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THE SPECIFICATION OF AN INTEGRATED
COMPUTER-AIDED SHIP DESIGN PROCESS
IN AN ACADEMIC ENVIRONMENT

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ABSTRACT

The increased use of Computer-Aided Design tools in the area of Naval ship design has generated a need for ship design engineers who are thoroughly familiar with the capabilities, limitations and operation of these tools. As a major source of these design engineers, the need for such a Computer-Aided Design (CAD) facility at the Massachusetts Institute of Technology is established. The current Naval ship design process is discussed and the place of the CAD system is established within this process.

Current CAD facilities and capabilities of the Naval Sea Systems Command and the Massachusetts Institute of Technology are investigated and system limitations are discussed. Inherent features required of a system which can overcome these limitations while providing an educational tool are developed. A prototype CAD system possessing many of these features is developed with guidance provided for future enhancement of this system.

Thesis Supervisor: David V. Burke
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1. INTRODUCTION

1.1 Background

Traditionally, the ship design process has begun with an idea for what a ship should do or a 'mission statement'. Using designer's knowledge and experience, tentative designs were chosen for close evaluation and testing. As the evaluation process progressed, the design was 'firmed up' through progressive stages until a final design was selected.

This systematic narrowing of possibilities was achieved by conducting time consuming and expensive numerical calculations and model construction which guided the designers in the proper direction. Because of the time and expense involved in a single concept evaluation, the designers have been severely restricted in the number of design possibilities which could be evaluated. Many potentially promising designs had to be discarded because they involved radical departures from traditional thinking or because the potential for acceptable results could not justify the expense of thorough investigation.

In recent years, however, the ease of access to computers has made the design sequence a more thorough and efficient process. Computer hardware and application routines are now readily available which will allow designers to investigate and analyze a design to a degree previously unheard of.

At the beginning of the computer age, most people were

impressed by the tremendous potential for computers to take over the laborious calculations normally associated with the design of a ship. Some felt that the computer would be able to take over the design process, and starting from a small set of mission requirements, would be able to produce a complete ship design without, or at least with minimal, human intervention. Of course, this has not come about nor will it in the near future. The ship design process is too complicated. The intuition and experience of a good designer are qualities that cannot yet be programmed into even the most capable computer.

Computers do, however, have a place in ship design. The main advantages of using a computer are its speed and flexibility because these capabilities allow us to investigate a large number of design alternatives and to choose the best from among them, i.e., to optimize. The design art has reached the stage where radical and unorthodox concepts can be investigated thoroughly to determine the feasibility of a given design with relatively little cost in time and money. The United States Navy through its Naval Sea Systems Command (NAVSEA) as well as many civilian institutions have instituted programs to standardize and streamline their design efforts. This will require that future ship designers be thoroughly familiar with the capabilities, limitations and procedures for ship design using these new design tools.

The world of ship design is an ever developing and expanding world. The ships that will be needed in the future

will be more complex and more sophisticated than could have even been imagined just a few short years ago. Much of this complexity arises from the need for these ships to perform a variety of missions. The ever escalating costs associated with design, building, operation and maintenance of our ships makes the need for diversity in their mission capabilities more imperative than ever. In order for these ships to fulfill the necessary mission areas, they must be designed to be the best that they can be. The very best design must be developed to meet a given set of mission requirements. No longer is the best of three or four alternatives to a given design detail good enough. We must have the capability to evaluate hundreds of design options so that we are confident that the best has been selected.

The process of ship design is an iterative process. Given a set of initial requirements, the designer proceeds through this iterative cycle until the 'best' solution is found. But what happens when a requirement is changed late in the design evolution? In some cases a complete reevaluation and redesign must be performed, again looking not just at a few options but looking at as many options as are needed to insure the best design. These requirements can of course be met by doing the design and evaluation by hand. But doing so would require years of effort by scores of naval architects to accomplish. Fiscal funding and time required to support the fleet of the future will not allow this expense in time and money.

A well equipped and current computer aided ship design facility is the only realistic solution to these problems. This facility would allow the necessary investigation of unorthodox solutions which, otherwise, could be investigated only superficially, if at all. By drawing upon the results of past designs, the naval architect would be able to quickly evaluate variations and modifications to these designs but would not limit him to doing only this, as has been the case in the past. The designer would be able to branch out and to look at possibilities that, until recently, could only be dreamed about.

This author believes that these arguments make the need for some type of computer aided ship design facility in industry quite evident. But why is such a capability as this needed at an academic institution? Briefly, for experience and appreciation of technology for new direction. In order for a new naval architect to perform satisfactorily in industry, he must be efficient in his work. But efficiency can be achieved only through education and experience. Just as he must have experience in calculating intact stability and floodable length, so must he also be experienced in using the computer aided design tools that he will be expected to interface with on the job. This type of experience must be gained while still in the academic environment. For this reason, if for no other, any academic institution awarding degrees in Naval Architecture must provide the means by which students can gain experience

with and an appreciation for the utility of these essential tools.

Currently the facilities for instructing these future ship designers at The Massachusetts Institute of Technology (MIT) are severely limited. The instructional facilities are composed of a collection of disjointed application routines on different computers which cannot communicate between themselves. These application routines, while very capable in their own right, lack the qualities which would make them more usable in the academic environment. These qualities include thorough documentation, both substantive derivations and descriptive user's guides, user friendliness and input/output compatibility with other routines.

1.2 Thesis Content

This thesis proposes to provide a guideline by which the computer aided ship design facility at MIT can be made more usable both as an instructional tool and as a research tool. These guidelines will include recommendations for hardware selection, directions for modification and development of application routines as well as recommendations for methods of keeping this design capability current and compatible with the ship design and shipbuilding industry.

Chapter two will briefly discuss the ship design process in its traditional form. This will cover the different stages of the ship design process from feasibility studies through detailed design. Chapter three will discuss the capabilities

of currently existing ship design CAD systems at MIT and in industry. Chapter four will provide guidelines for the creation of a usable ship design CAD facility at MIT. Included are discussions of the major factors concerning the design of this CAD capability. Chapter five discusses a prototype of a ship design CAD facility developed by this author which incorporates many of the guidelines discussed in chapter four.

It is hoped that the concepts discussed and the guidelines presented in this thesis will provide guidance for further development and implementation of a ship design CAD facility at MIT which will be useful in the preparation of future ship designers to meet the demands of the future.

2. THE DESIGN PROCESS

2.1 Background

The design of a ship is an iterative process. By this, it is meant that the design of a ship is not one which can be started at one point and worked through to a final result. Initial requirements are specified which generate early approximations of ship's characteristics. These characteristics are evaluated and corrected to provide more detailed characteristics. These are then compared with original requirements. A more correct set of gross characteristics are thus generated which lead the designer through a new cycle of the design. Thus, the early approximations are repeatedly corrected and expanded due to feedback from previous steps. Ship designers speak of a "design spiral" when describing this process of progressive convergence to a final configuration.

2.2 Design Phases

The ship design process traditionally encompasses five phases of design development. These phases are:

- 1 - Conceptual design
- 2 - Feasibility studies
- 3 - Preliminary design
- 4 - Contract design
- 4 - Detail design

During each successive phase, the definition of the ship is refined as more detail is added. Each of these design phases are briefly described in the following sections.[1] Frequently, the functions of the conceptual design phase and the feasibility design phase overlap, but they are presented separately here for clarity.

2.2.1 Conceptual Design Phase

The Conceptual Design phase is the first phase in the design of a new ship type. The objectives of this phase are as follows:

1. To create and assess new whole ship concepts.
2. To identify and prioritize technology "gaps" and research and development shortfalls.
3. To support the development of a new concept or technology.
4. To investigate "proof of concept" through feasibility demonstration.

The Conceptual Design phase is primarily concerned with far-term programs independent of planned ship acquisition and, therefore, is often characterized by innovation and high risk. The products of this phase are normally similar to the Feasibility Design phase defined in the next section. The level of detail is limited to the minimum needed to define the concept or proof of concept, although particular aspects, such as innovative subsystem or innovative combinations of existing subsystems, may require more detail. The products may also include tradeoff study reports and risk assessments for

developmental subsystems and components.

2.2.2 Feasibility Studies

The objectives of the Feasibility Study phase of ship development are as follows:

1. To define a set of feasible alternative whole ship solutions to a set of operational requirements.
2. To structure the studies to aid a ship acquisition decision maker to select a preferred balance between capability, cost, and risk.
3. To define each alternative sufficiently for preparation of a reasonable cost estimate.
4. To identify the major technical risk associated with each alternative.

Generally, Feasibility Studies are conducted to support selection of a ship concept in a contemplated or planned ship acquisition effort. They are normally based on a stated, though sometimes broadly stated, ship mission. These ship missions are normally stated using a document entitled Naval Warfare Mission Areas and Required Operational Capability, also known as OPNAV Inst. 3105.2E. This document designates Naval Warfare Mission Areas which are divided into two categories: (1) Fundamental mission areas and (2) Supporting mission areas. These are listed below.

Fundamental Mission Areas

Anti-air warfare
Anti-submarine warfare
Anti-surface ship warfare
Strike warfare
Amphibious warfare
Mine warfare

Supporting Mission Areas

Mobility

Command and control and communications

Intelligence

Electronics Warfare

Logistics

Fleet support operations

Construction

Noncombat operations

Each ship type must have varying degrees of capability for the performance of each of these fundamental and supporting mission areas. These mission capabilities define the ship mission.

The studies are usually done in the context of a desired schedule for design and construction and are conducted within the context of a recognized ship type. Thus, feasibility studies are generally more constrained with respect to program considerations and ship concept than are conceptual designs.

A partial listing of the products of the Feasibility Design phase are listed below.

1. Payload definition (e.g., weapons, troops, etc.).
2. Combat system description.
3. Survivability features description.
4. Description of other mission-critical subsystems.
5. Principal hull dimensions and form coefficients.
6. Full load and light ship weight estimates at the one-digit level.
7. Intact stability check.
8. Area/volume summary.
9. Propulsion machinery type, SHP and propeller number.
10. Speed and endurance estimates.

11. Installed electrical generating capacity.
12. Manning estimate.
13. General arrangements sketch.

In addition, major technical risks are identified as well as any unique aspects that would have major impacts on the acquisition schedule.

2.2.3 Preliminary Design

Preliminary Design is the next phase of ship design.

Its objectives include:

1. To refine the design estimates made during Feasibility Studies and to reduce or eliminate major technical and schedule risks.
2. To quantify ship performance to the fullest extent possible.

Emphasis is placed in the Preliminary Design phase on firmly establishing ship size (L, B, D, displacement), external configuration (hull and topside), the overall allocation of arrangement space to various functions, and major propulsion, electrical, and mission-essential mechanical and combat system elements. This is because these factors have the dominant influence on ship cost, performance and/or risk.

The principal product of the Preliminary Design phase is the Top Level Specification (TLS) which is a comprehensive description of the characteristics and capabilities of the ship at the end of preliminary design. Numerous drawings, studies, and analyses are developed in support of the TLS preparation.

2.2.4 Contract Design

The major objectives of the Contract Design phase are to establish a firm technical baseline which will:

1. Confirm to the sponsor that this, in all its detail, is the ship design he wants and can afford.
2. Provide a firm basis for timely and accurate ship-builder bids for a detail design and construction contract.
3. Enable the successful shipbuilder to develop the detail design and construct and test the ship in the most cost-effective manner while ensuring that all requirements are met.
4. Provide criteria for Navy acceptance of the ship.

Three major activities take place during the Contract Design phase: (1) engineering development of the preliminary design, (2) translation of the completed design into the specifications, drawings, and other data which are the technical portion of the contractual document, and (3) an extensive review and translation phase during which every effort is made to insure that the requirements and specifications are understood by perspective shipbuilders.

The products of the Contract Design phase include:

1. Ship Specifications
2. HVAC Design Criteria Manual
3. Contract Drawings
3. Contract Guidance Drawings
4. Contract Data Requirements List
5. Contract Design Weight Estimate
6. Master Equipment List

7. GFE Procurement Specifications
8. GFI Requirements
9. Preliminary Ship Manning Document
10. Test and Evaluation Requirements
11. Design History

2.2.5 Detail Design

The Detail Design phase is the final phase of a ship design. It includes the preparation by the shipbuilder of the working documents used to direct ship construction. This includes working drawings and detailed specifications which will be used by the shipbuilder for actual construction of the ship and must provide the level of exactness and correctness of detail necessary for successful construction.

3. Current Design Capabilities

3.1 Background

The design capabilities and facilities of the various institutions involved in major ship design projects varies greatly. This is due primarily to the fact that they differ in the areas of emphasis in their design work. For instance, the facilities of NAVSEA differ from those at MIT since the emphasis at MIT is on the teaching of design methodology while NAVSEA's objective is to produce actual platform designs. Also, NAVSEA's objectives differ from those of a subsystem contractor since a contractor would place more emphasis on detailed subsystem design rather than whole-ship design. For example, a contractor involved with designing an equipment cooling system would be more interested in space arrangements, obstructions, etc. and would not be concerned with ship resistance or hullform stability. A brief overview of current ship design capabilities at NAVSEA and at MIT follows.

3.2 NAVSEA Capabilities

Until recently, the emphasis in the computer aided design area at NAVSEA has been in developing individual application routines which would provide tools for calculation and evaluation in the design process. This project generated many fine software routines which are still in use at NAVSEA and elsewhere today. These routines, however, appear to have been developed in relative isolation. By this, is meant that

they seem to have been developed for use totally by themselves without regard for possible incorporation into larger design systems. As a result, most of these routines require their own individualistic inputs and generate their own style of output, neither of which is compatible with input/output requirements of other application routines.

These routines involved most major areas of ship design and evaluation and have been collected and cataloged under the Navy's Computer Aided Ship Design and Construction (CASDAC) Project. Examples of the broad realm of subject area covered by the CASDAC library of programs are listed below.

- Hull form generation
- Hull form derivation from a parent
- Speed and power calculations
- Surface definition and fairing
- Forces on a ship hull form
- Submarine motion simulation
- Structural analysis
- Arrangements of spaces
- Equipment arrangements
- Manpower models
- Reliability simulations
- Weight estimations
- Hydrofoil calculations
- Shafting bearing calculations
- Rudder coefficients

- Propeller calculations
- Turbine design
- Condenser design
- Signal interference
- Magnetic field evaluations
- Ductwork calculations

As stated previously, most of the programs in the CASDAC library will not communicate with each other. In 1976, however, a group of NAVSEA designers initiated a project whereby several existing routines would be coupled so that they could communicate.[2] This project, called the CASDAC Hull Subsystem Project, had as its objectives the maximization of the short-term benefits from the linked-use of the existing programs and the demonstration of the advantages of the unified data base approach to data management. The existing routines used in this project were:

- 1 - The Ship Hull Form Generator (HULGEN)
- 2 - The Ship Definition Program (HULDEF)
- 3 - The Ships Hull Characteristics Program (SHCP)
- 4- The MIT Motions Program (MITM)

HULGEN is used primarily during feasibility and concept design phases to provide rapid, approximate depictions of hull form from specific hull form parameters. These parameters are established as input variables and the hull form is stretched and distorted into shapes to maintain the required parameters thus producing initial estimates from which experimental and

informative variations can be tried. The outputs from HULGEN were translated via a translator routine so that they could be used as inputs to the HULDEF routine. HULDEF took the unfaired hullform data and manipulated it to make it architecturally fair while maintaining the required hullform parameters. This faired hullform data from HULDEF was then evaluated by the SHCP routine to generate hydrostatics characteristics, trim-lines, longitudinal strength, etc., and by the MITM routine to perform motion analysis. The results of this project were very encouraging and have helped to generate much enthusiasm for a fully integrated computer aided design system.

