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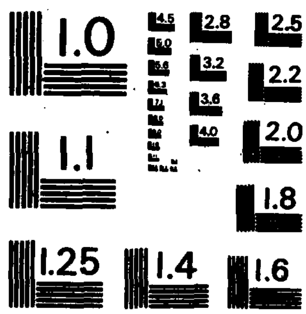

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

PRACTICAL METHODS FOR ASSESSING SEAKEEPING PERFORMANCE

by

D. A. Walden

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SHIP PERFORMANCE DEPARTMENT

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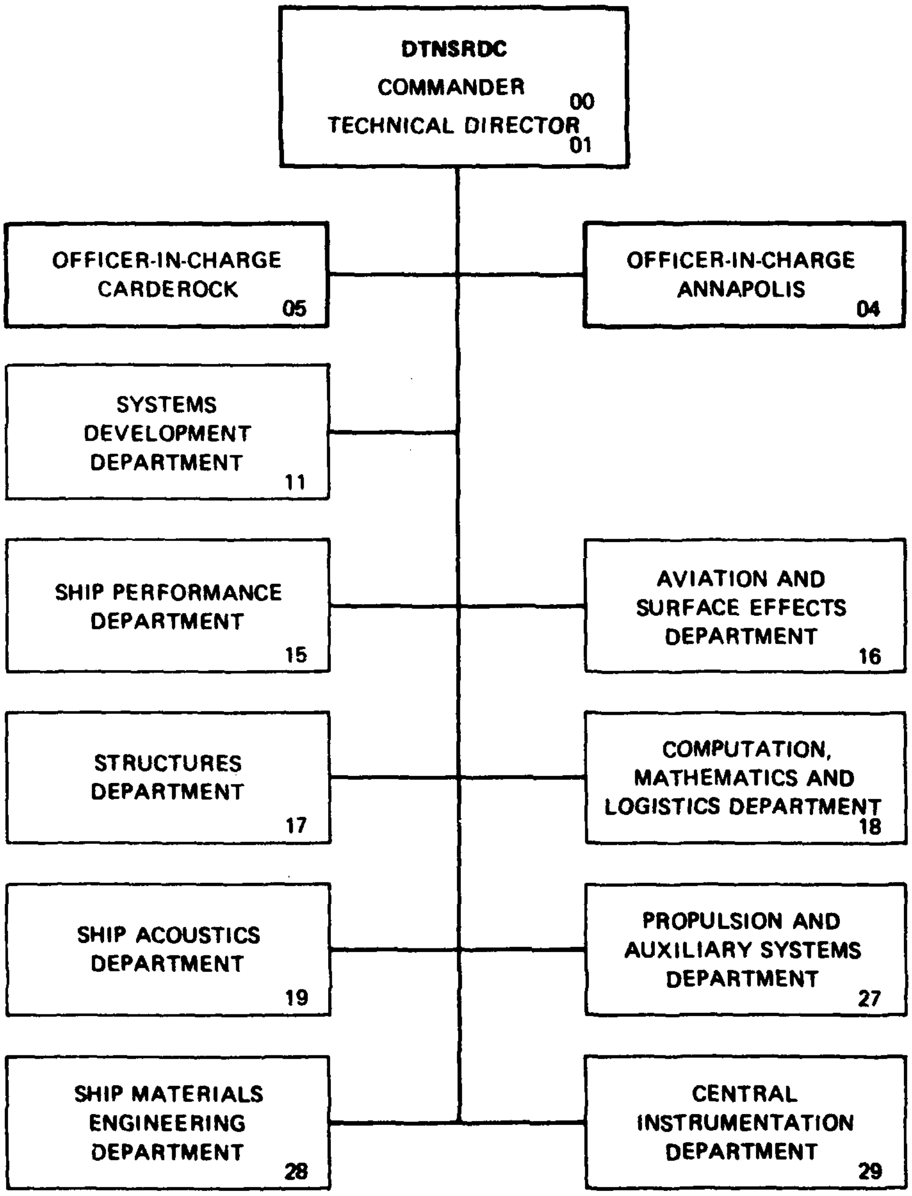

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Seakeeping performance measures are discussed. This is followed by the description of a method for efficiently calculating such performance measures. The relation of this method to the scheme used by NAVSEA to generate and describe hull forms at early design stages is discussed. An application of the hull form design, seakeeping assessment process is given. Finally, suggestions are made for future work.

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NOTATION

Symbol	Computer Variable	Definition
B	B	Beam
C_P	CP	Prismatic coefficient
C_{PA}	CPA	Prismatic coefficient aft of amidships
C_{WP}	C_{WP}	Waterplane coefficient
C_{WPA}	C_{WPA}	Waterplane coefficient aft of amidships
C_X	CX	Section coefficient
L	L	Length
R		Computed R value
$\hat{R}$		Estimated R value
T	T	Draft

ABSTRACT

Seakeeping performance measures are discussed. This is followed by the description of a method for efficiently calculating such performance measures. The relation of this method to the scheme used by NAVSEA to generate and describe hull forms at early design stages is discussed. An application of the hull form design, seakeeping assessment process is given. Finally, suggestions are made for future work.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

Increasing attention is being paid to the seakeeping of ships. In order to maximize seakeeping performance, it must receive attention at early design stages, when constraints are least limiting. To accomplish this, there must be a practical means of assessing seakeeping performance based on the information available to the designer early in the design process. In fact, the best approach is to couple the seakeeping assessment to the method used by the designer to generate hull forms. This is the subject addressed in the present report. The following sections describe the process.

SEAKEEPING PERFORMANCE MEASURES

The desirability of a ship with "good" seakeeping characteristics is indisputable. What is the subject of considerable discussion is the definition of good.[1*] There is much to be said for the performance measure devised by Bales[2] in terms of its simplicity and generality. It does not require details of a ship's particular mission, operating area or speed-heading profile. Yet there is little doubt that because of the generality of the Bales index, a ship which ranks high will also rank high when more specific information is available and more detailed performance assessments can be carried out.

