
STA LIFTBOAT

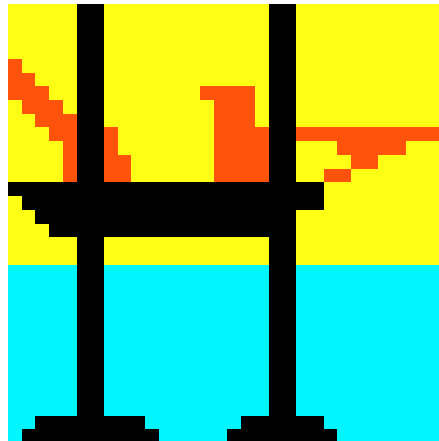
Version 4.01, August, 1998

USER MANUAL and THEORY

STA LIFTBOAT is a computer program for analyzing liftboats in the elevated mode. The program accounts for wind, wave and current loading on the unit and computes static and dynamic structural response, as well as pad reactions at the sea bed. This version of the program runs in the environment of Microsoft Windows, and Microsoft Excel. A mouse is used to click on option buttons in order to move rapidly through the analysis. No experience of Excel is required to use STA LIFTBOAT.

This program has been developed by Stewart Technology Associates (STA). All copyright for the software with STA. Users of the program experienced and careful interpreting the results from especially important with STA results can be obtained in This rapid speed and ease of attention needed from the user appropriate input vessel other important conditions. selecting certain structural leg preload levels, soil

This program has been developed by Stewart Technology Associates (STA). and documentation remains are cautioned to exercise engineering judgment when STA LIFTBOAT. This is LIFTBOAT since response seconds on a 486 based PC. use does not alter the care and associated with selecting the loading, environmental, and Care is also needed when response variables, including properties, and damping.



developed by Stewart Technology Associates (STA). All copyright for the software with STA. Users of the program experienced and careful interpreting the results from especially important with STA results can be obtained in This rapid speed and ease of attention needed from the user appropriate input vessel other important conditions. selecting certain structural leg preload levels, soil

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Stewart Technology Associates
5619 Val Verde
Houston, TX 77057

Tel: (713) 789-8341
Fax: (713) 789-0314
e-mail Stewart@neosoft.com

LIFT401
8/10/98

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CONTENTS

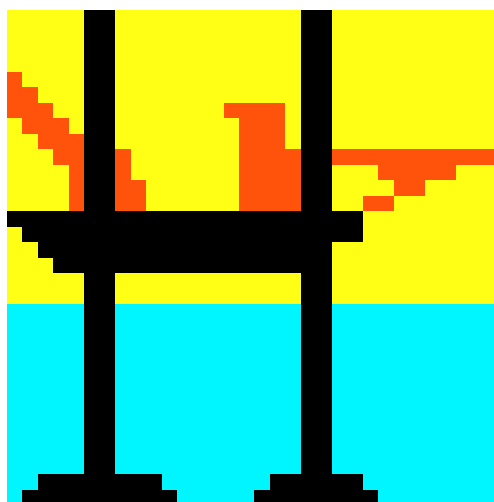
SUBJECT	Page #
1.0 INTRODUCTION	1
2.0 PROGRAM INSTALLATION AND QUICK START	3
2.1 Install Files and Create Directories	3
2.2 Install Icon.....	3
2.3 Program Files On Distribution Diskettes	4
2.4 Printer	4
2.5 Mouse.....	4
3.0 PROGRAM OPERATION	5
3.1 Quick Start	5
4.0 GENERAL PROGRAM OPERATION: Step By Step Process	9
5.0 BUTTON CONTROLS	15
5.1 STAINPT.XLS Buttons.....	15
5.2 Lift001.XLS Buttons	16
6.0 MAIN INPUT DATA (1st Data Screen)	31
Sign Convention	33
7.0 SECONDARY DATA INPUT (2nd Data Screen).....	36
7.1 Control and Miscellaneous Data	36
7.2 Jacking Tower Data	40
7.3 Pad Data.....	41
7.4 Leg Structural Data	41
8.0 TABULAR RESULTS.....	44
8.1 Input Summary	44
8.2 Results Summary	45
8.3 Pad Moment Results.....	53
8.4 Leg Hydrodynamic Coefficients	56
8.5 Unity Stress Checks - Global Leg Strength.....	57
8.6 Local Buckling Stress Checks.....	60
9.0 GENERAL THEORY AND ANALYSIS PROCEDURES.....	61
9.1 Overview	61
9.2 Soil Structure Interaction.....	61
9.3 Structural Calculations - Intoduction	61
9.4 Shear and Bending Stiffness	62
9.5 Pad Restraint	62
9.6 Jacking Mechanism Stiffness.....	62
9.7 Bending Moment Coefficients, Beta and Mu.....	63
9.8 Euler Leg Load	64
9.9 Equivalent Linear Damping.....	65
9.10 Natural Periods	65
9.11 Dynamic Amplification Factors (DAF)	66
9.12 Dynamic Response Analysis	67
9.13 Corrected Stabilizing Moment	67
9.14 Corrected Pad Reactions.....	69
9.15 Moment Amplification.....	69

10.0	REFERENCES	70
	INDEX	71

1.0 INTRODUCTION

Stewart Technology Associates (STA) has developed a suite of programs for the analysis of certain types of offshore structures. STA LIFTBOAT is the program offered by STA for the analysis of liftboats in the elevated and afloat (transit) modes. The program was originally developed in 1990 and has undergone continuous further development since that time. Initially, the program ran in the environment of Lotus Symphony. Since release 2.01 in 1992, the program has been available running in the environment of Microsoft Windows and Microsoft Excel. Instructions for loading and operating the program are given in Section 2 of this manual.

The purpose of STA LIFTBOAT is to calculate the structural response and pad reactions of liftboats in the elevated mode, subject to environmental and gravity loads. The program accounts for exposed sections of legs above the hull, as well as superstructure, including current loads are below the still water level. Shallow water wave theory is embodied in the ABS legs are modeled as with the correct equivalent coefficient and inertias leg (with rack). The drag wave attack angle, being the rack (or racks) on drag coefficient with wave attack angle is produced by the program once the user has input the rack geometry.



wind loading on in the air gap and on the hull and the crane. Wave and calculated on the legs and in the splash zone. theory is used, as MODU Rules and the equivalent cylinders diameter, drag which represent the full coefficient varies with strongly influenced by each leg. A graph of

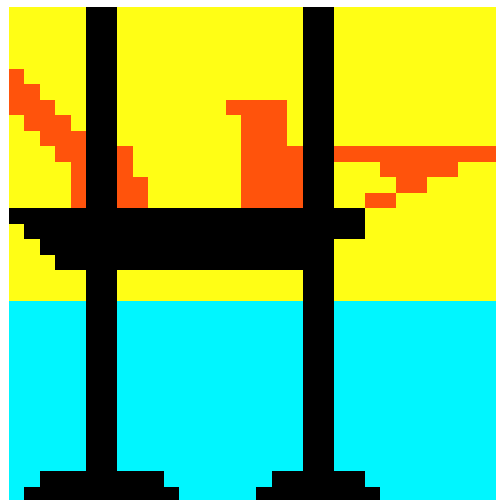
In order to calculate structural response, the vessel is treated as having a relatively stiff hull. Structural flexibility comes from the legs and the leg/hull connection. Rotational stiffness provided to the pad at the soil structure interface is also modeled. The structural characteristics for each unit to be analyzed are based primarily on the leg structural properties as input by the user. The user may alter the loading condition of the boat, the water depth, the air gap, the amount of pad penetration into the sea bed, and environmental conditions. Additionally, the user may control the stiffness of the pad restraint provided by the soil, by specifying soil strength and a coefficient used by the program to find a soil shear modulus. Alternatively the user may allow the program to calculate the minimum (cohesive) undrained shear strength of the soil necessary to give bearing support to each pad.. The user-specified soil stiffness may be varied from zero, representing a pin joint, through to completely fixed, if desired.

In version 2.0 (and onwards) of the program, the ultimate moment capacity of the soil is reported based upon either the user-specified value for the soil strength, or based upon the minimum soil strength necessary to provide bearing support to the pads. If the user specifies a large degree of fixity at the sea bed, or a rather stiff rotational spring, the

program will calculate large moments at the pads. If the calculated moment exceeds the theoretical ultimate moment capacity of the soil beneath the pad the program will issue a warning. In the a future release of the program, the DnV formulae for allowable moments in either sand or clay soils will be used. These maximum allowable moments are a function of the preload applied on each leg and the maximum leg reactions found during the analysis run. In both cases, the program has an iterative solution option which permits the user to maximize the soil stiffness in the analysis to either just meet the ultimate soil moment capacity, or to just satisfy the maximum allowable moment according to the DnV formulae.

Leg stresses typically limit liftboat operational envelopes. STA LIFTBOAT computes unity stress checks based upon both ABS MODU Rules (both pre-1988 and post-1988) and based upon a more rational stress check for slender axially loaded columns, as used by DnV. The US Coast Guard will accept any of these unity stress checks, subject to certain conditions (see Section 9).

STA LIFTBOAT also evaluates leg stresses induced by vessel roll and heave motions (plus lateral wind loads) in transit. The user may opt to use standard ABS criteria for MODUS, or use any combination of roll amplitude and natural roll period, or roll amplitude and roll period.



Other special features have been included in some versions of the program including the calculation of maximum stresses induced in the pads for certain boats.

A single page of results can be produced from each run which summarizes all important input data as well as all important response results including environmental forces calculated. Generally, the user is concerned with factors of safety against overturning, maximum vertical pad reactions induced (which should not usually exceed values achieved during preload), bending moments, and unity stress checks in the leg at the lower guide. In addition to the tabular results, the user may optionally print graphical results.

2.0 PROGRAM INSTALLATION AND QUICK START

The latest release (version 4.0, April, 1998) of the program runs in the environment of Windows 95 or NT, with Microsoft Excel version 8 (Office 97). The program is distributed as a series of Excel worksheet files with Visual Basic and macro controls on two 3.5" floppy disks. This document provides instructions for loading the program, setting up the Windows icon, and gives preliminary guidance for running the program.

2.1 Install Files and Create Directories

STA LIFTBOAT should be set up in a directory called LIFTBOAT on your hard disk drive. Before installing STA LIFTBOAT, **you must have Excel Version 8** already installed on your hard disk. The manual installation procedure is as follows:

- *Insert disk 1 of 2, click start button on the lower end of your windows screen. Type a:\setup in the given box, and click "ok".*
- *Welcome message will appear. Click "install" icon. Type a user name (must be at least 4 characters), and a company name in user information dialog box.*
- *Target directory will appear. Liftboat installation disk will automatically choose c:\liftboat as the target directory. User can change the hard drive directory from c to others (d for example). The director name can also be changed, say from Litboat to Liftboat1 when installing a new version of the program.*
- *Let the installation begin. Change to disk 2 of 2 whenever an instruction box to do so appears.*
- *Program group box will appear. Click "ok".*
- *Close the installation file.*
- *A Liftboat box should appear on the windows screen.*

2.2 Install Icon

You should set up an icon to run the software. An icon file is available inside the liftboat box. You can simply drag that icon to the windows screen in order to create a short cut. If by accident, you close the liftboat box, you may create the short cut icon through following:

An icon file is available inside the liftboat subdirectory. Right click the mouse on a blank area of the main Windows 95 desktop screen. You then select "new", followed by "shortcut". You will then be prompted to provide a "command line". Here you should give the path to the liftboat directory and to the file liftboatopen.xls. This will probably be as follows:

C:\LIFTBOAT\liftboatopen.xls

Having completed the command line, click *finish*. The new shortcut will appear on your desktop. Right click on it with the mouse and select *properties*. Select the tab *Shortcut* and then left click on the button *Change icon*. Another dialogue box will open and give you an option to browse for alternative icons. Click on the *Browse* button and select the

file *LIFTBOAT.ICO* from the list of files that should be displayed in the Liftboat directory in drive C. The icon for STA LIFTBOAT will then be shown as a picture in this dialogue box and you can click on *OK* to close the box. Click on *OK* to finish the process.

2.3 Program Files On Distribution Diskettes

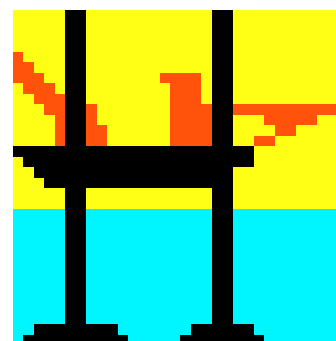
The files on your diskettes should be Setup.exe on Disk 1 and Setup.001 on Disk 2. After you have run setup, the files on your hard drive should be as listed in the table below.

File Name	Description
Liftboat.ico	Icon for STA LIFTBOAT. The icon is displayed by WINDOWS. Double click on the icon to start STA LIFTBOAT after program is installed.
liftboatopen.xls	This is the first file displayed to the user by Excel. The vessel to be analyzed is selected. Its files are then opened. If a new vessel is desired, an existing vessel is selected, its files are opened then saved with a new boat name. Up to 50 sets of vessel files can be stored.
Liftinpt.xls	This is the first file displayed to the user after a set of vessel files has been opened. The environment and other principal input data is specified in this file. This data is automatically linked to other files.
Lift001.xls	This is the rig/hull file with the structural data for the rig. This is the file displayed with the table of results and graphs when STA LIFTBOAT is running.
Readme.txt	The latest information on installation and running procedures, and program updates not included in manual are in this text file.
MASTERINPUT.xls	This file is used to enter and store up to 50 input data sets, or load cases. These generally include different environmental conditions and loading conditions for the vessel selected in liftboatopen.xls.

Note the directory structure is described later.

Note the file names are case sensitive.

The icon file is shown to the right.



2.4 Printer

As with any Excel application, you may print to a Windows configured printer. Most results include colored cells and objects. A color printer is recommended.

2.5 Mouse

A mouse is required to run STA LIFTBOAT.

3.0 PROGRAM OPERATION

Once the program files are installed on your hard disk, program operation is extremely simple.

3.1 Quick Start

For users of previous versions of STA LIFTBOAT, or for those who do not wish to spend time reading the User Manual until you have seen the program running, this Quick Start section is provided.

Note that unless you have a large amount of expanded memory, you may not be able to run other applications in Windows when running STA LIFTBOAT. This is because STA LIFTBOAT requires a large amount of graphics resources when it runs.

The first workbook that will be opened is Liftboatopen.xls. Three other workbooks, Liftinpt.xls, Lift001.xls and MASTERINPUT.xls will be opened. You will be prompted to provide the password for Lift001.xls.

STA LIFTBOAT v4.1 August 1998			Date of this run 08/13/98	
Licenced User: US Coast Guard. Copyright 1988 and onwards, Stewart Technology Associates				
Close Open Files Not Saving Data		Close and Save Active Liftboat Files		Close and Save Active Files in New Directory
			Save All Open Files In New Directory	Open Existing Liftboat Files
This worksheet keeps track of up to 50 Liftboat File Sets edited by the user			Number of boats in library: 2	1 Boat number selected
Boat #	Boat Name	Checksum	Name of active boat:	Dennis Doyle 5' Width Added
1	Dennis Doyle 5' Width Added	1	<div style="border: 1px solid black; padding: 5px;"> <p style="text-align: center; margin: 0;">Begin Editing Data</p> <p>Use the control buttons to select existing or add new vessels to Liftboat Library. The list can be manually edited, but the directory structure may become corrupted. The root directory is C:\LIFTBOAT. The directory containing the individual boat directories is C:\LIFTBOAT\PROJECTS Each set of boat files is then found in the projects directory in a directory (or folder) with the boat's name. This library is setup to hold up to 50 liftboats. Each boat has a master input file where up to 50 load cases can be stored. To enter a new boat into the library, select a new boat, change its name, click the File Management button, and come back to this sheet. Then press Save New Liftboat Files in New Directory.</p> <div style="border: 1px solid black; padding: 2px; margin-top: 5px;"> <p>c <<-- Drive letter where Liftboat Files are located</p> <p style="text-align: center;">Liftboat2 <<-- Directory Name</p> <p style="text-align: center;">User MUST give drive letter and Directory name where Liftboat Files are located</p> </div> </div>	
2	Dennis Doyle 5' Width Added1	1		
3		0		
4		0		
5		0		
6		0		
7		0		
8		0		
9		0		
10		0		
11		0		
12		0		
13		0		
14		0		
15		0		
16		0		
17		0		
18		0		
19		0		
20		0		
21		0		
22		0		
23		0		
24		0		

Your screen should now appear as above. All areas of the screen are protected, meaning that you cannot type data into them or change their formatting, with the

exception of the cells that will appear highlighted in yellow with bold blue or black data input (numbers) within them.

Type the hard disk drive letter and directory name where you have installed the program into the appropriate cells before proceeding.

STA LIFTBOAT v4.1 August 1998				08/12/98 Date of this run	
Licenced User: US Coast Guard.				Boat name: Dennis Doyle 5' Width Added	
Copyright 1990 and onwards, Stewart Technology Associates				Run Ref.: 40kn, 2kn, 14', 10s, 120'/15'4'	
THIS IS THE MAIN DATA INPUT SCREEN - CLICK BUTTON TO GO TO RESPONSE					
Go on to Structural Response		Print Input Screen and Wind Loads		Go to Master Input	
				File Management	
Only data in shaded cells can be edited. Last data used is displayed.					Build New Boat Master Input File
EDIT INPUT DATA					
25.00	AvShield	90.00	Wave attack angle (deg)		
10.00	Input wave height (ft)	4.00	4.00	4.00	Leg diams 1,2,3 (ft)
10.00	Input wave period (sec)	1.75	1.75	1.75	Cm1, Cm2, Cm3
120.0	Input water depth (ft)	0.70	0.70	0.70	CD1, CD2, CD3
0	Lattice area (sqft)	0.00	lattice av.ht.(ft)		40.0 wind v2 (kn)
30.00	WH1 (ft)	56.00	WH2 (ft)	2.00	tide vel (kn)
119.00	WB (ft)	55.00	WL (ft)	0.00	LeverArm
85.50	distance from aft to fwd legs (ft)			1500	Total weight (kips)
67.00	distance bet. fwd. leg centers (ft)			31.20	LCG (ft to foward legs)
12.46	pad penetration (ft)	1.00	leg buoy.1=dry 2=flood	0.00	init phase ang (deg)
0	windforce kips	15.00	air gap (ft)	0.00	wind elev (ft)
Wind force switch: 2 (1=input; 2=computed)				170.00	tot. leg length (ft)
22.54 ft leg length above hull bottom				29.21 ft	min.leg length to be above hull botto

Now you can open any available liftboats by clicking "Open Stored Liftboat Files". To create a new liftboat, you can edit the available liftboat that you've opened, change the name, and save it by clicking the "Save New Liftboat Files in New Directory". *liftboatopen.xls* can contain up to 50 liftboats. Once you have selected a vessel and the program has opened the appropriate files, you simply click the "Begin Editing Data" button. This will bring the screen to Liftinpt.xls

Once you have edited the data that you require for your first run (or at any time) you will see a table of calculated wind moments and forces will be displayed. Click on the *Print Input Screen and Wind Loads* button to print the input data and wind loads, assuming that your printer is hooked up correctly.

Click on the button marked *Go on to Structural Response* to move to the main results section of the program. Another data screen will be displayed. Along the top of this you will see the words *Microsoft Excel - Lift001.xls*. Your screen should appear as shown overleaf.

STA LIFTBOAT v4.1 August 1998		8/12/98 Date	
Stewart Technology Associates		Boat Name: Dennis Doyle 5' Width Added	
Licenced User: US Coast Guard.		Run Ref.: 40kn, 2kn, 14', 10s, 120'/15'4'	
<input type="button" value="Input Leg Data"/> <input type="button" value="Tabular Results"/> <input type="button" value="Input Summary"/> <input type="button" value="Back to Input File"/> <input type="button" value="UC"/> <input type="button" value="Stresses"/> <input type="button" value="Transit"/> <input type="button" value="Auto Calc. Penetration"/> <input type="button" value="Auto coeffs."/> <input type="button" value="Go to Master Input"/>			
<input type="button" value="Graphical Results"/> <input type="button" value="Print this screen"/> <input type="button" value="Print graphs"/> <input type="button" value="Print all tables"/> <input type="button" value="Print all results"/> <input type="button" value="Set 5' Penetrn."/> <input type="button" value="Manual coeffs."/>			
Leg Hydrodynamic coefficients shown below BELOW:			
4.02 DE, equiv. leg diam.(ft)		0.78 CDEaverage	
		0.86 CDEmax, max drag coef.	
INPUT CONTROL AND MISCELLANEOUS DATA BELOW:			
EDIT USER DEFINED VARIABLES			
		1	deflection multiplier (1 = normal)
4320000	Young's Modulus, leg steel (ksf)	1	MomSwitch, 0=off
1	nat.period multiplier (norm.=1; no dyn.=.01)	1.40	K-equivalent
60	yield stress for leg steel	40.0 psf	cu, surface
2	accept calc. wt/ft (1=no, 2=yes)	12.0 psf/ft	cu rate
2	accept hull gyrad. (1=no, 2=yes)	12.46 ft	pad pen.
190 psf	su needed to support pad (psf)	12.46 ft	pad pen.input
190 psf	su, soil und.shear str. below pad	10.56	pad equiv. radius (ft)
100	coef.on su to get soil G modulus	0.577	calculated leg kips/ft
1.55E+05	ks, calc.rot.stiff.soil (kip-ft/rad)	39.45	calculated hull gyrad.
800000	kj, rot.stiff.jack/hull (kip-ft/rad)	0.00	USER SPEC.leg kips/foot
0	Ke0, horiz.offset coef.	0.00	USER SPEC. gyrad. (ft)
0.64	cylinder drag coef.(w/marine growth)	0.00	Beta, calculated
0.00	marine growth thickness (inches)	-2.461778867	Mu, calculated
5.10		5.10	total damping (% crit.)
INPUT JACKING TOWER DATA BELOW:			
7.00	VCG lower guide (ft)	2	geometry select.switch
19.00	b, jack vcg (ft)	1	guide space multiplier (1 or 0)
0	h, jack support spacing (ft) used only if two racks	24.50	d, guide spacing (ft)
1		1	1 OR 2 RACK SWITCH

There are around 30 extra items of data that you may optionally edit in the cells with a yellow background and bold black (or red) characters within them. In the section below this, you will see:

INPUT LEG STRUCTURAL DATA BELOW:

The leg structural definition, including internal stiffening, and up to 5 different leg sections, is then defined.

You may jump to the main table of results simply by clicking on the gray button near the top of this screen labeled *Tabular Results*. Alternatively, you may jump to the input summary by clicking on the button labeled *Input Summary*. Other buttons at the locations around the screen that you jump to will permit you to either print the data displayed or to jump back to the "home" point in the upper left hand portion of the screen.

At any time you may click on the gray button *Go back to Input File*. This will jump you immediately back to the main input data file and you may change, for example, wave height or wind speed and jump back immediately to the structural response file by clicking the *Go on to Structural Response* button.

Master Data Input Sheet

A separate workbook with 50 worksheets is provided, MASTERINPUT.xls, in order to set up numerous load cases for a single vessel.

STA LIFTBOAT v4.1 August 1998				08/12/98 Date of this run		LC1		
Licenced User: US Coast Guard.				Rig Name: Dennis Doyle 5' Width Added				
Copyright 1990 and onwards, Stewart Technology Associates				Loadcase description: LC1				
<p style="color: red; text-align: center;">This data set will be pasted into the LIFTINPT.XLS file when the user presses the "Paste Data" button. The user may then immediately examine the results by pressing the "Go on to Structural Response" button.</p>								
<input type="button" value="Go on to Structural Response"/>		<input type="button" value="Print this screen"/>		<input type="button" value="Paste Data"/>		<input type="button" value="Go back to Input File"/>		
<i>Only data in shaded (yellow) cells can be edited. Last data used is displayed.</i>								
EDIT INPUT DATA				25.00	AvShield	90.00	Wave attack angle (deg)	
10.00	Input wave height (ft)			4.00	4.00	4.00	Leg diams 1,2,3 (ft)	
10.00	Input wave period (sec)			1.75	1.75	1.75	Cm1, Cm2, Cm3	
120.0	Input water depth (ft)			0.70	0.70	0.70	CD1, CD2, CD3	
0	Lattice area (sqft)			0.00	lattice av.ht.(ft)		40.0	wind v2 (kn)
30.00	WH1 (ft)	56.00	WH2 (ft)	2.00	tide vel (kn)			
119.00	WB (ft)	55.00	WL (ft)	0.00	LeverArm	1500	Total weight (kips)	
85.50	distance from aft to fwd legs (ft)					31.20	LCG (ft to foward legs)	
57.00	distance bet. fwd. leg centers (ft)					0.00	TCG (+ve towards L1)	
12.46	pad penetration (ft)	1.00	leg buoy. 1=dry 2=flood			0.00	init phase ang (deg)	
0	windforce kips	15.00	air gap (ft)			0.00	wind elev (ft)	
Wind force switch:		2	(1=input; 2=computed)			170.00	tot. leg length (ft)	
<input type="button" value="Select Load Case"/>								

Each of the 50 sheets appears similar to the figure above. In the upper right corner of the screen you will see the load case identifier (in this example LC1). You may use the *Select Load Case* button to choose another load case, or elect to use Excel's sheet tabs to move around the MasterInput workbook.