Currently, NAVSEA is involved in a major project which has the same goals as the CASDAC Hull Subsystem Project, but on a much larger scale. This project, entitled The Computer-Supported Design (CSD) Program, involves the development of a complete system built around existing application routines.[3] Once completed, this system will insure compatibility among all of the CASDAC routines by providing an executive command system for controlling the system operation, a common database management system for controlling data storage, retrieval and transfer as well as commonality of hardware. In addition, this project will include a stand-alone 'turn-key' computer aided design system for interactive generation and evaluation of platform hull forms, subsystem layouts and equipment design. This system will eventually be able to access and utilize the data base of the larger main CAD system. Currently, a

prototype 'turn-key' system, manufactured by Computervision, Inc., is being evaluated by using it as a parallel development tool in the NAVSEA DDG-51 design project. This system, with its own data base system, allows much faster generation of system and detail designs and has proven itself to be invaluable, especially when minor alterations are required since these alterations can be immediately viewed and their consequences evaluated more quickly.

Parallel development of their own CAD system by private contractors using compatible hardware and software is currently underway. This will allow these private companies to communicate with the database of the NAVSEA system, thereby allowing designs produced by the NAVSEA system to be accessible by detail designers outside NAVSEA. Data storage and transfer standards have been selected by NAVSEA to insure compatibility for data transfer between contractor and itself. These standards include the Initial Graphics Exchange Specification (IGES) format for graphical data, ASCII format for text data and the Relational Information Management (RIM) database system, developed by Boeing Computer Services, for geometrical data. Use of these standards will insure a more correct, accurate and timely transfer of the design data between parties involved, which should reduce design errors and design expense in addition to providing a completely detailed database for the actual construction of the ship by the selected shipbuilder.

3.3 MIT Capabilities

The ship design capabilities at MIT are not quite as extensive as those at NAVSEA, however, they do suffer from many of the same shortcomings found in the early NAVSEA system. A large number of the application routines currently available at MIT are the same as those developed by NAVSEA due to the existence of the Navy Postgraduate program at MIT and also due to the large amount of Navy sponsored research at MIT.

Three major reasons exist which have prevented these shortcomings from being corrected. First is the lack of continuity among personnel. With the exception of civilian faculty and staff, personnel involved with the Ocean Engineering Department's computer aided design facility rarely remain at MIT for more than two or three years. Since the integration and coordination needed to establish an integrated ship design CAD system is absent, the system has remained as a disjoint collection of application routines which are unable to communicate with each other. Also, due to changes in personal preferences in hardware and operating system which accompanies rapid personnel turnover, these application routines have become scattered through various computer systems on campus thus requiring excessive computer system familiarity to allow easy access by most students. Two independent ship design systems have been established at MIT. The Design Executive System (DEX) [4][5][6][7] provides detailed menu and command driven control of ship design related application routines as well as provisions for database management. This system,

though extremely capable, has not been incorporated for use by MIT ship design courses. The other system, the MIT XIII-A Computer Aided Design Lab Information Executive Manager System [8], also provides menu and command control of several ship design related application routines and has been used with several courses in the past. The application routines which receive the most use remain independent and scattered.

The second cause concerns the method in which the CAD system is used at MIT. Several courses require the use of two or three application routines by the students but their use is not of a continuous form. For instance, data outputs from one routine is usually completely different from data required for another since most projects calling for CAD usage are not of a follow-on 'building block' nature. Other courses which involve the CAD system require students to develop or to modify an application routine but the emphasis in this case has been on translating the theory associated with an idea to computer code and usually falls short of requiring that resulting routines be compatible with the existing CAD system. Also, largely due to instructor preference, these routines frequently are implemented on different computer systems thereby contributing to the disarray of the system.

The third cause concerns the type of personnel available to carry out a restructuring of the CAD system. The work must be done by students, either as part of a continuing course project or as thesis work. Due to the large realm of possible

academic areas of concentration available, however, the number of persons both interested and qualified to accomplish this task is severely limited.

4. Guidelines for Design System Development

4.1 Background

The need for some type of consolidated computer aided ship design system has been established. The next step is to determine guidelines for development of an acceptable system. Obviously, the new system cannot totally disregard the facilities, both hardware and software, which are currently available. In establishing guidelines for system development, the following points need to be considered:

1. System usage.
2. System management.
3. System hardware.
4. Data management.
5. System software capabilities.

These points will be addressed in the following sections.

4.2 System Usage

The computer aided design system envisioned must be designed to be used by graduate students as well as undergraduates as a tool in the instructional aspect of course work. Just as performing hand calculations have conventionally been assigned to stress methodology familiarity and concept understanding, so will the computer aided design system be used to enhance the attainment of these goals. This does not mean

that students should not be required to perform hand calculations, however. This type of hands-on instruction certainly has its place in the instruction process, however, when the sheer volume and complexity of calculations involved in ship and ship system design is concerned, the goal of concept understanding sometimes is overshadowed by pure tedium and exasperation. Once the goals of method familiarity and concept understanding have been attained, further repetition of hand calculations tend only to dull the student's appetite for more in-depth understanding. Conversely, the rapid turn-around time associated with CAD system calculations allows and even coaxes the student to try different inputs just to see what the results will be. This approach to the use of the CAD system will reduce the risk of students getting stuck with a 'black-box' system which accepts inputs and generates outputs but requires no knowledge of calculation methodology.

By requiring hands-on familiarity with calculation methodology prior to system usage, the student will better understand and appreciate the power of the CAD system and will be better able to evaluate system outputs and to recognize system weaknesses and shortcomings. The system is not intended to be used solely for course work, however. The technical nature of most MIT thesis work and much faculty and staff research involves investigation of 'what if' questions which is the mainstay of the CAD system.

4.3 System Management

Current CAD capabilities at MIT, as previously stated, involve many independent and segregated application routines. In order for these routines to be useful, and just as importantly, to be used by the students, a system is required which will bring these routines together in a cohesive package. Most main-frame computers possess their own operating system language, such as the Digital Control Language (DCL) used by Digital Equipment Corporation's VAX-11/782 computer, which provides the capabilities for the development of an executive control system. Such an executive control system would provide the management function required for system control. These management functions would include control of input/output, control of database access, application routine selection and program execution path control.

In order for any computer system, whether it be a business system or a CAD system, to be used by other than experienced computer users, its control system must possess certain inherent features. The most important of these is the so called 'user friendliness'. This over-worked and somewhat vague term describes the major stumbling block which, until recently and still in some cases, has restricted the use of most computer systems to only the experienced computer user. Because of the generally vague nature of this term, the features of an executive control system which make it 'user friendly' will be described.

The executive control system must be flexible so that both the novice user and the experienced user can be equally comfortable while using the system. This would be accomplished by providing a combination of command driven and menu driven operation. Upon initial system entry, typing a simple command will provide an overview of the current system status and a listing of the currently implemented application routines with more in-depth descriptions of each routine available for the asking. For example, to receive more information about the SHCP routine, the user might type HELP SHCP. In addition, the novice, unfamiliar with system commands and unsure of the types of inputs being requested by the system, could ask for help at any time by typing '?'. The system would respond by displaying a list of the options which the user could select at this point in program execution.

The experienced user would feel restricted with the tedium involved with having to read excessive program and command descriptions and would rather just get on with running the program. This capability could be provided by allowing system operation via direct commands rather than by selection of menu options. This would greatly reduce the time required to run a particular routine and would allow the user to concentrate on system operation rather than on finding the desired option from a menu of several options.

Other user friendly features should include error trapping and error correction schemes. Most data required as

input to a routine is input via separate data files which must be identified at the initiation of the particular routine. Additional data, especially that data which is to be varied, should be input interactively during program execution. The system should prompt the user for data using logical phraseology which could be expounded upon by typing '?'. Before the program actually accepts this data, however, the user should be given the opportunity to verify its correctness. This would reduce the possibility of having to abort a program because of one incorrectly entered data item. One final point involves the sometimes lengthy system pauses, which can occur between the display of system prompts and system responses, due to lengthy calculations or heavy system usage. When such a pause is anticipated, the system should inform the user that the system is still operating by displaying a PLEASE STAND BY ... message. This would verify that the system has not 'bombed' and could be very reassuring to the unsure user.

4.4 Hardware selection

Another important feature required by the CAD system involves its use specifically at MIT. The MIT system must provide education and experience so that the student, upon leaving MIT, will not be required to start totally from the beginning with respect to learning a new system in industry. A graduate should appreciate the trade-offs that are relevant in choosing a system and understand the essential elements that comprise a CAD system. This would include appreciation for the

role of the hardware's operating system (command language), the customized executive system (menu selection), the database and the application programs used. A student should be able to adapt to and be able to critically evaluate any system in industry with a minimum of on-the-job training. The shipbuilding industry in the United States is currently dominated by one institution -- The United States Navy and especially NAVSEA. As a result, most naval architects will be influenced by the CAD facilities used by NAVSEA. Also, the proposed CAD facility must be expected to be used extensively for long-range research sponsored by industry and especially by NAVSEA. Therefore, when planning a new CAD system, the system used by NAVSEA should be considered as a guide for development to avoid "reinventing-the-wheel". The system must not, however, be so restrictive that it cannot provide the flexibility required for use in an educational and research environment. Consequently, the MIT system should not be an exact duplication of the NAVSEA system. On the contrary, the level of design sophistication needed in an industrial environment such as NAVSEA would be largely unused in the academic world. The level of sophistication needed at MIT falls somewhere between its current level and the level needed by NAVSEA.

As discussed in Chapter 3, NAVSEA is currently redesigning its CAD facilities under the CSD Program. The major design issues at NAVSEA which impact on the design of the MIT system are (1) hardware selection and (2) data

management system selection. These issues are discussed in the following sections.

The hardware selected for inclusion in the MIT CAD system must be compatible with hardware currently used or expected to be used in the near future by industry but must also be flexible in order to provide the development capabilities needed in an academic environment. Also, some of the more sophisticated equipment capabilities required in a production environment need not be included in an instructional environment. Generally, the programming language and operating system language should be compatible with those currently used by industry. More specifically, hardware requirements at MIT falls into four categories:

1. A main-frame computer capable of executing large programs as well as having the capability of controlling the operation of the CAD facility while allowing multiple system users.
2. On-line text/graphics display terminals for use with the CAD system for program operation.
3. Off-line, stand-alone micro-computers for program development and other non-graphical related functions.
4. A semi-stand-alone 'turn-key' graphics oriented design system for detailed design and research functions.

Due to its current availability at MIT and since it is the main-frame selected by NAVSEA for its CAD system, the VAX-11/782 computer produced by Digital Equipment Corporation, should be considered for fulfilling the main-frame capacity. Many MIT ship design courses use programs written using the

Fortran programming language and which are currently residing on this computer. Other existing programs using the Fortran language can be relocated to this computer relatively easily with minor program modifications. This computer uses the DCL operating language which provides the necessary structure for development of an executive control system for CAD system management. In addition, the VAX-11/782 computer system possesses facilities and interfaces required for hardcopy production of text and graphics outputs.

Graphics plays a major role in ship and ship system design. Tabulated data requires much time-consuming analysis for result evaluations. This evaluation time can be greatly reduced by having the data displayed in graphical form. Also, interactive graphics capabilities allow the designer to immediately see the results of a design modification without having to wait for hardcopy generation. For these reasons, an on-line graphics display capability must be included as a part of the CAD system. Since the addition of graphics capabilities causes a relatively small cost increase, all on-line display terminals should have this capability.

Tentative selection of the TEMPLATE graphics system by NAVSEA and the requirement that all graphical data meet IGES standards restricts the available selection of graphical display terminals for the CAD system. NAVSEA currently uses the Tektronix 4010-Series terminals for its on-line graphical display. For this reason, the MIT system should use either the

same terminals or terminals which are compatible with them. The 4010-Series terminals feature a high level of sophistication in graphical display methods and also is relatively costly. Neither of these features fits the needs of the MIT system. Therefore, 4010-Series compatible display terminals which offer less sophistication, but which are generally less costly, must be considered. Two graphical display terminals, the Tektronix 4100-Series and the Visual 500-Series, have been investigated. Both of these terminals meet the graphical display requirements while providing a mix of color and non-color displays as well as featuring lower costs. These as well as other compatible text/graphics display terminals should be investigated for inclusion in the MIT CAD system.

Program development, which would be a major use of the CAD facility, does not require the full-time dedication of a graphics-capable display terminal. Non-graphic display terminals would easily provide that capability required for most program development work. These terminals, with their limited capabilities, however, would not provide the flexibility needed for the CAD system. Instead, stand-alone micro-computers, which would provide flexibility in their capabilities, should be used. A micro-computer, with adequate internal memory, language and external storage capabilities would provide a means by which application routines could be developed off-line. After completion, the program could be transferred, via modem, to the mainframe for graphical work-up and inclusion

into the CAD system.

The micro-computer could also be used for non-development functions such as document creation (user's guides, reports, etc.) as well as acting as a terminal for operating the CAD system's non-graphic routines. As an example, the Zenith Z-100 series micro-computers have capabilities of over one megabyte internal memory and over 10 megabytes external storage capabilities. A stand-alone system such as this would provide the capability for the development of very large application routines without requiring access to the main-frame at all. This would not only reduce the load seen by the main-frame computer but would also reduce the costs inherent with accessing a time-shared computer system.

The graphical capabilities of the TEMPLATE graphics system and others of its type, are excellent for the generation of two-dimensional graphical representations of tabular data. The graphical needs of the CAD system, however, exceed these capabilities. Detailed structural, internal arrangements and subsystem design creates requirements for a much more graphics-intensive capability. These requirements include rapid and easy generation, storage and retrieval of three-dimensional representations of system components and the ability to use the stored data associated with these components for the generation of detailed drawings. Many such systems are currently available from Computervision, Applicon and other manufacturers. Since systems such as these are currently used

widely throughout industry, especially for system and subsystem design, the design student needs to become familiar with their capabilities. Such a system would also provide an excellent tool for use in the development of future design and manufacturing techniques.

4.5 Data Management

The major advantage of using computers instead of performing calculations manually is the computer's ability to perform these calculations very rapidly while handling large quantities of data. Without a system for managing this data, however, operation of the system becomes cumbersome and prevents the user from utilizing the computer's full potential. As stated previously, the existing application routines are generally independent entities and use their own inefficient schemes for management of data. This usually involves reading input data from data files or interactively from the terminal, storing this data internally as variables, performing calculations using this data by referencing these variable names and then sending the calculation results to an output file. As a result, after program execution, two or more data files exist with many data items duplicated between the files. Subsequent development using these results requires accessing both data files.

A more efficient scheme for data management would allow each application routine to build upon the already existing data, thereby alleviating any duplication of data items. This

collection of data, called the database, would define the ship as it exists at the current point in time. Any further operation on the database should serve to refine and add detail to the existing ship definition. Any previously defined data items, such as length between perpendiculars or design draft, however, should not be modified in the database by subsequent operations since this would effectively change the ship definition rather than add to it. If a change to an existing data item should become necessary, due to the iterative nature of the process, then a new database, completely detached from the old one, should be created to define the new ship. The design process should then continue by refining and adding detail to this new ship. By the end of the design process, this database should contain all data necessary to completely define the resulting design. This would provide the capability for rapid data retrieval and examination as well as providing the precompiled data package necessary for ship construction. In addition, the smaller, less defined databases which were developed earlier in the design process, would provide valuable references for future design efforts. If a new vessel, similar to one of those described in an existing database, is desired, a copy of the database provides an excellent starting point to begin designing the new design and can save much redundant work.

