CONTENTS

1 INTRODUCTION AND OBJECTIVE

The purpose of the workshop is to benchmark the capabilities of different ship manoeuvring simulation methods such as those based on model tests, empirical calculations and CFD based methods by comparison of the results for the each of the following cases: a tanker in two versions, a container ship and a surface combatant. Predictions will be compared to each other and with free model test data. Predictions can be made using provided PMM and CMT (circular motion mechanism/rotating-arm) data. Empirical methods, hybrid methods and CFD based methods will be compared with both PMM/CMT and free model test data.

The comparisons with the free model tests will be blind in the sense that the free model test data will *not* be provided prior to the workshop. Before the workshop, participants can submit predictions, and the organizational committee will assemble all predictions and present the comparisons at the workshop. In order to make this comparison a manageable task, all participants are requested to submit data according to the pre-defined formats defined in this document.

The objective of the workshop is:

- To give feedback to participants on how their manoeuvring prediction method performs with respect to other prediction methods and in particular with respect to the 'ultimate results' i.e. in this case: the free model tests.
- To establish a platform in which one can freely discuss the used methods with other open-minded participants.

2 SET-UP AND PHILOSOPHY, MANOEUVRING PREDICTION METHODS

Participants should make manoeuvring predictions for one or more ships using one or more of the many methods that exist. The ships are described in section 3.1. An overview of (some of) the steps involved in different manoeuvring prediction methods is described in Figure 1.

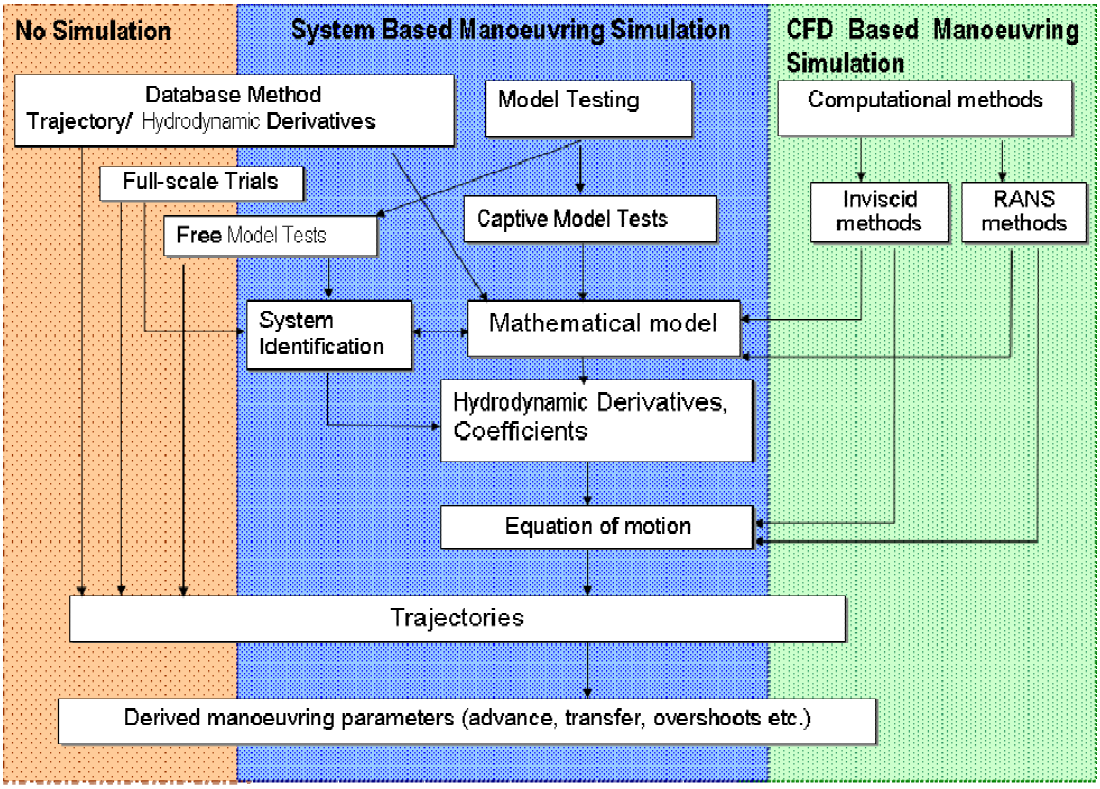

Figure 1: Overview of possible steps involved in manoeuvring predictions

In principle, there are many ways to make predictions. The following seven methods – at least – can be identified:

