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AN INTERACTIVE GRAPHICS HULL DESIGN PROGRAM USER'S MANUAL

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COLLEGE OF ENGINEERING

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PREFACE

Like most large computer programs developed in an academic setting, the current, engineering workstation-based Interactive Graphics Hull Design Program M-HULL has a long and involved history with many contributors. M-HULL is based upon the mathematical model introduced in the U. S. Navy's HULGEN program [1,2]. M-HULL is a descendent of the mainframe-based Computer-Aided Hull Definition Program (CAHDP) [3] developed here at Michigan. I will try to trace M-HULL's evolution and credit its principal authors.

I followed the development of the HULGEN program from its beginnings and in September, 1977, attended a lecture on the program by Art Fuller while I was teaching at the Computer-Aided Preliminary Ship Design Short Course No. 406 conducted at George Washington University. In our winter semester 1980 NA574 Computer-Aided Ship Design course, I suggested to Buck Younger (now with Tampa Shipyards, Inc.) that he undertake the development of a local version of this type of program as his term project. Using the HULGEN mathematical model as a starting point, he developed the initial version of CAHDP under the supervision of Professor Michael Bernitsas in NA574 and a subsequent independent study course. When Buck Younger graduated, the program was not fully completed and it laid dormant for over two years.

In the summer of 1982, we were fortunate to begin a five-year Cooperative Research Program in Shipbuilding Technology with the U. S. Navy's Naval Sea Systems Command (NAVSEA). The completion of the mainframe version of CAHDP was undertaken as one of the several tasks under this program. Visiting Associate Research Scientist Klaus-Peter Beier (now on the University of Michigan faculty) worked on the program some during the fall of 1982. Michael Meinhold (now with Science Applications International, Annapolis) worked on the program during 1982-1983 and added the Series 60 startup capability as his term project for Prof. Bernitsas in the Winter 1983 NA575 Computer-Aided Marine Design Project. In 1983-1984, Louise Durand (now with Norfolk Naval Shipyard) completed the mainframe Michigan Terminal System (MTS) version of CAHDP and its documentation [3]. At that point, the program was introduced into general educational use within my course NA470 Ship Design II.

The way M-HULL creates a hull is similar to the traditional process the naval architect uses to generate a lines plan. In order to approach fairness, all the transverse section properties should be continuous and smooth along the length. Therefore, several longitudinally continuous boundary condition curves are created to provide the desired hull characteristics. The Sectional Area curve, for example, is drawn to match the required displacement, longitudinal prismatic coefficient (C_P), longitudinal center of buoyancy (L_{CB}), and a continuous and smooth distribution of the sectional area along the length. The design water line is used to match the waterplane coefficient (C_{WP}) and the longitudinal center of flotation (L_{CF}). The hull profile, the deck at edge plan, and the bottom tangent plan are also necessary to help define smoothly varying sections. The hull sections are uniquely defined by these longitudinal control curves.

There are eight control curves used in the M-HULL program. They are the Sectional Area curve, Design Waterline, Deck at Edge, the Keel and Sheer Profile, Bottom Flat, and the transverse Angles of Sections from the horizontal at the bottom, design waterline, and deck edge. To define these control curves, the program requires a set of 74 input parameters. Once these control curves are calculated, M-HULL generates 21 sections of the body plan.

All the curves involved in the M-HULL program are internally represented as a collection of parametric or regular polynomial curves connected with certain orders of continuity. The input parameters are used as the boundary conditions necessary to determine the coefficients of the polynomials. Changing the input parameters will result in the recalculation of the coefficients of the affected control curve followed by the regeneration of the body plan. Hence, the hull modification is done indirectly through the direct modification of form parameters and the other control curve boundary conditions.

A unique feature of the program is that it allows the designer to adjust the magnitude of the tangent vectors at end points of the parametric polynomials used to represent Sectional Area curve and the Design Waterline curve. With this additional option, the designer is able to increase and decrease the 'fullness' of the parametric polynomial by varying the magnitude of the vector. With some experience, the user will find this a useful method needed to create realistic Sectional Area and Design Waterline curves.

In many aspects, the M-HULL program is similar to the U.S. Navy's hull generation program HULGEN [1][2]. These programs use almost the same mathematical model. The major difference is that HULGEN has been developed with more extensive capabilities requiring more input parameters and using more control curves, while the M-HULL program has been designed to be more compatible with typical single-screw merchant ship hulls. In addition, M-HULL program contains a Series 60 [3] startup capability which is not available in HULGEN.

Finally, it must be noted that although the M-HULL program is able to create a mathematically continuous and smooth form with the desired dimensions and form coefficients, it does not guarantee a fair hull. The result from M-HULL is intended to be used for the examination of the feasibility of a hull with specified characteristics and as input to further fairing and hull form development.

User Interface Design and Interactive Graphics Capabilities

A major part of the M-HULL program is dedicated to its interactive graphics capabilities and user interface design. The first version of the program was implemented in 1987 on the Apollo workstations of the University of Michigan, College of Engineering, Computer Aided Engineering Network (CAEN). The current program uses the M-PLOT portable graphics subroutine package (Version 3.0) [5] which utilizes the machine independent X-Window graphics primitives. With the M-PLOT graphics package, it is possible to open multiple logical workstations on a single physical workstation to create multiple windows on a terminal, thus, allowing the display of different objects at the same time. The current version of the M-HULL program creates two curve display windows for the user: one is for drawing the control curves, and the other is reserved for showing the body plan of the hull. With such a screen layout, the user is able to observe the modification of a selected control curve and see the global influence of such a modification on the body plan at the same time.

Although the question-answer dialogue is still used in some cases, the alpha-numeric menu is the dominate part of user-program interaction. A hierarchical alpha-numeric menu system is carefully designed and implemented in the M-HULL program in order to handle many different user actions. The program takes the UNIX command shell as the third logical window for the use of user-program dialogue. All the questions and menus options are listed in this window. The menus are always followed by a prompt message line to ask the user to select a menu item by typing in either a digit or a character. Figure 1 shows the screen layout and multiple window concept of the M-HULL program.

The M-HULL program includes a unique mechanism to aid the user in detecting curvature variation and irregularities of the body plan. The technique, referred to as the porcupine spike approach [6], is implemented as part of the graphics interface of the program. This method will plot spikes perpendicular to a hull section curve with a magnitude proportional to the curvature. The porcupine spikes allow the designer to easily recognize the curvature distribution along a section, and thus evaluate the fairness of the section. Although fair sections do not guarantee a globally smooth hull, the use of the porcupine technique is a constructive first attempt towards a complete hull quality visualization tool.

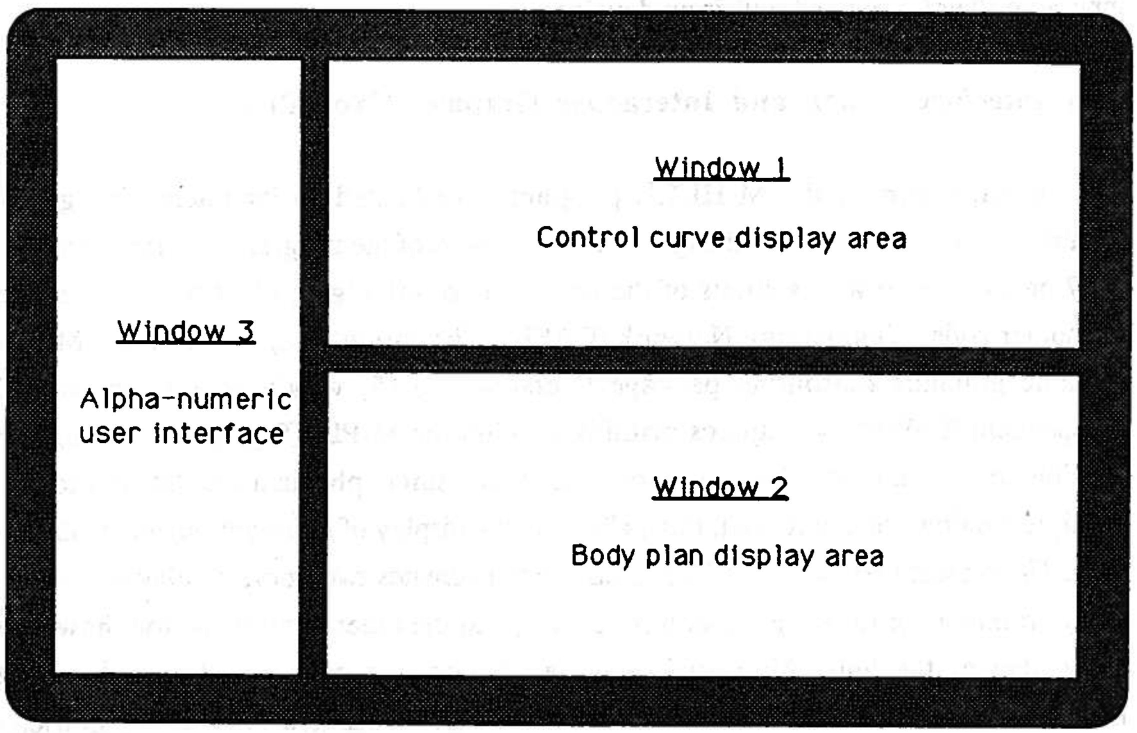

Figure 1. Screen layout of the M-HULL program.

GETTING STARTED

This section is organized as a sequence of basic step-by-step sessions designed to help the first-time user to get started with the M-HULL program. Throughout this manual, the user is assumed to know how to use the Apollo Domain series workstation of the CAEN Apollo network. Those who are not familiar with the machine are recommended to first read the appropriate sections of the CAEN handbook and a user's manual of the Apollo Domain system.

In this and the following sections, words which appear in **bold** typeface are used to indicate the commands that are entered into the computer. The output from the computer is represented by `Monaco plain` typeface. Words in upper case characters that are enclosed in <ANGLE_BRACKETS> signify keys on the keyboard. If an input command is followed by a <KEY>, the user should press that key to send it into the computer. The Apollo UNIX shell prompt is shown by **%**.

Before Starting the M-HULL Program

Although M-HULL runs on any of the Domain 3000, 3500, and 4000 machines of the CAEN Apollo network, it is recommended that a node of 3500 or above be used. The 3000 nodes will be much slower. After the user logs into a node, a UNIX shell window will be automatically opened with a prompt **%** in the command line area at the bottom of the window. If the user is not in a UNIX window indicated by **%**, type **/bin/csh** to recover a UNIX shell (see the Getting Started on Apollo handout for more details about Aegis vs. UNIX).

The user should link the M-HULL program directory to his or her current working directory. M-HULL is copied from a prescribed location in the CAEN network and is updated frequently. Consult the proper authority for instructions on accessing M-HULL. If the copying is successful, the user can list the names of all the files in the package using the unix command **ls** and check if they are as follows:

mhull_x	-The M-HULL object file that works with X-Window graphics package;
waf	-Workstation assignment file for use with X-Window version;
parent1	-Parent hull 1 datafile;
parent2	-Parent hull 2 datafile;
parent3	-Parent hull 3 datafile;
parent4	-Parent hull 4 datafile;
parent5	-Parent hull 5 datafile;
sxdata.d	-Data for Series 60 startup;
przmet	-File used to preview a metafile;
metips	-Utility file used to convert a metafile into a PostScript file;

Note that the user only needs to copy these files once. After this is done correctly, the files will stay in the user's directory for future use.

Starting the M-HULL Program

To start the M-HULL program, simply type the following command:

```
% mhull<RETURN>
```

The user next needs to enter the name of the workstation assignment file following prompt. This determines the position and size of the curve display windows on the screen. Entering **wafx** results in:

```
Enter Name of Workstation Assignment File:
wafx<RETURN>

WORKSTATION 1
 SAC
 DWL
 DECK
 BTFLT
 PRFIL
 ANGLE

WORKSTATION 2
 BODY
```

The workstation assignment file 'waf' creates two curve display windows (workstations) in the right portion of the screen. The corresponding curve names are printed in the command window as shown above. Directly following is a program header with a short description and a list of the hull control curves available:

```
==================================
DEPT.OF NAVAL ARCHITECTURE AND
      MARINE ENGINEERING
  THE UNIVERSITY OF MICHIGAN
      ANN ARBOR,MI 48109

       * * * M-HULL * * *

 (Version 2.0  December 1990)

A GRAPHICS PROGRAM THAT ALLOWS
THE INTERACTIVE GENERATION AND
MODIFICATION OF A HULL BY MANI-
PULATION THE FOLLOWING CONTROL
CURVES:

     1) SECTIONAL AREA
     2) DESIGN WATERLINE
     3) DECK AT EDGE
     4) BOTTOM FLAT
     5) PROFILE
     6) ANGLES OF SECTION AT:
        - KEEL
        - DWL
        - DECK
==================================

Press "RETURN" to continue ...
```

Press the RETURN key and the M-HULL Main Menu will appear on the screen as follows:

```
      * * * M-HULL * * *

      *** MAIN  MENU ***
==================================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==================================
Enter a digit:
```

Title A Design Session

The Title option under the Main Menu allows the user to name his or her design session. Once a title is entered, it will appear in the top area of both the curve display and body plan display windows when the curve review event happens. The following shows how to enter a session title:

(following the Main Menu prompt)
1 <RETURN>

```
Enter your session title
 (less than 73 characters):
```

USER'S MANUAL SAMPLE GRAPH<RETURN>.

Selecting the Input Data

The user must first perform an input action before he or she is able to review any curves or prepare any output data. To select the input option from the Main Menu, the user simply types in digit 2 following the prompt message and then presses the RETURN key. Program now enters into the input mode. An input menu appears on the screen with the following options:

```
      * * * M-HULL * * *

       ** Input Menu **
------------------------------
What?
1. Parent Ship
2. Series 60
3. Return
------------------------------
Enter a digit:
```

With these options, the user can choose between an existing parent hull and an approximate Series 60 hull as the input data. Both the parent hull and Series 60 are provided as a startup hull to help users to obtain an acceptable hull after a limited number of design iterations. Assume the parent hull is selected as the initial input, then the user is required to inform the program whether to read the parent hull data from keyboard input or from an existing file. If the user selects to input from an existing file, then he or she needs to enter the file name. All selections are done by typing in an entry number (an integer) that corresponds to the related menu item. Suppose the parent hull datafile 'parent1' is entered, then this procedure is demonstrated as follows:

(following the Input Menu prompt)

1 <RETURN>

```
----------------------------
Where?
1. From File
2. On Terminal
3. Return
----------------------------
Enter a digit:
```
1 <RETURN>

```
Enter data file name
 (less than 73 characters):
```
parent1 <RETURN>

After the selection of the input is completed, certain computations will be carried out by the program. The water density calculated from the input data will be printed on the screen. User will be asked to change the water density if necessary at this stage. Assume the user does not intend to modify the water density, then he types in the character N and presses the RETURN key. The program automatically returns to the Main Menu for the user's further selection.

Manipulating the Control Curves and Viewing the Body Plan

Upon selecting 'Curve Review' under the main menu by typing in digit 3 and pressing the RETURN key, the program enters into the curve display and manipulation mode. A Curve Review Menu with a list of all the control curves and the body plan will be printed on the screen as follows:

```
     * * * M-HULL * * *

   ** Curve Review  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
------------------------------
Enter a digit:
```

```
(following the Curve Review Menu prompt)
C <RETURN>

Enter CP ( Based on DWL)
0.66 <RETURN>

Enter a menu item
1 <RETURN>

==== Sectional Area Curve ====

A. AP Area       = 0.0000000
B. LCB           = -0.1000000
C. CP            = 0.6600000
D. FP Area       = 0.0000000
......

I. AP            = 0.3000000
J. Aft Mid       = 0.7000000
K. Fore Mid      = 0.3000000
L. FP            = 0.8000000
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
9. Overlap Draw of Ctrl.Curves
0. Overlap Draw of Body Plan
------------------------------
Enter a digit or a character:
```

The user can also choose the option 'Overlay Draw of Ctrl. Curves' or 'Overlay Draw of Body Plan' to draw the updated Sectional Area curve or body plan without erasing the existing curves. This feedback design makes it easier for the user to recognize the effect of the change(s) on the control curve and the global effect of the parameter change(s) on the body plan. Figures 4 and 5 show the overlay draw of the Sectional Area curve and the body plan, respectively, due to the modification of C_P in this example.

Similarly, the user can change any of the defining parameters to modify any selected control curve. In this way, the user is able to refine the hull to create his or her desired hull form. The user must periodically refresh the selected control curve as well as the body plan after the modification of a few parameters. The program is not designed to automatically update all the curves and the body plan whenever a parameter modification event occurs.

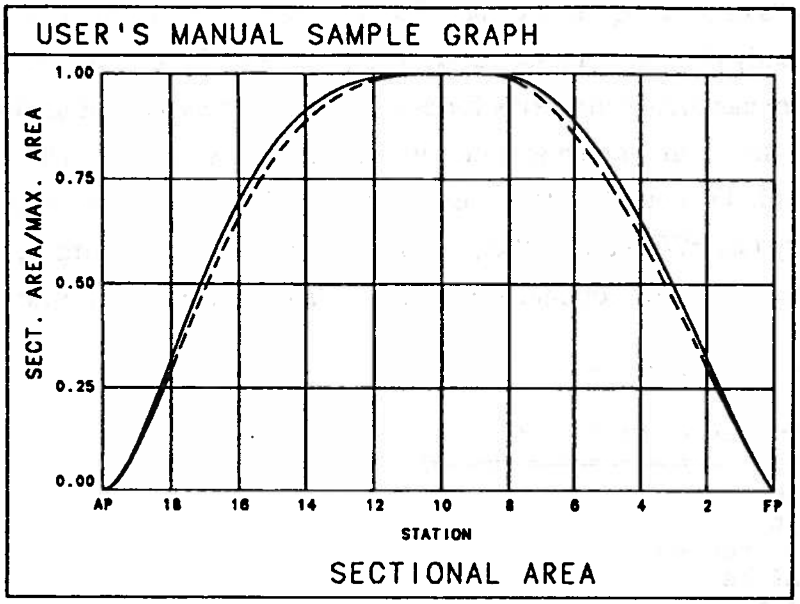

Figure 4. Overlay draw of Sectional Area curve (dashed curve is the new one).

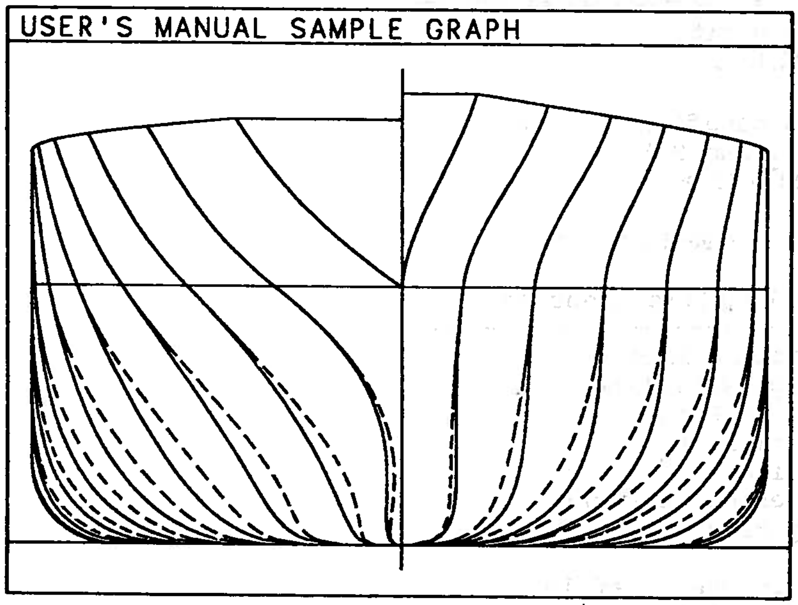

Figure 5. Overlay draw of Body Plan after the modification of Cp (dashed curves show the new sections of the hull).

Saving Data and Creating the Output

After the user achieves a feasible hull, it is important to save the design for future use. It is also wise to periodically save the current set of parameters so that hull refinement effort is not lost should there be a system error or program restart.

The results of the program are classified into the graphic output, like the control curve plots and the body plan, and numerical data sets like the offsets. To save the plots, the M-HULL program can create metafiles for each control curves as well as for the body plan. The metafile contains the screen graphics information. It can be converted into a PostScript file via the M-PLOT metafile interpreter 'metips'. This is used to reproduce the graphs on the high quality LaserWriter after the program execution. As an example, the procedure of creating a metafile for the Sectional Area curve is demonstrated as follows:

```
      * * * M-HULL * * *

      *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
4 <RETURN>

Enter a metafile ID number
(11 - 97 and 99):
22 <RETURN>

      * * * M-HULL * * *

     ** Metafile  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan

8. All in One Metafile
9. New Metafile
0. Return
------------------------------
Enter a digit:
1 <RETURN>

++++ METAF22 CREATED +++++
```

The M-HULL program creates the metafile with a upper case character name like METAF22. After the program exaction is ended (Main Menu 6. Stop), two steps are needed to print the metafile through the LaserWriter. The first step is to use the metafile interpreter 'metips' to convert the metafile into a PostScript file as follows:

```
% metips <RETURN>
......

ENTER NAME OF METAFILE: (OR X TO EXIT)
METAF22 <RETURN>
......
OPTIONS:  ......
              G GO - CREATE THE POSTSCRIPT FILE
G <RETURN>

NAME OF CURRENT METAFILE IS: METAF22
PLEASE ENTER NAME OF POSTSCRIPT FILE TO BE CREATED-(OR X TO EXIT)
PS22 <RETURN>

NOW READING AND CONVERTING THE METAFILE ......
+++ END OF METAFILE +++

PLEASE ENTER NAME OF POSTSCRIPT FILE TO BE CREATED-(OR X TO EXIT)
X <RETURN>
```

Note that program 'metips' is case sensitive to the name of the metafile. When entering the metafile, the user should always use the correct case. Consult the M-PLOT documentation for an explanation of the various options available within metips.

As a second step, the user needs to download the postscript file to the LaserWriter using the following command:

```
%prf PS22 -pr printer_name -transparent <RETURN>
```

and the LaserWriter 'printer_name' should print out the graph for the user. Here printer_name is a variable for the name of a LaserWriter. Each LaserWriter in the CAEN laboratory has its own name. The user should be able to find a right one.

One of the most important data sets the user should save before quitting the program is the control curve defining parameters. To keep a record of all the control curve parameters, the user can select menu entry 2 under the Output Menu. The parameters can be either sent to a user specified file or printed on the screen. In most cases, however, the user will find it desirable to create an output datafile which can be the input file of a new or restart design session. With this datafile, the user can start from his or her previous design results fairly easily whenever necessary. The following procedure shows how to send the 74 hull form and control curve parameters to a datafile called 'myctrl' in the standard M-HULL input format:

```
    * * * M-HULL * * *

    *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
```

5 <RETURN>

```
     * * * M-HULL * * *

     ** Output  Menu **
------------------------------
Where?
1. On Terminal
2. To Files
3. Return
------------------------------
Enter a digit:
```

2 <RETURN>

```
Enter file name
(less than 73 characters):
```

myctrl <RETURN>

```
------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
3. Hydrostatic Data
4. Calculated Hull Data
5. Table of Offsets

---  Formatted Output ---
6. MHCP Offsets
```

```
7. M-HULL Input File

8. New File
9. Return
------------------------------
Enter a digit:
7 <RETURN>
```

This file can now be used as a Parent Ship input file when restarting M-HULL. The definition of the hull form and control curve parameter datafile can be found in Appendix D. A sample can be found in Appendix E.

The M-HULL program creates the output offsets in two different formats depending on how the user is going to use them. For design review, the program can print the results in regular format. If the user takes the output of M-HULL as the input to the Michigan Hull Characteristics Program (MHCP) [7] system to calculate the hydrostatic and other characteristics of the resulting hull, the program can create the offsets in standard MHCP format. The user can choose either option under the Output Menu. As an example, the following shows how an MHCP file is created:

```
      * * * M-HULL * * *

      *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
5 <RETURN>

      * * * M-HULL * * *

      ** Output  Menu **
------------------------------
Where?
1. On Terminal
2. To Files
3. Return
------------------------------
Enter a digit:
2 <RETURN>

Enter the File Name
 (less than 73 characters):
HSIXTY <RETURN>
```

```
------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
3. Hydrostatic Data
4. Calculated Hull Data
5. Table of Offsets

---  Formatted Output ---
6. MHCP Offsets
7. M-HULL Input File

8. New File
9. Return
------------------------------
Enter a digit:
6 <RETURN>

Enter Ship Number
(an integer less than 10000):
10 <RETURN>

Enter Ship Name
(less than 31 characters):
PARENT1 <RETURN>
Enter "M" for Metric unit
system;  enter others for
British unit system:
B <RETURN>

Enter station spacing in
input units:
20.000 <RETURN>

Enter LBP:
400.00 <RETURN>

CREATING MHCP OFFSETS......

------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
 ......

---  Formatted Output ---
6. MHCP Offsets
7. M-HULL Input File

8. New File
   (not for terminal)
9. Return
------------------------------
Enter a digit:
9 <RETURN>
```

A sample MHCP offset file can be found in Appendix E.

The MHCP modules are available on the Macintosh computers of various models in the CAEN laboratory. To transfer a MHCP input file created by M-HULL from an Apollo to a Macintosh, a file transfer using the FTP (File Transfer Protocol) [8] is needed. FTP on a Macintosh works through NCSA Telnet. To use the FTP on a Macintosh to receive files form the Apollo ring, the following steps are necessary:

- Log into a Macintosh machine;
- Open the Communication Folder and double click the application 'NCSA Telnet 2.3';
- Click **Open Connection** under the **File** menu. A dialog box will appear on the screen;
- Enter the name or the Internet address of a desired Apollo node under the portion of the dialog box which is entitled **Session name.** Click **OK** when done;
- If the previous commands are successful, a new window for Apollo will be posted on the screen with a login prompt. Now enter the user ID and password;
- Once connected and logged in, change the current directory into the directory that includes the MHCP input file ready to be transferred;
- Select and click the **Send FTP Command** under the **Network** menu to get an `FTP>` command prompt;
- To transfer a file from the Apollo to Macintosh, use the 'put' command as follows:
  `FTP>`**put apollo_filename <RETURN>**;
- To exit FTP, type **bye** and press the RETURN key;
- Click **Close Connection** under the **File** menu to terminate the transfer process.

More detailed information about the file transfer via FTP can be found in reference [8].

M-HULL INPUT

The input of M-HULL is a set of 74 parameters. According to their usage in the program, the input parameters are divided into two major parts: Hull Form Parameters and Control Curve Boundary Conditions. Hull Form Parameters are the global hull dimensions and coefficients. Boundary conditions are used to define the control curves which are explained in detail in Appendix A. A complete list of the 74 input data can be found in Appendix D. The Control Curve Boundary Conditions are described in Appendix B.

Although users can prepare his or her own input data completely by following the input format shown in Appendix D, this is not recommended for new users. Instead, they are encouraged to take advantage of the startup capabilities of the M-HULL program. With the startup data included in the M-HULL package, the user is able to start with an initial hull form which is reasonable and, in many cases, not too far away from the desired shape. Thus, a tremendous amount of time can be saved.

There are two kinds of startup files available. One is the various parent hull files, the other is that of an approximate Series 60 hull form. The current M-HULL package provides five parent ship hulls for the user. The names of the parent hull files are 'parent1', 'parent2', 'parent3', 'parent4', and 'parent5'. The body plans and hull form parameters of the parent hulls are shown in Appendix F. The datafile of Series 60 is 'sxdata.d'.

To change the dimensions and the hull form coefficients of a parent in order to create a desired startup hull, the user can first make a copy of the selected datafile, then use the available edit system, like 'vi', to open and modify that datafile. Another way is to overwrite the current dimensions and form coefficients on the screen using the 'On Terminal' option under the Input Menu after a selected parent hull is inputted. To change the control curve parameters, it is best to not bother in the editor, but wait to change them interactively on the screen. With a good startup hull, the user is able to develop his or her own hull through a limited number of parameter modifications.

The Series 60 startup is provided basically for the same purpose. The only difference is that it doesn't include the main dimensions of the hull. The user needs to input the L_{WL}, beam, draft, displacement, block coefficient C_B, and L_{CB} of his or her hull before its initial configuration can be created.

Using the Series 60 startup, the user is also provided with some guidelines for improving the initial Sectional Area and Design Waterline curves. Crosses are printed on these curves, indicating the exact curve shape for the Series 60 hull. If desired, the user can then alter the necessary parameters to match the curves more closely to these points. Two examples are illustrated in Figures 6 and 7. In Figure 6, the initial Sectional Area curve (solid line) does not match the Series 60 sectional area (shown by crosses) well in the entrance. The magnitudes of slope vectors of the forward curved section may be modified interactively to improve the matching.

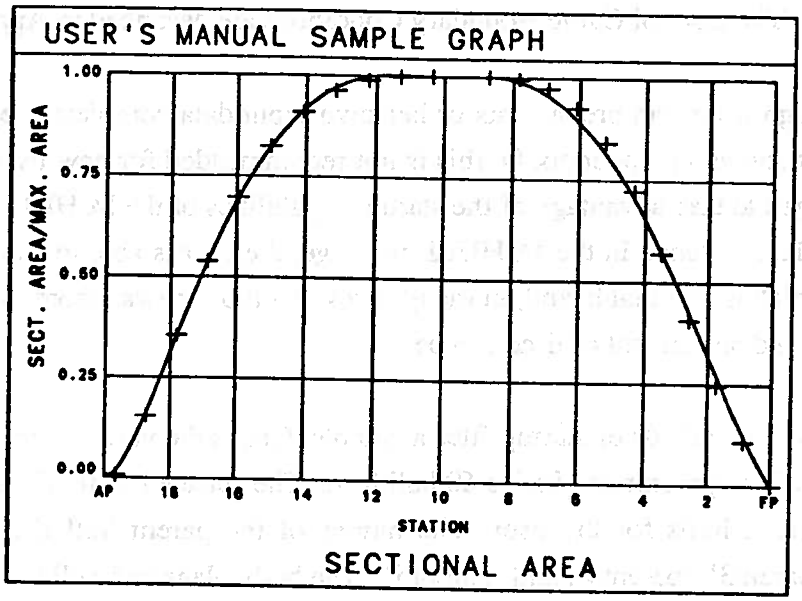

Figure 6. The guide Sectional Area curve of the Series 60 (shown by crosses).

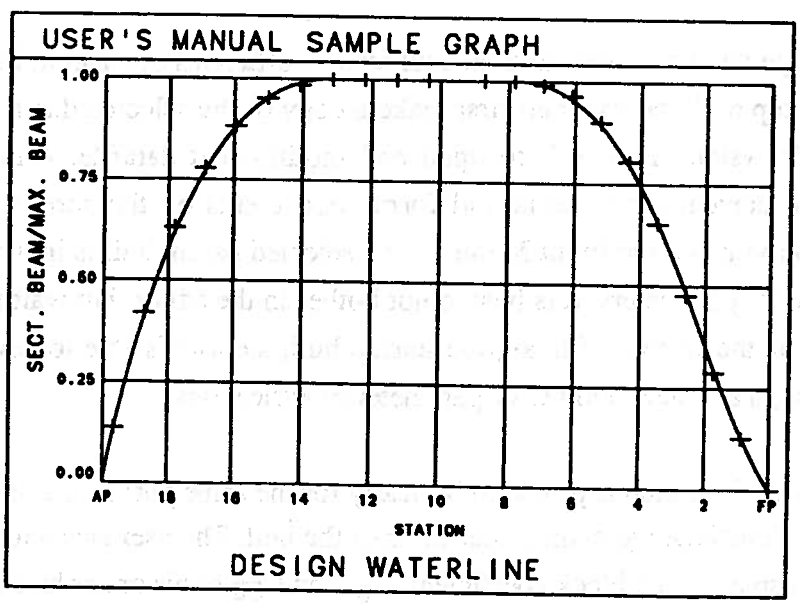

Figure 7. The guide Design Waterline curve of the Series 60 (shown by crosses).

M-HULL OUTPUT

The results of the M-HULL program are classified into the graphic output and numerical data sets. The graphic output includes the plots of following curves:

- Sectional Area curve;
- Design Waterline curve;
- Deck at Edge curve;
- Bottom Flat curve;
- Profile;
- Transverse Angles of Section from the horizontal at the bottom, design waterline, and deck edge;
- Body Plan.

The numerical output of M-HULL comprises the following data sets:

- Principal dimensions;
- Control curve parameters;
- Hydrostatic coefficients;
- Calculated hull data;
- Offsets;
- M-HULL input file.

All the numerical data sets can be saved in files or printed on the screen. The offsets can be printed either in an easily readable tabular form or in standard MHCP format for use in further computer aided analysis on the hull form. Control curves and body plan plots can be saved in metafiles which can be used to reproduce high resolution curve plots through the LaserWriter after the program execution. Also, the program allows the creation of the datafile in the M-HULL input format, which can serve as an input file of a new M-HULL design session. More information on the M-HULL output is found in the following sections on Metafile and Output Menus. Appendix E shows samples of the numerical output of M-HULL.

USING THE M-HULL MENU

M-HULL is a highly interactive graphics program. Its main program flow is largely determined by the user. The general sequence of execution, however, can be stated as follows:

- The user inputs initial hull form data and control curve boundary conditions;
- The user examines the control curves and body plan defined by the input, and modifies the data set until a satisfactory hull form is obtained;
- The user saves his or her design and creates the output.

The M-HULL Menu Hierarchy

A hierarchical menu structure is implemented in the M-HULL program. The purpose of the hierarchical menu structure is to facilitate the handling of many different user actions. Figure 8 shows the M-HULL menu structure and how it directs the main calculation flow. In the following, the usage of the M-HULL menus will be described in detail.

Main Menu

In M-HULL, Main Menu is the point of control of main program flow. The M-HULL Main Menu is a list of all six major user actions available, followed by a prompt message line as follows:

```
     * * * M-HULL * * *

     *** MAIN  MENU ***
================================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
================================
Enter a digit:
```

To select the desired action, the user simply enters a digit (an integer) that corresponds to the item of the menu and presses the RETURN key. A lower level menu will then be printed on the screen for the user's further selection. The lower level menu always includes a 'Return' item, which will return the user to the Main Menu. To terminate the program, enter the digit **6** and press the RETURN key.

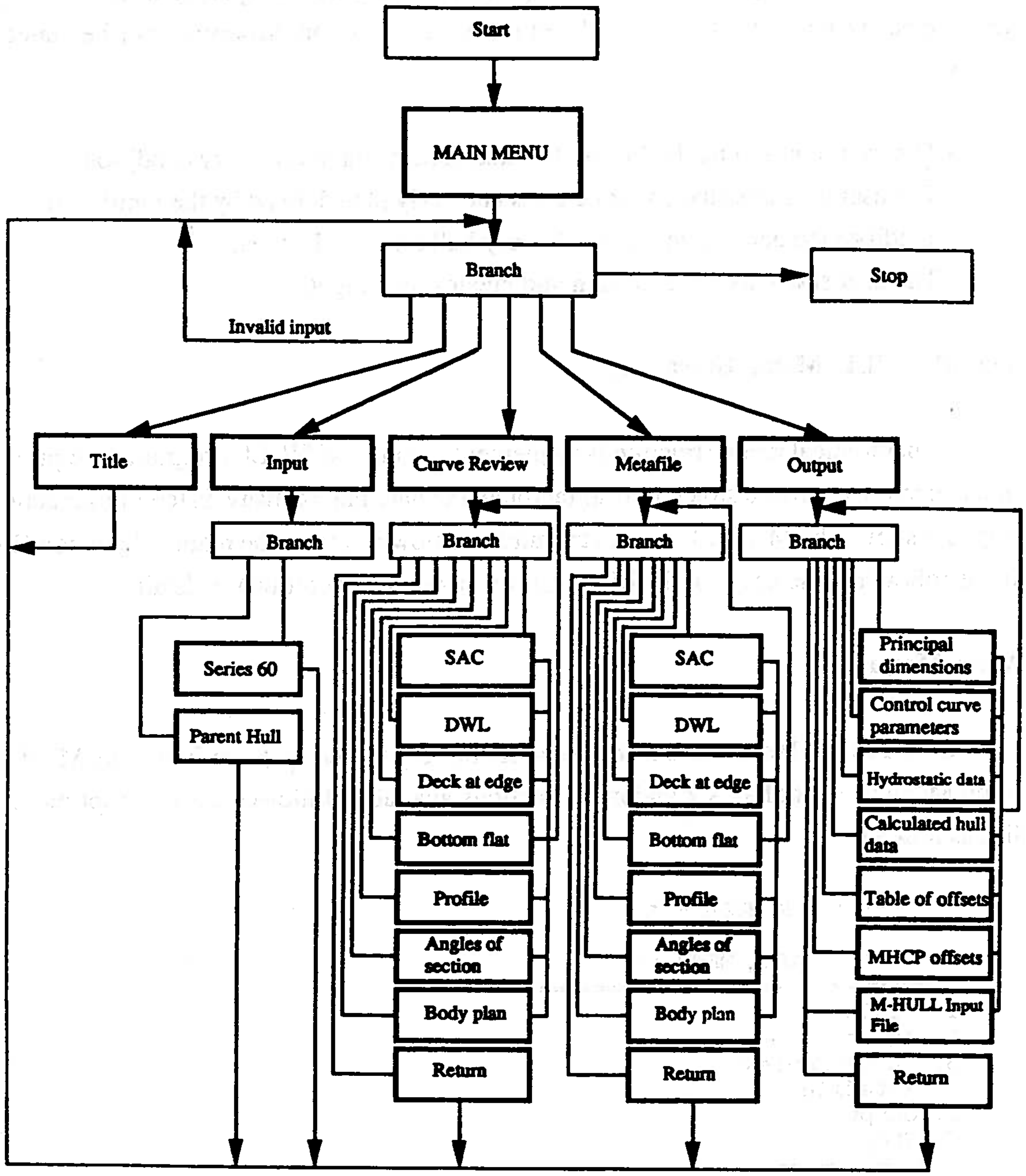

Figure 8. The hierarchical menu structure of the M-HULL program.

Note that under the Main Menu, not all the options are active at any time. For example, at the beginning of a session, the user must always enter the input data before he or she activates the 'Curve Review', 'Metafile', and 'Output' options. Otherwise, the user's selection will be ignored. A message line will be printed on the screen informing the user of the reason.

Title Option

The Title option under the Main Menu simply allows the user to name his or her design session. The maximum size of the title is 72 characters. Once the title is entered, it will be printed in the top of the curve display window and the body plan display window.

The Title option can be selected under the Main Menu any time during the program execution. Once a new name is entered, it will overwrite the existing name in memory and appear on the screen during the next control curve or the body plan refreshing process.

Input Menu

There are three steps included in the input procedure. As the first step, the program will let the user decide what kind of datafile is chosen as the input to M-HULL as follows:

```
      * * * M-HULL * * *

        ** Input Menu **
------------------------------
What?
1. Parent Ship
2. Series 60
3. Return
------------------------------
Enter a digit:
```

If the user selects the 'Parent Ship' item, then the second step requires the user to determine whether to enter the parent hull data through the terminal keyboard or to input the data set from an existing datafile as follows:

```
----------------------------
Where?
1. From File
2. On Terminal
3. Return
----------------------------
Enter a digit:
```

If the user selects to read the data from an existing datafile, then, in the third step, the program will ask the user for a filename as follows:

```
Enter data file name
 (less than 73 characters):
```

This step is not required if the user chooses to enter the data through the terminal keyboard. In the case that the user starts a session with Series 60, the Where? menu is skipped.