When you have edited a load case data set you wish to use for analysis, press the *Paste Data* button, and your data will be transferred to the Liftinpt.xls workbook. From there it is automatically linked to the structural response workbook (Lift001.xls).

For more details on controls, data input, and results read the rest of this manual.

4.0 GENERAL PROGRAM OPERATION: STEP BY STEP PROCESS

STA LIFTBOAT is designed so that almost all operations that the user may wish to perform can be undertaken by clicking with the mouse. Actual data entry is from the keyboard, but no keyboard commands are necessary. Figure 1 below shows the initial screen of data that is presented to the user when the program starts.

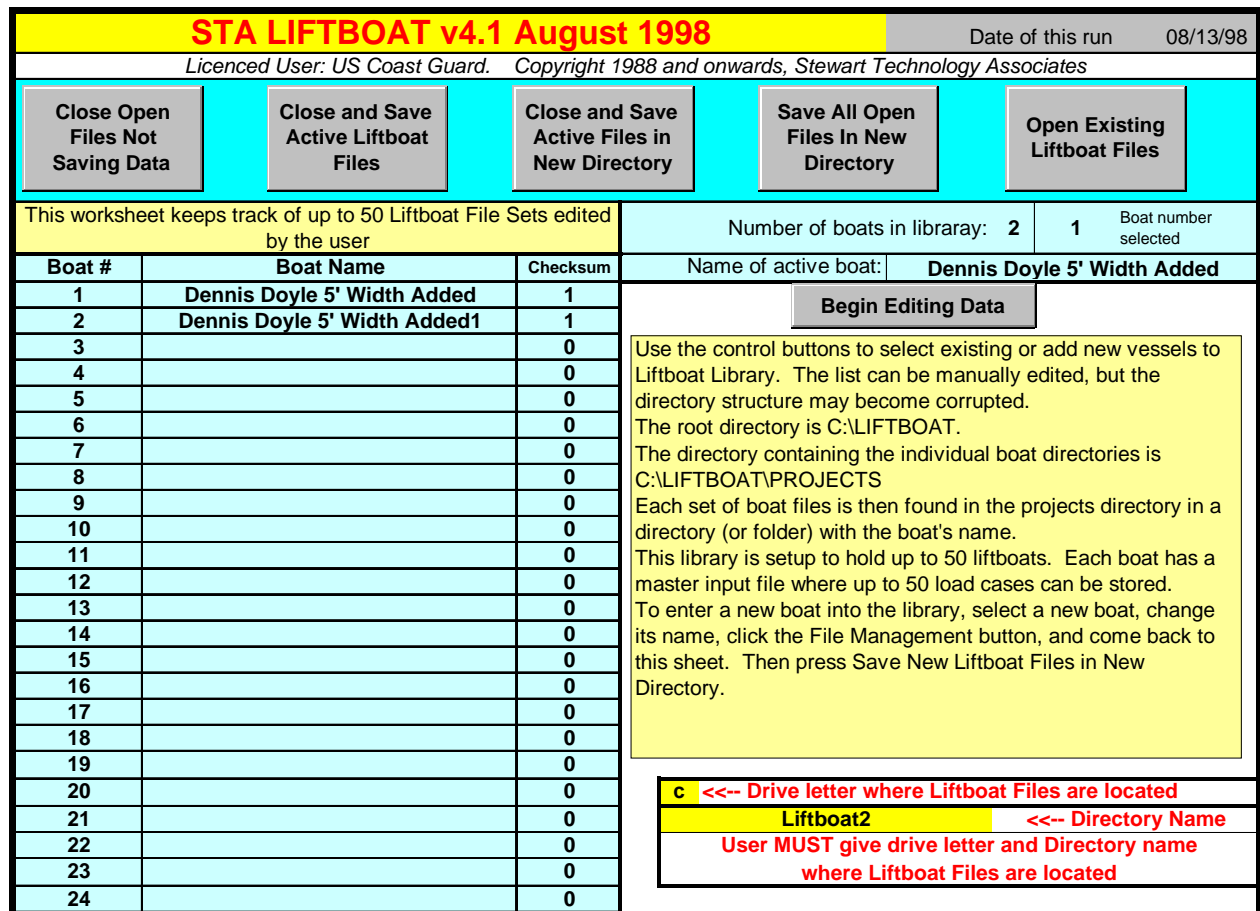


FIGURE 1 – liftboatopen.xls Main Screen

Step 1

If necessary change the drive letter and directory name where you installed the STA LIFTBOAT program.

Step 2

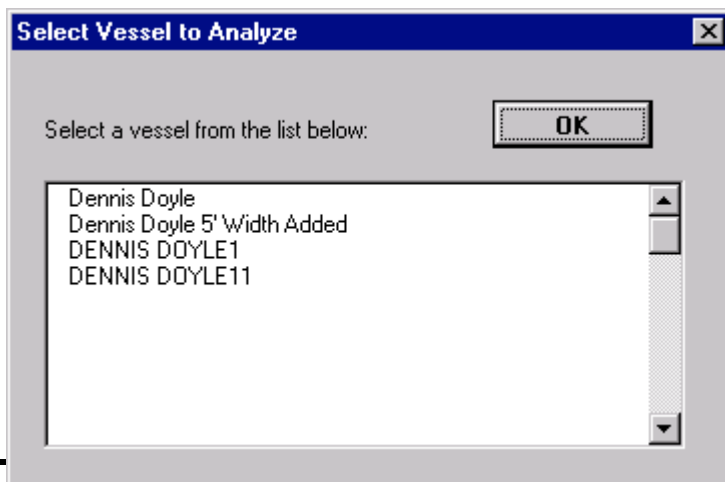
Open Stored Liftboat Files

Click this button next.

A scroll list will appear in a dialog box, as shown to the right.

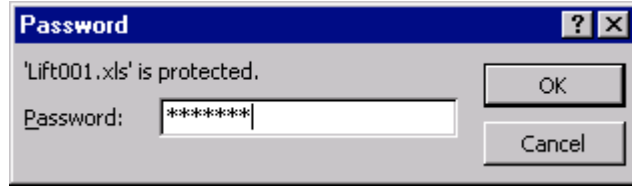
Step 3

Select a previously stored vessel and click OK.



Step 4

Enter password to required to open selected vessel data files.



Step 5

If you want to analyze the selected vessel begin editing data on the Liftinpt.xls screen shown in Figure 2, below.

If you want to input data for a new vessel (not already stored in the library) Edit the boat name in the upper right hand corner of Figure 1 and click the button *File Management*. Now go to Step 6.

STA LIFTBOAT v4.1 August 1998		08/12/98 Date of this run	
Licenced User: US Coast Guard.		Boat name: Dennis Doyle 5' Width Added	
Copyright 1990 and onwards, Stewart Technology Associates		Run Ref.: 40kn, 2kn, 14', 10s, 120'/15'4'	
THIS IS THE MAIN DATA INPUT SCREEN - CLICK BUTTON TO GO TO RESPONSE			
Go on to Structural Response		Print Input Screen and Wind Loads	
Go to Master Input		File Management	
Only data in shaded cells can be edited. Last data used is displayed.			Build New Boat Master Input File
EDIT INPUT DATA			
25.00	AvShield	90.00	Wave attack angle (deg)
10.00	Input wave height (ft)	4.00 4.00 4.00	Leg diams 1,2,3 (ft)
10.00	Input wave period (sec)	1.75 1.75 1.75	Cm1, Cm2, Cm3
120.0	Input water depth (ft)	0.70 0.70 0.70	CD1, CD2, CD3
0	Lattice area (sqft)	0.00	lattice av.ht.(ft) 40.0
30.00	WH1 (ft)	56.00	WH2 (ft)
119.00	WB (ft)	55.00	WL (ft)
85.50	distance from aft to fwd legs (ft)	0.00	LeverArm
67.00	distance bet. fwd. leg centers (ft)	1500	Total weight (kips)
12.46	pad penetration (ft)	31.20	LCG (ft to foward legs)
0	windforce kips	0.00	TCG (+ve towards L1)
15.00	air gap (ft)	0.00	init phase ang (deg)
2	Wind force switch: (1=input; 2=computed)	0.00	wind elev (ft)
22.54 ft	leg length above hull bottom	170.00	tot. leg length (ft)
		29.21 ft	min.leg length to be above hull botto

FIGURE 2 – Liftinpt.xls Workbook Main Screen (start of your analysis data entry)

Step 6

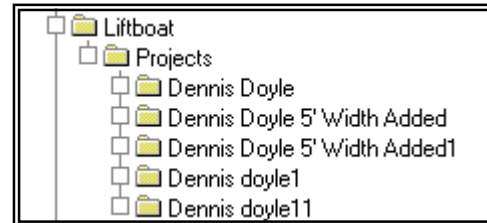
Any time the File Management button is clicked, the user is returned to the liftboatopen.xls workbook. If a new boat is to be created (see Step 5, above) the user should now click on the button *Save New Liftboat Files in New Directory*, as illustrated in Figure 3, below

STA LIFTBOAT v4.1 August 1998		date of this run 08/12/98	
Licenced User: US Coast Guard. Copyright 1988 and onwards,		Associates	
Close Open Files Not Saving Data	Close and Save Active Liftboat Files	Close and Save Active Files in New Directory	Save All Open Files In New Directory
This worksheet keeps track of up to 50 Liftboat File Sets edited by the user		Number of boats in libraray: 1	1 Boat number selected
Boat #	Boat Name	Checksum	Name of active boat: Dennis Doyle 5' Width Added
1	Dennis Doyle 5' Width Added	1	Begin Editing Data
2		0	




FIGURE 3 – Top Part of LIFTBOATSTART.XLS Screen.

If the new boat name you gave in Step 5 does not exist in the present Boat Name list, this will be the new name that will show up in the list after the new files have been saved. If the name already exists, a "1" will be added to the existing name and a new set of files for *Existing Name1*, for example, will be created.

The directory (or folder) structure used by STA LIFTBOAT is shown to the right. In this example the Dennis Doyle has been saved to a new set of files twice. Dennis Doyle1 and Dennis Doyle11 directories have been created.



In each of the Projects directories three workbook files exist. These files are shown in the figure below.

 Lift001.xls	657,408	8/9/98	12:18:18 PM	a
 Liftinpt.xls	264,704	8/9/98	12:18:22 PM	a
 MasterInput.xls	358,400	8/9/98	12:18:22 PM	a

In the main Liftboat directory, or folder, there should be the liftboatopen.xls workbook, the STA LIFTBOAT icon file, and the Projects directory.

See section on deleting unwanted files before trying to delete any saved liftboat files.

Step 7

If you are at the liftboatopen.xls workbook because you have clicked the *File Management* button, but you have an open set of liftboat files, click the *Begin Editing Data* button and you will be jumped to the Liftinpt.xls workbook. The screen you will see is illustrated in Figure 2.

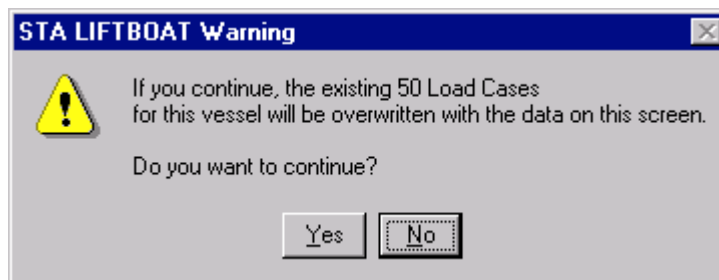
If you have simply selected a vessel to analyze and have already been jumped to the screen in Figure 2, you may begin editing data. There are several routes you can now take:

1. Simply change one or more environmental parameters and go on to Structural Response.
2. Change the basic vessel configuration, for example:
 - Change leg spacing
 - Change wind areas
 - Change total weight
 - Change leg diameters
 - Change legs from dry to flooded
 - Change Wind Loads from calculated to user input
 - Change LCG and TCG

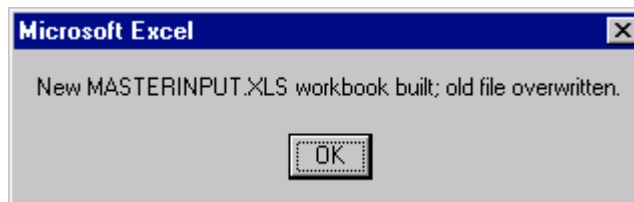
3. Change vessel site parameters, such as:
 - Air gap
 - Pad penetration
 - Water depth
4. Change a combination of all of the above.
5. Build a New Boat Master Input File.

If you select to build a new MASTERINPUT.xls file, by clicking on the orange button on the Liftinpt.xls screen (Figure 2) the data presently displayed in Liftinpt.xls will be pasted onto all 50 worksheets in the MASTERINPUT.xls workbook. You will be warned that all existing data will be overwritten.

The warning message box is shown to the right.



If you continue (by clicking Yes) the 50 load cases in MASTERINPUT.xls will be created from the data on the screen and a message box will appear as shown to the right.



The advantage of this procedure is that a new boat can be built with appropriate characteristics. However you will have to re-enter any environmental load cases you want to analyze.

Step 8

Instead of simply editing the data on the Liftinpt.xls screen, you can edit any one of 50 load cases in the MASTERINPUT.xls workbook. You can switch to this workbook by clicking the button *Go to Master Input*. Each of the 50 load cases in the MASTERINPUT.xls workbook looks like the Liftinpt.xls main screen. The buttons are a little different. An example is shown in Figure 4, overleaf.

You can either use the button *Select Load Case*, or you can display sheet tabs and move from one load case to another. When you want to use a load case in your analysis, simply press the button *Paste Data* and the load case data will be automatically pasted to the Liftinpt.xls workbook. From there it is automatically linked to the Lift001.xls workbook where the main analysis takes place.

STA LIFTBOAT v4.1 August 1998		08/12/98 Date of this run	LC1
Licenced User: US Coast Guard.		Rig Name: Dennis Doyle 5' Width Added	
Copyright 1990 and onwards, Stewart Technology Associates		Loadcase description: LC1	
<p style="color: red; text-align: center;">This data set will be pasted into the LIFTINPT.XLS file when the user presses the "Paste Data" button. The user may then immediately examine the results by pressing the "Go on to Structural Response" button.</p>			
Go on to Structural Response		Print this screen	Paste Data
			Go back to Input File
Only data in shaded (yellow) cells can be edited. Last data used is displayed.			
EDIT INPUT DATA		25.00 AvShield	90.00 Wave attack angle (deg)
10.00	Input wave height (ft)	4.00 4.00 4.00	Leg diams 1,2,3 (ft)
10.00	Input wave period (sec)	1.75 1.75 1.75	Cm1, Cm2, Cm3
120.0	Input water depth (ft)	0.70 0.70 0.70	CD1, CD2, CD3
0	Lattice area (sqft)	0.00 lattice av.ht.(ft)	40.0 wind v2 (kn)
30.00	WH1 (ft)	56.00 WH2 (ft)	2.00 tide vel (kn)
119.00	WB (ft)	55.00 WL (ft)	0.00 LeverArm
85.50	distance from aft to fwd legs (ft)		1500 Total weight (kips)
57.00	distance bet. fwd. leg centers (ft)		31.20 LCG (ft to foward legs)
12.46	pad penetration (ft)	1.00 leg buoy. 1=dry 2=flood	0.00 TCG (+ve towards L1)
0	windforce kips	15.00 air gap (ft)	0.00 init phase ang (deg)
	Wind force switch: 2 (1=input; 2=computed)		0.00 wind elev (ft)
			170.00 tot. leg length (ft)
Select Load Case			

FIGURE 4 – MASTERINPUT.xls Workbook Example Screen.

Step 9

Go on to structural response by pressing the appropriate button. Your screen will appear as shown in Figure 5, below.

STA LIFTBOAT v4.1 August 1998		8/12/98 Date
Stewart Technology Associates		Boat Name: Dennis Doyle 5' Width Added
Licenced User: US Coast Guard.		Run Ref.: 40kn, 2kn, 14', 10s, 120'/15'4'
Input Leg Data		
Tabular Results	Input Summary	Back to Input File
Graphical Results	Print this screen	Print graphs
	Print all tables	Print all results
	Set 5' Penetrn.	Manual coeffs.
		Go to Master Input
		UC Stresses Transit Auto Calc. Penetration Auto coeffs.
Leg Hydrodynamic coefficients shown below BELOW:		
4.02 DE, equiv. leg diam.(ft)	0.78 CDEaverage	0.86 CDEmax, max drag coef.
INPUT CONTROL AND MISCELLANEOUS DATA BELOW:		
EDIT USER DEFINED VARIABLES		1 deflection multiplier (1 = normal)
4320000	Young's Modulus, leg steel (ksf)	1.40 K-equivalent
1	nat.period multiplier (norm.=1; no dyn.=.01)	1037 Average maximum allowable pad moment
60	yield stress for leg steel	871 pad moment amplitude
2	accept calc. wt/ft (1=no, 2=yes)	1 add.mass coef.(1 = normal)
2	accept hull gyrad. (1=no, 2=yes)	19.00 VCG excluding legs (ft) (for transit)
190 psf	su needed to support pad (psf)	12.46 ft pad pen.input
190 psf	su, soil und.shear str. below pad	10.56 pad equiv. radius (ft)
100	coef.on su to get soil G modulus	0.577 calculated leg kips/ft
1.55E+05	ks, calc.rot.stiff.soil (kip-ft/rad)	39.45 calculated hull gyrad.
800000	kj, rot.stiff.jack/hull (kip-ft/rad)	0.00 USER SPEC.leg kips/foot
0	Ke0, horiz.offset coef.	0.00 USER SPEC. gyrad. (ft)
0.64	cylinder drag coef.(w/marine growth)	0.00 Beta, calculated
0.00	marine growth thickness (inches)	0.68 Mu, calculated
		-2.461778867 5.10 total damping (% crit.)

FIGURE 5 – Structural Response Screen in Workbook Lift001.xls.

Step 10

Edit soil strength data, if required. Edit pad penetration, if required. Edit coefficient on su to get soil G modulus, if required. Edit pad and leg data (these data are in the

structural file below the data shown in Figure 5). Once you have finished editing data you can look at the results in either tabular or graphical form. However there are now some important controls to consider. Button controls in the various program screens are described in the next section of this manual.

5.0 BUTTON CONTROLS

5.1 STAINPT.XLS Buttons

In the upper part of the screen on the right hand side, the boat name and run reference can be edited by the user. The run reference and boat name will appear on the graphs that are automatically produced when the program executes. Note that the date of the run shown in the upper right hand corner of the screen is taken from the computer's own system clock. Hence if this is incorrect, the date will appear to be wrong.

STA LIFTBOAT v4.1 August 1998		08/12/98 Date of this run	
<i>Licenced User: US Coast Guard.</i>		Boat name: Dennis Doyle 5' Width Added	
Copyright 1990 and onwards, Stewart Technology Associates		Run Ref.: 40kn, 2kn, 14', 10s, 120'/15'/4'	
THIS IS THE MAIN DATA INPUT SCREEN - CLICK BUTTON TO GO TO RESPONSE			
Go on to Structural Response		Print Input Screen and Wind Loads	
Go to Master Input		File Management	
Only data in shaded cells can be edited. Last data used is displayed.			Build New Boat Master Input File

FIGURE 6 – Buttons on STAINPT.XLS Screen

The buttons which appear gray on the screen appear white in the hard copy, as seen in Figure 6 above. Clicking the mouse once on any of the five buttons seen in Figure 6 will perform the following tasks:

- *Go On To Structural Responses* - This will move the user from the input data screen to the first screen of response data where further parameters that the user may edit are contained.
- *Print this screen* - This will instruct the system, through the printer that has been set up in Windows (in the control panel), to print the data displayed on the screen.
- *Go to Master Input* - This takes the user to the MASTERINPUT.xls workbook where up to 50 load cases can be stored and edited.
- *File Management* - This button takes the user back to the Liftboatopen.xls workbook where another set of files for another boat may be opened, a new boat may be saved, etc.

Most of the other information contained on the first input data screen is technical and is described in the next section of this manual. However, it is worth noting that there is one "switch" on this screen which is in the bottom row of the screen near the left hand side. This cell is labeled *Wind force switch*. If the value is set to one, then the program seeks to find a wind force on the left hand side of the screen in the cell labeled *wind force (kips)*. If the *Wind force switch* is set to two, the program uses the wind areas and velocities specified by the user to calculate wind loads on the boat.

5.2 Lift001.XLS Buttons

Figure 7, below, shows the screen that is presented to the user after clicking on the button on the first screen labeled *Go on to Structural Response*. A series of buttons is shown in the upper part of this screen. The actions of the buttons are generally intuitive, but for completeness are described below.

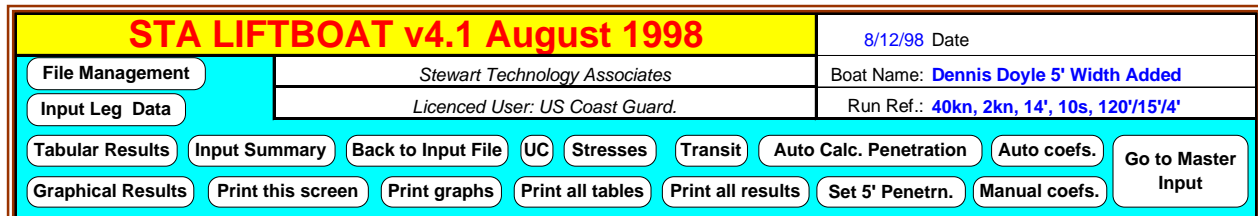


FIGURE 7 - Buttons on Upper Part of Lift001.XLS Screen

- *File Management* - This button takes the user back to the Liftboatopen.xls workbook where another set of files for another boat may be opened, or a new boat may be saved, etc.
- *Input Leg Data* - - Clicking on this button will jump the user to the section of the worksheet (directly below the upper left corner of the main input section) where detailed information on leg cross section data, internal stiffening, etc., is to be input.
- *Tabular Results* - This jumps to the section of the results file where a table of results is given.
- *Input Summary* - This jumps to the input summary contained within the results file.
- *Back to Input File* - This takes the user immediately back to the input data file where environmental conditions, for example, could be changed.
- *UC* - Clicking on this button jumps the user to the unity stress checks portion of the Results Summary.
- *Stresses* - This takes the user to the top of the portion of the worksheet where the stress calculations are performed. Use the scroll bars and the mouse to move down this section to investigate the stress calculations.
- *Transit* - Clicking on this button jumps the user to the top of the leg force, moment, and stress calculations associated with vessel roll and heave motions in transit. Use the scroll bars and the mouse to move down this section to investigate the leg stress-while-in-transit calculations.
- *Auto Calc Penetration* – Clicking on this button causes the program to iterate until it has penetrated all pads to a depth needed to get the bearing capacity equal to the maximum pad load computed in this run. The soil undrained shear strength is used as input by the user in cells D13 and D14 on this sheet. The pad penetration depth is modified in the Liftinpt.xls workbook and reflected in the Lift001.xls workbook on this sheet in cells D15 and D16. The assumption made with this approach is that all

three legs will be preloaded to this same level and all three legs will penetrate the same amount during preloading.

- *Auto coefficients* - Clicking on this button causes the program to perform two sequential sets of iterative calculations. First the program iterates until the induced pad moments balance with the soil rotational stiffness. The soil shear strength is set initially to the minimum value calculated to be necessary to provide the maximum calculated pad vertical reaction during the wave cycle. With this value and the user-defined *coefficient on cu to get soil G modulus*, the program then finds a rotational spring stiffness at the pad, and hence an applied moment from the soil resisting leg rotation, together with the global response of the vessel. Then the maximum pad vertical reaction is found. If the bearing capacity required to support this reaction is greater than the soil can provide, based on the soil shear strength and classical bearing capacity formulae, the program increases the soil shear strength. This increases the soil shear modulus and the rotational spring stiffness, reducing global response as pad moments increase. The program iterates until a solution is found (see Section 9 for further details). If *Auto Calc Penetration* has been selected, then the pad penetration depth is increased/decreased as the iterative calculations proceed. If the *Set 5' Penetrn.* button has been clicked, the pad penetration will remain at 5' (or any other constant value selected by the user in the Liftinpt.xls workbook)

Next the program changes the damping term until the calculated response is matched with the correct damping (see Section 9 for further details).

NOTE: If impossible input conditions are given (for example negative length of leg sections) the automatic coefficient calculation routines will fail. The program will show a warning message to the user advising that the *Manual Coefficients* button must be clicked after the input has been corrected. The *Auto Coefficients* button may be clicked only after input errors have been rectified. Also the user should click the *Set 5' Penetrn.* button before clicking the *Auto Coefficients* button if the program indicates errors in formulae.