An effective database is one that can be shared by many routines encountered in the ship design process, each of which has a different task to perform. Data should be stored in a

form that allows the user to extract the information required and to use it directly without having to pass it through some form of interpretation process. For example, it should contain sufficient offsets, properly organized, such that each one of the programs for hydrostatics, Bonjean curves, structures and seakeeping can directly access it and obtain the input required without having to go through a "black-box" interface program.

The minimum requirements for each database entry are:

- Variable name
- Variable type (integer, real, etc.)
- Assigned value
- Units

Additionally, comment space should be reserved for ease of database maintenance. The Design Executive System (DEX), developed jointly at MIT and the University of Michigan, provides an excellent example of the structure of such a database system [7].

4.6 Application Routine Implementation

4.6.1 Implementation Procedures

Application routines provide the meat of any CAD system. MIT's abundant supply of existing routines makes implementation difficult only in that decisions must be made concerning which routines should be included. Any routine which performs useful and accurate calculations should be made available to the student and researcher. Storage and maintenance costs associated with making all such routines

readily available to the user, however, would be prohibitive. Therefore, the need for establishing different levels of availability is indicated. These levels of availability could easily be incorporated by allowing the executive control system to coordinate access to routines at different levels.

A two-level system would be most easily implemented and would provide the needed ease of access while reducing associated costs. Routines maintained at level-one would be stored within the system and would be accessed directly from the executive system. Routines maintained at this level should be those used as instructional tools for courses and those expected to receive heavy usage. The level-two routines should be stored using an external storage medium such as magnetic tape or magnetic disks. When needed, these routines would be loaded into the system by following instructions presented by the executive control system. Application routines which fall into this category are those which are expected to receive light usage and those other routines which are not part of an established course curriculum.

The fact that these application routines exist and are available is not meant to imply that they are ready to be implemented as part of a CAD system. In order for the system to remain consistent and to be usable, certain criteria must be established for inclusion of new routines into the system. These criteria are discussed below.

- a. Calculation quality First, and foremost, the calculations and evaluations performed by the routine

must be accurate.

b. System compatibility Input, output and data storage schemes must be consistent with those existing within the system. Also, the routine must be formatted such that it can be interfaced with the executive control system.

c. Documentation Without proper documentation, an otherwise excellent routine will not be useful. Accurate and thorough documentation must be made available to the user if he is to be expected to use the routine. Required documentation must include an on-screen help document which provides a brief description of program function, operation, input/output and calculation/evaluation methodology, a hardcopy user's guide providing the same information but in more detail, and inclusion of a brief description of the routine in the system bank of available options.

Once these criteria have been met, the program can be implemented on the system. This involves transferring the executable machine code and on-line help documentation to the level-one or level-two storage section. Finally, the program is activated by modifying the executive control system to indicate that the new program is now available. By insuring that all candidates for system inclusion meet the above criteria and by following established implementation procedures, system integrity and usability can be maintained.

4.6.2 Available Application Routines

In order for the CAD system to be useful for instructional and research purposes, it must contain application routines which are useful in course work as well as research work. As previously stated, many such application routines currently exist at MIT. To provide guidance for application routine selection, a brief description of some of

the major routines are provided below along with recommendations for system inclusion.

- REED Reed ship synthesis model - Synthesizes a ship from the input constraints, equipment, and payload. This program provides the ships characteristics, weights and volumes. The program is good for destroyer/cruiser class ships.
Location: IPS (Information Processing Service)
Recommended level: one
- PBSYN Patrol Boat Synthesis - Synthesis model for 50 - 150 foot planing or near planing patrol boats. Model developed at MIT by John Tuttle and modified by J. Sander and S. Judson.
Location: IPS
Recommended level: one
- HULLCON Hullcon ship hull lines generation program. Given a minimum set of ship characteristics, assumes initial boundary condition and generates sectional area curve, body plan, profile, deck at edge and other curves on a Tektronix 4014 graphics terminal. Gives output in offsets suitable for input to HULLDEV. (Not currently operational)
Location: IPS
Recommended level: one
- HULLDEV Hulldev ship development program identifies the ship characteristics by allowing the user to run displacement and other curves program, seakeeping, and other programs.
(Not currently operational)
Location: JCF (Joint Computer Facility)
Recommended level: one
- SHCP Ships Hull Characteristics Program - Using a data file containing ship offsets and interactive user inputs, will calculate displacement, curves of form, floodable length and hydrostatic characteristics.
Location: JCF
Recommended level: one

GSHCP Graphics Ships Hull Characteristics Program - Graphical version of SHCP. Produces graphical representations of data and body plans.
Location: JCF
Recommended level: one

BALES Bale's seakeeping program - Calculates Bale's seakeeping rank estimator, water plane and vertical prismatic coefficients and waterplane areas.
Location: JCF
Recommended level: one

RES60 Calm water resistance estimate according to Series 60 data by interpolation.
Location: IPS
Recommended level: one

RESTA Calm water resistance estimate according Taylor Series.
Location: IPS
REcommended level: one

SEEKST Interpolated procedure for the prediction of the seakeeping performance of cruiser stern ships using the seakeeping standard series data.
Location: IPS
Recommended level: one

CURRENT Five degree of freedom ship motions program. Includes drift forces; nonlinear roll and motions in a current.
Location: IPS
Recommended level: one

LLL2 Develops optimum propeller characteristics using Lerb's lifting line theory. User may create new or modify existing data files for evaluation.
Location: JCF
Recommended level: one

PROPEL Propeller program evaluates the optimum propeller using the B-Series data.
Location: IPS
Recommended level: one

BALANCE Longitudinal weight balancing program.
Location: JCF
Recommended level: one

SHEAR Program for calculating shear stresses in the hull girder given longitudinal weight distribution.
Location: JCF
Recommended level: one

MIDSHIP Program for calculating optimal member sizes for required midship section modulus.
Location: JCF
Recommended level: one

GRILLAGE Program for calculating optimal member sizes for grillage structure.
Location: JCF
Recommended level: one

SWACEM Small waterplane thin hull (SWATH) concept exploration model. Given a range of principle ship characteristics and a range of payload, SWACEM looks at all possible combinations of ships. It rejects those that are not possible. Those that remain are output for further processing by CMPOST.
Location: IPS
Recommended level: two

CMPOST A graphical pose processor for the SWATH exploration model (SWACEM). Produces a plot of a given optimization function by ship produced by SWACEM.
Location: IPS
Recommended level: two

PROP Propeller design program for obtaining propeller with maximum efficiency while satisfying blade stress and propeller cavitation constraints.
Location: IPS
Recommended level: two

DISP Displacement and other curves. Calculates the hydrostatic properties and section areas of the hull.
Location: IPS
Recommended level: two

FLDLTH Floodable length program calculates the length of a compartment and its location relative to the forward perpendicular, which would sink the ship to a specific trim line if the compartment were filled with water.
Location: IPS
Recommended level: two

XCRVS Cross curves of stability program calculates the data necessary to plot the cross curves of stability for the hull inclined at different angles.
Location: IPS
Recommended level: two

GUNBLAST Produces a plot of the topside overpressurization from own ships guns.
Location: IPS
Recommended level: two

EXTREMES Finds the extreme values of a Gaussian random process for two cases: (1) maximum among N samples and (2) maximum in T seconds.
Location: IPS
Recommended level: two

FIFTH Fifth order wave data.
Location: IPS
Recommended level: two

HOGBENIN Provides ocean wave statistics according to Hogben and Lumb.
Location: IPS
Recommended level: two

HUNDRED Finds the hundred year wave as used by the classification societies.
Location: IPS
Recommended level: two

NORMAL1 Determines the probability of the peaks of a Gaussian random process exceeding a certain value of A.
Location: IPS
Recommended level: two

NORMAL2 Finds the average of the 1/Nth highest peaks of a Gaussian random process.
Location: IPS
Recommended level: two

SEA Simulates a sea generating wave elevation as a function of time.
Location: IPS
Recommended level: two

SECFOR Evaluates the slowly changing second order forces given the sea spectrum and the time average of the second order forces.
Location: IPS
Recommended level: two

SPEC Produces points for a Bretschneider ocean wave spectrum.
Location: IPS
Recommended level: two

SPECMOM Finds the first, second, and fourth moments of a spectrum.
Location: IPS
Recommended level: two

WEIBUL Finds a Weibull wave distribution.
Location: IPS
Recommended level: two

WINDY Generates points of a Davenport wave spectrum.
Location: IPS
Recommended level: two

5.0 Demonstration of the Design System

5.1 Background

Thus far, this author has limited himself to discussions of what 'should be' and what 'could be' with respect to the CAD system. To demonstrate some of the CAD features previously discussed, a prototype CAD system, entitled Ships Computer Aided Design System (SCADS) was developed. Incorporating all of the features discussed is beyond the scope of this thesis, however, those features which demonstrate the major ideas presented were incorporated.

5.2 System Features

SCADS was developed using the facilities of the Joint Computer Facility (JCF) at MIT. Those facilities specifically used by SCADS include a DEC VAX-11/782 mainframe computer, DEC VT-100 text terminals, a Visual-550 graphics/text terminal and an IMAGEN laser printer/plotter. In addition, much of the documentation was created using an Apple IIe micro-computer running the CP/M operating system and the WORDSTAR word processing system.

The SCADS executive control system (SCADS for short) was written using Digital Command Language (DCL). This language provides features which allow SCADS to control the selection and execution of available application routines as well as providing a means for input/output designation and on-line help features. A print-out of the SCADS command executive is listed

in Appendix A.

The principle feature of SCADS is that it maintains control of all system operations from initial system entry until final exit. System initiation is accomplished by typing

SCADS

at the terminal. A welcome/status message is displayed (Appendix B) followed by an option to review system operation procedures. An affirmative reply will cause the primary on-line help document to be displayed (Appendix C). This document presents a brief description of the SCADS system and operating procedures as well as a listing of implemented application routines and a brief description of each.

Next, the user is asked to enter either a SCADS command or a help command. The help command is

DESIGN

Typing this at the keyboard will cause the primary on-line help document to be displayed. If the user desires more information about a specific application routine, this is available by typing

DESIGN <argument>

where <argument> would be the name of one of the implemented routines. Typing errors or unrecognized commands entered at either of these points, will cause a SCADS error message to be displayed followed by another system prompt.

Typing only the name of one of the implemented routines will initiate execution of that routine. For this prototype of

the SCADS system, three routines have been implemented:

- SHCP - hydrostatics calculations
- GSHCP - graphical version of SHCP
- BALES - Bale's seakeeping

The detailed on-line documentation for these routines are listed in Appendices D, E and F. As an illustration of what the user sees during a SCADS session, a listing of a sample session during which the SHCP program is executed is presented in Appendix G. This listing has been edited to remove the on-screen documentation which would normally be displayed.

5.3 Graphical Displays

A feature important to any CAD system is its ability to represent system calculation results in a graphical manner. With this capability available, the user is able to view the results of a design decision without having to sort through lengthy listings of tabulated data. By providing this capability as an on-line feature, the CAD system makes immediate evaluation possible, thus greatly reducing the turn-around time in the decision-result cycle.

The SCAD system discussed in the previous section has included one program which possesses these capabilities. The program, Graphics Ships Hull Characteristics Program (GSHCP), which is a graphical version of SHCP, was developed by NAVSEA. GSHCP provides interactive graphics displays of hydrostatic properties and curves of form of the hullform being evaluated.

A description of the features of the program are provided here as an example of the features which should be incorporated as part of the interactive graphics capabilities of a CAD system.

Primary hullform data is input via a data file of offsets with the remaining hullform definition data entered interactively from the keyboard. After this definitive data has been entered, all further system interaction is via the terminal's graphical display. Appendix H provides samples of the various graphical displays presented during execution of GSHCP. The graphical display system used with this program is the BLOX GRAPHICS BUILDER system, developed by Rubel Software and provides menu driven interactive capabilities necessary for on-line graphical manipulation. The BLOX system meets the IGES standards requirements and is compatible with the TEMPLATE graphical system.

Initially, the user is offered the option of viewing the input offset data graphically. Three displays are available: (1) offset body plan, (2) splined body plan and (3) isometric view. These are illustrated in Figures H-1 through H-3 respectively. By reviewing these displays, the user is able to immediately locate any irregularities associated with the description of the hullform as the system sees it. Since GSHCP performs hullform evaluation rather than hullform generation, it cannot change this ship definition. Any irregularities must be corrected by modification of the data file of offsets. Obviously, having this capability available

as part of a hullform generation program would make it possible to locate irregularities and to correct them interactively before beginning the evaluation process.

Once correct hullform definition has been established, the user, by selecting options from the display screen, can view the hydrostatic properties associated with this hullform. Samples of the displays available are shown in Figures H-4 through H-12. In addition, the user may modify ship draft and trim and view the Curves of Form which result from these changes. These changes are made possible by providing a representation of a numeric keypad on the display screen. The user controls the keypad by using either the keyboard arrows or by using a data tablet to control movement of a screen cursor. As numbers are selected or deleted, the correct numerical value is displayed. If this value is acceptable to the user, he enters the value into the system, which then performs its calculations using this new data. The user may then view the Curves of Form which represent this new data and can immediately see the changes caused by this modification. Additionally, the user may direct the system to generate a hardcopy of the current graphical display.

This type of interactive graphical display and interactive data modification capability makes it possible for the user to be more efficient in his efforts. The short turn-around time associated with this capability makes the evaluation of more options possible. Also, having a graphical

display readily available allows the design to make better informed decisions concerning future design development alternatives.

5.4 System Shortfalls

As stated previously, SCADS is a prototype system and does not include all of the features needed for the final CAD system. The most important missing feature is a database management system. As currently implemented, SCADS does not have the ability to coordinate the input, output or storage of data for use between separate application routines. Although the three implemented routines do possess a degree of commonality of input, some data required to be entered interactively (ship name, station spacing, etc.) is data which actually defines the current stage of the design and should be included as part of the database.

SCADS has been installed on a DEC VAX-11/782 mainframe computer at MIT. This facility has the capability of providing all of the support functions needed to fully implement the CAD system. However, this computer is used on a time-shared basis with many other users and, as a result, system response is frequently less than desirable. This is especially evident during periods of heavy system usage such as occurs at the end of an academic term. Slow response is very distracting when operating a system such as SCADS which requires an extensive amount of user interaction.

The programs currently available on SCADS have not been

modified from their original format. Therefore, few internal help features exist within these routines. Also, once a routine has been entered, data entry errors may cause catastrophic results, requiring reentry into SCADS from the beginning.

6. Conclusions and Recommendations

The need for the existence of a ship design CAD capability for use in an academic environment has been established. In order for future ship designers to be able to function efficiently in an industrial setting, use of these capabilities must be made part of their academic curriculum. Structural guidelines for the creation of this CAD facility have also been presented and features required to make the system usable have been discussed. Also, a prototype, illustrating some of the more important features required for this facility, has been developed and is currently operational at MIT. The next step is to use this prototype and these guidelines as a guide for the further development of this facility.

Full implementation of the ideas discussed here is not an easy task and is not one which can be accomplished in a short time period. Because of the time required to implement a system which incorporates all of these features, development must be a multi-step process.

Short-term goals should involve making the application routines available for use under SCADS in their present format. Centralized storage, user documentation creation and implementation under SCADS must be accomplished quickly so that the system will be available, even if in a crude form, as soon as possible. Also, development and implementation of

application routines which fill the gaps currently existing in the design process must be started. Specifically, a hullform generation and definition capability must be established. This could easily be accomplished by implementing the HULGEN and HULDEF programs developed by NAVSEA, thus closing the gap in the design process which exists between gross ship characteristics specification (REED synthesis model) and hydrostatics (SHCP) and seakeeping evaluation (BALES). Major hardware items currently are available, although limited in numbers. Since most system development work will eventually be done by the students as course work or thesis work, additional hardware, especially terminals and accessories, must be made available quickly.

