Hydrostatic and Intact Stability Analysis for a Surface Ship

by

Joshua James Jahnke

B.S., Mathematics, University of West Florida, 2003

Submitted to the Department of Mechanical Engineering
In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Naval Architecture and Marine Engineering

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ABSTRACT

Ship's lines are designed such that they are fair. To the naval architect, fairness means that the lines exhibit a continuous second derivative. This is the definition of a spline. Before the advent of digital computers, naval architects checked every line on a lines plan for fairness by bending a thin stick of wood, called a batten, on the line. If the line followed the natural bend of the batten, the line was fair. This phenomenon follows from the beam equation, which shows that the minimum energy in the beam occurs when the beam has a continuous second derivative of position.

Hydrostatics lies at the heart of naval architecture. The hydrostatic properties of a hull are determined by the lines and their interpretation using rules of integration. The resulting analysis is presented in the form of graphs, termed the "curves of form" or "displacement and other curves." An intact stability analysis follows naturally from the hydrostatic analysis. Hydrostatics (determination of KM) coupled with a KG value can be used to predict initial stability. This intact stability analysis evaluates the range of stability at both small and large angles of inclination.

The responses of the hull to static and dynamic loading situations can be inferred from the curves of form. Their most basic use is to determine the static waterline in various loading scenarios. A more subtle use is to determine the correct placement of the vertical center of gravity to ensure a sea kindly roll period, stability in beam winds, and stability in high speed turns.

Various computational tools can be used to compute the hydrostatic and stability properties of a ship. This thesis explores the results from two computer aided design tools used by the U.S. Navy and commercial industry; Advanced Surface Ship and Submarine Evaluation Tool (ASSET) and Program for Operational Ship Salvage Engineering (POSSE).

Thesis Supervisor: Mark S. Welsh
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Lieutenant Joshua Jahnke is from Pensacola, Florida. He holds a Bachelor of Science degree in Mathematics with a minor in Law from the University of West Florida (2003). He received a direct commission from Naval Reactors and completed Officer Indoctrination School in Newport, Rhode Island. LT Jahnke then reported to Naval Nuclear Power Training Command in April 2004, and served in the Nuclear Power School (NPS) as an Enlisted Mathematics instructor, followed by instructor duty in the Enlisted Reactor Plant Technology division. In March 2006 he was assigned to Nuclear Field "A" School (NFAS), serving as the NFAS Mathematics division director and Assistant Director of Academics. After serving as the NFAS Command Training Evaluator, LT Jahnke was selected for lateral transfer into the Engineering Duty Corps and reported to the Massachusetts Institute of Technology in Cambridge, Massachusetts, as a graduate student in the Naval Construction and Engineering Program in the Department of Mechanical Engineering in May 2008. Lieutenant Jahnke has been awarded the Navy Commendation Medal, Navy Achievement Medal, and the Humanitarian Service Medal. He has been married to Mrs. Tricia Jahnke since November 2004. They have two daughters, Gracie and Juliana.

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First of all to God, who has so graciously kept me alive long enough to see the end of this endeavor.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ASSET	Advanced Surface Ship and Submarine Evaluation Tool
A_M	Area, Midships Section
Awp	Area of Waterplane
B	Beam
B/T	Beam to Draft Ratio
BML	Longitudinal Metacentric Radius
BM (BMT)	Transverse Metacentric Radius
C_B	Block Coefficient
C_{IL}	Longitudinal-Waterplane Inertia Coefficient
C_{IT}	Transverse-Waterplane Inertia Coefficient
C_M	Midships Section Coefficient
Cp	Prismatic Coefficient
C_{WP}	Waterplane Coefficient
Cx	Maximum Transverse Section Coefficient
D_{10}	Depth at Station 10
Disp (Δ)	Displacement
DWL	Design Load Waterline
FT	Feet
ft-BL	Feet from Baseline
ft-CL	Feet from Centerline
GM (GMT)	Transverse Metacentric Height
GML	Longitudinal Metacentric height
GZ	Righting arm
HECSALV	Commercial Version of POSSE
KB (VCB)	Distance from keel (baseline) to Vertical Center of Buoyancy
KG (VCG)	Distance from keel (baseline) to Vertical Center of Gravity
KM (KMT)	Distance from keel (baseline) to the Transverse Metacenter
KML	Distance from keel (baseline) to the Longitudinal Metacenter
KTS	Knots
L/B	Length to Beam Ratio
L/T	Length to Draft Ratio
LBP	Length Between Perpendiculars
LCB	Longitudinal Center of Buoyancy
LCF	Longitudinal Center of Floatation
LT	Long-Tons
LWL	Length of Ship on the Waterline
MT1"	Moment to Trim 1 inch

POSSE	Program for Operational Ship Salvage Engineering
T	Draft
TCG	Transverse Center of Gravity
TPI	Tons-Per-Inch Immersion
T_{roll}	Roll Period
WL	Any Waterline Parallel to Baseline

CHAPTER 1. INTRODUCTION

Naval architecture since the earliest attempts by man has begun ship design by focusing on the hydrostatics of a ship. Even the first efforts by a child at designing a paper sailboat focus on the forms that stabilize the ship while reducing drag to allow the greatest speed. Naval architects today focus on those same basic principles of stability and equilibrium and read these hydrostatic properties using graphs often called "curves of form". While many methods exist to determine the "curves of form", most today are created by a computer program which reduces the lengthy hand calculations required.

The first portion of this thesis will focus on generating and comparing a set of "curves of form" for two widely accepted computer programs, Advanced Surface Ship and Submarine Evaluation Tool (ASSET) and the Program for Operational Ship Salvage Engineering (POSSE), for which the commercial version is called HECSALV developed by Herbert Software Solutions, Inc. Additionally a hand calculation will be performed to verify these two models.

Completing the curves of form are the Bonjean curves, Displacement (SW), KB, LCB, Awp, LCF, TPI, BMT, KMT, BML, KML, MT1". By hand these graphs would have taken weeks while the computer analysis will provide the results within minutes. While this completes the analysis of a non-moving ship in still seas the analysis must continue to prove seaworthiness.

Once the static loading condition is determined from the curves of form, analysis begins in dynamic situations such as rolling induced by the sea. Correct placement of a vertical center of gravity determines the roll period which ensures stability without excessive roll or snap. Coupling KG with hydrostatics produces intact stability which illustrates the behavior of the ship at both small and large angles of inclination.

Both POSSE and ASSET are used again to independently create the righting arm (GZ) cross-curves and static stability curves for an expected displacement range a given hull. A maximum KG was determined for the 4 different conditions of beam winds (100 kts), high speed turning (35 kts), roll period ≥ 15 seconds, and GM ≥ 2.0 ft. These were based on the cross-curves of stability and the static stability curve produced by each of the two computer programs.

CHAPTER 2: SHIP HULLFORM DEVELOPMENT

The development of a ship's hullform can be a complex and involved exercise. The general size and characteristics of a ship are usually decided upon based on the ship's intended mission. Usually there is set of operational requirements for a ship such as a required payload (commercial cargo or military), speed, and range. There may also vessel size restrictions based on canal size, dry-docks, or channel depth. When these requirements and restrictions are put together, the ship's design characteristics can be developed. Although the hullforms of different ships are usually unique, they are typically based on proven past designs. The starting part of most design work is looking at what has been done in the past and using what works and improving upon what doesn't. The design of a ship's hull is no different.

Historically, once the size of a ship has been determined, a naval architect would develop a set of ship's lines that describe the shape of the hull. This was traditionally done by use of wood battens and lead ducks that were manipulated by hand to create 'fair lines'. These fair lines were necessary to ensure that the ship was hydrodynamically smooth. These lines were then used for several things. The naval architect would generate a table of offsets from the lines plan for numerical analysis of the hullform to ensure the exact hydrostatic properties were known. A shipyard would also use the lines plan and table of offsets to construct the vessel into the desired shape.

The use of computers now allows for the laborious process of developing lines plans by hand to be done by sophisticated naval architecture programs. Although this relieves the modern naval architect of the tedious task of fairing lines in on paper, these programs by themselves will not develop a satisfactory hullform unless the proper data and inputs are used. The Advanced Surface Ship and Submarine Evaluation Tool (ASSET) is a U.S. Navy computer program that allows for the creation of a ship's hullform using complex regression algorithms based on past designs and user inputs. This thesis utilized the ASSET program to assist in the development of a hullform based on desired characteristics.

2.1 FORM COEFFICIENTS

A ship's length, beam and molded depth are typically known when the ship's hullform is designed. As mentioned earlier, the size of a vessel is usually determined based on the mission. The ship's shape is also derived on the mission. For example, the hullform of a Very Large Crude Carrier (VLCC) which carries time-insensitive cargo at relatively slow speeds will not look like the hullform of a large containership carrying time-sensitive cargo at relatively high speeds. This is because the ability to either carry significant amounts cargo or travel at high rates of speed are related to how 'fine' the hullform is. A very fine hullform, such as those on navy destroyers allows for a ship to slice through water at high speeds. A 'fat' hullform, such as those on VLCCs provides a lot of volume to carry cargo but is not conducive to moving at fast speeds.

In naval architecture there are coefficients used to generalize how fine a hullform is. These are described below:

(1) Block Coefficient (C_B) is the ratio of the volume of displacement of a ship to the volume of a rectangular block having the same length, beam and draft of the ship at the maximum transverse section area. C_B can range from 0.53 for a fast naval destroyer to 0.87 for a slow moving bulk carrier.

(2) Prismatic Coefficient (C_P) is the ratio of the volume of displacement of a ship to the volume of a prism having a cross-sectional area equal to the maximum transverse section area and length of vessel. C_P will typically range from 0.55 for very fine hullforms to 0.88 for fat hullforms.

(3) Maximum Transverse Section Coefficient (C_X) is the ratio of the maximum transverse section area to area of a rectangle whose sides are equal to the beam and draft at that section. C_X can range from values ~ 0.75 for faster vessels to ~1.0 for bulk carriers.

Generally, the smaller the coefficient, the finer the hullform. Significant work has been done to assist naval architects in establishing the proper coefficients for a design through regression analysis. Several references provide a good summary of the parametric design work that has been done to date for naval architecture. [2] [3] [4] [7]

The hullform created was based on a naval surface combatant. The ASSET program was utilized to assist in the creation of a hullform. The specific characteristics used to develop the hull are listed in Table 2-1.

Characteristic	**Value**
LBP	380 ft
C_P	0.58
C_X	0.836
B	40.6 ft
D_{10}	26 ft
Draft at Design Waterline	14 ft

Table 2-1. Hullform Characteristics

Several data inputs were entered into ASSET to further assist in the program developing a hullform. These are described below:

(1) Ship Type Ind = Surface Combatant. This ensures the ASSET developed hullform is based on past surface combatant designs such as U.S. Navy destroyers and cruisers.

(2) Hull BC Ind = Conv DD. This ensures that the ASSET developed hullform is specifically based on 'conventional' destroyer-type hullforms developed before 1982.

(3) Design Mode Ind = Ship WT. This directs ASSET to use the full load weight of the ship as input and calculate the usable fuel weight and endurance based on that.

(4) Bilge Keel Ind = None. This directs ASSET to develop a hullform without a bilge keel.

(5) Skeg Ind = None. This directs ASSET to develop a hullform without a skeg. This directly affects the ship offsets.

(6) Appendage Ind = Without. This directs ASSET to perform hydrostatic calculations with just a bare hull.

(7) Aviation Facilities Ind = None. This directs ASSET to develop the hullform without factoring in and allocating for a indigenous aviation facility.

(8) Embarked Commander Ind = None. This directs ASSET to not account for the added weight and volume required for an embarked commander and staff.

(9) Hull Sta Ind = Optimum. This allows ASSET to automatically select a series of stations to develop the offsets that provides an optimal numerical model of the hullform.

(10) Hull Offsets Ind = Generate. This directs ASSET to internally generate the hull offsets based on the hull boundary conditions and the principal characteristics listed above.

2.2 HULL OFFSETS

With the principal characteristics and data inputs determined for the desired vessel, ASSET was used to develop the hull offsets. Hull offsets are typically provided at various stations along the length of the hull and at various waterlines to allow for an accurate numerical representation of the hull. The specific numerical value of each offset is for the half-breadth of the vessel – meaning the distance from the ship's centerline to the outside of the hull. For this project these offsets were done for the 0, 2, 4, 8, 12, 14, 16, 20, 24 foot waterlines and from station 0 (forward perpendicular) to station 20 (aft perpendicular). An additional half-station was added aft at station 19.5 and forward at stations 0.5, negative 0.43 and negative 0.86 to help define the hullform where there is significant curvature.

The resulting hull offsets are shown in Table 2-2.

Station	0	2	4	8	12	14	16	20	24
-0.86									
-0.43									0.01
0						0.10	0.32	1.26	2.81
0.5				0.26	1.00	1.30	1.64	2.79	4.49
1		0.07	0.28	1.17	2.15	2.55	2.99	4.34	6.15
2	0.25	1.24	1.96	3.38	4.64	5.19	5.78	7.34	9.33
3	0.87	2.95	4.19	5.98	7.33	7.92	8.55	10.20	12.23
4	1.00	4.66	6.60	8.77	10.05	10.60	11.22	12.83	14.73
5	1.00	6.32	8.94	11.46	12.63	13.11	13.66	15.09	16.79
6	1.00	7.94	11.08	13.87	14.93	15.31	15.76	16.95	18.32
7	1.00	9.49	12.95	15.88	16.85	17.13	17.47	18.36	19.37
8	1.00	10.85	14.47	17.47	18.35	18.54	18.75	19.35	19.99
9	1.00	11.77	15.57	18.63	19.41	19.53	19.64	19.96	20.28
10	1.00	12.11	16.10	19.29	20.05	20.13	20.17	20.29	20.39
11	1.00	11.91	15.90	19.31	20.28	20.39	20.41	20.42	20.43
12		10.60	15.09	19.04	20.21	20.36	20.41	20.42	20.44

13		7.94	13.58	18.47	19.89	20.10	20.22	20.35	20.40
14		3.11	10.88	17.44	19.32	19.63	19.84	20.17	20.38
15			6.02	15.76	18.51	18.97	19.27	19.83	20.18
16				13.05	17.43	18.09	18.50	19.26	19.75
17				7.74	15.94	16.99	17.52	18.47	19.10
18					13.78	15.64	16.28	17.46	18.24
19					9.23	14.09	14.85	16.23	17.18
19.5					2.31	13.27	14.08	15.56	16.59
20						12.45	13.33	14.85	15.95

Table 2-2. Hull Offsets

2.3 HULLFORM ISOMETRIC AND SECTION VIEWS

Along with the hull offsets, an ASSET developed body plan was created. The body plan is a presentation of what the transverse sections look like at each station. Figure 2-1 shows the body plan for this projects vessel. Stations -0.86 to 10, corresponding to the forward half of the vessel, are shown on the right side. Stations 10 to 20, corresponding to the after half of the vessel are shown on the left side. It is clear to see that the vessel generated, based on conventional destroyers, has a transom stern, no parallel midbody and a very fine bow to slice through seas. These features are typical of naval surface combatants and provide a good indication that the hullform shape is satisfactory.

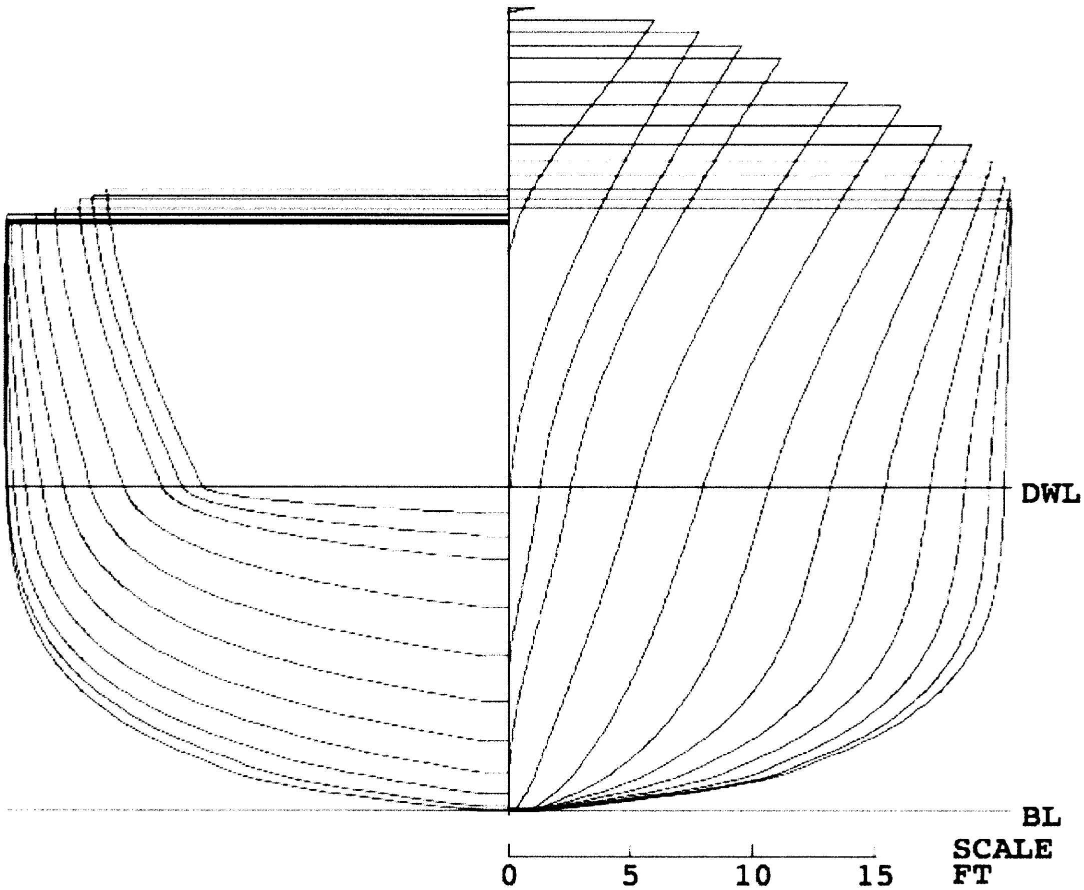

Figure 2-1. Body Plan

Figure 2-2 shows an isometric view of the hull. This view shows how fine the hull is in the bow and provides a good overall sense of the volume available to the designer in the hull for mission essential equipment.

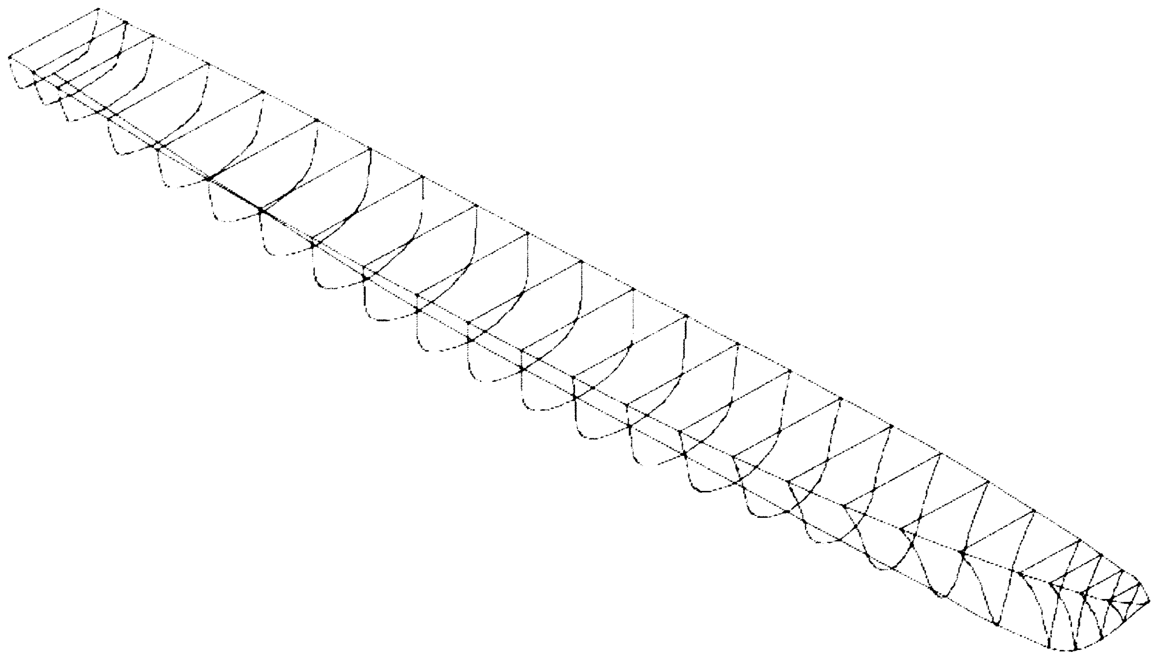

Figure 2-2. Hull Isometric View

Figure 2-3 shows the ship's hull profile and weather deck plan view. It should be noted that the actual vessel would have a deckhouse on top of the weather deck. This deckhouse is not shown in this view but the weight, size and shape of the deckhouse is taken into account in the stability analysis outlined in Chapter 4. Notable features on this hull are the upsweep of the keel as one moves aft of midships. This provides the space for the strut/shaft configuration typical of destroyers. Without this upsweep, the vessel would require an excessive propulsion shaft angle as well as increase the operating draft of the vessel. Figure 2-4 provides a view of the design waterplane of the vessel.

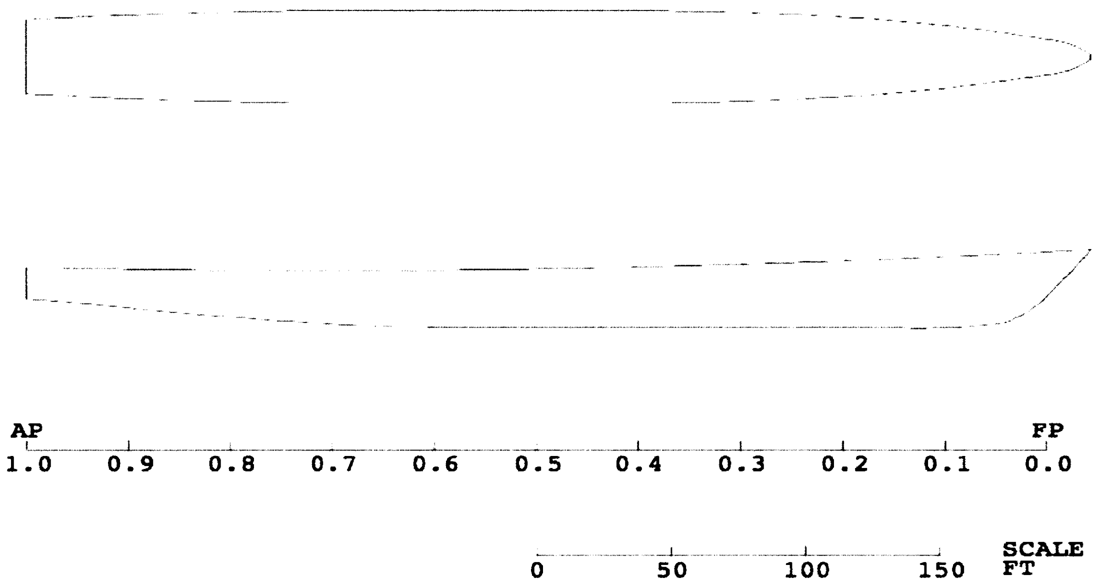

Figure 2-3. Hull Profile And Weather Deck View

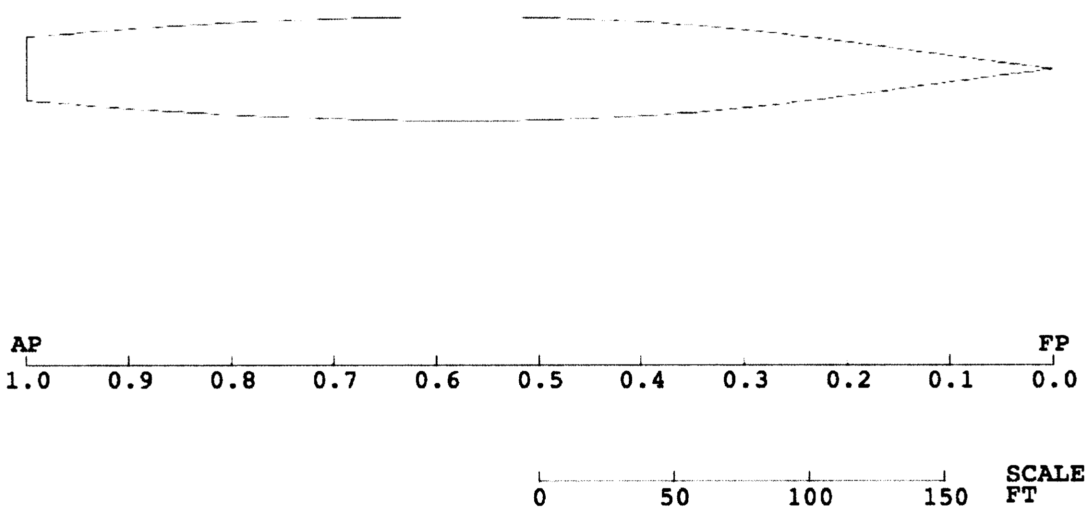

Figure 2-4. Ship's Waterline Plan View

The sectional area curve of the ship is shown in Figure 2-5. This curve can be extremely useful in hydrostatic analysis of the vessel. It is also a good indicator of the hullform fairness.