To enter the parent hull through the keyboard, the user can either type in all 74 parameters or type in only the principal dimensions and form parameters. The user must answer the following question before he or she begins to input the data:

```
Input principal dimensions
 only ?(Y/N)
(You have to enter all 74
  parameters if you do not
  enter "Y" or "y".)
```

In the principal dimensions option, the user can input only the following 15 values:

- L_{OA} and L_{WL};
- Maximum Beam at Deck and Waterline;
- Draft;
- Depth at FP, Midship, and AP;
- Displacement;
- L_{CB} and L_{CF};
- C_P, C_X, and C_{WP};
- Deadrise.

M-HULL will prompt the user for all data required. Note that this option is useful in the case where the user wants to scale a parent hull or change a certain number of its parameters and dimensions. The user must first input the parent hull and then overwrite its form coefficients and dimensions on the screen using this option.

If the user chooses to begin his or her session with an approximate Series 60 hull form, the user is prompted to input the following parameters on the terminal: L_{WL}, beam, draft, displacement, C_B, and L_{CB}. These values must be consistent with that of the Series 60 form as follows:

$5.500 < L_{WL}/Beam < 8.740;$
$1.900 < Beam/Draft < 4.100;$
$0.541 < C_B < 0.855;$
$-0.370 < L_{CB} < 0.273.$

The program will print out messages showing these ranges of L_{WL}/beam, beam/draft, C_B, and L_{CB}. The input data must satisfy these constraints, otherwise they will be ignored. In this case the program will continue with repeated requests for the correct data. The user must pay attention to this.

The Input Menu will remain on the terminal screen until all data are entered, at which time the program is automatically returned to the Main Menu. Any invalid input will be ignored by the program.

The Input Menu may be selected and data entered at any time during a M-HULL session. Both the hull form parameters and boundary conditions must be entered before M-HULL will automatically return to the Main Menu. All the related existing data will be completely overwritten. If the user accidently enters into the input mode, he or she can exit easily by selecting the 'Return' item without altering an active data set.

Curve Review Menu

The Curve Review Menu allows the user to select and modify one control curve at a time. The mathematical representations of all the control curves and the body plan are described in detail in Appendix A.

The layout of the Curve Review Menu appears differently depending on the latest review action. If the latest review action is the review of the Body Plan, then the menu includes nine items:

```
    * * * M-HULL * * *

  ** Curve Review  Menu **
```

```
-------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
9. Porcupine Spikes
-------------------------------
Enter a digit:
```

with which the user can draw a desired control curve, refresh the Body Plan, show the curvature distribution, or return to the Main Menu.

If the previous user selection is the review of a specific control curve, the following Curve Review Menu comprises two lists of items. The first list is a set of the current defining parameters of that control curve. The second is a list of items used to overlay draw the current control curve, display other control curves, refresh or overlay draw the Body Plan, or return to the Main Menu. As an example, the following shows Curve Review Menu with Design Waterline curve as the current control curve:

```
=== Design Waterline Curve ===

A. AP Offset     = 1.0000000E-03
B. LCF           = -2.1360000
C. CWP           = 0.7590000
D. FP Offset     = 1.0000000E-03
E. AP Slope      = 76.62800
F. Aft Stn Mid   = 12.35400
G. Fore Stn Mid  = 7.000000
H. FP Slope      = 49.39400

--- Vector Magnitudes ---
I. AP            = 1.474000
J. Aft Mid       = 0.3410000
K. Fore Mid      = 0.2500000
L. FP            = 0.8000000
-------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
9. Overlap draw of Ctrl.Curves
0. Overlap draw of Body plan
-------------------------------
Enter a digit or a character:
```

To modify a parameter of the current control curve, simply type in an character corresponding to this parameter under the first list and press the RETURN key. M-HULL will then print the name of the parameter and request a new value. Any parameter or a series of parameters can be modified in this way.

To review the modified control curve and its influence on the body plan, the user can simply redraw the updated control curve (2, in this example) and the Body Plan (7). Or, the user can overdraw the updated curves and the Body Plan without erasing the previous curves from the screen. This is done by selecting the 'Overlay draw of control curve' (9) and 'Overlay draw of body plan' (0) items. The updated curves are shown in dashed lines. In this way, the effect of the parameter modification can be visualized more readily. Figure 9 shows the overlay draw of the Design Waterline curve and Figure 10 shows the overlay draw of the Body Plan.

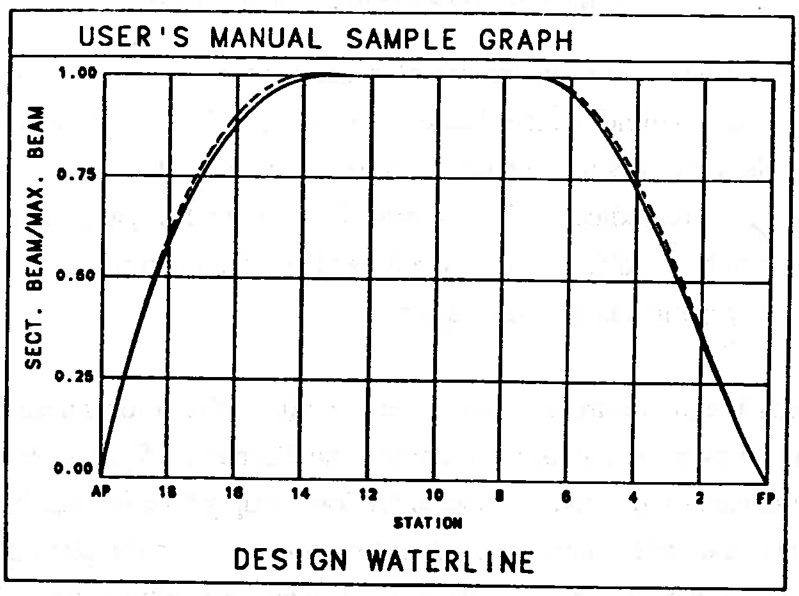

Figure 9. Overlay draw of the Design Waterline curve.

The overlay draw option may be used as many times as desired, but will eventually result in a cluttered screen. To refresh the current control curve or the body plan, simply redraw that curve or the Body Plan by typing in the appropriate digit under the Curve Review Menu.

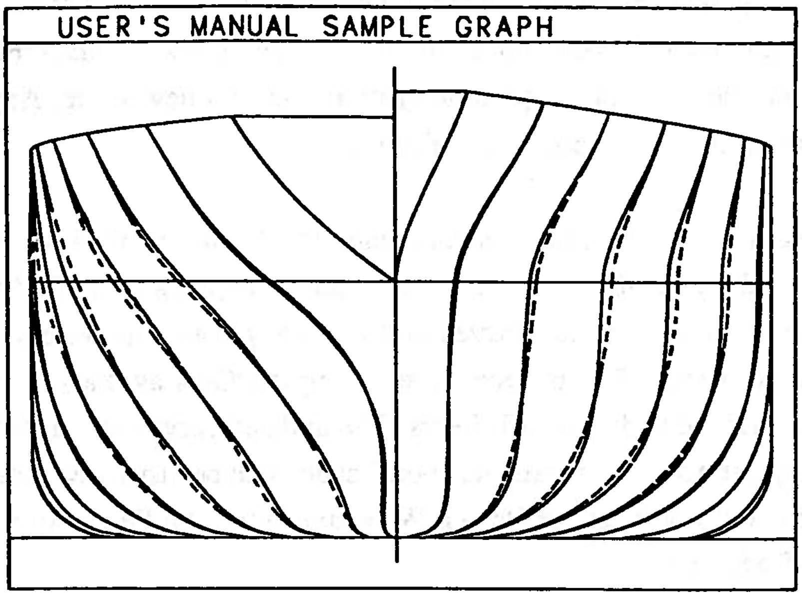

Figure 10. Overlay draw of Body Plan.

Note that after a new parameter of a selected control curve is entered into the program, M-HULL will not update that control curve and the body plan automatically. To keep tracing the current shape of that control curve as well as the body plan, the user should refresh them periodically after the modification of a few parameters. Also note that a control curve can be modified only when it has been the most recent curve drawn and its current parameter menu has been displayed.

To check the curvature distribution and evaluate the smoothness of any transverse section of the body plan, the user can choose the 'Porcupine Spikes' item. The porcupine spike can be plotted on top of any selected section. Simply type in digit 9 under the Review Curves Menu and enter the number of the selected section and the porcupine spikes will be drawn on that section. As an example, the following procedure shows how to draw the porcupine spikes on stations 5 and 15 as shown in Figure 11:

```
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Section
7. Body Plan
8. Return
9. Porcupine Spikes
------------------------------
```

```
Enter a digit:
9 <RETURN>

Enter an integer from 0 to 20
for a station number, enter"R"
to return:
15 <RETURN>

Enter an integer from 0 to 20
for a station number, enter"R"
to return:
5 <RETURN>

Enter an integer from 0 to 20
for a station number, enter"R"
to return:
R <RETURN>
```

The user may draw porcupine spikes on as many stations as needed. To erase the spikes, simply redraw the body plan. The data for the porcupine spikes are not preserved in the M-HULL program. As a result, all the porcupine spikes will be erased.

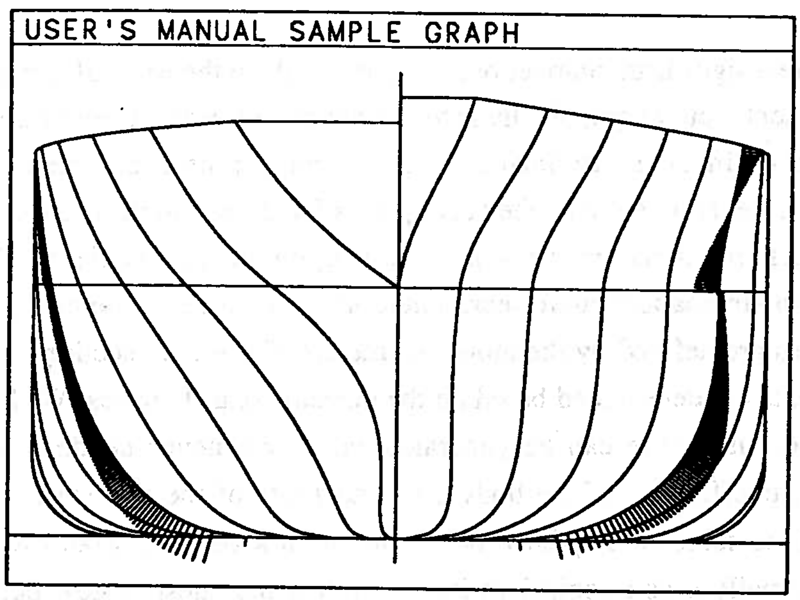

Figure 11. The porcupine spikes.

Metafile Menu

Before the Metafile Menu is described, it is worthwhile to discuss in more detail the metafile concept and its usage in M-HULL.

In the M-PLOT graphics, the metafile is a logical workstation. As mentioned previously, the purpose of the metafile is to save the screen graphs for future use. For example, the user can plot curves through the LaserWriter whenever he or she needs. Internally, an application program uses the same procedure to create the metafile as it uses to draw the curve on the screen. The only difference is that to draw a curve on the screen, the program sends the graphics information to the terminal, which is a physical workstation, but, to create a metafile, the same graphics information is sent to a logical workstation, the metafile. Sending the information to the screen can be independent of sending it to a metafile. Therefore, theoretically speaking, it is possible to create a metafile without first or simultaneously drawing the related object on the terminal.

The M-HULL user will, however, find that in order to create a metafile for the Body Plan and the control curve, he or she must first show the Body Plan on the screen. And, whenever the user modifies a control curve, he or she has to update the Body Plan before any metafile can be created. This restriction is due to the data structure used in the M-HULL program.

There are a significant number of curves involved in the M-HULL program. A typical way to represent a curve graphically is to approximate it using a set of connected straight line segments (linear approximation). Thus, many points on the curve need to be calculated. However, to store all the curve points for the use in different cases is obviously neither efficient nor dynamic. Thus, in M-HULL, only the coefficients of the polynomial used for the mathematical curve representation are recorded. The coefficients of all the control curves are defined by the input parameters. For the 21 sections of the body plan, the coefficients are determined based on the current control curves. With the coefficients precalculated, any curve can be generated easily whenever needed. In the M-HULL program, the coefficients of the body plan and those of the control curves that are not available on the screen are updated only if the review of Body Plan event happens. The program internally uses a logical variable to tell if the latest review curve action is the review of Body Plan or not. If the answer is no, the program prohibits the creation of any metafile as well as any offsets for safety purposes. Therefore, the user is always required to review the body plan before he or she creates a metafile. Once the body plan is reviewed, it can be, together with any control curve regardless of whether it is on the screen or not, sent to the user specified metafile. Note that all curves are updated with the review Body Plan action.

The metafile contains only the latest information of the hull, any previous curves cannot be recorded. As a result the user may choose to draw, in overlay mode, a control curve or the body plan, but the metafile is not able to produce the same picture. Under the overlay draw mode, the updated curve shown by the dashed line on the screen will appear in solid in the metafile and the solid line representing the original curve on the screen will be lost. The user should pay attention to this restriction.

We now consider the Metafile Menu in detail.

After the user elects to create a metafile under the Main Menu, the program will ask the user for a metafile identification number. The metafile ID is a two digit integer number ranging from 11 to 97, and 99. Thus, the maximum number of metafiles that can be created is 88, which is far beyond the requirement of most practical applications. The name of the metafile, for instance, METAF22, is the combination of five upper case characters: METAF and the user specified ID number, like 22. If the ID number is not valid, the program will keep requesting another input until a correct one is entered. The following shows how to enter the ID number:

```
Enter a metafile ID number
(11 - 97 and 99):
22 <RETURN>
```

Once a correct ID number is entered, the Metafile Menu will be posted on the screen as follows:

```
     * * * M-HULL * * *

    ** Metafile  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan

8. All in One Metafile
9. New Metafile
0. Return
------------------------------
Enter a digit:
```

To create a metafile for a chosen control curve or the Body Plan, simply type in the corresponding digit. Select the 'Return' item under the menu to return to the Main Menu. A message line will be printed on the screen informing the user what metafile has been created as follows:

```
++++ METAF22 CREATED ++++
```

In many cases, the user needs to save more than one curve. One way to do this is to send multiple graphs to a single metafile. As an example, the following procedure shows how to save both the Sectional Area curve and the Body Plan in one metafile:

```
Enter a metafile ID number
(11 - 97 and 99):
22 <RETURN>

     * * * M-HULL * * *

     ** Metafile  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan

8. All in one Metafile
9. New Metafile
0. Return
------------------------------
Enter a digit:
1 <RETURN>

     * * * M-HULL * * *

     ** Metafile  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan

8. All in one Metafile
9. New Metafile
0. Return
------------------------------
Enter a digit:
7 <RETURN>
```

```
     * * * M-HULL * * *

     ** Metafile  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan

8. All in one Metafile
9. New Metafile
0. Return
------------------------------
Enter a digit:
0 <RETURN>

++++ METAF22 CREATED ++++
```

However, if the user wants to save all the control curves as well as the Body Plan in one metafile, it is obviously more convenient to select 'All in one metafile' under the Metafile Menu.

Another way to save many pictures is to create a separate metafile for each picture. The 'New Metafile' item is provided for this purpose. The sequence of the menu item selections in this case will be to enter a metafile ID number, to select a control curve, and then to enter another ID number and to select another curve, and so on. The following procedure, as an example, shows how to create two different metafiles for the Sectional Area curve and the Design Waterline curve:

```
Enter a metafile ID number
(11 - 97 and 99):
22 <RETURN>

     * * * M-HULL * * *

     ** Metafile  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
......

9. New Metafile
0. Return
------------------------------
Enter a digit:
1 <RETURN>
```

```
     * * * M-HULL * * *

     ** Metafile  Menu **
-------------------------------
1. Sectional Area
2. Design Waterline
 ......

9. New Metafile
0. Return
-------------------------------
Enter a digit:
9 <RETURN>

++++ METAF22 CREATED ++++

Enter a metafile ID number
(11 - 97 and 99):
23 <RETURN>
     * * * M-HULL * * *

     ** Metafile  Menu **
-------------------------------
1. Sectional Area
2. Design Waterline
 ......

9. New Metafile
0. Return
-------------------------------
Enter a digit:

2 <RETURN>
     * * * M-HULL * * *

     ** Metafile  Menu **
-------------------------------
1. Sectional Area
2. Design Waterline
 ......

9. New Metafile
0. Return
-------------------------------
Enter a digit:
0 <RETURN>

++++ METAF23 CREATED ++++
```

As mentioned previously, to produce graphs through the LaserWriter, we need to convert a metafile into a PostScript file. A metafile can hold multiple frames of pictures, a PostScript file can only hold one. Thus, in the case that the user creates a metafile with multiple frames (called segments in the metafile concept), he or she will still need to create a PostScript file for each segment. Whether or not to create multiple segments in a metafile is usually application and user dependent. It is up to the user to decide.

After the program execution, the user can use application 'metips' to convert the metafile into the PostScript file. If needed, he or she can preview the metafile on the screen using another application called 'przmet'. What the user sees on the screen at this time should be exactly the same as will be created through the LaserWriter. Both applications are user friendly and well self-documented with on-line help capability. The user should find it easy to use them.

Output Menu

The Output Menu of M-HULL allows the user to review the hull data and related parameters on the screen or to save them in an external datafile. After the user selects 'Output' under the Main Menu, the program enters into the output mode.

There are three steps involved in the Output Menu action. As the first step, the program will let the user determine where to print as follows:

```
      * * * M-HULL * * *

      ** Output  Menu **
------------------------------
Where?
1. On Terminal
2. To Files
3. Return
------------------------------
Enter a digit:
```

If the user chooses to print data to a file, then the second step requires the user to type in a filename as follows:

```
Enter File Name
 (less than 73 characters):
```

In general, the filename should be less than 72 characters. If the name of the file is the same as that of an existing file, the existing one will be overwritten. The user should be very careful about that. If the user just wants to review some of the output parameters on the screen, this step is skipped.

The third step is to choose the data set to print. The program will give the user the following items to select:

```
--------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
3. Hydrostatic Data
4. Calculated Hull Data
5. Table of Offsets

---  Formatted Output ---
6. MHCP Offsets
7. M-HULL Input File

8. New file
9. Return
--------------------------------
Enter a digit:
```

The 'Principal Dimensions' option prints the following parameters:

L_{OA}	Depth at FP	Half-siding at midships
L_{WL}	Depth at midships	Deadrise
Waterline max. beam	Depth at AP	Displacement
Deck max.beam	Draft	Water density.

The 'Control Curve Parameters' option prints all the defining parameters of eight control curves. A detailed list of the parameters and their explanation are listed in Appendix B. The 'Hydrostatic Data' option provides the following information:

C_B	C_P	V_{CB}
C_X	L_{CB}	BM
C_{WP}	L_{CF}	KM.

The 'Calculated Hull Data' option displays the following parameters for each station:

Area	Waterline offset	Vertical center of buoyancy
Keel rise	Deck offset	Bottom flat angle
Bottom flat from baseline	Sheer Dept	Waterline angle
Half-siding	Bilge radius	Deck angle.

The 'Table of Offsets' option creates the height and half-breadth at 26 points on each station in the regular form.

The two options under the 'Formatted Output' are used to create the input data for two different programs. The 'MHCP Offsets' option generates the hull offsets in the standard MHCP format, which serves as the input data for the MHCP system. The 'M-HULL Input File' option allows the user to save the 74 hull form coefficients and control curve parameters in the M-HULL input format in a user specified file. This becomes an input parent hull datafile of a new M-HULL design session, if necessary. This option is especially useful in two cases. In the first case, the user is allowed to pause his or her current session. In this situation, the user can save his or her intermediate design in a datafile using this option. To resume the session, the user can simply start a new M-HULL session with his or her intermediate design using the datafile created previously as the parent hull input file. In the second case, the user is always recommended to periodically save his or her design using this option whenever a significant number of design modifications have been completed. This will provide backup, in case an unexpected system failure or program termination occurs.

Note that for the reason described in the Metafile Menu section, in order to create the offsets, the user must first redraw the Body Plan. Whenever a control curve is modified, the user should always refresh the Body Plan before creating offsets.

Similar to the creation of a metafile, the user can save all the data sets either in one file or in several different files. The following procedure shows how to save both the principal dimensions and control curve parameters into one file:

```
Enter File Name
 (less than 73 characters):
myfile <RETURN>

------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
......

8. New file
9. Return
------------------------------
Enter a digit:
1 <RETURN>
```

```
------------------------------
What?
--- For Design  Review ---
*. Principal Dimensions
2. Control Curve Parameters
......

8. New file
9. Return
------------------------------
```
2 <RETURN>

```
------------------------------
What?
--- For Design  Review ---
*. Principal Dimensions
*. Control Curve Parameters
......

8. New File
9. Return
------------------------------
```
9 <RETURN>

Note that asterisks will overwrite the item numbers corresponding to those data sets that have been successfully sent to a file or printed on the screen.

The 'New File' item under the Output Menu is used to create different files for different data sets. The procedure to create multiple datafiles is the same as that used to create multiple metafiles. As an example, the following procedure demonstrates the way to create multiple datafiles:

```
Enter File Name
 (less than 73 characters):
```
myfile1 <RETURN>

```
------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
......

8. New File
9. Return
------------------------------
Enter a digit:
```
1 <RETURN>

```
------------------------------
What?
--- For Design  Review ---
*. Principal Dimensions
2. Control Curve Parameters
```

```
......

8. New File
9. Return
------------------------------
Enter a digit:
```
8 <RETURN>

```
Enter File Name
 (less than 73 characters):
```
myfile2 <RETURN>

```
------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
......

8. New File
9. Return
------------------------------
Enter a digit:
```
2 <RETURN>

```
------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
*. Control Curve Parameters
......

8. New File
9. Return
------------------------------
Enter a digit:
```
9 <RETURN>

Stop Option

The Stop option under the Main Menu simply allows the user to terminate the program execution.

A DESIGN EXAMPLE

In order to demonstrate the fundamental hull development principle of the M-HULL program and some of its useful form modification tools, a design example is provided. In this example, file 'parent1' is used as the parent hull datafile. The initial hull form to be obtained by changing the longitudinal prismatic coefficient of the parent hull from 0.68 to 0.64. There are nine major steps in the design procedure. The example shows many effective ways to modify the hull form with M-HULL. More sophisticated modifications can be derived from these basic operations.

Before the Hull Development

It is usually helpful to study the initial hull form carefully and create a design strategy before the hull development. The design strategy should be to consider the most basic modifications needed and their priorities. Priorities will vary depending upon the user's particular application. In general, when the startup hull is obtained through the change of a form coefficient from a parent ship, these steps apply: first correct the obvious irregular portion of the initial hull; second, modify globally the control curves affected directly by that form coefficient to ensure consistency; and finally fine-tune the hull locally until a satisfactory configuration is achieved. The user should give priority to the underwater part of the hull during the modification procedure. The Sectional Area curve should be modified first followed by the Design Waterline curve. In many cases, it is best to first fix the major problems with the underwater portion of the hull, then consider the abovewater part. The example will illustrate these ideas.

As mentioned above, the initial hull of this example is obtained by decreasing the longitudinal prismatic coefficient of the parent hull (see Figure 2) from 0.68 to 0.64. Figure 12 shows the resulting body plan. Obviously, the stern portion of the hull is unacceptable since part of underwater area of station 19 is almost negative and needs to be corrected. Decreasing C_P reduces the block coefficient, C_B, when the maximum section coefficient, C_X, is maintained. Thus, the underwater body of the hull will shrink compared to the parent, provided the major hull dimensions are preserved. Therefore, it is reasonable to reduce the offsets of the design waterline by the reduction of the waterplane coefficient; reduce length of the parallel middle body; etc. If these modifications result in major improvements, we then fine-tune the hull wherever necessary until a satisfactory shape is attained.

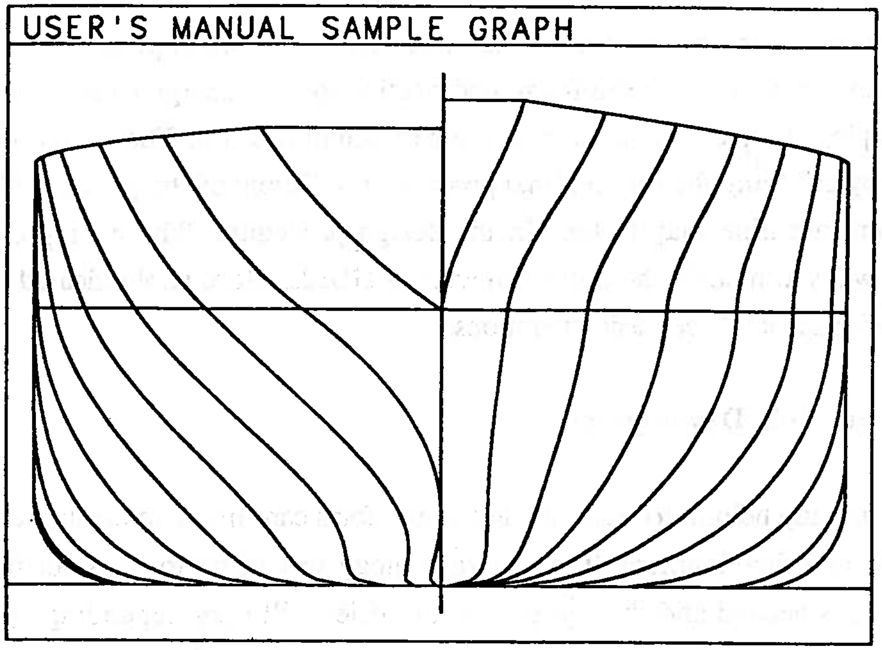

Figure 12. The Body Plan of the startup hull.

Step 1. Modify the Sectional Area Curve

The purpose of the Sectional Area curve modification is to correct the irregular stern portion of the startup hull (Figure 12). To correct the almost negative underwater part of station 19, try to increase the 'fullness' of the stern sections by moving some sectional area aft. This is done through the following parameter alterations:

- Decrease the AP Vector from 0.3 to 0.2;
- Decrease the Aft Mid Vector from 0.7 to 0.4.

Recall that these control parameters are actually the magnitudes of slope vectors of the parametric polynomial used to represent the Sectional Area curve. The larger the slope vector magnitude, the greater the tendency of the parametric curve to lie close to the tangent line. Decreasing the AP Vector and the Aft Mid Vector slightly changes the curved portion of the Sectional Area curve aft of midship and helps to accumulate a little more area in the very stern of the hull (Figure 13). The modification proves to be successful in solving the problem. The modified Body Plan is shown in the Figure 14 where the dashed line represents the updated hull configuration.

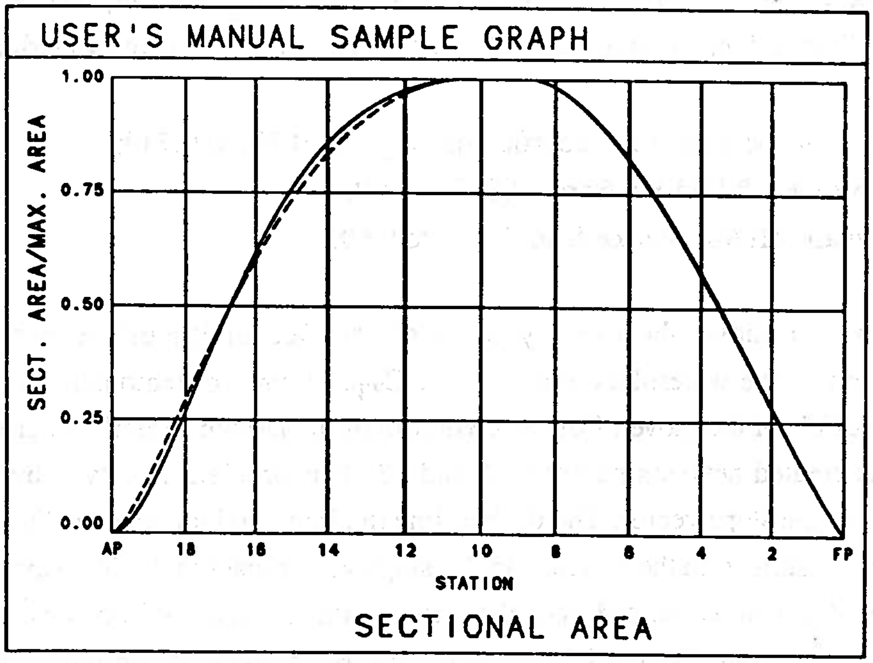

Figure 13. Overlay draw of the Sectional Area curve. The dashed line represents the Sectional Area curve resulting from Step 1.

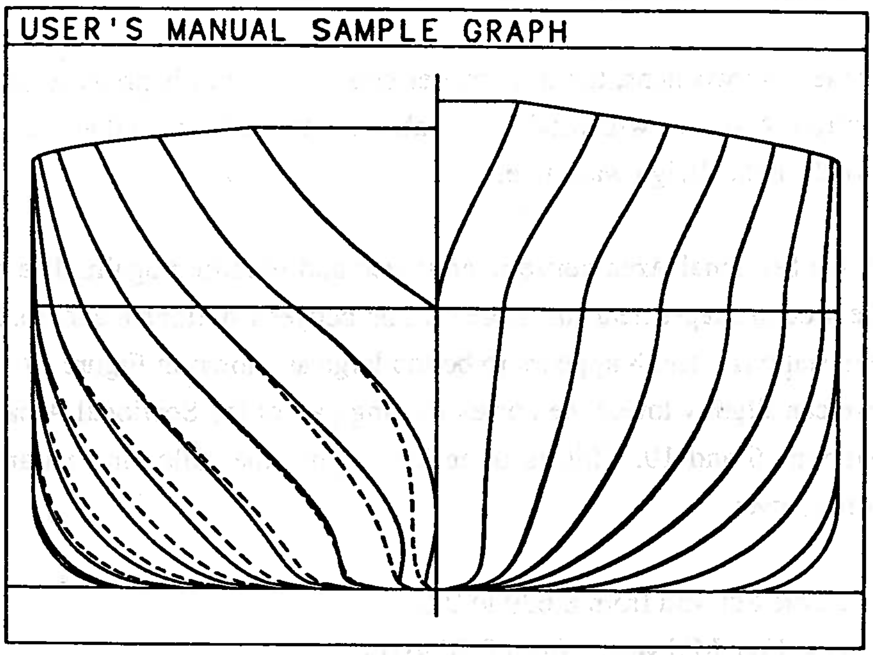

Figure 14. Overlay draw of the Body Plan. The Body Plan resulting from Step 1 is shown in dashed curves.

Step 2. Modify the Design Waterline Curve

To be consistent with the decease of C_P, the design waterplane should also be decreased. This is done through the global manipulation of the design waterline as follows:

- Decrease the waterplane coefficient C_{wp} from 0.759 to 0.740;
- Move the Aft Mid Stn from 12.354 to 11.0;
- Increase Aft Mid Vector from 0.341 to 0.60.

Figure 15 shows the overlay draw of the Design Waterline curve due to the modification of the waterplane coefficient: C_{wp}. Figure 16 demonstrates the undesired secondary effect of the move of the Aft Mid Stn of the Design Waterline curve (solid line). A bump is created between stations 11 and 13. This problem is solved by adjusting the magnitude of the slope vector. The dashed line in Figure 16 indicates the Design Waterline curve which results from the increase in the slope vector magnitude. Note that the increased magnitude of this slope vector forces the curve to stay close to its zero slope tangent longer and erases the bump. Figure 17 illustrates the Body Plan before and after the design waterline modification.

Step 3. Modify the Sectional Area Curve Again

After the first two steps, the underwater body of the hull is pretty good. Fine-tuning is now required. Also, we will modify the abovewater portion so that the two parts can match smoothly at the design waterline.

First, the Sectional Area curve is activated and modified again. The purpose is to regulate the section shapes near the bilge portion between stations 6 and 10. Note that the gap between stations 7 and 8 appears to be too large as shown in Figure 17. To solve this problem, we can slightly lower the corresponding part of the Sectional Area curve that is between stations 6 and 10. This is done by varying the following parameters of the Sectional Area curve:

- Move Fore Stn Mid from 8.699 to 9.5;
- Decrease Fore Mid vector from 0.30 to 0.25.

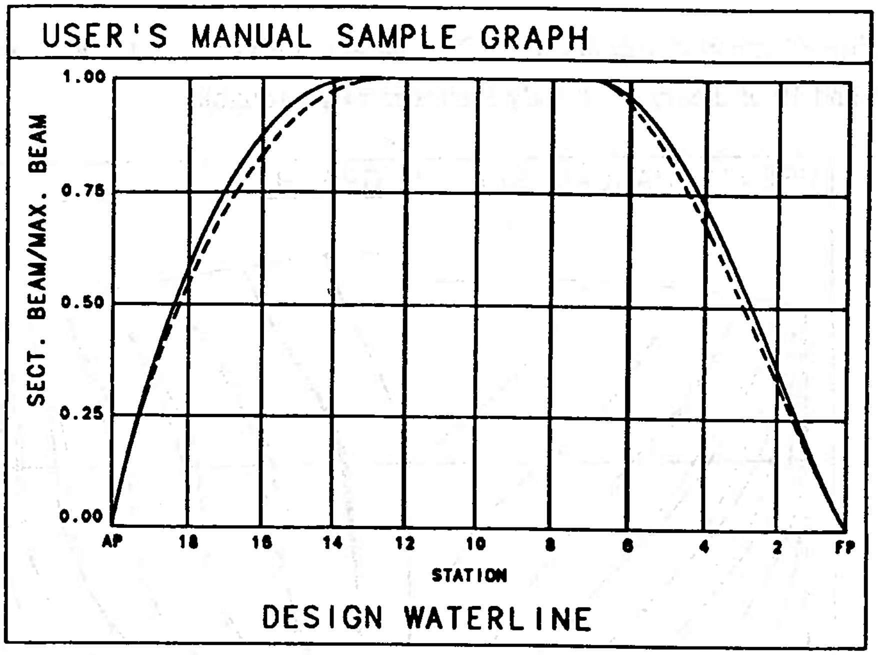

Figure 15. Overlay draw of the Design Waterline curve. The dashed line represents the design waterline resulting from the changing of C_{wp} in Step 2.

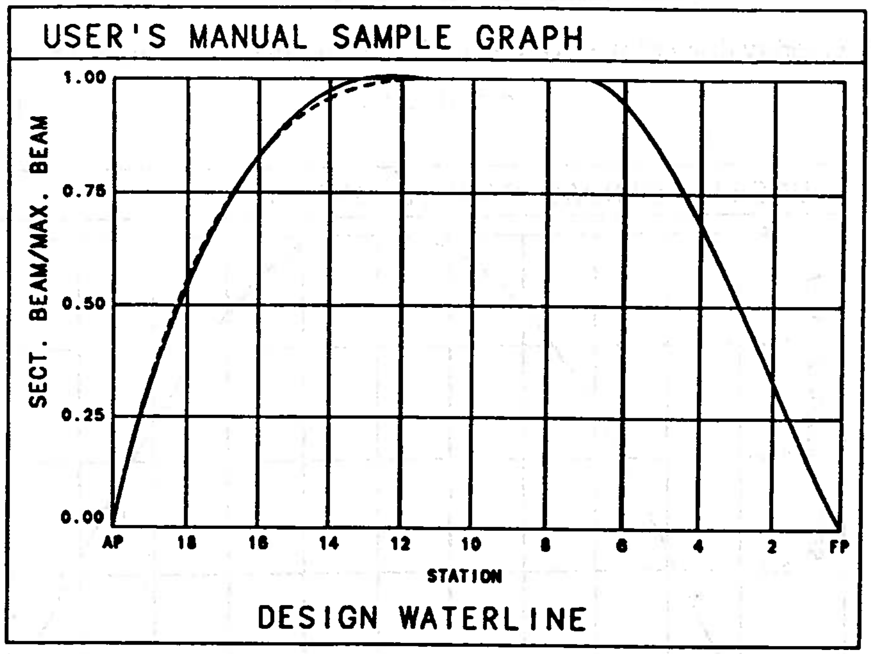

Figure 16. Overlay draw of the Design Waterline curve. The dashed line represents the design waterline resulting from the increase of the Aft Mid Vector in Step 2.

The affect of these changes on the Sectional Area curve is small. However, it does solve the problem. Figure 18 shows the updated Sectional Area curve together with the original one. Figure 19 illustrates the Body Plan after the Sectional Area curve modification. Compared with the Body Plan shown in Figure 17, the bilge portion between stations 6 and 10 of the updated Body Plan is more reasonable.

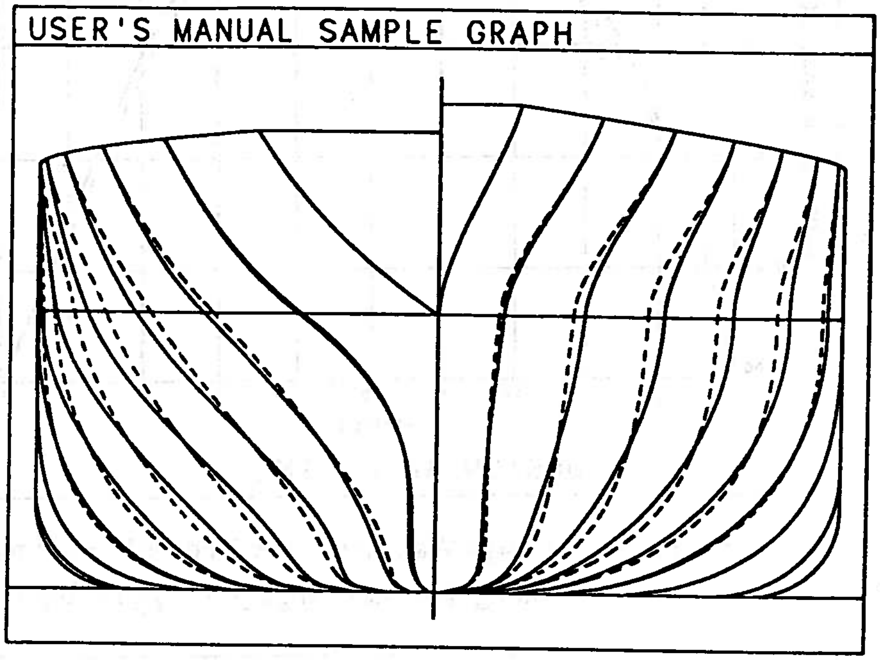

Figure 17. Overlay draw of the Body Plan. The Body Plan resulting from Step 2 is shown in dashed curves.

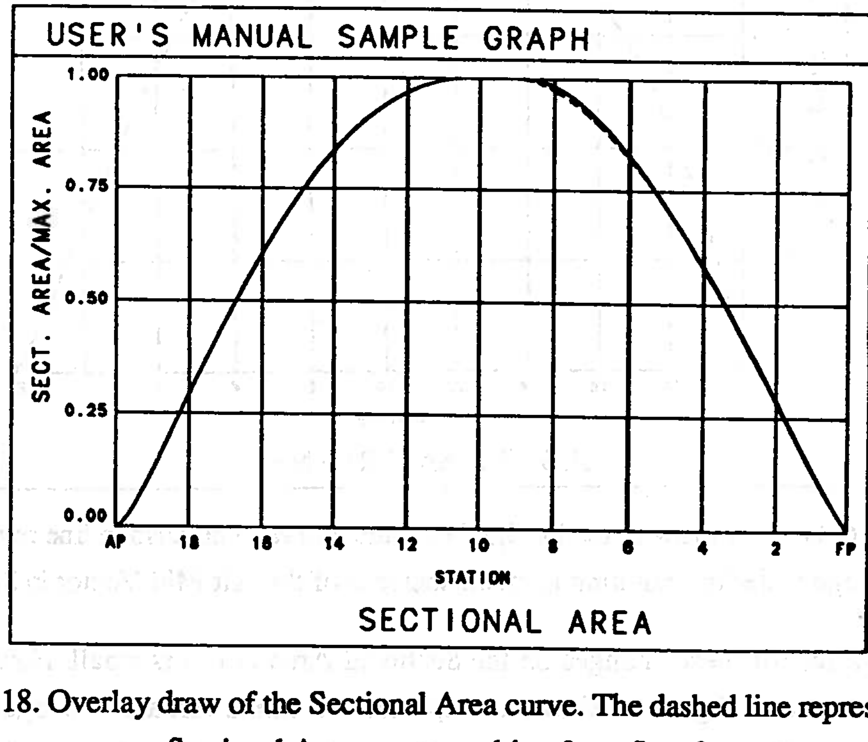

Figure 18. Overlay draw of the Sectional Area curve. The dashed line represents the Sectional Area curve resulting from Step 3.