---

*A complete list of references is given on page 6.

The Bales seakeeping rank R is based on the calculation of eight ship motion RMS values shown in Figure 1 at each of five speeds in five sea states. Figure 2 shows an example of the five pitch response amplitude operators (RAO's) for the five speeds, considered. Figure 3 shows the five heave RAO's and Figure 4 shows the five sea states used. Thus, the rank R is based on the average of 200 RMS responses, as shown in Table 1, obtained from the 200 response spectra resulting from the product of 40 RAO's each multiplied by five wave spectra. All of the eight responses used can be derived from the pitch and heave RAO's since all are related to vertical plane motion calculated in long-crested head seas.

The seakeeping rank R calculated as described above should not be confused with estimated rank $\hat{R}$ also described by Bales.[2] The seakeeping rank, R, can be calculated for any ship of any displacement with no limitations on length, beam, draft or any of the hull form coefficients. The value of R can range from less than -5 for small poor seakeeping ships to over 30 for large good seakeeping ships. In the following, concentration will be on the more general calculated R values, and on developing an efficient means of calculating R such that an estimation, i.e., $\hat{R}$, is not necessary on the grounds of time and cost.

SEAKEEPING PERFORMANCE COMPUTATIONS

Attention will now be given to the method of computing the 200 RMS responses required for the calculated seakeeping rank R described above. In the work by Bales,[2] a 20 station, close-fit representation[3] was used. In order to speed up the calculation, an investigation was made into the use of a Lewis-form representation (3, 4, 5, 6, 7) as in the Lewis-form option of YF-17, rather than a close-fit. A Lewis-form representation requires only beam, draft and sectional area at each station, while a close-fit representation requires a full set of offsets at each station. For Hull 14 from reference 2, the computed R using close-fit is 6.6. Using Lewis-form the computed R value is 6.3. The estimate $\hat{R}$ is 6.1. Thus, it can be seen that the agreement between the Lewis-form computation and the close-fit computation is better than the agreement between the close-fit computation and the estimated values. This is shown in Figure 5. This good agreement is not unexpected given the close match between the actual body plan and the Lewis-form representation shown in Figure 6.

It should be noted that although SMP-82 has a Lewis-form option, it merely uses beam, draft, and sectional area to generate offsets for a Lewis-form and then does a close-fit calculation using these offsets. Thus, SMP-82 does not utilize the efficient analytic method for calculating the added mass and damping for Lewis-forms. It was thus not considered as practical as other alternatives for use in the rapid assessment of seakeeping performance at early design stages.

GENERATION ON HULL FORMS

The method currently used by NAVSEA to generate hull forms at the early design stage is a program called HULGEN (8, 9). The program allows the user to interactively manipulate the hull form. Of importance to the present work are the sectional area curve, the design waterline curve, and the profile produced by HULGEN. Examples of these curves are given in Figures 7, 8 and 9. When the user is satisfied with the hull form, HULGEN can be used to generate output files containing selected portions of the hull form description. For this work, the option is selected to produce a file containing table versions of the curves in Figures 7, 8 and 9. This file is then read and reformatted by a HULGEN post-processor/Seakeeping Program pre-processor.

Since the data required by HULGEN is extensive, a pre-processor called PREHULL was developed by NAVSEA. Based on regression analysis of previous designs, it prepares a HULGEN input file given only L, B, T, depth of station 10, C_P and C_X. With this input file, HULGEN creates a "reasonable" ship which the user can then modify. For the present work, a new pre-processor called SEAHULL was developed. It prepares a HULGEN input file given L, B, T, C_P, C_X, C_{PA}, C_{WP} and C_{WPA}. It is thus possible to do studies of a series of hulls with systematic variations in C_{WP} for example, without having to use HULGEN to manually manipulate and iterate to get the desired coefficient. Other pre-processors could be written to produce values of other sets of hull form coefficients.

The Lewis-form seakeeping program, of course, does not require that the sectional areas, DWL and profile curves be produced by HULGEN. They can be created and entered manually, or values for an existing ship can be entered. Thus, the seakeeping performance of a proposed ship produced by HULGEN can easily be compared with the performance of an existing ship based on exactly the same computational procedure.

AN APPLICATION

In this section, more details are provided on the method developed giving a step-by-step example. Figure 10 shows a summary of the procedure including the data input and output by each program and gives typical file names for these data sets. In this example, we begin by running the SEAHULL program. This is an interactive program which solicits data on hull form coefficients and then prepares a HULGEN input file. As shown in Figure 11, the first set of input data is, LBP, beam, draft, C_P, C_X and C_{PA}. SEAHULL then draws the nondimensional sectional area curve shown in Figure 12. It next asks C_{WP} and C_{WPA}, as shown in Figure 13. It then draws the nondimensional DWL curve shown in Figure 14 and produces the output file shown in Table 2.

The next step is to run HULGEN using the file prepared above by SEAHULL. HULGEN is used to generate the SDH file containing the sectional area, DWL, and profile curves.

This output of HULGEN is used as the input to a post-processor called POSTHULL. POSTHULL reformats the HULGEN data and adds some information required by the seakeeping program for the R factor computation.

The final step is the running of the seakeeping program to compute the R factor. This is shown in Figure 15. The actual R factor value, i.e., 7.4624 is contained in the output file BRF, also shown in Figure 15.

FUTURE WORK

During the course of the present work, quite a number of topics for possible future work arose:

1. Incorporate into SMP Grim's method[10] for calculating the added mass and damping of Lewis forms. As described in the Seakeeping Performance Computation section, SMP now uses the close-fit method for all sections. This would enable SMP to run much faster for Lewis-form ships.

2. Investigate the differences in seakeeping predictions using the MIT bulb form,[4] which is a Lewis-type form representation versus a close fit representation. It may be possible to use Lewis-form type calculations of added mass and damping even for extreme bulbs.

3. Since the R factor computation can easily be carried out, a systematic study for other definitions of R is possible. For example R could be based on motions at 30 knots instead of 5 Froude numbers.

