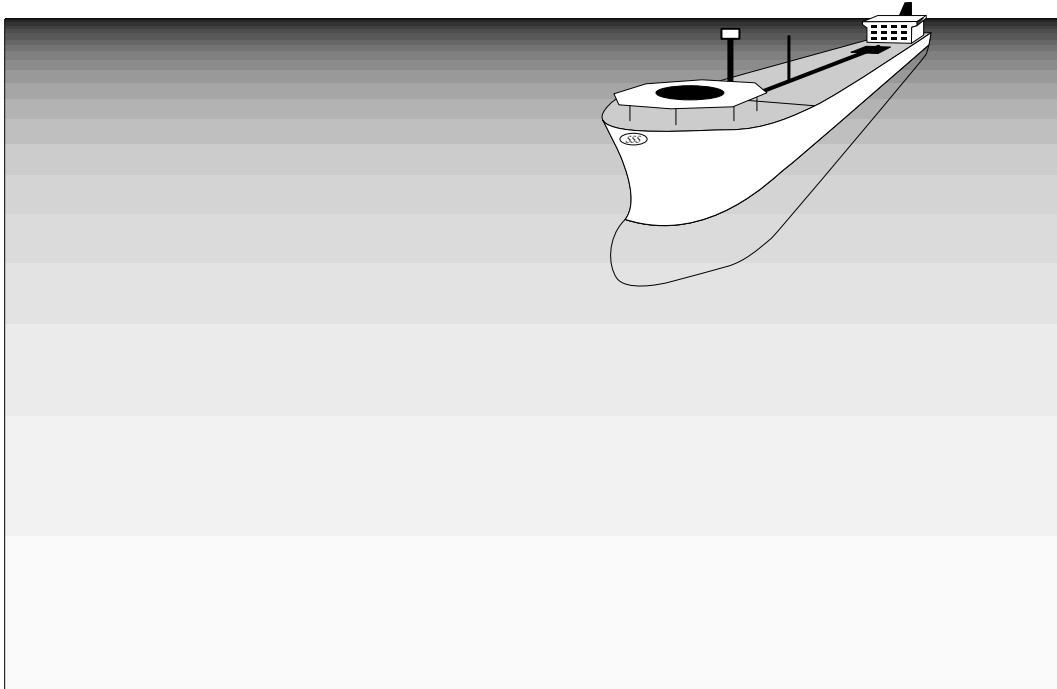# *The SeaSoft® Tanker Models*

Tanker Physical Property Estimation
from SeaSoft Systems

User Manual

April, 2005

The SeaSoft Tanker Models

Tanker Physical Property Estimation
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User Manual

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About the SeaSoft Library

The SeaSoft family of software products for the offshore industry has been developed in response to a need for high quality, easy to use analytical tools for numerical simulation of the dynamic and static characteristics of a wide variety of offshore vessels and mooring structures.

The variety of computing platforms now used in engineering and naval architectural environments requires that offshore engineering software be easily transportable to a wide variety of computers (Macintosh, Unix, Windows, etc.) so that software tools can easily be moved to new computing facilities as the need arises. The SeaSoft program library was developed with these considerations in mind.

SeaSoft's products are capable, in most circumstances, of exceeding the physical modeling capabilities of older, operationally more complex codes while far surpassing them in terms of versatility and ease of use. Benchmark efforts by the DeepStar Committee (http://www.deepstar.org), using high-quality model test data as simulation quality arbiter, have shown unequivocally that the quality of the SeaSoft simulations surpasses all other available mooring tools, be they time-domain, frequency-domain or hybrid.

In the development of this suite of programs, the principal objectives have been (1) to deliver state of the art computational abilities to the offshore industry in packages that would permit their utilization by any technically trained individual with a need for the information, and (2) to insure that the quality and robustness of the underlying physical and analytical modeling are second to none.

The software is oriented specifically towards the practicing marine/offshore engineer and naval architect. In order to be of maximum utility to this audience, the software has been designed so that first-time or infrequent users can produce meaningful results.

Table of Contents

Chapter 1

Introduction

Objectives

The SeaSoft Tanker Models (the "Models") have been developed to provide "typical" tanker properties in order that preliminary mooring and motion simulations for this class of vessel not be held hostage by a lack of data. The Models produce a complete set of physically reasonable and internally consistent simulation parameters required for execution of SeaSoft simulations from an absolute minimum of information about the "target" tanker. The Models comprise a comprehensive and complex synthesis of (i) empirical data on specific vessels from a wide variety of sources, (ii) publicly available summaries of "average tanker" characteristics and (iii) theoretical modeling.

Internal Consistency of Data

The notion of "internal consistency" is important and highlights a fundamental reason for the development of the Model. In gathering information for a dynamical simulation of a vessel, it is common that some subset of the required information is not readily available. Often the missing data is hydrostatic in nature, since detailed hydrostatic curves are not generally included in widely-disseminated vessel information summaries. Detailed information on mass distribution is also often lacking. In these cases, the missing information must be estimated, sometimes by engineers who are not naval architects and may not be well-versed in sound estimation procedures for these quantities. As a result the estimates, particularly hydrostatic estimates, may be internally inconsistent. For example, the waterplane area obtained directly from a published "Tons Per Inch" value may be physically inconsistent with a longitudinal metacentric height (KML) obtained by faulty or otherwise inadequate estimation procedures. Such internal inconsistencies may have an effect on simulation quality that is unexpectedly detrimental. That is, a slightly incorrect but *internally consistent* set of physical properties for a target tanker may in some cases be more representative than a set with a *single* erroneous physical property which is physically inconsistent with other input data. By proper use of SeaSoft modeling tools, these kinds of internal inconsistencies can be avoided.

Implementations

Three implementations of two distinct analytical models have been developed. The two analytical models are the "Minimal Data Tanker Model" (or, more simply, the "Minimal Data Model" or "Minimal Model") and the "Tanker Register Model". Each of the two independent analytical models has been implemented as a spreadsheet document, while the Minimal Model has a second realization in an on-line simulation "Help" facility. All implementations require as input certain intrinsic properties of the target vessel, discussed in detail elsewhere, and a measure of the desired load condition; "Simulation Draft" is used as a surrogate for the vessel loading condition in all cases.

Minimal Data Tanker Model

The Minimal Data Model provides an internally consistent complement of tanker properties from two input variables: (1) design deadweight (DWT) and (2) Simulation Draft. Using these inputs, the Model estimates other vessel parameters required for SeaSoft dynamical simulation programs, as well as a host of related vessel properties not directly required for SeaSoft simulations (such as vessel block and waterplane coefficients, lightship weights, etc.).

On-Line Support of Simulations

An implementation comprising a subset of the Minimal Model is accessible from within all SeaSoft simulations. This "bare bones" embodiment, which is separate and distinct from the spreadsheet Model, provides only tanker estimates which are directly required by the SeaSoft dynamical simulations.