Long-term goals should involve the modification of application routines to include error checking schemes, on-line help which is specific to each routine, and interactive graphics capabilities. In addition, a centralized database system should be implemented so that the logical flow of the design process can be established. NAVSEA has selected the Relational Information Management (RIM) system, distributed by Boeing Computer Services, as its database system. This system should be investigated for suitability as part of the proposed CAD system. Also, because the system must respond relatively quickly in order for it to be useful as a research tool, the possibility of obtaining a mainframe computer, designated specifically for the CAD facility, should be investigated.

The ground work for establishing a ship design CAD

facility has been laid. Continued emphasis on and support of system development will be needed, however, if a truly functional facility is to become reality.

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APPENDIX A

SCADS EXECUTIVE CONTROL SYSTEM


```

$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " ++++++"
$ WRITE SYS$OUTPUT " + "
$ WRITE SYS$OUTPUT " + M.I.T. + "
$ WRITE SYS$OUTPUT " + "
$ WRITE SYS$OUTPUT " + SHIPS COMPUTER AIDED DESIGN SYSTEM + "
$ WRITE SYS$OUTPUT " + "
$ WRITE SYS$OUTPUT " + VERSION 1.00 + "
$ WRITE SYS$OUTPUT " + "
$ WRITE SYS$OUTPUT " + BERNIE W. JOHNSON + "
$ WRITE SYS$OUTPUT " + "
$ WRITE SYS$OUTPUT " + APRIL 1984 + "
$ WRITE SYS$OUTPUT " ++++++"
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " "
$ !
$ !
$ ! DISPLAY WELCOME/SYSTEM STATUS MESSAGES
$ !
$ !
$ TYPE SCADMEL.DOC
$ !
$ !
$ ! GIVE USER THE OPTION OF REVIEWING COMMAND PROCEDURE SUMMARY
$ !
$ !
$ COM_PROCEDURE:
$ !
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "DO YOU WANT A REVIEW OF COMMAND PROCEDURES? (Y/N)"
$ WRITE SYS$OUTPUT " "
$ INQUIRE COM_INFO "-->"
$ !
$ IF COM_INFO .NES. "Y" .AND. COM_INFO .NES. "N" THEN GOTO COM_PROCEDURE
$ !
$ IF COM_INFO .EQS. "N" THEN GOTO COM_NO
$ !
$ !
$ COM_YES:
$ !
$ ! DISPLAY COMMAND PROCEDURE DOCUMENT
$ !
$ TYPE SCADCOM.DOC
$ !
$ !
$ COM_NO:
$ !
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "Enter a SCADS command or 'DESIGN' to view options."

```



```

$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " "
$ !
$ !
$ COM_GET:
$ !
$ !!!GET COMMAND
$ !
$ INQUIRE COM_NAME "--> "
$ !
$ !!!EXTRACT THE FIRST 4 CHARACTERS FOR COMPARISON
$ !
$ COM_NAME1 := 'F$EXTRACT(0,4,COM_NAME)'
$ !
$ MAIN_COM := ERR
$ !
$ IF COM_NAME1 .EQS. "SHCP" THEN MAIN_COM := SHCP.
$ !
$ IF COM_NAME1 .EQS. "GSHC" THEN MAIN_COM := GSHCP
$ !
$ IF COM_NAME1 .EQS. "BALE" THEN MAIN_COM := BALES
$ !
$ !*****
$ !* *
$ !* ADD OTHER APPLICATION ROUTINE COMPARISONS IN *
$ !* THIS AREA AS THEY ARE DEVELOPED *
$ !* *
$ !*****
$ !
$ IF COM_NAME1 .EQS. "EXIT" THEN GOTO EXIT
$ !
$ IF COM_NAME1 .EQS. "DESI" THEN GOTO MENU_CHECK
$ !
$ IF MAIN_COM .EQS. "ERR" THEN GOTO BAD_COM
$ !
$ @'MAIN_COM'
$ !
$ GOTO COM_GET
$ !
$ MENU_CHECK:
$ !
$ !!!CHECK FOR MODIFIER ON "DESIGN" COMMAND
$ !
$ COM_LEN := 'F$LENGTH(COM_NAME)'
$ !
$ SPACE := 'F$LOCATE(" ",COM_NAME)'
$ !
$ !!!MODIFIERS PRESENT
$ !
$ IF COM_LEN .NES. SPACE THEN GOTO MENU_AMP
$ !
$ TYPE SCADCOM.DOC
$ !

```



```

$ GOTO COM_GET
$ !
$ !
$ MENU_AHP
$ !
$ !!!DECIPHER MODIFIER TO "DESIGN" COMMAND
$ !
$ SUB_COM := ERR
$ !
$ SUB_MENU := 'F$EXTRACT(SPACE,3,COM_NAME)'
$ !
$ IF SUB_MENU .EQS. "SHC" THEN SUB_COM := SHCP.DOC
$ !
$ IF SUB_MENU .EQS. "GSH" THEN SUB_COM := GSHCP.DOC
$ !
$ IF SUB_MENU .EQS. "BAL" THEN SUB_COM := BALES.DOC
$ !
$ IF SUB_COM .EQS. "ERR" THEN GOTO BAD_COM
$ !
$ TYPE 'SUB_COM'
$ !
$ GOTO COM_GET
$ !
$ !
$ BAD_COM:
$ !
$ !!!ERROR TRAP FOR ILLEGAL COMMAND
$ !
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT "Unrecognized command. Please reenter."
$ WRITE SYS$OUTPUT " "
$ WRITE SYS$OUTPUT " "
$ !
$ GOTO COM_GET
$ !
$ !
$ EXIT:
$ !
$ EXIT

```


APPENDIX B

SCADS WELCOME/SYSTEM STATUS MESSAGE

Welcome to the SHIPS COMPUTER AIDED DESIGN SYSTEM

This system, which is currently under development, will aid you in the design and analysis of ship data. Although it will not make design decisions for you, it will provide many tools for your use so that the amount of time required for calculations and iterations can be reduced. Hopefully, this will allow for timely design decisions on your part.

This system has been designed to be as easy to use and as straight forward as possible. Help files are available for viewing at command input points as indicated below.

APPENDIX C

SHIPS COMPUTER AIDED DESIGN SYSTEM

ON-LINE HELP DOCUMENT

SHIPS COMPUTER AIDED DESIGN SYSTEM

THIS DESIGN SYSTEM CONTROLS THE OPERATION OF A COLLECTION OF USEFUL PROGRAMS TO AID YOU IN THE SHIP DESIGN PROCESS.

A SYSTEM PROMPT "-->" INDICATES THAT THE SYSTEM IS WAITING FOR YOU TO ENTER A COMMAND OR DATA FOR PROGRAMS WHICH ACCEPT DATA INTERACTIVELY.

TO VIEW THIS DOCUMENT AGAIN, TYPE "DESIGN" AT THE SYSTEM PROMPT OR FOR A MORE DETAILED DESCRIPTION OF A PARTICULAR PROGRAM INCLUDING INSTRUCTIONS, AT THE SYSTEM PROMPT TYPE:

--> DESIGN <ARGUMENT>

WHERE THE CURRENTLY AVAILABLE ARGUMENTS ARE:

SHCP
GSHCP *** OTHERS ADDED HERE AS IMPLEMENTED ***
BALES

FOR EXAMPLE:

--> DESIGN BALES

WOULD DISPLAY DETAILED INFORMATION ABOUT THE BALES SEAKEEPING PROGRAM.

TO RUN ONE OF THESE PROGRAMS, JUST TYPE THE NAME OF THE PROGRAM. FOR EXAMPLE:

--> SHCP

WOULD RUN THE PROGRAM "SHCP".

A BRIEF DESCRIPTION OF THE AVAILABLE PROGRAMS FOLLOWS.

SHCP USING A DATA FILE CONTAINING SHIP OFFSETS AND INTERACTIVE USER INPUTS, THIS PROGRAM WILL CALCULATE DISPLACEMENT, CURVES OF FORM, FLOODABLE LENGTH AND HYDROSTATIC CHARACTERISTICS. OUTPUT IS IN A TABULAR FORMAT.

GSHCP PERFORMS THE SAME CALCULATIONS AS 'SHCP' BUT PRODUCES GRAPHICAL REPRESENTATIONS OF THE DATA AS WELL AS BODY PLAN AND SHIP ISOMETRIC VIEW. DUE TO THE GRAPHICAL PRESENTATIONS, GRAPHICAL DISPLAY TERMINALS MUST BE USED TO RUN THIS PROGRAM. PRESENTLY, THESE INCLUDE THE 'VISUAL 550' AND THE 'VT-100'.

BALES USING A DATA FILE CONTAINING SHIP OFFSETS AND
 INTERACTIVE USER INPUT, THIS PROGRAM WILL
 CALCULATE BALE'S SEAKEEPING RANK ESTIMATOR,
 WATER PLANE AND VERTICAL PRISMATIC
 COEFFICIENTS AND WATER PLANE AREAS. OUTPUT
 IS IN A TABULAR FORMAT.

*** DESCRIPTIONS OF NEW ROUTINES ADDED AS IMPLEMENTED ***

APPENDIX D

SHIPS HULL CHARACTERISTICS PROGRAM

ON-LINE HELP DOCUMENTATION


```

*****
*                               *
*   SHIPS HULL CHARACTERISTICS PROGRAM   *
*                               *
*****
*           DEVELOPED BY NAVSEA           *
*                               *
*   IMPLEMENTED AT M.I.T. BY             *
*                               *
*           B.W. JOHNSON                 *
*           AND                           *
*           U.H. ROWLEY                   *
*           1983                          *
*****

```

During preliminary hull definition, many tedious and time consuming calculations are required. The Ships Hull Characteristics Program (SHCP) was developed to reduce the number of such calculations which must be performed by hand. SHCP was developed by NAVSEA and is currently being used in various forms throughout the Navy's design community. The output of SHCP consisted of volumetric properties, data points for calculating curves of form, floodable length and intact stability curves.

Since most of the data utilized by SHCP is in the form of "offsets", a separate file of this data must be created. Instructions for creating the offset file are provided below. Additional data required for specific portions of SHCP are entered interactively by the user at the terminal while the program is running. Prompts are provided to guide the user through a successful session. Descriptions of the different portions of SHCP are provided below.

The offsets which define the hull form are actually a collection of points, each having X,Y and Z coordinates. The points are entered by station number (X-coordinate) measured from the forward perpendicular, horizontal measure in feet (Y-coordinate) measured from the centerline, and vertical measure in feet (Z-coordinate) measured from the base line. In addition, a fourth number (control number) is required to indicate to the computer what type of point this point is. The offsets are entered as decimal values separated by commas. The control number is entered as an integer. Only one point is entered on each data line. Control numbers and their meanings are listed below.

- 1 - Ordinary offset data point
- 2 - Breakpoint or point of sharp hull curvature change
- 3 - Last data point for a station
- 4 - Last data point for the entire ship

A typical data line would be

6.75, 10.625, 22.0, 1

This would be translated as

- 6.75 - station number
- 10.625 - feet from centerline
- 22.0 - feet above the baseline
- 1 - control number (1 = ordinary data point)

All points for each station are entered before moving to the next station and the points for each station are entered starting at the keel and working to the deck edge. The following rules apply to station selection.

- a. A minimum of three and a maximum of forty-one stations can be specified.
- b. The total number of stations must be odd; each station must have a non-zero sectional area when totally immersed.
- c. The sequence of stations submitted must be from the bow aft. The tip of the bow and the stern should be included to define overall ship length (LOA). Stations forward of the FP should be entered using negative station numbers.
- d. The minimum station must have a half-breadth of at least .01 feet, and an incremental height of at least .01 feet.
- e. Regions of rapid change in station size or shape require many closely spaced stations (e.g. half and or quarter stations should be submitted near the bow and or stern).
- f. Longitudinal breakpoints (end of raised forecastle, end of skeg, etc.) are represented by three very closely spaced stations which must be odd-even-odd in the sequence of stations submitted. Do not confuse a station's position in the input sequence with its station number.
- g. Only three stations in the odd-even-odd sequence need be specified for the parallel mid body.

The following rules must be observed for points on each station.

- a. A minimum of two points and a maximum of twenty nine points per station can be processed. Since the program performs a second order interpolation fit of unequally spaced points, these must be considered as part of the maximum when building the input file. If no additional points are desired to be added by the program, the input file must have equally spaced points at each station. The spacing however does not have to be the same for each station since they are computed individually.
- b. The points at each station must be submitted in ascending order by height. Hulls with tunnel sterns and convex bottoms cannot be processed directly, because all points below the highest point of the convex surface are ignored.
- c. Only two horizontal lines are permitted on a station: one from the vertical centerline of the ship to the first point; and one from the last point on the station back to the centerline. Therefore, first or last points on the centerline must not be specified whenever a horizontal line would connect them with an adjacent point. If the slope of a straight line connecting two

adjacent points is less than or equal to 0.002 either the first or the second point will be ignored.

d. Regions of rapid change in curvature (e.g. the turn of the bilge) require many closely spaced points.

e. Points of abrupt changes in curvature (e.g. edge of the keel, knuckles, etc.) must be identified as vertical breakpoints. The maximum number of breakpoints permissible per station is six.

A typical data file is illustrated below.

```
-0.5, .875, 78.0, 1
-0.5, .875, 78.75, 3      last point of station
0.0, .875, 24.0, 1
0.0, 5.625, 36.0, 1
0.0, 11.375, 60.0, 1
0.0, 13.25, 76.625, 3     last point of station
2.0, 1.75, 0.0, 1
2.0, 1.75, 1.9, 2        breakpoint
2.0, 6.0, 4.31, 1
2.0, 28.375, 24.0, 1
2.0, 39.875, 68.375, 3   last point of station
5.0, 1.75, 0.0, 1
5.0, 1.75, 1.7, 2        breakpoint
5.0, 18.0, 5.75, 1
5.0, 46.625, 30.0, 1
5.0, 47.75, 48.0, 1
5.0, 47.8125, 54.0, 2     breakpoint
5.0, 47.8125, 58.75, 3   last point of station
10.0, 1.75, 0.0, 1
10.0, 1.75, 1.7, 2        breakpoint
10.0, 3.0, 3.6875, 1
10.0, 24.0, 15.6875, 1
10.0, 44.25, 42.0, 1
10.0, 44.75, 45.6875, 2   breakpoint
10.0, 45.375, 52.3125, 3  last point of station
11.8, 0.5, 21.625, 1
11.8, 18.0, 30.6875, 1
11.8, 33.0, 42.0, 1
11.8, 35.9375, 46.3125, 2 breakpoint
11.8, 37.3625, 52.9762, 3 last point of station
13.417, 0.0, 47.9375, 1
13.417, 9.625, 54.5, 4   last point of ship
```

SHCP is selected by typing "SHCP" at the SCADS prompt "-->".

The SHCP program contains four sections:

- Hydrostatic properties
- Curves of form
- Floodable length

-Curves of statical stability

Upon initial selection of SHCP, the user will be asked to enter:

- Input file name (file with offsets data)
- Output file name
- Ship name
- Serial number (for user's records only)
- Execution date

The program then reads in the file of offsets and performs a second-order interpolation to provide data points for use with the Simpson's 1-4-1 integration for volume and area calculations for the hydrostatic properties. The user is then asked whether these interpolated points should be included in the output file. The user is now asked for these additional data items:

- Length between perpendiculars (decimal feet)
- Station spacing (decimal feet)
- Maximum half-beamwidth (decimal feet)
- Design input type:
 - 1--Design draft and trim
 - 2--Design displacement and trim
 - 3--Design displacement and LCG
- Data matching this choice (decimal values)
- Water density

The user is now asked which of the three remaining portions of SHCP should be executed. Upon completion of each selected section, the user is allowed to select another section (or the same one) or is allowed to exit the program.