4. Develop an SMP-HULGEN interface. This would be particularly useful if item 1 above could be accomplished. Seakeeping results could be obtained interactively from the SMP-HULGEN combination.

5. Modify the existing LEWIS2D seakeeping program to read the HULGEN output file XX.SDH directly. This is quite straightforward to do and would streamline the procedure.

6. Extending item 5 above, modify LEWIS2D to read the HULGEN input file. If the user did not need to modify a ship created by SEAHULL or PREHULL, they need never run HULGEN.

7. Possibilities exist for further speeding up the calculations in LEWIS2D, see Ravenscroft.[11] These results could also be carried over into item 1 above.

ACKNOWLEDGEMENT

The work described here would not have been possible without the assistance of Ron Nix of NAVSEA. During his three month tour at DTNSRDC he wrote several of the programs described. His knowledge of NAVSEA design procedures was of great help.

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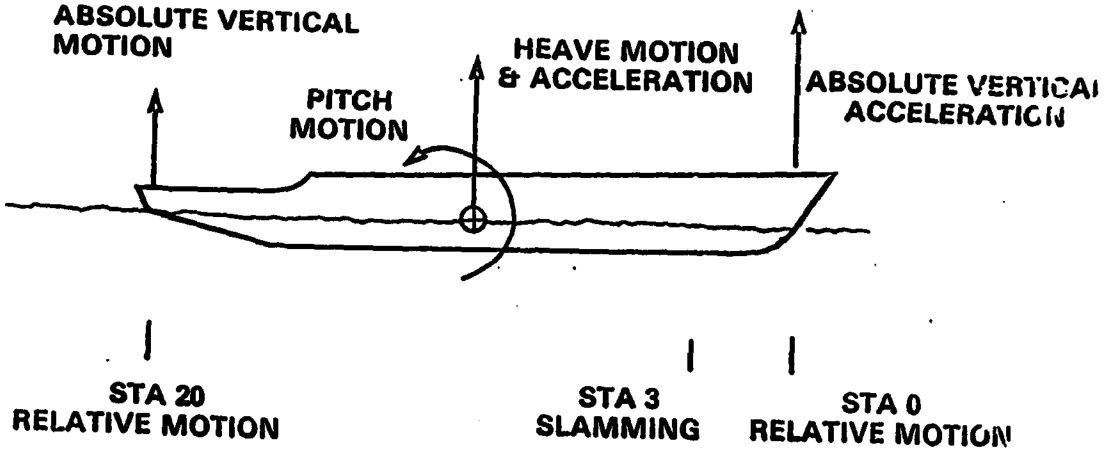