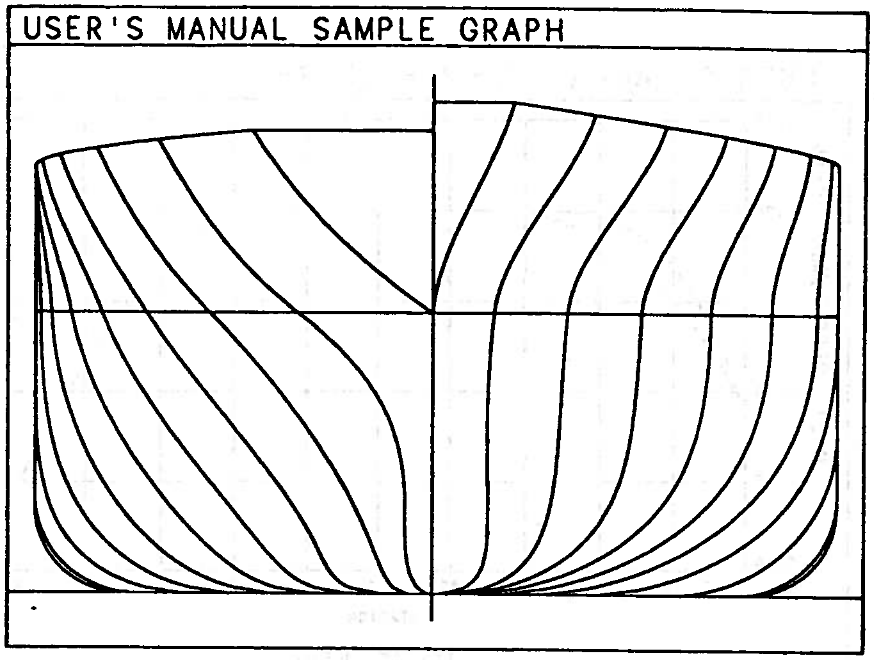

Figure 19. The Body Plan after first three steps.

Step 4. Modify the Deck at Edge

The purpose of the deck at edge alteration is to match the previous modification of the Design Waterline curve (Step 2). Since the Design Waterline curve has been shrunk, we are going to reduce the 'fullness' of the Deck at Edge curve accordingly. In this particular example, the Deck at Edge curve aft of midship is displaced towards the centerplane in order to refine the obvious irregular abovewater portion between stations 12 and 16 (Figure 19). This is done in two steps:

- Move the Aft Stn Mid from 14.16 to 13.0;
- Decrease the AP slope from 65.0° to 45.0°.

The resulting Deck at Edge curve is shown in Figure 20 and the effect of the modifications on the Body Plan is shown in Figure 21.

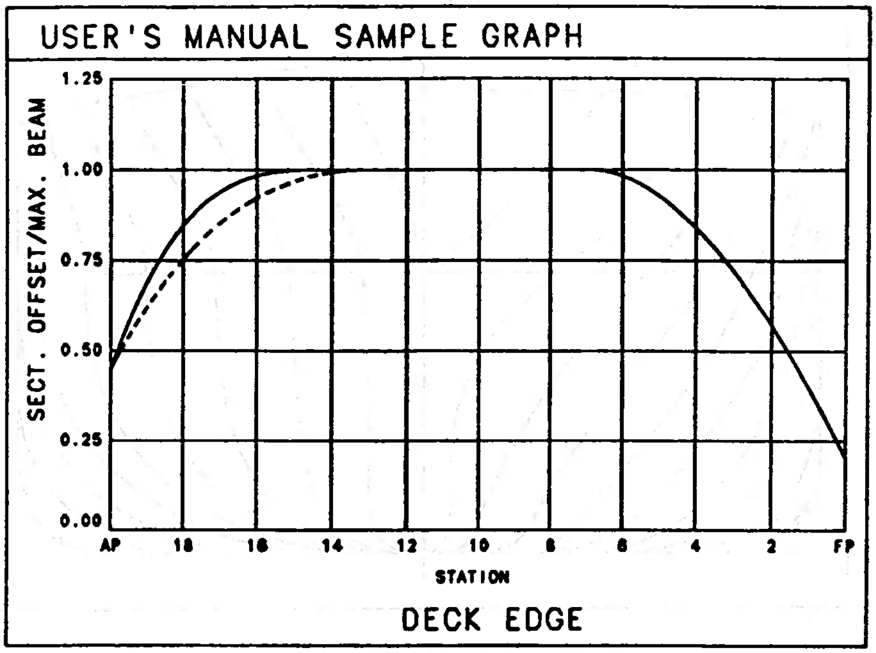

Figure 20. Overlay draw of the Deck at Edge curve. The dashed curve represents the deck edge resulting from Step 4.

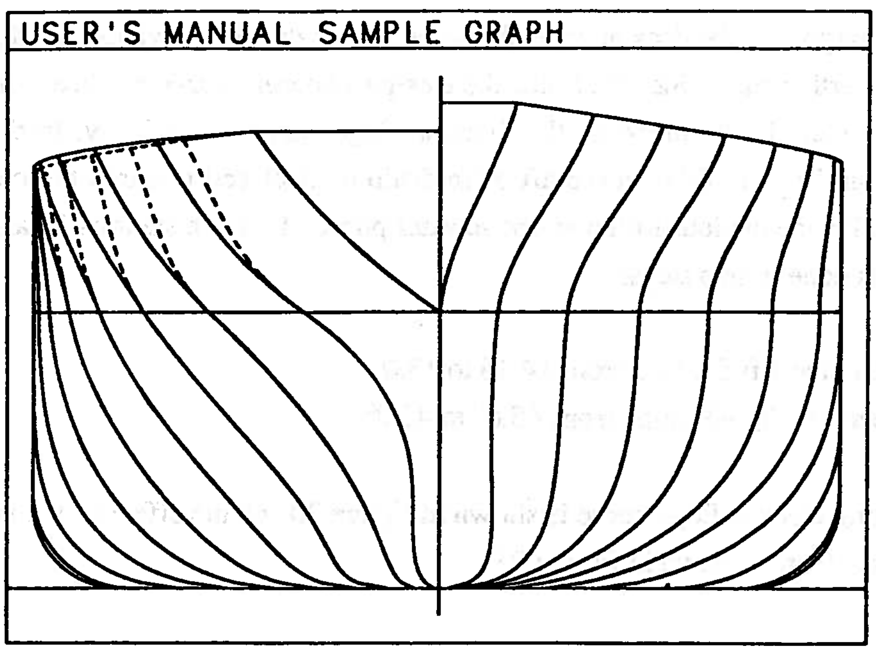

Figure 21. Overlay draw of the Body Plan. The Body Plan resulting from Step 4 is shown in dashed curves.

Step 5. Modify the Angles of Sections

Note that the abovewater portion of the hull between stations 17 to 19 is not satisfactory because of undesired inflection points of the curves (Figure 21). One way to improve the shape of these curves is to vary the transverse angle of the hull section at the deck edge and at the design waterline. In this particular case, we first try to increase the slope of the stations 17, 18, and 19 at the deck edge by modifying the angle at deck curve as follows:

- Increase the AP Angle of Deck from 57.85° to 70.0°;
- Increase the AP Slope of Deck from 0.0° to 5.0°.

Figure 22 shows the result of this modification. The corresponding local variation of the body plan is shown in Figure 23.

Next, further refine the same part of the hull to improve the 'fullness' of its section curves. One way to achieve this is to slightly raise the transverse section angles at the design waterline between stations 17 and 19 through the modification of the angle at design waterline as follows:

- Increase the AP angle of DWL from 35.0° to 40.0°;
- Increase the AP slope of DWL from 0.0° to 5.0°.

The result of the changes in the angle at design waterline is shown in Figure 24 and the influence of the modification on the body plan is shown in Figure 25.

Step 6. Modify the Design Waterline Again

Notice that the abovewater and underwater parts of the current hull between stations 13 and 16 do not match properly. The offsets of the design waterline between these stations appear to be too small. Thus, in this step, the design waterline is activated and modified again as follows:

- Move Aft Mid Stn from 11.0 to 12.0;
- Decrease Aft Mid Vector from 0.60 to 0.30.

The purpose of the change is to increase the offsets of the design waterline between stations 14 and 16 (Figure 26). As we expected, this local variation of the design waterline does improve the matching of the abovewater and underwater portions of the hull at the design waterline between stations 14 and 16 (Figure 27).

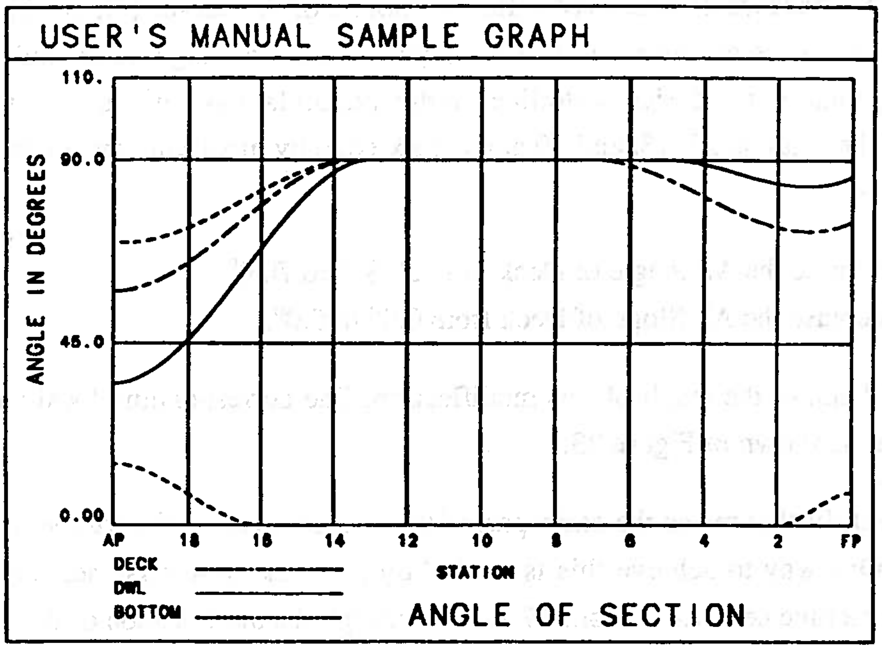

Figure 22. Overlay draw of the Angles of Sections curves. The dashed curve near the angle at deck curve represents the modified deck angle curve in Step 5.

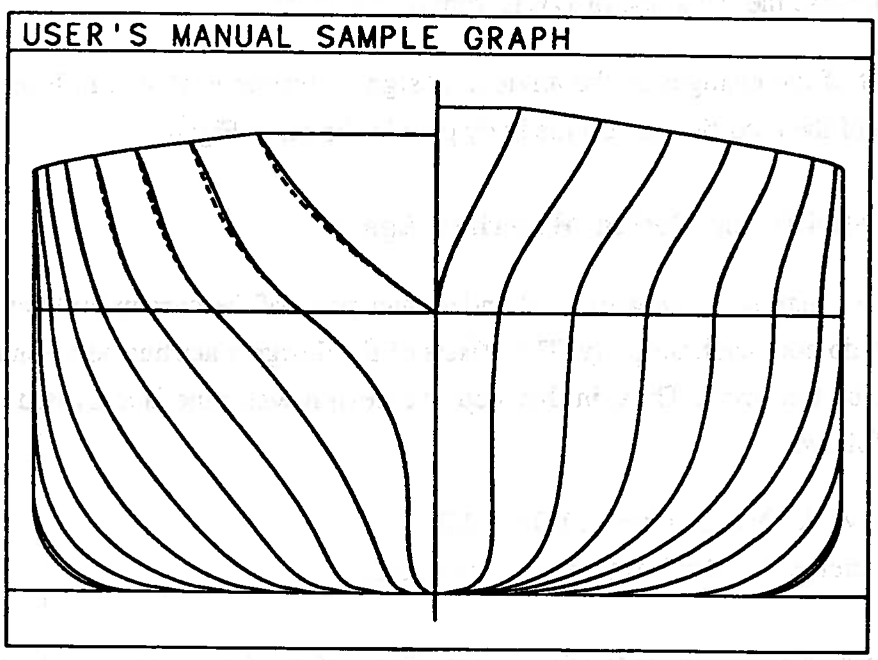

Figure 23. Overlay draw of the Body Plan. The Body Plan resulting from the modification of angle at deck curve in Step 5 is shown in dashed curves.

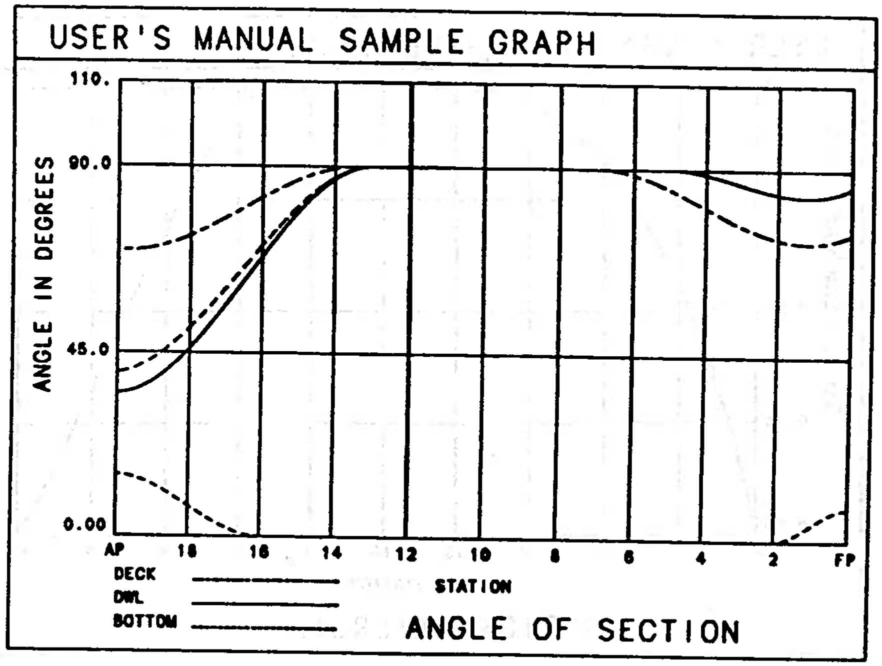

Figure 24. Overlay draw of the Angles of Sections curves. The dashed curve near the angle at DWL represents the modified angle at DWL curve in Step 5.

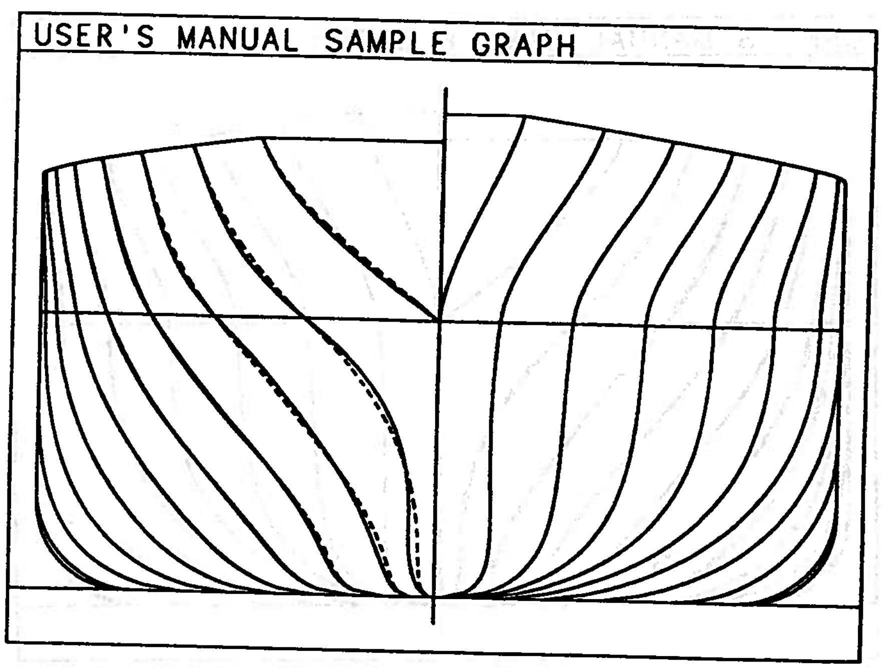

Figure 25. Overlay draw of the Body Plan. The Body Plan resulting from Step 5 is shown in dashed curves.

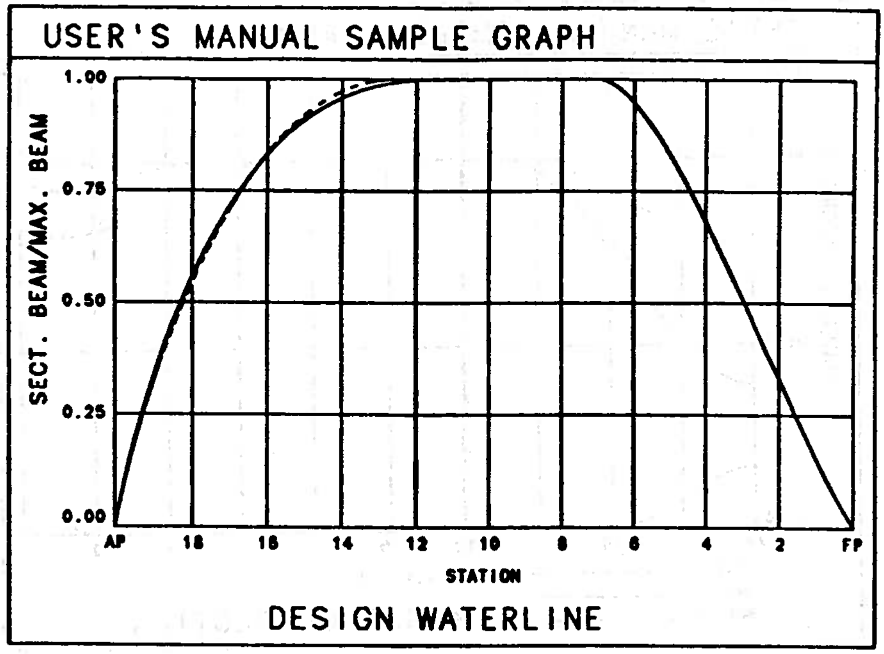

Figure 26. Overlay draw of the Design Waterline curve. The dashed line represents the design waterline resulting from Step 6.

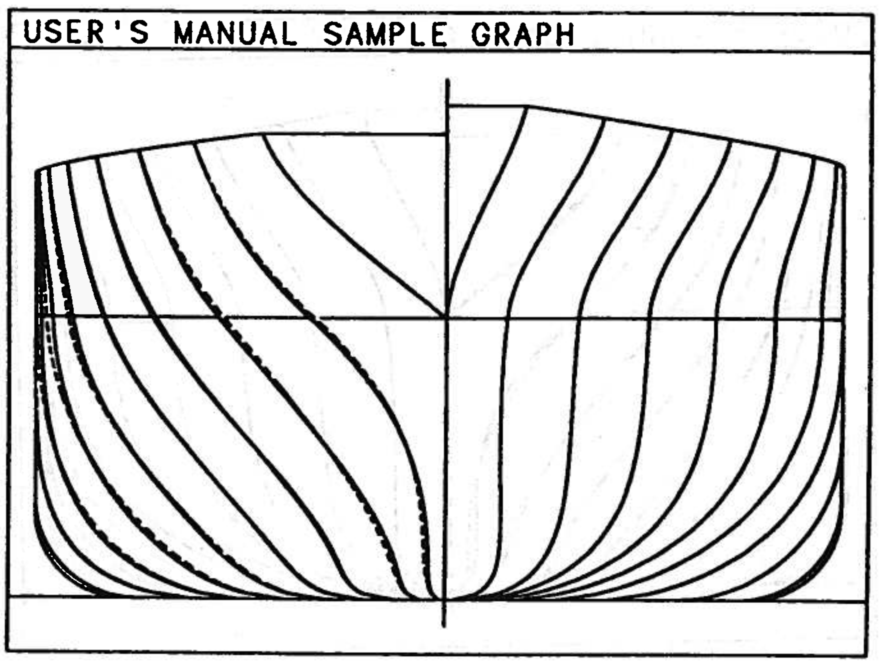

Figure 27. Overlay draw of the Body Plan. The Body Plan resulting from Step 6 is shown in dashed curves.

Step 7. Modify the Angle of Sections Again

We are now going to treat the abovewater portion of the forward hull. Notice that the major problem of this portion is the over bent section curves just above the design waterline (Figure 27) which fail to match smoothly with their corresponding underwater sections of the hull. To improve these curves, we can either reduce their transverse angles at the deck edge or decrease their angles at the design waterline. In this case, we do not want to alter the angles at the design waterline, since they will influence the underwater part of the hull, which is already satisfactory. We can also see a need to reduce the angle at deck slightly between station 14 and 18 to refine the abovewater hull aft. we modify the angles at deck edge curve as follows:

- Move Aft Stn Mid of Deck from 13.4 to 12;
- Decrease the FP Angle of Deck from 75.0° to 60.0°.

The updated Angles of Sections curves and Body Plan of the hull from the modification are shown in Figure 28 and 29, respectively.

Step 8. Modify the Deck at Edge Again

The purpose of the Deck at Edge curve modification is to further fine-tune the abovewater portion of the hull between stations 14 and 16. We try to gently tighten these section curves by raising the deck edge offsets at these stations slightly:

- Move the Aft Stn Mid from 13.0 to 13.5.

The result of this modification and its effect on the Body Plan are shown in Figures 30 and 31, respectively.

Step 9. Modify the Angles of Sections Again

Lastly, we further modify the Angles of Sections curves. For the angle of deck at edge curve, we make following changes:

- Reduce the Deck FP Angle from 60.0° to 55.0°;
- Reduce the Deck FP Slope from -30.0° to -35.0°;
- Move the Deck Fore Mid Stn from 7.0 to 8.0.

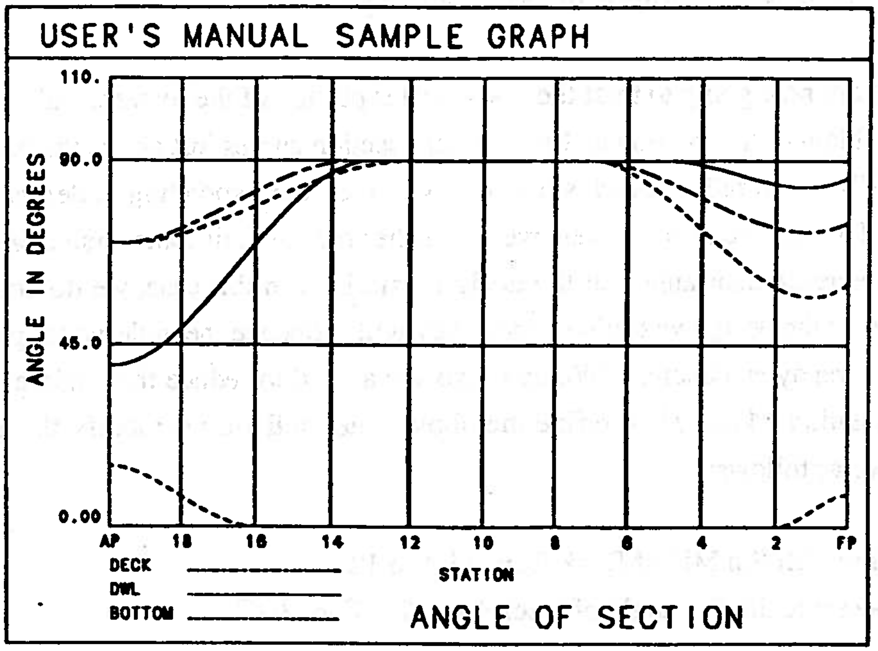

Figure 28. Overlay draw of the Angles of Sections curve. The dashed curve near the deck angle curve represents the modified deck angle curve in Step 7.

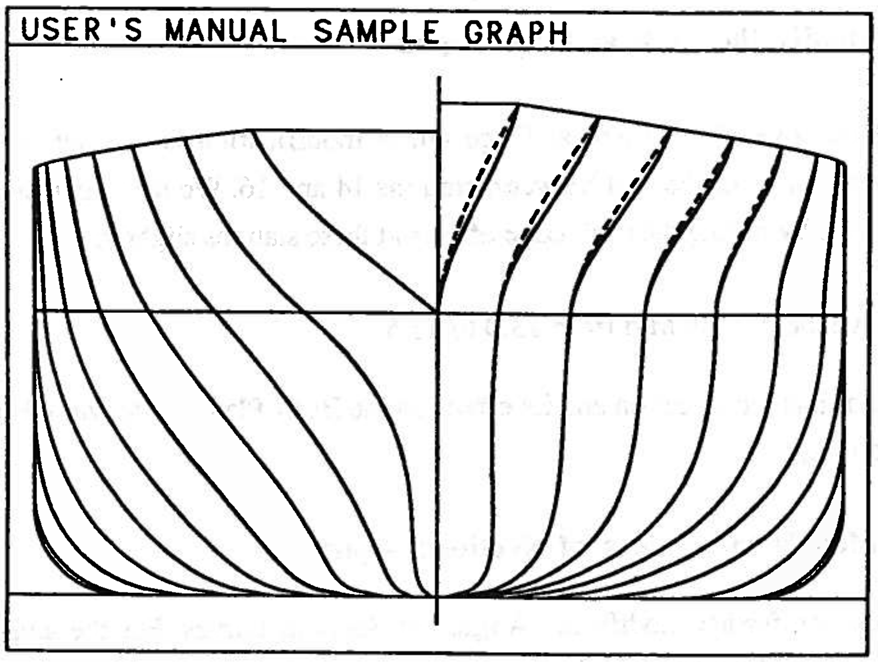

Figure 29. Overlay draw of the Body Plan. The Body Plan resulting from the first part of Step 7 is shown in solid curves; the Body Plan resulting from the second part of step 7 is shown in dashed curves.

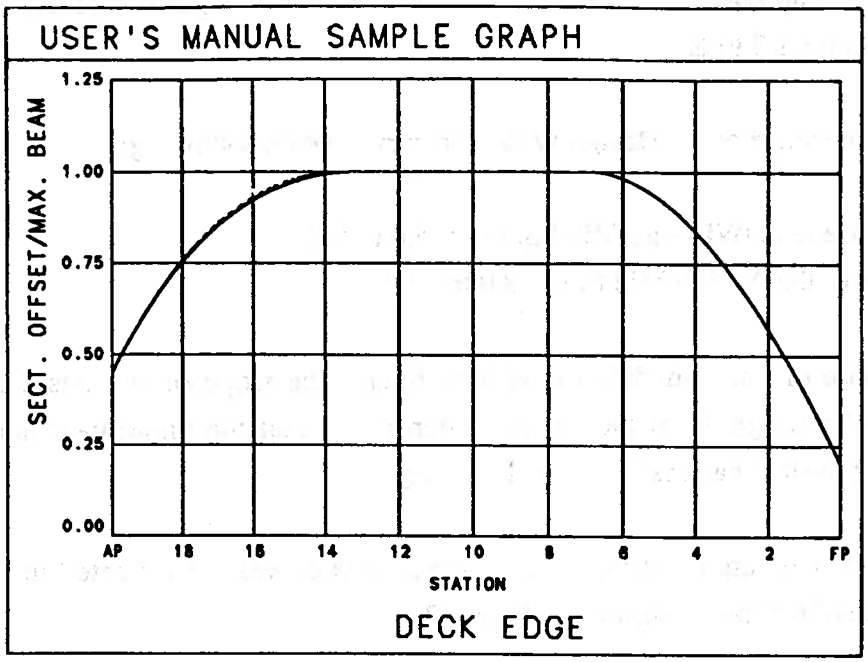

Figure 30. Overlay draw of Deck at Edge curve. The dashed curve represents the deck edge resulting from Step 8.

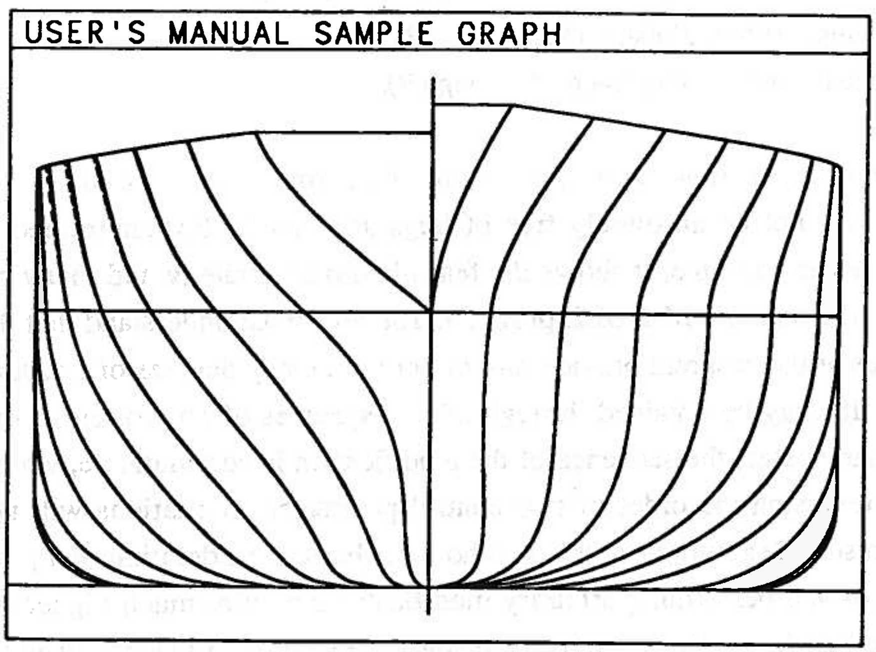

Figure 31. Overlay draw of the Body Plan. The Body Plan resulting from Step 8 is shown in dashed curves.

These modifications further reduce the forward abovewater section curve slopes at the deck at edge and improve the shape of the forward abovewater portion of the hull, especially between stations 3 to 6.

For the angle of the Design Waterline curve, we do following:

- Move the DWL Fore Mid Stn From 5.0 to 6.0;
- Move the Aft Stn Mid from 13.0 to 12.5;

The purpose of these modifications is to reduce the slope of stations 2 through 5 and stations 14 through 17 at the design waterline so that the underwater and abovewater portions of the hull can match more effectively.

The modifications of the Angles of Sections curves are reflected in Figure 32. The final shape of the hull is shown in Figure 33.

We may summarize the nine steps by three basic steps as follows:

- Fix the major irregular portion of the hull (Step 1);
- Change the hull globally (Steps 2 and 3);
- Tune the hull locally (Steps 4 through 9).

The example shows how to develop a hull from a parent ship. The result of this example may not be absolutely free of bugs and can be further refined if necessary. However, as an example, it shows the feasible design strategy and many basic skills to reshape a hull with the M-HULL program. The user must understand that the interactive capabilities of the program provide him or her with many degrees of freedom. Similar or better results may be obtained through other sequences of control curve modifications. And, in many cases, the sequence of the modification is commutative, which means, for instance, reversing the order of two control parameter alternations will not produce a different result. Beginning a session without the basic consideration of a proper series of design steps and performing arbitrary modifications require much higher cost to gain a reasonable hull form. Thus, take time to study the startup hull carefully and decide what steps to take first. This is an important starting point toward an efficient design session.

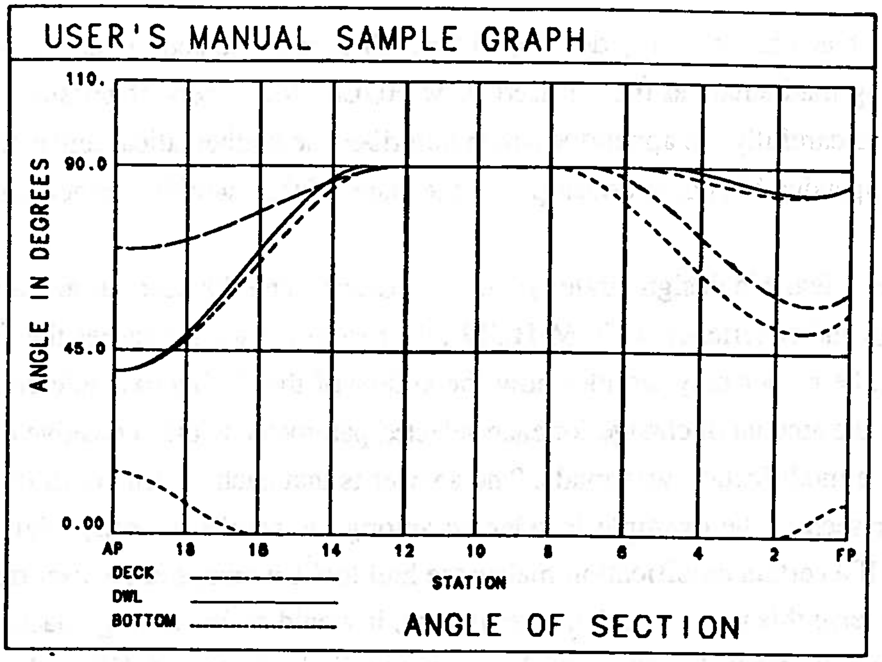

Figure 32. Overlay draw of the Angles of Sections curves. The dashed lines near the deck angle and the DWL angle curves represent their final shape.

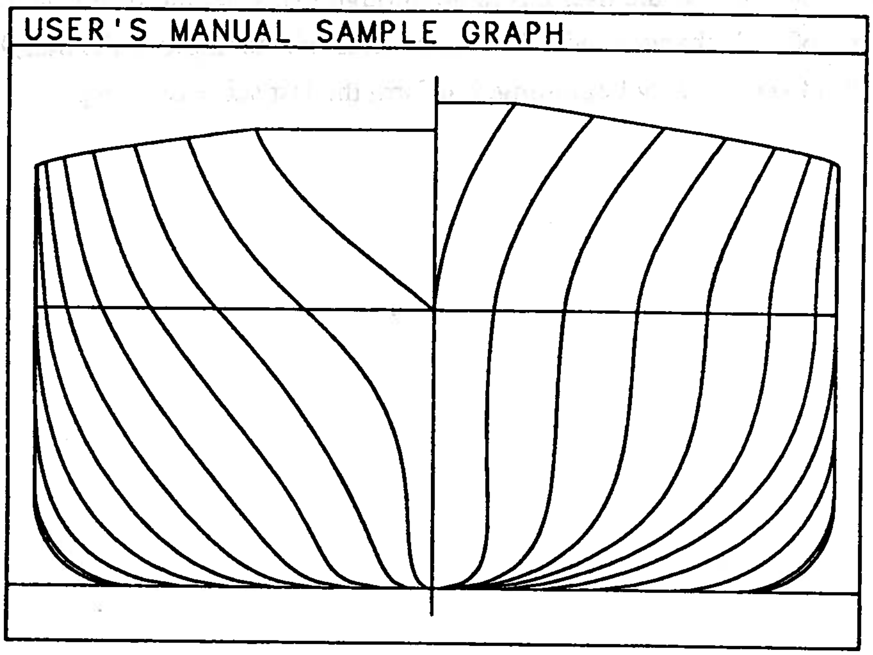

Figure 33. The Body Plan of the final hull.

As we know, in M-HULL, reshaping a hull is done indirectly through the interactive variation of control curve parameters. The user, therefore, should always be able to correctly interpret the change of the hull geometry in terms of the change of numerical values. Such an ability is only developed through experience and the understanding of the underlaying mathematical model used in M-HULL. New users, if possible, should take time to read carefully the appendix which describes the mathematical representation of the curves (Appendix A) and to develop an understand of their working principles.

After a feasible design strategy has been created and the user has accumulated some knowledge and experience with M-HULL, the rest of the work requires the patience from the user. The reader may wonder how the author of the design example could precisely determine the amount of change for each selected parameter so that a positive effect resulted whenever a modification was made. The answer is that each increment or decrement of a parameter seen in the example is selected among the results of many trials. Patience is essential. If a certain modification makes the hull looks worse, and the user does not know how to reverse this trend by other alternations, it would be better to go back one step and start again. Otherwise, the previous design can easily be destroyed. When the user decides to change a parameter, he or she may have to try many times before a reasonable amount of change is found. Do not try rapid changes. Always vary the parameter gradually and take time to check the result. If the user has to go through many iterations, it is helpful to keep a written record of each change made. In case the user fails to improve the hull, he or she can start again, not from the very beginning, but form the last successful step.

LIMITATIONS, ERROR CONDITIONS, AND DEFAULT VALUES

Not all values are acceptable for some boundary conditions. M-HULL itself will correct some unacceptable values, while others must be corrected by the user. It is important to understand the limits which may be automatically imposed by M-HULL without direct input from the user. Such instances are listed in this section.

Sectional Area, Design Waterline, Deck at Edge, and Bottom Flat

All curve slopes must be between 0° and 90°, and all vector magnitudes must be positive. Negative slopes are reset to their absolute values. Input slopes with magnitudes over 90° are ignored by the program.

In the region of full sections, the deck and waterline slopes must be constant and vertical (90°). The bottom flat must have a constant slope, and the keel rise must be zero in this region.

If the deck and waterline slopes are not 90°, the length of full sections is reset to zero and the start is located at the center of the parallel middle body. If any of the other conditions mentioned above are not met, the region of full sections is limited to the region in which these conditions are met.

If the bilge radius which is calculated by M-HULL to obtain the required area for a section is too large ($R>B/2$ or $R>T$) or too small ($R<0$), the region of full sections is ended where this occurs. If no selection has an acceptable bilge radius, a warning message is displayed and suggestions are given to help eliminate the difficulty.

Keel Rise

If the AP coefficient is input by the user as less than .001, it is reset to 1.

Singular Matrices

M-HULL solves linear systems of equations to find the coefficients for the various curve defining equations. If a coefficient matrix is created with a zero determinant, a warning message is displayed indicating the presence of a singular matrix and the subroutine in which it occurred. The user must then alter the boundary conditions used to define that particular curve until the problem is eliminated. This most commonly occurs due to improper zero values in curve parameters.

Division by Zero

This error usually occurs if the user accidentally inputs an integer value (which is read by the program as a very large floating number). All program inputs must include a decimal point.

Body Plan

Although the user may choose zero deadrise, the bottom tangent is set to 3° for the purpose of generating the section shapes. This minor change is introduced to avoid a divide-by-zero error and to improve the numerical properties of the matrices.

HINTS AND SUGGESTIONS

Following are some suggestions for obtaining a reasonable hull form with M-HULL. It is not an exhaustive list of problems which may be encountered, but is meant to help the beginner avoid unnecessary frustration.

1. To get an initial data set, use data from an existing hull form and vary it to suit your needs or use the Series 60 input option if this satisfies your initial requirements.