***** CURVES OF FORM *****

This section calculates data for requested waterlines and trims. If none of the requested waterlines is within .001 feet of the design waterline, it is added to the list of waterlines for which calculations are performed. The following properties are calculated.

- Displacement
- Prismatic coefficient
- Waterplane coefficient
- Transverse waterplane inertia coefficient
- Longitudinal metacentric radius
- Transverse metacentric radius
- Height of longitudinal metacenter above baseline
- Height of transverse metacenter above baseline
- Tons per inch immersion
- Change in displacement per foot of trim aft
- Moment to trim one inch

Inputs:

- Maximum draft for calculations (decimal feet)
- Draft increment for calculations (decimal feet)
- Number of different trims (integer)
- Trims (+ by stern) separated by commas (decimal feet)

The user is now allowed to select another section of SHCP to execute or to exit.

***** FLOODABLE LENGTH *****

Floodable length determines the lengths of shell-to-shell compartments of specified permeabilities that, when flooded, will cause the ship to settle to the waterline tangent to the margin line. For these calculations, the margin line is assumed to be 3 inches below the uppermost point on each station described in the offset table. The added weight method is used to calculate floodable lengths.

Inputs:

- Number of permeabilities (integer - 7 maximum)
- These permeabilities, separated by commas (decimal)

The user is now asked to select another section to execute or to exit.

***** CURVES OF STATICAL STABILITY *****

This portion of SHCP calculates curves of statical stability for 10 different heel angles. Up to seven sets of initial conditions are permitted. These initial conditions may be in the form of either displacements and LCG's, displacements and trims or drafts and trims. For each input combination, the ship is balanced at each heel angle to obtain draft and trim which yield the required volume and LCG.

Inputs:

- Format for data entry
 - 1--Displacements and LCG's
 - 2--Displacements and Trims
 - 3--Drafts and Trims
- Number of these data sets for which calculations are desired (integer, 7 maximum)
- Data for selected format (decimal values)
- Maximum heel angle (decimal degrees)

The user is now asked to select execution of another section or to exit.

Upon exit, the user may choose to run another portion of SCADS or to exit the system.

APPENDIX E

GRAPHICS SHIPS HULL CHARACTERISTICS PROGRAM

ON-LINE HELP DOCUMENTATION


```

*****
*                                     *
*   GRAPHIC SHIPS HULL CHARACTERISTICS PROGRAM   *
*                                     *
*****
*               BASED ON SHCP               *
*           DEVELOPED BY NAVSEA             *
*                                     *
*   GRAPHICS FEATURES INCORPORATED BY       *
*                                     *
*               U.H. ROWLEY                 *
*               1983                         *
*****

```

The Graphic Ships Hull Characteristics Program (GSHCP) is a modified version of the Ships Hull Characteristics Program (SHCP) developed by NAVSEA. This version incorporates graphical routines which allow displaying of the output generated by SHCP in a graphical format. The graphics system utilized in development of GSHCP consists of the BLOX core graphics system with BLOX GRAPHICS BUILDER, developed by RUBEL SOFTWARE of Cambridge, MA.

Two output devices are currently available for displaying the graphics associated with GSHCP. These are the VT-100 terminal and the Visual-550 terminal. Upon initial program entry, the user will be asked to designate which terminal is being used.

GSHCP has the capability of HARDCOPY output. Upon hardcopy request, a hardcopy file, BGBFIL.DAT, is created in two versions. The procedure for plotting these files is as follows:

1--Type the command

```
BGBPLT BGBFIL IMAGEN
```

This will create an image file called IMFILE.DAT

2--Rename the most recent version (n) of BGBFIL.DAT by typing the command

```
RENAME BGBFIL.DAT;n NEWNAME.DAT
```

By renaming this file, the next lower version number of BGBFIL.DAT is made available for processing and the original file is saved as NEWNAME.DAT

3--Now plot the image file by typing

```
PRINT/QUE=IMAGEN IMFILE.DAT;a
```

Where (a) is the version number of the image file.
This will plot the image on the Imagen Laser Plotter.

Since most of the data utilized by SHCP is in the form of "offsets", a separate file of this data must be created. Instructions for creating the offset file are provided below. Additional data required for initializing GSHCP is entered interactively by the user at the terminal while the program is running. After generation of the first graphical display, further data input and system control is performed by using the arrow keys and/or data tablet, depending on the terminal being used. Descriptions of the different portions of SHCP are provided below.

The offsets which define the hull form are actually a collection of points, each having X,Y and Z coordinates. The points are entered by station number (X-coordinate) measured from the forward perpendicular, horizontal measure in feet (Y-coordinate) measured from the centerline, and vertical measure in feet (Z-coordinate) measured from the base line. In addition, a fourth number (control number) is required to indicate to the computer what type of point this point is. The offsets are entered as decimal values separated by commas. The control number is entered as an integer. Only one point is entered on each data line. Control numbers and their meanings are listed below.

- 1 - Ordinary offset data point
- 2 - Breakpoint or point of sharp hull curvature change
- 3 - Last data point for a station
- 4 - Last data point for the entire ship

A typical data line would be

6.75, 10.625, 22.0, 1

This would be translated as

- 6.75 - station number
- 10.625 - feet from centerline
- 22.0 - feet above the baseline
- 1 - control number (1 = ordinary data point)

All points for each station are entered before moving to the next station and the points for each station are entered starting at the keel and working to the deck edge. The following rules apply to station selection.

- a. A minimum of three and a maximum of forty-one stations can be specified.
- b. The total number of stations must be odd; each station must have a non-zero sectional area when totally immersed.
- c. The sequence of stations submitted must be from the bow aft. The tip of the bow and the stern should be included to define overall ship length (LOA). Stations forward of the FP are entered with negative station numbers.

d. The minimum station must have a half-breadth of at least .01 feet, and an incremental height of at least .01 feet.

e. Regions of rapid change in station size or shape require many closely spaced stations (e.g. half and or quarter stations should be submitted near the bow and or stern).

f. Longitudinal breakpoints (end of raised forecastle, end of skeg, etc.) are represented by three very closely spaced stations which must be odd-even-odd in the sequence of stations submitted. Do not confuse a station's position in the input sequence with its station number.

g. Only three stations in the odd-even-odd sequence need be specified for the parallel mid body.

The following rules must be observed for points on each station.

a. A minimum of two points and a maximum of twenty nine points per station can be processed. Since the program performs a second order interpolation fit of unequally spaced points, these must be considered as part of the maximum when building the input file. If no additional points are desired to be added by the program, the input file must have equally spaced points at each station. The spacing however does not have to be the same for each station since they are computed individually.

b. The points at each station must be submitted in ascending order by height. Hulls with tunnel sterns and convex bottoms cannot be processed directly, because all points below the highest point of the convex surface are ignored.

c. Only two horizontal lines are permitted on a station: one from the vertical centerline of the ship to the first point; and one from the last point on the station back to the centerline. Therefore, first or last points on the centerline must not be specified whenever a horizontal line would connect them with an adjacent point. If the slope of a straight line connecting two adjacent points is less than or equal to 0.002 either the first or the second point will be ignored.

d. Regions of rapid change in curvature (e.g. the turn of the bilge) require many closely spaced points.

e. Points of abrupt changes in curvature (e.g. edge of the keel, knuckles, etc.) must be identified as vertical breakpoints. The maximum number of breakpoints permissible per station is six.

A typical data file is illustrated below.

-0.5, .875, 78.0, 1

-0.5, .875, 78.75, 3 last point of station


```

0.0, .875, 24.0, 1
0.0, 5.625, 36.0, 1
0.0, 11.375, 60.0, 1
0.0, 13.25, 76.625, 3      last point of station
2.0, 1.75, 0.0, 1
2.0, 1.75, 1.9, 2          breakpoint
2.0, 6.0, 4.31, 1
2.0, 28.375, 24.0, 1
2.0, 39.875, 68.375, 3     last point of station
5.0, 1.75, 0.0, 1
5.0, 1.75, 1.7, 2          breakpoint
5.0, 18.0, 5.75, 1
5.0, 46.625, 30.0, 1
5.0, 47.75, 48.0, 1
5.0, 47.8125, 54.0, 2       breakpoint
5.0, 47.8125, 58.75, 3     last point of station
10.0, 1.75, 0.0, 1
10.0, 1.75, 1.7, 2         breakpoint
10.0, 3.0, 3.6875, 1
10.0, 24.0, 15.6875, 1
10.0, 44.25, 42.0, 1
10.0, 44.75, 45.6875, 2     breakpoint
10.0, 45.375, 52.3125, 3    last point of station
11.8, 0.5, 21.625, 1
11.8, 18.0, 30.6875, 1
11.8, 33.0, 42.0, 1
11.8, 35.9375, 46.3125, 2   breakpoint
11.8, 37.3625, 52.9762, 3   last point of station
13.417, 0.0, 47.9375, 1
13.417, 9.625., 54.5, 4     last point of ship

```

GSHCP is selected by typing "GSHCP" at the SCADS prompt "-->".

The GSHCP program currently has two sections operational:

- Hydrostatic properties
- Curves of form

Upon initial selection of GSHCP, the user will be asked to enter:

- Input file name (file with offsets data)
- Output file name
- Ship name
- Serial number (for user's records only)
- Execution date

***** HYDROSTATIC PROPERTIES *****

The program now reads in the file of offsets and performs a second-order interpolation to provide data points for use with the Simpson's 1-4-1 integration for volume and area calculations for the hydrostatic properties. The user is then asked whether these interpolated points should be included in the output file. The user is now asked for these additional data items:

- Length between perpendiculars (decimal feet)
- Station spacing (decimal feet)
- Maximum half-beamwidth (decimal feet)
- Design input type:
 - 1--Design draft and trim
 - 2--Design displacement and trim
 - 3--Design displacement and LCG
- Data matching this choice (decimal values)
- Water density

At this point, GSHCP enters its graphical mode and further system interaction is via either the arrow keys or via the data tablet. The user selects the portions of GSHCP he wishes to view or enters data modifications via the key-pad shown on the screen.

The initial graphical screen displayed offers the user six options for system operation. These options are:

- 1--OFFSET BODY PLAN - Displays body plan consisting of points that were input and interpolated by GSHCP. This merely connects these points and does no fairing.
- 2--SPLINED BODY PLAN - Uses a cubic spline to attempt a fairing of the input offset point. Gives a rough approximation of the fairness of the points. Note that this routine will not handle a major discontinuity such as a breakpoint.
- 3--ISOMETRIC VIEW - Displays a three dimensional view of offset data points as entered and interpolated.
- 4--VOLUME PROPERTIES - Displays volumetric properties of the hull. These properties are also automatically written to the output data file.
- 5--CURVES OF FORM - Cycles to a new screen that has a menu for available curves and prompts for input. The options are described below in the CURVES OF FORM section.
- 6--EXIT - Stops program execution and returns the user to the SCADS prompt.

***** CURVES OF FORM *****

This section calculates data for requested waterlines and trims. If none of the requested waterlines is within .001 feet of the design waterline, it is added to the list of waterlines for which calculations are performed. The following properties are calculated.

The actuation of CURVES OF FORM will result in a prompt for "Desired maximum draft waterline (in decimal feet)" to be placed on

the graphs and "Desired trim (decimal feet + by the stern)". These are input using the arrow keys or data tablet by selecting values from the keypad on the lower right of the screen. Selections are displayed in the area directly above the keypad and corrections may be made using the "delete" indicator on the keypad. The maximum draft waterline acceptable is 50.0 feet, however, the maximum cannot exceed the deck edge of the ship. After the information is accepted, the user will be prompted when calculations are completed and a curve may be selected. The curves available for selection are listed in the upper right side of the screen. Upon selection of one of these curves, it will be displayed on the screen complete with annotations. As each curve is selected, the last one will be erased. Curves available are:

- Displacement
- Waterplane area
- LCB/LCF
- TPI/KB
- Moment to trim one inch
- Change in displacement per foot of trim aft
- Prismatic coefficient/waterplane coefficient
- KML/BML
- KMT/BMT

The other menu items available on the bottom of the screen are listed below:

- NEW TRIM LINE - Prompts for new desired trim (decimal feet + by the stern) and recalculates curves for this new trim.
- NEW MAX DRAFT - Prompts for new maximum draft and new trim for curves and recalculates data.
- HARDCOPY - Creates output hardcopy files for graph currently being viewed.
- OUTPUT FILE - Writes an output file for all curves for the given trim in two foot intervals up to the maximum draft waterline requested.
- RETURN - Returns to the initial screen.

For more information concerning program execution and the calculation methods used by GSHCP, consult the GSHCP users guide.

APPENDIX F

BALES SEAKEEPING PROGRAM

ON-LINE HELP DOCUMENT

BALES SEAKEEPING PROGRAM

DEVELOPED AT

M.I.T.

BY

ROBIN. L. HIDDENEN

1983

This program, based on work done by Nathan Bales, calculates the relative seakeeping performance of a defined ship hullform. This performance criteria, known as Bales Seakeeping Rank Estimator, R, is based on the following equation.

$$R = 8.42 + 45.1 * CWPf + 10.1 * CWPA - 37.8 * (T/L) \\ + 1.27 * (C/L) - 23.5 * CVPF - 15.9 * CVPA$$

Where:

CWPf = waterplane coefficient forward of midships

CWPA = waterplane coefficient aft of midships

T = draft

L = length between perpendiculars

C = cutup point, distance aft of the forward perpendicular where the keel rises

CVPF = vertical prismatic coefficient forward

CVPA = vertical prismatic coefficient aft

Bale's Rank Estimator can have values between 0 and 10, with 10 indicating the best seakeeping performance.

In addition to calculation of R-factor, the following values are also calculated:

- Sectional areas for input stations
- Interpolated values for 21 evenly spaced stations:
 - station number
 - distance aft of the forward perpendicular
 - design waterline offset
 - sectional area
- Area of the waterplane forward/aft of midships
- Waterplane coefficient forward/aft of midships
- Displaced volume forward/aft of midships
- Vertical prismatic coefficient forward/aft of midships
- Cutup point

Additionally, if R is not satisfactory, the program will give recommendations for further improvements on the seakeeping characteristics of the hull.

INPUTS REQUIRED:

Ship name (up to 32 characters)

Serial number (4 digits, for record keeping only)

Length between perpendiculars (decimal feet)

Maximum half-beamwidth (decimal feet)
 Design draft (decimal feet)
 Filename of input data file containing ship offsets
 example: INFILE.DAT
 Filename of file for output data
 example: OUTFILE.DAT

The input data file contains the ship's offsets in the form of XYZ coordinates of data points which define the hullform. The points entered by station number (X-coordinate) measured from the forward perpendicular, horizontal measure in feet (Y-coordinate) measured from the centerline, and vertical measure in feet (Z-coordinate) measured from the baseline. In addition, a fourth number (control number) is required to indicate to the program what type of point this is. The offsets are entered as decimal values separated by commas. The control number is entered as an integer. Only one point is entered on each data line. Control numbers and their meanings are listed below.