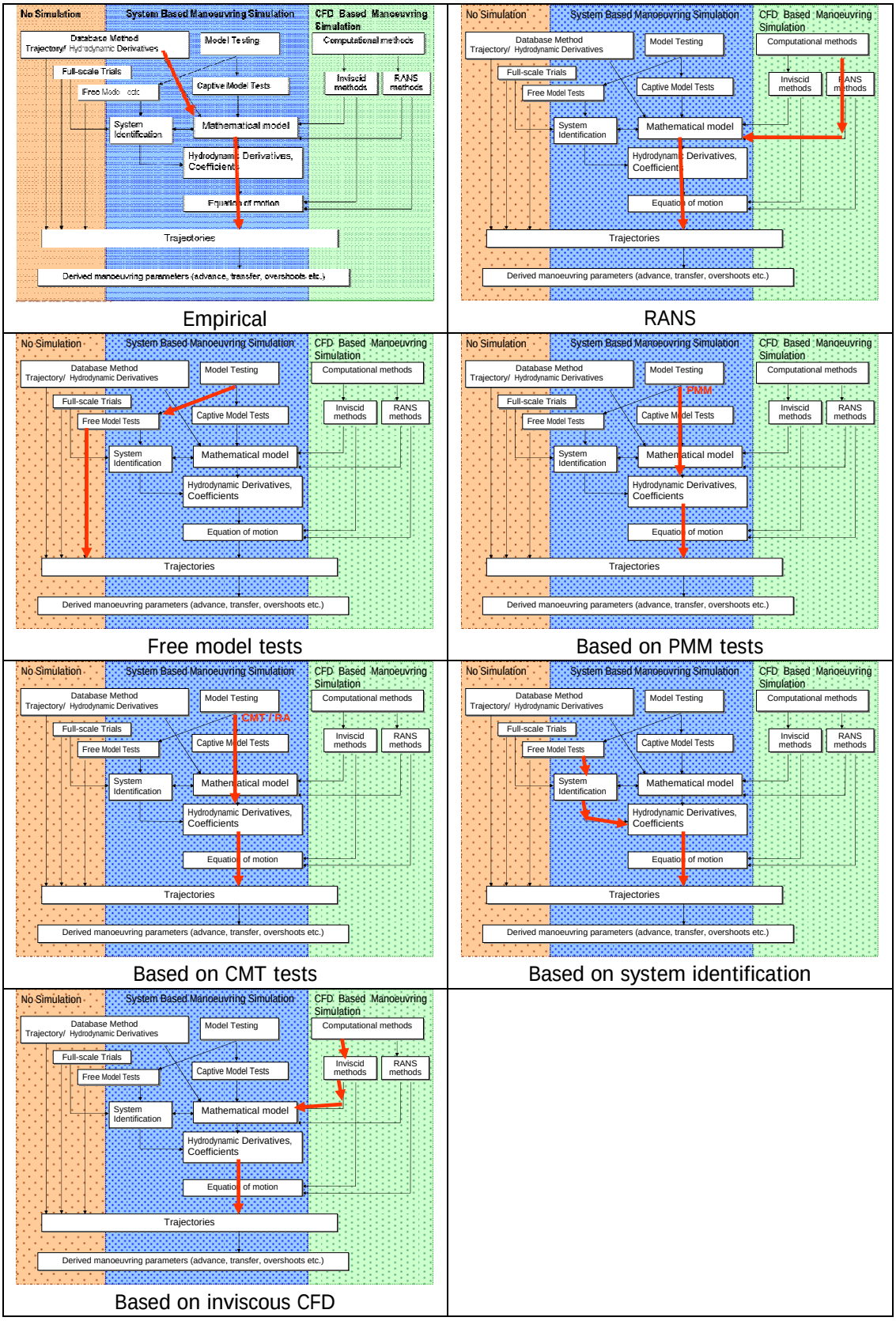

Figure 2: Exmples of different methods for prediction of manoeuvres

3 SHIPS AND MANOEUVRES

3.1 Selectable ships

The participants can select one or more of the following ships:

Name	Ship type
KVLCC1	Full block single screw tanker, barge type stern with relatively V-shaped lines
KVLCC2	Identical to KVLCC1 but with more U-shaped stern lines
KCS	Single screw container ship
5415	Twin screw naval combatant

Table 1: Selectable ships

The necessary data for these ships is available on the website www.simman2008.dk. Here lines plans, hydrostatic data and data of appendages including rudders and propellers can be downloaded.

3.2 Manoeuvres to be simulated

The participants are asked to make simulations of the following manoeuvres:

- 10/10 deg zig-zag tests including at least the first two overshoots with first execute of rudder to both port and starboard[1]
- 20/20 deg zig-zag tests including at least the first two overshoots with first execute of rudder to both port and starboard
- 35 deg turning circle tests with rudder to both port and starboard including pull-out, where rudder is put back at 0 deg after steady state has been reached
- 5, 10 and 20 deg turning circle tests with rudder to both port and starboard

Simulations should be performed for the speeds and test conditions given in the following table:

	Approach speed	Froude number[2]	Helm rate	Propeller RPM corresponding to self-propulsion point of	RPM strategy during manoeuvre	Corresp. captive test series (PMM / CMT)
KVLCC1 KVLCC2	15.5 kn	0.142	2.32 deg/s	model	const. RPM (optionally also const. torque)	INSEAN / NMRI
KCS	24.0 kn	0.260	2.32 deg/s	model	const. torque (optionally also const. RPM)	CEHIPAR / NMRI
5415	30.0 kn (optionally also 18.0 kn)	0.413 (optionally also 0.248)	9.0 deg/s	model (optionally also ship)	const. RPM (optionally also const. torque)	FORCE[3]

Table 2: Speeds and test conditions for manoeuvring simulations

These simulations will be compared with the results of the corresponding free model tests.