2. Ignore the above waterline shape until the underwater shape is reasonable. It is helpful to set the depth early, however, so you begin to visualize the entire final hull.

3. Step through the control curves to eliminate any obvious problems. Priority should be given first to the Sectional Area curve and the Design Waterline curve.

4. Keep a written record of parameter values, changes made, and their results. This can be valuable in recovering from "mistakes."

5. Use the vector slope magnitudes to eliminate bumps on the Sectional Area and Design Waterline curves and alter these curves until they look "reasonable."

6. Work next to get a reasonable Profile curve. This should be done early since it depends on both the Sectional Area and Design Waterline curves which have global boundary conditions (area and centroid) and thus affect both the bow and stern whenever altered.

7. Check the lengths of parallel sections to make sure that everything is constant in the parallel midbody region. M-HULL does not guarantee this. M-HULL will limit the bottom flat region of full sections in a consistent manner so allow it to be large and let M-HULL cut it down as needed. Sections with too large a radius can be spotted on the body plan and the region of full sections can be changed accordingly.

8. Look at the body plan and determine if the sectional area and waterplane are compatible; i.e., if the required area will fit under the given beam without bulging or crossing the centerline to create a mathematically "negative" area. Deadrise has a large effect on this. The beam may need to be increased or decreased or the required area may have to be increased or decreased at some stations. It is sometimes helpful to globally adjust the Deck at Edge curve to be consistent with the Design Waterline curve as the Design Waterline curve nears completion.

9. Record the numbers of sections which need changing and work again with the control curves to affect the necessary improvements.

10. Once the stations fit properly, adjust the keel rise again as needed.

11. With the Sectional Area curve, Design Waterline curve, and keel rise reasonably set, the Angles of Sections curves are the only tools left to control the section shapes. Increasing the angle at the bottom flat can help alleviate bulging problems, while the angles at the waterline and deck can be used to smooth out the section shapes at and above the waterline.

12. Once a good underwater shape is achieved, the deck edge and angle at the deck can be changed without affecting the underwater shape.

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8. "File Transfer Protocol - FTP," CAEN Technical Notes, August, 1989.

APPENDIX A

MATHEMATICAL REPRESENTATION OF CURVES

In the M-HULL program, all curves are represented mathematically as the collection of polynomials connected with C^0 or C^1 continuity. The detailed procedures to construct the different polynomials for different curves are described in the following.

1. Control Curves

1.1. Sectional Area Curve

The Sectional Area curve is composed of two curved segments and an optional straight line between them. The two parametric polynomials and one straight line are used to represent this curve as follows (see Figure A-1):

(I) For x in the range from X_1 to X_2,

$$x = A_0 + A_1 * t + A_2 * t^2 + A_3 * t^3$$

$$y = B_0 + B_1 * t + B_2 * t^2 + B_3 * t^3 + B_4 * t^4$$

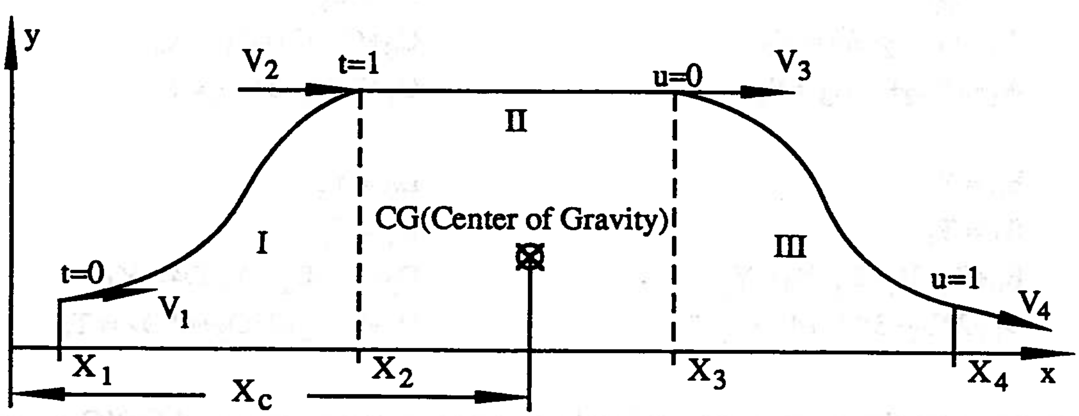
(II) The straight line segment from X_2 to X_3, if present, is defined by:

$$y = Y_2 + (Y_3 - Y_2) * (x - X_2)/(X_3 - X_2)$$

(III) For x in the range from X_3 to X_4,

$$x = C_0 + C_1 * u + C_2 * u^2 + C_3 * u^3$$

$$y = D_0 + D_1 * u + D_2 * u^2 + D_3 * u^3 + D_4 * u^4$$



X_C= the distance from y axis to CG; AC= area under the curve from X_1 to X_4.

Figure A-1. The Sectional Area curve and its defining conditions.

There are eighteen unknown coefficients involved in the above formulations. To determine the curve completely, we need eighteen conditions. The boundary conditions for segment (I) are:

at $t = 0$	at $t = 1$
$x = X_1$	$x = X_2$
$y = Y_1$	$y = Y_2$
$dx/dt = S_1 = V_1*\cos\theta_1$	$dx/dt = S_2 = V_2*\cos\theta_2$
$dy/dt = T_1 = V_1*\sin\theta_1$	$dy/dt = T_2 = V_2*\sin\theta_2$

The boundary conditions for segment (III) are:

at $u = 0$	at $u = 1$
$x = X_3$	$x = X_4$
$y = Y_3$	$y = Y_4$
$dx/du = S_3 = V_3*\cos\theta_3$	$dx/du = S_4 = V_4*\cos\theta_4$
$dy/du = T_3 = V_3*\sin\theta_3$	$dy/du = T_4 = V_4*\sin\theta_4$

The parameters V_1, V_2, V_3, and V_4 are the magnitudes of the slope vectors at the end points of the two parametric polynomial curves.

The above boundary conditions define sixteen simultaneous equations as follows:

$A_0 = X_1$	$C_0 = X_3$
$A_1 = S_1$	$C_1 = S_3$
$A_0+A_1+A_2+A_3 = X_2$	$C_0+C_1+C_2+C_3 = X_4$
$A_1+2*A_2+3*A_3 = S_2$	$C_1+2*C_2+3*C_3 = S_4$
$B_0 = Y_1$	$D_0 = Y_3$
$B_1 = T_1$	$D_1 = T_3$
$B_0+B_1+B_2+B_3+B_4= Y_2$	$D_0+D_1+D_2+D_3+D4= Y_4$
$B_1+2*B_2+3*B_3+4*B_4 = T_2$	$D_1+2*D_2+3*D_3+4*D_4 = T_4$

The area under the entire curve: AC and its moment about the y axis: AC*XC are used to set up two additional equations necessary to solve for all the unknown coefficients:

$$AC = \int_{t=0}^{t=1} y*dx + .5*(X_3 - X_2)*(Y_2 + Y_3) + \int_{u=0}^{u=1} ydx$$

$$AC*XC = \int_{t=0}^{t=1} x*ydx + (X_3 - X_2)*(Y_2*(2*X_2 + X_3) + Y_3*(X_2 + 2*X_3))\Big/ 6 + \int_{u=0}^{u=1} x*ydx$$

The straight line segment is always parallel to the x axis, that is: $Y_2 = Y_3$, so we obtain:

$$\sum_{i=0}^{i=4} \sum_{k=1}^{k=3} \left(\frac{k}{i+k}\right)*(B_i*A_k + D_i*C_k) = AC - Y_2*(X_3 - X_2)$$

$$\sum_{i=0}^{i=4} \sum_{j=1}^{j=3} \sum_{k=1}^{k=3} \left(\frac{k}{i+j+k}\right)*(B_i*A_j*A_k + D_i*C_j*C_k) = AC*XC - Y_2*(X_3^2 - X_2^2)/2$$

The first eight equations are solved for coefficients of x functions:

$A_0 = X_1$ | $C_0 = X_3$
$A_1 = S_1$ | $C_1 = S_3$
$A_2 = 3*(X_2-X_1)-2*S_1-S_2$ | $C_2 = 3*(X_4-X_3)-2*S_3-S_4$
$A_3 = S_1+S_2-2*(X_2-X_1)$ | $C_3 = S_3+S_4-2*(X_4-X_3)$

Four out of the ten y coefficients can be determined directly from the boundary conditions: $B_0 = Y_1$, $B_1 = T_1$, $D_0 = Y_3$, and $D_1 = T_3$. Let us denote:

$$E_i = \sum_{k=1}^{k=3} \left(\frac{k}{i+k}\right)*A_k \qquad F_i = \sum_{k=1}^{k=3} \left(\frac{k}{i+k}\right)*C_k$$

$$G_i = \sum_{j=0}^{j=3} \sum_{k=1}^{k=3} \left(\frac{k}{i+j+k}\right)*A_j*A_k \qquad H_i = \sum_{j=0}^{j=3} \sum_{k=1}^{k=3} \left(\frac{k}{i+j+k}\right)*C_j*C_k$$

Then the last six simultaneous equations become:

$B_2+B_3+B_4 = Y_2-Y_1-T_1$
$2*B_2+3*B_3+4*B_4 = T_2-T_1$
$D_2+D_3+D_4 = Y_4-Y_3-T_3$
$2*D_2+3*D_3+4*D_4 = T_4-T_3$

$$E_2*B_2 + E_3*B_3 + E_4*B_4 + F_2*D_2 + F_3*D_3 + F_4*D_4 =$$
$$AC - Y_2*(X_3 - X_2) - E_0*Y_1 - E_1*T_1 - F_0*Y_3 - F_1*T_3$$

$$G_2*B_2 + G_3*B_3 + G_4*B_4 + H_2*D_2 + H_3*D_3 + H_4*D_4 =$$
$$AC*YC - Y_2*\left(X_3^2 - X_2^2\right)/2 - G_0*Y_1 - G_1*T_1 - H_0*Y_3 - H_1*T_3$$

In M-HULL, this system of linear equations system is solved numerically.

We summarize all the necessary information for a Sectional Area curve representation by three segment fitting method as follows:

$x = X_1 = 0$ ship forward perpendicular (FP),
$x = X_2$ = (distance from FP to fwd. end of parallel section)/LBP,
$x = X_3$ = (distance from FP to aft end of parallel section)/LBP,
$x = X_4 = 1.0$ ship aft perpendicular (AP),
$y = Y_1$ = (section area at FP)/(maximum section area),
$y = Y_2 = Y_3 = 1.0$,
$y = Y_4$ = (section area at AP)/(maximum section area),
θ_1 = angle of the the Sectional Area curve at FP, degrees (shown positive),
$\theta_2 = 0$, angle of the Sectional Area curve at X_2,
$\theta_3 = 0$, angle of the Sectional Area curve at X_3,
θ_4 = angle of the Sectional Area curve at AP, degrees (shown negative),
AC = CP = longitudinal prismatic coefficient = (hull volume)/(LBP*$Area_{max}$),
XC= (longitudinal distance from FP to LCB)/LBP,
V_1, V_2, V_3, and V_4 = magnitudes of four slope vectors ($0 =< V_1, V_2\ V_3, V_4$),

Altering the end slope vector magnitude is a powerful way to reshape a parametric polynomial curve. Increasing the magnitude of this vector will cause the curve to remain close to the direction of that particular slope for a larger part of its length and, therefore, give more 'fullness' to the curve (Figure A-2). Thus, the magnitude of the slope vector gives additional control over the polynomial curve without changing the offset or slope at each end.

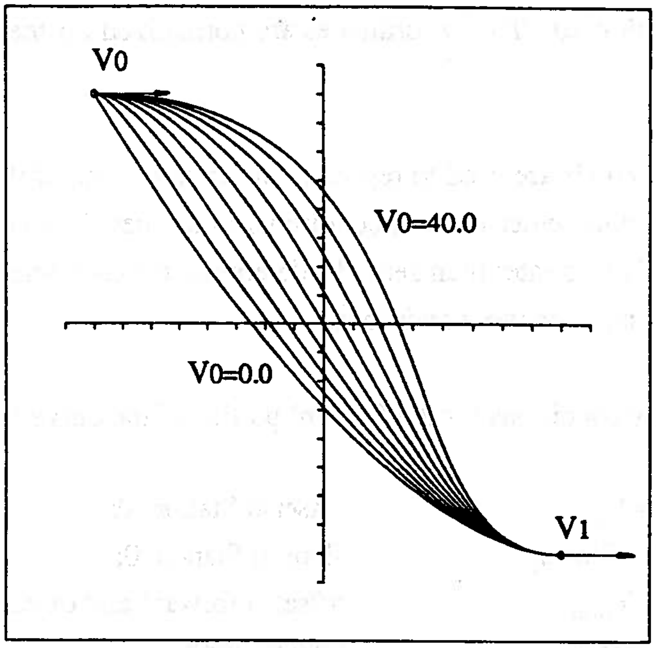


Figure A-2. Manifestation of the affect of the slope vector magnitude V0 on the shape a parametric cubic polynomial.

1.2. Design Waterline Curve

The Design Waterline curve is determined in the same way as the Sectional Area curve. The characteristics required for a representation of the Design Waterline curve are the same as those required for the Sectional Area curve, except for the following:

$y = Y_1$ = (beam at FP)/(maximum beam),
$y = Y_4$ = (beam at AP)/(maximum beam),
θ_1 = angle of the Design Waterline curve at FP,
θ_2 = 0.0, angle of the Design Waterline curve at X_2,
θ_3 = 0.0, angle of the Design Waterline curve at X_3,
θ_4 = angle of the Design Waterline curve at AP,
AC = CWP = waterplane coefficient = (area of the waterplane)/(LBP*B_{max}),
XC = (longitudinal distance from FP to LCF)/LBP.

1.3. Deck at Edge Curve

The Deck at Edge curve is the projected shape of the main deck at edge on the X-O-Y base plane. It is composed of two curved parts and an optional straight line between them (Figure A-3).

The x coordinates are normalized on L_{BP} so that it goes from $x = 0.0$ at station 0 to $x = -1.0$ at station 20. The y ordinates are normalized on the beam at the station of maximum area.

Cubic polynomials are used to represent the curved parts of the Deck at Edge curve. There are no area and center of area conditions to be met. The constant middle section exists only if X_2-X_1 is greater than zero. To determine the coefficients of the polynomials, we again need to find boundary conditions.

The boundary conditions for the forward portion of the curve are:

$x = 0.0$, $y = Y_0$	offset at Station 0;
$x = 0.0$, $y' = Slope_0$	slope at Station 0;
$x = X_1$, $y = Y_{mid}$	offset at forward end of constant middle section;
$x = X_1$, $y' = 0.0$	by definition.

Similar boundary conditions are used to define the aft portion of the curve.

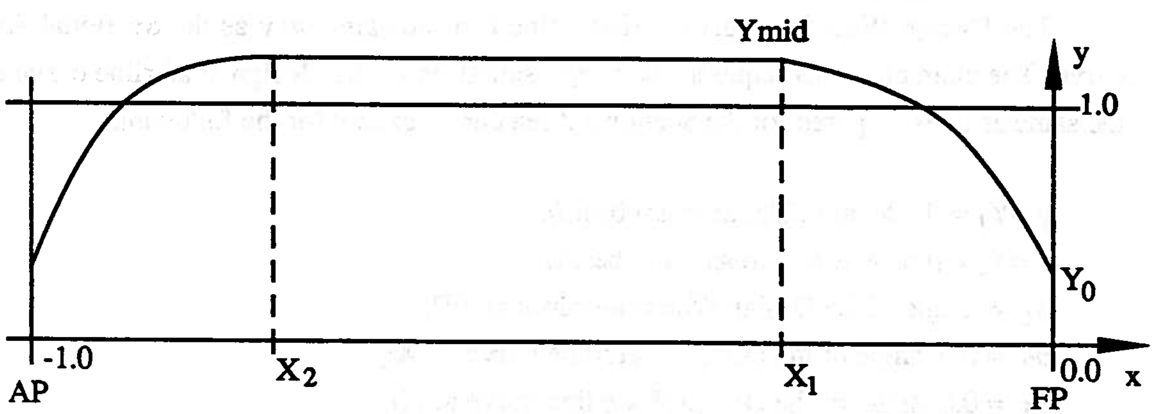


Figure A-3 . The Deck at Edge curve.

1.4. Profile

The sheer curve is generated using a single quadratic polynomial. Its coefficients are determined by the depth at Stations 0, 10, and 20. The amount of sheer is defined by the selection of the depths required. The hull has a plumb bow at Station 0 and a plumb transom at Station 20.

The rise of keel portion of the profile is generated by first producing a single local section coefficient curve. The local section coefficient (CI) is defined as the local area of the section divided by the local beam on the design waterline and the *local* draft.

The station of keel rise is defined as the point at which the local section coefficient curve diverges from a section coefficient CI_H based on local beam and maximum draft (see Figure A-4). The local section coefficient curve is produced by selecting the desired local section coefficient at the AP and by specifying the station of keel rise. The coordinate CI_H and the slope CI_H' of the curve based on maximum draft are calculated at the station of keel rise, using values from the Sectional Area curve and the Design Waterline curve. The local section coefficient is then represented by a quadratic curve from the point of keel rise X_R=-(Station of keel rise)/20 to the AP(x=-1); i.e.,

$$CI(x) = A_0 + A_1 x + A_2 x^2 \quad , \quad -1 \le x \le X_R \quad ,$$

where the coefficients are obtained using the three boundary conditions,

$$CI(X_R) = CI_H(X_R)$$
$$CI'(X_R) = CI_H'(X_R)$$
$$CI(-1) = \text{AP COEFF.}$$

The section coefficient based upon maximum draft CI_H is given by,

$$CI_H(x) = \frac{SA(x)}{H_x B(x)} = \frac{SA(x)CX}{B_x H_x B(x) CX} = \left(\frac{SA(x)}{SA_x(x)}\right)\left(\frac{B_x}{B(x)}\right)CX = \frac{SAY}{WLY}CX \quad ,$$

where, SA(x) = sectional area as a function of x (local sectional area),

H_x = maximum section draft,

B(x) = beam as a function of x ,

B_x = maximum section beam,

CX = maximum section coefficient,

SA_x = maximum sectional area,

SAY = ordinate of the Sectional Area curve,

WLY = ordinate of the Design Waterline curve.

With the curve of local section coefficient CI(x) available, the local draft H(x) and thus the normalized keel rise KR(x) can be obtained as follows:

$$\frac{H(x)}{H_x}=\frac{B_xH(x)CX}{B_xH_xCX}=\frac{B_xH(x)CX}{SA_x}=\frac{\left(\frac{SA(x)}{SA_x}\right)CX}{\left(\frac{B(x)}{B_x}\right)\frac{SA(x)}{B(x)H(x)}}=\frac{SAY*CX}{WLY*CI(x)},$$

$$KR(x)=1-\frac{H(x)}{H_x}.$$

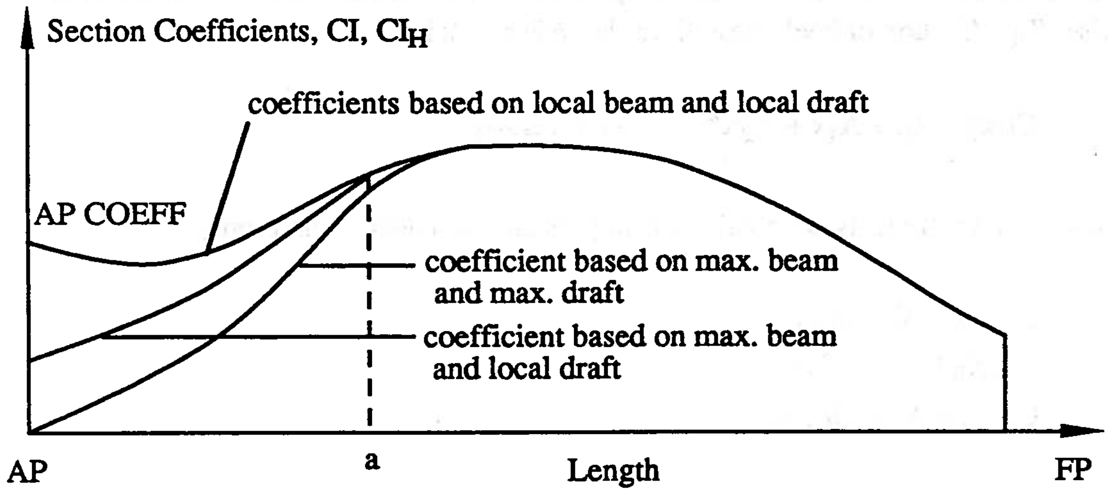


Figure A-4. Section Coefficient curves (Point (a) is the start of the keel rise).

1.5. <u>Flat of Bottom Curve</u>

The bottom flat is defined in M-HULL as shown in Figure A-5. It may consist of both a halfsiding and the rest of the bottom flat which can either be on the baseline or the projection of the bottom flat on the baseline, if there is a deadrise angle. The flat of bottom curve is represented in seven sections as shown in Figure A-6. The mathematical representation of these sections is as follows:

(I) $X_1 \le x \le 0$, if $X_1 = 0$ go to II

$y = A_1+A_2*x+A_3*x^2$

X_1, the start of forward half-siding, Y_1, and the slope at Y_1 are user defined. The half-siding is faired to zero forward using a quadratic polynomial.

(II) $X_2 \le x \le X_1$, if $Y_1=Y_2$ then use a straight line, otherwise

$y = A_1+A_2*x+A_3*x^2+A_4*x^3$

X_2, the start of the flat of bottom curve, Y_2, and the slope at Y_2 are user defined. The other two conditions come from Y_1 and the slope at Y_1.

(III) $X_3 \le x \le X_2$, $y = A_1 + A_2*x + A_3*x^2 + A_4*x^3$

The location of X_3 is user defined. The offset and slope at X_3 are found as shown below. The other two conditions come from the offsets and slopes at X_2.

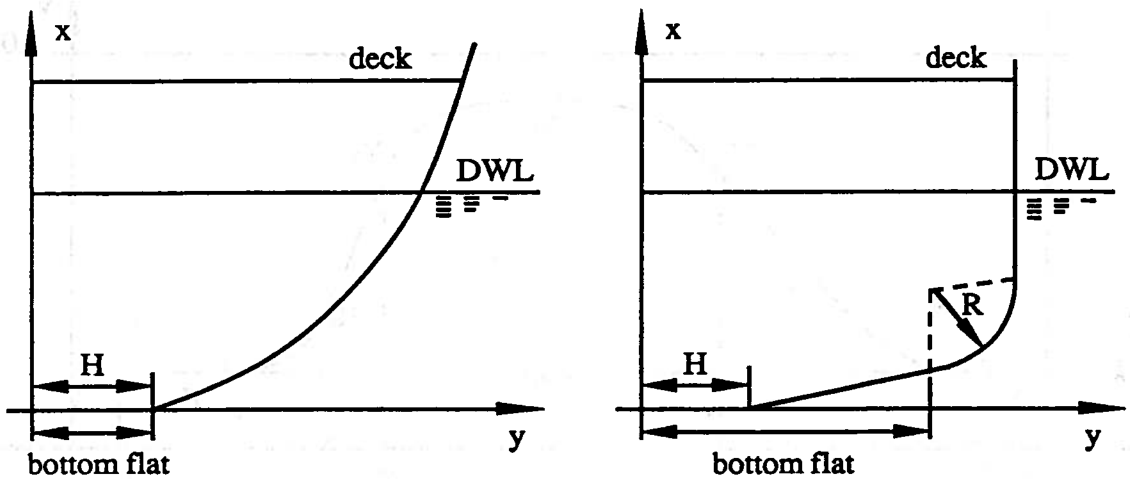


Figure A-5. The definition of bottom flat.

(IV) $X_4 \le x \le X_3$, $y = A_1 + A_2*x + A_3*x^2 + A_4*x^3$

The locations of X_3 and X_4 are user defined and specify the extent over which full sections will be used in the body plan. Thus Y_4 and the slopes of the curve at these points are calculated from the Sectional Area curve.

(V) $X_5 \le x \le X_4$, Similar to section (III) above.

(VI) $X_6 \le x \le X_5$, Similar to section (II) above, except that X_6 does not have to be at the AP. This allows the curve to end at the keel rise point.

(VII) $X_5 \le x \le X_2$, if $Y_5=Y_2$ then use a straight line, otherwise

$y = A_1 + A_2*x + A_3*x^2 + A_4*x^3$

and the coefficients are calculated from the offset and slopes at X2 and X5. If there is a deadrise then this line represents the half-siding of each section.

If there is deadrise then the Bottom Flat curve shown is the projection of the actual offsets onto the baseline. For example, in Figure A-7, we have:

$$HBBF(x) = (y(x) - HF(x))/\cos\theta_B$$
$$HBF(x) = HBBF(x) * \sin\theta_B \quad ,$$

where $\theta_B(x)$ is the deadrise or angle of the bottom flat as specified in the Angles of Sections curves.

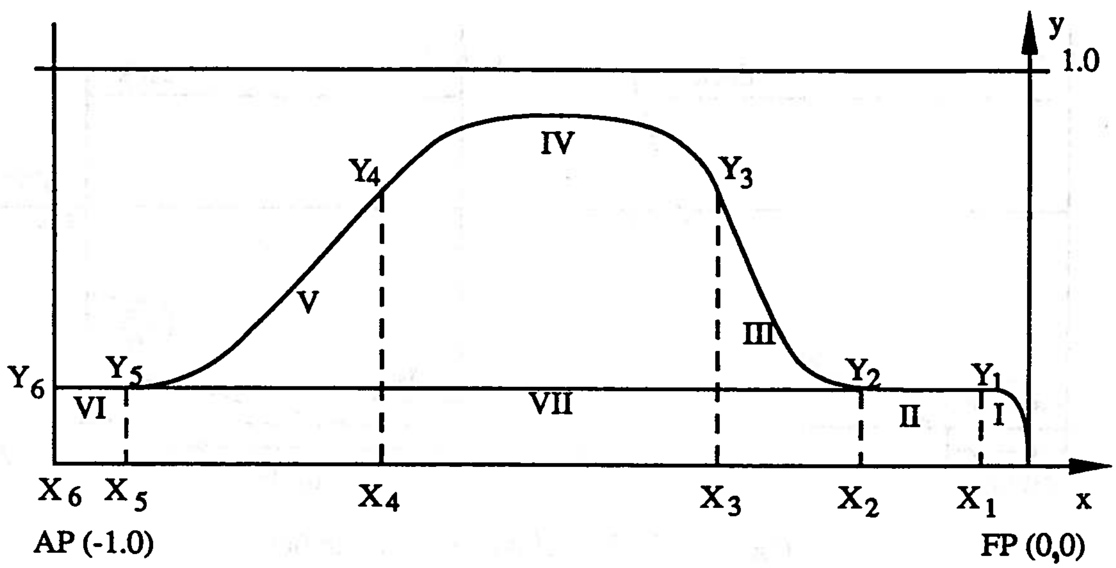


Figure A-6. The Bottom Flat curve approximation.

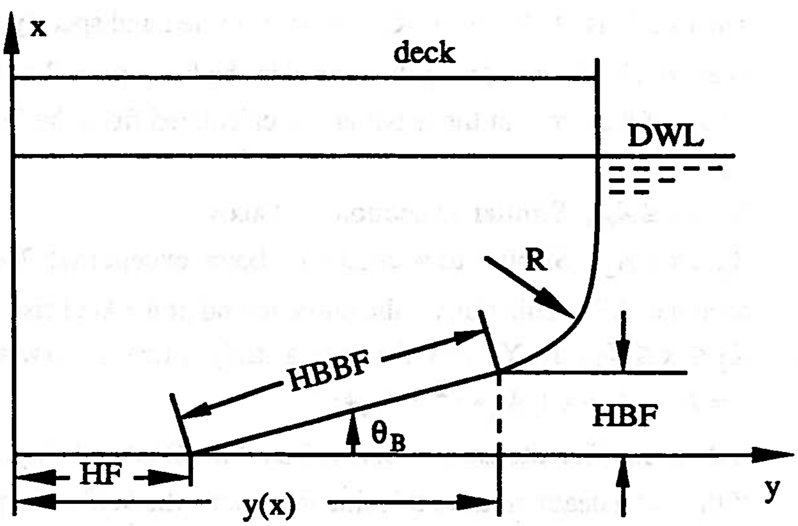


Figure A-7. Bottom flat with a deadrise.

1.6 Angles at Sections

In an attempt to assure reasonable longitudinal fairness in the hull form being produced, controls are placed on the longitudinal variation of the angles of the section shapes at the deck at the edge, design waterline, and bottom. The definitions are shown in Figure A-8. The angles as seen on the screen are represented as functions of the normalized length using the same formulation as used for the Deck at Edge curve; i.e., cubic polynomials are used to approximate the forward and aft curved portions and an optional straight line is used to describe the constant middle portion. The boundary conditions are the magnitude and extent of the constant section and the ordinates and slopes of the curves at the forward and after perpendiculars.

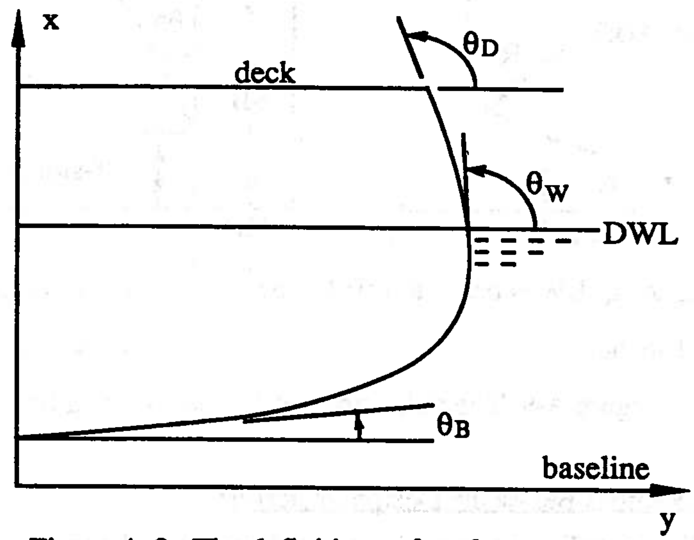


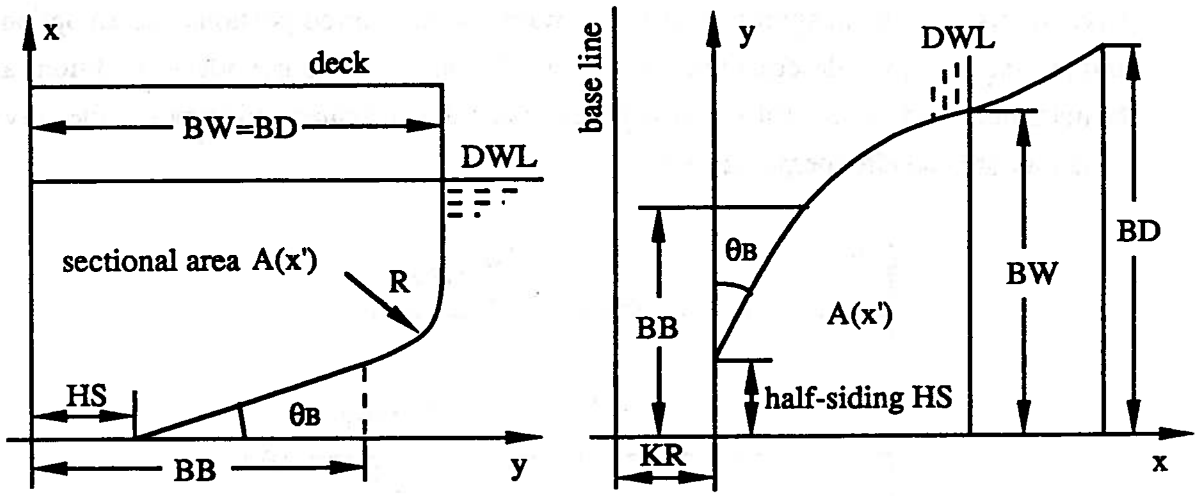
Figure A-8. The definitions of angles at a section.

2. Body Plan

Body plan sections are divided into two parts, the above and below design waterline parts. The mathematical representation for the below design waterline part depends on whether it is a full or fine section.

Full sections below the design waterline are defined as sections with a flat vertical side, a flat bottom at some deadrise angle outboard of the half-siding, and a bilge radius properly sized to give the required section area (Figure A-9(a)). The required information to define a full section is given by the Sectional Area curve, the Angles of Sections curves, and the Bottom Flat curve. Fine sections are represented by a single polynomial below the design waterline with the station height as the independent variable (Figure A-9(b)). This approach makes it possible to create vertical sides without numerical difficulties and allows bulb-like stations without dealing with a multivalued function.

The above design waterline part is fitted by a cubic polynomial. The two parts are matched at the design waterline with position and slope continuity.



BD = beam at deck; BW = beam at DWL; BB = beam at bottom; R = bilge radius.

a. A full section. b. A fine section.

Figure A-9. The definitions of full section and fine section.

2.1. <u>Fine Sections Below the Design Waterline</u>

The modeling coordinate system is oriented such that the independent variable x runs from the base of the section up to the design waterline. The y coordinate represents the offsets at any given waterline.

The section is normalized on local draft (H-KR) and local beam (BW) such that $0 \le x \le 1.0$ and $0 \le y \le 1.0$. The boundary conditions which must be met to generate a section are:

(1) $x = 0.0$ $y = HS$ — HS is the normalized half-siding of the keel plate or the flat of bottom defined by the Bottom Flat curve.

(2) $x = 0.0$ $y' =$ bottom slope — normalized bottom slope is defined by the Angles of Sections curves. This value must be

greater than 0. If zero deadrise is defined, then the bottom tangent is fixed at 3° to eliminate mathematical difficulties.

(3) $x = 1.0, \; y = 1.0$ — by definition at design waterline.

(4) $x = 1.0, \; y' = \text{slope at DWL}$ — normalized slope at the design waterline as defined by the Angles of Sections curves.

(5) $\int_0^1 y\,dx = SA$ — normalized area from the Sectional Area curve.

A simple fifth-order polynomial which could be defined by these five boundary conditions is not suitable for this curve. The following curve is well behaved and produces ship-like sections:

$$y = A_0 + A_1 x + A_2 x^2 + A_3 (x+1)^{-2} + A_4 (x+k)^{1/2}$$

Parameter k is chosen as 0.001 so that a singularity will not occur in the calculation of the derivative of the curve at x=0. Variations of k do not significantly affect the resulting shape of the section curves.

2.2. Full Sections Below the Design Waterline

These sections are characterized by a bilge curve of fixed radius intersecting a vertical side and flat bottom. Non-dimensionalized coordinates are not satisfactory for these sections because of the distortion of the bilge curve into an elliptical form during scaling.

The general development provides for a half-siding HS plus an additional bottom flat region at an angle θ_B as defined by the Bottom Flat curve and the Angles of Sections Curves, respectively. The resulting section is defined in Figure A-9(a). The bilge radius is determined to provide the required section area and the other section parameters.

2.3. Sections Above the Design Waterline

The coordinate system is the same as the one used for sections below the design waterline but with the origin shifted. The above DWL Section and the below DWL Section are matched for ordinate and slope at the DWL. If X_1 is the local depth of the ship normalized on the draft; i.e.,

$X1 = \text{Depth}(x)/H_x - 1.0$

and Y_1 is the offset at the deck at edge normalized on the local offset of the design waterline; i.e.,

$Y_1 = \text{Deck at Edge}(x)/B(x) - 1.0.$

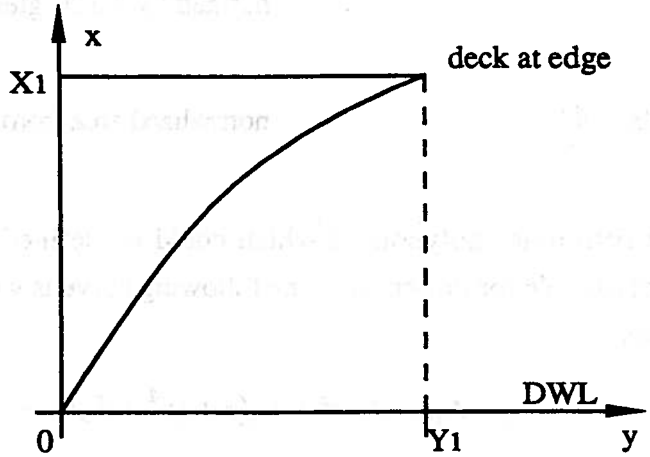


Figure A-10. Normalized section above DWL.

The boundary conditions to be met are:

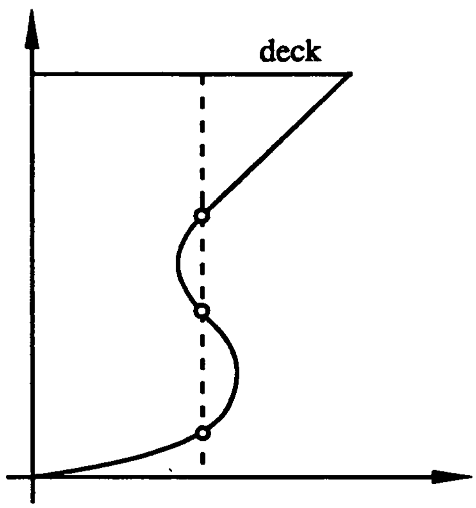
1.	$x = 0,\ y = 0$	by definition of local coordinates
2.	$x = 0,\ y' =$ slope at DWL	normalized slope from the Angles of Sections curves
3.	$x = X_1,\ y = Y_1$	local depth and beam obtained from sheer curve on the Profile and the Deck at Edge curve, respectively.
4.	$x = X_1,\ y' =$ slope at deck at edge	normalized slope from the Angles of Sections curves.

The cubic polynomial is used for these curves.

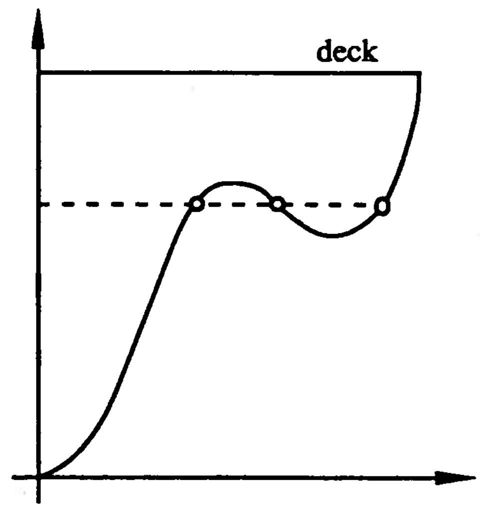
3. Some Limitations

The mathematical models of M-HULL result in some limitations on the resulting hull configuration as follows:

- No above or below waterline hull can be shaped forward of the forward perpendicular (FP) or aft of the after perpendicular (AP); i.e., no projecting bulb or bow or projecting stern is designed, but the section area at the FP or AP need not be zero;
- No drag can be designed to the keel;
- No tunnel shaped sections (See Figure A-11);
- Discontinuous deck profiles cannot be constructed;
- No chines are permitted;
- Long raised deck ships and other stepped deck hulls cannot be handled directly.



a. Permissible section.



b. Non-permissible (tunnel) section.

Figure A-11. The Limitation of M-HULL.

The M-HULL program works internally with several different coordinate systems, but in general the user needs only to be concerned with the system presented on the screen. The control curves are presented versus station number, with the bow to the right, and with station numbers increasing aft from station zero at the FP to station twenty at the AP. Ordinates vary with the control curve as described below. The body plan is drawn to scale in the traditional manner, with no dimensions indicated.