- *Graphical Results* - Clicking on this button opens a dialogue box where the user may select which of ten graphs he or she may wish to view. Once a graph is selected from the dialogue box, the user should click *OK* in the dialogue box and the program will jump to the graph selected. Buttons on the graphs provide the user an option to either return to the main menu at the top of the screen or to print the graph. After the graphs have printed, the user will be returned back to the main area at the top of the screen.

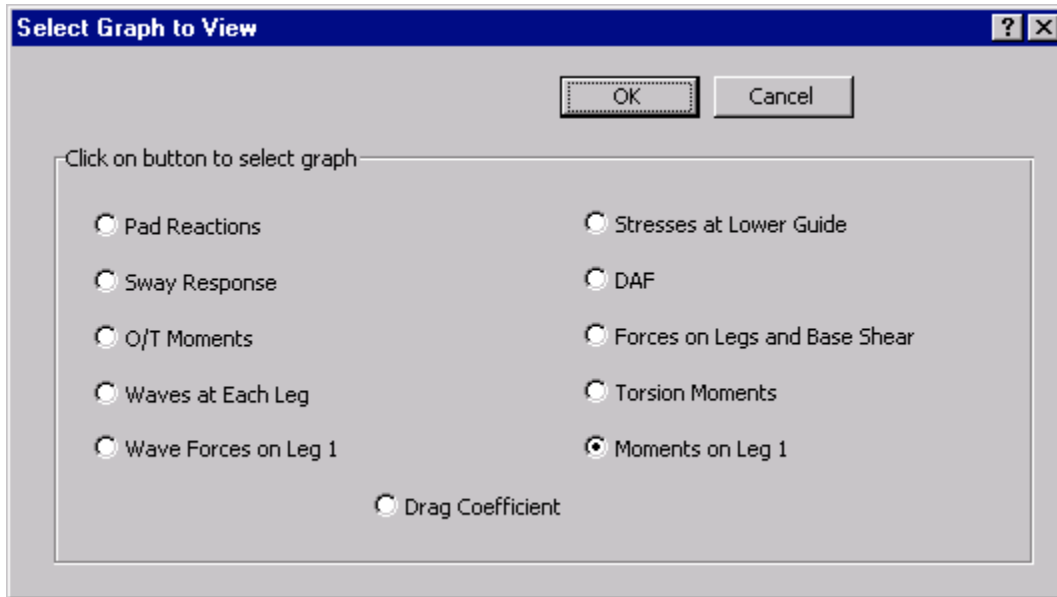


FIGURE 8 – Graph Selection Dialog Box

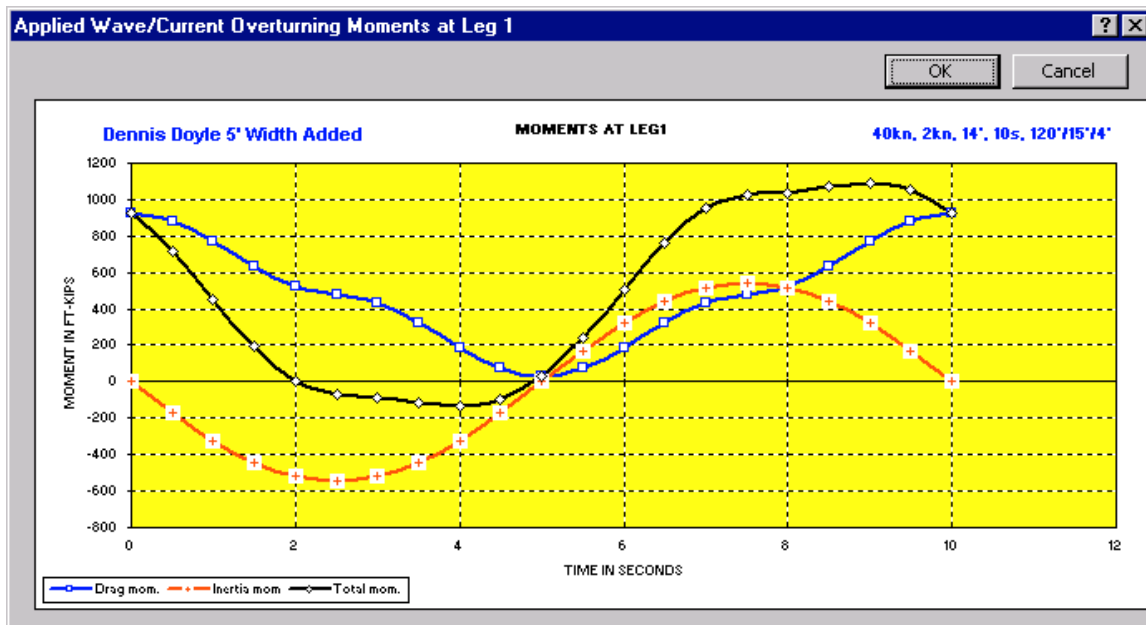


FIGURE 9 – Example Graph

- *Print this screen* - Clicking on this button will cause the computer to print the data screen as shown in Figure 10. Note that depending upon the display monitor you are using, you may be able to see all of this data screen or just a part of it. You may use the scroll bars to move around in the spread sheet to view different parts of this and any other screen.

STA LIFTBOAT v4.1 August 1998				8/12/98 Date	
File Management		Stewart Technology Associates		Boat Name: Dennis Doyle 5' Width Added	
Input Leg Data		Licenced User: US Coast Guard.		Run Ref.: 40kn, 2kn, 14', 10s, 120'/15/4'	
Tabular Results	Input Summary	Back to Input File	UC	Stresses	Transit
Graphical Results	Print this screen	Print graphs	Print all tables	Print all results	Set 5' Penetrn.
				Auto Calc. Penetration	Auto coefs.
				Manual coefs.	Go to Master Input
Leg Hydrodynamic coefficients shown below BELOW:					
4.02 DE, equiv. leg diam.(ft)		0.78 CDEaverage		0.86 CDEmax, max drag coef.	
INPUT CONTROL AND MISCELLANEOUS DATA BELOW:					
EDIT USER DEFINED VARIABLES					
				1	deflection multiplier (1 = normal)
4320000	Young's Modulus, leg steel (ksf)	1	MomSwitch, 0=off	1.40	K-equivalent
1	nat.period multiplier (norm.=1; no dyn.=.01)			1037	Average maximum allowable pad moment
60	yield stress for leg steel	40.0 psf	cu, surface	871	pad moment amplitude
2	accept calc. wt/ft (1=no, 2=yes)	12.0 psf/ft	cu rate	1	add.mass coef.(1 = normal)
2	accept hull gyrad. (1=no, 2=yes)	12.46 ft	pad pen.	19.00	VCG excluding legs (ft) (for transit)
190 psf	su needed to support pad (psf)	12.46 ft	pad pen.input	10.56	pad equiv. radius (ft)
190 psf	su, soil und.shear str. below pad			0.577	calculated leg kips/ft
100	coef.on su to get soil G modulus			39.45	calculated hull gyrad.
1.55E+05	ks, calc.rot.stiff.soil (kip-ft/rad)		Maximum pad moment	0.00	USER SPEC.leg kips/foot
8000000	kj, rot.stiff.jack/hull (kip-ft/rad)		1585 kp-ft	0.00	USER SPEC. gyrad. (ft)
0	Ke0, horiz.offset coef.			0.00	Beta, calculated
0.64	cylinder drag coef.(w/marine growth)			0.68	Mu, calculated
0.00	marine growth thickness (inches)	-2.461778864		5.10	total damping (% crit.)
INPUT JACKING TOWER DATA BELOW:					
7.00	VCG lower guide (ft)			2	geometry select.switch
19.00	b, jack vcg (ft)	1	guide space multiplier (1 or 0)	24.50	d, guide spacing (ft)
0	h, jack support spacing (ft) used only if two racks			1	1 OR 2 RACK SWITCH
INPUT PAD DATA BELOW:					
2.00	pad 1/2 height (ft)	28.30 kips	pad buoyancy	25.00	pad length (ft)
20.5 kips	weight of 1 pad (kips)	-6.67 ft	spare leg length	14.00	pad width (ft)

FIGURE 10 – Printout Resulting From Clicking *Print This Screen* Button

- *Print graphs* - This will print all eleven of the graphs. They print on four separate pages as shown on the next four pages.
- *Print all tables* - Clicking on this option will print both the data screen shown in Figure 10, the Input Summary and Results Summary table shown in Figure 15, the Leg Structural Input Data shown in Figures 16 and 17, the Stress Check Intermediate Results table shown in Figure 18, and the Transit Condition Leg Stress Check table shown in Figure 19.