[1] Positive rudder angles make ship turn to port; negative rudder angles make ship turn to starboard.

[2] Froude number based on Lpp.

[3] NB. ship self-propulsion point

4 PROCEDURES

This chapter describes what the participants have to submit prior to the workshop. Naturally, each organization can participate with several methods and is also welcome to make predictions for more than one ship.

Participants should submit 3 types of data files as follows:

For each predicted manoeuvre:

1. Time series of positions and motions i.e. time varying values of ship position, velocities, rudder angle and propeller RPM, referred to as the "motion file".
2. Time series of separate hull, rudder and propeller forces during the manoeuvre, referred to as the "force file".

To document the mathematical model:

3. Tables of total hydrodynamic forces (hull + propeller + rudder) used in the mathematical model, referred to as the "table file".

When making comparisons, it will be difficult to understand why the different methods are giving different results. This cannot be done solely by comparison of the time series of motions and forces. Instead it is the intention to compare the hydrodynamic forces used in the different mathematical models, which is the reason for including type no. 3.

If it is not possible (for example due to restraints in the prediction program) to submit all 3 types of data, participants should at least submit time series of the motions (type 1).

All data files are to be supplied in ASCII format, either a comma separated file or a fixed format file. The data files should be prepared as described in the following sections.

4.1 General

4.1.1 Definitions

The following definitions are used:

total ship speed: $V_s = \sqrt{u^2 + v^2}$, where u is longitudinal velocity and v is transverse velocity

drift angle: $\beta = -a\tan\frac{v}{u}$

rate of turn: $\gamma = r' = \frac{r \cdot L_{pp}}{V_s}$

4.1.2 Coordinate system and sign convention

The general coordinate system is ship-fixed, horizontal and right-handed with the z-axis downwards. The origin is defined at midships, on the centerline and at the waterline. This means that the forces are positive for: X-force forwards, Y-force to starboard, K-moment starboard into the water and N-moment bow to starboard.

The ship position (x_0,y_0) should be given in an Earth-fixed coordinate system with x_0 pointing North and y_0 pointing East. Heading angle at start of manoeuvre is defined as 0 deg.

All angles are defined positive clockwise i.e. heading positive for bow to starboard; rudder angle positive to portside.

4.1.3 Scale and units

Prediction data should be submitted in full scale values. Note that no scale effect corrections should be made on the resistance (or other forces) i.e. only Froude scaling should be applied. This enables direct comparison of results based on different model sizes.

SI units should be used throughout (i.e. m, m/s, etc). Exceptions are angles in degrees and propeller revolutions in RPM.

4.2 Naming of data files

The name of data files should be: *organisation_method_ship_manoeuvre_rudder_type.dat*

where:

manoeuvre	is 'tc' for turning circle or 'zz' for zig-zag
rudder	is the applied rudder angle
type	is 'm' for motion time series, 'f' for force time series or 't' for tables of forces

For example:

HSVA_PMM_KVLCC1_tc_-35_m.dat	indicates HSVA's file of motions based on PMM for the KVLCC1 in a turning circle test with -35 degrees (starboard) rudder angle.
MARIN_EMP-MPP_5415_zz_10_f.dat	indicates MARIN's file of hull, rudder and propeller forces based on an empirical prediction using the code MPP for the 5415 in a zig-zag test with 10 degrees rudder (and heading change) angles.
NMRI_CMT_KCS_tc_5_t.dat	indicates NMRI's file of tabular hydrodynamic forces based on CMT tests for the KCS for a turning circle test with 5 degrees rudder angle.

The following code names should be used for the different methods:

PMM	for manoeuvres predicted based on the analysis of PMM tests
CMT	for manoeuvres predicted based on the analysis of rotating arm / circular motion tests
EMP-xxyy	for manoeuvres predicted using an empirical method "xxyy"
NONV-zz	for manoeuvres predicted using a CFD method based on the non-viscous code "zz"
RANS-TD	for manoeuvres predicted using a full time domain RANS CFD method
RANS-COEF	for manoeuvres predicted using a RANS CFD method for determination of hydrodynamic derivatives for subsequent use in simulations
SI	for manoeuvres predicted based on system identification: the analysis of free model tests and the prediction of other free model tests from them
FREE	for free model test results (benchmark)

4.3 Contents of data files

4.3.1 Type 1 – Time series of positions and motions

The "motion file" with time series of motions should have the following layout:

- The first 4 lines are comment lines, where the participant should identify the contents of the file.