Figure 1 - Selected Responses

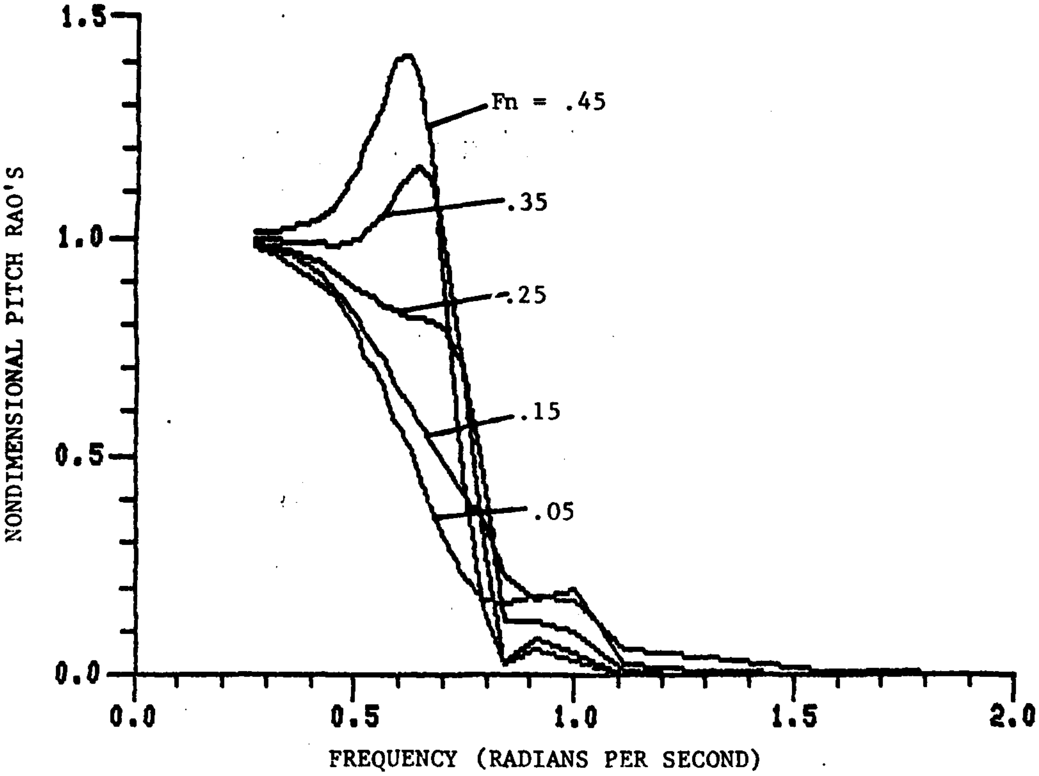


Figure 2 - Pitch RAO's

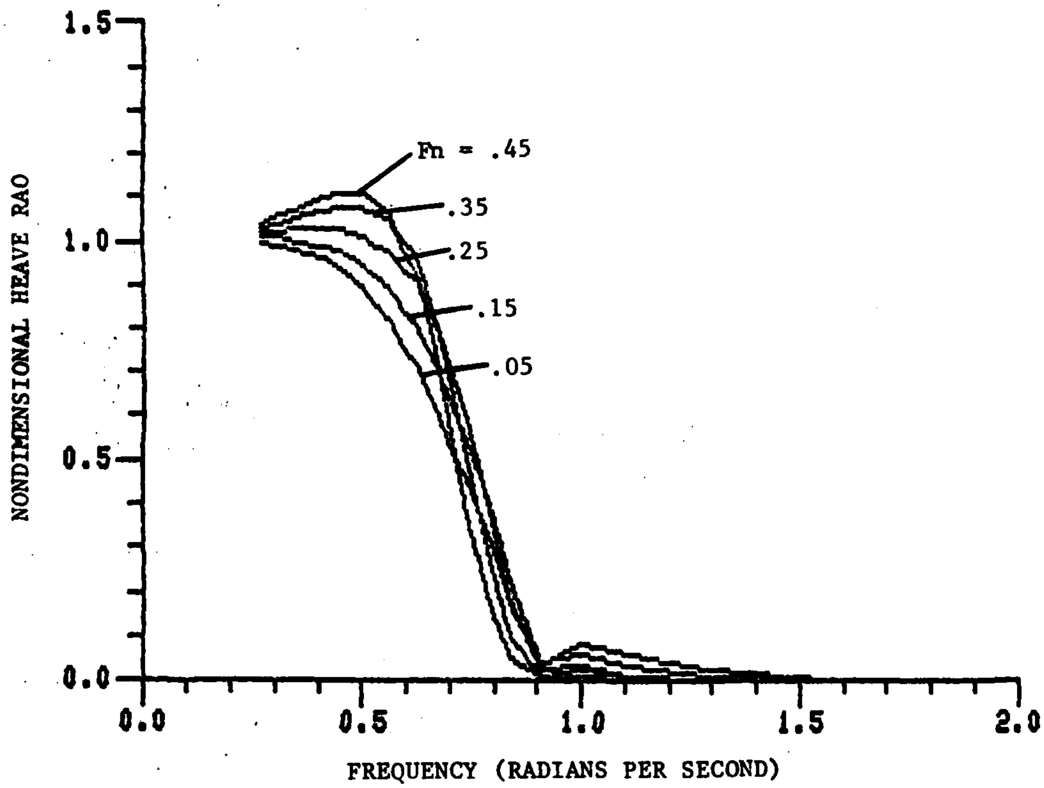


Figure 3 - Heave RAO's

