                          WaveHt is the wave height, and Motion is the
                          name of the motion (finds the first partial match
                          without case sensitivity).
        -f                read commands from <bmofile> as if they had been
                          entered on the command line.
        -d                performs a complete listing of the BMO file
                          to the file specified by <otherfile>.
```

This shows the syntax for using any of the eight execution options. The first two options (-c and –c95) are used to create a single BMO format file from the ASCII text output of the SMP84 or SMP95 versions of the Navy's Standard Ship Motions Program. If an SMP84 output is being converted to BMO format, then the user must enter the full file name and extension. If an SMP95 format output is being converted to BMO format, only the file name (no extension) is entered. In this case, the program assumes that the output uses the file extensions OUT and OOT for the results from the SMPREGW and SMPIRGW programs, respectively. If only the OOT output file exists, the BMOFILE program will generate the BMO format file, but the SMP95 input that is placed in the BMO file will only be the input that was used in the SMPIRGW program. If the OUT file is found, however, the BMO file will also contain the input used in the SMPREGW program. In all cases, the OOT file must exist, since it contains the motion output tables (responses). It should be noted that the BMOFILE program requires that the user specify to the SMPIRGW program that the Toes are to be printed. If the Toes are not printed, an error will result.

APPENDIX C: ADMINISTRATOR USER GUIDE TO PROGRAM SHIPMO

The administrative options for the SHIPMO database may be used to alter the contents of the database with the exception of the actual motions data contained in the BMO files. All administrative options are accessed from the dialog box shown in Figure 1 by selecting "Administrative Tools". Access to the administrative functions is restricted to authorized individuals and requires a password, as shown in Figure C1. The password is hard coded into the program and can not be changed or deleted. As of this writing, the password is "abc123". Once the correct password has been entered, the "Administrative Functions" menu in Figure C2 will appear. For the initial release of the SHIPMO program, the two time domain buttons are inactive and reserved for future functions. When "Manage Frequency Domain Database" is selected, the dialog box shown in Figure C3 appears.

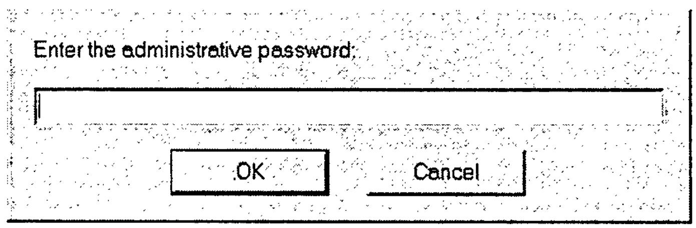

Figure C1. Prompt for Administrative Password Dialog Box

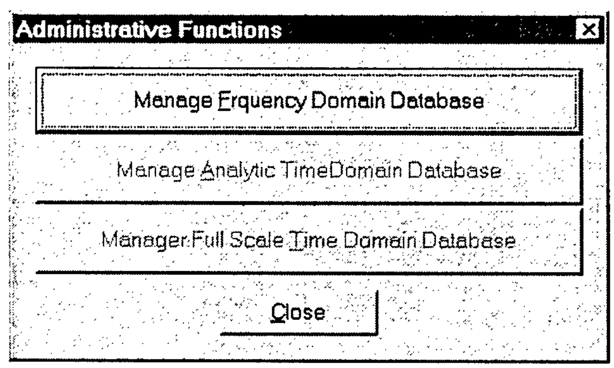

Figure C2. Main Administrative Menu Dialog Box

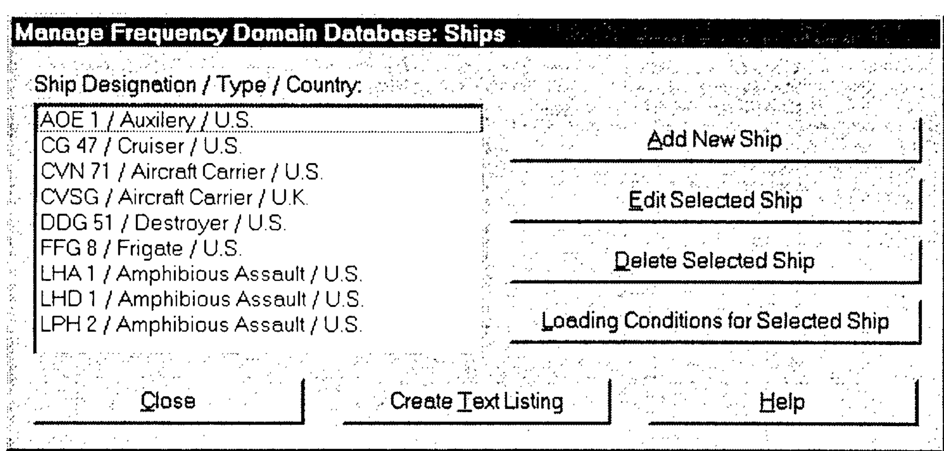

Figure C3. Manage Frequency Domain Database: Ships Dialog Box

Create Text Listing

This option is selected by the button in the lower center of the dialog box shown in Figure C3. The listing created is the same as that created by the "Create Summary Listing" button on the dialog box shown in Figure 3.