There should not be any sharp corners, edges, or knuckles in a sectional area curve. An examination of the sectional area curve reveals no sharp edges or discontinuities, indicating a fair hullform.

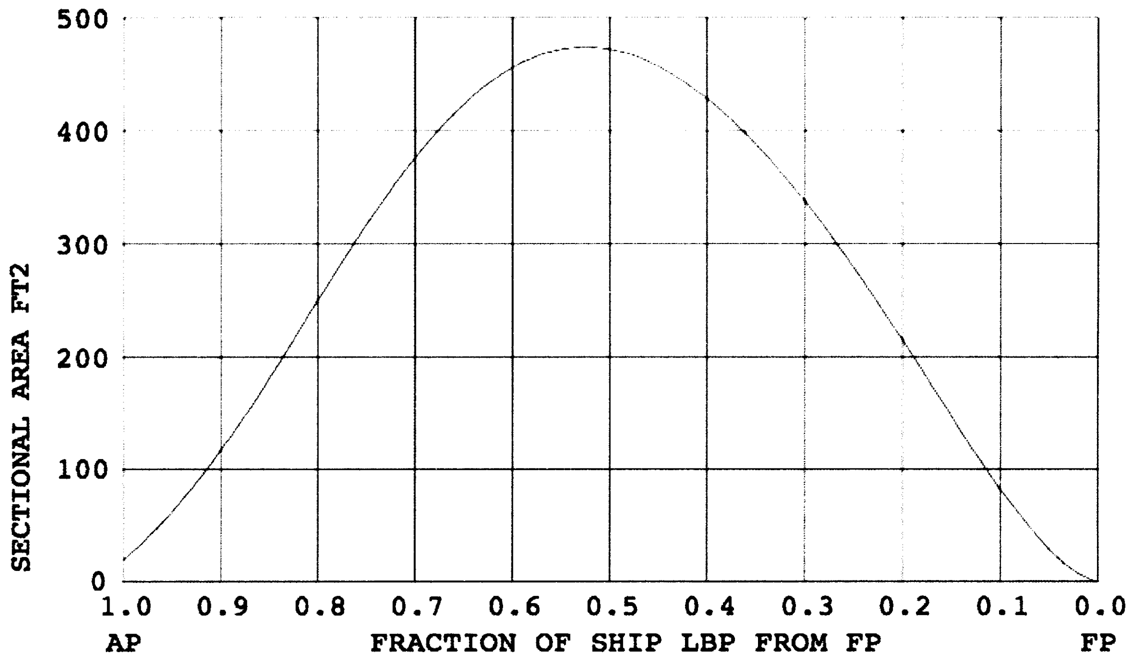

Figure 2-5. Sectional Area Curve

CHAPTER 3. SHIP HYDROSTATIC CHARACHTERISTICS AND PROPERTIES

To put it in layman's terms, a ship's hydrostatic characteristics and properties are the means by which a ship is described; whereas humans are described by height, weight, hair color, etc., ships are defined by displacement, waterplane area, and a series of coefficients. These characteristics go beyond "just descriptions;" the characteristics represent definitions. From these characteristics selected by a naval architect, the architect can manipulate their design to be fast or slow, bulky for carrying cargo or graceful for pleasure. The "trial and error" process to choose these characteristics to meet the customer's requirements requires iterations of the design spiral; doing this procedure manually can be "very time consuming."[7] Each iteration of the design spiral generally results in refinements to one or more characteristics; manually redrawing the design each time the characteristics change is where a significant amount of time can be consumed.

To expedite the design process, computer programs have been developed to assist the naval architect with his selection; "with the aid of computers, it is possible to make a study of a large number of varying design parameters and to arrive at a ship design which is not only technically feasible but, more importantly, is the most economically efficient."[3] Rather than hand-drawing and recalculating the characteristics after each refinement, programs like ASSET and POSSE become invaluable as they have been specifically designed to do these calculations rapidly.

This chapter details the ship's characteristics and demonstrates how the aforementioned tools can be used to aid in the design process.

3.1 BONJEAN CURVES

Bonjean Curves are the curves of cross sectional area for all body plan stations. [7] Translating this, the Bonjean Curves display the submerged area at a given location (or station) along the length of the ship, for a given draft. To further illustrate this concept, an example is shown in Figure 3-1.

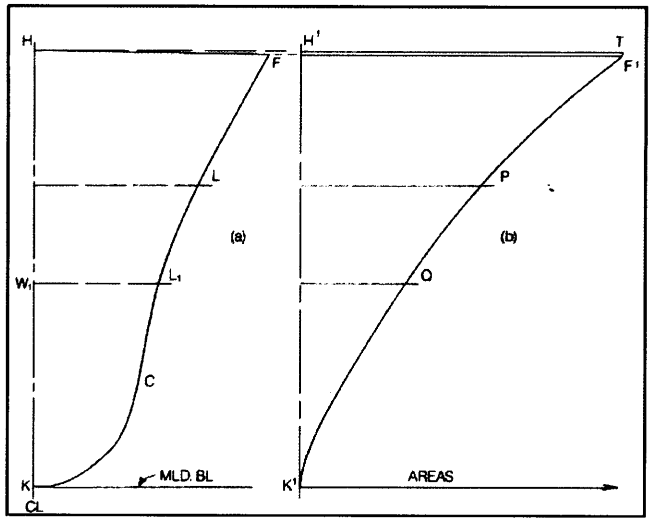

Figure 3-1. Body plan section (a) and Bonjean Curve (b) [7]

In Figure 3-1, the curve on the left is a sample station curve of the body plan of a ship; generally, as most vessels are symmetrical about the vertical axis, only half of the ship is shown in most body plans. The curve on the right is the Bonjean Curve. Assume that the draft of the ship is at the level "W_1" as seen in the left picture. To derive the area under the curve (which is equal to half the submerged area at that station) the curve would be integrated from point "K" to point "L_1." This value, when doubled, would equal the value "Q" in the curve on the right.

Bonjean Curves can provide a great deal of useful data to a naval architect. One of the principle characteristics defining any ship is its displacement (how heavy the ship is). By integrating the values of obtained at a given draft from the Bonjean Curves, the submerged volume of the ship can be determined. By accounting for the density of the fluid which the ship is floating, the displacement of the ship can subsequently be calculated. Knowing the displacement is a vital factor which further affects almost all stages of the design process.

While the plotting of, and withdrawing data from the Bonjean Curves is a complicated method for determining displacement, determination via any other method for a ship not at even keel, would be significantly more complicated. Figure 3-2 displays the ease at which submerged data can be easily obtained for a ship trimmed by the stern.

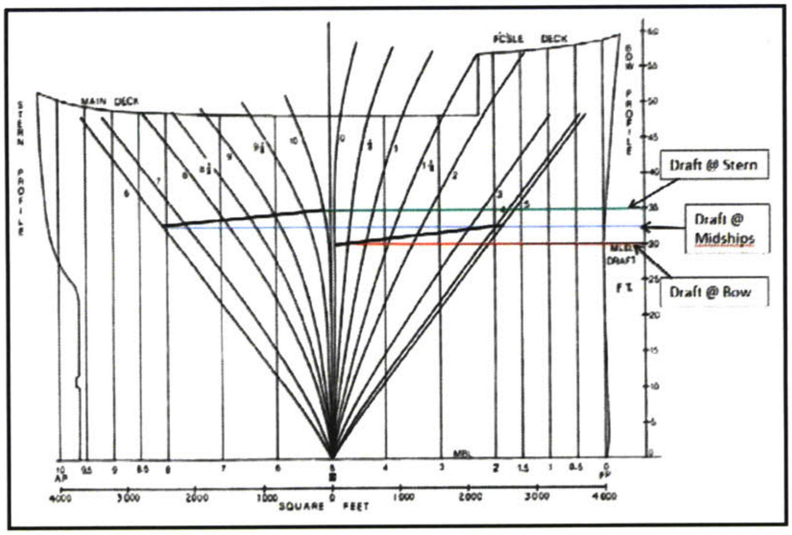

Figure 3-2. Bonjean curves [7]

The ship in the image above is shown to have a draft at the bow of 30 feet and a draft of 35 feet at the stern. The lines plotted on the Bonjean Curves highlight the sectional areas at each station down the length of the ship. Integrating the data obtained from this curve will give the displacement for the ship at the 5 foot, trimmed by the stern, condition.

To plot these curves by hand would take some time. Each sectional area at each draft, for each station would have to be measured so it could be plotted. In working through the iterative design process, if the ship is found to not have enough internal volume (for cargo or passenger space) and has to lengthened or widened, the sectional areas would change, and subsequently so would the curves. The ASSET and POSSE programs can perform the re-calculations and re-plotting significantly faster than a human can, thereby expediting the design process.

For the ship, POSSE was the tool utilized to plot the Bonjean Curves. With each revision made to the design (changing dimensional coefficients or dimensions), the curves were automatically updated. Figure 3-3demonstrates why POSSE is such a valuable tool as it clearly displayed the curves in moments vice what would have taken hours to produce by hand.

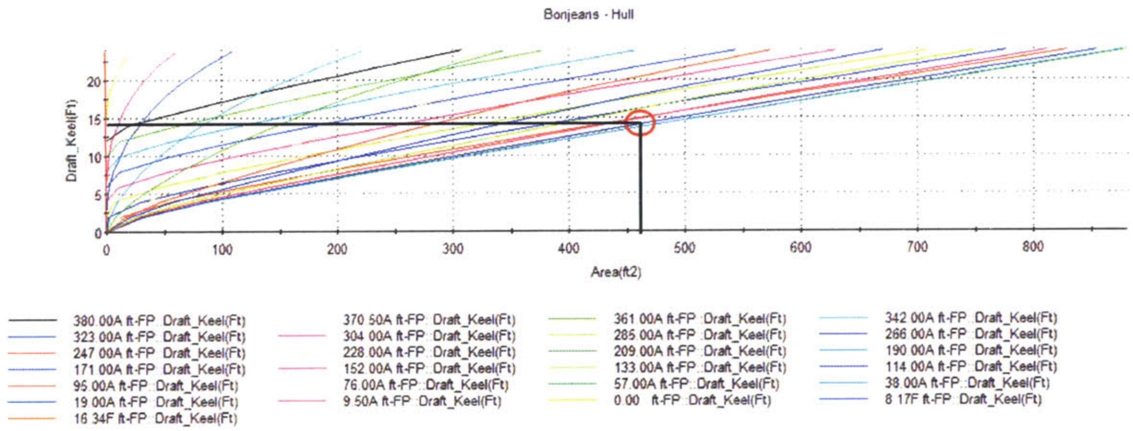

Figure 3-3. POSSE generated Bonjean Curves

ASSET, on the other hand, cannot directly output the Bonjean curves but it can provide data which can be used to verify the curves; to compare the outputs of both ASSET and POSSE, the sectional area for a given draft can be checked. Table 3-1displays the ASSET sectional area data for the designed vessel at a draft of 14 feet. The ASSET and POSSE data correlate.

Station	Location ft aft of FP	Area ft^2
1	-16.28	0
2	-8.14	0
3	0	0
4	9.5	10.22
5	19	29.06
6	38	83.1
7	57	147.86
8	76	214.81
9	95	278.99
10	114	337.35
11	133	387.75
12	152	428.29
13	171	457.14
14	190	472.42
15	209	472.38
16	228	456.26
17	247	423.9
18	266	376.48
19	285	317.04
20	304	250.1
21	323	181.34
22	342	116.9
23	361	62.1
24	370.5	39.33
25	380	19.67

Table 3-1. ASSET sectional area output

3.2 CURVES OF FORM

The curves of form, like the Bonjean curves, are another method of graphically displaying the characteristics and properties of a ship; "these curves represent the standard presentation of hull characteristics that are functions of form."[2] The following paragraphs briefly explain what each of the curves are and how they are obtained. The main take-away is that the hand calculation and plotting of these curves is highly time intensive. Like with the Bonjean curves, each modification made to the design will affect each curve and require their recalculation and re-plotting. The use of a computer aided tool to plot these curves again expedites the design process.

Displacement – Measurement of weight of water displaced.

$$\Delta = \nabla * \rho$$

MT1 – Moment to Trim 1 Inch. The moment necessary to change trim by a fixed quantity.

$MT1'' = (\Delta * GM_L) / (12 * L)$

TPI – Tons Per Inch Immersion. Amount of weight (in long tons) that would need to be added to the ship to increase its draft by one inch, with no change in overall trim.

$TPI = A_{WP} / 420$

BM_T – Transverse Metacentric Radius. The vertical distance from the center of buoyancy to the transverse metacenter.

$BM_T = I_T / \nabla$

BM_L – Longitudinal Metacentric Radius. The vertical distance from the center of buoyancy to the longitudinal metacenter.

$BM_L = I_L / \nabla$

KB – Vertical Center of Buoyancy. Height of the center of buoyancy above the vessel's baseline.

LCB – Longitudinal Center of Buoyancy. The geometric centroid of the submerged volume of a body or ship through which the total buoyancy may be assumed to act. It's position is measured as the distance from midships.

LCF – Longitudinal Center of Flotation. The geometric centroid of the area of the waterplane of any waterline. Its position is measured as the distance from midships.

A sample demonstrating one potential method of performing the hand calculations is shown in Figure 3-4.

Station	Half-breadth (m)	½SM	Prod.	Lever	Prod.	Lever²	Prod.	(Half-breadth)³	Prod.
0	0	0.25	0	5.0	0	25.0	0	0	0
½	1.245	1.0	1.245	4.5	5.603	20.25	25.211	1.93	1.93
1	3.140	0.50	1.570	4.0	6.280	16.0	25.120	30.96	15.48
1½	5.359	1.0	5.359	3.5	18.757	12.25	65.648	153.90	153.90
2	7.597	0.75	5.698	3.0	17.094	9.0	51.282	438.46	328.84
3	10.956	2.0	21.912	2.0	43.824	4.0	87.648	1315.09	2630.18
4	12.007	1.0	12.007	1.0	12.007	1.0	12.007	1731.03	1731.03
5	12.039	2.0	24.078	0	0	0	0	1744.90	3489.80
6	12.039	1.0	12.039	−1.0	−12.039	1.0	12.039	1744.90	1744.90
7	11.899	2.0	23.798	−2.0	−47.596	4.0	95.192	1684.73	3369.46
8	10.271	0.75	7.703	−3.0	−23.109	9.0	69.327	1083.52	812.64
8½	8.417	1.0	8.417	−3.5	−29.460	12.25	103.108	596.31	596.31
9	5.962	0.5	2.981	−4.0	−11.924	16.0	47.696	211.92	105.96
9½	3.057	1.0	3.057	−4.5	−13.756	20.25	61.904	28.57	28.57
10	0	0.25	0	−5.0	0	0	0	0	0
			Σ_1 = 129.864		Σ_2 = −34.319		Σ_3 = 656.182		Σ_4 = 15009.00

Station sp., $s = \frac{L}{10} = \frac{154.99}{10} = 15.499$ m

Waterplane area, $A_{WP} = \Sigma_1 \times \frac{4}{3} \times s = (129.864 \times 20.666) = 2{,}683.77$ m²

Waterplane coeff., $C_{WP} = A_{WP}/(L \times B) = 2683.77/(154.99 \times 24.078) = 0.719$

Tonnes per cm immersion = $2{,}683.77 \times 1.025/100 = 27.51$ t (S.W.)

Long'l Center of Flotation $LCF = (\Sigma_2/\Sigma_1) \times s = (-34.319/129.864) \times 15.499 = 4.10$ m abaft Sta. 5

Long'l moment of inertia about Sta. 5 = $\Sigma_3 \times \frac{4}{3} \times s^3 = 656.182 \times \frac{4}{3} \times (15.499)^3 = 3{,}257{,}400$ m⁴

Long'l moment of inertia about LCF, $I_l = 3{,}257{,}400 - 2{,}683.77 \times (4.10)^2 = 3{,}212{,}300$ m⁴

Trans. moment of inertia, $I_T = \Sigma_4 \times \frac{4}{9} s = 15{,}009 \times 6.8884 = 103{,}390$ m⁴

Vol. of displacement, ∇ (from displacement curve) = 17,845 m³

Long'l $\overline{BM} = I_L/\nabla = 3{,}212{,}300/17{,}845 = 180.0$ m

Transverse $\overline{BM} = I_T/\nabla = 103{,}390/17{,}845 = 5.79$ m.

Figure 3-4. Calculation of waterplane characteristics [7]

While the use of a spreadsheet program like EXCEL© would help to expedite the hand calculations and minimize errors, it would take a great many spreadsheets to obtain all of the data for all of the drafts to plot the curves of form. Just as with the data for the Bonjean Curves, ASSET and POSSE can be used to generate the data and plots and facilitate design modifications by minimizing the time to produce these curves for each variant. When viewed side-by-side, the plots from both programs are similar; this indicates that either program can be used to successfully generate the curves of form.

3.2.1 ASSET DERIVED CURVES OF FORM

For the design studied, Figure 3-5 shows the curves of form.

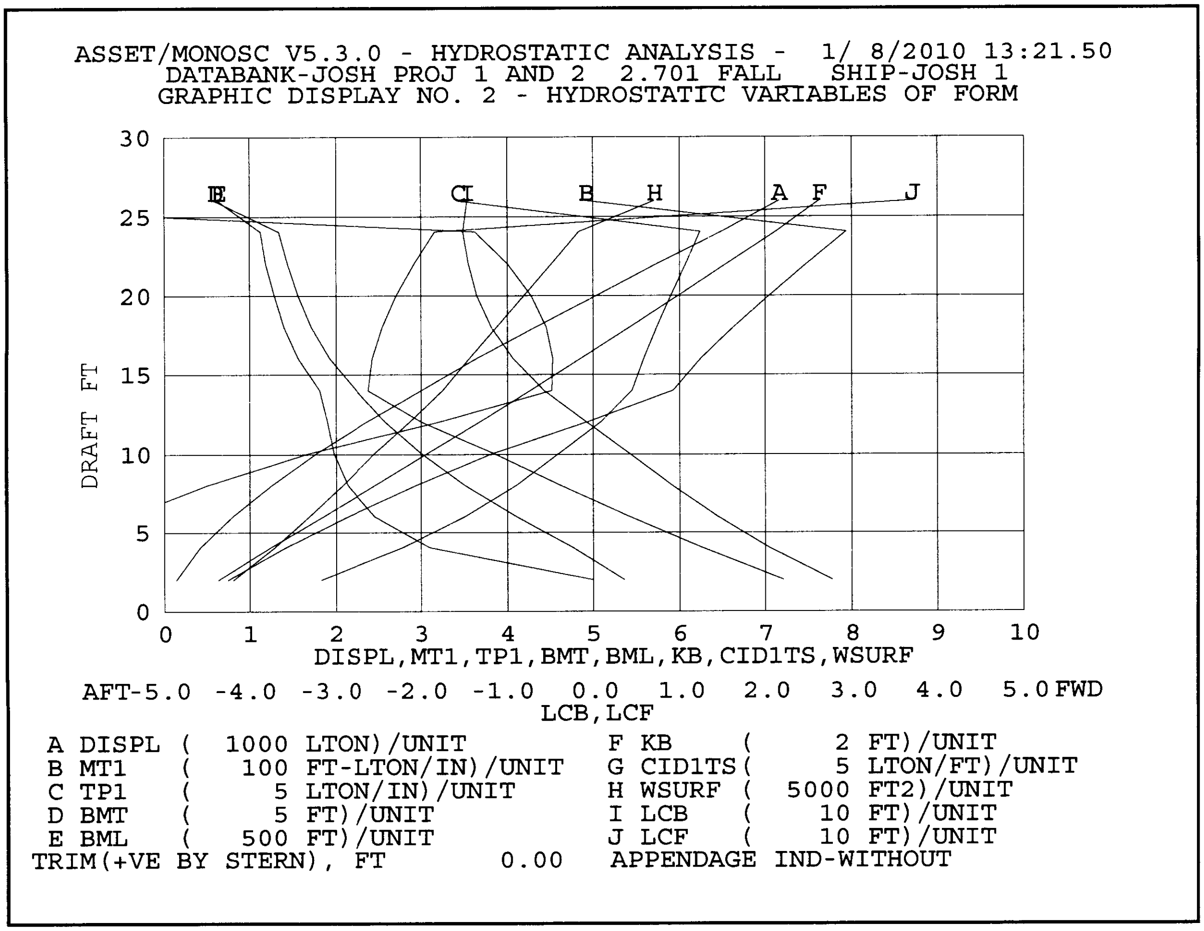

Figure 3-5. ASSET generated curves of form

There are several different ways to illustrate the curves of form. The plot shown above is one of the more standard methods where all of the curves are drafted on a single sheet. The scaling factor for each curve is printed in the legend.

3.2.2 POSSE DERIVED CURVES OF FORM

While the image shown above is one of the standard display methods, it can be seen how this viewing can be complicated. POSSE gives the opportunity to display each curve separately. A similar analysis of the design was run using POSSE; the results are displayed in Figures 3-6 through 3-13.