Although most of the actual calculations are performed nondimensionally, the user is required to input several dimensional quantities. The units of these are chosen by the user and need only to be self-consistent. The dimensional output will then be in these same units. Most of the inputs are, however, nondimensional. The definitions for these inputs can be found in Appendix B.

The length used in all definitions of coefficients is the waterline length, which is constrained to be the length between perpendiculars. The beam used is the maximum beam at the design waterline.

APPENDIX B
CONTROL CURVE PARAMETERS

The control curve parameters are specified by the user to define the control curves. All parameters are listed in the following with the same order as they appear in the menu on the screen.

1. Sectional Area

Ordinate = (Sectional area to DWL)/(Maximum sectional area)

A. AP Area............ Ordinate of the Sectional Area curve at the AP.

B. LCB................. Location of the longitudinal center of buoyancy forward of amidships, as a percent of LWL (5% of LWL = 1 station).

C. CP.................... Longitudinal prismatic coefficient based on LWL.

D. FP area............. Ordinate of the Sectional Area curve at the FP.

E. AP Slope.......... Slope of the Sectional Area curve at the AP as it appears on the screen, in degrees counterclockwise from the horizantal, positive for increasing area forward.

F. Aft Stn Mid......... Station at which the parallel midbody ends (where the ordinate becomes 1.0 and the slope becomes 0.0).

G. Fore Stn Mid....... Station at which the parallel midbody starts (where the ordinate becomes 1.0 and the slope becomes 0.0).

H FP Slope............ Slope of the Sectional Area curve at the FP as it appears on the screen, in degrees clockwise from the horizontal, positive for increasing area aft.

I. AP Vector........... Magnitude of the slope vector at the AP.

J. Aft Mid Vector..... Magnitude of the slope vector at the end of parallel midbody.

K. Fore Mid Vector... Magnitude of the slope vector at the start of parallel midbody.

L FP Vector........... Magnitude of the slope vector at the FP.

2. Design Waterline

Ordinate = (DWL beam)/(Maximum beam on DWL)

A. AP Offset........... Ordinate of the Design Waterline curve at the AP.

B. LCF.................. Location of the longitudinal center of flotation forward of amidships, as a percent of LWL (5% of LWL = 1 station).

C Cwp................. Waterplane area coefficient based on LWL.

D. FP Offset............ Ordinate of the Design Waterline curve at the FP.

E. AP Slope............ Slope of the Design Waterline curve at the AP as it appears on the screen, in degrees counterclockwise from the horizontal, positive for increasing beam forward.

F. Aft Stn Mid......... Station at which the parallel waterline ends (where the ordinate becomes 1.0 and the slope becomes 0.0)

G. Fore Stn Mid....... Station at which the parallel waterline starts (where the ordinate becomes 1.0 and the slope becomes 0.0).

H. FP Slope............ Slope of the Design Waterline curve at the FP as it appears on the screen, in degrees clockwise from the horizontal, positive for increasing beam aft.

I. AP Vector........... Magnitude of the slope vector at the AP.

J. Aft Mid Vector..... Magnitude of the slope vector at the end of parallel waterline.

K. Fore Mid Vector.... Magnitude of the slope vector at the start of parallel waterline.

L. FP Vector........... Magnitude of the slope vector at the FP.

3. Deck at Edge

Ordinate = (Beam at projected deck edge)/(Maximum beam on DWL)

A. AP Offset........... Ordinate of the Deck at Edge curve at the AP.

B. Mid Offset.......... Ordinate at the parallel deck edge.

C. FP Offset............ Ordinate of the Deck at Edge curve at the FP.

D. AP Slope............ Slope of the Deck at Edge curve at the AP as it appears on the screen, in degrees counterclockwise from centerline, positive for increasing beam forward.

E. Aft Stn Mid......... Station at the end of parallel deck edge (where the ordinate becomes Mid Offset and the slope becomes 0.0).

F. Fore Stn Mid....... Station at the start of parallel deck edge (where the ordinate becomes Mid Offset and the slope becomes 0.0).

G. FP Slope............ Slope of the Deck at Edge curve at the FP as it appears on the screen, in degrees clockwise from the horizontal, positive for increasing beam aft.

4. Bottom Flat

Ordinate = (Beam at flat-of-bottom)/(Maximum beam on DWL)

A. Aft Halfside......... Offset at Aft End H'side.

B. Mid Halfside........ Offset of the half-siding at the center of the region of full sections. This is the same as the hull parameter, HALFMD.

C. CX.................... Maximum section coefficient, (Maximum sectional area)/((Maximum DWL Beam)*Draft).

D. Fore Halfside....... Offset at Fore End H'side.

E. Aft Slope............ Slope of the Bottom Flat curve at Aft End FoB, in degrees counterclockwise from the horizontal, positive for increasing beam forward.

F. Aft Stn Full......... Station at which full sections (vertical side and a bilge radius) are to begin.

G. Fore Stn Full....... Station at which full sections (vertical side and a bilge radius) are to end.

H. Fore Slope.......... Slope of the Bottom Flat curve at Fore End FoB, in degrees clockwise from the horizontal, positive for increasing beam aft.

I. Aft End H'side..... Station at which the half-siding ends.

J. Aft End FoB........ Station at which the Bottom Flat curve ends.

K. Fore End FoB...... Station at which the Bottom Flat curve starts.

L. Fore End H'side... Station at which the half-siding starts (it is faired to an offset of 0.0 at the FP forward of this point).

5. Profile

Ordinate = (Profile height / Draft)

A. AP Local Ca .... Local area coefficient at the AP, based on local beam and local draft.

B. Start Rise .... Station at which the keel rises above the baseline.

C. AP Depth................ Depth to the deck edge at AP, dimensional the same units as beam, draft, and length.

D. Mid Depth............... Depth to the deck edge amiships (station 10), dimensional.

E. FP Depth................ Depth to the deck edge at FP, dimensional.

6. Angles of Sections

Ordinate = angle of the section at deck, DWL and bottom; in degrees from the horizontal.

A. AP Angle of DWL...... Angle at the DWL at the AP.

B. Mid Angle of DWL..... Angle in the region of constant DWL angle.

C. FP Angle of DWL...... Angle at the DWL at the FP.

D. AP Slope of DWL...... Slope of the DWL angle curve at the AP as it appears on the screen, in degrees counterclockwise from the horizontal, positive for increasing ordinate forward.

E. Aft Stn Mid of DWL.... Station at the end of constant DWL angle.

F. Fore Stn Mid of DWL.. Station at the start of constant DWL angle.

G. FP Slope of DWL...... Slope of the DWL angle curve at the FP as it appears on the screen, in degrees clockwise from the horizontal, positive for increasing ordinate aft.

H. AP Angle of Bottom.... Angle at the bottom flat at the AP.

I. Deadrise................. Angle of deadrise, or the bottom angle in the region of constant bottom slope. This is the same as the hull parameter, DEDRIS

J. FP Angle of Bottom.... Angle at the bottom flat at FP.

K. AP Slope of Bottom.... Slope of the bottom angle curve at the AP as it appears on the screen, in degrees counterclockwise from the horizontal, positive for increasing ordinate forward.

L. Aft Stn Mid of Bottom.. Station at the end of constant bottom angle.

M. Fore Stn Mid of Bottom................... Station at the start of constant bottom angle.

N. FP Slope of Bottom.... Slope of the bottom angle curve at the FP as it appears on the screen, in degrees clockwise from the horizontal, positive for increasing ordinate aft.

O.	AP Angle of Deck......	Angle at the deck edge at the AP.
P.	Mid Angle of Deck.....	Angle in the region of constant deck edge angle.
Q.	FP Angle of Deck......	Angle at the deck edge at FP.
R.	AP Slope of Deck......	Slope of the deck edge angle curve at the AP as it appears on the screen, in degrees counterclockwise from the horizontal, positive for increasing ordinate forward.
S.	Aft Stn Mid of Deck....	Station at the end of constant deck edge angle
T.	Fore Stn Mid of Deck..	Station at the start of constant deck edge angle.
U.	FP Slope at Deck.......	Slope of the deck edge angle curve at the FP as it appears on the screen, in degrees clockwise from the horizontal, positive for increasing ordinate aft.

APPENDIX C

SAMPLE USER-PROGRAM DIALOGUE

```
% m-hull_x

Enter Name of Workstation Assignment File:
waf <RETURN>

WORKSTATION 1
  SAC
  DWL
  DECK
  BTFLT
  PRFIL
  ANGLE

WORKSTATION 2
  BODY

==============================================
DEPT.OF NAVAL ARCHITECTURE AND
      MARINE ENGINEERING
  THE UNIVERSITY OF MICHIGAN
      ANN ARBOR,MI 48109


      * * * M-HULL * * *

 (Version 2.0  December 1990)

A GRAPHICS PROGRAM THAT ALLOWS
THE INTERACTIVE GENERATION AND
MODIFICATION OF A HULL BY MANI-
PULATION THE FOLLOWING CONTROL
CURVES:

   1) SECTIONAL AREA
   2) DESIGN WATERLINE
   3) DECK AT EDGE
   4) BOTTOM FLAT
   5) PROFILE
   6) ANGLES OF SECTION AT:
      - KEEL
      - DWL
      - DECK

==============================================

Press "RETURN" to continue ...
<RETURN>
```

```
      * * * M-HULL * * *

      *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
1 <RETURN>

Enter your session title
(less than 73 characters):
hull_1  <RETURN>

      * * * M-HULL * * *

      *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
2 <RETURN>

      * * * M-HULL * * *

       ** Input Menu **
------------------------------
What?
1. Parent Ship
2. Series 60
3. Return
------------------------------
Enter a digit:
1 <RETURN>

----------------------------
Where?
1. From File
2. On Terminal
3. Return
----------------------------
Enter a digit:
1 <RETURN>

Enter data file name
(less than 73 characters):
m-hull.dat1  <RETURN>
```

```
     * * * M-HULL * * *

     *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
3 <RETURN>

     * * * M-HULL * * *

   ** Curve Review  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
------------------------------
Enter a digit:
1 <RETURN>

==== Sectional Area curve ====

A. AP Area        = 0.0000000
B. LCB            = -0.1000000
C. CP             = 0.6800000
D. FP Area        = 0.0000000
E. AP Slope       = 0.0000000
F. Aft Stn Mid    = 10.35400
G. Fore Stn Mid   = 8.699000
H. FP Slope       = 45.52200

--- Vector Magnitudes ---
I. AP             = 0.3000000
J. Aft Mid        = 0.7000000
K. Fore Mid       = 0.3000000
L. FP             = 0.8000000
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
9. Overlap draw of Ctrl.Curves
0. Overlap draw of Body plan
------------------------------
```

```
Enter a digit or a character:
7 <RETURN>

------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
9. Porcupine Spikes
------------------------------
Enter a digit:
9 <RETURN>

Enter an integer from 0 to 20
for a station number, enter"R"
to return:
14 <RETURN>

Enter an integer from 0 to 20
for a station number, enter"R"
to return:
R <RETURN>

------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan
8. Return
9. Porcupine Spikes
------------------------------
Enter a digit:
8 <RETURN>

        * * * M-HULL * * *

        *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
4 <RETURN>

Enter a metafile ID number
(11 - 97 and 99):
18 <RETURN>
```

```
        * * * M-HULL * * *

       ** Metafile  Menu **
------------------------------
1. Sectional Area
2. Design Waterline
3. Deck at Edge
4. Bottom Flat
5. Profile
6. Angles of Sections
7. Body Plan

8. All in one Metafile
9. New Metafile
0. Return
------------------------------
Enter a digit:
0 <RETURN>

+++ METAF18 CREATED +++


        * * * M-HULL * * *

        *** MAIN  MENU ***
==============================
1. Title
2. Input
3. Curve Review
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
5 <RETURN>
        * * * M-HULL * * *

        ** Output  Menu **
------------------------------
Where?
1. On Terminal
2. To Files
3. Return
------------------------------
Enter a digit:
2 <RETURN>

Enter file name
(less than 73 characters):
myfile  <RETURN>

------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
3. Hydrostatic Data
```

```
4. Calculated Hull Data
5. Table of Offsets

---  Formatted Output ---
6. MHCP Offsets
7. M-HULL Input File

8. New file
9. Return
------------------------------
Enter a digit:
1 <RETURN>

------------------------------
What?
--- For Design  Review ---
1. Principal Dimensions
2. Control Curve Parameters
3. Hydrostatic Data
4. Calculated Hull Data
5. Table of Offsets

---  Formatted Output ---
6. MHCP Offsets
7. M-HULL Input File

8. New File
9. Return
------------------------------
Enter a digit:
9 <RETURN>

          * * * M-HULL * * *

          *** Main  Menu ***
==============================
1. Title
2. Input
3. Review Curves
4. Metafile
5. Output
6. Stop
==============================
Enter a digit:
6 <RETURN>

Fortran Stops.
```

APPENDIX D

A SAMPLE PARENT HULL DATA FILE

```
  400.000                          ! LOA
  400.000                          ! LWL
   56.000                          ! Maximum beam at deck
   56.000                          ! Maximun Beam on DWL
   20.000                          ! Draft
 8573.398                          ! Displacement, in weight units
   -0.100                          ! LCB, % LWL, +fwd of midship
   -2.136                          ! LCF, % LWL, +fwd of midship
    0.680                          ! CP
    0.985                          ! CX, Maximum sectional area
                                   !     coefficient for given draft
    0.759                          ! CWP
    0.000                          ! Deadrise angle at the station of
                                   !  maximum area
    0.000                          ! Half siding, in linear dimensions
                                   !
                                   ! The Sectional Area curve
    8.699    10.354                ! Fore Stn Mid, Aft Stn Mid
    0.000    45.522                ! FP Area, FP Slope on graph
    0.000     0.000                ! AP Area, AP Slope on graph
    0.800     0.300                ! FP Vector, Fore Mid Vector
    0.700     0.300                ! Aft Mid Vector, AF Vector
                                   !
                                   ! The Design Waterline curve
    7.000    12.354                ! Fore Stn Mid, Aft Stn Mid
    0.001    49.394                ! FP Offset, FP Slope
    0.001    76.628                ! AP Offset, AP Slope
    0.800     0.250                ! FP Vector, Fore Mid Vector
    0.341     1.474                ! Aft Mid Vector, AP Vector
                                   !
                                   ! The Deck at Edge curve
    6.959    14.160                ! Fore Stn Mid, Aft Stn Mid
    0.200    57.564                ! FP Offset, FP Slope
    0.450    65.000                ! AP Offset, AP Slope
                                   !
                                   ! The Profile curve
   35.000    30.000    33.000      ! FP Depth, Mid Depth, AP Depth in
                                   !  linear dimensions
   19.291     1.000                ! Start Rise of Keel, AP Local Ca
                                   !
                                   ! The Bottom Flat curve
    0.263    19.291                ! Fore End H'side Station, Aft End
                                   !  H'side Station
    7.699    11.354                ! Fore Stn Full, Aft Stn Full
    0.263    13.430     0.000      ! Fore End FoB Station, Fore Slope,
                                   !  Fore Halfside
   19.291    18.906     0.000      ! Aft End FoB Station, Aft Slope, Aft
                                   !  Halfside
                                   !
                                   ! The Angles of Sections curves
   90.000    90.000                ! Mid Angle of DWL, Mid Angle of Deck
```

```
  2.000     5.000     7.000   ! Fore Stn Mid of Bottom, Fore Stn Mid
                              !  of DWL, Fore Stn Mid of Deck
 16.000    13.000    13.400   ! Aft Stn Mid of Bottom, Aft Stn Mid
                              !  of DWL, Aft Stn Mid of Deck
  8.000    86.000    75.000   ! FP Angle of Bottom, FP Angle of DWL,
                              !  FP Angle of Deck
  0.000   -20.000   -20.000   ! FP Slope of Bottom, FP Slope of DWL,
                              !  FP Slope of Deck
 15.000    35.000    57.850   ! AP Angle of Bottom, AP Angle of DWL,
                              !  AP Angle of Deck
  0.000     0.000     0.000   ! AP Slope of Bottom, AP Slope of DWL,
                              !  AP Slope of Deck.
```

The M-HULL program uses the following FORTRAN read statements to read the input file:

```
C  READ HULL DIMENSIONS AND FORM COEFFICIENTS:
      READ(ITR,10) LOA
      READ(ITR,10) LWL
      ......
      READ(ITR,10) HALFSIDE
C
C  READ BOUNDARY CONDITIONS OF THE SECTIONAL AREA CURVE:
      READ(ITR,20) FORE_STN_MID, AFT_STN_MID
      READ(ITR,20) AP_AREA, AP_SLOPE
      ......
      READ(ITR,20) AFT_MID_VECTOR, AF_VECTOR
C
C  READ BOUNDARY CONDITIONS OF THE DESIGN WATERLINE CURVE:
      ......


C  READ BOUNDARY CONDITIONS OF THE ANGLES OF SECTION CURVES:
      READ(ITR,20) MID_ANGLE_DWL, MID_ANGLE_DECK
      READ(ITR,30) FORE_STN_BOTTOM, FORE_STN_DWL, FORE_STN_DECK
       ......
      READ(ITR,30) AP_SLOPE_BOTTOM, AP_SLOPE_DWL, AP_SLOPE_DECK
C
C
10    FORMAT( F10.4)
20    FORMAT(2F10.4)
30    FORMAT(3F10.4)
C.
```

APPENDIX E

SAMPLE PROGRAM OUTPUT

```
PRINCIPAL DIMENSIONS FOR:

LOA................... 400.000
LWL................... 400.000
WATERLINE MAX. BEAM...  56.000
DECK MAX. BEAM........  56.000
DEPTH AT FP...........  35.000
DEPTH AT MIDSHIPS.....  30.000
DEPTH AT AP...........  33.000
DRAFT.................  20.000
HALF SIDING at midship in real units =  0.0000
DEADRISE..............  0.0000
DISPLACEMENT (tons)...   8573.
Water Density (tons / unit volume) =  0.02857


Control Curve Parameters:

==== Sectional Area Curve ====

AP Area        = 0.0000000
LCB            = -0.1000000
CP             = 0.6800000
FP Area        = 0.0000000
AP Slope       = 0.0000000
Aft Stn Mid    = 10.35400
Fore Stn Mid   = 8.699000
FP Slope       = 45.52200

--- Vectors Magnitudes ---
AP             = 0.3000000
Aft Mid        = 0.7000000
Fore Mid       = 0.3000000
FP             = 0.8000000
------------------------------

=== Design Waterline Curve ===

AP Offset      = 1.0000000E-03
LCF            = -2.136000
Cwp            = 0.7590000
FP Offset      = 1.0000000E-03
AP Slope       = 76.62800
Aft Stn Mid    = 12.35400
Fore Stn Mid   = 7.000000
FP Slope       = 49.39400

--- Vectors Magnitudes ---
AP             = 1.474000
Aft Mid        = 0.3410000
Fore Mid       = 0.2500000
```

```
FP            = 0.8000000
------------------------------

===== Deck at Edge Curve =====

AP Offset     = 0.4500000
Mid Offset    = 1.000000
FP Offset     = 0.2000000

AP Slope      = 65.00000
Aft Stn Mid   = 14.16000
Fore Stn Mid  = 6.959000
FP Slope      = 57.56400
------------------------------

===== Bottom Flat Curve =====

Aft Halfside    = 0.0000000
Mid Halfside    = 0.0000000
 (fraction of B at LWL)
CX              = 0.9850000
Fore Halfside   = 0.0000000

Aft Slope       = 18.90600
Aft Stn Full    = 11.35400
Fore Stn Full   = 7.699000
Fore Slope      = 13.43000

--- Stations ---
Aft End H"side   = 19.29100
Aft End FoB      = 19.29100
Fore End FoB     = 0.2630000
Fore End H"side  = 0.2630000
------------------------------

======== Profile Curve ========
--- Keel ---
AP Local Ca = 1.000000
Start Rise  = 19.29100

--- Deck ---
AP Depth     = 33.00000
Mid Depth    = 30.00000
FP Depth     = 35.00000

== Angles of Section Curve  ==
--- DWL ---
AP Angle   = 35.00000
Mid Angle  = 90.00000
FP Angle   = 86.00000

AP Slope      = 0.0000000
Aft Stn Mid   = 13.00000
Fore Stn Mid  = 5.000000
FP Slope      = -20.00000

--- Bottom ---
AP Angle      = 15.00000
```

```
Deadrise      = 0.0000000
FP Angle      = 8.000000

AP Slope      = 0.0000000
Aft Stn Mid   = 16.00000
Fore Stn Mid  = 2.000000
FP Slope      = 0.0000000

--- Deck ---
AP Angle      = 57.85000
Mid Angle     = 90.00000
FP Angle      = 75.00000

AP Slope      = 0.0000000
Aft Stn Mid   = 13.40000
Fore Stn Mid  = 7.000000
FP Slope      = -20.00000
------------------------------

HYDROSTATIC DATA FOR:

CB.......    0.670
CX.......    0.985
CWP......    0.759
CP.......    0.680
LCB......   -0.100  (+ FWD. MIDSHIPS)
LCF......   -2.136  (+ FWD. MIDSHIPS)
VCB......   10.583
BM.......   12.022
KM.......   22.606
```

1 CALCULATED HULL DATA FOR:

STATION	AREA	KEEL	BOTTOM FLAT	HALF SIDING	DWL	DECK	SHEER	RADIUS
0.00	0.0000	20.000	0.000	0.000	0.028	5.600	35.000	0.000
1.00	162.2050	0.000	0.676	0.000	4.597	11.128	34.140	0.000
2.00	357.4223	0.000	2.076	0.000	10.089	16.006	33.360	0.000
3.00	549.0128	0.000	4.009	0.000	15.501	20.158	32.660	0.000
4.00	721.7020	0.000	6.451	0.000	20.334	23.509	32.040	0.000
5.00	867.2765	0.000	9.377	0.000	24.253	25.983	31.500	0.000
6.00	980.5087	0.000	12.765	0.000	26.949	27.505	31.040	0.000
7.00	1057.6981	0.000	16.589	0.000	28.000	28.000	30.660	0.000
8.00	1096.8289	0.000	20.652	0.000	28.000	28.000	30.360	7.348
9.00	1103.2000	0.000	21.744	0.000	28.000	28.000	30.140	6.256
10.00	1103.2000	0.000	21.744	0.000	28.000	28.000	30.000	6.256
11.00	1102.1251	0.000	21.547	0.000	28.000	28.000	29.940	6.453
12.00	1092.0662	0.000	20.117	0.000	28.000	28.000	29.960	0.000
13.00	1063.3212	0.000	17.737	0.000	28.033	28.000	30.060	0.000
14.00	1005.9437	0.000	14.733	0.000	27.764	28.000	30.240	0.000
15.00	910.3280	0.000	11.389	0.000	26.675	27.957	30.500	0.000
16.00	768.7708	0.000	7.993	0.000	24.522	27.531	30.840	0.000
17.00	578.7942	0.000	4.830	0.000	21.125	26.252	31.260	0.000
18.00	350.3372	0.000	2.185	0.000	16.273	23.650	31.760	0.000
19.00	121.9929	0.000	0.344	0.000	9.605	19.256	32.340	0.000
20.00	0.0000	20.000	0.000	0.000	0.028	12.600	33.000	0.000

1 CALCULATED HULL DATA FOR:

STATION	VCB	BOTTOM FLAT ANGLE	WATERLINE ANGLE	DECK ANGLE
0.00	0.000	8.000	86.000	75.000
1.00	10.434	4.000	83.710	72.725
2.00	10.689	0.000	84.364	73.660
3.00	10.797	0.000	86.563	76.762
4.00	10.809	0.000	88.908	80.990
5.00	10.752	0.000	90.000	85.301
6.00	10.627	0.000	90.000	88.651
7.00	10.410	0.000	90.000	90.000
8.00	10.177	0.000	90.000	90.000
9.00	10.131	0.000	90.000	90.000
10.00	10.131	0.000	90.000	90.000
11.00	10.139	0.000	90.000	90.000
12.00	10.210	0.000	90.000	90.000
13.00	10.363	0.000	90.000	90.000
14.00	10.574	0.000	86.953	89.251
15.00	10.810	0.000	79.096	85.248
16.00	11.105	0.000	68.352	78.963
17.00	11.539	2.344	56.647	71.739
18.00	12.452	7.500	45.904	64.917
19.00	14.182	12.656	38.046	59.840
20.00	0.000	15.000	35.000	57.850

TABLE OF OFFSETS FOR:

WATERLINE	FP	1	2	3	4	5	6	7	8	9	10
BASELINE	0.000	0.676	2.076	4.009	6.451	9.377	12.765	16.589	20.652	21.744	21.744
0.30	0.000	2.138	4.157	6.247	8.775	11.725	15.080	18.836	22.731	23.658	23.658
0.60	0.000	2.709	5.081	7.366	10.002	12.982	16.297	19.967	23.561	24.417	24.417
0.90	0.000	3.069	5.723	8.202	10.947	13.958	17.234	20.815	24.176	24.976	24.976
1.20	0.000	3.322	6.217	8.884	11.736	14.778	18.016	21.509	24.677	25.428	25.428
1.95	0.000	3.711	7.098	10.199	13.306	16.425	19.576	22.855	25.638	26.282	26.282
2.70	0.000	3.918	7.694	11.177	14.515	17.710	20.786	23.860	26.343	26.891	26.891
3.45	0.000	4.034	8.126	11.943	15.489	18.757	21.768	24.651	26.881	27.335	27.335
4.20	0.000	4.096	8.450	12.556	16.291	19.629	22.584	25.287	27.292	27.652	27.652
4.95	0.000	4.127	8.699	13.056	16.960	20.364	23.271	25.807	27.598	27.862	27.862
5.70	0.000	4.139	8.894	13.466	17.521	20.988	23.855	26.234	27.813	27.975	27.975
6.45	0.000	4.140	9.048	13.804	17.995	21.520	24.354	26.586	27.945	28.000	28.000
7.20	0.000	4.134	9.170	14.083	18.394	21.975	24.780	26.877	27.999	28.000	28.000
8.80	0.000	4.118	9.358	14.529	19.052	22.739	25.498	27.337	28.000	28.000	28.000
10.40	0.000	4.109	9.482	14.826	19.509	23.283	26.012	27.634	28.000	28.000	28.000
12.00	0.000	4.119	9.575	15.024	19.821	23.664	26.375	27.817	28.000	28.000	28.000
13.60	0.000	4.154	9.655	15.159	20.028	23.923	26.625	27.923	28.000	28.000	28.000
15.20	0.000	4.217	9.736	15.256	20.162	24.091	26.788	27.976	28.000	28.000	28.000
16.80	0.000	4.311	9.831	15.336	20.247	24.190	26.886	27.997	28.000	28.000	28.000
18.40	0.000	4.437	9.946	15.413	20.299	24.240	26.935	28.001	28.000	28.000	28.000
20.00	0.028	4.597	10.089	15.501	20.334	24.253	26.949	28.000	28.000	28.000	28.000
21.99	0.339	5.035	10.511	15.832	20.548	24.367	26.990	28.000	28.000	28.000	28.000
23.98	0.938	5.832	11.299	16.501	21.039	24.657	27.092	28.000	28.000	28.000	28.000
25.96	1.739	6.870	12.322	17.378	21.692	25.044	27.226	28.000	28.000	28.000	28.000
27.95	2.658	8.030	13.449	18.334	22.394	25.452	27.361	28.000	28.000	28.000	28.000
SHEER	5.600	11.128	16.006	20.158	23.509	25.983	27.505	28.000	28.000	28.000	28.000

TABLE OF OFFSETS FOR:

WATERLINE	11	12	13	14	15	16	17	18	19	AP
BASELINE	21.547	20.117	17.737	14.733	11.389	7.993	4.830	2.185	0.344	0.000
0.30	23.491	22.231	19.912	16.941	13.602	10.136	6.811	2.991	0.787	0.000
0.60	24.264	23.197	20.956	18.029	14.696	11.147	7.624	3.340	0.947	0.000
0.90	24.834	23.879	21.718	18.839	15.514	11.885	8.169	3.585	1.038	0.000
1.20	25.295	24.412	22.330	19.501	16.187	12.483	8.583	3.781	1.093	0.000
1.95	26.169	25.380	23.491	20.791	17.512	13.648	9.339	4.171	1.150	0.000
2.70	26.796	26.051	24.342	21.776	18.543	14.556	9.909	4.504	1.151	0.000
3.45	27.259	26.544	25.005	22.574	19.396	15.320	10.402	4.821	1.132	0.000
4.20	27.594	26.919	25.538	23.242	20.127	15.992	10.860	5.142	1.112	0.000
4.95	27.822	27.208	25.973	23.812	20.767	16.601	11.308	5.474	1.102	0.000
5.70	27.956	27.432	26.334	24.307	21.337	17.162	11.754	5.823	1.113	0.000
6.45	28.000	27.606	26.635	24.740	21.849	17.688	12.204	6.191	1.149	0.000
7.20	28.000	27.741	26.887	25.121	22.315	18.184	12.662	6.579	1.217	0.000
8.80	28.000	27.930	27.298	25.796	23.181	19.169	13.663	7.476	1.484	0.000
10.40	28.000	28.026	27.579	26.324	23.913	20.076	14.698	8.468	1.943	0.000
12.00	28.000	28.063	27.769	26.739	24.540	20.923	15.756	9.552	2.614	0.000
13.60	28.000	28.065	27.892	27.066	25.084	21.720	16.831	10.726	3.514	0.000
15.20	28.000	28.049	27.967	27.320	25.560	22.474	17.911	11.988	4.655	0.000
16.80	28.000	28.027	28.009	27.515	25.978	23.190	18.992	13.334	6.046	0.000
18.40	28.000	28.008	28.028	27.661	26.348	23.872	20.065	14.763	7.694	0.000
20.00	28.000	28.000	28.033	27.764	26.675	24.522	21.125	16.273	9.605	0.028
21.99	28.000	28.000	28.029	27.852	27.022	25.257	22.340	18.034	11.907	2.695
23.98	28.000	28.000	28.022	27.910	27.305	25.892	23.387	19.504	13.794	5.042
25.96	28.000	28.000	28.012	27.947	27.539	26.443	24.294	20.746	15.358	7.103
27.95	28.000	28.000	28.004	27.973	27.736	26.925	25.092	21.823	16.689	8.911
SHEER	28.000	28.000	28.000	28.000	27.957	27.531	26.252	23.650	19.256	12.600

OFFSETS IN MHCP FORMAT

10 PARENT1 B

20.000	0.005	0.005	400.000	
0.00	0.000	0.000	0	
0.00	0.000	10.000	0	
0.00	0.000	20.000	7777	
0.00	0.339	21.988	0	
0.00	0.938	23.976	0	
0.00	1.739	25.964	0	
0.00	2.658	27.952	0	
0.00	5.600	35.000	8888	
1.00	0.676	0.000	0	
1.00	2.138	0.300	0	
1.00	2.709	0.600	0	
1.00	3.069	0.900	0	
1.00	3.322	1.200	0	
1.00	3.711	1.950	0	
1.00	3.918	2.700	0	
1.00	4.034	3.450	0	
1.00	4.096	4.200	0	
1.00	4.127	4.950	0	
1.00	4.139	5.700	0	
1.00	4.140	6.450	0	
1.00	4.134	7.200	0	
1.00	4.118	8.800	0	
1.00	4.109	10.400	0	
1.00	4.119	12.000	0	
1.00	4.154	13.600	0	
1.00	4.217	15.200	0	
1.00	4.311	16.800	0	
1.00	4.437	18.400	0	
1.00	4.597	20.000	0	
1.00	5.035	21.988	0	
1.00	5.832	23.976	0	
1.00	6.870	25.964	0	
1.00	11.128	34.140	8888	
2.00	2.076	0.000	0	
2.00	4.157	0.300	0	
2.00	5.081	0.600	0	
2.00	5.723	0.900	0	
2.00	6.217	1.200	0	
2.00	7.098	1.950	0	
2.00	7.694	2.700	0	
2.00	8.126	3.450	0	
2.00	8.450	4.200	0	
2.00	8.699	4.950	0	
2.00	8.894	5.700	0	
2.00	9.048	6.450	0	
2.00	9.170	7.200	0	
2.00	9.358	8.800	0	
2.00	9.482	10.400	0	
2.00	9.575	12.000	0	
2.00	9.655	13.600	0	
2.00	9.736	15.200	0	
2.00	9.831	16.800	0	
2.00	9.946	18.400	0	

2.00	10.089	20.000	0
2.00	10.511	21.988	0
2.00	11.299	23.976	0
2.00	12.322	25.964	0
2.00	16.006	33.360	8888
3.00	4.009	0.000	0
3.00	6.247	0.300	0
3.00	7.366	0.600	0
3.00	8.202	0.900	0
3.00	8.884	1.200	0
3.00	10.199	1.950	0
3.00	11.177	2.700	0
3.00	11.943	3.450	0
3.00	12.556	4.200	0
3.00	13.056	4.950	0
3.00	13.466	5.700	0
3.00	13.804	6.450	0
3.00	14.083	7.200	0
3.00	14.529	8.800	0
3.00	14.826	10.400	0
3.00	15.024	12.000	0
3.00	15.159	13.600	0
3.00	15.256	15.200	0
3.00	15.336	16.800	0
3.00	15.413	18.400	0
3.00	15.501	20.000	0
3.00	15.832	21.988	0
3.00	16.501	23.976	0
3.00	17.378	25.964	0
3.00	20.158	32.660	8888
4.00	6.451	0.000	0
4.00	8.775	0.300	0
4.00	10.002	0.600	0
4.00	10.947	0.900	0
4.00	11.736	1.200	0
4.00	13.306	1.950	0
4.00	14.515	2.700	0
4.00	15.489	3.450	0
4.00	16.291	4.200	0
4.00	16.960	4.950	0
4.00	17.521	5.700	0
4.00	17.995	6.450	0
4.00	18.394	7.200	0
4.00	19.052	8.800	0
4.00	19.509	10.400	0
4.00	19.821	12.000	0
4.00	20.028	13.600	0
4.00	20.162	15.200	0
4.00	20.247	16.800	0
4.00	20.299	18.400	0
4.00	20.334	20.000	0
4.00	20.548	21.988	0
4.00	21.039	23.976	0
4.00	21.692	25.964	0
4.00	23.509	32.040	8888
5.00	9.377	0.000	0
5.00	11.725	0.300	0
5.00	12.982	0.600	0

5.00	13.958	0.900	0
5.00	14.778	1.200	0
5.00	16.425	1.950	0
5.00	17.710	2.700	0
5.00	18.757	3.450	0
5.00	19.629	4.200	0
5.00	20.364	4.950	0
5.00	20.988	5.700	0
5.00	21.520	6.450	0
5.00	21.975	7.200	0
5.00	22.739	8.800	0
5.00	23.283	10.400	0
5.00	23.664	12.000	0
5.00	23.923	13.600	0
5.00	24.091	15.200	0
5.00	24.190	16.800	0
5.00	24.240	18.400	0
5.00	24.253	20.000	0
5.00	24.367	21.988	0
5.00	24.657	23.976	0
5.00	25.044	25.964	0
5.00	25.983	31.500	8888
6.00	12.765	0.000	0
6.00	15.080	0.300	0
6.00	16.297	0.600	0
6.00	17.234	0.900	0
6.00	18.016	1.200	0
6.00	19.576	1.950	0
6.00	20.786	2.700	0
6.00	21.768	3.450	0
6.00	22.584	4.200	0
6.00	23.271	4.950	0
6.00	23.855	5.700	0
6.00	24.354	6.450	0
6.00	24.780	7.200	0
6.00	25.498	8.800	0
6.00	26.012	10.400	0
6.00	26.375	12.000	0
6.00	26.625	13.600	0
6.00	26.788	15.200	0
6.00	26.886	16.800	0
6.00	26.935	18.400	0
6.00	26.949	20.000	0
6.00	26.990	21.988	0
6.00	27.092	23.976	0
6.00	27.226	25.964	0
6.00	27.505	31.040	8888
7.00	16.589	0.000	0
7.00	18.836	0.300	0
7.00	19.967	0.600	0
7.00	20.815	0.900	0
7.00	21.509	1.200	0
7.00	22.855	1.950	0
7.00	23.860	2.700	0
7.00	24.651	3.450	0
7.00	25.287	4.200	0
7.00	25.807	4.950	0
7.00	26.234	5.700	0

7.00	26.586	6.450	0
7.00	26.877	7.200	0
7.00	27.337	8.800	0
7.00	27.634	10.400	0
7.00	27.817	12.000	0
7.00	27.923	13.600	0
7.00	27.976	15.200	0
7.00	27.997	16.800	0
7.00	28.001	18.400	0
7.00	28.000	20.000	0
7.00	28.000	21.988	0
7.00	28.000	23.976	0
7.00	28.000	25.964	0
7.00	28.000	30.660	8888
8.00	20.652	0.000	0
8.00	22.731	0.300	0
8.00	23.561	0.600	0
8.00	24.176	0.900	0
8.00	24.677	1.200	0
8.00	25.638	1.950	0
8.00	26.343	2.700	0
8.00	26.881	3.450	0
8.00	27.292	4.200	0
8.00	27.598	4.950	0
8.00	27.813	5.700	0
8.00	27.945	6.450	0
8.00	27.999	7.200	0
8.00	28.000	8.800	0
8.00	28.000	10.400	0
8.00	28.000	12.000	0
8.00	28.000	13.600	0
8.00	28.000	15.200	0
8.00	28.000	16.800	0
8.00	28.000	18.400	0
8.00	28.000	20.000	0
8.00	28.000	21.988	0
8.00	28.000	23.976	0
8.00	28.000	25.964	0
8.00	28.000	30.360	8888
9.00	21.744	0.000	0
9.00	23.658	0.300	0
9.00	24.417	0.600	0
9.00	24.976	0.900	0
9.00	25.428	1.200	0
9.00	26.282	1.950	0
9.00	26.891	2.700	0
9.00	27.335	3.450	0
9.00	27.652	4.200	0
9.00	27.862	4.950	0
9.00	27.975	5.700	0
9.00	28.000	6.450	0
9.00	28.000	7.200	0
9.00	28.000	8.800	0
9.00	28.000	10.400	0
9.00	28.000	12.000	0
9.00	28.000	13.600	0
9.00	28.000	15.200	0
9.00	28.000	16.800	0

9.00	28.000	18.400	0
9.00	28.000	20.000	0
9.00	28.000	21.988	0
9.00	28.000	23.976	0
9.00	28.000	25.964	0
9.00	28.000	30.140	8888
10.00	21.744	0.000	0
10.00	23.658	0.300	0
10.00	24.417	0.600	0
10.00	24.976	0.900	0
10.00	25.428	1.200	0
10.00	26.282	1.950	0
10.00	26.891	2.700	0
10.00	27.335	3.450	0
10.00	27.652	4.200	0
10.00	27.862	4.950	0
10.00	27.975	5.700	0
10.00	28.000	6.450	0
10.00	28.000	7.200	0
10.00	28.000	8.800	0
10.00	28.000	10.400	0
10.00	28.000	12.000	0
10.00	28.000	13.600	0
10.00	28.000	15.200	0
10.00	28.000	16.800	0
10.00	28.000	18.400	0
10.00	28.000	20.000	0
10.00	28.000	21.988	0
10.00	28.000	23.976	0
10.00	28.000	25.964	0
10.00	28.000	30.000	8888
11.00	21.547	0.000	0
11.00	23.491	0.300	0
11.00	24.264	0.600	0
11.00	24.834	0.900	0
11.00	25.295	1.200	0
11.00	26.169	1.950	0
11.00	26.796	2.700	0
11.00	27.259	3.450	0
11.00	27.594	4.200	0
11.00	27.822	4.950	0
11.00	27.956	5.700	0
11.00	28.000	6.450	0
11.00	28.000	7.200	0
11.00	28.000	8.800	0
11.00	28.000	10.400	0
11.00	28.000	12.000	0
11.00	28.000	13.600	0
11.00	28.000	15.200	0
11.00	28.000	16.800	0
11.00	28.000	18.400	0
11.00	28.000	20.000	0
11.00	28.000	21.988	0
11.00	28.000	23.976	0
11.00	28.000	25.964	0
11.00	28.000	29.940	8888
12.00	20.117	0.000	0
12.00	22.231	0.300	0