- 1 - Ordinary offset data point
- 2 - Breakpoint or point of sharp hull curvature change
- 3 - Last data point for a station
- 4 - Last data point for the entire ship

A typical data line would be

6.75,10.625,22.0,1

This would be translated as

6.75 - station number
 10.625 - feet from centerline
 22.0 - feet above baseline
 1 - control number, 1 = ordinary data point

all points for each station are entered before moving to the next station and the points for each station are entered starting at the keel and working to the deck edge. Points for the keel and deck edge must be included. Although stations are not required to be evenly spaced, an odd number of stations is required. Each station must have at least 2 but not more than 29 data points. Stations forward of the Forward Perpendicular may be entered using negative station numbers. A typical data file is illustrated below.

-0.5,	.875,	78.0,	1	
-0.5,	.875,	78.75,	3	last point of station
0.0,	.875,	24.0,	1	
0.0,	5.625,	36.0,	1	
0.0,	11.375,	60.0,	1	
0.0,	13.25,	76.625,	3	last point of station
2.0,	1.75,	0.0,	1	
2.0,	1.75,	1.9,	2	breakpoint
2.0,	6.0,	4.31,	1	

2.0,	28.375,	24.0,	1	
2.0,	39.875,	68.375,	3	last point of station
5.0,	1.75,	0.0,	1	
5.0,	1.75,	1.7,	2	breakpoint
5.0,	18.0,	5.75,	1	
5.0,	46.6,	30.0,	1	
5.0,	47.75,	48.0,	1	
5.0,	47.8,	54.0,	2	breakpoint
5.0,	47.825,	58.75,	4	last point of ship

NOTE: The blank spaces are included for readability only and are not required.

Additional information concerning input data requirements may be found in the Ships Hull Characteristics Program (SHCP) User's Guide.

APPENDIX G

SAMPLE SCADS SESSION

NOTE: Document files which would be displayed during an actual SCADS session have been edited out of this listing for brevity and are listed in Appendices A - F.

\$ SCADS

```
+++++
+
+           M.I.T.           +
+
+ SHIPS COMPUTER AIDED DESIGN SYSTEM +
+
+           VERSION 1.00      +
+
+           BERNIE W. JOHNSON  +
+
+           APRIL 1984        +
+++++
```

Welcome to the SHIPS COMPUTER AIDED DESIGN SYSTEM

```
***** The SCADS welcome/system status message *****
***** would normally be seen here *****
```

DO YOU WANT A REVIEW OF COMMAND PROCEDURES? (Y/N)

--): Y

SHIPS COMPUTER AIDED DESIGN SYSTEM

```
***** The SCADS on-line help documentation *****
***** would normally be seen here *****
```

Enter a SCADS command or 'DESIGN' to view options.

--> : DESIGN BALES

BALES SEAKEEPING PROGRAM

```
***** The on-line help documentation for the Bales *****
***** Seakeeping Program would normally be seen here *****
```

--> : DISIGN

Unrecognized command. Please reenter.

--> : DESIGN BOLES

Unrecognized command. Please reenter.

--> : SHCP

```
+++++  
+                               +  
+ SHIPS HULL COMPUTER PROGRAM +  
+                               +  
+++++
```

ENTER NAME OF INPUT DATA FILE

--> : GAILDATA.DAT

ENTER NAME OF OUTPUT DATA FILE

--> : OUTPUT.DAT

INPUT: Ship Name (up to 32 characters)

S.S. SUSAN GAIL

INPUT: Four digit serial number for run

1001

INPUT: Date of run (MM-DD-YY)

05-09-84

INDICATE OFFSETS DESIRED IN OUTPUT

```
0--Original and interpolated offsets  
1--Original offsets only  
2--Interpolated offsets only  
3--No offsets in output desired
```

3

ENTER: Length between
perpendiculars (decimal feet)

300.0

ENTER: Station spacing (decimal feet)

24.0

ENTER: Maximum beam-halfwidth (decimal feet)

48.0

For design input you must enter either:

- 1--Design draft and trim
- 2--Design displacement and trim
- 3--Design displacement and LCG

ENTER: Your choice.

1

ENTER: Design draft (decimal feet)

36.0

ENTER: Design trim (+ by stern) (decimal feet)

0.0

ENTER: Water density (decimal cu-ft/ton)

35.0

What portion of SHCP would you like to run?

- 1--Curves of Form.
- 2--Floodable Length.
- 3--Curves of Statical Stability.
- 4--Exit

INPUT: your choice.

2

ENTER: Number of different permeabilities
(integer, 7 maximum)

1

ENTER: 1 permeabilities separated
by commas (decimal)

0.95

Floodable Length Completed

What portion of SHCP would you like to run?

- 1--Curves of Form.
- 2--Floodable Length.
- 3--Curves of Statical Stability.
- 4--Exit

INPUT: your choice.