Tanker Register Model

The Tanker Register Model is designed primarily for use in conjunction with The Tanker Register (the "**Register**"), a useful source book produced annually in London by the H. Clarkson & Company, Ltd. This important volume publishes, for nearly every tanker afloat, basic vessel information including gross geometrical properties (beam, length, draft), cargo capacity and limited hydrostatic data. The **Register** is widely available and contains much of the information required for accurate dynamical modeling; as a result the "SeaSoft Tanker Register Model", utilizing data from the **Register**, has been developed. In combination with data provided in the **Register** and the desired vessel load condition (as specified by the "Simulation Draft"), this Model provides realistic and internally consistent estimates of the physical characteristics necessary for an engineering analysis of vessel seakeeping performance.

Computing Platforms

Both Models have been developed as Microsoft Excel™ spreadsheets. They can therefore be used with most advanced spreadsheet programs on most computing platforms by utilization of Excel-importation capabilities common to widely-used spreadsheet applications. However, spreadsheet formatting and other application-specific features may not be properly transferred between spreadsheet applications so that some reformatting of the spreadsheet may be necessary if applications other than Excel are used.

Caveats: Minimal Data Tanker Model

The Minimal Data Model is *by no means* a substitute for actual physical properties of a target tanker. It is intended to be used for "first look" applications to provide hard-to-obtain vessel information such as the KM's, VKB, VKG, water plane area, wind areas, gyradii, etc. *In this regard it should be noted that the variation in any of these quantities about "mean" values for a particular DWT across the tanker fleet is considerable and can in some cases exceed 20%.* That is, despite the sophistication and internal consistency of the Minimal Model, its use to represent a particular target tanker can

nonetheless lead to *substantial* modeling errors because of wide variations in tanker design. Refer to Appendix C for further discussion of the cross-fleet variability of tanker properties.

Caveats: Tanker Register Model

As for the Minimal Data Model, the success of the Tanker Register Model in accurately modeling particulars of a target tanker depends on the degree of variation amongst tankers with nearly identical **Register** descriptions. Despite the severe limitations placed on vessel hydrostatic properties by **Register** data, apparently "identical" tankers can still differ in important ways. For example, deckhouse design has an important effect on wind load coefficients; bilge design can have an important bearing on wave-frequency roll performance and current loading; the presence of a double hull will effect mass distribution and total displacement (and therefore natural periods, roll in particular); load distribution and storage tank levels of partially-loaded vessels can strongly influence important natural periods and hence both wave-frequency and low-frequency dynamical performance. In short, despite the considerable modeling power of the SeaSoft Tanker Register Model, it is nonetheless important, particularly for critical applications, to obtain and use precise tanker-specific data for final "production" simulation runs.

Chapter 2

Program Package Contents

The "**Model Package**" comprises the user manual, the spreadsheet files, and support services provided by SeaSoft. The latter include bug reports, corrections and support of possible bug-related problems encountered during program execution.

Model Files

The files provided with the Package comprise disc-based spreadsheet documents for the two spreadsheet implementations: The SeaSoft Minimal Tanker Model and the SeaSoft Tanker Register Model. Each of these files can be loaded into an appropriate spreadsheet program for viewing and manipulation. The Model Package *does not* include a spreadsheet application to access the Models; the user must possess an application for viewing, manipulating and printing information within the supplied Model files.

The User Interface

The user interface is that of the user's spreadsheet application. Most of the cells are locked to prevent inadvertent modification of the underlying formulae.

Chapter 3

Input Data Requirements

Minimal Data Tanker Model

The Minimal Data Tanker Model (also "Minimal Data Model" or "Minimal Model") requires as input only the design Deadweight (DWT) of the target tanker and the vessel draft ("Simulation Draft") desired for simulation. The Simulation Draft should lie between the full-load draft ("Loaded Draft") and Lightship Draft or physically impossible Model Tanker values will appear in some spreadsheet cells. The Loaded Draft is computed and displayed on the first ("Input") spreadsheet page; the Lightship Draft may be determined by trial and error, sequentially altering Simulation Draft values until the indicated "Cargo Weight" is near zero.

It is possible, because of inevitable differences between the Minimal Model Tanker and the actual target tanker, that a specified Simulation Draft for a particular DWT will be *greater* than the Full Load Draft estimate for that DWT. In this case, two acceptable courses of action are available:

> 1. In the spreadsheet (or on-line facility) adjust DWT upwards from the target value until the estimated Full Load Draft matches the required draft; use the Tanker Model estimates associated with the *adjusted* DWT to define the (slightly larger) target tanker in the desired SeaSoft simulation.

> 2. In the spreadsheet (or on-line facility) use the *specified* DWT and its Full Load Draft estimate to define the target tanker for the desired SeaSoft simulation, changing *only* the draft in the simulation input data (but *not* in the spreadsheet Model or on-line facility) to reflect the required value.

Either of these procedures will produce physically reasonable estimates of target tanker properties while maintaining the correct simulation draft, which determines the vertical location of mooring fairleads, VKGs, etc.

Note: When using the Tanker Register Model, the DWT/Draft conflict cannot arise since Full Load Draft is an *input* value and not an estimate.

Tanker Register Model

The Tanker Register publishes an important subset of tanker physical properties for virtually every tanker in service worldwide. The published information generally includes, in addition to the vessel name and other information of no immediate modeling relevance, seven vessel parameters useful in the preparation of a more comprehensive tanker model: (1) Design Deadweight ("DWT"), (2) Length Over All (LOA), (3) Length Between Perpendiculars (LBP or Lpp), (4) Moulded Depth, (5) Extreme Breadth, (6) Full Load Draft ("Summer Draught") and (7) Tons Per Inch immersion (TPI) at Full Load

Draft. The SeaSoft Tanker Register Model is uniquely defined by these seven parameters and the desired load condition as determined from the (user-specified) Simulation Draft.

Required vs. Optional Data

Because the **Register** lacks TPI and/or moulded depth data for some vessels, the SeaSoft Tanker Register Model has been constructed to estimate these quantities when they are unavailable. Further, because the Lpp is more strongly correlated to important tanker physical properties than LOA, the LOA is not used in a modeling capacity and its specification is thus also optional.

Required input data therefore comprises (1) DWT, (2) Lpp, (3) Beam, (4) Full Load Draft and (5) Simulation Draft. The *optional* input data comprises (1) TPI, (2) Moulded Depth, (3) LOA and (4) bilge keel information. LOA and bilge keel data is for documentation purposes only; neither impacts any other estimated vessel properties. Note that of the two "important" optional items, an accurate full load TPI (or, equivalently, full load waterplane or waterplane coefficient) is *very* important to the estimation of other vessel properties and should be supplied whenever possible. Accurate moulded depth information, though important, has a smaller influence on the remaining vessel property estimates.

Note: Very recent (post 1990) editions of the **Register** omit Lpp information, publishing only the LOA. In the event LOA but not Lpp is available, use Lpp = 0.95*LOA in the "Required" input section of the Tanker Register Model. Also, try to obtain an earlier version of the **Register** which *does* include Lpp data.