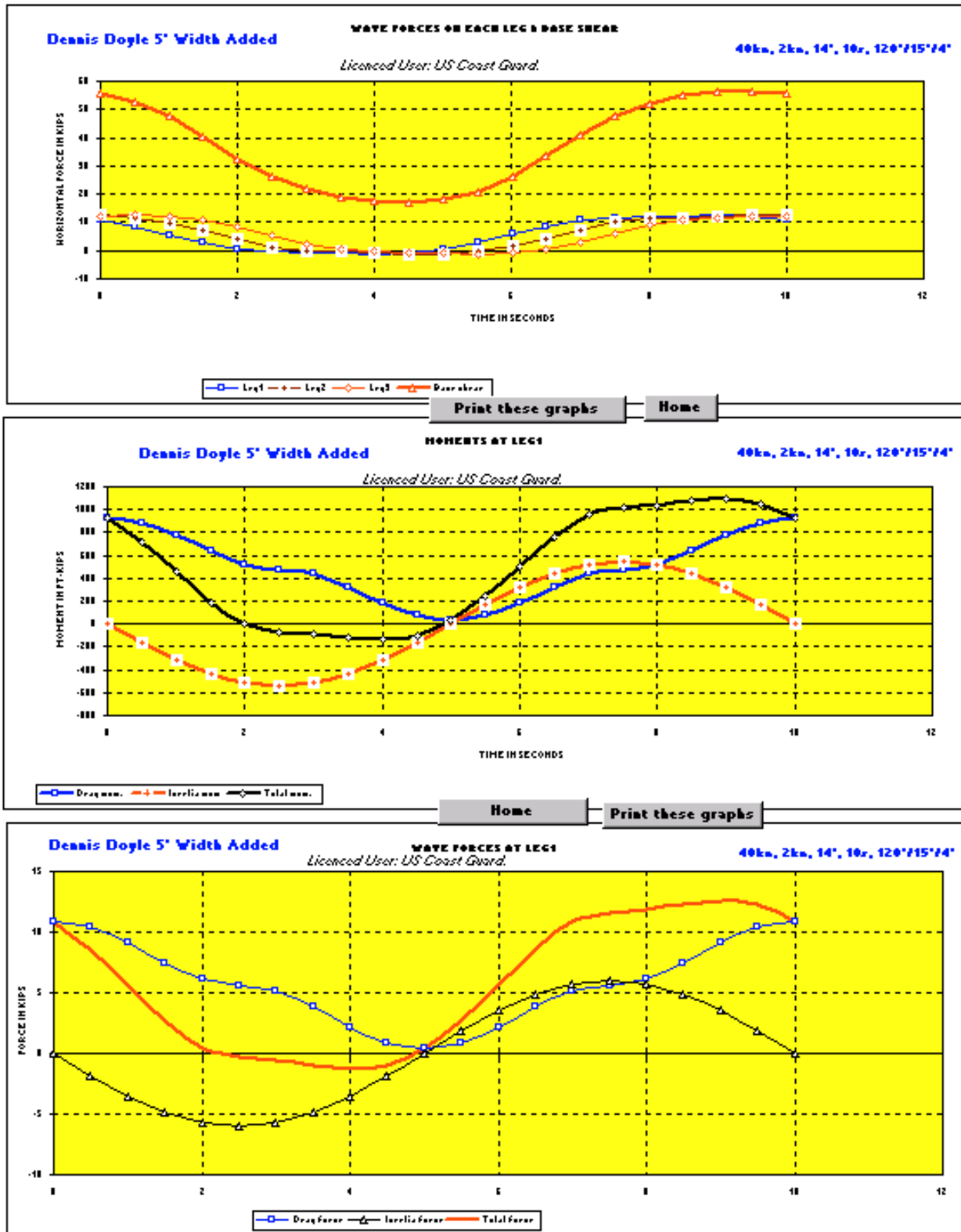


FIGURE 11 – First Set of Graphs

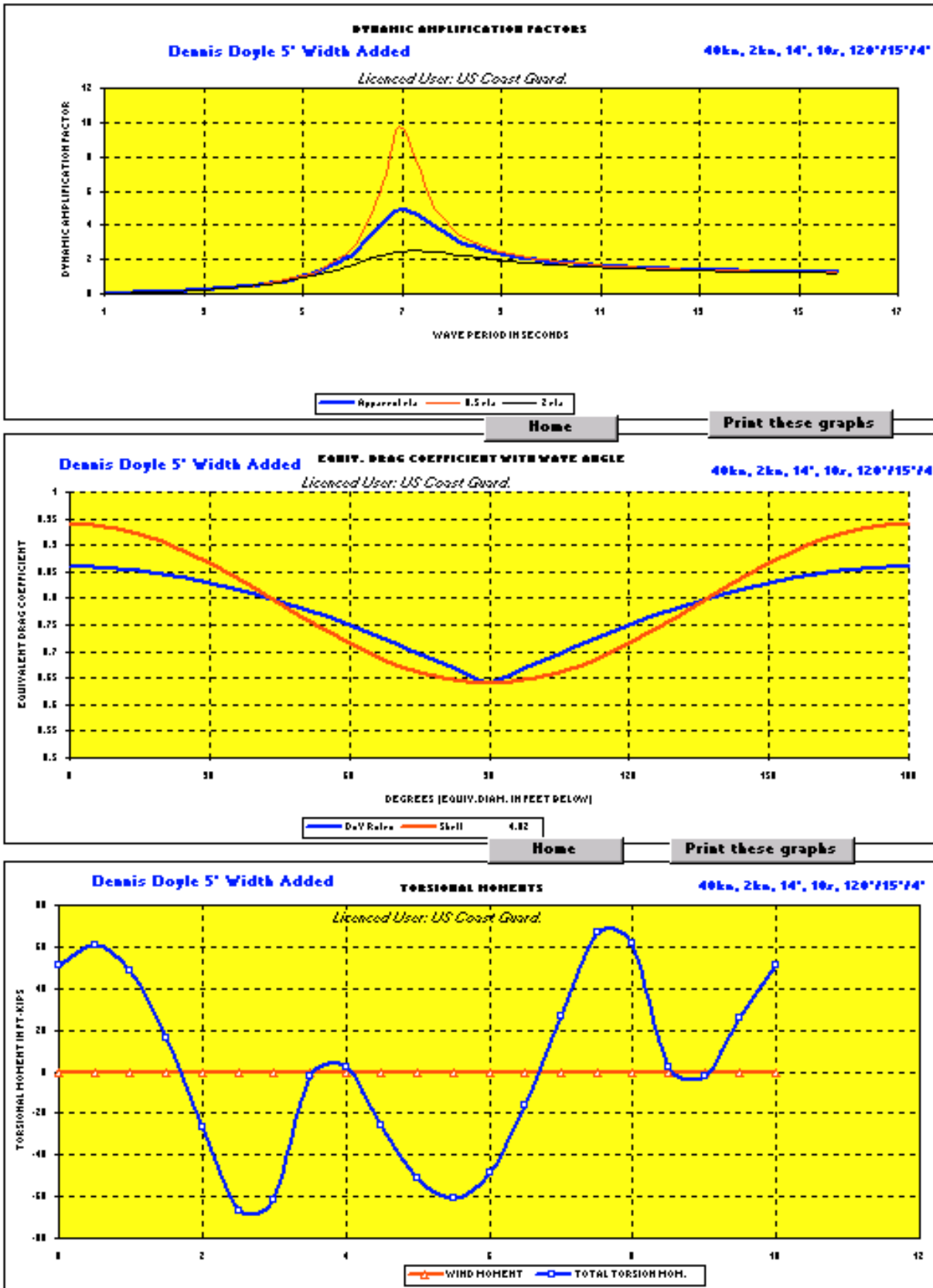


FIGURE 12 – Second Set of Graphs

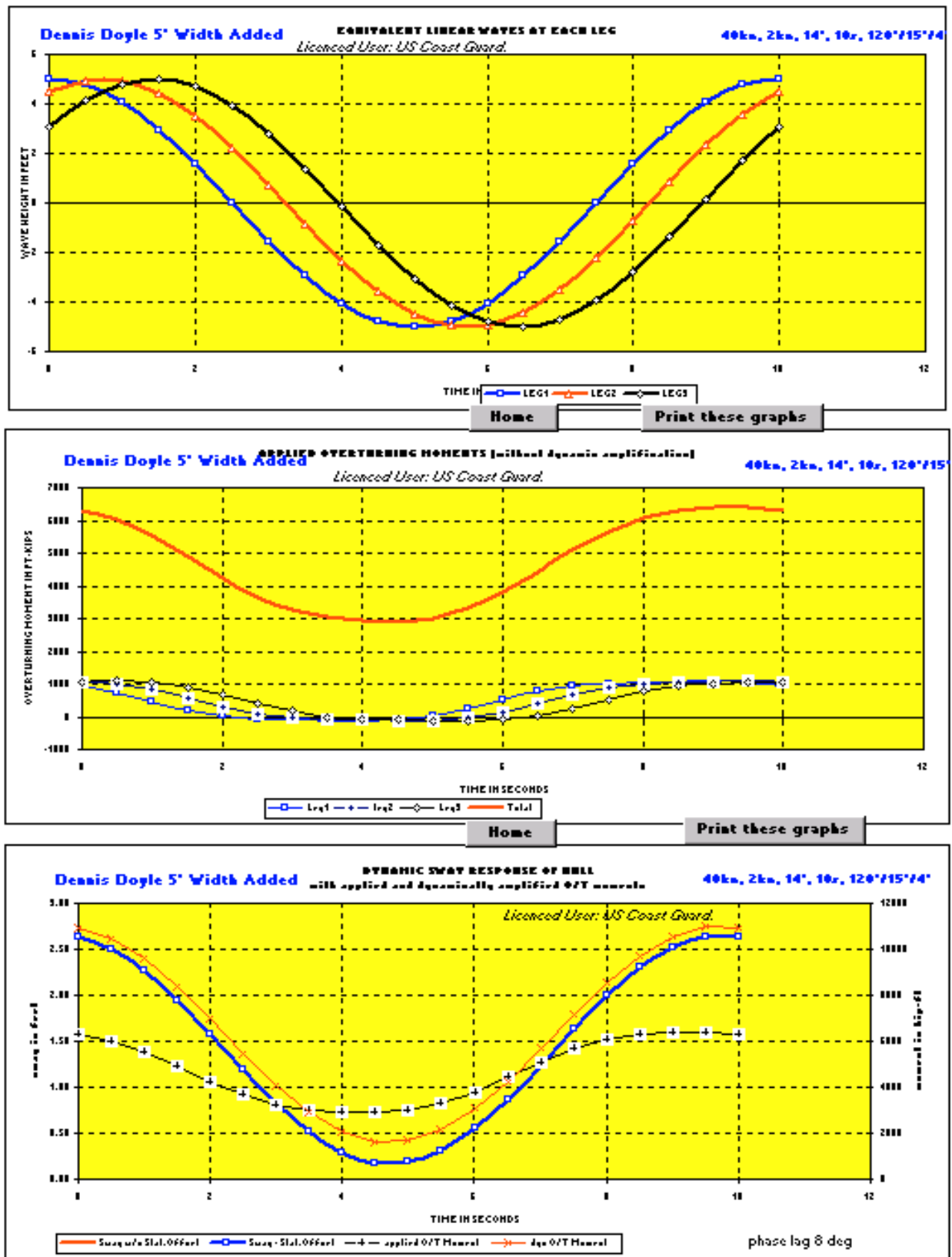


FIGURE 13 – Third Set of Graphs

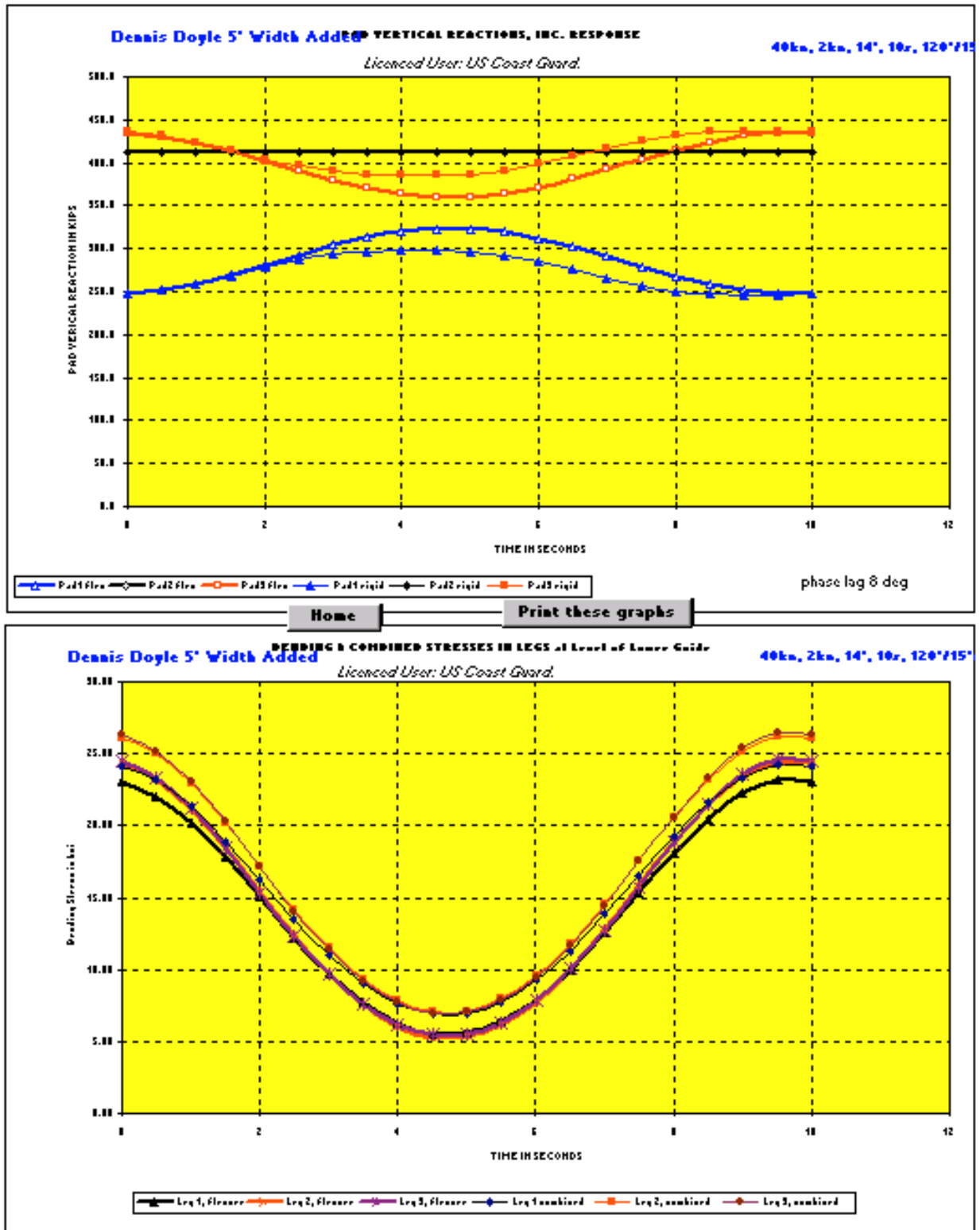


FIGURE 14 – Fourth Set of Graphs

STA LIFTBOAT v4.1 August 1998				Run date: 8/12/98	
<i>Copyright: Stewart Technology Associates, 1990 and onwards</i>			<i>Licensed User: US Coast Guard.</i>		
STA LIFTBOAT v4.1 August 1998				Boat Name: Dennis Doyle 5' Width Added	
INPUT SUMMARY				Run Ref: 40kn, 2kn, 14', 10s, 120'/15'4'	
Wave height	10.00	feet	Tidal current	2.00	knots
Wave period	10.00	seconds	Wave crest elevation	5.14	feet
Water depth	120.00	feet	Pad penetration	12.46	feet
theta, wave/wind direction	90.00	degrees	Air gap	15.00	feet
Wind force	COMPUTED	BELOW	Wind speed	40.00	knots
Leg equiv.av.diameter	4.00	feet	Av. leg mass coef.	1.75	coef.
Damping ratio	5.10	% crit.	Av. leg drag coef.	0.70	coef.
Total weight	1500	kips	Beta, top fixity	0.00	ratio
ks, soil rotational stiffness	1.55E+05	kipft/rad	Mu, bottom fixity	0.68	ratio
su, soil undnd.shear strnth.	189.54	psf	kj, Jack/Hull stiffness	8.00E+05	kipft/rad
coef.on su to get Gsoil	100.00	coef.	Equivalent pad radius	10.56	feet
LCG	31.20	feet	TCG	0.00	feet
Ke0, Offset coef.	0	LegLength	VCG excluding legs	19.00	feet
Fwd-aft leg dist	85.50	feet	Fwd leg spacing	67.00	feet
LegLength extended	154.46	feet	Total leg length	170.00	feet
Graphical Results				Print this screen	
STA LIFTBOAT v4.1 August 1998				Legs are dry internally	
RESULTS SUMMARY				Boat Name: Dennis Doyle 5' Width Added	
Pad1 before envmt. loads	341	kips	Pad2 before envmt.loads	413	kips
Pad3 before envmt. loads	341	kips	Weight - buoyancy	1096	kips
Av.leg buoyancy	135	kips	Total buoyancy	404	kips
Lateral Stiffness used	28.5	kips/ft	lateral x-stiffness	39.8	kips/ft
Wind force	20	kips	lateral y-stiffness	28.5	kips/ft
Max wave-current force	36.25	kips	Mean wave-current force	17	kips
Wind O/T moment	3232	ft-kips	Max. total force	56	kips
Amp.wav/cur.O/Tm	1740	ft-kips	Mean wav-cur.O/Tm	1434	ft-kips
Tnxw sway period	5.89	seconds	Max.apparent O/Tm	6406.10	ft-kips
Tnyy sway period	6.96	seconds	Max torsion moment	66.71	ft-kips
Natural torsional period	5.39	seconds	DAF (stochastic)	1.87	ratio
Mean hull deflection	1.41	feet	Hull deflection amplitude	1.24	feet
Max hull deflection	2.65	feet	Offset+deflection	2.65	feet
Uncorrected stabilizing mom.	23383	ft-kips	Euler leg load	1627	kips
Corrected stabilizing mom.	18661	ft-kips	Max. base shear	74	kips
Max.Up.guide reac.	171	kips	Max.low.gde.reac.	179	kips
Max.equiv.top load	62	kips	Max.horiz.pad reaction	21	kips
Pad max.calc.bend.mom.	1591	ft-kips	BM.hull max.w/oPD.	1724	ft-kips
PDelta leg BM.max	1150	ft-kips	BM.hull max. w/PD.	4190	ft-kips
PadMax.Id.uncorrd.	437	kips	PadMin.Id.uncorrd.	246	kips
Pad mean angle	0.3209	degrees	Pad max.angle	0.5901	degrees
Max.OT w/o PDelta	7871.26	ft-kips	Max.OT.mom.w.PD	10987	ft-kips
Max axial load at lower guide, Leg1	371.52	kips	Pad Ultimate Moment Capacity	1037	kip-ft
Max axial load at lower guide, Leg2	467.22	kips	Hull max.shr.str.	0.78	ksi
Max axial load at lower guide, Leg3	560.15	kips	K-Equivalent	1.40	coef.
Max axial stress at lower guide, Leg1	1.61	ksi	Uncorr. O/T SF	3.65	ratio
Max axial stress at lower guide, Leg2	2.02	ksi	Corrected O/T SF	2.13	ratio
Max axial stress at lower guide, Leg3	2.43	ksi	DnV O/T Safety F.	2.37	ratio
Max bend.str. at lower guide, Leg1	23.15	ksi	ABS pre-88 unity str.chk leg 1	0.71	ratio
Max bend.str. at lower guide, Leg2	24.41	ksi	ABS pre-88 unity str.chk leg 2	0.80	ratio
Max bend.str. at lower guide, Leg3	24.59	ksi	ABS pre-88 unity str.chk leg 3	0.86	ratio
fa/Fa ABS leg 1 (K-effective)	0.23	ratio	fb/Fb ABS leg 1 (K-effective)	0.48	ratio
fa/Fa ABS leg 2 (K-effective)	0.29	ratio	fb/Fb ABS leg 2 (K-effective)	0.51	ratio
fa/Fa ABS leg 3 (K-effective)	0.35	ratio	fb/Fb ABS leg 3 (K-effective)	0.51	ratio
			Rational Unity str.chk.leg 1	0.74	ratio
PadMax.Id.corrected	434.51	kips	Rational Unity str.chk.leg 2	0.80	ratio
PadMin.Id.corrected	248.46	kips	Rational Unity str.chk.leg 3	0.86	ratio

FIGURE 15 – Input Summary and Summary Results

INPUT LEG STRUCTURAL DATA BELOW:

Leg section properties are permitted to vary along a liftboat leg, with up to five different sections being specified. The diagram below shows how stiffeners are defined inside the leg. A single pair of stiffeners on the x-axis and up to 3 sets of 4 stiffeners (only 2 sets shown) may be defined at angles relative to the x-axis, as shown below. An additional stiffener may be defined behind the rack, and another stiffener may be opposite this. For each stiffener, the area & radius of the center of area from the leg center must be defined. The area input is that for a single stiffener. Hence if there are four stiffeners in a group, the group area will be four times the single stiffener area input.

Pad 1 is fwd. port
Pad 2 is aft, center.
Pad 3 is fwd, stbd.

Total leg length inc. pad (ft)	Pad height (ft)	Number of sections	Rack width (in)	rack ht.to top teeth (in)	Rack ht.to bot.teeth (in)	No. racks (1 or 2)	appendage wt. factor	OD (in)
170	2	2	5.10	5.000	2.900	1	0.05	48.00

Define bottom length Boat Name: **Dennis Doyle 5' Width Added** Run Ref.: **40kn, 2kn, 14', 10s, 120'/15'/4'**

Bottom length: 85.000

Top length: 0.000

Opp length (ft): 85.000

Click buttons to move around worksheet, or use scroll bars at RHS & bottom.

Define 2 section properties (others ignored)

Stiffener properties	bottom sect.					top section	average	max
Thickness (in)	0.625	0.000	0.000	0.000	0.625	0.250	0.63	
Stiff.area inside rack (sqin)	7.000	0.000	0.000	0.000	24.080	6.216	24.08	
Inside rack area radius (in)	19.920	0.000	0.000	0.000	19.920	7.968	19.92	
Stiff.area opposite rack (sqin)	7.000	0.000	0.000	0.000	24.080	6.216	24.08	
Opp. rack area radius (in)	19.920	0.000	0.000	0.000	19.920	7.968	19.92	
Stiff.area x-axis (sqin)	0.000	0.000	0.000	0.000	25.600	5.120	25.60	
X-axis area radius (in)	0.000	0.000	0.000	0.000	17.125	3.425	17.13	
Theta1 area (sqin)	0.000	0.000	0.000	0.000	9.600	1.920	9.60	
Theta1 angle (deg)	0.000	0.000	0.000	0.000	45.000	9.000	45.00	
Theta1 radius (in)	0.000	0.000	0.000	0.000	20.375	4.075	20.38	
Theta2 area (sqin)	0.000	0.000	0.000	0.000	0.000	0.000	0.00	
Theta2 angle (deg)	0.000	0.000	0.000	0.000	0.000	0.000	0.00	
Theta2 area radius (in)	0.000	0.000	0.000	0.000	0.000	0.000	0.00	
Theta3 area (sqin)	0.000	0.000	0.000	0.000	0.000	0.000	0.00	
Theta3 angle (deg)	0.000	0.000	0.000	0.000	0.000	0.000	0.00	
Theta3 area radius (in)	0.000	0.000	0.000	0.000	0.000	0.000	0.00	

DATA INPUT COMPLETE AT THIS POINT!! Information below is based upon user input above.

FIGURE 16 – Leg Structural Data

Calculated Leg Structural and Weight Data					
Boat Name: Dennis Doyle 5' Width Added		Run Ref.: 40kn, 2kn, 14', 10s, 120'/15'4'			
Calculate Area Moment Contributions for each component (rack direction bending)					
Tube (in ⁴)	26101.36	0.00	0.00	0.00	26101.36
Rack (in ⁴)	9579.52	0.00	0.00	0.00	9579.52
Stiff.area inside rack (in ⁴)	2777.64	0.00	0.00	0.00	9555.10
Stiff.area opposite rack (in ⁴)	2777.64	0.00	0.00	0.00	9555.10
Theta1 y lever arm (in)	0.00	0.00	0.00	0.00	14.41
Theta2 y lever arm (in)	0.00	0.00	0.00	0.00	0.00
Theta3 y lever arm (in)	0.00	0.00	0.00	0.00	0.00
Theta1 contribution (in ⁴)	0.00	0.00	0.00	0.00	7970.70
Theta2 contribution (in ⁴)	0.00	0.00	0.00	0.00	0.00
Theta3 contribution (in ⁴)	0.00	0.00	0.00	0.00	0.00
Total Y-area moments (in ⁴)	41236.17	0.00	0.00	0.00	62761.78
Calculate Area Moment Contributions for each component (non-rack direction bending)					
Tube (in ⁴)	26101.36	0.00	0.00	0.00	26101.36
X-axis stiffeners (in ⁴)	0.00	0.00	0.00	0.00	15015.20
Theta1 x lever arm (in)	0.00	0.00	0.00	0.00	14.41
Theta2 x lever arm (in)	0.00	0.00	0.00	0.00	0.00
Theta3 x lever arm (in)	0.00	0.00	0.00	0.00	0.00
Theta1 contribution (in ⁴)	0.00	0.00	0.00	0.00	7970.70
Theta2 contribution (in ⁴)	0.00	0.00	0.00	0.00	0.00
Theta3 contribution (in ⁴)	0.00	0.00	0.00	0.00	0.00
Total X-area moments (in ⁴)	26101.36	0.00	0.00	0.00	49087.26
Calculate Average Properties for Extended and for Whole Leg					
154.4618 tot.leg length extended inc.pad	101.38 total weight 1 leg w/o pad (kips)				
152.4618 total leg length extended - pad	93.58 total weight 1 leg w/pad (kips)				
Leg section length y-area moment (rack bending) below LG					
Bottom length (ft)					top length (ft)
85.00	0.00	0.00	0.00	0.00	85.00
LxM (ft.in ⁴)	3505074.49	0.00	0.00	0.00	4234021.13
deltaL (ft)	85.00	0.00	0.00	0.00	67.46
Av.area mom.below LG (in ⁴)	50760.89	average for whole leg (in ⁴)		51998.97	
Leg section length x-area moment (non-rack bending) below LG					
Bottom length (ft)					top length (ft)
85.00	0.00	0.00	0.00	0.00	85.00
LxM (ft.in ⁴)	2218615.68	0.00	0.00	0.00	3311513.94
deltaL (ft)	85.00	0.00	0.00	0.00	67.46
Av.area mom.below LG (in ⁴)	36272.24	average for whole leg (in ⁴)		37594.31	
Leg section length cross-sectional area below LG					
Bottom length (ft)					top length (ft)
85.00	0.00	0.00	0.00	0.00	85.00
deltaL (ft)	85.00	0.00	0.00	0.00	67.46
Area (in ²)	107.02	0.00	0.00	0.00	230.78
Area.deltaL (ft.in ²)	9096.75	0.00	0.00	0.00	15568.87
Av.sect.area below LG (in ²)	161.78	Equiv.wall t.for unstiff.tube (in)		1.098	
Leg Section Properties at the Lower Guide & Av. Area					
Area moment (rack bending) at lower guide (in ⁴)				62761.78	
Area moment (non-rack bending) at lower guide (in ⁴)				49087.26	
Cross section area of leg at lower guide (in ²)				230.78	
Equivalent wall thickness for unstiffened tube (in)				1.583	
Average cross section area for whole leg. (in²)				168.90	

Print this screen of leg cross-section data

FIGURE 17 Calculated Leg Structural Data

Home		STA LIFTBOAT v4.1 August 1998				Transit	
STRESS CHECK INTERMEDIATE RESULTS				08/12/98 Date of this run			
Boat Name: Dennis Doyle 5' Width Added				Geometry Switch Selected -> 2			
Run Ref: 40kn, 2kn, 14', 10s, 120'/15'/4'				Licenced User: <i>US Coast Guard.</i>			
Leg Area Moments of Inertia and area at lower guide						<input type="button" value="Tabular Results"/> <input type="button" value="Graphical Results"/> <input type="button" value="Print this screen"/>	
Leg #	1 (port)	2 (stern)	3 (stbd)	Area(in^2)	230.78		
lxx	3.0267	3.0267	3.0267	fore-aft bending direction (ft4)			
lyy	2.3672	2.3672	2.3672	lateral bending direction (ft4)			
laa	2.3672	2.3672	2.3672	results used for this loading direction (elevated)			
lyy	1.2587	1.2587	1.2587	<<--results for bottom leg section (for transit calcs)			
Column Buckling Stresses				Legs are dry internally			
For definition of K-equivalent see manual				K = 2 for stress check		K-equiv	
K-equiv	1.40			181.52	<<-(F2y/4Pi2E)(Kl/r)2-->		89.47
Kl/r	244.37	(with K = 2.00)		4.96	<<-Pi2E/(Kl/r)2-->		10.06
Kl/r	171.57	(with K-equiv.)		48.00	leg outer diameter, D (in)		171.57
Cc	99.35	[SQRT(2PIPIE/Fy)]		1.124	wall average equiv.thickness, t (in)		99.35
Fcr	4.96	ksi (crit.overall buckling str., ABS)		Fcr from DnV method for K value		10.06	
F.S.	1.44	(combined loads)		60.00	Fy, for leg (ksi)		F.S. 1.44
D/t (avg.)	42.72	ratio		(D/t).25= 2.56	(D/t to power .25)		D/t (at low.guide) 28.33
E/9Fy	55.56	ratio		4320000	Young's modulus for leg (ksf)		E/9Fy 55.56
Is D/t > E/9Fy?				No, hence no local buckling check required.			
Allowable Axial Compressive Stresses				5 <<-leg section @ lower guide			K-equiv
0.12E/r	164.70	<<--ksi (Younger) (value for K=2 shown left, K-equivalent shown right)-->					164.70
2CEt/D	411.74	<<-ksi (Fxe, elastic local buckling str: API with C = 0.3)-->					411.74
Fxc	60.00	<<-ksi (inelastic local buckling stress: API)-->					60.00
Faa	48.00	<<-ksi (ABS allowable axial stress 1), Para: 3.11.4)-->					48.00
Fab	3.44	<<-ksi (ABS allowable axial stress 2), Para: 3.11.4)-->					6.99
Fac	48.00	<<-ksi (ABS allowable axial stress 3), Para: 3.11.4)-->					48.00
Fa	3.44	<<-ksi (min.val.of above 3; ABS allow. axial comp.str.)-->					6.99
Fb	48.00	<<-ksi (ABS allowable comp.str.due to bending)-->					48.00
fa/Fa 1	0.47	<<<using K = 2 using K-equiv>>				0.23	
fb/Fb 1	0.48	<<<using K = 2 using K-equiv>>				0.48	
fa/Fa 2	0.59	<<<using K = 2 using K-equiv>>				0.29	
fb/Fb 2	0.51	<<<using K = 2 using K-equiv>>				0.51	
fa/Fa 3	0.70	<<<using K = 2 using K-equiv>>				0.35	
fb/Fb 3	0.51	<<<using K = 2 using K-equiv>>				0.51	
Is fa/Fa > 0.15?				Yes, hence ABS require 2nd unity check (but not appropriate for liftboats).			
Unity Checks at Lower Guide for Each Leg				0			
1st ABS Unity Check				2nd ABS Unity Check			
K = 2	K-equiv.	0.85 Cm coefficient		K = 2	K-equiv.		
0.95	0.71	<<--legs 1 (fwd leg)-->		0.40	0.05		
1.10	0.80	<<--leg 2 (stern)-->		0.52	0.12		
1.22	0.86	<<--legs 3 (fwd leg)-->		0.63	0.17		
3.45	7.00	<<-ksi, F'e, ABS Euler str.*4/3		2nd ABS unity check is inappropriate for liftboats.			
ABS Unity Check at "member ends" (lower guide) for combined and static loadings							
0.52 combined; leg 1 (fwd leg)				0.04 static; leg 1			
0.55 combined; leg 2 (stern)				0.06 static; leg 2			
0.56 combined; leg 3 (fwd leg)				0.07 static; leg 3			
<input type="button" value="Print this screen"/>		DnV Usage Factor/Rational Stress Check Calculations				<input type="button" value="Input Leg Sections"/>	
1.61	sigma_x, tot.axial stress comp.leg 1	59.91	sigma_cr, critical stress leg 1				
2.02	sigma_x, tot.axial stress comp.leg 2	59.92	sigma_cr, critical stress leg 2				
2.43	sigma_x, tot.axial stress comp.leg 3	59.93	sigma_cr, critical stress leg 3				
24.80	sigma_e, von Mises equiv. leg 1	0.74 Rational (DnV) unity check Leg 1					
26.47	sigma_e, von Mises equiv. leg 2	0.80 Rational (DnV) unity check Leg 2					
27.05	sigma_e, von Mises equiv. leg 3	0.86 Rational (DnV) unity check Leg 3					
<input type="button" value="Home"/>		<input type="button" value="Transit"/>		<input type="button" value="Graphical Results"/>		<input type="button" value="Tabular Results"/>	
				<input type="button" value="Print local buckling"/>			

FIGURE 18 – Stress Check Intermediate Data

STA LIFTBOAT v4.1 August 1998		08/12/98 Date printed	
TRANSIT CONDITION - ROLL MOTION STRESS CHECKS ON LEGS			
Run ref: 40kn, 2kn, 14', 10s, 120'/15'/4'		Boat name: Dennis Doyle 5' Width Addec	
15.00	roll angle (sing.amp.) (deg)	33.33	z0, reference height wind vel. (ft)
10.00	roll period (sec)	174.72	zH, top of leg abv.SWL (ft)
0	leg length extended (0=fully raised) (ft)	0.00001	wind force coefficient on leg
120%	gravity force multiplier, from ABS	33.5	d, half distance bet.fwd.legs (ft)
2.28	vessel draft (ft)	145.50	leg length abv.up.guide (ft)
19	VCG for boat excluding legs & pads (ft)	29.22	distance b (ft)
36.81	VCG calculated including legs (ft)	0.60	leg weight/ft inc. appendages (kip/ft)
Home Stresses Tabular Results Graphical Results Print this screen			
TRANSVERSE LEG FORCES		<i>STA copy</i>	
87.80	ML, weight one leg above upper guide (kip)	5.10	Vwind1 (kt) user selected wind velocity
27.27	FTS, stat.trans. force w/ABS multiplier (kip)	105.18	parameter c
101.97	xS, vertical lever arm for FTS (ft)	4.02	parameter zW
28.74	FTD, inertia transverse force (kips)	7.88	FW1, wind force on leg in Vwind1 (kip)
119.27	xD, vertical lever arm for FTD (ft)	107.86	FW70, wind force on leg in 70 kt. wind (kip)
<i>Licensed User: US Coast Guard.</i>			
AXIAL LEG FORCES		<i>Note that nomenclature in this section is as in DnV Class Note 31.5, May '84</i>	
101.78	FLS, static axial force w/ABS multiplier (kips)	168.90	average cross section area of leg (sqin)
9.44	FLD, inertia axial force (kips) (does not act on aft leg which is on vessel centerline)		
BENDING MOMENT @ UPPER GUIDE AND REACTIONS AT UPPER & LOWER GUIDES			
1983.94	MTS, static transverse BM (ft-kips)	<i>Leg moments are resisted by the horizontal guide reactions.</i>	
2587.88	MTD, inertial transverse BM (ft-kips)	0.00	Beta, moment coefficient for pinions/jacks
316.07	MTW1, wind transverse BM Vwind1 (ft-kips)	139.48	RL, lower guide reaction with Vwind1 (kip)
619.51	MTW70, wind transverse BM 70 kt (ft-kips)	199.51	RU, upper guide reaction w/ Vwind1 (kips)
4887.89	total leg BM in wind speed Vwind1 (ft-kip)	148.00	RL, lower guide reaction 70 kt wind (kip)
5191.32	total leg BM in 70 kt wind (ft-kip)	211.89	RU, upper guide reaction 70 kt wind (kips)
FWD LEG RESULTS (rolling)		AFT LEG RESULTS (rolling)	
1.2587	area moment of inertia, bot section (ft ⁴)	1.2587	area moment of inertia, bot section (ft ⁴)
1.2587	area moment of inertia bot. section (ft ⁴)	1.2587	area moment of inertia bot. section (ft ⁴)
53.93	fb, bend.str. fwd legs w/Vwind1 (ksi)	53.93	fb, bend.stress aft.leg w/ Vwind1 (ksi)
0.48	fa, axial stress in fwd leg (ksi)	0.44	fa, axial stress in aft legs (ksi)
57.28	fb, bend.str. fwd leg w/70 kt.wind (ksi)	57.28	fb, bend.str. aft.leg w/70 kt.wind (ksi)
NATURAL ROLL PERIOD CALCULATIONS FOR VESSEL			
		<i>Licensed User: US Coast Guard.</i>	
130.00	user input waterline length of hull (ft)	<i>Hydrodynamic Calculation Method Note</i>	
79.00	user input beam (ft)	<i>As of 04/18/91 the calculation of roll</i>	
10270.00	water plane area (sqft)	<i>period is approximate, as the program</i>	
1.00	CW, coefficient - roll center assumed at still water level	<i>assumes a rectangular water plane area</i>	
107.33	di-fwd, distance to fwd.leg cg from roll center (ft)	<i>and approx. hull dimensions based on</i>	
101.97	di-aft, distance to aft.leg cg from roll center (ft)	<i>leg spacing. The method is fast and</i>	
105609.25	IL, mass moment of inertia of legs (ft ² *kip/g)	<i>consistent, and will be improved shortly.</i>	
38.40	MH, mass of hull (kip/g)	Roll Period Calculation Results	
20132.70	IH, mass moment of inertia hull (ft ² *kip/g)	1.17	KB approx. based on leg lengths extnd. (ft)
176122.11	IA, hydrodynamic add.mass mom.(ft ² *kip/g)	192.25	GM (ft) approximate calculation
80.50	r0, radius of gyration of boat (ft)	6.43	T0, roll period (sec) approx. calc.
Application Notes:			
Only data values in shaded cells need be edited. For example, the user should specify roll amplitude and period, as well as vessel draft (if not correctly calculated by program), and leg length extended (which should be zero for fully raised legs).			
The user may investigate leg stresses and forces, as well as roll period changes when the legs are lowered, simply by specifying a leg length extended greater than zero in the input data block.			
If leg stresses are unacceptable at the upper guide, the user may increase the leg area moments at this location by changing the stiffening in the bottom section of the leg (see leg structural input data).			
Normally the load cases caused by 6 degrees roll amplitude at the vessel natural period, and 15 degrees roll amplitude at a 10 seconds period should be investigated to satisfy ABS criteria. For restricted service liftboats, use a 70 knot wind speed.			
Home Stresses Tabular Results Graphical Results Print this screen			

FIGURE 19 – Transit Results

Vessel List Caused by Raising a Flooded Leg (linear method, GM constant)	
120.00 ft	water depth from input (assumed to be flood water height in leg)
87.88 kip	weight of water in flooded leg (internal leg area accounts for stiffeners)
67.00 ft	vcg of flood water in leg
38.48 ft	vcg of vessel if upright, with one leg flooded
1.67 ft	rise in vcg caused by flood water in one leg
190.58 ft	GM with flooded leg
2944 kip-ft	inclining moment caused by upright flooded leg
0.59 deg	list caused by upright flooded leg
0.70 ft	additional moment arm caused by inclination of flooded leg
3006 kip-ft	total inclining moment caused by inclined flooded leg
0.60 deg	list caused by inclined flooded leg (found iteratively)
0.83 deg	vessel heel angle where bilge emerges above SWL
Vessel bilge remains submerged	
13.00 ft	hull depth (user must input)
10.72 ft	freeboard
3.88 deg	vessel heel angle at which deck edge submerges
Deck edge is not predicted to submerge by linear method.	

Reset if
Iteration Failed

FIGURE 20 – Check On Effect Of Raising a Flooded Leg

Immediately beneath the Transit Results section in the workbook, the data seen in Figure 20 can be found. This is simply a useful check to see if raising a flooded leg could lead to capsize. The loaded condition of the rig is based upon the data provided by the user in the Liftinpt.xls (starting) workbook.

Because of deliberate use of a circular reference in the calculation of the list angle, the result may become corrupted (you will see a result REF!). If this happens click the reset button (see Figure 20). No other formulae are affected.

- *Print all* - This will print all tables and all graphs.
- *Set 5' Penetration* – This button sets a 5' pad penetration on the Liftinpt.xls workbook. The user can change this to any value desired. However, the program will calculate the actual penetration caused by the environmental loads on the heaviest loaded leg and warn the user if the pad penetration specified is too much or too little (in cells D17-E17). Setting pad penetration calculations to automatic by clicking *Auto Calc. Penetration* will override the user input fixed pad penetrations.
- *Manual coefficients* - Clicking on this button will set the *Auto coefficient* (see above) iterative calculation feature off. The soil *su* value will be set to 160 psf and the *total damping* value will be set to 2% of critical. Both terms can be changed to other values by the user.

NOTE: If impossible input conditions are given (for example negative length of leg sections) the automatic coefficient calculation routines will fail. The program will show a warning message to the user advising that the *Manual Coefficients* button must be clicked after the input has been corrected. The user should also click the

button *Set 5' Penetration* if this has not been clicked and the *Auto Calc. Penetration* button has been clicked. The *Auto Coefficients* button may be clicked only after input errors have been rectified.