4

--> : EXIT

\$

APPENDIX H

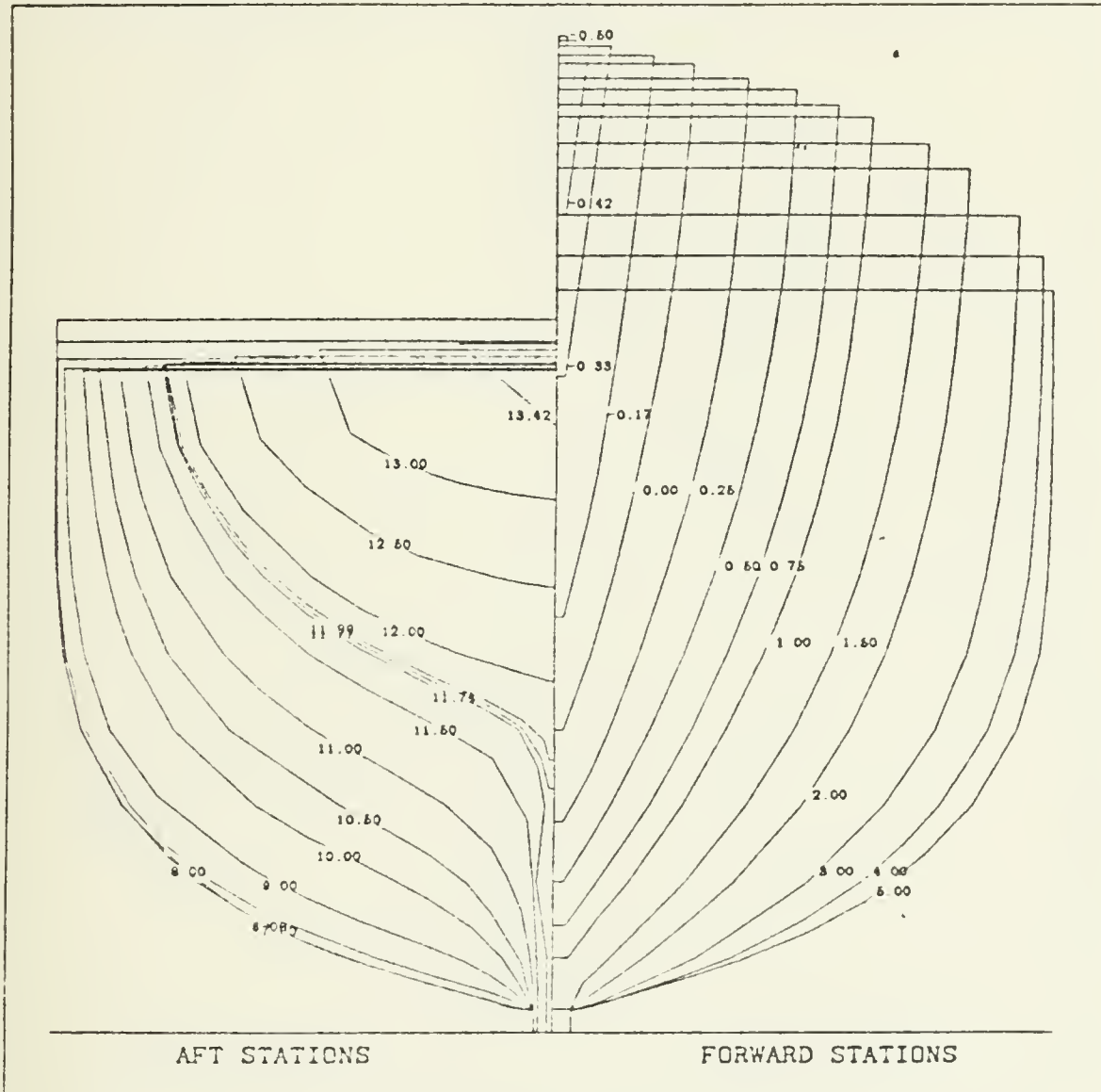
SAMPLE GSHCP GRAPHICAL OUTPUT

OFFSET BODY PLAN

S.S. SUSAN GAIL

1001

05-03-84



HARDCOPY SPLINED BODY PLAN RETURN

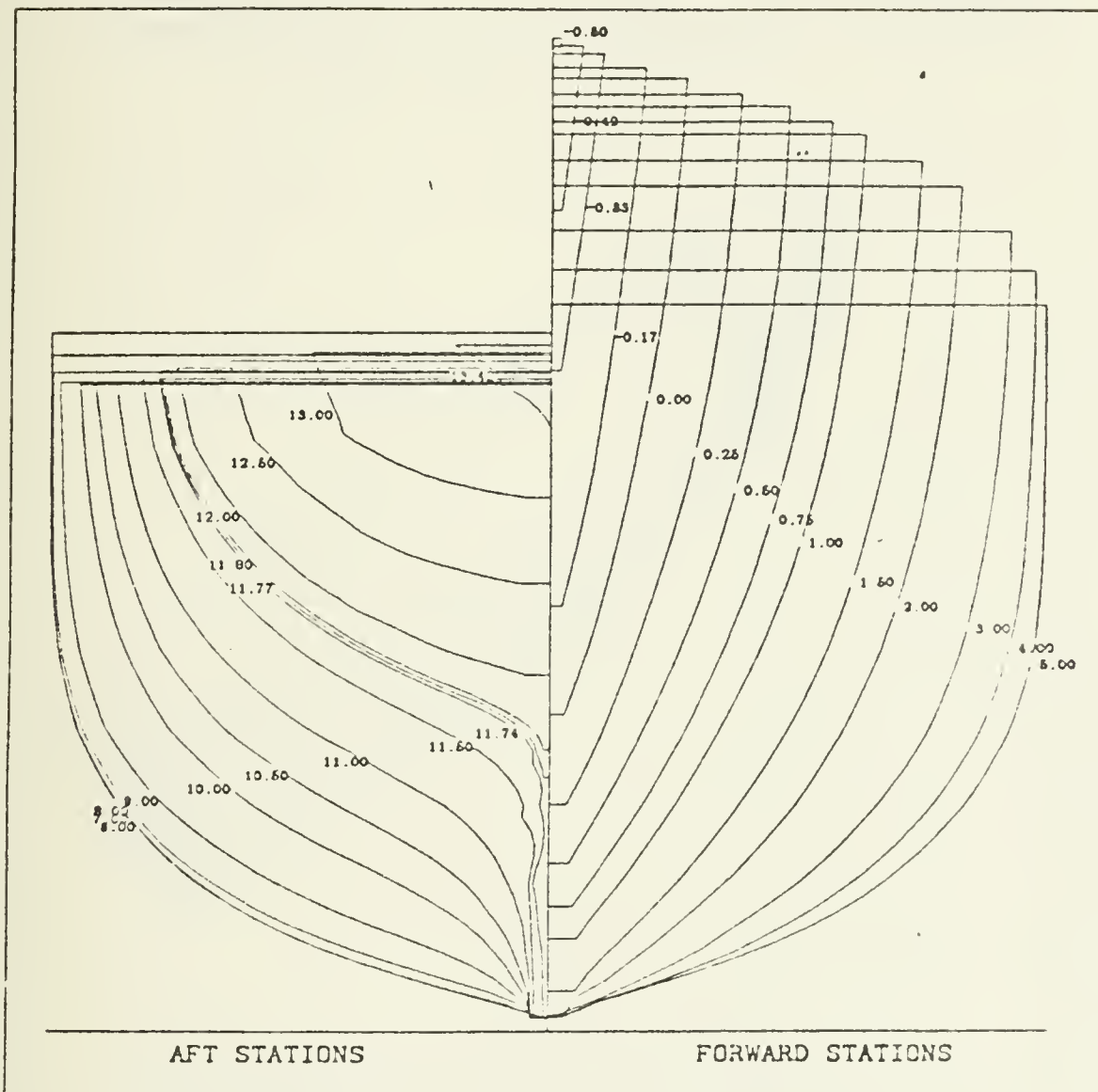
Figure H-1. Offset Body Plan

SPLINED BODY PLAN

S.S. SUSAN GAIL

1001

05-05-84



HARDCOPY SPLINED BODY PLAN RETURN

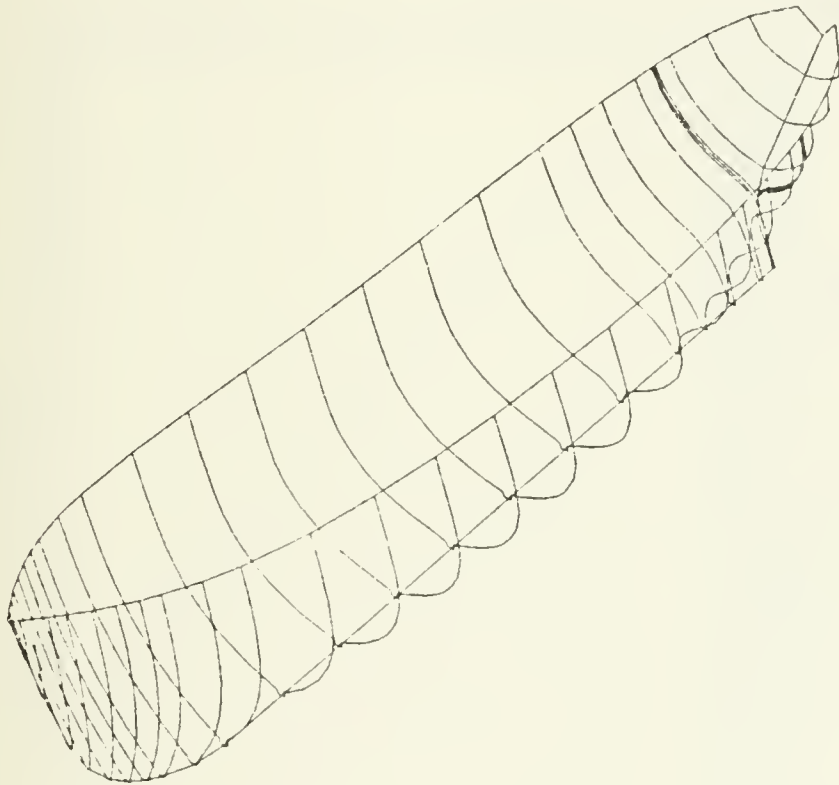
Figure H-2. Splined Body Plan

ISOMETRIC 3-D VIEW

S.S. SUSAN GAIL

1001

05-03-84



HARDCOPY

RETURN

Figure H-3. Isometric 3-D View

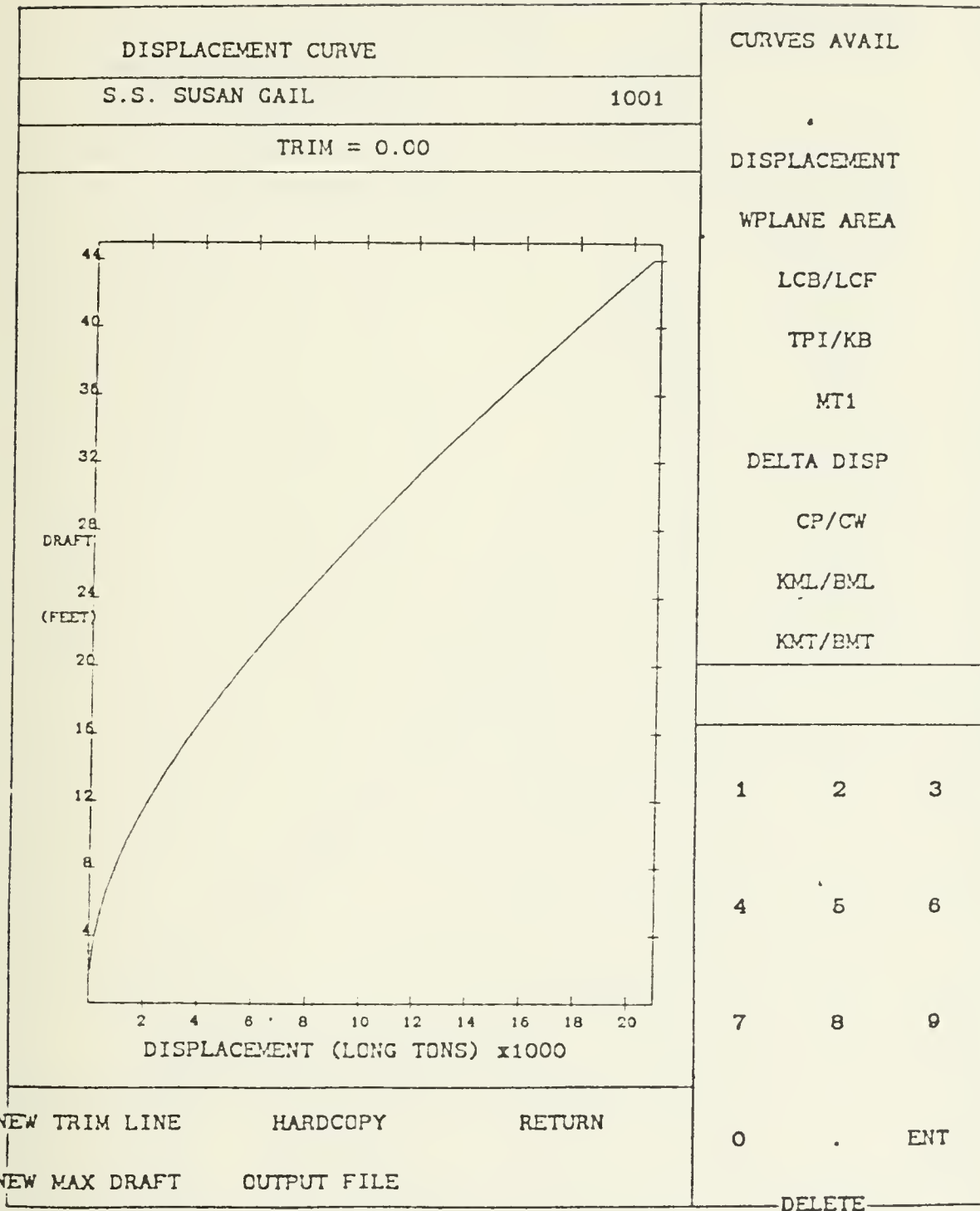


Figure H-4. Displacement Curve

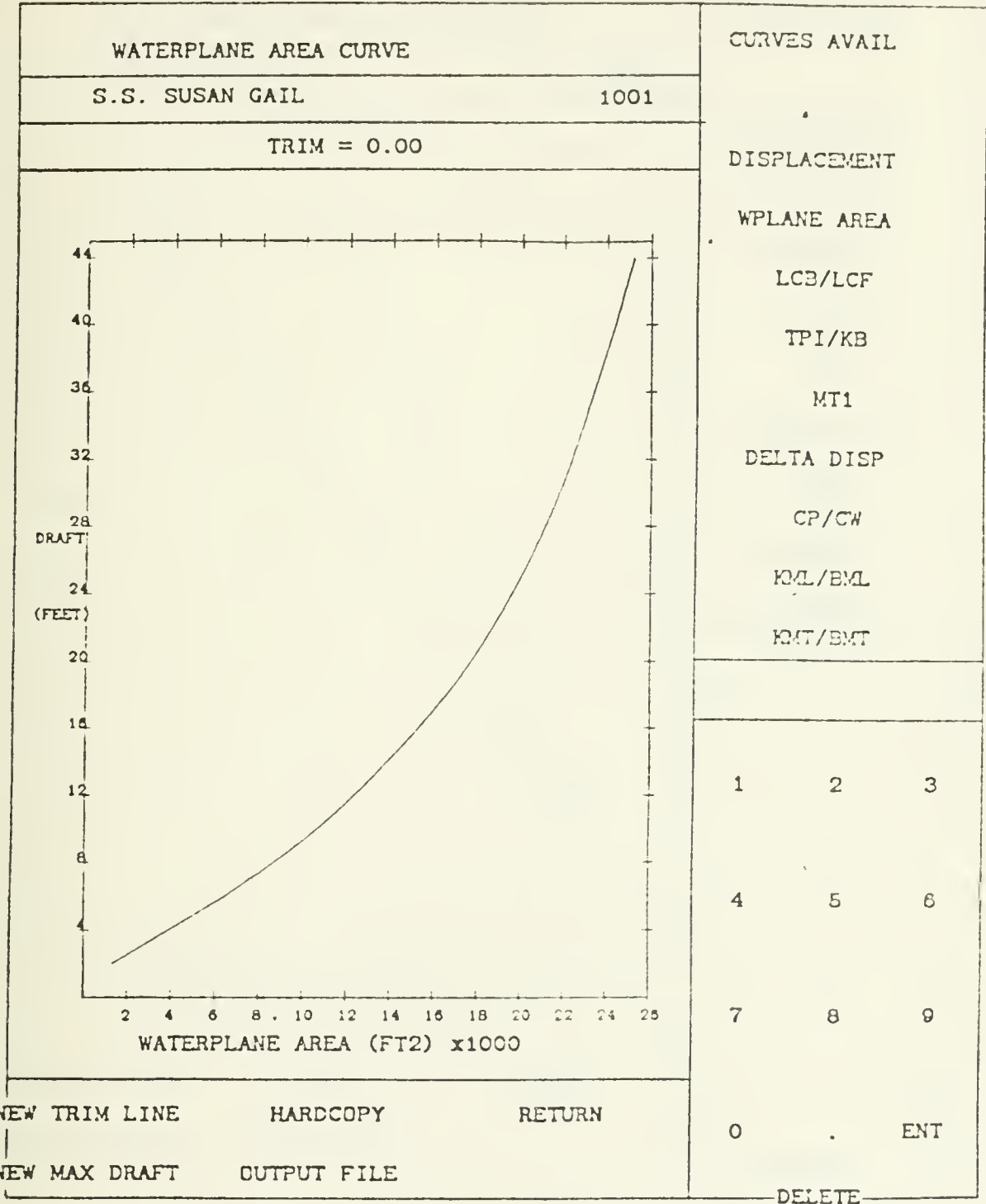


Figure H-5. Waterplane Area Curve

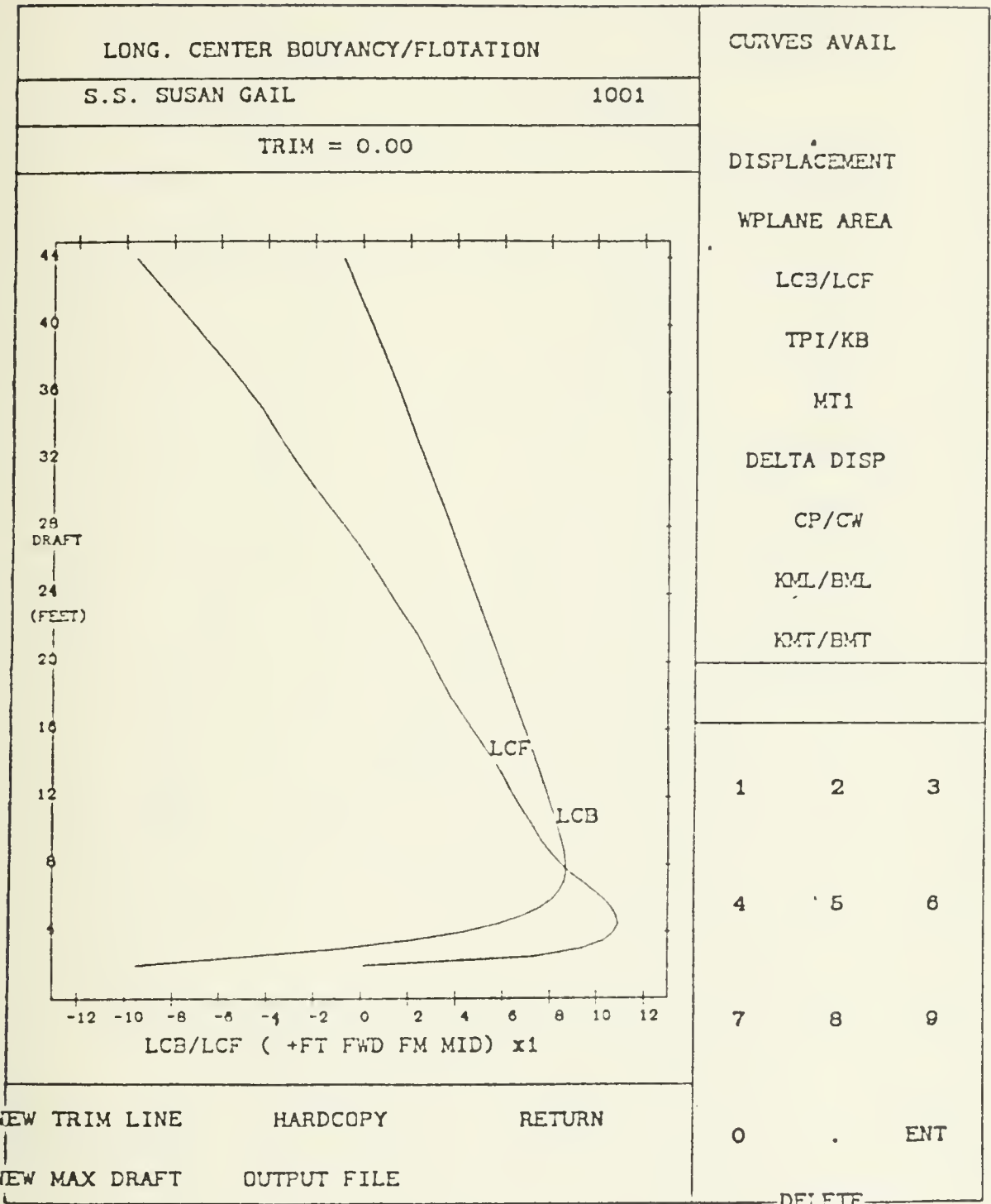


Figure H-6. Longitudinal Center of Buoyancy/ Longitudinal Center of Flotation Curves