- Below follows a block of columns containing the time series data in the order given in Table 3.

Column	Symbol	Unit	Meaning	Reference
1	t	s	time	manoeuvre starts at zero i.e. the rudder starts to move at t=0. Time step for example 0.5 s (full scale).
2	x	m	x-position	position of ship origo[4] in Earth-fixed coordinate system (North). t=0 should conform to x=0. The starting track means that the ship moves along the x-axis.
3	y	m	y-position	position of ship origo in Earth-fixed coordinate system (East). t=0 should conform to y=0.
4	phi	deg	heel angle	starboard side in the water is a positive
5	psi	deg	heading angle	bow to starboard is positive
6	u	m/s	long. velocity	speed through the water of ship origo
7	v	m/s	transv. velocity	speed through the water of ship origo
8	p	deg/s	roll velocity	ship origo, starboard downwards is positive
9	r	deg/s	yaw velocity	ship origo, bow towards starboard is positive
10	delta	deg	rudder angle	trailing edge to portside is positive
11	n	RPM	prop. revolutions	positive clockwise seen from aft

Table 3: List of columns in "motion file"

An example of a (section of a) data file with time series of motions is given in Appendix I.

4.3.2 Type 2 – Time series of hull, rudder and propeller forces

The "force file" with time series of hull, rudder and propeller forces should have the following layout:

- The first 4 lines are comment lines, where the participant should identify the contents of the file.

- Below follows a block of columns containing the time series data in the order given in Table 4.

Column	Symbol	Unit	Meaning	Reference
1	t	s	time	manoeuvre starts at zero i.e. the rudder starts to move at t=0. Time step for example 0.5 s (full scale).
2,3,4,5	Xh,Yh,Kh,Nh	kN/kNm	hull forces and moments	contribution of total forces/moments originating from the hull, in ship-fixed, horizontal coord. system
6,7,8,9	Xr,Yr,Kr,Nr[5]	kN/kNm	rudder forces and moments	contribution of total forces/moments originating from the rudder, in ship-fixed, horizontal coord. system
10,11,12,13	Xp,Yp,Kp,Np	kN/kNm	propeller forces and moments	contribution of total forces/moments originating from the propeller, in ship-fixed, horizontal coord. system

[4] Origo of ship: intersection between midships, centerline and waterline.

[5] Note that for the twin screw ship (5415) columns nos. 6-13 should refer to the starboard side and corresponding columns for the port side should be added as columns nos. 14-21.

Table 4: List of columns in "force file".

4.3.3 Type 3 – Tables of total hydrodynamic forces

The "table file" containing tables of total hydrodynamic forces should have the following layout:

The first 4 lines are comment lines, where the participant should identify the contents of the file.

Below follows 3 x 4 (X, Y, K, N) tables containing the total hydrodynamic force/moment in kN/kNm for the appended hull (hull + propeller + rudder) in the self-propulsion state at the approach speed. The 3 sets of tables are the combinations of:

1 drift angle (β) and rate of turn (γ)
2 drift angle (β) and rudder angle (δ)
3 rate of turn (γ) and rudder angle (δ)

Here the ranges should be: β from -20 to 20 deg in steps of 2 deg
γ from -1.0 to 1.0 in steps of 0.2
δ from -35 to 35 deg in steps of 5 deg

An example of a (section of a) file with tabular hydrodynamic forces is given in appendix II.

4.4 Upload of data

Participants should supply the data files by uploading them to the FORCE Technology FTP server. Data files should be placed in the folder 'simman2008-submit' in a sub-folder with the participant's name. Login instructions and deadline for submission is given on the website www.simman2008.dk.

5 PRESENTED RESULTS AT THE WORKSHOP

It is the intention to compare and discuss various aspects at the workshop. Prior to the workshop the organizers will prepare comparison plots for every submitted ship/manoeuvre/method and the results will be presented and discussed.

5.1 Plots of time series of motions

The following plots will be generated:

- Ship position x_0 versus y_0
- Time series of δ, r, ϕ , β, V_s and sin β/γ
- β versus γ

The free model test results will be used as benchmark data on these plots.

5.2 Plots of time series of hull, rudder and propeller forces

Time series of hull, rudder and propeller forces and moments will be plotted against each other to see where differences occur between the various prediction methods and, where available, also against the free model tests results that were carried out with rudder- and/or propeller force measurements.

5.3 Plots of hydrodynamic forces

The hydrodynamic forces and moments will be plotted against drift angle, turn rate and rudder angle to see where differences occur between the predictions and the PMM/CMT test results.