Appendix A

Glossary

added mass	Refers to the enhancement of inertial properties of a body undergoing accelerated motion in a surrounding fluid.
bilge	The area at the bottom of a vessel where the nearly flat bottom turns upwards to form the nearly vertical side.
bilge keel	A protuberance, situated near the bilge, whose function is to create turbulence in the surrounding fluid during rolling motions, thereby dissipating roll energy and reducing the magnitude of roll excursions.
block coefficient	The displacement of a vessel at a given waterline divided by the product of its molded beam, length, and draft; a measure of the "boxiness" of the hull form (symbolized by Cb).
Cargo Weight	The difference between "Displacement" and "Lightship Weight".
conventional bow	Refers to a conventional tanker bow design with prominent bulbous protrusion and a deeply notched profile; this bow is generally more sharply pointed in plan view than the contrasting "cylindrical" bow shape.
cylindrical bow	Refers to a tanker bow configuration which, viewed from the side, is indented to such a small degree that it appears almost cylindrical; when viewed from the top, this bow type is considerably more blunt and rounded that the contrasting "conventional" type.
deadweight (DWT)	Formally, the deadweight is simply cargo weight and comprises the difference between displacement and lightship weight; it is therefore a continuous function of mean vessel draft condition. However, for our purposes DWT refers to the *design maximum* deadweight, which corresponds to the maximum cargo carrying capacity of a VLCC and is commonly used as a standard measure of tanker size.
dynamically similar box	A special construct whose most important dynamical properties, including all mass, added mass and hydrostatic properties, are chosen to closely approximate those of the simulated vessel. The selection process insures, in particular, that the important natural periods of roll, pitch and heave are properly modeled.

Epsilon	The "Fullness Parameter", or "Epsilon", is a measure of variation in waterplane area as draft is varied; an imaginary vessel whose waterplane area was independent of draft would have Epsilon = 1, while a "knife-keeled" vessel whose waterplane went to zero at zero draft would have Epsilon = 0. Epsilon is used internally to model variations of certain vessel hydrostatic properties with changes of draft.
floating point	Refers to a numerical variable in Fortran which is used and stored in memory in exponential format as opposed to simple integer ("fixed point") format.
Full Load Draft	The design maximum draft of a vessel corresponding to the design maximum load for seagoing operations. This is sometimes known as Maximum Draft, Design Draft, Loaded Draft, Summer Draft, or in England as the Summer Draught.
GM	The vertical distance between the center of gravity and metacenter. Equal to KM minus KG. Transverse and longitudinal values are associated respectively with KMT and KML.
gyradius	The square root of the ratio between the mass moment of inertia of a body about its center of gravity and its mass. A measure of the angular inertia of a body.
Hull Area	The above- or below-water projected area of the hull, neglecting contribution from any superstructure such as deck houses or production equipment, subject to hydrodynamic forces of wind or current.
KB, KG, KML, KMT	The vertical positions of the center of buoyancy, center of gravity, and longitudinal and transverse metacenters, all measured from the keel baseline.
kip	The unit of weight used when English units are selected. Equal to 1000 pounds.
Lpp, LBP	The "length between perpendiculars" is a common measure of vessel length that is generally quite close to the length of the waterline at maximum draft condition. It is usually about 5% less than the overall vessel length (LOA).
Lightship Weight	The weight of vessel and machinery without crew, cargo or consumables such as stores or fuel.
metric ton	The unit of weight used when metric units are selected. Equal to the weight of 1000 kilograms at a nominal gravitational acceleration of 9.8 meters/second**2, or roughly 2205 pounds.
moulded depth	For practical purposes, this is the profile height of the hull from keel to main deck level; it is *by definition* draft plus freeboard in this document.

Simulation Draft   The mean draft associated with the desired partial loading condition for the target vessel.

superstructure wind area The projected areas (beam-on and head-on) of above-deck structures, primarily comprising the aft-end deckhouse in conventional VLCC designs.

toggle   This is a generic mechanism used to change an input variable having two possible values, such as metric versus English units specification.

ULCC   "Ultra Large Crude Carrier".

VLCC   "Very Large Crude Carrier".

waterplane coefficient   The waterplane area of a vessel at a given waterline divided by the product of its waterline beam and length; a measure of the rectangularity of the waterplane (symbolized by Cwp).

Appendix B

Sample Problem

As a tutorial aid in the use of the SeaSoft Tanker Models, this appendix illustrates the use of Model spreadsheets for estimating the physical properties of a nominal 140,000 DWT VLCC. The target vessel was identified in the 1975 edition of <u>The Tanker Register</u> as the "Britta". Output from both ***Minimal Data*** and ***Tanker Register*** Models will be presented and compared. A description and discussion of the Model output pages will be found at the end of the appendix.

Minimal Data Model Input

We assume a vessel with the following physical characteristics:

    1. DWT... 136,188 Long Tons

    2. Simulation Draft.................................... 40.00 Ft

The output stream associated with these characteristics may be found on the following pages. Note in particular the estimates of Lpp, Beam, Moulded Depth, Full Load Draft and TPI and contrast them with the **Register** data (see table below) for the simulated vessel. The variability between the Minimal Model estimates and the **Register** values, which ranges from about 2% for Lpp to 9% for TPI, is typical. As discussed elsewhere, the tanker fleet exhibits physical property variability of up to 20% for a given DWT.

Minimal Model/Register Comparison Table

	Minimal Model	**Register**	Variation
Lpp	868.99	853.06	+1.9%
Beam	151.37	144.52	+4.7%
Moulded Depth	71.71	73.49	-2.5%
Full Load Draft	52.06	55.92	-7.4%
TPI	282.94	260.40	+8.7%

Minimal Data Model   *SeaSoft Systems*

SeaSoft® Minimal Data Tanker Model
Input Variables: DWT & Draft
(English Units)

Version 2.3, Copyright © 1993-1999 by SeaSoft Systems

Tanker: "Britta" (1975 Tanker Register)

>>> *Input Data:*

```
Full Load Deadweight ("DWT") ...................    136,188  Long Tons
Simulation Draft ...............................      40.00  Feet
Bilge Keel? (Yes/No) ...........................        Yes
```

>>> *Selected Estimates:*

```
Deadweight (Simulation Units) ..................    305,061  Kips
Overall Length .................................     912.44  Feet
Length Between Perpendiculars ..................     868.99  Feet
Beam ...........................................     151.37  Feet
Moulded Depth ..................................      71.71  Feet
Full Load Draft ................................      52.06  Feet

T.P.I. at Full Load Draft ......................     282.94  Long Tons/Inch

Full-Load Block Coefficient ....................      0.817
Full-Load Waterplane Coefficient ...............      0.903

Simulation Freeboard ...........................      31.71  Feet
Simulation Center of Buoyancy (VKB) ............      20.55  Feet
Simulation Center of Gravity (VKG) .............      36.42  Feet
Simulation GMT = KMT - VKG .....................      31.75  Feet
Simulation GML = KML - VKG .....................    1286.31  Feet

Lightship Weight ...............................     53,075  Kips
Cargo Weight ...................................    215,400  Kips
```

Minimal Data Model   **SeaSoft Systems**

Tanker: "Britta" (1975 Tanker Register)

