REPORT

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MV Estonia Manoeuvring tests and Bow Ramp Flooding tests	4006 4100-1 Project manager Björn Allenström
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Manoeuvring tests in calm water and in waves, and flooding tests through the bow ramp, have been carried out both in upright and heeled conditions with a model of MV Estonia in SSPA manoeuvring and seakeeping basin (MDL). The tests in waves were performed in irregular sea at different speeds and wave directions with complete ship model and with partly and fully open ramp.

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SUMMARY

Manoeuvring tests in calm water and in waves, and flooding tests through the bow ramp, have been carried out both in upright and heeled conditions with a model of MV Estonia in SSPA manoeuvring and seakeeping basin (MDL). The tests in waves were performed in irregular sea at different speeds and wave directions with complete ship model and with partly and fully open ramp.

The results from the manoeuvring tests will form the base for the planned manoeuvring simulations concerning the initial phase of the foundering of the ship. It can however be concluded that the calm water manoeuvring tests indicated good manoeuvring properties.

The bow ramp flooding tests indicated that the flooding was very sensitive to speed. Also heading and heel angles have a significant influence on the flooding, as well as trim. The tests indicated that initial flooding in the order of 2000-2500 tons/min could be expected with a fully open bow ramp in high speed and heeled condition. With only a gap of one meter in the upper part of the ramp the inflow was only 65 tons/min.

1 SHIP AND MODEL PARTICULARS

The hull model 3191-A was manufactured in carbon fibre according to information from the Joint Accident Investigation Commission final report [1] and from Meyer Werft.

Model scale is 1:40.00. The model is shown in Figure 1 to 4 in Appendix C.

The length of the forward bilge keels is 35.2 m (#7.95 to #13.07) and the aft bilge keels 13.6 m (#5.38 to #7.36). The span of the bilge keels is 0.6 m.

The main data of the ship at the tests are given below.

Table 1: Main data of MV Estonia

		Ship	Model
Lbp	[m]	137.4	3.435
Beam	[m]	24.2	0.605
Draft, aft	[m]	5.61	0.140
Draft, fwd	[m]	5.17	0.129
Displacement	[tonnes]	12 046	0.1864
Block coefficient	[-]	0.683	0.683
LCB (fwd of Lbp/2)	[m]	-4.66	-0.116
LCB (% rel Lbp/2)	[%]	-3.39	-3.39
VCG	[m]	10.62	0.2655
GM (corrected)	[m]	1.17	0.0292
Radius of gyration (kxx)	[m]	8.954 (0.37*B)	0.224
Radii of gyration (kyy/kzz)	[m]	37.1 (0.27*Lbp)	0.928
Rudders:			
Area (one rudder), movable	[m^2]	8.75	
Area (one rudder), total	[m^2]	10.85	
Rudder height	[m]	4.00	
% of Lbp · T per rudder	[%]	2.93	
Rudder rate	[°/sec]	2.321	
Max rudder angle	[°]	35	

SSPA stock propeller models were used at the tests:

Table 2: SSPA stock propeller data

Diameter (model scale)	0.1044 m
Diameter (full scale)	4.18 m
No of blades, Z	4
Pitch P/D at 0.7R	0.806
Blade area ratio	0.611

The water depth corresponded to 102 m in full scale at the tests.

2 TEST ARRANGEMENT AND INSTRUMENTATION

The manoeuvring and seakeeping tests were carried out in the Maritime Dynamics Laboratory (MDL).

MDL has a basin with the dimensions 88 m x 39 m with variable water depth up to 3 m. At these tests the water depth was 2.55 m. Wave generators for regular and irregular long-crested waves are installed on two perpendicular sides of the basin. A multi-motion carriage, used for data logging and model control, spans the whole basin.

The tests were carried out with a free-running (free-sailing) model. In a free-running test the model is accelerated by the carriage and at the proper speed the model is disconnected from the carriage and continues self-propelled with constant propeller revolution and controlled by an autopilot. The model is then free to move in all six degrees of freedom.

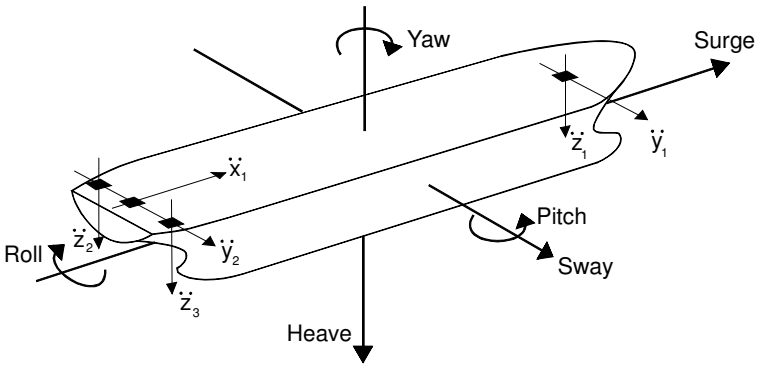
Measured signals from the model are transferred to the carriage via a light-weight measuring arm which does not influence the model motions. Control signals from the arm are directly linked to the carriage control computer and data logging system. The carriage is controlled to hunt the model.

Measurements

- Wave height
- Ship speed
- Propeller rate of revolution port & starboard
- Rudder angle
- Surge, sway, heave, roll, pitch, yaw
- One video camera showing the bow from aside and one from above. (The video cameras were mounted on the carriage)

The following right-handed co-ordinate system and sign conventions are used:

Parameter	**Positive for**
Wave height	Downwards
Surge	Forwards
Sway	To starboard
Heave	Downwards
Roll	Starboard down
Pitch	Bow up
Yaw	Bow to starboard



Sign conventions

2.1 Data handling

The signals from the gauges were sampled with a frequency of 50 Hz in model scale corresponding to 7.9 Hz in full scale.

All seakeeping tests were recorded with video cameras, one showing a side view of the bow part and one showing the bow from above.

Some still photos of the bow and stern were also taken.

2.2 Statistics

2.2.1 Irregular waves

Statistical analysis of all measured signals includes min, mean, max and significant values according to:

Number of samples = N

Measured signal x_i (i= 1,2,3... N)

Minimum value $x_{min} < x_i$ (i= 1,2,3... N)

Mean value $\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$

Maximum value $x_{max} > x_i$ (i= 1,2,3... N)

Significant single amplitude $2 \cdot \sigma$

-"- double amplitude $4 \cdot \sigma$

where $\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2$

All significant values of measured signals are given as significant single amplitudes except wave height, which is given as significant double amplitude.

Zero crossing period

Suppose the total number of zero up crossings is nc+1 = t_0 , t_1 ... t_{nc} then the zero crossing period, T_z is estimated according to:

$$T_z = (t_{nc} - t_0)/nc$$

3 WAVES

The tests were carried out in irregular waves in a wave spectrum of JONSWAP type.

The spectral density for a JONSWAP wave spectrum is given by:

$$S(\omega) = k * A * B * \omega^{-5} * e^{-B*\omega^{-4}} * \gamma^{e^{-\frac{1}{2\sigma^2}(0.159*\omega*Tp-1)^2}}$$

where	ω = wave frequency	[rad/s]
	$A = 0.25 * (H_{1/3})^2$	[m^2]
	$B = 691/(T_1)^4$	[$1/s^4$]
	$H_{1/3}$ = sign. wave height	[m]
	T_P = peak wave period	[s]
	$T_1 = 0.772 * T_P$	[s]
	$\sigma = 0.07$ for $\omega < 2\pi/T_P$	
	$\sigma = 0.09$ for $\omega \geq 2\pi/T_P$	

For a standard JONSWAP spectrum which was used here $\gamma = 3.3$ and $k = 0.658$.

The spectrum parameters at the tests are:

Significant wave height,	$H_{1/3}$:	4.3 m
Peak wave period,	Tp:	8.3 s

The wave spectra were measured in the middle of the basin without the model in the basin. Measured and theoretical spectra are shown in Figure 1. The left figure shows the results from the wave makers on the long side and the right figure from the wave makers on the short side. At the tests the wave heights were measured with a wave probe in front of the model.

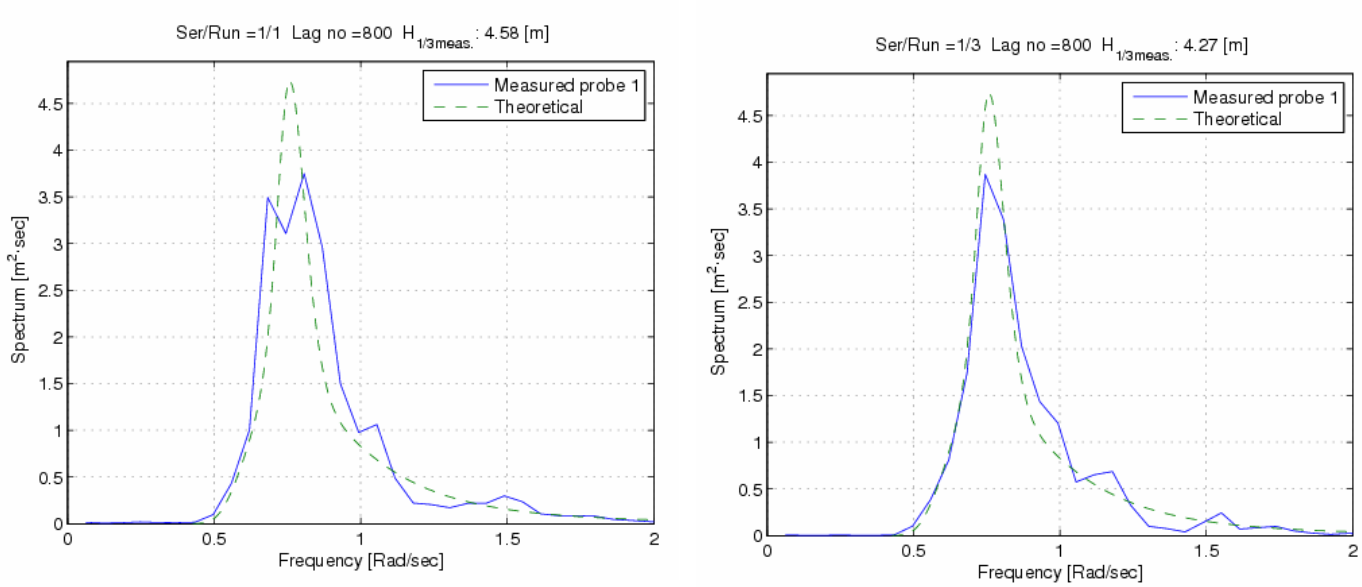


Figure 1: *Results from wave calibrations*

4 TESTS CARRIED OUT

4.1 Speed calibration in calm water

The tests started with runs in calm water to determine the proper propeller rate at various speeds.

4.2 Manoeuvring tests

Turning circle and zigzag tests were carried out both in calm water and in waves. The main purpose with these tests was to give support to the mathematical model in the subsequent simulations. The test program for the manoeuvring tests is shown below.

Table 3: Manoeuvring tests in calm water - Test program (Series 2)

Run [No]	Type of test	Initial speed [knots]		Rudder angle	Course angle [deg]	Heel angle [deg]
		Nom.	Meas.			
41	Turning circle	14.5	14.5	SB35	-	0
40	"	"	14.5	P35	-	"
26	"	"	14.2	P30	-	SB25
25	Straight course	"	14.3	0	-	SB25
35	Zigzag	"	14.3	SB10	10	0
36	"	"	14.3	P10	10	"
37	"	"	14.4	SB20	20	"
38	"	"	14.3	P20	20	"

Table 4: Drift tests in waves ($H_{1/3}$: 4.3 m T_p: 8.3 s) – Test program (Series 2)

Run [No]	Type of test	Initial speed [knots]	Wave direction [deg]	Heel angle [deg]
14	Drift	0	180	SB25
15	"	"	"	"

The drift tests started in a wave direction close to head sea. At Run 14 the bow of the model turned to starboard and at Run 15 the bow turned to port.

Table 5: Manoeuvring tests in waves ($H_{1/3}$: 4.3 m T_p: 8.3 s) - Test program (Series 2)

Run [No]	Type of test	Initial speed [knots]		Rudder angle	Wave direction [deg]	Heel angle [deg]
		Nom.	Meas.			
13	Zero rudder	7.0	6.7	0	150	SB25
12	"	10.0	9.5	"	"	"
11	Turning test	7.0	6.8	P20	"	"
8	"	10.0	9.0	"	"	"
34	"	12.0	12.0	"	"	"
7	"	4.0	4.0	P30	"	"
6	"	7.0	6.0	"	"	"
9	"	10.0	9.0	"	"	"

At the turning tests in waves the rudder angle was put to 0° when 180° change of course angle was achieved.

4.3 Roll decay tests

Roll decay test were carried out in calm water at 0 and 14.5 knots, see Figure 2.
From the recorded decay curves the damping coefficients may be derived from the decrease of motion amplitude for the successive oscillations. Also natural period may be derived from these tests.

The roll decay may be described by:

$$\ddot{\phi} + 2\zeta\omega_0\dot{\phi} + \omega_0^2\,\phi + d\dot{\phi}\,|\dot{\phi}| = 0$$

where ζ is the linear damping ratio
ω_0 is the natural frequency
and d is the non-linear damping

At the evaluation of the roll decay tests the non-linear damping is assumed to be 0 and the successive damping ratios between the n:th and the n+1 amplitude are calculated. The damping ratios are thus calculated according to the expression below.

$\xi = \ln(\phi_n/\phi_{n+1})/2\pi$

where

ξ = damping ratio
ϕ_n = roll amplitude at n:th roll/pitch oscillation
ϕ_{n+1} = roll amplitude at n+1:th roll/pitch oscillation
ln = natural logarithm

Time histories from the roll decay tests at 0 and 14.5 knots are shown below:

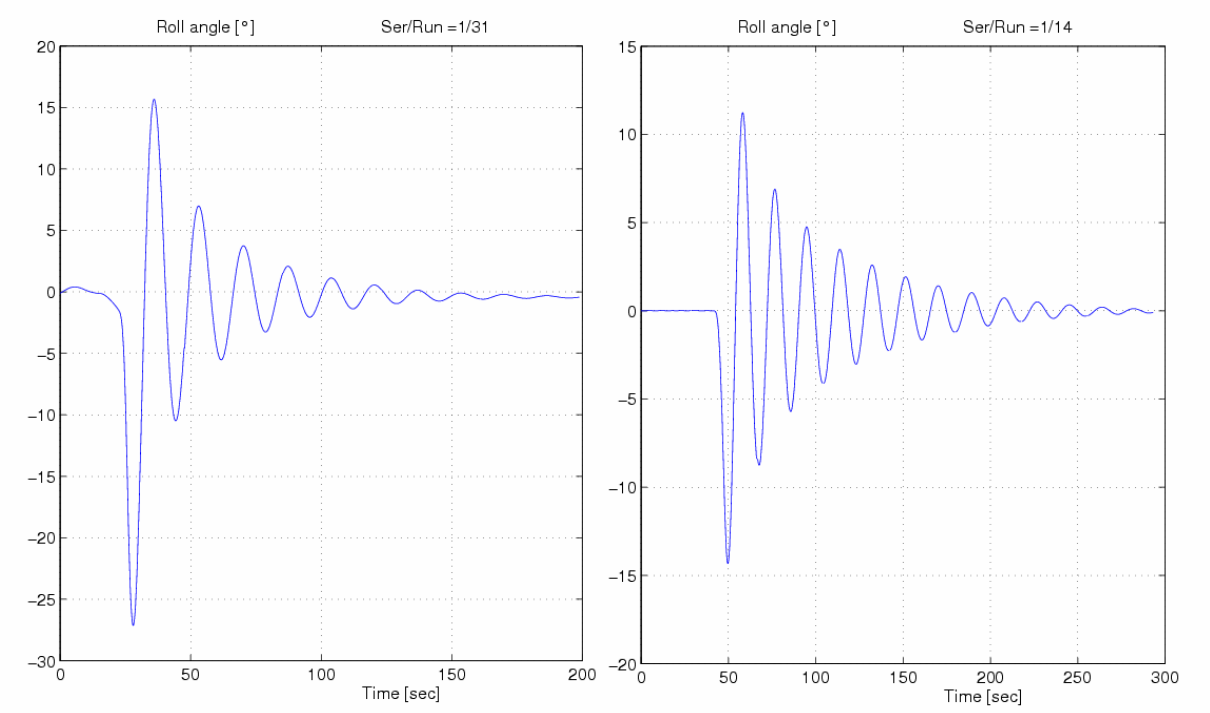


Figure 2: *Results from roll decay tests at 0 and 14.5 knots*

The roll damping and natural roll period are:

Table 6: Results from roll decay tests

Speed Knots	Natural period T_ϕ [sec]	Mean damping, ζ [-]
0	18.74	0.055
14.5	16.67	0.093

The magnitude of the roll damping factor is normal for a RoRo ship.

4.4 Tests in irregular waves with visor and closed bow ramp

The model tests in irregular waves with visor and closed bow ramp were carried out according to the test program in Table 7 below. The significant wave height was 4.3 m and the peak wave period was 8.3 in all tests.

Table 7: Test program at seakeeping tests (Series 2)

Run [No]	Trim [m]	Speed [knots]	Wave dir. [deg]	Visor/ramp	Heel angle [deg]
14	0	0.0	180	On/Closed	25 (SB)
15	"	"	"	"	"
28	"	12.0	180	"	"
29	"	"	"	"	"
30	"	"	150	"	"
31	"	"	"	"	"
32	"	"	120	"	"
33	"	"	"	"	"
43	"	14.5	180	"	0
44	"	"	150	"	"
45	"	"	"	"	"
46	"	"	"	"	"
47	"	"	"	"	"
48	"	"	120	"	"

To get more reliable statistical values some runs were repeated as the table above shows.

4.5 Tests in irregular waves without visor and open bow ramp

The model tests in irregular waves without visor and with partly or completely open bow ramp were carried out according to the test program in Table 8 below. The significant wave height was 4.3 m and the peak wave period was 8.3 in all tests.

At the tests the bow ramp was opened when the recordings started and closed when the recordings stopped. During the tests the water was momentarily pumped into a container. When the recordings stopped and

the ramp was closed all remaining water were pumped out into the container. The container was then weighted to determine the amount of water that flooded the model. A sketch of the pump arrangement is shown in Figure 3 below. Initial tests were carried out in the towing tank at SSPA in head sea only. From these tests it was discovered that the inflow at high speeds were higher than expected. Therefore the model was equipped with one extra pump. The main pump was placed in the pit, while the extra pump was placed behind the pit.

Table 8: Test program at initial inflow tests (Series 3)

Run [No]	Trim [m]	Speed [knots]	Wave dir. [deg]	Bow ramp opening	Heel angle [deg]
3	0	10.0	180	1 m	0
5	"	"	"	"	"
7	"	"	165	"	"
9	"	"	150	"	"
11	"	5.0	"	"	"
13	"	14.5	"	"	"
15	"	10.0	180	Completely open	"
19	"	"	"	"	"
22	"	"	165	"	"
24	"	"	"	"	"
26	"	"	150	"	"
28	"	"	"	"	"
30	"	5.0	"	"	"
32	"	12.0	"	"	"
34	"	5.0	"	"	"
42	1.0 m by bow	10.0	"	"	"
44	"	5.0	"	"	"
48	1.0 m by stern	"	"	"	"
51	0.0	"	180	"	25 (SB)
53	"	10.0	"	"	"
55	"	"	"	"	"
57	"	8.5	165	"	"
59	"	"	150	"	"
61	"	"	"	"	"

Some of the runs in the table above were repeated in order to see if the amount of ingressed water was the same.

The wave direction of the vessel is defined as the angle between the direction of wave propagation and the vessel's bow.

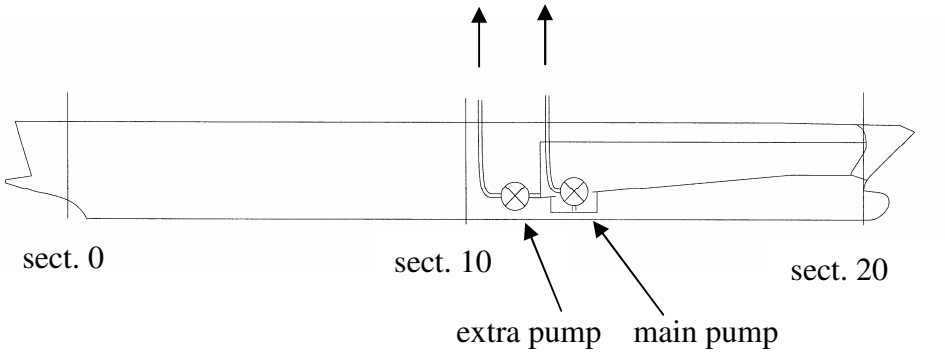


Figure 3. *Sketch of pump arrangement for the inflow tests*

5 RESULTS

5.1 Manoeuvring tests

5.1.1 Manoeuvring tests in calm water

The results from the manoeuvring tests in calm water are concluded in tables below together with recommendations in IMO standards. The approach speed is 14.5 knots in all tests:

Table 9: Results of turning circle tests, Port & Stbd 30°

Condition	IMO	Heel angle: 0°			Heel angle: SB25°
Starting to		Stbd	Port	Mean	Port
Advance/L_{bp}	4.5	3.58	3.61	2.60	2.27
Transfer/L_{bp}		1.17	1.20	1.18	1.16
Tactical Diameter/L_{bp}	5.0	2.97	3.01	2.98	2.49
Steady Turn Diam/L_{bp}		2.76	2.87	2.82	2.09

Table 10: Results of 10°/10° Zig-Zag tests

Condition	IMO	Heel angle: 0°		
Starting to		Stbd	Port	Mean
1st Overshoot angle [°]	14.2	8.0	8.6	8.3
2nd Overshoot angle [°]	29.2	10.5	10.7	10.6
Initial turning ability/L_{bp}	2.5	1.73	1.45	1.59
Period [s]		186	186	186
Time to 2nd execute [s]		32.5	27.1	29.8
Time to check yaw [s]		23.0	23.4	23.2

Table 11: Results of 20°/20° Zig-Zag tests

Condition	IMO	Heel angle: 0°		
Starting to		Stbd	Port	Mean
1st Overshoot angle [°]	25	16.7	16.6	16.6
2nd Overshoot angle [°]	-	17.3	18.5	17.9
Initial turning abilitty/L_{bp}	2.5	1.73	1.67	1.70
Period [s]		194	194	194
Time to 2nd execute [s]		33.0	31.9	32.4
Time to check yaw [s]		24.3	24.7	24.5

The manoeuvring results in calm water show that the recommendations in IMO standards are fulfilled in all tests.

5.2 Water flow through the bow ramp opening

The tests carried out to determine the water ingress at the bow ramp are shown in the Table 12 below. In addition to these test some initial tests were carried out in the towing tank at SSPA, then only in head sea and in upright condition. During these tests the model were towed. The tests were carried out at 5, 10 and 12 knots with a measured water ingress of 216, 514 and 908 tons/min resp. All tests were carried out with 4.3 m significant wave height and period 8.3 s (peak).

It should be stressed the measured inflow represents the initial inflow, i.e. since all water flow down into a pit and was momentarily pumped out, the influence on trim and sinkage from the water that flooded the model was assumed to be negligible. However, for two test runs, No. 32 and 42, the pumps didn't manage to keep the pit empty during the test run why these values must be taken with care due to an increase in forward trim.

Table 12: Initial flow of ingressed water (Series 3)

Run [No]	Trim [m]	Speed (nom.) [knots]	Speed (meas.) [knots]	Wave dir. [deg]	Bow ramp opening	Heel angle [deg]	Initial flow [tons/min]
3	0	10.0	9.35	180	1 m	0	32.2
5	"	"	10.70	"	"	"	36.1
7	"	"	9.60	165	"	"	38.6
9	"	"	9.63	150	"	"	46.6
11	"	5.0	4.13	"	"	"	18.0
13	"	14.5	13.39	"	"	"	64.2
15	"	10.0	9.89	180	Completely open	"	540.0
19	"	"	10.32	"	"	"	526.7
22	"	"	9.74	165	"	"	589.4
24	"	"	9.85	"	"	"	626.7
26	"	"	9.78	150	"	"	705.7
28	"	"	9.77	"	"	"	709.9
30	"	5.0	5.33	"	"	"	342.1
32	"	12.0	11.36	"	"	"	1108.9*
34	"	5.0	5.62	"	"	"	380.1
42	1.0 m by bow	10.0	9.28	"	"	"	1050.7*
44	"	5.0	5.56	"	"	"	482.9
48	1.0 m by stern	"	5.56	"	"	"	214.8
51	0.0	"	5.35	180	"	25 (SB)	355.2
53	"	10.0	8.01	"	"	"	553.2
55	"	"	8.73	"	"	"	615.5
57	"	8.5	8.70	165	"	"	641.5
59	"	"	8.56	150	"	"	654.6
61	"	"	8.77	"	"	"	661.8

* The capacity of the pumps was not sufficient enough to keep the model on nominal mean trim.

Looking at the inflow at head sea (180 deg.) the agreement between the towing tank and the MDL is very good. Also when repeating tests in MDL the values are quite similar, see Figure 4 below.

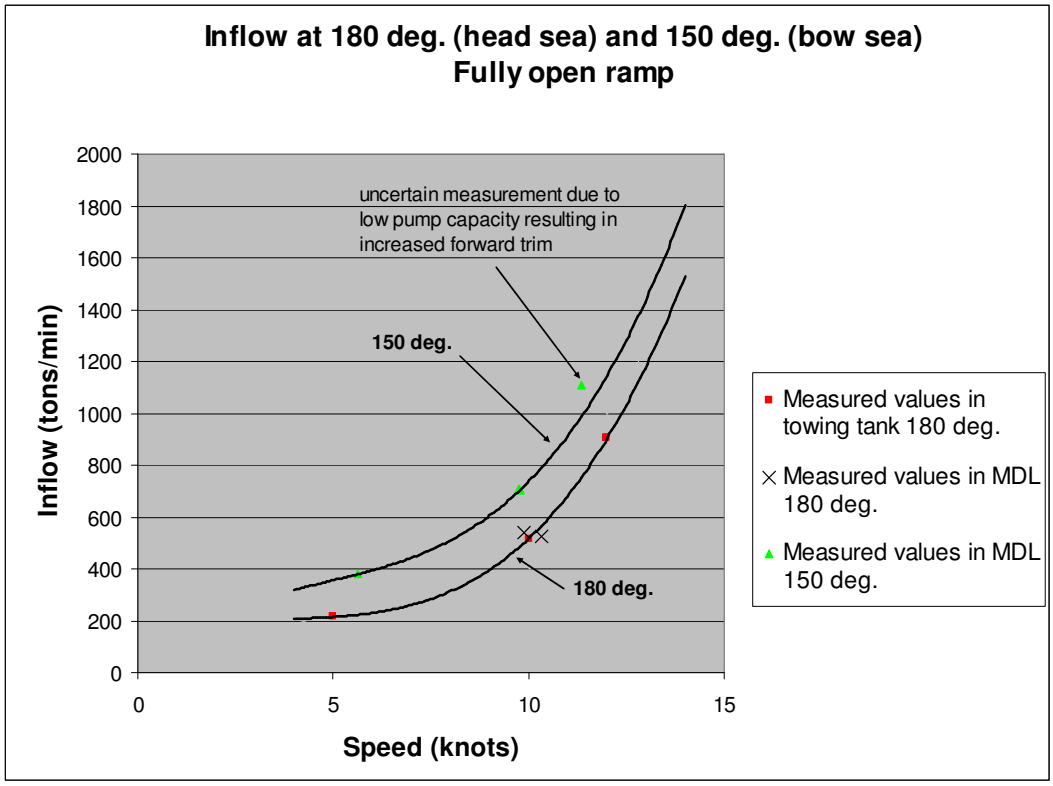


Figure 4: *Initial inflow at 180 deg. and 150 deg. heading (head and bow sea)*

In Figure 4 also the initial inflow at 150 deg. heading is shown. As can be seen the inflow here is some 50% higher compared to head sea at low speeds. The main reason for this is that the pitch motion is higher at 150 deg. The increase in pitch motion is in the same order as the increase in inflow. The measurement at 11.36 knots must be regarded as uncertain because of the lack of pump capacity. From Figure 16 in Appendix B it can be seen that the mean pitch angle is about 0.25 degrees higher than normal. This corresponds to about 0.5 m forward trim. Knowing that 1 m forward trim increases the inflow by roughly 25%, the curve extrapolated from 5 and 10 knots is at a trustworthy level at 11-12 knots.

The influence of heading is also shown in Figure 5 below.

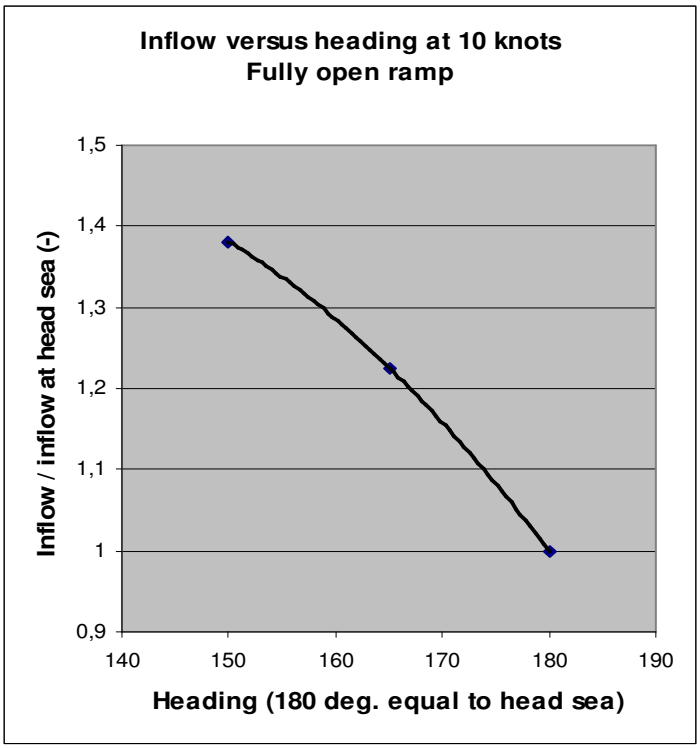


Figure 5: *Initial inflow versus heading at 10 knots*

The initial inflow, going from 180 deg. (head sea) to 150 deg. (bow sea), is increasing almost linear.

Tests were also carried out to see the influence of trim. These tests were carried out to give a guidance to the coming simulations. As explained above, all tests carried out are aimed at showing the initial inflow, since the pumps are momentarily pumping out the water that flows into the model. Taking into the account the possibilities that the water in reality stays in the forebody of the ship alternatively flows back to the aftbody of the ship, some tests with static trim were planned at 1 m forward and aft trim respectively for 10 knots. However, the influence of forward trim was significant, so the tests could not be performed at higher speed than 5-6 knots, not exceeding the pump capacity, see Figure 6 below.

