Graphical User's Interface for Grounding Damage Assessment of Hull Girder

by

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ABSTRACT

DAMAGE (Damage Assessment in Grounding Events) is a windows driven computer application developed for the prediction of structural damage in ship grounding events. DAMAGE was one of the main deliverables of Phase I of the Joint MIT-Industry Tanker Safety Project, a consortium formed to develop hull designs, fabrication methods, and performance standards for the new generation of spill-resistant oil tankers which reconcile the competing requirements of cost effective construction and operation with environmental safety. Phase I of DAMAGE was made available in 1995 to the consortium, and could assess damage in a target area comprising the flat bottom of the ship along the length of the cargo area, and within the turn of the bilge. The software application was organized in a modular fashion so that new features could be added easily as they are developed. The first major expansion to the program is a result of the first year of Phase II of the Joint MIT-Industry Tanker Safety Project , which began in 1996, and is scheduled to continue until 1999. A Bilge Utility was created to include the turn of the bilge in the target damage area, making DAMAGE capable of analyzing the entire bottom of the vessel. The new target damage area adds curved plates and curved plate intersections to the previously established flat plate analysis via equations derived from the First Principles of Mechanics, based on Superfolding and Supertearing elements, and experimentally validated. The Graphical User's Interface of DAMAGE, a pre- and post- processor used to build input files and examine results, was improved and expanded to include the Bilge Utility. The bilge area of a large number of tanker ships was surveyed, and supported by research accomplished to date, the essential primary structural components and attachments were identified and defined by the fewest possible number of critical parameters necessary to retain completeness and accuracy. Thus the application can build a customized model of a vessel, but is capable of analyzing a wide variety of tanker vessels. The design of the new features and the additions to the previous version of DAMAGE are discussed and the Graphical User's Interface is described through the User's Manual and Modelling Guide. The software package DAMAGE v.2.0, the accompanying User's Manual and Modelling Guide, and the newly revised and updated Theoretical Manual are the first of a series of deliverables from Phase II of the Joint MIT-Industry Tanker Safety Project.

TABLE OF CONTENTS

LIST OF FIGURES

Graphical User's Interface for Grounding Damage Assessment of Hull Girder

Introduction

This document discusses the graphical user's interface to a computer program for the assessment of grounding damage to a hull girder by following the User's Manual and Modeling Guide for the second phase development of the computer program DAMAGE (DAMage Assessment in Grounding Events), version 2.0. DAMAGE v.2.0, is the first major update of the computer program initially released in June 1995 for Phase I of the Joint MIT-Industry Tanker Safety Project.. The first major upgrade of the program, DAMAGE v.2.0, was distributed in June 1997 as the main deliverable of the first year for Phase II of the Joint Project, and includes the Hull Bottom Structure Utility developed in Phase I, the animation features introduced in DAMAGE v1.2, and a new Bilge Utility for modeling the bilge area.

This introduction contains background information on the Joint MIT-Industry Tanker Safety Project and the computer program DAMAGE for Phase II of the Project. In addition to explaining the graphical user's interface and the basic premise of the calculation schemes in DAMAGE, the future plans of the joint project are described.

BACKGROUND

The Joint MIT-Industry Tanker Safety Project was formed in the wake of the catastrophic grounding of the EXXON VALDEZ and the subsequent Oil Pollution Act of 1990 (OPA 90), when the international maritime industry began efforts to develop spill-resistant oil tankers in accordance with the newly established regulations. The project was inaugurated in 1992, with an initial consortium of twenty-four companies and organizations comprising six major classification societies, sixteen of the world's largest shipyards, shipping companies, regulatory agencies, and the United States Navy. Phase I of the project was sucessfully concluded in June 1995. Phase II of the joint project was intiated in September 1996, and is expected to be concluded in June of 1999. The Consortium supporting Phase II of the Joint MIT-Industry Tanker Safety Project was considerably reduced in size from that of Phase I. In the first year of the second phase, there were nine confirmed members and eight companies of undecided status from the pool of twenty-four companies and organizations which were members of the Phase I consortium.

The overall objective of the research program was to develop engineering knowledge through experimental and theoretical research in the area of ship structural mechanics to assess, design, build, certify and operate a future fleet of spill-resistant tankers. In the beginning of the joint project, the research agenda was divided into two major phases, the first of which was focused on developing failure models of flat plates and flat plate intersections. The fracture intiation, failure mode, and damage resistance of ship bottom structural units were predicted from theory, and the results of the theoretical and experimental research tasks were incorporated into a software application named DAMAGE. The second phase of the project is devoted to the failure mechanisms and damage resistance of curved plates and curved plate intersections; as results are produced from theory and experimentation, they will be introduced into DAMAGE in modular stages.

Phase II of the Joint MIT-Industry Tanker Safety Project began September 1, 1996, and is scheduled to continue until August 31, 1999. The total budget of approximately $1,000,000 is expected to cover the entire core project of updating and validating the user's interface and calculation routines of the DAMAGE program. There are four expansion projects, the first of which, the development of structural models of cylindrical shell plating, was used in version 2.0 of DAMAGE to assess grounding damage to the bilge. In addition, Phase II incorporates many of the results of the Side Collision Research Project, concluded in September, 1996.

DAMAGE is a PC-based interactive computer program for the rapid calculation of grounding damage to oil tanker structure. It is based on theory derived from the First Principles of Mechanics, and uses the methodology of Superfolding and Supertearing Elements. These two features separate DAMAGE from both traditional empiricism and finite element methods. The Superfolding Element is a structural unit which is described by local crushing processes on two or more intersection flanges; the Supertearing Element is part of a cut or fractured plastically deforming plate which extends from the tip of the penetrating wedge to its "shoulder."

DAMAGE is windows-driven for user-friendliness . C++ was chosen for the language of the source code because of its suitability for modular applications and its demonstrated stability for large, complex code. C++ is object-oriented, which allows the desirable characteristics of portability between platforms, uncomplicated updating, and easy operating.

A graphical user's interface (GUI) for windows is implemented as a pre-processor for building the DAMAGE input file and a post-processor for retrieving analysis and results from the DAMAGE processor. The data acquisition procedure implemented by the pre-processor can build customized descriptions of an oil tanker, but is still capable of analyzing a wide variety of oil tanker variants.

This is made possible by modeling the tanker with groups of periodically recurring structure. The total number of components and parameters in the input file was reduced by assuming that most structural elements are evenly spaced and identical to other members of the group. Although periodicity might not describe the ship perfectly, the assumption was judged to be sufficiently accurate within the context of the calculation methodology. A large number of oil tankers was surveyed to determine the structural components of the flat bottom and bilge area. From the compiled data, and supported by the research already completed by the joint project, the essential components and attachments were identified, and described by the minimum number of ciritical parameters necessary for completeness and accuracy.

The data acquisition procedure in DAMAGE first solicits global data about the ship, the rock and their interaction before proceeding to gather detail data about the structure. This input sequence provides default information from the global parameters to the detail parameters, reducing the amount of overall information the user has to enter. The input procedure has been standardized so that facility with the interface can be gained quickly. On the detail level, structural components are constructed via a dialog box which varies only by the pictures shown of primary structure.

As mentioned previously, the Joint MIT-Tanker Safety Project is a multi-stage effort. Phase I of the project, conducted from 1992 to 1995, addressed the damage to flat plates and intersections of flat plates; Phase II of the project considers damage to curved panels of hull plating and is scheduled to continue improvement to the theory and calculations. Eventually the program will include damage to the bow, stern, and machinery sections of the ship, non-periodic structures, and will address modifications suggested by the Consortium.

The modular design of the graphical user's interface will easily accommodate the planned expansions of DAMAGE.

The update and original design of the graphical user's interface of DAMAGE is the product of extensive collaborative efforts by Dr. Wlodek Abramowicz, the program developer for DAMAGE software, with the Computer Applications Team of the Joint MIT-Industry Tanker Safety Project.

Use of the interface is described in the DAMAGE User's Manual & Modeling Guide contained in this document. The Manual & Guide conventions are discussed below.

MANUAL AND GUIDE CONVENTIONS

The User's Manual describes software features and the general procedure for building DAMAGE input files. A full example is provided which can be used as a tutorial for the novice user. The Modeling Guide provides a catalog of the basic ship components and parameters used to develop a complete model.

A combination of mouse and keyboard actions are used to operate DAMAGE. The following conventions will be used to describe these actions throughout the DAMAGE documentation:

"Mouse pointer" refers to the screen image that moves corresponding to moving the mouse on the desk. The image changes depending upon the activity executed in the application as follows:

> The "arrow" image is a pointer used to select or choose on-screen menu commands or buttons. The "hourglass" image may appear to alert the user to pause until the computer completes a function or command. The "I-bar" image indicates that the user has chosen a screen area for input by keyboard; press **<Return>** to complete keyboard input and return to the mouse "arrow" image.

"Click" means to place the mouse pointer over a menu item or a dialog box button and press the left mouse button. An alternative way to "click" an item is to use the keyboard to "select" that item and press **<Return>**. This procedure executes the selected command.

"Select" means to highlight a menu item, either by using the arrow keys to move the cursor box to the item, using **<Alt>** + underscored letter on the menu entry, or holding down the left mouse button while dragging the mouse pointer over an item. This procedure does not execute the selected command.

"Choose" means to execute a command by "clicking" an item or by "selecting" an item and pressing **<Return>**.

"Enabled" indicates that an item or button is active, or a valid choice, for clicking, selecting, or choosing. An enabled item is active because it is an executable command. An enabled item or button is indicated on-screen using **bold** letters.

"Disabled" indicates that an item or button is inactive, or not a valid choice, for clicking, selecting, or choosing. A disabled item is inactive because it is not an executable command. A disabled item or button is indicated on-screen using gray letters.

"Browse" means to search through status bar descriptions of menu bar commands using "select."

"**<Ctrl>**" means to press the **<Control>** key, where the bold type and symbols "< >" indicate a key selection.

"**<Ctrl+S>**" means to press the **<Control>** key at the same time as the **<S>** key, where the symbol "+" indicates a simultaneous key selection.

"**<Return>**" and "**<Enter>**" denote the same key function.

"**[Apply]**" means to click the button marked **[Apply]** from the active dialog box, where the bold type and symbols "**[ ]**" indicate a dialog box button.

The **"[Apply]"** button is used to send data completely defining the current secondary dialog box to storage in the input file. **[Apply]** closes the current secondary dialog box.

The **"[Done]"** button is used to indicate that data completely defining all secondary dialog boxes associated with the current primary dialog box have been applied. **[Done]** closes the current primary dialog box.

The **"[Cancel]"** button is used to close the current dialog box or window without applying data.

"Item" refers to a command that appears as a menu bar or pull-down menu option.

"**//File//**" means menu item **//File//**, where the bold type and symbols "**// //**" indicate items from a menu bar.

"**/Open/**" means menu item **/Open/**, where the bold type and symbols "**/ /**" indicate items from a pull-down menu.

DAMAGE
User's Manual & Modeling Guide

Part I:

DAMAGE User's Manual

Chapter 1 - Getting Started

Chapter 1 provides information on DAMAGE licensing agreement, product support, installation, and startup.

1.1 Installing DAMAGE

Before installing DAMAGE to hard disk, make sure that MS-Windows (version 3.1 or later) is already installed on the computer or workstation. Also, check that the system has at least 8 Megabytes extended RAM and 3 Megabytes of free hard disk space, which is required to run DAMAGE.

To install DAMAGE, insert Disk 1 into drive A or B. Start Windows. In the Windows File Manager, choose Copy from the File menu. At the "From:" prompt, type **a:*.*** in the Command Line box if the DAMAGE program disk is in drive A (or **b:*.*** if the DAMAGE program disk is in drive B). At the "To:" prompt, type **c:\damage*.*** in the Command Line box if the user wishes to install DAMAGE to the C-directory (or replace **c:** with the desired installation directory name and path). Choose the OK button. When prompted to create subdirectory **\damage**, choose the Yes button. Similarly, copy the contents of Disk to the **damage**\ directory. Disk 3 contains DAMAGE program source code; to install DAMAGE, it is not necessary to copy Disk 3, labeled "SOURCE CODE," to hard drive.

The installation procedure can also be accomplished with the drag-and-drop technique described in the MS-Windows™ User's Manual. Using this method, copy the entire contents of Disk 1 to the subdirectory **\damage** with a single mouse click. As before, repeat these steps for Disk 2; again it is not necessary to copy Disk 3 with the "SOURCE CODE" to hard drive.

If working under the Windows95 operating system, first open the Windows Explorer file manager, or any other file managing program. Create a subdirectory **damage**\ within the path you wish to work in. Put Disk 1 in the floppy drive, switch to the **a:** drive (or **b:**), and select all of the folders and files. To copy the files, drag them to the icon of the damage subdirectory on the **C:** drive (or the appropriate hard drive) and drop them there. Repeat the drag-and-drop technique for the contents of Disk 2. Alternatively, after selecting all of the files from Disk 1 in the **a:** drive, choose **/Copy/** from the **//Edit//** pull-down menu. Then click on the **\damage** folder icon, and click **/Paste/** from the **//Edit//** pull-dwon menu. Repeat this procedure for the contents of Disk 2.

This procedure copies DAMAGE and its resource subdirectory from the program disks to the **\damage** subdirectory of the installation directory on hard disk. Note that the user <u>must</u> install the executable file **dmg.exe** with all resource subdirectory structure to a single subdirectory (**\damage** in the example above). A properly installed DAMAGE directory structure in Windows File Manager is shown in Figure 1.

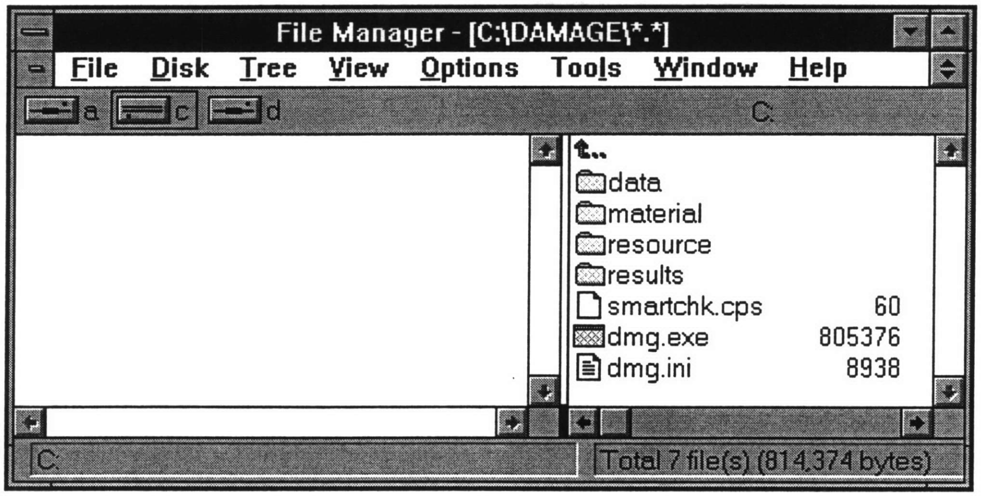


FIGURE 1. C:\damage\ directory structure in Windows File Manager.

The basic installation of DAMAGE is now complete.

Installation by the above methods enables DAMAGE startup from the Windows File Manager environment. Simply open the subdirectory **\damage** in the File Manager window and double-click the executable program file **dmg.exe**.

After basic installation has been completed, DAMAGE can be further configured as an iconized item in a separate program group in the Microsoft Windows Program Manager. From the Program Manager menu bar choose //**File**// /**New**/. In the small dialog box opened, choose the radio button for "Program Group" and click the **[OK]** button. Type **DAMAGE** in the box after the "Description:" prompt and click the **[OK]** button. The group file DAMAGE.grp will automatically be created, and the group's dialog box will appear on screen with the name "DAMAGE" in the title bar. With the DAMAGE group dialog box selected (click in the DAMAGE group dialog box), choose //**File**// /**New**/ from the Program Manager menu bar. In the small dialog box opened, this time choose the radio button for "Program Item" and click the **[OK]** button. Type **DAMAGE** in the box after the "Description" prompt. Type **c:\damage\dmg.exe** in the box after the "Command Line" prompt, and type **c:\damage** in the box after the "Working Directory" prompt. Click the **[OK]** button. DAMAGE has now been installed as a separate program item called "DAMAGE," as shown in Figure 2. The executable file of the program is represented here by the DAMAGE icon.

Installation as an item to a program group enables DAMAGE startup from the Windows Program Manager environment. Simply double-click the DAMAGE icon in the Program Manager window.

In Windows95, DAMAGE can be added to the "Start" menu by going to **//Settings// /Taskbar/** under the **[Start]** button. When the Taskbar Properties dialog box opens, click the tab entitled "Start Menu Programs," and click the **[Add]** button. Follow the prompts to conclude the procedure. DAMAGE can now be started by a single click on the damage icon, located in the listing contained under **//Start// /Programs/**.

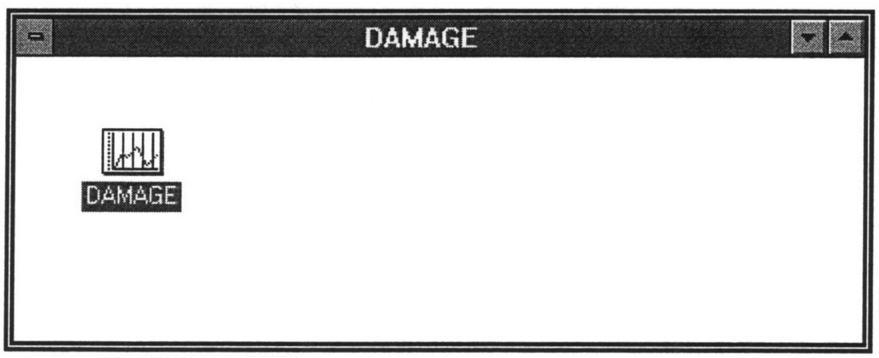


FIGURE 2. DAMAGE icon in Windows Program Manager.

1.2 Starting DAMAGE

DAMAGE is started by double-clicking the DAMAGE icon in the Windows Program Manager, or by single clicking the DAMAGE icon located under **/Start/Programs/** in Windows95. The window that appears at startup of the application DAMAGE is shown in Figure 3.

The menu bar appears below the title bar at the top of the window. Click the down or up arrow icons to the right of the bars to minimize or restore the size of the application window. Double-click the control-menu box to the left of the bars to exit the application. The status bar appears at the bottom of the window. The status bar is active at the startup, first, and second menu levels and provides a description of browsed commands.

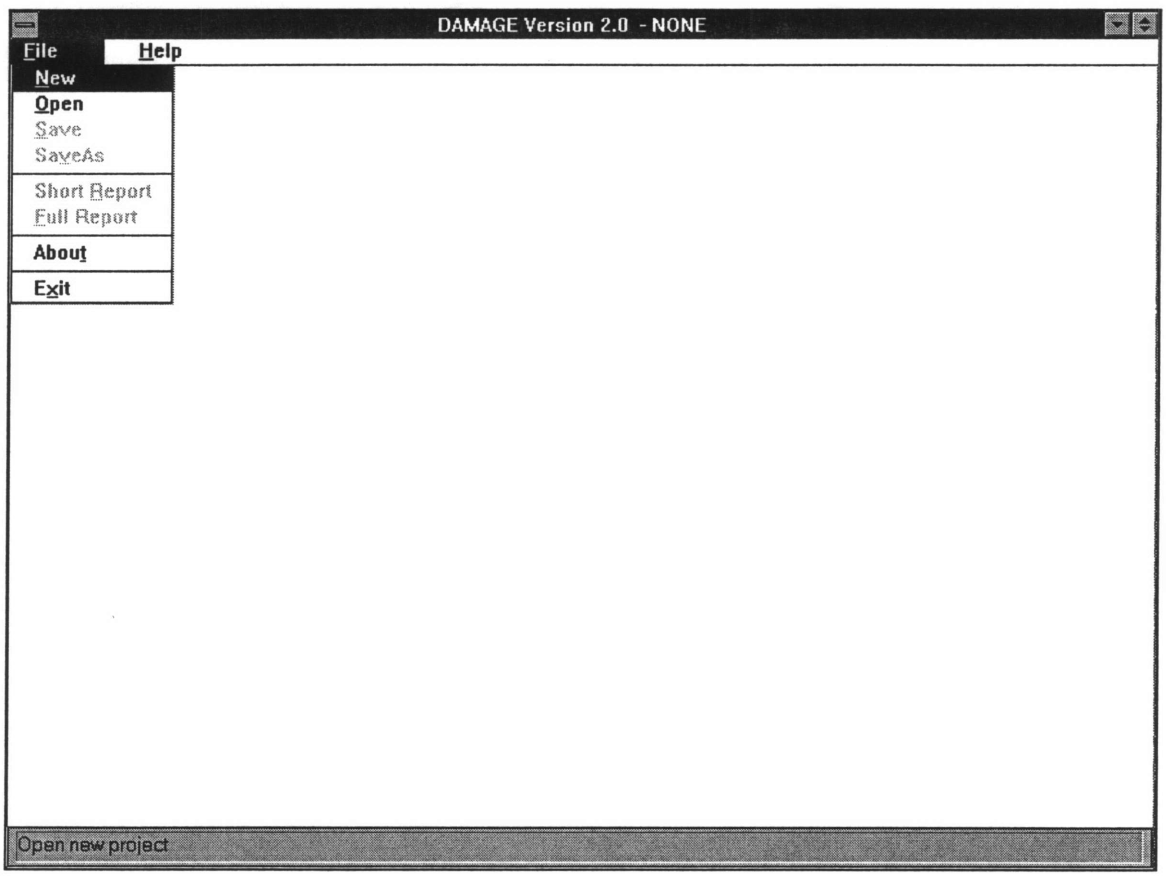


FIGURE 3. DAMAGE startup menu.

The menu bar commands, //**File**// or //**Help**//, can be accessed by clicking the desired item from the menu bar using the mouse, or by pressing **<Alt>** and selecting the desired menu item using the keyboard. Click or select a command from the menu bar to display the items in its associated pull-down menu. If available, a pull-down menu will appear on screen in a box below the selected command in the menu bar. The enabled items, or active options, in the pull-down menu box appear in **bold,** the disabled items appear in **gray**; after choosing a menu bar command, the user may choose from the enabled pull-down menu items only.

The convention and procedure for choosing menu items is consistent throughout DAMAGE for all startup, first, and second menu levels.

At startup, the two options for beginning a DAMAGE session are enabled in the **//File//** pull-down menu. To create a new file, choose **//File// /New/**. To edit or evaluate an existing file, choose **//File// /Open/** and the desired file name from the file-handling dialog box. (See Chapter 2 - Managing Files for a detailed description of these and other file-managing commands.) The user may also exit the application from the startup menu by choosing **//File// /Exit/**.

This preliminary selection initializes a DAMAGE session. Now, the startup menu bar expands to include commands comprising the first menu level in DAMAGE shown in Figure 4.

At the first menu level, there are five commands in the menu bar:

//File// contains the file-managing commands (see Chapter 2 - Managing Files).

//Input// contains the commands for building and editing DAMAGE input files (see Chapter 3 - Building an Input File, and Chapter 4 - Editing an Input File).

//Calculations// processes the coupled or uncoupled grounding damage assessment for developed input files (see Chapter 5 - Calculations).

//Results// presents the grounding damage assessment results (see Chapter 6 - Results).

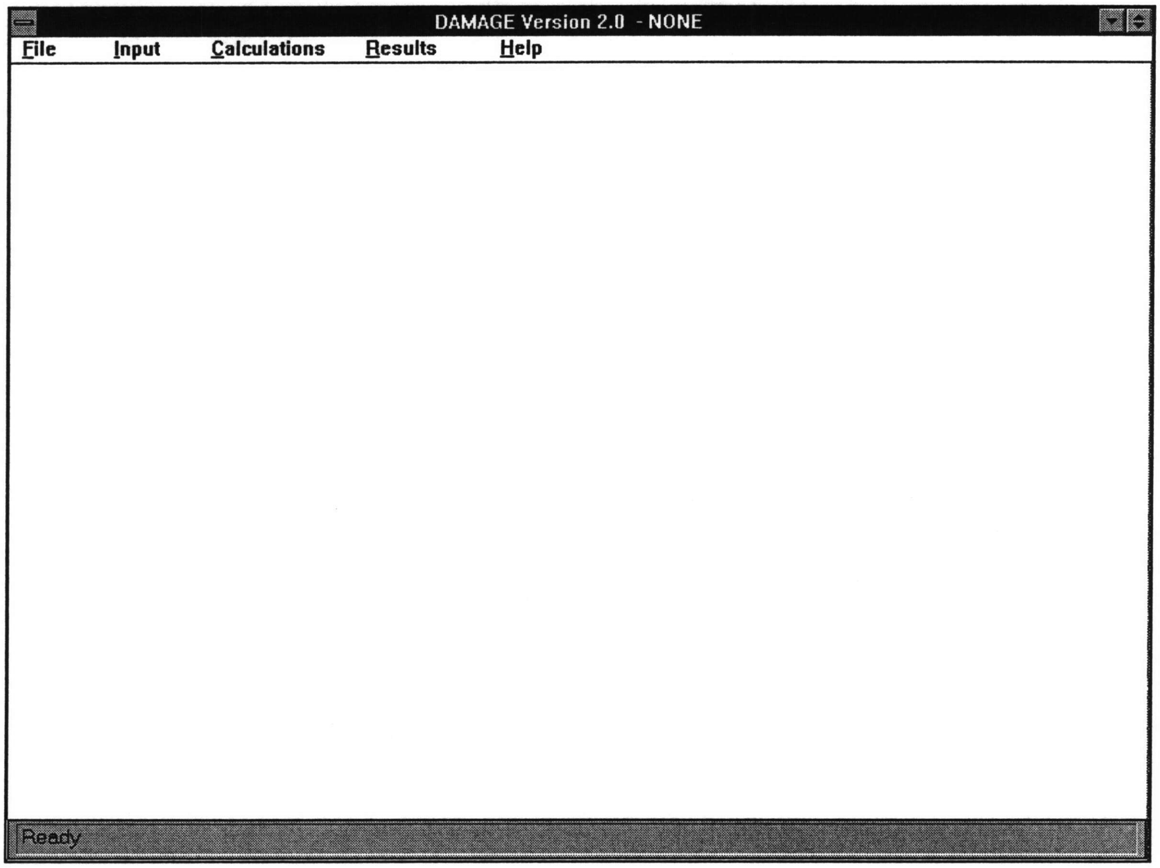


FIGURE 4. DAMAGE first menu level.

//**Help**// describes the use of the context-specific on-line reference tool available during a DAMAGE session (see Chapter 8 - Help). Damage Release Notes, containing useful developer's notes following the publication of the Manual & Guide, are also included under this item.

Chapter 2 - Managing Files

Chapter 2 describes how to load and save DAMAGE input files.

The files created using DAMAGE software are assigned either the *.dmg extension for input files, or the *.mat extension for material files. The commands to load and save *.dmg input files use a file-handling dialog box like the one shown in Figure 5.

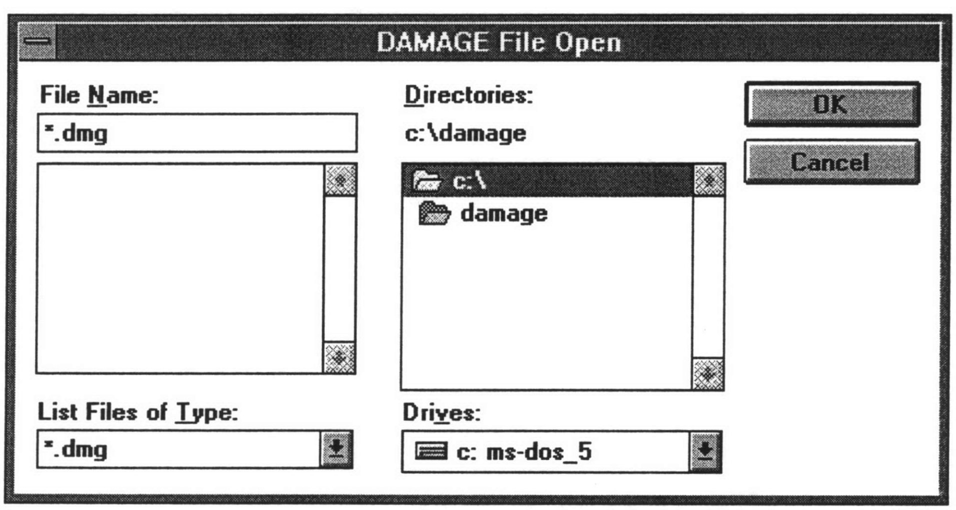


FIGURE 5. DAMAGE file-handling dialog box.

Drives selects the current drive name. To switch drives, click the arrow at the right of the box and click the desired drive name.

Directories displays the current directory and its subdirectories below the name of the drive or directory containing it. To switch to a directory displayed in the list, double-click the desired directory name. To back up one directory level, double-click the top drive or directory name. By default, the dialog box is set to display files in the start-up directory c:\damage\ or the user-defined installation directory, at the start of each session. Each subsequent time that a file is loaded or saved in a directory other than the start-up directory, this alternative directory becomes the default directory displayed when the next file-handling dialog box is opened.

List Files of Type specifies the extension of the file names that are to be listed in the File Name box. The dialog box is set to display input files with the extension *.dmg each time that a file-handling dialog box is opened. Only files with the *.dmg extension may be opened as input files in DAMAGE.

File Name displays the name of the file to be handled. The user can type the name of the file at the Command Line prompt or automatically display the name of a file by clicking the desired name listed in the box below.

To complete a file command, click the button marked **[OK]** in the file-handling dialog box or double-click the name of the file selected in the File Name box. To cancel a file command and close the file-handling dialog box, click the button marked **[Cancel]**, double-click the control-menu box to the right of the file-handling dialog box title bar, or press **<Escape>**.

For example, to select a file named "CASE1.dmg" to be opened from or saved to the damage default directory in the C:\ drive, the user should check that:

1. "C:" is shown for **Drives**.
2. "C:\damage" is chosen for **Directories**.
3. "*.dmg" is specified for **List Files of Type**.
4. "CASE1.dmg" has been keyed in or selected for **File Name**.

The commands used for managing DAMAGE files are located in the //**File**// pull-down menu, shown in Figure 6, and will be referred to throughout the remainder of Chapter 2.

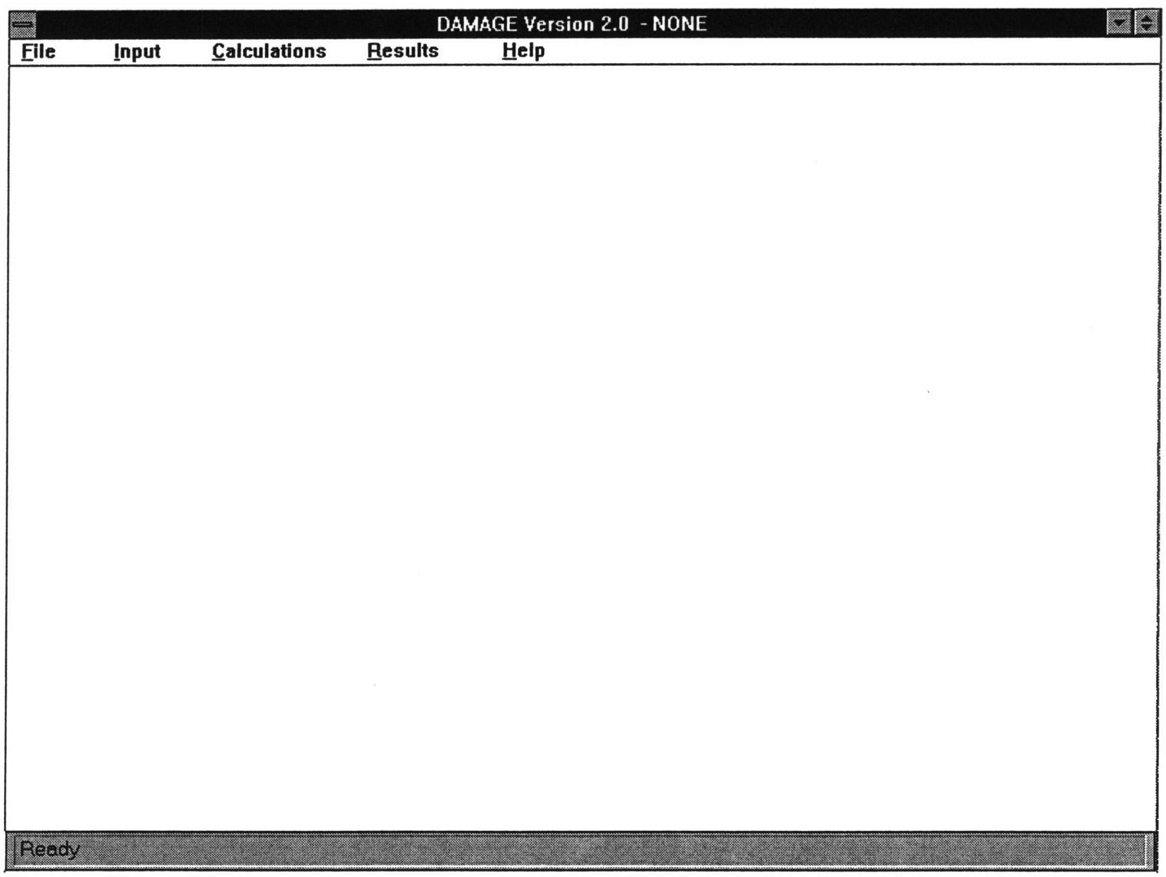


FIGURE 6. Commands in the //**File**// pull-down menu.

2.1 Loading a File

Two options are available for beginning a DAMAGE session and building multiple input files during a single session.

Choose **/New/** from the **//File//** pull-down menu to create a new DAMAGE input file. This command opens the first menu level window. If another DAMAGE file is already open, the user should save the open file using the **/Save/** or **/SaveAs/** options discussed below before creating the new file. Unlike many other Windows programs, DAMAGE does not prompt the user to save before closing the current file and opening the next.

Choose **/Open/** from the **//File//** pull-down menu to open an existing DAMAGE input file. This command opens a file-handling dialog box. Specify the name of the file to be opened either by choosing a name listed in the **File Name** box (using Drives and Directories to specify the path to the desired file name as illustrated in the above example for file "CASE1.dmg") or by typing the file name at the prompt. If another DAMAGE file is already open, the user should save the open file using the **/Save/** or **/SaveAs/** options discussed below before opening the next file.

2.2 Saving a File

Two options are available for saving files during a DAMAGE session: **/Save/** and **/Save As/**. Before exiting, the user is reminded to save a file whenever changes are made during a DAMAGE session.

Choose **/Save/** from the **//File//** pull-down menu, or use the keyboard shortcut **<ctrl+s>** to save and replace an existing DAMAGE input file under the same name. If the current file was created using **//File//** **/New/**, the file-handling dialog box will automatically open prompting the user to assign a name to the new file.

Choose **/Save As/** from the **//File//** pull-down menu to assign a new name before saving the current DAMAGE input file. The **//File// /Save As/** command can be used to create a systematic series of related input files by modifying some structural or grounding events data and saving each modified input case under a different file name. This command opens a file-handling dialog box. Choose a file name listed in the dialog box (using Drives and Directories to specify the path to the desired file name as illustrated in the above example for file "CASE1.dmg") or type in a new name at the File Name prompt. If the modified file has previously been saved under another assigned name, **//File// /Save As/** will save the current file under the new assigned name and will not overwrite the pre-existing version of the file saved under the previous name. If a file already exists by the name entered at the prompt, the user will be asked for an alternative name or to continue saving by replacing the existing version of the file saved under that name.

Chapter 3 - Building an Input File

Chapter 3 describes the general procedure for building a DAMAGE input file. The input file is an inventory of all relevant structural and grounding event data, subdivided into related data groups.

The commands used for building DAMAGE input files are located in the //**Input**// pull-down menu, shown in Figure 7, and will be referred to throughout the remainder of Chapter 3.

The data acquisition procedure in DAMAGE is sequence-sensitive. The order in which a data group appears in the //**Input**// pull-down menu acquires information about the grounding event from the user in a sequence which builds the entire input file from the global level down to the detailed structural level. The data acquisition procedure for DAMAGE is illustrated in Figure 8.

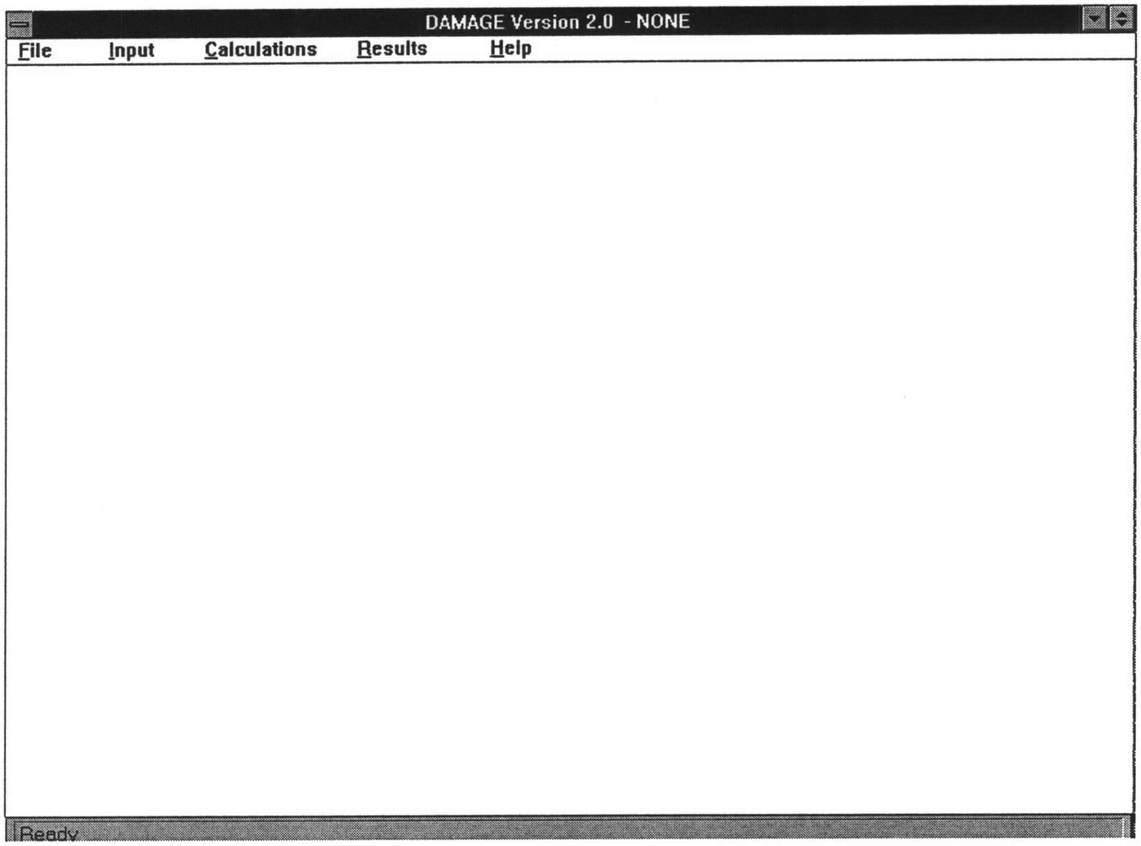


FIGURE 7. Commands in the //**Input**// pull-down menu.