>>> *Simulation Load Estimates:*

```
Draft ........................................        40.00  Feet
Displacement .................................       268,475  Kips
Displacement Volume ..........................     4,194,923  Cubic Feet
Cargo Weight .................................       215,400  Kips
Freeboard ....................................        31.71  Feet


Loaded Freeboard/Simulation Freeboard ..........      0.62
Simulation Draft/Loaded Draft ..................      0.77
Simulation Displacement/Loaded Displacement ....      0.75


Water Plane Area .............................       113,585  Square Feet
Block Coefficient ............................         0.797
Waterplane Coefficient .......................         0.863


Center of Buoyancy (VKB) .....................        20.55  Feet
Center of Gravity (VKG) ......................        36.42  Feet


IWPxx/Delta ..................................        47.62  Feet
IWPyy/Delta ..................................      1302.17  Feet


Transverse Metacentric Height (KMT) ..........        68.17  Feet
Longitudinal Metacentric Height (KML) ........      1322.73  Feet
GMT = KMT - VKG ..............................        31.75  Feet
GML = KML - VKG ..............................      1286.31  Feet


Cargo Roll Gyradius (Kxx) ....................        48.35  Feet
Cargo Pitch Gyradius (Kyy) ...................       217.60  Feet
Cargo Yaw Gyradius (Kzz) .....................       220.97  Feet


Vessel Roll Gyradius .........................        50.95  Feet
Vessel Pitch Gyradius ........................       227.15  Feet
Vessel Yaw Gyradius ..........................       230.58  Feet


Head-On Hull Area - Wind .....................         4,800  Square Feet
Beam-On Hull Area - Wind .....................        27,553  Square Feet
Head-On Total Area - Wind ....................        10,952  Square Feet
Beam-On Total Area - Wind ....................        33,394  Square Feet


Head-On Total Area - Current .................         6,055  Square Feet
Beam-On Total Area - Current .................        34,760  Square Feet
```

Tanker: "Britta" (1975 Tanker Register)

>>> *Lightship Estimates:*

```
Deadweight ......................................  136,188  Long Tons
Deadweight (Simulation Units) ..................  305,061  Kips
Overall Length .................................   912.44  Feet
Length Between Perpendiculars ..................   868.99  Feet
Beam ...........................................   151.37  Feet
Moulded Depth ..................................    71.71  Feet

Bulkhead Weight ................................   12,874  Kips
Shell Weight ...................................   40,201  Kips
Bulkhead Weight/Shell Weight ...................     0.32
Lightship Weight ...............................   53,075  Kips

Vertical C.G. (VKG) ............................    38.72  Feet

Roll Gyradius (Kxx) ............................    60.30  Feet
Pitch Gyradius (Kyy) ...........................   262.35  Feet
Yaw Gyradius (Kzz) .............................   266.03  Feet

Head-on Superstructure Wind Area ...............    6,152  Square Feet
Beam-on Superstructure Wind Area ...............    5,841  Square Feet

Bilge Radius ...................................    10.60  Feet
Bilge Keel? (Yes/No) ...........................      Yes
```

>>> *Full Load Estimates:*

```
Draft ..........................................    52.06  Feet
Displacement ...................................  358,136  Kips
Displacement Volume ............................ 5,595,870 Cubic Feet
Freeboard ......................................    19.65  Feet
Scale Length ( = Volume^.333) ..................   177.54  Feet
Water Plane Area ...............................  118,835  Square Feet

Block Coefficient ..............................    0.817
Waterplane Coefficient .........................    0.903
Fullness Parameter ("Epsilon") .................    0.809

Head-On Hull Area - Wind .......................    2,975  Square Feet
Beam-On Hull Area - Wind .......................   17,077  Square Feet
Head-On Total Area - Wind ......................    9,127  Square Feet
Beam-On Total Area - Wind ......................   22,918  Square Feet

Head-On Total Area - Current ...................    7,880  Square Feet
Beam-On Total Area - Current ...................   45,236  Square Feet
```

Minimal Data Model *SeaSoft Systems*

Tanker: "Britta" (1975 Tanker Register)

>>> *Simulation Input Stream:*

```
Displacement ................................... 268,475  Kips
Transverse metacentric height (KMT) ............    68.17  Feet
Longitudinal metacentric height (KML) .......... 1322.73  Feet
Vertical center of buoyancy (VKB) ..............    20.55  Feet
Vertical center of gravity (VKG) ...............    36.42  Feet
Vessel water plane area ........................ 113,585  Square Feet
Length of vessel at waterline ..................  868.99  Feet
Beam of vessel at waterline ....................  151.37  Feet
Vessel draft ...................................    40.00  Feet

Pitch Gyradius .................................  227.15  Feet
Roll Gyradius ..................................    50.95  Feet
Yaw Gyradius ...................................  230.58  Feet
Bilge radius at maximum beam station ...........    10.60  Feet
Is there a bilge keel? (Yes/No).................      Yes

Tanker Load Condition (Draft-Based) ............    76.84  Percent
Tanker Load Condition (Freeboard-Based) ........    61.98  Percent
Tanker Deadweight .............................. 305,061  Kips

Head-on wind effective drag area ...............   10,952  Square Feet
Beam-on wind effective drag area ...............   33,394  Square Feet

Head-on current effective drag area ............    6,055  Square Feet
Beam-on current effective drag area ............   34,760  Square Feet
```

>>> *Notes:*

```
1. Form Coefficients are based on Lpp
2. "Lightship" is without cargo, crew or consumables
3. All displacement values assume seawater density (64.0 lbs/ft^3)
4. Common Load Condition Conventions:
   a. Percent of fully loaded displacement
   b. Percent of fully loaded draft
   c. 100*[Full-load freeboard]/[Simulation freeboard]
```

Tanker Register Input Data

The Tanker Register 1975 edition published the following data for the "Britta".

1. DWT.. 136,188 Long Tons

2. Lpp .... 853.06 Ft

3. Beam .... 144.52 Ft

4. Full Load Draft.................................... 55.92 Ft

5. Simulation Draft.................................. 40.00 Ft

6. TPI.. 260.4 Long Tons/inch

7. Moulded Depth .... 73.49 Ft

8. LOA .... 889.15 Ft

The associated Tanker Register Model spreadsheet pages follow directly; a description of the output occurs at the end of the appendix.

SeaSoft® Tanker Register Model
Input Variables: Data from "The Tanker Register"
(English Units)

Version 2.3, Copyright © 1993-1999 by SeaSoft Systems

Tanker: "Britta" (1975 Tanker Register)

>>> *Required Input Data*

```
Full Load Deadweight ("DWT") ....................  136,188 Long Tons

Length Between Perpendiculars ("LBP", "Lpp") ....   853.06 Feet
Maximum Beam ("Ext. Bdth.") .....................   144.52 Feet
Full Load Draft ("Summer Draught") ..............    55.92 Feet

Simulation Draft ................................    40.00 Feet
```

>>> *Optional Input Data*

```
T.P.I. at Full Load Draft .......................   260.40 Long Tons/Inch
Moulded Depth ("Mld. Depth") ....................    73.49 Feet
Length Overall ("LOA") ..........................   889.15 Feet
Bilge Keel? (Yes/No) ............................      Yes
```

>>> *Selected Estimates:*

```
Full-Load Block Coefficient .....................    0.812
Full-Load Waterplane Coefficient ................    0.887

Simulation Freeboard ............................    33.49 Feet
Simulation Center of Buoyancy (VKB) .............    20.46 Feet
Simulation Center of Gravity (VKG) ..............    37.37 Feet
Simulation GMT = KMT - VKG ......................    25.28 Feet
Simulation GML = KML - VKG ......................  1176.57 Feet

Lightship Weight ................................   53,075 Kips
Cargo Weight ....................................  196,326 Kips
```