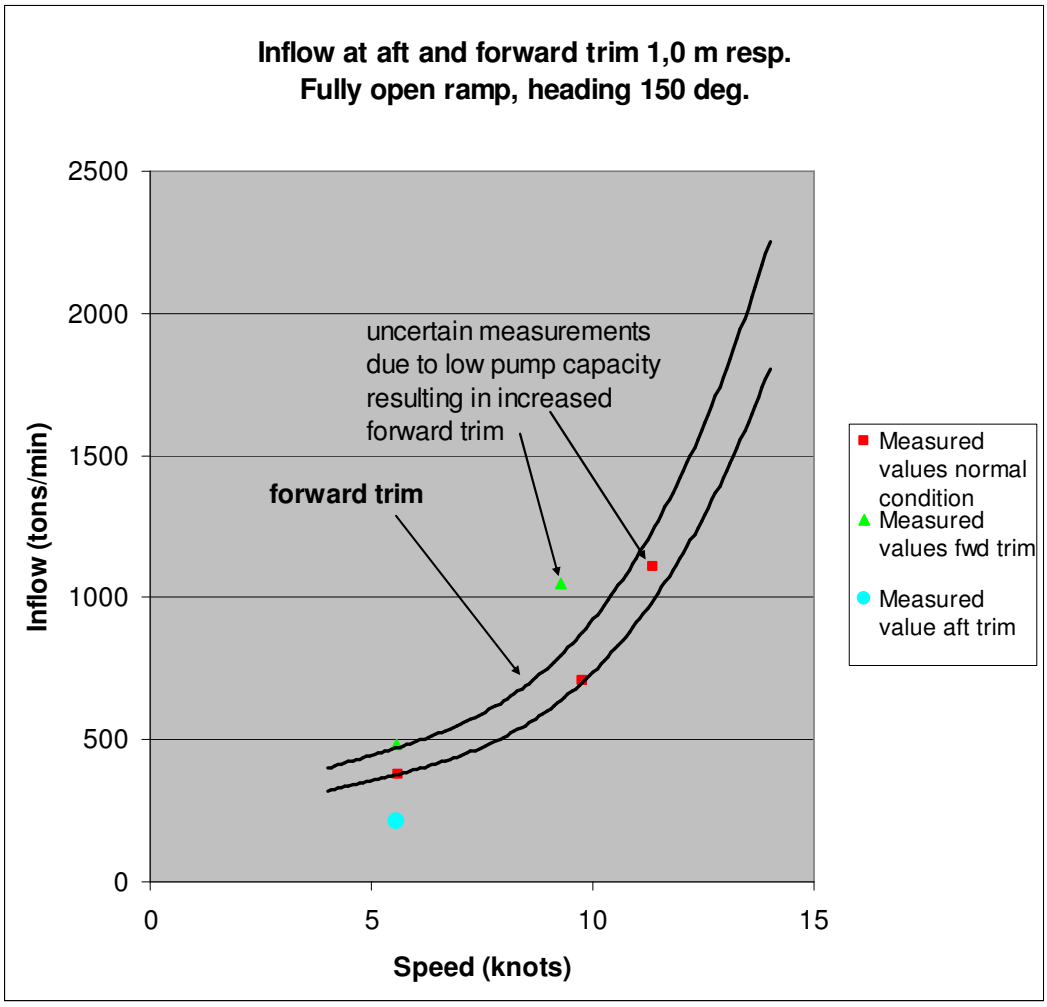


Figure 6: *Initial inflow at forward and aft trim*

The curve presented for forward trim is therefore only based on the measurement at 5.5 knots. Here, the increase in inflow due to forward trim is about 25 %, a figure that also has been used for higher speeds. Looking at Figure 17 in Appendix B it can be seen that the mean pitch angle for the measured value at 9.3 knots is around 0.5 deg. lower than at normal condition. Looking at the diagram the curve is therefore to be regarded as conservative rather than indicating a too high value. Nevertheless, the measurements strongly indicate that trim has a major influence on inflow. Going from 1 m aft trim to 1 m forward trim, the initial inflow more than doubles in the 5 knots region.

Also the influence of heel angle was studied, see Figure 7 below.

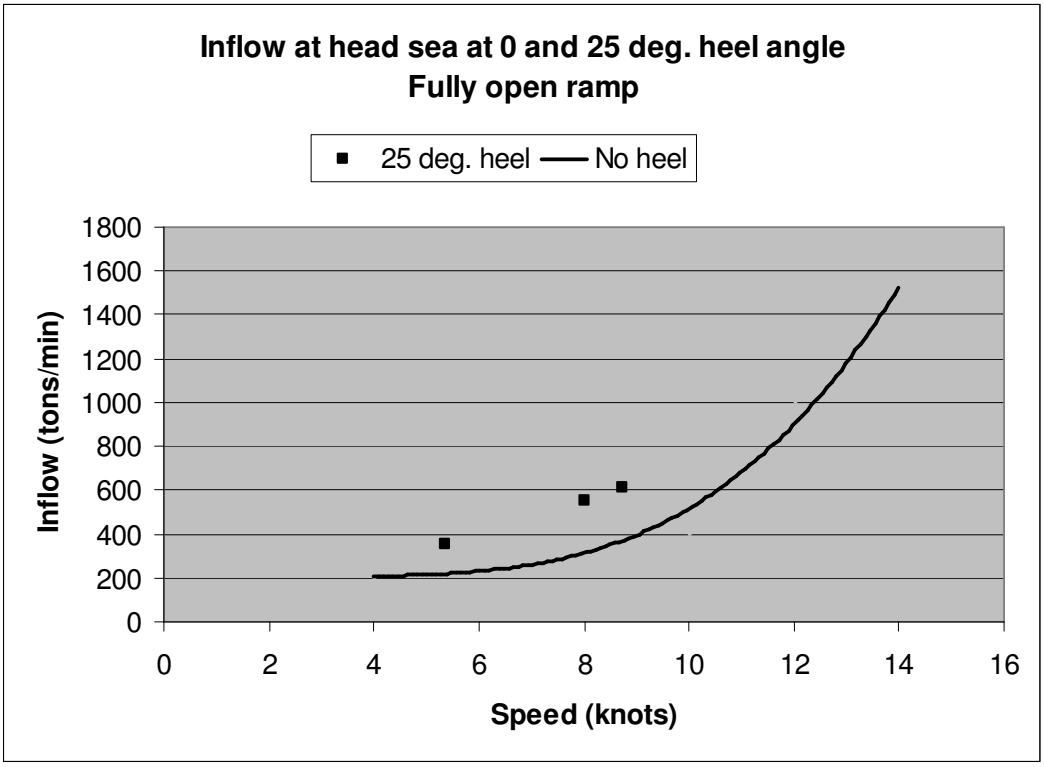


Figure 7: *Relation between initial inflow at head sea in upright position and at 25 deg. heel*

As can be seen above, heel angle has a great influence on initial inflow at head sea. Compared to inflow at upright position, the inflow at 25 deg. heel is almost the double. Again the pump capacity limited the speed where measurements were possible. A few tests were also carried out at bow seas with 25 deg. heel angle, see Figure 8 below.

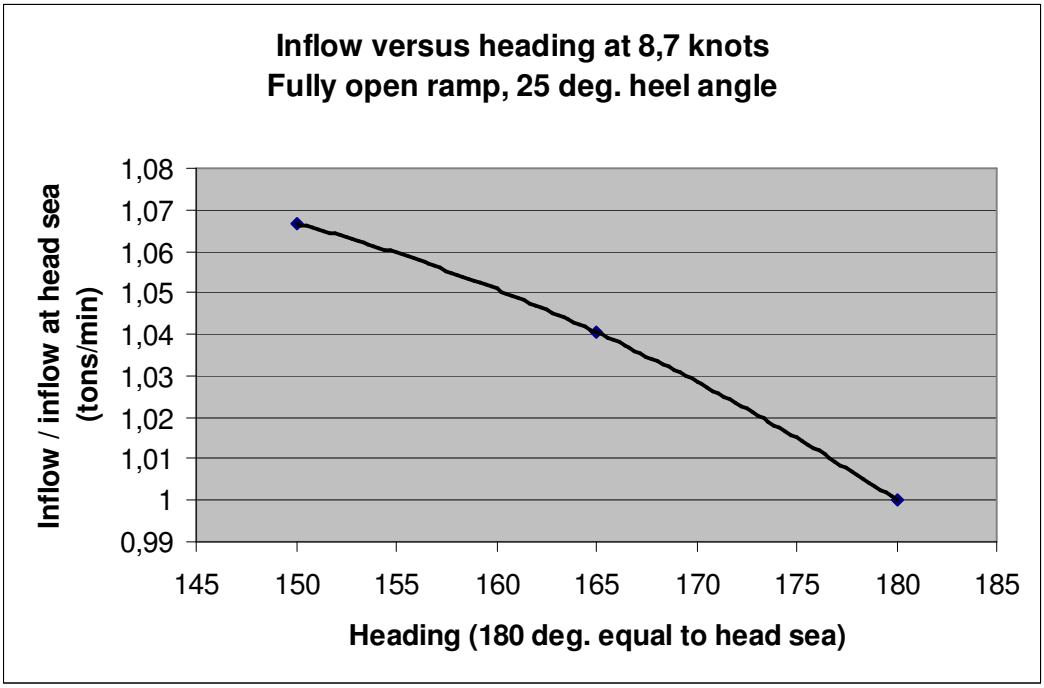


Figure 8: *Initial inflow versus heading at 25 deg. heel angle*

Compared to upright position (see Fig. 5), the influence of heading at 25 deg. heel angle is much less. Again this can be explained by the pitch motion. The difference in pitch motions at 25 deg. heel for different headings is much less than compared to the situation at upright position.

Finally some tests were carried out with only a small ramp opening. From the initial tests in the towing tank mentioned above it was discovered that the difference in inflow having a ramp opening of 1 or 2 m were almost negligible. For the tests in MDL it was therefore decided to only study the inflow at 1 m ramp opening, see Figure 9 below.

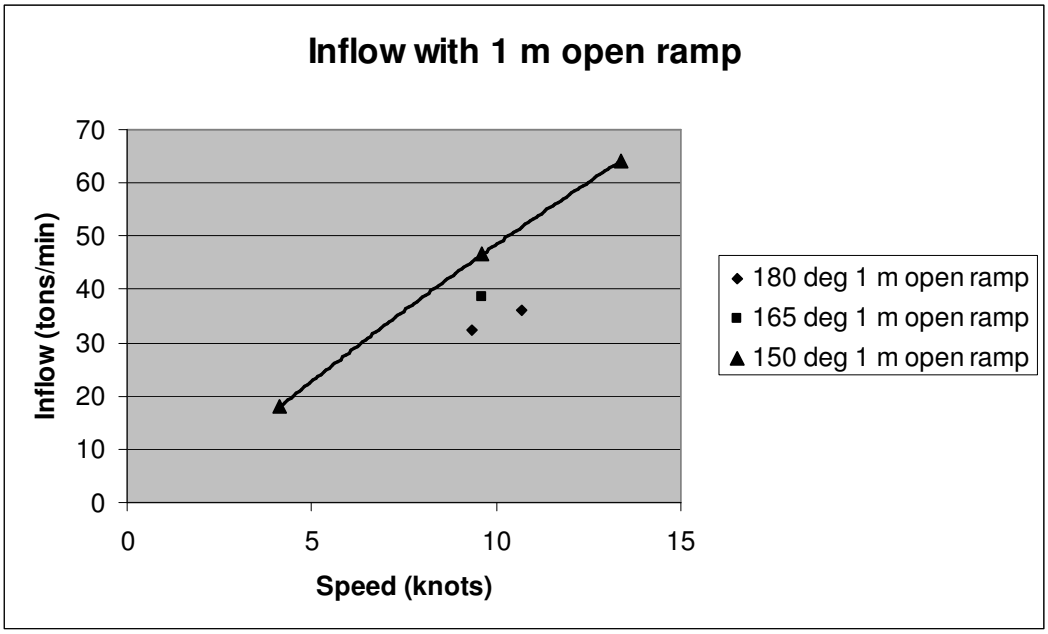


Figure 9: *Initial inflow at different headings and speeds with 1 m open ramp*

Now the amount of water entering the ship was very small compared to the fully open ramp. Therefore there were no problems running at 14 knots, i.e. no problems occurred regarding pump capacity. The inflow at 150 deg. heading (bow seas) shows almost a linear behaviour from zero speed up to 14 knots. As before the inflow at 165 deg. and 180 deg. heading was lower, again due to smaller pitch motions.

It should be mentioned that the case with 1 m ramp opening was chosen just to get a rough estimate of the amount of water that could enter the ship with a certain gap at bow. It should also be mentioned that in the initial tests in the towing tank one test run was carried out with the ramp open 1 m but also with the visor on with a horizontal gap all over of 1 m. The inflow was then reduced by approx. 70 %.

To summarise the results from the initial inflow tests, it can be estimated that if the visor fell off and opened the ramp completely at the speed of about 14 knots, 1500-1800 tons per minute enter the car deck initially depending on the heading. If the speed should remain at 14 knots, within short a heel angle of 25 deg. would occur, and due to the heel the inflow would increase significantly more. Due to problems with pump capacity it was not possible to measure this at 14 knots, but in the speed range 8-9 knots the increase due to 25 deg. heel was in the order of 20-30 %. If this is the case also at 14 knots, the inflow would reach the order of 2000-2500 tons/min. A forward trim could then increase the inflow even more.

If the ramp is only partly open, maybe with the visor still on, the inflow can be from a few tons per minute up to the order of 100 tons per minute.

5.3 Motions responses

In Appendix B statistical results from the wave tests are shown as minimum, mean, maximum and significant values of the measured parameters.

In Figures 10 to 12 significant values (single amplitude) of heave motion, roll angle and pitch angle are plotted versus wave direction. In the left diagram results are shown from the tests with visor and closed bow ramp, while the right diagram shows results from tests with the visor dismounted and the bow ramp completely open.

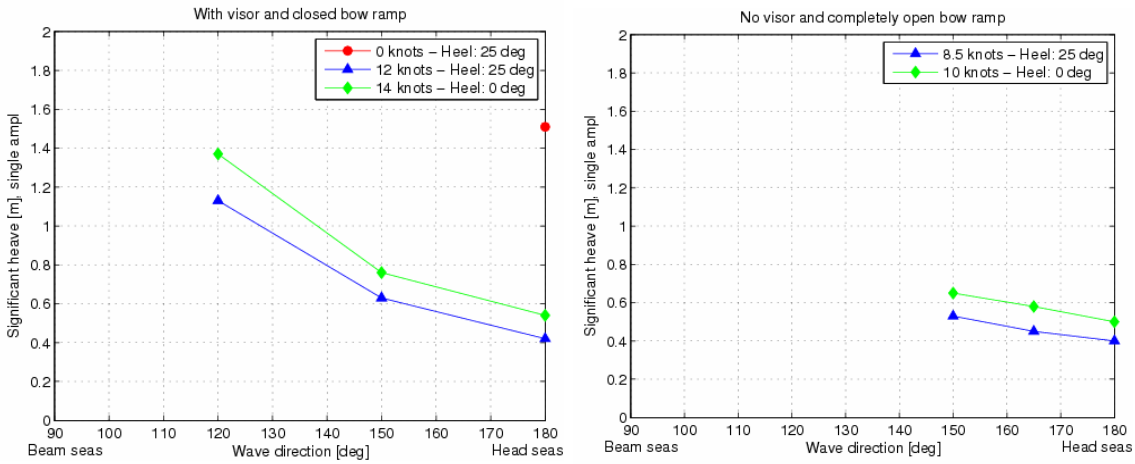


Figure 10: *Significant heave motion in irregular seas*

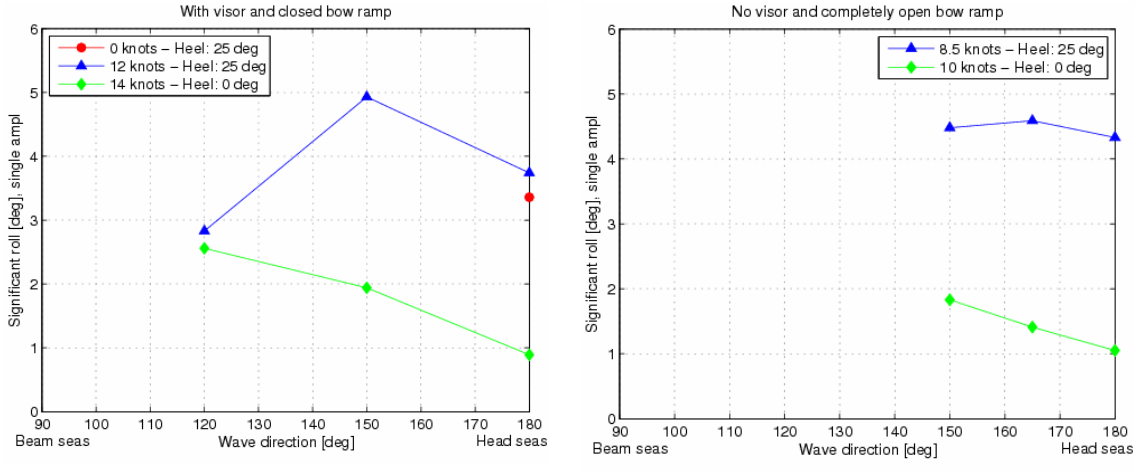


Figure 11: *Significant roll motion in irregular seas*

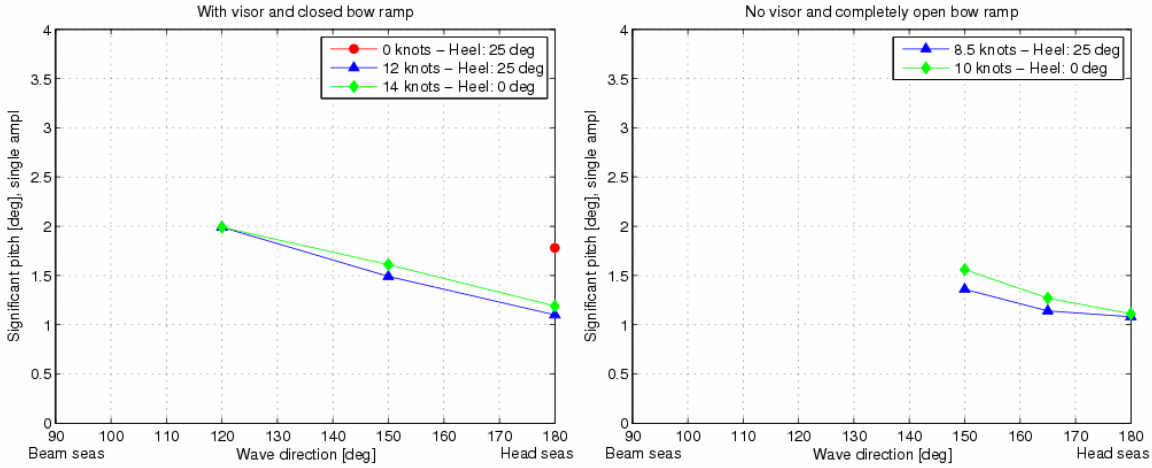


Figure 12: *Significant pitch motion in irregular seas*

6 REFERENCES

[1] The Joint Accident Investigation Commission of Estonia, Finland and Sweden, 'Final report on the capsizing on 28 September 1994 in the Baltic Sea of the ro-ro passenger vessel MV ESTONIA'. Edita Ltd. Helsinki 1997.

Appendix A

Track plots and time histories from manoeuvring tests

List of figures

Figure		
1	P30° turning circle test in calm water; 14.5 knots - 25° heel	Ser/Run:2/26
2	P30° turning circle test in calm water; 14.5 knots - No heel	Ser/Run:2/40
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4	P30° turning test in waves; 7 knots - 25° heel	Ser/Run:2/6
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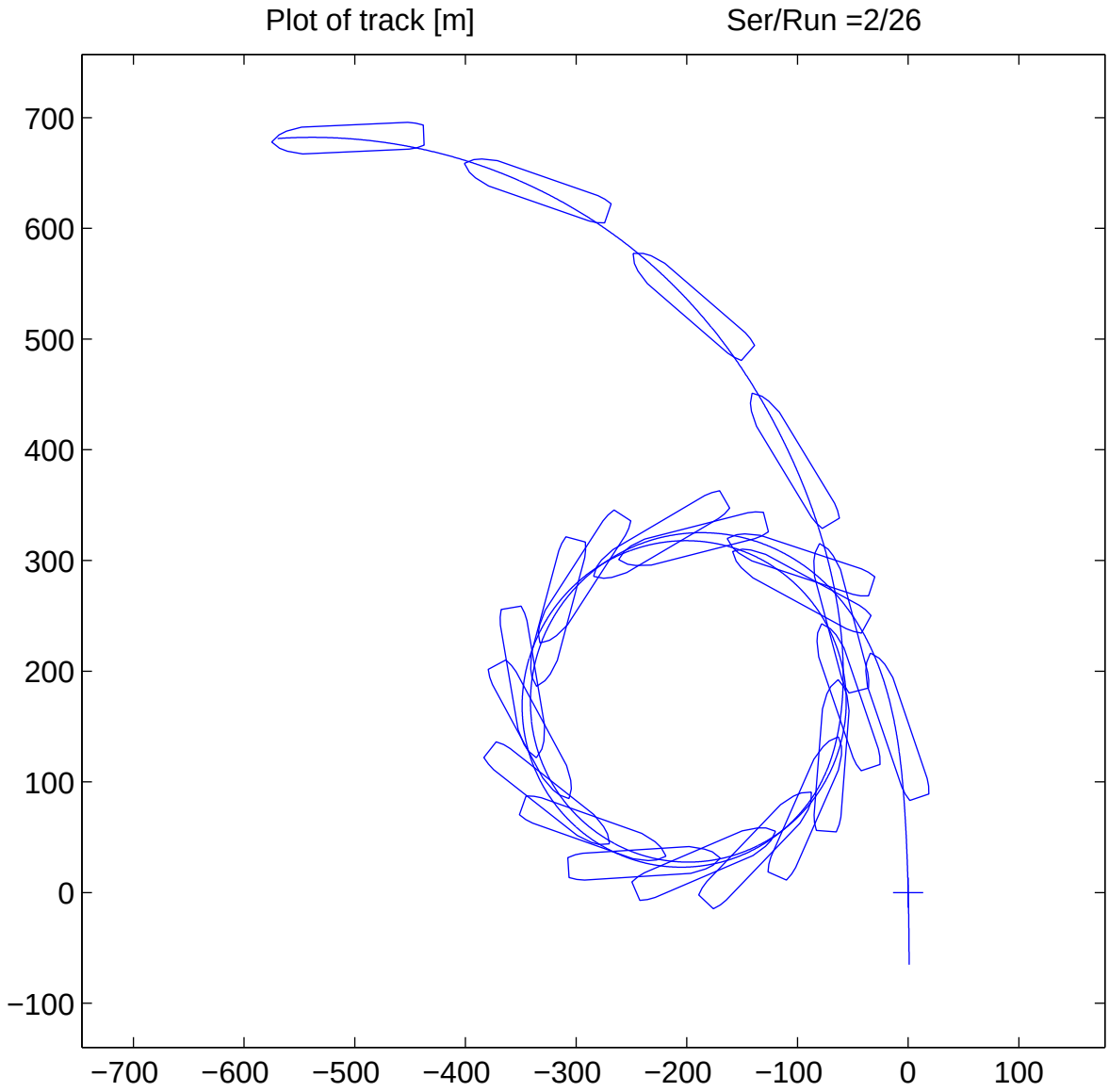
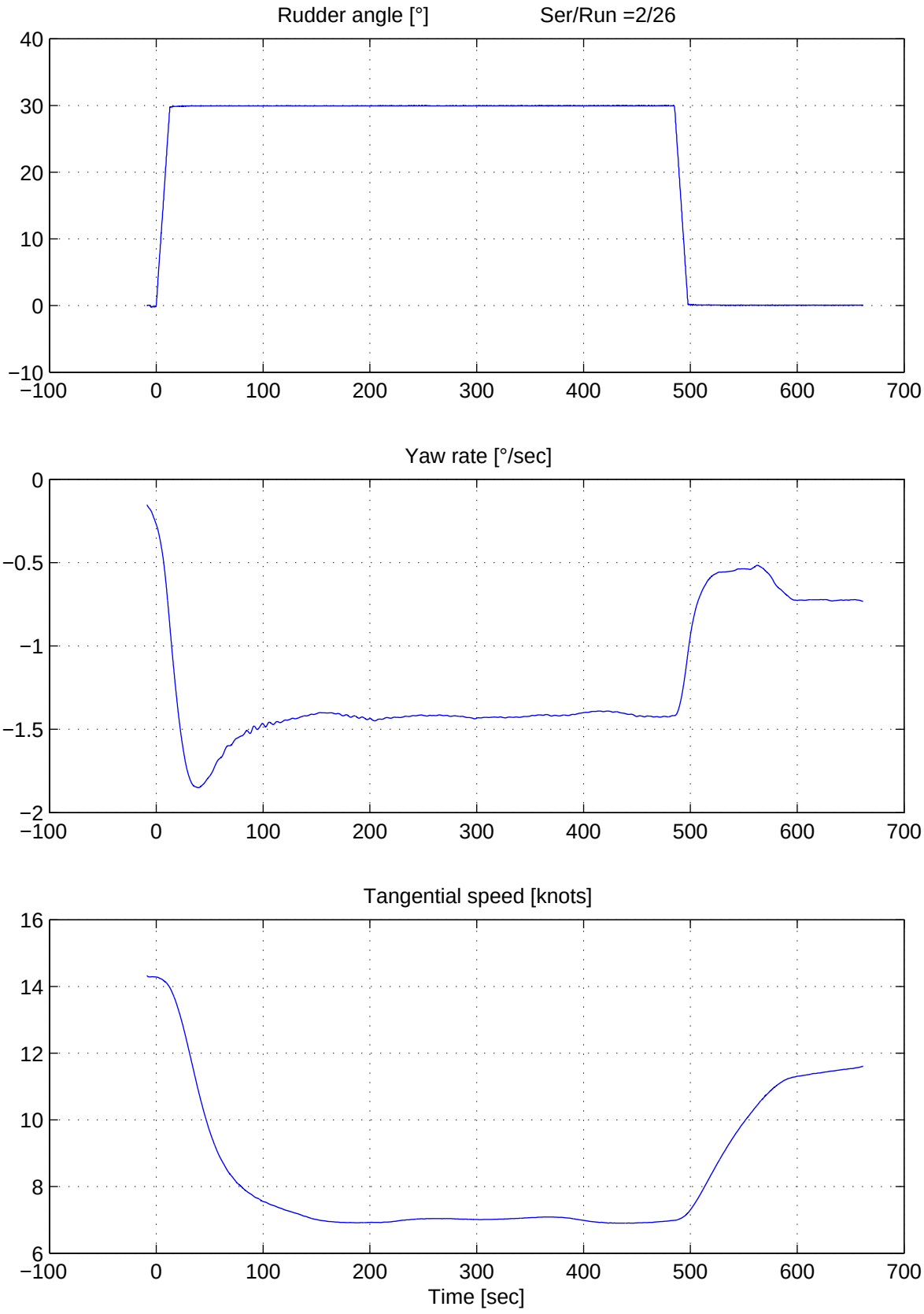
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 1.1 Report 40064100−1

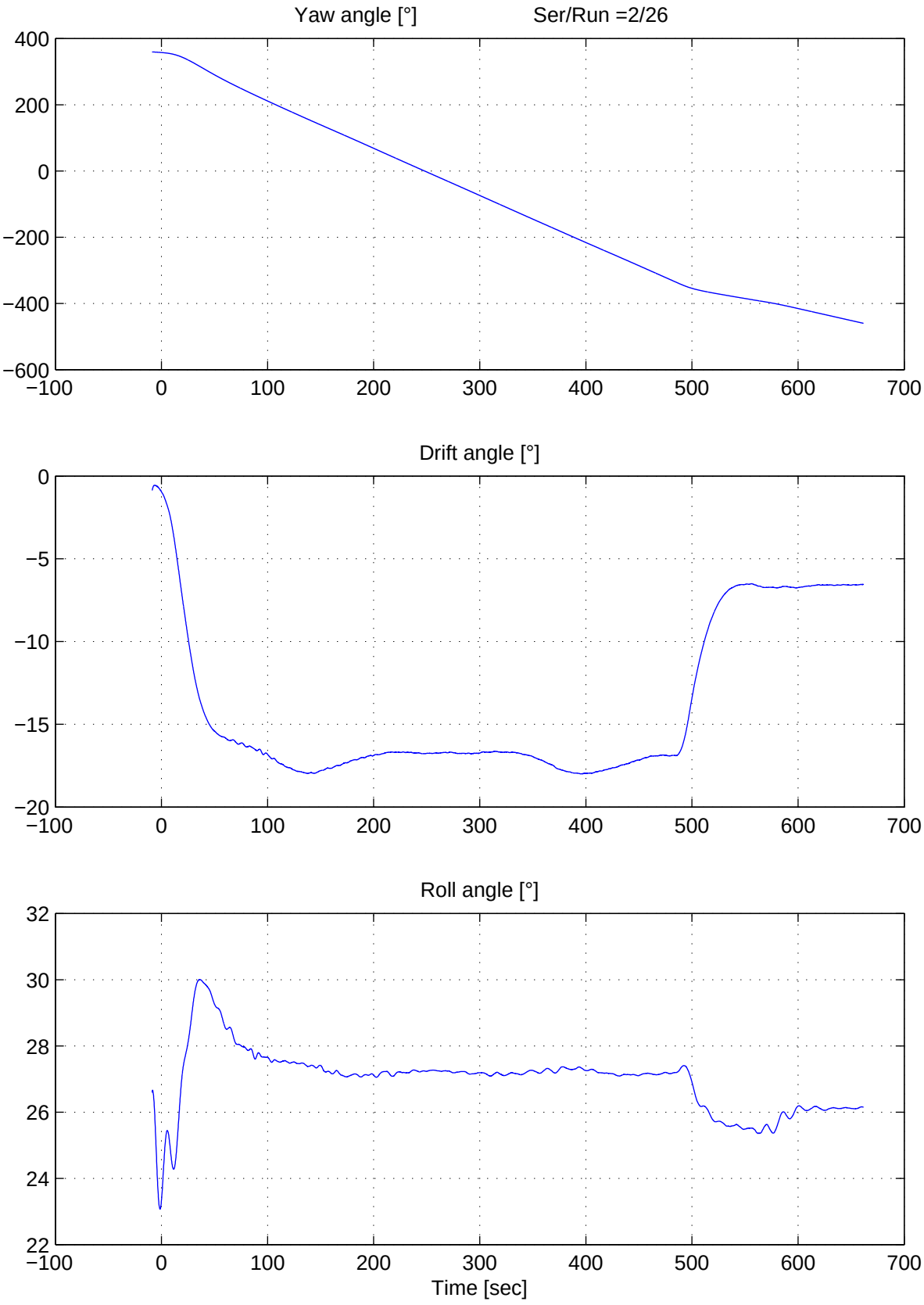


Time step between plots of ship	:	30	(sec)			
Advance	:	312	(m)	−	2.27	L_{pp}
Transfer	:	159	(m)	−	1.16	L_{pp}
Tactical diameter	:	342	(m)	−	2.49	L_{pp}
Steady turning diameter	:	287	(m)	−	2.09	L_{pp}