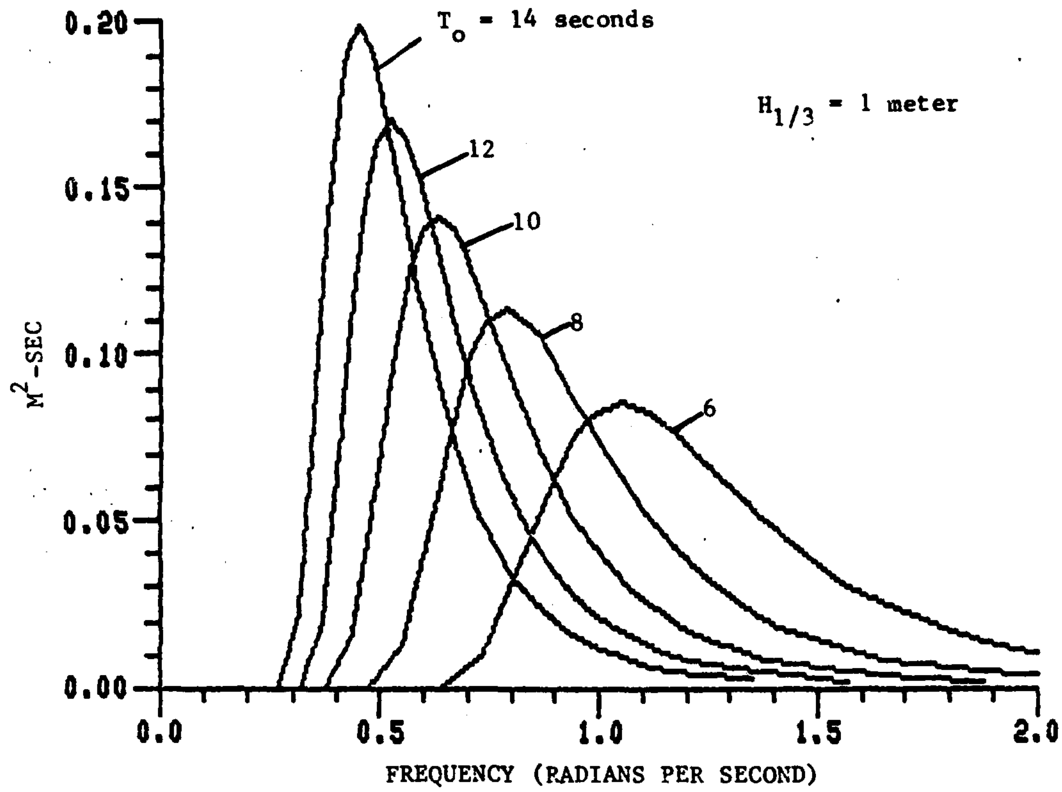


Figure 4 - Wave Spectra

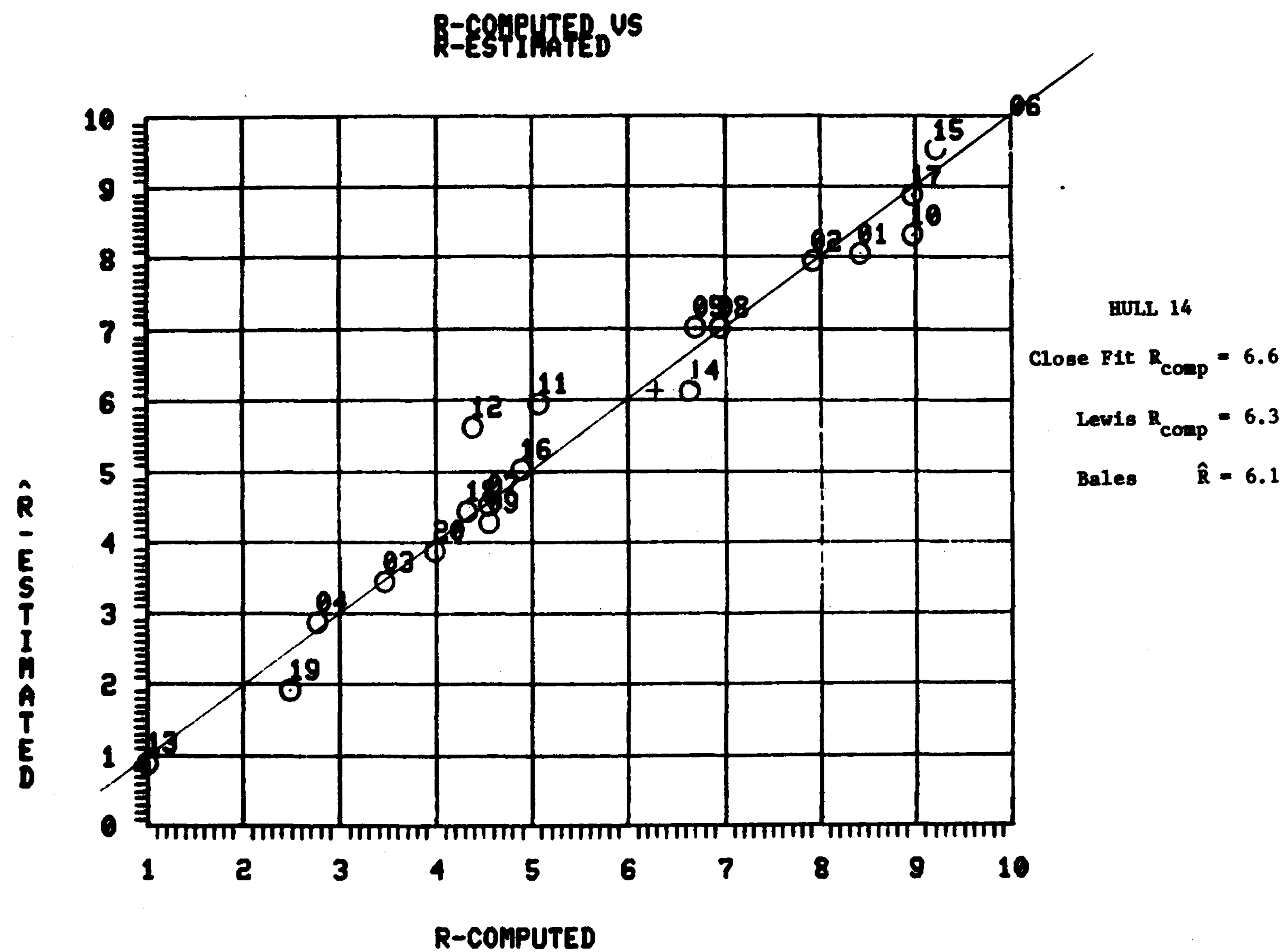
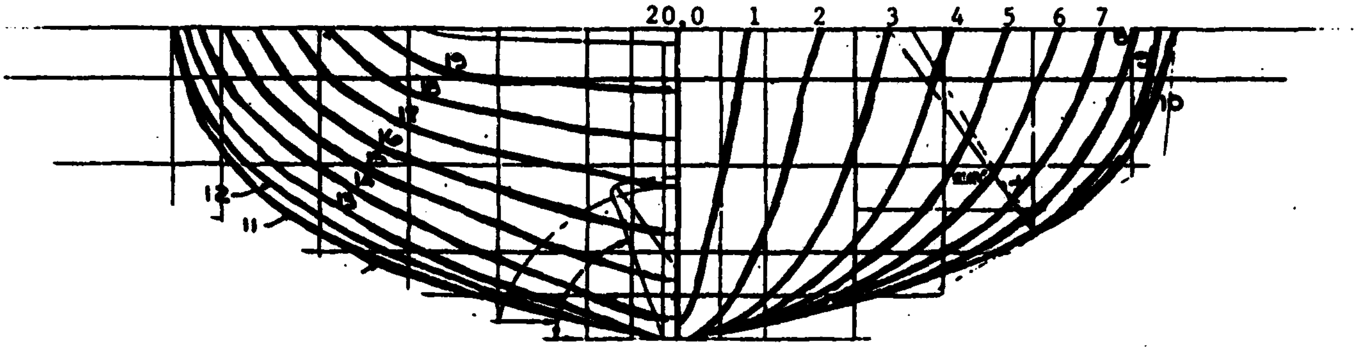