In addition to the operational features described above, using the in-built macros that are invoked when the various buttons are clicked, the experienced user may make use of some of the Excel functions that are still provided within the normal Excel main menu that is available when STA LIFTBOAT is run. From the File menu, the experienced user may choose to save certain sets of results in separate files, or to print separate sections of the screen without using the STA macros. Users are cautioned not to make modifications to any of the main program files that would normally be used by STA LIFTBOAT.

For inexperienced users, the normal Excel Help facility can be invoked by clicking on *Help* on the Excel main menu.

6.0 MAIN INPUT DATA (1st Data Screen)

The previous chapter has described how to run the program. This chapter describes the technical and control data that the user may input to the program. The first part of this section describes data that is entered in the cells of the main input data screen (first worksheet, Liftinpt.xls; see Figure 2).

In the upper right hand corner of the main input data screen, the user can specify the boat name and the run reference. These terms will appear on the all the tabular output from the program, as well as on the input data screen (which can also be printed) and on all the graphs.

Each of the headings below represent the labels adjacent to the input data cells that can be edited in the main input data screen or on any of the Load Case sheets in the MASTERINPUT.xls workbook (and then pated into Liftinpt.xls with the *Paste Data* button).

Input wave height (ft)

This is the height, from trough to crest, of a regular wave which is used for the wave loading. This wave is stepped through the structure at twenty phase angles. At each phase angle, the drag and inertia forces are calculated using ABS shallow water wave theory. The current velocity is added in an equivalent vectorial manner to the wave particle velocity before the drag loads are calculated using Morison's equation (see results later).

Input wave period (sec)

This is the wave period that is used in the analysis. The wave length and water particle kinematics are influenced by both the water depth and the selection of this wave period.

Input water depth (ft)

This is the water depth to be used in the analysis from the sea bed to the still water level. If the analysis is to account for a change in water elevation because of storm surge or tidal elevation changes, the user should incorporate all terms within this one input value. In the ABS wave theory used, the wave crest is generally further above the still water level than the wave trough is below the still water level. The value of crest elevation above the mean water level is reported in the input summary (see Figure 5).

Lattice area (sqft)

This is the area of all structures on the boat which are not solid but present significant wind area. This typically includes the crane boom(s) if of the lattice type, and may include a lattice structure supporting the helideck. The area should be equivalent to the projected outline of these structures. They are assumed to have two sides, and ABS Rules to calculate wind viscous drag forces on these areas are used. See the Appendix on wind loading calculations.

WH1 (ft)

This is the average height of the solid structures (typically the hull, jacking towers if appropriate, and deck houses plus other equipment, for example including the crane base) which are exposed to beam winds. See the Appendix on wind loading.

WB (ft)

This is the equivalent width of the solid structures, typically including the hull, deck houses, etc., which are exposed to beam winds. See the Appendix on wind loading.

Distance from aft to fwd. legs (ft)

This is the leg spacing, from center of leg to center of leg between the center of the aft leg with the line joining the center of the forward two legs.

Distance bet. fwd. leg centers (ft)

This is the spacing, from center to center, of the fwd. pair of legs.

Pad penetration (ft)

This is the average penetration of each pad from sea bed surface to pad tip. Note that the average distance must be used and that it is to the pad tip from the sea bed surface.

Wind force (kips)

This term is only used if the *wind force switch* on the last line of the main input data screen is set to 1. This term represents a total wind force to be used in the analysis. This can be useful if wind tunnel test data or other data is known. The exposed wind areas (WH1, WB, lattice area, etc.) are then no longer used. The wind velocity (v_2 , see below) is not used either, but the user must specify a wind elevation (on the right hand side of the main input data screen) at which the specified wind forces acts.

WH2 (ft)

This is the average height of the solid area exposed to head wind forces. See Appendix on wind loading.

WL (ft)

This is the average width of the solid area of the boat exposed to beam wind forces. See Appendix on wind loading.

Leg buoy. 1=dry 2=flood

If this term is set to 1, the program considers the legs to be dry internally. If this term is set to 2, the program assumes the legs to be flooded up to the still water level. The weight of the water inside the legs is not included in the *total weight* input term.

Air gap (ft)

This is the distance beneath the bottom of the hull to the still water level. In this area, the wind force is calculated on each of the legs. This term is also used to calculate the total leg length extended (in combination with the *pad penetration* and *water depth* input terms).

AvShield

This term describes the average amount of leg which is hidden by the solid components of the boat. At a minimum, it should be equal to the hull thickness. However, there may be shielding from other structures, such as the jacking towers, which may have been described by the user in computing the terms WH1, WB, etc. In addition, there may be justification in providing larger amounts of shielding for different wind directions, such as when the wind is on the stern and the main accommodation block and other deck houses shield the aft leg significantly. The program calculates wind force on the leg sections which remain above the bottom of the hull from the tops of the legs down to a distance equal to *AvShield* above the bottom of the hull.

Lattice av.ht.

This is the average height of the lattice area defined by the user previously. This height is related to the bottom of the hull, or keel line. See section on wind loading.

Tide vel.(kn)

This is a current velocity, uniform with depth throughout the water column. It is typically attributed to a tidal velocity, hence its name.

LeverArm

This is the horizontal distance from the geometric leg center to the center of the lateral area exposed to wind. The program reports torsional forces on the boat. If the geometric wind center is not at the geometric leg center, this contributes to torsional forces. However, note that torsional forces, although reported, are not included in leg moments or forces.

Wave direction (deg)

This is the direction of the wind and waves and current relative to the boat. The sign convention for defining this direction is shown in Figure 4, below. This term should normally be varied in order to find which direction provides most critical results. Typically there will be a "worst" direction for maximum leg bending moments and a different "worst" direction for maximum pad reactions.

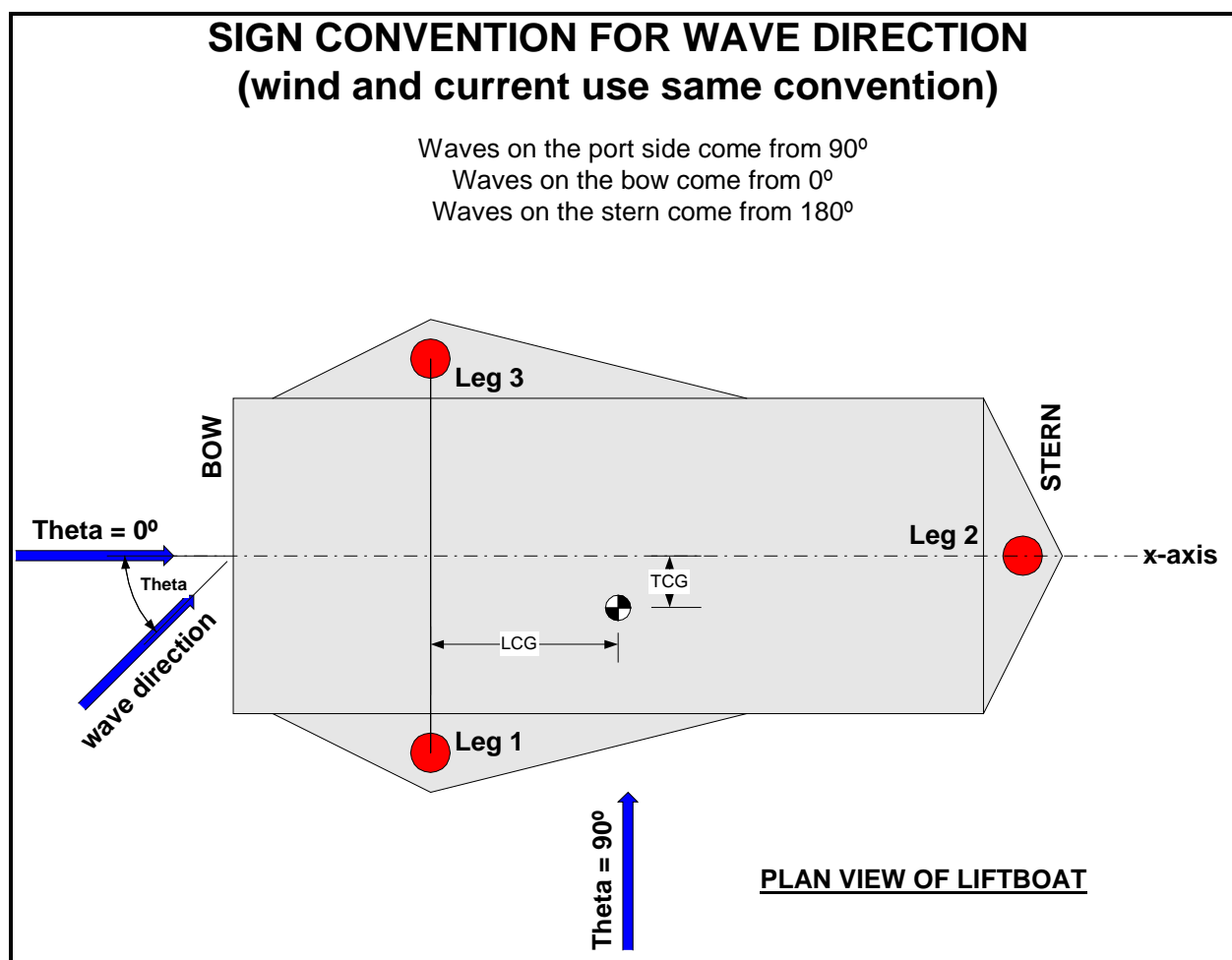


FIGURE 21 - SIGN CONVENTION FOR WAVE DIRECTION

Leg diams 1,2,3 (ft)

Three terms must be input to the program for this single data description. These are the equivalent diameters for each of the three legs. They are normally equal, but in the event that the user wishes to study an unusual phenomenon, perhaps of additional marine growth on one leg, or additional secondary structures added to one leg, this may be done. Note that the equivalent leg diameter is multiplied by the inertia coefficient in order to find inertia forces and is multiplied by the drag coefficient in order to find drag forces. Similarly, this leg diameter is multiplied by the drag coefficient in order to find wind loading on the exposed parts of the legs. Additionally it should be noted that the leg diameter is used in order to

calculate buoyancy forces on each leg. These buoyancy forces have the effect of reducing the vertical leg reaction on the sea bed.

Cm1, Cm2, Cm3

These are the leg inertia coefficients used in Morison's equation. They are normally all equal and a typical value is 1.75 to 2.0. However, lower values down to 1.5 are often used.

CD1, CD2, CD3

These are the leg drag coefficients. Although they are frequently equal, there are many times when it is more appropriate to use different drag coefficients for different wave loading directions. For example if the boat has twin racks on each leg, with the racks in the fore-and-aft direction on the forward legs and in the side-to-side direction on the aft leg, then the drag on the two forward legs will be lowest when the drag on the aft leg is highest (wind and waves on the bow or stern). A graph of leg drag coefficient variation with wave attack angle is drawn by the program. From this graph it can be seen that there is often a large variation in the leg drag coefficient, for different wave attack directions

Wind v2 (kn)

This is the wind velocity to be used in conjunction with the user specified wind areas in order to compute wind loading on the vessel.

Total weight (kips)

This term is the total boat weight in air, excluding water in the pads (and legs if flooded), but including the weight in air of the cans and legs, plus all variable loads, any drill string loads, light ship weight, crane loads (if required), etc. If the user wishes to study the boat during preload, then the weight of all preload water should be included in this term. If the user wishes to study the operational weight of the boat, or the boat condition under any storm loading, then preload weight should not be included, but **all** other weight must be included in this term. No deductions for buoyancy of the legs should be made as the program automatically calculates these terms based upon the user specified water depth, pad penetration, and leg diameter.

LCG (ft to forward legs)

This is the distance of the longitudinal center of gravity of the boat to the center line of the forward legs (see Figure 4). Note that the longitudinal center of gravity is defined in this case as being related to the total boat weight specified above. In other words, the weight of the legs and cans (excluding water in the cans) must be included.

TCG (+ve towards L1)

This is the distance of the transverse center of gravity of the boat from the boat center line. Note that it also relates to the total boat weight as for the LCG above. TCG is positive towards the port side (see Figure 4)

Init phase ang.(deg)

In most cases, the user will set this to zero, meaning that the wave crest will be at the center line of leg 1 at time $t = 0$ seconds. Any phase angle may be specified. This can be useful as some of the graphs are drawn to show hydrodynamic forces on the legs at time $t = 0$ seconds.

Wind elevation (ft)

This term is only used if the *wind force switch* is set to 1 and a user specified *wind force* has been given. The elevation is relative to the bottom of the hull or the keel line. It is the elevation at which the *wind force* is assumed to act.

Total leg length (ft)

This is the length of the legs of the boat from the bottom of the pad (pad tip) to top of the legs.

Min. leg length to be above hull bottom (ft)

This is the minimum acceptable length of the legs to be above the hull bottom. It will usually be the distance from the hull bottom to the top of the jacking towers, plus around one foot, so that the top of the leg can still be seen above the jacking tower. Cell A20 shows the calculated value of this term. If the calculated value is less than the minimum acceptable value the legs have been extended too far. Note this term is not included in the data pasted from MASTERINPUT.xls.

7.0 SECONDARY DATA INPUT (2nd Data Screen)

The secondary data that may be edited by the user is in the workbook Lift001.xls, on the data screen that appears after the button *Go on to Structural Response* has been clicked by the user on the main (first) data input screen. Only the cells highlighted in yellow, containing bold text, can be edited. The first of these cells are shown shaded in Figures 5 and 10 (which is a print out of the second data screen). The input data terms are described below.

7.1 Control and Miscellaneous Data

Young's Modulus, leg steel (ksf)

Normally 4248000 ksf, this term can be changed by the user to simulate special steels or other leg materials, if required.

natural period multiplier

This term permits the user to investigate the effect of dynamics on the response of the structure. The natural period of the structure is multiplied by this term. Hence a value of 0.5 for the term will reduce the natural sway period by 50%. Hence dynamic amplification will generally be reduced and results will tend towards the static solution as the DAF tends towards 1.0. For dynamics to be correctly calculated this term should be set to 1.0. However, experimenting with this term can give an immediate and useful insight into how changes in the natural sway period can either increase or decrease response results. See the discussion on dynamic response results later.

accept calc. wt/ft

If this term is set to 1, the user specified leg weight per foot is used (see below). If the term is set to 2, the programs calculated equivalent weight per foot is used for the legs. The user specified weight per foot may be useful if additional non-structural weight is added to the legs. Or the term may simply be used for parametric variation studies of boat responses.

accept hull gyrad.

If this term is set to 1, the user specified hull gyradius is used (see below). If the term is set to 2, the gyradius estimated by the program is used. The hull gyradius is used by the program to calculate the torsional natural period of the boat.

soil su needed to support pad (psf) (input in cell below)

This term is reported by the program and indicates to the user, based upon the pad geometry and maximum calculated pad reaction during the analysis, what the equivalent minimum cohesive soil shear strength must be in order to support the pad. The user may input this value manually to the next cell below, or may use the *Auto coefs.* option.

su, soil undrained shear strength beneath pad (psf)

The user may either input this term based upon site-specific soil data, or alternatively may input the minimum su value needed to support the maximum pad reaction found during a wave cycle (which should be equal to the preload reaction achieved during the preload process). If the user clicks on the Manual coefs. button, the value of su is over-written by the program as 160 psf. If the user clicks on the Auto coefs. button the program iterates while adjusting the soil su value until it is equal to the minimum value needed to support the maximum pad reaction during the wave cycle. This iteration process involves the recalculation of the soil shear modulus, G, at each cycle. This in turn creates a new value for the equivalent linear rotational spring beneath each leg at each iteration cycle. The stiffer the rotational spring, the smaller is the leg effective length, the smaller is the lateral hull deflection, and the lower is the pad vertical reaction. Strictly, the method is only correct for cohesive sea bed soils, but practically may be used for cohesionless soils also. The magnitude of the soil shear modulus also depends upon the coefficient in the next data input cell.

The equation used for the soil shear strength needed to give the minimum necessary bearing capacity is given below:

$$s_u = (\text{max pad load}) / \{(\text{pad length} \times \text{pad width}) \times N_c\}$$

The bearing capacity coefficient, N_c , is defined by:

$$N_c = 5 \{1 + 0.2(\text{pad width})/(\text{pad length})\} \times \{1 + 0.2(\text{penetration})/(\text{pad width})\}$$

coef. on s_u to get soil G modulus

In order to account for rotational soil restraint to the pads, STA LIFTBOAT uses a rotational linear spring at the pads. The stiffness, k_s of this spring is a function of the soil G modulus and the user specified coefficient, G_{factor} according to the following equations:

$$G = G_{\text{factor}} s_u$$

$$k_s = 8 G r^3 / 3(1-\nu)$$

Where:

r = pad radius

ν = Poisson's ratio for the soil (taken by the program as 0.5).

The stiffness equation is based upon the equation for a disk in an elastic half-space. Reliable estimation of G_{factor} is not presently possible, as the soil is generally highly non-linear. For small rotations and deep penetrations in cohesive soil, a value of 100 has been suggested (Reference 1). STA cautions against using values of G_{factor} in excess of 1000. Generally the coefficient should be in the range 40 to 300. See section on General Theory.

Ke0, LEG OUT OF STRAIGHT. coef.

This term is used to multiply the extended leg length to give the hull an initial lateral offset in the same direction as the applied loading. This results in larger sway response from vertical than would be found for a perfectly level boat with perfectly straight (initially) legs. Typical values for this term are in the range 0.001 to 0.006, resulting in offsets of 0.1% to 0.6% of extended leg length. A value of zero results in no initial offset. A value of 0.003 is suggested.

cylinder drag coef.(w/marine growth)

This is the drag coefficient to be applied to a clean cylindrical leg with no rack. The hydrodynamic leg model accounts for mass, volume displaced, and drag force on the cylindrical portion of the leg and on the rack(s). This detailed model is used to compute the equivalent hydrodynamic volume of a unit length of the leg, from which the equivalent leg diameter is found. The drag coefficient for the cylindrical portion of the leg alone is provided for the user to experiment with. The cylinder drag coefficient will strongly influence the total drag coefficient found for the equivalent leg. The normal drag force coefficient used by STA for cylindrical members of liftboat legs is 0.64. Lower values may be achieved for new clean cylinders, and higher values may be appropriate for members with excessive marine growth. The larger the rack, the higher will be the maximum drag coefficient when flow is perpendicular to the rack direction. The graph of leg drag coefficient shows two formulae for the drag coefficient as influenced by the rack. The formula attributed to DnV is suggested, rather than that attributed to Shell.

Changing the cylinder drag coefficient will change the result for the equivalent leg drag coefficient and will change the graph of drag coefficient produced by the program. However, these calculated values are reported to the user but not used in the response calculations. The user must specify the drag force coefficient to be used in the analysis at the first data input screen for each leg (see Section 5, page 15).

marine growth thickness (inches)

This term is used to increase the diameters of the cylindrical portion only (not the rack dimensions) of the leg. The resulting leg equivalent diameter is reported to the user. As with the cylinder drag coefficient above, it is necessary for the user to tell the program what equivalent leg diameter is to be used at the first data input screen, for the purposes of wave loading and buoyancy calculations. However there is an important difference in changes to the leg diameter, which affects structural response. The program uses the calculated leg equivalent diameter, not the input leg diameter, in order to calculate leg added mass. Leg added hydrodynamic mass is used in the calculation of the boat's natural periods.

deflection multiplier (1 = normal)

This term is normally to be set to 1.00. However, the user may investigate the importance of secondary bending effects by varying this term as the calculated deflections are directly multiplied by this term. When this term is set to zero, deflections are set to zero before calculating secondary stresses. Note that any initial static offset will remain after deflection responses have been set to zero.

add.mass coef.(1 = normal)

This term is normally to be set to 1.00. The user may experiment with the effect of added hydrodynamic leg mass by varying this term which is a direct multiplier on leg added hydrodynamic mass. For example, setting this term to zero puts added leg mass to zero and will reduce the natural sway period. This term does not effect the internal mass of water inside legs where the user has specified flooded legs.

VCG excluding legs (ft) (for transit)

This is the height of the vertical center of gravity of the boat, excluding the legs and pads, above the hull bottom, or keel line. It is used to calculate natural roll periods for transit conditions.

weight of one pad (kips)

This is the weight in air of a single pad, without any internal ballast water. All pads are assumed to be equal weight, hence an average value should be used if they are not equal. The pads are assumed to flood and provide negligible buoyancy when the vessel is elevated.

USER SPEC. leg kips/ft excl. pads

This is the average leg weight per foot in air, excluding the pads. If the second switch in this input data block (see above) is set to 1, the program will use this user specified leg weight per foot rather than the value computed by the program. Otherwise the data is ignored.

USER SPEC. gyrad (ft)

This is the hull (excluding legs) gyradius in feet. If the third switch in this input data block (see above) is set to 1, the program will use this user specified leg weight per foot rather than the value computed by the program. Otherwise the data is ignored.

total damping (% crit.)

Percentage critical damping, ε . This is an important term if wave period and natural boat sway periods are close. Values in the range 2% to 7% are appropriate. The term ε is used to compute the dynamic amplification factor, DAF. The method for calculating the DAFs is conventional, being based upon an equivalent single degree of freedom system. The equation involves the vessel's natural period and the period of the waves, together with the damping value selected.

The dynamic amplification factor is found from:

$$DAF = [(1 - (T_0/T)^2)^2 + (2 \varepsilon T_0/T)^2]^{-1/2}$$

Where T_0 is the vessel natural period and T is the period of the wave.

The above equation is appropriate to response evaluation in long crested regular waves and may be unreasonably conservative in real sea conditions. To account for this, DnV introduced the concept of a *stochastic dynamic amplification factor*, SDAF. The accepted result of this approach is to compute DAFs

with twice the equivalent linear damping term, ε . This method is also adopted in STA LIFTBOAT, where input ε values are doubled in order to find reasonable stochastic DAFs. If the user wishes to evaluate response in long crested regular waves, a value of only one half of the desired damping coefficient should be input.

Damping alone limits vessel response values at resonance, where the wave period and the vessel first natural period are coincident. Away from resonance, as is the normal case with storm waves, the damping value is less critical. However, because of the uncertainty in the damping value, the program also produces a graph which shows the (stochastic) DAFs that result for values of one half the selected ε and for twice the selected ε . The actual DAF used to calculate response amplification is that for the selected value of ε at the selected wave period. The user can judge from the DAF curves if the selection of a different ε value would have a strong influence on the DAF. If this is the case, it is advisable to try a different value for ε and repeat the analysis. This takes only a few seconds.

The selection of an appropriate value for ε is a trial and error process since ε increases with increasing response amplitude. STA has automated the selection of ε in STA LIFTBOAT v2.01. Automatic selection of this term occurs when the user clicks on the *Auto coefficients* button (see page 12). The equation used to find ε is shown below:

$$\varepsilon = \{2 + 5 (\text{hull deflection amplitude})/(\text{leg radius})\} \%$$

Hence when the response amplitude is zero, the percentage critical damping will be set to 2%. When the response amplitude increases to one leg radius, the percentage critical damping will be set to 7%, if the user clicks on the *Auto coefficients* button. The user may always over-write the value for this term, or introduce another functional relationship if desired. Contact STA if you wish to enter another relationship.

MomSwitch, 0=off

If this cell is set to 1, the reduction in hull lateral deflection coming from moment at the pads is correctly accounted for. If the cell is set to zero, the hull lateral deflection will be over-estimated and the P-delta effect will be exaggerated.

cu, surface

This is the undrained shear strength of the surface soil on the sea bed. Typically for a soft sediment, as in many places in the Gulf of Mexico, the surface shear strength is around 40 pounds per square foot (psf). For over-consolidated clays, as in many places in the North Sea, the cu value may be 1000 psf. If a firm sandy sea bed is to be modelled, a cu value of 100 may also be appropriate.

Cu rate

This is the rate of increase of undrained shear strength with depth. A value of 10 psf/ft is typical in many muddy sea beds. If a value of 10 psf/ft is used for the cu rate and a value of 40 psf is used for cu at the surface of the sea bed, then at a depth of 20 feet below the surface the undrained shear strength will be 240 psf. This is calculated as follows:

$$20 \times 10 + 40 = 240$$

7.2 Jacking Tower Data

VCG lower guide (ft)

This is the height above the keel, or hull baseline, to the center of the lower guide. For transit conditions the program makes the assumption that the top of the pad will be 6" below this guide center when the legs are fully elevated.

b. jack vcg (ft)

This is the height of the center of the pinions above the keel, or hull baseline.

h, jack support spacing (ft) used only if two racks

This term is ignored unless there are two racks on each leg, in which case it will be used to limit the maximum value of Beta, the top fixity coefficient. Beta is zero with a single rack. For modeling Beta correctly with two racks, please consult with STA.

geometry select switch

There are three settings for this switch. They indicate rack arrangements corresponding to those shown in the diagram in Figure 22, below. Valid inputs are 1, 2, or 3. Values outside this range may cause unpredictable results. Use only integer values.