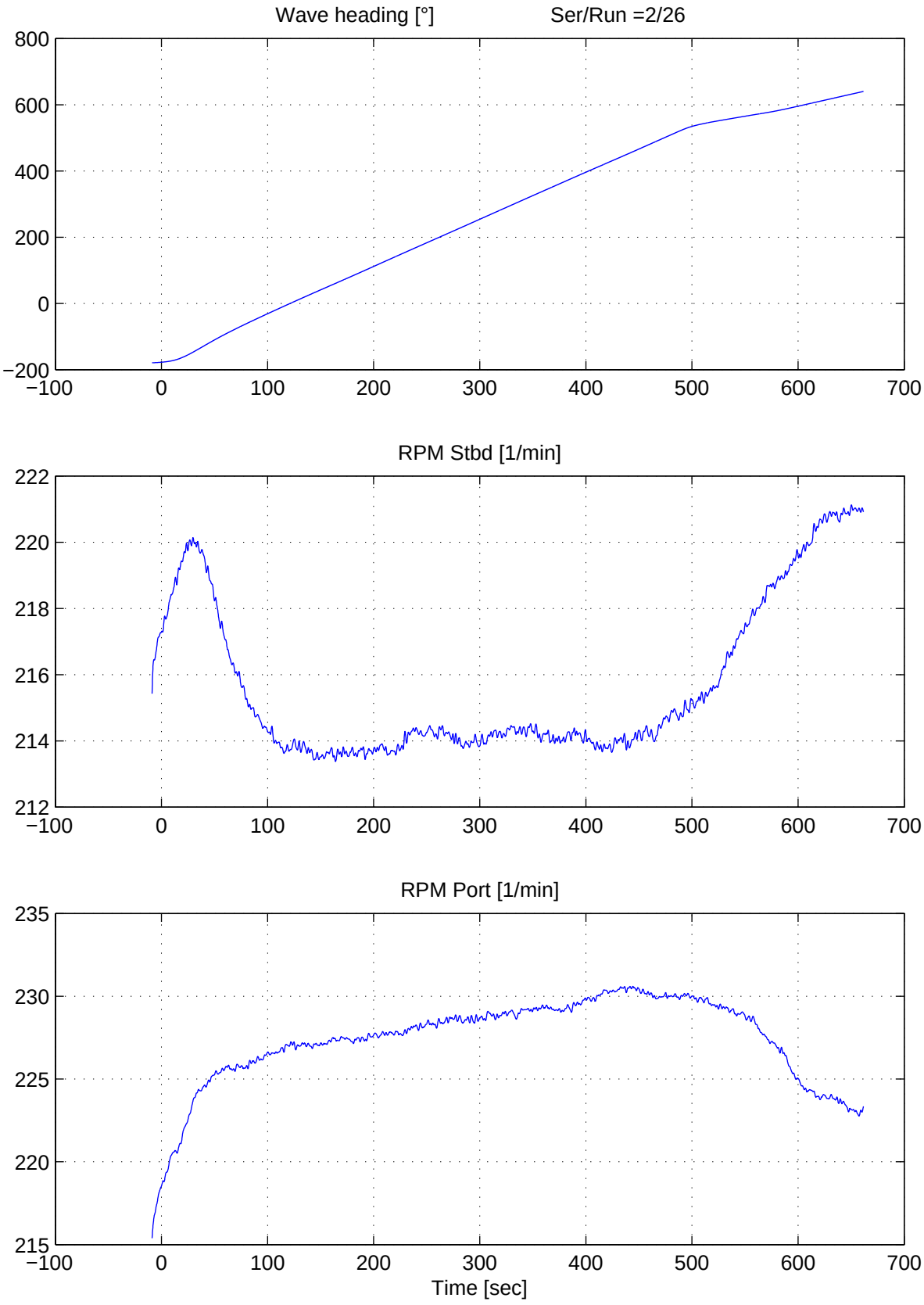
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 1.2 Report 40064100−1



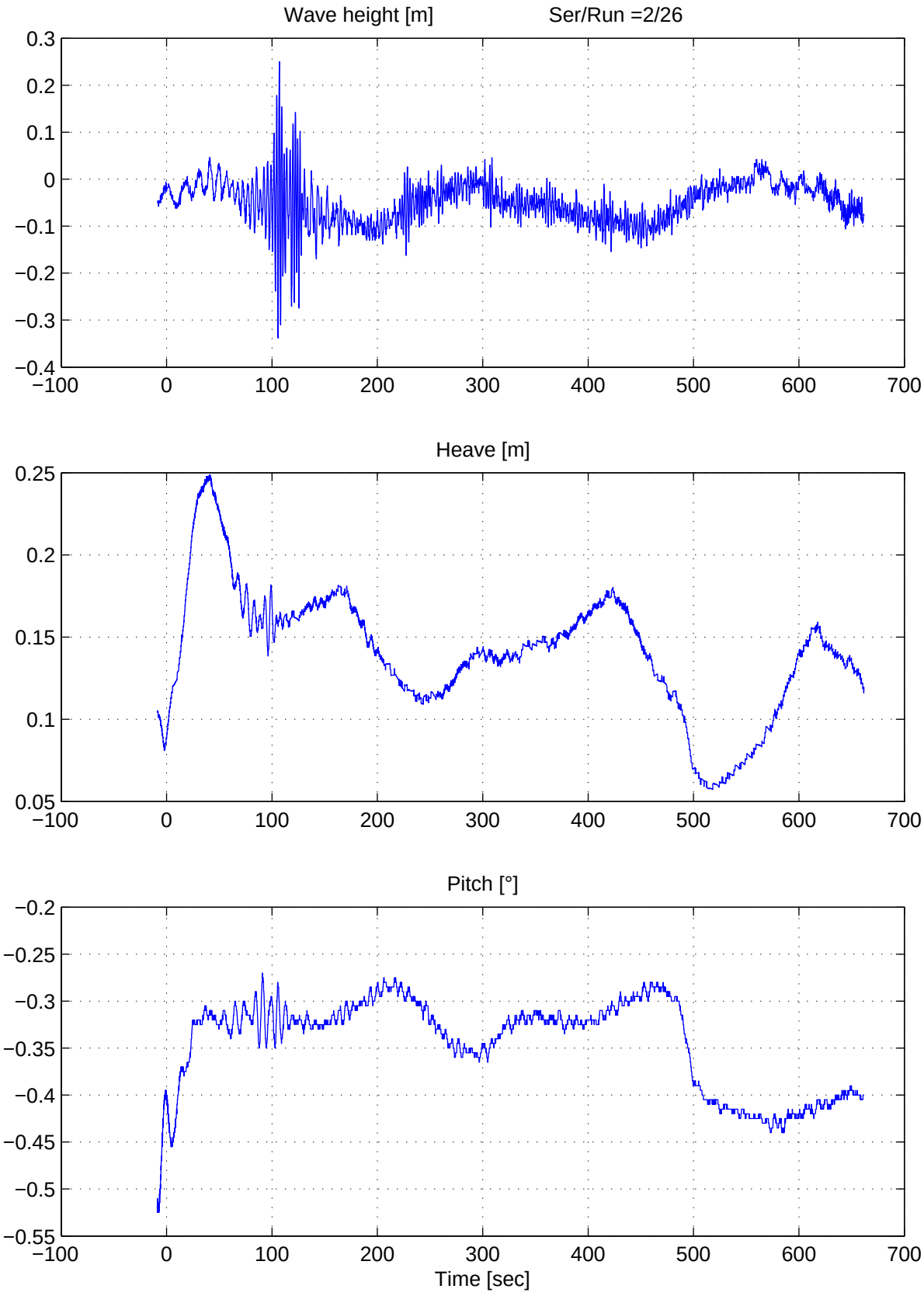
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 1.3 Report 40064100−1



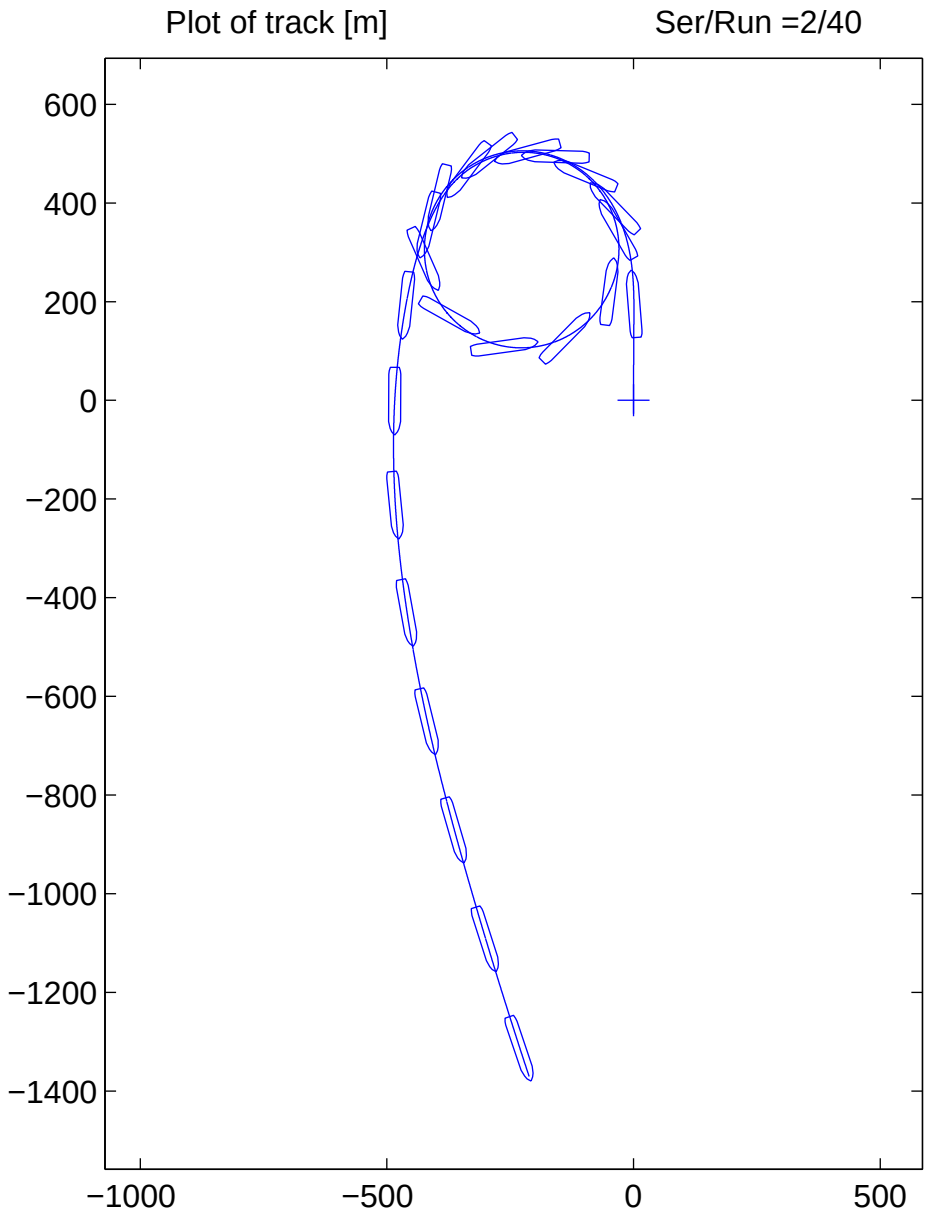
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 1.4 Report 40064100−1



SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 1.5 Report 40064100−1

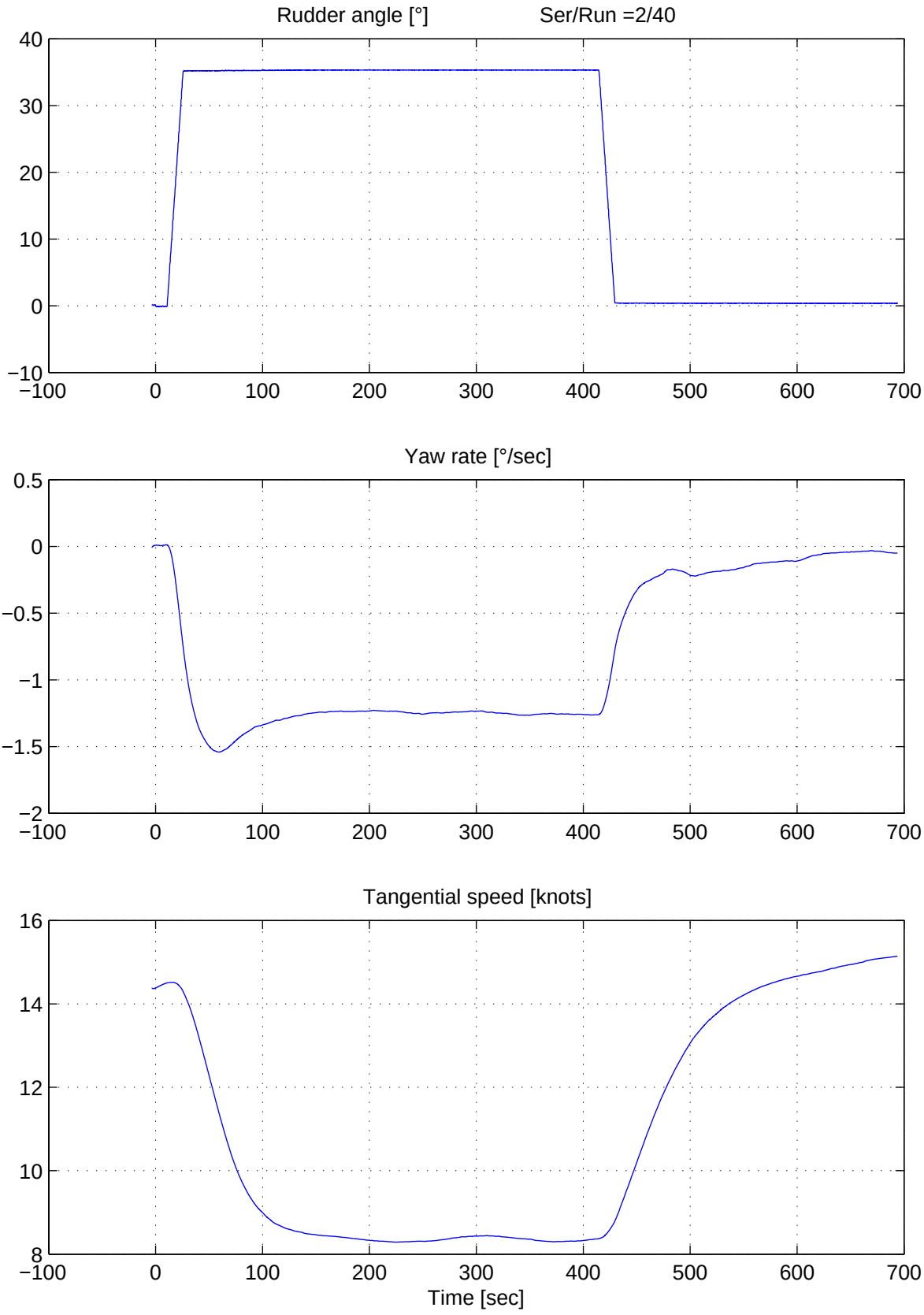


SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 2.1 Report 40064100−1

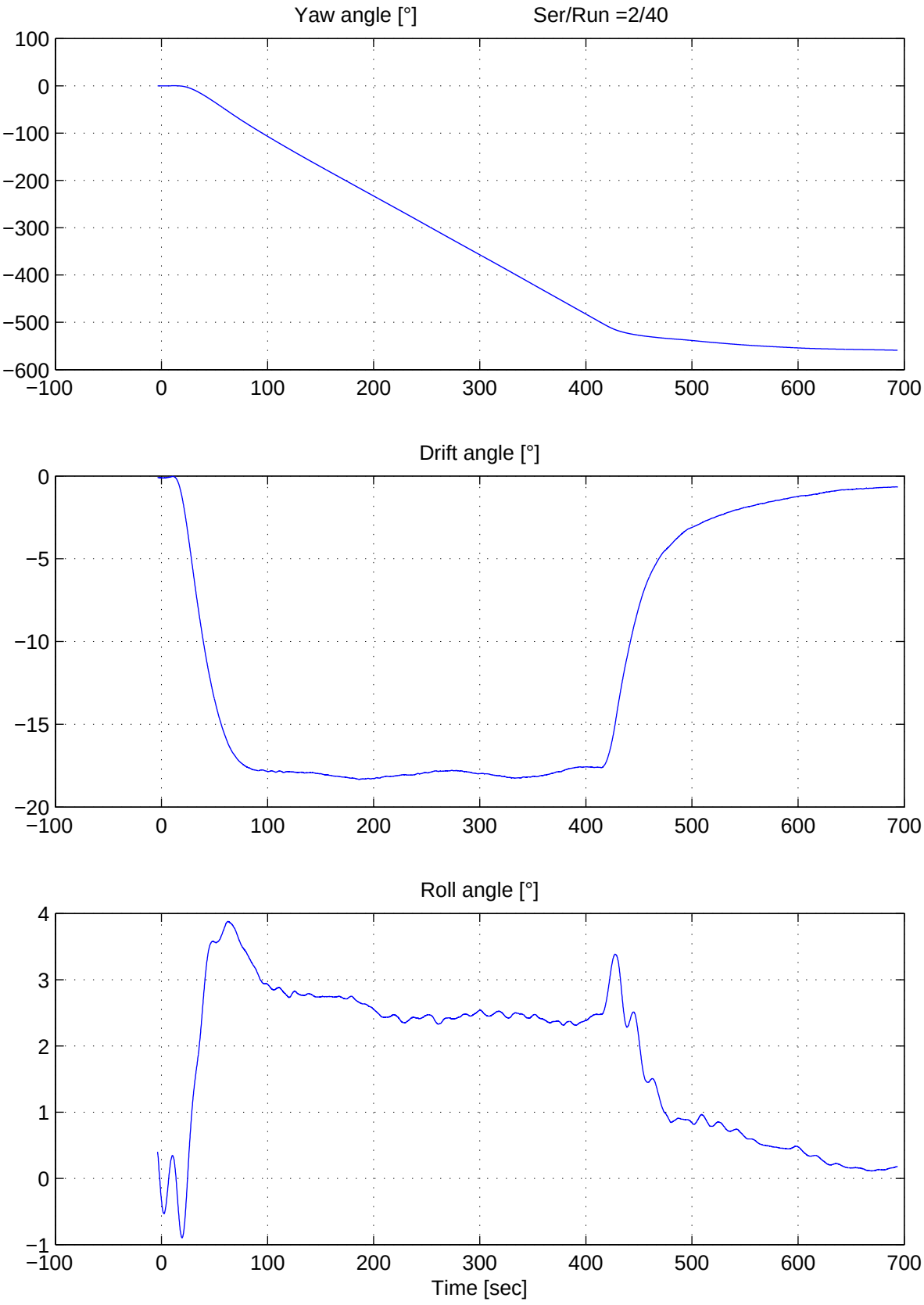


Time step between plots of ship	:	30	(sec)		
Advance	:	496	(m)	−	3.61 L_{pp}
Transfer	:	165	(m)	−	1.2 L_{pp}
Tactical diameter	:	414	(m)	−	3.01 L_{pp}
Steady turning diameter	:	395	(m)	−	2.87 L_{pp}

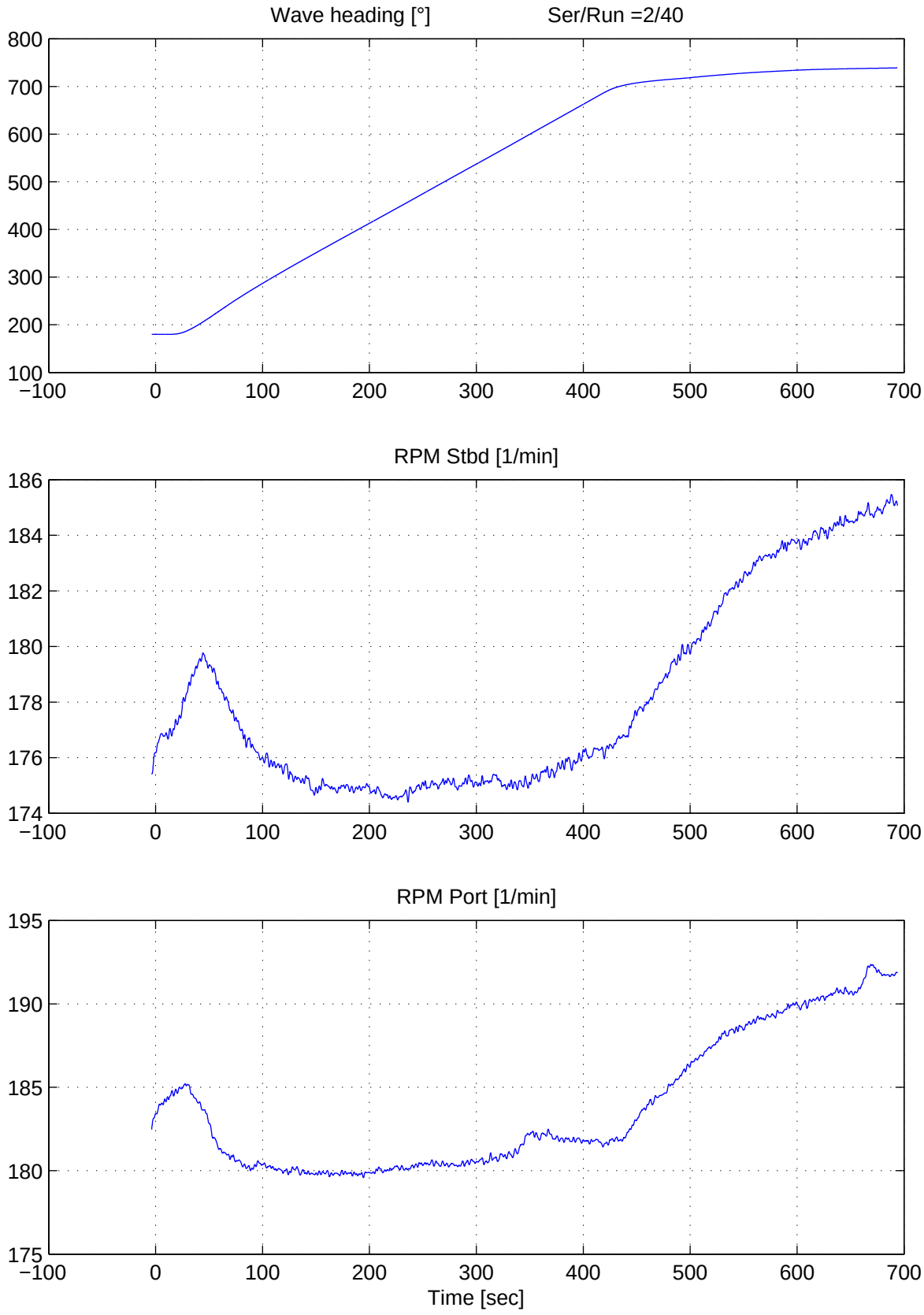
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 2.2 Report 40064100−1



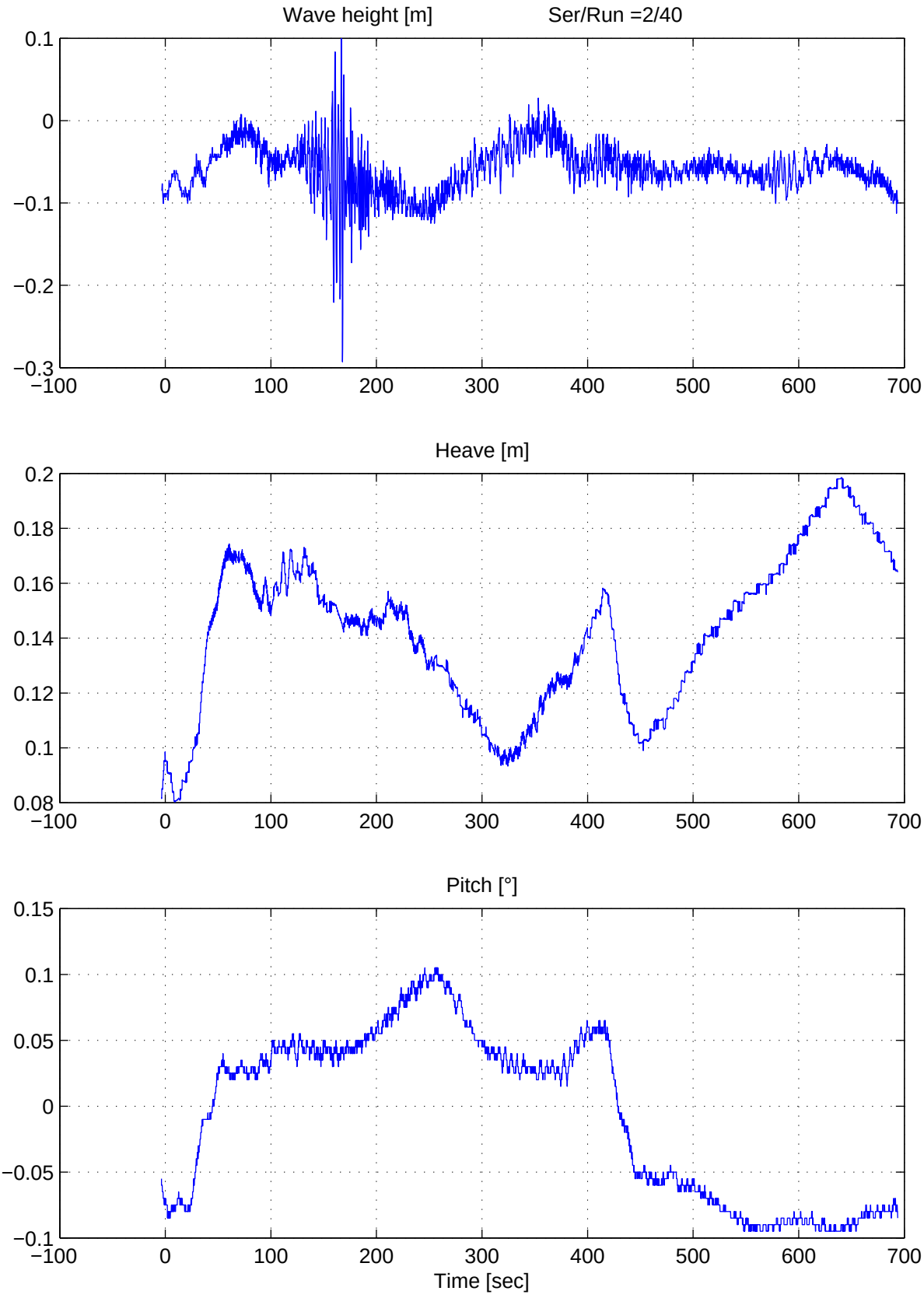
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 2.3 Report 40064100−1



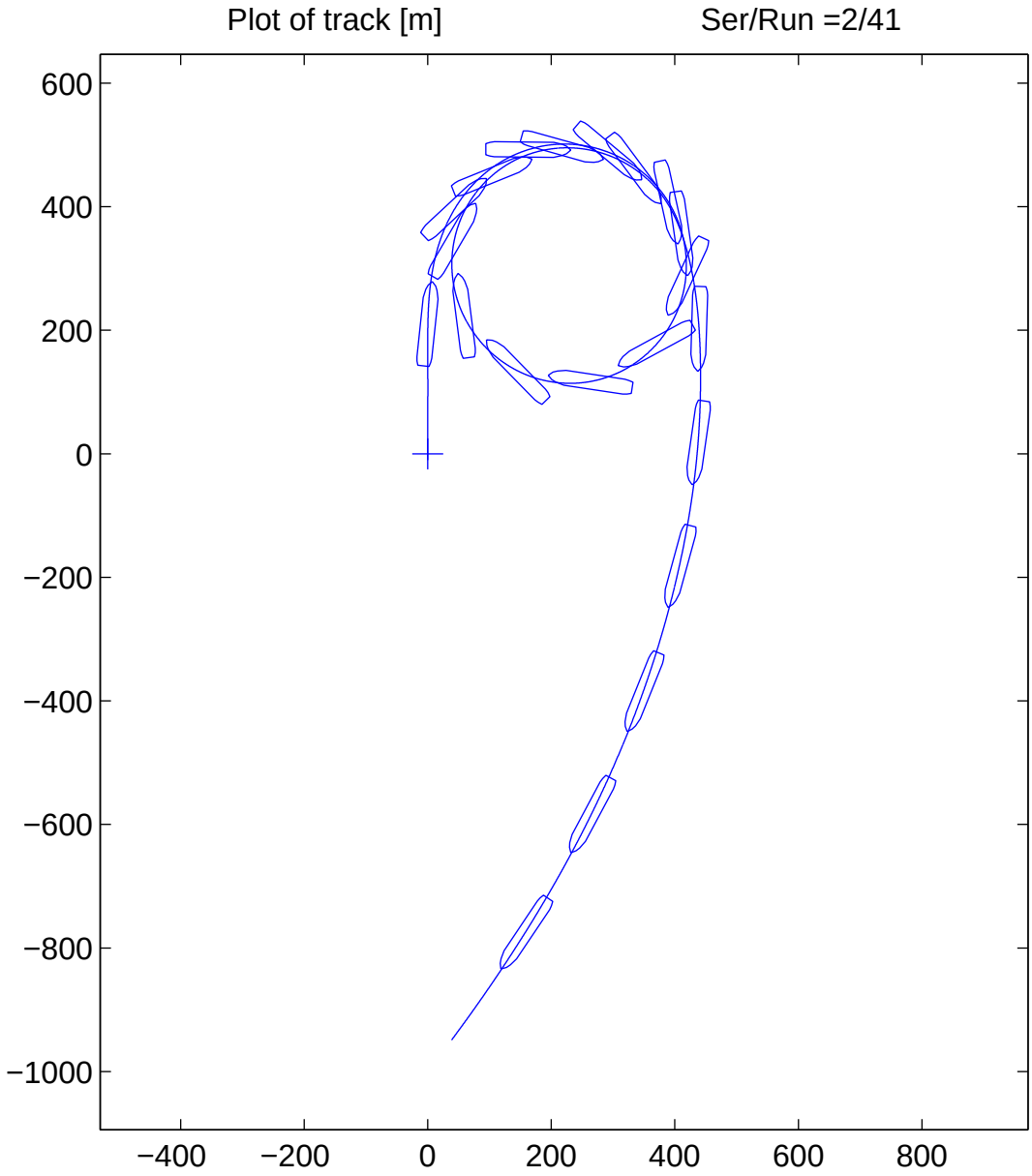
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 2.4 Report 40064100−1



SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 2.5 Report 40064100−1

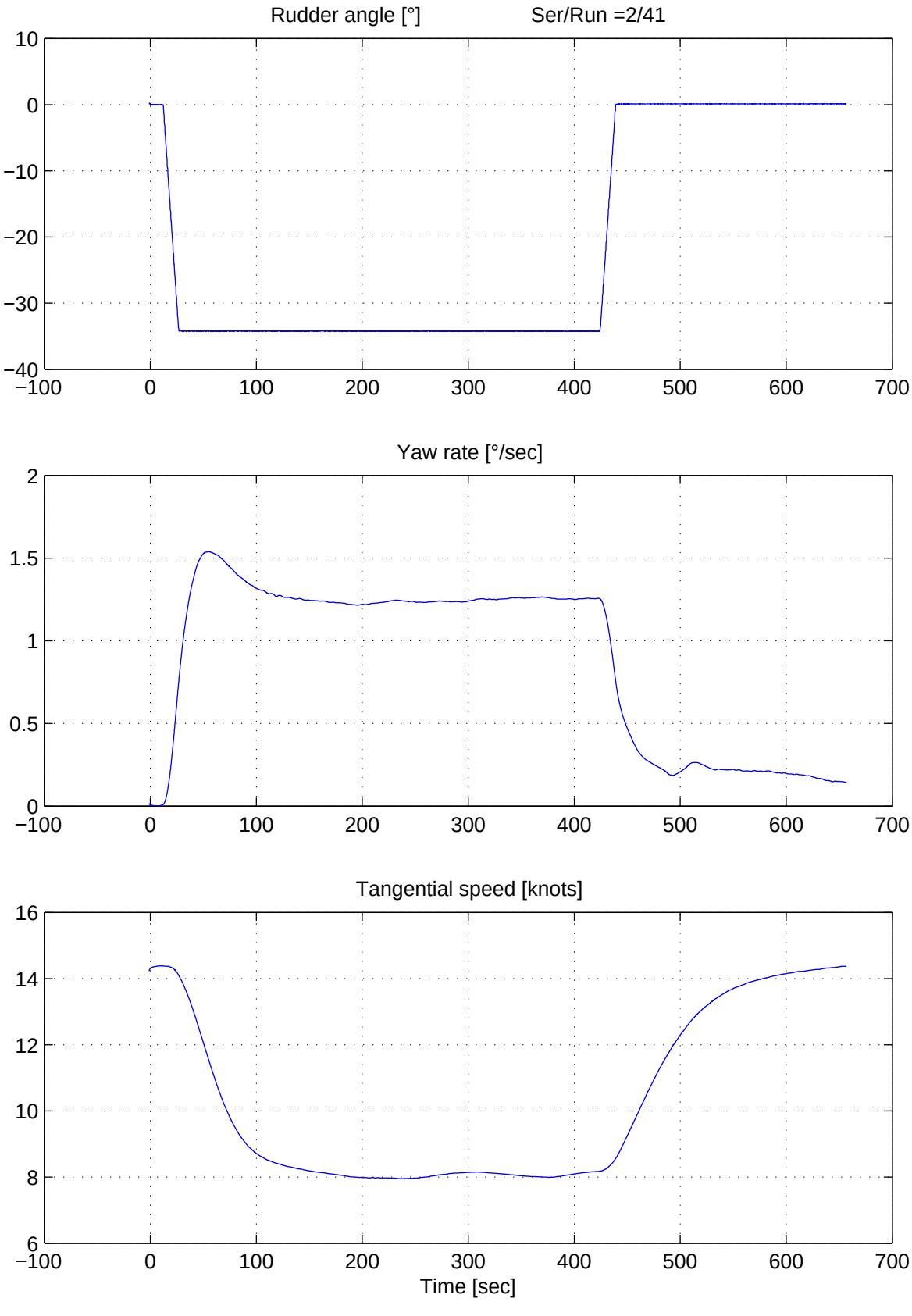


SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 3.1 Report 40064100−1

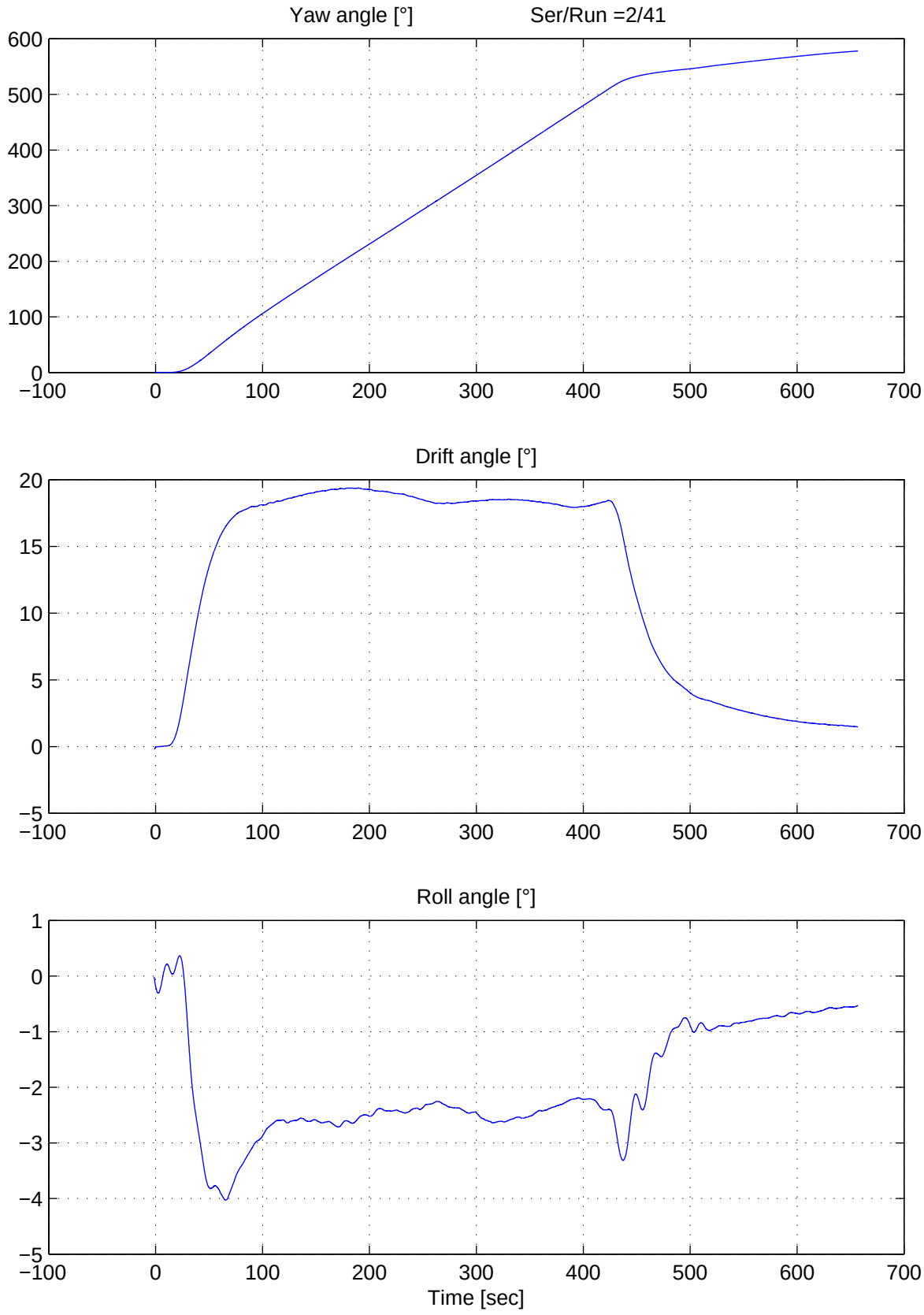


Time step between plots of ship	:	30	(sec)		
Advance	:	492	(m)	−	3.58 L_{pp}
Transfer	:	161	(m)	−	1.17 L_{pp}
Tactical diameter	:	408	(m)	−	2.97 L_{pp}
Steady turning diameter	:	379	(m)	−	2.76 L_{pp}

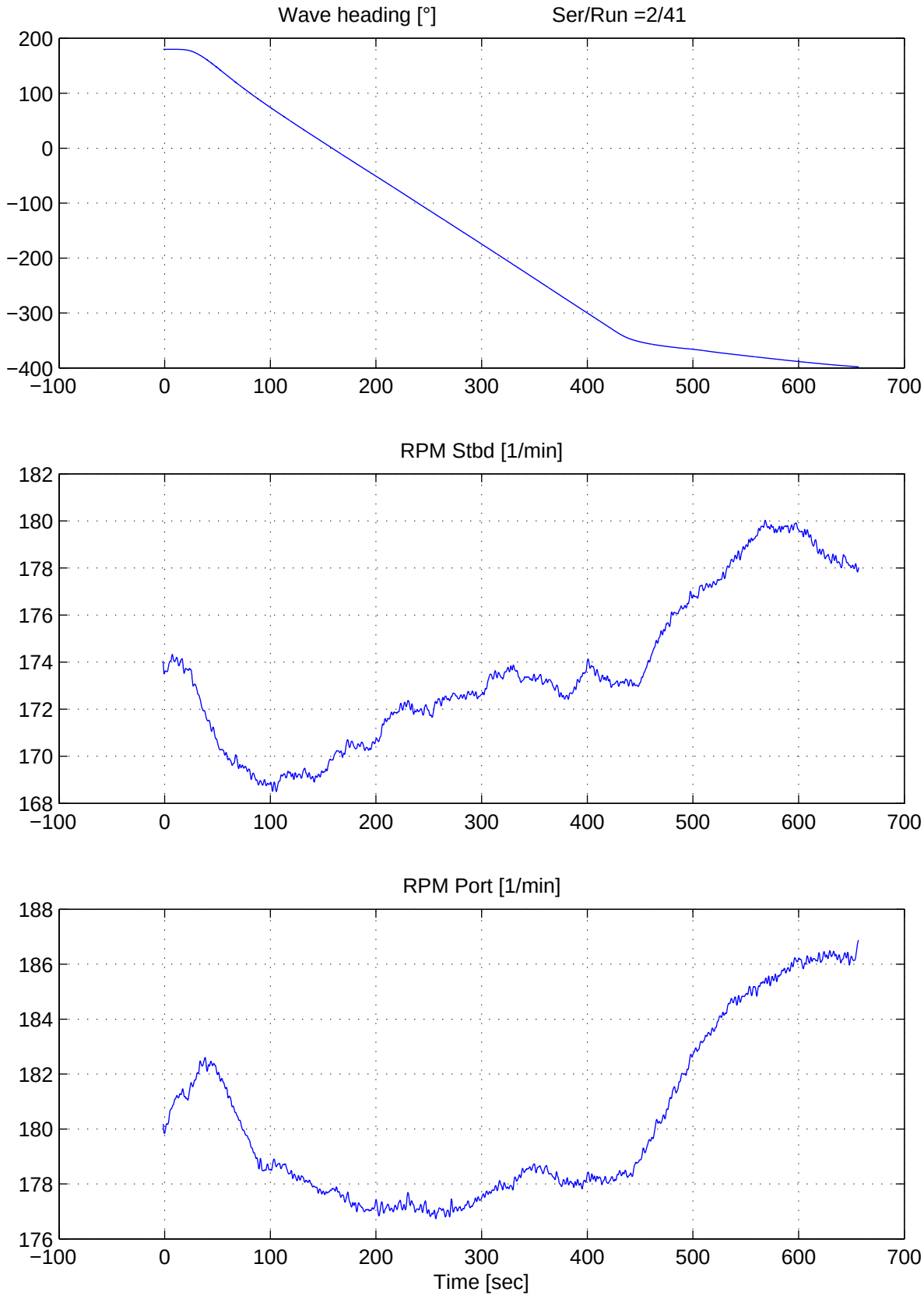
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 3.2 Report 40064100−1



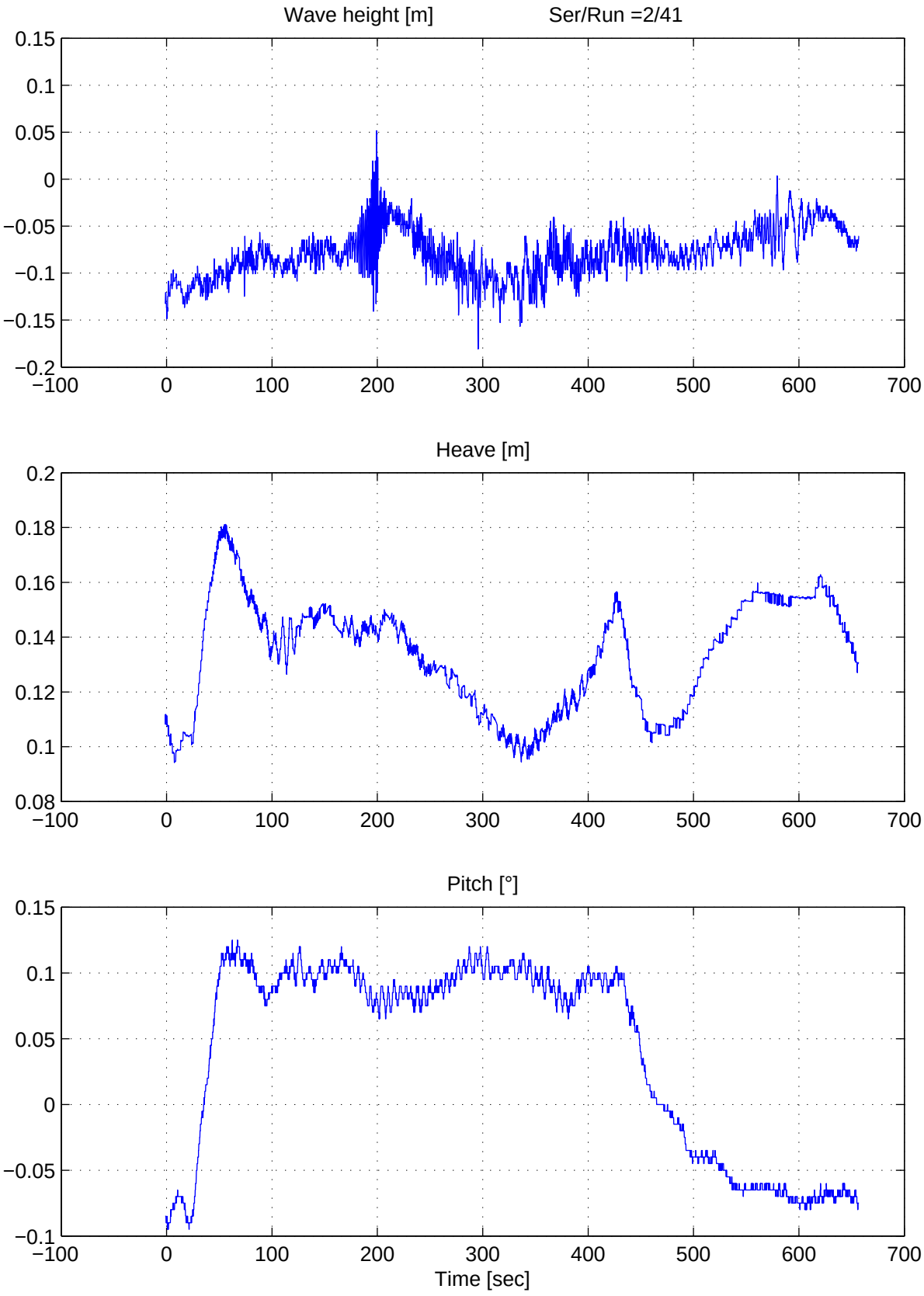
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 3.3 Report 40064100−1



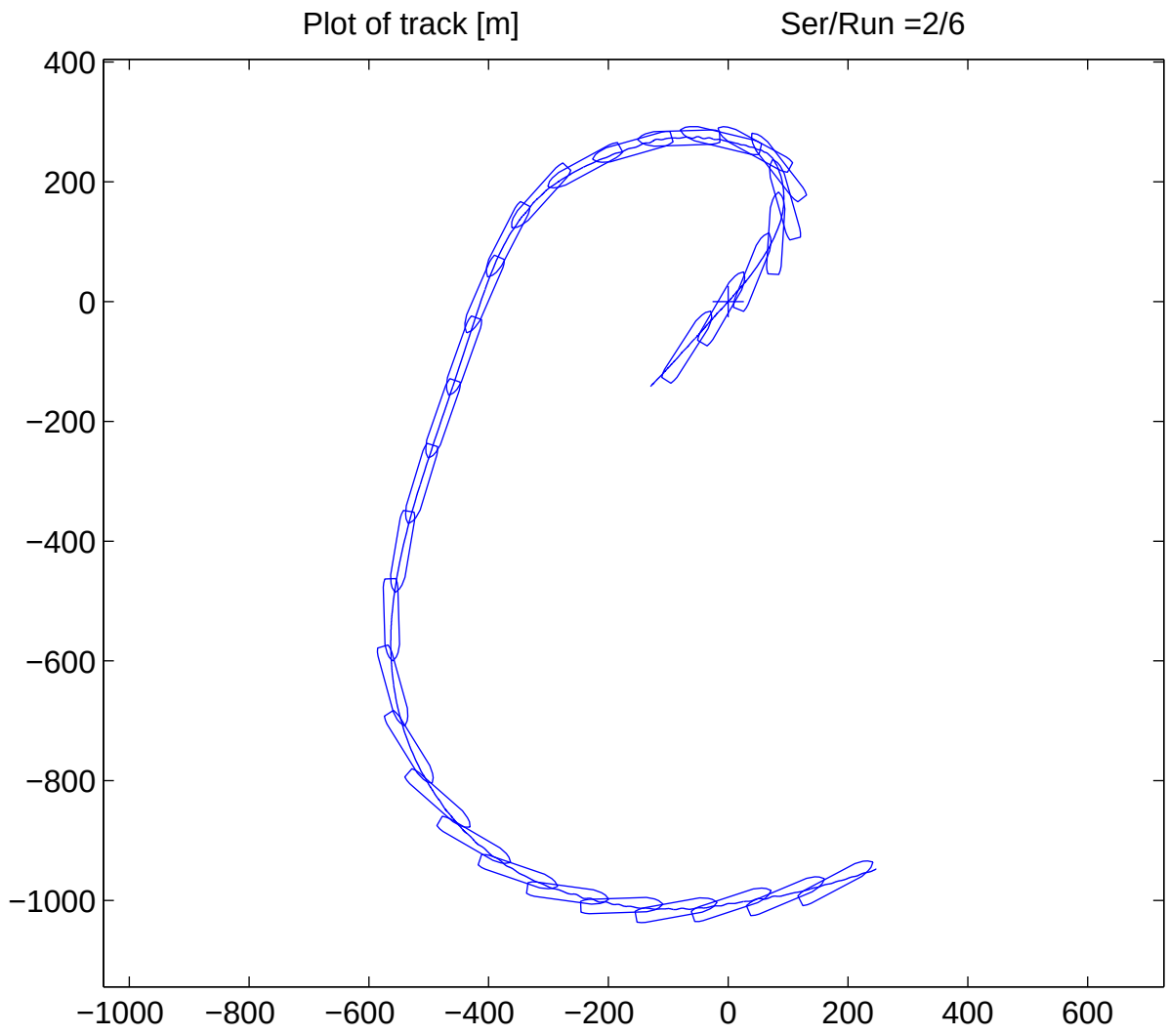
SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 3.4 Report 40064100−1



SSPA	MV Estonia Turning test in calm water Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 3.5 Report 40064100−1

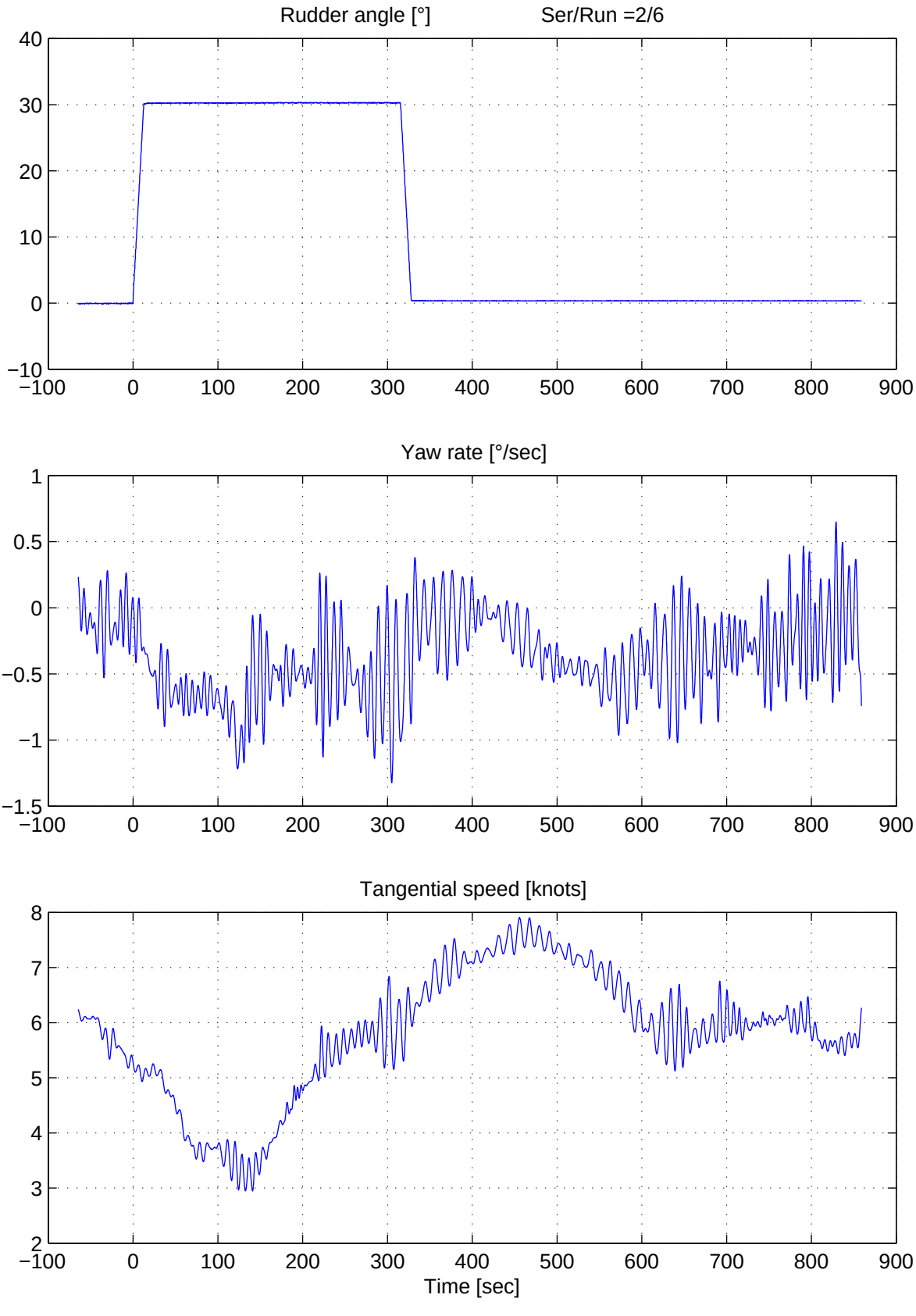


SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 4.1 Report 40064100−1

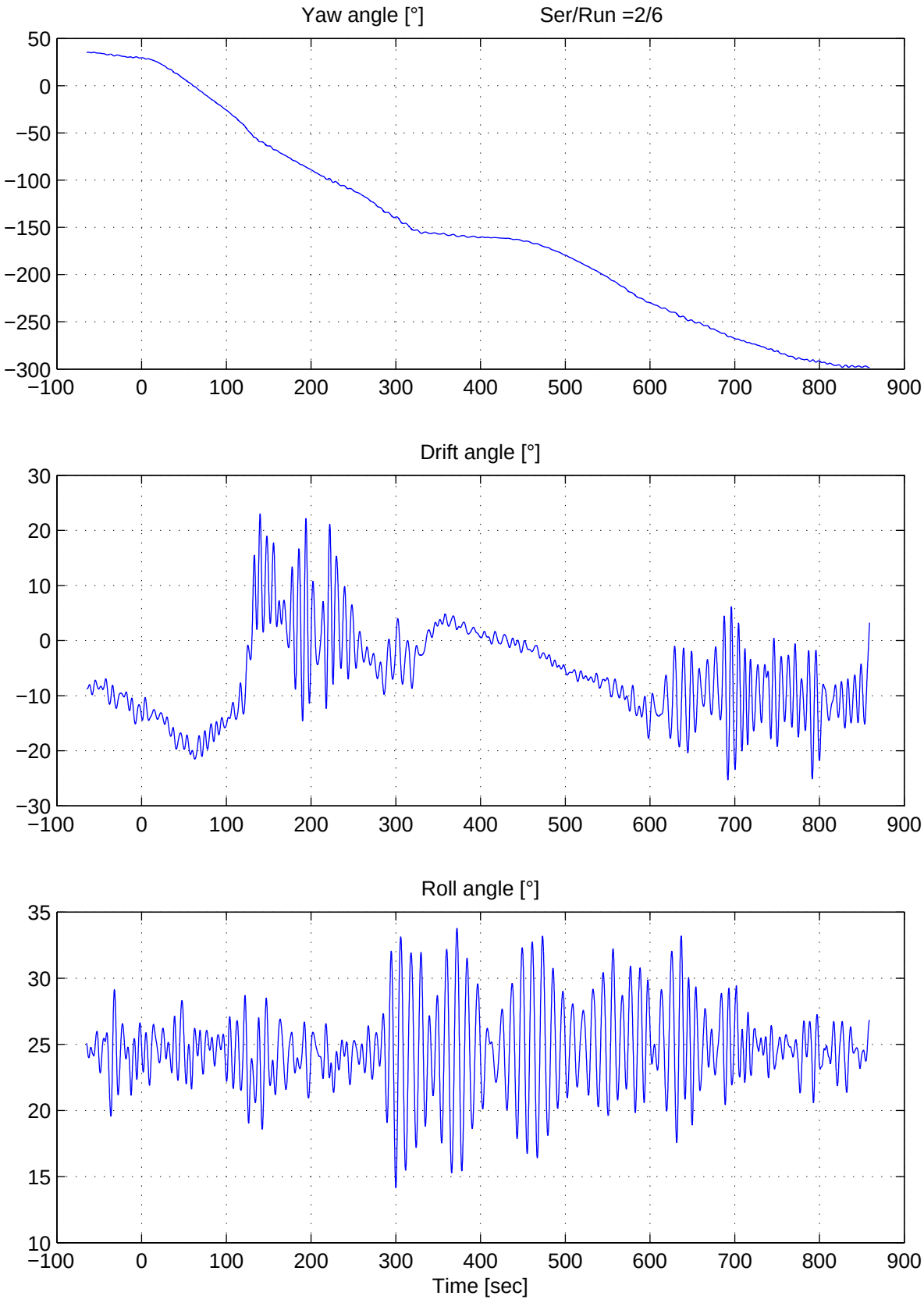


Time step between plots of ship	:	30	(sec)
Advance	:	274	(m) − 1.99 L_{pp}
Transfer	:	75	(m) − 0.546 L_{pp}
Tactical diameter	:	561	(m) − 4.08 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

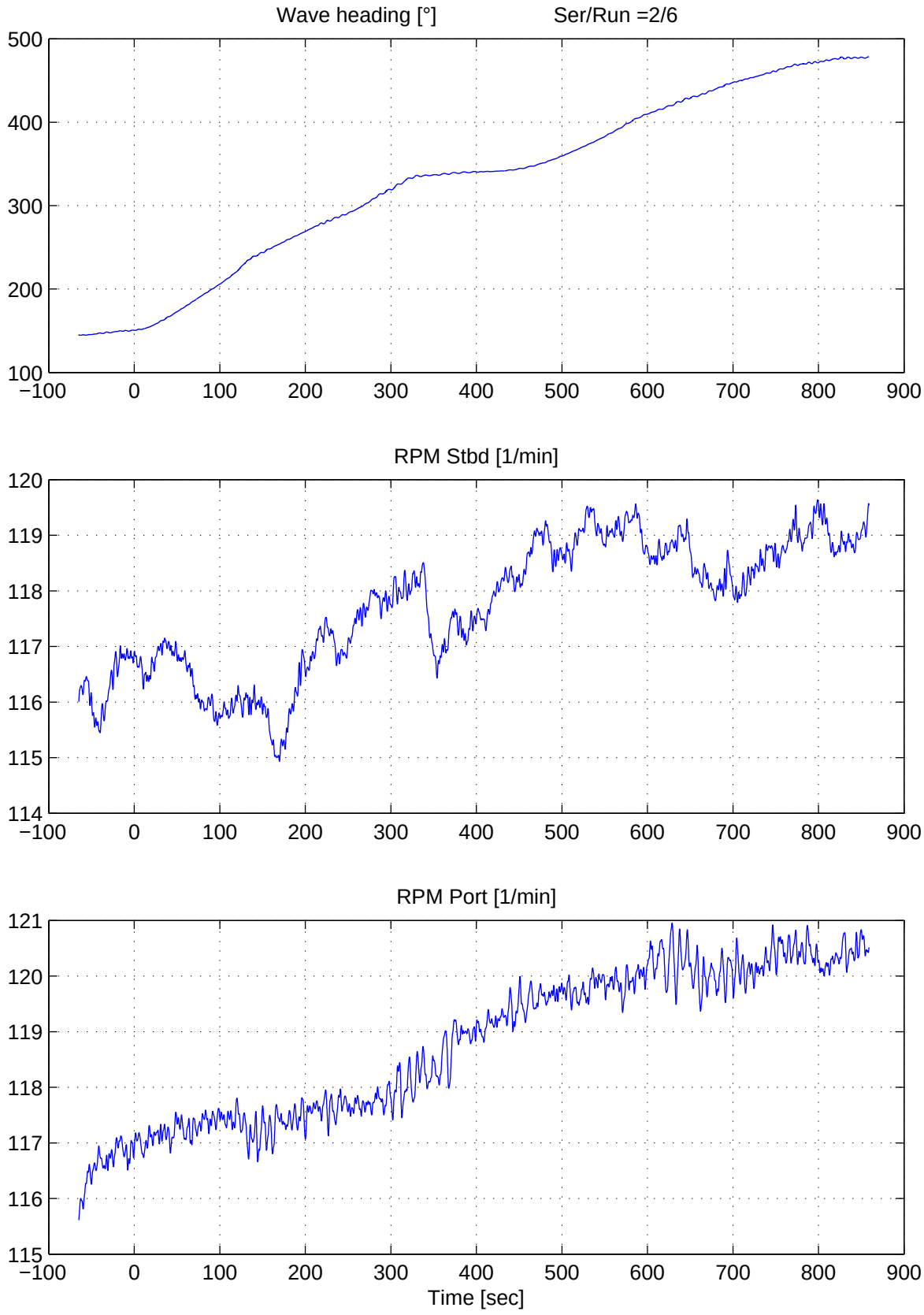
SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 4.2 Report 40064100−1