Tanker Register Model   *SeaSoft Systems*

Tanker: "Britta" (1975 Tanker Register)

>>> Lightship Estimates:

```
Deadweight ......................................    136,188   Long Tons
Deadweight (Simulation Units) ...................    305,061   Kips
Overall Length ..................................     889.15   Feet
Length Between Perpendiculars ...................     853.06   Feet
Beam ............................................     144.52   Feet
Moulded Depth ...................................      73.49   Feet

Bulkhead Weight .................................     12,874   Kips
Shell Weight ....................................     40,201   Kips
Bulkhead Weight/Shell Weight ....................       0.32
Lightship Weight ................................     53,075   Kips

Vertical C.G. (VKG) .............................      39.68   Feet

Roll Gyradius (Kxx) .............................      58.81   Feet
Pitch Gyradius (Kyy) ............................     257.84   Feet
Yaw Gyradius (Kzz) ..............................     261.13   Feet

Head-on Superstructure Wind Area ................      6,152   Square Feet
Beam-on Superstructure Wind Area ................      5,841   Square Feet

Bilge Radius ....................................      10.12   Feet
Bilge Keel? (Yes/No) ............................        Yes
```

>>> Full Load Estimates:

```
Draft ...........................................      55.92   Feet
Displacement ....................................    358,136   Kips
Displacement Volume .............................  5,595,870   Cubic Feet
Freeboard .......................................      17.57   Feet
Scale Length ( = Volume^.333) ...................     177.54   Feet
Water Plane Area ................................    109,368   Square Feet

Block Coefficient ...............................      0.812
Waterplane Coefficient ..........................      0.887
Fullness Parameter ("Epsilon") ..................      0.830

Head-On Hull Area - Wind ........................      2,539   Square Feet
Beam-On Hull Area - Wind ........................     14,988   Square Feet
Head-On Total Area - Wind .......................      8,691   Square Feet
Beam-On Total Area - Wind .......................     20,829   Square Feet

Head-On Total Area - Current ....................      8,082   Square Feet
Beam-On Total Area - Current ....................     47,703   Square Feet
```

Tanker Register Model   *SeaSoft Systems*

Tanker: "Britta" (1975 Tanker Register)

>>> Simulation Load Estimates:

```
Draft .......................................      40.00  Feet
Displacement ................................   249,400  Kips
Displacement Volume .........................  3,896,877 Cubic Feet
Cargo Weight ................................   196,326  Kips
Freeboard ...................................      33.49  Feet


Loaded Freeboard/Simulation Freeboard ..........    0.52
Simulation Draft/Loaded Draft ..................    0.72
Simulation Displacement/Loaded Displacement ....    0.70


Water Plane Area ............................   104,073  Square Feet
Block Coefficient ...........................      0.790
Waterplane Coefficient ......................      0.844


Center of Buoyancy (VKB) ....................      20.46  Feet
Center of Gravity (VKG) .....................      37.37  Feet


IWPxx/Delta .................................      42.19  Feet
IWPyy/Delta .................................    1193.48  Feet


Transverse Metacentric Height (KMT) .........      62.65  Feet
Longitudinal Metacentric Height (KML) .......    1213.94  Feet
GMT = KMT - VKG .............................      25.28  Feet
GML = KML - VKG .............................    1176.57  Feet


Cargo Roll Gyradius (Kxx) ...................      46.80  Feet
Cargo Pitch Gyradius (Kyy) ..................     208.96  Feet
Cargo Yaw Gyradius (Kzz) ....................     212.03  Feet


Vessel Roll Gyradius ........................      49.62  Feet
Vessel Pitch Gyradius .......................     220.28  Feet
Vessel Yaw Gyradius .........................     223.38  Feet


Head-On Hull Area - Wind ....................     4,840  Square Feet
Beam-On Hull Area - Wind ....................    28,569  Square Feet
Head-On Total Area - Wind ...................    10,992  Square Feet
Beam-On Total Area - Wind ...................    34,410  Square Feet


Head-On Total Area - Current ................     5,781  Square Feet
Beam-On Total Area - Current ................    34,122  Square Feet
```

Tanker Register Model   *SeaSoft Systems*

Tanker: "Britta" (1975 Tanker Register)

>>> *Simulation Input Stream:*

```
Displacement ...................................  249,400  Kips
Transverse metacentric height (KMT) .............     62.65  Feet
Longitudinal metacentric height (KML) ...........  1213.94  Feet
Vertical center of buoyancy (VKB) ...............     20.46  Feet
Vertical center of gravity (VKG) ................     37.37  Feet
Vessel water plane area .........................  104,073  Square Feet
Length of vessel at waterline ...................   853.06  Feet
Beam of vessel at waterline .....................   144.52  Feet
Vessel draft ....................................    40.00  Feet

Pitch Gyradius ..................................   220.28  Feet
Roll Gyradius ...................................    49.62  Feet
Yaw Gyradius ....................................   223.38  Feet
Bilge radius at maximum beam station ............    10.12  Feet
Is there a bilge keel? (Yes/No).................      Yes

Tanker Load Condition (Draft-Based) .............    71.53  Percent
Tanker Load Condition (Freeboard-Based) .........    52.46  Percent
Tanker Deadweight ...............................  305,061  Kips

Head-on wind effective drag area ................   10,992  Square Feet
Beam-on wind effective drag area ................   34,410  Square Feet

Head-on current effective drag area .............    5,781  Square Feet
Beam-on current effective drag area .............   34,122  Square Feet
```

>>> *Notes:*

```
1. Form Coefficients are based on Lpp
2. When Lpp is unavailable, use Lpp = .95*LOA in required data
3. "Lightship" is without cargo, crew or consumables
4. All displacement values assume seawater density (64.0 lbs/ft^3)
5. Common Load Condition Conventions:
     a. Percent of fully loaded displacement
     b. Percent of fully loaded draft
     c. 100*[Full-load freeboard]/[Simulation freeboard]
```

Output Data Discussion

Aside from their initial (input) pages, which are largely self-explanatory, the output format of the Minimal Data and Tanker Register Models are identical and will be discussed together. The physical property estimates have been combined into several logically connected groups of data with some duplication of information:

1. Selected Property Estimates
2. Lightship Estimates
3. Full Load Estimates
4. Simulation Load Estimates
5. SeaSoft Simulation Input Stream

Page 1: Title, Input and Selected Estimates

The first ("Input") page for both implementations displays, in addition to the input data stream, a self-explanatory short selection of estimated properties for the target vessel. In particular, the "Cargo Weight" can be used iteratively to determine the "Lightship Draft". By varying Simulation Draft, with other input data held constant, the Cargo Weight can be adjusted to near zero, at which point the Simulation Draft will approximate the mean draft of the empty vessel. Two important full load dimensionless form coefficients, the Block Coefficient (Cb) and the Waterplane Coefficient (Cwp), are displayed on this page along with selected hydrostatic and mass distribution variables.