Displacement:

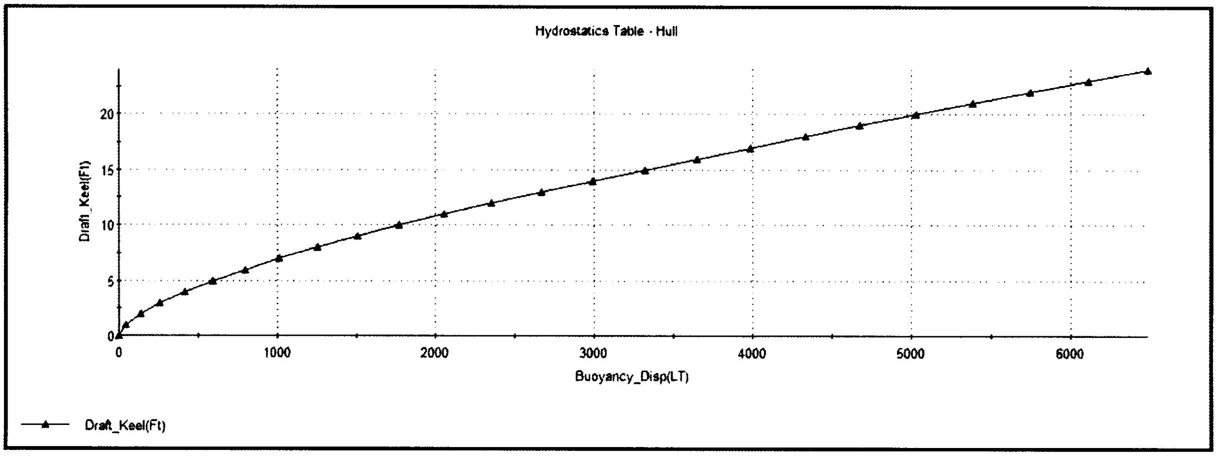

Figure 3-6. POSSE generated displacement curve

MT1":

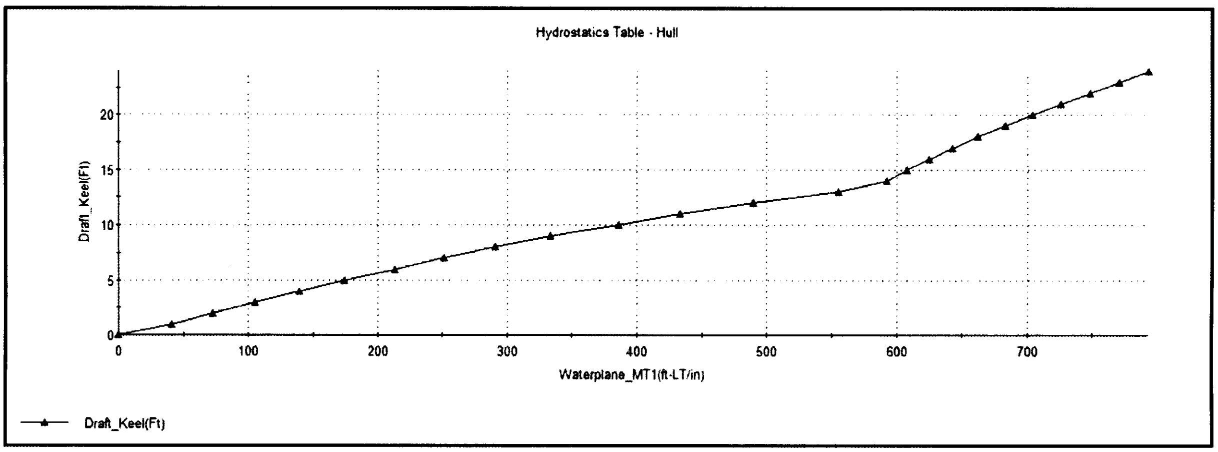

Figure 3-7. POSSE generated MT1" curve

TPI:

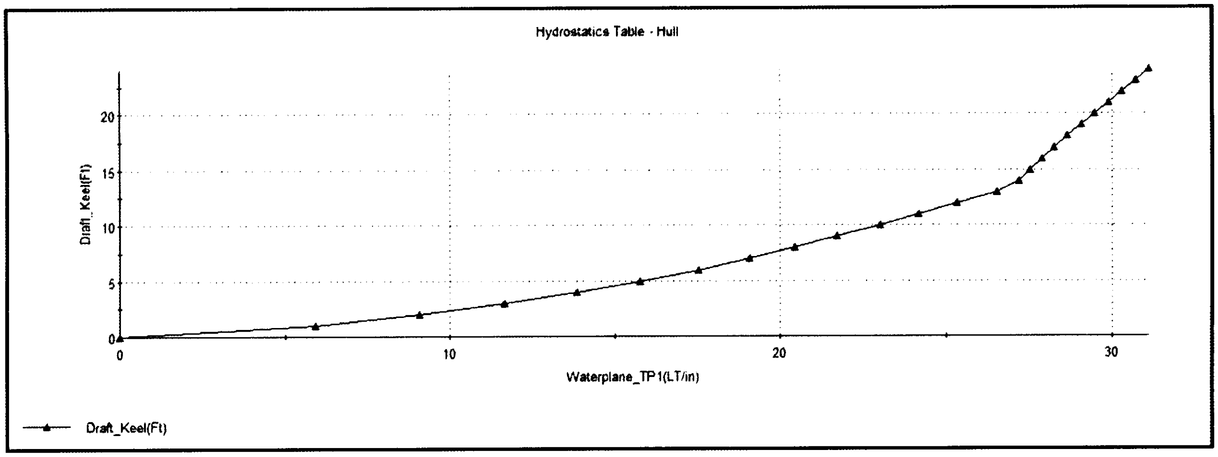

Figure 3-8. POSSE generated TPI curve

BM_T:

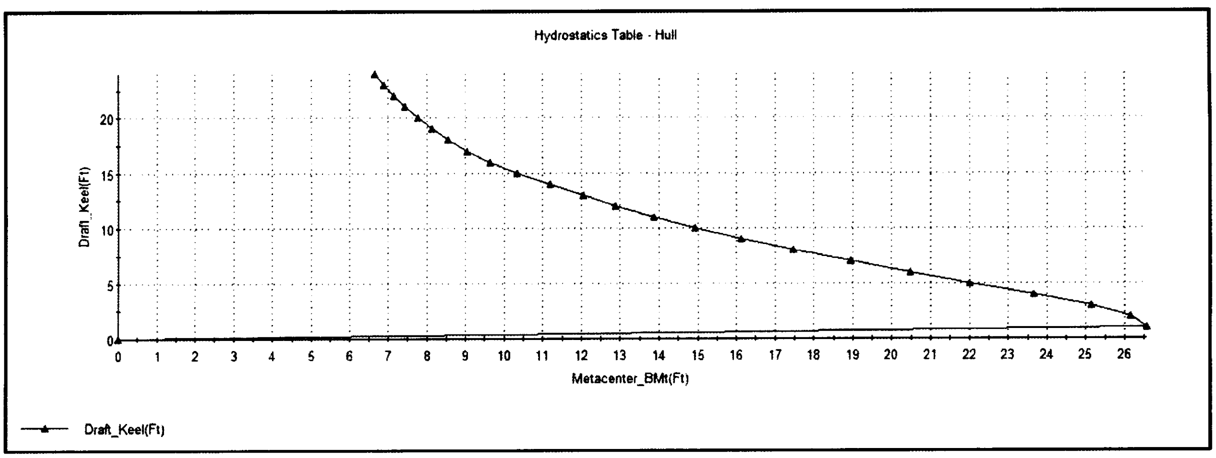

Figure 3-9. POSSE generated BM_T curve

BM_L:

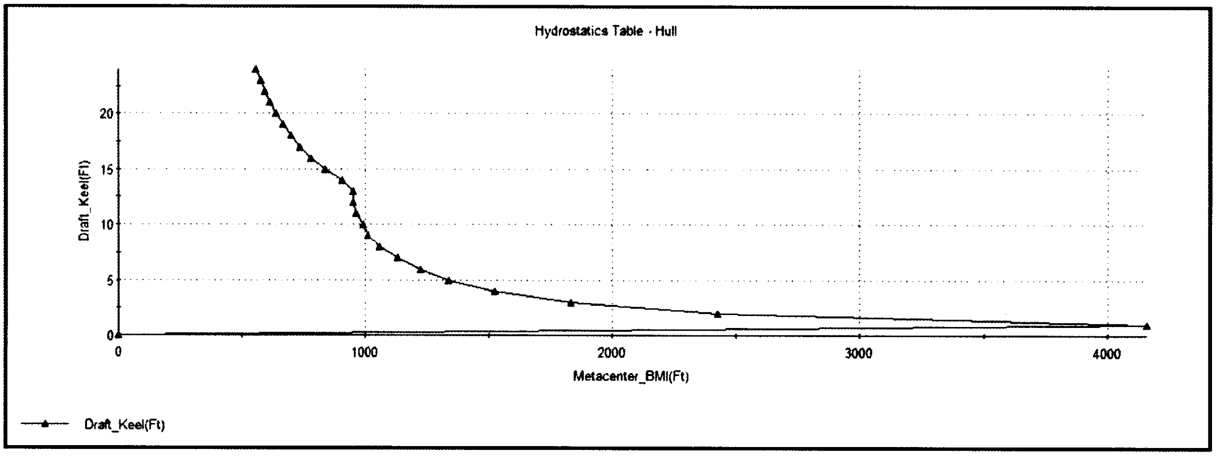

Figure 3-10. POSSE generated BM_L curve

KB:

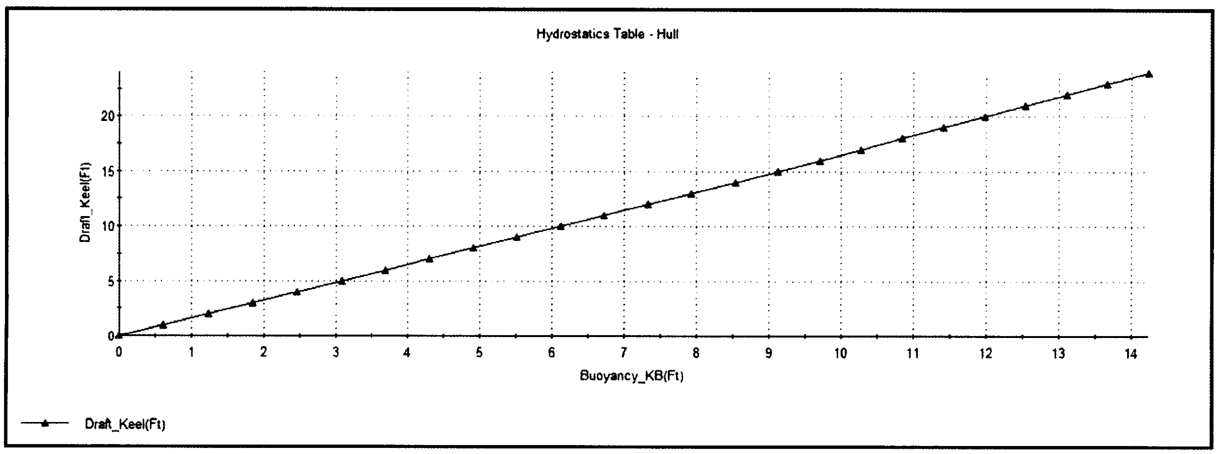

Figure 3-11. POSSE generated KB curve

LCB:

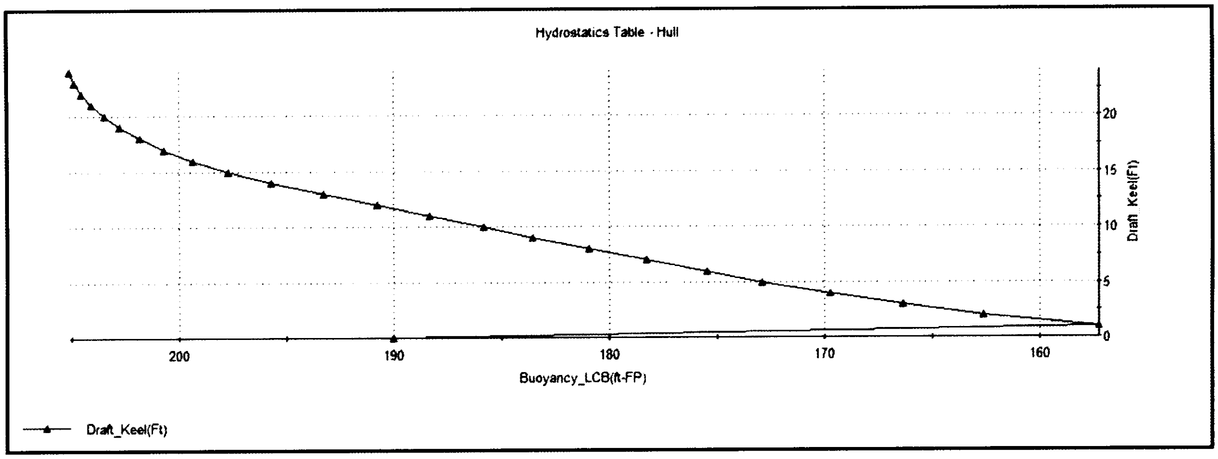

Figure 3-12. POSSE generated LCB curve

LCF:

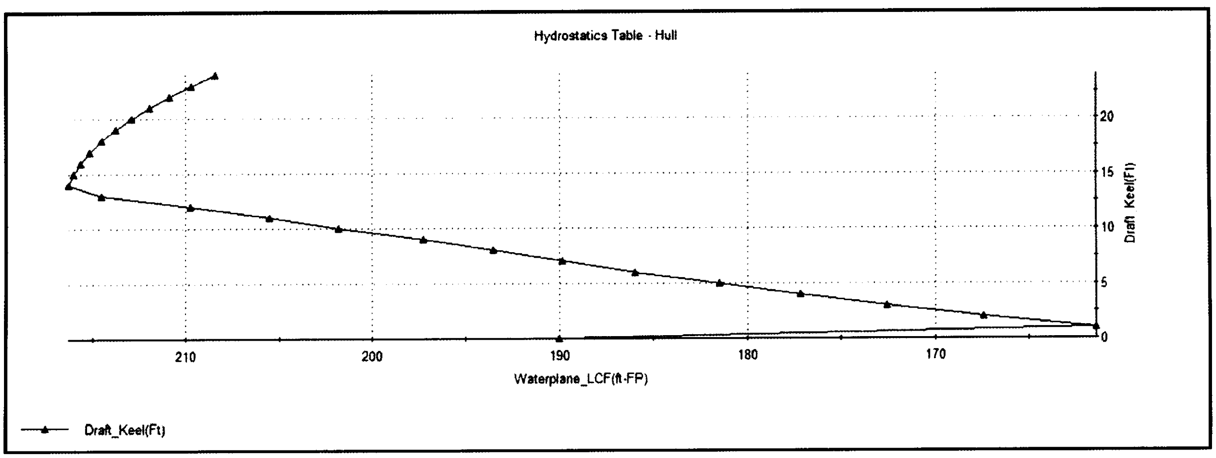

Figure 3-13. POSSE generated LCF curve

3.3 DESIGN WATERLINE CHARACTERISTICS

For this and for other assessments, a design waterline (DWL) draft of 14 feet was selected based on design criteria. *Introduction to Naval Architecture* by Gilmer and Johnson [2] gives the most comprehensive explanation of "waterline:"

The intersection line of the free-water surface with the molded surface of a ship, either in still water or when she is surrounded by waves of her own making. The intersection line of any selected plane, parallel to the baseplane, with the molded surface of a ship. The angle of the waterline at the bow in the horizontal plane neglecting local shape at the stem is the angle of entrance. The angle of the waterline at the stern in the horizontal plane neglecting local shape of stern frame is the angle of run.

To verify that ASSET and POSSE could produce reliable results for a given condition, several design waterline characteristics were hand calculated, as well as outputted from ASSET and POSSE to be compared. The chosen characteristics used for the comparison were the DWL AWP, LCF, Transverse Waterplane Inertia Coefficient (C_{IT}), and the Longitudinal Waterplane Inertia Coefficient (C_{IL}). Any of the characteristics could have been chosen to compare against, but these thought to be complex and well rounded comparison data points.

3.3.1 ASSET DERIVED DESIGN WATERLINE CHARACTERISTICS

ASSET's analysis tools can provide the naval architect with virtually all required design characteristics and properties, though not necessarily explicitly (to be further illustrated below). Figures 3-14 through 3-16 show samples of these outputs and how the aforementioned comparison characteristics can be obtained.

```
        ASSET/MONOSC V5.3.0 - HULL GEOM MODULE -  1/ 8/2010 13:19.35
          DATABANK-JOSH PROJ 1 AND 2  2.701_FALL_  SHIP-JOSH 1

PRINTED REPORT NO.  1 - HULL GEOMETRY SUMMARY
HULL OFFSETS IND- GENERATE
HULL DIM IND- NONE                          MIN BEAM, FT                 30.00
HULL STA IND- GIVEN                         MAX BEAM, FT                105.60
HULL BC IND- CONV DD                        HULL FLARE ANGLE, DEG          .00
                                            FORWARD BULWARK, FT           4.00
                 HULL PRINCIPAL DIMENSIONS (ON DWL)
                 ==================================
LBP, FT                        380.00       PRISMATIC COEF               0.580
HULL LOA, FT                   396.28       MAX SECTION COEF             0.836
BEAM, FT                        40.60       WATERPLANE COEF              0.737
BEAM @ WEATHER DECK, FT         40.82       LCB/LBP                      0.515
DRAFT, FT                       14.00       HALF SIDING WIDTH, FT         1.00
DEPTH STA 0, FT                 33.60       BOT RAKE, FT                  0.00
DEPTH STA 3, FT                 30.42       RAISED DECK HT, FT            0.00
DEPTH STA 10, FT                26.00       RAISED DECK FWD LIM, STA
DEPTH STA 20, FT                26.76       RAISED DECK AFT LIM, STA
FREEBOARD @ STA 3, FT           20.42       BARE HULL DISPL, LTON      2992.55
STABILITY BEAM, FT              39.33       AREA BEAM, FT                38.00
      BARE HULL DATA ON LWL                      STABILITY DATA ON LWL
      =====================                      =====================
LGTH ON WL, FT                 379.98       KB, FT                        8.44
BEAM, FT                        40.60       BMT, FT                      11.01
DRAFT, FT                       13.97       KG, FT                       15.60
FREEBOARD @ STA 3, FT           20.45       FREE SURF COR, FT             0.00
PRISMATIC COEF                  0.580       SERV LIFE KG ALW, FT          0.00
MAX SECTION COEF                0.834
WATERPLANE COEF                 0.741       GMT, FT                       3.85
WATERPLANE AREA, FT2         11431.11       GML, FT                     880.11
WETTED SURFACE, FT2          16220.88       GMT/B AVAIL                  0.095
                                            GMT/B REQ                    0.080

BARE HULL DISPL, LTON         2983.02
APPENDAGE DISPL, LTON           61.29
FULL LOAD WT, LTON            3044.31
```

Figure 3-14. ASSET hull geometry summary output

```
        ASSET/MONOSC V5.3.0 - HULL GEOM MODULE -  1/ 8/2010 13:19.35
          DATABANK-JOSH PROJ 1 AND 2  2.701_FALL_  SHIP-JOSH 1

PRINTED REPORT NO. 3 - HULL BOUNDARY CONDITIONS
HULL OFFSETS IND-GENERATE
HULL BC IND-CONV DD                        HULL STA IND-GIVEN
LBP, FT                        380.00      LCB/LBP                       0.515
BEAM, FT                        40.60      LCF/LBP                       0.569
DRAFT, FT                       14.00      HALF SIDING WIDTH, FT          1.00
DEPTH STA 0, FT                 33.60      BOT RAKE, FT                   0.00
DEPTH STA 3, FT                 30.42      FWD RAISED DECK LIMIT
DEPTH STA 10, FT                26.00      AFT RAISED DECK LIMIT
DEPTH STA 20, FT                26.76      RAISED DECK HT, FT             0.00
PRISMATIC COEF                  0.580      WATERPLANE COEF               0.737
MAX SECTION COEF                0.836
NO POINTS BELOW DWL               15.      FWD KEEL/BL LIMIT             0.087
NO POINTS ABOVE DWL               12.      AFT KEEL/BL LIMIT             0.550
POINT DIST FAC ABOVE DWL        1.000      BOW ANGLE, DEG                50.00
POINT DIST FAC BELOW DWL        1.000      BOW SHAPE FAC                 0.000
BOW OVERHANG                    0.043      STA 20 SECTION COEF           0.700
STERN OVERHANG                  0.007      HULL FLARE ANGLE, DEG
```

Figure 3-15. ASSET hull boundary conditions output

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:22.43
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 2 - HYDROSTATIC VARIABLES OF FORM

DRAFT FT	TOTAL VOLUME FT3	APPDG VOLUME FT3	TOTAL DISPL LTON	LCB FT	KB FT	LCF FT
2.00	4716.	0.	134.8	27.72	1.25	22.08
4.00	14492.	0.	414.3	20.36	2.48	12.52
6.00	27760.	0.	793.7	14.46	3.70	4.06
8.00	43774.	0.	1251.5	9.15	4.92	-3.80
10.00	62075.	0.	1774.7	4.15	6.13	-11.58
12.00	82407.	0.	2356.1	-0.78	7.33	-19.90
14.00	104633.	0.	2991.8	-5.72	8.54	-26.27
16.00	127788.	0.	3653.5	-9.40	9.71	-25.68
18.00	151557.	0.	4333.1	-11.87	10.85	-24.54
20.00	175993.	0.	5031.7	-13.52	11.99	-22.92
22.00	201120.	0.	5750.1	-14.57	13.11	-20.86
24.00	226938.	0.	6488.2	-15.15	14.24	-18.42
26.00	250524.	0.	7162.6	-14.63	15.24	37.10

-------------HULL ONLY-------------

DRAFT FT	CIDITSIITS LTON/FT	LONG BM FT	TRNSV BM FT	LONG KM FT	TRNSV KM FT	MT1 FT-LTON/IN
2.00	-6.38	2496.23	26.82	2497.48	28.07	73.8
4.00	-5.50	1546.11	23.79	1548.59	26.27	140.5
6.00	-2.25	1226.94	20.52	1230.64	24.23	213.5
8.00	2.46	1070.15	17.52	1075.07	22.43	293.7
10.00	8.43	986.73	14.97	992.86	21.09	384.0
12.00	15.95	952.30	12.91	959.64	20.24	492.0
14.00	22.60	903.55	11.21	912.09	19.75	592.8
16.00	22.65	780.26	9.64	789.97	19.35	625.1
18.00	22.24	697.57	8.57	708.42	19.42	662.9
20.00	21.36	638.42	7.78	650.40	19.76	704.5
22.00	19.99	593.68	7.16	606.80	20.27	748.6
24.00	18.12	557.99	6.66	572.23	20.89	793.9
26.00	-20.06	313.11	2.97	328.35	18.21	491.8

Figure 3-16. ASSET hydrostatic variables of form output

As stated above, not all output data from ASSET is explicit. To obtain the LCF value from ASSET, the LCF/LBP ratio must be multiplied by the LBP provided. To obtain the C_{IL} and C_{IT} values, the equations have to be used:

$$C_{IT} = (12 * BM_T * \nabla) / (B^3 * L)$$

$$C_{IL} = (12 * BM_L * \nabla) / (B * L^3)$$

Each of the values required for these equations are provided in the figures above.

3.3.2 POSSE DERIVED DESIGN WATERLINE CHARACTERISTICS

POSSE, on the other hand, provides significantly less of a detailed output, however, it does print the output in a much more tabular and user-friendly format. Figure 3-17 is the POSSE output for the selected design.

HYDROSTATIC TABLE - HULL

Options

Density	LT/ft3	0.029
Long Draft Ref		LCF
Trim	ft	0.00
Heel	deg	0
Master Draft		Baseline

Hydrostatic Properties

Draft	Buoyancy			Waterplane			Metacenter				Waterplane	Coefficients			Wetted
Keel	Disp	KB	LCB	Area	LCF	TP1	BMt	KMt	BMl	KMl	MT1	Cit	Cil	Cm	Max Beam
Ft	LT	Ft	ft-FP	ft2	ft-FP	LT/in	Ft	Ft	Ft	Ft	ft-LT/in				Ft
0.00	0	---	190.00A	---	190.00A	---	---	---	---	---	---	---	---	---	---
1.00	45	0.61	157.24A	2,492.4	161.42A	5.9	26.57	27.18	4,159.07	4,159.68	41	0.020	0.046	0.279	17.37
2.00	137	1.23	162.62A	3,811.6	167.39A	9.1	26.15	27.39	2,425.82	2,427.05	73	0.059	0.073	0.399	24.27
3.00	262	1.85	166.34A	4,895.3	172.57A	11.7	25.14	26.99	1,832.09	1,833.94	105	0.109	0.098	0.486	28.93
4.00	416	2.47	169.71A	5,817.2	177.14A	13.8	23.66	26.13	1,523.79	1,526.26	139	0.162	0.125	0.553	32.25
5.00	595	3.08	172.86A	6,625.9	181.47A	15.8	22.01	25.09	1,337.09	1,340.17	174	0.216	0.153	0.608	34.66
6.00	794	3.69	175.45A	7,366.9	185.96A	17.5	20.47	24.16	1,227.11	1,230.80	214	0.268	0.184	0.652	36.42
7.00	1,014	4.30	178.24A	8,010.3	189.84A	19.1	18.94	23.25	1,131.50	1,135.80	252	0.317	0.216	0.690	37.69
8.00	1,252	4.91	180.90A	8,584.8	193.51A	20.4	17.48	22.39	1,059.71	1,064.62	291	0.362	0.251	0.721	38.64
9.00	1,507	5.52	183.52A	9,121.2	197.25A	21.7	16.11	21.63	1,009.04	1,014.56	333	0.401	0.289	0.747	39.40
10.00	1,774	6.12	185.80A	9,678.1	201.80A	23.0	14.94	21.06	991.50	997.62	386	0.438	0.339	0.770	39.94
11.00	2,058	6.73	188.32A	10,155.3	205.51A	24.2	13.87	20.60	959.90	966.63	433	0.472	0.386	0.789	40.32
12.00	2,356	7.33	190.79A	10,641.9	209.73A	25.3	12.89	20.22	947.99	955.32	490	0.502	0.443	0.805	40.56
13.00	2,667	7.93	193.28A	11,148.8	214.49A	26.5	12.06	19.99	950.35	958.28	556	0.531	0.514	0.820	40.71
14.00	2,990	8.54	195.70A	11,434.7	216.27A	27.2	11.21	19.74	903.17	911.70	592	0.554	0.552	0.832	40.78
15.00	3,319	9.13	197.73A	11,577.2	216.02A	27.6	10.35	19.47	835.40	844.52	608	0.567	0.565	0.843	40.81
16.00	3,652	9.71	199.38A	11,727.5	215.65A	27.9	9.64	19.35	780.36	790.07	625	0.582	0.579	0.853	40.84
17.00	3,989	10.28	200.73A	11,884.8	215.16A	28.3	9.06	19.34	735.05	745.33	643	0.597	0.593	0.862	40.87
18.00	4,331	10.85	201.85A	12,049.5	214.52A	28.7	8.56	19.41	697.58	708.43	663	0.613	0.609	0.870	40.88

Figure 3-17. POSSE hydrostatic table output

The DWL draft of 14 feet has been highlight above. Obtaining data from this figure is much less complicated than trying to extract it from the numerous ASSET reports; therefore, based on the level of design detail the naval architect is looking for, one tool might be preferred over the other.