Figure 5 - R-Computed vs. $\hat{R}$-Estimated

AS BUILT



LEWIS FORM

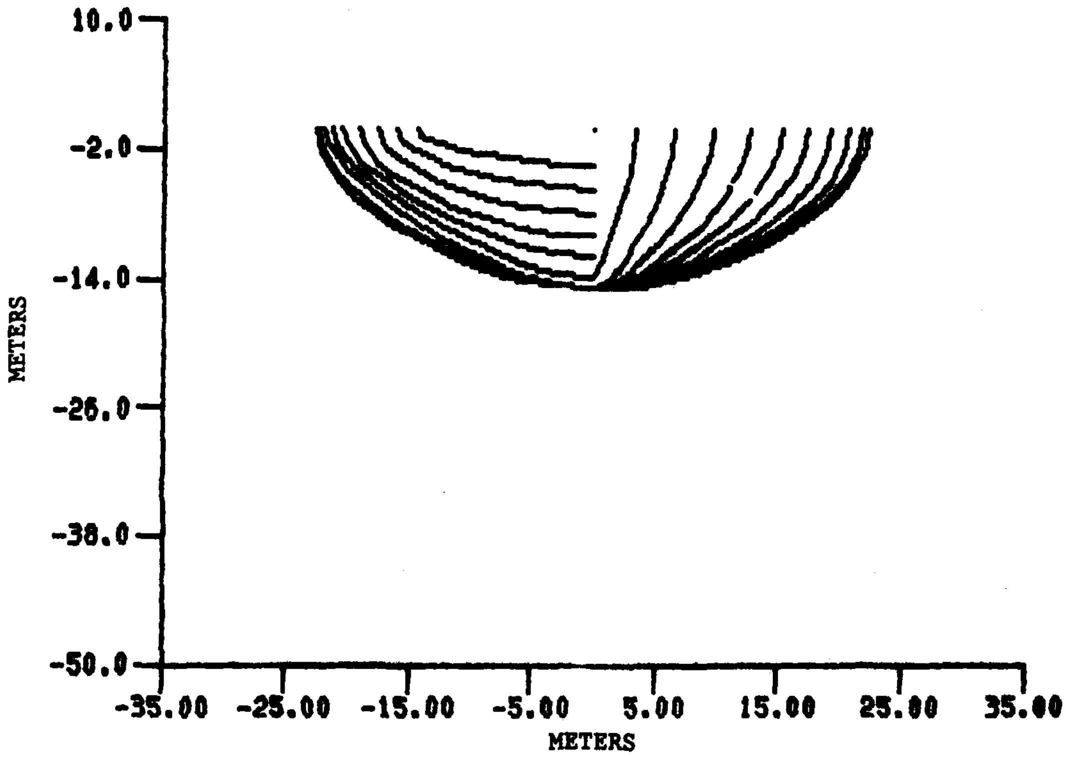


Figure 6 - Hull 14 Body Plans

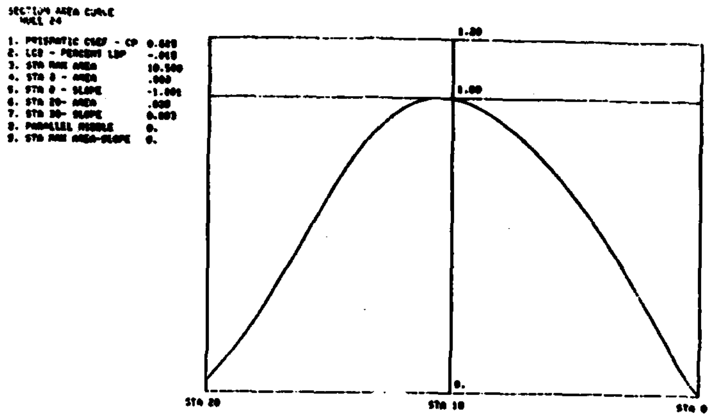


Figure 7 - Computer Generated Section Area Curve

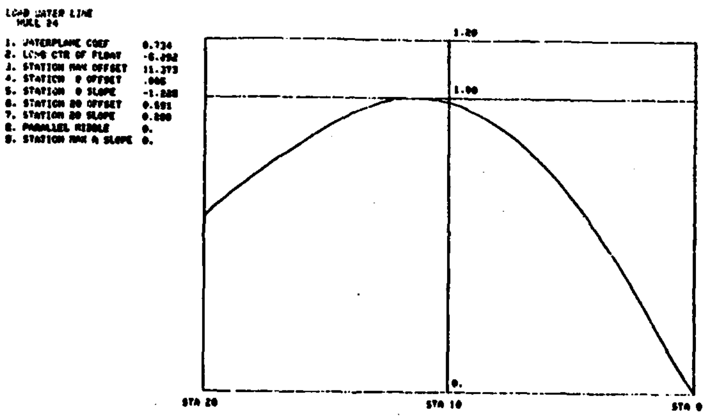


Figure 8 - Computer Generated DWL Curve

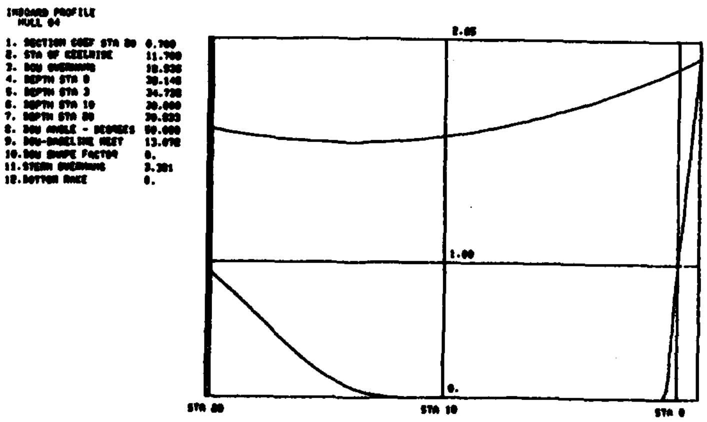


Figure 9 - Computer Generated Profile

Program	Input/Output	Location
	L, B, T, D_{10}, C_P, C_X, C_{PA}, C_W, C_{WA}	Manual Entry
SEAHULL (2 minutes)		
	HULGEN Input Data	HULL04HG.DAT
HULGEN (3 minutes)		
	SA, DWL & Profile Curves	HULL04HG.SDH
POSTHULL (2 minutes)		
	Seakeeping Input Data	HULL04SK.DAT
LEWIS2D (4 minutes)		
	Seakeeping Performance R Factor	HULL04SK.BRF

*Times shown are elapsed time on the NAVSEA VAX 11/780.