The information is subdivided into ten data groups in the //**Input**// pull-down menu plus a /**Material Editor**/ and /**Input Summary**/. When building a new DAMAGE input file, the items in the pull-down menu are to be completed in the following sequence:

1. /**Material Editor**/

TOP-LEVEL DATA GROUPS:

2. /**Global Ship Parameters**/
3. /**Ground Characterization**/
4. /**Ship-Ground Interaction**/

BOTTOM-LEVEL DATA GROUPS:

5. **/Tank Arrangement/**

6. **/Hull Bottom Structure/**

7. **/Bilge/**

Bottom-level Data Groups to be developed for future versions of DAMAGE8. **/Hull Side Structure/**

9. **/Bow/** (Not shown.)

10. **/Machinery Space/** (Not shown.)

11. **/Stern/** (Not shown.)

SUMMARY

12. **/Input Summary/**

//Input//:	First Menu Level	Second Menu Level
	TOP LEVEL DATA GROUPS	
[1] Global Ship Parameters	**Ship Data** Enter global ship data **Tank Spacing** Locate tank boundaries	
[2] Ground Characterization	**Configuration** Choose rock type **Define/ Edit** Define ground geometry	
[3] Ship-Ground Interaction	**Define/ Edit**	
	BOTTOM LEVEL DATA GROUPS	
[4] Tank Arrangement	**Configuration** Choose transverse tank arrangement **Define/ Edit** Locate longitudinal bulkhead, if applicable **Continue**	**Longitudinal Bulkheads** **Transverse Bulkheads**
[5] Hull Bottom Structure	**Configuration** Choose type of bottom structure **Continue**	**Centerline Structure** **Longitudinal Structure** **Transverse Structure**
[6] Bilge Structure	**Configuration** Choose shape of bilge area **Define/ Edit** Enter general dimensions of bilge area **Continue**	**Longitudinal Structure** **Transverse Structure**

FIGURE 8. DAMAGE data acquisition procedure.

3.1 The Material Editor

The /**Material Editor**/ is used to develop material data files for all ship structure. The material data files provide a database for all materials, relevant to the analysis, which appear in ship structure. Material data files are called by data groups across all levels of the input and calculation routines. For this reason, all necessary material data files must be prepared and available prior to building the top- and bottom-level data groups.

The material files are not linked to the ship structural files, but instead, are referenced once, when the ship data file is first constructed. For this reason, it is important to ensure the accuracy of the material data before proceeding to build the ship data files. If the material data is changed after it has been used in a ship data file, the material choice within the ship data file must be manually updated, *even if the filename is unchanged.*

Choose /**Material Editor**/ from the //**Input**// pull-down menu to develop material data files. The material data files are created using the "Material Editor" module in DAMAGE, shown in Figure 9.

The following material characteristics are required parameters for the successful definition of each material file. To enter each value, click in the appropriate box and key in the data. Use <**Tab**> and/or the mouse pointer to move across the various entry fields. (NOTE: Do <u>not</u> press <**Return**> prior to the completion of all fields; pressing <**Return**> is equivalent to clicking the **[EXIT]** button and will terminate the data entry session!)

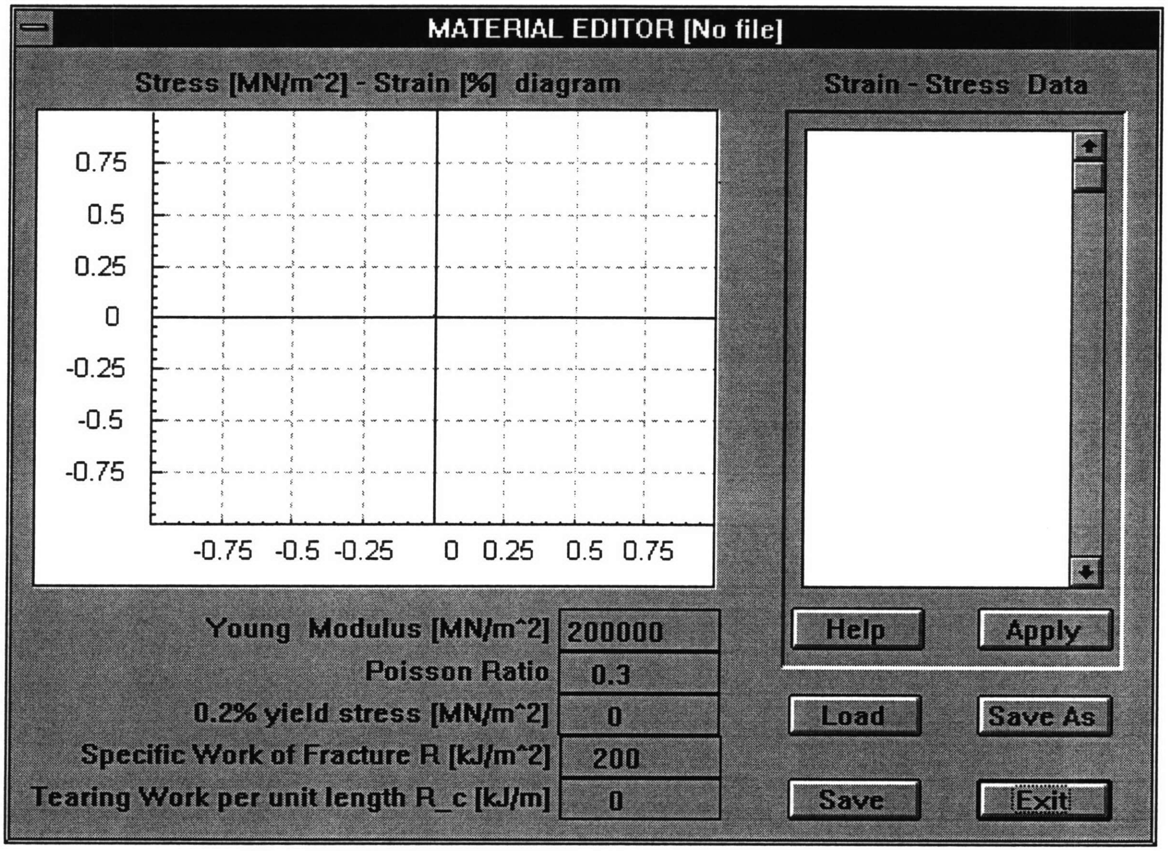


FIGURE 9. /Material Editor/ module dialog box.

1. Young's Modulus, E.

   The default value for steel is E=210 GPa.

2. Poisson's Ratio, ν.

   The default value for steel is ν=0.3.

3. Yield Stress, σ_y.

   This is the 0.2% proof stress.

4. Specific Work of Fracture, R.

   If R is not prescribed by the user, a default value of R=200 KJ/m^2 will be used.

5. Tearing Work per unit length for weldments, R_c.

   (Reserved for future enhancements.)

6. Tensile Strain-Stress characteristics.

   A precise representation of the material stress-strain tensile characteristic is extremely important to the reliability of DAMAGE results. Guidance for defining the material stress-strain characteristics and the procedure for building the stress-strain curve using the Material Editor are discussed below.

To alter the appearance of the stress-strain graph, double-click the graph image to open the "Graph Configuration" dialog box. Each axes can be scaled separately using the "Max/Min." options under either "X-axis" or "Y-axis." The axes can also be divided by major and minor intervals, using the appropriate entry fields.

The completed material data files are managed using a file-handling dialog box similar to the one shown in Figure 3. Save each different material data file under a different file name. Choose **[Save As]** to assign a new name, following the same procedure described in Chapter 2. Choose **[Load]** to view or update an existing material data file and choose **[Save]** to replace an existing file, following the same procedure described in Chapter 2. When all material data files have been created and saved, choose **[Exit]** to close the material editor and proceed with building top-level and bottom-level data groups.

If any material data files are edited after being used in a ship data file, the material selection in the ship data file must be updated, even if the filename of the material is unchanged.

DATA GROUPS

Three top-level data groups and three bottom-level data groups comprise the six data groups from the **//Input//** pull-down menu implemented for DAMAGE Phase II:

TOP-LEVEL DATA GROUPS

The top-level data groups in the **//Input//** pull-down menu acquire the general data which characterize the grounding event: the global ship parameters, the grounding environment, and the interactions that couple the ship with the grounding environment (see Chapter 5 - Calculations). The three data groups are: **/Global Ship Parameters/**, **/Ground Characterization/**, and **/Ship-Ground Interaction/**.

The top level data groups use the identical procedure to acquire data. Choosing any one of the three commands first opens a <u>primary</u> dialog box. The primary dialog box provides labeled diagrams associated with the data group and displays buttons for toggling to secondary dialog boxes. The <u>secondary</u> dialog boxes are used to choose configurations and to key the group data into convenient tables. The secondary dialog boxes may also provide an additional diagram of a detail, enlarged from the primary dialog box. (See Figure 10.)

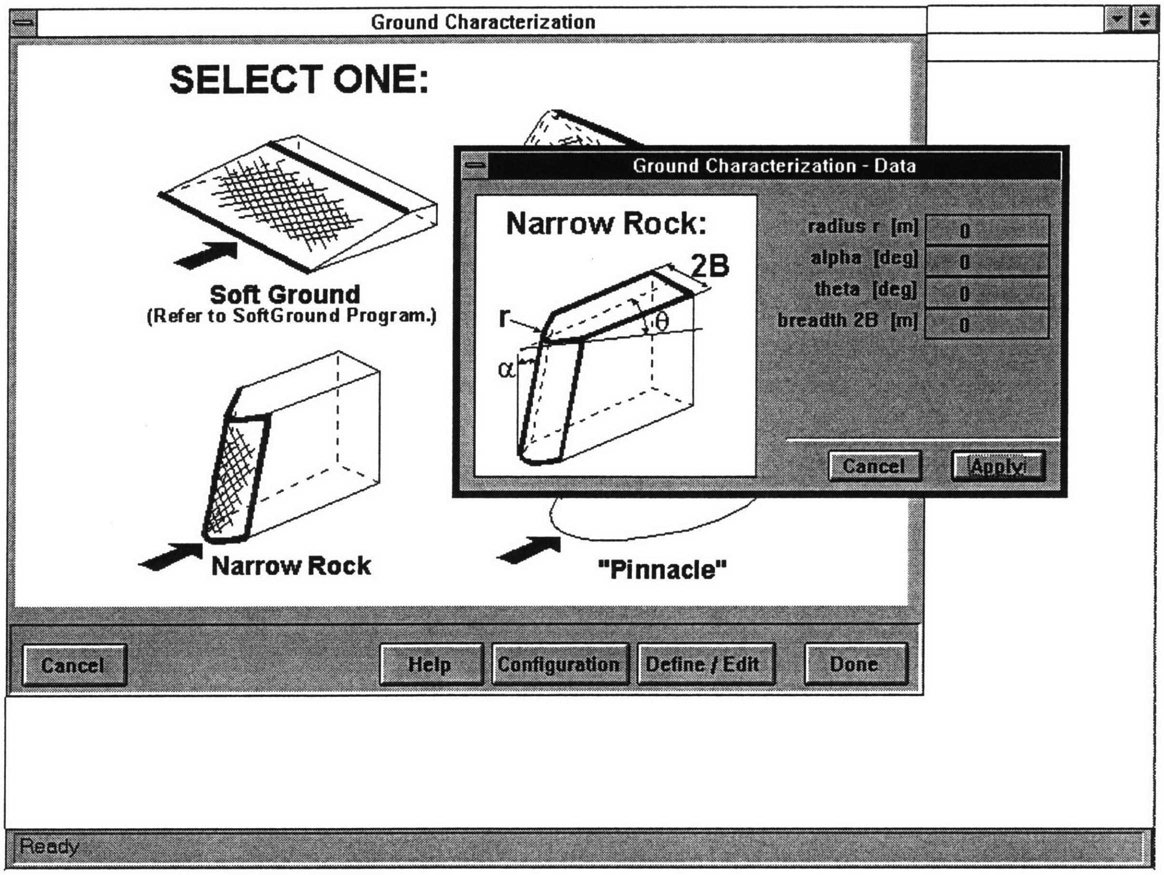


FIGURE 10. Typical primary and secondary dialog boxes used in top-level data group procedure.

The three top-level data groups are discussed separately in the sections that follow.

3.2 Global Ship Parameters

Choose **/Global Ship Parameters/** from the **//Input//** pull-down menu to characterize general ship geometry.

The primary dialog box, shown in Figure 11, displays schematic diagrams of a general oil tanker in profile view and in section view looking aft. Both sections are dimensioned with those parameters which are necessary to describe the ship's structure.

In the secondary dialog box associated with **[Ship Data]**, all of the dimensions and the remaining parameters which control the ship's motions must be entered into the table labeled "Global Ship Parameters- Data". Within the table, displacement, waterplane area, and metacentric heights are used to model the interaction between the rock and the ship; the required accuracy of these values depends on the confidence which the user desires in this aspect of the results.

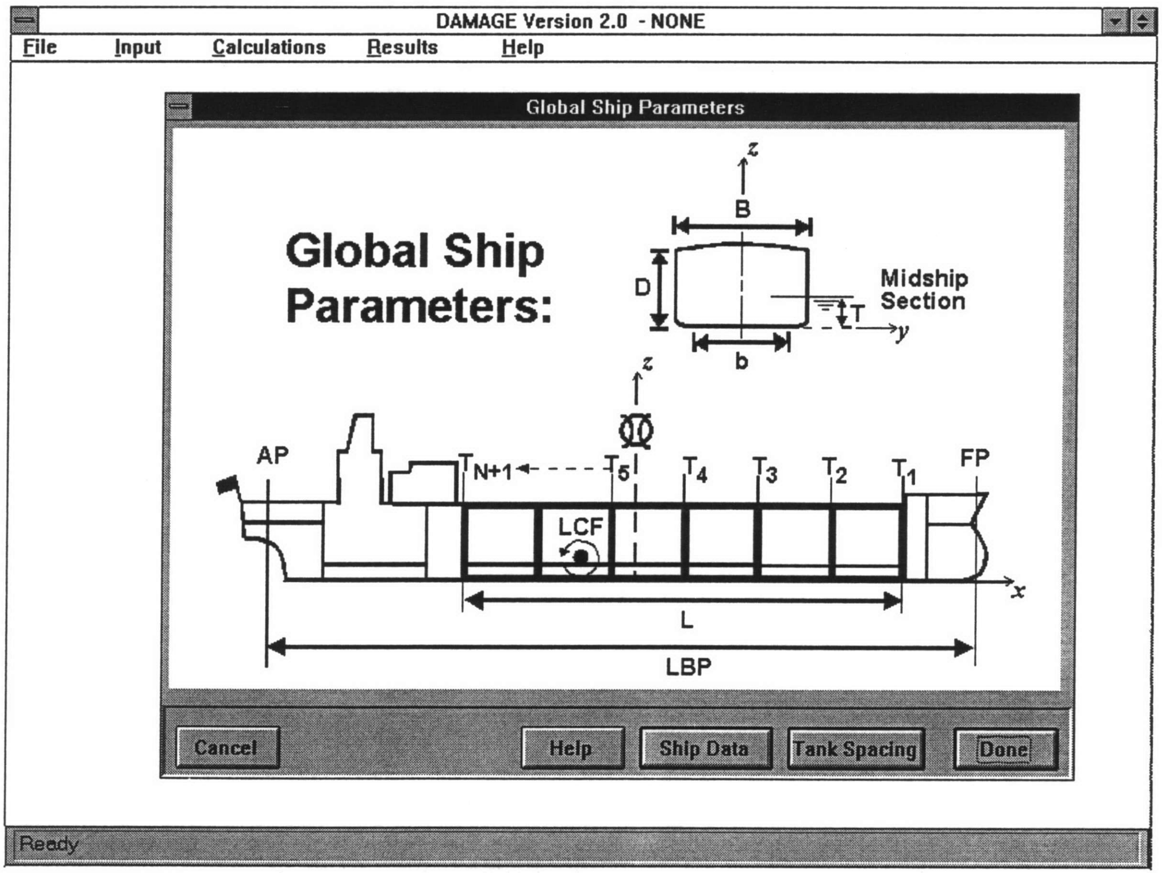


FIGURE 11. /Global Ship Parameters/ primary dialog box.

First, click on the button **[Ship Data]** to toggle to the secondary dialog box entitled "Global Ship Parameters - Data," shown in Figure 12. The user enters data into the table by clicking in the appropriate box and keying in the value. Use **<Tab>** and/or the mouse pointer to move across the various entry fields. (NOTE: Do not press

<Return> prior to the completion of all fields; pressing **<Return>** is equivalent to clicking the **[EXIT]** button and will terminate the data entry session!)

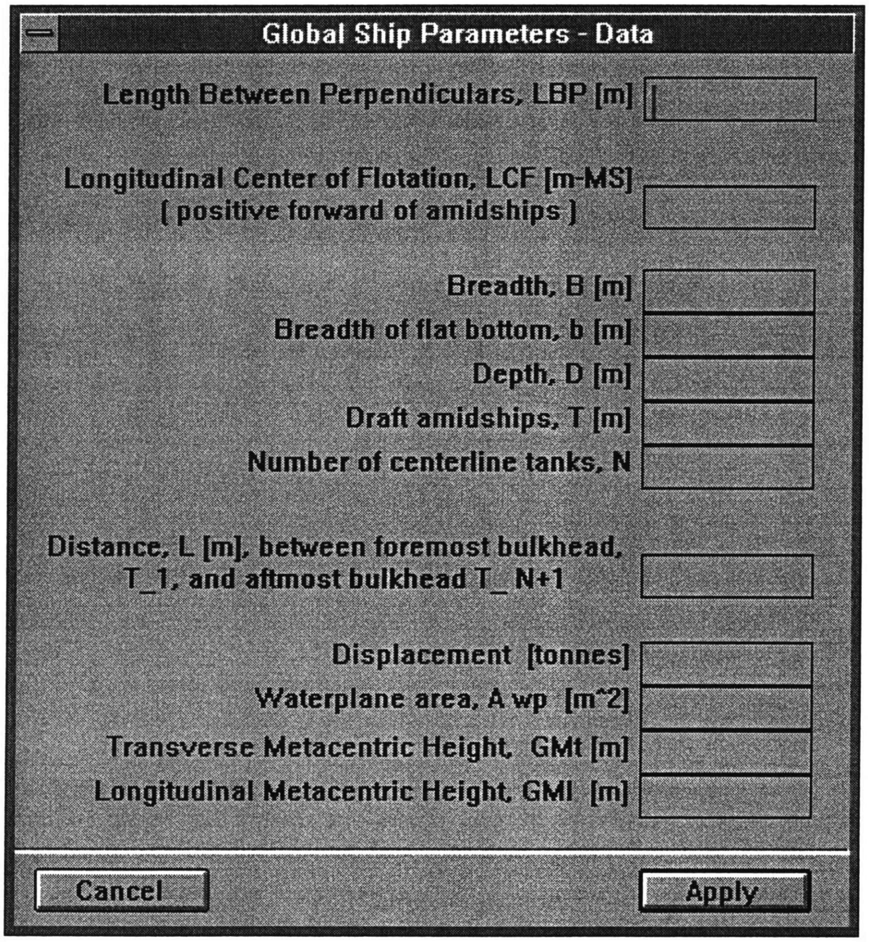


FIGURE 12. /Global Ship Parameters/ secondary dialog box for **[Ship Data]**.

1. Length Between Perpendiculars, LBP (m)

   The LBP is used to calculate the change in trim due to the moment arm created by the contact with the ground.

2. Longitudinal Center of Flotation, LCF (m-MS) (positive forward of amidships)

The longitudinal center of flotation, LCF, locates the pivot about which changes to trim caused by the contact with the ground is applied.

3. Breadth, B (m)

   The breadth, B, at amidships should be used. The breadth is used to calculate the change in heel due to the moment arm created by the contact with the ground.

4. Breadth of flat bottom, b (m)

   The ship is considered to be wall-sided with a flat bottom spanning the entire width, b. For any ship with a bilge area clearly demarcated by the shape of the transverse frames stiffening the bilge, the breadth of flat bottom, b, is calculated by subtracting twice the width of the bilge area from the beam, B, of the ship at amidships.

   If the shape of the frame does not clearly mark the bilge area, the breadth of flat bottom, b, is calculated by subtracting twice the bilge radius from the breadth, B, of the ship at amidships, for a ship <u>without double sides</u>, while for a ship <u>with double sides</u>, the breadth of flat bottom, b, is calculated by subtracting twice the double side depth from the breadth, B, of the ship at amidships. The value of b demarcates the transverse bounds within which only hull bottom structure is evaluated.

   <u>Note 1</u>: For tank ships whose waterplane coefficient, C_{WP}, deviates considerably from 0.90, the breadth of flat bottom, b, can be calculated by subtracting twice the width of the bilge area from the <u>average</u> of the breadth, B, at amidships and at the most narrow location along the target damage area.

   <u>Note 2</u>: For grounding damage expected primarily in the forward length of the ship, the breadth of flat bottom, b, can be calculated by subtracting twice the bilge radius or double side depth from an average value of B at locations near the likely damage zone.

The use of either alternative value for b adjusts for some fineness in hull form at fore and aft ends by reducing the transverse bounds of the target damage area.

5. Depth, D (m)

   The depth, D, at amidships should be used.

6. Draft amidships, T (m)

   The draft, T, at amidships should be used. The value T is used to calculate draft along the remaining length of the ship. The draft, along with initial rock elevation and trim angle, determines the location of first engagement of the hull bottom structure with the ground and, therefore, the lever arm of the pitch moment.

7. Number of centerline tanks, N

   The number of centerline tanks, N, determines the number of transverse watertight bulkheads, N+1. The value N primes the **[Tank Spacing]** dialog box to prompt for N+1 locations of transverse watertight bulkheads.

8. Distance, L (m), between foremost bulkhead, T_1, and aftmost bulkhead, T_{N+1}

   The distance, L, between foremost bulkhead and aftmost bulkhead divided by the number of centerline tanks, N, results in even bulkhead spacing throughout the entire cargo tank region. The value L/N is used to calculate default locations of Bulkheads T_2 through T_{N+1}, based upon even bulkhead spacing from a user-specified reference location for Bulkhead T_1.(see discussion below on **[Tank Spacing]** secondary dialog box).

9. Displacement (tonnes)

   The displacement, or buoyancy, is used to calculate the initial kinetic energy of the ship and the changes in heave, trim, and heel due to the moment arm created by the contact with the ground.

10. Waterplane area, A_{wp} (m^2)

The waterplane area, A_{wp}, is used to calculate the parallel rise due to grounding. Parallel rise describes the change in draft which would occur if the ground contacted the ship at the LCF.

11. Transverse Metacentric Height, GM_t (m)

The transverse metacentric height, GM t, is used to calculate the change in heel due to the moment arm created by the contact with the ground.

12. Longitudinal Metacentric Height, GM_l (m)

The longitudinal metacentric height is used to calculate the change in trim due to the moment arm created by the contact with the ground.

Note that all entries 1 through 12 above are necessary in order to include coupling effects between local hull damage and global ship motions in the calculations. If one or more of the above values are not specified, the program will automatically calculate only grounding damage <u>without</u> interaction, using **//Calculations// /2. Uncoupled/**.

To calculate grounding damage coupled with global ship motions, complete the table in Figure 12. Click the **[Apply]** button to close the secondary dialog box, send the ship global parameters data to the input file, and toggle back to the primary dialog box.

Next, click the button **[Tank Spacing]** to toggle to the secondary dialog box entitled "Transverse Bulkhead Locations," shown in Figure 13.

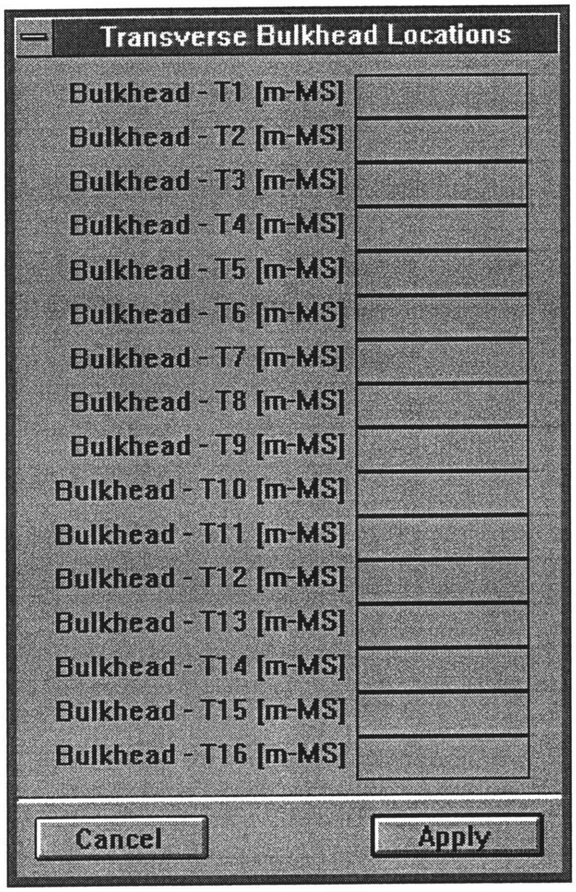


FIGURE 13. /Global Ship Parameters/ secondary dialog box for **[Tank Spacing]**.

The number of centerline tanks, N, determines the number of transverse watertight bulkhead locations, N+1, displayed. For even spacing of the transverse watertight bulkheads along the entire cargo length, L (entry number 8 in "Global Ship Parameters - Data" discussed above), specify the location of the foremost bulkhead only. Key in the location of the foremost bulkhead at the prompt "Bulkhead - T1 (m-MS)" and press return or click the **[Apply]** button to close the dialog box. The default locations for the remaining Bulkheads T_2 through T_{N+1} are automatically calculated by DAMAGE and can be viewed by reopening the **[Tank Spacing]** dialog box. Alternatively, the user may enter all of the transverse bulkhead locations individually, or alter any default data manually by opening the **[Tank Spacing]** dialog box, clicking in the appropriate box in the table, and keying in a new value.

When the table has been completed, click the **[Apply]** button to close the secondary dialog box, send the transverse bulkhead locations data to the input file, and toggle back to the primary dialog box.

For on-line help related to **//Input//** **/Global Ship Parameters/**, choose **[Help]** from the primary dialog box. Use the scroll bar to the right of the help dialog box to search the help text. Choose **[Exit]** to close the help dialog box and return to the primary dialog box.

Choose **[Done]** to close the **/Global Ship Parameters/** data group when the global ship parameters data and the transverse bulkhead location data have been completed.

3.3 Ground Characterization

Choose **/Ground Characterization/** from the **//Input//** pull-down menu to characterize the ground configuration and geometry.

The primary dialog box, shown in Figure 14, opens featuring four ground configuration options. The surfaces of the ground that experience contact with ship structure during grounding are shown in cross-hatch pattern. The edges which bound the contact faces are shown in bold. From the depictions of each ground configuration, it is clear that each will have a different effect upon the ship structure it impacts; therefore the parameters governing rupture strain and fracture mode of the damaged plating must change for each combination of ship and ground geometry. The **/Ground Characterization/** module of DAMAGE allows the user to thoroughly describe the shape of the rock by specifying those variables which affect both the initiation of fracture and the development of the fracture mode.

The fracture initiation mechanism discussed previously was based upon the geometry of the damage zone and on the properties of the material of which the structure was comprised. Experimental testing conducted at MIT and subsequent comparison to the NSWC quarter-scale groundings (Puente 1995) (Report #44) demonstrated that this expression was valid as long as the displacement profile of the plating does not interfere with the penetration of the ground. For cases where there is interference, the effect of the rock on fracture initiation becomes significant; a more accurate expression of the critical penetration depth is used, as described in the updated version of the theoretical manual.

The evolution of the crushing and tearing inflicted upon flat structure by grounding events was the focus of Phase I of the Joint MIT-Industry Program, and is of continuing interest, along with the behavior of curved plating, in Phase II. The user is referred to the publications of the Joint MIT-Industry Program for in depth discussion of this topic.

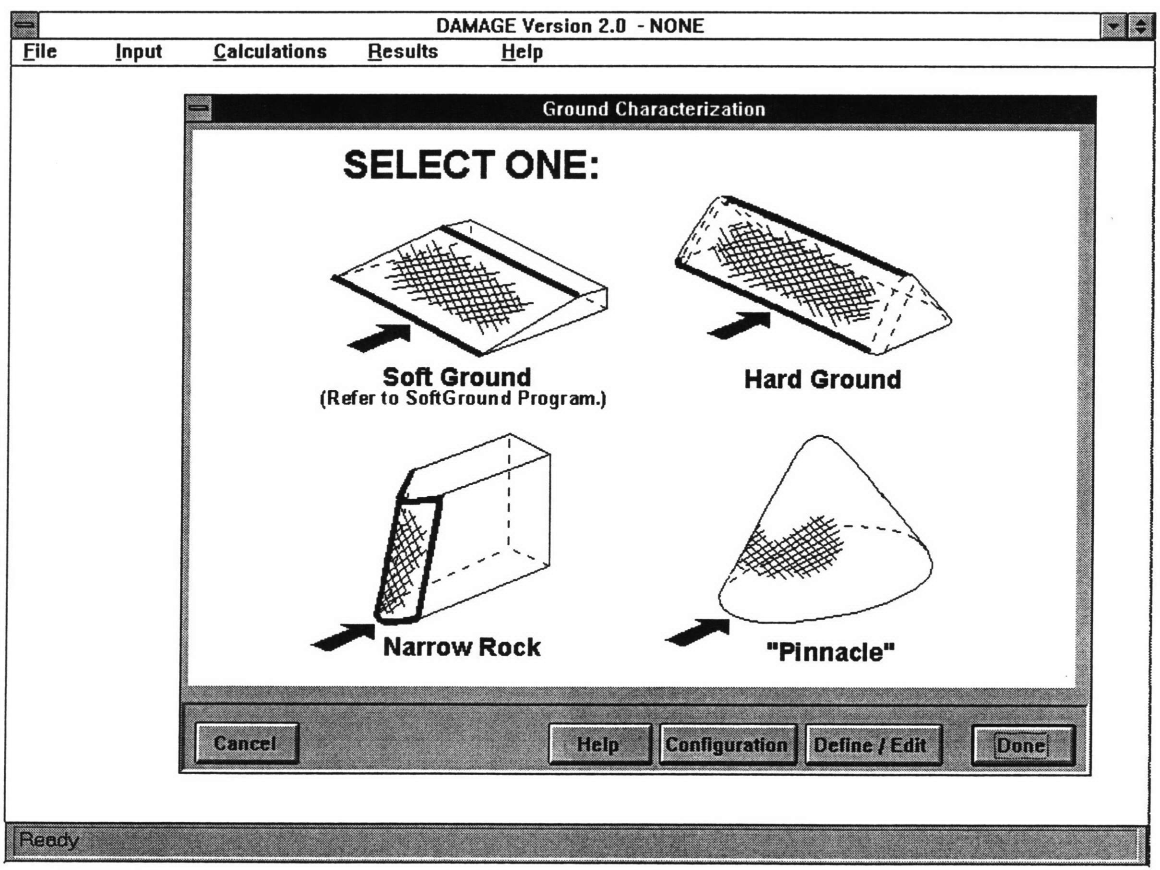


FIGURE 14. /Ground Characterization/ primary dialog box.

First, click the button **[Configuration]** to toggle to the secondary dialog box entitled "Ground Configuration," shown in Figure 15. The user chooses from the ground configurations by clicking the appropriate radio button:

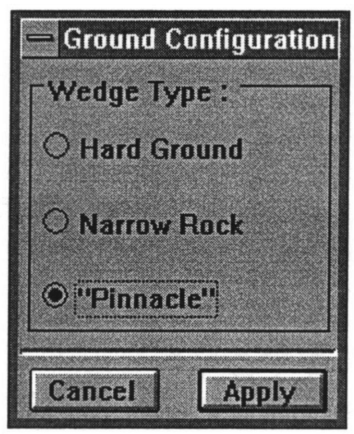


FIGURE 15. /Ground Characterization/ secondary dialog box for **[Configuration]**.

1. Soft Ground

   The behavior of soft ground types is described by soil mechanics. Gravel, sand, and silt fall into the category of soft grounds; ship structure which strikes an obstacle of this sort will not encounter any cutting or tearing projections. The option for soft ground is not enabled in DAMAGE; instead the user is referred to the program "SOFTGROUND." SOFTGROUND was developed independently by the Technical University of Denmark (DTU) and distributed in March 1995 to all members of the Joint MIT-Industry Tanker Safety Project. The user's manual for SOFTGROUND is available as Report #45 (Simonsen, 1995).

2. Wide Rock

   The option for hard ground is due for development in the later years of Phase II of the Joint MIT-Industry Tanker Safety Project. Hard ground includes wide obstacles such as reefs; the environmental sensitivity of these structures, and the international conservation efforts directed toward them, provides an obvious impetus to examine both their effect on ships, and ships' effects on the reefs.

3. Narrow Rock

   The option for narrow rock is one of the two ground categories currently enabled within DAMAGE. Click **[Narrow Rock]** to choose a deep, narrow rock. This type of ground configuration produces cutting or tearing of structure. <u>Cutting or tearing</u> of the structure, accompanied by curling flaps, concertina folding, or other energy dissipating reactions, proceeds for a fixed breadth along the depth of the rock. The sloping angle of the engaging surface of the rock will, in general, produce a vertical force on the flat bottom, and a combination of vertical and side force on the on the bilge. The magnitude of this force, and the evolution of the fracture mode, will vary with the shape of narrow rock described by the user. The six limiting cases of narrow rock geometries which can be described are shown in Figure 16 and are discussed in paragraphs that follow.

4. "Pinnacle"

Click [**"Pinnacle"**] to choose a deep pinnacle. This type of ground configuration produces crushing of hull structure with or without tearing, depending upon the initial rock elevation and other geometrical parameters of the hull and rock. Damage of the ship structure proceeds with lift and/or side force induced on the ship by the sloping and spreading angle of the conical ground.

When the configuration has been chosen, click the **[Apply]** button to close the secondary dialog box, send the configuration data to the input file, and toggle back to the primary dialog box.

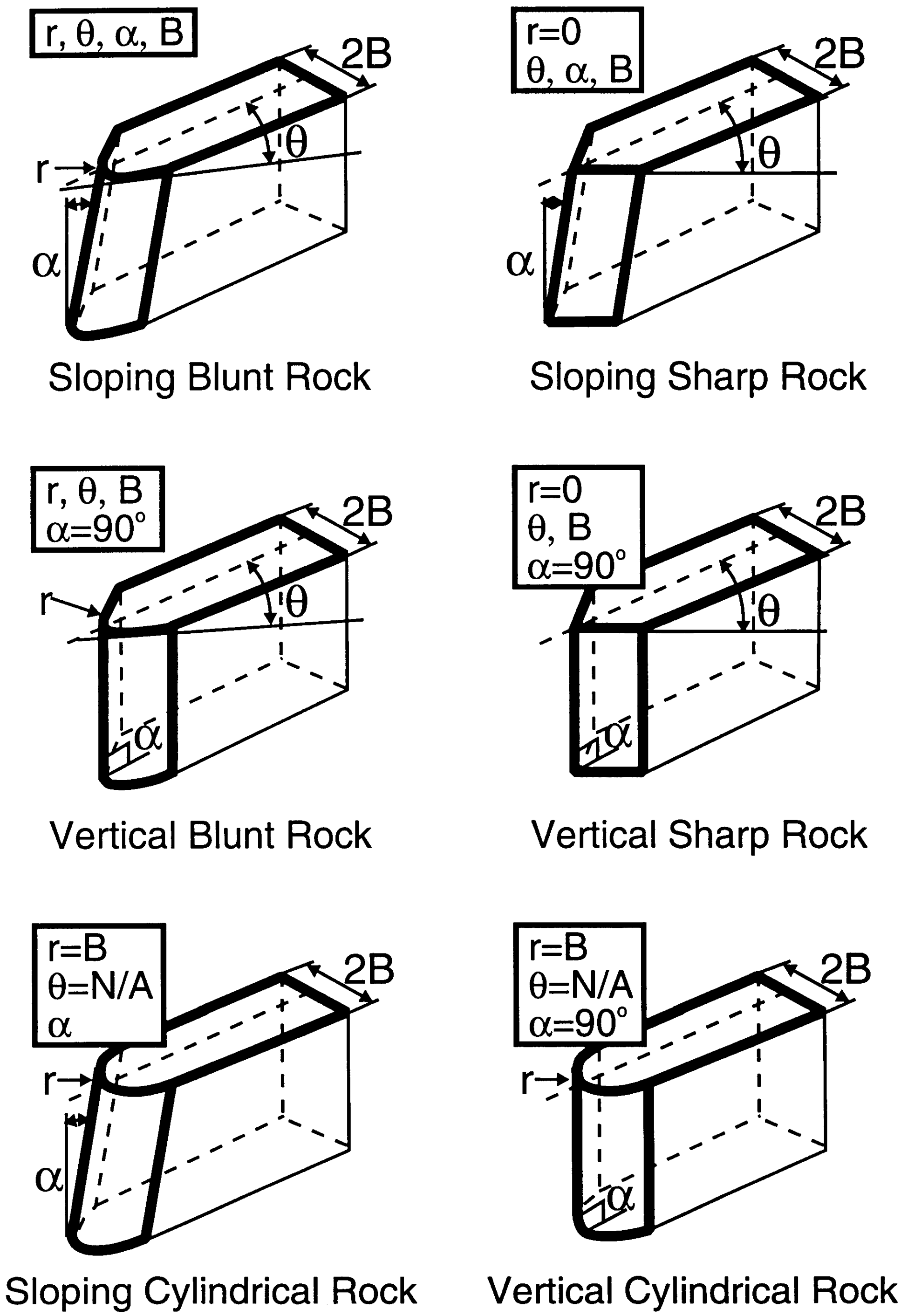


FIGURE 16. Six combinations of narrow rock geometries.