3.3.3 MANUAL DERIVED DESIGN WATERLINE CHARACTERISTICS

To demonstrate the hand calculations, several tools were used. The first tool was EXCEL©. As a cross-platform accepted standard, EXCEL© was the chosen spreadsheet. The second tool applied was a numerical rule called Simpson's Rule. Simpson's Rule is an integration tool that "rigorously integrates the area under a curve of the type $y = a + bx + cx^2$, which is a second order parabola, or polynomial of degree 2, by applying multipliers to groups of three equally spaced ordinates." [7]

Using these two rules and the table of offsets for the hullform, Table 3-2 was created. Note the Simpson's Rule multipliers inserted as the "1st (SM)" column.

			AREA	My	Mx	Iy	Ix
x	y	1st (SM)	y*SM	x*y*SM	(y^2*SM)/2	x^2*y*SM	(y^3*SM)/3
0.00	0.102	0.5	0.05	0.00	0.00	0.00	0.00
9.50	1.298	2	2.60	24.65	1.68	234.22	1.46
19.00	2.547	1.5	3.82	72.60	4.87	1379.43	8.27
38.00	5.185	4	20.74	788.15	53.77	29949.61	185.88
57.00	7.917	2	15.83	902.49	62.67	51442.18	330.77
76.00	10.603	4	42.41	3223.46	224.87	244982.99	1589.59
95.00	13.106	2	26.21	2490.21	171.78	236569.76	1500.91
114.00	15.309	4	61.24	6981.02	468.75	795835.74	4784.10
133.00	17.133	2	34.27	4557.30	293.53	606120.73	3352.64
152.00	18.539	4	74.15	11271.53	687.37	1713273.24	8495.27
171.00	19.527	2	39.05	6678.22	381.30	1141975.91	4963.78
190.00	20.127	4	80.51	15296.83	810.23	2906398.58	10871.83
209.00	20.388	2	40.78	8522.35	415.69	1781170.35	5650.12
228.00	20.364	4	81.46	18571.88	829.38	4234388.33	11259.57
247.00	20.102	2	40.20	9930.20	404.07	2452758.98	5415.04
266.00	19.632	4	78.53	20888.89	770.86	5556445.47	10089.28
285.00	18.966	2	37.93	10810.53	359.70	3081002.33	4548.05
304.00	18.091	4	72.37	21999.06	654.59	6687713.41	7894.97
323.00	16.988	2	33.98	10974.21	288.59	3544670.42	3268.37
342.00	15.644	4	62.58	21401.45	489.49	7319295.53	5105.17
361.00	14.091	1.5	21.14	7630.49	148.93	2754608.01	1399.05
370.50	13.269	2	26.54	9832.27	176.06	3642856.48	1557.46
380.00	12.449	0.5	6.22	2365.35	38.75	898832.24	321.57
		SUM	902.60	195213.15	7736.93	49681903.95	92593.12
		s	19.00	19.00	19.00	19.00	19.00
		mult	0.33	0.33	0.33	0.33	0.33
	SUM*s*mult		5716.49	1236349.96	49000.54	314652058.32	586423.10
	The Other Side		5716.49	1236349.96	49000.54	314652058.32	586423.10
	Totals		11432.98	2472699.93	98001.09	629304116.65	1172846.19

A_{WP}	11432.98	ft2
LCF	216.28	ft2
I_{xbar}	1172846.19	ft4
C_{IT}	0.55	
I_{ybar}	94514099.56	ft4
C_{IL}	0.51	

Table 3-2. Hand calculated hull characteristic spreadsheet

3.3.4 COMPARISON OF RESULTS

Table 3-3 shows how the hand calculated values compare with those derived using the computer based software.

	Hand	ASSET	% Error	POSSE	% Error
A_{WP} (ft^2)	11433.0	11432.8	0.00%	11434.7	0.02%
LCF (ft)	216.28	216.22	0.03%	216.27	0.00%
C_{IT}	0.553	0.554	0.10%	0.554	0.10%
C_{IL}	0.509	0.509	0.02%	0.552	8.43%

Table 3-3. Modeling method comparison table

The "% Error" columns measure the difference between the hand calculations and each of the computer programs. The primary source of error expected stems from the Simpson's rule integration simplifications. With the average error being less than 1.1%, ASSET and POSSE can be deemed as useful and adequate tools for the naval architect. The significant error in C_{IL} also illustrates the point that no single tool should be relied upon for the data.

CHAPTER 4. STATIC STABILITY CHARACTERISTICS

The basic tenets of ship design evaluation are that the ship float and float upright. From the earlier analysis, the metacentric height has been shown to be positive, and the draft of the ship is less than the available free-board. While these two conditions indicate that the ship has initial stability, that is it will float and float upright, more analysis is needed to determine the suitability of the ship's stability. Stability cannot be confined to a still water case with no other influences on the ship. The following analysis determines the stability characteristics for the ship.

The art of ship design has led to many thumb-rules that can be used to evaluate a ship's potential performance based on the ship's parameters, mentioned above. However, an in-depth analysis of the ship's stability must be completed to insure the ship remains stable through a series of likely and expected conditions. Additionally, the stability of the ship should be quantified to help operators plan their actions in a truly safe manner. Furthermore, ship stability is not a set of go-no go requirements. Each type of ship has different operational requirements which will compete with each in a design compromise to achieve the most appropriate characteristics for each ship type.

The ship is evaluated using ASSET and POSSE to validate the data and results. Additionally, calculations are performed where required to provide a comprehensive analysis. The Naval Architect performs all of these analyses prior to ensuring a hull is adequate for further consideration.

4.1 CROSS-CURVES OF STABILITY

While an adequate design does vary somewhat based on the ship's purpose as mentioned above, the stability also changes with the displacement of the ship as well as at large angles of inclination. For a given hullform, one can imagine that the draft will influence the effects of the freeboard on producing a righting force.

The Cross-Curves of Stability are shown below in Figure 4-1. Evaluating the hull requires knowledge of the center of gravity. An initial estimate of KG is 0.6 of the depth at station 10. This yields 15.6 feet for this hullform. The Cross-Curves show that the hullform produces a positive righting arm for all heel angles from 0 to 89 degrees.

At this stage of evaluating the hullform, it is difficult to determine whether the righting arm developed is adequate. Most ship designs will have a target displacement range that will be much smaller than that shown below. The data from the Cross-Curves will likely be taken for a given displacement for the desired ship design evaluating a range for loading and design changes.

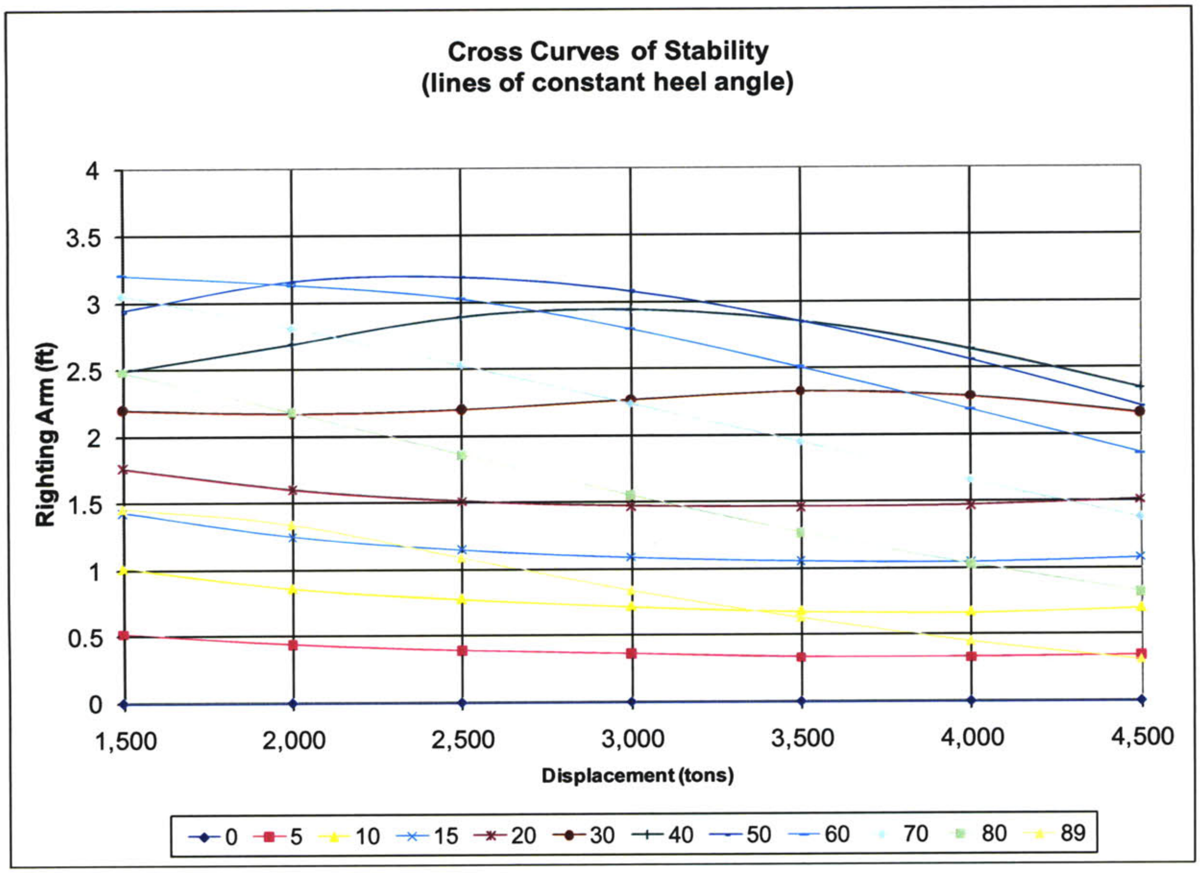

Figure 4-1. POSSE Data plotted in Excel

4.2 GENERAL STABILITY CURVE

While the above data provides a broad evaluation of the hullform, draft is another parameter that is often specified. The hullform is only valuable in as much as it will be used in an eventual ship design which comes with a function and often areas where it must operate which dictate limits on draft. Based on the desired draft of 14ft and the hull volume below the water, the displacement of the ship to analyze is approximately 2990 long tons. General stability curves are formed by taking the data from the Cross-Curves of Form for a certain displacement and plotting righting arm versus heel angle. These graphs are perhaps more useful because they remove the unneeded displacement data from consideration.

4.2.1 ASSET DERIVED GENERAL STABILITY CURVE

ASSET produces General Stability curves for various displacements as shown in Appendix A. These curves are produced from the hull offsets which ASSET generated for the hull type and characteristics as defined in chapter 2.

4.2.2. POSSE DERIVED GENERAL STABILITY CURVE

POSSE takes the offsets from ASSET and the center of gravity as estimated above and determines its own curves of form for the ship. The program can then calculate the righting arm data and produce its own general stability curves. The output from POSSE is shown in Table 4-1 below. The curves shown in Figure 4-2 represent the righting arm for the entire range of displacements.

POSSE																			
	Heel Angle (deg)																		
Disp	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	89
1,500	0	0.52	1.01	1.43	1.76	2.01	2.2	2.35	2.49	2.68	2.94	3.13	3.21	3.16	3.05	2.82	2.48	2.06	1.46
2,000	0	0.44	0.86	1.25	1.6	1.9	2.17	2.42	2.69	2.98	3.16	3.21	3.14	3.02	2.81	2.53	2.18	1.75	1.34
2,500	0	0.39	0.78	1.15	1.51	1.86	2.2	2.55	2.89	3.11	3.19	3.15	3.03	2.81	2.53	2.22	1.86	1.45	1.09
3,000	0	0.36	0.72	1.09	1.47	1.86	2.27	2.67	2.94	3.08	3.08	2.98	2.8	2.54	2.24	1.91	1.55	1.17	0.84
3,500	0	0.33	0.68	1.06	1.46	1.89	2.33	2.66	2.85	2.91	2.85	2.72	2.51	2.24	1.95	1.62	1.27	0.92	0.63
4,000	0	0.33	0.67	1.05	1.47	1.92	2.29	2.53	2.64	2.64	2.56	2.4	2.19	1.94	1.66	1.35	1.03	0.7	0.45
4,500	0	0.34	0.7	1.08	1.51	1.9	2.16	2.3	2.35	2.31	2.21	2.06	1.86	1.63	1.38	1.11	0.82	0.53	0.31
4,500	0	0.34	0.7	1.08	1.51	1.9	2.16	2.3	2.35	2.31	2.21	2.06	1.86	1.63	1.38	1.11	0.82	0.53	0.31

Table 4-1: POSSE Static Stability Data

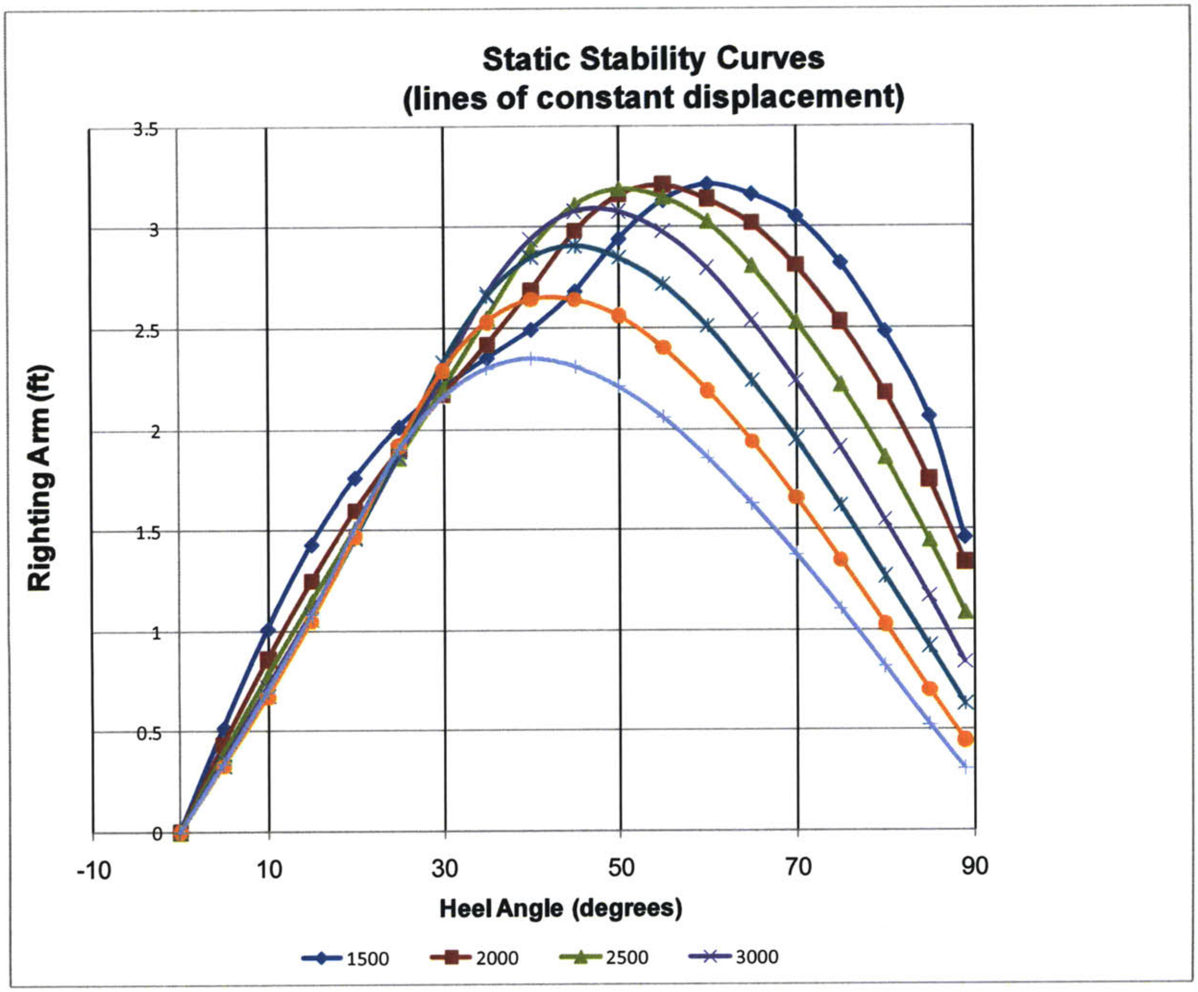

Figure 4-2: POSSE Curves

4.2.3 COMPARISON OF DERIVED GENERAL STABILITY CURVES

With an expected nominal displacement of 2990 LT for the final ship design, the ASSET and POSSE data for this particular configuration are compared. With the complexities inherent in ship design and the immense number of calculations being performed by the different analysis tools, it is a good idea to verify that the data is consistent. Figure 4-3 shows the comparison of the ASSET data for 2992 LT to the POSSE data for 3000 LT. It is evident that both programs provide nearly identical predictions of static stability.

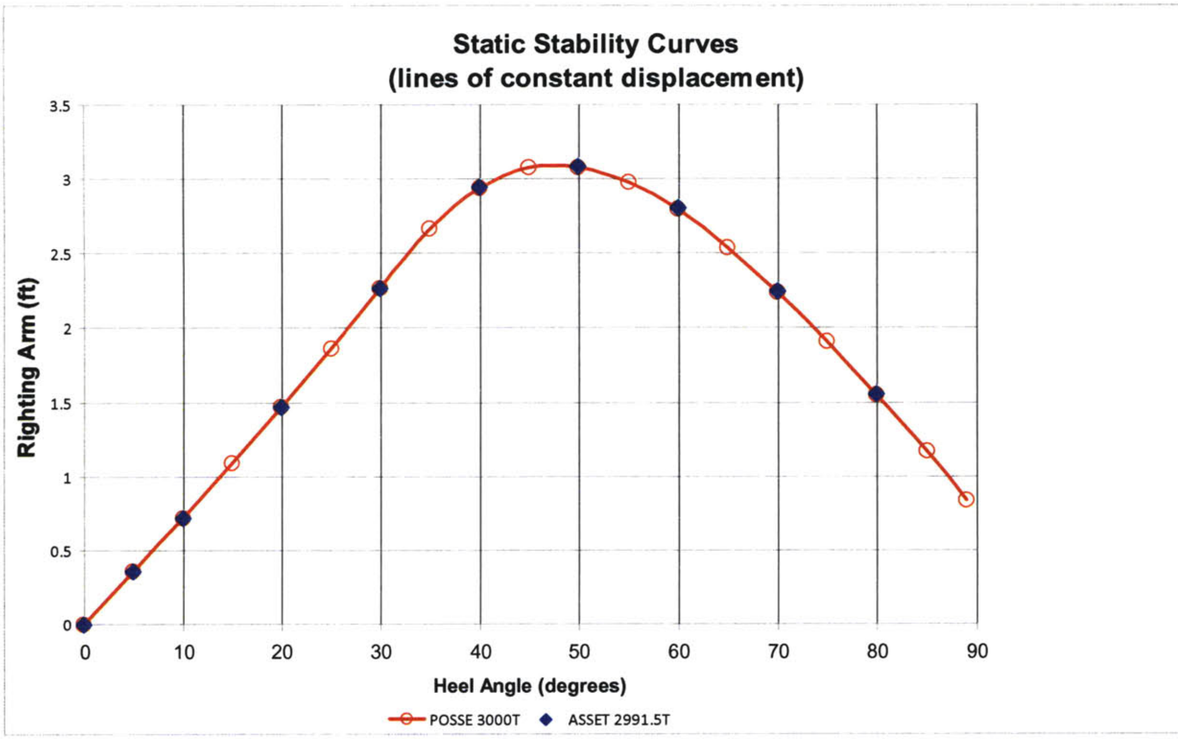

Figure 4-3 ASSET data overlay

4.3 LIMITING CONDITIONS

The Cross Curves of Stability and the General Stability Curves provide the righting arm values for consideration, but if this was the only factor, any value greater than zero would be adequate. Of course, the ship will be operating in conditions with wind and seas that will tend to roll the ship as well as maneuvering and other operations and conditions. The moments produced from these plausible circumstances will be compared to the righting arm to determine if the ship remains upright. However, a hullform's characteristics also include the speed at which the ship corrects itself from a roll. If the ship responds too quickly, the sailors could become sick, equipment could damaged, or even personnel injured. Several key parameters are evaluated below to provide a first pass of the suitability of the hullform.

The close correlation shown in Figure 4-3 helps to verify the analysis completed in ASSET. Now ASSET is also used to determine the suitability of the hullform in a variety of conditions that are meant to simulate worst reasonable cases of real-world conditions. The results of these analyses will give the ship designers an idea of the superstructure that can be placed on the ship as well as the loading necessary to provide adequate stability.

The analysis was based on the range of likely ship displacements of 2991.5 LT plus or minus 500 tons to allow for variations in the eventual design as well as loading changes. The height of the transverse metacenter, KM, was determined from the curves of form for the different displacements.

4.3.1 BEAM WINDS

All ships except a submerged submarine experience wind loading. A common approach is to evaluate beam winds which produce the highest roll moment on the ship. As should be expected, the more surface area and the higher from the waterline that surface area is, the larger the moment that will be produced. A 100 knot beam wind is a common specification used for Naval Vessels and is used for this analysis. A notional sail area factor of 1.25 was used. ASSET also predicts a notional superstructure to determine the center of the wind loading. Appendix A shows the results in graphical forms for different displacement ships.

4.3.2 HIGH SPEED TURNING

Another large moment that ships experience occurs during high speed maneuvers. A surface ship rolls outward during the steady state turn. To prevent the ship from rolling over, a moment must be produced by the righting arm.

4.3.3 ROLL PERIOD

The roll period is important for several reasons. If the roll period of the ship corresponds to the period of the waves, the ship will exhibit a much larger response without additional mitigations. Also, if the ship rolls too quickly, the crew tends to suffer higher rates of seasickness, and equipment and cargo can be forcibly moved about the ship. The roll period was calculated and analyzed. [2] The equation below provides a good first estimate of the roll period. The typical range for the constant C is 0.38 to 0.55 for this size vessel. [2] A value of 0.44 was selected. The roll period was required to be greater than 15 seconds to allow operation in a probable sea-state 7 in the Northern Hemisphere. [2] The metacentric height, GM, was determined from the relationship between KM and KG. From these two equations, a maximum KG was then determined to maintain the desired roll period.

$$GM=KM-KG$$

$$T_{roll} = C*B/GM^{1/2}$$

4.3.4 METACENTRIC HEIGHT

The metacentric height is typically required to be greater than 1 foot for operations. However, as a ship design evolves and a ship is modified throughout its life, the metacentric height typically decreases. As a result a margin of 1 foot minimum is typically added. This results in a minimum GM of 2 feet.

The table below shows the results of the above analyses. Over the range of displacements, the most limiting case for KG is the high speed turns. Based on the desired draft of approximately 14ft, the ship would displace 2991.5 LT. Loading and modifications to a ship design typically increase the weight which would make 2991.5 to 3491.5 LT the most likely range for this vessel's final displacement. Even so, the estimated 15.6 ft KG is a little bit high. If the ship is designed with a lower KG, this would increase the stability marginally.