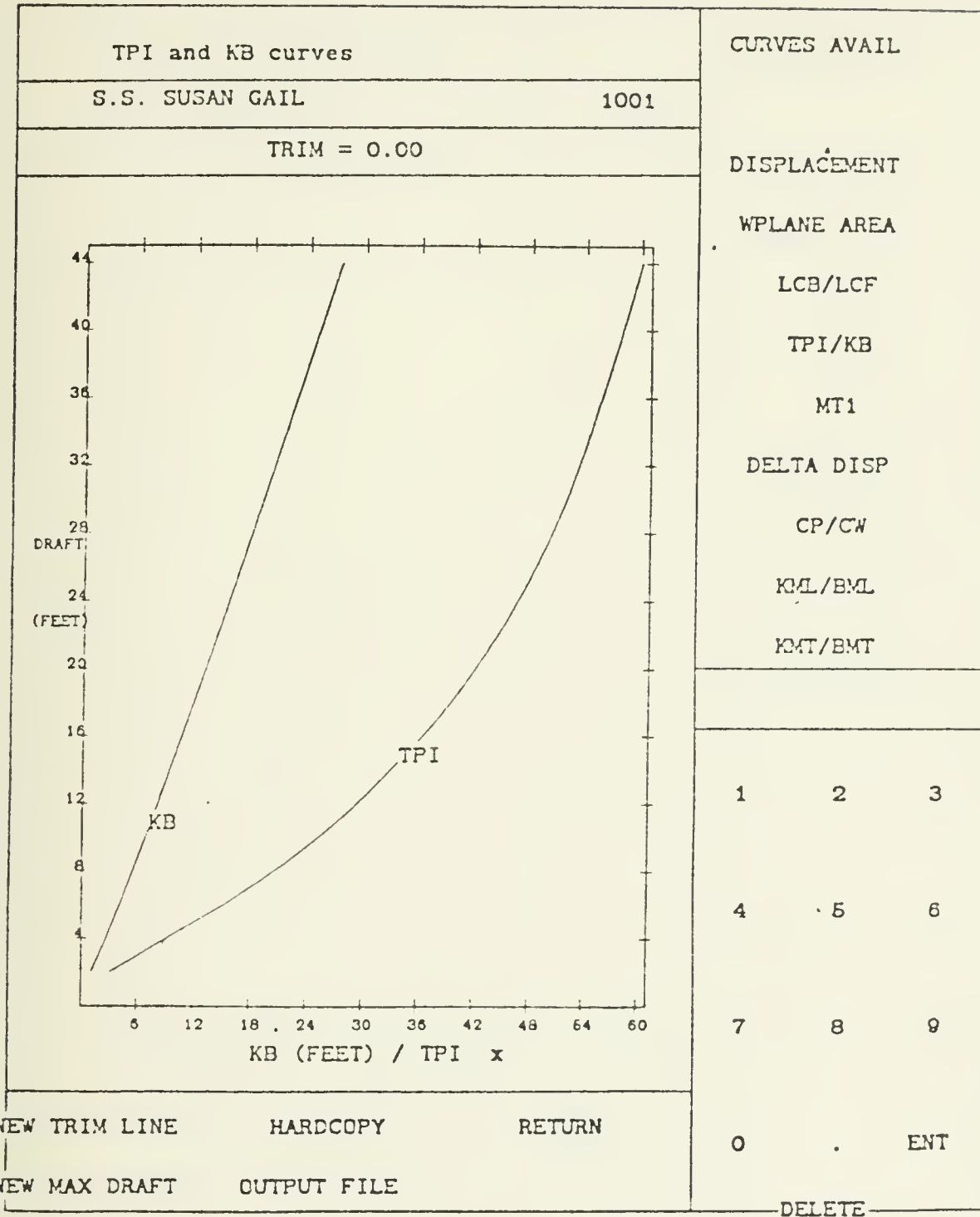


Figure H-7. TPI and KB Curves

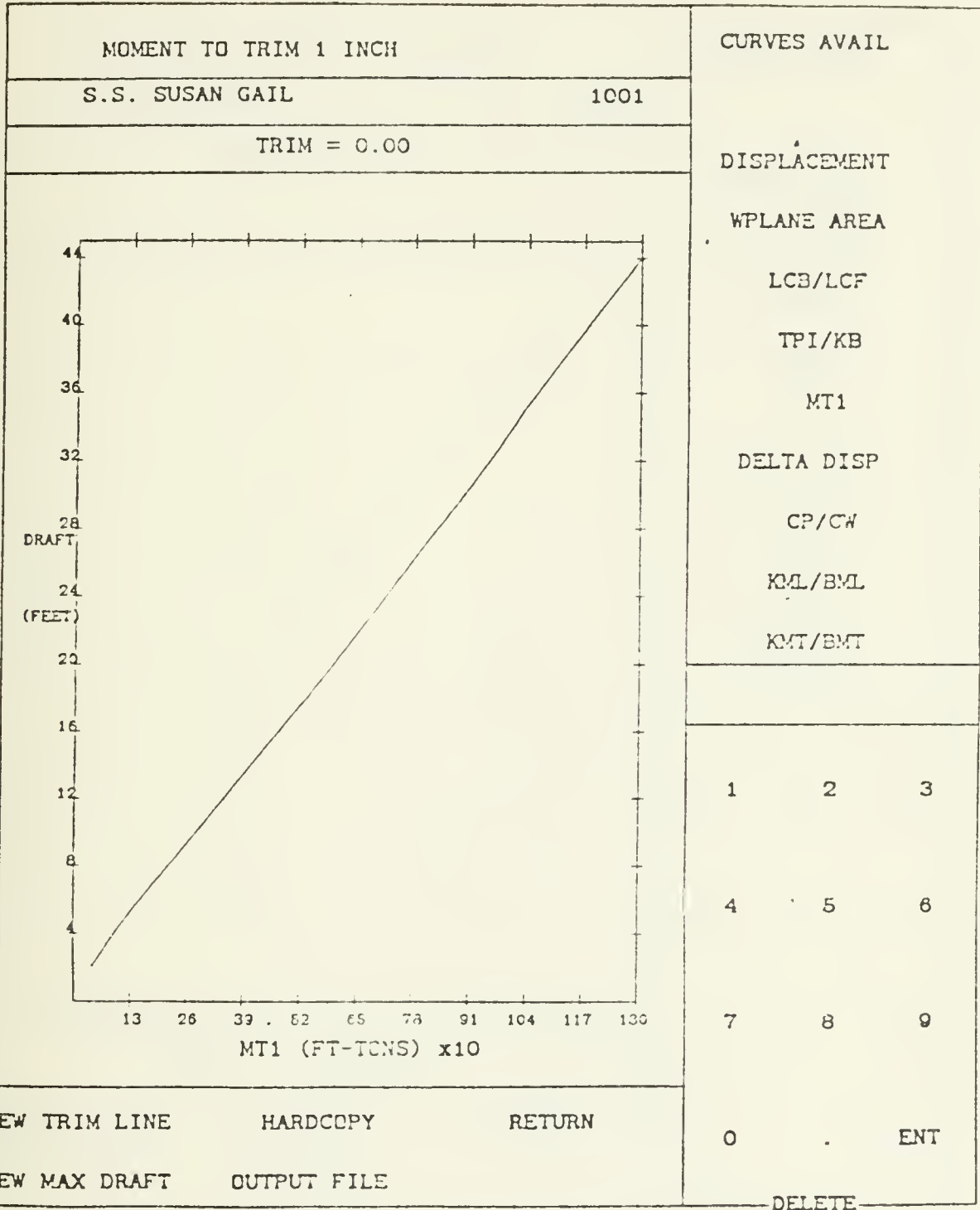


Figure H-8. Moment-to-Trim-One-Inch Curve

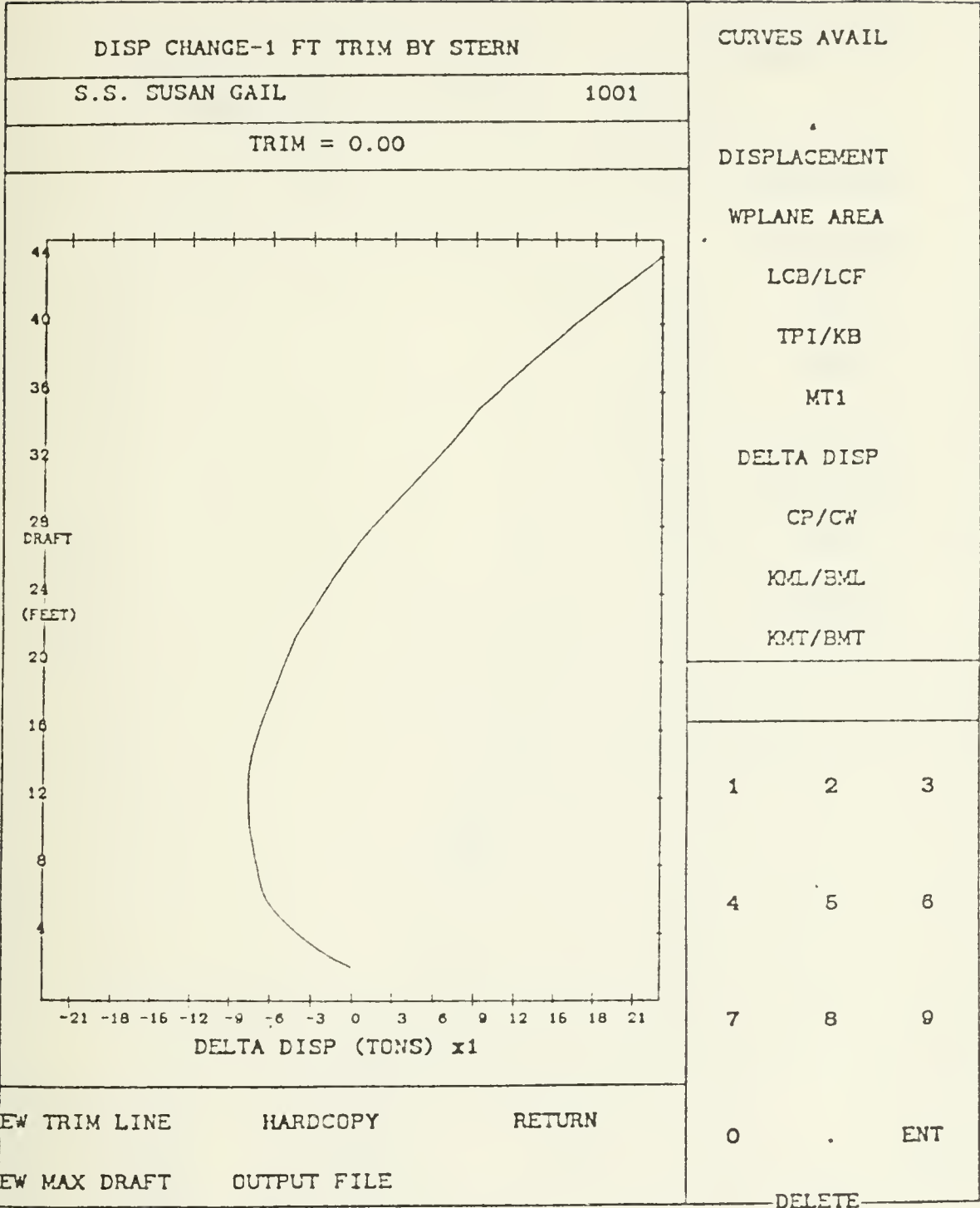


Figure H-9. Displacement Change per Foot Trim Curve

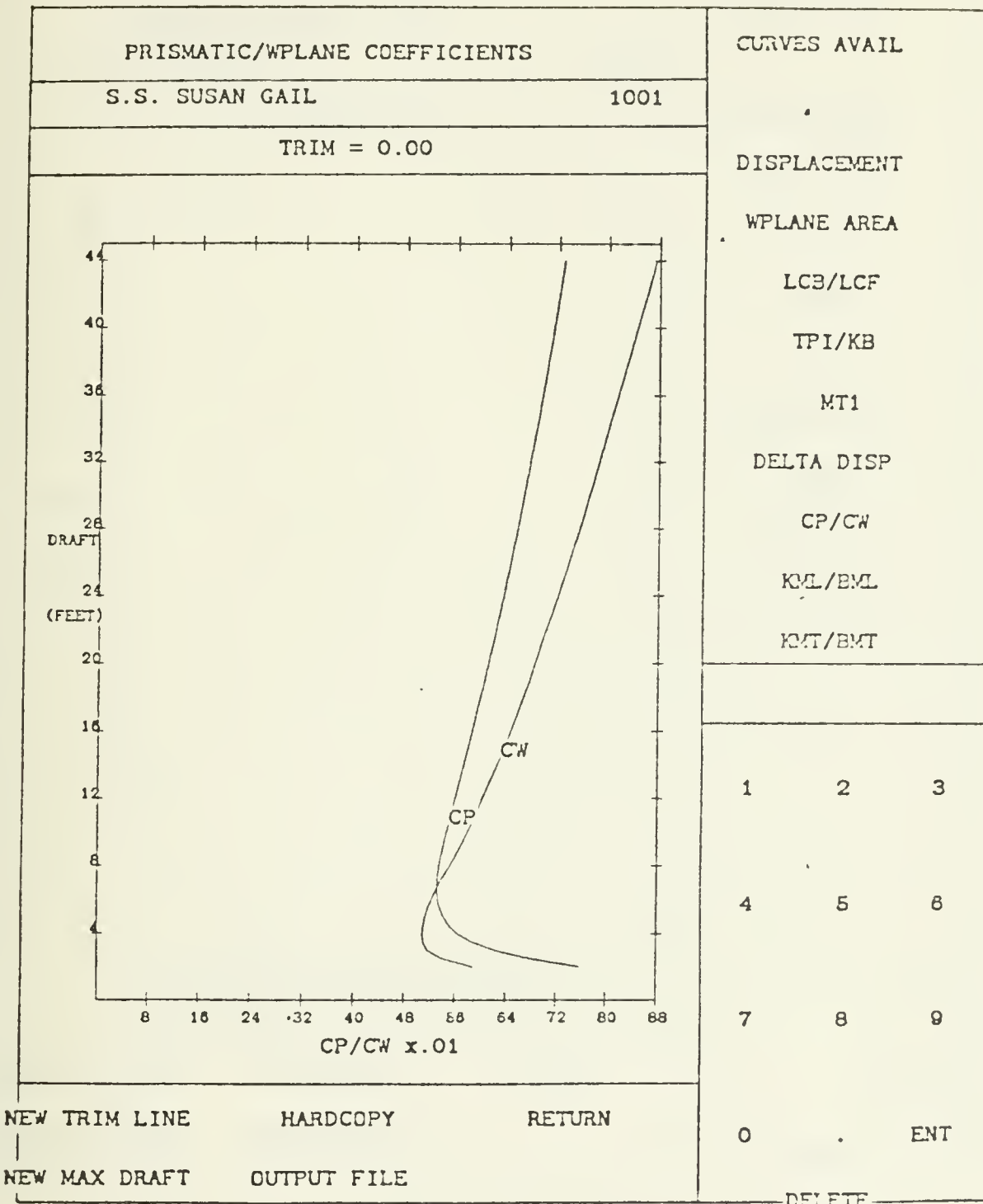


Figure H-10. Prismatic Coefficient/Waterplane Coefficient Curves.

LONGITUDINAL KM/BM CURVES		CURVES AVAIL									
S.S. SUSAN GAIL	1001										
TRIM = 0.00											
		DISPLACEMENT WPLANE AREA LCB/LCF TPI/KB MT1 DELTA DISP CP/CW KWL/BML KMT/BMT									
		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; text-align: center;">1</td> <td style="width: 33%; text-align: center;">2</td> <td style="width: 33%; text-align: center;">3</td> </tr> <tr> <td style="text-align: center;">4</td> <td style="text-align: center;">5</td> <td style="text-align: center;">6</td> </tr> <tr> <td style="text-align: center;">7</td> <td style="text-align: center;">8</td> <td style="text-align: center;">9</td> </tr> </table>	1	2	3	4	5	6	7	8	9
1	2	3									
4	5	6									
7	8	9									
NEW TRIM LINE	HARDCOPY	RETURN									
NEW MAX DRAFT	OUTPUT FILE	0 . ENT									
		DELETE									

Figure H-11. Longitudinal KM/KB Curves

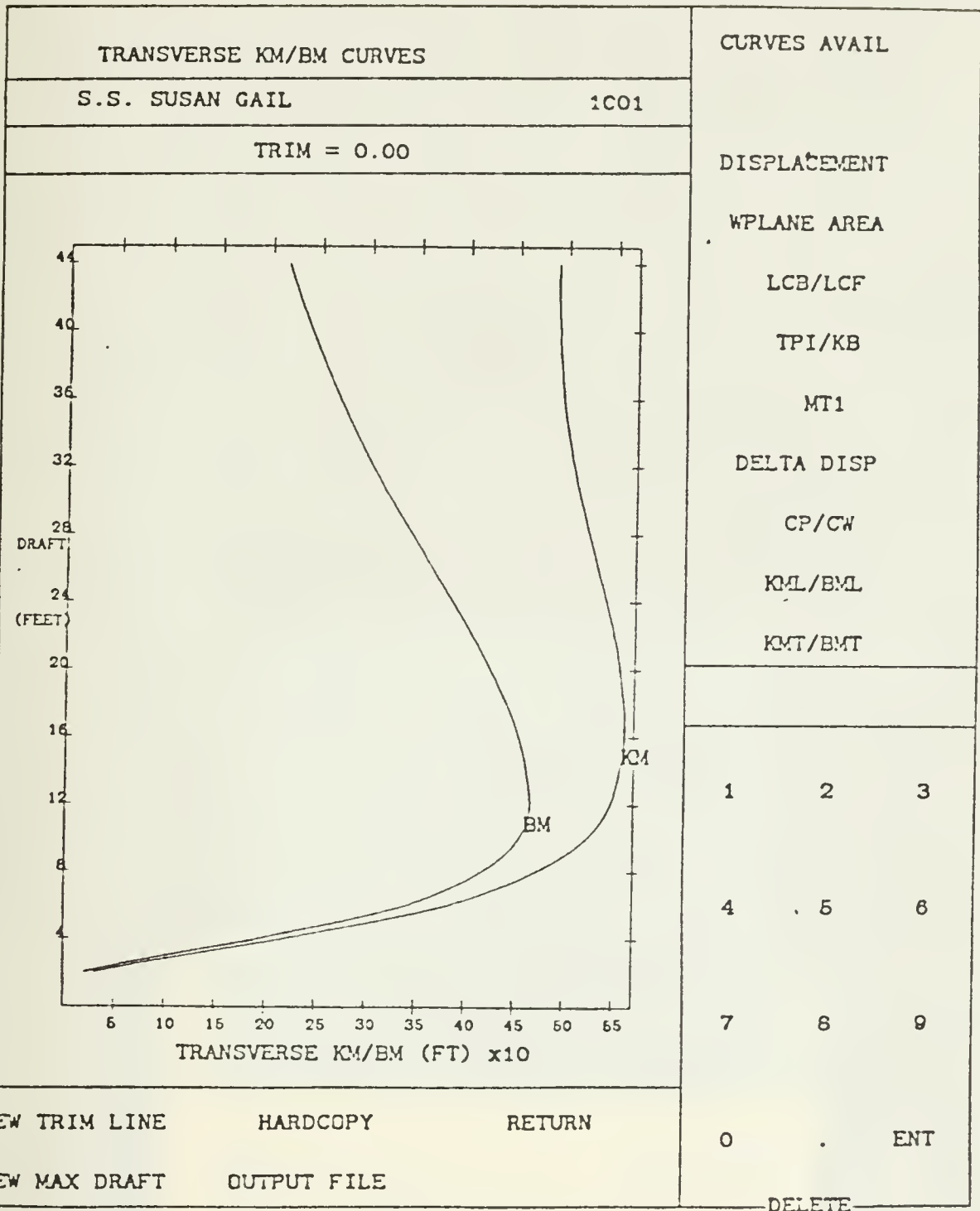


Figure H-12. Transverse KM/BM Curves

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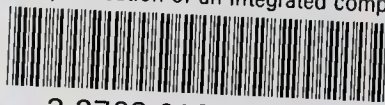
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