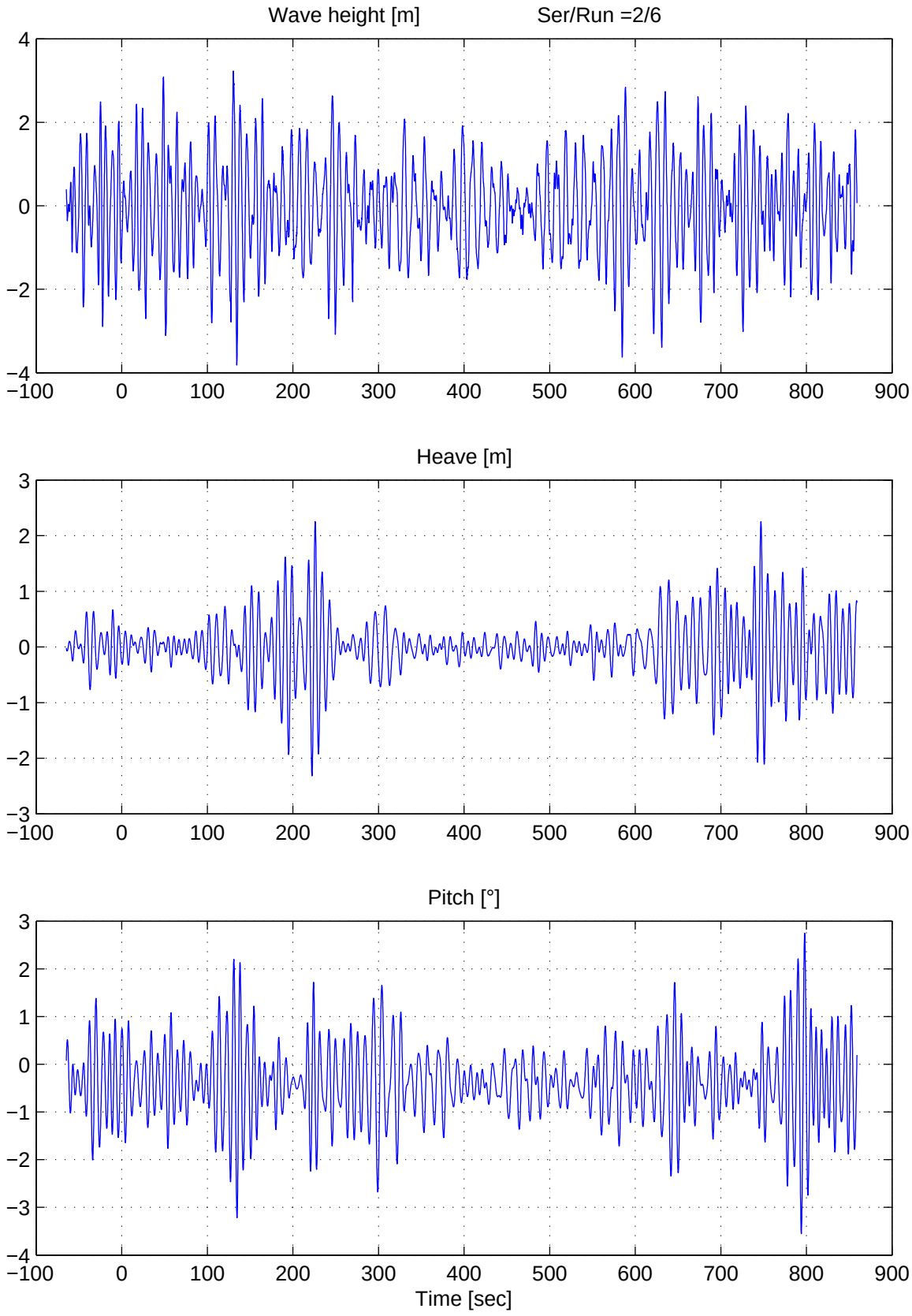
SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 4.3 Report 40064100−1



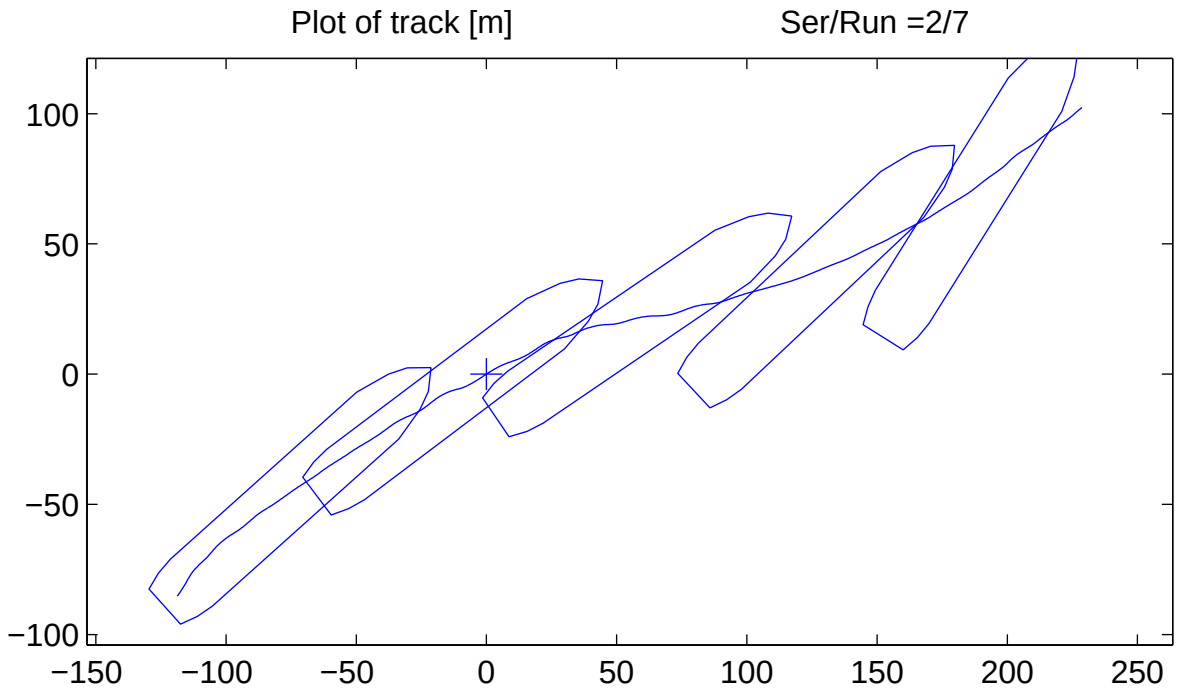
SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 4.4 Report 40064100−1



SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 4.5 Report 40064100−1

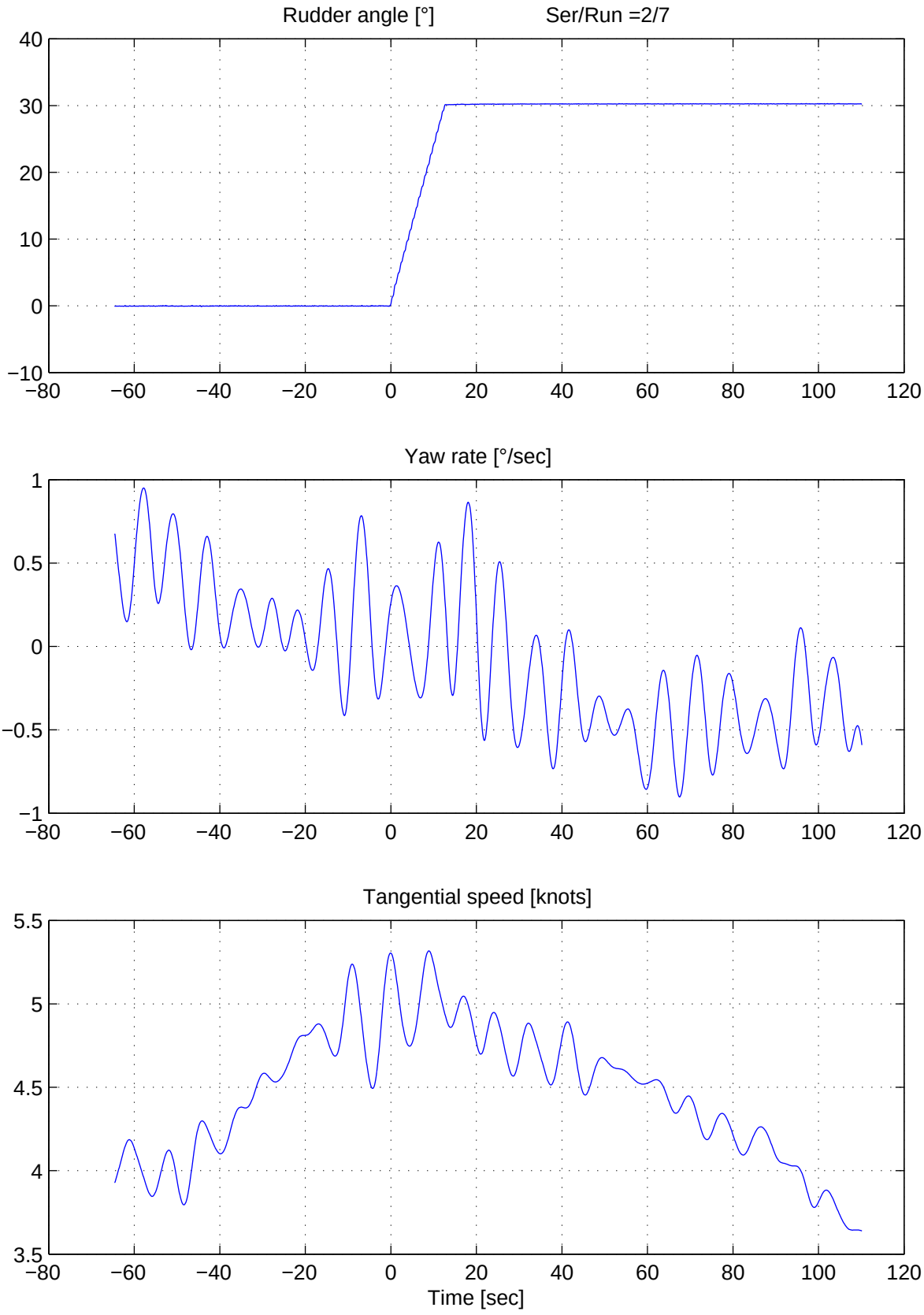


SSPA	MV Estonia Turning test in irregular waves Initial speed: 4 knots Draught Ta/Tf: 5.61/5.17 m	Figure 5.1 Report 40064100−1

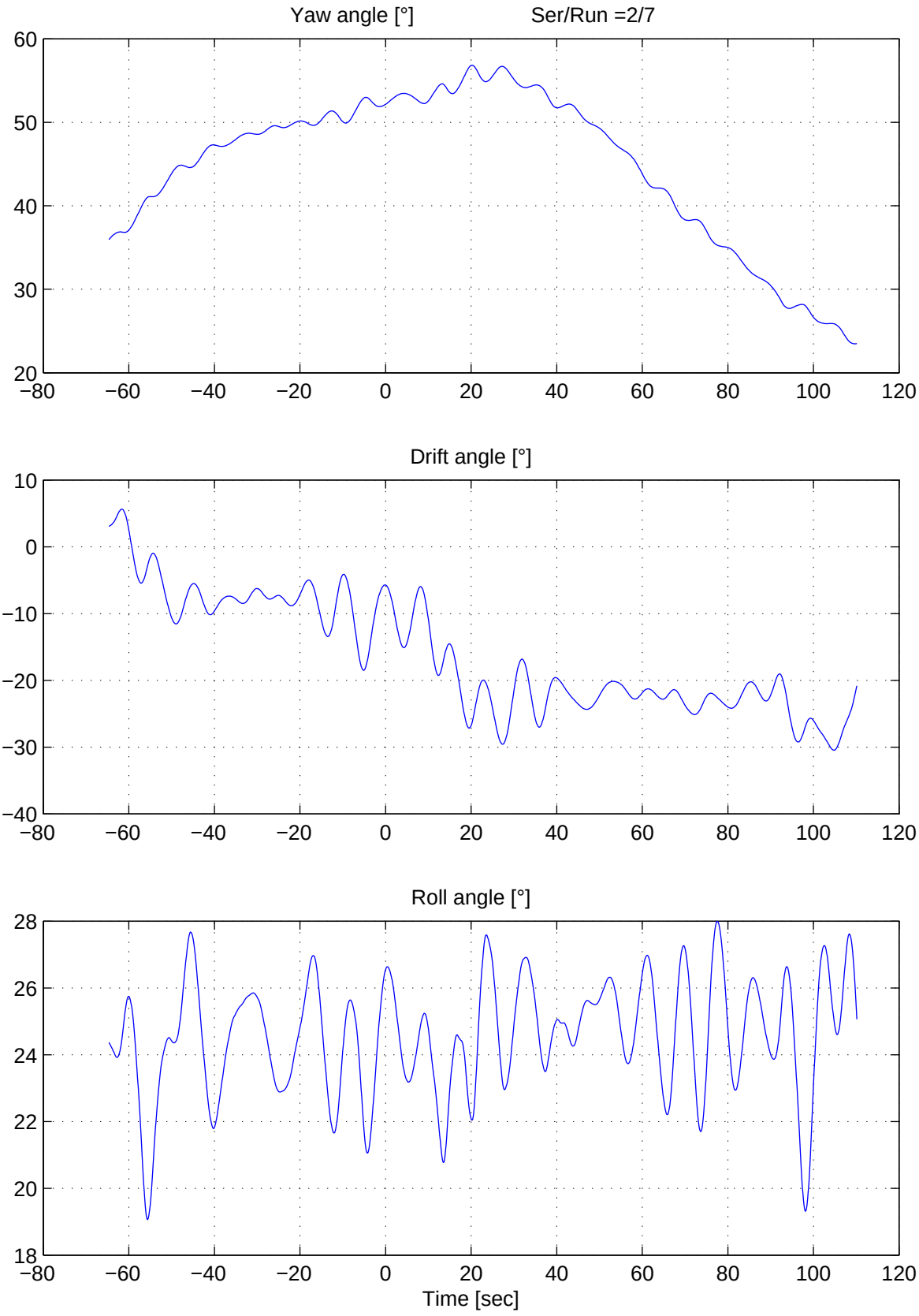


Time step between plots of ship	:	30	(sec)
Advance	:	0	(m) − 0 L_{pp}
Transfer	:	0	(m) − 0 L_{pp}
Tactical diameter	:	0	(m) − 0 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

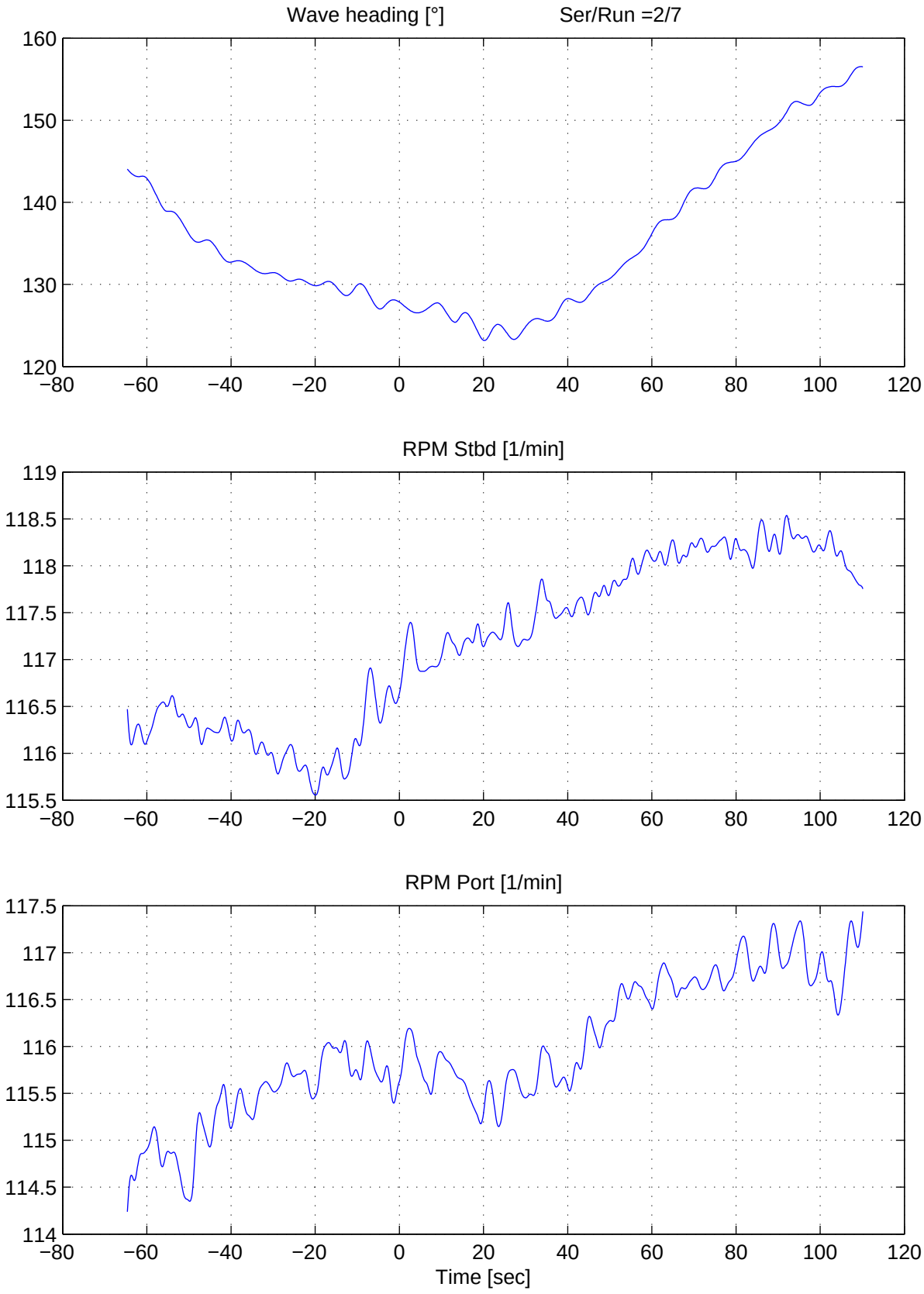
SSPA	MV Estonia Turning test in irregular waves Initial speed: 4 knots Draught Ta/Tf: 5.61/5.17 m	Figure 5.2 Report 40064100−1



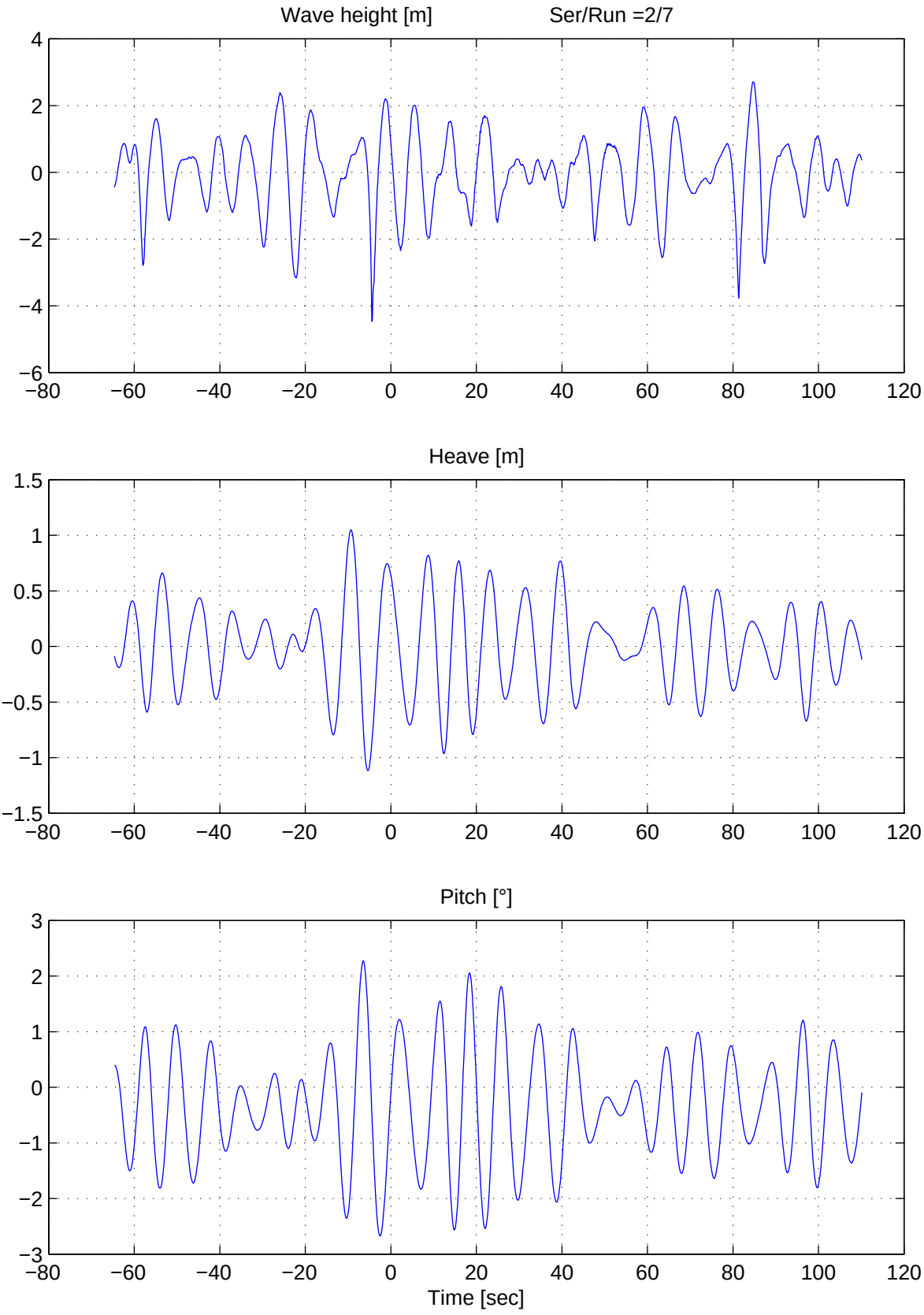
SSPA	MV Estonia Turning test in irregular waves Initial speed: 4 knots Draught Ta/Tf: 5.61/5.17 m	Figure 5.3 Report 40064100−1



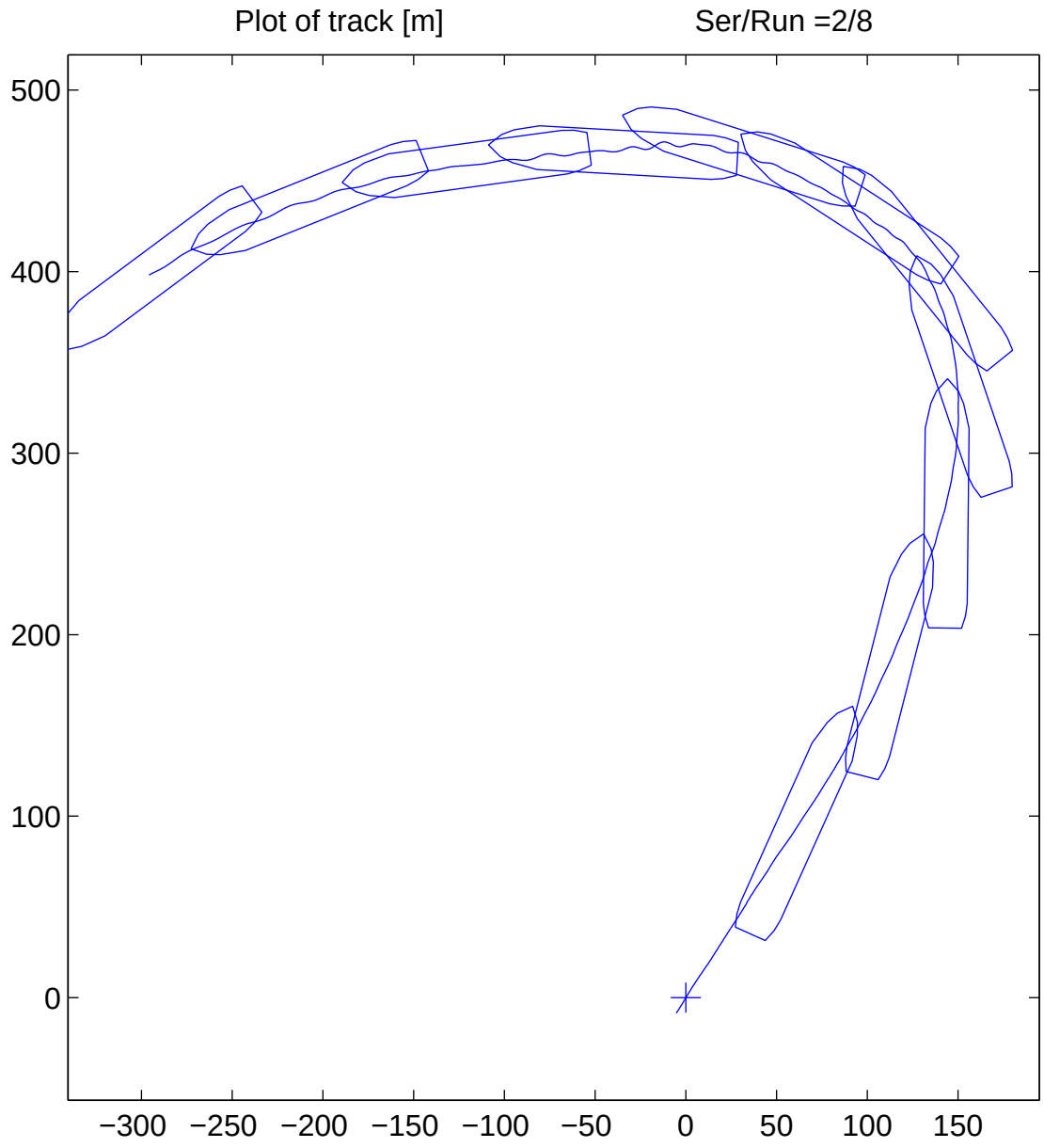
SSPA	MV Estonia Turning test in irregular waves Initial speed: 4 knots Draught Ta/Tf: 5.61/5.17 m	Figure 5.4 Report 40064100−1



SSPA	MV Estonia Turning test in irregular waves Initial speed: 4 knots Draught Ta/Tf: 5.61/5.17 m	Figure 5.5 Report 40064100−1

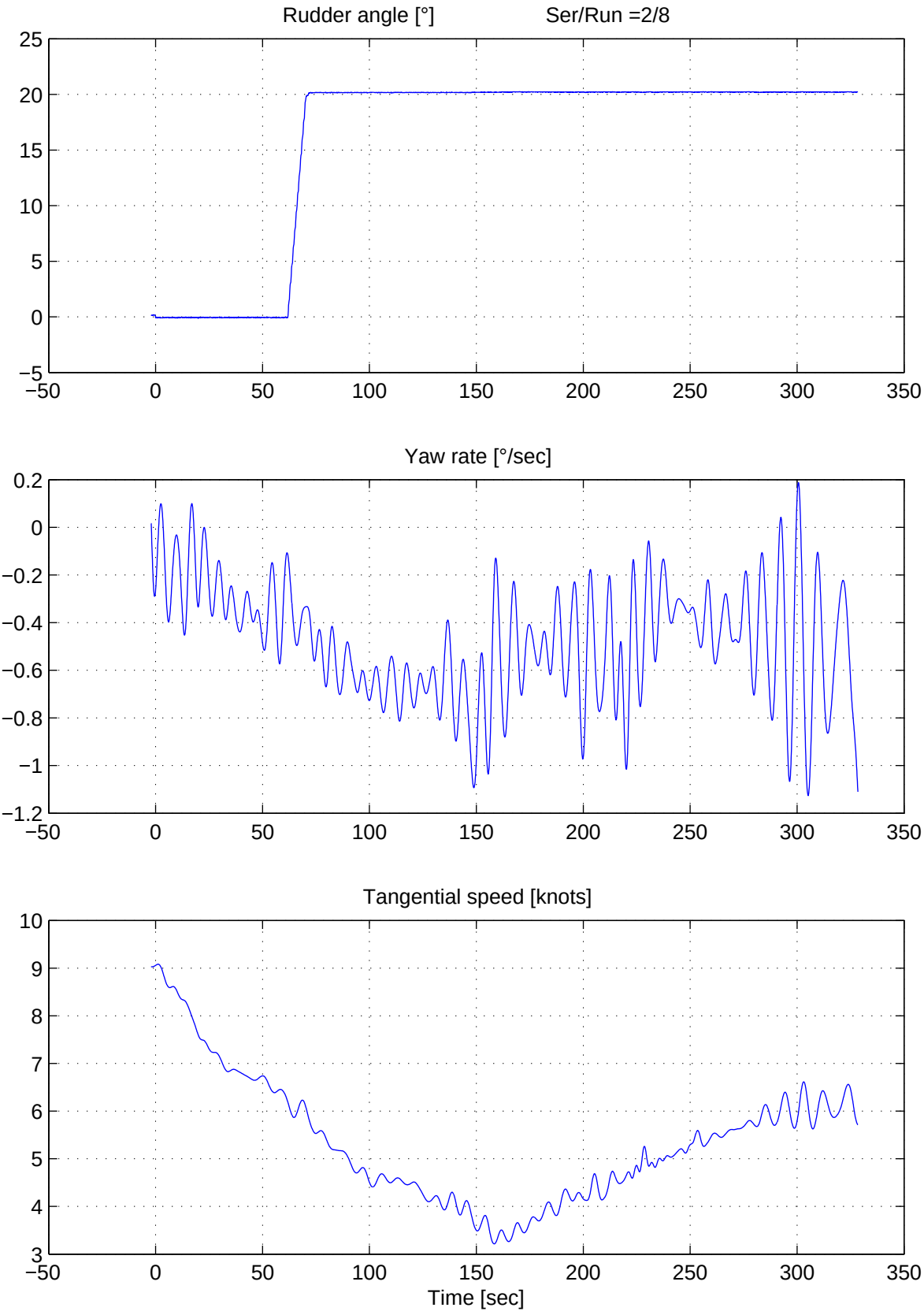


SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 6.1 Report 40064100−1

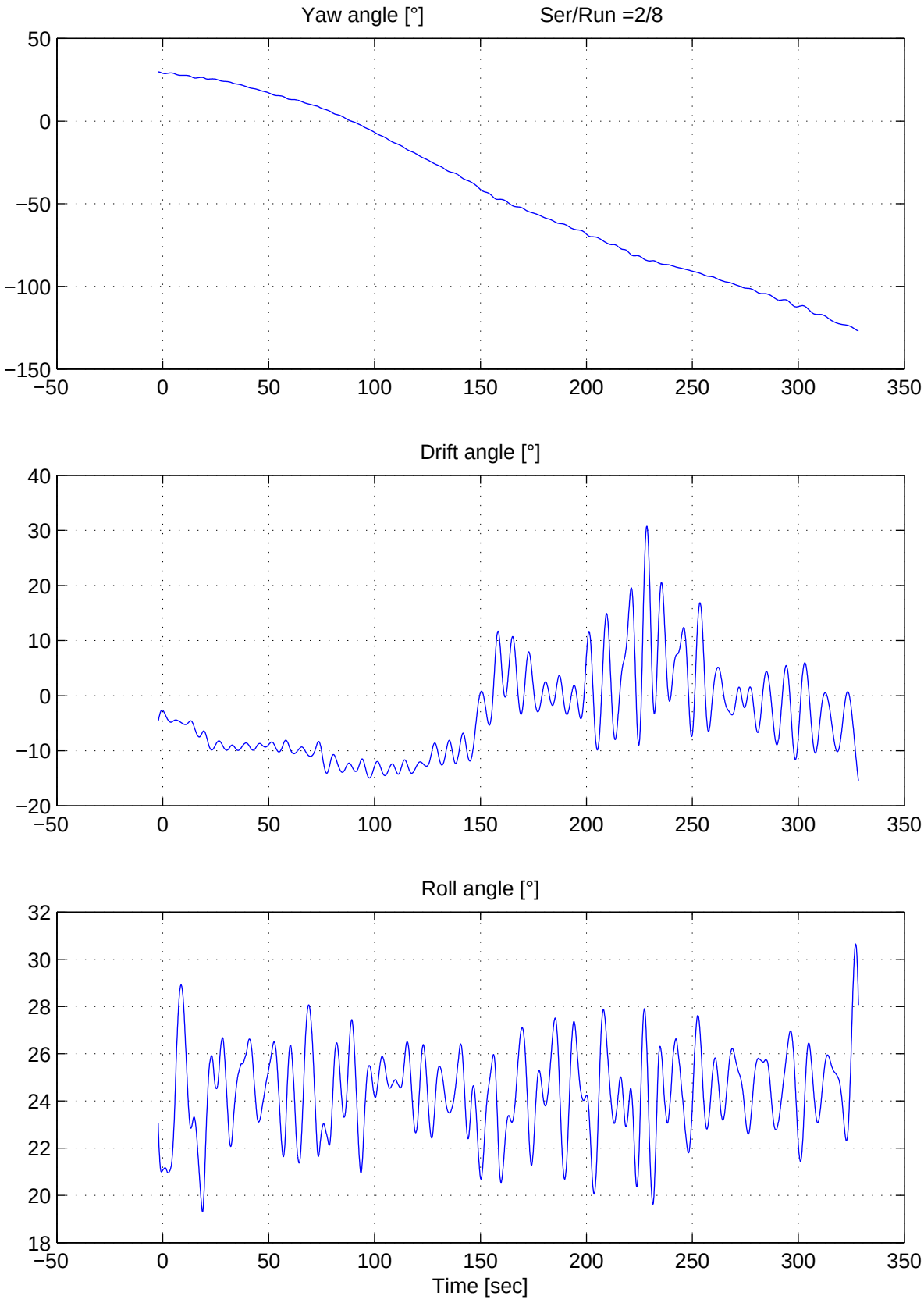


Time step between plots of ship	:	30	(sec)	
Advance	:	464	(m)	− 3.38 L_{pp}
Transfer	:	66	(m)	− 0.48 L_{pp}
Tactical diameter	:	0	(m)	− 0 L_{pp}
Steady turning diameter	:	0	(m)	− 0 L_{pp}