Maximum KG for given condition and displacemt				
Displacement		2491.5	2991.5	3491.5
KM		20.10	19.74	19.20
100 kt beam wind		19.19	19.32	19.38
35 kt turn		15.06	15.24	15.52
roll period >15 seconds		21.52	21.16	20.62
GM >2 ft.		22.10	21.74	21.20

Table 4-2 Maximum KG limits

CHAPTER 5. SUMMARY AND CONCLUSIONS

While ships have historically been designed and analyzed using well-proven manual methods and hand calculations, computer systems have enabled the naval architect to design, analyze under various conditions, and modify a hullform in a fraction of the time that was previously possible, even with a team of experienced naval architects. The two programs currently used by the US Navy for conducting initial design and analysis, ASSET and POSSE, are used to develop a hullform, quickly calculate the numerous hull coefficients and curves of form used in naval architecture, and analyze the hullform under stable and certain dynamic conditions.

The hullform is found to be within safe limits at all cases with the exception of high-speed turning, where KG is limiting. This provides invaluable information to the naval architect when further design work commences; special attention can be paid during detailed design to lower KG prior to conducting a second round of stability analysis on POSSE.

A comparison of the two programs with standard hand-calculations, derived from naval architecture references, is performed to validate the accuracy of both programs. Both programs matched well with each other and with the hand-calculations, within ±1.1% on average, with the exception of Longitudinal Waterplane Inertia Coefficient (C_{IL}), where POSSE's value differed from ASSET and hand-calculations by over 8%. This provides a reminder for any naval architect to never rely solely on any one design tool or method but to consider all tools.

ASSET and POSSE are both well-established tools in the US Navy. Each has its strengths and weaknesses and should be used together to provide an efficient composite analysis tool. 'Composite' here refers to the concurrent use of both tools in designing and evaluating a new or existing hullform. ASSET is most useful in creating the hullform and deriving the initial hull coefficients. POSSE is found to present the information in a clearer format and provides the bulk of analysis tools for various loading conditions. Finally, hand calculations provide the final back-up check to verify the tools have been used correctly and the results can be trusted for a safe, efficient design.

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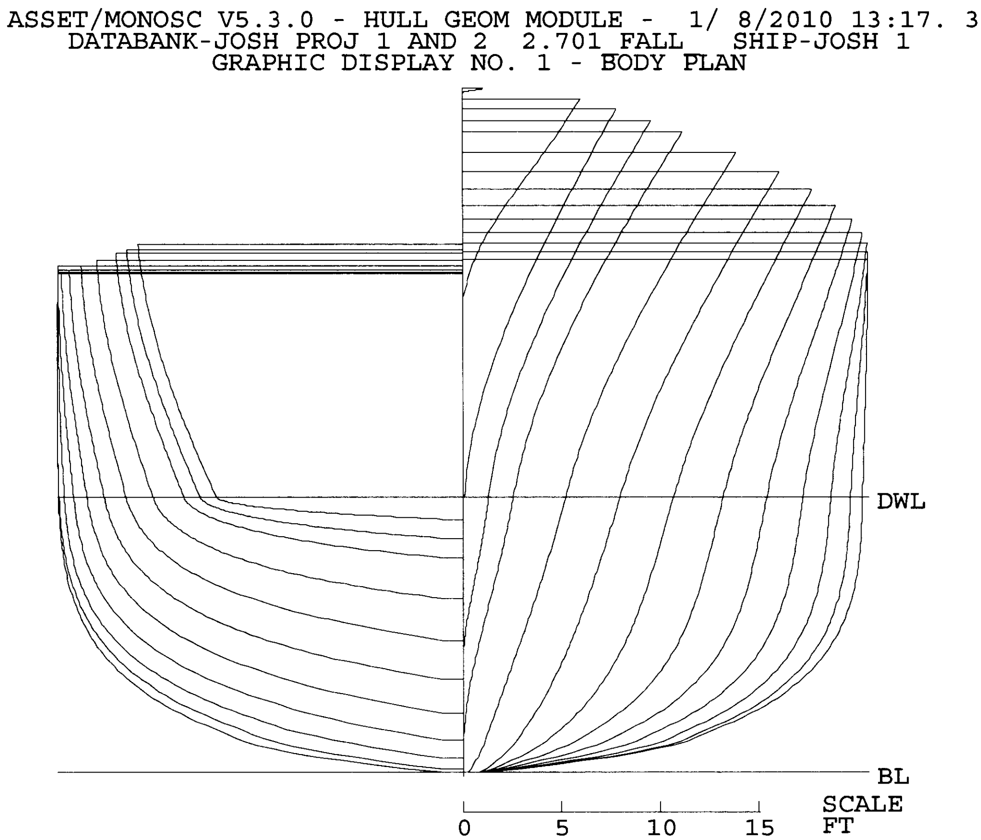
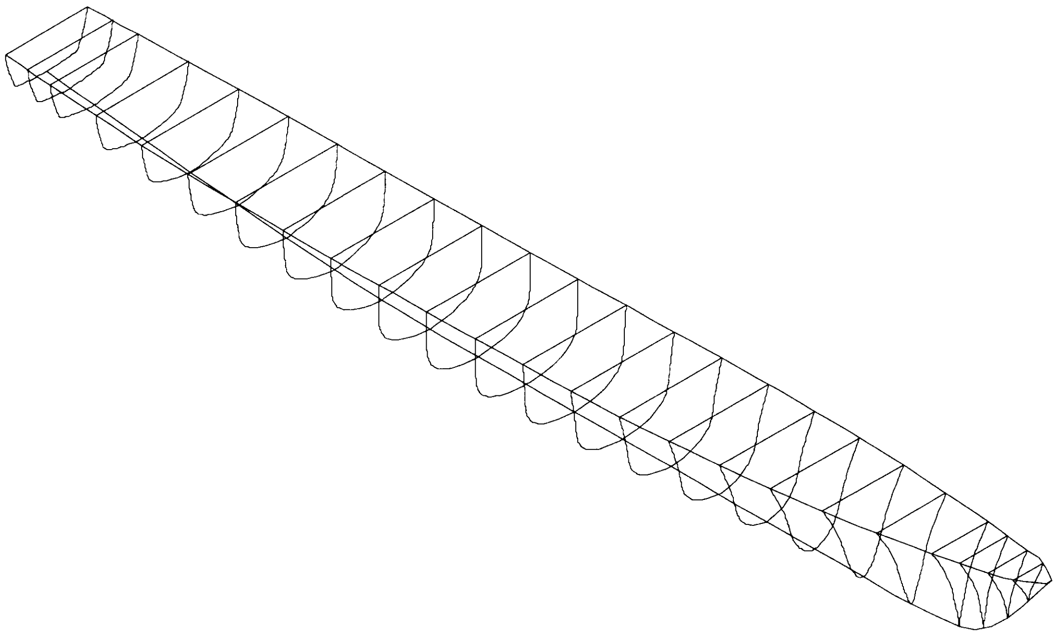
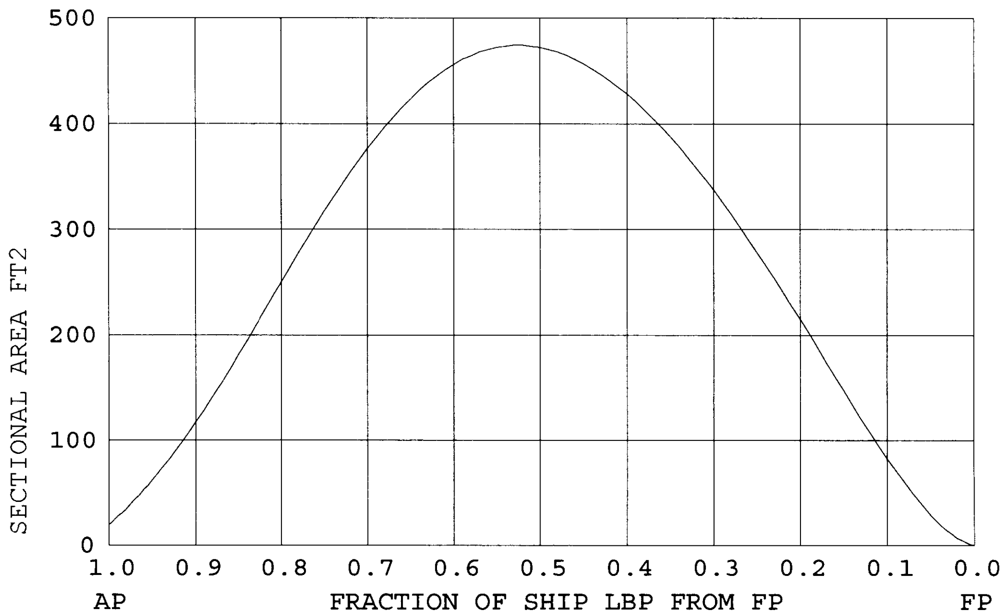
APPENDIX A. ASSET PRINTED AND GRAPHIC REPORTS



ASSET/MONOSC V5.3.0 - HULL GEOM MODULE - 1/ 8/2010 13:17. 3
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 2 - HULL ISOMETRIC VIEW



ASSET/MONOSC V5.3.0 - HULL GEOM MODULE - 1/ 8/2010 13:17. 3
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - HULL SECTIONAL AREA CURVE



ASSET/MONOSC V5.3.0 - HULL GEOM MODULE - 1/ 8/2010 13:19.35
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - HULL GEOMETRY SUMMARY

HULL OFFSETS IND- GENERATE			
HULL DIM IND- NONE		MIN BEAM, FT	30.00
HULL STA IND- GIVEN		MAX BEAM, FT	105.60
HULL BC IND- CONV DD		HULL FLARE ANGLE, DEG	.00
		FORWARD BULWARK, FT	4.00

HULL PRINCIPAL DIMENSIONS (ON DWL)
==================================

LBP, FT	380.00	PRISMATIC COEF	0.580
HULL LOA, FT	396.28	MAX SECTION COEF	0.836
BEAM, FT	40.60	WATERPLANE COEF	0.737
BEAM @ WEATHER DECK, FT	40.82	LCB/LBP	0.515
DRAFT, FT	14.00	HALF SIDING WIDTH, FT	1.00
DEPTH STA 0, FT	33.60	BOT RAKE, FT	0.00
DEPTH STA 3, FT	30.42	RAISED DECK HT, FT	0.00
DEPTH STA 10, FT	26.00	RAISED DECK FWD LIM, STA	
DEPTH STA 20, FT	26.76	RAISED DECK AFT LIM, STA	
FREEBOARD @ STA 3, FT	20.42	BARE HULL DISPL, LTON	2992.55
STABILITY BEAM, FT	39.33	AREA BEAM, FT	38.00

BARE HULL DATA ON LWL	
LGTH ON WL, FT	379.98
BEAM, FT	40.60
DRAFT, FT	13.97
FREEBOARD @ STA 3, FT	20.45
PRISMATIC COEF	0.580
MAX SECTION COEF	0.834
WATERPLANE COEF	0.741
WATERPLANE AREA, FT2	11431.11
WETTED SURFACE, FT2	16220.88
BARE HULL DISPL, LTON	2983.02
APPENDAGE DISPL, LTON	61.29
FULL LOAD WT, LTON	3044.31

STABILITY DATA ON LWL	
KB, FT	8.44
BMT, FT	11.01
KG, FT	15.60
FREE SURF COR, FT	0.00
SERV LIFE KG ALW, FT	0.00
GMT, FT	3.85
GML, FT	880.11
GMT/B AVAIL	0.095
GMT/B REQ	0.080

ASSET/MONOSC V5.3.0 - HULL GEOM MODULE - 1/ 8/2010 13:19.35
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 2 - HULL OFFSETS

STATION NO. 1, AT X = -16.282 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	0.000	34.393
2	0.121	34.410
3	0.172	34.428
4	0.248	34.445
5	0.344	34.462
6	0.453	34.479
7	0.569	34.496
8	0.686	34.514
9	0.797	34.531
10	0.896	34.548
11	0.977	34.565
12	1.035	34.582
13	1.061	34.600

STATION NO. 2, AT X = -8.141 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	0.000	23.937
2	0.219	24.782
3	0.468	25.626
4	0.829	26.471
5	1.283	27.316
6	1.812	28.161
7	2.394	29.006
8	3.011	29.850
9	3.643	30.695
10	4.271	31.540
11	4.876	32.385
12	5.437	33.230
13	5.935	34.074

STATION NO. 3, AT X = 0.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	0.102	14.000
2	0.256	15.630
3	0.540	17.261
4	0.940	18.891
5	1.445	20.521
6	2.042	22.152

7	2.718	23.782
8	3.461	25.412
9	4.259	27.043
10	5.099	28.673
11	5.968	30.304
12	6.855	31.934
13	7.746	33.564

STATION NO. 4, AT X = 9.500 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	0.000	5.542
2	0.031	6.147
3	0.083	6.751
4	0.160	7.355
5	0.255	7.959
6	0.362	8.563
7	0.475	9.167
8	0.592	9.771
9	0.709	10.375
10	0.823	10.979
11	0.932	11.584
12	1.036	12.188
13	1.132	12.792
14	1.220	13.396
15	1.299	14.000
16	1.551	15.582
17	1.913	17.165
18	2.377	18.747
19	2.931	20.329
20	3.567	21.912
21	4.275	23.494
22	5.046	25.077
23	5.869	26.659
24	6.736	28.241
25	7.636	29.824
26	8.560	31.406
27	9.499	32.988

STATION NO. 5, AT X = 19.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	0.000	1.558
2	0.097	2.447
3	0.181	3.336
4	0.314	4.224
5	0.485	5.113
6	0.683	6.002
7	0.898	6.890
8	1.122	7.779
9	1.349	8.668
10	1.574	9.557
11	1.792	10.445
12	2.002	11.334
13	2.199	12.223
14	2.383	13.111
15	2.550	14.000
16	2.875	15.536
17	3.296	17.072
18	3.805	18.608
19	4.394	20.144
20	5.057	21.681
21	5.784	23.217
22	6.569	24.753

23	7.404	26.289
24	8.281	27.825
25	9.192	29.361
26	10.130	30.897
27	11.088	32.433

STATION NO. 6, AT X = 38.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	0.248	0.000
2	0.869	1.000
3	1.244	2.000
4	1.604	3.000
5	1.964	4.000
6	2.324	5.000
7	2.682	6.000
8	3.035	7.000
9	3.381	8.000
10	3.716	9.000
11	4.040	10.000
12	4.351	11.000
13	4.647	12.000
14	4.926	13.000
15	5.189	14.000
16	5.598	15.449
17	6.082	16.898
18	6.635	18.346
19	7.254	19.795
20	7.930	21.244
21	8.659	22.693
22	9.434	24.142
23	10.250	25.590
24	11.101	27.039
25	11.981	28.488
26	12.885	29.937
27	13.806	31.385

STATION NO. 7, AT X = 57.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	0.865	0.000
2	2.147	1.000
3	2.958	2.000
4	3.625	3.000
5	4.201	4.000
6	4.712	5.000
7	5.173	6.000
8	5.595	7.000
9	5.985	8.000
10	6.350	9.000
11	6.694	10.000
12	7.020	11.000
13	7.332	12.000
14	7.632	13.000
15	7.921	14.000
16	8.345	15.368
17	8.832	16.737
18	9.378	18.105
19	9.976	19.474
20	10.620	20.842
21	11.306	22.210
22	12.026	23.579
23	12.777	24.947
24	13.551	26.316

25	14.343	27.684
26	15.148	29.053
27	15.959	30.421

STATION NO. 8, AT X = 76.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000
2	3.250	1.000
3	4.673	2.000
4	5.760	3.000
5	6.620	4.000
6	7.313	5.000
7	7.885	6.000
8	8.364	7.000
9	8.775	8.000
10	9.137	9.000
11	9.463	10.000
12	9.765	11.000
13	10.051	12.000
14	10.330	13.000
15	10.608	14.000
16	10.999	15.295
17	11.445	16.590
18	11.940	17.885
19	12.478	19.180
20	13.054	20.475
21	13.660	21.770
22	14.292	23.065
23	14.942	24.360
24	15.605	25.655
25	16.275	26.950
26	16.945	28.245
27	17.609	29.540

STATION NO. 9, AT X = 95.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000
2	4.323	1.000
3	6.343	2.000
4	7.832	3.000
5	8.959	4.000
6	9.827	5.000
7	10.502	6.000
8	11.035	7.000
9	11.464	8.000
10	11.817	9.000
11	12.117	10.000
12	12.383	11.000
13	12.630	12.000
14	12.869	13.000
15	13.110	14.000
16	13.438	15.228
17	13.813	16.457
18	14.230	17.685
19	14.683	18.914
20	15.164	20.142
21	15.668	21.371
22	16.189	22.599
23	16.719	23.828
24	17.253	25.056
25	17.785	26.285
26	18.308	27.513

27	18.816	28.742

STATION NO. 10, AT X = 114.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000
2	5.461	1.000
3	7.969	2.000
4	9.768	3.000
5	11.101	4.000
6	12.100	5.000
7	12.855	6.000
8	13.430	7.000
9	13.872	8.000
10	14.216	9.000
11	14.493	10.000
12	14.724	11.000
13	14.929	12.000
14	15.120	13.000
15	15.312	14.000
16	15.563	15.169
17	15.854	16.338
18	16.179	17.507
19	16.532	18.676
20	16.907	19.844
21	17.298	21.013
22	17.699	22.182
23	18.103	23.351
24	18.506	24.520
25	18.899	25.689
26	19.279	26.858
27	19.638	28.027

STATION NO. 11, AT X = 133.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000
2	6.667	1.000
3	9.524	2.000
4	11.518	3.000
5	12.971	4.000
6	14.046	5.000
7	14.847	6.000
8	15.445	7.000
9	15.892	8.000
10	16.228	9.000
11	16.485	10.000
12	16.686	11.000
13	16.851	12.000
14	16.996	13.000
15	17.135	14.000
16	17.308	15.116
17	17.513	16.233
18	17.744	17.349
19	17.997	18.465
20	18.265	19.581
21	18.544	20.698
22	18.828	21.814
23	19.112	22.930
24	19.390	24.046
25	19.657	25.163
26	19.908	26.279
27	20.136	27.395

STATION NO. 12, AT X = 152.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000
2	7.791	1.000
3	10.884	2.000
4	12.986	3.000
5	14.498	4.000
6	15.607	5.000
7	16.426	6.000
8	17.031	7.000
9	17.476	8.000
10	17.803	9.000
11	18.041	10.000
12	18.216	11.000
13	18.348	12.000
14	18.451	13.000
15	18.540	14.000
16	18.644	15.071
17	18.771	16.141
18	18.917	17.212
19	19.077	18.282
20	19.247	19.353
21	19.424	20.423
22	19.602	21.494
23	19.778	22.565
24	19.947	23.635
25	20.105	24.706
26	20.248	25.776
27	20.371	26.847

STATION NO. 13, AT X = 171.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000
2	8.510	1.000
3	11.806	2.000
4	14.018	3.000
5	15.595	4.000
6	16.742	5.000
7	17.581	6.000
8	18.192	7.000
9	18.633	8.000
10	18.946	9.000
11	19.164	10.000
12	19.313	11.000
13	19.413	12.000
14	19.480	13.000
15	19.528	14.000
16	19.579	15.032
17	19.643	16.064
18	19.717	17.095
19	19.799	18.127
20	19.886	19.159
21	19.975	20.191
22	20.064	21.223
23	20.150	22.255
24	20.231	23.286
25	20.303	24.318
26	20.363	25.350
27	20.411	26.382

STATION NO. 14, AT X = 190.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000

2	8.702	1.000
3	12.147	2.000
4	14.471	3.000
5	16.129	4.000
6	17.334	5.000
7	18.212	6.000
8	18.847	7.000
9	19.300	8.000
10	19.617	9.000
11	19.831	10.000
12	19.969	11.000
13	20.054	12.000
14	20.102	13.000
15	20.128	14.000
16	20.149	15.000
17	20.175	16.000
18	20.203	17.000
19	20.233	18.000
20	20.263	19.000
21	20.294	20.000
22	20.322	21.000
23	20.349	22.000
24	20.372	23.000
25	20.391	24.000
26	20.404	25.000
27	20.411	26.000

STATION NO. 15, AT X = 209.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.000
2	8.575	1.000
3	11.949	2.000
4	14.252	3.000
5	15.926	4.000
6	17.171	5.000
7	18.105	6.000
8	18.803	7.000
9	19.322	8.000
10	19.702	9.000
11	19.973	10.000
12	20.159	11.000
13	20.281	12.000
14	20.353	13.000
15	20.389	14.000
16	20.406	14.975
17	20.419	15.950
18	20.426	16.925
19	20.430	17.900
20	20.431	18.876
21	20.430	19.851
22	20.427	20.826
23	20.422	21.801
24	20.418	22.776
25	20.414	23.751
26	20.411	24.726
27	20.411	25.701

STATION NO. 16, AT X = 228.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.165
2	7.639	1.153
3	11.056	2.141

4	13.490	3.129
5	15.301	4.118
6	16.670	5.106
7	17.708	6.094
8	18.495	7.082
9	19.085	8.071
10	19.522	9.059
11	19.840	10.047
12	20.064	11.035
13	20.215	12.024
14	20.311	13.012
15	20.365	14.000
16	20.396	14.957
17	20.418	15.914
18	20.432	16.872
19	20.439	17.829
20	20.441	18.786
21	20.439	19.743
22	20.434	20.700
23	20.427	21.657
24	20.420	22.615
25	20.414	23.572
26	20.411	24.529
27	20.411	25.486

STATION NO. 17, AT X = 247.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	0.704
2	6.541	1.654
3	10.029	2.604
4	12.616	3.553
5	14.572	4.503
6	16.059	5.453
7	17.188	6.402
8	18.041	7.352
9	18.679	8.302
10	19.151	9.252
11	19.494	10.201
12	19.739	11.151
13	19.909	12.101
14	20.025	13.050
15	20.103	14.000
16	20.162	14.946
17	20.212	15.892
18	20.255	16.838
19	20.290	17.785
20	20.320	18.731
21	20.344	19.677
22	20.362	20.623
23	20.377	21.569
24	20.389	22.515
25	20.398	23.462
26	20.405	24.408
27	20.411	25.354

STATION NO. 18, AT X = 266.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	1.661
2	5.782	2.542
3	9.164	3.424
4	11.739	4.305
5	13.716	5.186

6	15.239	6.068
7	16.409	6.949
8	17.305	7.830
9	17.987	8.712
10	18.501	9.593
11	18.885	10.475
12	19.168	11.356
13	19.375	12.237
14	19.525	13.119
15	19.634	14.000
16	19.733	14.942
17	19.827	15.884
18	19.917	16.826
19	20.002	17.768
20	20.081	18.710
21	20.153	19.653
22	20.217	20.595
23	20.274	21.537
24	20.321	22.479
25	20.359	23.421
26	20.386	24.363
27	20.402	25.305

STATION NO. 19, AT X = 285.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	3.030
2	5.194	3.814
3	8.371	4.597
4	10.838	5.381
5	12.765	6.164
6	14.272	6.948
7	15.451	7.732
8	16.372	8.515
9	17.089	9.299
10	17.644	10.082
11	18.071	10.866
12	18.396	11.649
13	18.643	12.433
14	18.829	13.216
15	18.968	14.000
16	19.114	14.945
17	19.258	15.890
18	19.400	16.835
19	19.537	17.780
20	19.667	18.725
21	19.789	19.670
22	19.899	20.615
23	19.997	21.560
24	20.081	22.505
25	20.147	23.450
26	20.196	24.395
27	20.224	25.339

STATION NO. 20, AT X = 304.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	4.756
2	4.672	5.416
3	7.585	6.076
4	9.892	6.737
5	11.725	7.397
6	13.187	8.057
7	14.353	8.717

8	15.283	9.378
9	16.024	10.038
10	16.612	10.698
11	17.076	11.359
12	17.438	12.019
13	17.719	12.679
14	17.933	13.340
15	18.094	14.000
16	18.293	14.955
17	18.491	15.910
18	18.685	16.864
19	18.873	17.819
20	19.051	18.774
21	19.218	19.729
22	19.371	20.683
23	19.506	21.638
24	19.622	22.593
25	19.715	23.548
26	19.783	24.502
27	19.823	25.457

STATION NO. 21, AT X = 323.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	6.732
2	4.168	7.251
3	6.775	7.771
4	8.883	8.290
5	10.593	8.809
6	11.986	9.328
7	13.121	9.847
8	14.047	10.366
9	14.800	10.885
10	15.410	11.404
11	15.901	11.924
12	16.290	12.443
13	16.593	12.962
14	16.823	13.481
15	16.991	14.000
16	17.250	14.971
17	17.506	15.943
18	17.756	16.914
19	17.997	17.886
20	18.226	18.857
21	18.439	19.829
22	18.634	20.800
23	18.807	21.772
24	18.955	22.743
25	19.075	23.715
26	19.164	24.686
27	19.218	25.658