Page 2: Lightship and Full Load Estimates

Physical properties relating to the simulation-independent lightship and full load condition are summarized on this page. Much of this information is *not* required by SeaSoft simulations and is provided only for general interest. Because the lightship and full load conditions are intrinsic to the target vessel and independent of vessel loading, the properties on this page are independent of Simulation Draft.

Although most of the items are self-explanatory, the following limited discussion may be of some reference value:

> 1. Bulkhead and Shell weights comprise the portions of the Lightship Weight respectively proportional to vessel volume and surface area. The ratio of these numbers is used internally for estimation of various mass distribution variables such as VKG's and gyradii.

> 2. Lightship Gyradii are by definition associated with the lightship center of gravity.

> 3. The "Scale Length" parameter is used internally for various scale-sensitive estimates.

> 4. The Block and Waterplane form coefficients are based on the Lpp rather than LOA or any other length measure.

5. The "Fullness Parameter", or "Epsilon", is a measure of the variation in vessel waterplane area with draft; a barge-like vessel whose waterplane area was independent of draft is associated with Epsilon = 1, while a vessel with a "knife-edged" keel whose waterplane vanished at zero draft would have Epsilon = 0. Epsilon is used internally to model the variation with draft of certain hydrostatic properties.

6. "Total" wind areas comprise the sum of the "Hull" and "Superstructure" contributions.

Page 3: Simulation Load Estimates

Page 3 contains physical properties relating to the target vessel in the requested load condition (as determined by the Simulation Draft). Again, much of this information is *not* required by SeaSoft simulations and is provided only for general interest. A brief discussion of selected items follows:

1. The "Cargo Weight" is the difference between the computed "Simulation Displacement" and "Lightship Weight".

2. The Waterplane Area, Block and Waterplane coefficients on this page relate to the displaced volume *at the Simulation Draft* and will differ in general from the full-load values indicated on Page 2.

3. The transverse and longitudinal waterplane moments of inertia ("IWP" in "IWP/Delta") are used in the calculation of Metacentric Heights (KML, KMT). "Delta" here refers to the Displaced Volume at Simulation Draft.

4. "Cargo" gyradii comprise gyradii of the cargo independent of the surrounding vessel; "Vessel" gyradii comprise the net gyradii of Lightship plus Cargo combination.

5. The "Total" wind and current areas refer to a vessel in the Simulation Draft load condition.

Page 4: Simulation Input Stream

A subset of data from Page 3 required for execution of SeaSoft simulations is presented in a single place for convenience.

Appendix C

Theoretical Considerations

Specifying a tanker for model test or simulation purposes requires limited knowledge of:

1. Tanker geometry
2. Tanker & cargo mass and mass distribution

Geometry

If all tankers were "geometrically similar" (or, more succinctly, "similar") then the fundamental dimensionless geometrical quantities (length/beam, length/depth, block coefficient, etc.) would be the same for all vessels and a single parameter such as Length Between Perpendiculars (Lpp) or design deadweight (DWT) would be sufficient to determine precisely every other purely geometrical property (beam, overall length, moulded depth, cross-sectional shapes and areas at any station, displaced volume, etc.). This is, in fact, the basis for scale modeling of vessels in wave-basin test facilities: a single number, the model scale factor, uniquely determines all geometrical properties of the full-scale vessel given those of the model.

Unfortunately for simulation and modeling purposes, all tankers are *not* geometrically similar, although as a group their geometrical similarity is qualitatively far greater than that of seagoing vessels as a whole or of groups which exhibit great design diversity (e.g., semisubmersibles). Lack of perfect similarity means in general that more than a single number is necessary to *perfectly* define all geometrical characteristics of a particular tanker. (Indeed, the *huge* number of "variables" embodied in a comprehensive set of shipyard construction drawings will be required in the most general case.)

On the other hand, it is not in general necessary to duplicate the *exact* geometry of a target vessel, for either simulation or model test, to obtain useful engineering performance estimates. To make progress on simplification it is nonetheless vital to carefully understand what information is required for accurate simulation and what is (relatively) unimportant. In some cases, what matters for wave-frequency simulation may be unimportant for statics or low-frequency dynamical simulation and vice-versa. For example, wave-frequency motions of a vessel are notoriously insensitive to the detailed shape of the bow and stern. This is because "meaningful" waves (i.e., waves which produce vessel motions large enough to be of interest) have very long wavelengths compared to distances over which vessel bow and stern sections change appreciably. Therefore, in estimating first-order response to these waves, the finely crafted bow and stern of a seagoing tanker are little different than the flat ends of a simple box barge.

Although bow and stern shapes may be relatively unimportant for wave-frequency response, they *do* have a significant impact on quasi-static current, wind and wave-drift loads and therefore can be *extremely* important in determining low-frequency motions of a moored vessel or "sailing" properties

of a free-running vessel. Again, however, the *intimate* details of bow and stern shape may be relatively unimportant, while their *qualitative* nature (for example, the relative bluntness or fineness of the bow/stern waterplane geometry) may be very important.

In any event, the infinite geometrical detail comprising construction drawings vastly exceeds the information necessary to produce meaningful engineering performance estimates; this provides a window of opportunity for the development and use of simplified tanker modeling tools such as the SeaSoft Tanker Models.

Mass and Mass Distribution

Once the large-scale geometry of a vessel, characterized by length, beam, draft, bilge radius, etc., has been established, it is necessary in addition to specify vessel mass and mass distribution. These "mass properties" can be reduced, for most purposes, to four independent numbers usually taken to be the displacement and three gyradii (pitch, roll and yaw).

If tankers of various sizes, in addition to being geometrically similar, were constructed of identical materials with perfectly scaled skin and structure thicknesses, the rules of geometrical similarity would apply to the mass and mass distribution of the empty tanker as well; that is, a single number such as the overall length of the vessel would uniquely determine not only its geometrical properties (e.g., beam, draft, etc.) but also its mass and mass distribution (e.g., the gyradii). If all tankers held identical cargo in their geometrically similar cargo bays, the mass and mass properties of the cargo as well would obey the rules of simple geometric similarity. In such a simple world, we would need only provide two numbers to completely specify the most minute dynamical and geometrical properties of a tanker: its length and its load (or any other two independent variables, such as beam and draft, or DWT and displacement, or even roll gyradius and bilge radius).

Unfortunately again, "mass similarity" across tanker sizes could not materialize even if all tankers were geometrically similar with regard to length, beam, depth, etc. This is because the strength of materials does not scale with dimensional changes in a way which permits structures to grow in size at the same rate as the environmental and gravitational forces which the structure must oppose. This is commonly referred to as "the elephant problem" and supplies one reason why animals of size many times greater than elephants have not evolved on land; an elephant scaled up fourfold in all linear dimensions would weigh sixty-four times as much and would require bones of impractical size to support its enormous weight. Ultimately, in fact, the bones *alone* of still greater creatures could not be self-supporting. Tankers and other floating bodies do not have the same size/structure scale mismatch as terrestrial objects, but qualitatively similar considerations apply; in this case there exists a scale-related inconsistency between vessel size and the structural requirements to withstand hydrostatic and wave loads. (In fact, floating bodies have a *favorable* scale mismatch, compared to elephants, in the sense that the structural weight requirement for tankers becomes smaller, relative to cargo capacity, as tanker size is increased. Creatures having evolved *wholly* submerged in a fluid environment require virtually no structural component whatever; their size limitations relate to metabolic and food supply constraints.)