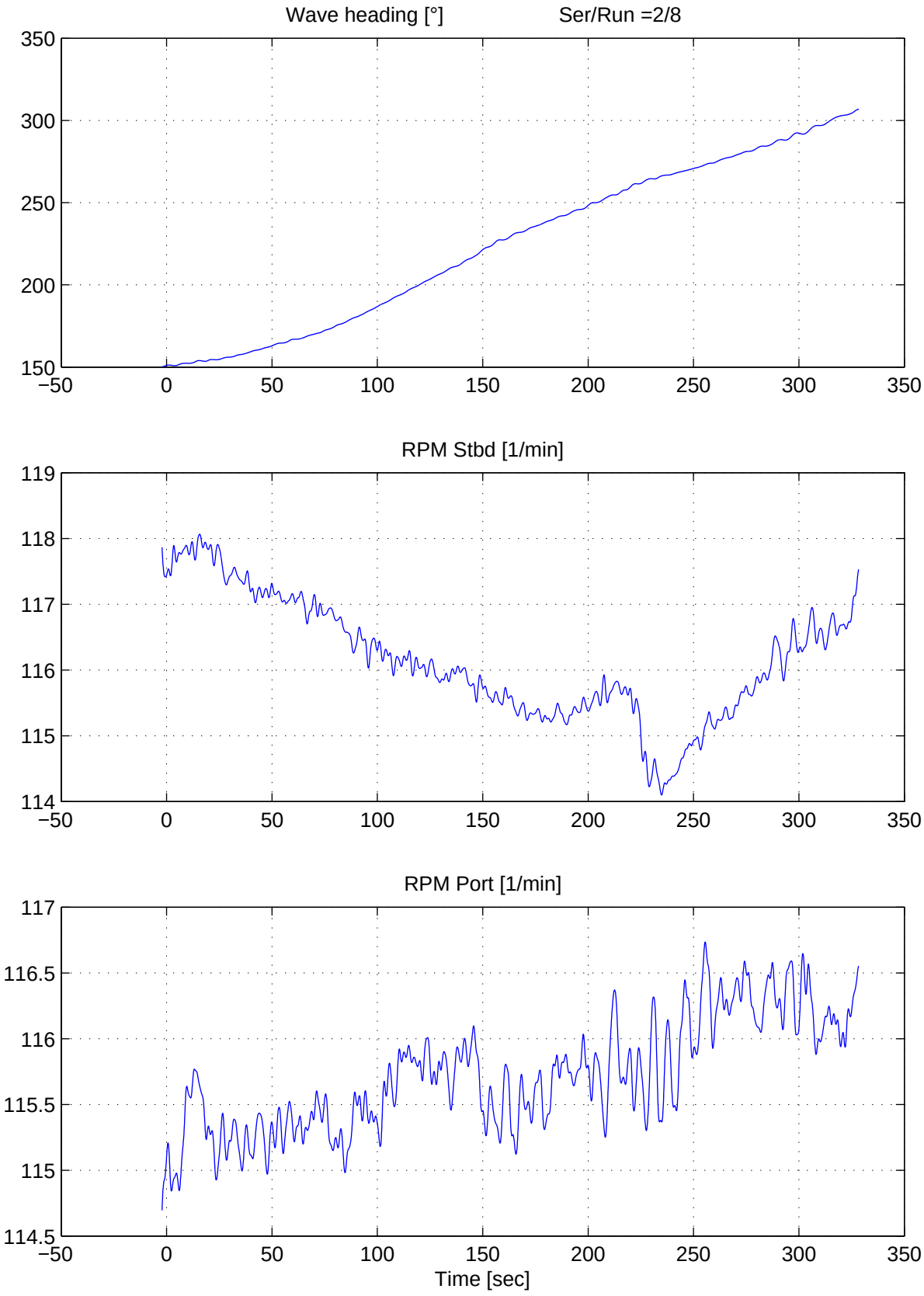
SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 6.2 Report 40064100−1



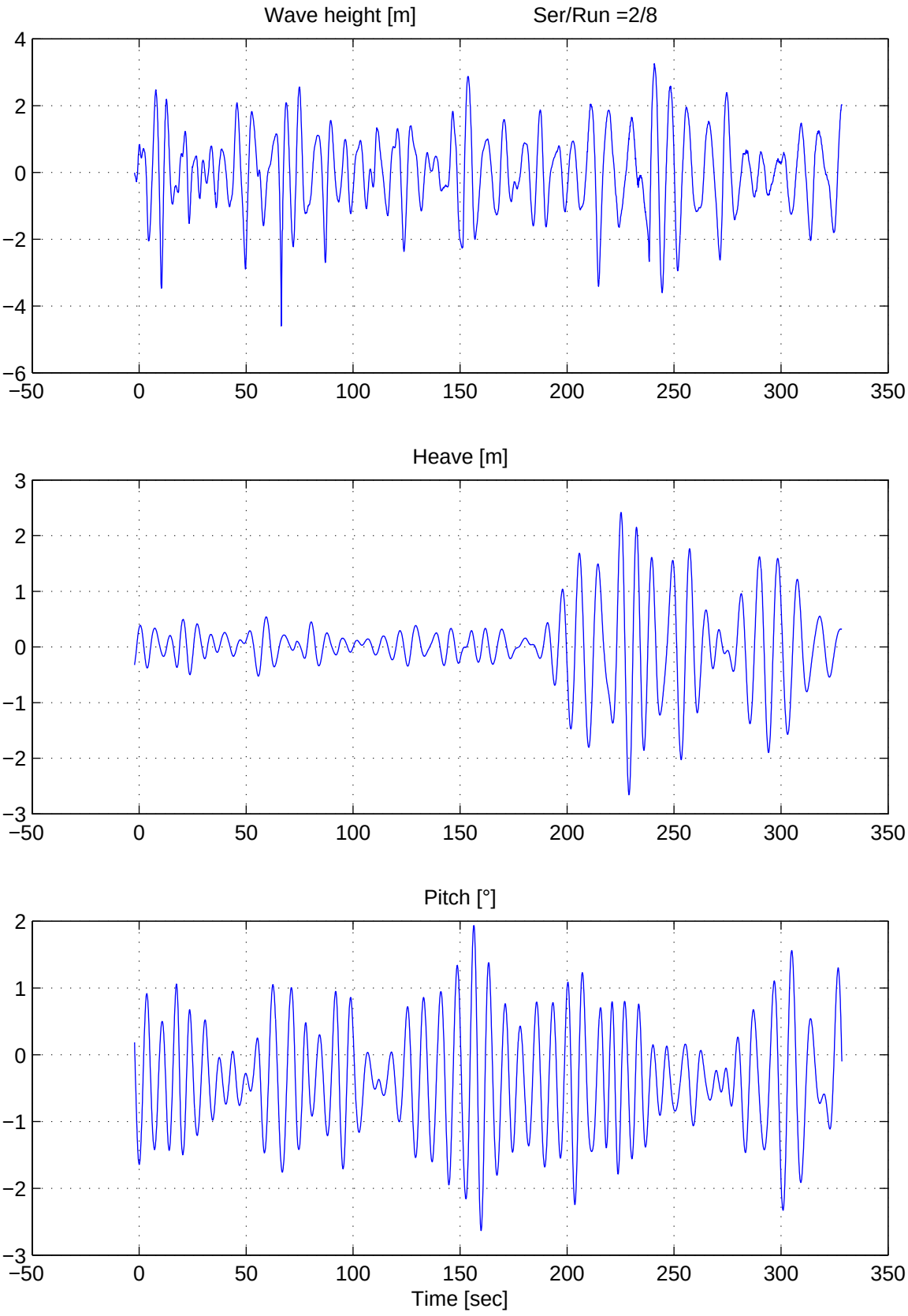
SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 6.3 Report 40064100−1



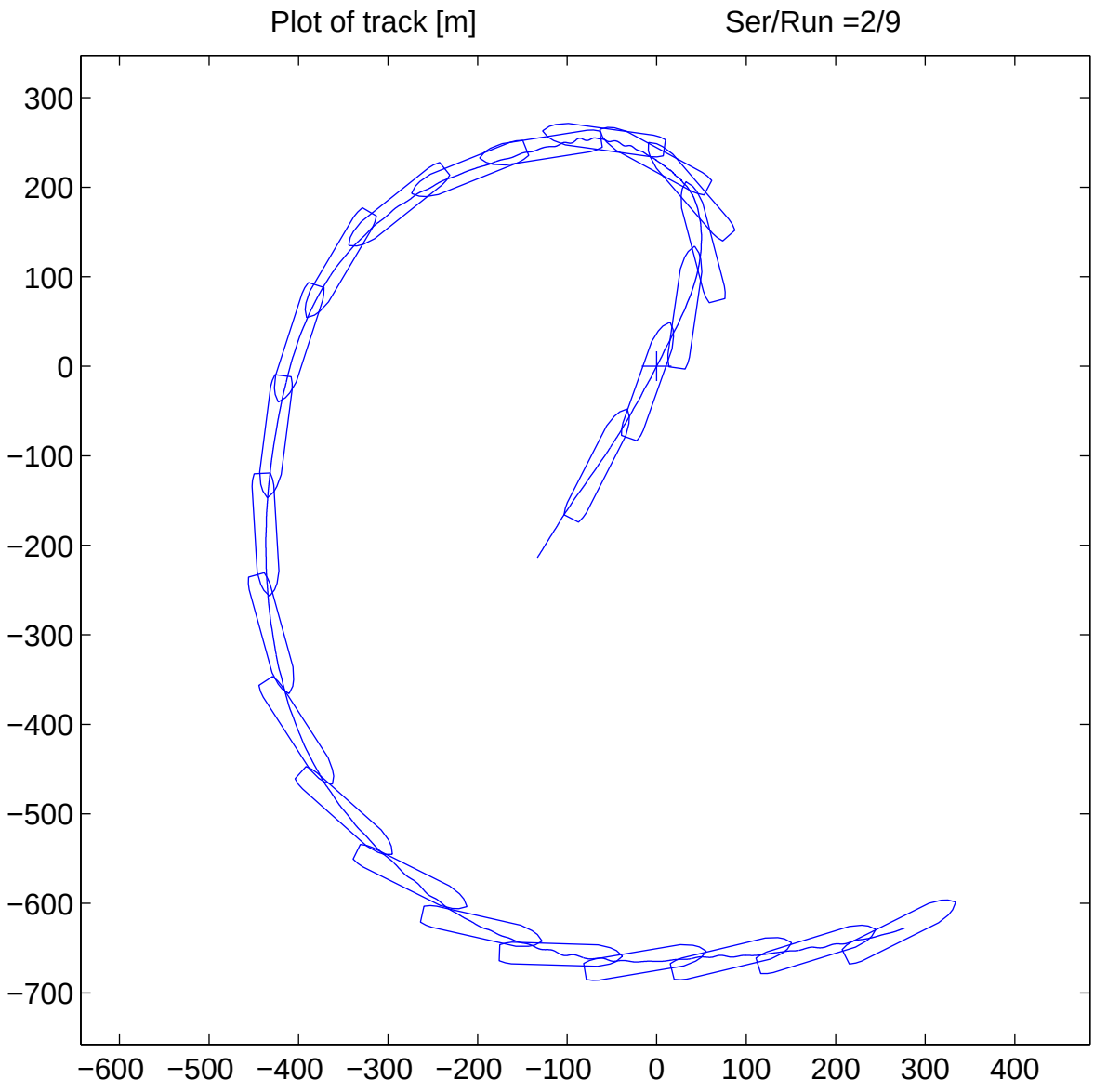
SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 6.4 Report 40064100−1



SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 6.5 Report 40064100−1

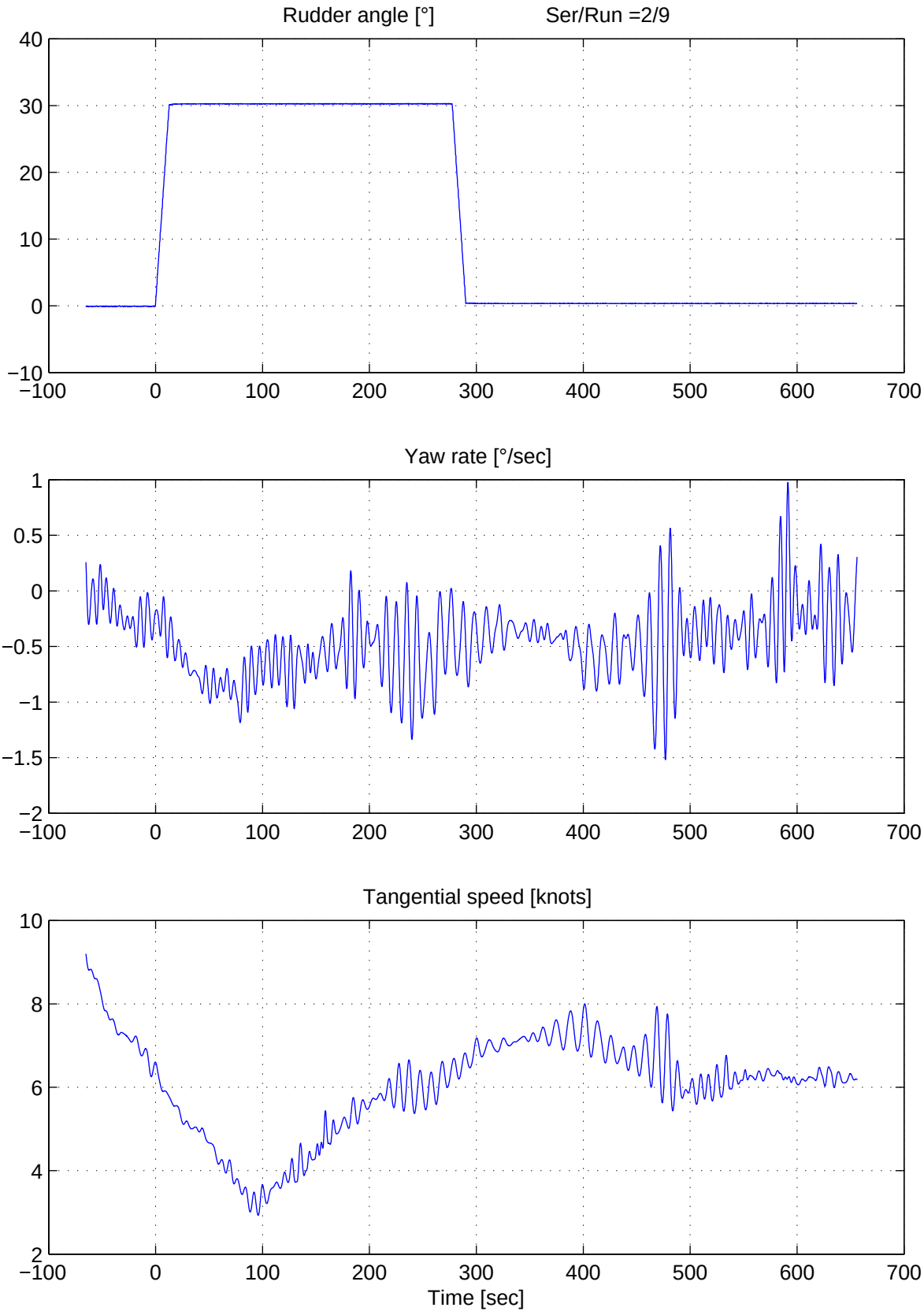


SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 7.1 Report 40064100−1

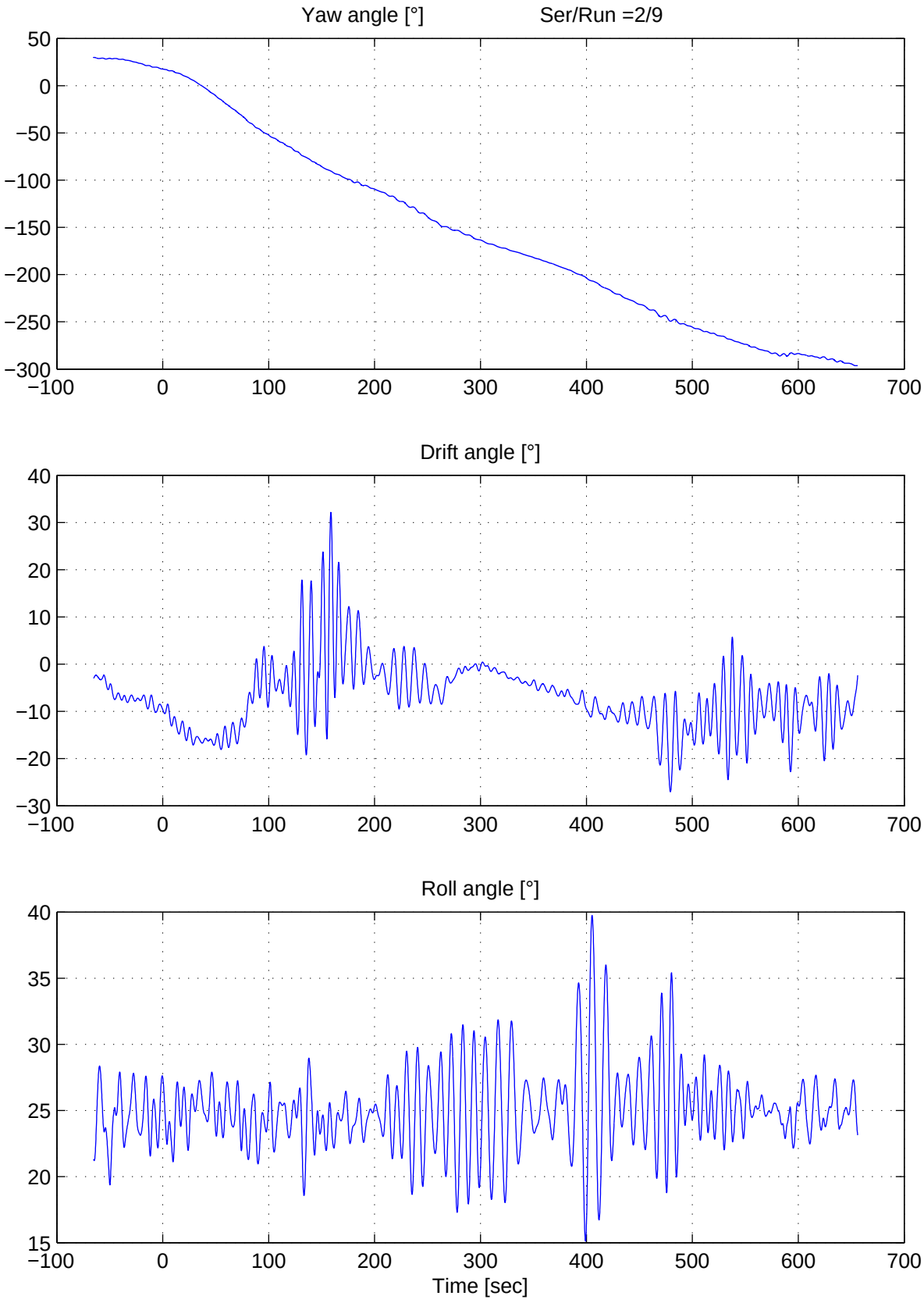


Time step between plots of ship	:	30	(sec)
Advance	:	253	(m) − 1.84 L_{pp}
Transfer	:	89	(m) − 0.648 L_{pp}
Tactical diameter	:	435	(m) − 3.17 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

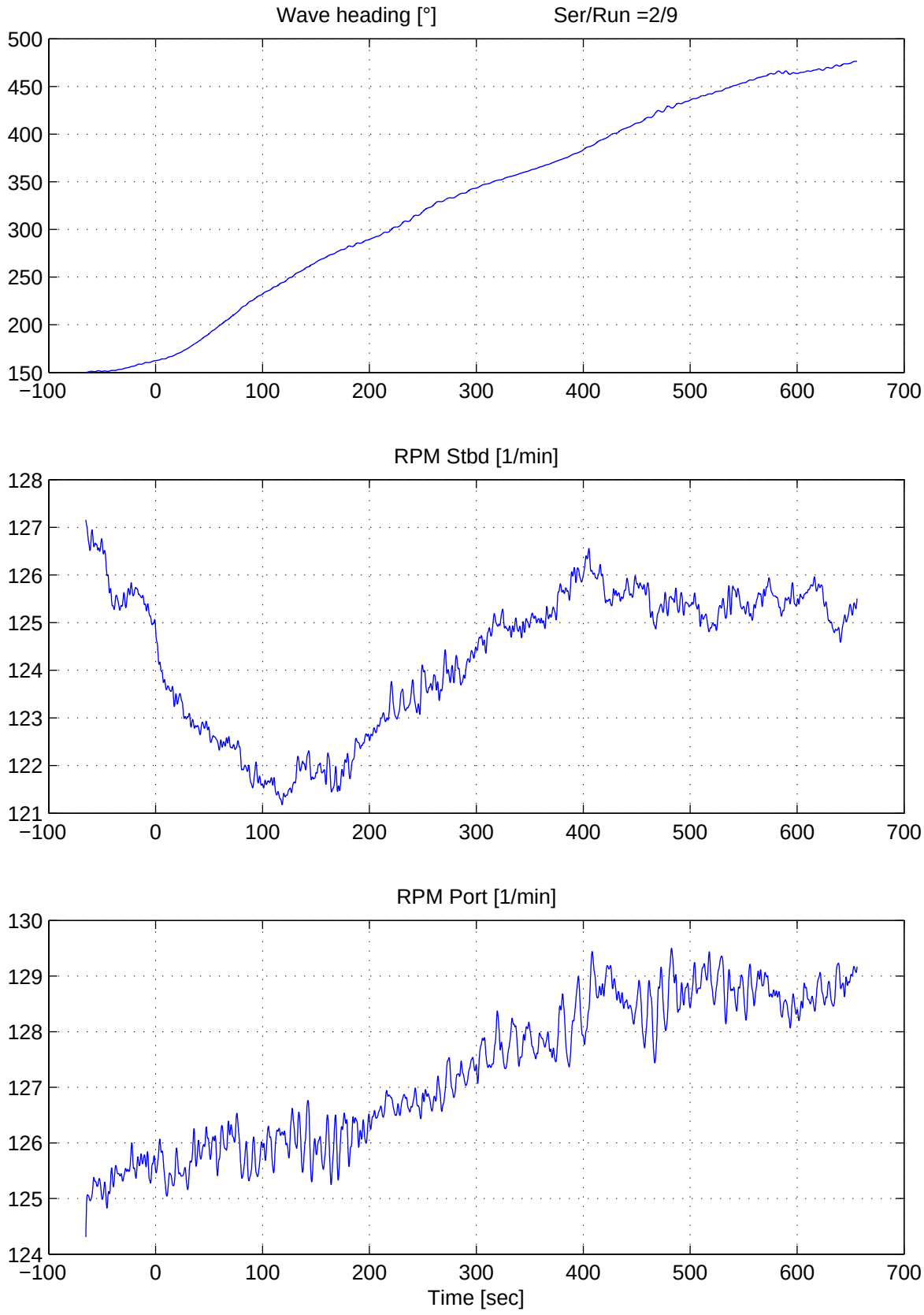
SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 7.2 Report 40064100−1



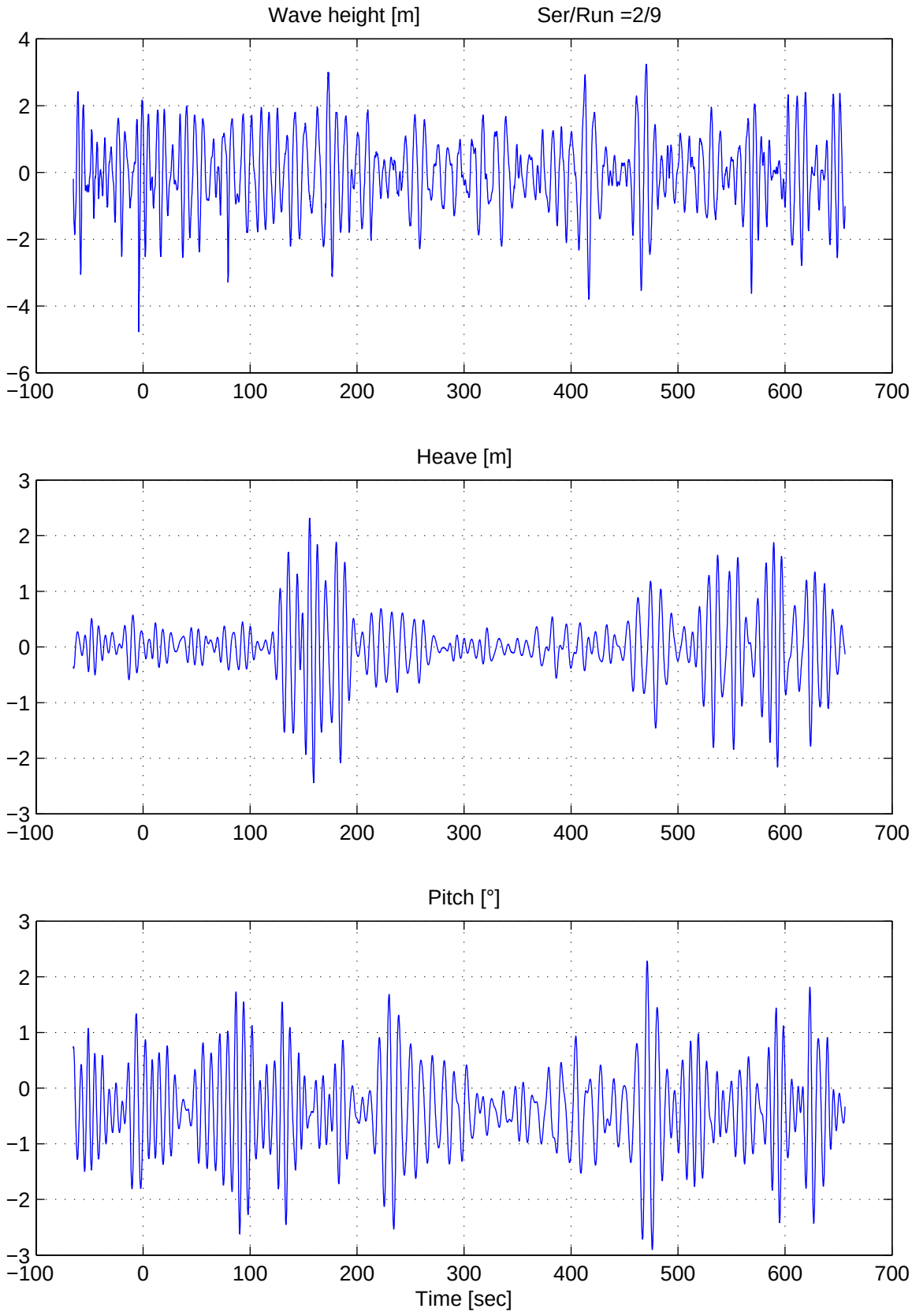
SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 7.3 Report 40064100−1