Add New Ship

This allows the administrator to add the name of a new ship to the list. The resulting dialog box is shown in Figure C4. "Ship Designation", "Ship Type", and "Ship Country" can be entered. All three fields must be entered. The ship types that may be selected are; aircraft carrier, amphibious assault, auxiliary, container ship, cruiser, destroyer, frigate, mine hunter, patrol craft, ro-ro, and tanker.

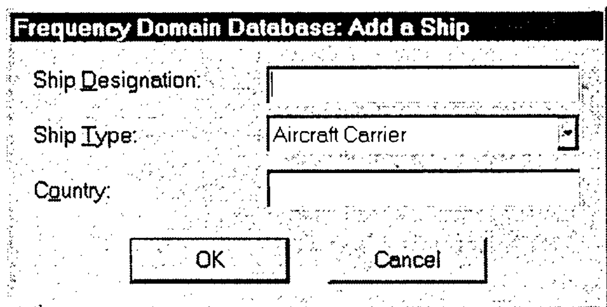

Figure C4. Manage Frequency Domain Database: Add a New Ship Dialog Box

Edit Selected Ship

This allows the administrator to edit either the Ship Designation or the Ship Type for the highlighted ship, as shown in Figure C5.

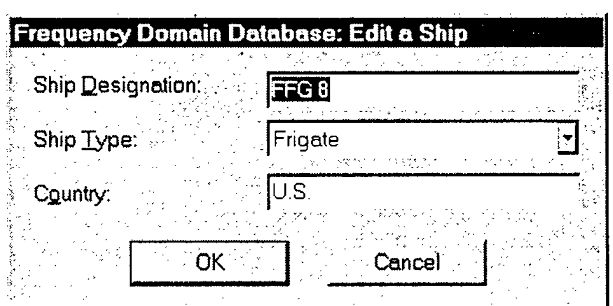

Figure C5. Manage Frequency Domain Database: Edit Selected Ship Dialog Box

Delete Selected Ship

This provides the means to permanently eliminate all data associated with the ship highlighted in the dialog box shown in Figure C3. All data related to the ship, including all variants (loading conditions) and run conditions will be eliminated from the database. This deletion is permanent and the change is immediately committed to disk. The dialog box shown in Figure C6 will appear before this is executed, allowing the user to continue or back out of an unintended action.