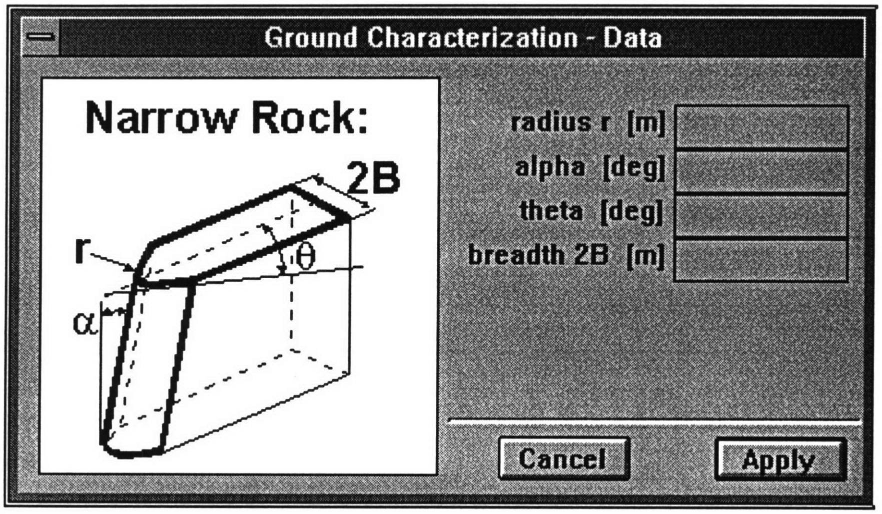


FIGURE 17. /Ground Characterization/ secondary dialog box for **[Define/Edit]** for a narrow rock.

Next, click the button **[Define/Edit]** to toggle to the secondary dialog box which bears the name of the chosen ground configuration in the title bar. The two define/edit secondary dialog boxes correspond to the two ground configuration options enabled for DAMAGE; they provide dimensioning diagrams with data tables for the narrow rock and "pinnacle," shown in Figures 17 and 18, respectively. For each of the two ground configurations, a wide range of ground shapes can be defined using creative combinations of the parameters, as discussed below.

The narrow rock is described by the fixed breadth, 2B, and the sloping angle of the wedge surface, α. The wedge semi-angle, θ, and the wedge radius, r, characterize the cutting or tearing mechanism by which the damage proceeds. The height of the narrow rock with respect to the ship is specified in the next data group, **/Ship-Ground Interaction/**.

Note that the narrow rock approaches six limiting cases of rock shapes (see Figure 16) depending upon the choice of the four parameters r, θ, α, and B. The two major groups of rock shapes are vertical (sloping angle α=90°) and sloping; within each group, the rock may be sharp, blunt, or cylindrical. The semi-angle and radius of the narrow rock tend towards zero for tearing by a sharp rock, as shown by "Sloping Sharp Rock" and "Vertical Sharp Rock". Conversely, blunt rocks have large θ and r, as shown by "Sloping Blunt Rock" and "Vertical Blunt Rock". The maximum value of the wedge tip radius is r=B, which characterizes a "Sloping Cylindrical Rock" or a "Vertical Cylindrical Rock". The deep "pinnacle" is described by the sloping and spreading angle, θ, and the tip radius, r. The spreading angle produces lift on the flat bottom and bilge, as well as some measure of side force against the bilge, depending upon the angle of incidence. The height of the "pinnacle" with respect to the baseline of the ship is specified in the next data group, **/Ship-Ground Interaction/**.

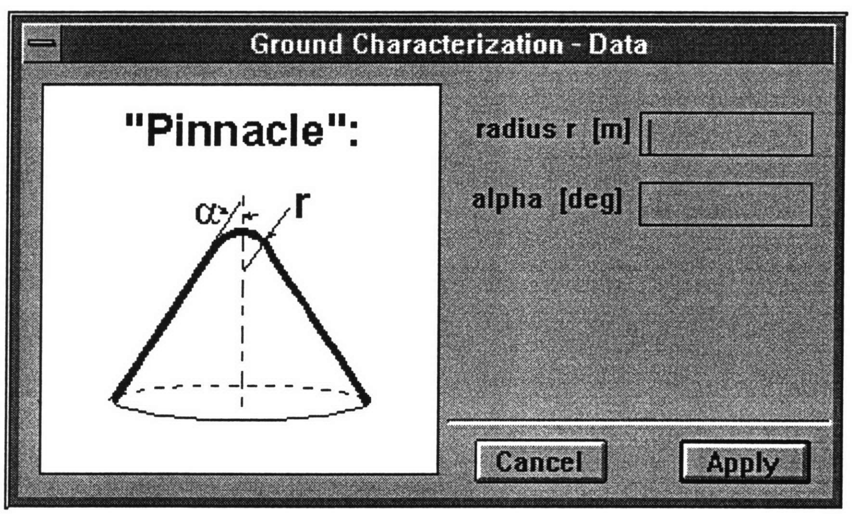


FIGURE 18. /Ground Characterization/ secondary dialog box for **[Define/Edit]** for a "pinnacle."

Note that in NSWC quarter-scale experiments, the cone semi-angle was θ=45° and the tip radius was taken to be half of the separation distance between the double hulls. A similar geometry was used in MIT 1:60 scale experiments and in tests performed by NTH in Norway.

Using the "pinnacle" and narrow rock parameters reviewed above for guidance, enter the ground geometry data by clicking in the appropriate box in the table and keying in the value. Use **<Tab>** and/or the mouse pointer to move across the various entry fields. (NOTE: Do not press **<Return>** prior to the completion of all fields; pressing **<Return>** is equivalent to clicking the **[EXIT]** button and will terminate the data entry session!)

When the table has been completed, click the **[Apply]** button to close the secondary dialog box, send the ground geometry data to the input file, and toggle back to the primary dialog box.

For on-line help related to **//Input// /Ground Characterization/**, choose **[Help]** from the primary dialog box. Use the scroll bar to the right of the help dialog box to search the help text. Choose **[Exit]** to close the help dialog box and return to the primary dialog box.

Choose **[Done]** when the ground configuration and geometry data has been completed to close the /**Ground Characterization/** data group.

3.4 Ship-Ground Interaction

The development of the dynamics model implemented in Phase I of DAMAGE began at the consideration that the ship responded to grounding with six degrees of freedom, shown in Figure 19. The degrees were divided into horizontal and vertical ship motions, and evaluated according to their effect upon the static equilibrium of the ship, the energy balance of the system, and the assumption of a linear path of damage after grounding (Simonsen and Wierzbicki, 1996). (Report #55)

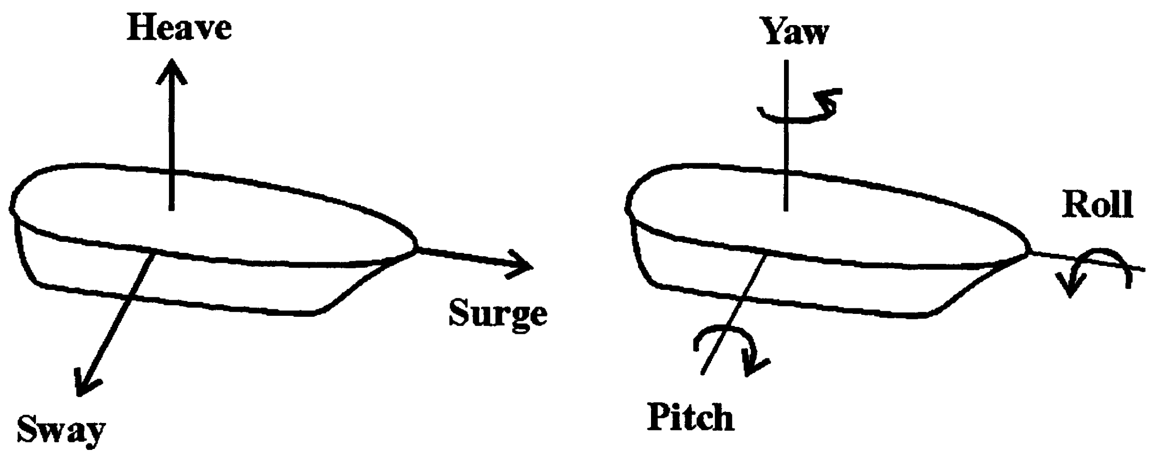


FIGURE 19. The six degrees of ship motions.

A numerical solution of the equations of motion of the system showed that two of the horizontal motions, sway and yaw, have small impact on the accuracy of the solution. The results obtained are further minimized by including the strength of the major longitudinal structural members, which will tend to restrain transverse motion. This implies that the path of damage is sufficiently close to linear for the purposes of this model.

Of the remaining four degrees of freedom, heave, pitch and roll can be evaluated from the static equilibrium of the system; the values defined under **/Global Ship Parameters/** and **/Ground Characterization/** contribute to these calculations. The motion of the ship in the direction of its velocity, surge, is taken from the energy balance of the system. Error is introduced into the calculation by neglecting the contribution of major transverse structural members, but the magnitude of it has been judged to be acceptably small. For the supporting calculation, the reader is referred to the Theoretical Manual, Report #55 (Simonsen and Wierzbicki, 1996).

Choose **/Ship-Ground Interaction/** from the **//Input//** pull-down menu to characterize interactions between the ship and the ground environment.

The primary dialog box, shown in Figure 20, opens displaying schematic diagrams of a general oil tanker grounded upon a rock in profile view and in section view looking aft. The relevant dimensions are labeled in both views; they are pertinent to the external dynamics of the grounding event.

First, click the button **[Define/Edit]** to toggle to the secondary dialog box entitled "Ship-Ground Interaction - Data," shown in Figure 21. The user enters the following data by clicking in the appropriate box in the table and keying in the value. Use **<Tab>** and/or the mouse pointer to move across the various entry fields. (NOTE: Do not press **<Return>** prior to the completion of all fields; pressing **<Return>** is equivalent to clicking the **[EXIT]** button and will terminate the data entry session!)

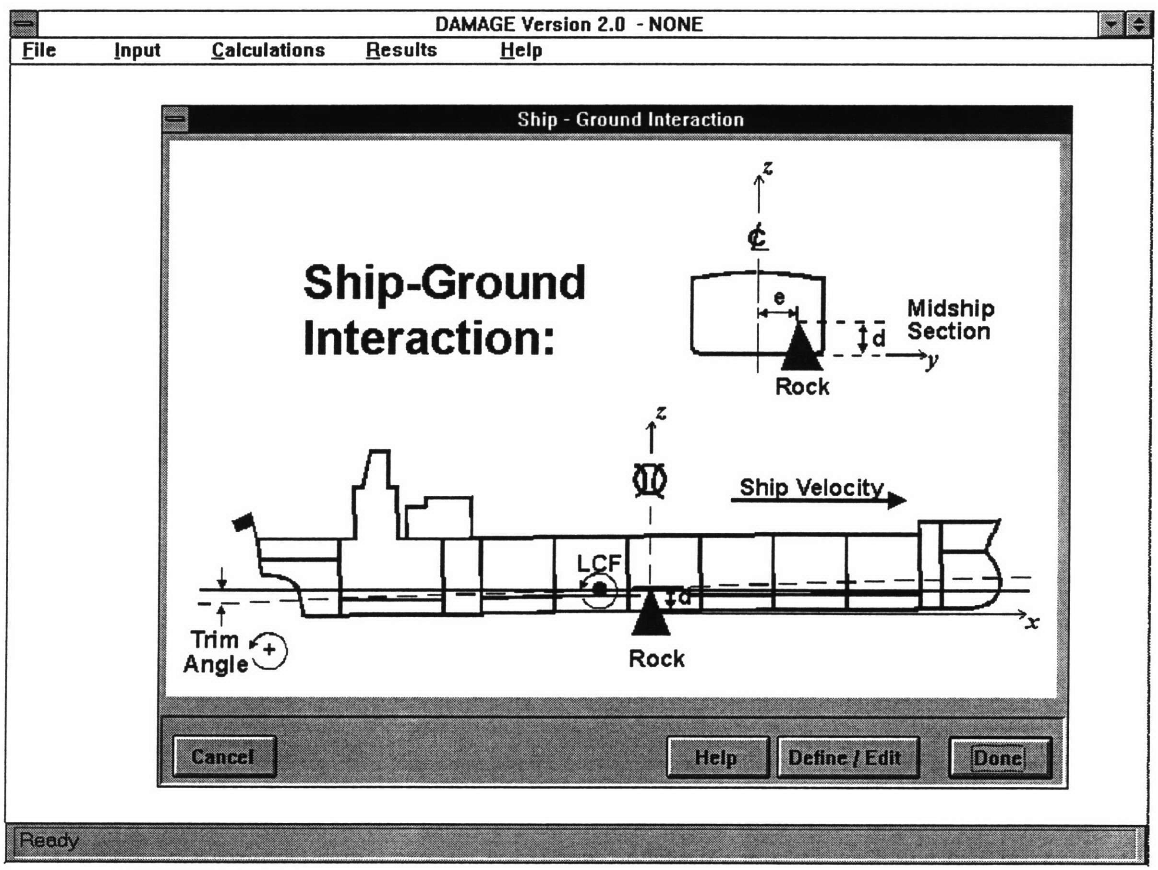


FIGURE 20. /Ship-Ground Interaction/ primary dialog box.

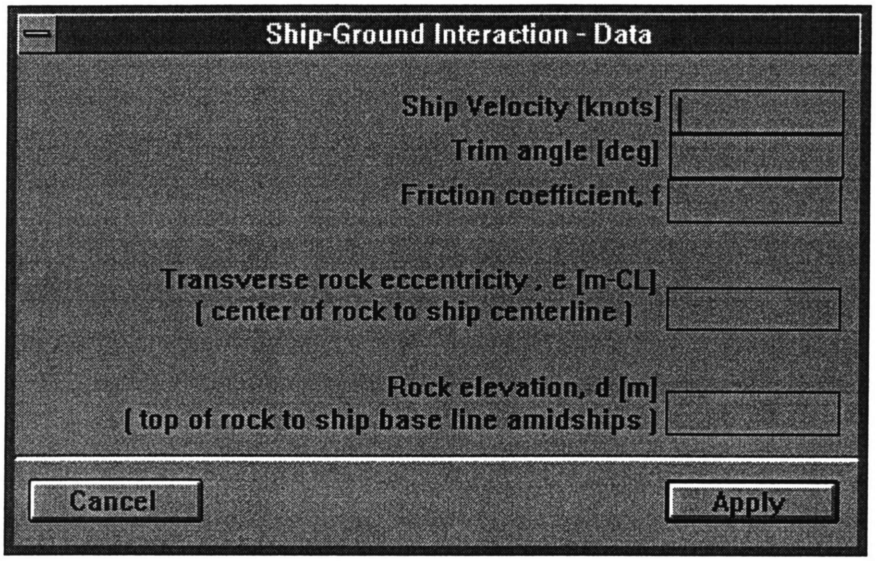


FIGURE 21. /Ship-Ground Interaction/ secondary dialog box for **[Define/Edit]**.

1. Ship Velocity (knots)

   The ship velocity characterizes the magnitude of the kinetic energy and, thus, the length of damage of the hull bottom structure by the ground.

2. Trim angle (deg)

   The trim angle is used to calculate draft along the length of the ship. The trim angle, along with initial rock elevation and draft, determines the location of first engagement of the hull bottom structure with the ground and, therefore, the lever arm of the pitch moment.

3. Friction coefficient, f

   The friction coefficient, f, determines the contribution of the frictional forces to the longitudinal hull resisting force and the vertical reaction force. A default value of the friction coefficient is f=0.3. The user can introduce another value, whenever appropriate.

4. Transverse rock eccentricity, e (m-CL) (center of rock to ship centerline)

   The transverse rock eccentricity with respect to the centerline of the approaching vessel, e, is the lever arm of the roll moment. The transverse rock eccentricity also locates the transverse bounds within which the ground may engage and damage ship bottom structure.

5. Rock elevation, d (m) (top of rock to ship base line amidships.)

   The rock elevation, d, with respect to the midship of the approaching vessel locates the vertical bounds within which the ground may engage and damage ship bottom structure. The initial rock elevation, along with draft and trim angle, determines the location of first engagement of the hull bottom structure with the ground and, therefore, the lever arm of the pitch moment.

When the table has been completed, click the **[Apply]** button to close the secondary dialog box, send the ship-ground interaction data to the input file, and toggle back to the primary dialog box.

For on-line help related to **//Input// /Ship-Ground Interaction/**, choose **[Help]** from the primary dialog box. Use the scroll bar to the right of the help dialog box to search the help text. Choose **[Exit]** to close the help dialog box and return to the primary dialog box.

Choose **[Done]** when the ship-ground interaction data has been completed to close the **/Ship-Ground Interaction/** data group.

BOTTOM-LEVEL DATA GROUPS

The bottom-level data groups in the **//Input//** pull-down menu acquire detail data which describe the structure contributing to hull strength in the target damage area. The cargo tank arrangement module and the hull bottom structure module were established in Phase

I of DAMAGE. As part of the Phase II initiative, a module has been added for bilge structure; the bow, machinery space, stern, and side structure are also scheduled for development in the future continuation of the project. The three active data group commands in DAMAGE Phase II are enabled in the **//Input//** pull-down menu, and are named **/Tank Arrangement/**, **/Hull Bottom Structure/** and **/Bilge/**, respectively.

These bottom-level data group commands use the identical procedure to acquire data. Choosing any of the commands opens a primary dialog box in the first menu level. This dialog box provides labeled diagrams associated with the data group and displays buttons for toggling to the secondary dialog boxes and to the second menu level. The secondary dialog boxes acquire general ship structural configuration data for the group from the options offered in the first dialog box; the second menu level acquires detailed ship structural data for the group.

For ease of use, all second level menus use the same nomenclature and tools. All primary structural members are developed from basic ship components selected from a dialog box similar to the one shown in Figure 22.

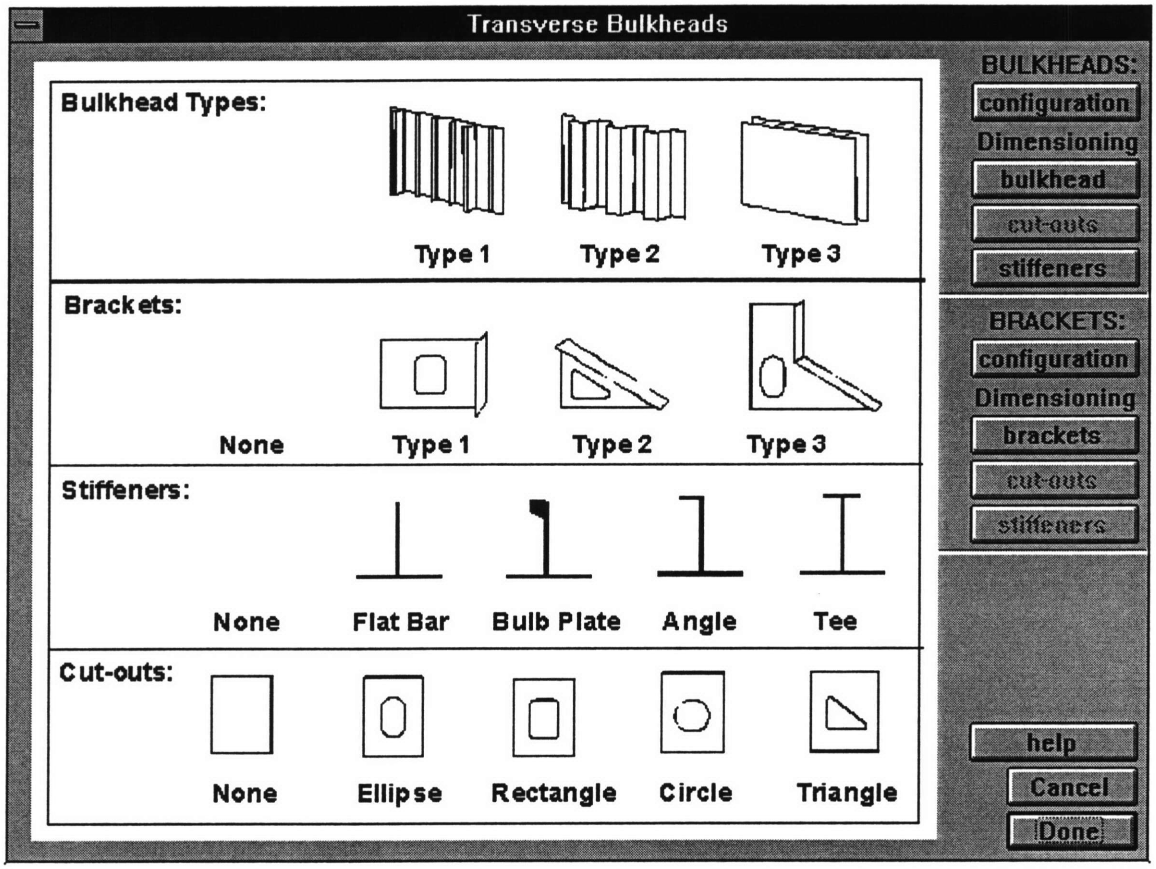


FIGURE 22. Typical structural components primary dialog box used in bottom-level data group procedure.

The primary and secondary dialog boxes in the second menu level acquire data in a fashion similar to the primary and secondary dialog boxes in the first menu level (discussed in **Top-level Data Groups** and in **Bottom-level Data Groups**). In the second menu level, the primary dialog box displays icons of the structural components on the left, and buttons for toggling to the secondary dialog boxes on the right. The secondary dialog boxes are used for choosing configurations or for entering group data into convenient tables. The secondary dialog boxes also provide a labeled diagram of the associated ship structure, enlarged from the icon chosen in the primary dialog box. (See Figure 23.)

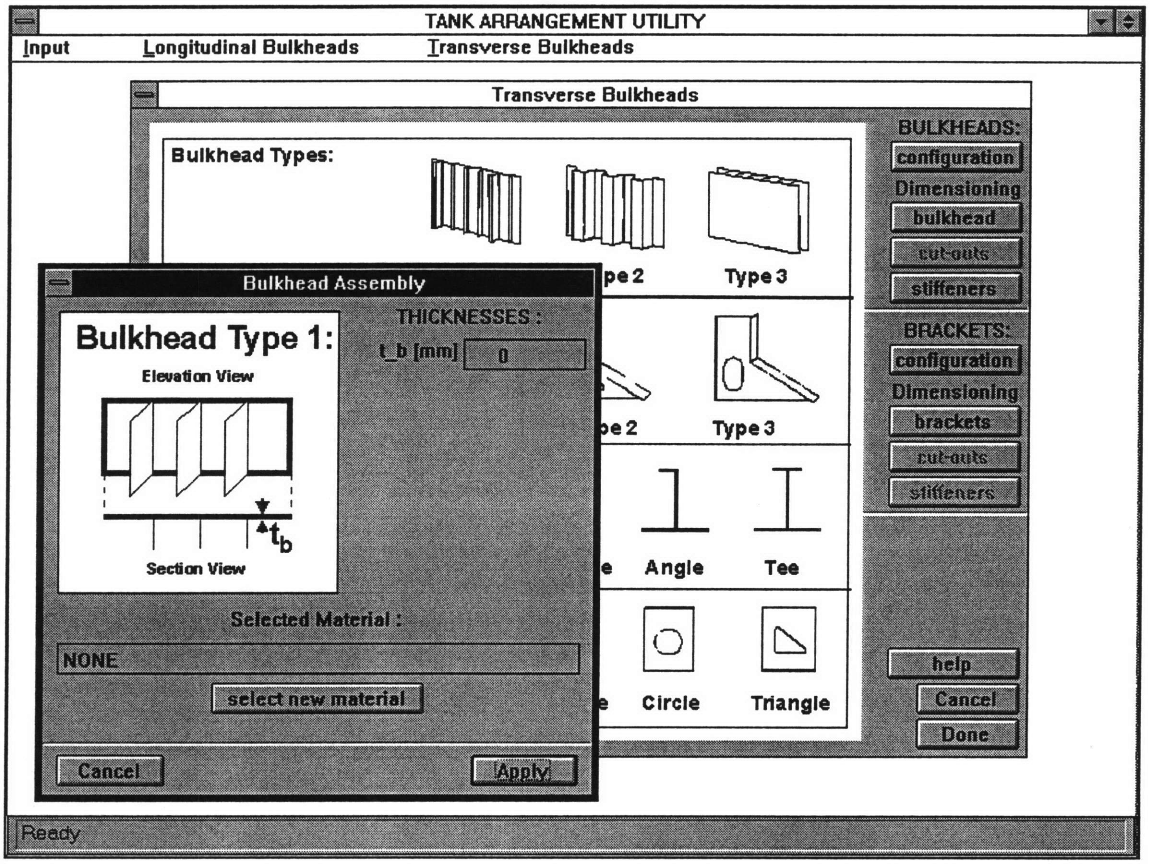


FIGURE 23. Typical primary and secondary dialog boxes used in bottom-level data group procedure.

The procedure for building the primary structure assemblies (e.g., bulkheads, centerline structure, etc.) is described below. For information detailing the assignment of dimensions and other data for all basic structural components, the user is referred to **Part II: DAMAGE Modeling Guide**.

In the second menu level, the left side of the primary dialog box, shown in Figure 24, features the ship structure icons. The target damage area for DAMAGE Phase II is the hull bottom structure and the bilge structure in the cargo tank region (plus the bulkhead strake adjacent to the outer bottom or tank top). The structural assemblies associated with this damage area are

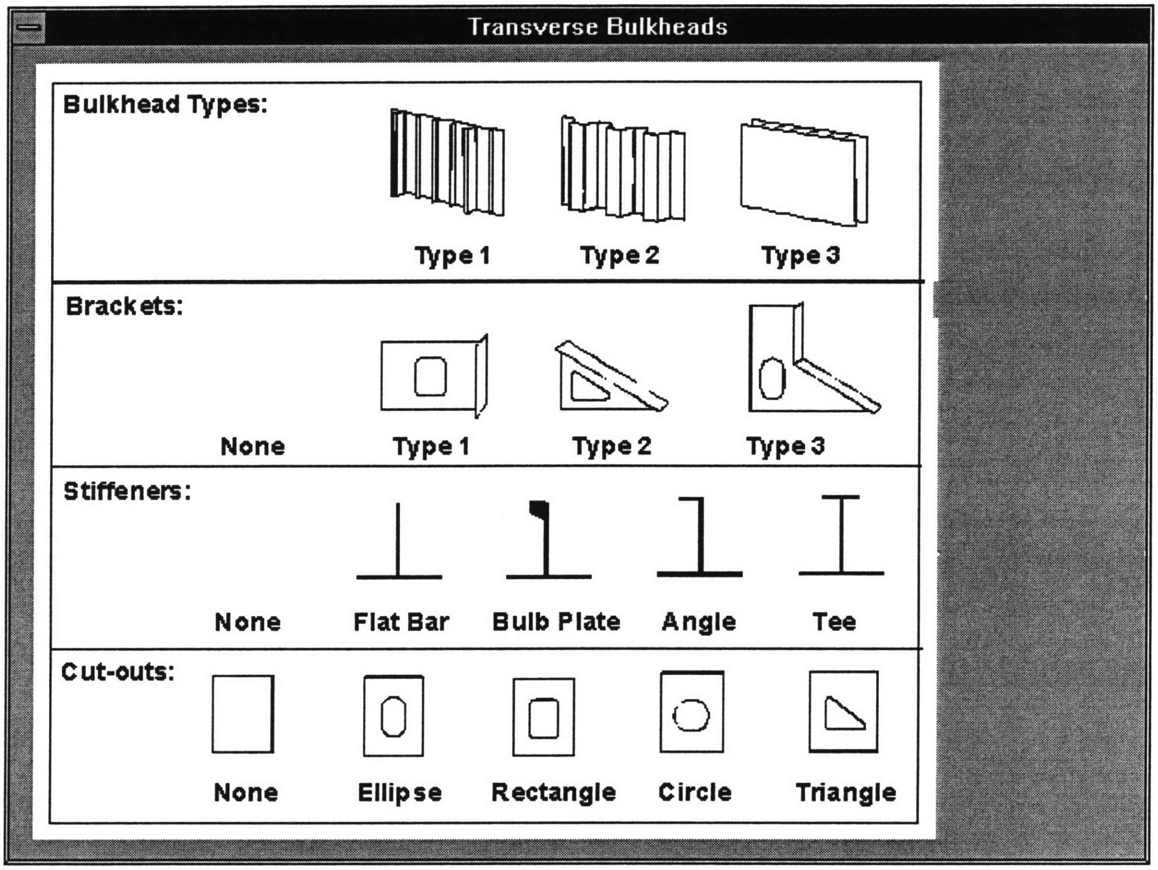


FIGURE 24. Structural icons in the structural components dialog box.

subdivided into four types of ship structure represented by the icons: the **primary structure type**, the **bracket type**, the **stiffener type**, and the **cut-out type**. Each component is represented by several of the variations most frequently encountered in tanker ship structure.

1. Primary Structure Type.

The top row features icons representing primary structure type. The hull bottom structure is constructed with a combination of **bulkheads**, **centerline** structure, **inner bottom** assembly, **outer bottom** assembly, **webs/frames** & **longitudinals**, and **floors/frames**; the **bilge frames**, **inner bilge** assembly, **outer bilge** assembly, **stringers**, and **girders** comprise the primary structure types associated with the bilge area. The icons pictured in primary structure type will vary depending upon the primary structure chosen by the user from the second menu level menu bar and the accompanying pull-down menu items. This feature is discussed further in 3.5 Tank Arrangement and 3.6 Hull Bottom Structure. In Figure 23, the current primary structure type is the **Bulkhead Type**.

2. Bracket Type

   The second row features icons representing bracket type. The brackets are understood to be attached to the current structure chosen in the primary structure type above. The rectangular, triangular, and L-shaped brackets are three typical bracket configurations which are frequently fitted longitudinally along the ship's centerline and tank sides, and transversely against the bases of bulkheads. They are at intermediate frame spaces between the primary supporting structure.. Bracket types may be simple plates or plates fitted with a flange.

3. Cut-out Type

   The fourth row features icons representing cut-out type. The ellipse, rectangle, circle, and triangle cut-out types approximate four typical cut-outs made in ship structure.

4. Stiffener Type

   The third row features icons representing stiffener type. The flat bar, bulb plate, angle, and tee stiffeners are four typical stiffener cross-sections used in ship construction.

The primary structure, pictured in the top row, is the assembly that is modified by a combination of the basic structural components featured in the three rows of icons below it. The user chooses the configuration of the primary structure and describes the associated components using the construction buttons on the right side of the primary dialog box, shown in Figure 25.

The top four buttons in the structural components dialog box configure the primary structure and its associated stiffeners and cut-outs. Click a button to toggle to its associated secondary dialog box and click **[Apply]** to close it.

Choose the **[configuration]** construction button to specify the type of primary structure to be constructed and its configuration with attached stiffeners and cut-outs. This button toggles to a secondary dialog box, shown in Figure 26, which features four groups of radio buttons. Choose the primary structure type from the top left set of radio buttons; this set of buttons is discussed separately for each different kind of primary structure in 3.5 Tank Arrangement, 3.6 Hull Bottom Structure, and 3.7 Bilge Structure. Next, choose the shape of the cut-outs present in the primary structure from the top right group of buttons. Finally, choose the cross-section of the stiffeners on the primary structure from the bottom left group. The bottom right set of buttons is reserved for cut-outs on the stiffeners of the primary structure. A default **[None]** is specified here, indicating no cut-outs on stiffeners to primary structure.

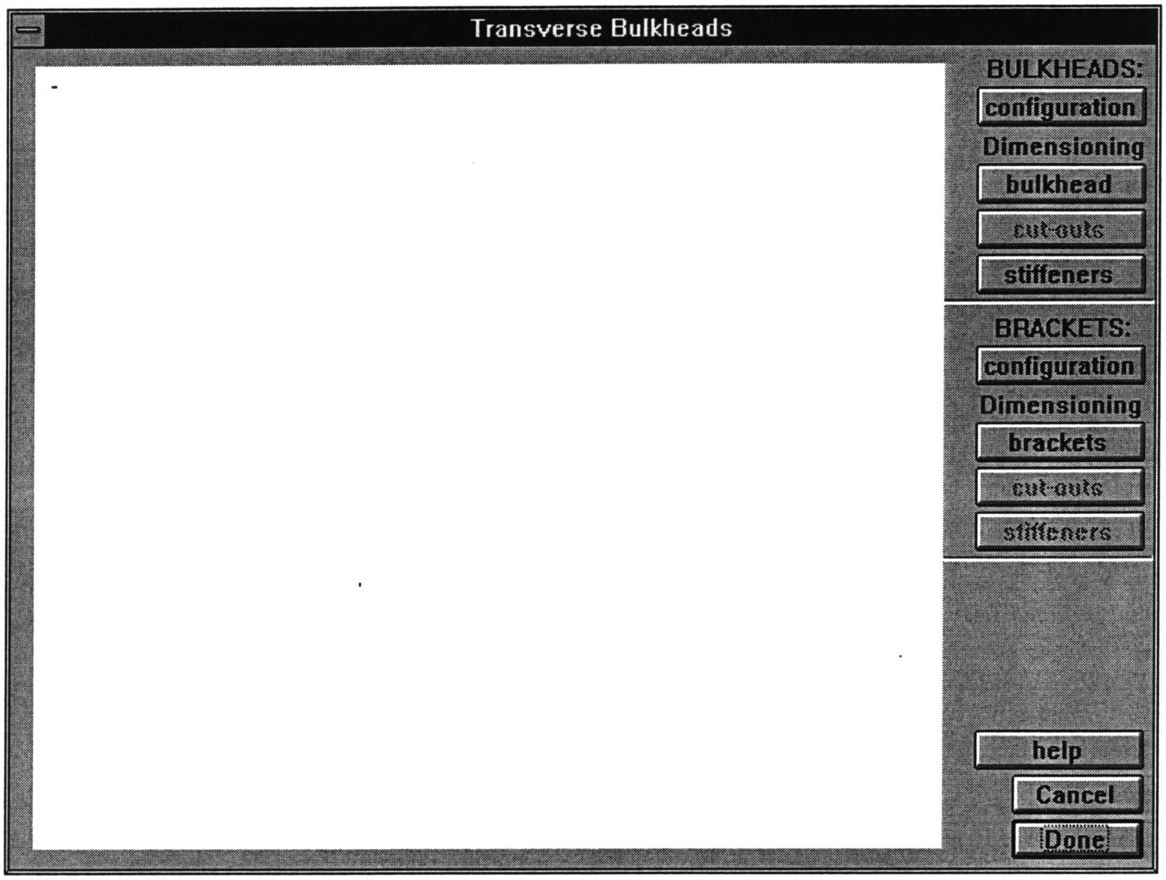


FIGURE 25. Construction buttons in the structural components dialog box.

Choose the **[<primary structure kind>]** construction button, under **Dimensioning**, to apply dimensions to the type of primary structure chosen above. The label, <primary structure kind>, which appears on this construction button varies with the name of the primary structure being built. This button toggles to a secondary dialog box featuring an enlarged, schematic drawing of the chosen structure with a table for its dimensions. The number of parameters to specify varies with the kind and type of primary structure. The description of dimensions for all of the primary structure is discussed in the DAMAGE Modeling Guide.

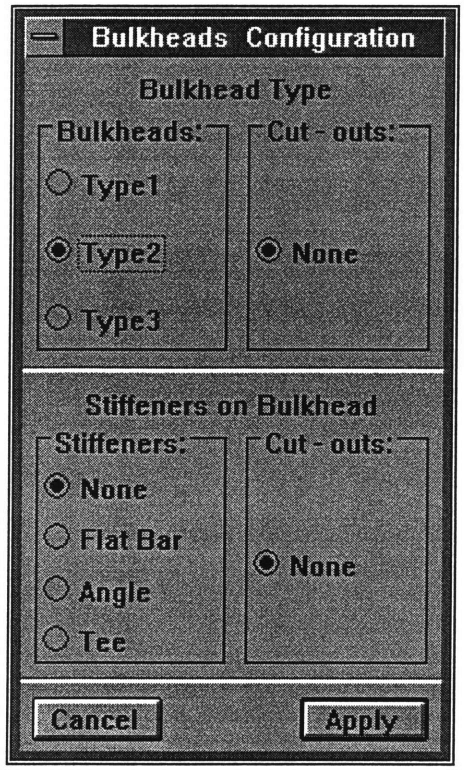


FIGURE 26. Primary structure **[configuration]** key dialog box.

Choose the **[cut-outs]** construction button to dimension the cut-outs, if any, in the primary structure chosen above. This button toggles to a secondary dialog box featuring an enlarged, schematic drawing of the chosen cut-out with a table for its dimensions. The number of parameters that must be specified varies with the type of cut-out. The description of dimensions for different cut-outs is discussed in the DAMAGE Modeling Guide.

Choose the **[stiffeners]** construction button to dimension the stiffeners, if any, on the primary structure chosen above. This button toggles to a secondary dialog box featuring an enlarged, schematic drawing of the chosen stiffener with a table for its dimensions. The number of parameters to specify varies with the type of stiffener. The description of dimensions for different stiffeners is discussed in the DAMAGE Modeling Guide.

The middle four buttons in the structural components dialog box configure the brackets flanking the primary structure. The brackets are modified with stiffeners and cut-outs in a similar fashion to the primary structure using construction buttons. Click a button to toggle to its associated secondary dialog box and click **[Apply]** to close it when finished.

Choose the **[configuration]** construction button to choose the type of bracket to be constructed and its configuration of associated stiffeners and cut-outs. This button toggles to a secondary dialog box, similar to the one shown in Figure 26, featuring groups of radio buttons. Choose the bracket type from the top left set of buttons. The top right set of buttons is reserved for the cut-outs, if any, in the bracket. The bracket stiffeners and the cut-outs in the bracket stiffeners can be chosen in the bottom left and bottom right button sets, respectively. None of the three modification options for the bracket are enabled in DAMAGE; the default for all of them is **[None]**.

Choose the **[bracket]** construction button to dimension the type of bracket chosen above. This button toggles to a secondary dialog box featuring an enlarged, schematic drawing of the chosen structure with a table for its dimensions. The number of parameters to specify varies with the type of bracket. The description of dimensions for different brackets is discussed in the DAMAGE Modeling Guide.

Choose **[cut-outs]** to dimension the cut-outs in the bracket chosen above. The development of this button is deferred to the next phase of the Project.

Choose the **[stiffeners]** construction button to dimension the stiffeners on the bracket chosen above. The development of this button is deferred to the next phase of the Project.

The **[Help]** button is available for on-line help related to each of the structural components dialog box. Use the scroll bar to the right of the help dialog box to search the help text. Choose **[Exit]** to close the help dialog box and return to the primary dialog box.

When all of the configurations and dimensions for the chosen primary structure assembly have been applied, click the **[Done]** button to close the structural components dialog box.

The three bottom-level data groups enabled for DAMAGE Phase II invoke the procedure presented above for the structural components dialog boxes.

The data groups are discussed further in the sections that follow.

3.5 Tank Arrangement

Choose **/Tank Arrangement/** from the **//Input//** pull-down menu to characterize the general arrangement of the cargo space and detail the dimensions of the bulkhead structure.

The primary dialog box, shown in Figure 27, displays representative diagrams of half of the ship transverse section in way of the cargo space. These diagrams are used to select the general tank arrangement in the transverse direction and to locate the relevant longitudinal bulkheads. For this reason, the specifics of hull bottom and bilge structure are omitted from the section views.

Six section views are featured showing the varieties of transverse tank arrangement for most oil tanker variants. These views represent the categories of ships currently analyzed by DAMAGE; additional ship types may be included during the course of Phase II of the Joint MIT-Industry Program on Tanker Safety. .