STATION NO. 22, AT X = 342.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	8.825
2	3.664	9.195
3	5.930	9.565
4	7.809	9.934
5	9.372	10.304
6	10.675	10.673
7	11.762	11.043
8	12.669	11.413
9	13.421	11.782

10	14.041	12.152
11	14.546	12.522
12	14.948	12.891
13	15.260	13.261
14	15.490	13.630
15	15.647	14.000
16	15.972	14.995
17	16.293	15.990
18	16.605	16.986
19	16.905	17.981
20	17.189	18.976
21	17.453	19.971
22	17.694	20.966
23	17.908	21.961
24	18.092	22.957
25	18.242	23.952
26	18.354	24.947
27	18.425	25.942

STATION NO. 23, AT X = 361.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	10.899
2	3.162	11.121
3	5.065	11.342
4	6.694	11.564
5	8.090	11.785
6	9.287	12.007
7	10.311	12.228
8	11.184	12.450
9	11.922	12.671
10	12.539	12.893
11	13.043	13.114
12	13.445	13.336
13	13.750	13.557
14	13.965	13.779
15	14.093	14.000
16	14.492	15.026
17	14.882	16.052
18	15.260	17.077
19	15.622	18.103
20	15.964	19.129
21	16.282	20.155
22	16.571	21.180
23	16.829	22.206
24	17.050	23.232
25	17.232	24.258
26	17.370	25.284
27	17.460	26.309

STATION NO. 24, AT X = 370.500 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	11.899
2	2.918	12.049
3	4.637	12.199
4	6.138	12.349
5	7.447	12.499
6	8.587	12.649
7	9.577	12.799
8	10.429	12.949
9	11.156	13.099
10	11.767	13.249
11	12.267	13.400

12	12.663	13.550
13	12.960	13.700
14	13.162	13.850
15	13.271	14.000
16	13.707	15.044
17	14.133	16.087
18	14.543	17.131
19	14.934	18.175
20	15.303	19.218
21	15.645	20.262
22	15.957	21.306
23	16.233	22.350
24	16.472	23.393
25	16.668	24.437
26	16.819	25.481
27	16.919	26.524

STATION NO. 25, AT X = 380.000 FT

POINT	HALF BEAM,FT	WATERLINE,FT
1	1.000	12.872
2	2.690	12.952
3	4.227	13.033
4	5.600	13.113
5	6.822	13.194
6	7.905	13.275
7	8.859	13.355
8	9.691	13.436
9	10.406	13.516
10	11.009	13.597
11	11.504	13.678
12	11.893	13.758
13	12.179	13.839
14	12.365	13.919
15	12.450	14.000
16	12.925	15.063
17	13.384	16.127
18	13.824	17.190
19	14.240	18.253
20	14.631	19.317
21	14.992	20.380
22	15.320	21.443
23	15.611	22.507
24	15.862	23.570
25	16.070	24.633
26	16.231	25.697
27	16.341	26.760

ASSET/MONOSC V5.3.0 - HULL GEOM MODULE - 1/ 8/2010 13:19.35
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 3 - HULL BOUNDARY CONDITIONS

HULL OFFSETS IND-GENERATE
HULL BC IND-CONV DD   HULL STA IND-GIVEN

LBP, FT	380.00	LCB/LBP	0.515
BEAM, FT	40.60	LCF/LBP	0.569
DRAFT, FT	14.00	HALF SIDING WIDTH, FT	1.00
DEPTH STA 0, FT	33.60	BOT RAKE, FT	0.00
DEPTH STA 3, FT	30.42	FWD RAISED DECK LIMIT	
DEPTH STA 10, FT	26.00	AFT RAISED DECK LIMIT	

DEPTH STA 20, FT	26.76	RAISED DECK HT, FT	0.00
PRISMATIC COEF	0.580	WATERPLANE COEF	0.737
MAX SECTION COEF	0.836		

NO POINTS BELOW DWL	15.	FWD KEEL/BL LIMIT	0.087
NO POINTS ABOVE DWL	12.	AFT KEEL/BL LIMIT	0.550
POINT DIST FAC ABOVE DWL	1.000	BOW ANGLE, DEG	50.00
POINT DIST FAC BELOW DWL	1.000	BOW SHAPE FAC	0.000
BOW OVERHANG	0.043	STA 20 SECTION COEF	0.700
STERN OVERHANG	0.007	HULL FLARE ANGLE, DEG	

SECTIONAL AREA AND DWL CURVES

	AREA	DWL
STA 0 ORDINATE	0.000	0.005
STA 0 SLOPE	-0.206	-1.146
STA 20 ORDINATE	0.041	0.610
STA 20 SLOPE	0.767	0.790
PARALLEL MID LGTH	0.000	0.000
STA MAX ORDINATE	10.500	11.400
STA MAX AREA SLOPE	0.000	0.000
TENSOR NO 1	0.000	0.000
TENSOR NO 2	0.000	0.000
TENSOR NO 3	0.000	0.000
TENSOR NO 4	0.000	0.000
TENSOR/POLY SWITCH	-1.000	-1.000

DECK AT EDGE CURVE		FLAT OF BOTTOM CURVE	
STATION 0 OFFSET	0.380	STA OF TRANS START	10.000
STA 0 SLOPE	-1.800	SLOPE-STA OF TRANS START	0.000
STA 10 OFFSET	1.000	STA OF START OF MID	10.000
STA 10 SLOPE	0.000	STA OF END OF MID	10.000
STATION 20 OFFSET	0.801	STA OF TRANS END	10.000
STA 20 SLOPE	0.584	SLOPE-STA OF TRANS END	0.000
PARALLEL MID LGTH	0.254	FLAT OF BOT ANGLE, DEG	0.050
STA OF PARALLEL MID	11.205	ELLIPSE RATIO	1.000

SLOPES AT SECTION CURVES

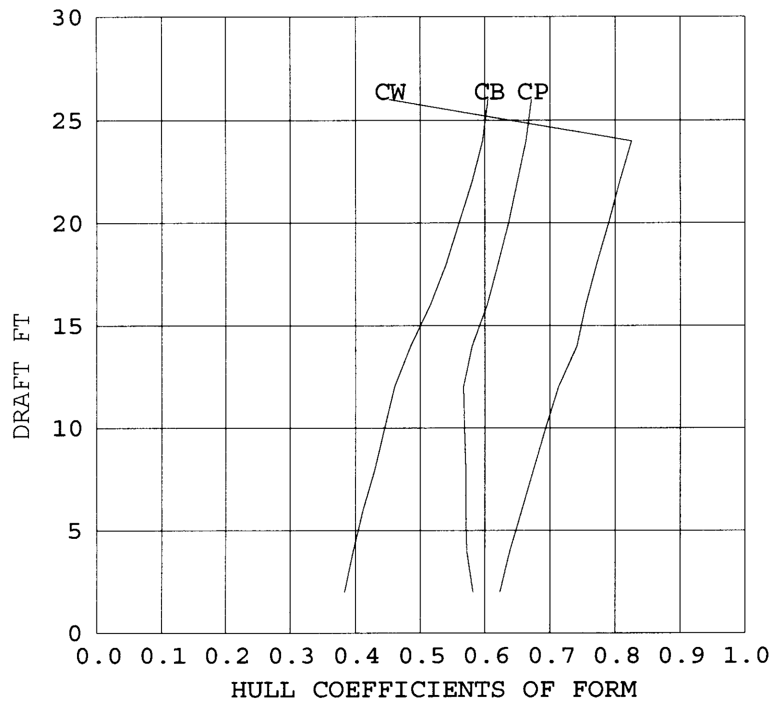
	BOT	DWL	DAE
STA 0 ORDINATE, DEG	36.750	87.000	61.389
STA 0 SLOPE	104.161	88.097	52.185
STA 10 ORDINATE, DEG	1.570	89.000	90.000
STA 10 SLOPE	-0.500	0.000	0.000
STA 20 ORDINATE, DEG	3.000	65.641	85.497
STA 20 SLOPE	60.000	28.462	9.359
PARALLEL MID LGTH	0.060	0.000	0.000
STA OF PARALLEL MID	10.500	10.335	10.369

ASSET/MONOSC V5.3.0 - HULL GEOM MODULE - 1/ 8/2010 13:19.35
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - HULL SECTIONAL AREA CURVE

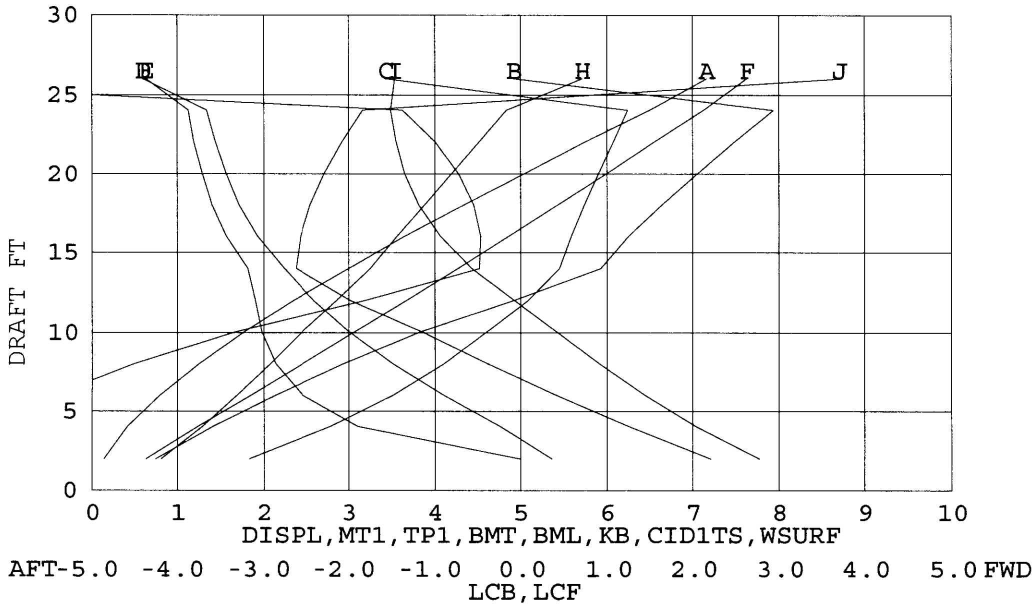
STATION	LOCATION, FT	AREA, FT2
1	-16.28	0.00
2	-8.14	0.00
3	0.00	0.00
4	9.50	10.22
5	19.00	29.06
6	38.00	83.10
7	57.00	147.86
8	76.00	214.81
9	95.00	278.99
10	114.00	337.35
11	133.00	387.75
12	152.00	428.29
13	171.00	457.14
14	190.00	472.42
15	209.00	472.38
16	228.00	456.26
17	247.00	423.90
18	266.00	376.48
19	285.00	317.04
20	304.00	250.10
21	323.00	181.34
22	342.00	116.90
23	361.00	62.10
24	370.50	39.33
25	380.00	19.67

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:21.50
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 1 - HULL COEFFICIENTS OF FORM



TRIM(+VE BY STERN), FT 0.00 APPENDAGE IND-WITHOUT

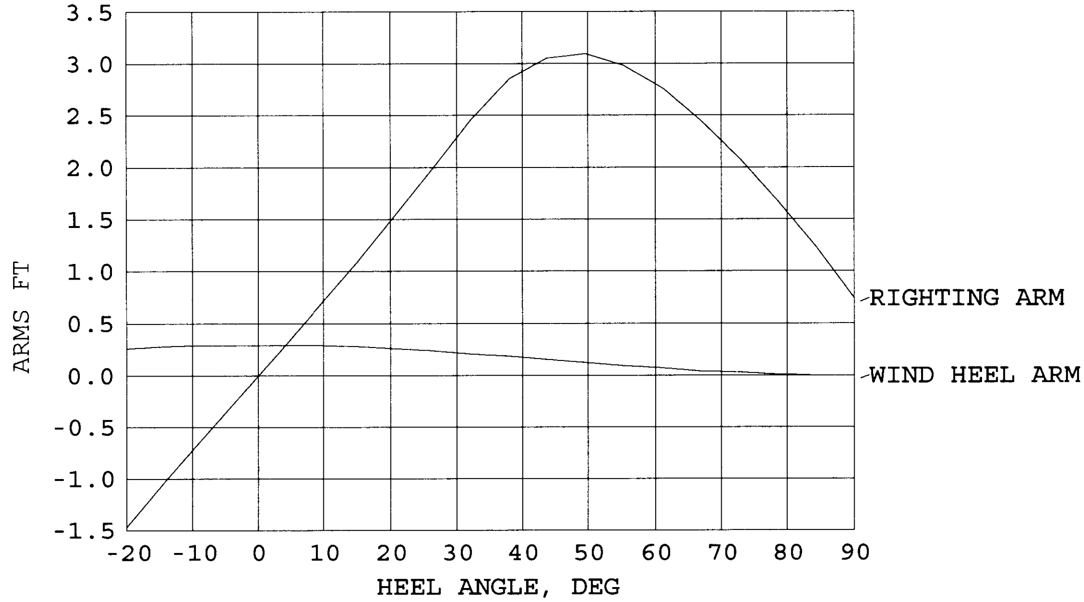
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:21.50
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 2 - HYDROSTATIC VARIABLES OF FORM



A DISPL (1000 LTON)/UNIT	F KB (2 FT)/UNIT
B MT1 (100 FT-LTON/IN)/UNIT	G CID1TS (5 LTON/FT)/UNIT
C TP1 (5 LTON/IN)/UNIT	H WSURF (5000 FT2)/UNIT
D BMT (5 FT)/UNIT	I LCB (10 FT)/UNIT
E BML (500 FT)/UNIT	J LCF (10 FT)/UNIT

TRIM(+VE BY STERN), FT 0.00 APPENDAGE IND-WITHOUT

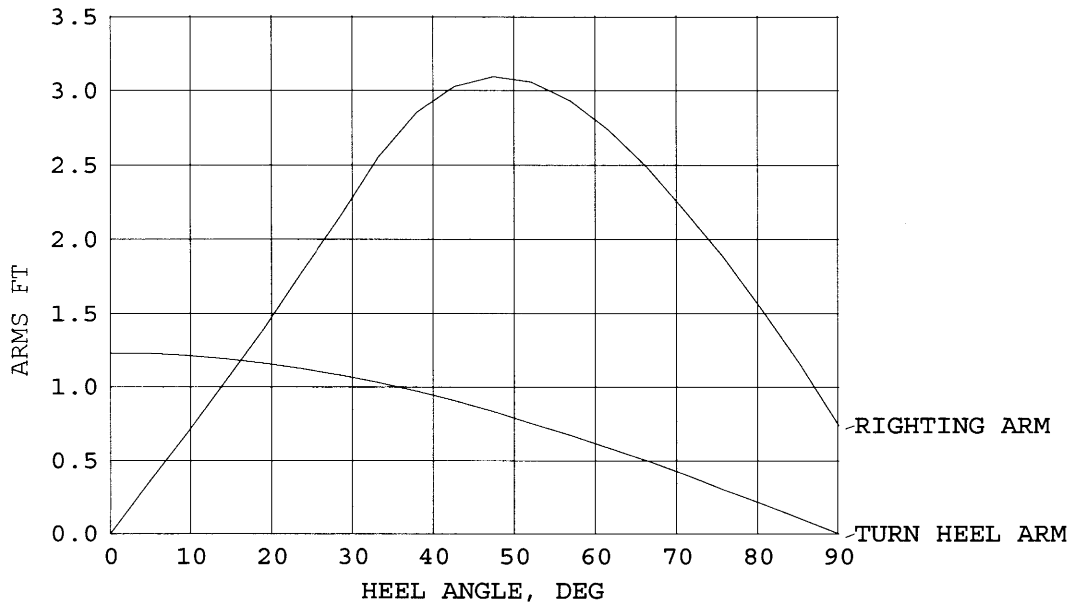
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:34.47
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 4 - INTACT STATIC STABILITY WITH WIND HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	2991.50	LCG LOC(+VE FWD MID), FT	-5.72
KG, FT	15.60	WIND SPEED, KT	100.00
APPENDAGE IND-WITHOUT			

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:34.47
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - INTACT STATIC STABILITY WITH TURN HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	2991.50	LCG LOC(+VE FWD MID), FT	-5.72
KG, FT	15.60	TURN SPEED, KT	35.00
APPENDAGE IND-WITHOUT		TURN RADIUS, FT	760.00

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:22.43
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - SUMMARY

APPENDAGE IND-WITHOUT
HYSTAT IND-WT TRIM
COMP DEF IND-

DISPLACEMENT, LTON	2991.5	MAX AREA STA LOC FM FP,FT	199.44
LCG LOC(+VE FWD MID), FT	-5.72	AREA AT MAX AREA STA, FT2	474.3
MIDSHIP DRAFT, FT	14.00	BEAM AT MAX AREA STA, FT	40.60
TRIM(+ BY STERN), FT	0.00	DRAFT AT MAX AREA STA, FT	14.00
KG, FT	15.60	BLOCK COEF	0.484
SHIP LBP, FT	380.00	PRISMATIC COEF	0.581
METACENTRIC HT(GM), FT	4.15	SECTIONAL AREA COEF	0.834
WATERPLANE AREA,FT2	11434.7	WATERLINE LENGTH, FT	380.00
WETTED SURF AREA, FT2	16241.0		

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:22.43
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 2 - HYDROSTATIC VARIABLES OF FORM

DRAFT FT	TOTAL VOLUME FT3	APPDG VOLUME FT3	TOTAL DISPL LTON	LCB FT	KB FT	LCF FT
2.00	4716.	0.	134.8	27.72	1.25	22.08
4.00	14492.	0.	414.3	20.36	2.48	12.52
6.00	27760.	0.	793.7	14.46	3.70	4.06
8.00	43774.	0.	1251.5	9.15	4.92	-3.80
10.00	62075.	0.	1774.7	4.15	6.13	-11.58
12.00	82407.	0.	2356.1	-0.78	7.33	-19.90
14.00	104633.	0.	2991.5	-5.72	8.54	-26.27
16.00	127788.	0.	3653.5	-9.40	9.71	-25.68
18.00	151557.	0.	4333.1	-11.87	10.85	-24.54
20.00	175993.	0.	5031.7	-13.52	11.99	-22.92
22.00	201120.	0.	5750.1	-14.57	13.11	-20.86
24.00	226938.	0.	6488.2	-15.15	14.24	-18.42
26.00	250524.	0.	7162.6	-14.63	15.24	37.10

	-------------HULL	ONLY-------------				
DRAFT FT	WETTED SURFACE FT2	BLOCK COEFF -	PRISMATIC COEFF -	WPLANE COEFF -	WPLANE AREA FT2	TP1 LTON/IN
2.00	4039.1	0.383	0.582	0.623	3838.0	9.14
4.00	6404.6	0.396	0.572	0.638	5836.5	13.91
6.00	8453.8	0.412	0.570	0.657	7367.7	17.55
8.00	10377.6	0.430	0.570	0.676	8605.7	20.50
10.00	12295.2	0.446	0.569	0.694	9667.7	23.03
12.00	14295.1	0.459	0.567	0.713	10654.5	25.38
14.00	16241.0	0.484	0.581	0.741	11434.7	27.24
16.00	17802.5	0.515	0.603	0.755	11725.7	27.94
18.00	19378.7	0.539	0.621	0.772	12048.5	28.71
20.00	20968.4	0.561	0.636	0.789	12389.8	29.52
22.00	22570.0	0.580	0.650	0.807	12737.8	30.35
24.00	24181.9	0.597	0.663	0.825	13080.3	31.16
26.00	28523.2	0.606	0.672	0.452	7188.0	17.13

DRAFT FT	CID1TS LTON/FT	LONG BM FT	TRNSV BM FT	LONG KM FT	TRNSV KM FT	MT1 FT-LTON/IN
2.00	-6.38	2496.23	26.82	2497.48	28.07	73.8
4.00	-5.50	1546.11	23.79	1548.59	26.27	140.5
6.00	-2.25	1226.94	20.52	1230.64	24.23	213.5
8.00	2.46	1070.15	17.52	1075.07	22.43	293.7
10.00	8.43	986.73	14.97	992.86	21.09	384.0
12.00	15.95	952.30	12.91	959.64	20.24	492.0
14.00	22.60	903.55	11.21	912.09	19.75	592.8
16.00	22.65	780.26	9.64	789.97	19.35	625.1
18.00	22.24	697.57	8.57	708.42	19.42	662.9
20.00	21.36	638.42	7.78	650.40	19.76	704.5
22.00	19.99	593.68	7.16	606.80	20.27	748.6
24.00	18.12	557.99	6.66	572.23	20.89	793.9
26.00	-20.06	313.11	2.97	328.35	18.21	491.8

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:22.43
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - INTACT STATIC STABILITY

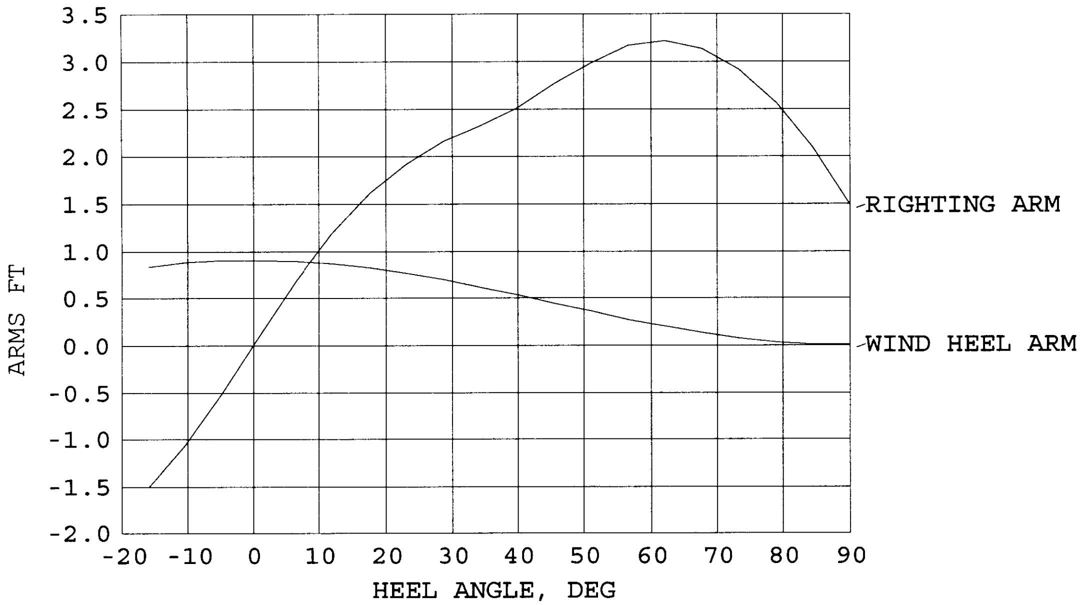
COMP DEF IND-

INTACT WIND SPEED, KT	100.00	LAT RESIST CENTER, FT	7.00
SAIL AREA, FT2	5250.7	TURN SPEED, KT	35.00
SAIL AREA FACTOR	1.25	TURN RADIUS, FT	760.00
SAIL AREA CTR ABV WL, FT	7.13	TURN HEEL ANGLE, DEG	16.15
WIND ARM RATIO	0.10	TURN ARM RATIO	0.38
WIND AREA RATIO	7.29	TURN AREA RATIO	0.66
WIND LEVER ARM, FT	0.30	TURN LEVER ARM, FT	1.23
WIND LIMITING KG, FT	19.32	TURN LIMITING KG, FT	15.24

TABLE OF INTACT RIGHTING ARMS(GZ), DRAFTS, AND TRIMS, FT

HEEL, DEG	0.00	5.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
GZ	0.00	0.36	0.72	1.47	2.27	2.95	3.09	2.81	2.25	1.56
TRIM	0.00	-0.03	-0.15	-0.71	-1.74	-3.12	-4.63	-6.41	-9.57	-18.35
DRAFT	14.00	13.99	13.95	13.76	13.27	12.38	11.16	9.34	6.03	-3.40