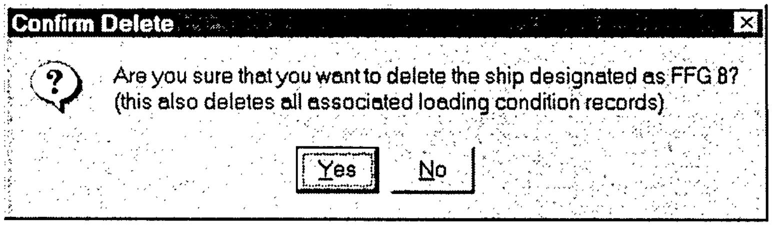

Figure C6. Dialog Box Related to Delete Option

Loading Conditions for Selected Ship

This option is used to expand or alter the population of the frequency domain ship motion database. The data displayed in Figure C7 is the same that is displayed in the dialog box shown in Figure 2 and is not directly linked to the SMP motions data in an associated BMO format file. In order to add a loading condition, select the "Add New" button, and begin entering data in the appropriate edit fields. The description field should identify the nature of the loading condition and/or the source of the information. While adding/editing a loading condition record, the "Add New" button is replaced with an "Accept Record" button, the "Delete Current Loading Condition" button is replaced with a "Cancel Record" button, and the remaining buttons are made inactive.

The VCR style control buttons at the bottom of the dialog (<< < > >>) can be used to step through different defined loading conditions. As before, a mouse click on << accesses the first loading condition, >> the last, < accesses the previous loading condition, and > the next.

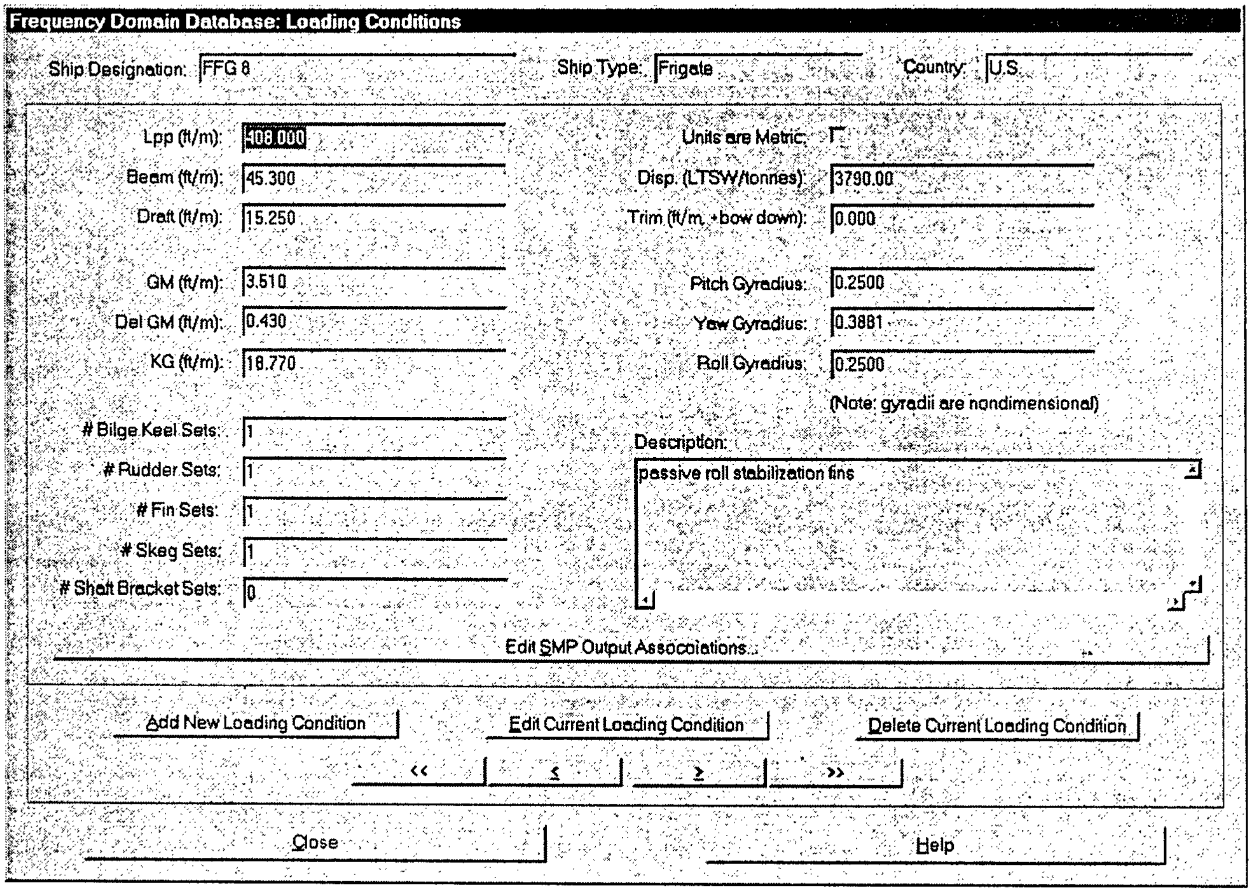

Figure C7. Manage Frequency Domain Database: Loading Conditions Dialog Box

Figure C8 shows the dialog that is displayed when the user selects "SMP Output Associations" from the loading condition entry dialog in Figure C7. From this dialog box, the user can assign one or more sets of SMP output (as BMO format files) to the loading condition previously displayed. The BMO format file name entered here should be the full file name and extension. DO NOT include a disk drive or directory specification with the file name