First, click the button **[Configuration]** to toggle to the secondary dialog box entitled "Transverse Configuration," shown in Figure 28, to choose the transverse section. The user may choose from the following transverse tank arrangements:

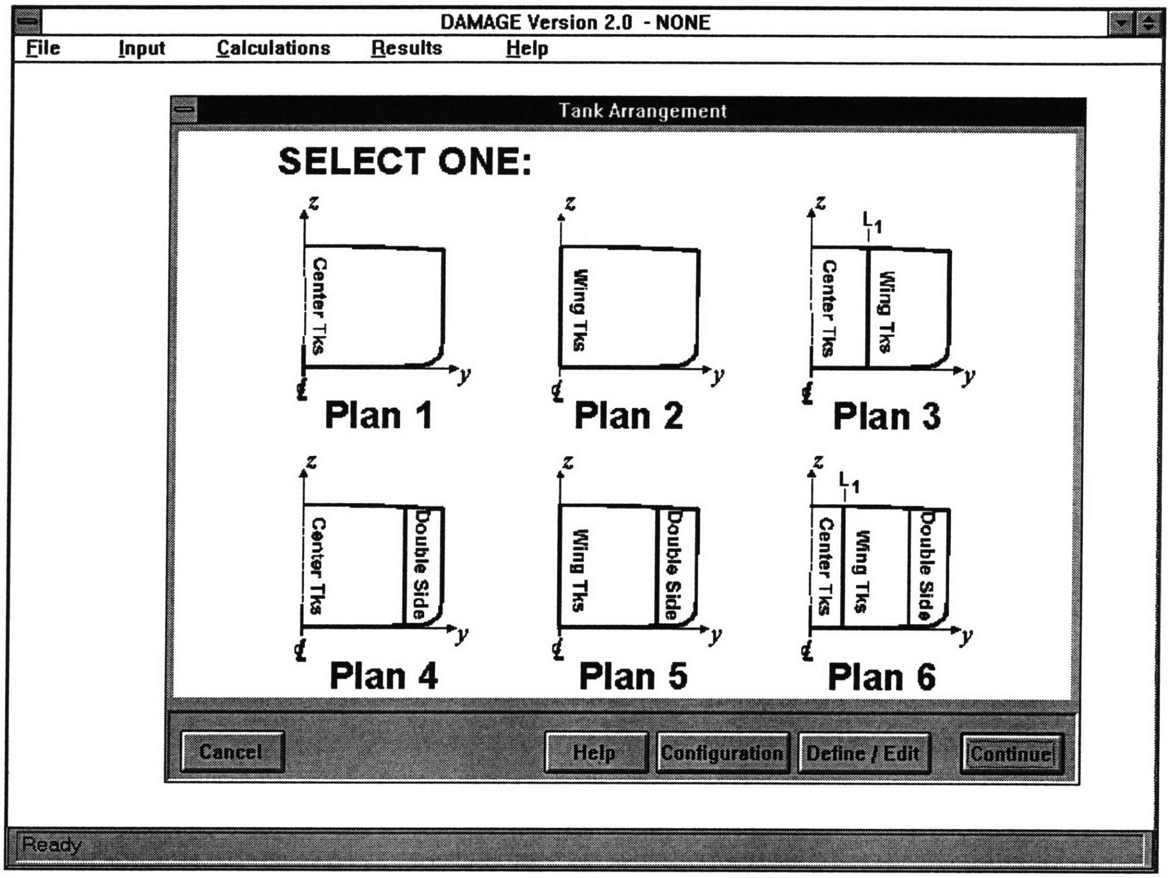


FIGURE 27. /Tank Arrangement/ primary dialog box at the first menu level.

1. Center tanks only.
2. Port/starboard wing tank pairs only.
3. Center tanks flanked by port/starboard wing tank pairs.
4. Center tanks flanked by double sides.
5. Port/starboard wing tank pairs flanked by double sides.
6. Center tanks flanked by port/starboard wing tank pairs and double sides.

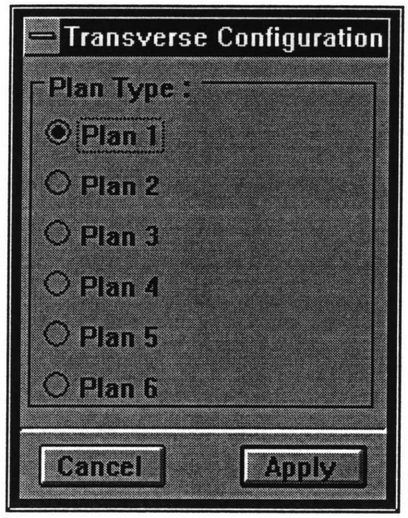


FIGURE 28. /Tank Arrangement/ secondary dialog box for **[Configuration]**.

When the transverse configuration has been chosen, click **[Apply]** to close the secondary dialog box, send the configuration data to the input file, and toggle back to the primary dialog box.

Recall that the breadth of flat bottom, b, specified in **/Global Ship Parameters/ [Ship Data]** determines the transverse bounds of the hull bottom structure; . the calculation of b (see section 3.2 Global Ship Parameters) excludes the double side region, if double sides are fitted. The double side region near the hull bottom is defined under bilge structure in Phase II of DAMAGE, and will be developed further when the Hull Side Structure Utility is enabled in the calculation routines of DAMAGE. For this reason, only those longitudinal bulkheads which are fitted within the transverse breadth of b are specified under **/Tank Arrangement/**. . The relevant bulkhead, L_1, is the bulkhead that is not on centerline, and can be fitted in **Plan 3** and **Plan 6** only.

<u>If Plan 3 or Plan 6 only is chosen above</u>, click the button **[Define/Edit]** to toggle to the secondary dialog box entitled "Location of Longitudinal Bulkhead." This dialog box, shown in Figure 29, allows the user to specify the transverse location of the relevant longitudinal bulkhead, L_1.

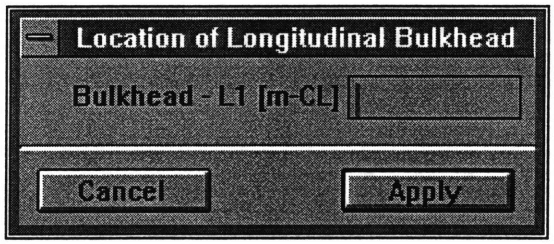


FIGURE 29. /Tank Arrangement/ secondary dialog box for **[Define/Edit]**.

When the transverse location of the relevant longitudinal bulkhead has been specified for Plan 3 or Plan 6, click **[Apply]** to close the secondary dialog box, send the configuration data to the input file, and toggle back to the primary dialog box.

When the transverse configuration has been chosen and the location of the relevant bulkhead, where one is fitted, has been specified, click **[Continue]** to toggle to the second menu level entitled "Tank Arrangement Utility."

The Tank Arrangement Utility is used to construct the transverse and longitudinal bulkhead assemblies. The bulkheads are located in the transverse and longitudinal directions using information already sent from the secondary dialog boxes under **/Global Ship Parameters/ [Tank Spacing]** and **/Tank Arrangement/ [Define/Edit]**.

The primary structures constructed within Tank Arrangement Utility invoke the standard procedure described above for bottom-level data groups (see Bottom-level Data Groups) using the appropriate structural components dialog boxes. For on-line help related to the Tank Arrangement Utility, choose **[Help]** from the primary dialog box. Use the scroll bar on the right of the help dialog box to search the help text. Choose **[Exit]** to close the help dialog box and return to the Tank Arrangement Utility.

Choose **/Bulkhead/** from the **//Transverse Bulkhead//** pull-down menu on the Tank Arrangement Utility menu bar to construct the transverse bulkhead assembly.

The transverse bulkhead structural components dialog box opens, shown in Figure 30. Three typical bulkhead types are pictured as options under **Bulkhead Types:** in the row of primary structure icons. The choices are summarized below, and the user should refer to **Part II: DAMAGE Modeling Guide** for additional guidance:

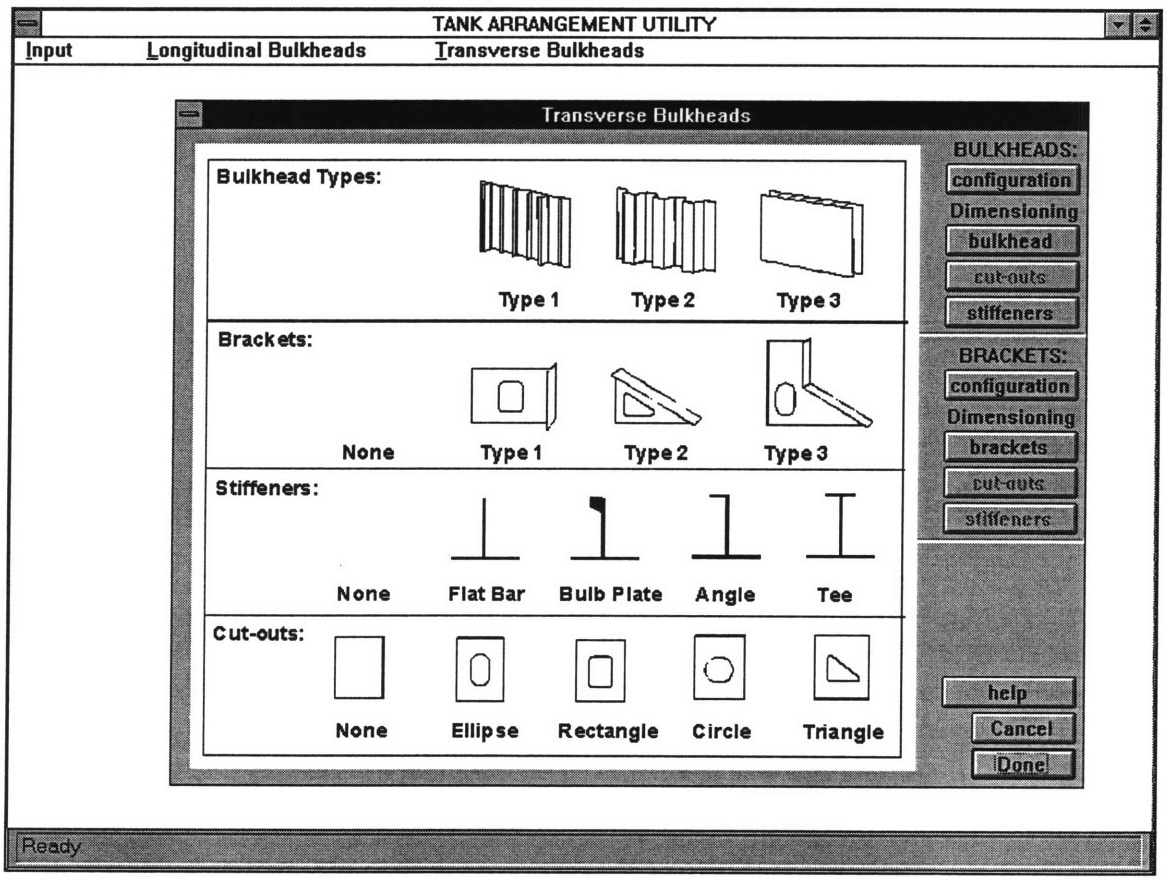


FIGURE 30. Structural components dialog box for transverse (and longitudinal) bulkhead assemblies.

1. Type 1

   Type 1 is the conventional panel bulkhead with external stiffeners.

2. Type 2

   Type 2 is the corrugated bulkhead.

3. Type 3

   Type 3 is the panel bulkhead with internal stiffeners.

Choose **[configuration]** from the construction buttons under **BULKHEADS:** to choose the bulkhead assembly configuration. The bulkheads are considered to be watertight and, therefore, **[None]** is the default for cut-outs, indicating *no* cut-outs on bulkheads. Since all of the transverse bulkheads in the cargo spaces are also considered to be identical to one another, the user should define a bulkhead assembly that is representative of the majority of the bulkheads, if they are not actually identical.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **//Transverse Bulkheads//**.

If the transverse bulkheads have been braced by frames, choose **/Bulkhead Frames/** from the **//Transverse bulkhead//** pull-down menu. The bulkhead frames, where fitted, are at a 90° angle to the bulkhead, with their bases on the inner bottom or outer hull plating.

The top row of the transverse bulkhead - frames dialog box, contains two icons for bulkhead frames, one for each frame shape. Choose **[configuration]** to select the frame shape and configuration. The procedure to dimension and modify the frames follows the previous discussion; the user is referred to Part II: Modelling Guide, for assistance in completing the data for **/Bulkhead Frames/**.

Choose **//Longitudinal Bulkheads//** from the Tank Arrangement Utility menu bar to construct the longitudinal bulkhead assembly, only if a relevant longitudinal bulkhead is fitted (i.e., where Plan 3 or Plan 6 has been specified in **/Tank Arrangement/ [Configuration]** for transverse tank arrangement).

The longitudinal bulkhead structural components dialog box opens. This dialog box is similar to the transverse bulkhead structural components dialog box, and the procedure for constructing the longitudinal bulkhead assembly using this dialog box is identical to the one described above for the transverse bulkhead assembly. The user is referred to the structural dialog box shown in Figure 30 and the procedure for **/Transverse Bulkheads/** described above for instructions on implementing **/Longitudinal Bulkheads/**.

If the longitudinal bulkheads are supported by frames, choose **/Bulkheaad Frames/ //Longitudinal Bulkhead//**. The dialog box and procedure for completing the data is identical to the above discussion of **/Bulkhead Frames/ //Transverse Bulkheads//**. The user is referred to this discussion, and to the Part II: Modelling Guide, for instruction.

When all of the specifications for the relevant bulkhead assemblies have been properly described, choose **/Tank Arrangement/** from the **//Input//** pull-down menu in the Tank Arrangement Utility to return to the DAMAGE first menu level.

3.6 Hull Bottom Structure

Choose **/Hull Bottom Structure/** from the **//Input//** pull-down menu to characterize the type of hull bottom configuration and detail the dimensions of the hull bottom structure.

The primary dialog box, shown in Figure 31, opens displaying representative section diagrams of the hull bottom structure in way of the cargo space. These diagrams are used to select the general type of hull bottom configuration. For this reason, the longitudinal bulkheads, bilge frames, and bilge area structure are omitted from the section views. (Bulkhead structure is discussed in 3.5 Tank Arrangement.)

Three section views are featured showing the types of hull bottom configuration analyzed by DAMAGE and are inclusive of most oil tanker variants.

Click the button **[Configuration]** to toggle to the secondary dialog box entitled "Hull Bottom Configuration," shown in Figure 32, to choose the type of hull bottom structure. The user may choose from the following types of hull bottom structure configurations:

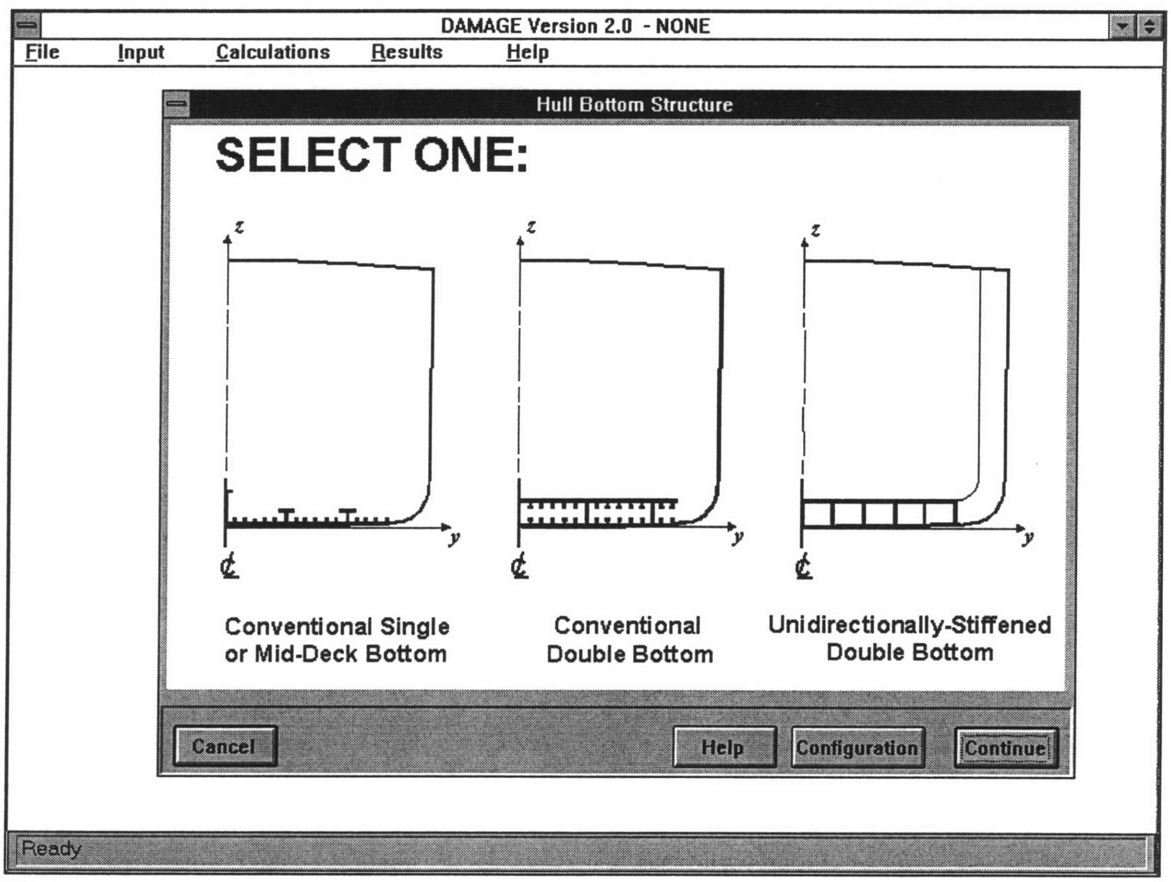


FIGURE 31. /Hull Bottom Structure/ primary dialog box at the first menu level.

1. Single Hull / Mid-Deck.

   Recall that the target damage area for DAMAGE Phase II is the hull bottom structure and bilge area in the cargo tank region plus the lower strake of bulkheads and frames immediately adjacent to the outer hull plating or tank top. The bottom structure of the Mid-Deck design, viewed by DAMAGE within this depth, is structurally similar to the Single Hull bottom structure.

2. Conventional Double Hull.

3. Unidirectionally-Stiffened Double Hull.

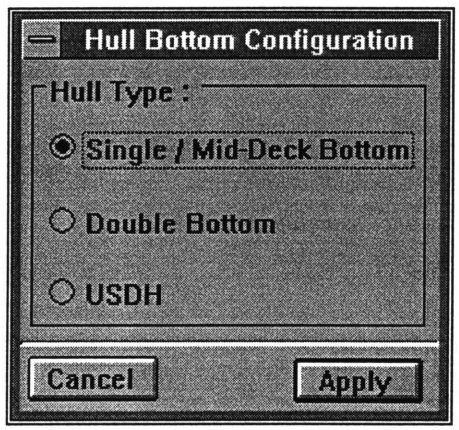


FIGURE 32. /Hull Bottom Structure/ secondary dialog box for **[Configuration]**.

When the bottom structure type has been chosen, click **[Apply]** to close the secondary dialog box, send the configuration data to the input file, and toggle back to the primary dialog box.

From the primary dialog box, click **[Continue]** to toggle to the second menu level entitled "Hull Bottom Structure Utility."

The Hull Bottom Structure Utility is used to construct the following primary structure: the centerline (keel) assembly, the inner bottom assembly, the outer bottom assembly, the webs/frames & longitudinals, and the floors/frames. It is divided into three menu subdivisions, **//Centerline Structure//**, **//Longitudinal Structure//**, and **//Transverse Structure//**, each of which is discussed separately in the following sections.

The primary structure constructed within the Hull Bottom Structure Utility invokes the standard procedure described above for bottom-level data groups (see Bottom-level Data Groups), using the appropriate structural components dialog boxes. For on-line help related to any of the primary structural components in the Hull Bottom Structure Utility, choose **[Help]** from the primary dialog box of the specific component. Use the scroll bar to the right of the help dialog box to search the help text. Choose **[Exit]** to close the help dialog box and return to the Hull Bottom Structure Utility.

CENTERLINE STRUCTURE:

Choose **//Centerline Structure//** from the Hull Bottom Structure Utility menu bar to construct the centerline keel assembly.

The centerline structure structural components dialog box opens, shown in Figure 33. Three typical centerline keel types are pictured as options under **Keel Types:** in the row of primary structure icons. The choices are summarized below, and the user should refer to **Part II: DAMAGE Modeling Guide** for additional guidance:

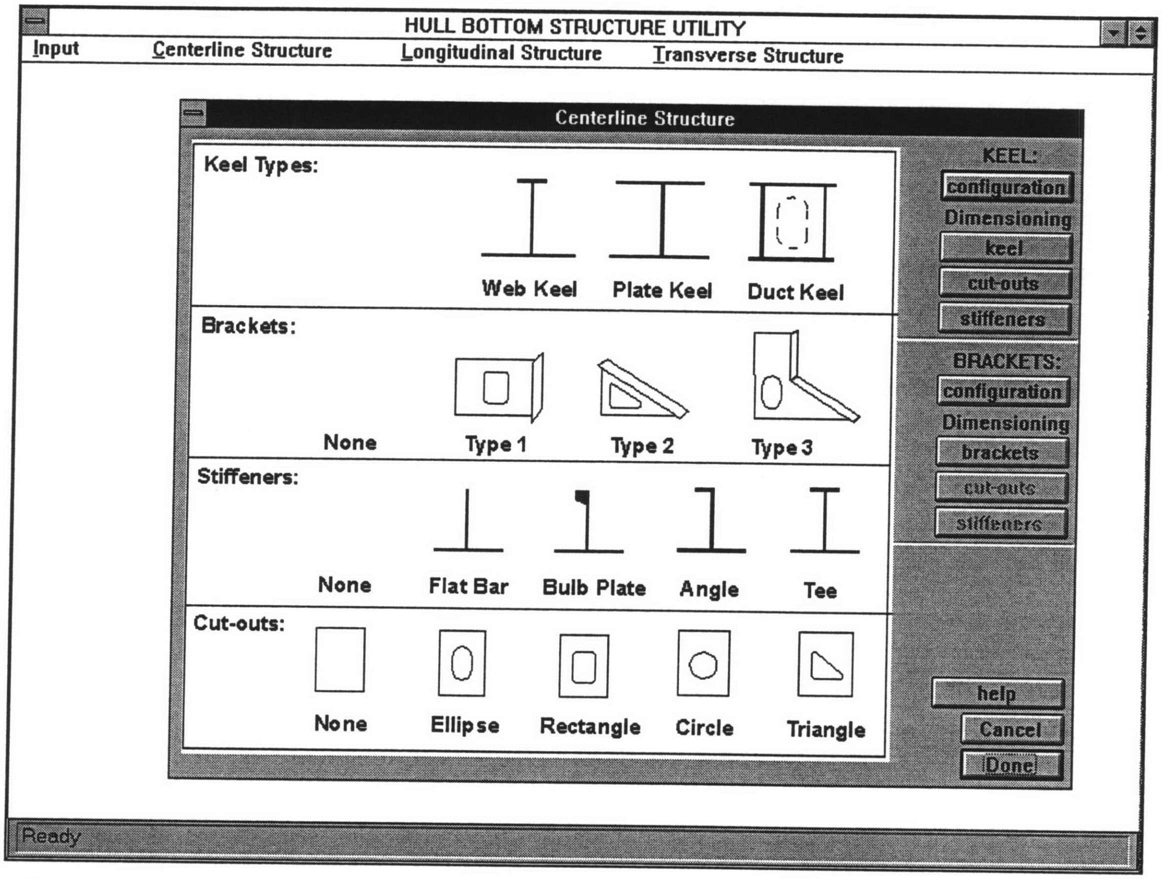


FIGURE 33. Structural components dialog box for centerline keel assemblies.

1. Web Keel

   This type of keel is permitted for single bottom construction only.

2. Plate Keel

   This type of keel is permitted for double bottom construction only.

3. Duct Keel

   This type of keel is permitted for double bottom construction only.

Choose **[configuration]** from the construction buttons under **KEEL:** to choose keel assembly configuration.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **//Centerline Structure//**.

LONGITUDINAL STRUCTURE:

Choose **//Longitudinal Structure//** from the Hull Bottom Structure Utility menu bar to construct the longitudinal bottom structure assemblies. The assemblies which comprise longitudinal hull bottom structure are: the inner bottom, the outer bottom, and the webs/frames & longitudinals.

For a tanker ship with longitudinal framing, define the inner bottom and outer bottom assembly using the data groups **/Inner Bottom/** and **/Outer Bottom** from the **//Longitudinal Structure//** pull-down menu.

Choose **/Inner Bottom/** from the **//Longitudinal Structure//** pull-down menu to construct the inner bottom plate-stiffener assembly, where an inner bottom has been fitted. The scantlings of any stiffeners defined using **//Longitudinal Structure// /Inner Bottom/** will be aligned in the longitudinal direction. Alternatively, the inner bottom can be defined using **//Transverse Structure// /Inner Bottom/**, and the scantlings will be aligned in the transverse direction. The identical value for inner bottom plating thickness, once entered under **//Longitudinal Structure//** or **//Transverse Structure//**, will appear under both headings.

The longitudinal structure - inner bottom structural components dialog box opens, shown in Figure 34. The typical inner bottom plate-stiffener assembly is pictured under **Inner Bottom Structure:** in the row for primary structure icons.

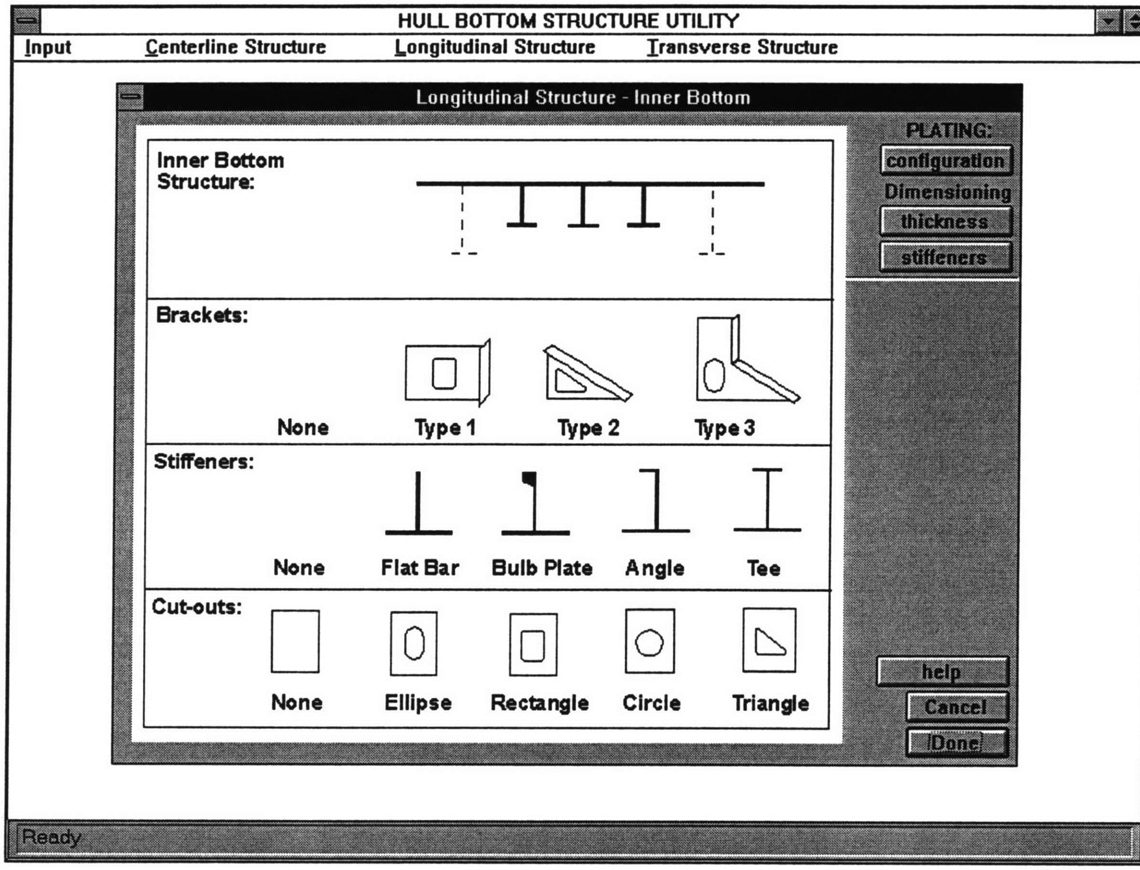


FIGURE 34. Structural components dialog box for inner bottom assembly.

Choose **[configuration]** from the construction buttons under **PLATING:** to configure the inner bottom plate-stiffener assembly. For **/Inner Bottom/**, the stiffener is the only type of modification that may be chosen. Brackets in the inner bottom are disabled. Brackets should be specified with the attached keel, webs, floors, or frames.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **/Inner Bottom/**.

Choose **/Webs/Frames/** from the pull-down menu of **//Longitudinal Structure//** in the Hull Bottom Structure Utility menu bar to construct the webs/frames or longitudinals.

The longitudinal structure - webs/frames structural components dialog box opens, shown in Figure 35. Two typical configurations for longitudinals fitted in way of the hull bottom are pictured as options under **Longitudinal Structure:** in the row of primary structure icons. The choices are summarized below, and the user should refer to **Part II: DAMAGE Modeling Guide** for additional guidance:

1. Webs

   The choice "Webs" applies to ships for which there is an inner bottom fitted, as shown by the icon. The webs are considered to be at regularly prescribed spacing between longitudinal bulkheads.

2. Webs/Frames or Longitudinals

   The choice "Webs/Frames or Longitudinals" applies to ships for which there is no inner bottom fitted, as shown by the icon. "Webs/Frames" describes hull bottom assembly for which secondary stiffeners are fitted to the outer bottom plating between the webs/frames. "Longitudinals" describes hull bottom assembly for which secondary stiffeners are not fitted to the outer bottom plating between the webs/frames. The webs/frames and longitudinals are considered to be at regularly prescribed spacing between longitudinal bulkheads.

Choose **[configuration]** from the construction buttons under **WEBS / FRAMES:** to choose the assembly configuration.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **/Webs/Frames/**.

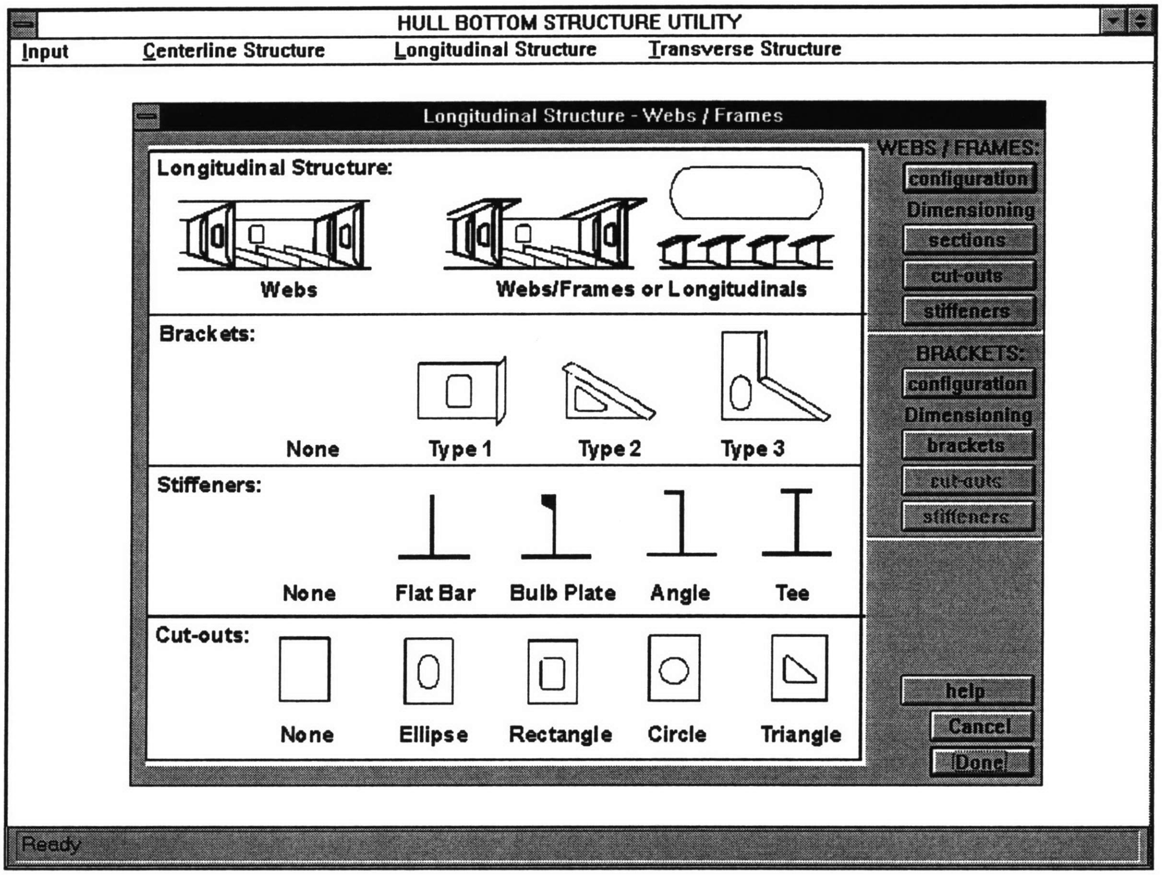


FIGURE 35. Structural components dialog box for webs/frames & longitudinals assemblies.

Choose **/Outer Bottom/** from the **//Longitudinal Structure//** pull-down menu to construct the outer bottom plate-stiffener assembly. The scantlings and stiffeners defined using **//Longitudinal Structure// /Outer Bottom/** are aligned in the longitudinal direction. Alternatively, the outer bottom can be created under **//Transverse Structure// Outer Bottom/**, and the scantlings are aligned in the transverse direction. The identical outer bottom plating thickness, once entered under **//Longitudinal Structure//** or **//Transverse Structure//**, will appear under both headings.

The longitudinal structure - outer bottom structural components dialog box opens, shown in Figure 36. The typical outer bottom plate-stiffener assembly is pictured under **Outer Bottom Structure:** in the row for primary structure icons.

Choose **[configuration]** from the construction buttons under **PLATING:** to configure the outer bottom plate-stiffener assembly.

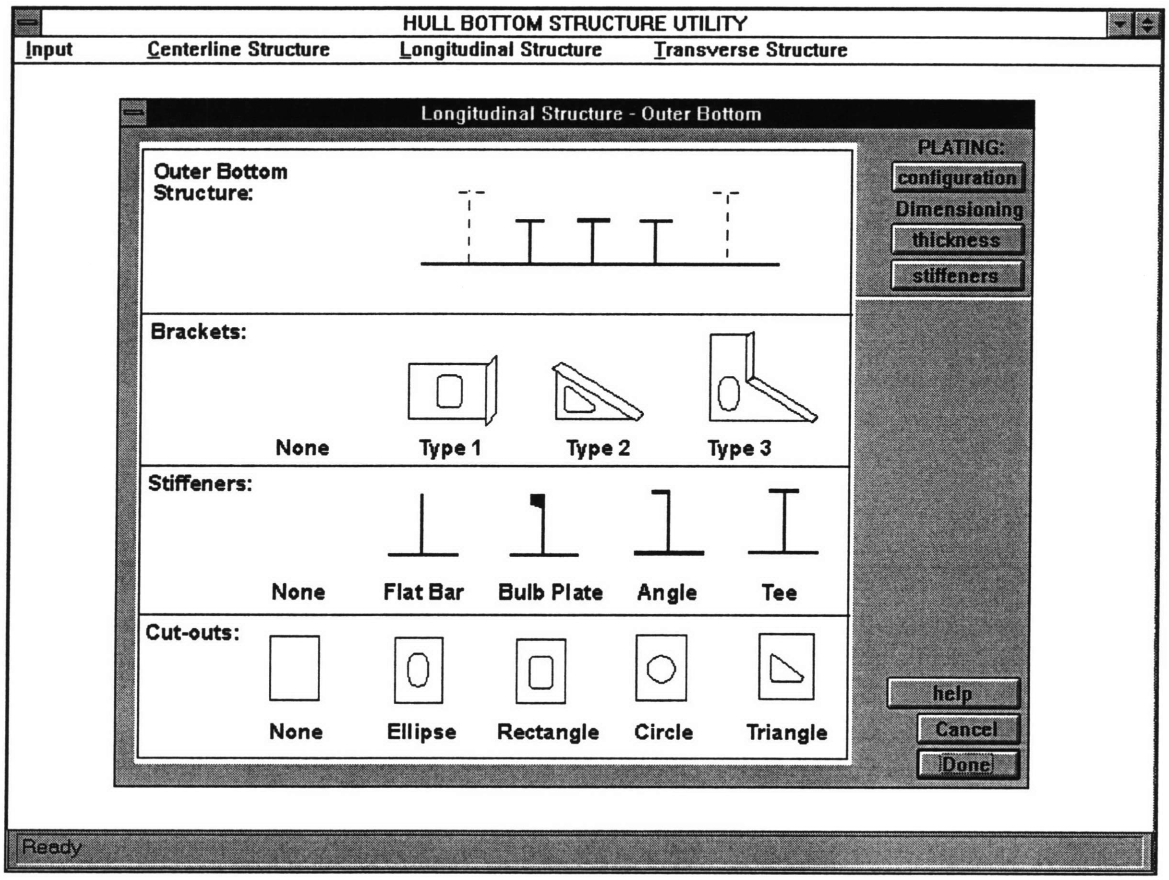


FIGURE 36. Structural components dialog box for outer bottom assembly.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **/Outer Bottom/**.

TRANSVERSE STRUCTURE:

Choose **//Transverse Structure//** from the Hull Bottom Structure Utility menu bar to construct the transverse bottom structure assemblies. The primary structures which comprise transverse hull bottom structure are: the inner bottom assembly, the outer bottom assembly, and the floors/frames.

For a tanker ship with transverse framing, define the inner bottom and outer bottom assembly using the data groups **/Inner Bottom/** and **/Outer Bottom/** from the **//Transverse Structure//** pull-down menu.

Choose **/Inner Bottom/** from the **//Transverse Structure//** pull-down menu to construct the inner bottom plate-stiffener assembly, where an inner bottom has been fitted. The stiffeners defined using **//Transverse Structure// /Inner Bottom/** will be aligned in the transverse direction. Alternatively, the inner bottom can be defined using **//Longitudinal Structure// /Inner Bottom/**, and the scantlings will be aligned in the longitudinal direction. The identical inner bottom plating thickness, once entered under **//Longitudinal Structure//** or **//Transverse Structure//**, will appear under both headings.

The transverse structure - inner bottom structural components dialog box opens similarly to the one shown for **//Longitudinal Structure// /Inner Bottom/**. The procedure for describing the inner bottom assembly using **//Transverse Structure// /Inner Bottom/** (for a ship with transverse framing) is similar to the one described above for **//Longitudinal Structure// /Inner Bottom/** (for a ship with longitudinal framing). The user is referred to the above discussion accompanying Figure 34.