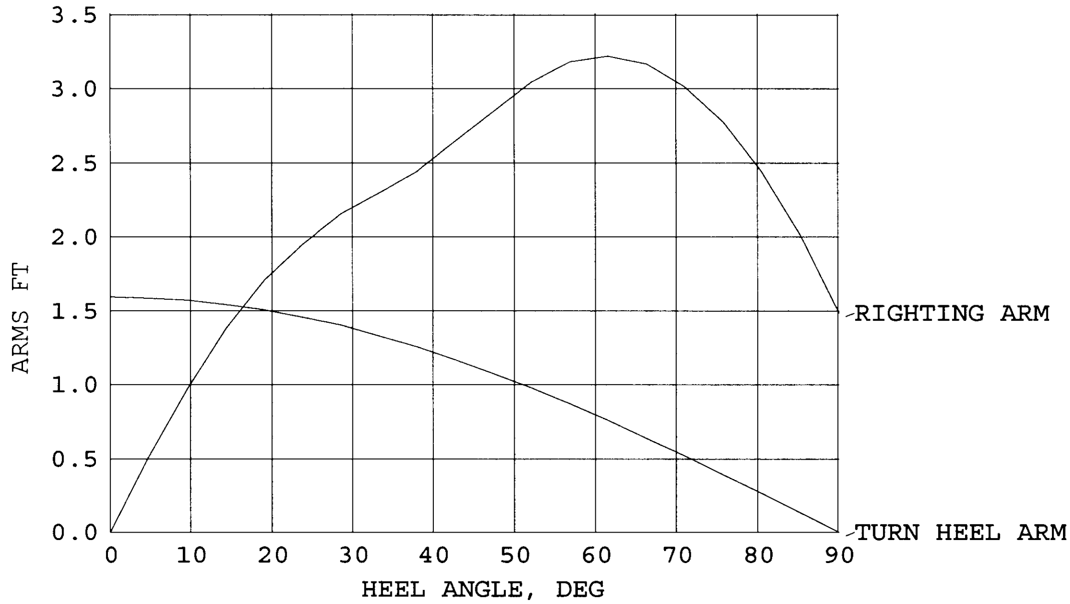
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:24. 7
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 4 - INTACT STATIC STABILITY WITH WIND HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	1491.50	LCG LOC(+VE FWD MID), FT	6.76
KG, FT	15.60	WIND SPEED, KT	100.00
APPENDAGE IND-WITHOUT			

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:33.13
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - INTACT STATIC STABILITY WITH TURN HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	1491.50	LCG LOC(+VE FWD MID), FT	6.76
KG, FT	15.60	TURN SPEED, KT	35.00
APPENDAGE IND-WITHOUT		TURN RADIUS, FT	760.00

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:24.28
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - SUMMARY

APPENDAGE IND-WITHOUT
HYSTAT IND-WT TRIM
COMP DEF IND-

DISPLACEMENT, LTON	1491.5	MAX AREA STA LOC FM FP,FT	195.92
LCG LOC(+VE FWD MID), FT	6.76	AREA AT MAX AREA STA, FT2	271.1
MIDSHIP DRAFT, FT	8.95	BEAM AT MAX AREA STA, FT	39.38
TRIM(+ BY STERN), FT	0.00	DRAFT AT MAX AREA STA, FT	8.95
KG, FT	15.60	BLOCK COEF	0.438
SHIP LBP, FT	380.00	PRISMATIC COEF	0.569
METACENTRIC HT(GM), FT	6.13	SECTIONAL AREA COEF	0.770
WATERPLANE AREA,FT2	9124.6	WATERLINE LENGTH, FT	338.14
WETTED SURF AREA, FT2	11280.8		

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:24.28
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - INTACT STATIC STABILITY

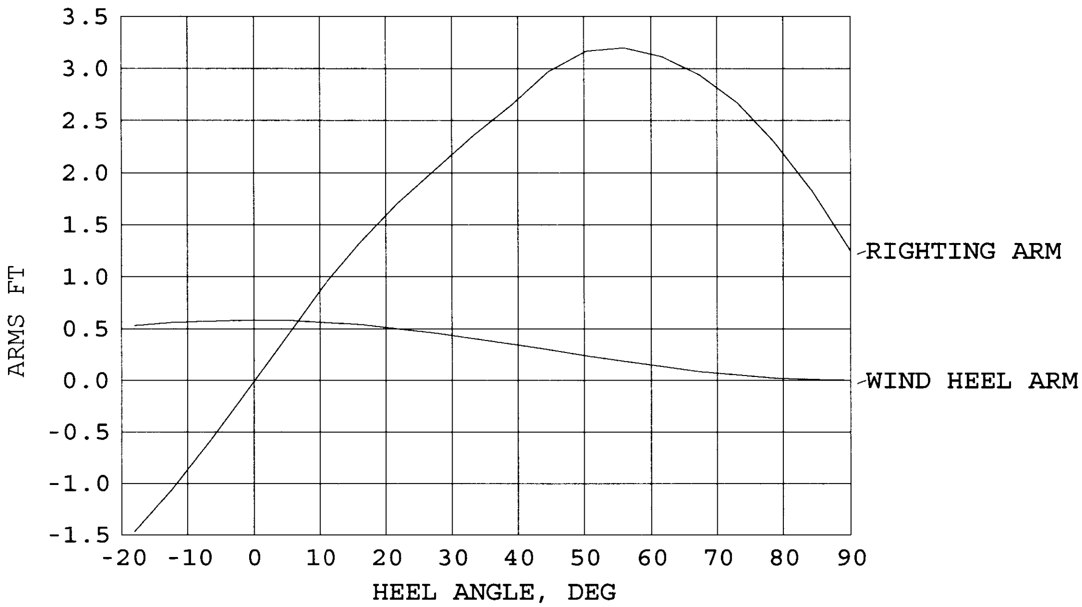
COMP DEF IND-

INTACT WIND SPEED, KT	100.00	LAT RESIST CENTER, FT	4.47
SAIL AREA, FT2	7108.1	TURN SPEED, KT	35.00
SAIL AREA FACTOR	1.25	TURN RADIUS, FT	760.00
SAIL AREA CTR ABV WL, FT	9.74	TURN HEEL ANGLE, DEG	16.23
WIND ARM RATIO	0.27	TURN ARM RATIO	0.47
WIND AREA RATIO	5.17	TURN AREA RATIO	0.61
WIND LEVER ARM, FT	0.90	TURN LEVER ARM, FT	1.59
WIND LIMITING KG, FT	17.70	TURN LIMITING KG, FT	15.22

TABLE OF INTACT RIGHTING ARMS(GZ), DRAFTS, AND TRIMS, FT

HEEL, DEG	0.00	5.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
GZ	0.00	0.53	1.02	1.77	2.21	2.51	2.95	3.21	3.06	2.48
TRIM	0.00	-0.11	-0.44	-1.70	-3.73	-6.58	-10.54	-16.50	-27.69	-56.81
DRAFT	8.95	8.91	8.81	8.37	7.48	5.91	3.12	-1.67	-10.99	-38.76

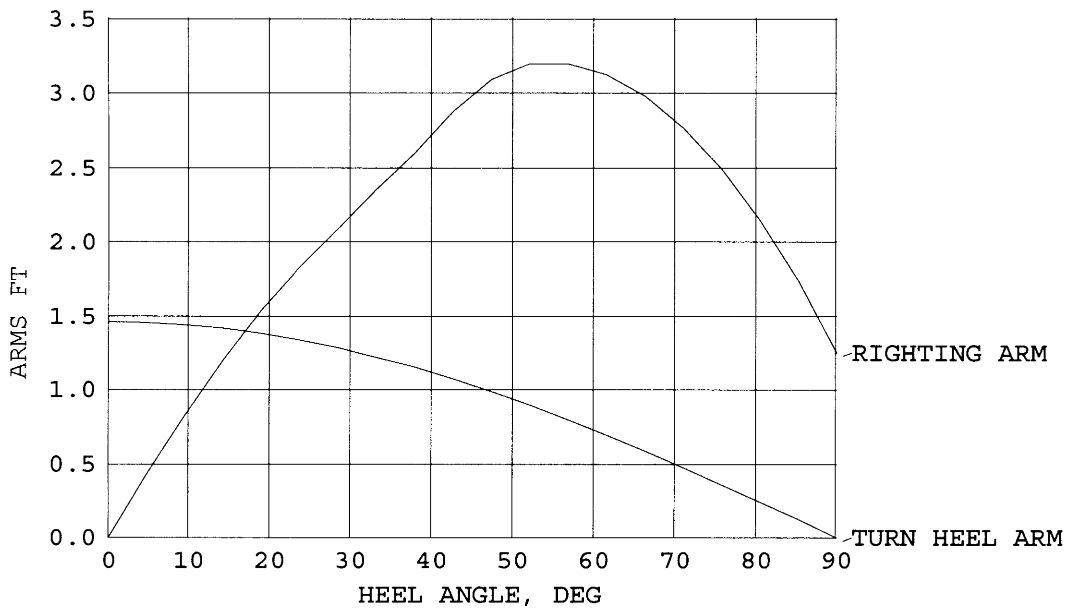
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:25.18
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 4 - INTACT STATIC STABILITY WITH WIND HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	1991.50	LCG LOC(+VE FWD MID), FT	2.24
KG, FT	15.60	WIND SPEED, KT	100.00
APPENDAGE IND-WITHOUT			

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:25.18
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - INTACT STATIC STABILITY WITH TURN HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	1991.50	LCG LOC(+VE FWD MID), FT	2.24
KG, FT	15.60	TURN SPEED, KT	35.00
APPENDAGE IND-WITHOUT		TURN RADIUS, FT	760.00

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:26. 1
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - SUMMARY

APPENDAGE IND-WITHOUT
HYSTAT IND-WT TRIM
COMP DEF IND-

DISPLACEMENT, LTON	1991.5	MAX AREA STA LOC FM FP,FT	197.19
LCG LOC(+VE FWD MID), FT	2.24	AREA AT MAX AREA STA, FT2	343.7
MIDSHIP DRAFT, FT	10.77	BEAM AT MAX AREA STA, FT	40.13
TRIM(+ BY STERN), FT	0.00	DRAFT AT MAX AREA STA, FT	10.77
KG, FT	15.60	BLOCK COEF	0.452
SHIP LBP, FT	380.00	PRISMATIC COEF	0.568
METACENTRIC HT(GM), FT	5.11	SECTIONAL AREA COEF	0.795
WATERPLANE AREA,FT2	10044.1	WATERLINE LENGTH, FT	356.72
WETTED SURF AREA, FT2	13043.2		

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:26. 1
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - INTACT STATIC STABILITY

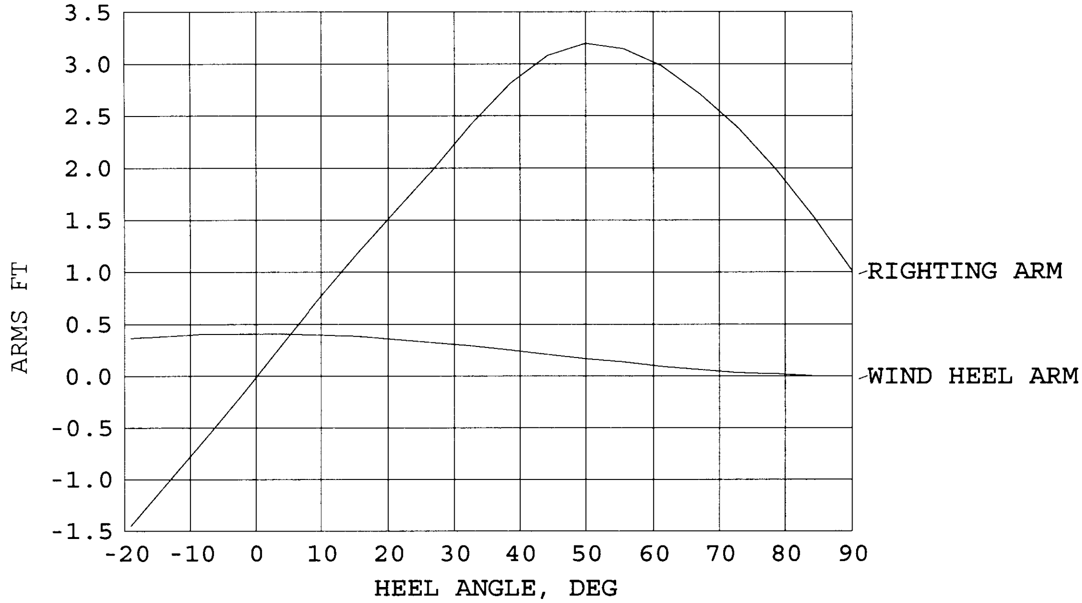
COMP DEF IND-

INTACT WIND SPEED, KT	100.00	LAT RESIST CENTER, FT	5.38
SAIL AREA, FT2	6437.1	TURN SPEED, KT	35.00
SAIL AREA FACTOR	1.25	TURN RADIUS, FT	760.00
SAIL AREA CTR ABV WL, FT	8.73	TURN HEEL ANGLE, DEG	16.90
WIND ARM RATIO	0.18	TURN ARM RATIO	0.44
WIND AREA RATIO	6.34	TURN AREA RATIO	0.63
WIND LEVER ARM, FT	0.58	TURN LEVER ARM, FT	1.46
WIND LIMITING KG, FT	18.59	TURN LIMITING KG, FT	15.02

TABLE OF INTACT RIGHTING ARMS(GZ), DRAFTS, AND TRIMS, FT

HEEL, DEG	0.00	5.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
GZ	0.00	0.44	0.87	1.61	2.18	2.70	3.17	3.15	2.82	2.18
TRIM	0.00	-0.09	-0.38	-1.48	-3.21	-5.61	-8.83	-13.80	-22.65	-47.29
DRAFT	10.77	10.75	10.68	10.34	9.63	8.28	5.93	2.14	-5.19	-26.58

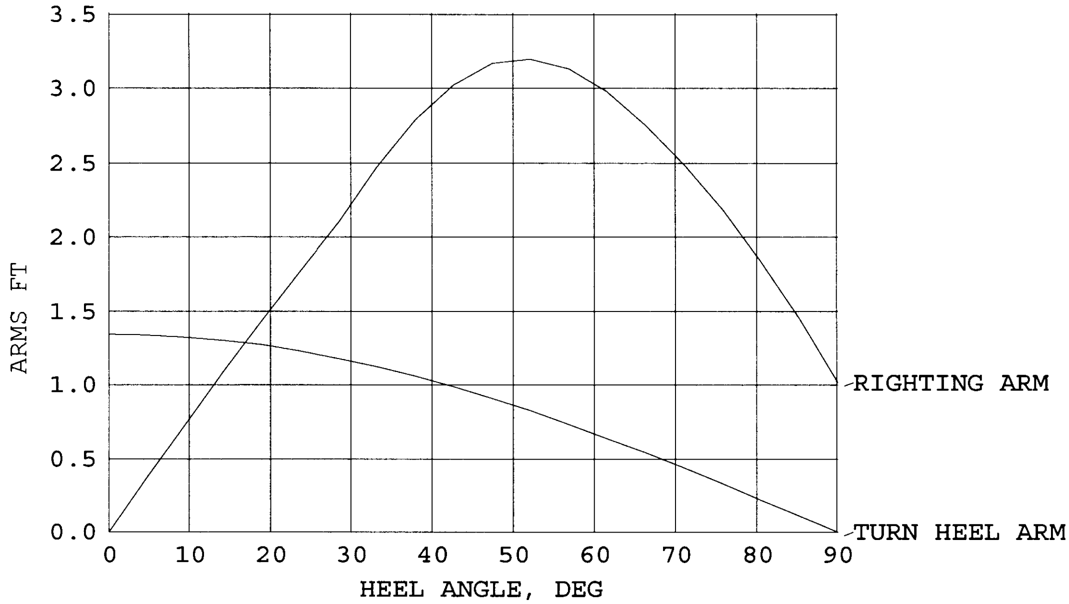
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:26.36
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 4 - INTACT STATIC STABILITY WITH WIND HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	2491.50	LCG LOC(+VE FWD MID), FT	-1.87
KG, FT	15.60	WIND SPEED, KT	100.00
APPENDAGE IND-WITHOUT			

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:26.36
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - INTACT STATIC STABILITY WITH TURN HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	2491.50	LCG LOC(+VE FWD MID), FT	-1.87
KG, FT	15.60	TURN SPEED, KT	35.00
APPENDAGE IND-WITHOUT		TURN RADIUS, FT	760.00

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:27. 1
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - SUMMARY

APPENDAGE IND-WITHOUT
HYSTAT IND-WT TRIM
COMP DEF IND-

DISPLACEMENT, LTON	2491.5	MAX AREA STA LOC FM FP,FT	198.38
LCG LOC(+VE FWD MID), FT	-1.87	AREA AT MAX AREA STA, FT2	411.1
MIDSHIP DRAFT, FT	12.44	BEAM AT MAX AREA STA, FT	40.46
TRIM(+ BY STERN), FT	0.00	DRAFT AT MAX AREA STA, FT	12.44
KG, FT	15.60	BLOCK COEF	0.463
SHIP LBP, FT	380.00	PRISMATIC COEF	0.566
METACENTRIC HT(GM), FT	4.52	SECTIONAL AREA COEF	0.817
WATERPLANE AREA,FT2	10872.9	WATERLINE LENGTH, FT	374.32
WETTED SURF AREA, FT2	14756.4		

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:27. 1
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - INTACT STATIC STABILITY

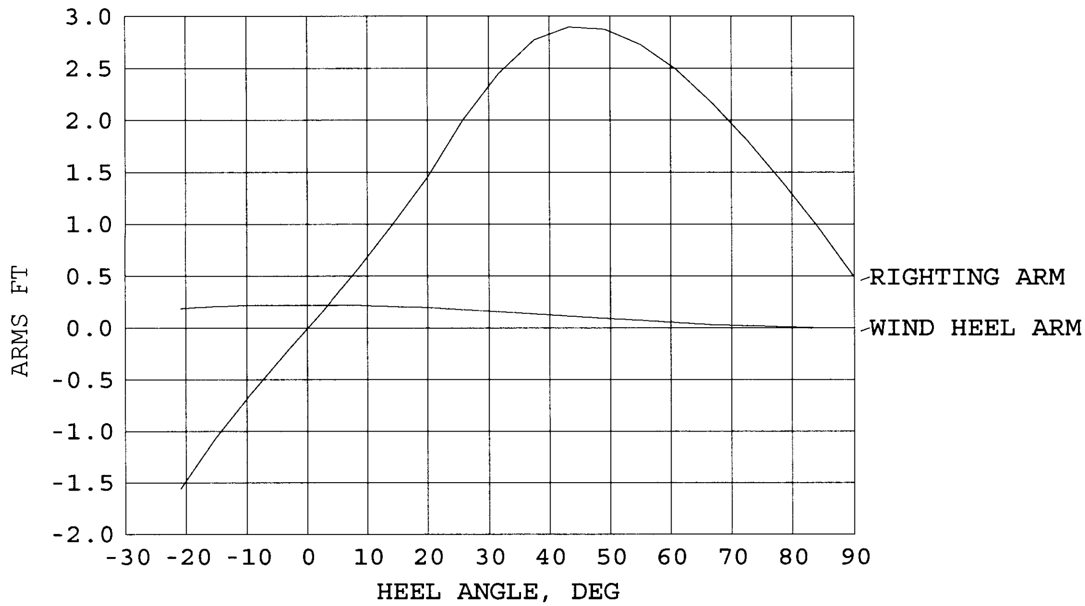
COMP DEF IND-

INTACT WIND SPEED, KT	100.00	LAT RESIST CENTER, FT	6.22
SAIL AREA, FT2	5859.0	TURN SPEED, KT	35.00
SAIL AREA FACTOR	1.25	TURN RADIUS, FT	760.00
SAIL AREA CTR ABV WL, FT	7.89	TURN HEEL ANGLE, DEG	16.75
WIND ARM RATIO	0.13	TURN ARM RATIO	0.40
WIND AREA RATIO	7.05	TURN AREA RATIO	0.65
WIND LEVER ARM, FT	0.41	TURN LEVER ARM, FT	1.34
WIND LIMITING KG, FT	19.19	TURN LIMITING KG, FT	15.06

TABLE OF INTACT RIGHTING ARMS(GZ), DRAFTS, AND TRIMS, FT

HEEL, DEG	0.00	5.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
GZ	0.00	0.39	0.78	1.52	2.21	2.90	3.20	3.04	2.55	1.87
TRIM	0.00	-0.09	-0.33	-1.20	-2.59	-4.52	-7.00	-10.46	-16.73	-34.17
DRAFT	12.44	12.42	12.37	12.12	11.54	10.38	8.57	5.74	0.44	-14.89

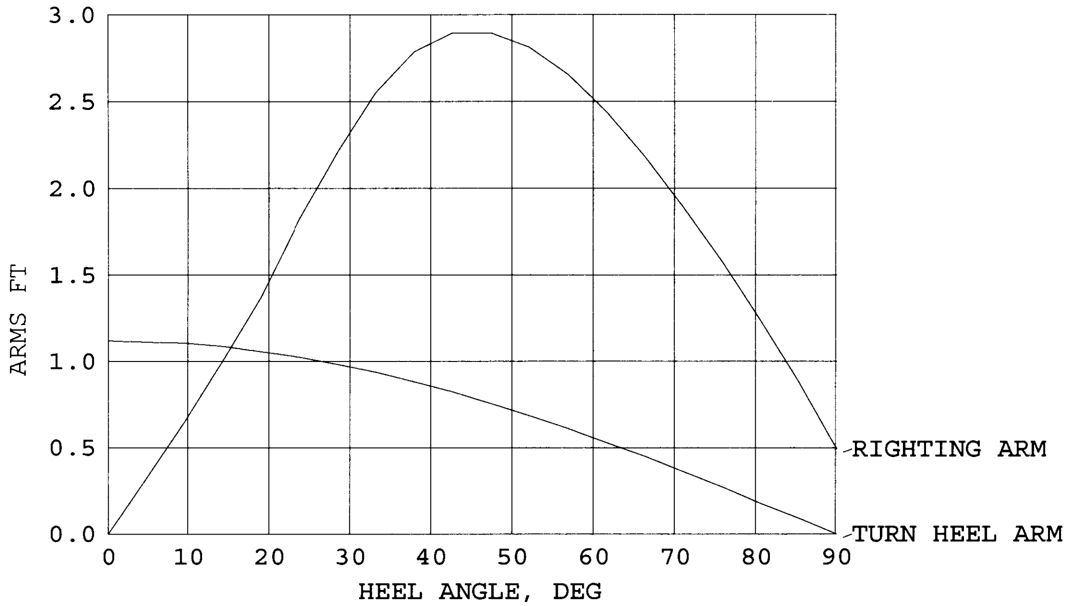
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:27.38
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 4 - INTACT STATIC STABILITY WITH WIND HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	3491.50	LCG LOC(+VE FWD MID), FT	-8.64
KG, FT	15.60	WIND SPEED, KT	100.00
APPENDAGE IND-WITHOUT			

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:27.38
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - INTACT STATIC STABILITY WITH TURN HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	3491.50	LCG LOC(+VE FWD MID), FT	-8.64
KG, FT	15.60	TURN SPEED, KT	35.00
APPENDAGE IND-WITHOUT		TURN RADIUS, FT	760.00

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:28. 6
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - SUMMARY

APPENDAGE IND-WITHOUT
HYSTAT IND-WT TRIM
COMP DEF IND-

DISPLACEMENT, LTON	3491.5	MAX AREA STA LOC FM FP,FT	200.36
LCG LOC(+VE FWD MID), FT	-8.64	AREA AT MAX AREA STA, FT2	535.9
MIDSHIP DRAFT, FT	15.52	BEAM AT MAX AREA STA, FT	40.67
TRIM(+ BY STERN), FT	0.00	DRAFT AT MAX AREA STA, FT	15.52
KG, FT	15.60	BLOCK COEF	0.508
SHIP LBP, FT	380.00	PRISMATIC COEF	0.598
METACENTRIC HT(GM), FT	3.80	SECTIONAL AREA COEF	0.849
WATERPLANE AREA,FT2	11651.7	WATERLINE LENGTH, FT	381.27
WETTED SURF AREA, FT2	17422.6		

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:28. 6
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - INTACT STATIC STABILITY