12.00	23.197	0.600	0
12.00	23.879	0.900	0
12.00	24.412	1.200	0
12.00	25.380	1.950	0
12.00	26.051	2.700	0
12.00	26.544	3.450	0
12.00	26.919	4.200	0
12.00	27.208	4.950	0
12.00	27.432	5.700	0
12.00	27.606	6.450	0
12.00	27.741	7.200	0
12.00	27.930	8.800	0
12.00	28.026	10.400	0
12.00	28.063	12.000	0
12.00	28.065	13.600	0
12.00	28.049	15.200	0
12.00	28.027	16.800	0
12.00	28.008	18.400	0
12.00	28.000	20.000	0
12.00	28.000	21.988	0
12.00	28.000	23.976	0
12.00	28.000	25.964	0
12.00	28.000	29.960	8888
13.00	17.737	0.000	0
13.00	19.912	0.300	0
13.00	20.956	0.600	0
13.00	21.718	0.900	0
13.00	22.330	1.200	0
13.00	23.491	1.950	0
13.00	24.342	2.700	0
13.00	25.005	3.450	0
13.00	25.538	4.200	0
13.00	25.973	4.950	0
13.00	26.334	5.700	0
13.00	26.635	6.450	0
13.00	26.887	7.200	0
13.00	27.298	8.800	0
13.00	27.579	10.400	0
13.00	27.769	12.000	0
13.00	27.892	13.600	0
13.00	27.967	15.200	0
13.00	28.009	16.800	0
13.00	28.028	18.400	0
13.00	28.033	20.000	0
13.00	28.029	21.988	0
13.00	28.022	23.976	0
13.00	28.012	25.964	0
13.00	28.000	30.060	8888
14.00	14.733	0.000	0
14.00	16.941	0.300	0
14.00	18.029	0.600	0
14.00	18.839	0.900	0
14.00	19.501	1.200	0
14.00	20.791	1.950	0
14.00	21.776	2.700	0
14.00	22.574	3.450	0
14.00	23.242	4.200	0
14.00	23.812	4.950	0

14.00	24.307	5.700	0
14.00	24.740	6.450	0
14.00	25.121	7.200	0
14.00	25.796	8.800	0
14.00	26.324	10.400	0
14.00	26.739	12.000	0
14.00	27.066	13.600	0
14.00	27.320	15.200	0
14.00	27.515	16.800	0
14.00	27.661	18.400	0
14.00	27.764	20.000	0
14.00	27.852	21.988	0
14.00	27.910	23.976	0
14.00	27.947	25.964	0
14.00	28.000	30.240	8888
15.00	11.389	0.000	0
15.00	13.602	0.300	0
15.00	14.696	0.600	0
15.00	15.514	0.900	0
15.00	16.187	1.200	0
15.00	17.512	1.950	0
15.00	18.543	2.700	0
15.00	19.396	3.450	0
15.00	20.127	4.200	0
15.00	20.767	4.950	0
15.00	21.337	5.700	0
15.00	21.849	6.450	0
15.00	22.315	7.200	0
15.00	23.181	8.800	0
15.00	23.913	10.400	0
15.00	24.540	12.000	0
15.00	25.084	13.600	0
15.00	25.560	15.200	0
15.00	25.978	16.800	0
15.00	26.348	18.400	0
15.00	26.675	20.000	0
15.00	27.022	21.988	0
15.00	27.305	23.976	0
15.00	27.539	25.964	0
15.00	27.957	30.500	8888
16.00	7.993	0.000	0
16.00	10.136	0.300	0
16.00	11.147	0.600	0
16.00	11.885	0.900	0
16.00	12.483	1.200	0
16.00	13.648	1.950	0
16.00	14.556	2.700	0
16.00	15.320	3.450	0
16.00	15.992	4.200	0
16.00	16.601	4.950	0
16.00	17.162	5.700	0
16.00	17.688	6.450	0
16.00	18.184	7.200	0
16.00	19.169	8.800	0
16.00	20.076	10.400	0
16.00	20.923	12.000	0
16.00	21.720	13.600	0
16.00	22.474	15.200	0

16.00	23.190	16.800	0
16.00	23.872	18.400	0
16.00	24.522	20.000	0
16.00	25.257	21.988	0
16.00	25.892	23.976	0
16.00	26.443	25.964	0
16.00	27.531	30.840	8888
17.00	4.830	0.000	0
17.00	6.811	0.300	0
17.00	7.624	0.600	0
17.00	8.169	0.900	0
17.00	8.583	1.200	0
17.00	9.339	1.950	0
17.00	9.909	2.700	0
17.00	10.402	3.450	0
17.00	10.860	4.200	0
17.00	11.308	4.950	0
17.00	11.754	5.700	0
17.00	12.204	6.450	0
17.00	12.662	7.200	0
17.00	13.663	8.800	0
17.00	14.698	10.400	0
17.00	15.756	12.000	0
17.00	16.831	13.600	0
17.00	17.911	15.200	0
17.00	18.992	16.800	0
17.00	20.065	18.400	0
17.00	21.125	20.000	0
17.00	22.340	21.988	0
17.00	23.387	23.976	0
17.00	24.294	25.964	0
17.00	26.252	31.260	8888
18.00	2.185	0.000	0
18.00	2.991	0.300	0
18.00	3.340	0.600	0
18.00	3.585	0.900	0
18.00	3.781	1.200	0
18.00	4.171	1.950	0
18.00	4.504	2.700	0
18.00	4.821	3.450	0
18.00	5.142	4.200	0
18.00	5.474	4.950	0
18.00	5.823	5.700	0
18.00	6.191	6.450	0
18.00	6.579	7.200	0
18.00	7.476	8.800	0
18.00	8.468	10.400	0
18.00	9.552	12.000	0
18.00	10.726	13.600	0
18.00	11.988	15.200	0
18.00	13.334	16.800	0
18.00	14.763	18.400	0
18.00	16.273	20.000	0
18.00	18.034	21.988	0
18.00	19.504	23.976	0
18.00	20.746	25.964	0
18.00	23.650	31.760	8888
19.00	0.344	0.000	0

19.00	0.787	0.300	0
19.00	0.947	0.600	0
19.00	1.038	0.900	0
19.00	1.093	1.200	0
19.00	1.150	1.950	0
19.00	1.151	2.700	0
19.00	1.132	3.450	0
19.00	1.112	4.200	0
19.00	1.102	4.950	0
19.00	1.113	5.700	0
19.00	1.149	6.450	0
19.00	1.217	7.200	0
19.00	1.484	8.800	0
19.00	1.943	10.400	0
19.00	2.614	12.000	0
19.00	3.514	13.600	0
19.00	4.655	15.200	0
19.00	6.046	16.800	0
19.00	7.694	18.400	0
19.00	9.605	20.000	0
19.00	11.907	21.988	0
19.00	13.794	23.976	0
19.00	15.358	25.964	0
19.00	19.256	32.340	8888
20.00	0.000	20.000	0
20.00	0.028	20.000	0
20.00	2.695	21.988	0
20.00	5.042	23.976	0
20.00	7.103	25.964	0
20.00	8.911	27.952	0
20.00	12.600	33.000	9999

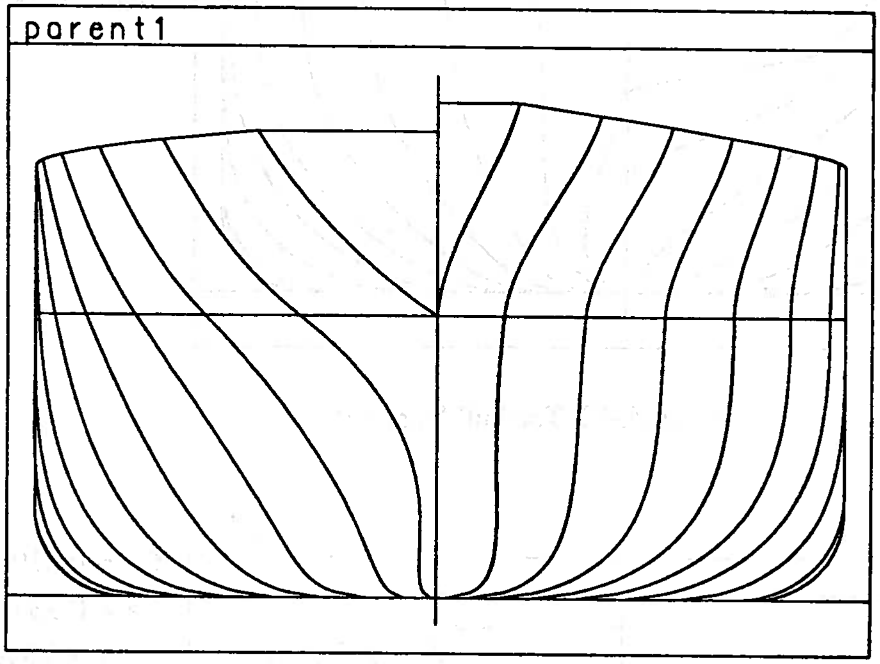
M-HULL Input File

400.000	
400.000	
56.000	
56.000	
20.000	
8573.398	
-0.100	
-2.136	
0.680	
0.985	
0.759	
0.000	
0.000	
8.699	10.354
0.000	45.522
0.000	0.000
0.800	0.300
0.700	0.300
7.000	12.354
0.001	49.394
0.001	76.628
0.800	0.250
0.341	1.474

6.959	14.160	
0.200	57.564	
0.450	65.000	
35.000	30.000	33.000
19.291	1.000	
0.263	19.291	
7.699	11.354	
0.263	13.430	0.000
19.291	18.906	0.000
90.000	90.000	
2.000	5.000	7.000
16.000	13.000	13.400
8.000	86.000	75.000
0.000	-20.000	-20.000
15.000	35.000	57.850
0.000	0.000	0.000

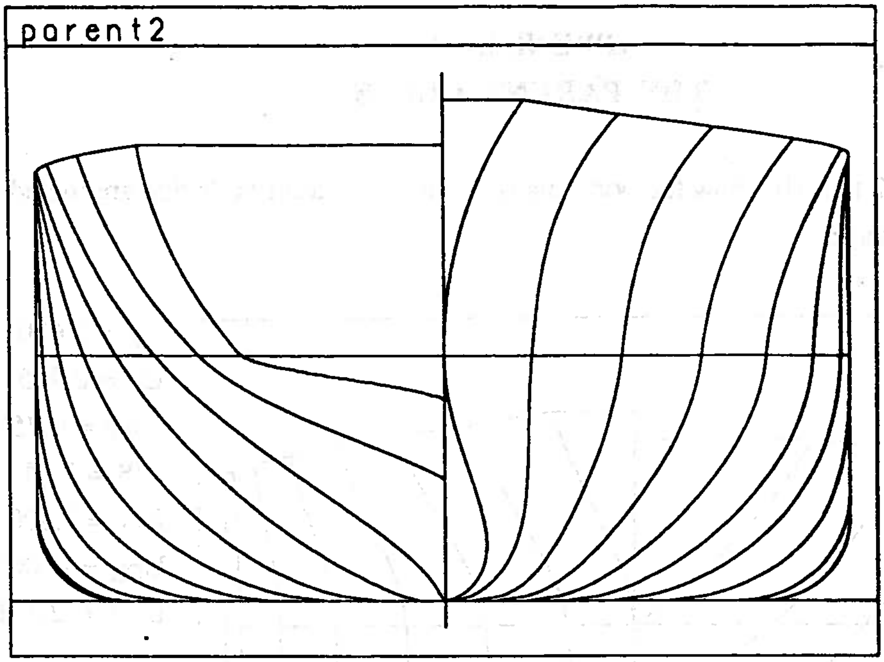
APPENDIX F
THE PARENT HULLS

Figures A-12 to A-16 show the body plans of the five parent hulls that are included in the M-HULL package.



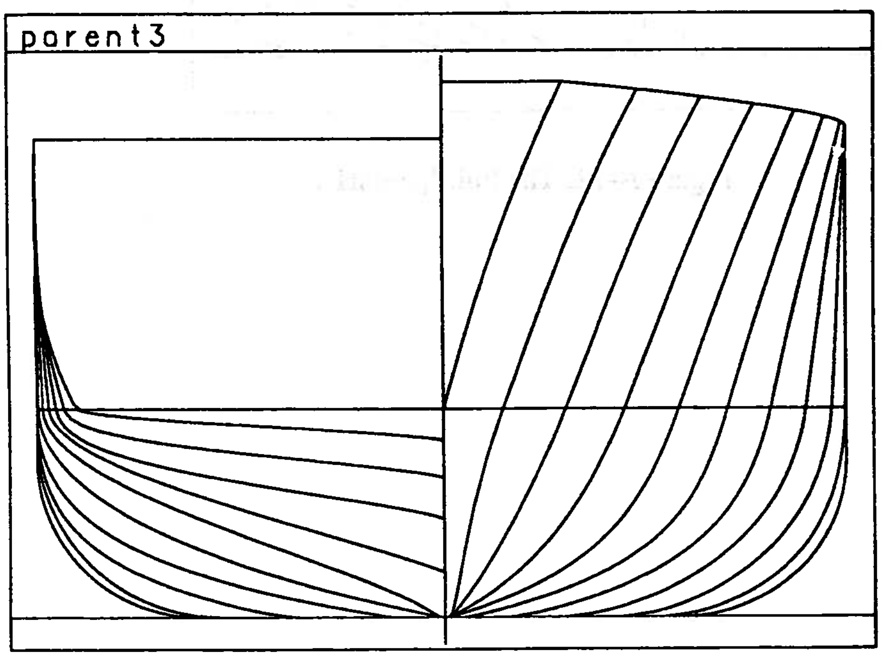
$C_p = 0.680$
$C_x = 0.985$
$C_{wp} = 0.759$
$L/B = 7.143$
$B/T = 2.800$
$L_{CB} = -1.000$
$L_{CF} = -2.136$

Figure A-12. The hull 'parent1'.



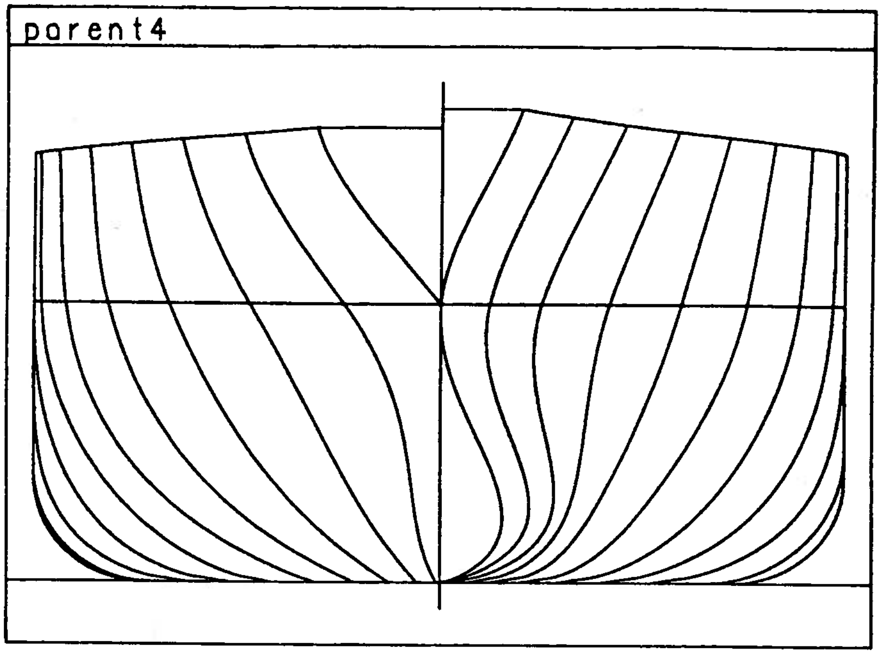
Cp = 0.680
Cx = 0.985
Cwp = 0.810
L/B = 5.636
B/T = 3.260
L_{CB} = -0.100
L_{CF} = -3.000

Figure A-13. The hull 'parent2'.



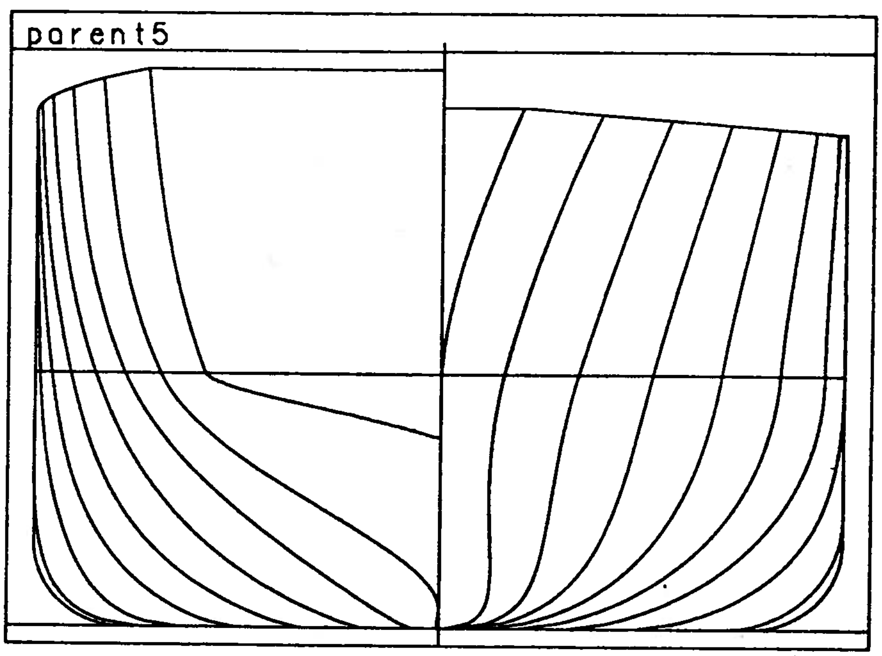
Cp = 0.610
Cx = 0.935
Cwp = 0.810
L/B = 4.214
B/T = 3.798
L_{CB} = -3.000
L_{CF} = -7.700

Figure A-14. The hull 'parent3'.



$C_p = 0.620$
$C_x = 0.978$
$C_{wp} = 0.707$
$L/B = 7.143$
$B/T = 2.800$
$L_{CB} = -1.000$
$L_{CF} = -2.500$

Figure A-15. The hull 'parent4'.



$C_p = 0.695$
$C_x = 0.984$
$C_{wp} = 0.800$
$L/B = 6.390$
$B/T = 3.050$
$L_{CB} = -3.000$
$L_{CF} = -4.750$

Figure A-16. The hull 'parent5'.

ADDENDUM

To: M-HULL users
From: Yifan Chen
Date: October 20, 1992

Since the "M-HULL, AN INTERACTIVE GRAPHICS HULL DESIGN PROGRAM - User's Manual" (the M-HULL user's manual) was published in February, 1991, the M-HULL package has been undergone a series of modifications. The major modifications of the M-HULL program include the reduction of the total number of waterlines, the rearrangement of waterline spacing, the interpolation of two half stations at the bow and stern portions of the hull, and the implementation of an optional bow tip for volume compensation. Some minor user interface modifications have also been made. In addition, the five existing parent hulls have been slightly refined and four new parent hulls have been added into the M-HULL package. Finally, a new workstation assignment file 'wafx' has been installed in the package for running the M-HULL program under the X Window system.

1. Total Number of Waterlines Changed

The number of waterlines (excluding the baseline) used in the M-HULL program to generate offset table and MHCP input file has been reduced from twenty four to seventeen. The spacing of the waterlines is therefore readjusted, too. Table 2 shows the modified table of offsets as compared with the table of offsets listed under Appendix E on pages A35 and A36 of the M-HULL user's manual.

2. Two Half Stations Generated

Two half stations have been implemented. One is located midway between stations 0 and 1, and the other midway between stations 19 and 20. They are indexed as stations 0.5 and 19.5, respectively (see Figure 1). This modification affects both the MHCP input file and the display of the Body Plan on the screen. The offsets of both half stations will be printed into the MHCP input file when it is being generated. Table 3 shows the MHCP input data after the modification. The original MHCP input file is listed on pages A37 through A46 of the M-HULL user's manual. The two half stations are also made visible on the Body Plan for the user. They are drawn in dashed lines instead of solid ones for easy recognition. Note that the porcupine spikes (curve curvature plot) are not allowed to be plotted on the half stations.

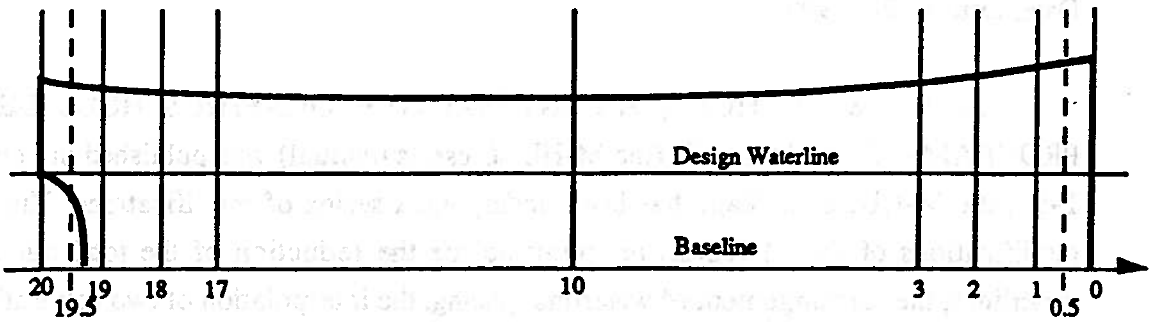


Figure 1. The locations of the half stations (shown in dashed lines).

3. The Five Parent Hulls Refined

As one of the consequences of the implementation of the half stations, the five original parent hulls have been slightly refined to make sure that the profile of the half stations looks reasonable on the Body Plan. The five updated parent hulls are shown in Figures 2 through 6 together with some important hull form parameters.

4. New Hulls Included in the Package

Besides the five original parent hulls, four new hulls have also been made available to the M-HULL user. They are named after 'parent6' through 'parent9'. The Body Plan of these hulls are shown in Figures 9 through 12 together with some important hull form parameters.

5. Option to Create the Bow Tip

The latest version of the M-HULL program provides the user with an option to add a bow tip to the hull for volume compensation. This option is available only when the user chooses to output the offsets to an external datafile in the MHCP format. In such a case, the program will ask the user whether a bow tip needs to be created. If the answer is yes, the program will then let the user input the location of the tip, based on which the profiles of the bow tip portion will be interpolated using explicit quadratic polynomials. The interpolation mechanism guarantees C^1 continuity between the tip portion and the main body of the hull. The results will be shown on both the Profile Curves and Body Plan for user's evaluation. A station midway between the tip and station 0 will also be generated and drawn on the Body Plan. If the results are satisfactory, the program will proceed to create the MHCP file. Otherwise, the user can go back to modify the tip location until he or she is satisfied with the results.

One of the limitations is that the construction of the bow tip part is only temporary. As soon as the user exits the output mode, this part will be lost and will not be visible on any control curve as well as the Body Plan. However, the program offers the user an option to save into a metafile the Profile or Body Plan with the tip portion right after the MHCP file is completed. With the metafile, the user is able to generate printout through LaserWriters as a permanent record (see Figures 2 and 3 for examples).

The following is a sample sequence of using the option of bow tip generation:

```
Add an optional bow tip?(y/n)
Y<RETURN>

Enter bow tip length
(In station spacing unit):
0.4<RETURN>

Enter bow tip height
(Sheer at FP=35.00):
35.4<RETURN>

PLEASE CHECK RESULT ON
PROFILE AND BODY PLAN ...

Modify bow tip parameters?(y/n)
N<RETURN>

Enter Ship ID Number (0-9999):
....

CREATING MHCP DATAFILE...

Save Profile with bow tip
into a metafile?(y/n)
Y<RETURN>

Enter a metafile ID number
(11-97 & 99):
22<RETURN>

Save Body Plan with bow tip
into a metafile?(y/n)
Y<RETURN>
```

```
Enter a metafile ID number
(11-97 & 99):
23<RETURN>

CREATING METAF FOR PROFILE...

CREATING METAF FOR BODY PLAN...
```

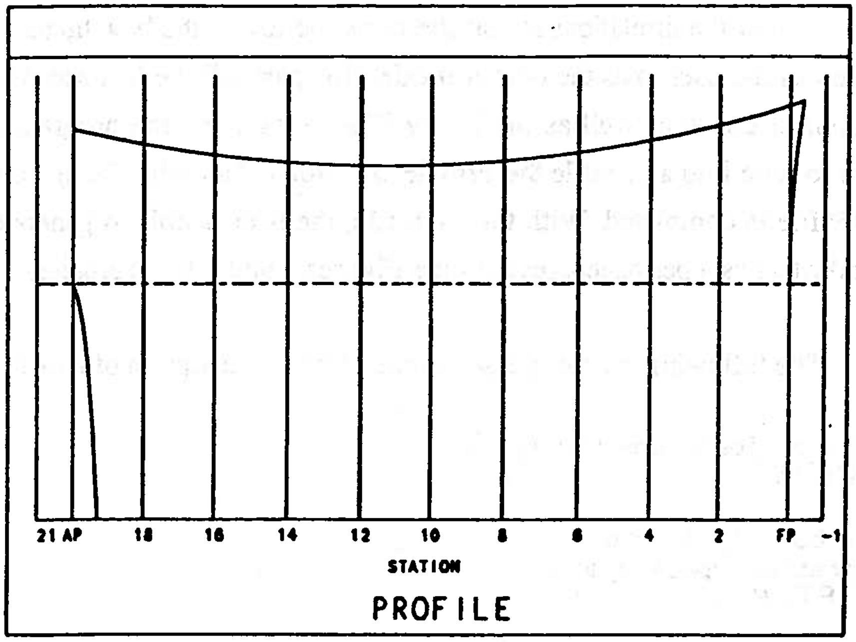


Figure 2. Profile of a parent hull with a bow tip.

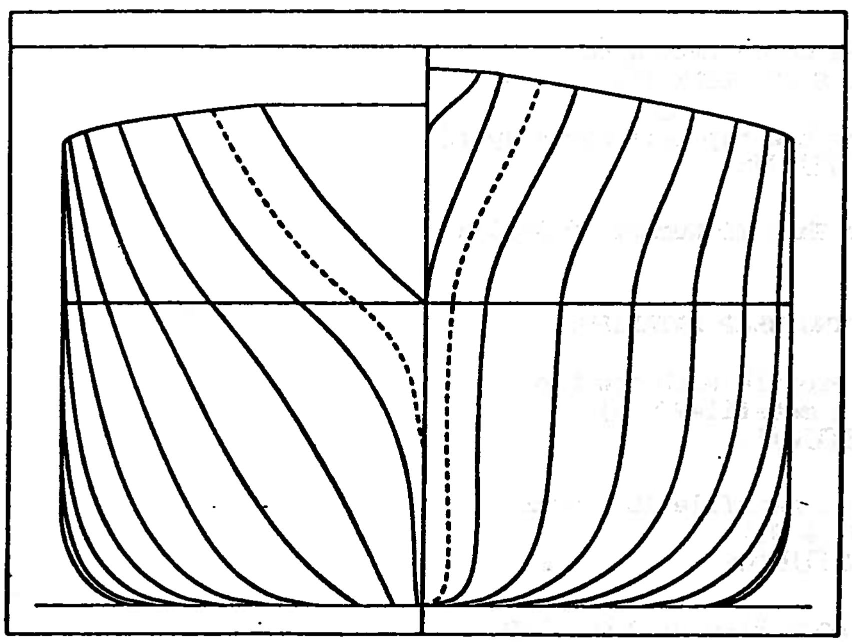


Figure 3. Body Plan of a parent hull with a bow tip.

To create a satisfactory bow tip portion, it is important to give a reasonable estimation for the location of the tip. We recommend that the user estimate the length of the bow tip based on the shape of the Deck at Edge curve near the bow and the height of the tip the shape of the sheer curve near the bow.

Two new stations located at the tip of the bow and the midway between the tip and station 0 will be added into the MHCP file. In order to build a correct transition of the bow profile from the added bow tip to the main body of the hull, two additional stations are created which are very closely spaced and located almost at station 0. These stations, together with station 0, act like the interface between the bow tip and the main body. An example is given in the sample MHCP file shown from pages 8 to 15.

6. Minor Changes of User Interface

The process of creating a MHCP input file originally begins with a request (see page 18 of the M-HULL user's manual):

```
Enter Ship Number
(an integer less than 10000):
```

which has been changed into the following request:

```
Enter Ship ID Number (0-9999):.
```

The prompt

```
Enter "M" for metric unit
system;  enter others for
British unit system:
```

has been modified into:

```
Enter "M" for Metric unit
system. Otherwise CR for
British unit system:
```

7. Running M-HULL Under X Windows

On those Apollo workstations with Domain/OS SR10.2 operating system, one can run the M-HULL program directly under the regular Apollo Domain windows. On the machines currently running Domain/OS SR10.3 operating system, however, the M-HULL program must be executed under the X Window system. Most of the Apollo workstations in the CAEN labs are now running SR10.3. Table 1 shows some of the machines in the NAME building, their models, operating systems, and their X Window performances.

To activate an X Window on machines running SR10.3 operating system, enter the following command after the UNIX prompt % under the regular Apollo window:

% x11start<RETURN>

Note that it takes time to initialize a fully functional X Window, especially on the Domain 3000 machines where sometimes the user has to wait more than fifteen minutes to get an X Window. Once an X Window is created, the M-HULL program can be executed in the same manner as described in page 6 of the M-HULL user's manual, except that the workstation assignment file 'waf' must be replaced with 'wafx' in order to obtain a proper layout of M-HULL's two graphics windows.

NO	NAME	MODEL	OPERATING SYSTEM	LOCATION IN NAME	COMMAND TO GET X	X PERFORMANCE
1	YACHT	DOMAIN 3500	SR10.2	ROOM 203	xterm	-
2	NEPTUNE	DOMAIN 3500	SR10.2	ROOM 203	xterm	-
3	MARINA*	DOMAIN 3500	SR10.2	ROOM 229	xterm	-
4	CHAOS	DOMAIN 3500	SR10.2	ROOM 229	xterm	-
5	CLIPPER	DOMAIN 5500	SR10.3	ROOM 236C	x11start	GOOD
6	SCUTTLE	DOMAIN 3000	SR10.3	ROOM 236C	x11start	FAIR
7	TORPEDO	DOMAIN 3000	SR10.3	ROOM 236C	x11start	VERY POOR
8	PLIMSOLL	DOMAIN 3000	SR10.3	ROOM 236C	x11start	VERY POOR

* NOTE: M-HULL currently does not work on MARINA.

Table 1. Some Apollo workstations in the NAME building.

TABLE OF OFFSETS FOR:

WATERLINE	FP	1	2	3	4	5	6	7	8	9	10
BASELINE	0.000	0.671	2.053	3.961	6.378	9.286	12.669	16.509	20.618	21.744	21.744
1.00	0.000	3.154	5.871	8.388	11.148	14.157	17.422	20.993	24.328	25.137	25.137
2.00	0.000	3.717	7.109	10.214	13.319	16.436	19.588	22.874	25.671	26.329	26.329
3.00	0.000	3.959	7.844	11.444	14.853	18.075	21.133	24.152	26.559	27.086	27.086
4.00	0.000	4.068	8.332	12.344	16.020	19.339	22.320	25.092	27.180	27.579	27.579
5.00	0.000	4.113	8.675	13.027	16.933	20.343	23.260	25.807	27.605	27.873	27.873
6.00	0.000	4.125	8.922	13.554	17.658	21.152	24.018	26.358	27.869	27.995	27.995
7.00	0.000	4.122	9.105	13.963	18.238	21.809	24.634	26.784	27.990	28.000	28.000
8.00	0.000	4.113	9.242	14.283	18.703	22.343	25.135	27.115	28.000	28.000	28.000
10.00	0.000	4.099	9.430	14.728	19.373	23.131	25.877	27.562	28.000	28.000	28.000
12.00	0.000	4.112	9.557	15.001	19.795	23.642	26.361	27.812	28.000	28.000	28.000
14.00	0.000	4.163	9.664	15.172	20.053	23.960	26.664	27.938	28.000	28.000	28.000
16.00	0.000	4.258	9.777	15.291	20.203	24.142	26.840	27.989	28.000	28.000	28.000
18.00	0.000	4.402	9.914	15.392	20.286	24.230	26.926	28.001	28.000	28.000	28.000
20.00	0.000	4.597	10.089	15.501	20.334	24.253	26.949	28.000	28.000	28.000	28.000
22.49	0.465	5.205	10.679	15.973	20.649	24.426	27.011	28.000	28.000	28.000	28.000
24.97	1.318	6.328	11.789	16.922	21.352	24.843	27.157	28.000	28.000	28.000	28.000
27.46	2.421	7.735	13.165	18.095	22.220	25.352	27.329	28.000	28.000	28.000	28.000
SHEER	5.600	11.128	16.006	20.158	23.509	25.903	27.505	28.000	28.000	28.000	28.000

TABLE OF OFFSETS FOR:

WATERLINE	11	12	13	14	15	16	17	18	19	AP
BASELINE	21.627	20.450	18.199	15.210	11.803	8.295	5.005	2.249	0.348	0.000
1.00	25.054	24.341	22.340	19.523	16.154	12.365	6.620	2.803	0.485	0.000
2.00	26.263	25.646	23.904	21.281	17.973	13.950	7.991	3.379	0.579	0.000
3.00	27.034	26.430	24.924	22.494	19.263	15.079	9.107	3.950	0.641	0.000
4.00	27.542	26.954	25.660	23.419	20.276	15.997	10.244	4.521	0.695	0.000
5.00	27.850	27.319	26.214	24.156	21.112	16.791	11.192	5.095	0.760	0.000
6.00	27.989	27.577	26.641	24.760	21.822	17.506	12.051	5.679	0.851	0.000
7.00	28.000	27.758	26.974	25.263	22.438	18.164	12.841	6.276	0.903	0.000
8.00	28.000	27.885	27.235	25.686	22.980	18.780	13.575	6.889	1.166	0.000
10.00	28.000	28.023	27.600	26.350	23.894	19.917	14.927	8.177	1.721	0.000
12.00	28.000	28.068	27.818	26.835	24.642	20.961	16.181	9.560	2.572	0.000
14.00	28.000	28.063	27.941	27.190	25.268	21.933	17.393	11.053	3.759	0.000
16.00	28.000	28.037	28.003	27.449	25.[illegible]2	22.846	18.603	12.664	5.314	0.000
18.00	28.000	28.011	28.028	27.635	26.266	23.707	19.840	14.403	7.257	0.000
20.00	28.000	28.000	28.033	27.764	26.675	24.522	21.125	16.273	9.605	0.000
22.49	28.000	28.000	28.028	27.869	27.098	25.424	22.617	18.426	12.414	3.311
24.97	28.000	28.000	28.017	27.931	27.428	26.177	23.856	20.150	14.611	6.186
27.46	28.000	28.000	28.005	27.967	27.690	26.810	24.901	21.566	16.373	8.480
SHEER	28.000	28.000	28.000	28.000	27.957	27.531	26.252	23.650	19.256	12.600

Table 2. Table of offsets.

```
  1  parent1                       B
   20.000      0.005      0.005   400.000
-0.400   0.010 35.360     0
-0.400   0.010 35.380     0
-0.400   0.010 35.400  8888
-0.200   0.010 30.889     0
-0.200   0.612 31.965     0
-0.200   1.910 33.040     0
-0.200   3.248 34.115     0
-0.200   3.980 35.190  8888
 0.000   0.001 20.000     0
 0.000   0.465 22.485     0
 0.000   1.318 24.970     0
 0.000   2.421 27.455     0
 0.000   5.600 35.000  8888
 0.001   0.300  0.000     0
 0.001   0.300 10.000     0
 0.001   0.300 20.000  7777
 0.001   0.465 22.485     0
 0.001   1.318 24.970     0
 0.001   2.421 27.455     0
 0.001   5.600 35.000  8888
 0.002   0.300  0.000     0
 0.002   0.300 10.000     0
 0.002   0.300 20.000  7777
 0.002   0.465 22.485     0
 0.002   1.318 24.970     0
 0.002   2.421 27.455     0
 0.002   5.600 35.000  8888
 0.500   0.300  0.000     0
 0.500   1.602  1.000     0
 0.500   1.879  2.000     0
 0.500   1.968  3.000     0
 0.500   1.980  4.000     0
 0.500   1.957  5.000     0
 0.500   1.919  6.000     0
 0.500   1.875  7.000     0
 0.500   1.833  8.000     0
 0.500   1.765 10.000     0
 0.500   1.733 12.000     0
 0.500   1.746 14.000     0
 0.500   1.809 16.000     0
 0.500   1.923 18.000     0
 0.500   2.092 20.000     0
 0.500   2.646 22.485     0
 0.500   3.684 24.970     0
 0.500   4.999 27.455     0
 0.500   8.441 34.560  8888
 1.000   0.671  0.000     0
 1.000   3.154  1.000     0
 1.000   3.717  2.000     0
 1.000   3.959  3.000     0
 1.000   4.068  4.000     0
 1.000   4.113  5.000     0
 1.000   4.125  6.000     0
 1.000   4.122  7.000     0
 1.000   4.113  8.000     0
 1.000   4.099 10.000     0
 1.000   4.112 12.000     0
```

Table 3. The MHCP input data file.

1.000	4.163	14.000	0
1.000	4.258	16.000	0
1.000	4.402	18.000	0
1.000	4.597	20.000	0
1.000	5.205	22.485	0
1.000	6.328	24.970	0
1.000	7.735	27.455	0
1.000	11.128	34.140	8888
2.000	2.053	0.000	0
2.000	5.871	1.000	0
2.000	7.109	2.000	0
2.000	7.844	3.000	0
2.000	8.332	4.000	0
2.000	8.675	5.000	0
2.000	8.922	6.000	0
2.000	9.105	7.000	0
2.000	9.242	8.000	0
2.000	9.430	10.000	0
2.000	9.557	12.000	0
2.000	9.664	14.000	0
2.000	9.777	16.000	0
2.000	9.914	18.000	0
2.000	10.089	20.000	0
2.000	10.679	22.485	0
2.000	11.789	24.970	0
2.000	13.165	27.455	0
2.000	16.006	33.360	8888
3.000	3.961	0.000	0
3.000	8.388	1.000	0
3.000	10.214	2.000	0
3.000	11.444	3.000	0
3.000	12.344	4.000	0
3.000	13.027	5.000	0
3.000	13.554	6.000	0
3.000	13.963	7.000	0
3.000	14.283	8.000	0
3.000	14.728	10.000	0
3.000	15.001	12.000	0
3.000	15.172	14.000	0
3.000	15.291	16.000	0
3.000	15.392	18.000	0
3.000	15.501	20.000	0
3.000	15.973	22.485	0
3.000	16.922	24.970	0
3.000	18.095	27.455	0
3.000	20.158	32.660	8888
4.000	6.378	0.000	0
4.000	11.148	1.000	0
4.000	13.319	2.000	0
4.000	14.853	3.000	0
4.000	16.020	4.000	0
4.000	16.933	5.000	0
4.000	17.658	6.000	0
4.000	18.238	7.000	0
4.000	18.703	8.000	0
4.000	19.373	10.000	0
4.000	19.795	12.000	0
4.000	20.053	14.000	0
4.000	20.203	16.000	0

Table 3. The MHCP input data file (continued).