Choose **/Floors/Frames/** from the Hull Bottom Structure Utility menu bar to construct the floors/frames assemblies.

The longitudinal structure - floors/frames structural components dialog box opens, shown in Figure 37. Two typical configurations for transverses fitted in way of the hull bottom are pictured as options under **Transverse Structure:** in the row of primary structure icons. The choices are summarized below, and the user should refer to **Part II: DAMAGE Modeling Guide** for additional guidance:

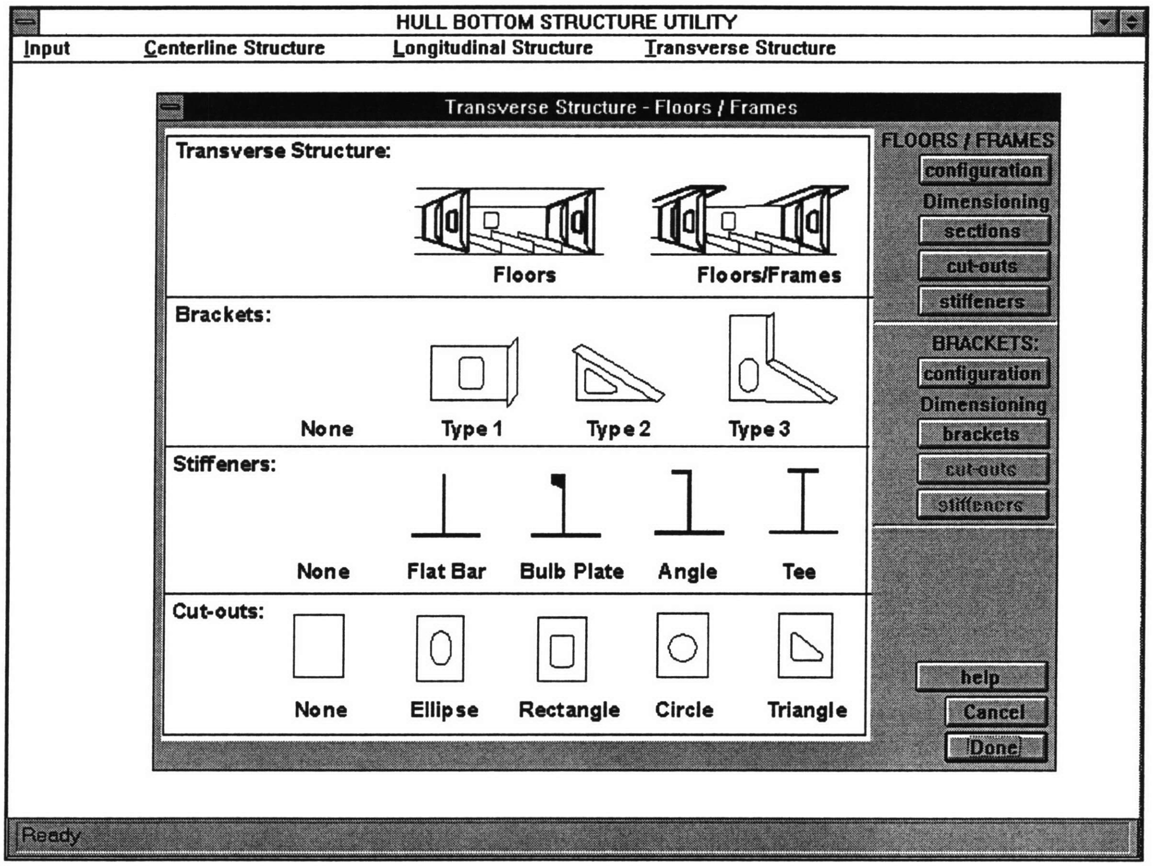


FIGURE 37. Structural components dialog box for floors/frames assemblies.

1. Floors

   The choice "Floors" applies to ships for which there is an inner bottom fitted, as shown by the icon; they are the transverse equivalent of the longitudinal primary structure, "Webs". The floors are considered to be at regular prescribed spacing between transverse bulkheads.

2. Floors/Frames

The choice "Floors/Frames" applies to ships for which there is no inner bottom fitted, as shown by the icon; they are the transverse equivalent of the longitudinal primary structure, "Webs/Frames". "Floors/Frames" describes hull bottom assembly for which secondary stiffeners may be fitted on the outer bottom plating between the floors/frames. The floors/frames are considered to be at regular prescribed spacing between transverse bulkheads.

Choose **[configuration]** from the construction buttons under **FLOORS / FRAMES:** to choose the assembly configuration.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **/Floors/Frames/**.

Choose **/Outer Bottom/** from the **//Transverse Structure//** pull-down menu to construct the outer bottom plate-stiffener assembly. The stiffeners defined using **//Transverse Structure// /Outer Bottom/** will be aligned in the transverse direction. Alternatively, the outer bottom can be created under **//Longitudinal Structure// Outer Bottom/**, and the stiffeners will be aligned in the longitudinal direction. The identical outer bottom plating thickness, once entered under **//Longitudinal Structure//** or **//Transverse Structure//**, will appear under both headings.

The <u>transverse structure - outer bottom</u> structural components dialog box opens. The procedure for describing the outer bottom assembly using **//Transverse Structure// /Outer Bottom/** (for a ship with transverse framing) is identical to the one described above for **/Longitudinal Structure/ //Outer Bottom//** (for a ship with longitudinal framing). The user is referred to the above discussion accompanying Figure 36.

When all of the specifications for the hull bottom structure assemblies have been properly described, chose **/Hull Bottom Structure/** from the **//Input//** pull-down menu in the Hull Bottom Structure Utility to return to the DAMAGE first menu level.

3.7 Bilge Structure

Choose **/Bilge Structure/** from the **//Input//** pull-down menu to characterize the shape of the bilge frames and to describe the configuration of the bilge area structure.

The <u>bilge frame type</u> primary dialog box, shown in Figure 38, displays four representative frame shapes which typify the main shape of the bilge structure through the length of the ship's cargo space. These four transverse frame shapes have been found to representative of most major oil tanker structures, and are currently the only bilge frame options analyzed in the Phase II version of DAMAGE.

To choose a frame type, click the **[Configuration]** button to toggle the secondary dialog box entitled "Bilge Frame Type", and select one of the radio buttons for the following frame types:

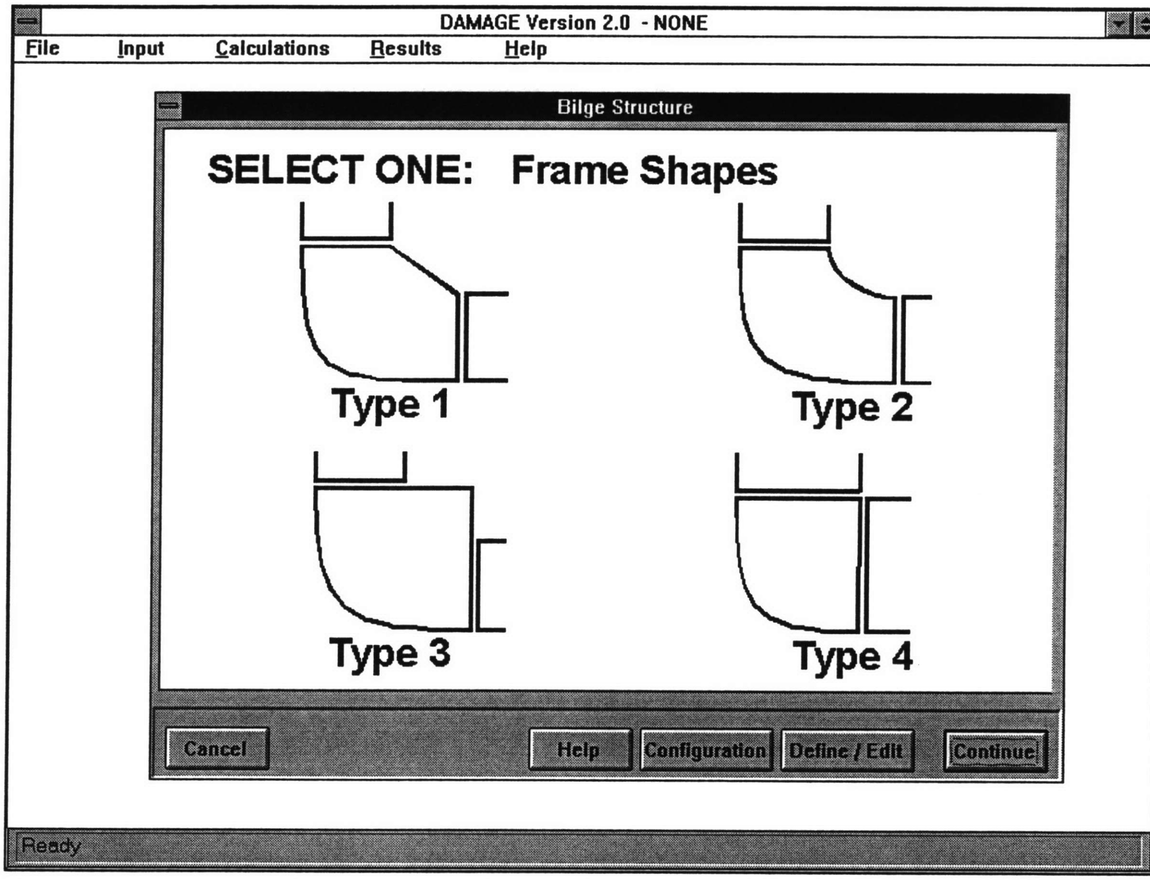


Figure 38. /Bilge/ primary dialog box at the first menu level.

1. Type 1

   This frame type is common in both single and double hull ships of conventional construction. The angled edges of the frames can join the frames/floors of the bottom structure and/or the frames of the side shell to form larger transverse deep frames. In double hull ships, these frames are connected to both the inner and outer plating.

2. Type 2

   This type is almost identical to Type 1, but the inside edge is curved, rather than straight.

3. Type 3

   This frame shape is used only in double hull ships, where a horizontal stringer and vertical girder combine with the inner side and inner bottom to form an enclosed volume which runs most of the length of the ship.

4. Type 4

   This bilge frame shape results when a side frame is allowed to join a bottom floor without interruption

When the frame type has been chosen, select the **[Apply]** button to confirm the data, close the secondary dialog box, and return to the primary display.

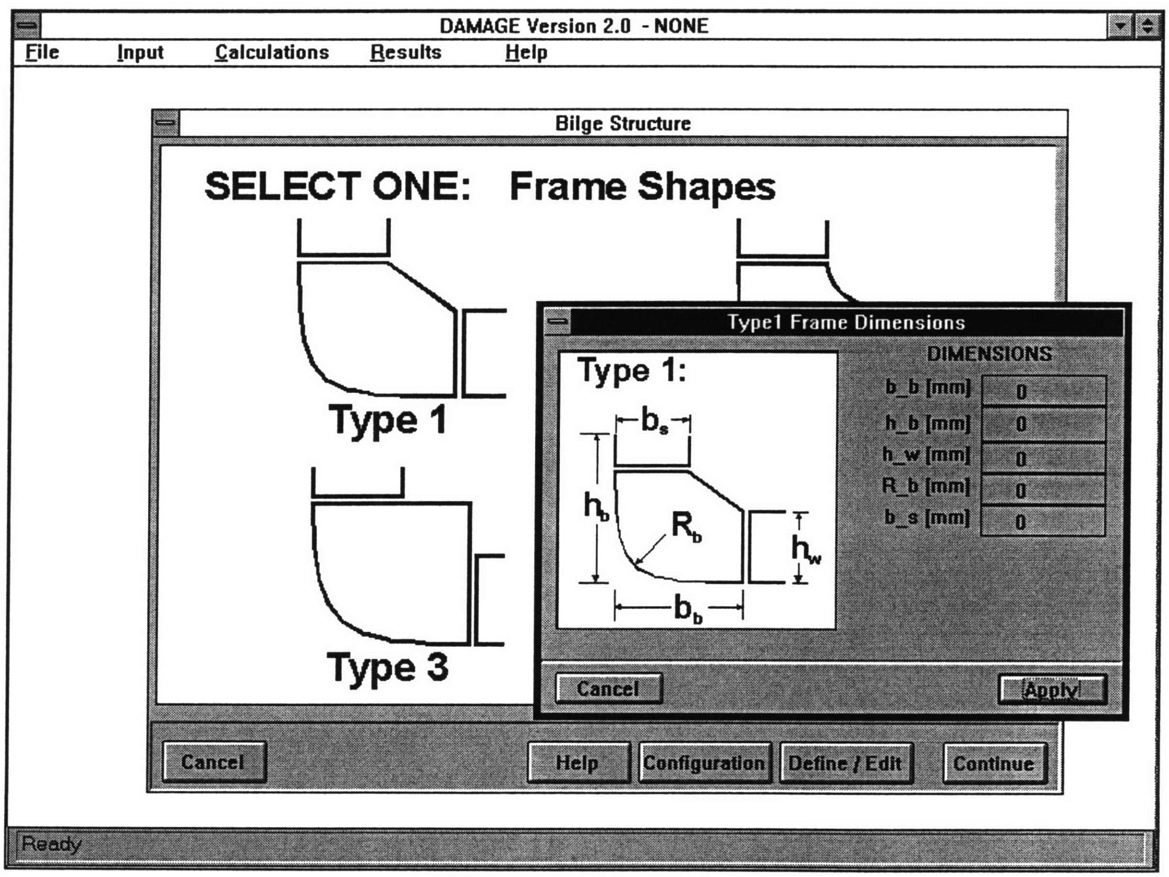


Figure 39. Secondary dialog box used to dimension the bilge area.

Click **[Define/Edit]** to enter the general dimensions for the deep frames in the bilge. A secondary dialog box, Typical frame dimensions, appears as shown in Figure 39. The user is referred to Part II: Modeling Guide for explicit definitions of each parameter.

It must be noted that the damage area for Phase II of DAMAGE includes not only the hull bottom in way of the cargo tanks, but also the entire bilge structure bounding the cargo tanks. The bilge area may extend in height from the baseline to the top of the hull bottom framing assemblies, or higher, to a point above which the angles and curves of the bilge structure give way to the straight plates and frames of the sideshell and decking. This definition of the damage zone leads to a very flexible interpretation of the vertical limits of both bilge area and sideshell; it is intended that the user be able to build greater detail into the bilge than would be possible with a strict height rule. Nevertheless, some limit must be imposed to reduce the complexity of the calculation procedure in DAMAGE: a maximum bilge height of three (3) times the depth of the bottom frames or inner bottom is enforced, and should allow sufficient flexibility.

In the primary dialog box, select **[Continue]** to toggle to the second menu level of the Bilge Utility.

Within the Bilge Utility, the menu is divided into two sections: **//Longitudinal Structure//** and **//Transverse Structure//**. **//Longitudinal Structure//** allows the definition of girders and stringers, as well as the exterior and interior bilge plating. The **//Transverse Structure//** section is where the frame details, such as plate thickness, flange size and spacing, can be entered.

The primary structures constructed within the Bilge Utility invoke the standard procedure previously described for the bottom-level data groups, using the appropriate structural components dialog boxes. For on-line help related to a primary structure in the Bilge Utility, choose **[Help]** from the primary dialog box. Use the scroll bar to the right of the help dialog box search the help text. Choose **[Exit]** to close the help box and return to the structural components dialog box. The user is also referred to the User's Manual and Modelling Guide for assistance with DAMAGE.

LONGITUDINAL STRUCTURE:

Choose **//Longitudinal Structure//** to construct the girders and stringers; for a longitudinally framed ship, the exterior and interior bilge plating is also defined here.

Click the data group **/girder/** from the **//Longitudinal Structure//** pull down menu to construct the girder that marks the inboard edge of the bilge area, where a bilge girder has been fitted.

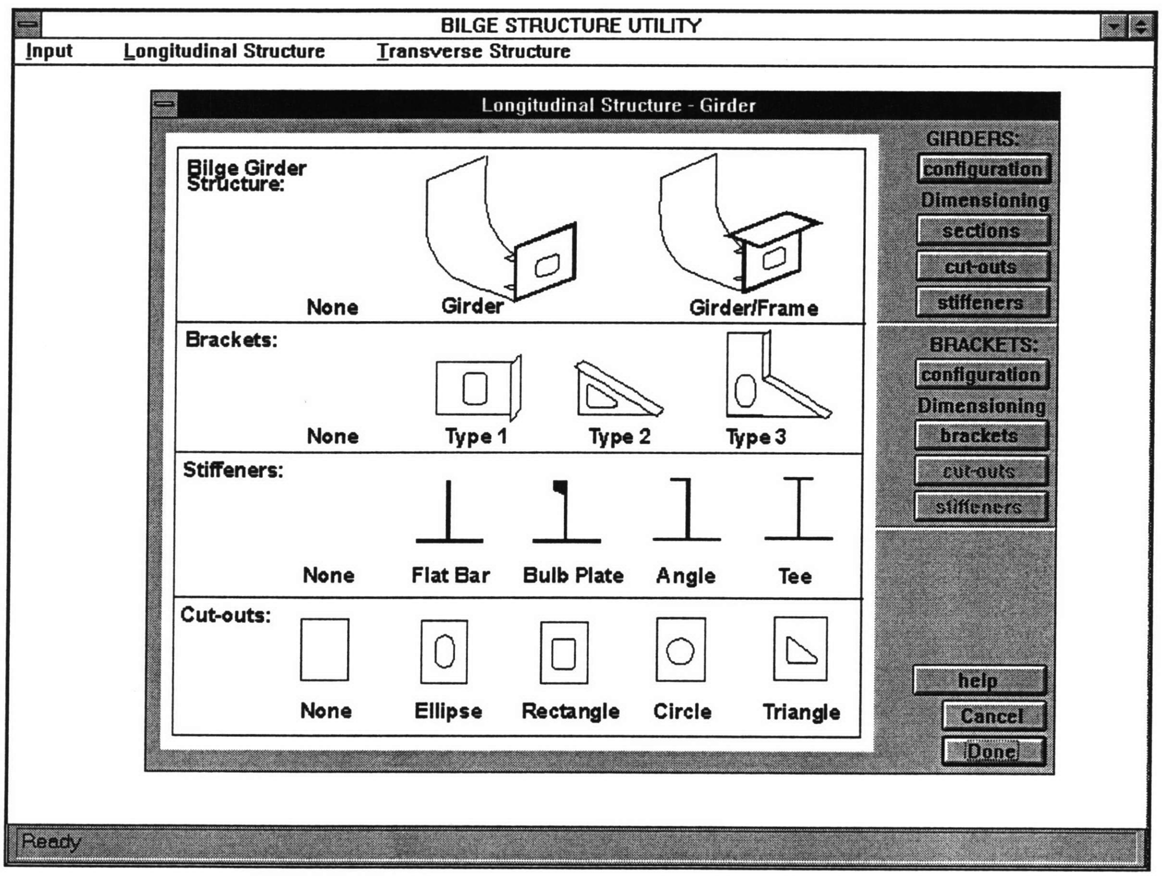


Figure 40. Structural components dialog box for girder assembly.

The longitudinal structure- girder primary dialog box opens, as depicted in Figure 40. Two sketches of standard girders are shown in the top left section of the box: the first, labeled "girder" is typical for double hull ships, while the second, flanged option, labeled "girder/frame", might be found in a single hull ship. Choose **[configuration]** from the construction buttons under **GIRDER:** to select the appropriate girder type and configuration.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **/Girder/**.

Choose **/Stringer/** under the **//Longitudinal Structure//** pull-down menu to invoke the primary dialog box labeled "longitudinal structure- stringers", under which two different stringer arrangements are offered. (See Figure 41) Typically, there is a stringer at the top of the bilge area, demarcating the upper end of the bilge and the lower edge of the side shell; however, it is not uncommon to place an additional stringer within the bilge area, at the level of bottom framing assembly. Thus the user may specify none, one, or two stringers in the bilge.

Choose **[configuration]** under **STRINGERS:** to select the number of stringers and their configuration. The user may refer to **Part II: DAMAGE Modeling Guide** for further details.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **/Stringer/**.

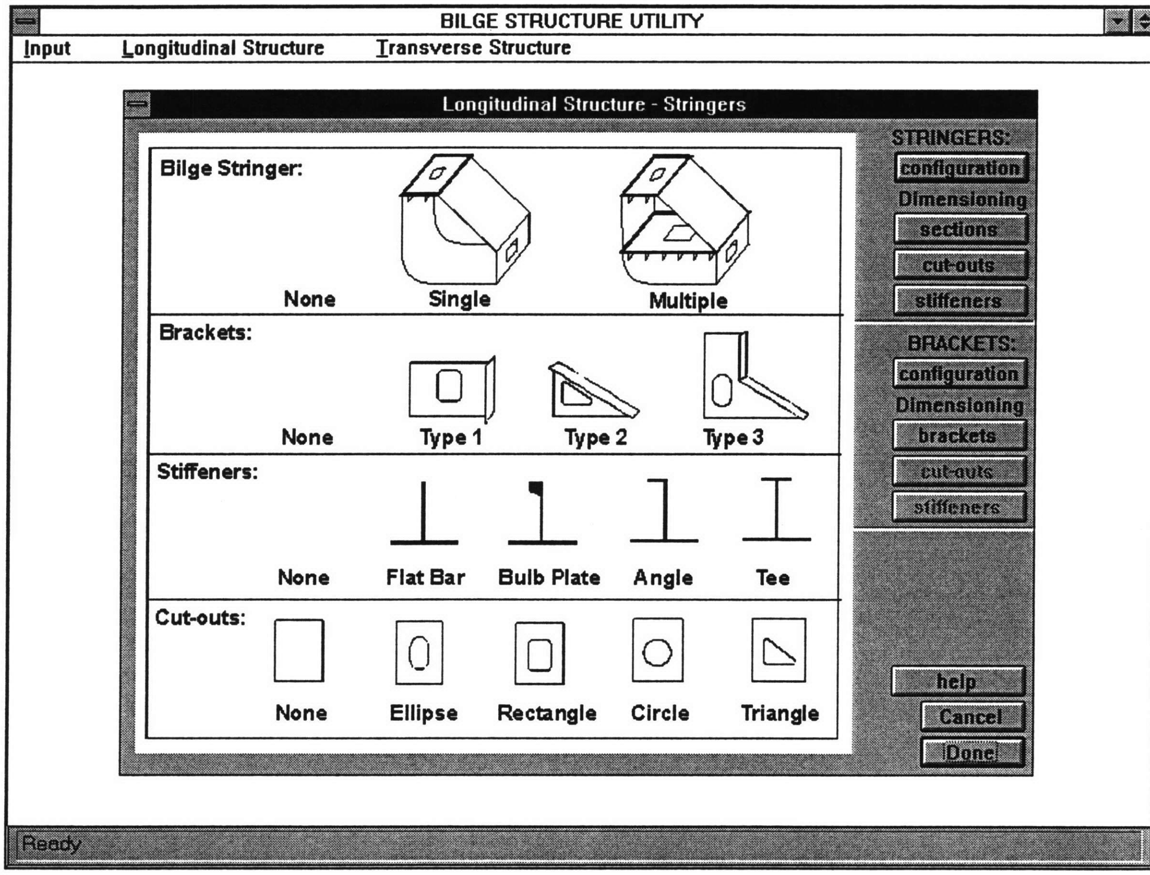


Figure 41. Structural components dialog box for stringer assembly.

The last two data groups under **//Longitudinal Structure//** are **/outer bilge/** and **/inner bilge/**. These options are appropriate for longitudinally framed ships, since the stiffeners will be aligned with the plating in the longitudinal direction. However, if transverse framing is dominant in the bilge area, then the plating should be constructed under the **//Transverse Structure//** section of the Bilge Utility, where the stiffeners will be arranged in the transverse direction.

Choose **/inner bilge/** from the **//Longitudinal Structure//** pull-down menu if the bilge area is enclosed into a separate volume from the cargo space. It is fairly common in double hull ships for the bilge volume to form the leg of L-shaped ballast tanks; the interior plating of the bilge comprises part of the tank walls. The plate thickness entered here for the interior of the bilge will appear identically under the **//Transverse Structure//**, **/Inner Bilge/** portion of the Bilge Utility.

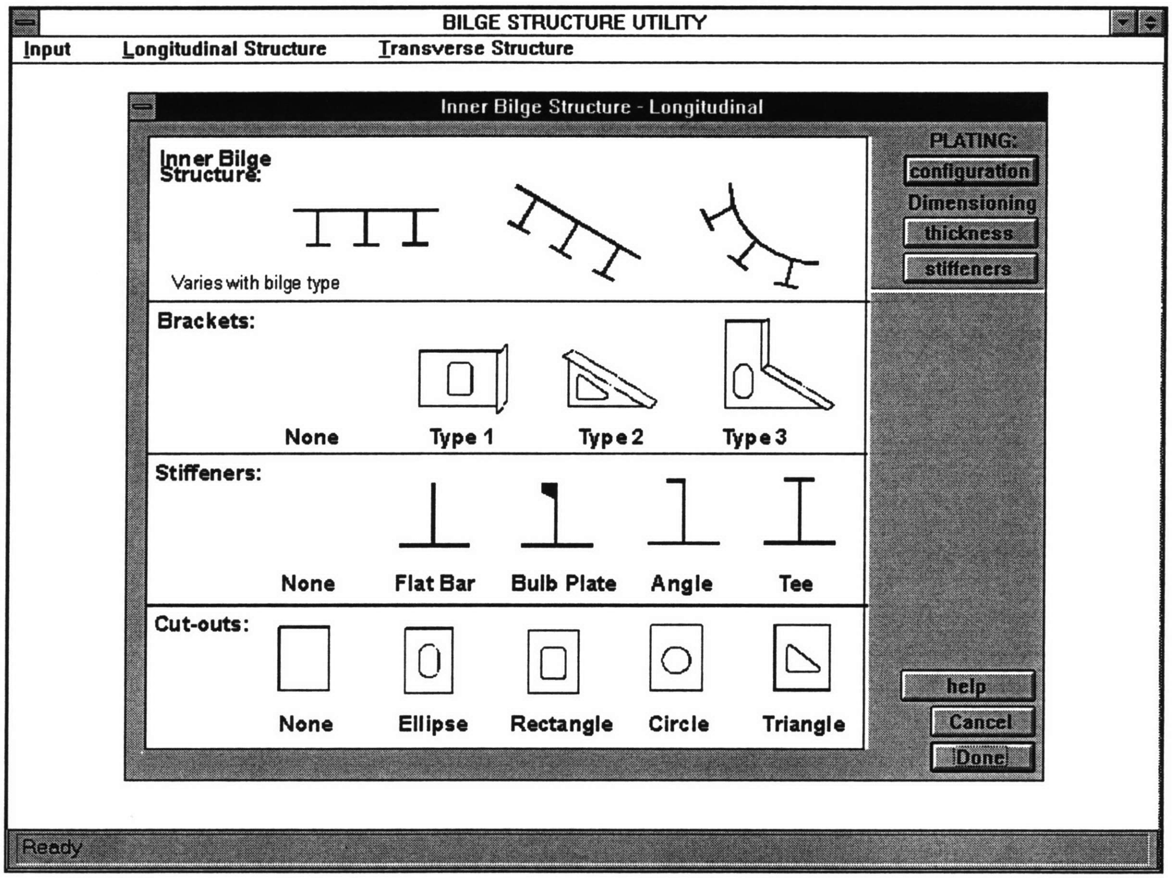


Figure 42. Structural components dialog box for inner bilge assembly.

The longitudinal structure - inner bilge structural components dialog box opens, as shown in Figure 42. In the primary icons row, there are several sketches of typical inner bilge assemblies under **Inner Bilge Structure:**.

Following the procedure discussed above for applying dimensions to bottom-level data group structure using the structural components dialog box, complete the data for **/Inner Bilge/**.

The user should note that interior bilge plating is only applicable to Bilge Frame Types 1 and 2, since, for a double hull ship, the inner plating of a Type 3 bilge is replaced by a girder and a stringer, and Type 4 bilges are bounded internally by the sideshell and the inner bottom.

Choose **/Outer Bilge/** from the **//Longitudinal Structure//** pull-down menu to construct the outer bilge assembly for longitudinally framed ships. If the ship is transversely framed through the bilge, the outer bilge plate-stiffener assembly should instead be described under **//Transverse Structure//**. The plate thickness entered under **[configuration]**, **PLATING:**, will appear identically under the **//Transverse Structure// /outer bilge/**.

The longitudinal structure - outer bilge primary dialog box, shown in Figure 43, displays a sketch of a typical outer bilge assembly. Choose **[configuration]** from the buttons under **PLATING:** to configure the outer bilge.

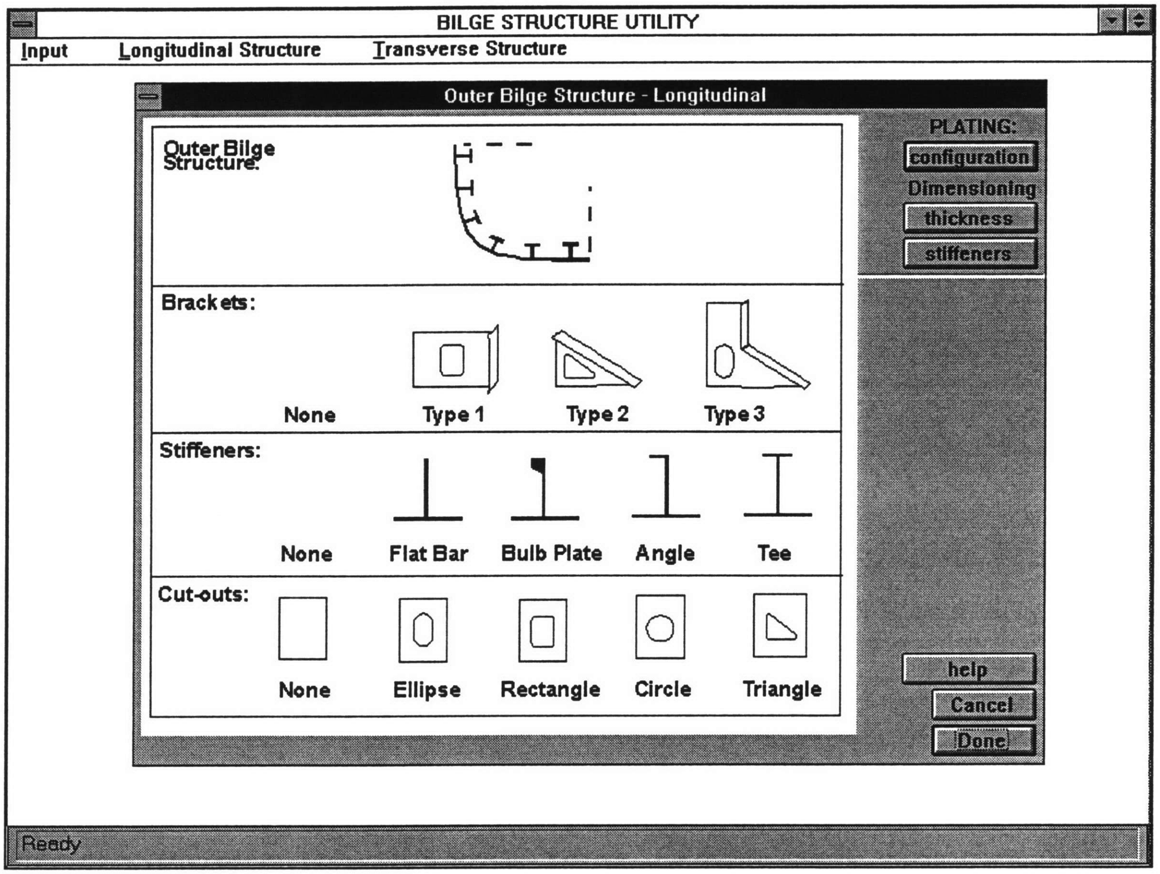


Figure 43. Structural components dialog box for longitudinal outer bottom assembly.

TRANSVERSE STRUCTURE:

Choose **//Transverse Structure//** from the menu of the Bilge Utility to build the transverse inner bilge, outer bilge, and bilge frame structure.

Select **/Frames/** from the pull-down menu under **//Transverse Structure//** to configure the frames. Although the bilge frame type and the general dimensions of the bilge area were described under **/Bilge Frame/**, the specifics of the frame structure are entered separately, where the user can differentiate between single and double hulled ships.

The Transverse Structure- Bilge Frames primary dialog box, shown in Figure 44, displays two examples of typical bilge framing: the left sketch is representative of frames in double hull ships; the right sketch depicts single hull framing. The significant difference between these options is found in the boundary condition: the single hull frames are fixed to the hull on one side, but free on the other, while the double hull frames are doubly constrained by the outer and inner hulls. Despite the resemblance of these representative sketches to Type 1 bilge framing, the parameters defined in this area of DAMAGE are equally applicable to any of the frame shapes.

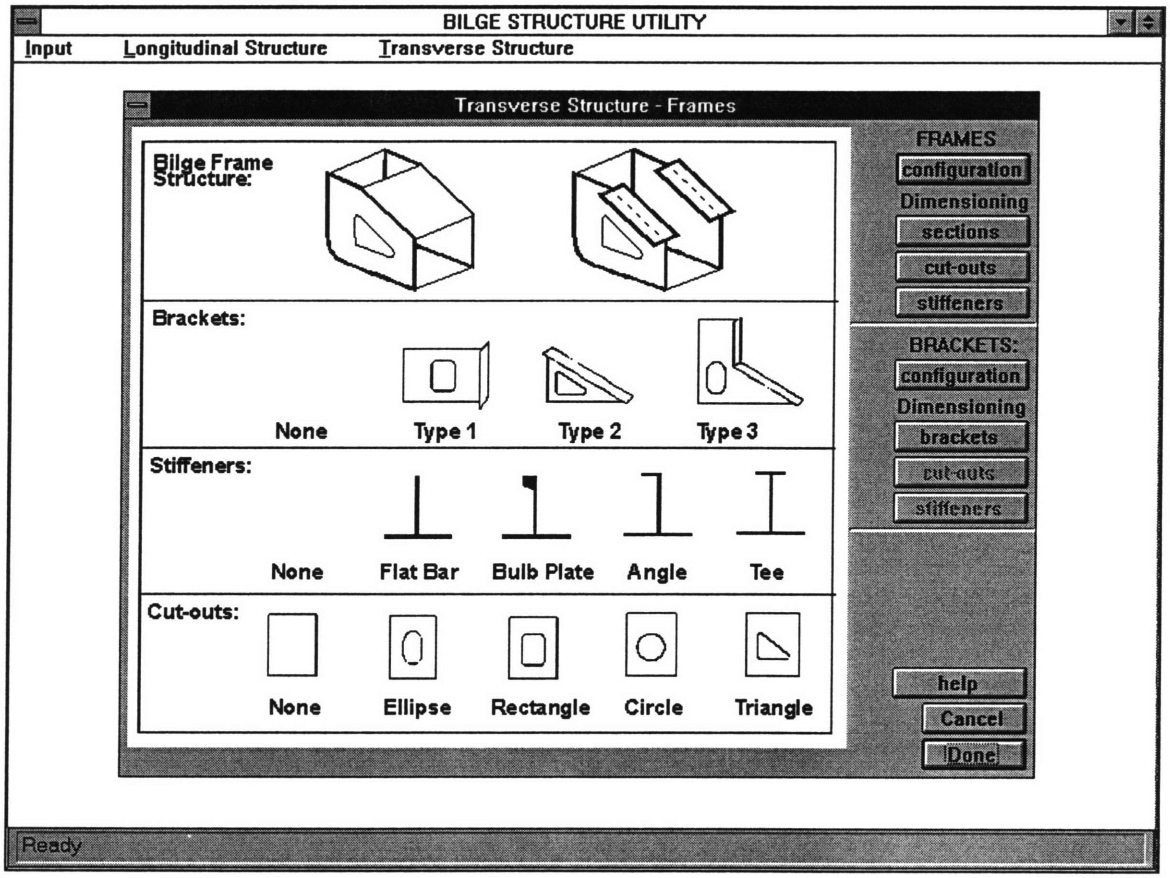


Figure 44. Structural components dialog box for bilge frames.

Select **[configuration]** under the **FRAMING:** heading to describe the frame configuration, and use the procedure discussed above to complete the data for **/Frames/**.

Choose **/Inner Bilge/** from the **//Transverse Structure//** pull-down menu to build the inner bilge assembly for transversely framed ships. The plating and stiffeners created will be aligned in the transverse direction; if the bilge is longitudinally framed, the inner bilge assembly should be constructed under **//Longitudinal Structure// /Inner Bilge/**. The plating thickness entered here for the inner bilge will appear identically under **//Longitudinal Structure// /Inner Bilge/**.

When the transverse structure - inner bilge structural components dialog box, shown in Figure 45, opens, it contains a picture of typical inner bilge configuration in the primary icon row under **Inner Bilge Structure:**. The procedure for defining the inner bilge assembly is very similar to the one described under **//Longitudinal Structure// /Inner Bilge/**, and illustrated by Figure 41.

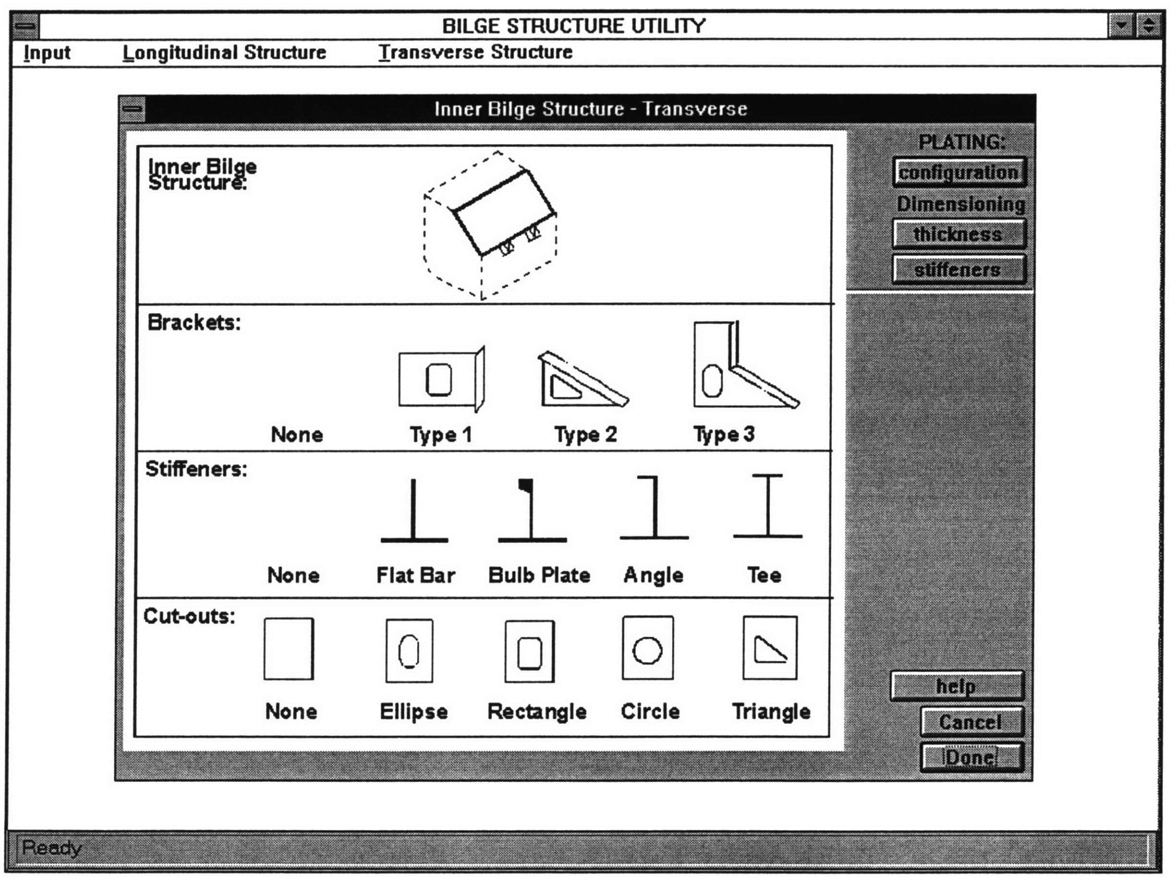


Figure 45. Structural components dialog box for transverse inner bilge assembly.