The delightfully interesting theoretical considerations of structural and dimensional scale mismatch aside, in the final analysis existing tankers span a range of lengths that is modest (only a factor of 3 or so). The structural component of total weight for this range of lengths is generally small compared to the cargo component so that "mass similarity" of geometrically similar tankers of different size is qualitatively high, which simplification can be used in modeling.

SeaSoft Models Contrasted

The two SeaSoft tanker models, though related, differ considerably in their fundamental approach to tanker modeling. The Minimal Data Model, which produces estimates for tanker physical properties from knowledge of only the design deadweight (DWT), is a carefully constructed statistical average of tanker properties across a randomly chosen sample of tankers. The "average tanker" is more complex than a simple average of each independent tanker dimension for all tankers in a narrow DWT range, but rather is constructed in a way which preserves certain important geometrical *combinations* that happen to be nearly scale-invariant (the beam-draft product is one example). A statistical model which simply returned the average beam, length and maximum draft for production tankers of a given DWT would not necessarily preserve these combinations. To the extent possible, the Minimal Model takes into account important scale-invariant (or approximately scale-invariant) combinations while at the same time providing good statistical "average" values for the important linear dimensions (beam, length, draft, etc.).

Minimal Data Model

The fact that tankers of widely diverse sizes are reasonably similar in both geometry and mass distribution suggests that a *single parameter* "average tanker" geometry could be usefully constructed. This geometry should be sufficiently sophisticated to vary with tanker size so that the family of "average" tankers would *not* simply be scale models of one another. This model could provide a useful dynamical surrogate when no information for a target tanker other than its deadweight is available.

The *simplest* single-parameter model of a tanker follows from the scaling considerations discussed earlier in this appendix. That is, because volumes, areas and linear dimensions transform under a change of linear scale "s" according to

Full-Load Displacement, DWT, etc. $\propto s^3$

Full-Load Water-Plane Area, Wind Areas, etc. $\propto s^2$

Length, Beam, Full-Load Draft, Moulded Depth, etc. $\propto s^1$,

then once a "fundamental" tanker design is chosen, the dimensions, displacement, and other physical properties of a geometrically similar tanker of any other size can be determined from the scaling formulae. Thus, doubling every linear dimension of a 40,000 ton displacement tanker will produce a geometrically equivalent tanker of 320,000 ton displacement (i.e., $2^3 = 8$ times greater displacement). In this model length ratios, for example, are scale independent.

A more complex single-parameter methodology permits scale-*dependent* length ratios by using the following slightly more elaborate relationships:

Displacement $\propto s^3 xD(s)$,

Water-Plane Area $\propto s^2 xW(s)$,

Length $\propto s^1 xL(s)$, ..., etc.

In this one-parameter representation, the dimensionless quantities D, W, L and so forth represent arbitrary (but presumably slowly varying) functions of the scale s and permit incorporation into our simple model a systematic variation in "average" tanker properties as one goes from the smallest to the largest production tankers. This is the approach taken by the SeaSoft Minimal Data Tanker Model; the family of functions represented by D(s), W(s), and L(s) (and similar functions for each of the remaining tanker properties to be estimated) are developed from a statistical sample of production tankers supplemented by consideration of fundamental theoretical constraints.

In summary, all dynamical and geometrical properties in the Minimal Data Model are completely determined by specifying the Deadweight (DWT) and the Simulation Draft. It must however be emphasized once again that the range of production tanker geometries for a *given* DWT is substantial, so that the Minimal Data Model, while extremely handy, must be used with care. The accompanying figure gives an idea of the scatter about the "Minimal Model" curve in a typical dimensionless variable, the "Length/Draft" ratio. Note that the tanker sample used for this figure comprises only a randomly selected subset of data used to define the "Minimal Model" curves. Note also that the simple linear scaling model discussed at the beginning of this appendix would produce a constant L/D value independent of DWT; the Minimal Data Model, by contrast, reflects a tendency towards systematically declining L/D with increasing DWT.

Selected Tankers & "Minimal Model L/D Comparison
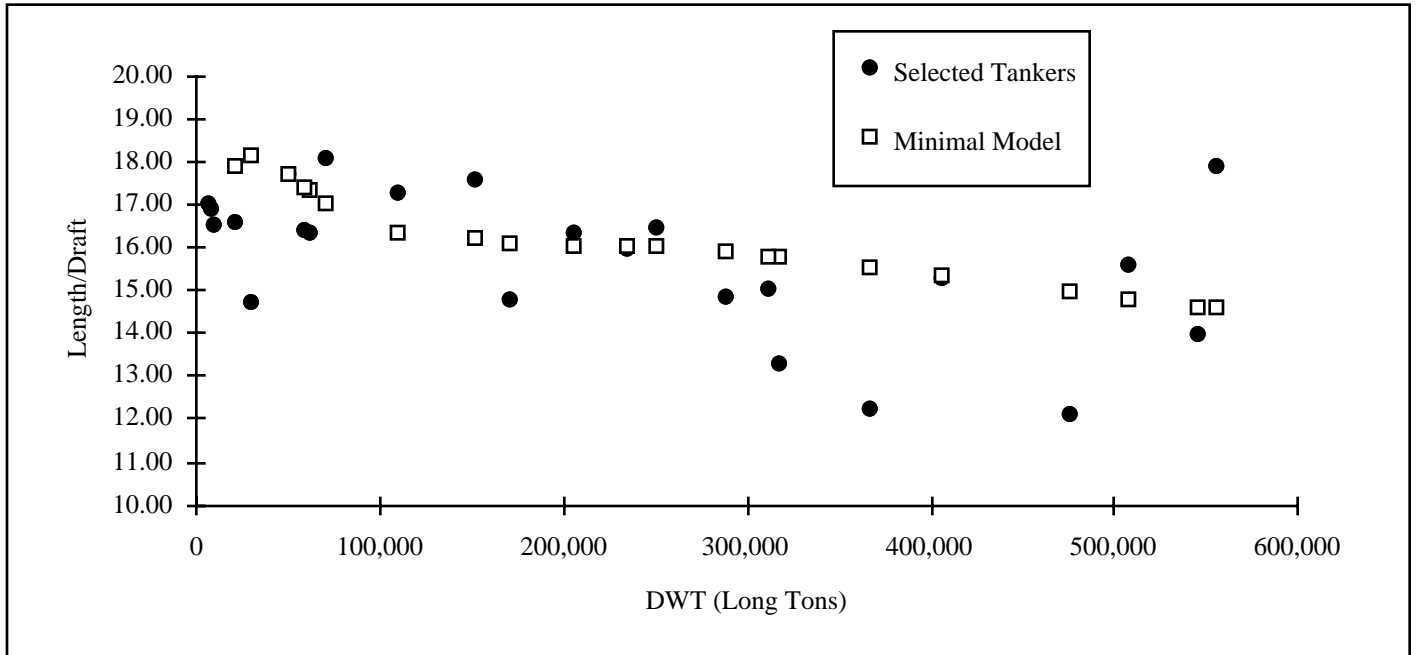
Tanker Register Model

Clearly, physical variations among tankers having identical values for all seven quantities published in The Tanker Register will be *much* less than among tankers having in common only DWT. In fact, the **Register** input data insures that most of the basic dimensionless geometrical ratios of a simulated tanker will be *exactly* represented, since L/B, L/D and Cwp, for instance, are exactly determined by the seven input quantities. It is worth noting that because the block coefficient Cb depends upon full load displacement (which is not published in the **Register**), a lightship estimate must be made before the full load displacement can be computed. Therefore, the block coefficient does not follow directly from data in the **Register** but is rather an estimated quantity. Nonetheless, the **Register** data so narrowly restricts the freedom in the estimation process that the Model block coefficient, and indeed all other SeaSoft estimated variables that do not follow directly from the seven input variables (such as VKG, VKB, KML, KMT, wind and current areas, etc.) are *generously* adequate for preliminary vessel performance estimates.