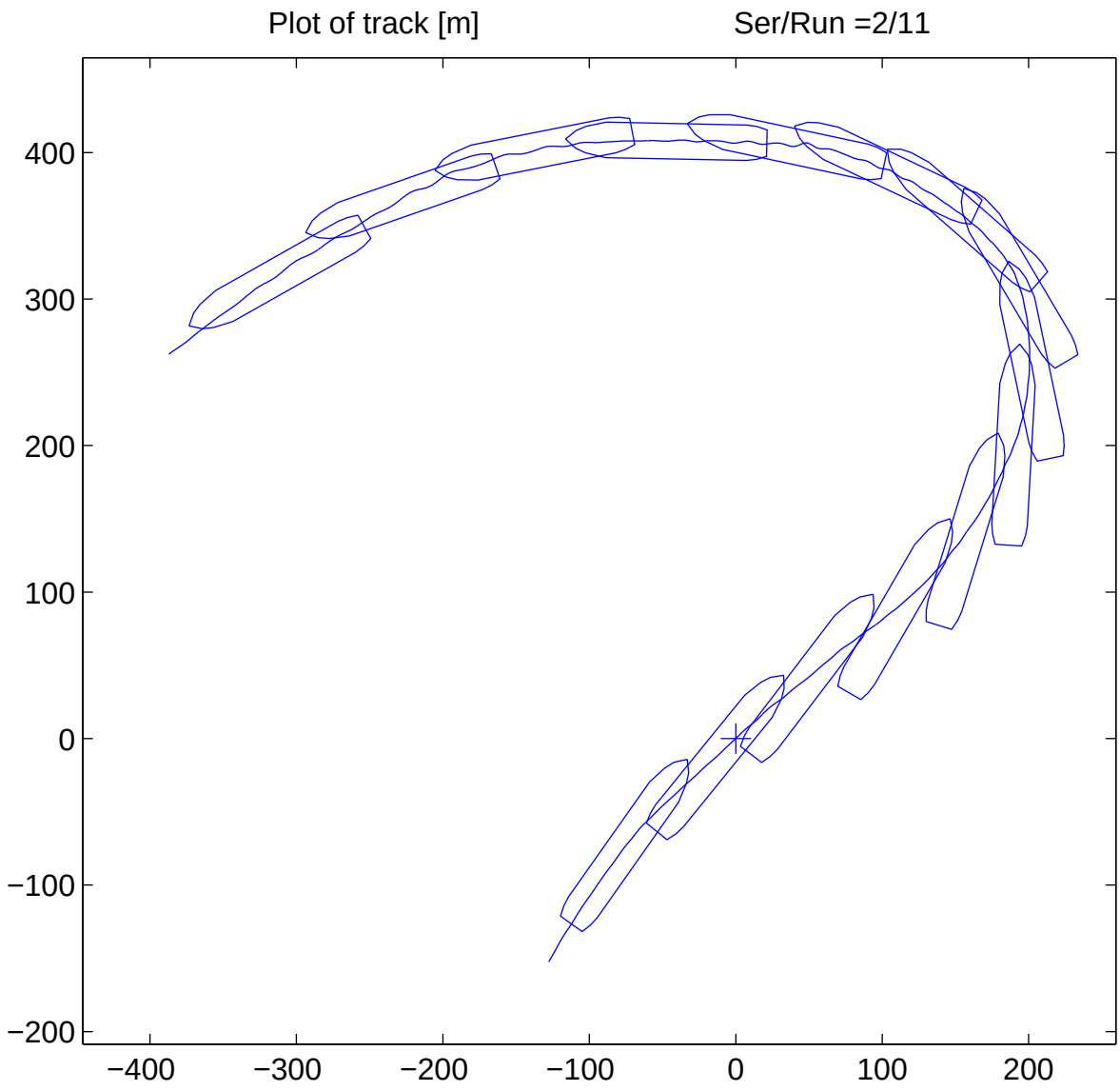
SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 7.4 Report 40064100−1



SSPA	MV Estonia Turning test in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 7.5 Report 40064100−1

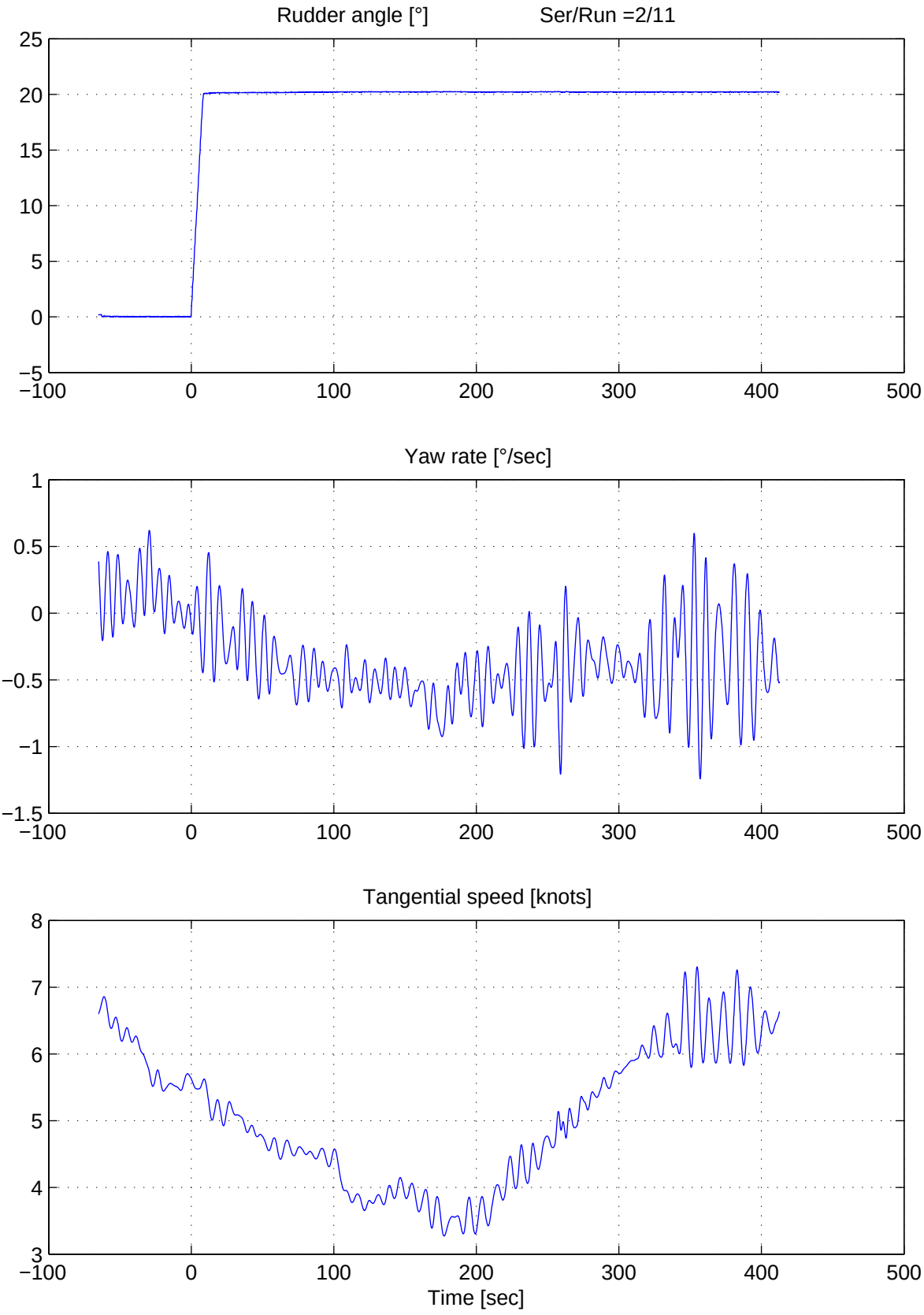


SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 8.1 Report 40064100−1

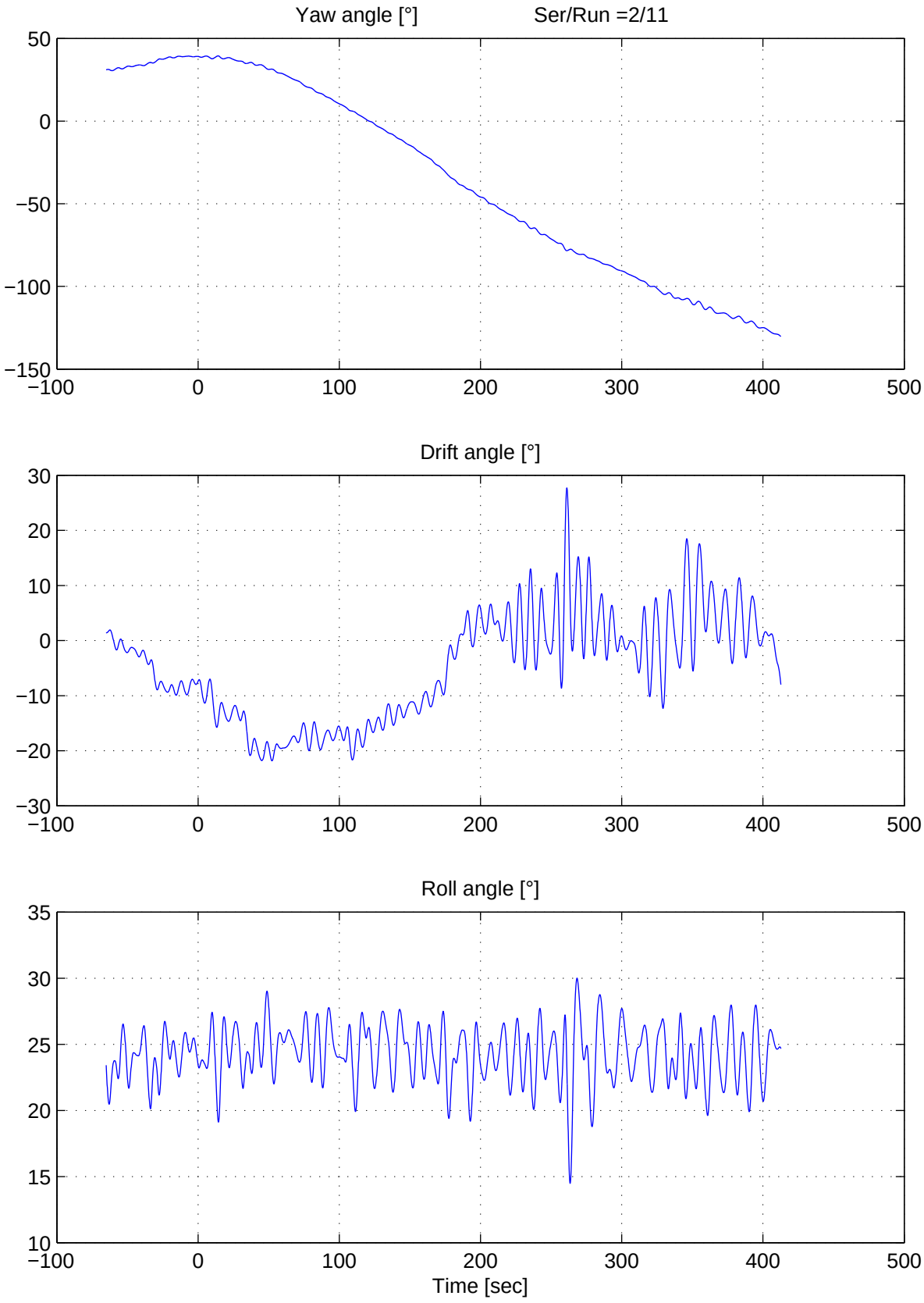


Time step between plots of ship	:	30	(sec)
Advance	:	408	(m) − 2.97 L_{pp}
Transfer	:	54	(m) − 0.393 L_{pp}
Tactical diameter	:	0	(m) − 0 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

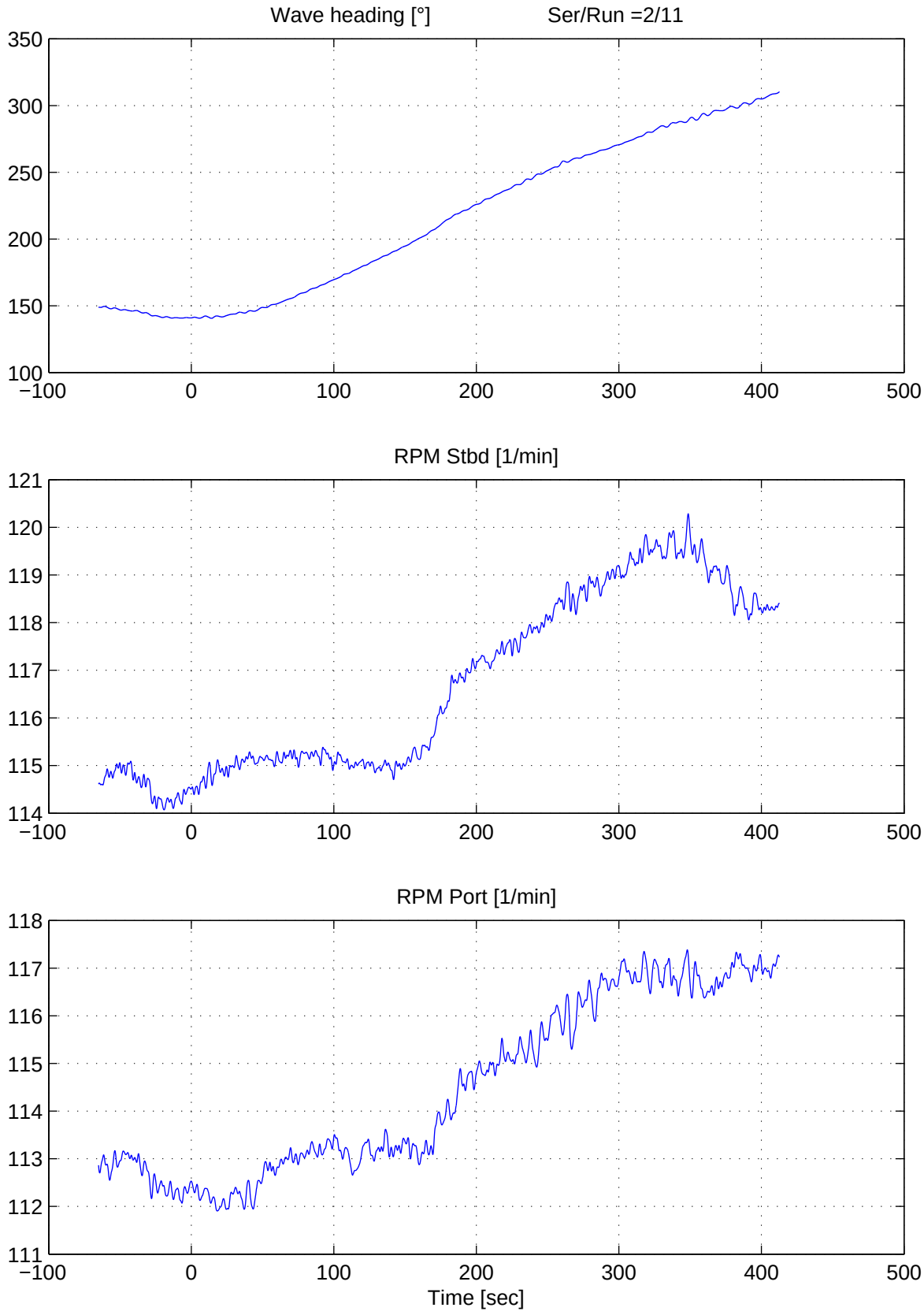
SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 8.2 Report 40064100−1



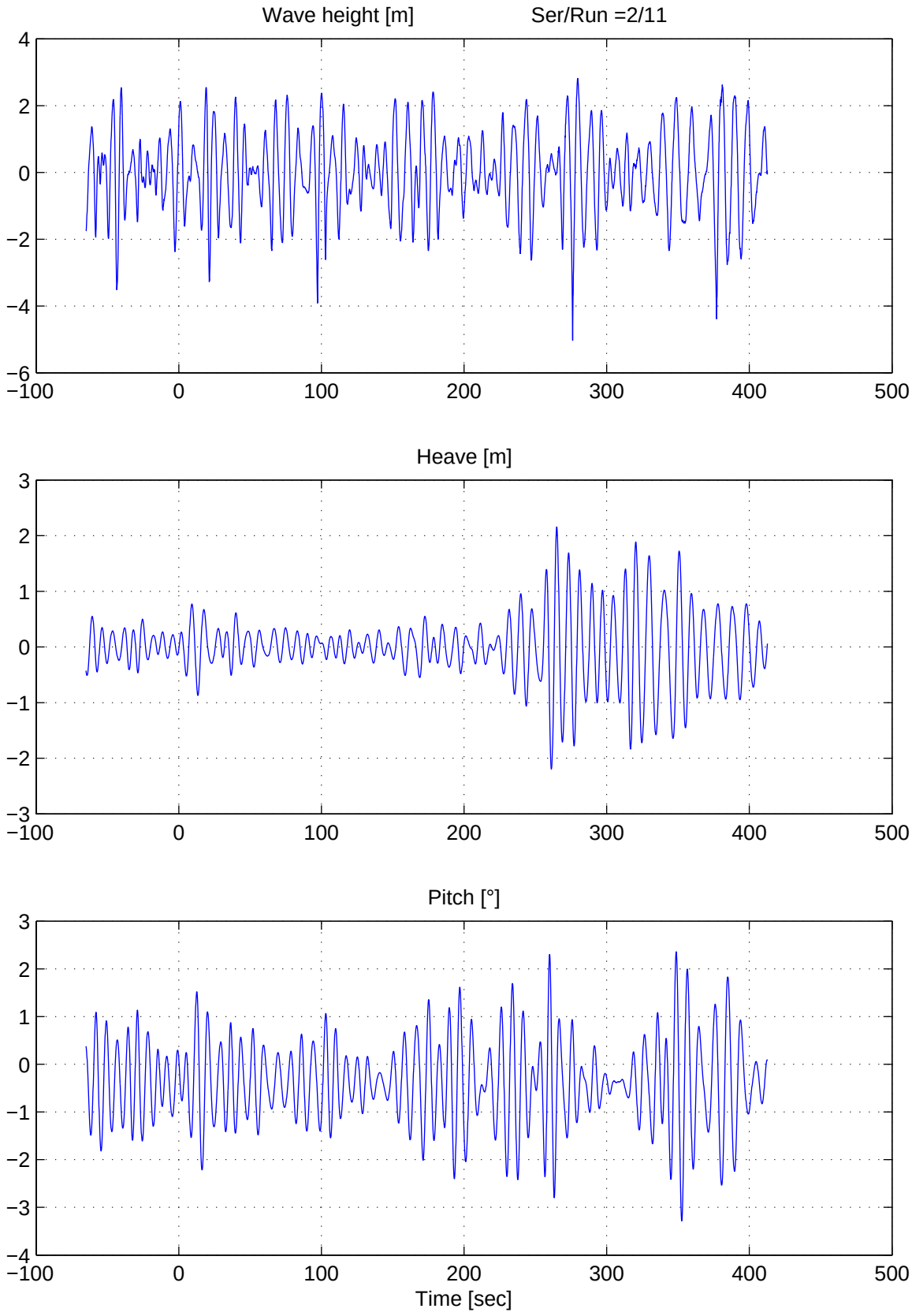
SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 8.3 Report 40064100−1



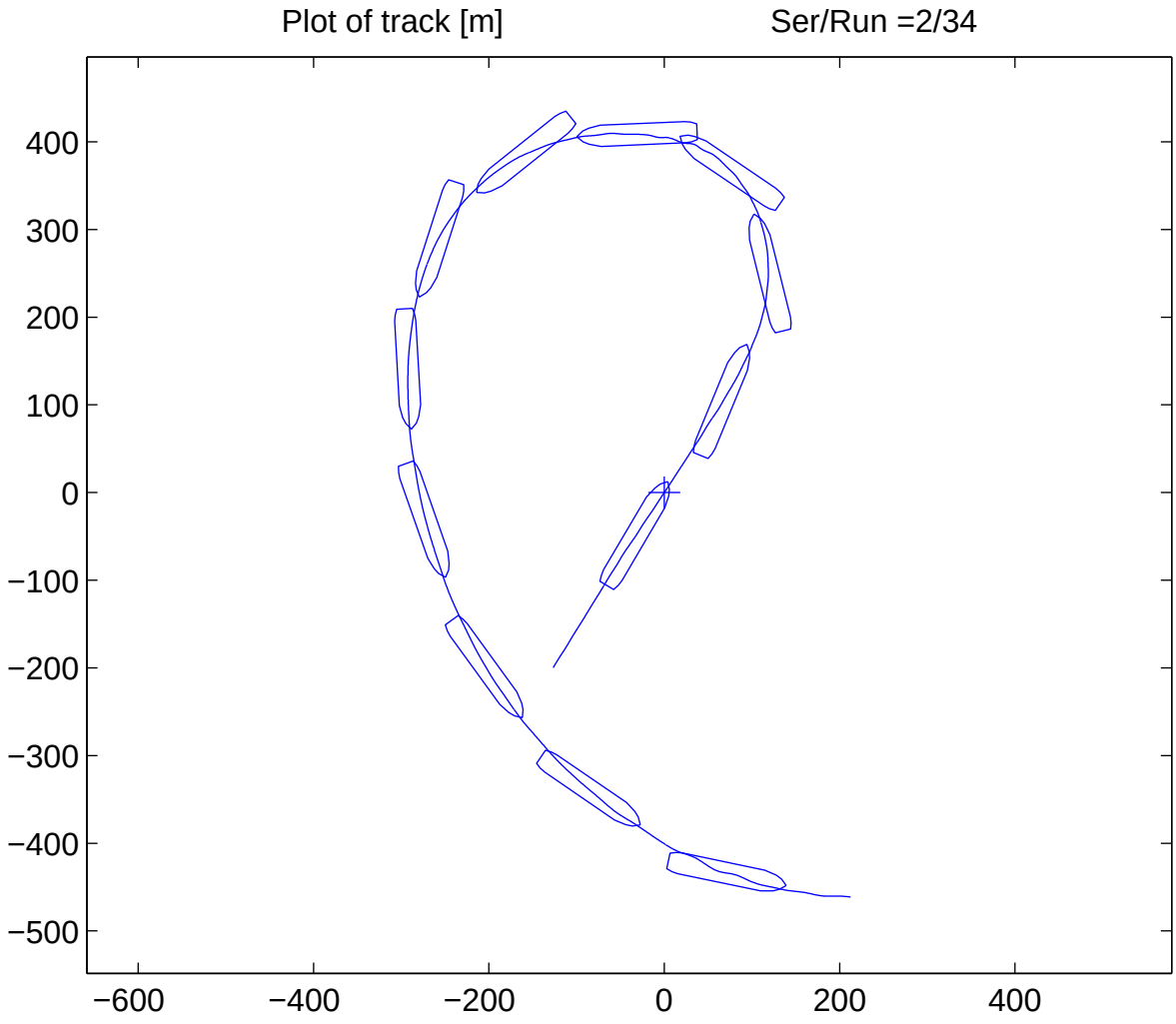
SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 8.4 Report 40064100−1



SSPA	MV Estonia Turning test in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 8.5 Report 40064100−1

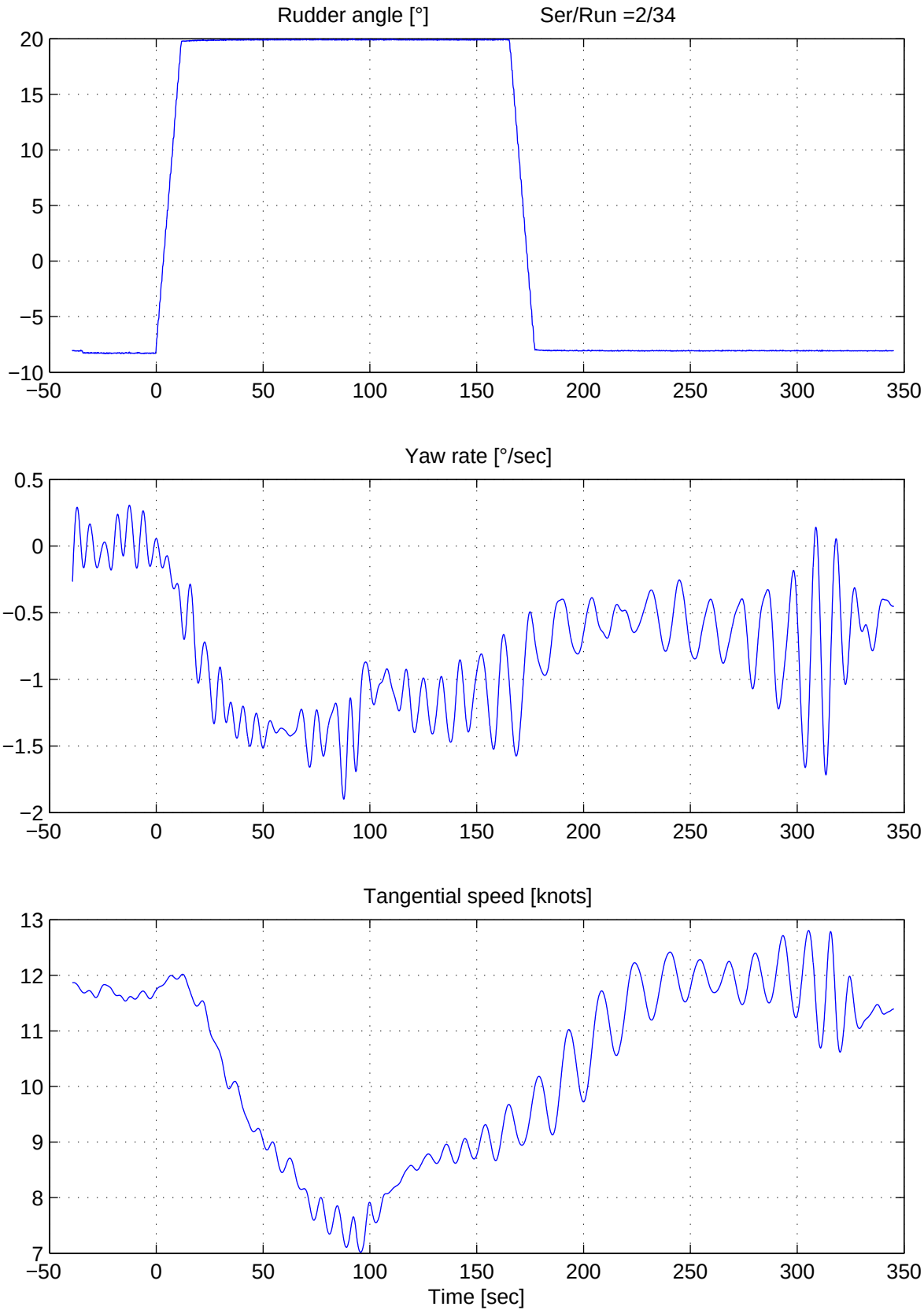


SSPA	MV Estonia Turning test in irregular waves Initial speed: 12 knots Draught Ta/Tf: 5.61/5.17 m	Figure 9.1 Report 40064100−1

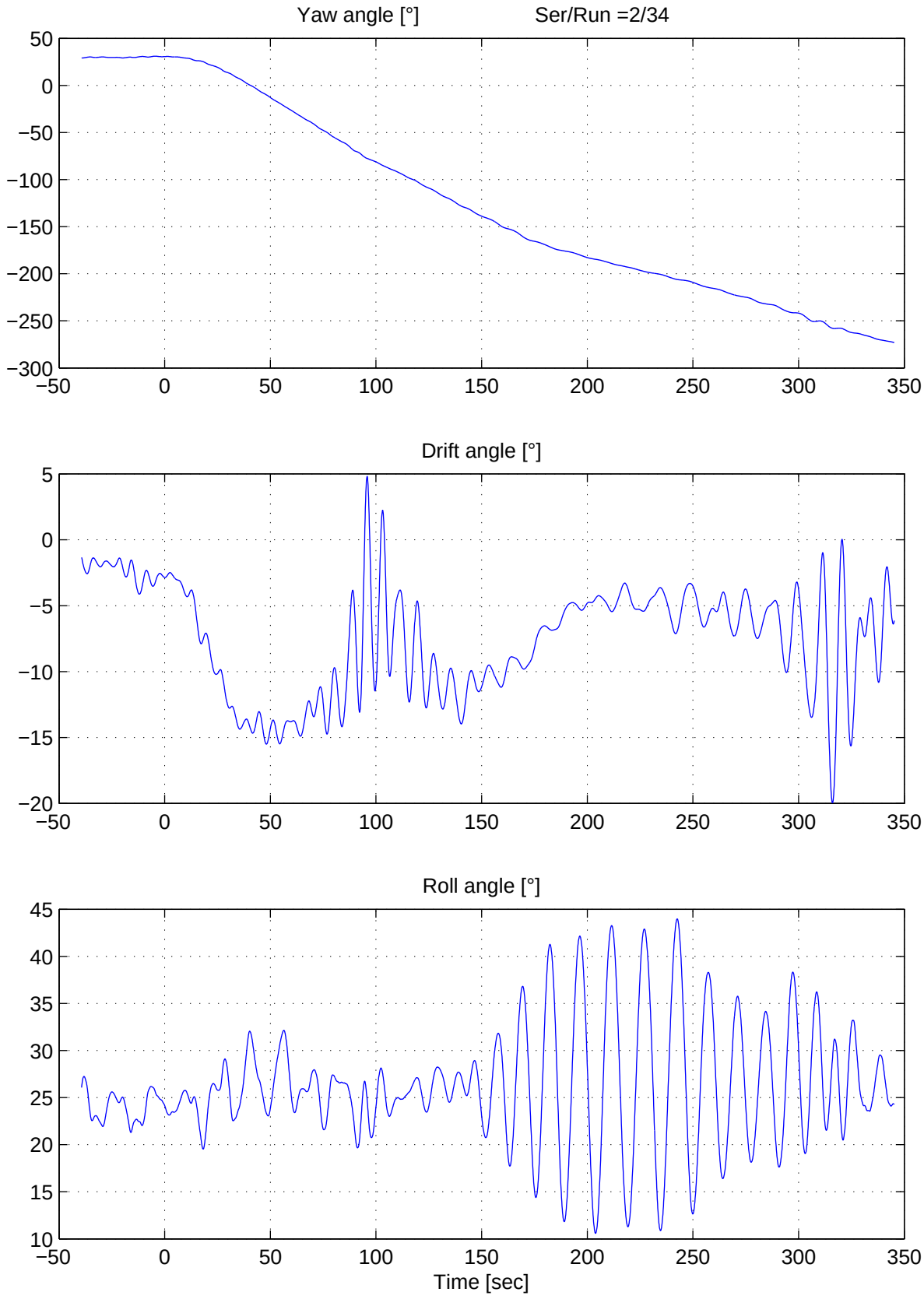


Time step between plots of ship	:	30	(sec)
Advance	:	408	(m) − 2.97 L_{pp}
Transfer	:	21	(m) − 0.153 L_{pp}
Tactical diameter	:	291	(m) − 2.12 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