APPENDIX I: EXAMPLE OF FILE WITH TIME SERIES OF MOTIONS

```
Organisation N, Empirical method XXYY
KCS container vessel
Zig-zag manoeuvre :  10.0 / -10.0
Time series of motions
0         0.00E+00  0.00E+00  0.00E+00  0.00E+00  5.14E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  4.14E+02
0.5       2.57E+00  9.76E-06  1.23E-04  -4.80E-05 5.14E+00  7.66E-05  4.81E-04  -3.17E-04 1.16E+00  4.14E+02
1         5.14E+00  1.02E-04  5.44E-04  -4.38E-04 5.14E+00  3.66E-04  1.15E-03  -1.36E-03 2.32E+00  4.14E+02
1.5       7.72E+00  3.63E-04  1.22E-03  -1.51E-03 5.14E+00  8.78E-04  1.53E-03  -3.05E-03 3.48E+00  4.14E+02
2         1.03E+01  8.67E-04  2.05E-03  -3.59E-03 5.14E+00  1.62E-03  1.76E-03  -5.35E-03 4.64E+00  4.14E+02
2.5       1.29E+01  1.68E-03  2.96E-03  -6.96E-03 5.14E+00  2.58E-03  1.88E-03  -8.22E-03 5.80E+00  4.14E+02
3         1.54E+01  2.84E-03  3.92E-03  -1.19E-02 5.14E+00  3.77E-03  1.93E-03  -1.16E-02 6.96E+00  4.14E+02
3.5       1.80E+01  4.39E-03  4.87E-03  -1.87E-02 5.14E+00  5.19E-03  1.84E-03  -1.55E-02 7.93E+00  4.14E+02
4         2.06E+01  6.35E-03  5.72E-03  -2.74E-02 5.15E+00  6.77E-03  1.54E-03  -1.96E-02 8.60E+00  4.14E+02
4.5       2.32E+01  8.69E-03  6.39E-03  -3.83E-02 5.14E+00  8.47E-03  1.11E-03  -2.38E-02 9.05E+00  4.14E+02
5         2.57E+01  1.14E-02  6.83E-03  -5.12E-02 5.14E+00  1.02E-02  6.82E-04  -2.79E-02 9.35E+00  4.13E+02
5.5       2.83E+01  1.43E-02  7.08E-03  -6.61E-02 5.14E+00  1.21E-02  3.05E-04  -3.19E-02 9.56E+00  4.13E+02
6         3.09E+01  1.75E-02  7.15E-03  -8.30E-02 5.14E+00  1.39E-02  -1.07E-05 -3.57E-02 9.70E+00  4.13E+02
6.5       3.34E+01  2.07E-02  7.08E-03  -1.02E-01 5.14E+00  1.58E-02  -2.64E-04 -3.95E-02 9.80E+00  4.13E+02
7         3.60E+01  2.41E-02  6.89E-03  -1.23E-01 5.14E+00  1.77E-02  -4.60E-04 -4.30E-02 9.86E+00  4.13E+02
7.5       3.86E+01  2.74E-02  6.63E-03  -1.45E-01 5.14E+00  1.96E-02  -6.06E-04 -4.65E-02 9.91E+00  4.13E+02
8         4.12E+01  3.06E-02  6.29E-03  -1.69E-01 5.14E+00  2.15E-02  -7.12E-04 -4.97E-02 9.94E+00  4.13E+02
8.5       4.37E+01  3.37E-02  5.92E-03  -1.95E-01 5.14E+00  2.34E-02  -7.86E-04 -5.29E-02 9.96E+00  4.13E+02
9         4.63E+01  3.65E-02  5.51E-03  -2.22E-01 5.14E+00  2.53E-02  -8.34E-04 -5.59E-02 9.97E+00  4.13E+02
9.5       4.89E+01  3.90E-02  5.09E-03  -2.51E-01 5.14E+00  2.72E-02  -8.63E-04 -5.89E-02 9.98E+00  4.13E+02
10        5.14E+01  4.12E-02  4.65E-03  -2.81E-01 5.14E+00  2.90E-02  -8.77E-04 -6.17E-02 9.99E+00  4.13E+02
10.5      5.40E+01  4.29E-02  4.21E-03  -3.12E-01 5.14E+00  3.09E-02  -8.81E-04 -6.44E-02 9.99E+00  4.13E+02
11        5.66E+01  4.40E-02  3.77E-03  -3.45E-01 5.14E+00  3.28E-02  -8.77E-04 -6.71E-02 9.99E+00  4.13E+02