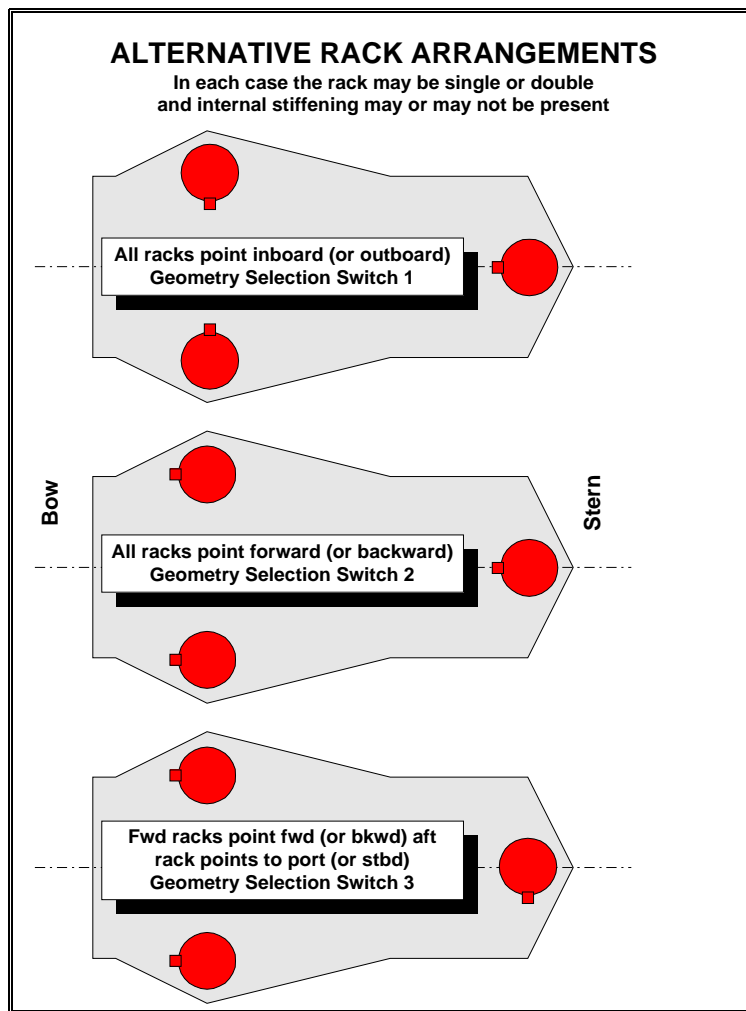


FIGURE 22 - GEOMETRY SELECT SWITCH FOR RACK ORIENTATION

d, guide spacing (ft)

This is the height between the lower guide (vcg defined above) and the upper guide centers. The leg is considered pinned to the hull at the guides and free to flex between them unless there are two racks and Beta is non-zero.

1 OR 2 RACK SWITCH

Set this switch to 1 if each leg has one rack, or to 2, if each leg has 2 racks.

7.3 Pad Data

pad 1/2 height (ft)

This is the height of the pad from the bottom tip (if it has one) to the top surface at which the bottom of the leg begins. Overall leg length is defined from the bottom of the pad (the tip) to the top of the leg. The leg is "fixed" at the pad mid-point.

pad length (ft)

This is the longitudinal (fore-aft) dimension of the liftboat forward rectangular pads and the lateral (beam) dimension of the aft pad. If dimensions of pads are not identical, use the average of these values.

pad width (ft)

This is the lateral (beam) dimension of the liftboat forward rectangular pads and the longitudinal (fore-aft) dimension of the aft pad. If dimensions of pads are not identical, use the average of these values.

7.4 Leg Structural Data

Figures 16 and 17 show the input and standard pages of output from the program for the detailed leg structural data. Up to 5 different cross sections can be defined within a single leg. All legs must be the same, although they may be oriented differently (see Figure 22). For each leg section a group of internal stiffeners may be defined, or there may be no stiffeners in a section (or in any section). The diagram in Figure 16 shows how stiffeners may be arranged in a single section. The general principles of stiffener specification are described below.

A single stiffener may be specified immediately behind the rack. You must define its area and the radial distance of the center of its area from the cylindrical leg center. A similar single stiffener may be defined on the opposite side of the leg, away from the rack. (if a double rack is defined, these stiffeners should be identical). The rack direction is referred to as the local leg section y-axis as shown in Figure 16.

A pair of stiffeners may be defined on the local leg x-axis. You specify the area and radial distance of the center of area of one of these stiffeners from the cylindrical leg center. The total area of the stiffeners on the x-axis is twice the area you input.

Up to three additional sets (of four stiffeners in each set) may be specified. Each of these sets is arranged symmetrically about the x-axis, as illustrated in Figure 16. You specify the area, the radial distance of this area from the cylindrical leg center, and the angle from the x-axis, of just one stiffener in each set of four. The total area of each of these (maximum three) sets is four times the individual stiffener area you input. These

three sets of stiffeners are referred to by their angles off the x-axis, as theta1, theta2, and theta3.

In addition to the stiffeners, you must also input the wall thickness of the cylindrical part of each leg section and the rack properties (which are assumed constant throughout the leg length. The paragraphs below describe the data input in detail. Only the yellow cells may be edited (cells shown shaded with bold numbers in them in Figure 16).

Number of sections

This must be an integer number from 1 to 5 inclusive, and represents the number of different sections within each leg for which you wish to define different properties. In response to your input the program will prompt you with different requests to enter data. For example, if you specify 5 sections, the program will respond with "Define bottom 4 sections" just below (see Figure 16). Alternatively, if you specify only 2 sections the program will respond with "Define bottom length". The program will give a column title for the stiffeners for however many sections you defined (see Figure 16). Unless there is only one section, there will always be a top section, but only those existing intermediate sections (all called "next section") columns will be titled. If a column for section properties is not titled the data in it will be ignored. This obviates the need to delete data that you have entered if you elect to reduce the number of sections within a leg. You may move down the worksheet with the scroll bars to investigate the area moments for each leg section to ensure your data input is as you expected it to be.

Rack width (in)

This is the width of the rack on the leg. The rack is assumed to be of constant properties throughout the length of the leg.

rack ht.to top teeth (in)

this is the distance from the outside of the leg, at the rack center, to the top of the rack teeth.

rack ht.to bot.teeth (in)

This is the distance from the outside of the leg, at the rack center, to the bottom of the rack teeth. The rack within this dimension, multiplied by the rack width dimension, is treated as structural steel, adding to the leg stiffness. The teeth above this are considered only as adding weight (and hydrodynamic drag and volume) to the leg.

No.racks (1 or 2)

If this number is 1, the program accounts for the stiffness, weight, and drag of one rack. Otherwise the input rack properties (described above) are used to model these characteristics for two racks.

appendage wt. factor

This term is used to model additional non-structural weight attached to the leg. A value of around 0.02 may be used to account for excess weld metal in heavily stiffened legs. This term may also be used to account for anodes on the legs, if present. The leg final weight is found as:

$$\text{final leg wt.} = \text{input for all cross sections} \times (1 + \text{appendage factor})$$

OD (in)

This is the outside diameter for the leg, assumed constant throughout the leg length, although the wall thickness may change from section to section.

Bottom Length (ft)

This input prompt will only appear if you have specified more than one leg section. Input the value for the bottom leg length (from the pad bottom tip to the elevation of the first section change). If you change from having more than one, to having only one section length, the value that was in the input cell next to "bottom length" will be ignored and the program will assume the first section properties are used throughout the leg length.

next length (ft)

This input prompt will only occur if you have specified three or more leg sections. Specify the length of each one in turn. Up to three "next section" prompts may occur, depending upon how many leg sections (five maximum) you specify. Note that you may get error messages if you input impossible leg section lengths and this may occur inadvertently while you are editing data. You should see messages appear **"Error!! Correct leg sections & click Manual coefs. button !!"** if you give the program impossible data. Simply follow the instructions and click the *Manual coefficients* button after you have got the data correct, then click the *Auto coefficients* button again if you want automatic damping and soil iterative calculations.

top length (ft)

This information will appear if you have specified two or more leg sections. The program calculates this value based on the overall leg length, plus the bottom and any intermediate ("next length") leg section lengths you have specified.

Thickness (in)

You must specify a wall thickness for each section of leg you have defined.

Stiff.area inside rack (sqin)

You may specify a stiffener area immediately behind the rack for each of the leg sections you have defined (see Figure 16).

Inside rack area radius (in)

This is the radial distance of the center of area of the stiffener behind the rack in each leg section from the cylinder center.

Stiff.area opposite rack (sqin)

You may specify a stiffener area opposite to the stiffener immediately behind the rack for each of the leg sections you have defined (see Figure 16).

Inside rack area radius (in)

This is the radial distance of the center of area of the stiffener opposite the rack in each leg section from the cylinder center.

Stiff.area x-axis (sqin)

This is the area of one of an optional pair of stiffeners on the x-axis of the leg (see Figure 16) in each of the leg sections you have defined.

X-axis area radius (in)

This is the distance from the leg cylinder center of one of the centers of area of the x-axis stiffeners.

Theta1 area (sqin)

This is the area of one of an optional set of four stiffeners arranged symmetrically about the x-axis, as shown in Figure 16, in each of the leg sections you have defined.

Theta1 radius (in)

This is the radial distance from the leg cylinder center to one of the centers of area of the Theta1 stiffeners.

Theta2, Theta3, input - as for Theta1

8.0 TABULAR RESULTS

For maximum efficiency in program operation and results reporting, STA has made concerted efforts to try and keep to a format of a single page of data which describes all important input and output for a single analysis "run". As the capabilities of STA LIFTBOAT have expanded, the amount of results produced and required input and control data has grown. Nevertheless, a single page summarizing all critical input data and results is still produced. For complete reporting on a run, the user will probably wish to print the main input data screen, the second data input screen (which also contains pad moment results), the single page Input Summary and Results Summary, the detailed leg section properties, the intermediate stress check results, the transit stress checks, and the ten standard graphs. The following pages describe the tabular results in detail.

8.1 Input Summary

The input summary table is printed with other results (on one page with the Results Summary) when the user clicks on the button at the top of the input summary screen marked *Print all tables* (see Figure 15) or when the user clicks on the button marked *Print all results* on this same data screen. Alternatively the user may print the table in isolation by clicking on one of the buttons marked *Print this screen* when the user is viewing the table. Most of the terms in the input summary are self-explanatory and were entered by the user either at the main input data screen (first screen) or at the second input data screen. A few terms require further explanation as described below:

Wind force

The result for wind force appearing in the Input Summary will either read *COMPUTED BELOW* or a value for wind force in kips will be given. The value in kips will only be given if the user has set the *wind force switch* to be equal to 1 in the main (first) data input screen. Where the result is shown as *COMPUTED BELOW*, the value for wind force will be shown in the Results Summary table.

Beta top fixity coefficient

This term is a ratio representing the effective stiffness of the leg/hull connection coming from the jacking system, or from the rack chock system if appropriate. A value of $\beta = 1.0$ implies that the rack chocks, or pinions, have taken the full moment at the top of the leg, and that no moment is supplied by horizontal reactions at the guides. Conversely, a low value of β implies that the horizontal guides are taking most of the leg bending moment into the hull. In this case, the guide horizontal reactions will be high. See section on theory for further explanation. For single rack liftboats, the value of β is always zero.

Mu, bottom fixity coefficient

This term describes the relative magnitude of the moment at the pads compared to the moment at the hull for the legs. A value of $Mu = 0$ implies that the pads are pinned. A high value of Mu implies that the pads are nearly fully fixed. See section on theory for further explanation.

Wave crest elevation

This is the elevation of the wave crest above the still water level.

8.2 Results Summary

Pad1 before environmental load

This is the vertical soil reaction on pad #1 (port fwd pad, see sign convention, Figure 4, Page 16) before environmental loads or any static offset (due to hull not being level, or legs not straight) are applied.

Pad3 before environmental load

This is the vertical soil reaction on pad #3 (stbd fwd pad, see sign convention, Figure 4, Page 16) before environmental loads or any static offset (due to hull not being level, or legs not straight) are applied.

Pad3 before environmental load

This is the vertical soil reaction on pad #2 (stern pad, see sign convention, Figure 4, Page 16) before environmental loads or any static offset (due to hull not being level, or legs not straight) are applied.

Average leg buoyancy

This is the average buoyancy of the legs which is a vertically upwards force having the effect of decreasing the weight on the pads. It is the average of the three leg buoyancy forces which may each be different, if the user has specified a different diameter for each leg. It is calculated for each leg from:

$$(water\ depth + pad\ penetration) \times leg\ diameter \times weight\ density\ of\ water$$

Note that the weight density of the water in STA LIFTBOAT is taken as 0.064 kips per cubic foot.

Lateral Stiffness used

This is the effective lateral stiffness of the unit in kips/foot. The physical explanation of this term can be understood by considering the horizontal force applied to the hull needed to displace the hull horizontally by a distance of one foot.

Wind force

This is the calculated wind force acting on the exposed areas of the legs and hull, for the particular loading direction under consideration. Note that this term will not be displayed if the user has set the *wind force switch* to 1 and given a specific wind force in the first data input screen. The user specified wind force will then appear in the Input Summary.

Max wave-current force

This is the maximum force found during the wave cycle by the program on the legs, coming from wave and current drag and inertia terms on each leg element.

Wind O/T moment

This is the overturning moment coming from the wind force. The moment is taken about the center of the pads.

Amplitude wave-current O/T moment

This is the amplitude of the wave and current force overturning moment. Note that this term is subsequently multiplied by the dynamic amplification factor (DAF). This is the only term which is treated dynamically on the forcing function side of the dynamic response equations.

Tnxx sway period

This is the natural period of the vessel in beam direction sway. This term is influenced by the mass of the hull, the distributed mass of the legs, the added mass of the legs, the stiffness of the pad rotational springs, the flexural and shear stiffness of the legs, the stiffness of the hull-leg connection, and the leg length extended. Note that the added hydrodynamic mass of the legs is a function of the leg diameter found in the leg/hull file, rather than the leg diameter specified by the user. Note also that the natural sway period can be altered in the second data input screen by the user selectable term *natural period multiplier*, the first term in this second data screen. For correct dynamics, the *natural period multiplier* should be set to 1. If the user wishes to completely remove dynamics, the *natural period multiplier* may be set to any value less than 0.1. If the user wishes to investigate the effect of arbitrary changes in the

natural period on the overall response of the structure, the *natural period multiplier* may be set to any value. A value of 2 for this term will double the natural period. A value of 0.5 for the *natural period multiplier*, will halve the natural period.

Tnyy sway period

This is the same as for Tnxx, above, but for sway in the fore-aft direction.

Natural torsional period

This is the natural period of the vessel in torsion. The vessel is assumed to twist about the leg geometric center. Note that the torsional natural period is reported but not used in the calculations associated with leg forces or moments.

Mean hull deflection

This is the mean lateral deflection of the hull. It is caused by the wind loads, which are treated as steady, and the mean value of the wave current load. There is no contribution in this term from an initial static offset.

Max hull deflection

This is the maximum deflection of the hull caused by environmental forces. It is made up of the mean hull lateral deflection and a dynamic component of deflection which is influenced by the dynamic amplification factor. There is no contribution to this term from any initial static offset.

Uncorrected stabilizing moment

This is equal to the weight acting on the sea bed through the pads multiplied by the distance of the center of weight to the center line of the nearest pair of pads. This term is calculated with the vessel in the undeflected position, meaning before application of environmental loads.

Corrected stabilizing moment

This is the stabilizing moment computed from the weight of the vessel acting through the pads on to the sea bed multiplied by the distance to the center line of the nearest pair of pads. Unlike the uncorrected stabilizing moment, the vessel position is considered to be in the maximum deflected position, including a static offset plus the maximum hull lateral deflection caused by environmental forces. Hence the hull has deflected laterally, moving the weight center closer to the nearest pair of pads. Both the uncorrected and the corrected stabilizing moment account for total hull weight, less buoyancy.

Max.Upper guide reaction

This is the maximum force provided to the leg by the upper guide in a horizontal direction. See theoretical section.

Max.equivalent lateral top load

This is the equivalent horizontal load that would have to be applied to the hull to cause the same lateral deflection as calculated to be caused by the environmental forces.

Pad max.calc.bend.mom.

This is the maximum bending moment at the pad. If this value exceeds the ultimate moment capacity of the soil/pad system, a warning is printed at the top of the Results Summary.

PDelta leg BM.max

This is the maximum contribution to leg bending moment caused by the P-delta effect.

PadMax.Id.uncorrected

This is the maximum pad vertical reaction found during the wave cycle, without the influence of the flexural response of the structure, or consideration of the dynamics.

PadMax.Id.corrected

This is the maximum computed vertical reaction beneath a pad during the wave cycle, accounting for the flexural, or sway response of the structure. The response is considered dynamically and the initial static offset is included.

Pad mean angle

This is the mean rotation angle of the pads during the wave cycle. A value of zero implies that the pads are fully fixed and do not rotate. Under this condition there would be a larger moment calculated at the pads. The maximum pad rotation that would occur during a wave cycle, for the same applied environmental forces and same structural model, would be with the model pinned at the pads.

Max.O/T w/o P-delta

This is the maximum overturning moment computed during a wave cycle, without the effect of structural response. In other words, the structure is treated as being infinitely rigid and does not move. This result is generally greater than the *max. apparent O/T moment*, as the amplitude of the wave-current force must be multiplied by the DAF.

Max.hull ax.F1,F3

This is the maximum axial load calculated at the level of the hull for either of the two forward legs (F1 port, F3 stbd) accounting for all vessel responses.

Max.hull ax.F2

This is the maximum axial load calculated at the level of the hull for the aft leg, accounting for all responses.

max fb, legs 1,3

This is the maximum bending stress induced in either leg 1 (port) or leg 3 (stbd) at the level of the lower guide and accounts for all structural responses including so-called secondary bending (P-delta) effects.

max fb, top leg 2

This is the maximum bending stress induced in leg 2 (aft leg) at the level of the lower guide and accounts for all structural responses including so-called secondary bending (P-delta) effects.

max fa, legs 1,3

This is the maximum axial stress induced in either leg 1 (port) or leg 3 (stbd) at the level of the lower guide and accounts for all structural responses.

max fa, top leg 2

This is the maximum axial stress induced in leg 2 (aft leg) at the level of the lower guide and accounts for all structural responses.

Hull max.shr.str

This is the maximum shear stress induced in the heaviest loaded leg at the level of the lower guide.

fa/Fa ABS legs 1,3 (note: if leg 2 is the heaviest loaded leg, this term will be **fa/Fa ABS leg 2**)

This is the maximum calculated axial leg stress (from leg axial loads F1, F2, or F3) induced in either leg 1 (port) or leg 3 (stbd) at the lower guide, divided by the maximum allowable axial stress, Fa, in this leg. Fa is calculated according to ABS rules (see section on stress checks). If leg 2 is heavier loaded than either legs 1 or 3, the fa/Fa value for leg 2 will be shown.

fb/Fb ABS legs 1,3 (note: if leg 2 is the heaviest loaded leg, this term will be **fb/Fb ABS leg 2**)

This is the maximum bending stress (from bending moment at lower guide) induced in either leg 1 (port) or leg 3 (stbd) divided by the maximum allowable bending stress, Fb, calculated according to ABS Rules (pre 1988). The effective leg length, or K-factor, used to calculate Fb is that shown in the right hand column of the Results Summary. If leg 2 is heavier loaded than either legs 1 or 3, the fb/Fb value for leg 2 will be shown.

Weight - buoyancy

This is the total weight reaction on the pads resisted by the soil. It is equal to the total weight of the boat specified by the user in the main data input minus the buoyancy on each of the three legs. Note that the effect of water inside the legs (see leg buoyancy option in input data) is not to increase leg weight, but to reduce leg buoyancy. However, water inside the legs adds mass to the vessel and increases natural sway periods.

Total buoyancy

This is the force calculated by summation of buoyancy (accounting for leg internal flooding) on each of the three legs.

Lateral x-stiffness

This is the effective lateral stiffness of the unit in kips/foot in the x-direction (fore-aft sway). The physical explanation of this term can be understood by considering the horizontal force applied to the hull needed to displace the hull horizontally by a distance of one foot.

Lateral y-stiffness

This is the effective lateral stiffness of the unit in kips/foot in the y-direction (side sway). The physical explanation of this term can be understood by considering the horizontal force applied to the hull needed to displace the hull horizontally by a distance of one foot.

Mean wave-current force

This is the mean value of the horizontal force on the legs coming from wave and current loads during a single wave cycle.

Max. total force

This is the maximum horizontal force on the boat calculated from wave and current loading, plus wind loading, during a wave cycle.

Mean wave-current O/T moment

This is the mean value of the applied overturning moment caused by wave and current forces on the legs.

Max.apparent O/T moment

This is the maximum applied overturning moment coming from environmental forces. It is described as the maximum "apparent" moment because the response of the structure is not included. The sway response of the structure increases the effective overturning moment.

Max. torsional moment

This is the maximum torsional moment computed from environmental loads applied to the structure. Like the term above, it is the force available and does not include the effect of structural response. This term is reported but is not used to calculate additional force or moment contributions to the legs.

DAF (stochastic)

This is the stochastic dynamic amplification factor as described previously. This term is used to multiply the amplitude of the applied loads from wave and current in order to compute the structural response of the vessel dynamically.

Hull deflection amplitude

This is the lateral deflection amplitude of the hull during a wave cycle and includes both static and dynamic effects.

Offset+deflection

This is the maximum lateral deflection of the hull found during a wave cycle, including the initial static offset. If the static offset is zero, this term will be equal to the *max hull deflection*.

Euler leg load

This is the Euler load of the leg (the axial load that would theoretically cause Euler buckling). It accounts for the top and bottom leg fixity conditions as well as the bending and shear stiffness of the leg.

Max. base shear

This is the maximum horizontal force that must be resisted by soil reactions on the pads during a wave cycle. It is the total of the force resisted by all three pads.

Max.low.gde.reac.

This is the maximum horizontal force applied by the lower guides to the legs during a wave cycle.

Max. horizontal pad reaction

This is the maximum horizontal soil/pad reaction found during a wave cycle and is equal to one-third of the maximum base shear as the program considers the pad horizontal reactions to be shared equally.

BM.hull max w/oPD

This is the maximum bending moment found in the legs at their connection with the hull during a wave cycle, before P-delta effects and dynamics are applied. In other words, it is the bending moment that would be found for a structure without any deflections.

BM.hull max. w/PD

This is the maximum leg bending moment computed at the hull connection, including all response effects.

Max. axial leg load @ lower guide

This is the maximum axial load found in a leg at the lower guide during a wave cycle including, all response effects.

PadMin.Id.uncorrd.

This is the minimum pad vertical reaction found during the wave cycle before structural response is accounted for.

PadMin.Id.corrected

This is the minimum vertical pad reaction found during a wave cycle accounting for static and dynamic structural response. If this term goes to less than zero, it indicates that there would be uplift on one or more of the pads during the wave cycle. This does not necessarily imply that the structure would topple for several reasons. Firstly, the structure has significant inertia and the forces applied to it during a wave cycle are oscillatory. Unless the **mean** value of the pad reaction during a wave cycle is less than zero, it is unlikely that the structure can topple. Secondly, especially in soft cohesive soils, there is generally a significant force required to extract the pad quickly (within a wave cycle) from the sea bed. The extraction force may be negligible if the pad is sitting on hard sand and is not fully penetrated.

Pad max.angle

This is the maximum angle to which the pad is computed to rotate during a wave cycle.

Max.OT.mom.w.PD

This is the maximum overturning moment computed from the environmental forces, including dynamics and the additional overturning moment that results from the deflection of the structure.

Pad Ultimate Moment Capacity

This is the calculated ultimate moment that the soil can apply to the pad, based upon a cohesive soil, an circular pad of equivalent area to the actual rectangular pad, and a hemispherical failure surface with the same radius as the equivalent circular pad. The center of rotation is assumed at the pad center and the soil shear strength is assumed to increase beneath the pad at 4 psf/ft of depth. If this maximum calculated moment at the pad exceeds this value, a warning is printed at the top of the Results Summary. In the Version 4.0 STA LIFTBOAT program, this ultimate moment is no longer used and the methodology described in the 1997 City University Jack-Up Conference paper by Stewart is now implemented. This

paper is included as an appendix to this manual. This method involves Pad Soil Yield Surface Checks. Combined vertical, horizontal and rotational pad loads are considered. See Section 8.3 of this manual.

K-Equivalent

This is the effective leg length factor, or K-factor, which is calculated by the program, based upon leg top and bottom fixities, and relative flexural and shear stiffnesses. This term is used in the calculation of allowable stresses in the unity stress checks.

Uncorr. O/T SF

This is the safety factor against overturning computed from the environmental loading applied to the undeflected structure. In other words, the loading is treated as static, the structure is treated as being rigid and without deflections, and the uncorrected stabilizing moment is used. The equation used is:

$$\text{Uncorrected O/T safety factor} = (\text{uncorrected stabilizing moment}) / (\text{max. O/T moment})$$

Corrected O/T SF

This is a safety factor against overturning. This term is found dividing the *uncorrected stabilizing moment* by the *maximum overturning moment with P-delta effect*. Note that if the wave loading direction is not perpendicular to the line joining the pair of legs nearest to the center of gravity, the reported overturning safety factors are not strictly correct. The error is always conservative. A *corrected overturning safety factor* = 1, implies that the environmental forces and structural response during the passage of a wave result in a maximum overturning moment which is just equal to the uncorrected stabilizing moment.