Appendix D

On-line Tanker Model

A third implementation of the SeaSoft Tanker Model is available, on-line, within the user interface of all relevant SeaSoft mooring and motion simulations. This implementation is analytically identical to the Minimal Data Tanker Model and produces a subset of Minimal Model properties corresponding to the supplied deadweight (as usual, in Long Tons of 2240 pounds) and Simulation Draft. Note that SeaSoft simulation requirements for vessel properties are simulation-dependent; Moorsim®, for example, needs wind and current areas for execution while Shipsim® does not. Because the same tanker help routine is shared by all simulations, not all displayed variables are relevant for every simulation.

Operation of the on-line model is largely self-explanatory; in addition it has an internal on-line help facility. There are only two user-specifiable variables (DWT in Long Tons and Simulation Draft in appropriate simulation units) from which the remaining vessel physical properties are inferred. The on-line window (shown below), which is updated with every change in either input variable, only *displays* estimates; it *does not* transfer data into the simulation data file until specifically so instructed by the user.

```
.>>> Independent variables for     1. Deadweight (DWT).... 100000. Long Tons
     tanker property estimates:    2. Simulation Draft ...  22.00  feet

A. Vessel Displacement      123121. Kips    L. Freeboard-based load...    37.6%
B. Displacement-based load      44.1%       M. Draft-based load.......    46.6%

C. Length (LPP) ..........   799.76         N. Transverse KM .........    80.72
D. Beam ..................   135.81         O. Longitudinal KM .......  2030.93
E. Draft ................    22.00          P. VKB...................    11.97
F. Roll Gyradius.........    56.93          Q. VKG ..................    36.53
G. Pitch Gyradius .......   205.92          R. Bilge radius ..........    6.24
H. Yaw Gyradius ..........  213.64

I. Water Plane Area ......   96876.         W. Deadweight (DWT).......  100000.
J. Head-on Current Area ..    2988.         T. Head-on Wind Area .....   11157.
K. Beam-on Current Area ..   17595.         U. Beam-on Wind Area .....   37922.

>>> Change items 1 or 2 for new estimates or input letter(s) ("ACD...")
    to select individual replacements (or "Z" to replace all);
    "?" for help, <Return> to continue WITHOUT replacement:
```

On-Line Tanker Model Work Window

Moorsim and Shipsim are registered trademarks of SeaSoft Systems

Data Replacement Options:

Options for selecting subsets of the displayed data for simulation use include (i) any single property, (ii) any subset of displayed properties or (iii) all estimated properties. To select a single property for inclusion in the simulation data file, supply the appropriate letter designator at the Screen-bottom prompt (e.g., "A", without the quotation marks). To select *all* properties input "Z" at the prompt. A subset of displayed properties is selected by supplying the desired letter designators with or without a non-letter separator; for example, to transfer to the simulation data file a subset comprising items "A", "C" and "Q" from the displayed estimates, any of the following are acceptable input strings: "ACQ", "A,C,Q", "A-C-Q". Input of letter values to the editor (as always, *without* quotation marks) is case insensitive; "Z" and "z" achieve the same result. A <return> is required at the end of any input string to activate the input process.

On first-time entry to the on-line tanker model facility during a given program execution, the tanker properties initially displayed depend on the value assigned to DWT and draft *prior* to first-time entry. If *either* DWT or draft are zero on entry, displayed variables take on values contained in the data file, if any. Otherwise, the displayed variables take on values associated with the entry [DWT, draft] combination. In this regard, it should be noted that since DWT is *not* required for Shipsim execution (or indeed anywhere *displayed* outside the tanker properties facility), DWT *will* generally be zero on first entry from within Shipsim (unless, perhaps, the data file in use was imported from a simulation, like Moorsim, which *may* contain a nonzero deadweight value).

Full Load and Lightship Data:

For a given DWT, the properties of either the *fully-loaded* vessel or the *lightship* can be obtained from the help facility in the following way:

> To obtain vessel properties associated with the fully loaded vessel, input a draft which is unrealistically large (e.g., 1000 feet or meters). After issuing a nonfatal error message, the facility will, if requested, return properties associated with the full load condition.

> To obtain vessel properties associated with the lightship (zero cargo) condition, input a draft which is unrealistically small (e.g., 1 foot or meter). Again, after issuing an error message the facility will, if requested, return properties associated with the lightship condition.

The minimum size vessel that can be accommodated by the on-line model is 2000 DWT. There is no maximum vessel size, although no tanker larger than about 600,000 DWT has been constructed at this writing.

The "freeboard-based load percentage" is defined as 100 times the ratio [(fully loaded freeboard)/(simulation freeboard)]; other load measures are simple ratios of the simulated quantities to their full load counterparts (e.g., [simulation draft]/[fully loaded draft]).

Appendix E

Execution Errors

Spreadsheet Models

The only execution errors applicable to the spreadsheet tanker models are those caused by physically impossible input data. For example, a Simulation Draft of zero will cause some internal expressions to be invalid due to division by zero or attempted square root of a negative number. The actions required to correct such problems should be readily apparent because of the limited number of input variables.

The Tanker Register Model will display written warning messages on each output page whenever *all* required data has not been supplied. In this regard, note the comments at the end of Chapter 3 regarding unavailability of the required input variable Lpp.

A second class of execution problem is caused by input data which produces physically unrealizable loading conditions *without* causing attempted evaluation of undefined mathematical expressions. In this category would fall an attempt to work with a vessel draft less than lightship draft. In this case a negative cargo weight would be indicated (as would be relevant to a cargo of helium gas). Experimentation with the spreadsheet using physically impossible vessel configurations is considered by some to be a form of sport.

Because the formulae contained in the spreadsheet cells have been locked to prevent inadvertent alteration and the production of incorrect results, any attempt to change these formulae may result in error messages which will differ amongst various spreadsheet applications.

On-Line Model

The On-Line Model is internally protected against unphysical combinations of deadweight and draft. It traps for deadweights outside its range of validity (deadweight less than 2000 Long Tons) and for draft values outside the physically permissible range (Lightship Draft < Draft < Full Load Draft). Combinations of [DWT, Draft] outside the physical range result in a warning message and an option to estimate the "nearest" physically meaningful combination. This capability can be used simply to obtain the Lightship Draft and Full Load Draft as discussed on pages 5 and 20.

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