Figure 10 - Seakeeping Assessment Flow Chart

```
 WHAT DO YOU WANT TO CALL
 YOUR OUTPUT FILE
 SOON TO BE INPUT FOR HULLGEN
?HULL04.DAT
         WHAT TITLE WOULD YOU LIKE TO ASSIGN TO YOUR SHIP?
HULL04.DAT

         PLEASE INPUT THE FOLLOWING DATA SEPARATED BY COMMAS:
417       LBP, BEAM, DRAFT, CP, AND CX
46.62
15.58
.608
.808
 WHAT IS THE Cpa
 CPA
?.613
```

Figure 11 - SEAHULL Computer Program Example Run

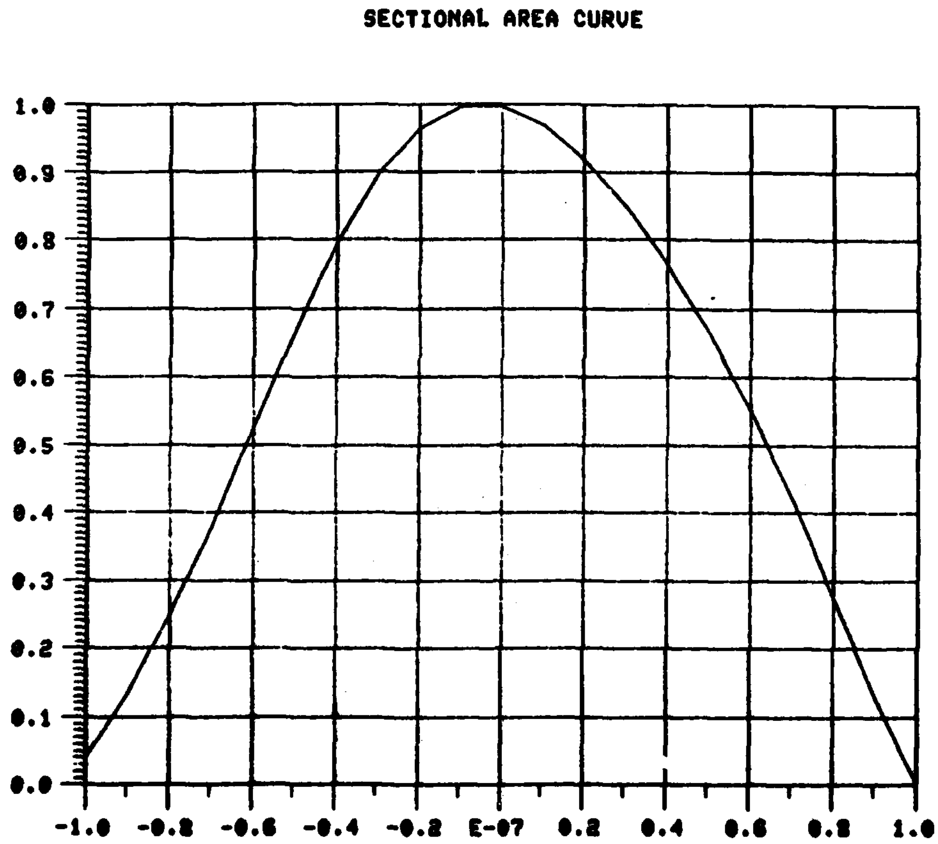


Figure 12 - SEAHULL SA Curve

```
 WHAT IS THE CWP
?.734
 WHAT IS THE CWPA
?.864
 CWP=   0.7340000      CWPA=   0.8640000
 Y or N
?Y
```

Figure 13 - SEAHULL Computer Program Input

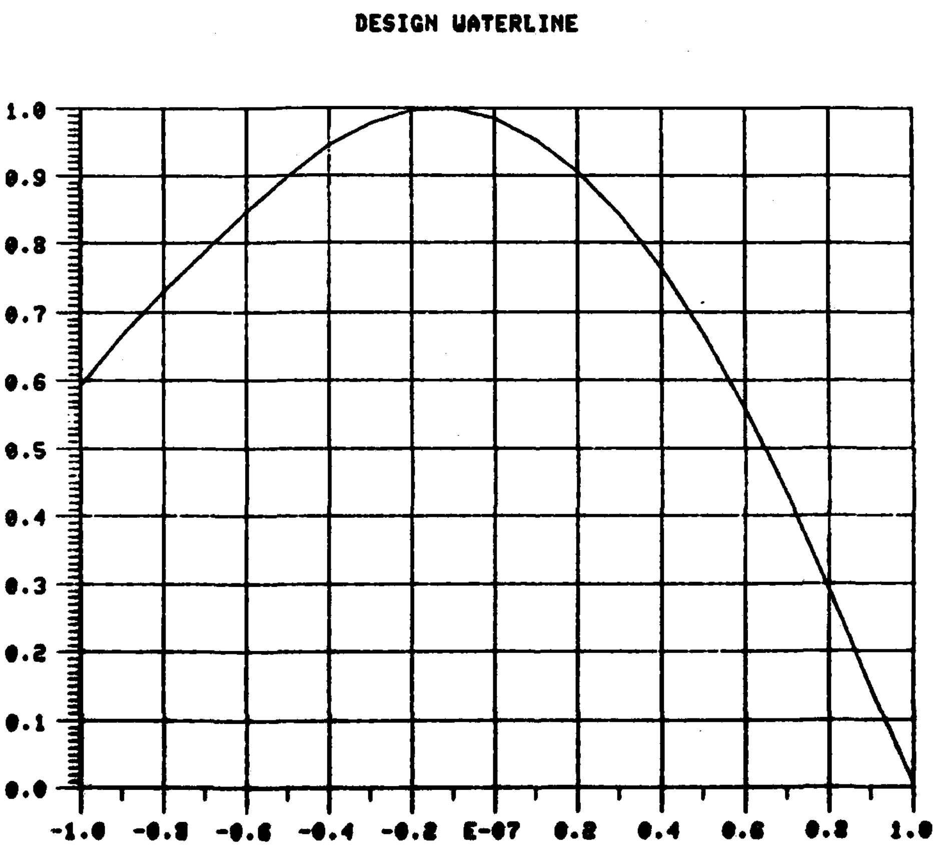


Figure 14 - SEAHULL DWL Curve

```
$ RUN LEWIS2D
 WHAT IS THE NAME THE FILE CONTAINING
 THE INPUT DATA
?HULL04SK.DAT
 WHAT DO YOU WANT THE FILE CALLED THAT
 WILL CONTAIN YOUR
 OUTPUT DATA
?HULL04SK.OUT
 WHAT DO YOU WANT THE FILE CALLED THAT
 WILL CONTAIN YOUR
 BRIEF OUTPUT
?HULL04SK.BRF
 WHAT IS THE DW FACTOR
?1.0
 DO YOU WANT A RCOMP
 INPUT FILE CREATED
?N
 DO YOU WANT THE BALES MATRIX
 DUMPED INTO A FILE
?N
FORTRAN STOP
$


$TY HULL04SK.BRF
DW FACTOR=  1.0000000
CALCULATED FROM INPUT-      CB =       0.4914
                            XCG=      -0.0123
                        WEIGHT =    4255.0391

  7.4624
```