DnV O/T Safety F

This is the factor of safety against overturning computed by dividing the *corrected stabilizing moment* by the *maximum overturning moment without the P-delta effect*. Generally, the value found is close to that described above for the *corrected overturning safety factor*.

ABS pre-88 unity str.chk legs 1,3

This is the maximum calculated unity stress check in either of the liftboat legs 1 or 3, at the location of the lower guide, using the calculated stresses with all so-called secondary effects, and using the value of K-Equivalent defined above. The equation for this stress check is given by:

$$\text{Stress check value} = f_a/F_a + f_b/F_b$$

ABS pre-88 unity str.chk leg 2

This is the maximum calculated unity stress check in leg 2, at the location of the lower guide, using the calculated stresses with all so-called secondary effects, and using the value of K-Equivalent defined above. The equation for this stress check is given by:

$$\text{Stress check value} = f_a/F_a + f_b/F_b$$

Rational Unity str.chk.legs 1,3

This is the rational stress check used by DnV for jack-up rigs with tubular legs applied to the heaviest loaded of either leg 1 (port) or leg 3 (stbd). The interaction equation for this stress check is given by the maximum of either:

$$\begin{aligned} \text{Stress check value} &= 1.25 \left\{ f_a/f_{cr} + (f_b' + f_{b0})/f_{cr} \right\} \\ \text{Stress check value} &= 1.25 \left\{ f_a/f_{cr} + (f_b + f_{b0})/f_{cr} \times 1/(1 - P/P_E) \right\} \end{aligned}$$

Where:

f_b' is as defined above and includes secondary bending stress components

f_a and f_b are defined as above (but f_b does not include secondary stress components)

f_{cr} = local critical stress

P = average axial leg load due to functional, or self-weight loads, only. (see Note 1, below)

P_E = Euler load for leg (using weakest axis)

The safety factor of 1.25 is equivalent to making the unfactored interaction equation equal to a maximum "usage factor" of 0.80, appropriate for design storm loading.

f_{cr} is determined from the yield criterion (see Note 2, below) as:

$$f_{cr} = (f_x/f_e) f_Y$$

Where:

- f_x = actual value of axial stress component in the leg
- f_e = von Mises equivalent stress component.
- f_Y = yield stress of leg steel

In practice the von Mises stress is almost identical to the axial stress component, as shear stress is small (and in any case, the point of maximum shear stress is at 90 degrees around the leg circumference from the point of maximum bending stress). Consequently the critical stress, f_{cr} , is generally approximately equal to the leg yield stress (see Note 2, below).

Rational Unity str.chk.leg 2

This is the rational stress check used by DnV for jack-up rigs with tubular legs applied to leg 2 (aft). The interaction equation for this stress check is given by the maximum of either:

$$\text{Stress check value} = 1.25 \left\{ f_a/f_{cr} + (f_b' + f_{b0})/f_{cr} \right\}$$

$$\text{Stress check value} = 1.25 \left\{ f_a/f_{cr} + (f_b + f_{b0})/f_{cr} \times 1/(1 - P/P_E) \right\}$$

Where:

- f_b' is as defined above and includes secondary bending stress components
- f_a and f_b are defined as above (but f_b does not include secondary stress components)
- f_{cr} = local critical stress
- P = average axial leg load due to functional, or self-weight loads, only (see Note 1, below).
- P_E = Euler load for leg (using weakest axis)

The safety factor of 1.25 is equivalent to making the unfactored interaction equation equal to a maximum "usage factor" of 0.80, appropriate for design storm loading.

f_{cr} is determined from the yield criterion (see Note 2, below) as:

$$f_{cr} = (f_x/f_e) f_Y$$

Where:

- f_x = actual value of axial stress component in the leg
- f_e = von Mises equivalent stress component.
- f_Y = yield stress of leg steel

In practice the von Mises stress is almost identical to the axial stress component, as shear stress is small (and in any case, the point of maximum shear stress is at 90 degrees around the leg circumference from the point of maximum bending stress). Consequently the critical stress, f_{cr} , is generally approximately equal to the leg yield stress (see Note 2, below).

Note 1. In STA LIFTBOAT version 1, the value for P, the average axial leg load, was put equal to the average axial leg load at the point of maximum response. This was overly conservative and was in part due to some ambiguity in the 1984 version of the DnV Classification Note 31.5. In the 1992 version of this Classification Note, the definition of P has been clarified. In STA LIFTBOAT the value for P (calculated for each leg) is equal to the load coming onto the leg through the pinions, plus half the weight of the leg beneath the lower guide, in the absence of environmental loads.

Note 2. The above stress checks are governing only if the legs are proportioned and stiffened in such a way that local buckling is excluded. If the effective D/t (internal diameter divided by average equivalent thickness for the leg beneath the lower guide) ratio exceeds the

E/9fy (Young's modulus divided by nine times yield stress) ratio, then a local buckling check must also be performed in order to ensure local buckling will not occur.

8.3 Pad Moment Results

The moments calculated at the pads are dependent upon the rotational spring stiffness simulated at the pads. This stiffness is user specified by input of the undrained soil shear strength, su , and the term *coef.on su to get soil G modulus* in the second input data screen. In general, the stiffer the soil spring, the larger will be the moment generated in response to environmental loads. If the spring has zero stiffness, the pads will not find any moment and their rotation will be a maximum. If the spring is very stiff, the pads will hardly rotate at all and the moment generated will be high.

Moment Capacity of Pads

It is becoming accepted that the maximum moment capacity of a fully embedded spudcan in clay can be described by the yield function given below (Reference 9):

$$16 \left[\frac{F_{VHM}}{V_{L0}} \right]^2 \left[1 - \frac{F_{VHM}}{V_{L0}} \right] \left[1 - \frac{F_{VHM}}{V_{L0}} \right] - \left[\frac{F_{HM}}{H_{L0}} \right]^2 - \left[\frac{F_M}{M_{L0}} \right]^2 = 0 \quad \text{when } F_{VHM} \geq \frac{1}{2} V_{L0}$$

$$1 - \left[\frac{F_{HM}}{H_{L0}} \right]^2 - \left[\frac{F_M}{M_{L0}} \right]^2 = 0 \quad \text{when } F_{VHM} < \frac{1}{2} V_{L0} \quad \text{Equation 2}$$

where

- F_{VHM} = vertical foundation capacity in combination with horizontal and moment load,
- F_{HM} = horizontal foundation capacity in combination with moment,
- F_M = moment capacity of foundation,
- V_{L0} = maximum vertical foundation load during preloading,
- $H_{L0} = A c_{u0} + (c_{u0} + c_{ut}) A_s$, the maximum sliding capacity factor in clay (occurring at $V = 0.5 V_{L0}$ and $M = 0$),
- $M_{L0} = 0.1 V_{L0} B$, maximum moment capacity (occurring at $V \approx 0.5 V_{L0}$ and $H = 0$)
- A = spudcan effective bearing area based on cross-section taken at uppermost part of bearing area in contact with soil,
- A_s = spudcan laterally projected embedded area,
- B = effective spudcan diameter at uppermost part of bearing are in contact with the soil (for rectangular footing B = width),
- c_{u0} = undrained cohesive shear strength at maximum bearing area (D below mudline,
- c_{ut} = undrained cohesive shear strength at spudcan tip,
- D = distance from mudline to spudcan maximum bearing area.

The load combination (vertical, horizontal, and moment) lies outside the yield surface if the left hand side of Equation 2 is less than zero and inside the yield surface if greater than zero.

Equation 2 can be rewritten so that the maximum permissible spudcan moment (on the yield surface) becomes a function of the horizontal and vertical loads as is shown in Equation 3:

$$F_M = M_{L0} \left\{ 16 \left[\frac{Q_V}{V_{L0}} \right]^2 \left[1 - \frac{Q_V}{V_{L0}} \right] \left[1 - \frac{Q_V}{V_{L0}} \right] - \left[\frac{Q_H}{H_{L0}} \right]^2 \right\}^{0.5} \quad \text{Equation 3}$$

where:

- Q_V = applied vertical load,
- Q_H = applied horizontal load.

For a given combination of applied vertical and horizontal loads, the moment at the spudcan cannot exceed the value defined above (Reference 9). If the maximum permissible spudcan moment is exceeded during a wave cycle, there will be plastic deformation of the soil. The path in unloading will be different from the path when the maximum loads were reached. Stable conditions are unlikely to develop after a single wave cycle but will tend towards a condition where a permanent rotation is locked in. This is especially true where the leeward leg of a vessel is loaded close to, or even above, its preload level. This commonly occurs with liftboats and further pad penetration during storms is simply compensated for by jacking the hull up. When the pad penetrates further into the soil, under a large vertical load, simultaneously experiencing a rotation caused by the environmental overturning moments, the pad ends up at an angle. The upper bounds for the final pad angle may be the pad angles that would occur during the wave cycle if the leg was pinned. However, because of some plastic resistance of the soil to the pad rotation, the maximum equivalent pinned angle is unlikely to be reached.

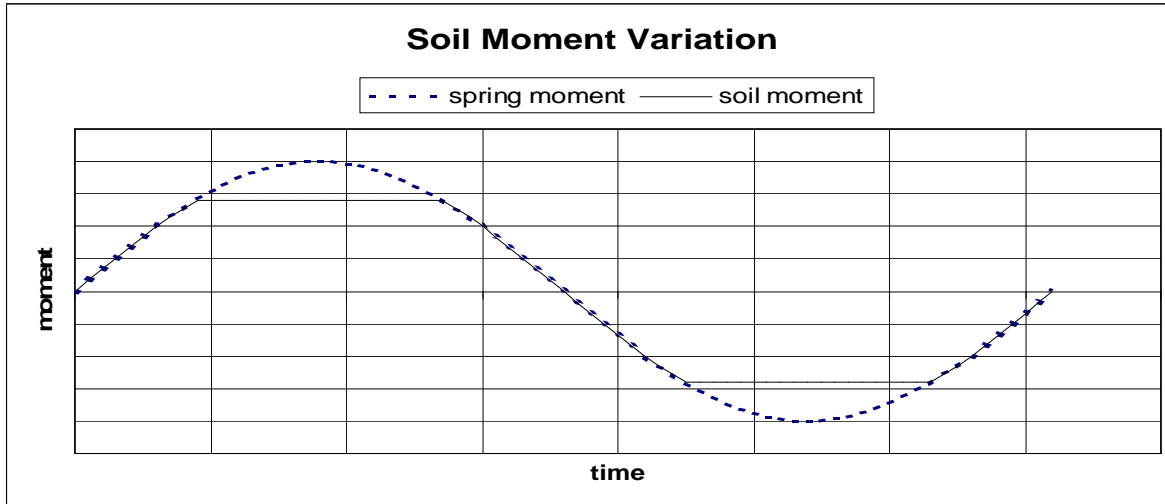
The liftboat analysis procedure used in STA LIFTBOAT now uses the pad mean angle calculated as if the soil rotational stiffness was correctly assessed. Then the amplitude of pad rotation about this mean is used to determine the maximum pad moments during a wave cycle. This procedure assumes that the pads will bed down during a storm as has been suggested by Hambley (Reference 12). The geotechnical portion of Reference 9 was verified and improved upon in 1996-1997 following a study performed by SINTEF (Reference 13) commissioned by SNAME. SINTEF cited Hambley's work and noted that he suggested *"this condition may be approached analytically by calculating the deformations due to the "static" wind + current loads with a pinned foundation, and then evaluate the rotation foundation stiffness for the wave loads only. The dynamic analysis would then only include wave loads"*.

In STA LIFTBOAT it is now assumed that the mean pad inclination angle should correspond to the mean angle during a wave cycle, given the full environmental load (wind, current, and waves) and a cyclically degraded soil shear modulus for rotational loading. As the pad rotates to this mean angle, there will be some further penetration. The cyclic motions of the pad caused by further wave loading will then result in pad moments oscillating about a zero mean value, with pad rotations oscillating about a nonzero value. An iterative (trial and error) process is used to find an allowable stiffness for the equivalent linear rotational spring representing the soil.

Where the leeward leg induces soil moment amplitudes which peak outside the yield surface but the windward legs have load conditions inside the yield surface, then the average of the maximum allowable moments are taken. For simplification of the dynamic response analysis each pad is considered to have the same horizontal load and the same moment (same rotation) at every instant during the wave cycle. Provided that the amplitude of this induced moment is less than the average allowable moment (calculated using Equation 3) the vessel is considered to be responding reasonably. In order to achieve this balance, the shear stiffness of the soil (G/s_u) is adjusted manually. For liftboat pads in storm conditions experience has shown that shear stiffness values in the range of 15 to 50 are required when this methodology is applied. In the mild

conditions generally associated with liftboat “design” much larger values of shear stiffness, sometimes up to 1000, are possible. However, values larger than 300 are generally not recommended.

It is considered that in storm conditions, where the leeward leg moment at the pad fails to stay within the yield surface after the pad has ceased to penetrate further, the time



history of the moment at the pad will be as shown idealized in the figure above. The nonlinearity induced by the elasto-plastic behavior of the pad moment induces hysteresis which is not accounted for in the linear SDOF approach.

The calculated and ultimate pad moments are reported to the user on the second data input screen and in the Results Summary. A warning is printed on both screens if the calculated moment exceeds the ultimate moment. The user may decrease the *coef.on su to get soil G modulus* until the warning disappears. Alternatively, the *coef.on su to get soil G modulus* may be increased (up to a recommended maximum value of 300) to maximize the soil restraint, provided the calculated pad moments do not exceed the ultimate capacities.

Increasing the size of the pads, keeping them as nearly square as possible, is the best way to improve pad moment capacity.

8.4 Leg Hydrodynamic Coefficients

At the beginning of each run, the user must input the leg hydrodynamic coefficients. However, the program *calculates* the equivalent leg diameter, the leg average and maximum drag coefficients, and the variation of the drag coefficient with wave attack angle, in the last worksheet (Lift001.xls). The drag coefficient varies with direction as a consequence of the leg rack(s). The user must select the drag coefficient for the cylindrical part of the leg in the last worksheet. The equivalent leg diameter, average and maximum drag coefficients are reported near the top of the second data input screen. Normally the user would input the calculated equivalent diameter and average drag coefficient at the first data input screen. The input diameter is then used for wave loading calculations and for leg buoyancy calculations. However it should be noted that the equivalent leg diameter **as computed** in each leg/hull file is used to calculate the added hydrodynamic mass of each leg. This added mass contributes to the terms used to compute the natural sway period of the boat. For most liftboat legs the rack effect is small and the actual leg cylinder OD is virtually the same as the computed leg equivalent diameter.

The leg drag coefficients calculated in each leg/hull file should also be input by the user to the first input data screen as described for the leg equivalent diameter above. The average drag coefficient found as the wave attack angle is varied may not be appropriate for all wave attack angles and the user should consult the graph of drag coefficient variation with wave attack angle produced by the program.

8.5 Unity Stress Checks - Global Leg Strength

Rational Stress Check

STA LIFTBOAT uses a rational formula for its unity stress checks of the liftboat legs. Only the maximum stresses at the level of the lower guide are directly checked. The input stresses are calculated correctly accounting for the second order stresses induced by large sway deflections. An interaction equation relating combined axial and bending stresses on a slender column is used. The formula for this rational stress check is adopted from DnV (Reference 2). This formula is usually stated by DnV in the form of a Usage Factor, η , which should not exceed 0.8 for storm load conditions, in the intact condition. (A value of unity for η is used to evaluate structural integrity in a damaged condition.) The maximum value of η is found from the following two equations:

$$\eta = f_a/f_{cr} + (f_b + f_{b0})/((1 - P/P_E)f_{cr})$$

$$\eta = f_a/f_{cr} + (f_b' + f_{b0})/f_{cr}$$

Where:

f_a	=	axial stress due to design loadings
f_b	=	bending stress due to design loadings, not including secondary bending
f_b'	=	bending stress due to design loadings, including secondary bending amplification and dynamic effects
f_{cr}	=	local critical stress (see below)
f_{b0}	=	bending stress induced by $P \times e_0$
P	=	average axial load on leg due to self weight only
P_E	=	Euler buckling load, as defined below.
f_{cr}	=	((leg total axial stress)(yield stress))/(leg von Mises stress)
P_E	=	$\pi^2 EI/(Kl)^2$
K	=	effective length factor
l	=	leg length extended.
e_0	=	static horizontal offset of the leg at the elevation of the lower guide caused by the legs not being perfectly straight, the hull not being perfectly level, and the guides not being perfectly tight.

The same type of formula can be derived by a combination of the AISC plastic design formula N4-2 on page 5-95 of Reference 9, and the simple (prior to 1988) unity check adopted by the ABS (which is represented by formulae H1-1, H1-2, and H1-3 in Reference 9).

Expressing the DnV formula as a unity check yields both:

$$1.25 f_a/f_{cr} + 1.25 (f_b + f_{b0})/((1 - P/P_E)f_{cr}) \geq 1.0$$

$$1.25 f_a/f_{cr} + 1.25 (f_b' + f_{b0})/f_{cr} \geq 1.0$$

The program STA LIFTBOAT reports a value for f_b which equals $f_b' + f_{b0}$. The value of e_0 is controlled by the input term Ke_0 , **LEG OUT OF STRAIGHT. coef.**

The local critical stress, f_{cr} , for legs which are proportioned and stiffened in such a way that local buckling is excluded, is determined from the yield criterion as:

$$f_{cr} = (f_x/f_e) f_Y$$

Where:

f_x	=	actual value of axial stress component in the leg
f_e	=	von Mises equivalent stress component.
f_Y	=	yield stress of leg steel

In practice the von Mises stress is almost identical to the axial stress component, as shear stress is small (and in any case, the point of maximum shear stress is at 90 degrees around the leg circumference from the point of maximum bending stress). Consequently the critical stress, f_{cr} , is generally approximately equal to the leg yield stress.

Note: *The above stress checks are governing only if the legs are proportioned and stiffened in such a way that local buckling is excluded. If the effective D/t (internal diameter divided by average equivalent thickness for the leg beneath the lower guide) ratio exceeds the $E/9f_y$ (Young's modulus divided by nine times yield stress) ratio, then a local buckling check must also be performed in order to ensure local buckling will not occur.*

ABS Stress Checks

In addition to the rational stress checks described above, STA LIFTBOAT also computes unity stress checks according to ABS Rules (Reference 4), which follow the AISC stress check convention (Reference 3). Prior to the 1988 ABS Rules, the stress check required (for structures similar to liftboat legs) was the simple interaction equation:

$$f_a/F_a + f_b/F_b \geq 1.0$$

Where:

f_a	=	actual axial stress
F_a	=	allowable axial stress
f_b	=	actual bending stress
F_b	=	allowable bending stress

In 1988 the ABS modified their rules to follow the AISC rules more closely and introduced the interaction equation:

$$f_a/F_a + C_m f_b / ((1 - f_a/F'_e) F_b) \geq 1.0$$

Where:

F'_e	=	$12p^2 E / (23(Kl/r)^2)$
F'_e	=	ABS/AISC-defined Euler buckling stress and may be increased under ABS rules by 1/3 for combined (static and environmental) loadings.

K	=	effective length factor.
C_m	=	coefficient which relates to joint translational freedoms. For liftboats this coefficient is to be taken as 0.85.

This second unity stress check is to be applied if f_a/F_a is greater than 0.15, which is usually the case for liftboats under design maximum conditions. However, the AISC allowable stress design rules (Reference 3) (and most derivatives) were written with structural steel buildings in mind, with relatively stiff frames. The second unity stress check, above, is designed to take account of secondary bending stresses in frames subject to sidesway, **but this stress check is meant to be applied to first order stresses which are calculated from a linear analysis and do not include secondary bending effects**. When stresses are rigorously calculated to include secondary bending effects (caused by the P-delta effect) this stress check is incorrect and overly conservative. Furthermore, because the sidesway of liftboats is generally much larger than the sidesway of normal building frames and the leg slenderness ratio is very large, the AISC stress check may give unpredictable results even if applied, as it is intended to be, to first order stresses only.

Since STA LIFTBOAT computes secondary bending amplification effects, the ABS stress check in use prior to 1988 is used instead of the second stress check, above. However, although the results of this ABS/AISC stress check are reported, they are generally overly conservative and rather misleading. The procedure for computing the ABS unity check is described below.

Allowable axial stresses, F_a , are computed which are to be the least of:

- a) yield stress divided by appropriate factor of safety
- b) overall buckling stress divided by appropriate factor of safety
- c) local buckling stress divided by appropriate factor of safety

The appropriate factors of safety for a) and c) are generally 1.25, as they represent combined (live) loadings. The factor of safety for b) is either 1.25 or 1.44, depending on the slenderness ratio, the yield stress, etc. The overall buckling stress is defined in Reference 3. The local buckling stress must be found from another source. API RP 2A is used (Reference 5) to find elastic and inelastic local buckling stresses.

Note that stresses at the bottom of the legs may be high under some situations, and fatigue damage may occur at the leg and pad connection. Initially, a through-thickness fatigue crack would permit the leg to flood with water. On re-floating the vessel, the water in the flooded leg may not drain as quickly as the leg is raised. This may lead to a complete loss of afloat stability and capsize, if the problem is not quickly recognized.

8.6 Local Buckling Stress Checks

If the leg diameter/thickness ratio exceeds the ratio of Young's modulus divided by nine times the steel yield stress, the leg column section is no longer regarded as "compact". In this case a local buckling check must be performed. The method used in the program is that used by DnV and is fully described in Reference 6.

STA LIFTBOAT always performs a local buckling stress check , but only prompts the user to check the results if the leg properties require the check. The figure below illustrates the output from the program in a case where the local buckling stress check is required. Note that the results shown in below indicate that the factor of safety against local buckling is not satisfactory, since the unity stress checks for both cases (aft leg and forward legs) exceed 1.00. Either the leg section properties must be increased, or the loads reduced. Note that if the leg section properties are increased until $D/t > E/9F_y$, then the leg section will be "compact" and local buckling will not be a problem, whether or not the local buckling unity stress check is greater or less than 1.00.

DnV Class Note 31.5 (global buckling)		D/t>E/9Fy ?	No, hence no local buckling check required.	leg 3
0.249	$(\sigma_b + \sigma_{b0}) / (\sigma_{cr})$ (legs2&3)	0.249	$(\sigma_b + \sigma_{b0}) / (\sigma_{cr})$ (leg2)	0.249
0.105	σ_a / σ_{cr} (legs1&3)	0.152	σ_a / σ_{cr} (leg2)	0.178
0.354	DnV usage factor (legs 1&3)	0.402	DnV usage factor (leg2)	0.427
0.443	rational unity stress chk.(legs1)	0.502	rational unity stress check (leg2)	0.534
DnV Class Note 30.1 (local buckling)		Yield stress (ksi)-> 60		
1.030	max. σ_a / σ_{cr} , DnV (legs1&3)	Safety factor of 1.25 used against local buckling.		
1.079	max. σ_a / σ_{cr} , DnV (leg2)	9.573	λ / λ_0	
15.081	i, average radius of gyration (in)	0.343	μ , coeff.for calc. σ_{cr}	
169.037	Kl, effective length to 1/2 pad ht.(ft)	0.243	σ_{cr} / σ_F	
134.503	λ_k , column slenderness	0.105	σ_a / σ_{cr} (legs1&3)	
16.367	σ_E , Euler stress (ksi)	0.226	$\alpha \sigma_b / ((1 - \sigma_a / \sigma_E) \sigma_{cr})$ (leg1)	
1.915	λ , reduced slenderness 1.915	0.414	local buckling stress check (DnV) (leg 1)	leg 3
0.200	λ_0 , coef. for buckling curve a.	0.152	σ_a / σ_{cr} (leg2)	0.178
0.200	α , coef. for non-dim.buckl.curve a.	0.248	$\alpha \sigma_b / ((1 - \sigma_a / \sigma_E) \sigma_{cr})$	0.254
13.839	σ_{cr} (ksi) from 2.3.2 CN30.1	0.500	local buckling stress check (DnV) (leg2)	0.540

9.0 GENERAL THEORY AND ANALYSIS PROCEDURES

9.1 Overview

STA LIFTBOAT computes wave, wind, and current forces on a liftboat. The forces are calculated at twenty phase angles during the passage of a single regular wave. Wind forces are considered to be steady. Wave forces are combined with current forces.

The forces calculated as described above, are applied to a structural model of the boat. The forces cause deflections in the structural model which result in secondary bending moments and changes in the pad vertical reactions at the sea bed. The structural model is described in more detail later.

The pads at the sea bed are treated as having a rotational stiffness which may be varied from zero to fully fixed by the user. The flexural and shear stiffnesses of the legs (which both generally vary along the length of each leg) is set within the program for each leg/hull model. The overall sway stiffness of the boat will vary depending upon the leg length extended and the variable loads included within the total weight of the boat. The stiffness of the leg to hull connection is set within the program for each leg/hull model.