11.5      5.92E+01  4.46E-02  3.34E-03  -3.79E-01 5.14E+00  3.46E-02  -8.68E-04 -6.97E-02 1.00E+01  4.13E+02
12        6.17E+01  4.46E-02  2.91E-03  -4.15E-01 5.14E+00  3.64E-02  -8.56E-04 -7.22E-02 1.00E+01  4.13E+02
12.5      6.43E+01  4.38E-02  2.48E-03  -4.51E-01 5.14E+00  3.82E-02  -8.41E-04 -7.47E-02 1.00E+01  4.13E+02
13        6.69E+01  4.23E-02  2.07E-03  -4.89E-01 5.14E+00  4.00E-02  -8.26E-04 -7.71E-02 1.00E+01  4.13E+02
13.5      6.94E+01  3.99E-02  1.66E-03  -5.29E-01 5.14E+00  4.18E-02  -8.10E-04 -7.94E-02 1.00E+01  4.13E+02
14        7.20E+01  3.66E-02  1.26E-03  -5.69E-01 5.14E+00  4.36E-02  -7.93E-04 -8.17E-02 1.00E+01  4.13E+02
14.5      7.46E+01  3.24E-02  8.63E-04  -6.10E-01 5.14E+00  4.53E-02  -7.78E-04 -8.40E-02 1.00E+01  4.13E+02
15        7.72E+01  2.72E-02  4.78E-04  -6.53E-01 5.14E+00  4.71E-02  -7.62E-04 -8.62E-02 1.00E+01  4.13E+02
15.5      7.97E+01  2.09E-02  1.01E-04  -6.96E-01 5.14E+00  4.88E-02  -7.47E-04 -8.84E-02 1.00E+01  4.13E+02
16        8.23E+01  1.35E-02  -2.69E-04 -7.41E-01 5.14E+00  5.05E-02  -7.33E-04 -9.05E-02 1.00E+01  4.13E+02
16.5      8.49E+01  4.90E-03  -6.33E-04 -7.87E-01 5.14E+00  5.22E-02  -7.20E-04 -9.26E-02 1.00E+01  4.13E+02
17        8.74E+01  -4.93E-03 -9.89E-04 -8.34E-01 5.14E+00  5.39E-02  -7.07E-04 -9.47E-02 1.00E+01  4.13E+02
17.5      9.00E+01  -1.60E-02 -1.34E-03 -8.82E-01 5.14E+00  5.55E-02  -6.95E-04 -9.67E-02 1.00E+01  4.13E+02
18        9.26E+01  -2.85E-02 -1.68E-03 -9.30E-01 5.14E+00  5.72E-02  -6.84E-04 -9.88E-02 1.00E+01  4.13E+02
18.5      9.51E+01  -4.24E-02 -2.02E-03 -9.80E-01 5.14E+00  5.88E-02  -6.73E-04 -1.01E-01 1.00E+01  4.13E+02
19        9.77E+01  -5.77E-02 -2.36E-03 -1.03E+00 5.14E+00  6.04E-02  -6.63E-04 -1.03E-01 1.00E+01  4.13E+02
19.5      1.00E+02  -7.45E-02 -2.69E-03 -1.08E+00 5.14E+00  6.20E-02  -6.53E-04 -1.05E-01 1.00E+01  4.13E+02
20        1.03E+02  -9.28E-02 -3.01E-03 -1.14E+00 5.14E+00  6.36E-02  -6.43E-04 -1.07E-01 1.00E+01  4.13E+02
20.5      1.05E+02  -1.13E-01 -3.33E-03 -1.19E+00 5.14E+00  6.52E-02  -6.34E-04 -1.09E-01 1.00E+01  4.13E+02
21        1.08E+02  -1.34E-01 -3.64E-03 -1.24E+00 5.14E+00  6.67E-02  -6.26E-04 -1.10E-01 1.00E+01  4.13E+02
21.5      1.11E+02  -1.58E-01 -3.96E-03 -1.30E+00 5.14E+00  6.82E-02  -6.18E-04 -1.12E-01 1.00E+01  4.13E+02
22        1.13E+02  -1.83E-01 -4.26E-03 -1.36E+00 5.14E+00  6.97E-02  -6.10E-04 -1.14E-01 1.00E+01  4.13E+02
22.5      1.16E+02  -2.10E-01 -4.57E-03 -1.41E+00 5.14E+00  7.13E-02  -6.02E-04 -1.16E-01 1.00E+01  4.13E+02
23        1.18E+02  -2.38E-01 -4.86E-03 -1.47E+00 5.14E+00  7.27E-02  -5.94E-04 -1.18E-01 1.00E+01  4.13E+02
23.5      1.21E+02  -2.69E-01 -5.16E-03 -1.53E+00 5.14E+00  7.42E-02  -5.87E-04 -1.19E-01 1.00E+01  4.13E+02