4.000	20.286	18.000	0
4.000	20.334	20.000	0
4.000	20.649	22.485	0
4.000	21.352	24.970	0
4.000	22.220	27.455	0
4.000	23.509	32.040	8888
5.000	9.286	0.000	0
5.000	14.157	1.000	0
5.000	16.436	2.000	0
5.000	18.075	3.000	0
5.000	19.339	4.000	0
5.000	20.343	5.000	0
5.000	21.152	6.000	0
5.000	21.809	7.000	0
5.000	22.343	8.000	0
5.000	23.131	10.000	0
5.000	23.642	12.000	0
5.000	23.960	14.000	0
5.000	24.142	16.000	0
5.000	24.230	18.000	0
5.000	24.253	20.000	0
5.000	24.426	22.485	0
5.000	24.843	24.970	0
5.000	25.352	27.455	0
5.000	25.983	31.500	8888
6.000	12.669	0.000	0
6.000	17.422	1.000	0
6.000	19.588	2.000	0
6.000	21.133	3.000	0
6.000	22.320	4.000	0
6.000	23.260	5.000	0
6.000	24.018	6.000	0
6.000	24.634	7.000	0
6.000	25.135	8.000	0
6.000	25.877	10.000	0
6.000	26.361	12.000	0
6.000	26.664	14.000	0
6.000	26.840	16.000	0
6.000	26.926	18.000	0
6.000	26.949	20.000	0
6.000	27.011	22.485	0
6.000	27.157	24.970	0
6.000	27.329	27.455	0
6.000	27.505	31.040	8888
7.000	16.509	0.000	0
7.000	20.993	1.000	0
7.000	22.874	2.000	0
7.000	24.152	3.000	0
7.000	25.092	4.000	0
7.000	25.807	5.000	0
7.000	26.358	6.000	0
7.000	26.784	7.000	0
7.000	27.115	8.000	0
7.000	27.562	10.000	0
7.000	27.812	12.000	0
7.000	27.938	14.000	0
7.000	27.989	16.000	0
7.000	28.001	18.000	0
7.000	28.000	20.000	0

Table 3. The MHCP input data file (continued).

7.000	28.000	22.485	0
7.000	28.000	24.970	0
7.000	28.000	27.455	0
7.000	28.000	30.660	8888
8.000	20.618	0.000	0
8.000	24.328	1.000	0
8.000	25.671	2.000	0
8.000	26.559	3.000	0
8.000	27.180	4.000	0
8.000	27.605	5.000	0
8.000	27.869	6.000	0
8.000	27.990	7.000	0
8.000	28.000	8.000	0
8.000	28.000	10.000	0
8.000	28.000	12.000	0
8.000	28.000	14.000	0
8.000	28.000	16.000	0
8.000	28.000	18.000	0
8.000	28.000	20.000	0
8.000	28.000	22.485	0
8.000	28.000	24.970	0
8.000	28.000	27.455	0
8.000	28.000	30.360	8888
9.000	21.744	0.000	0
9.000	25.137	1.000	0
9.000	26.329	2.000	0
9.000	27.086	3.000	0
9.000	27.579	4.000	0
9.000	27.873	5.000	0
9.000	27.995	6.000	0
9.000	28.000	7.000	0
9.000	28.000	8.000	0
9.000	28.000	10.000	0
9.000	28.000	12.000	0
9.000	28.000	14.000	0
9.000	28.000	16.000	0
9.000	28.000	18.000	0
9.000	28.000	20.000	0
9.000	28.000	22.485	0
9.000	28.000	24.970	0
9.000	28.000	27.455	0
9.000	28.000	30.140	8888
10.000	21.744	0.000	0
10.000	25.137	1.000	0
10.000	26.329	2.000	0
10.000	27.086	3.000	0
10.000	27.579	4.000	0
10.000	27.873	5.000	0
10.000	27.995	6.000	0
10.000	28.000	7.000	0
10.000	28.000	8.000	0
10.000	28.000	10.000	0
10.000	28.000	12.000	0
10.000	28.000	14.000	0
10.000	28.000	16.000	0
10.000	28.000	18.000	0
10.000	28.000	20.000	0
10.000	28.000	22.485	0
10.000	28.000	24.970	0

Table 3. The MHCP input data file (continued).

10.000	28.000	27.455	0
10.000	28.000	30.000	8888
11.000	21.627	0.000	0
11.000	25.054	1.000	0
11.000	26.263	2.000	0
11.000	27.034	3.000	0
11.000	27.542	4.000	0
11.000	27.850	5.000	0
11.000	27.989	6.000	0
11.000	28.000	7.000	0
11.000	28.000	8.000	0
11.000	28.000	10.000	0
11.000	28.000	12.000	0
11.000	28.000	14.000	0
11.000	28.000	16.000	0
11.000	28.000	18.000	0
11.000	28.000	20.000	0
11.000	28.000	22.485	0
11.000	28.000	24.970	0
11.000	28.000	27.455	0
11.000	28.000	29.940	8888
12.000	20.450	0.000	0
12.000	24.341	1.000	0
12.000	25.646	2.000	0
12.000	26.430	3.000	0
12.000	26.954	4.000	0
12.000	27.319	5.000	0
12.000	27.577	6.000	0
12.000	27.758	7.000	0
12.000	27.885	8.000	0
12.000	28.023	10.000	0
12.000	28.068	12.000	0
12.000	28.063	14.000	0
12.000	28.037	16.000	0
12.000	28.011	18.000	0
12.000	28.000	20.000	0
12.000	28.000	22.485	0
12.000	28.000	24.970	0
12.000	28.000	27.455	0
12.000	28.000	29.960	8888
13.000	18.199	0.000	0
13.000	22.340	1.000	0
13.000	23.904	2.000	0
13.000	24.924	3.000	0
13.000	25.660	4.000	0
13.000	26.214	5.000	0
13.000	26.641	6.000	0
13.000	26.974	7.000	0
13.000	27.235	8.000	0
13.000	27.600	10.000	0
13.000	27.818	12.000	0
13.000	27.941	14.000	0
13.000	28.003	16.000	0
13.000	28.028	18.000	0
13.000	28.033	20.000	0
13.000	28.028	22.485	0
13.000	28.017	24.970	0
13.000	28.005	27.455	0
13.000	28.000	30.060	8888

Table 3. The MHCP input data file (continued).

14.000	15.210	0.000	0
14.000	19.523	1.000	0
14.000	21.281	2.000	0
14.000	22.494	3.000	0
14.000	23.419	4.000	0
14.000	24.156	5.000	0
14.000	24.760	6.000	0
14.000	25.263	7.000	0
14.000	25.686	8.000	0
14.000	26.350	10.000	0
14.000	26.835	12.000	0
14.000	27.190	14.000	0
14.000	27.449	16.000	0
14.000	27.635	18.000	0
14.000	27.764	20.000	0
14.000	27.869	22.485	0
14.000	27.931	24.970	0
14.000	27.967	27.455	0
14.000	28.000	30.240	8888
15.000	11.803	0.000	0
15.000	16.154	1.000	0
15.000	17.973	2.000	0
15.000	19.263	3.000	0
15.000	20.276	4.000	0
15.000	21.112	5.000	0
15.000	21.822	6.000	0
15.000	22.438	7.000	0
15.000	22.980	8.000	0
15.000	23.894	10.000	0
15.000	24.642	12.000	0
15.000	25.268	14.000	0
15.000	25.802	16.000	0
15.000	26.266	18.000	0
15.000	26.675	20.000	0
15.000	27.098	22.485	0
15.000	27.428	24.970	0
15.000	27.690	27.455	0
15.000	27.957	30.500	8888
16.000	8.295	0.000	0
16.000	12.365	1.000	0
16.000	13.950	2.000	0
16.000	15.079	3.000	0
16.000	15.997	4.000	0
16.000	16.791	5.000	0
16.000	17.506	6.000	0
16.000	18.164	7.000	0
16.000	18.780	8.000	0
16.000	19.917	10.000	0
16.000	20.961	12.000	0
16.000	21.933	14.000	0
16.000	22.846	16.000	0
16.000	23.707	18.000	0
16.000	24.522	20.000	0
16.000	25.424	22.485	0
16.000	26.177	24.970	0
16.000	26.810	27.455	0
16.000	27.531	30.840	8888
17.000	5.005	0.000	0
17.000	6.620	1.000	0

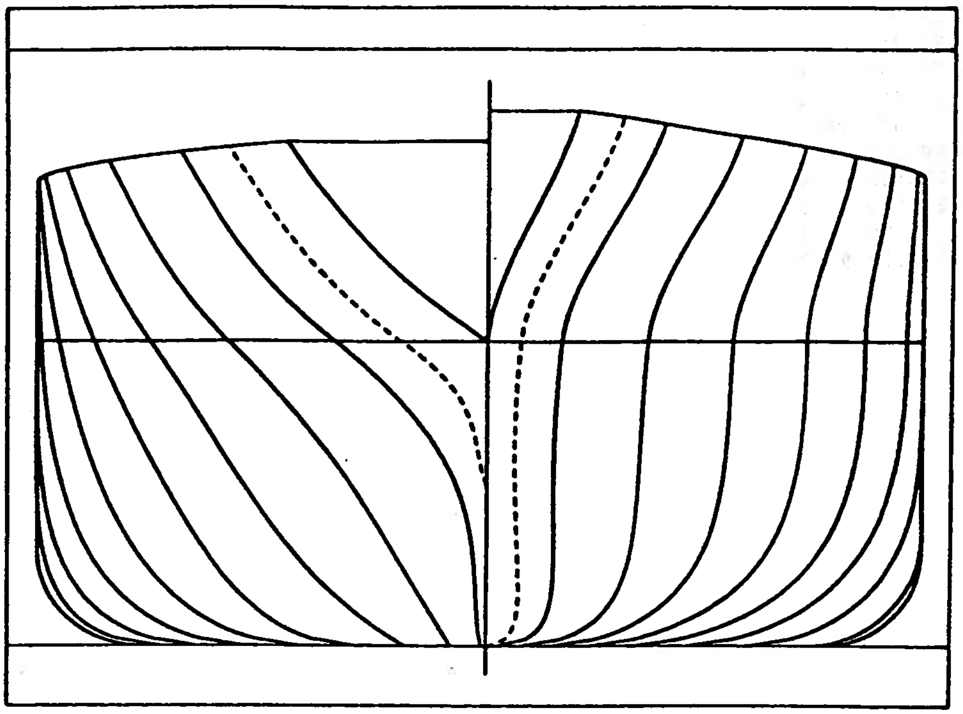
Table 3. The MHCP input data file (continued).

17.000	7.991	2.000	0
17.000	9.187	3.000	0
17.000	10.244	4.000	0
17.000	11.192	5.000	0
17.000	12.051	6.000	0
17.000	12.841	7.000	0
17.000	13.575	8.000	0
17.000	14.927	10.000	0
17.000	16.181	12.000	0
17.000	17.393	14.000	0
17.000	18.603	16.000	0
17.000	19.840	18.000	0
17.000	21.125	20.000	0
17.000	22.617	22.485	0
17.000	23.856	24.970	0
17.000	24.901	27.455	0
17.000	26.252	31.260	8888
18.000	2.249	0.000	0
18.000	2.803	1.000	0
18.000	3.379	2.000	0
18.000	3.950	3.000	0
18.000	4.521	4.000	0
18.000	5.095	5.000	0
18.000	5.679	6.000	0
18.000	6.276	7.000	0
18.000	6.889	8.000	0
18.000	8.177	10.000	0
18.000	9.560	12.000	0
18.000	11.053	14.000	0
18.000	12.664	16.000	0
18.000	14.403	18.000	0
18.000	16.273	20.000	0
18.000	18.426	22.485	0
18.000	20.150	24.970	0
18.000	21.566	27.455	0
18.000	23.650	31.760	8888
19.000	0.348	0.000	0
19.000	0.485	1.000	0
19.000	0.579	2.000	0
19.000	0.641	3.000	0
19.000	0.695	4.000	0
19.000	0.760	5.000	0
19.000	0.851	6.000	0
19.000	0.983	7.000	0
19.000	1.166	8.000	0
19.000	1.721	10.000	0
19.000	2.572	12.000	0
19.000	3.759	14.000	0
19.000	5.314	16.000	0
19.000	7.257	18.000	0
19.000	9.605	20.000	0
19.000	12.414	22.485	0
19.000	14.611	24.970	0
19.000	16.373	27.455	0
19.000	19.256	32.340	8888
19.500	0.300	10.518	0
19.500	0.439	12.000	0
19.500	0.826	14.000	0
19.500	1.583	16.000	0

Table 3. The MHCP input data file (continued).

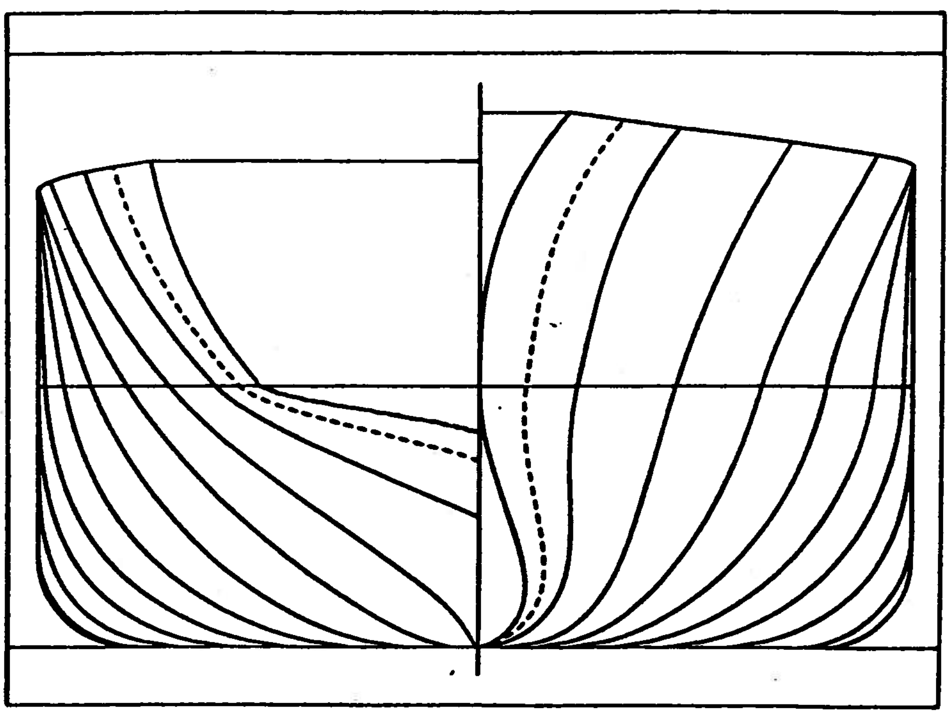
19.500	3.034	18.000	0
19.500	5.343	20.000	0
19.500	8.422	22.485	0
19.500	10.875	24.970	0
19.500	12.864	27.455	0
19.500	16.240	32.660	8888
20.000	0.300	20.000	0
20.000	3.311	22.485	0
20.000	6.106	24.970	0
20.000	8.480	27.455	0
20.000	12.600	33.000	9999

Table 3. The MHCP input data file (continued).



C_p=0.680
C_x=0.985
C_{wp}=0.759
L/B=0.7143
B/T=2.800
L_{CB}=-1.000
L_{CF}=-2.136

Figure 4. The hull 'parent1'.



C_p=0.680
C_x=0.985
C_{wp}=0.810
L/B=5.636
B/T=3.260
L_{CB}=-0.100
L_{CF}=-3.000

Figure 5. The hull 'parent2'.

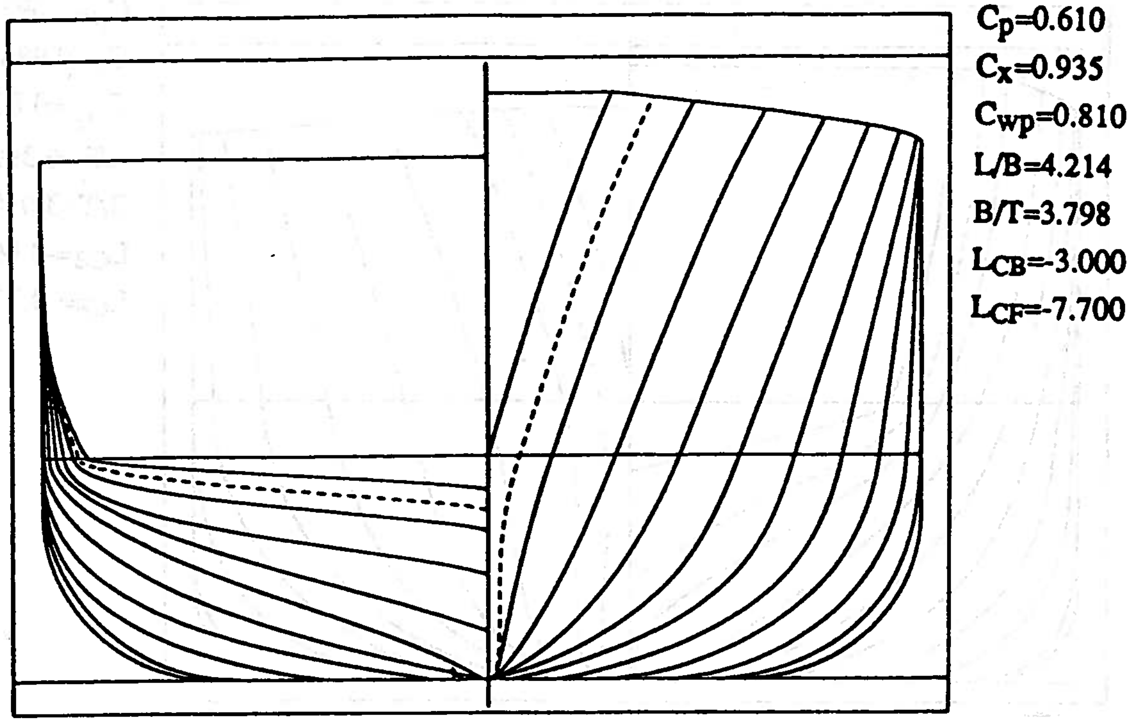


Figure 6. The hull 'parent3'.

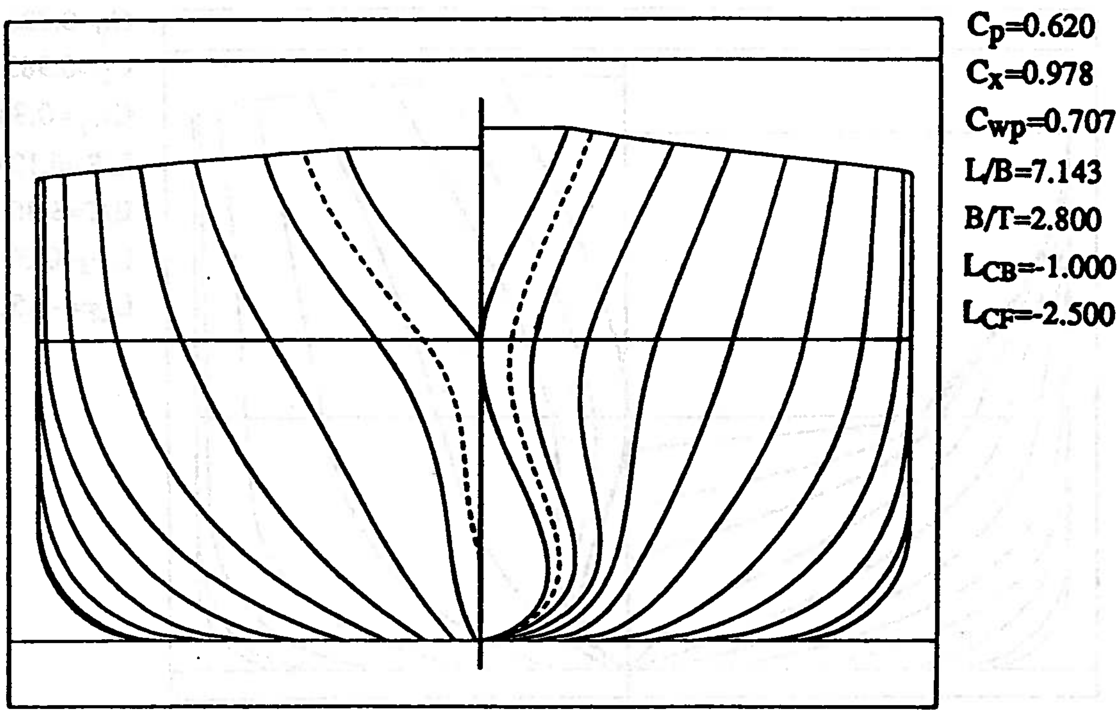


Figure 7. The hull 'parent4'.

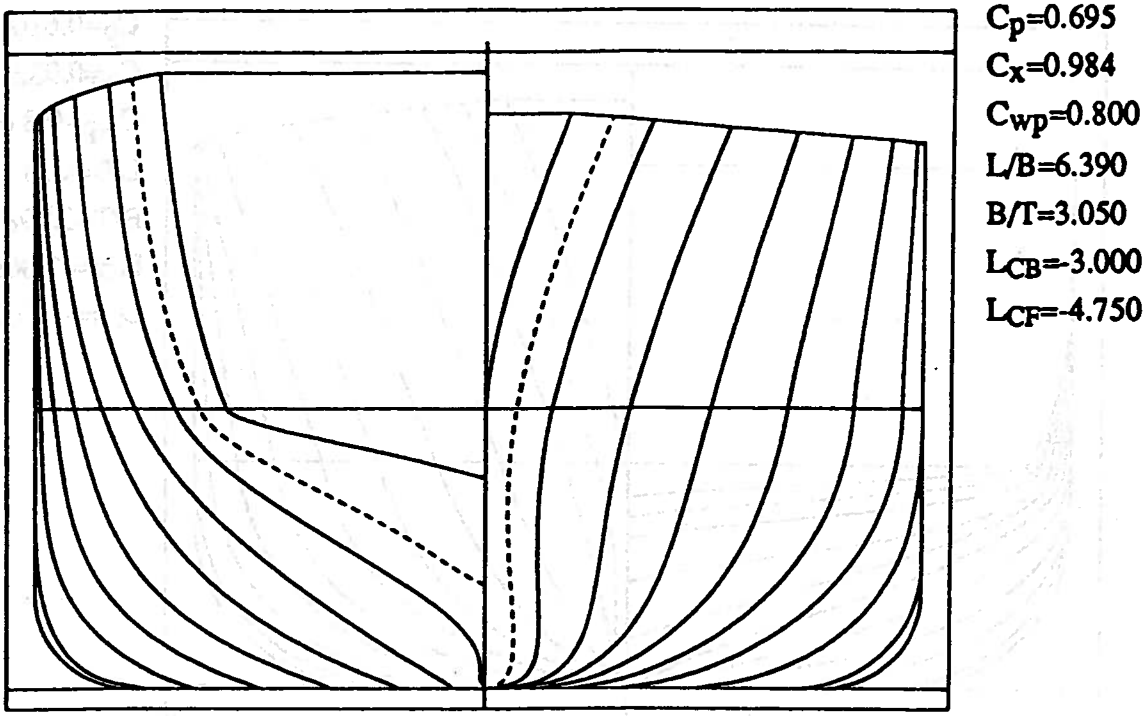


Figure 8. The hull 'parent5'.

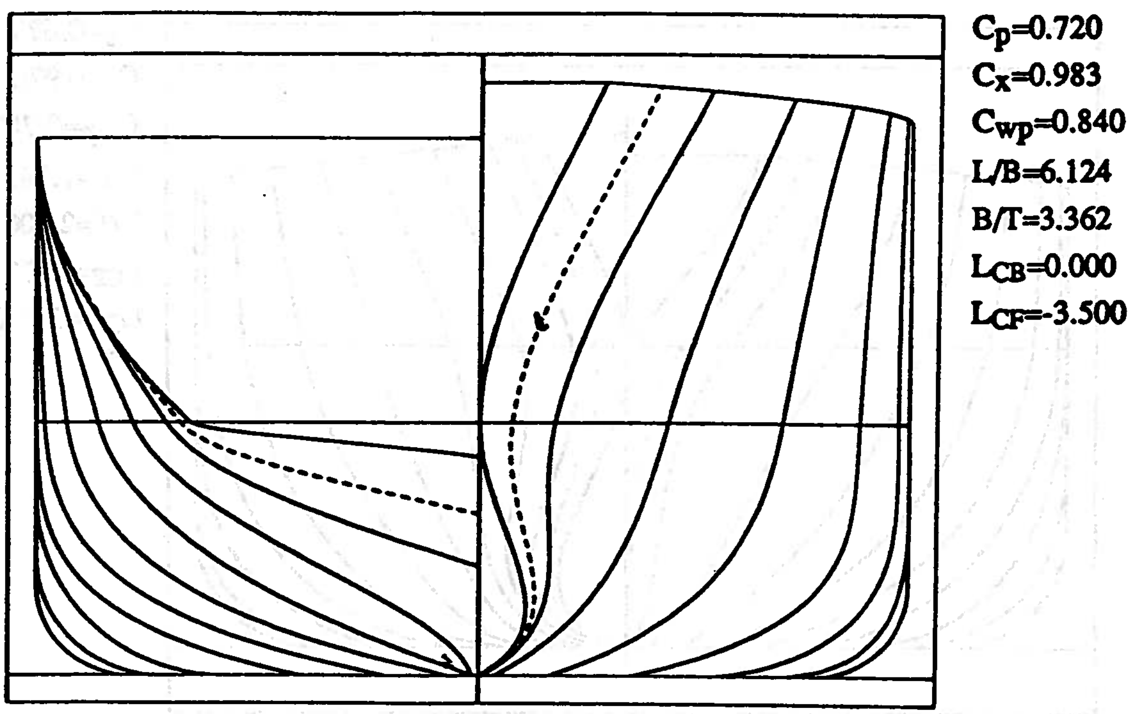


Figure 9. The hull 'parent6'.

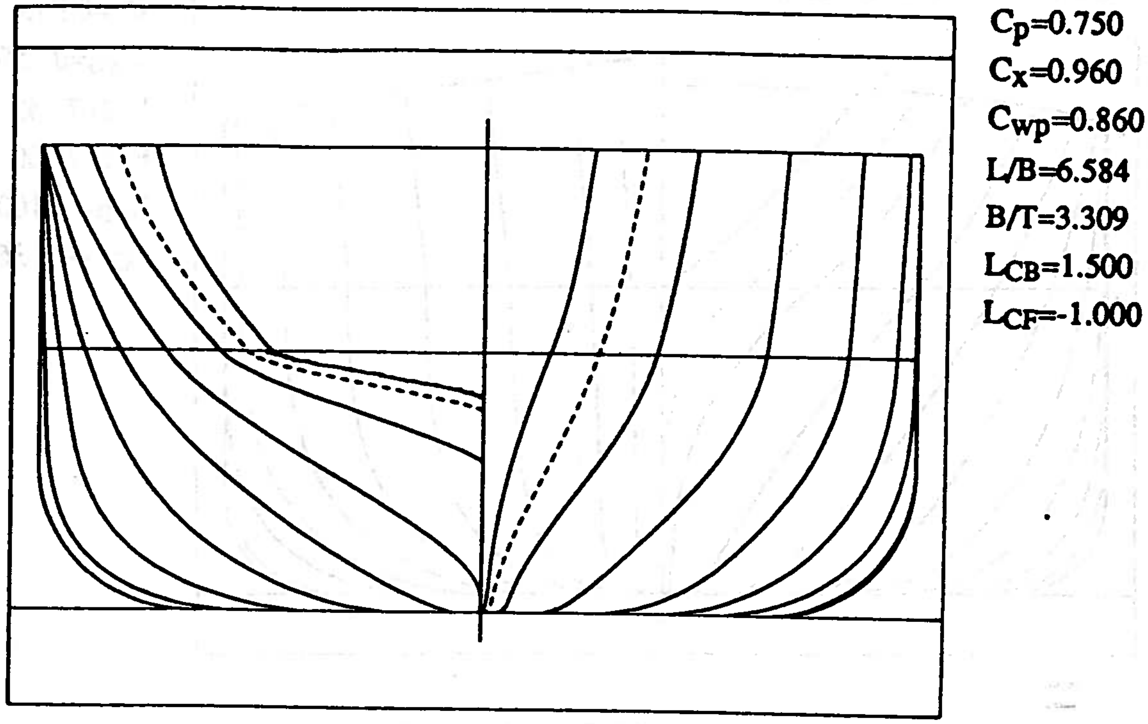


Figure 10. The hull 'parent7'.

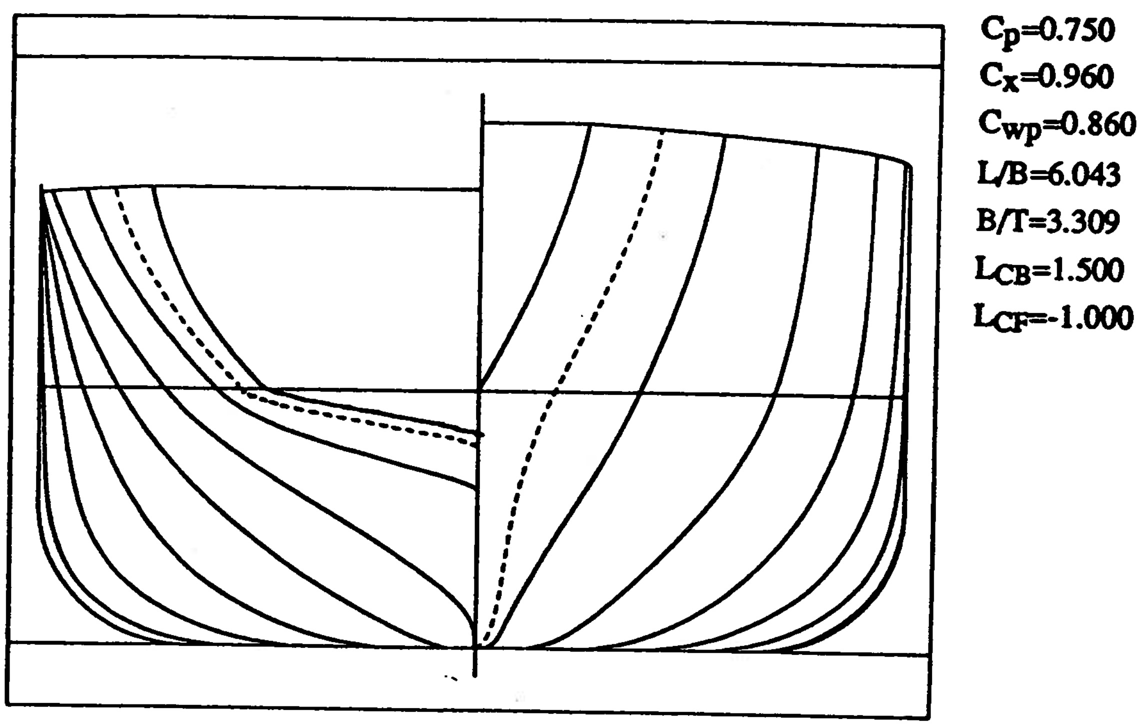


Figure 11. The hull 'parent 8'.

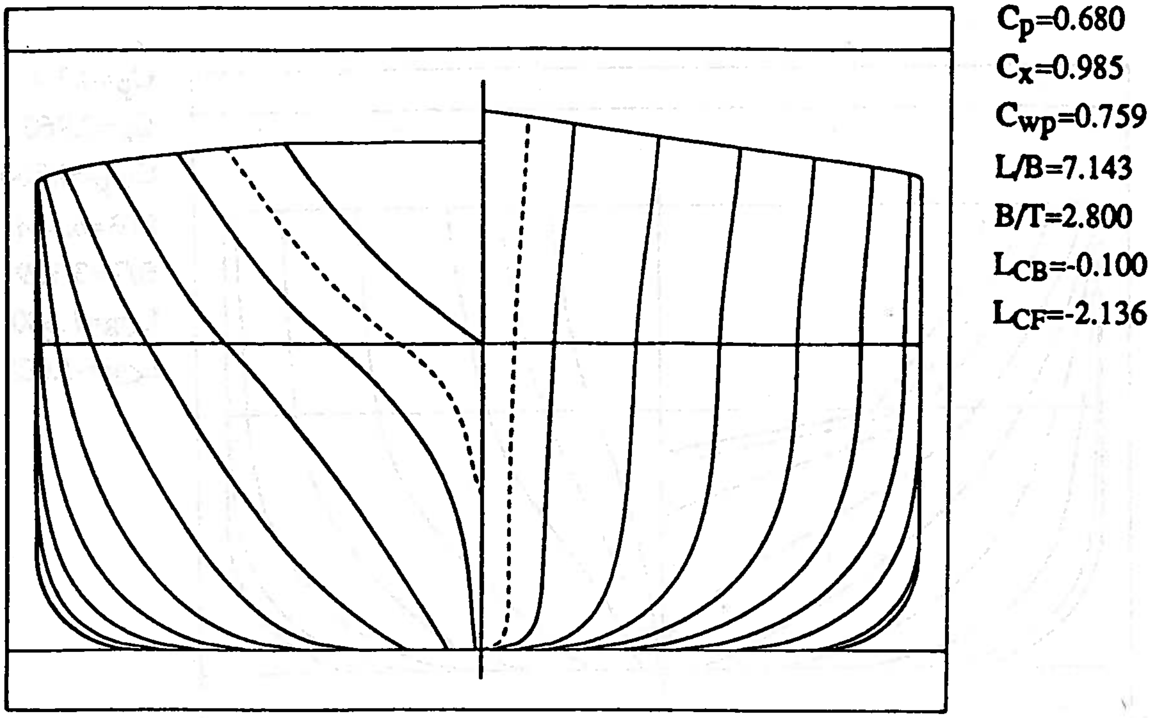


Figure 12. The hull 'parent 9'.

ADDENDUM 315

To: M-HULL users
From: Yifan Chen
Date: January 16, 1992

Since the "M-HULL, AN INTERACTIVE GRAPHICS HULL DESIGN PROGRAM - User's Manual" (the M-HULL user's manual) was published in February, 1991, the M-HULL package has been undergone a series of modifications. The major modifications of the M-HULL program include the reduction of the total number of waterlines, the rearrangement of waterline spacing, and the implementation of two half stations at the bow and stern portions of the hull. Some minor user interface modifications have also been made. In addition, the five existing parent hulls have been slightly refined and four new parent hulls have been added into the M-HULL package. Finally, a new workstation assignment file 'wafx' has been installed in the package for running the M-HULL program under the X Window system.

1. Total Number of Waterlines Changed

The number of waterlines (excluding the baseline) used in the M-HULL program to generate offset table and MHCP input file has been reduced from twenty four to seventeen. The spacing of the waterlines is therefore readjusted, too. Table 2 shows the modified table of offsets as compared with the table of offsets listed under Appendix E on pages A35 and A36 of the M-HULL user's manual.

2. Two Half Stations Generated

Two half stations have been implemented. One is located midway between stations 0 and 1, and the other midway between stations 19 and 20. They are indexed as stations 0.5 and 19.5, respectively (see Figure 1). This modification affects both the MHCP input file and the display of the Body Plan on the screen. The offsets of both half stations will be printed into the MHCP input file when it is being generated. Table 3 shows the MHCP input data after the modification. The original MHCP input file is listed on pages A37 through A46 of the M-HULL user's manual. The two half stations are also made visible on the Body Plan for the user. They are drawn in dashed lines instead of solid ones for easy recognition. Note that the porcupine spikes (curve curvature plot) are not allowed to be plotted on the half stations.

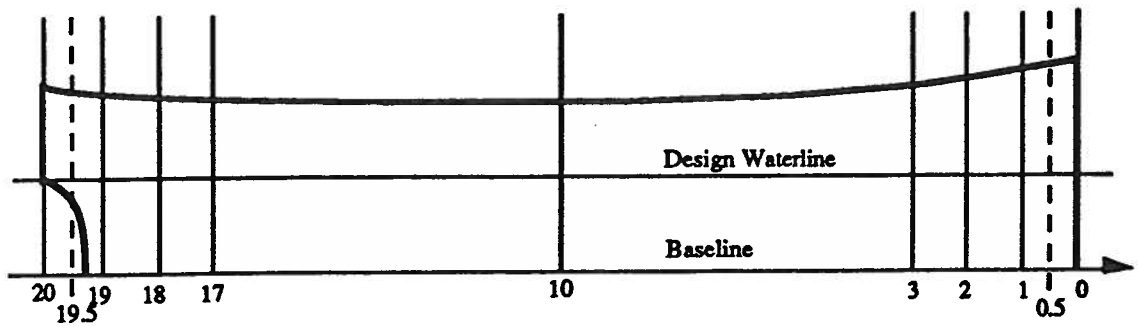


Figure 1. The locations of the half stations (shown in dashed lines).

3. The Five Parent Hulls Refined

As one of the consequences of the implementation of the half stations, the five original parent hulls have been slightly refined to make sure that the profile of the half stations looks reasonable on the Body Plan. The five updated parent hulls are shown in Figures 2 through 6 together with some important hull form parameters.

4. New Hulls Included in the Package

Besides the five original parent hulls, four new hulls have also been made available to the M-HULL user. They are named after parent 6 through parent 9. The Body Plan of these hulls are shown in Figures 7 through Figure 10 together with some important hull form parameters.

5. Minor Change of User Interface

The process of creating a MHCP input file originally begins with a request (see page 18 of the M-HULL user's manual):

```
Enter Ship Number
(an integer less than 10000):
```

which has been changed into the following request:

```
Enter Ship ID Number (0-9999):.
```

6. Running M-HULL Under X Windows

On those Apollo workstations with Domain/OS SR10.2 operating system, one can run the M-HULL program directly under the regular Apollo Domain windows. On the machines currently running Domain/OS SR10.3 operating system, however, the M-HULL program must be executed under the X Window system. Most of the Apollo workstations in the CAEN labs are now running SR10.3. Table 1 shows some of the machines in the NAME building, their models, operating systems, and their X Window performances.

To activate an X Window on machines running SR10.3 operating system, enter the following command after the UNIX prompt: % under the regular Apollo window:

% x11start<RETURN>

Note that it takes time to initialize a fully functional X Window, especially on the Domain 3000 machines where sometimes the user has to wait more than fifteen minutes to get an X Window. Once an X Window is created, the M-HULL program can be executed in the same manner as described in page 6 of the M-HULL user's manual, except that the workstation assignment file 'waf' must be replaced with 'wafx' in order to obtain a proper layout of M-HULL's two graphics windows.

NO	NAME	MODEL	OPERATING SYSTEM	LOCATION IN NAME	COMMAND TO GET X	X PERFORMANCE
1	YACHT	DOMAIN 3500	SR10.2	ROOM 203	xterm	-
2	NEPTUNE	DOMAIN 3500	SR10.2	ROOM 203	xterm	-
3	MARINA	DOMAIN 3500	SR10.2	ROOM 229	xterm	-
4	CHAOS	DOMAIN 3500	SR10.2	ROOM 229	xterm	-
5	CLIPPER	DOMAIN 5500	SR10.3	ROOM 236C	x11start	GOOD
6	SCUTTLE	DOMAIN 3000	SR10.3	ROOM 236C	x11start	FAIR
7	TORPEDO	DOMAIN 3000	SR10.3	ROOM 236C	x11start	VERY POOR
8	PLIMSOLL	DOMAIN 3000	SR10.3	ROOM 236C	x11start	VERY POOR

Table 1. Some Apollo workstations in the NAME building.