The response of the structure to loading is computed both statically and dynamically. The dynamic model is a relatively simple single degree of freedom model with carefully balanced distributed mass and inertias of the main structural components. The dynamic response reported is effectively a steady state response to the environmental forcing function which is treated as being sinusoidal

9.2 Soil Structure Interaction

The soil is treated as providing a rotational spring stiffness to each pad. This stiffness is nominally modeled by selection of two input terms. One is a coefficient and the other is the soil undrained shear strength. The combination of these terms, as described below results in a rotational spring stiffness. The response of the structural model is computed and the moment applied by the rotational spring to each pad is then found. The large pads on liftboats give the legs significant bottom rotational restraint.

The ultimate moment capacity of the soil is reported and a warning is given if the maximum calculated moment at the pad exceeds this theoretical upper bound limit.

9.3 Structural Calculations - Introduction

Having found the environmental loads and their distribution, the next step in evaluating boat response is to model the structural characteristics of the system. The methodology is adapted from that described in the DnV Classification Note 31.5, February, 1992.

Details of the most important calculations (and explanation of user input required) are given below.

9.4 Shear and Bending Stiffness

Average shear areas, A_Q , and moments of inertia, I , are used and corrections to these terms within the guides are made, depending upon the leg length extended in the run in question. For uniform legs the method is quite accurate. For non-uniform legs, there may be localized errors of the order 10% - 20%, but this is generally acceptable in view of other uncertainties in response and load evaluation. By running upper and lower bound stiffness cases, STA has found that *response* results are normally within 5% of those found with a detailed FE model.

9.5 Pad Restraint, k_s

The pad support spring needs the user input of undrained shear strength, s_u , for the soil and a term, G_{factor} , which will yield a soil shear modulus, G , based upon s_u . The program uses the input G_{factor} as follows:

$$G = G_{\text{factor}} s_u$$

The program will calculate a value k_s , for a rotational spring representing the pad-soil restraint at the bottom of the legs. The stiffness, k_s , is based upon the equation for a circular disk, radius r , in an elastic half-space, taking Poisson's ratio, ν , as 0.5:

$$k_s = 8 G r^3 / 3(1-\nu)$$

The user may set k_s equal to zero (pin jointed pads) by either specifying soil undrained shear strength equals zero, or G_{factor} equals zero. In cohesionless soils, the user should use the same terms to select a soil shear modulus, realizing that the undrained shear strength term is now simply a multiplier for specifying G .

The program will automatically find the soil undrained shear strength needed to support the legs, based upon the user specified pad penetration into the sea bed and the maximum calculated pad vertical reaction during a single wave cycle. Just click on the *Auto coefficients* button to use this feature.

9.6 Jacking Mechanism Stiffness, k_j

This rotational spring stiffness, k_j , is zero for boats with a single rack on each leg. For boats with two racks per leg, some advantage can be taken of the jacking mechanism stiffness. This stiffness can work to reduce leg bending moments at the lower guide. Consult STA when you have legs with double racks.

9.7 Bending Moment Coefficients, Beta and Mu

Two coefficients are used, Beta and Mu. Beta determines the fraction of the upper leg bending moment which is reacted by vertical forces in the chords. It is found automatically by the program from the following equation:

$$\text{Beta} = 1/(1 + G A_{Q0} d/k_j)$$

Where G is the shear modulus of steel, A_{Q0} is the average shear area of the leg portion within the guides, d is the vertical distance between the guides, and k_j is the jack stiffness defined above. For leg models where the shear area varies along the leg, the program automatically selects the correct value for A_{Q0} depending upon the leg length extended in the particular run. For single rack legs, Beta is always zero.

Mu determines the bottom leg bending moment and is a function of two other coefficients as shown below:

$$a = A_Q (1 - \text{Beta})/A_{Q0}$$

$$i = l [1 - \text{Beta}(1 - 3b/d + 3(b/d)^2/2)]/I_0$$

Where l is the average moment of inertia of the leg, A_Q is the average shear area of the leg, I_0 is the average moment of inertia of the leg portion within the guides, and d is the height of the jack support point above the lower guides. To get Mu we have:

$$\text{numerator} = 1 + 2id/3l + 2a E I/(l d G A_Q)$$

$$\text{denominator} = 1 + 2E I/(k_s l)$$

$$\text{Mu} = \text{numerator}/\text{denominator}$$

Where l is the leg length from the lower guide to the mid-height of the pad and all other terms are defined above.

The transverse overall stiffness of one leg is then given by:

$$k = 1/(f_B + f_Q)$$

Where f_B and f_Q are the bending and shear flexibilities of the leg and are given by:

$$f_B = \text{Beta} \beta [1 - 3\text{Mu}/2(1 + \text{Mu}) + id/l(1 + \text{Mu})]/3EI$$

$$f_Q = l [1 + a/d(1 + \text{Mu})]/GA_Q$$

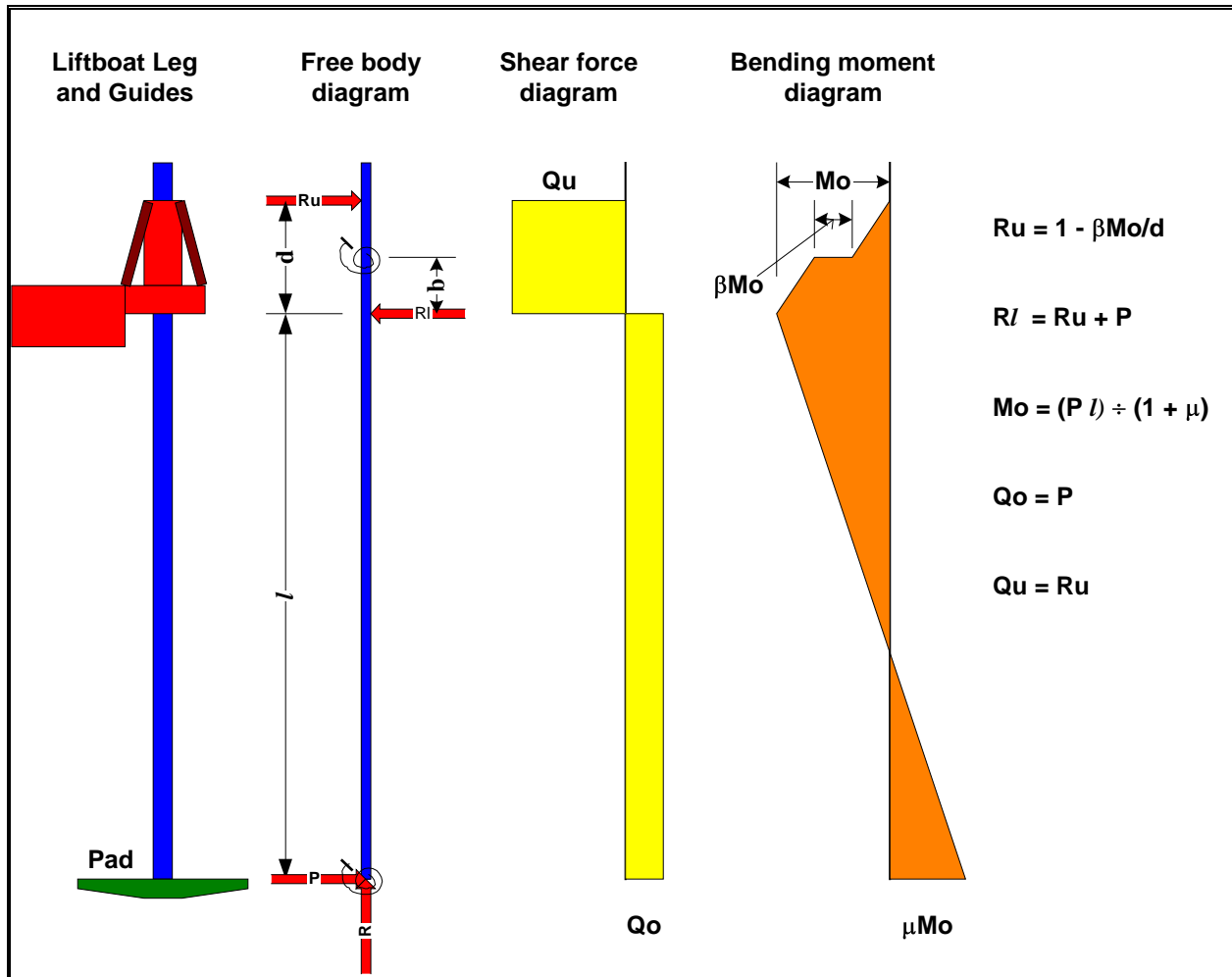
Alternatively, the overall transverse stiffness of one leg may be represented by:

$$k = 3EI/c\beta$$

Where:

$$c = 1 - 3\mu u/2(1 + \mu u) + id/l(1 + \mu u) + 3EI[1 + a/l d(1 + \mu u)]/P^2GA_Q$$

The simplified (wave forces not shown) leg force and moment diagram is shown in the figure below.



LEG FORCE AND MOMENT DIAGRAM
(Wave forces not shown)

9.8 Euler Leg Load, P_E

STA LIFTBOAT finds the Euler load, P_E , of a leg from:

$$P_E = \pi^2 EI / (Kl)^2$$

Where K is an effective length factor given by:

$$K = 2 / c$$

9.9 Equivalent Linear Damping, Eta

The user may change the default value for Eta, the equivalent linear damping term. STA LIFTBOAT will show results with the user selected value for Eta, as well as results with twice this value and half this value. Note also that STA LIFTBOAT accounts for the effect of irregular seas when computing response and uses a stochastic DAF as described in Reference 2.

Since hydrodynamic damping increases with vessel response, it is often difficult to predict what damping may be appropriate in advance of determining response. STA has automated the selection of ε in STA LIFTBOAT v2.01. Automatic selection of this term occurs when the user clicks on the *Auto coefficients* button (see page 12). The equation used to find ε is shown below:

$$\varepsilon = \{2 + 5 (\text{hull deflection amplitude})/(\text{leg radius})\} \%$$

Hence when the response amplitude is zero, the percentage critical damping will be set to 2%. When the response amplitude increases to one leg radius, the percentage critical damping will be set to 7%, if the user clicks on the *Auto coefficients* button,

9.10 Calculation of Boat Natural Periods

After leg mass and stiffness properties (including hydrodynamic added mass) have been found, the program computes vessel natural periods in sway and torsion. Full account is taken of the hull inertia and relative position of the center of gravity position. Values for Mu and Beta both influence natural period results. The longer the natural period, the larger will be the vessel's response in normal conditions, where the natural period is less than the wave period.

The boat's natural periods are given by:

$$T_0 = 2 \pi [m_e/k_e]^{1/2}$$

Where:

k_e = effective stiffness of one leg
 m_e = effective mass related to one leg

For the elevated condition the effective stiffness is taken as:

$$k_e = k (1 - P/P_E)$$

The effective mass for one leg is taken as:

$$m_e = c_1 M_H + c_2 M_L$$

Where:

M_H = total mass of the hull with all equipment and the portions of the legs located above the lower guides

M_L = mass of the portion of one leg located between the lower guides and the top of the pads, including hydrodynamic added mass.

c_1 = $1/n$ for sway modes

c_1 = $1/n (r_0/r)^2$ for torsion mode

c_2 = $0.5 - 0.25Mu$

n = number of legs

r = distance from center of legs to hull's cg

r_0 = radius of gyration of the mass M_H with respect to vertical axis through center of gravity

9.11 Dynamic Amplification Factor (DAF)

The method for calculating the DAFs is conventional, being based upon an equivalent single degree of freedom system. The equation involves the vessel's natural period and the period of the waves, together with the damping value selected.

The dynamic amplification factor is found from:

$$DAF = [(1 - (T_0/T)^2)^2 + (2 \text{ Eta } T_0/T)^2]^{-1/2}$$

Where T_0 is the vessel natural period and T is the period of the wave.

The above equation is appropriate to response evaluation in long crested regular waves and may be unreasonably conservative in real sea conditions. To account for this, DnV introduced the concept of a *stochastic dynamic amplification factor*, SDAF. The accepted result of this approach is to compute DAFs with twice the equivalent linear damping term, Eta. This method is also adopted in STA LIFTBOAT, where input Eta values are doubled in order to find reasonable DAFs. If the user wishes to evaluate response in long crested regular waves, a value of only one half of the desired damping coefficient should be input.

Damping alone limits vessel response values at resonance, where the wave period and the vessel first natural period are coincident. Away from resonance, as is the normal case with storm waves, the damping value is less critical. However, because of the uncertainty in the damping value, the program also shows the (stochastic) DAFs that result for values of one half the selected Eta and for twice the selected Eta. The stochastic DAFs are presented graphically for a wide range of wave periods. The actual DAF used to calculate response amplification is that for the selected value of Eta at the selected wave period. The user can judge from the DAF curves if the selection of a different Eta value would have a strong influence on the DAF. If this is the case, it is advisable to try a different value for Eta and repeat the analysis. This takes only a few seconds.

9.12 Dynamic Response Analysis

Having found the environmental loading, the program applies this loading to the structural model and finds deflections. The loading is divided into a mean, or steady part, and an amplitude, or dynamic part. The response is found from the combination of static response to the steady loading and dynamic response to the dynamic loading. The dynamic response is found from multiplying the equivalent static response to the amplitude of the dynamic forces, multiplied by the DAF found above. Where the DAF is small, the total response is approximately the same as would have been found by static analysis alone. Where the DAF is large, there may be significant differences.

9.13 Corrected Stabilizing Moment

The minimum static stabilizing moment, found from boat weight multiplied by distance to the centerline of the nearest pair of legs, must be reduced by a factor which accounts for secondary leg bending effects. This factor is a function of the maximum deflection of the hull (center of gravity) the average axial leg loads, and the Euler buckling loads of the legs (lengths extended beneath the hull). The reduced stabilizing moment is tabulated in the Results Summary and is determined from the formula below:

$$M_S = M_{S0} - n P (e_0 + e)/(1 - P/P_E)$$

Where:

- M_{S0} = stabilizing moment as calculated if the legs are perfectly straight and vertical
- n = number of legs
- e_0 = maximum static horizontal offset of platform in absence of environmental loads
- e = maximum horizontal deflection of platform caused by static and dynamic effects of wind wave and current
- P = average axial leg load
- P_E = Euler load of one leg

Note that e_0 is calculated by the program using Ke_0 the leg *out of straightness* coefficient. The term Ke_0 is multiplied by the leg length extended to give a static offset of the hull accounting for leg out of straightness, hull/leg clearances, and a slight heel of the platform. DnV recommend a minimum value of 0.005 for the coefficient.

The value of e is made up from the *mean hull deflection* plus the *hull deflection amplitude*, which is where the DAF is used. The mean hull deflection is determined statically. In the Results Summary the *maximum hull deflection* is e , and the term *Offset plus deflection* is $(e + e_0)$. If the user does not wish to consider the static offset associated with leg out of straightness, simply set Ke_0 to zero.

9.14 Corrected Pad Reactions

As indicated in the section describing pad loads, pad reactions must be corrected for the effect of the lateral movement of the center of gravity of the boat as a result of response to environmental forces. This effect is especially important in deep water where hull deflections of several feet may occur.

Maximum and minimum corrected pad loads are tabulated in the RESULTS SUMMARY. Additionally, *PAD1*, *PAD2*, and *PAD3*, pad loads (with legs assumed vertical, and hull level) before environmental loading is applied, are tabulated. Note that the summation of these loads is equal to the result of *weight - buoyancy*, with *average leg buoyancy* and *total buoyancy* shown also. Buoyancy is calculated for each leg from the *equivalent diameter* and *water depth plus pad penetration*.

9.15 Moment Amplification

The industry recognizes two moment amplification effects. The first is accounted for simply as a result of the dynamic amplification of sway response. As described above, the pad reactions are calculated by the program for the maximum deflected position (including static offset). In the Results Summary the equivalent corrected maximum overturning moment, including the additional overturning moment effect from hull sway, is shown. The corresponding corrected overturning safety factor is also tabulated. This overturning safety factor is the ratio between the maximum overturning moment and the minimum corrected stabilizing moment. Where the cg is above the lower guides the corrected O/T moment, M_u , is found from:

$$M_c = M_u + W (e + e_0)$$

Where M_u is the uncorrected moment and W is the boat weight. Where the cg is below the lower guides, the program compensates for a smaller lateral movement of the cg than of the hull.

The second approach adopted in the industry (and recommended by DnV) is to multiply the amplitude of the environmental forces moment by the DAF. This method may differ significantly from the method described above. For many location approvals it is pad loading which limits operability, and the above discrepancy in calculation of overturning safety factor becomes somewhat irrelevant.

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INDEX

- 11 OR 2 RACK SWITCH, 41
- ABS pre-88 unity str.chk, 50
- ABS Stress Checks, 58
- accept calc. wt/ft, 36
- accept hull gyrad., 36
- add.mass coef, 38
- added mass, 56
- afloat stability*, 59
- Air gap (ft), 32
- Airy wave theory, 1
- Amplitude wave-current O/T moment, 45
- appendage wt. factor, 42
- Auto coefficients*, 17, 39
- Auto Coefficients*, 17
- Average leg buoyancy, 45
- AvShield, 32
- axial stress component, 51
- b. jack vcg, 40
- Back to Input File*, 16
- Bending Moment Coefficients, 63
- Bending Stiffness, 62
- Beta and Mu, 63
- Beta top fixity coefficient, 44
- BM.hull max w/oPD, 49
- BM.hull max. w/PD, 49
- buttons, 15
- capsize*, 59
- CD1, CD2, CD3, 34
- Cm*, 59
- Cm1, Cm2, Cm3, 34
- coef. on su to get soil G modulus, 37
- coefficient on cu*, 17
- compact, 60
- CONTENTS**, 3
- Corrected O/T safety factor, 50
- Corrected Spud Can Reactions, 69
- Corrected stabilizing moment, 46
- Corrected Stabilizing Moment, 68
- Cu rate, 39
- Cu, surface, 39
- cylinder drag coef.(w/marine growth), 37
- DAF, 38, 39, 67
- DAF (dynamic amplification factor), 48
- damping, 38, 39
- Damping, 65
- Data Screen, 31
- deflection multiplier, 38
- Distance bet. fwd. leg centers, 32
- Distance from aft to fwd. legs, 32
- Distribution Diskettes, 4
- DnV O/T safety factor, 50
- double racks, 63
- drag coefficient, 56
- dynamic amplification factor, 38
- Dynamic Amplification Factor, 67
- Dynamic Response Analysis, 68
- effective length factor, 65
- effective mass, 66
- End Session*, 15
- equivalent leg diameter, 56
- Euler buckling stress*, 58
- Euler leg load, 49
- Euler Leg Load, 65
- expanded memory, 5
- F1,F3, 47
- F2, 47
- fa/Fa, 47
- factors of safety, 59
- fatigue crack*, 59
- fatigue damage*, 59
- fb/Fb, 47
- flooded leg*, 59
- GENERAL THEORY, 61
- geometry select switch, 40
- Gfactor, 37
- Global Leg Strength, 57
- Go on to Structural Response*, 36
- Go On To Structural Responses*, 15
- Graphical Results*, 17
- graphics resources, 5
- gyrad (ft), 38
- Hull deflection amplitude, 48
- Hull max.shr.str, 47

-
- hydrodynamic added mass, 66
 - hydrodynamic coefficients, 56
 - Init phase ang.(deg), 34**
 - INPUT DATA, 31**
 - Input Leg Sections, 16*
 - Input Summary, 16, 44*
 - Input water depth (ft), 31**
 - Input wave height (ft), 31
 - Input wave period (sec), 31**
 - interaction equation, 58
 - irregular seas, 66
 - jack support spacing, 40**
 - Jacking Mechanism, 63**
 - Jacking Tower Data, 40**
 - Ke0, LEG OUT OF STRAIGHT. coef., 37**
 - K-Equivalent, 50**
 - ks, 37, 62
 - Lateral Stiffness, 45, 48**
 - Lattice area (sqft), 31**
 - Lattice av.ht., 32**
 - LCG (ft to aft legs), 34**
 - Leg buoy. 1=dry 2=flood, 32**
 - Leg diams 1,2,3 (ft), 33**
 - Leg Hydrodynamic Coefficients, 56**
 - LeverArm, 33**
 - liability, 2
 - LICENSE AGREEMENT, 2**
 - local buckling, 58
 - Local Buckling Stress Checks, 60**
 - Lotus Symphony, 1
 - Manual coefficients, 29*
 - Manual Coefficients, 17*
 - marine growth, 37
 - marine growth thickness (inches), 38**
 - max fa, legs 1,3, 47**
 - max fa, top leg 2, 47**
 - max fb, legs 1,3, 47**
 - max fb, top leg 2, 47**
 - Max hull lateral deflection, 46**
 - Max wave-current force, 45**
 - Max. axial leg load @ lower guide, 49**
 - Max. base shear, 49**
 - Max. horizontal pad reaction, 49**
 - Max. torsional moment, 48**
 - Max. total force, 48**
 - Max.apparent O/T moment, 48**
 - Max.equivalent lateral top load, 46**
 - Max.lower guide reaction, 49**
 - Max.O/T moment w/o P-delta, 47**
 - Max.OT.mom.w.PD, 49**
 - Max.upper guide reaction, 46**
 - Mean hull lateral deflection, 46**
 - Mean wave-current force, 48**
 - Mean wave-current O/T moment, 48**
 - Microsoft Excel, 1
 - Microsoft Windows, 1
 - Min. leg length to be above hull bottom, 35**
 - Moment Amplification, 69**
 - moment diagram, 64
 - MomSwitch, 0=off, 39**
 - Mouse, 4**
 - Mu, bottom fixity coefficient, 44
 - natural period multiplier, 36**
 - Natural Periods, 66**
 - Natural sway period, 45, 46**
 - Natural torsional period, 46**
 - next section, 42
 - Number of sections, 42**
 - Offset+deflection, 49**
 - pad 1/2 height, 41**
 - Pad Data, 41**
 - pad length, 41**
 - Pad max.angle, 49**
 - Pad max.calc.bend.mom., 46**
 - Pad mean angle, 47**
 - Pad Moment Results, 53**
 - Pad penetration, 32**
 - Pad Restraint, 62**
 - Pad Ultimate Moment Capacity, 49**
 - pad width, 41**
 - PAD1 before environmental load, 45**
 - PAD2 before environmental load, 45**
 - PAD3 before environmental load, 45**
 - PadMax.Id.corrected, 47**
 - PadMax.Id.uncorrected, 46**
 - PadMin.Id.corrected, 49**
 - PadMin.Id.uncorrd, 49**
 - P-delta effect, 59
 - PDelta leg BM.max, 46**
 - Penetration (ft), 32**
-

phase angles, 61
Poisson's ratio, **37**
Print all graphs, 19
Print all results, 29, 44
Print all tables, 19, 44
Print this screen, 15, 18, 44
Printer, 4
Quick Start, 5
rack ht.to top teeth, 42
Rack width, 42
radius, **37**
Rational Stress Check, 57
Rational Unity str.chk, 50, 51
resonance, 67
Results Summary, 45
rotational spring stiffness, 61
secondary bending amplification, 59
SECONDARY DATA INPUT, 36
Shear, 62
shear flexibilities, 64
shear modulus of steel, 63
shear stress, 51
sidesway, 59
SIGN CONVENTION, **33**
slenderness ratio, 59
soil shear modulus, 62
Soil Structure Interaction, 61
soil su needed to support pad, 36
Stabilizing Moment, 68
stiffeners, 41, 43
stochastic DAF, 66
stochastic dynamic amplification factor, 39
stochastic dynamic amplification factor, SDAF, 67
Stresses, 16
Structural Calculations, 62
structural model, 61
su,, 36
su, soil undrained shear strength, 36
Tabular Results, 16
TCG (+ve towards L1), 34
Thickness, 43
Tide vel.(kn), 32
Tnxx, 45
Tnyy, 46
torsion, 46
Total buoyancy, 48
total damping (% crit.), 38
Total leg length (ft), 34
Total weight (kips), 34
Transit, 16
transverse stiffness, 64
UC, 16
ultimate, 49
ultimate moment capacity, 61
Uncorrected O/T safety factor, 50
Uncorrected stabilizing moment, 46
undrained shear strength, 61
Unity Stress Checks, 57
USER SPEC. gyrad (ft), 38
USER SPEC. leg kips/ft excl. cans, 38
VCG excluding legs (ft), 38
VCG lower guide, 40
von Mises, 51
wall thickness, 43
WARRANTY, 2
Wave crest elevation, 44
Wave direction (deg), 33
WB (ft), 31
Weight - buoyancy, 48
WH1 (ft), 31
WH2 (ft), 32
Wind elevation (ft), 34
Wind force, 44, 45
Wind force (kips), 32
Wind force switch, 15
Wind loading results, 15, 16
Wind O/T moment, 45
Wind v2 (kn), 34
WL (ft), 32
Young's Modulus, 36