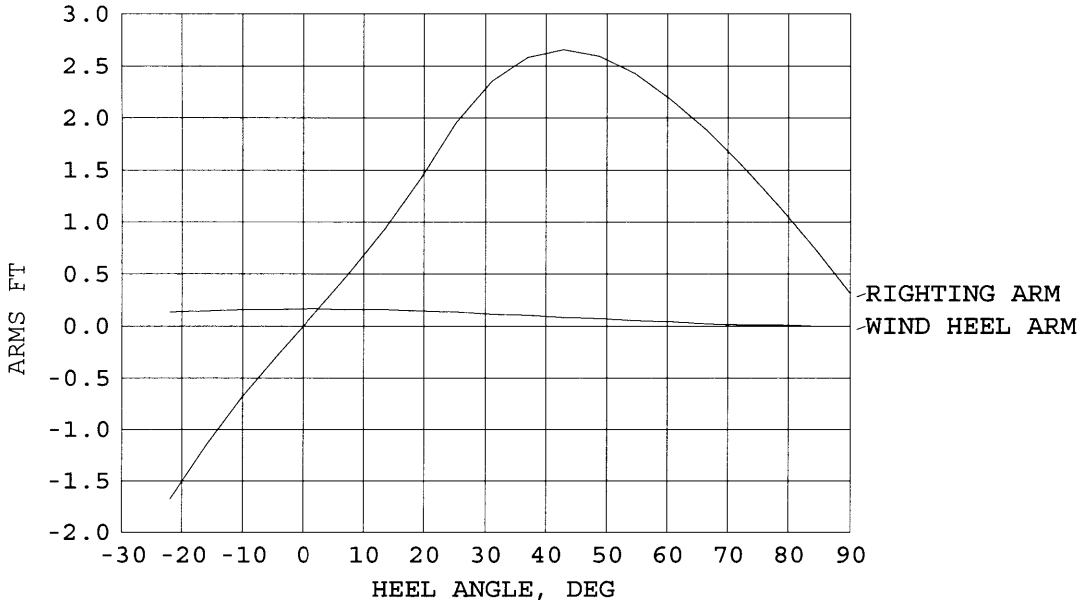
COMP DEF IND-

INTACT WIND SPEED, KT	100.00	LAT RESIST CENTER, FT	7.76
SAIL AREA, FT2	4695.0	TURN SPEED, KT	35.00
SAIL AREA FACTOR	1.25	TURN RADIUS, FT	760.00
SAIL AREA CTR ABV WL, FT	6.44	TURN HEEL ANGLE, DEG	15.25
WIND ARM RATIO	0.08	TURN ARM RATIO	0.37
WIND AREA RATIO	7.14	TURN AREA RATIO	0.66
WIND LEVER ARM, FT	0.22	TURN LEVER ARM, FT	1.12
WIND LIMITING KG, FT	19.38	TURN LIMITING KG, FT	15.52

TABLE OF INTACT RIGHTING ARMS(GZ), DRAFTS, AND TRIMS, FT

HEEL, DEG	0.00	5.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
GZ	0.00	0.33	0.69	1.46	2.33	2.86	2.86	2.53	1.96	1.28
TRIM	0.00	-0.01	-0.05	-0.35	-1.01	-1.65	-2.02	-2.18	-2.25	-2.29
DRAFT	15.52	15.51	15.48	15.32	14.91	14.37	13.77	12.98	11.62	7.95

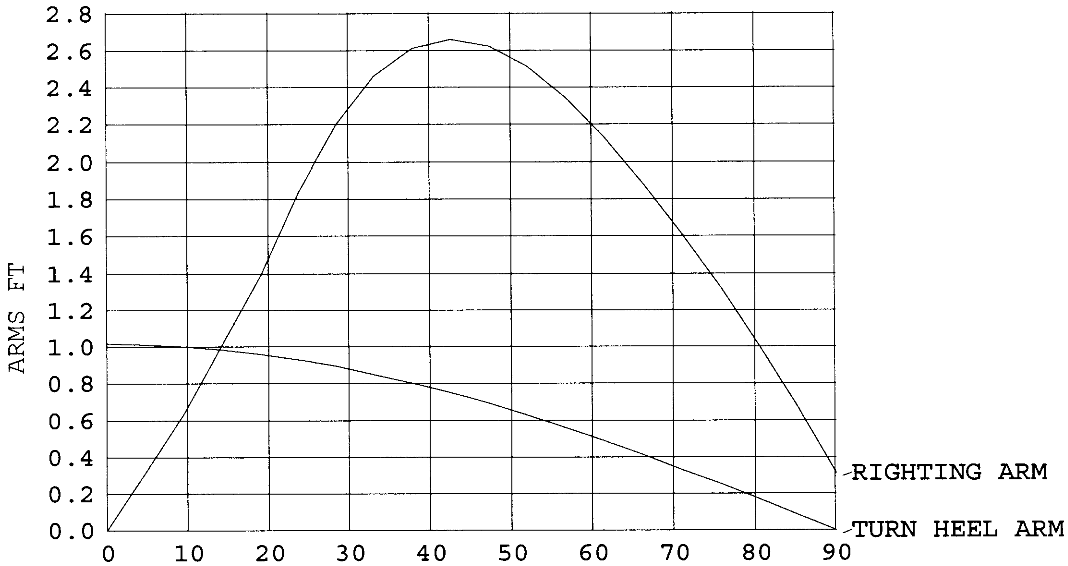
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:30.17
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 4 - INTACT STATIC STABILITY WITH WIND HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	3991.50	LCG LOC(+VE FWD MID), FT	-10.75
KG, FT	15.60	WIND SPEED, KT	100.00
APPENDAGE IND-WITHOUT			

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:30.17
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - INTACT STATIC STABILITY WITH TURN HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	3991.50	LCG LOC(+VE FWD MID), FT	-10.75
KG, FT	15.60	TURN SPEED, KT	35.00
APPENDAGE IND-WITHOUT		TURN RADIUS, FT	760.00

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:30.53
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - SUMMARY

APPENDAGE IND-WITHOUT
HYSTAT IND-WT TRIM
COMP DEF IND-

DISPLACEMENT, LTON	3991.5	MAX AREA STA LOC FM FP,FT	201.10
LCG LOC(+VE FWD MID), FT	-10.75	AREA AT MAX AREA STA, FT2	596.4
MIDSHIP DRAFT, FT	17.00	BEAM AT MAX AREA STA, FT	40.73
TRIM(+ BY STERN), FT	0.00	DRAFT AT MAX AREA STA, FT	17.00
KG, FT	15.60	BLOCK COEF	0.527
SHIP LBP, FT	380.00	PRISMATIC COEF	0.612
METACENTRIC HT(GM), FT	3.74	SECTIONAL AREA COEF	0.861
WATERPLANE AREA,FT2	11884.2	WATERLINE LENGTH, FT	382.50
WETTED SURF AREA, FT2	18590.0		

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:30.53
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - INTACT STATIC STABILITY

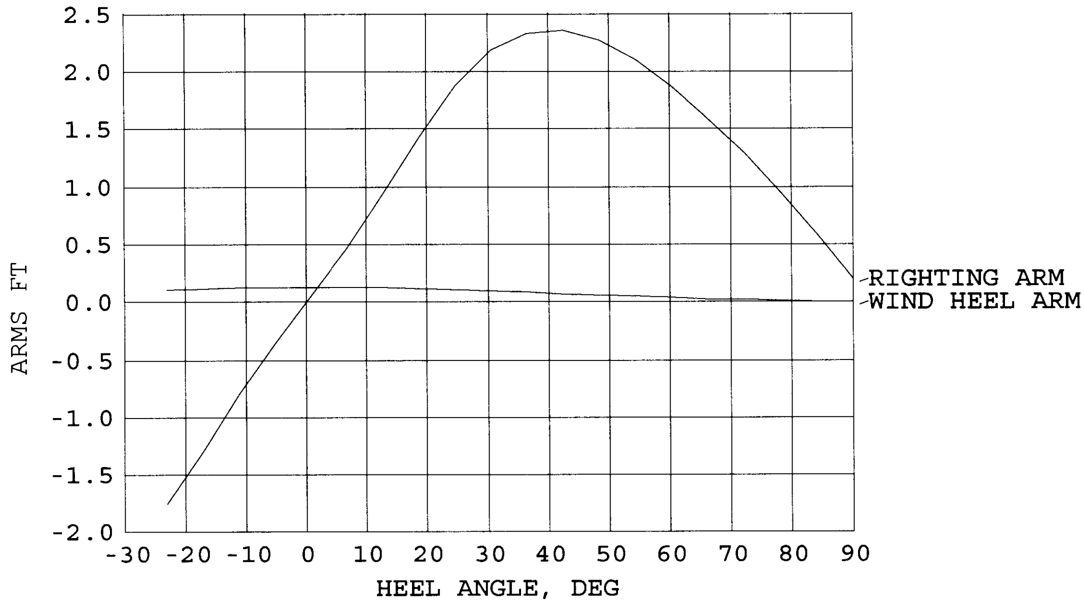
COMP DEF IND-

INTACT WIND SPEED, KT	100.00	LAT RESIST CENTER, FT	8.50
SAIL AREA, FT2	4106.2	TURN SPEED, KT	35.00
SAIL AREA FACTOR	1.25	TURN RADIUS, FT	760.00
SAIL AREA CTR ABV WL, FT	5.70	TURN HEEL ANGLE, DEG	13.91
WIND ARM RATIO	0.06	TURN ARM RATIO	0.37
WIND AREA RATIO	6.51	TURN AREA RATIO	0.66
WIND LEVER ARM, FT	0.16	TURN LEVER ARM, FT	1.01
WIND LIMITING KG, FT	19.37	TURN LIMITING KG, FT	15.95

TABLE OF INTACT RIGHTING ARMS(GZ), DRAFTS, AND TRIMS, FT

HEEL, DEG	0.00	5.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
GZ	0.00	0.33	0.68	1.47	2.30	2.65	2.57	2.21	1.67	1.04
TRIM	0.00	-0.01	-0.02	-0.13	-0.34	-0.11	0.69	2.11	5.08	13.48
DRAFT	17.00	16.99	16.96	16.82	16.54	16.40	16.42	16.66	17.27	19.34

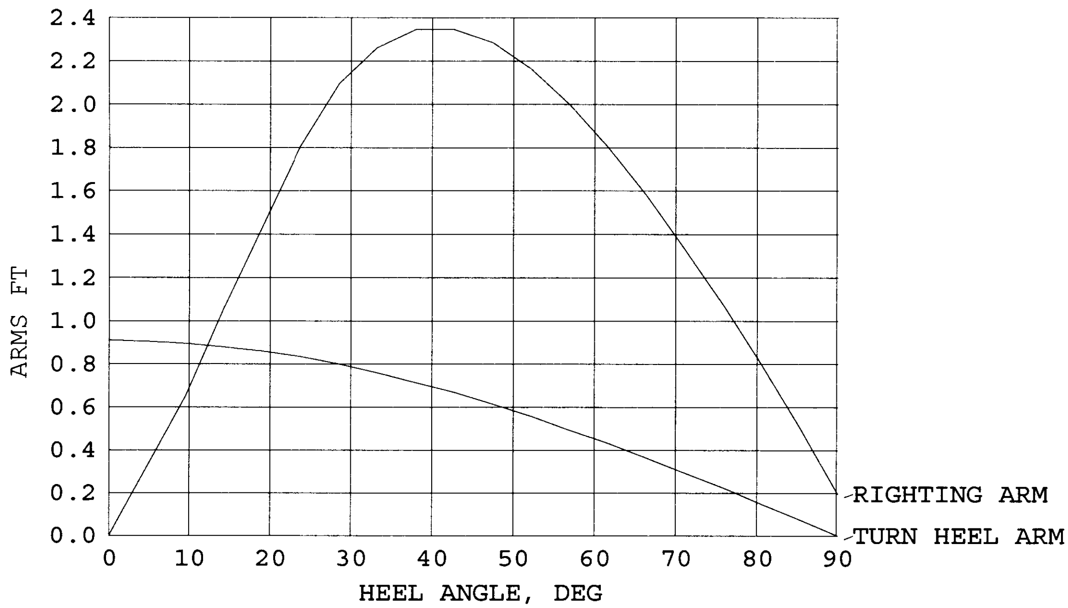
ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:31.33
DATABANK-JOSH PROJ 1 AND 2 2.701 FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 4 - INTACT STATIC STABILITY WITH WIND HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	4491.50	LCG LOC(+VE FWD MID), FT	-12.31
KG, FT	15.60	WIND SPEED, KT	100.00
APPENDAGE IND-WITHOUT			

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:31.33
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL SHIP-JOSH 1
GRAPHIC DISPLAY NO. 5 - INTACT STATIC STABILITY WITH TURN HEELING ARM



INTACT STATIC STABILITY

DISPLACEMENT, LTON	4491.50	LCG LOC(+VE FWD MID), FT	-12.31
KG, FT	15.60	TURN SPEED, KT	35.00
APPENDAGE IND-WITHOUT		TURN RADIUS, FT	760.00

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:31.53
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 1 - SUMMARY

APPENDAGE IND-WITHOUT
HYSTAT IND-WT TRIM
COMP DEF IND-

DISPLACEMENT, LTON	4491.5	MAX AREA STA LOC FM FP,FT	201.67
LCG LOC(+VE FWD MID), FT	-12.31	AREA AT MAX AREA STA, FT2	655.8
MIDSHIP DRAFT, FT	18.46	BEAM AT MAX AREA STA, FT	40.78
TRIM(+ BY STERN), FT	0.00	DRAFT AT MAX AREA STA, FT	18.46
KG, FT	15.60	BLOCK COEF	0.544
SHIP LBP, FT	380.00	PRISMATIC COEF	0.624
METACENTRIC HT(GM), FT	3.88	SECTIONAL AREA COEF	0.871
WATERPLANE AREA,FT2	12125.4	WATERLINE LENGTH, FT	383.71
WETTED SURF AREA, FT2	19741.9		

ASSET/MONOSC V5.3.0 - HYDROSTATIC ANALYSIS - 1/ 8/2010 13:31.53
DATABANK-JOSH PROJ 1 AND 2 2.701_FALL_ SHIP-JOSH 1

PRINTED REPORT NO. 4 - INTACT STATIC STABILITY

COMP DEF IND-

INTACT WIND SPEED, KT	100.00	LAT RESIST CENTER, FT	9.23
SAIL AREA, FT2	3571.8	TURN SPEED, KT	35.00
SAIL AREA FACTOR	1.25	TURN RADIUS, FT	760.00
SAIL AREA CTR ABV WL, FT	5.05	TURN HEEL ANGLE, DEG	12.19
WIND ARM RATIO	0.05	TURN ARM RATIO	0.38
WIND AREA RATIO	5.63	TURN AREA RATIO	0.65
WIND LEVER ARM, FT	0.12	TURN LEVER ARM, FT	0.91
WIND LIMITING KG, FT	19.24	TURN LIMITING KG, FT	16.55

TABLE OF INTACT RIGHTING ARMS(GZ), DRAFTS, AND TRIMS, FT

HEEL, DEG	0.00	5.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
GZ	0.00	0.34	0.70	1.51	2.17	2.36	2.23	1.88	1.39	0.83
TRIM	0.00	0.00	0.00	0.01	0.39	1.52	3.41	6.48	12.42	29.24
DRAFT	18.46	18.45	18.41	18.27	18.21	18.50	19.16	20.43	23.04	30.93

APPENDIX B. POSSE DATA/OUTPUT

MIT - 2011 POSSE Ship Project Editor 4.3
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Hull

HYDROSTATIC TABLE - HULL

Options

Density	LT/ft3	0.029
Long Draft Ref		LCF
Trim	ft	0.00
Heel	deg	0
Master Draft		Baseline

Hydrostatic Properties

Draft	Buoyancy			Waterplane				Metacenter			Waterplane	Coefficients			Wetted
Keel	Disp	KB	LCB	Area	LCF	TP1	BMt	KMt	BMl	KMl	MT1	Cb	Cp	Cm	Max Beam
Ft	LT	Ft	ft-FP	ft2	ft-FP	LT/in	Ft	Ft	Ft	Ft	ft-LT/in				Ft
0.00	0	—	190.00A	—	190.00A	—	—	—	—	—	—	—	—	—	—
1.00	45	0.61	157.24A	2,492.4	161.42A	5.9	26.57	27.18	4,159.07	4,159.68	41	0.020	0.046	0.279	17.37
2.00	137	1.23	162.62A	3,811.6	167.39A	9.1	26.15	27.39	2,425.82	2,427.05	73	0.059	0.073	0.399	24.27
3.00	262	1.85	166.34A	4,895.3	172.57A	11.7	25.14	26.99	1,832.09	1,833.94	105	0.109	0.098	0.486	28.93
4.00	416	2.47	169.71A	5,817.2	177.14A	13.8	23.66	26.13	1,523.79	1,526.26	139	0.162	0.125	0.553	32.25
5.00	595	3.08	172.86A	6,625.9	181.47A	15.8	22.01	25.09	1,337.09	1,340.17	174	0.216	0.153	0.608	34.66
6.00	794	3.69	175.45A	7,366.9	185.96A	17.5	20.47	24.16	1,227.11	1,230.80	214	0.268	0.184	0.652	36.42
7.00	1,014	4.30	178.24A	8,010.3	189.84A	19.1	18.94	23.25	1,131.50	1,135.80	252	0.317	0.216	0.690	37.69
8.00	1,252	4.91	180.90A	8,584.8	193.51A	20.4	17.48	22.39	1,059.71	1,064.62	291	0.362	0.251	0.721	38.64
9.00	1,507	5.52	183.52A	9,121.2	197.25A	21.7	16.11	21.63	1,009.04	1,014.56	333	0.401	0.289	0.747	39.40
10.00	1,774	6.12	185.80A	9,678.1	201.80A	23.0	14.94	21.06	991.50	997.62	386	0.438	0.339	0.770	39.94
11.00	2,058	6.73	188.32A	10,155.3	205.51A	24.2	13.87	20.60	959.90	966.63	433	0.472	0.386	0.789	40.32
12.00	2,356	7.33	190.79A	10,641.9	209.73A	25.3	12.89	20.22	947.99	955.32	490	0.502	0.443	0.806	40.56
13.00	2,667	7.93	193.28A	11,148.8	214.49A	26.5	12.06	19.99	950.35	958.28	556	0.531	0.514	0.820	40.71
14.00	2,990	8.54	195.70A	11,434.7	216.27A	27.2	11.21	19.74	903.17	911.70	592	0.554	0.552	0.832	40.78
15.00	3,319	9.13	197.73A	11,577.2	216.02A	27.6	10.35	19.47	835.40	844.52	608	0.567	0.565	0.843	40.81
16.00	3,652	9.71	199.38A	11,727.5	215.65A	27.9	9.64	19.35	780.36	790.07	625	0.582	0.579	0.853	40.84
17.00	3,989	10.28	200.73A	11,884.8	215.16A	28.3	9.06	19.34	735.05	745.33	643	0.597	0.593	0.862	40.87
18.00	4,331	10.85	201.85A	12,049.5	214.52A	28.7	8.56	19.41	697.58	706.43	663	0.613	0.609	0.870	40.88

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Hull

Draft	Buoyancy			Waterplane				Metacenter			Waterplane	Coefficients			Wetted
Keel	Disp	KB	LCB	Area	LCF	TP1	BMt	KMt	BMl	KMl	MT1	Cb	Cp	Cm	Max Beam
Ft	LT	Ft	ft-FP	ft2	ft-FP	LT/in	Ft	Ft	Ft	Ft	ft-LT/in				Ft
19.00	4,678	11.42	202.76A	12,218.3	213.76A	29.1	8.14	19.56	665.71	677.13	683	0.629	0.624	0.878	40.88
20.00	5,029	11.98	203.49A	12,390.5	212.90A	29.5	7.77	19.76	638.39	650.38	704	0.646	0.640	0.884	40.88
21.00	5,386	12.55	204.08A	12,564.4	211.92A	29.9	7.45	20.00	614.63	627.18	726	0.663	0.657	0.890	40.88
22.00	5,747	13.11	204.54A	12,738.0	210.85A	30.3	7.16	20.27	593.56	606.67	748	0.680	0.673	0.895	40.88
23.00	6,114	13.67	204.87A	12,910.3	209.68A	30.7	6.89	20.57	574.75	588.43	771	0.696	0.689	0.900	40.88
24.00	6,485	14.24	205.10A	13,079.2	208.42A	31.1	6.65	20.89	557.61	571.85	793	0.713	0.706	0.904	40.88

BONJEAN DATA

No.		1	2	3	4	5	6	7	8	9	10	11	12	13
Long (ft-FP)		380.00A	370.50A	361.00A	342.00A	323.00A	304.00A	285.00A	266.00A	247.00A	228.00A	209.00A	190.00A	171.00A
Draft Keel Ft	Draft Ref ft-BL	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2
0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	12.8	25.3	31.9	32.4	31.7
4.00	4.00	0.0	0.0	0.0	0.0	0.0	0.0	7.1	31.2	57.0	77.7	88.6	89.8	87.3
6.00	6.00	0.0	0.0	0.0	0.0	0.0	10.8	45.3	84.1	118.3	143.6	157.0	158.9	154.1
8.00	8.00	0.0	0.0	0.0	0.0	11.8	52.9	102.3	149.7	189.1	217.2	232.1	234.2	226.7
10.00	10.00	0.0	0.0	0.0	11.5	55.6	111.6	169.5	222.3	266.2	295.1	310.8	312.6	302.4
12.00	12.00	0.0	0.3	12.4	57.1	115.0	178.8	241.9	298.5	343.9	375.3	391.4	392.4	379.6
14.00	14.00	19.7	39.3	62.1	116.9	181.3	250.0	317.0	376.5	424.9	456.5	472.8	472.8	457.5
16.00	16.00	71.2	94.1	120.0	180.8	250.3	323.3	393.5	455.4	504.6	536.1	554.4	553.4	535.9
18.00	18.00	126.2	152.0	180.9	247.2	321.4	396.1	471.2	535.1	585.7	619.8	636.1	634.2	614.7
20.00	20.00	184.2	212.9	244.6	316.0	394.4	474.5	550.0	615.5	667.9	701.6	717.8	715.3	694.2
22.00	22.00	245.0	276.3	310.6	386.7	469.1	552.1	629.7	696.5	748.4	783.3	799.5	796.6	774.4
24.00	24.00	307.9	341.9	378.6	459.1	545.0	630.7	710.2	777.9	830.0	866.0	881.2	878.1	855.2

No.		14	15	16	17	18	19	20	21	22	23	24	25
Long (ft-FP)		152.00A	133.00A	114.00A	95.00A	76.00A	57.00A	38.00A	19.00A	9.50A	0.00	8.17F	16.34F
Draft Keel Ft	Draft Ref ft-BL	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2	Area ft2
0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00	2.00	29.1	25.1	20.7	16.5	12.5	8.3	3.4	0.0	0.0	0.0	0.0	0.0
4.00	4.00	80.6	70.7	59.4	47.6	35.4	22.8	9.8	0.7	0.0	0.0	0.0	0.0
6.00	6.00	142.8	126.7	107.7	86.8	64.6	41.6	19.1	2.5	0.0	0.0	0.0	0.0
8.00	8.00	210.8	188.4	161.3	130.8	98.0	63.9	31.2	6.2	0.5	0.0	0.0	0.0
10.00	10.00	282.0	253.3	218.1	178.0	134.5	89.3	46.1	12.0	2.3	0.0	0.0	0.0
12.00	12.00	354.8	320.0	277.0	227.6	173.5	117.4	63.4	19.6	5.6	0.0	0.0	0.0
14.00	14.00	428.6	388.0	337.5	279.0	214.8	147.9	83.1	29.1	10.2	0.0	0.0	0.0
16.00	16.00	503.2	457.2	399.6	332.6	258.5	180.8	105.0	40.1	16.1	0.8	0.0	0.0
18.00	18.00	578.8	527.9	463.8	388.6	304.9	216.6	129.6	53.3	23.6	2.8	0.0	0.0
20.00	20.00	655.5	600.4	530.3	447.5	354.6	256.7	157.2	69.1	33.5	6.8	0.0	0.0
22.00	22.00	733.6	674.8	599.5	509.5	407.8	298.5	188.5	88.2	46.3	13.3	0.0	0.0
24.00	24.00	813.0	751.4	671.4	575.0	464.8	345.4	223.8	110.9	62.5	22.8	0.0	0.0