TABLE OF OFFSETS FOR:

WATERLINE	FP	1	2	3	4	5	6	7	8	9	10
BASELINE	0.000	0.671	2.053	3.961	6.378	9.286	12.669	16.509	20.618	21.744	21.744
1.00	0.000	3.154	5.871	8.388	11.148	14.157	17.422	20.993	24.328	25.137	25.137
2.00	0.000	3.717	7.109	10.214	13.319	16.436	19.588	22.874	25.671	26.329	26.329
3.00	0.000	3.959	7.844	11.444	14.853	18.075	21.133	24.152	26.559	27.086	27.086
4.00	0.000	4.068	8.332	12.344	16.020	19.339	22.320	25.092	27.180	27.579	27.579
5.00	0.000	4.113	8.675	13.027	16.933	20.343	23.260	25.807	27.605	27.873	27.873
6.00	0.000	4.125	8.922	13.554	17.658	21.152	24.018	26.358	27.869	27.995	27.995
7.00	0.000	4.122	9.105	13.963	18.238	21.809	24.634	26.784	27.990	28.000	28.000
8.00	0.000	4.113	9.242	14.283	18.703	22.343	25.135	27.115	28.000	28.000	28.000
10.00	0.000	4.099	9.430	14.728	19.373	23.131	25.877	27.562	28.000	28.000	28.000
12.00	0.000	4.112	9.557	15.001	19.795	23.642	26.361	27.812	28.000	28.000	28.000
14.00	0.000	4.163	9.664	15.172	20.053	23.960	26.664	27.938	28.000	28.000	28.000
16.00	0.000	4.258	9.777	15.291	20.203	24.142	26.840	27.989	28.000	28.000	28.000
18.00	0.000	4.402	9.914	15.392	20.286	24.230	26.926	28.001	28.000	28.000	28.000
20.00	0.000	4.597	10.089	15.501	20.334	24.253	26.949	28.000	28.000	28.000	28.000
22.49	0.465	5.205	10.679	15.973	20.649	24.426	27.011	28.000	28.000	28.000	28.000
24.97	1.318	6.328	11.789	16.922	21.352	24.843	27.157	28.000	28.000	28.000	28.000
27.46	2.421	7.735	13.165	18.095	22.220	25.352	27.329	28.000	28.000	28.000	28.000
SHEER	5.600	11.128	16.006	20.158	23.509	25.983	27.505	28.000	28.000	28.000	28.000

TABLE OF OFFSETS FOR:

WATERLINE	11	12	13	14	15	16	17	18	19	AP
BASELINE	21.627	20.450	18.199	15.210	11.803	8.295	5.005	2.249	0.348	0.000
1.00	25.054	24.341	22.340	19.523	16.154	12.365	6.620	2.803	0.485	0.000
2.00	26.263	25.646	23.904	21.281	17.973	13.950	7.991	3.379	0.579	0.000
3.00	27.034	26.430	24.924	22.494	19.263	15.079	9.187	3.950	0.641	0.000
4.00	27.542	26.954	25.660	23.419	20.276	15.997	10.244	4.521	0.695	0.000
5.00	27.850	27.319	26.214	24.156	21.112	16.791	11.192	5.095	0.760	0.000
6.00	27.989	27.577	26.641	24.760	21.822	17.506	12.051	5.679	0.851	0.000
7.00	28.000	27.758	26.974	25.263	22.438	18.164	12.841	6.276	0.983	0.000
8.00	28.000	27.885	27.235	25.686	22.980	18.780	13.575	6.889	1.166	0.000
10.00	28.000	28.023	27.600	26.350	23.894	19.917	14.927	8.177	1.721	0.000
12.00	28.000	28.068	27.818	26.835	24.642	20.961	16.181	9.560	2.572	0.000
14.00	28.000	28.063	27.941	27.190	25.268	21.933	17.393	11.053	3.759	0.000
16.00	28.000	28.037	28.003	27.449	25.862	22.846	18.603	12.664	5.314	0.000
18.00	28.000	28.011	28.028	27.635	26.266	23.707	19.840	14.403	7.257	0.000
20.00	28.000	28.000	28.033	27.764	26.675	24.522	21.125	16.273	9.605	0.000
22.49	28.000	28.000	28.028	27.869	27.098	25.424	22.617	18.426	12.414	3.311
24.97	28.000	28.000	28.017	27.931	27.428	26.177	23.856	20.150	14.611	6.106
27.46	28.000	28.000	28.005	27.967	27.690	26.810	24.901	21.566	16.373	8.480
SHEER	28.000	28.000	28.000	28.000	27.957	27.531	26.252	23.650	19.256	12.600

Table 2. Table of offsets.

```
 10  PARENT1                               B
   20.000      0.005      0.005    400.000
0.000  0.500  0.000    0
0.000  0.500 10.000    0
0.000  0.500 20.000 7777
0.000  0.500 22.485    0
0.000  1.318 24.970    0
0.000  2.421 27.455    0
0.000  5.600 35.000 8888
0.500  0.500  0.000    0
0.500  1.604  1.000    0
0.500  1.883  2.000    0
0.500  1.972  3.000    0
0.500  1.985  4.000    0
0.500  1.962  5.000    0
0.500  1.924  6.000    0
0.500  1.880  7.000    0
0.500  1.837  8.000    0
0.500  1.768 10.000    0
0.500  1.736 12.000    0
0.500  1.748 14.000    0
0.500  1.809 16.000    0
0.500  1.923 18.000    0
0.500  2.092 20.000    0
0.500  2.646 22.485    0
0.500  3.684 24.970    0
0.500  4.999 27.455    0
0.500  8.441 34.560 8888
1.000  0.676  0.000    0
1.000  3.163  1.000    0
1.000  3.729  2.000    0
1.000  3.973  3.000    0
1.000  4.083  4.000    0
1.000  4.128  5.000    0
1.000  4.140  6.000    0
1.000  4.136  7.000    0
1.000  4.126  8.000    0
1.000  4.110 10.000    0
1.000  4.119 12.000    0
1.000  4.167 14.000    0
1.000  4.260 16.000    0
1.000  4.403 18.000    0
1.000  4.597 20.000    0
1.000  5.205 22.485    0
1.000  6.328 24.970    0
1.000  7.735 27.455    0
1.000 11.128 34.140 8888
2.000  2.076  0.000    0
2.000  5.901  1.000    0
2.000  7.145  2.000    0
2.000  7.882  3.000    0
2.000  8.372  4.000    0
2.000  8.714  5.000    0
2.000  8.960  6.000    0
2.000  9.140  7.000    0
2.000  9.274  8.000    0
2.000  9.455 10.000    0
2.000  9.575 12.000    0
2.000  9.674 14.000    0
```

Table 3. The MHCP input data file.

2.000	9.782	16.000	0
2.000	9.915	18.000	0
2.000	10.089	20.000	0
2.000	10.679	22.485	0
2.000	11.789	24.970	0
2.000	13.165	27.455	0
2.000	16.006	33.360	8888
3.000	4.009	0.000	0
3.000	8.443	1.000	0
3.000	10.273	2.000	0
3.000	11.505	3.000	0
3.000	12.405	4.000	0
3.000	13.086	5.000	0
3.000	13.609	6.000	0
3.000	14.014	7.000	0
3.000	14.328	8.000	0
3.000	14.763	10.000	0
3.000	15.024	12.000	0
3.000	15.186	14.000	0
3.000	15.297	16.000	0
3.000	15.393	18.000	0
3.000	15.501	20.000	0
3.000	15.973	22.485	0
3.000	16.922	24.970	0
3.000	18.095	27.455	0
3.000	20.158	32.660	8888
4.000	6.451	0.000	0
4.000	11.224	1.000	0
4.000	13.396	2.000	0
4.000	14.929	3.000	0
4.000	16.092	4.000	0
4.000	17.000	5.000	0
4.000	17.720	6.000	0
4.000	18.294	7.000	0
4.000	18.753	8.000	0
4.000	19.410	10.000	0
4.000	19.821	12.000	0
4.000	20.068	14.000	0
4.000	20.210	16.000	0
4.000	20.288	18.000	0
4.000	20.334	20.000	0
4.000	20.649	22.485	0
4.000	21.352	24.970	0
4.000	22.220	27.455	0
4.000	23.509	32.040	8888
5.000	9.377	0.000	0
5.000	14.245	1.000	0
5.000	16.520	2.000	0
5.000	18.153	3.000	0
5.000	19.411	4.000	0
5.000	20.409	5.000	0
5.000	21.211	6.000	0
5.000	21.861	7.000	0
5.000	22.389	8.000	0
5.000	23.164	10.000	0
5.000	23.664	12.000	0
5.000	23.973	14.000	0
5.000	24.148	16.000	0
5.000	24.231	18.000	0

Table 3. The MHCP input data file (continued).

5.000	24.253	20.000	0
5.000	24.426	22.485	0
5.000	24.843	24.970	0
5.000	25.352	27.455	0
5.000	25.983	31.500	8888
6.000	12.765	0.000	0
6.000	17.509	1.000	0
6.000	19.666	2.000	0
6.000	21.202	3.000	0
6.000	22.380	4.000	0
6.000	23.313	5.000	0
6.000	24.064	6.000	0
6.000	24.673	7.000	0
6.000	25.169	8.000	0
6.000	25.899	10.000	0
6.000	26.375	12.000	0
6.000	26.673	14.000	0
6.000	26.844	16.000	0
6.000	26.926	18.000	0
6.000	26.949	20.000	0
6.000	27.011	22.485	0
6.000	27.157	24.970	0
6.000	27.329	27.455	0
6.000	27.505	31.040	8888
7.000	16.589	0.000	0
7.000	21.060	1.000	0
7.000	22.930	2.000	0
7.000	24.198	3.000	0
7.000	25.130	4.000	0
7.000	25.838	5.000	0
7.000	26.383	6.000	0
7.000	26.805	7.000	0
7.000	27.131	8.000	0
7.000	27.572	10.000	0
7.000	27.817	12.000	0
7.000	27.940	14.000	0
7.000	27.990	16.000	0
7.000	28.001	18.000	0
7.000	28.000	20.000	0
7.000	28.000	22.485	0
7.000	28.000	24.970	0
7.000	28.000	27.455	0
7.000	28.000	30.660	8888
8.000	20.652	0.000	0
8.000	24.353	1.000	0
8.000	25.691	2.000	0
8.000	26.576	3.000	0
8.000	27.193	4.000	0
8.000	27.615	5.000	0
8.000	27.875	6.000	0
8.000	27.992	7.000	0
8.000	28.000	8.000	0
8.000	28.000	10.000	0
8.000	28.000	12.000	0
8.000	28.000	14.000	0
8.000	28.000	16.000	0
8.000	28.000	18.000	0
8.000	28.000	20.000	0
8.000	28.000	22.485	0

Table 3. The MHCP input data file (continued).

8.000	28.000	24.970	0
8.000	28.000	27.455	0
8.000	28.000	30.360	8888
9.000	21.744	0.000	0
9.000	25.137	1.000	0
9.000	26.329	2.000	0
9.000	27.086	3.000	0
9.000	27.579	4.000	0
9.000	27.873	5.000	0
9.000	27.995	6.000	0
9.000	28.000	7.000	0
9.000	28.000	8.000	0
9.000	28.000	10.000	0
9.000	28.000	12.000	0
9.000	28.000	14.000	0
9.000	28.000	16.000	0
9.000	28.000	18.000	0
9.000	28.000	20.000	0
9.000	28.000	22.485	0
9.000	28.000	24.970	0
9.000	28.000	27.455	0
9.000	28.000	30.140	8888
10.000	21.744	0.000	0
10.000	25.137	1.000	0
10.000	26.329	2.000	0
10.000	27.086	3.000	0
10.000	27.579	4.000	0
10.000	27.873	5.000	0
10.000	27.995	6.000	0
10.000	28.000	7.000	0
10.000	28.000	8.000	0
10.000	28.000	10.000	0
10.000	28.000	12.000	0
10.000	28.000	14.000	0
10.000	28.000	16.000	0
10.000	28.000	18.000	0
10.000	28.000	20.000	0
10.000	28.000	22.485	0
10.000	28.000	24.970	0
10.000	28.000	27.455	0
10.000	28.000	30.000	8888
11.000	21.547	0.000	0
11.000	24.997	1.000	0
11.000	26.217	2.000	0
11.000	26.998	3.000	0
11.000	27.515	4.000	0
11.000	27.834	5.000	0
11.000	27.984	6.000	0
11.000	28.000	7.000	0
11.000	28.000	8.000	0
11.000	28.000	10.000	0
11.000	28.000	12.000	0
11.000	28.000	14.000	0
11.000	28.000	16.000	0
11.000	28.000	18.000	0
11.000	28.000	20.000	0
11.000	28.000	22.485	0
11.000	28.000	24.970	0
11.000	28.000	27.455	0

Table 3. The MHCP input data file (continued).

11.000	28.000	29.940	8888
12.000	20.117	0.000	0
12.000	24.070	1.000	0
12.000	25.432	2.000	0
12.000	26.265	3.000	0
12.000	26.828	4.000	0
12.000	27.224	5.000	0
12.000	27.507	6.000	0
12.000	27.708	7.000	0
12.000	27.849	8.000	0
12.000	28.008	10.000	0
12.000	28.063	12.000	0
12.000	28.063	14.000	0
12.000	28.038	16.000	0
12.000	28.012	18.000	0
12.000	28.000	20.000	0
12.000	28.000	22.485	0
12.000	28.000	24.970	0
12.000	28.000	27.455	0
12.000	28.000	29.960	8888
13.000	17.737	0.000	0
13.000	21.935	1.000	0
13.000	23.555	2.000	0
13.000	24.626	3.000	0
13.000	25.406	4.000	0
13.000	26.000	5.000	0
13.000	26.461	6.000	0
13.000	26.824	7.000	0
13.000	27.112	8.000	0
13.000	27.519	10.000	0
13.000	27.769	12.000	0
13.000	27.915	14.000	0
13.000	27.992	16.000	0
13.000	28.025	18.000	0
13.000	28.033	20.000	0
13.000	28.028	22.485	0
13.000	28.017	24.970	0
13.000	28.005	27.455	0
13.000	28.000	30.060	8888
14.000	14.733	0.000	0
14.000	19.073	1.000	0
14.000	20.864	2.000	0
14.000	22.113	3.000	0
14.000	23.074	4.000	0
14.000	23.848	5.000	0
14.000	24.487	6.000	0
14.000	25.024	7.000	0
14.000	25.479	8.000	0
14.000	26.203	10.000	0
14.000	26.739	12.000	0
14.000	27.135	14.000	0
14.000	27.424	16.000	0
14.000	27.628	18.000	0
14.000	27.764	20.000	0
14.000	27.869	22.485	0
14.000	27.931	24.970	0
14.000	27.967	27.455	0
14.000	28.000	30.240	8888
15.000	11.389	0.000	0

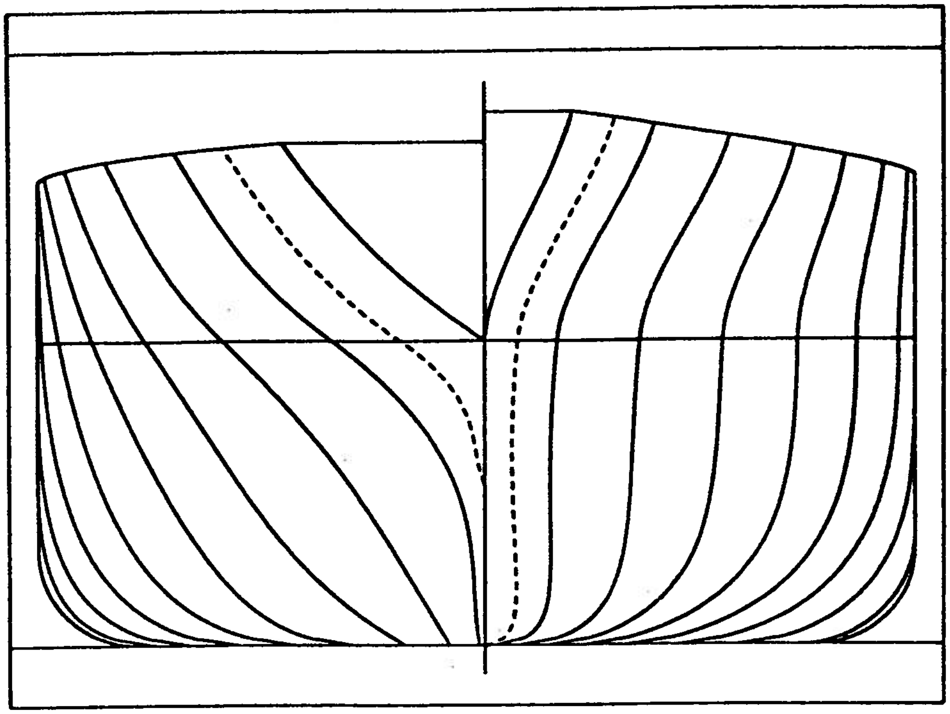
Table 3. The MHCP input data file (continued).

15.000	15.751	1.000	0
15.000	17.588	2.000	0
15.000	18.901	3.000	0
15.000	19.942	4.000	0
15.000	20.807	5.000	0
15.000	21.548	6.000	0
15.000	22.195	7.000	0
15.000	22.767	8.000	0
15.000	23.740	10.000	0
15.000	24.540	12.000	0
15.000	25.209	14.000	0
15.000	25.776	16.000	0
15.000	26.260	18.000	0
15.000	26.675	20.000	0
15.000	27.098	22.485	0
15.000	27.428	24.970	0
15.000	27.690	27.455	0
15.000	27.957	30.500	8888
16.000	7.993	0.000	0
16.000	12.096	1.000	0
16.000	13.715	2.000	0
16.000	14.875	3.000	0
16.000	15.820	4.000	0
16.000	16.639	5.000	0
16.000	17.376	6.000	0
16.000	18.054	7.000	0
16.000	18.688	8.000	0
16.000	19.855	10.000	0
16.000	20.923	12.000	0
16.000	21.912	14.000	0
16.000	22.837	16.000	0
16.000	23.705	18.000	0
16.000	24.522	20.000	0
16.000	25.424	22.485	0
16.000	26.177	24.970	0
16.000	26.810	27.455	0
16.000	27.531	30.840	8888
17.000	4.830	0.000	0
17.000	8.318	1.000	0
17.000	9.381	2.000	0
17.000	10.112	3.000	0
17.000	10.740	4.000	0
17.000	11.337	5.000	0
17.000	11.933	6.000	0
17.000	12.539	7.000	0
17.000	13.158	8.000	0
17.000	14.436	10.000	0
17.000	15.756	12.000	0
17.000	17.101	14.000	0
17.000	18.452	16.000	0
17.000	19.797	18.000	0
17.000	21.125	20.000	0
17.000	22.617	22.485	0
17.000	23.856	24.970	0
17.000	24.901	27.455	0
17.000	26.252	31.260	8888
18.000	2.185	0.000	0
18.000	3.654	1.000	0
18.000	4.194	2.000	0

Table 3. The MHCP input data file (continued).

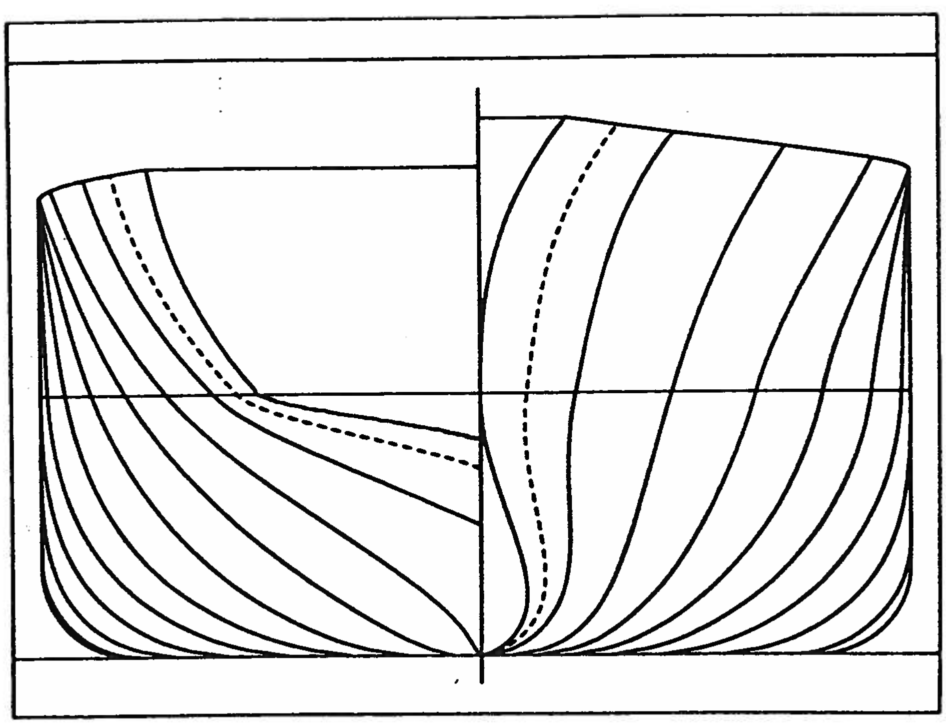
18.000	4.631	3.000	0
18.000	5.055	4.000	0
18.000	5.497	5.000	0
18.000	5.968	6.000	0
18.000	6.474	7.000	0
18.000	7.016	8.000	0
18.000	8.211	10.000	0
18.000	9.552	12.000	0
18.000	11.034	14.000	0
18.000	12.650	16.000	0
18.000	14.398	18.000	0
18.000	16.273	20.000	0
18.000	18.426	22.485	0
18.000	20.150	24.970	0
18.000	21.566	27.455	0
18.000	23.650	31.760	8888
19.000	0.500	0.000	0
19.000	1.059	1.000	0
19.000	1.151	2.000	0
19.000	1.145	3.000	0
19.000	1.116	4.000	0
19.000	1.102	5.000	0
19.000	1.124	6.000	0
19.000	1.195	7.000	0
19.000	1.328	8.000	0
19.000	1.809	10.000	0
19.000	2.614	12.000	0
19.000	3.776	14.000	0
19.000	5.319	16.000	0
19.000	7.257	18.000	0
19.000	9.605	20.000	0
19.000	12.414	22.485	0
19.000	14.611	24.970	0
19.000	16.373	27.455	0
19.000	19.256	32.340	8888
19.500	0.500	10.151	0
19.500	2.113	12.000	0
19.500	0.760	14.000	0
19.500	0.744	16.000	0
19.500	2.599	18.000	0
19.500	5.337	20.000	0
19.500	8.422	22.485	0
19.500	10.875	24.970	0
19.500	12.864	27.455	0
19.500	16.240	32.660	8888
20.000	0.500	20.000	0
20.000	3.311	22.485	0
20.000	6.106	24.970	0
20.000	8.480	27.455	0
20.000	12.600	33.000	9999

Table 3. The MHCP input data file (continued).



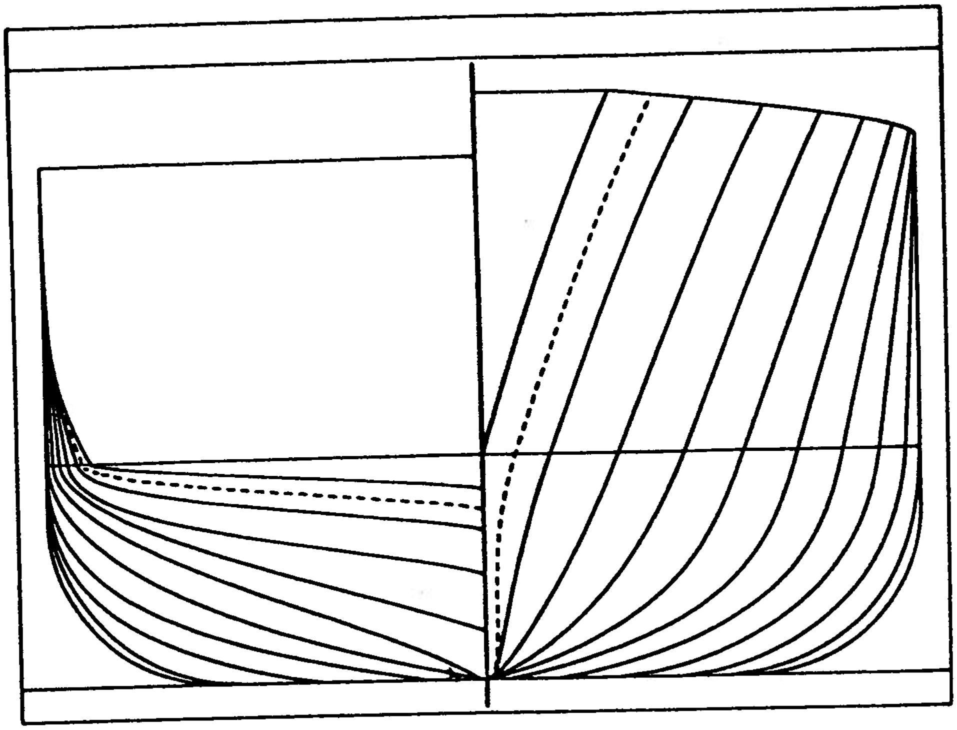
C_p=0.680
C_x=0.985
C_{wp}=0.759
L/B=0.7143
B/T=2.800
L_{CB}=-1.000
L_{CF}=-2.136

Figure 2. The hull 'parent1'.



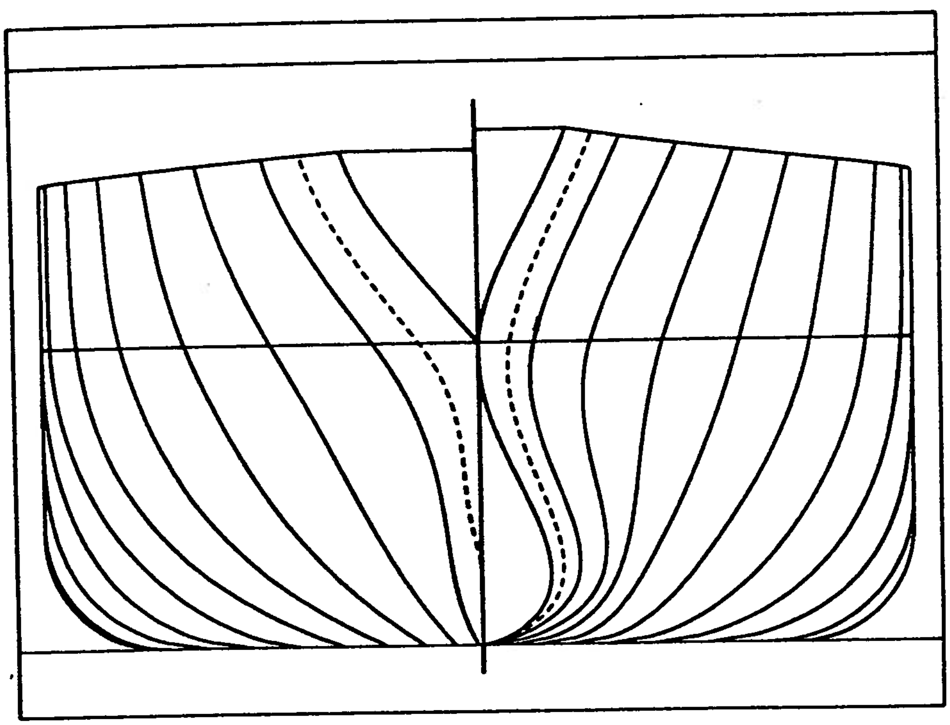
C_p=0.680
C_x=0.985
C_{wp}=0.810
L/B=5.636
B/T=3.260
L_{CB}=-0.100
L_{CF}=-3.000

Figure 3. The hull 'parent2'.



$C_p=0.610$
$C_x=0.935$
$C_{wp}=0.810$
$L/B=4.214$
$B/T=3.798$
$L_{CB}=-3.000$
$L_{CF}=-7.700$

Figure 4. The hull 'parent3'.



$C_p=0.620$
$C_x=0.978$
$C_{wp}=0.707$
$L/B=7.143$
$B/T=2.800$
$L_{CB}=-1.000$
$L_{CF}=-2.500$

Figure 5. The hull 'parent4'.

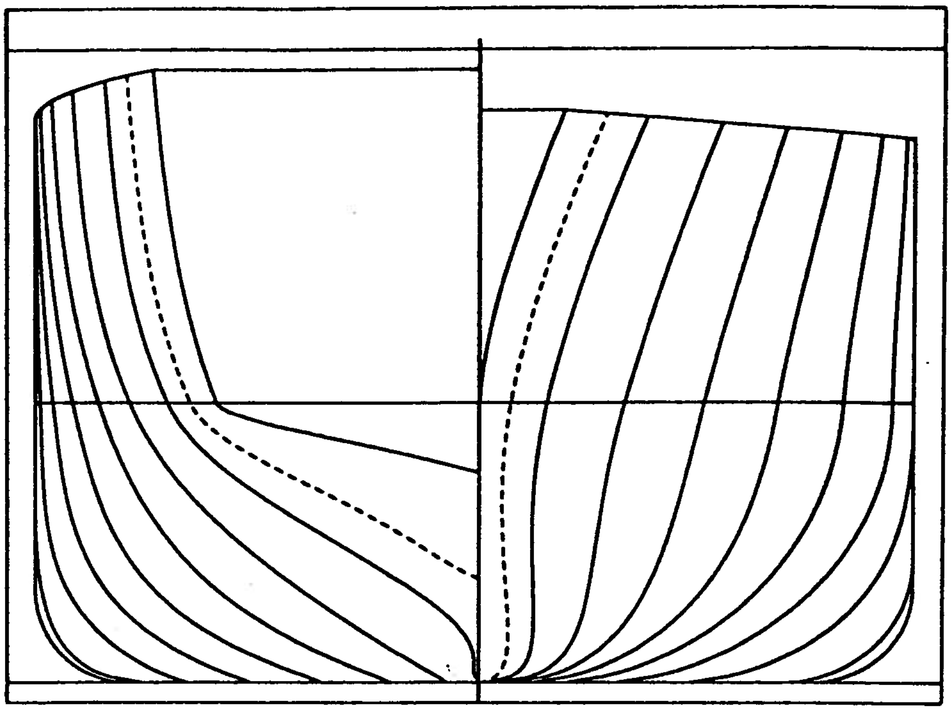


Figure 6. The hull 'parent5'.

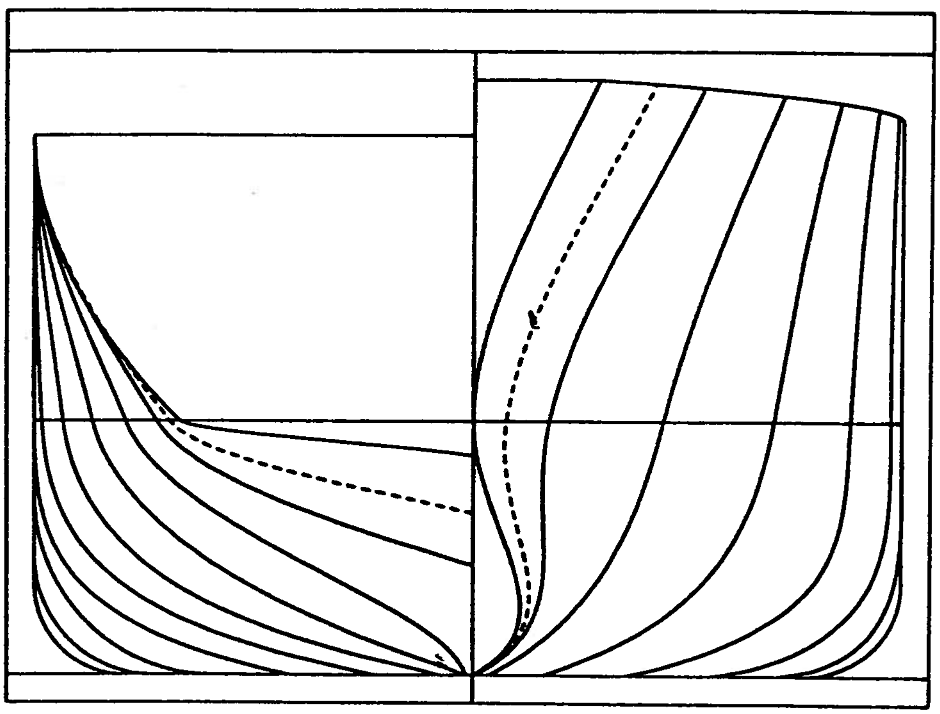
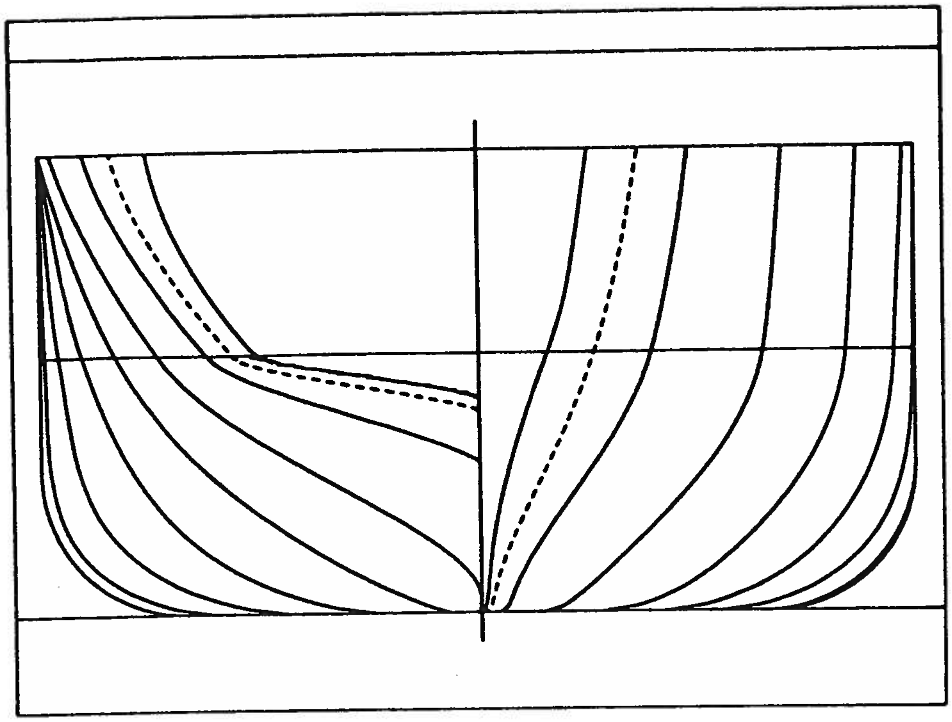
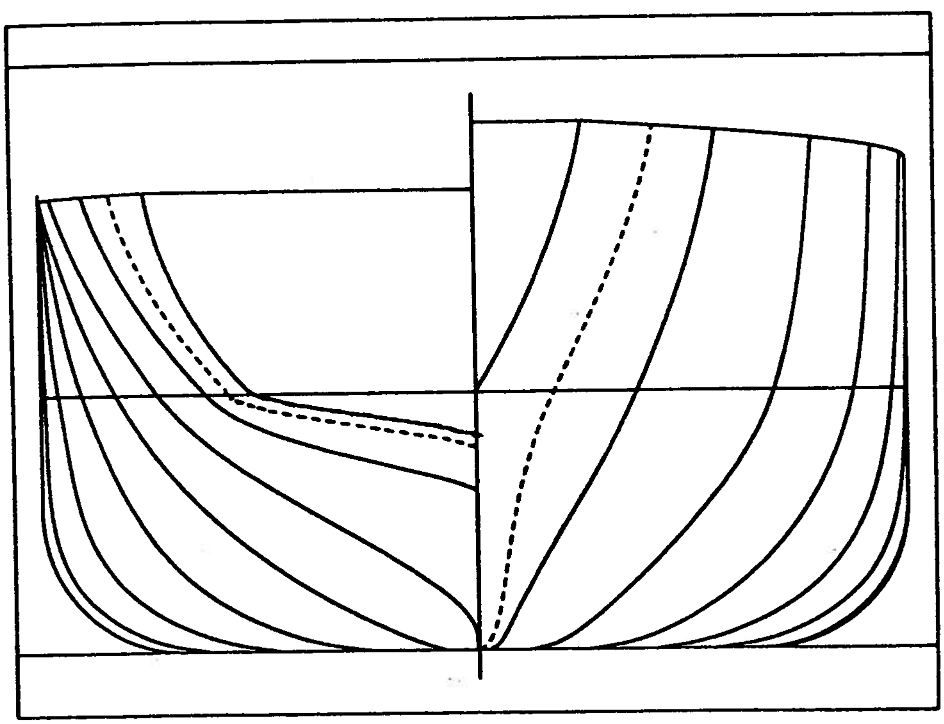


Figure 7. The hull 'parent6'.



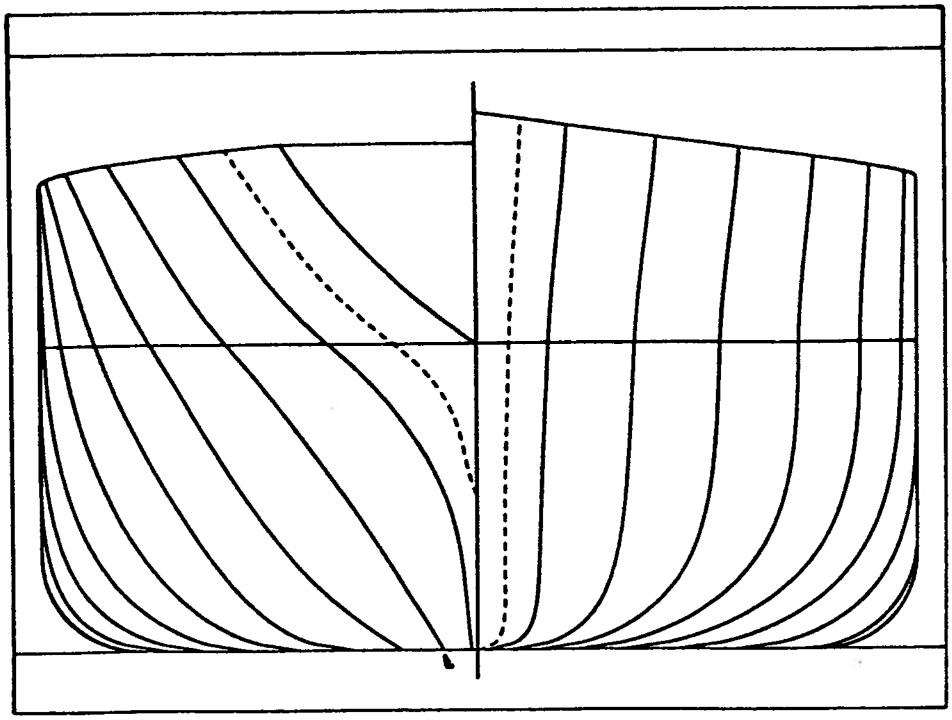
C_p=0.750
C_x=0.960
C_{wp}=0.860
L/B=6.584
B/T=3.309
L_{CB}=1.500
L_{CF}=-1.000

Figure 8. The hull 'parent7'.



C_p=0.750
C_x=0.960
C_{wp}=0.860
L/B=6.043
B/T=3.309
L_{CB}=1.500
L_{CF}=-1.000

Figure 9. The hull 'parent 8'.



C_p=0.680
C_x=0.985
C_{wp}=0.759
L/B=7.143
B/T=2.800
L_{CB}=-0.100
L_{CF}=-2.136

Figure 10. The hull 'parent 9'.