Choose **/Outer Bilge/** from the **//Transverse Structure//** pull-down menu to define the outer bilge plate-stiffener assembly. The plating and stiffeners created will be aligned in the transverse direction; if the bilge is longitudinally framed, the outer bilge assembly should be constructed under **//Longitudinal Structure// /Outer Bilge/**. The plating thickness entered here for the outer bilge will appear identically under **//Longitudinal Structure// /Outer Bilge/**.

Figure 46 shows the <u>transverse structure - outer bilge</u> primary dialog box. The procedure for the configuration of the outer bilge is identical to that described under **//Longitudinal Structure// /Outer Bilge/**. The user is guided to that discussion and to Figure 43 for instruction.

When the specifications of primary structure in the Bilge Utility have been completed, select **/Bilge Structure/** from the **//Input//** pull-down menu to return to the first menu level in DAMAGE.

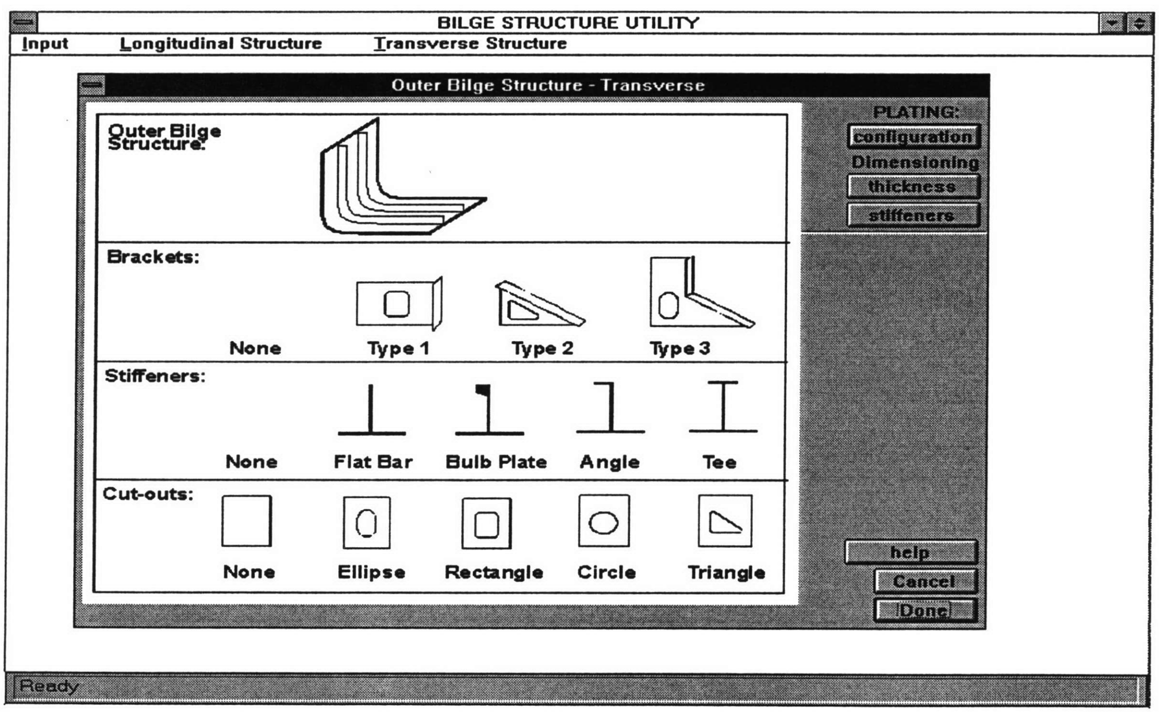


Figure 46. Structural components dialog box for transverse outer bilge assembly.

3.8 Input Summary

By choosing **/Input Summary/** from the **//Input//** pull-down menu, the user can view a running summary of completed input data. The summary is displayed via the notepad feature of Windows, and can be printed to an ASCII text file. (See Chapter 7 Printing.) A sample **/Input Summary/** dialog box follows:

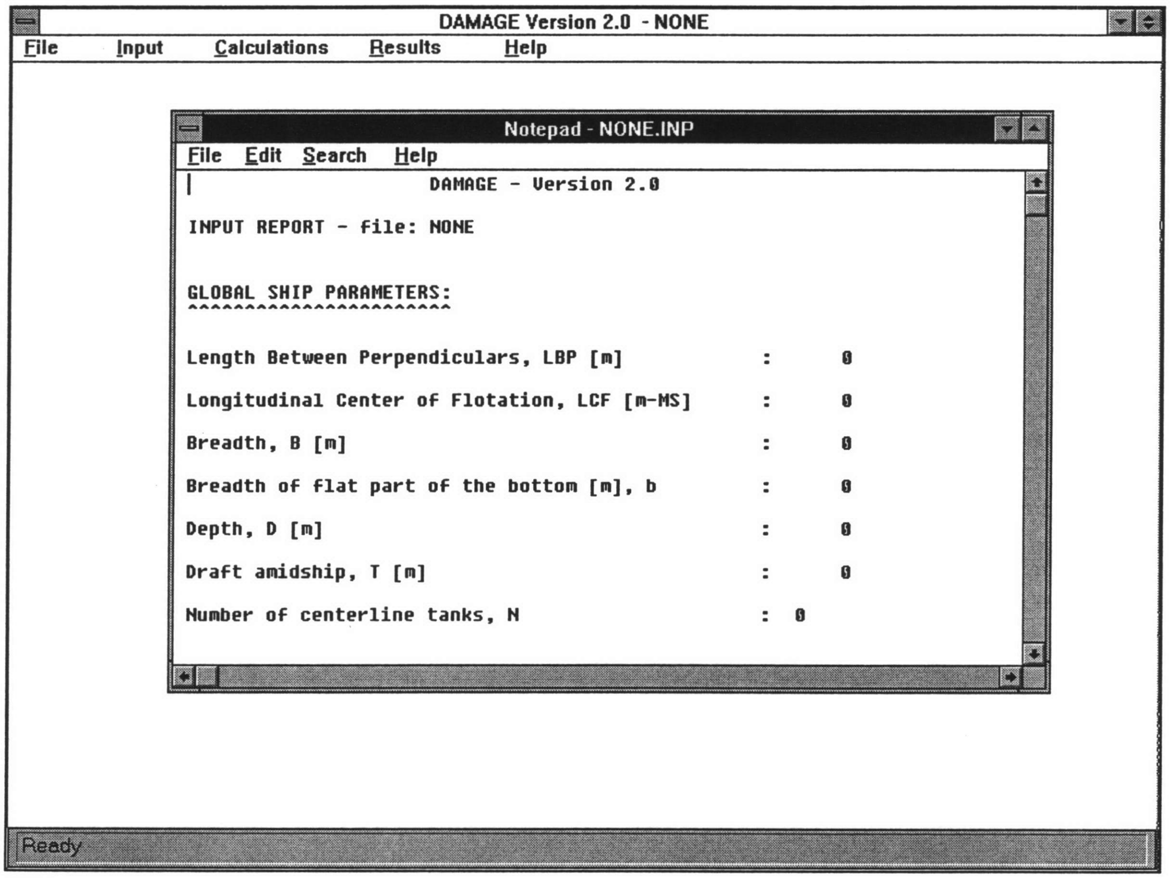


FIGURE 47. Sample **/Input Summary/**.

Chapter 4 - Editing an Input File

Chapter 4 describes how modifications to existing input files should be made.

Each of the seven data groups are stored as separate modules in the the DAMAGE preprocessor. Thus each input file can be created or edited in random order, as long as the material files are current and available before structural data is entered. The number of parameters required for a successful input file is so enormous, however, that the user is encouraged to follow the procedure outlined in Chapter 3- Building an Input File, step by step, so that crucial information is not missed.

Unless the user is intimately familiar with all of the input parameters required for analysis by the DAMAGE calculations processor, the user is strongly encouraged to follow the procedure described in Chapter 3 - Building an Input File.

When the modifications are complete, and the user is confident that the new data are correct, save the input file, using either the same file name if the old file is being replaced, or under a new file name, if the old input file is being retained.

Chapter 5 - Calculations

Chapter 5 describes the link between the DAMAGE input file and the calculations module. The two analysis options in the calculations module are discussed.

When the completed input file is sent to the DAMAGE calculations module to be evaluated, the user can choose to generate either a coupled or an uncoupled analysis. The damage prediction delivered by coupled calculations considers the interaction between the ground and the ship responding in four degrees of freedom (surge, pitch, roll, heave). Uncoupled calculations neglect the effect of every ship motion, except surge, on the grounding damage.

The model sent to the calculations module is a virtual ship assembled from the data entered by the user. The virtual ship is a periodic, simplified representation of the actual vessel, and is composed of the Superfolding and Supertearing elements which form the foundation of the theoretically derived and experimentally validated equations in DAMAGE. (The user is referred to the DAMAGE Theoretical Manual for extensive discussion of the equations used in the analysis.)

Choose **/Coupled/** from the **//Calculations//** pull-down menu to calculate damage to the vessel by the ground when coupled with global ship motions. The effect of coupling the grounding event with these global ship motions will, in general, reduce ground penetration into the hull structure due to vertical lift applied to the ship by the force of contact with the ground. As discussed in 3.3 Ground Characterization, the remaining global ship motions, sway and yaw, are irrelevant to the grounding events for which DAMAGE Phase II is applicable.

Choose **/Uncoupled/** from the **//Calculations//** pull-down menu to calculate damage to the vessel by the ground when all global ship motions except for surge are neglected. The uncoupled grounding damage assessment will, in general, predict more severe damage incurred to the hull bottom structure without the potentially mitigating effect of vertical lift of the ship by the ground.

Comparison of both analyses will delineate the impact of ship motions on the prediction of grounding damage to the hull structure.

Chapter 6 - Results

Chapter 6 summarizes the results delivered by DAMAGE Phase II and the formats available for presenting these results.

In Phase II of the Joint MIT-Tanker Safety Project, DAMAGE was expanded to include the turn of the bilge within the target damage area. Accordingly, curved plates are considered in the analysis, and the results display the effects of the grounding event on both the flat plating of the hull bottom and the curved plating of the bilge.

Choose //**Results**// from the menu bar to retrieve DAMAGE results. The commands under the //**Results**// pull-down menu enable the user to access the numerical results and view them through an ASCII text file, a large variety of graphing options, and the animation feature. (Note: results are not available until the calculations have been completed.)

Certain graphs of DAMAGE results are displayed automatically upon completion of the calculations: vertical penetration vs location, dissipation vs location, transverse damage vs location, and kinetic energy vs location. These four graphs are the most immediately significant results to the designer, builder, classifier, or operator, since they make clear the extent of damage incurred by the grounding and the energy characteristics of the ship-ground system during the grounding event.

To create other graphs, choose **/Graph Utility/** from the **//Results//** pull-down menu. The Graph Configuration dialog box appears, Figure 48, with 15 different variables listed as options for either the X- or Y- axes. Select a variable for each axis, and click **[Apply]** to view the graph. The options listed enable the user to quickly and easily observe any correlations (or lack thereof) between the chosen variables.

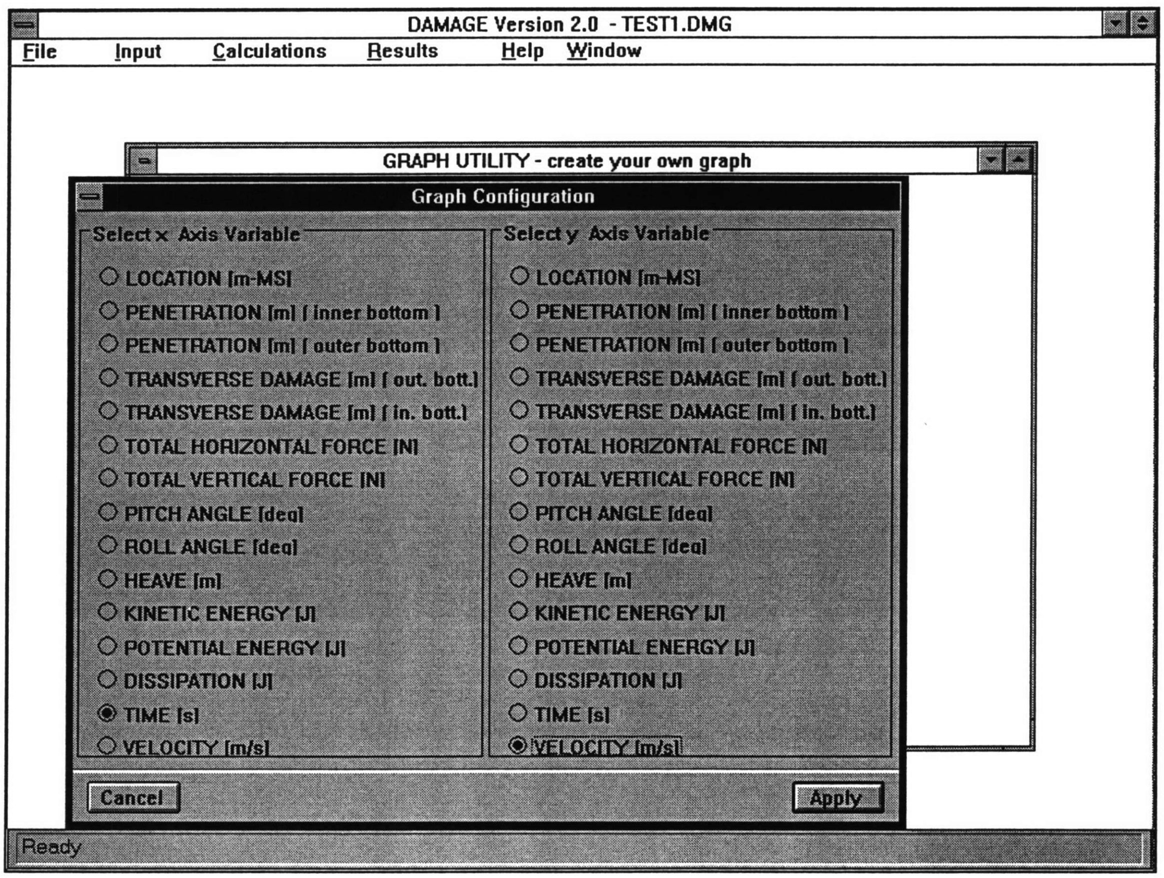


Figure 48. Graph Utility dialog box.

Any of the graphs created in the Graph Utility can be custom configured by the user. Double click the graph to invoke the configuration dialong box, Figure 49. Both of the axes can be scaled using the top two rows of entry fields, and major and minor intervals can be specified.

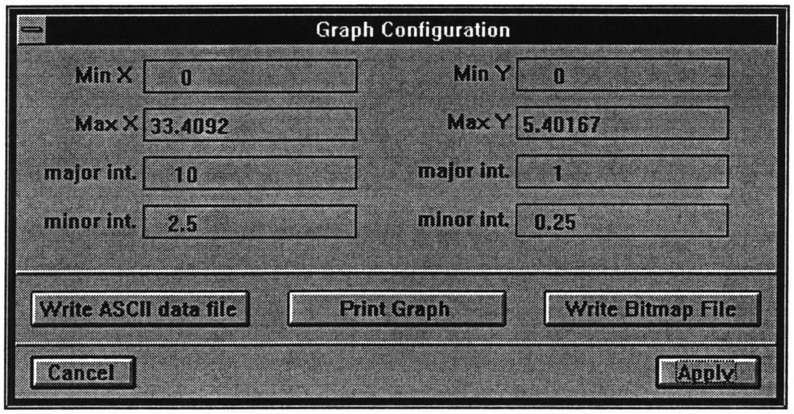


Figure 49. Graph Configuration dialog box.

The graph data can be exported from DAMAGE in three different ways. Click **[Write ASCII data file]** to export the raw data of a graph to a text file. This file can be used for further processing and can be printed at the later convenience of the user. **[Print Graph]** sends the graph to the default printer to provide visual documentation of the results. **[Write Bitmap File]** creates a Windows bitmap file of the graph which can be imported into other applications. Exit the Graph Configuration dialog box by clicking **[Apply]**.

Graphs can be displayed in DAMAGE individually or in groups. From the **//Results//** pull-down menu, choose **/Open All/** to display the four default graphs. If a custom graph has been created, it can be viewed simultaneously with the existing four plots. Under **//Window//**, choose **/Cascade/** from the pull-down menu. All five plots will appear, and can be moved and sized using standard Windows techniques. Only one custom graph can be viewed at a time within DAMAGE.

An animation module was added to DAMAGE to allow the user to view the grounding event as it occurs to the virtual ship. The animation can be viewed from start to finish, continuously or frame by frame. The magnitudes of the ship motions, velocity, and rock penetration are all displayed with the animation, and vary with time. Click **[Exit]** to return to the main menu level.

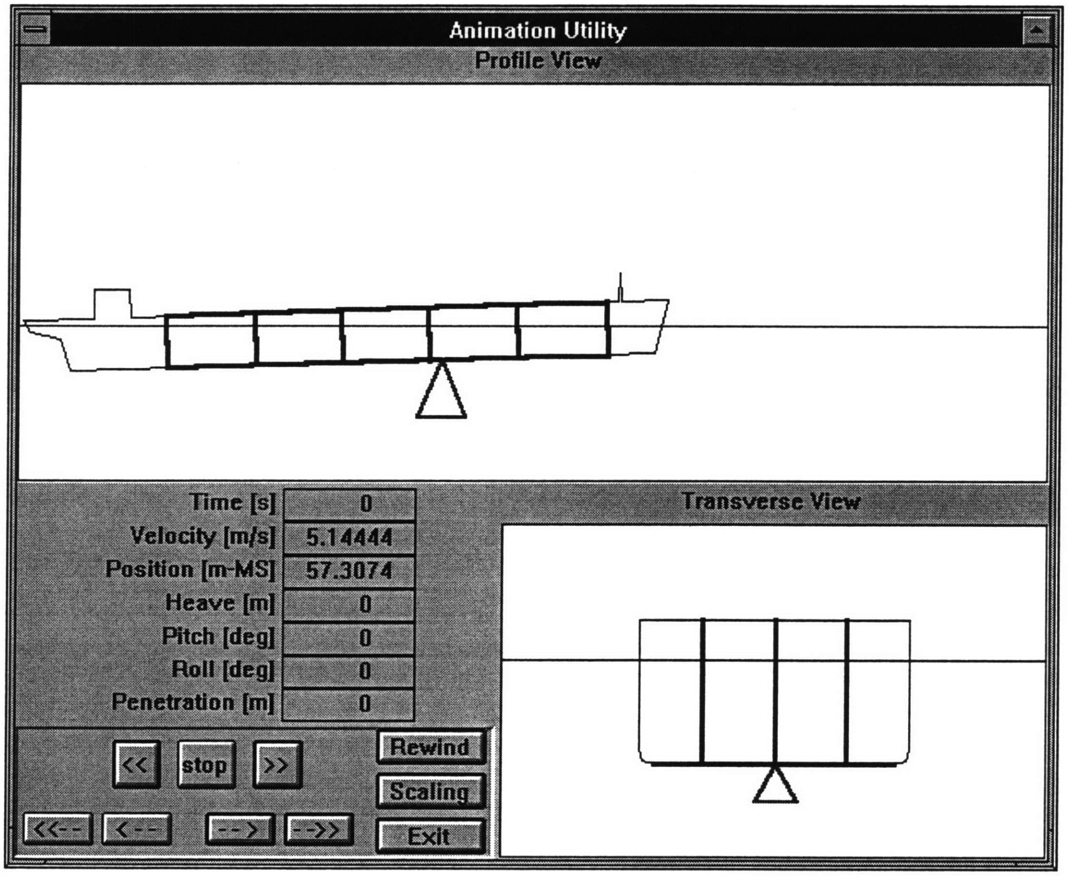


Figure 50. Animation Utility dialog box.

The results files are stored in the subdirectory **\damage\results**. These are temporary files that will be deleted and written over with new data during the next session of calculations. New names must be assigned to all results files that the user wishes to save prior to executing the next session of calculations. The temporary files can be renamed using a file managing application outside of DAMAGE.

A summary of the results in automatically created, similarly to the Input Summary. Choose /**Results Summary**/ to view the ASCII text file in the notepad application.

Chapter 7 - Printing

Chapter 7 discusses printing options available for DAMAGE Results.

The data contained in each DAMAGE case file may be printed using the Report commands under the //**File**// pull-down menu. Use /**Full Report**/ to print all of the considerable data generated by DAMAGE, or /**Short Report**/ for a listing of the key results.

Alternatively, data can be printed to a default printer and/or exported to ASCII text files for further processing, as mentioned in Chapter 3- Building an Input File, and Chapter 6- Results. Results graphs can be printed using the **[Print Graph]** button in the graph configuration dialog box, as discussed in Chapter 6.

The input (*.inp), results (*.res), and graph (*.tmp) files are stored in the subdirectory **\damage\results**. These are temporary files that will be deleted and written over with new data during the next session of calculations. New names must be assigned to all files that the user wishes to save prior to executing the next session of calculations. The temporary files can be renamed using a file managing application outside of DAMAGE.

Chapter 8 - Help

Chapter 8 describes Help available on-line in DAMAGE.

User's information is available on-line in DAMAGE.

Help related to input is available through a **[Help]** key in all first and second menu level primary dialog boxes. Help related to output is available through the **<F1>** access key from any active graph dialog box opened from **//Results//** or the **/Graph Utility/**.

In all cases, a separate Help dialog box is opened. The information contained in the Help text that is accessed is keyed to the input data group or results graph dialog box from which Help is opened. DAMAGE on-line Help has been made context-specific in this way for the quickest access to information related to the current activity.

The user may scroll the Help text using the up and down arrows along the right side of the Help dialog box. Click on **[Exit]** to close the Help text and return to the window from which Help was accessed.

DAMAGE on-line Help is intended only to provide brief explanations, guidance, cautions, and instructions related to commonly-asked questions. The Help text is condensed from the DAMAGE User's Manual. The user is encouraged to use on-line Help while running a DAMAGE session and, for additional information, the user is referred to the DAMAGE User's Manual. See also **//Help// /Release Notes/** for other helpful comments supplemental to DAMAGE User's Manual.

Part II:

DAMAGE Modeling Guide

Chapter 1 - Ship Structure

Chapter 1 is a catalog of the primary structure and the components from which the primary structure are constructed in DAMAGE.

The ship structure in this catalog is subdivided into primary structure and components from which the primary structures are constructed. Primary structure are discretized for analysis into Superfolding and Supertearing Elements developed for the Joint MIT-Industry Tanker Safety Project. Components are smeared into effective thicknesses along the lengths of associated primary structure.

The catalog is a modeling guide providing information on how to apply dimensions and construct the primary structure using the basic components. The catalog is intended for use in conjunction with Part I: DAMAGE User's Manual, Chapter 3 - Building an Input File.

Each primary structure and component has its own entry in the catalog.

Primary Structure

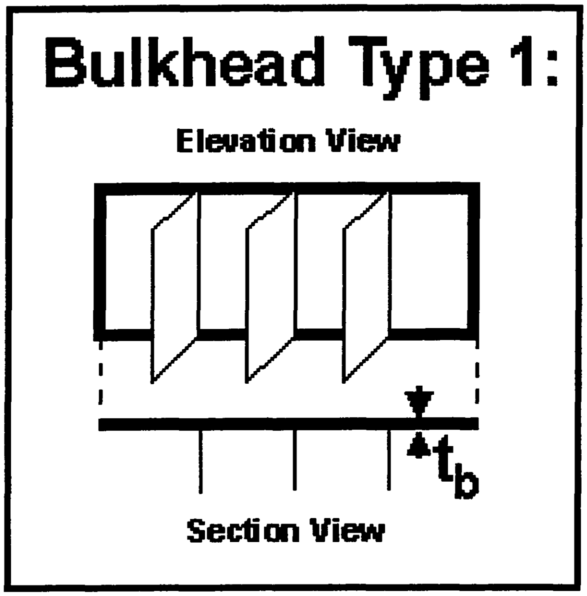
1.1 Bulkheads

The target damage area defines the region within which the ground may navigate and damage ship structure during the grounding event. The target damage area for DAMAGE Phase I is the hull bottom structure in the cargo tank region plus the bulkhead structure adjacent to the outer bottom or tank top.

It has been shown and is assumed that the height of damage penetration into the bulkhead region defines an upper limit to the target damage area that does not extend beyond the first strake of bulkhead. The first strake of bulkhead is defined to include that height of bulkhead structure within which bulkhead dimensions can be taken to be constant. This is the first strake of structure before there are reductions in plating thickness with bulkhead height.

Some options are enabled in the bulkhead **[configuration]** dialog box to allow for variations from typical construction. The stiffener and bracket options used for configuring bulkheads vary with bulkhead type, as discussed in the entries which follow. All bulkheads are considered to be watertight, and a default "None" has been chosen for cut-outs in bulkhead **[configuration]** for all bulkhead types.

Bulkhead Type 1: External Stiffeners



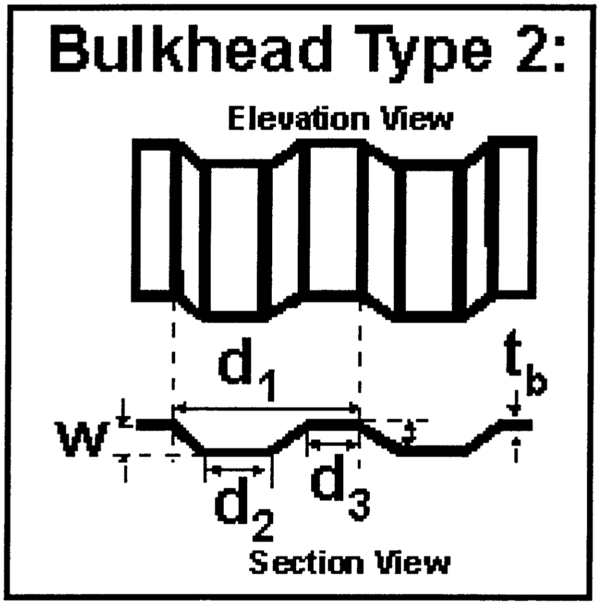
Parameter(s):

1. t_b, **thickness of bulkhead plating** - Use the value of the thickness of the bottom-most strake of bulkhead plating adjacent to the outer bottom plating for a single hull ship or tank top for a double hull ship. If the height of this first strake is significantly smaller than approximately twice "e" (the elevation of the rock with respect to the midship of the approaching ship), the user may specify a smaller average thickness to adjust for reductions in bulkhead plating thickness with height.

Configuration:

1. **stiffeners** - This bulkhead may be configured with any one of four available stiffener types (see 1.7 Stiffeners), or choose "None" using bulkhead **[configuration]** key.
2. **brackets** - This bulkhead may be configured with either bracket type (see 1.8 Brackets), or choose "None" using bulkhead **[configuration]** key.

Bulkhead Type 2: Corrugated



Parameter(s):

1. t_b, **thickness of bulkhead plating** - Use the value of the thickness of the bottom-most strake of bulkhead plating adjacent to the outer bottom plating for a single hull ship or tank top for a double hull ship. If the height of this first strake is significantly smaller than approximately twice "e" (the elevation of the rock with respect to the midship of the approaching ship), the user may specify a smaller average thickness to adjust for reductions in bulkhead plating thickness with height.
2. d_1, **distance of corrugation offset** - Use the offset length between the end of one complete corrugation and the beginning of the next corrugation wave.
3. d_2, **length of corrugation face 1** - Use the length of one face, or length of fold of corrugation which runs parallel with the bulkhead alignment.

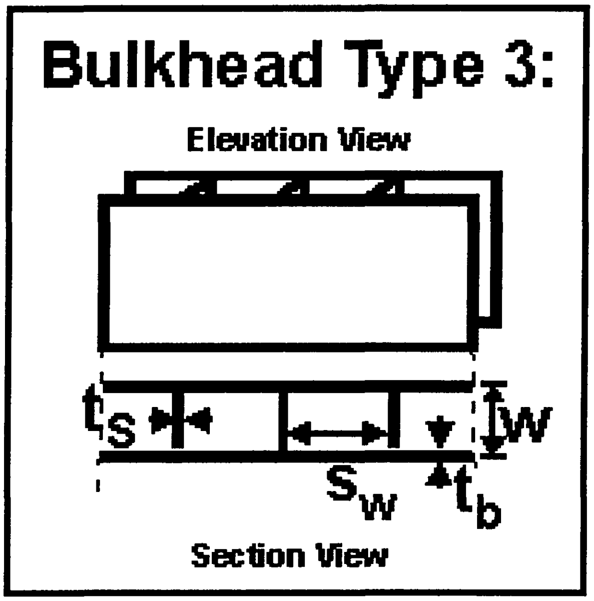
4. **d_3, length of corrugation face 2** - Use the length of the opposite face, or length of fold of corrugation which runs parallel with the bulkhead alignment. For standard corrugated plate sections, this length is usually the same as length "d_2".

5. **W, depth of corrugation** - Use the depth of corrugation, or the length separating face 1 and face 2.

Configuration:

1. **stiffeners** - This bulkhead should not be configured with any stiffeners.
2. **brackets** - This bulkhead should not be configured with any brackets.

Bulkhead Type 3: Internal Stiffeners



Parameter(s):

1. **t_b, thickness of bulkhead plating** - Both external bulkhead panels flanking the internal stiffeners are considered to be of the same thickness, t_b. Use the value of the thickness of the bottom-most strake of bulkhead plating adjacent to the outer bottom plating for a single hull ship or tank top for a double hull ship. If the height of this first strake is significantly smaller than approximately twice "e" (the elevation of the rock with respect to the midship of the approaching ship), the user may specify a smaller average thickness to adjust for reductions in bulkhead plating thickness with height.
2. **t_s, thickness of internal stiffeners** - Use the thickness of the plating of the stiffeners internal to the bulkhead.
3. **W, separation width** - Use distance separating the external bulkhead panels flanking the internal stiffeners.

4. S_W, **stiffener spacing** - Use the spacing of stiffeners internal to the bulkhead panels.

Configuration:

1. **stiffeners** - This bulkhead should not be configured with any stiffeners.
2. **brackets** - This bulkhead should not be configured with any brackets.

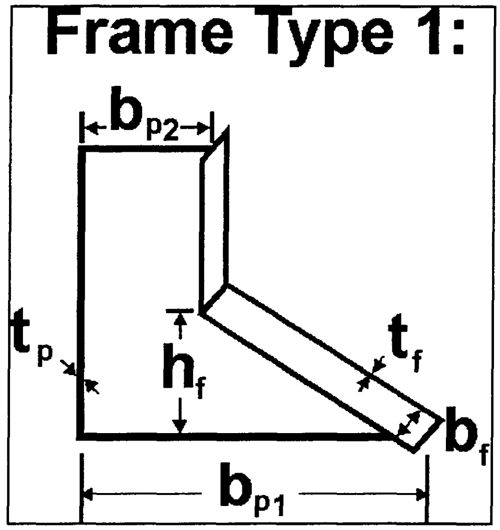
1.2 Bulkhead Frames

Depending on the type of bulkhead used in construction, bulkhead frames might be included as additional support members, for both longitudinal and transverse structures. The bulkhead frames are most logically used for type 1 bulkheads, which tend to be less stiff than corrugated or internally stiffened bulkheads.

While the frame style adopted for bulkheads depends on the location and type of bulkhead being supported, the frames in general are very similar to deep frames found elsewhere in the ship's construction. There are two types of bulkhead frames offered in DAMAGE, both of which are L-shaped: the first has an angled base, the base of the second is curved. The frames are orthogonally attached to the bulkheads, so that a longitudinal bulkhead has frames aligned in the transverse direction, and transverse bulkheads have frames in the longitudinal direction.

These frames, contributing as they do to the structural rigidity of the cargo space, are part of the target region that DAMAGE evaluates during a grounding event. Each frame may be configured with stiffeners, brackets, or cutouts, but as these are all smeared into an equivalent thickness on the web of the frame, their specifications do not have to be too accurately detailed.

Bulkhead Frame Type 1



Parameter(s):

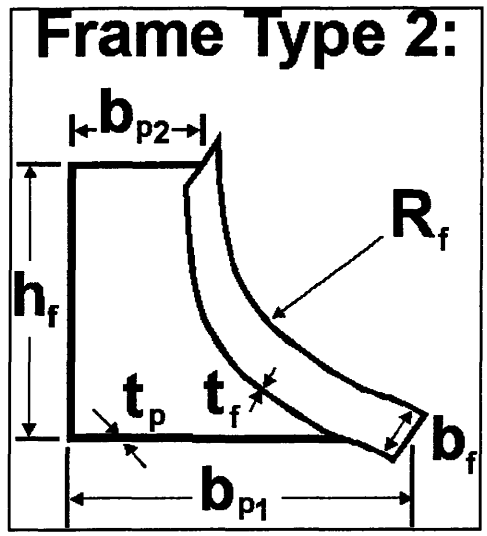
1. **b_f, breadth of frame flange**: Enter the width of the frame's flange
2. **t_f, thickness of frame flange**: Enter the thickness of the frame's flange
3. **h_f, height of frame foot**: Enter the height of the triangular base of the frame. Above this point, the frame is vertical.
4. **b_{p1}, breadth of frame foot**: Enter the distance the frame foot extends from the bulkhead.
5. **b_{p2}, breadth of frame stem**: Enter the width of the frame above the triangular foot.
6. **t_p, thickness of frame plate**: Enter the thickness of the frame's web.

Configuration:

1. **stiffeners**: The stem of the frame may be configured with stiffeners perpendicular to the bulkhead to which the frame is attached.
2. **cut-outs**: The triangular base of the frame may be fitted with a cutout.

3. **brackets**: The base of the frame may be supported by any of the bracket types. If present, the brackets are fitted along the base of the frame, from the bulkhead to the edge of the foot.

Bulkhead Frame Type 2



Parameter(s):

1. **b_f, breadth of frame flange**: Enter the width of the frame's flange.
2. **t_f, thickness of frame flange**: Enter the thickness of the frame's flange.
3. **b_p, breadth of frame**: Enter the distance the frame extends from the bulkhead.
4. **t_p, thickness of frame plate**: Enter the thickness of the frame's web.

Configuration

1. **stiffeners**: The frame may be configured with stiffeners perpendicular to the bulkhead to which the frame is attached.
2. **cut-outs**: The frame may be fitted with cutouts.
3. **brackets**: The base of the frame may be supported by any of the bracket types. If present, the brackets are fitted along the base of the frame, from the bulkhead to the edge of the foot.

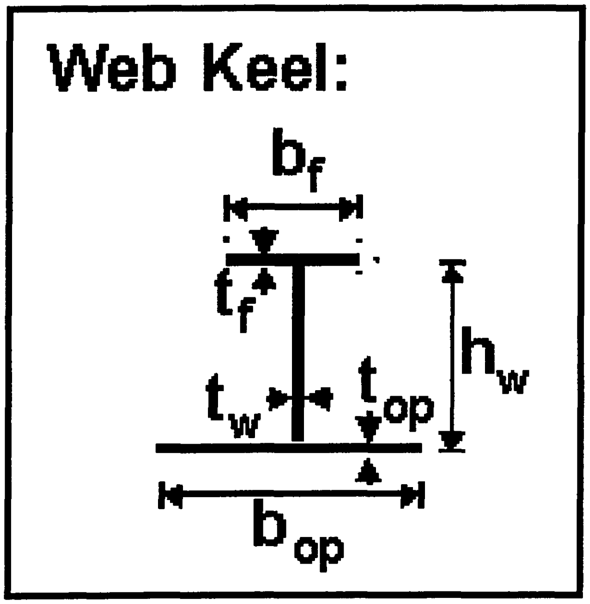
1.3 Centerline Structure

Three types of centerline keels are frequently fitted on the tanker ship. These are the web girder keel, the plate keel, and the duct keel. The web girder keel is specific only to vessels not fitted with a double bottom. The plate keel and duct keel are specific only to vessels fitted with a double bottom.

The following options are enabled in the centerline keel **[configuration]** dialog box to allow for variations in construction. All centerline keels may be configured with stiffeners, cut-outs, and brackets. All stiffeners, cut-outs, and brackets on centerline keels are aligned along the direction of h_w, shown in the diagrams accompanying the following entries.

Note that the height of the centerline keel should always correspond to the depth specified for longitudinal webs and transverse floors. In particular, for double bottom ships with sloping inner bottoms, an average depth along the transverse direction should be determined and used. If contradicting values are entered for center keels, webs, and floors, the most recent update will be written to the input file.

Web Keel



Parameters:

1. **h_w, height of web** - Use the vertical height of the center web girder from the top of the outer plating to the top of the flange.
2. **t_w, thickness of web** - Enter the thickness of the center web girder.
3. **b_f, breadth of flange** - Enter the width of the center girder flange.
4. **t_f, thickness of flange** - Enter the thickness of the center girder flange.

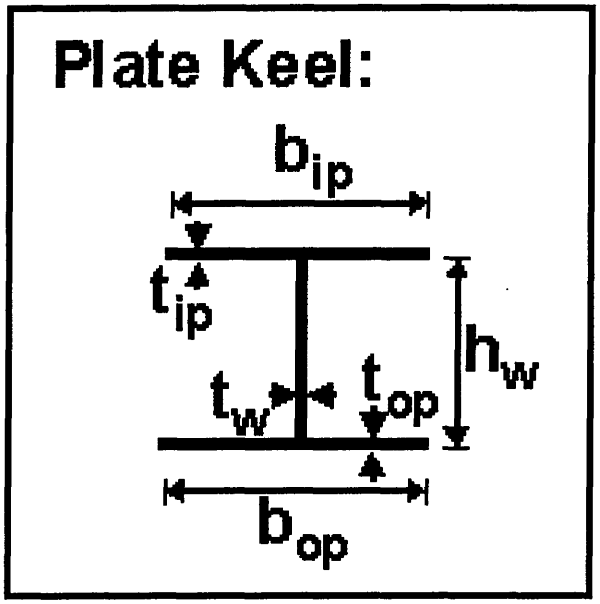
The center keel is associated with a reinforced center strake of plating.