as the program always looks for the BMO files in a specific location (see Appendix D for details). The user is prevented from actually entering a blank file name. The user can optionally enter a multi-line description. It is suggested that the wave heights, speeds, and motion point locations be entered. While adding/editing a motion output file association record, the "Add New Output Record" button is replaced with an "Accept Record" button, the "Delete Current Output Record" button is replaced with a "Cancel Record" button, and the remaining buttons are made inactive

The VCR style control buttons at the bottom of the dialog (<< | < | > | >>) can be used to step through the different output files associated with the loading condition. As before, a mouse click on << accesses the first file association, >> the last, < accesses the previous file association, and > the next.

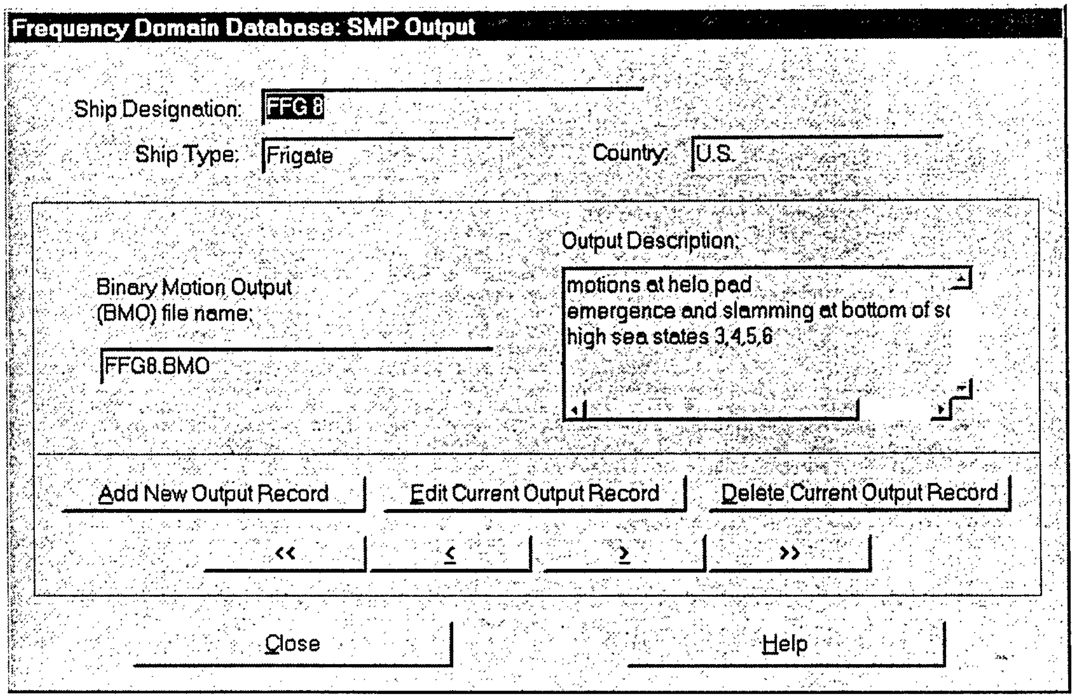

Figure C8. Manage Frequency Domain Database: SMP Output Associations

APPENDIX D: INTERNAL ARCHITECTURE OF PROGRAM SHIPMO

All of the programs discussed in this report (SHIPMO, POLAR, and BMOFILE) have been written using the C++ programming language and make use of object oriented programming methods. The SHIPMO and BMOFILE programs were compiled using the Microsoft Visual C++ compiler, version 6. SHIPMO uses the Microsoft Foundation Class library (MFC). POLAR was compiled using the Borland C++ compiler, version 5, and makes use of the Object Windows Library (OWL). Both MFC and OWL provide an object oriented C++ wrapper of the Windows application programming interface (API). The grid control used in the SHIPMO program was the Ultimate Grid 97/MFC package from Dundas Software (http://www.dundas.com).