24        1.23E+02  -3.01E-01 -5.45E-03 -1.59E+00 5.14E+00  7.57E-02  -5.80E-04 -1.21E-01 1.00E+01  4.13E+02
24.5      1.26E+02  -3.36E-01 -5.74E-03 -1.65E+00 5.14E+00  7.71E-02  -5.73E-04 -1.23E-01 1.00E+01  4.13E+02
25        1.29E+02  -3.73E-01 -6.03E-03 -1.71E+00 5.14E+00  7.85E-02  -5.67E-04 -1.25E-01 1.00E+01  4.13E+02
25.5      1.31E+02  -4.11E-01 -6.31E-03 -1.78E+00 5.14E+00  7.99E-02  -5.60E-04 -1.26E-01 1.00E+01  4.13E+02
26        1.34E+02  -4.52E-01 -6.59E-03 -1.84E+00 5.14E+00  8.13E-02  -5.54E-04 -1.28E-01 1.00E+01  4.13E+02
26.5      1.36E+02  -4.95E-01 -6.86E-03 -1.91E+00 5.14E+00  8.27E-02  -5.48E-04 -1.30E-01 1.00E+01  4.13E+02
27        1.39E+02  -5.40E-01 -7.13E-03 -1.97E+00 5.14E+00  8.41E-02  -5.41E-04 -1.31E-01 1.00E+01  4.13E+02
27.5      1.41E+02  -5.87E-01 -7.40E-03 -2.04E+00 5.14E+00  8.54E-02  -5.35E-04 -1.33E-01 1.00E+01  4.13E+02
28        1.44E+02  -6.37E-01 -7.67E-03 -2.10E+00 5.14E+00  8.68E-02  -5.29E-04 -1.34E-01 1.00E+01  4.13E+02
28.5      1.47E+02  -6.89E-01 -7.93E-03 -2.17E+00 5.14E+00  8.81E-02  -5.24E-04 -1.36E-01 1.00E+01  4.13E+02
29        1.49E+02  -7.44E-01 -8.19E-03 -2.24E+00 5.14E+00  8.94E-02  -5.18E-04 -1.38E-01 1.00E+01  4.13E+02
29.5      1.52E+02  -8.00E-01 -8.45E-03 -2.31E+00 5.13E+00  9.07E-02  -5.12E-04 -1.39E-01 1.00E+01  4.13E+02
30        1.54E+02  -8.60E-01 -8.70E-03 -2.38E+00 5.13E+00  9.20E-02  -5.07E-04 -1.41E-01 1.00E+01  4.13E+02
30.5      1.57E+02  -9.22E-01 -8.96E-03 -2.45E+00 5.13E+00  9.33E-02  -5.01E-04 -1.42E-01 1.00E+01  4.13E+02
31        1.59E+02  -9.86E-01 -9.20E-03 -2.52E+00 5.13E+00  9.45E-02  -4.96E-04 -1.44E-01 1.00E+01  4.13E+02
31.5      1.62E+02  -1.05E+00 -9.45E-03 -2.59E+00 5.13E+00  9.58E-02  -4.90E-04 -1.45E-01 1.00E+01  4.13E+02
32        1.65E+02  -1.12E+00 -9.70E-03 -2.67E+00 5.13E+00  9.70E-02  -4.85E-04 -1.47E-01 1.00E+01  4.13E+02
32.5      1.67E+02  -1.20E+00 -9.94E-03 -2.74E+00 5.13E+00  9.82E-02  -4.80E-04 -1.48E-01 1.00E+01  4.13E+02
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APPENDIX II: EXAMPLE OF FILE WITH TABULAR FORCES

Organisation N, Empirical method XXYY
KCS container vessel
Hydrodynamic forces
Drift angle and Rate of turn, Y-force

	-1.00	-0.80	-0.60	-0.40	-0.20	0.00	0.20
-20.0	3.45E+06	2.33E+06	1.93E+06	1.64E+06	1.43E+06	1.28E+06	1.21E+06
-18.0	2.84E+06	1.97E+06	1.64E+06	1.38E+06	1.19E+06	1.06E+06	1.03E+06
-16.0	2.27E+06	1.65E+06	1.38E+06	1.15E+06	9.74E+05	8.63E+05	8.61E+05
-14.0	1.76E+06	1.36E+06	1.14E+06	9.38E+05	7.82E+05	6.90E+05	7.13E+05
-12.0	1.31E+06	1.10E+06	9.28E+05	7.48E+05	6.10E+05	5.39E+05	5.81E+05
-10.0	8.99E+05	8.70E+05	7.38E+05	5.80E+05	4.59E+05	4.09E+05	4.64E+05