5. **b_{op}, width of outer plating** - Enter the width of the center strake of outer plating.
6. **t_{op}, thickness of outer plating** - Enter the thickness of the center strake of outer plating.

Configuration:

1. **stiffeners** - All keel types can be configured with any of the four available stiffener geometries. The stiffeners on the keel are vertically aligned.
2. **cut-outs** - All keel types can be configured with any of the four available cut-out geometries. The cut-outs on the keel are vertically aligned.
3. **brackets** - All keel types can be fitted at a regular interval along the length with either bracket type. The brackets are aligned vertically and orthogonal to the plane of the keel web.

Plate Keel



Parameters:

1. $\mathbf{h_w}$, **height of web** - Use the vertical height of the plate keel from the top of the outer plating to the bottom of the inner plating. If the height of the longitudinal web or transverse floor has already been entered, this value should automatically appear.
2. $\mathbf{t_w}$, **thickness of web** - Enter the thickness of the plate keel girder.

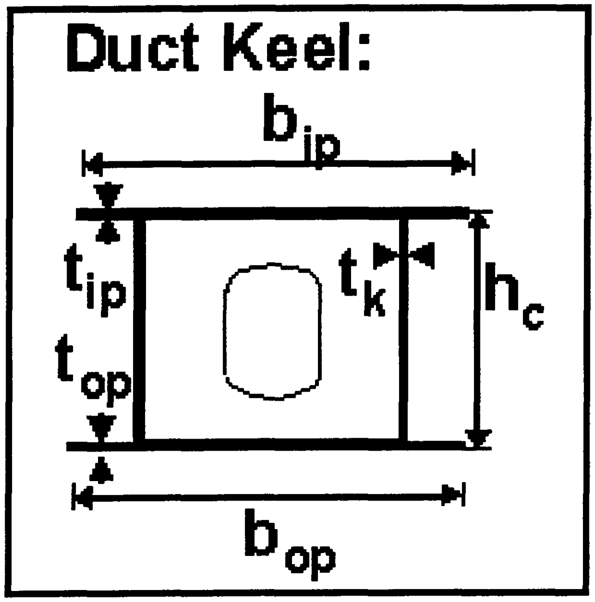
The center keel is associated with reinforced center strakes of plating.

3. $\mathbf{b_{ip}}$, **width of inner plating** - Enter the width of the center strake of inner plating.
4. $\mathbf{t_{ip}}$, **thickness of inner plating** - Enter the thickness of the center strake of inner plating.
5. $\mathbf{b_{op}}$, **width of outer plating** - Enter the width of the center strake of outer plating.
6. $\mathbf{t_{op}}$, **thickness of outer plating** - Enter the thickness of the center strake of outer plating.

Configuration:

1. **stiffeners** - All keel types can be configured with any of the four available stiffener geometries. The stiffeners on the keel are vertically aligned.
2. **cut-outs** - All keel types can be configured with any of the four available cut-out geometries. The cut-outs on the keel are vertically aligned.
3. **brackets** - All keel types can be fitted at a regular interval along the length with either bracket type. The brackets are aligned vertically and orthogonal to the plane of the keel plate.

Duct Keel



Parameters:

1. **h_c, height of keel** - Use the vertical height of the duct keel from the top of the outer plating to the bottom of the inner plating. If the height of the longitudinal web or transverse floor has already been entered, this value should automatically appear.
2. **t_k, thickness of duct keel webs** - Enter the thickness of the pair of webs forming the duct keel sides.

The center keel is associated with reinforced center strakes of plating.

3. **b_{ip}, width of inner plating** - Enter the width of the center strake of inner plating.
4. **t_{op}, thickness of inner plating** - Enter the thickness of the center strake of inner plating.
5. **b_{op}, width of outer plating** - Enter the width of the center strake of outer plating.

6. $\mathbf{t_{op}}$, **thickness of outer plating** - Enter the thickness of the center strake of outer plating.

Configuration:

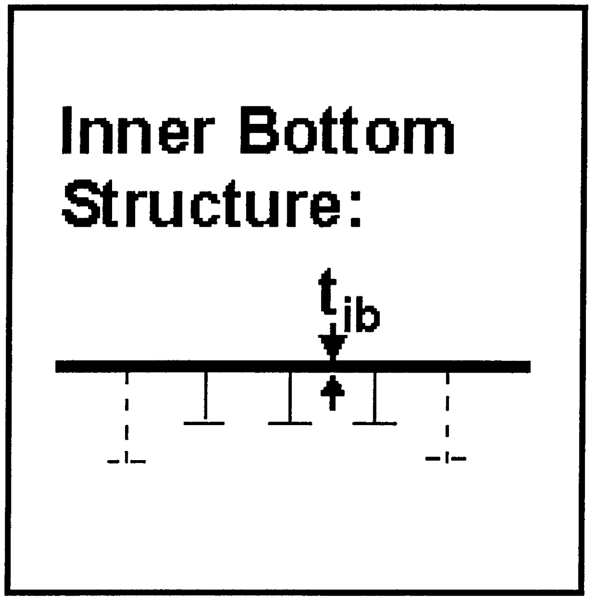
1. **stiffeners** - All keel types can be configured with any of the four available stiffener geometries. The stiffeners on the keel are vertically aligned.
2. **cut-outs** - All keel types can be configured with any of the four available cut-out geometries. The cut-outs on the keel are vertically aligned.
3. **brackets** - The duct keel is fitted internally with brackets at regular intervals along the length of the keel. Define these brackets using **[brackets]**. Choose Type 1 brackets and specify zero for flange dimensions to define a plate bracket only. The "cut-outs" feature on these brackets is not yet implemented for Phase I of DAMAGE and the user may opt to reduce the thickness applied to these brackets to account for any material removed for cut-outs. All keel types can be fitted with either bracket type. The brackets are aligned vertically and orthogonal to the plane of the keel webs. Note: If the user chooses not to fit brackets in the duct keel, the user must still use **[brackets]** to specify the width between the web pair forming the duct sides and enter zero for all other bracket dimension values.

1.4 Inner Bottom Structure

The inner bottom is considered to be formed from plate-stiffener assemblies. The inner bottom should only be described for vessels fitted with a double bottom.

A single parameter, thickness, defines the inner bottom plating. This plating may be configured with any of the four available stiffener geometries. The alignment of these scantlings is longitudinal when the inner bottom assembly is defined using **//Longitudinal Structure//** and transverse when the inner bottom assembly is defined using **//Transverse Structure//**. With this in mind, the inner bottom assembly should be defined under the appropriate data group using the "Hull Bottom Structure Utility."

Inner Bottom Structure



Parameters:

1 t_{ib},**thickness of inner bottom plating** - Estimate the average thickness of the inner bottom plating over the target damage area.

Configuration:

1. **stiffeners** - The inner bottom may be configured with any of the four geometry of stiffeners available. The scantlings, if fitted, are aligned longitudinally when the inner bottom is defined using **/Longitudinal Structure/** and transversely when the inner bottom is defined using **/Transverse Structure/**.

Note: Any brackets connected to the inner bottom should be defined with the associated webs, floors, frames, or outer bottom assemblies.

1.5 Webs/Frames & Longitudinals

There are two types of longitudinal members comprising this data group. The type "webs" is the category of longitudinal members fitted in ships with double bottoms. The type "webs/frames & longitudinals" is the category of longitudinal members fitted in ships without double bottoms.

For a vessel fitted with a double bottom, choose radio button **[Webs]**. It is assumed that the webs are fitted at a prescribed regular spacing, which is an integer multiple of the frame spacing in the transverse direction. The number of webs fitted between the center keel and the location "1/2 b" (half the width of flat bottom) from the centerline depends on the spacing prescribed.

Note that the depth of longitudinal webs should always correspond to the depth specified for the centerline keel and transverse floors. In particular, for double bottom ships with sloping inner bottoms, an average depth along the transverse direction should be determined and used. If contradicting values are entered for center keels, webs, and floors, the most recent update will be written to the input file.

The type "webs" denotes plate type longitudinals fitted between inner and outer bottoms, with possible scantlings between webs. For DAMAGE Phase I, the dimensions of the webs are also used to approximate the structure in the double bottom space fitted below the relevant longitudinal bulkheads, if a pair is present. It is recognized that this structure is frequently reinforced. Future versions of DAMAGE could provide an enhanced feature to better describe the structure and to accomodate options such as stools and other associated structure.

For a vessel without a double bottom, choose radio button **[Frames]**. It is assumed that webs/frames and longitudinals are also fitted at a regular spacing, which is an integer multiple of the frame spacing in the transverse direction. The number of webs/frames or longitudinals fitted between the center keel and the location "1/2 b" (half the width of flat bottom) from the centerline depends on the spacing prescribed.

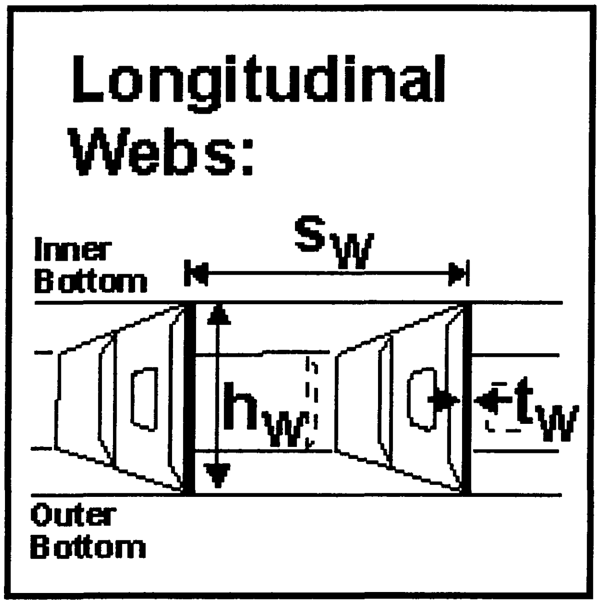
The type "webs/frames" denotes web girder type longitudinals fitted to the outer bottom, with possible secondary scantlings between the webs/frames. Webs/frames are described using the same dialog box as longitudinals. To construct webs/frames, the user should also configure the outer bottom assembly data group for stiffeners. For webs/frames, it is recognized that any longitudinal web frames which may be fitted are generally more massive than the longitudinal webs intermittent to these frames. However, for DAMAGE Phase I, the web frames are approximated by the dimensions of the longitudinal webs. Future versions of DAMAGE may enhance the description of web frame details.

The type "longitudinals" denotes flanged web type longitudinals fitted to the outer bottom, with no additional secondary scantlings between the longitudinals. Longitudinals are described using the same dialog box as webs/frames. To construct longitudinals, the user should not configure the outer bottom assembly data group for any stiffeners. For a single bottom vessel with primary and secondary framing in the longitudinal direction, the user should construct webs/frames, instead of longitudinals, as per the above paragraph.

Some options are enabled in the associated **[configuration]** dialog box to allow for variations from typical construction. Brackets and cut-outs are available options for "webs," "webs/frames," and "longitudinals." The types "webs" and "webs/frames" should be configured with secondary scantlings. These scantling dimensions are described with the appropriate orientation of inner or outer bottom assembly data groups. The alignment of the stiffeners on the web girders is vertical.

The intersection of the longitudinal bottom structure (webs, webs/frames, and longitudinals) with the transverse bottom structure (floors, floors/frames) creates a grillage of inner and outer bottom regions across which all stiffeners, cut-outs, and brackets are smeared.

Webs



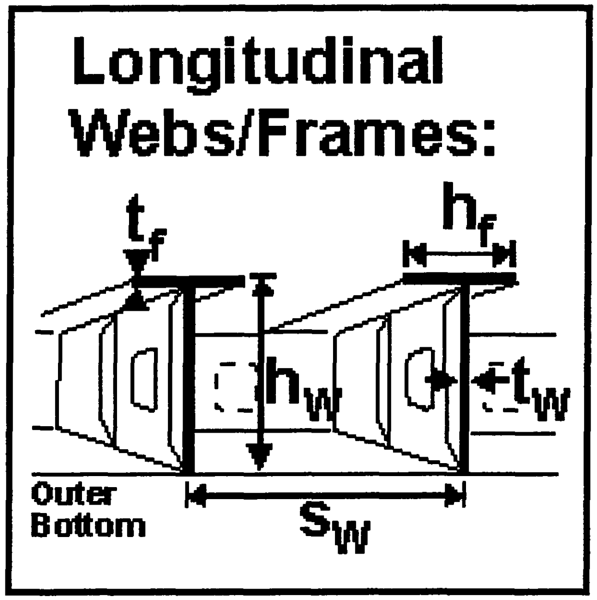
Parameters:

1. h_W, **depth of web plate** - Enter the depth of the web plate. If the height of the centerline keel or transverse floor has already been entered, this value should automatically appear.
2. t_f, **thickness of web plate** - Enter the thickness of the web plate.
3. **Spacing of webs** - Specify the distance between webs. This should be an integer multiple of the frame spacing in the transverse direction.

Configuration:

1. **stiffeners** - Webs may be configured with vertical stiffeners only.
2. **cut-outs** - Webs may be configured with cut-outs.
3. **brackets** - Webs may be configured with brackets.

Webs/Frames or Longitudinals



Parameters:

1. h_W, **height of web** - Use the vertical height of web from the top of the outer bottom to the top of the flange.
2. t_W, **thickness of web** - Enter the thickness of the web.
3. h_f, **breadth of web flange** - For both tee section and angle section, enter the full width of the web's flange.
4. t_f, **thickness of web flange** - Enter the thickness of the web's flange.
5. **Spacing of webs** - Specify the distance between webs. This should be an integer multiple of the frame spacing in the transverse direction.

Configuration:

1. **stiffeners** - Webs may be configured with vertical stiffeners only.
2. **cut-outs** - Webs may be configured with cut-outs.
3. **brackets** - Webs may be configured with brackets.

1.6 Floors/Frames

There are two types of transverse members comprising this data group. The type "floors" is the category of transverse members fitted in ships with double bottoms. The type "floors/frames" is the category of transverse members fitted in ships without double bottoms.

For a vessel fitted with a double bottom, choose the radio button **[Floors]**. It is assumed that the floors are fitted at a prescribed regular spacing, which is an integer multiple of the scantling spacing in the longitudinal direction. The number of floors fitted between the fore and aft cargo tank bulkheads depends on the spacing prescribed.

Note that the depth of transverse floors should always correspond to the depth specified for the centerline keel and longitudinal webs. In particular, for double bottom ships with sloping inner bottoms, an average depth along the transverse direction should be determined and used. If contradicting values are entered for center keels, webs, and floors, the most recent update will be written to the input file.

The type "floors" denotes plate type transverses fitted between inner and outer bottoms, with possible secondary scantlings between floors. For DAMAGE Phase I, the dimensions of the floors are also used to approximate the structure in the double bottom space fitted below all transverse bulkheads. It is recognized that this structure is frequently reinforced. Future versions of DAMAGE could provide an enhanced feature to better describe the structure and to accomodate options such as stools and other associated structure.

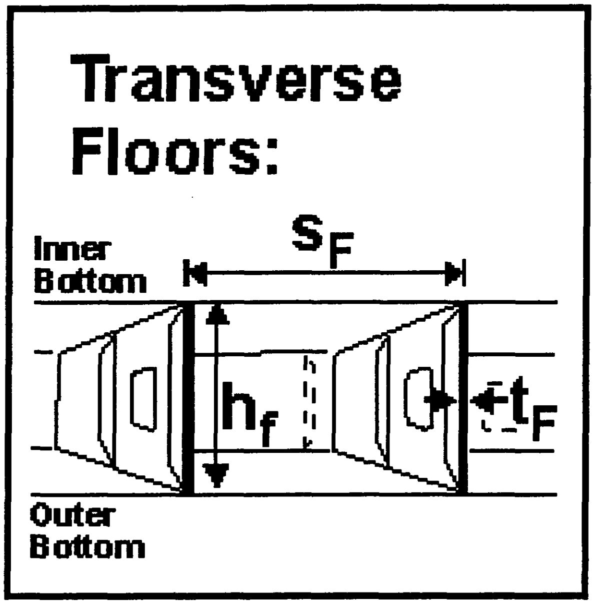
For a vessel without a double bottom, choose the radio button **[Frames]**. It is assumed that floors/frames are also fitted at a regular spacing, which is an integer multiple of the scantling spacing in the longitudinal direction. The number of floors/frames fitted between the fore and aft cargo tank bulkheads depends on the spacing prescribed.

The type "floors/frames" denotes web girder type transverses fitted to the outer bottom, with possible scantlings between the floors/frames. To construct floors/frames, the user should configure the outer bottom assembly data group for stiffeners. For floors/frames, it is recognized that any transvere web frames which may be fitted are generally more massive than the transverse floors intermittent to these frames. However, for DAMAGE Phase I, the transverse frames are approximated by the dimensions of the transverse floors. Future versions of DAMAGE may enhance the description of transverse frame details.

Some options are enabled in the associated **[configuration]** dialog box to allow for variations from typical construction. Brackets and cut-outs are available options for "floors" and "floors/frames." The types "floors" and "floors/frames" can also be configured with secondary scantlings. These stiffener dimensions are described with the appropriate orientation of inner or outer bottom assembly data groups. Stiffeners are aligned vertically only transverse frames.

The intersection of the transverse bottom structure (floors, floors/frames) with the longitudinal bottom structure (webs, webs/frames, and longitudinals) creates a grillage of inner and outer bottom regions across which all stiffeners, cut-outs, and brackets are smeared.

Floors



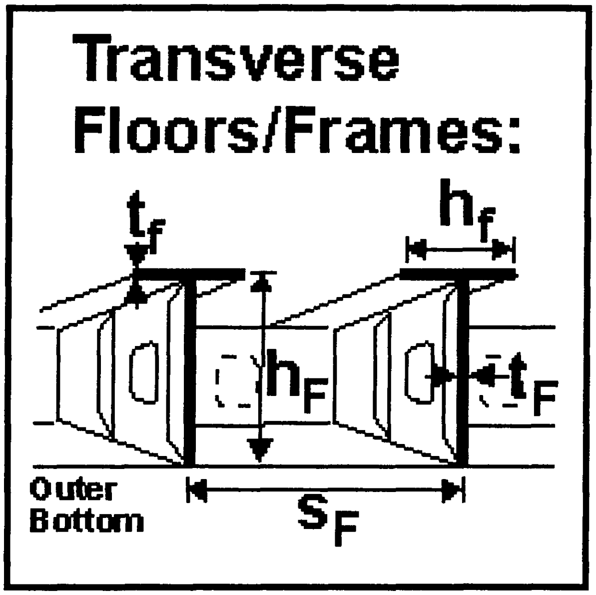
Parameters:

1. **h_f, depth of floor** - Enter the depth of the floor plate. If the height of the centerline keel or longitudinal web has already been entered, this value should automatically appear.
1. **t_F, thickness of floor** - Enter the thickness of the floor plate.
2. **Spacing of floors** - Specify the distance between floors. This should be an integer multiple of the frame spacing in the longitudinal direction.

Configuration:

1. **stiffeners** - Floors may be configured with vertical stiffeners only.
2. **cut-outs** - Floors may be configured with cut-outs.
3. **brackets** - Floors may be configured with brackets.

Floors/Frames



Parameters:

1. $\mathbf{h_F}$, **height of floor** - Use the vertical height of floor's web from the top of the outer bottom to the top of the flange.
2. $\mathbf{t_F}$, **thickness of floor** - Enter the thickness of the floor's web.
3. $\mathbf{h_f}$, **breadth of floor flange** - Enter the width of the floor's flange.
4. $\mathbf{t_f}$, **thickness of floor flange** - Enter the thickness of the floor's flange.
5. **Spacing of floors** - Specify the distance between floors. This should be an integer multiple of the frame spacing in the longitudinal direction.

Configuration:

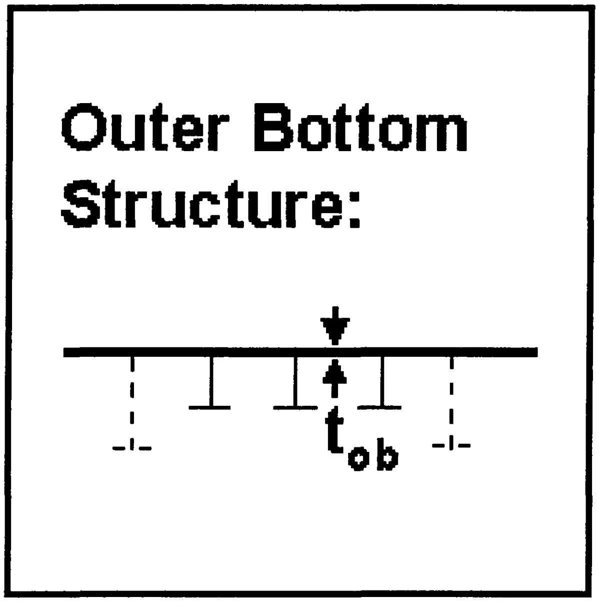
1. **stiffeners** - Floors may be configured with vertical stiffeners only.
2. **cut-outs** - Floors may be configured with cut-outs.
3. **brackets** - Floors may be configured with brackets.

1.7 Outer Bottom Structure

The outer bottom is considered to be formed from plate-stiffener assemblies. The outer bottom is considered to be flat over the length and breadth of the target damage area.

A single parameter, thickness, defines the outer bottom plating. This plating may be configured with any of the four available stiffener geometries. The alignment of these scantlings is longitudinal when the outer bottom assembly is defined using **/Longitudinal Structure/** and transverse when the outer bottom assembly is defined using **/Transverse Structure/**. With this in mind, the outer bottom assembly should be defined under the appropriate data group using the "Hull Bottom Structure Utility."

Outer Bottom Structure



Parameters:

1 **t_{ob},thickness of outer bottom plating** - Estimate the average thickness of the outer bottom plating over the target damage area.

Configuration:

1. **stiffeners** - The outer bottom may be configured with any of the four geometry of stiffeners available. The scantlings, if fitted, are aligned longitudinally when the outer bottom is defined using **/Longitudinal Structure/** and transversely when the outer bottom is defined using **/Transverse Structure/**.

Note: Any brackets connected to the outer bottom should be defined with the associated webs, floors, frames, or outer bottom assemblies.

1.8 Bilge Frame Type

The shape of the bilge area determines the type of frame which must be used to support it. Within DAMAGE, however, the perspective is shifted from that of the ship designer to that of a model builder, and the frame type determines the shape of the bilge area. The shift leads the user to progress in logical steps as the input file is built: from the selected frame shape, it is clear which other primary structures (inner bilge plating, bilge girder, stringers) must be included in the model. The four frame shapes offered in DAMAGE include most of the common tanker variants; with judicious mixture of scantlings and primary structures, it is possible to represent some of the uncommon variants as well.

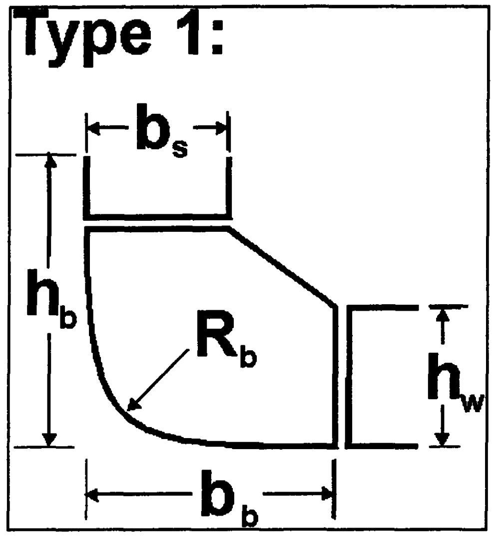
Of the four frame shapes, all are appropriate for either single or double hull construction, although frame types 3 and 4 are generally found in double hull ships. The two major categories of bilge frame type are the four sided frames, which include types 1 and 2, and the three sided frames, which include types 3 and 4. These designations are taken from the appearance of the frame elbows, the section which is located in the turn of the bilge, and joins the flat bottom structure to the sideshell.

The label and description of each edge of a four sided frame are as follows: *top*, which marks the top of the bilge area and the bottom of the sideshell; *inboard*, the inboard edge of the bilge area and the boundary of the flat bottom; *inside*, the inside edge of the frame, forming the interior of the elbow; and *outside*, the outer curve which joins the flat bottom to the sideshell, via the bilge.

The three sided frames lack the inside edge; instead, the inboard and top edges join directly together. This can be seen clearly in bilge frame types 3 and 4. In double hull ships with 3 sided frames, the inner plating assembly is replaced by a combination of stringer and bilge girder, or is obviated entirely when the inner side joins the inner bottom.

In real construction, the bilge frames might be part of continuous transverse deep frames which sweep from the flat bottom, through the bilge, and up the sideshell to the deck. This is not the case in DAMAGE, because each section of the ship has been developed separately in the calculation routines. To simulate this continuity, the inboard and top edges should be the same height or width as the transverse deep frames they abut in the flat bottom and sideshell, respectively.

Bilge Frame Shape: Type 1



Parameter(s):

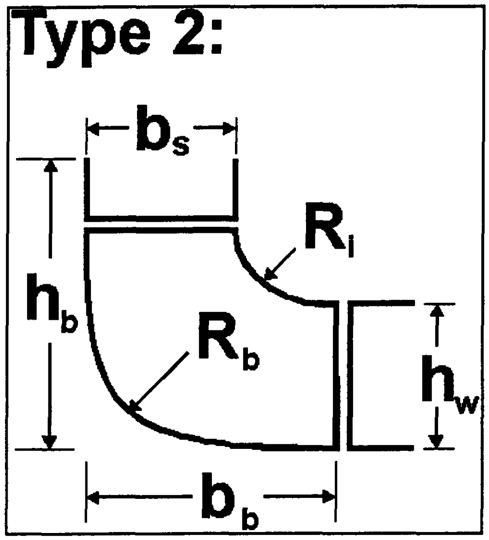
1. **b_b, breadth of bilge area**: Enter the width of the bilge area from the maximum beam to the edge of the flat bottom. The inboard bound of the bilge area is typically indicated in double hull ships by a longitudinal girder in the inner bottom. In ships of single hull construction, the inboard bound can be located where the bilge frame joins the transverse frames of the flat bottom. The total bilge area must be wide enough to include the frames which stiffen the bilge.
2. **h_b, height of bilge area**: Enter the height of the bilge area extending from the baseline to the upper bound of the bilge. The upper bound may be delineated by a longitudinal stringer in double hull construction, or by the connection of the bilge frame to the transverse frame of the side shell. The upper bound of the bilge area may also be described as the point above which the vertical structural arrangement of the side shell prevails.
3. **R_b, bilge radius**: Use the radius of the curved plating which joins the vertical side shell to the horizontal flat bottom. The center of the 90° section of plating is R_b up from the baseline and R_b in from the maximum beam.

4. b_s, **breadth of side**: Enter the width of the vertical section of the transverse frame, or the width of the double side of a double hull ship.
5. h_w, **height of inboard edge of bilge area**: Use either the height of the webs or frames of the flat bottom, or the height of the inner bottom of a double hull ship. If a bilge girder is fitted, it is of this height.

Configuration:

The details of the cutouts and of the brackets are specified under //**Transverse Structure**//.

Bilge Frame Shape: Type 2

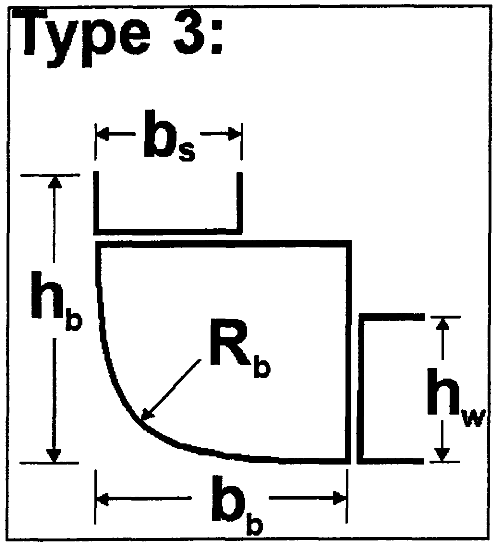


Parameter(s):

1. **b_b., breadth of bilge area** : The width of the bilge area from the maximum beam to the edge of the flat bottom. The inboard bound of the bilge area is typically indicated in double hull ships by a longitudinal girder in the inner bottom. In ships of single hull construction, the inboard bound can be located where the bilge frame joins the transverse frames of the flat bottom. The total bilge area must be wide enough to include the frames which stiffen the bilge.
2. **h_b, height of bilge area**: The height of the bilge area extends from the baseline to the upper bound of the bilge. The upper bound may be delineated by a longitudinal stringer in double hull construction, or by the connection of the bilge frame to the transverse frame of the side shell. The upper bound of the bilge area may also be described as the point above which the vertical structural arrangement of the side shell prevails.
3. **R_b, bilge radius**: The radius of the curved plating which joins the vertical side shell to the horizontal flat bottom. The center of the 90° section of plating is R_b up from the baseline and R_b in from the maximum beam.

4. **R_i, radius of inner plating**: The radius of the curved plating which forms the inner bound of the bilge frame. In a double hull ship, this is also the radius of the curved plating which encloses the bilge area.
5. **b_s, breadth of side**: The width of the vertical section of the transverse frame, or the width of the double side of a double hull ship.
6. **h_w, height of inboard edge of bilge area**: The height of the webs or frames of the flat bottom; also the height of the inner bottom of a double hull ship. If a bilge girder is fitted, it is of this height.

Bilge Frame Structure: Type 3

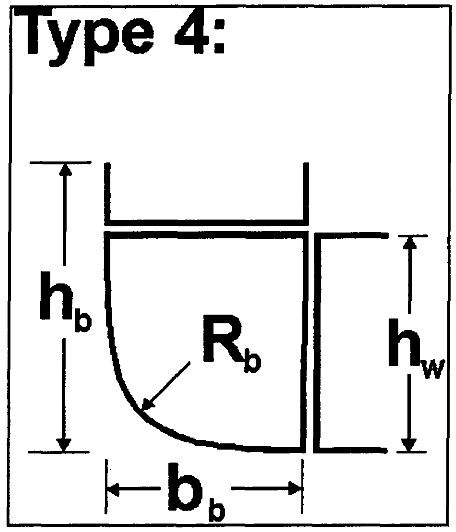


Parameter(s):

1. **b_b, breadth of bilge area**: The width of the bilge area from the maximum beam to the edge of the flat bottom. The inboard bound of the bilge area is indicated by a longitudinal girder which rises above the in inner bottom. The total bilge area must be wide enough to include the frames which stiffen the bilge.
2. **h_b, height of bilge area**: The height of the bilge area extends from the baseline to the upper bound of the bilge. This height may correspond to the height of the stringer which both defines the bilge frame shape and is a boundary of the enclosed bilge volume which runs the length of the ship. The upper bound of the bilge area may also be described as the point above which the vertical structural arrangement of the side shell prevails.
3. **R_b, bilge radius**: The radius of the curved plating which joins the vertical side shell to the horizontal flat bottom. The center of the 90° section of plating is R_b up from the baseline and R_b in from the maximum beam.
4. **b_s, breadth of side**: The width of the vertical section of the transverse frame, or the width of the double side of a double hull ship.

5. **h_w, height of inboard edge of bilge frame**: The height of the webs or frames of the flat bottom; also the height of the inner bottom of a double hull ship.

Bilge Frame Structure: Type 4



Parameter(s):

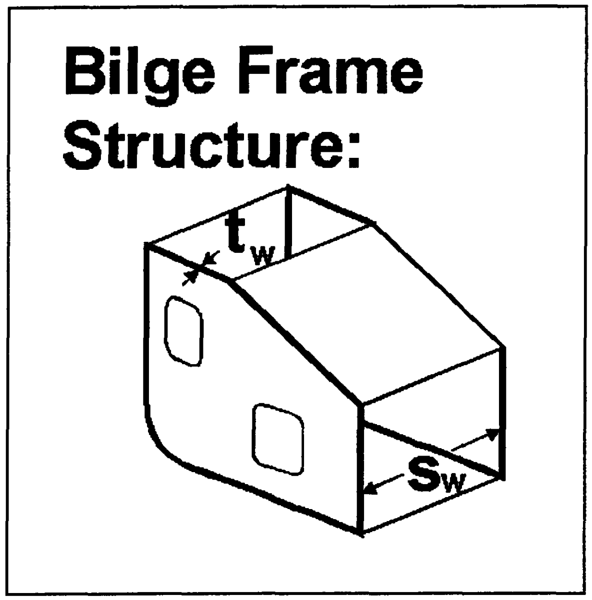
1. **b_b, breadth of bilge area**: The width of the bilge area from the maximum beam to the edge of the flat bottom. For a rectangular frame, the width of the bilge area is either the width of the frame, or in a double hull ship, the width of the double side.
2. **h_b, height of bilge area**: The height of the bilge area extends from the baseline to the upper bound of the bilge. The upper bound may be delineated by a longitudinal stringer in double hull construction, or by the connection of the bilge frame to the transverse frame of the side shell. The upper bound of the bilge area may also be described as the point above which the vertical structural arrangement of the side shell prevails.
3. **R_b, bilge radius**: The radius of the curved plating which joins the vertical side shell to the horizontal flat bottom. The center of the 90° section of plating is R_b up from the baseline and R_b in from the maximum beam.
4. **h_w, height of inboard edge of bilge area**: The height of the webs or frames of the flat bottom; also the height of the inner bottom of a double hull ship. If a bilge girder is fitted, it is of this height.

1.9 Bilge Frame Structure

The bilge frame structure includes the scantlings and spacing of the bilge frames, and is distinct from the bilge frame type, which only describes the shape of the frame. The frames are considered to be identical, and are treated as if they were evenly distributed along the length of the cargo spacing.

The scantlings of a frame are described by no more than 4 parameters: plate thickness, flange thickness, flange width, and spacing. The plating may be additionally configured with stiffeners, cut-outs, and brackets. The stiffeners are aligned normal to the inboard edge of the frame, and are smeared in the calculations to yield equivalent thicknesses for both the bending rigidity and membrane strength.

Bilge Frame Structure: Double Hull



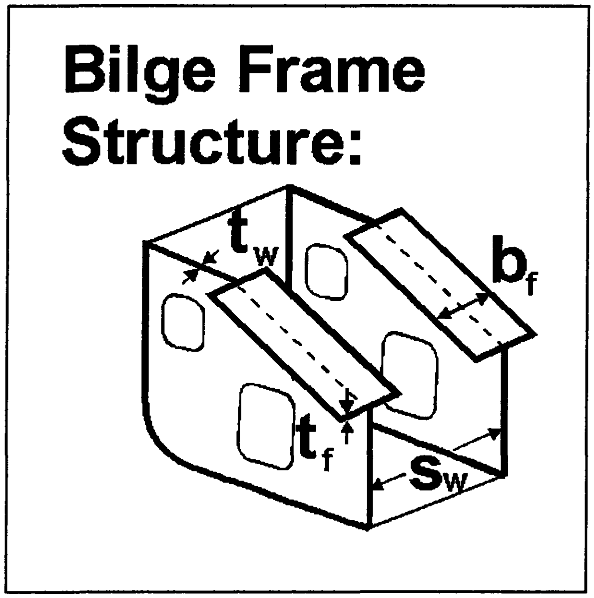
Parameters(s):

1. **s_w, spacing of frames**: Enter the distance between bilge frames. The number of frames depends upon the distance between each pair of oiltight transverse bulkheads.
2. **t_w, thickness of frame**: The thickness of the frame plating.

Configuration:

1. **stiffeners**: The frames can not currently be stiffened in the bilge area.
2. **cutouts**: A maximum of two cutouts can be fitted in the bilge frame. Each cutout is shaped and sized individually, and is located by height above baseline and distance inboard from maximum beam, B.
3. **brackets**: Each frame may be supported by brackets; these are orthogonal to the transverse frames, and thus are aligned in the longitudinal direction.

Bilge Frame Structure: Single Hull



Parameter(s):

1. s_w, **spacing of frames**: Enter the distance between bilge frames. The number of frames depends upon the distance between each pair of oiltight transverse bulkheads.
2. t_w, **thickness of frame**: Estimate the thickness of the frame plating in the bilge area.
3. b_f, **breadth of frame flange**: Enter the width of the frame's flange.
4. t_f, **thickness of frame flange**: Enter the thickness of the frame's flange.

Configuration:

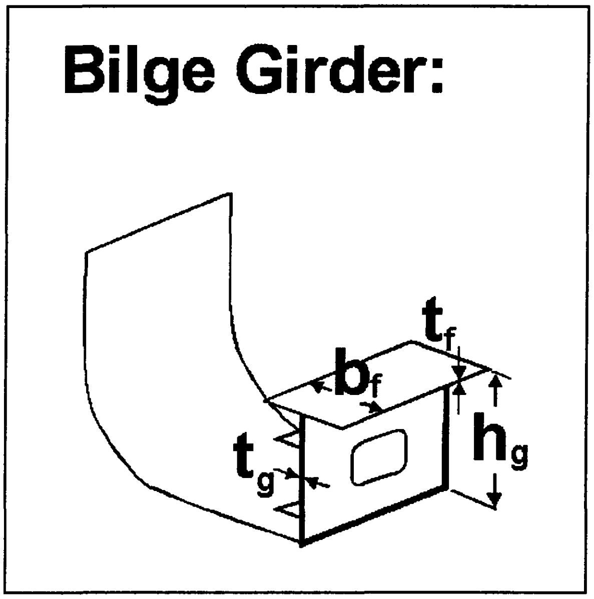
1. **stiffeners**: The frames can not currently be stiffened in the bilge area.
2. **cutouts**: A maximum of two cutouts can be fitted in the bilge frame. Each cutout is shaped and sized individually, and is located by height above baseline and distance inboard from maximum beam, B.
3. **brackets**: Each frame may be supported by brackets; these are orthogonal to the transverse frames, and thus are aligned in the longitudinal direction.

1.10 Bilge Girder

In either single or double hull ships, the inboard edge of the bilge area is often marked by a longitudinal girder which continues the length of the cargo space, and provides a clear demarcation between the flat bottom and the bilge. The bilge girder is essentially similar in form to the longitudinal webs and web/frames of the flat bottom, but is defined separately in DAMAGE so that it can be dimensioned and configured individually.

If one is to be used, the type of girder chosen depends on the construction of the ship. Flanged girders can be fitted in single hull ships only, since the top of the girder is unattached to any other structure. In double hull ships, where the girder is located in the double bottom and must connect to the inner plating, flanges can not be used. The configuration of the girder also depends on the ship construction: cut-outs, for instance, are clearly inappropriate in the girder for ships that must have water-tight bilge areas.