In order for the SHIPMO and POLAR programs to execute, they both require their own sets of dynamic link libraries (DLL's). The dynamic link libraries must be available either in the directory from which the program is executed or somewhere in the system path. SHIPMO requires the following library files; MFC42.DLL, MFCO42.DLL, MFCD42.DLL, MSVCRT.DLL, and MSVCP50.DLL. For POLAR, the library files are: BDS501F.DLL, CW3230.DLL, and OWL501F.DLL. Note that the BMOFILE program is a command line (console mode) application and does not require any DLL files to execute.

In addition to the requirement for the availability of the DLL files previously discussed, the SHIPMO program also makes certain assumptions about the location of the POLAR program executable file as well as the actual database files and accompanying BMO files. When a user requests a speed-polar plot of a motion data table, the SHIPMO program calls the WIN32 spawnlp function to start execution of the POLAR program. The spawnlp function is passed the name of a speed-polar data file (DATA.SPD) as a command argument and the P_NOWAITO parameter is used. This allows the POLAR program to execute separately and independently of the SHIPMO program which started it's execution and the SHIPMO program will not wait for POLAR to end. See the WIN32 SDK documentation for more information about the spawnlp function and the P_NOWAITO parameter.

There are two known problems with the POLAR program. When printing a polar plot under Windows 95, the resulting image on paper is not correct. This problem is due to limitation of the Windows 95 print drivers when certain WIN32 GDI functions are called. Printing under Windows NT is correct, however printing has not been tested under Windows 98. The other problem occurs when producing certain filled contour plots. If the data being plotted contains one or more contour levels that form self connected regions, the filled contours may not be displayed properly. This problem is a result of the way contour flooding is performed and effects both Windows 95 and Windows NT platforms.

The frequency domain database file must be located in a subdirectory named "FreqDomainDB" under the directory containing the SHIPMO program file. The file is named "FreqDomain.mdb" and is a Microsoft Access 97 format file. Microsoft Access does not need to be installed on a computer system running the SHIPMO program. The Microsoft MFC library uses the Jet Database Engine to provide access to the database file via a set of Data Access Object (DAO) classes.

The BMO data files, which contain the ship motion data tables, are written in a binary format (hence the term Binary Motions Output – BMO). All aspects of reading and writing BMO files are encapsulated in a C++ class called BMOfile. This class has a single data member which is a reference to a SMPout class object. The SMPout class encapsulates all of the motions data contained in a SMP output file as well as listings of the SMP input file that generated the output and also the hydrostatic properties as calculated by the SMP program. The SMPout class has member functions to read both SMP84 format as well as SMP95 format output but has no member function to write or save the data. In addition to abstracting the saving and retrieval of the binary representation of SMP output files, the BMOfile class also implements member functions that are used to save ASCII format files containing the SMP input listing , SMP calculated hydrostatics, and a speed-polar data set for a motions table (used to create POLAR input data files). There are also member functions which write ASCII format files listing the names of the motion tables and the contents of a motion table. By using the two classes, BMOfile and SMPout, it has been possible to separate the representation and reading of SMP output from the BMO specific functions of storage and extraction of individual table data.