Figure 15 - LEWIS2D Computer Program Example Run

TABLE 1 - RMS RESPONSES

PITCH	HEAVE	REL 0	ACC 0	SLAM	ACC 10	MOT 20	REL 20	Fn	To
0.1438	0.0466	0.5785	0.2756	156.68	0.0576	0.1532	0.4458		6
0.3368	0.0952	0.8061	0.3487	156.20	0.0742	0.3541	0.5305		8
0.4964	0.1790	0.9051	0.3800	193.77	0.0856	0.5371	0.5507	.05	10
0.5476	0.2620	0.8450	0.3581	279.22	0.0920	0.6206	0.4998		12
0.5398	0.3259	0.7383	0.3084	421.80	0.0913	0.6451	0.4304		14
0.1275	0.0555	0.5509	0.3285	130.08	0.1009	0.1372	0.4366		
0.3712	0.1252	0.8669	0.5599	99.27	0.1459	0.3621	0.4598		
0.5502	0.2110	1.0288	0.6433	107.65	0.1614	0.5528	0.4718	.15	
0.6008	0.2876	0.9770	0.5925	148.45	0.1588	0.6352	0.4318		
0.5859	0.3455	0.8584	0.5129	219.28	0.1480	0.6568	0.3742		
0.0996	0.0436	0.5263	0.3203	129.78	0.1003	0.1032	0.4620		
0.3797	0.1552	0.8893	0.7696	77.22	0.2082	0.3353	0.4229		
0.5803	0.2622	1.1336	0.9513	70.87	0.2604	0.5324	0.3999	.25	
0.6371	0.3339	1.1069	0.8916	90.80	0.2576	0.6206	0.3603		
0.6204	0.3819	0.9841	0.7744	128.98	0.2351	0.6455	0.3116		
0.0757	0.0326	0.5101	0.2993	134.98	0.0910	0.0790	0.4795		
0.3523	0.1813	0.8572	0.9143	72.00	0.2805	0.3063	0.4161		
0.5692	0.3215	1.1808	1.2130	55.84	0.3942	0.5007	0.3590	.35	
0.6392	0.3967	1.1954	1.1709	65.89	0.3956	0.5913	0.3102		
0.6281	0.4341	1.0802	1.0280	89.68	0.3583	0.6806	0.2632		
0.0653	0.0225	0.5012	0.2693	139.91	0.0797	0.0613	0.4806		
0.3041	3.1838	0.7866	0.9455	75.83	0.3307	0.2931	0.4831		
0.5878	0.3618	1.1600	1.3701	50.95	0.5199	0.4880	0.3403	.45	
0.6110	0.4516	1.2272	1.3737	55.14	0.5402	0.5744	0.2905		
0.6099	0.4884	1.1334	1.2264	71.76	0.4937	0.6020	0.2307		

TABLE 2 - HULGEN INPUT FILE

```
  TY HULL04HG.DAT
        1
 HULL04
 DIMEN      417.000    46.620    15.560     4.608      0.802    -0.015    -2.050
 DEPTH       39.307    35.899    31.160    31.994
 FMB          0.000     0.000     1.000
        2
 HULL04                                                SA POLY   DHL POLY  -1-1
 0.39333336E-01  0.89359200E+00  0.10500000E+02  0.60799998E+00  0.00000000E+00
-0.10015517E+01  0.59145998E+00  0.68092089E+00  0.00000000E+00  0.73400003E-00
 0.49999999E-02 -0.12284299E+01 -0.12588463E-01 -0.60926428E+01  0.42000000E+02
 0.11944598E+03  0.20919991E+01 -0.50000000E+00  0.30000000E+01  0.60000000E+02
 0.87000000E+02  0.83910953E+02  0.89000000E+02  0.00000000E+00  0.65730690E+02
 0.30096279E+02  0.62248455E+02  0.44555679E+02  0.90000000E+02  0.00000000E+00
 0.86265121E+02  0.62693119E+01  0.77544004E+00  0.69275010E+00  0.10000000E+01
 0.00000000E+00  0.37580001E+00 -0.18000000E+01  0.69999999E+00  0.11700000E+02
 0.00000000E+00  0.10000000E+02  0.10000000E+02  0.10000000E+02  0.00000000E+00

.000000E+000.000000E+000.000000E+000.000000E+00  0.11372536E+02  0.11242001E+02
 0.27100003E+00  0.10500000E+02  0.59999999E-01  0.10296440E+02  0.00000000E+00
 0.10426938E+02  0.00000000E+000.000000E+000.000000E+000.000000E+000.000000E+00
        3
 HULL04
BC NO.2        16.000    13.000    13.909    50.000    13.073     0.000
BC NO.2         3.639     0.000     3.000     1.000     0.125     0.000
BC NO.2         0.000     1.000     2.000     3.000     4.000     5.000     6.000
BC NO.2         7.000     8.000     9.000    10.000    11.000    12.000    13.000
BC NO.2        14.000    15.000    16.000    17.000    18.000    19.000    20.000
BC NO.2        99.000    99.000    99.000    99.000    99.000    99.000    99.000
 0.62248455E+02  0.00000000E+00  0.62248455E+02  0.00000000E+00
 0.87000000E+02  0.00000000E+00  0.87000000E+02  0.00000000E+00
 0.10000000E+02  0.10000000E+00  0.10000000E+01
 0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
 0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
 0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
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 0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
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DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

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