Bilge Girder: Single Hull



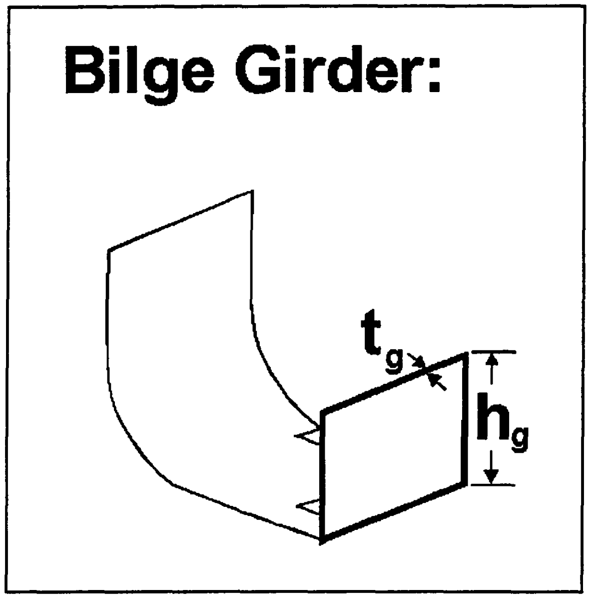
Parameter(s):

1. **h_g, height of bilge girder**: The girder which is the inboard bound of the bilge area is typically the same height as the longitudinal webs/frames of the bottom structure. If a girder is not fitted, use zero height.
2. **t_g, thickness of bilge girder**: Enter the thickness of the girder's web.
3. **b_f, breadth of girder flange**: Enter the width of the girder's flange, if present.
4. **t_f, thickness of girder flange**: Enter the thickness of the girder's flange.

Configuration:

1. **stiffeners**: Stiffeners are aligned horizontally in the longitudinal direction of the ship. If, in fact, the girder stiffeners are vertical, the user should calculate an equivalent plate thickness for the web of the girder, instead of using stiffeners.
2. **cut-outs**: The girder can be configured with any of the available cut-outs.
3. **brackets**: Brackets can be fitted at the base of the girder, orthogonal to the primary structure.

Bilge Girder: Double Hull



Parameter(s):

1. **h_g, height of bilge girder**: The girder which is the inboard bound of the bilge area is typically the same height as the longitudinal frames of the bottom structure. If a girder is not fitted, the height is zero.
2. **t_g, thickness of bilge girder**: Enter the thickness of the girder's web.

Configuration:

1. **stiffeners**: Stiffeners are aligned horizontally in the longitudinal direction of the ship. If, in fact, the girder stiffeners are vertical, the user should calculate an equivalent plate thickness for the web of the girder, instead of using stiffeners.
2. **cut-outs**: The girder should not be configured with cut-outs if it forms a tank wall.
3. **brackets**: Brackets can be fitted at the base of the girder, orthogonal to the primary structure.

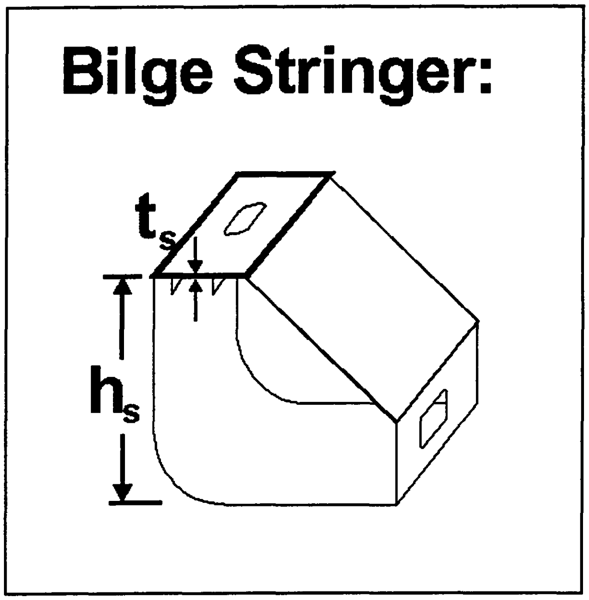
1.11 Bilge Stringers

Stringers are horizontal structures which contribute to the longitudinal strength of the ship. In the bilge area, stringers are not always utilized, but when they do appear, they may be used singly or in pairs. Stringers almost never appear in the bilge area of single hull ships, however, they are used frequently in double hull bilges, both to serve as the top of the bilge area, and to provide reinforcement internal to the bilge.

When building a model in DAMAGE, the user may choose to include one stringer or two, if any are used at all. Typically, if one stringer is fitted, it is located at the top of the bilge area, near the plating seam which marks the first strake of the sideshell. This stringer is watertight only if the bilge area is a separate enclosed volume from the other ballast spaces, and is otherwise merely a strength member within a tank. If two stringers are fitted within the bilge area, it is common for one to be at the top of the bilge area and for the other to be at the level of the inner bottom, providing additional stiffening.

Of course, it is possible to locate the stringers at any vertical location within the bilge area, as necessary. The stringers may be configured with stiffeners, cut-outs, or brackets, as appropriate, but the user should note that all of the configuration will be longitudinal. If the secondary structure is not longitudinal in reality, an equivalent thickness should be used for the stringer plating.

Bilge Structure: Single Stringer



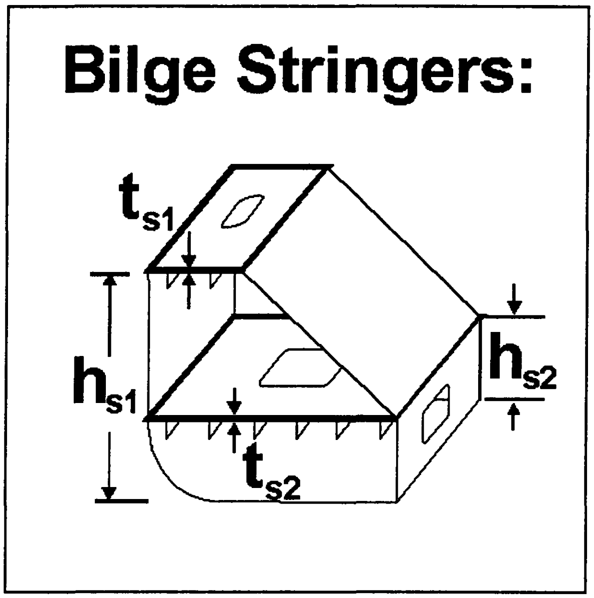
Parameter(s):

1. **h_s, height of stringer**: Enter the height of the bilge stringer above baseline. The stringer typically marks the upper end of the bilge area, but may also be located at any height above the webs/frames or floors of the flat bottom. The width of the stringer is defined by the dimensions of the bilge frame.
2. **t_s, thickness of stringer**: Enter the thickness of the stringer plate.

Configuration:

1. **stiffeners**: The stiffeners run in the longitudinal direction.
2. **cut-outs**: The stringer may be configured with cut-outs.
3. **brackets**: The stringer may be fitted with brackets.

Bilge Structure: Two Stringers



Parameter(s):

1. **h_{s1}, height of upper stringer**: The height of the upper stringer above baseline. The stringer typically marks the upper end of the bilge area. The width of the stringer is defined by the dimensions of the bilge frame.
2. **t_{s1}, thickness of upper stringer**: The thickness of the upper stringer plating.
3. **h_{s2}, height of lower stringer**: The height of the lower stringer above baseline. The lower stringer is typically located at the height of the inner bottom in double hull ships.
4. **t_{s2}, thickness of lower stringer**: The thickness of the lower stringer plating.

Configuration:

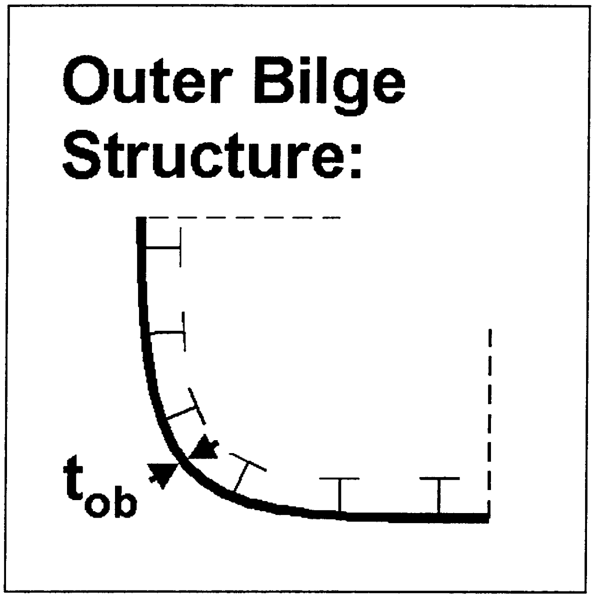
1. **stiffeners**: The stiffeners run in the longitudinal direction.
2. **cut-outs**: The stringers may be configured with cut-outs.
3. **brackets**: The stringers may be fitted with brackets.

1.12 Outer Bilge Structure

The outer bilge is a plate-stiffener assembly which joins the flat bottom to the side shell. The central part of its span is composed of curved plating described by the bilge radius, but it might also contain flat plate sections.

Only the thickness of the plating and the stiffener details are needed to define the outer bilge structure. The alignment of the stiffeners corresponds to the definition of the plating, so that stiffeners defined under **//Longitudinal Structure// /outer bilge/** will be longitudinal, and stiffeners entered under **//Transverse Structure// /outer bilge/** will be transverse members. This effect should be considered as the outer bilge structure is built.

Outer Bilge Structure



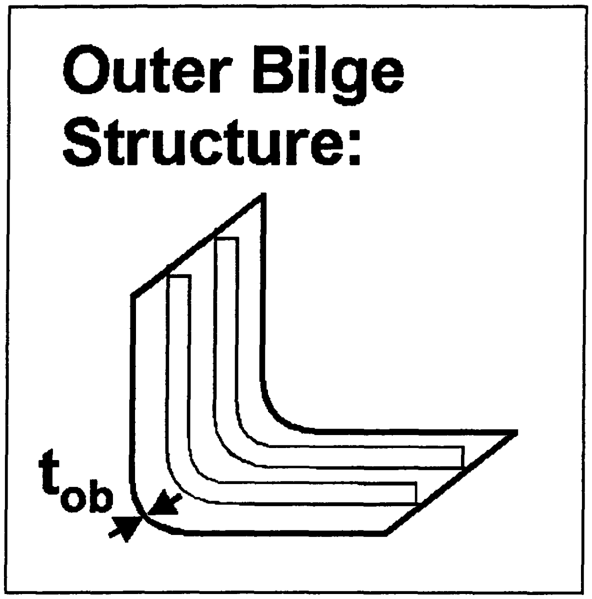
Parameter(s):

1. **t_{ob}, thickness of outer bilge plating**: Estimate the average plate thickness of the bilge plating. It is assumed that the plating is of constant thickness along the length of the bilge curve.

Configuration:

1. **stiffeners**: The stiffeners will be aligned in the same direction as the plating.

Outer Bilge Structure: Transverse Bilge Plating



Parameter(s):

1. **t_{ob}, thickness of outer bottom plating**: The thickness of the plating which joins the flat outer bottom to the vertical side shell.

Configuration:

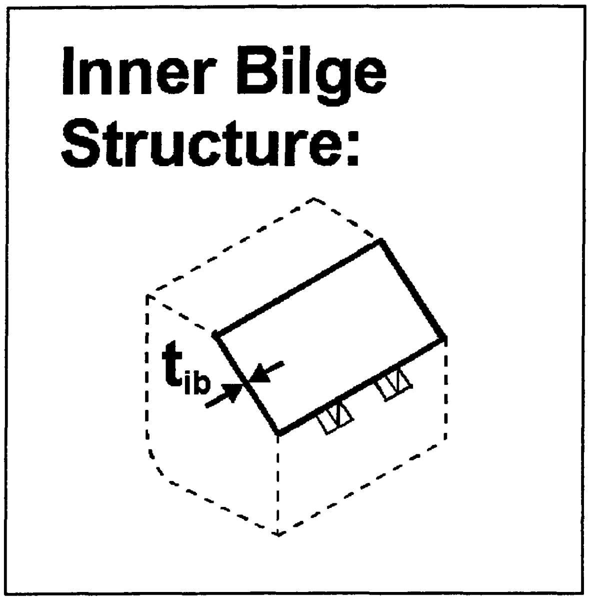
1. **stiffeners**: The stiffeners are in the transverse direction.

1.13 Inner Bilge Structure

The inner bilge structure is a plate stiffener assembly whose orientation from the horizontal depends upon the shape of the bilge frame. It is only present when the bilge area must be separate from the cargo space, as is the case for double sided and double hulled ships. The assembly may be flat or curved plating, and in double hull ships, connects the inner bottom to the inner sideshell.

The orientation of its scantlings depends upon the definition of the plate as longitudinal or transverse structure. The plate may be fitted with any of the four stiffener types available in DAMAGE.

Inner Bilge Structure: Interior Bilge Plating



Parameter(s):

1. **t_{ib}, thickness of inner bottom plating**: The average thickness of the plating which joins the inner bottom to the inner side shell.

Configuration:

1. **stiffeners**: The stiffeners are in the transverse direction.
2. **brackets**: Any brackets should be defined with the primary structure which they support.

Basic Components

1.14 Stiffeners

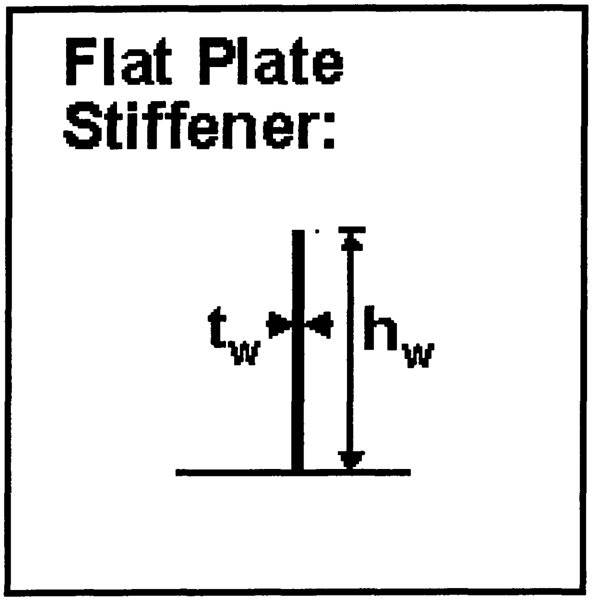
Stiffeners are the scantlings which stiffen the panels of plating used in ship construction. Stiffeners should be defined with the primary structure on which they are fitted. The primary structure with an available option for stiffeners are the bulkheads, center keel structure, inner and outer bottom assemblies, webs, floors, and frames, allowing the user some latitude to customize. If no stiffeners are present, "None" can be chosen for stiffeners using the associated primary structure **[configuration]** key.

Four geometries of stiffeners, described in the entries which follow, are frequently encountered in hull bottom structure within the target damage region. The webs of the stiffeners, as they appear in the dimension drawings, are always at a right angle with respect to the plane of the plate to which the stiffener is attached. The direction of stiffener alignment with respect to the primary structure is determined by the type and alignment of the primary structure.

All stiffeners on bulkheads, centerline structure, webs, floors, and frames are aligned vertically. All stiffeners on the inner and outer bottom panels are aligned longitudinally when defined with **/Longitudinal Structure/** and transversely when defined with **/Transverse Structure/**. The number of stiffeners specified are considered to be evenly distributed between any other webs, floors, frames, or longitudinals which are fitted on the primary structure. The stiffeners are smeared in this alignment into an increased effective thickness distributed along the length of the adjacent plating of primary structure.

Like cut-outs, stiffeners are the most basic component and have no other added configuration components.

Flat Plate Stiffener



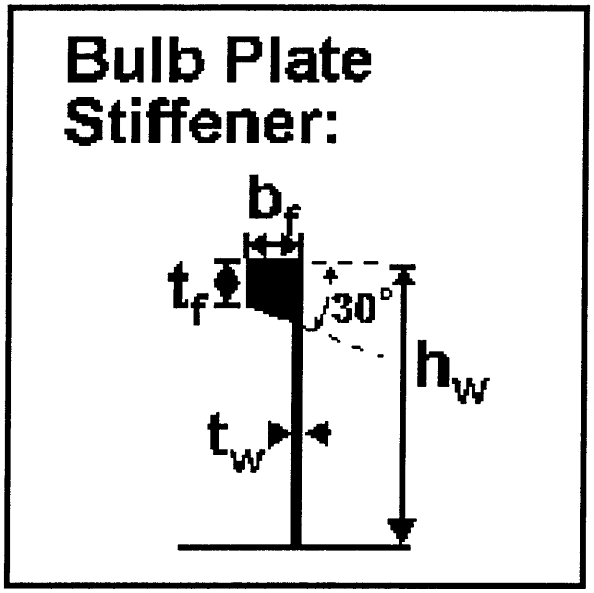
Parameters:

1. **h_w, height of web** - Use the vertical height of the stiffener web.
2. **t_w, thickness of web** - Enter the thickness of the stiffener web.
3. **#, number of stiffeners** - Specify the number of stiffeners with the above geometry that should be smeared across the span of the adjacent plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration:

(Not applicable.)

Bulb Plate Stiffener



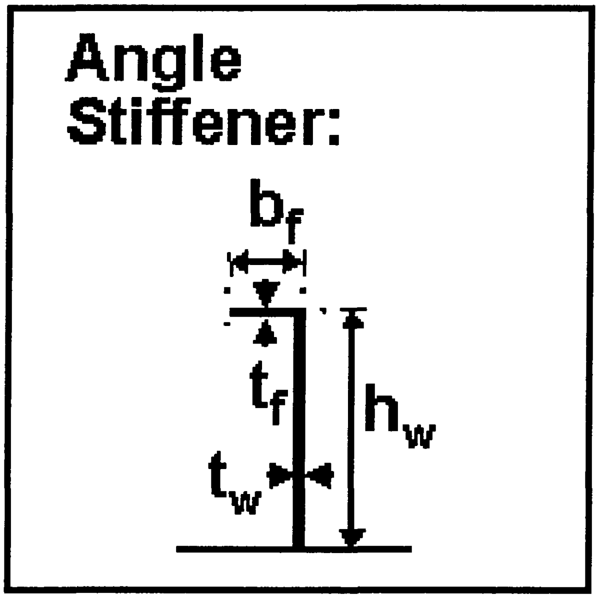
Parameters:

1. **h_w, height of web** - Use the vertical height of the stiffener web from the top of the primary structure plating to the top of the bulb.
2. **t_w, thickness of web** - Enter the thickness of the stiffener web at the end opposite the bulb flange.
3. **b_f, breadth of flange** - Estimate the width of the top of the bulb flange.
4. **t_f, thickness of flange** - Estimate the thickness of the bulb flange at the narrow edge of the bulb.
5. **#, number of stiffeners** - Specify the number of stiffeners with the above geometry that should be smeared across the span of the adjacent plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Note: For bulb stiffeners, geometry is estimated by neglecting all fillet radii and using a default bulb angle of 30 degrees.

Configuration: (Not applicable.)

Angle Stiffener

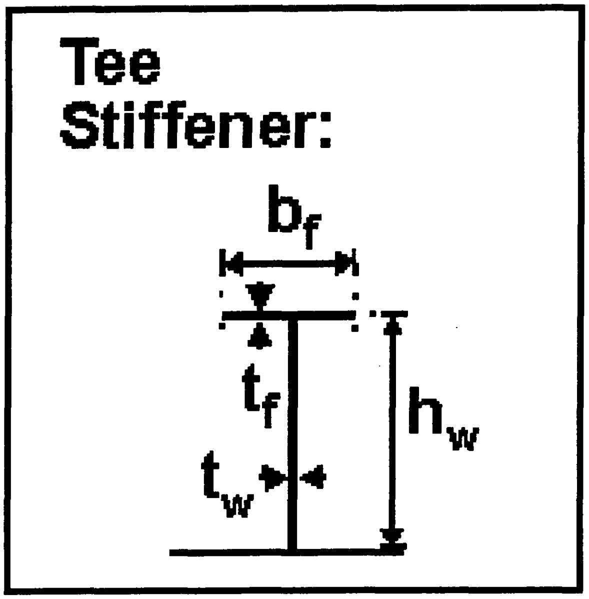


Parameters:

1. **h_w, height of web** - Use the vertical height of the stiffener web from the top of the primary structure plating to the top of the flange.
2. **t_w, thickness of web** - Enter the thickness of the stiffener web.
3. **b_f, breadth of flange** - Enter the width of the flange.
4. **t_f, thickness of flange** - Enter the thickness of the flange.
5. **#, number of stiffeners** - Specify the number of stiffeners with the above geometry that should be smeared across the span of the adjacent plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration: (Not applicable.)

Tee Stiffener



Parameters:

1. h_w, **height of web** - Use the vertical height of the stiffener web from the top of the primary structure plating to the top of the flange.
2. t_w, **thickness of web** - Enter the thickness of the stiffener web.
3. b_f, **breadth of flange** - Enter the width of the flange.
4. t_f, **thickness of flange** - Enter the thickness of the flange.
5. **#, number of stiffeners** - Specify the number of stiffeners with the above geometry that should be smeared across the span of the adjacent plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration: (Not applicable.)

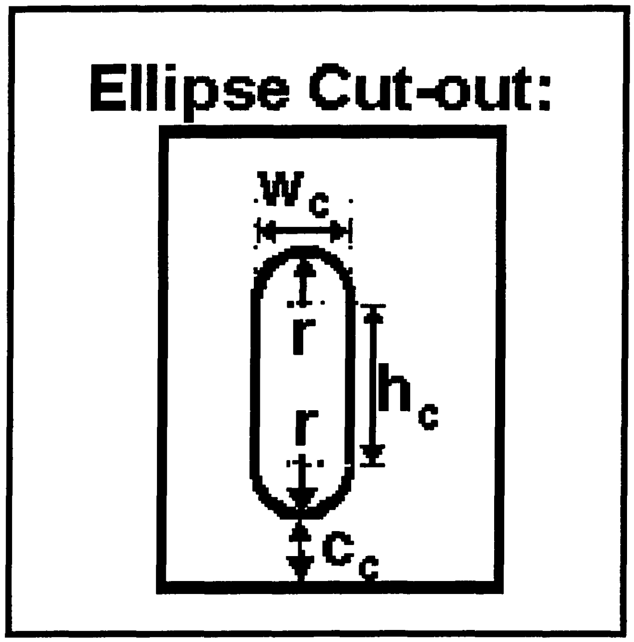
1.15 Cut-outs

Cut-outs in ship construction are primarily used to provide access or for reductions in weight at intermittent locations along structure. Cut-outs should be defined with the vertical primary structure from which they are cut. The primary structures with a cut-out option available are the center keel structure, webs, floors, and frames, allowing the user some latitude to customize. If no cut-outs are present, "None" can be chosen for cut-outs from the associated primary structure **[configuration]** key.

Variations of four geomteries of cut-outs, described in the entries which follow, are frequently encountered in hull bottom structure within the target damage region. The vertical symmetry line of the cut-outs, as they appear in the dimension drawings, are always at a right angle with respect to the hull bottom plating. The number of cut-outs are smeared in this alignment into a reduced effective thickness distributed across the length of adjacent plating of primary structure. The band of reduced effective thickness spans the height of the cut-out and is located at the vertical distance C_c of the cut-out above the baseline of adjacent plating of primary structure.

Like stiffeners, cut-outs are the most basic component and have no other added configuration components.

Ellipse Cut-out



Parameters:

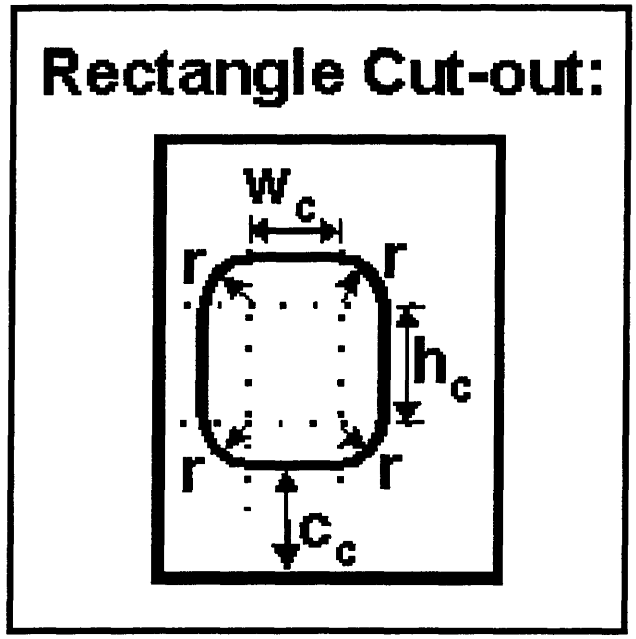
1. **h_c, height of "rectangle"** - The ellipse is approximated as two semi-circles joining a rectangular region defined horizontally by w_c and vertically by h_c. Enter the vertical height of the "rectangle."
2. **w_c, width of cut-out** - Enter the horizontal width of the "rectangle." The horizontal width of the rectangle, from the above approximation of an ellipse, is twice "r."
3. **r, radius of cut-out** - Enter the radius of the semi-circles forming the ellipse from the above approximation as $1/2W_C$.
4. **c_c, height to baseline of cut-out** - This is the vertical height from the baseline of the cut-out to the baseline of the primary structure from which the cut-out was removed.
5. **#, number of cut-outs** - Specify the number of cut-outs with the above geometry that should be smeared across the span of plating of primary structure. (Recall that for

transverse structures this length is “b” length of flat bottom, and for longitudinal structures this length is “L“ distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration:

(Not applicable.)

Rectangle Cut-out



Parameters:

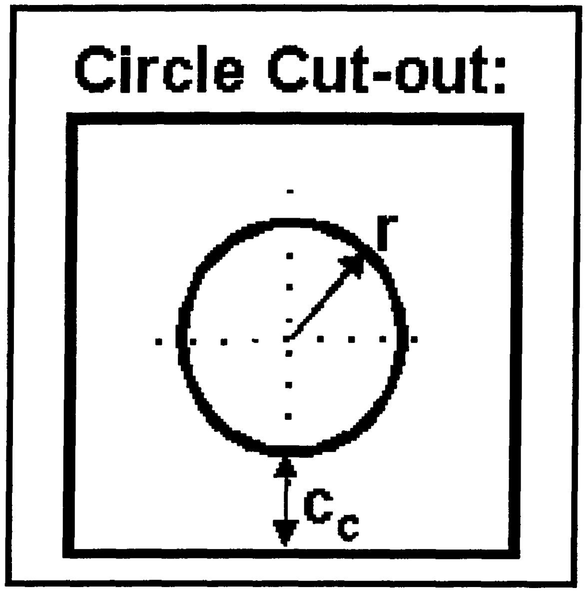
1. **h_c, height of rectangle** - The rounded rectangle is approximated as four quarter-circles joined vertically by height h_c and horizontally by width w_c at right angles to each other. Enter the vertical height.
2. **w_c, width of cut-out** - The rounded rectangle is approximated as four quarter-circles joined vertically by height h_c and horizontally by width w_c at right angles to each other. Enter the horizontal width.
3. **r, radius of cut-out** - Enter the radius of the quarter-circles forming the rounded rectangle.
4. **c_c, height to baseline of cut-out** - This is the vertical height from the baseline of the cut-out to the baseline of the primary structure from which the cut-out was removed.

5. **#, number of cut-outs** - Specify the number of cut-outs with the above geometry that should be smeared across the span of plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration:

(Not applicable.)

Circle Cut-out



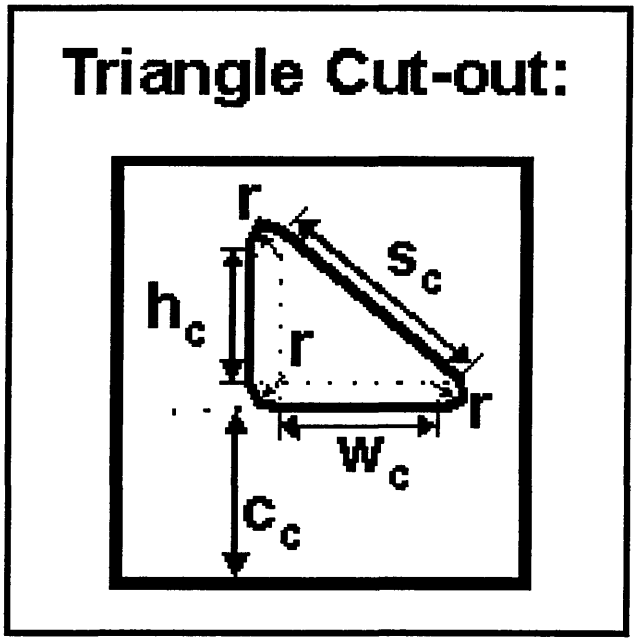
Parameters:

1. **r, radius of cut-out** - Enter the radius of the circular approximation of the cut-out.
2. **c_c, height to baseline of cut-out** - This is the vertical height from the baseline of the cut-out to the baseline of the primary structure from which the cut-out was removed.
3. **#, number of cut-outs** - Specify the number of cut-outs with the above geometry that should be smeared across the span of plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration:

(Not applicable.)

Triangle Cut-out



Parameters:

1. **h_c, height of cut-out** - The rounded right triangle is approximated as a triangle with three rounded corners of the same radius, r, joined vertically by height h_c and horizontally by width w_c. Enter the vertical height.
2. **w_c, width of cut-out** - The rounded right triangle is approximated as a triangle with three rounded corners of the same radius, r, joined vertically by height h_c and horizontally by width w_c. Enter the horizontal height.
3. **r, radius of cut-out** - Enter the radius of the quarter-circles forming the corner between any two legs of the rounded right triangle. The rounded right triangle is considered to have three corners with this same radius, r.

4. **C_c, height to baseline of cut-out** - This is the vertical height from the baseline of the cut-out to the baseline of the primary structure from which the cut-out was removed.
5. **#, number of cut-outs** - Specify the number of cut-outs with the above geometry that should be smeared across the span of plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration:

(Not applicable.)

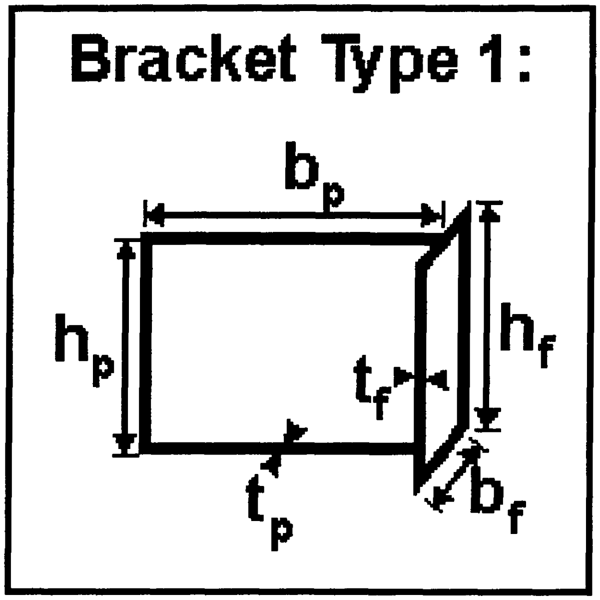
1.16 Brackets

Brackets in ship construction are primarily used at intermittent locations along centerline structure or at tank sides between bulkheads or frames. Brackets should be defined with the bulkheads, centerline structure, webs, floors, frames, or outer bottom assemblies to which they are welded. If no brackets are present, "None" can be chosen for brackets using the brackets **[configuration]** key. Note that the brackets at outer-most breadth at tank sides are not included in Phase I analysis because the specification of "b" (breadth of flat bottom) excludes the bulkhead or longitudinal bottom section member, located at or beyond the bounds of "b," to which tank side brackets would be attached.

Variations of two geomteries of brackets, described in the entries which follow, are frequently encountered in hull bottom structure within the target damage region. Both brackets are vertical and aligned at right angles to the primary structure to which they are welded. The brackets may have a flange welded at the free end opposite from the edge that is welded to the primary structure. The user should enter zero for any or all of the following to indicate no flange on the bracket: h_f (flange height), b_f (flange breadth), t_f (flange thickness). The number of brackets are smeared in this alignment into an added effective thickness distributed across the length of its adjacent primary structure.

Currently, stiffeners and cut-outs on brackets are not implemented. The contribution to effective thickness is clearly minimal. (This feature is reserved for future development of DAMAGE software.)

Bracket Type 1: Rectangle



Parameters:

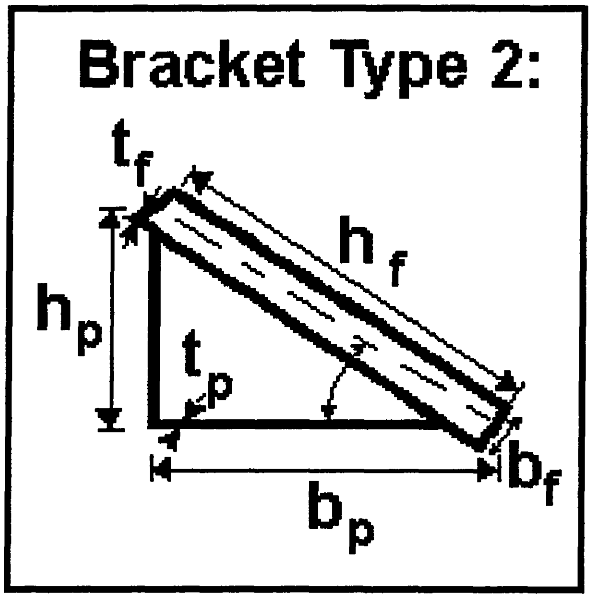
1. **h_p, height of bracket plate** - Use the vertical height of the retangular bracket plate. The two opposite vertical edges are considered to have the same length. This is the edge considered to be connected to the associated vertical primary structure.
2. **b_p, breadth of bracket plate** - Use the horizontal width of the rectangular bracket plate. The horizontal width at top and bottom edges are considered to have the same length. These are the two edges that are considered to be connected to the inner and outer bottom plating, respectively, when fitted in the double bottom.
3. **t_p, thickness of bracket plate** - Enter the thickness of the rectangular bracket plate.
4. **h_f, height of bracket flange** - Use the vertical height of the bracket flange if a flange is fitted. The flange is fitted to the plate edge opposite from the edge considered to be connected to the associated vertical primary structure. Enter zero to indicate that no flange is fitted.

5. $\mathbf{b_f}$**, breadth of bracket flange -** Use the horizontal width of the bracket flange if a flange is fitted. These are the two edges that are considered to be connected to the inner and outer bottom plating, respectively, when fitted in the double bottom. Enter zero to indicate that no flange is fitted.
6. $\mathbf{t_f}$**, thickness of bracket flange** - Enter the thickness of the bracket flange if a flange is fitted. Enter zero to indicate that no flange is fitted.
7. **#, number of brackets** - Specify the number of brackets with the above geometry that should be smeared across the span of adjacent plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration:

(This feature is reserved for future enhancements of DAMAGE software.)

Bracket Type 2: Triangle



Parameters:

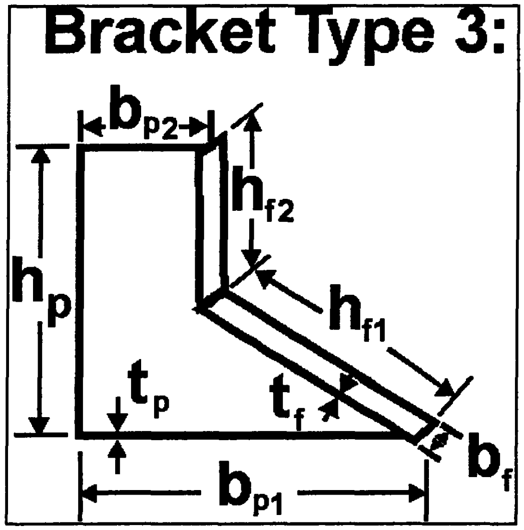
1. h_p, **height of bracket plate** - Use the height of the vertical leg of the triangular bracket plate. This is the edge considered to be connected to the associated vertical primary structure.
2. b_p, **breadth of bracket plate** - Use the width of the horizontal leg of the triangular bracket plate. This is the edge that is considered to be connected to the outer bottom plating in the single or double bottom.
3. t_p, **thickness of bracket plate** - Enter the thickness of the triangular bracket plate.
4. h_f, **height of bracket flange** - Use the vertical height of the bracket flange if a flange is fitted. The flange is fitted to the plate edge opposite from the edge considered to be connected to the associated vertical primary structure. Enter zero to indicate that no flange is fitted.

5. $\mathbf{b_f}$, **breadth of bracket flange -** Use the horizontal width of the bracket flange if a flange is fitted. These are the two edges that are considered to be connected to the primary structure and the outer bottom plating, respectively. Enter zero to indicate that no flange is fitted.
6. $\mathbf{t_f}$, **thickness of bracket flange** - Enter the thickness of the bracket flange if a flange is fitted. Enter zero to indicate that no flange is fitted.
7. **#, number of brackets** - Specify the number of brackets with the above geometry that should be smeared across the span of adjacent plating of primary structure. (Recall that for transverse structures this length is "b" length of flat bottom, and for longitudinal structures this length is "L" distance between aftmost cargo space bulkhead and foremost cargo space bulkhead.)

Configuration:

(This feature is reserved for future enhancements of DAMAGE software.)

Bracket Type 3: L-Shape



Parameter(s):

1. **b_{p1}, breadth of bracket foot**: Specify the distance the foot of the bracket extends from the primary structure.
2. **b_{p2}, breadth of bracket stem**: Enter the width of the bracket above its angled foot.
3. **h_p, height of bracket**: Use the height of the bracket along the edge connected to the primary structure.
4. **t_p, thickness of bracket plating**: Enter the thickness of the plating of the L-shaped bracket.
5. **b_f, breadth of bracket flange**: Enter the continuous width of the flange fronting both the triangular and vertical sections of the bracket.
6. **h_{f1}, length of lower bracket**: Enter the length of the free edge of the triangular base of the bracket.
7. **h_{f2}, length of upper bracket**: Use the length of the free edge of the rectangular stem of the bracket.
8. **t_f, thickness of bracket flange**: Enter the thickness of the bracket flange. Zero thickness indicates no flange.

APPENDIX A:

List of Joint MIT-Industry Tanker Safety Consortium Members

Consortium Membership

May 1997

- **American Bureau of Shipping**
- **Bureau Veritas**
- **Det norske Veritas**
- **Germanischer Lloyd**
- **Ishikawajima-Harima Heavy Industries Co., Ltd.**
- **Kawasaki Heavy Industries Co.**
- **Lloyd's Register**
- **Naval Surface Warfare Center**
- **Nippon Kaiji Kyokai**
- **NKK Corporation**
- **Technical University of Denmark**
- **United States Coast Guard (on behalf of Ship Structure Committee)**

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