-8.0	5.38E+05	6.63E+05	5.65E+05	4.31E+05	3.27E+05	2.98E+05	3.60E+05
-6.0	2.22E+05	4.74E+05	4.06E+05	2.97E+05	2.13E+05	2.04E+05	2.70E+05
-4.0	-5.42E+04	2.99E+05	2.58E+05	1.76E+05	1.17E+05	1.25E+05	1.91E+05
-2.0	-2.95E+05	1.35E+05	1.19E+05	6.33E+04	3.46E+04	5.77E+04	1.16E+05
0.0	-5.06E+05	-2.00E+04	-1.47E+04	-4.34E+04	-4.17E+04	0.00E+00	4.17E+04
2.0	-5.41E+05	-1.53E+05	-1.41E+05	-1.45E+05	-1.16E+05	-5.77E+04	-3.46E+04
4.0	-6.02E+05	-2.88E+05	-2.65E+05	-2.44E+05	-1.91E+05	-1.25E+05	-1.17E+05
6.0	-6.88E+05	-4.26E+05	-3.87E+05	-3.42E+05	-2.70E+05	-2.04E+05	-2.13E+05
8.0	-7.98E+05	-5.65E+05	-5.08E+05	-4.38E+05	-3.60E+05	-2.98E+05	-3.27E+05
10.0	-9.29E+05	-7.05E+05	-6.27E+05	-5.36E+05	-4.64E+05	-4.09E+05	-4.59E+05
12.0	-1.08E+06	-8.46E+05	-7.44E+05	-6.42E+05	-5.81E+05	-5.39E+05	-6.10E+05
14.0	-1.24E+06	-9.88E+05	-8.65E+05	-7.62E+05	-7.13E+05	-6.90E+05	-7.82E+05
16.0	-1.42E+06	-1.13E+06	-9.91E+05	-8.96E+05	-8.61E+05	-8.63E+05	-9.74E+05
18.0	-1.60E+06	-1.28E+06	-1.13E+06	-1.04E+06	-1.03E+06	-1.06E+06	-1.19E+06
20.0	-1.79E+06	-1.43E+06	-1.28E+06	-1.21E+06	-1.21E+06	-1.28E+06	-1.43E+06

Organisation N, Empirical method XXYY
KCS container vessel
Hydrodynamic forces
Drift angle and Rate of turn, N-moment

	-1.00	-0.80	-0.60	-0.40	-0.20	0.00	0.20
-20.0	1.84E+08	1.24E+08	1.00E+08	8.05E+07	6.36E+07	4.89E+07	3.58E+07
-18.0	1.60E+08	1.11E+08	9.07E+07	7.24E+07	5.62E+07	4.23E+07	3.14E+07
-16.0	1.38E+08	9.91E+07	8.13E+07	6.46E+07	4.93E+07	3.63E+07	2.71E+07
-14.0	1.18E+08	8.77E+07	7.24E+07	5.70E+07	4.27E+07	3.07E+07	2.30E+07
-12.0	9.92E+07	7.72E+07	6.37E+07	4.97E+07	3.65E+07	2.56E+07	1.90E+07
-10.0	8.26E+07	6.74E+07	5.54E+07	4.25E+07	3.05E+07	2.08E+07	1.51E+07
-8.0	6.79E+07	5.83E+07	4.74E+07	3.55E+07	2.48E+07	1.64E+07	1.14E+07
-6.0	5.51E+07	4.98E+07	3.99E+07	2.87E+07	1.92E+07	1.22E+07	7.72E+06
-4.0	4.42E+07	4.20E+07	3.27E+07	2.23E+07	1.38E+07	8.16E+06	4.11E+06
-2.0	3.50E+07	3.48E+07	2.60E+07	1.63E+07	8.71E+06	4.12E+06	2.30E+05
0.0	2.75E+07	2.81E+07	1.98E+07	1.08E+07	4.00E+06	0.00E+00	-4.00E+06
2.0	2.84E+07	2.29E+07	1.42E+07	5.83E+06	-2.30E+05	-4.12E+06	-8.71E+06
4.0	2.85E+07	1.79E+07	9.05E+06	1.29E+06	-4.11E+06	-8.16E+06	-1.38E+07
6.0	2.81E+07	1.33E+07	4.43E+06	-2.76E+06	-7.72E+06	-1.22E+07	-1.92E+07
8.0	2.73E+07	9.22E+06	3.93E+05	-6.30E+06	-1.14E+07	-1.64E+07	-2.48E+07
10.0	2.61E+07	5.61E+06	-3.05E+06	-9.39E+06	-1.51E+07	-2.08E+07	-3.05E+07
12.0	2.49E+07	2.62E+06	-5.86E+06	-1.23E+07	-1.90E+07	-2.56E+07	-3.65E+07
14.0	2.37E+07	2.86E+05	-8.12E+06	-1.52E+07	-2.30E+07	-3.07E+07	-4.27E+07
16.0	2.27E+07	-1.38E+06	-9.94E+06	-1.81E+07	-2.71E+07	-3.63E+07	-4.93E+07
18.0	2.20E+07	-2.43E+06	-1.15E+07	-2.10E+07	-3.14E+07	-4.23E+07	-5.62E+07
20.0	2.18E+07	-2.91E+06	-1.30E+07	-2.39E+07	-3.58E+07	-4.89E+07	-6.36E+07