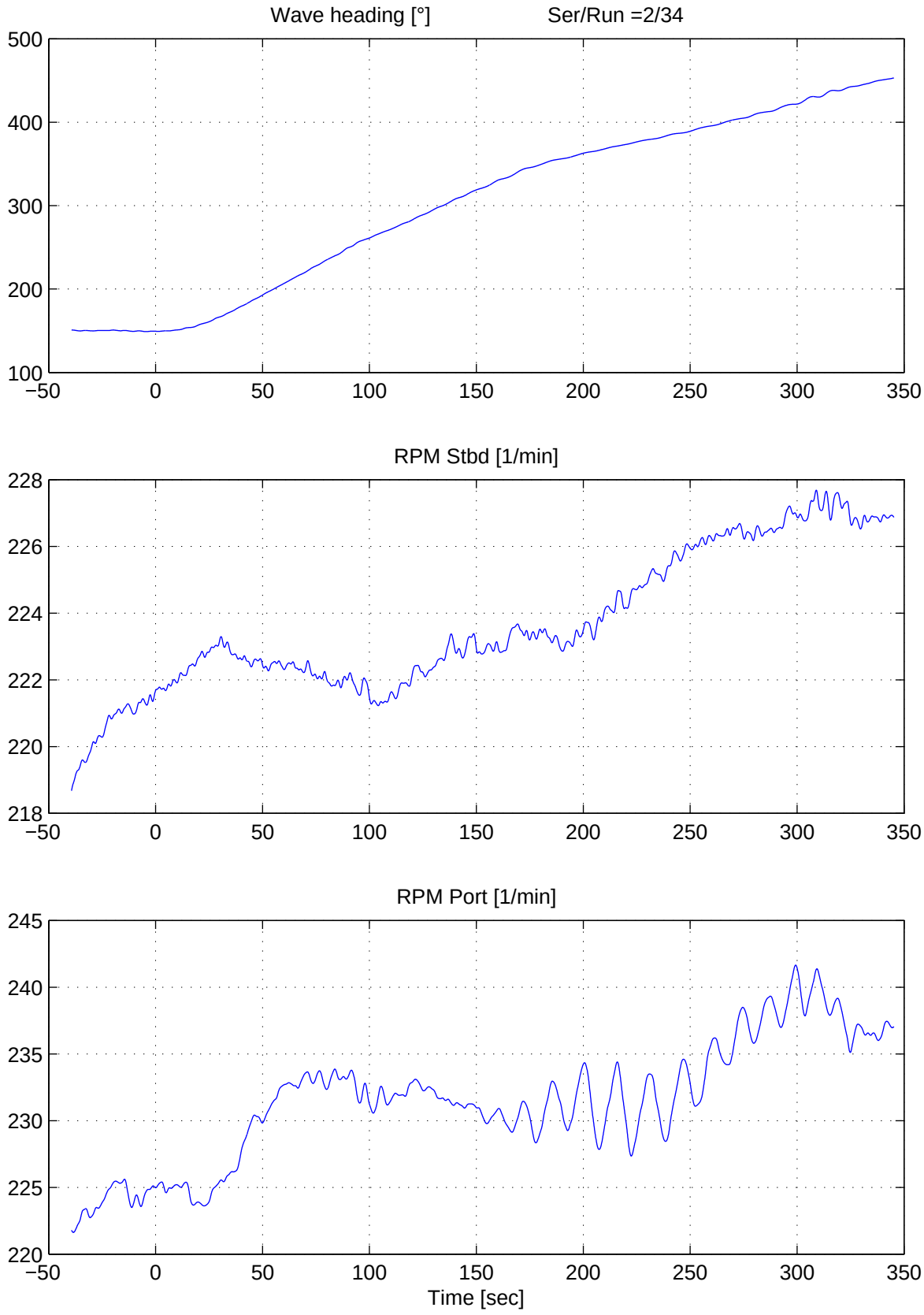
SSPA	MV Estonia Turning test in irregular waves Initial speed: 12 knots Draught Ta/Tf: 5.61/5.17 m	Figure 9.2 Report 40064100−1



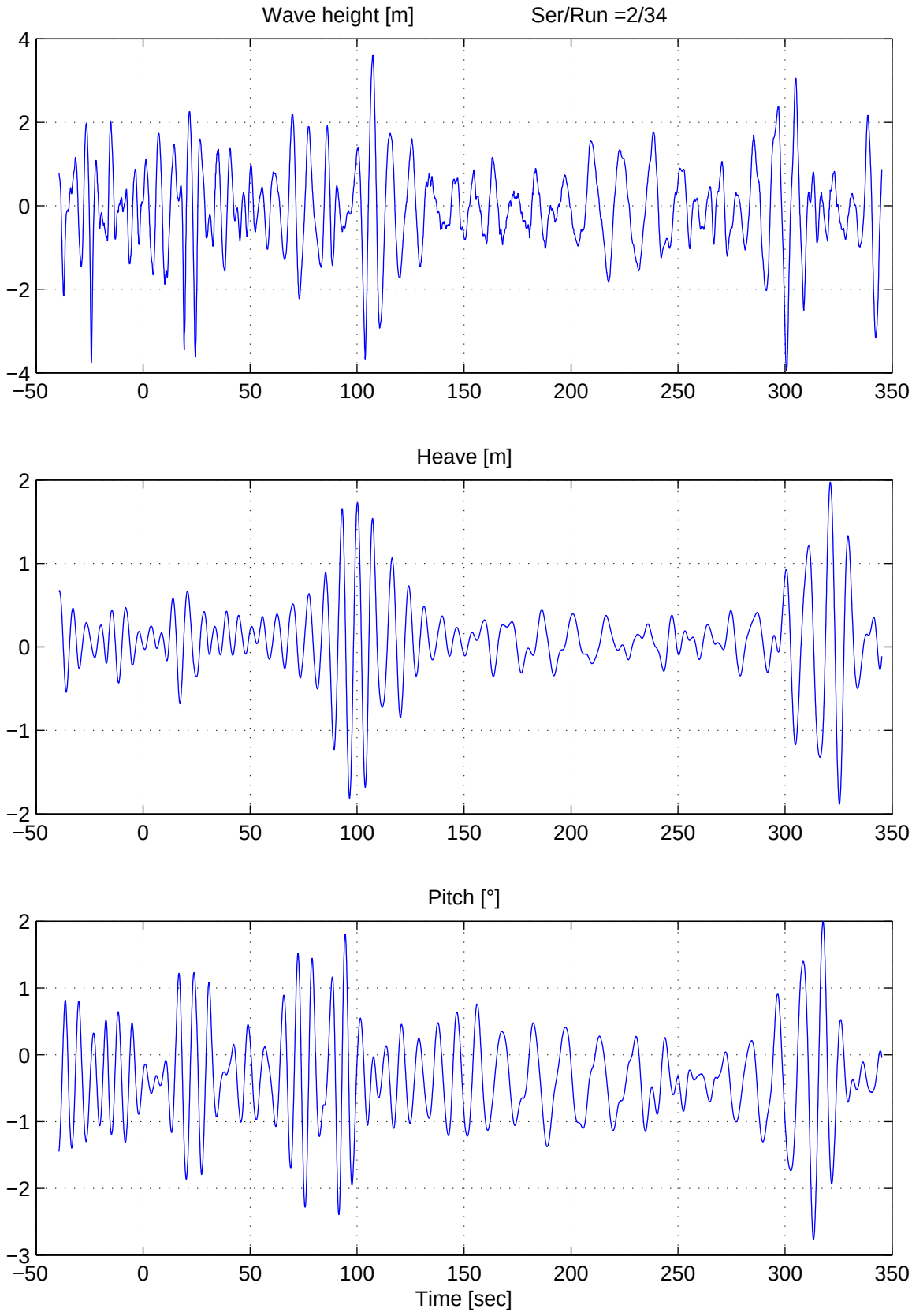
SSPA	MV Estonia Turning test in irregular waves Initial speed: 12 knots Draught Ta/Tf: 5.61/5.17 m	Figure 9.3 Report 40064100−1



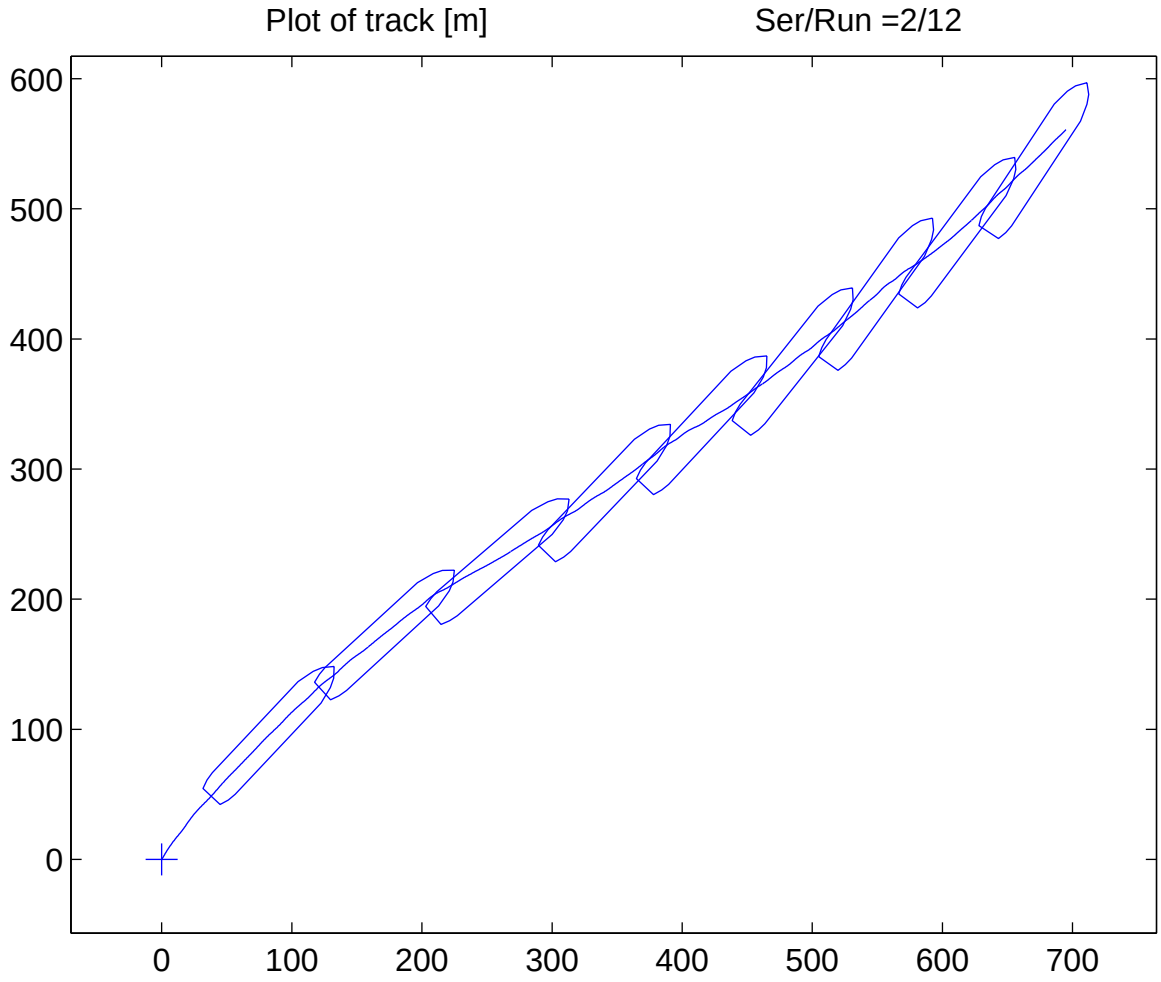
SSPA	MV Estonia Turning test in irregular waves Initial speed: 12 knots Draught Ta/Tf: 5.61/5.17 m	Figure 9.4 Report 40064100−1



SSPA	MV Estonia Turning test in irregular waves Initial speed: 12 knots Draught Ta/Tf: 5.61/5.17 m	Figure 9.5 Report 40064100−1

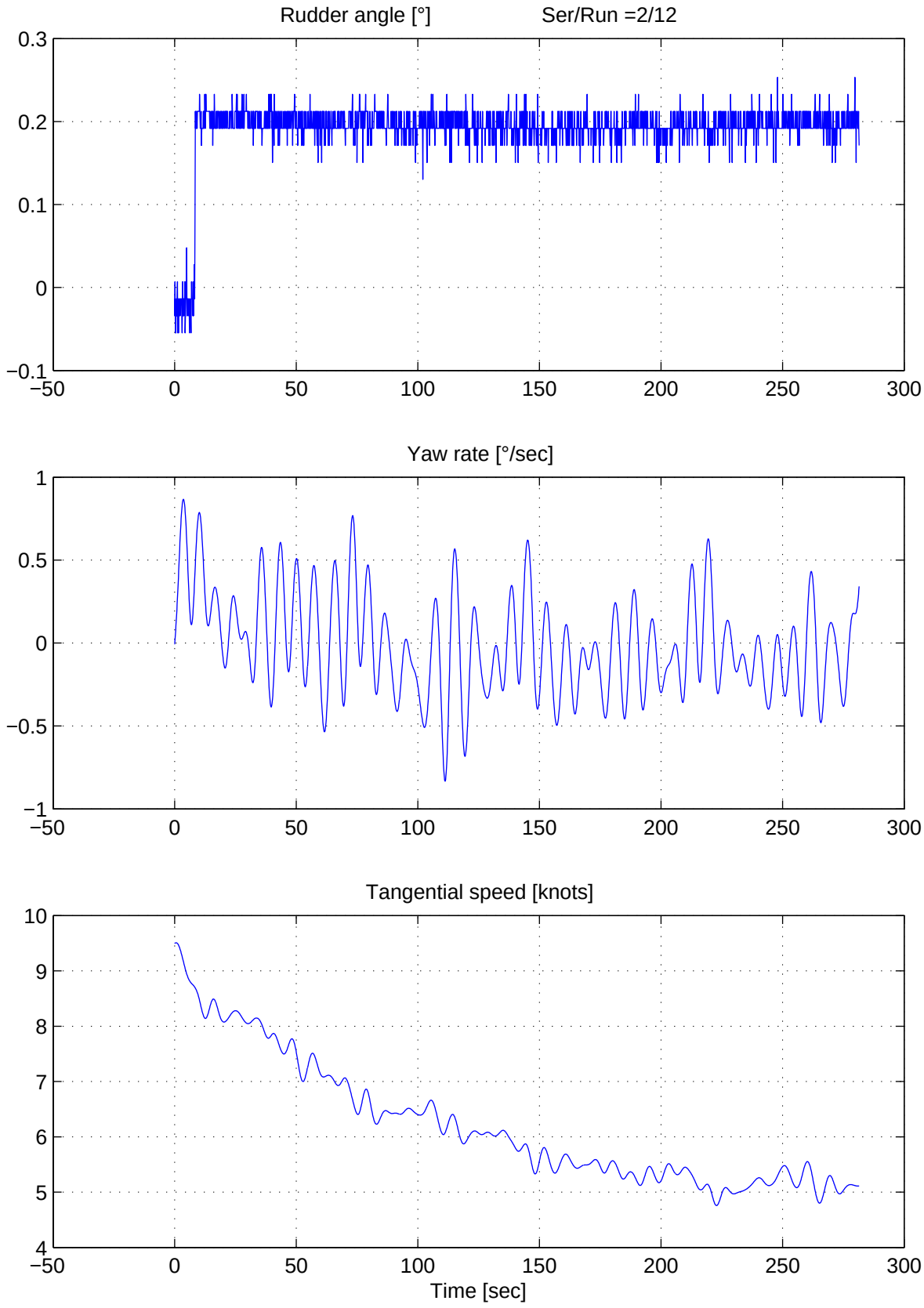


SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 10.1 Report 40064100−1

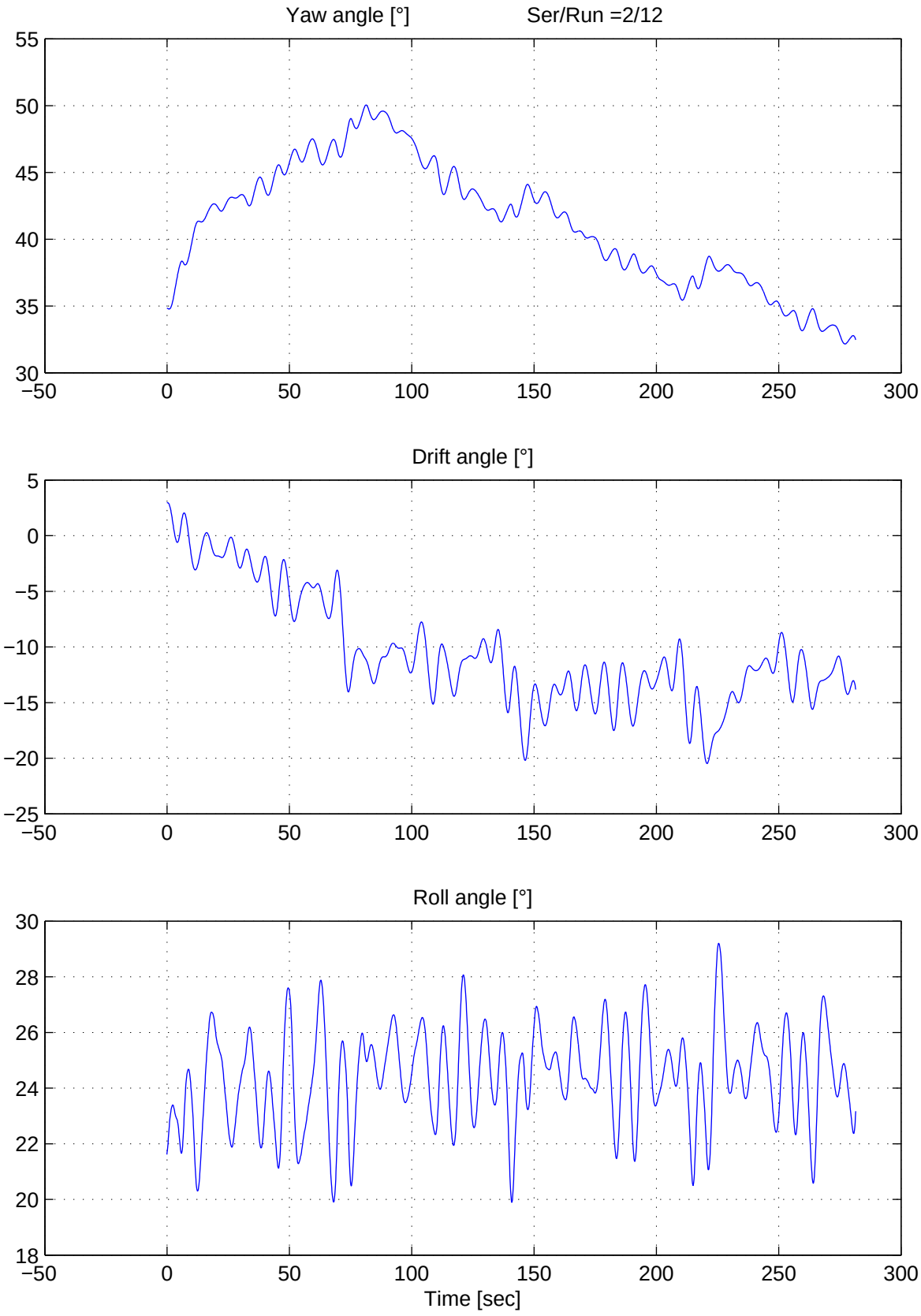


Time step between plots of ship	:	30	(sec)
Advance	:	0	(m) − 0 L_{pp}
Transfer	:	0	(m) − 0 L_{pp}
Tactical diameter	:	0	(m) − 0 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

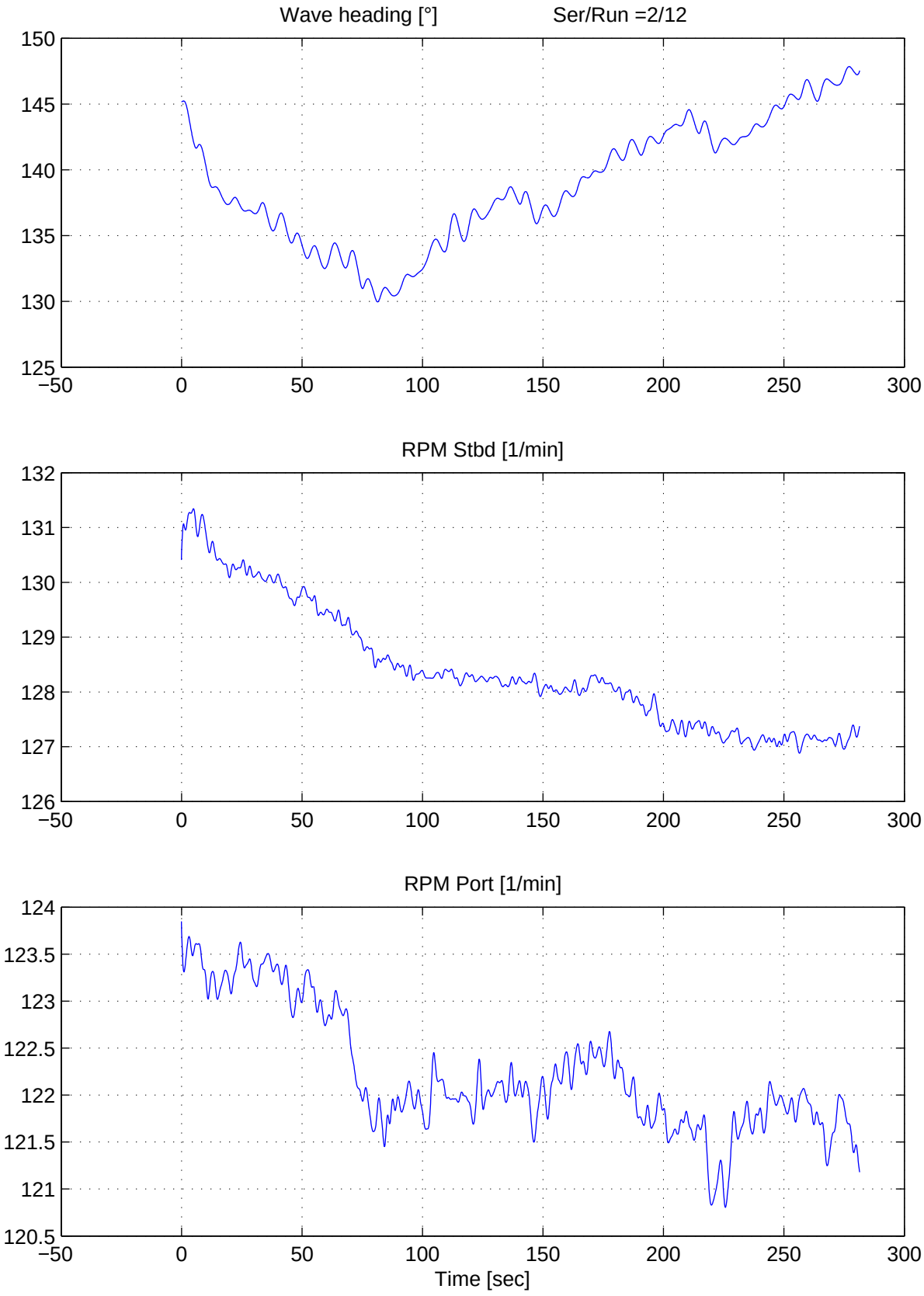
SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 10.2 Report 40064100−1



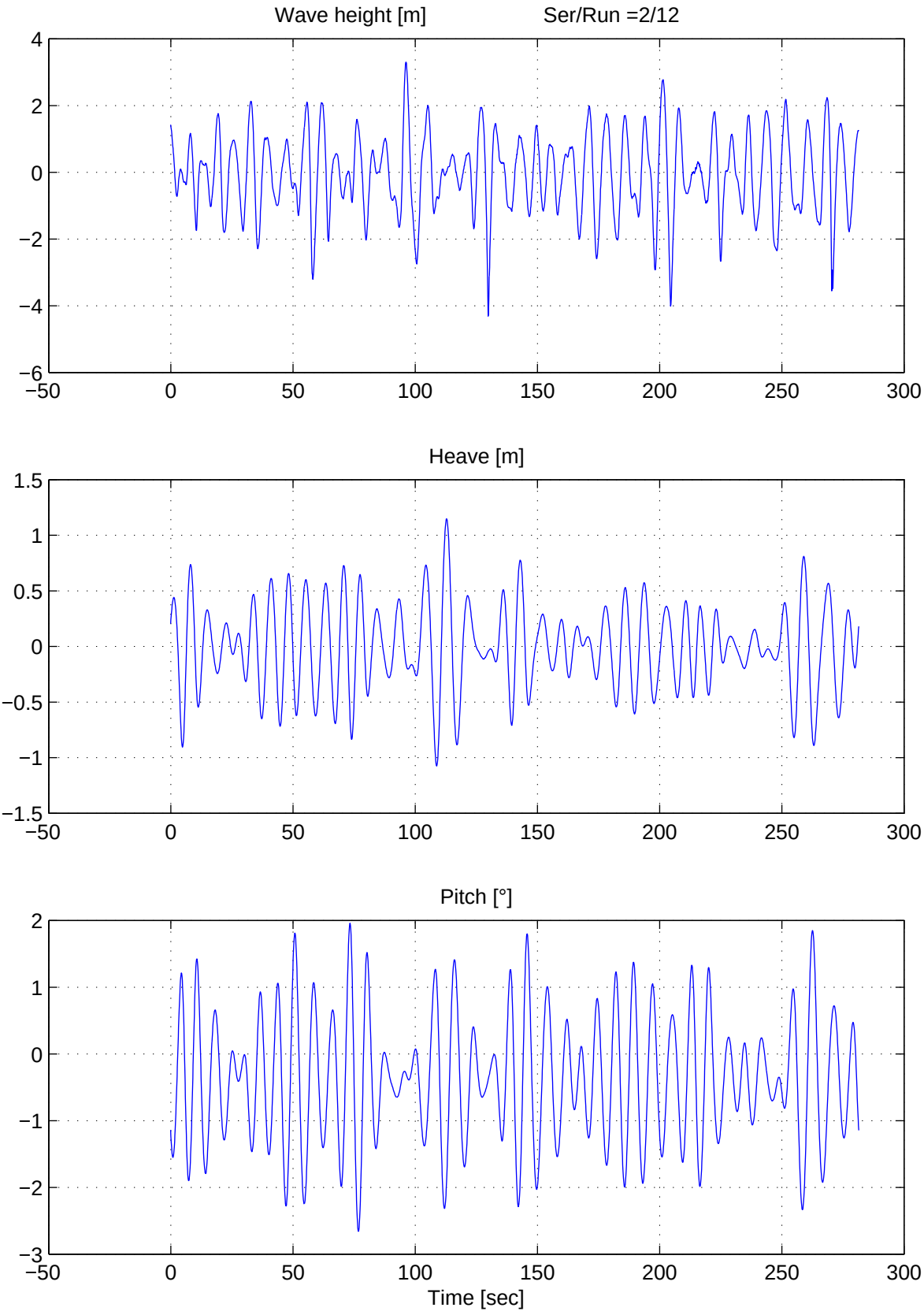
SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 10.3 Report 40064100−1



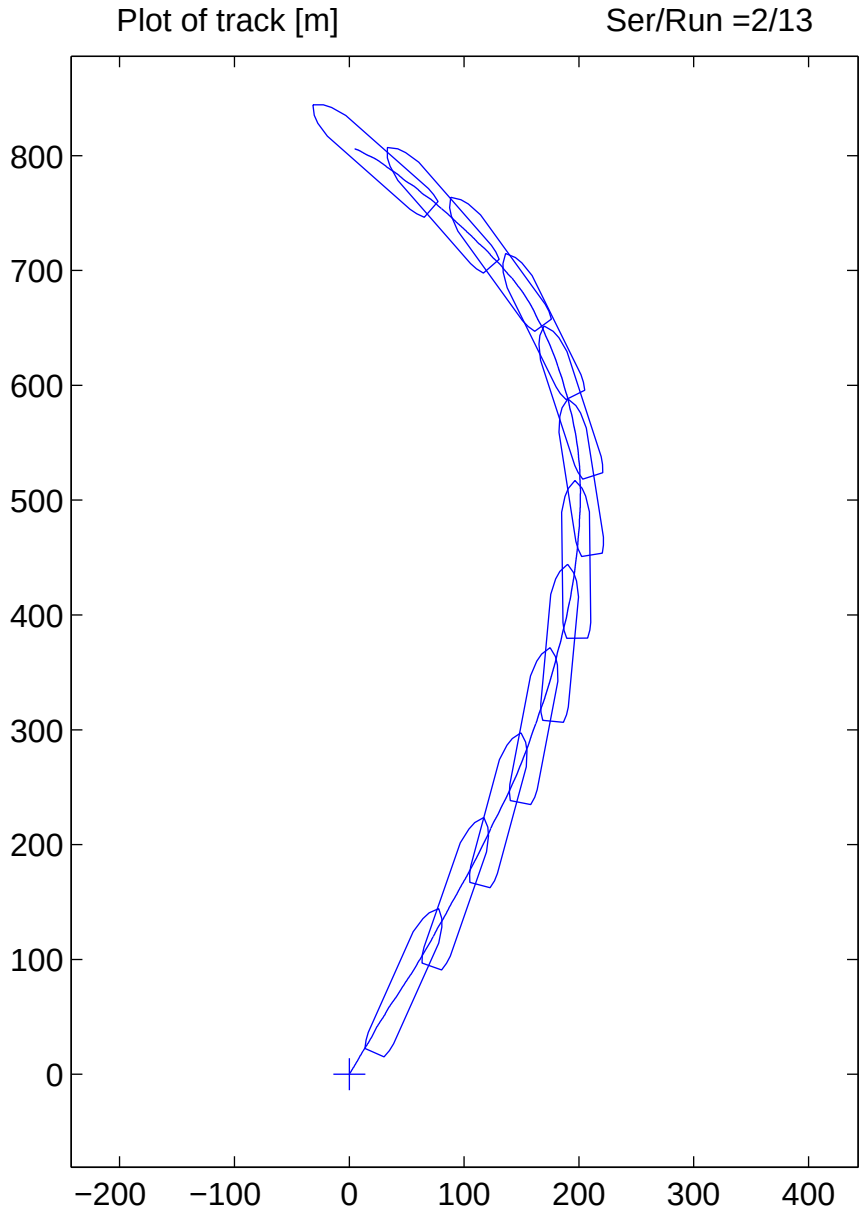
SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 10.4 Report 40064100−1



SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 10 knots Draught Ta/Tf: 5.61/5.17 m	Figure 10.5 Report 40064100−1

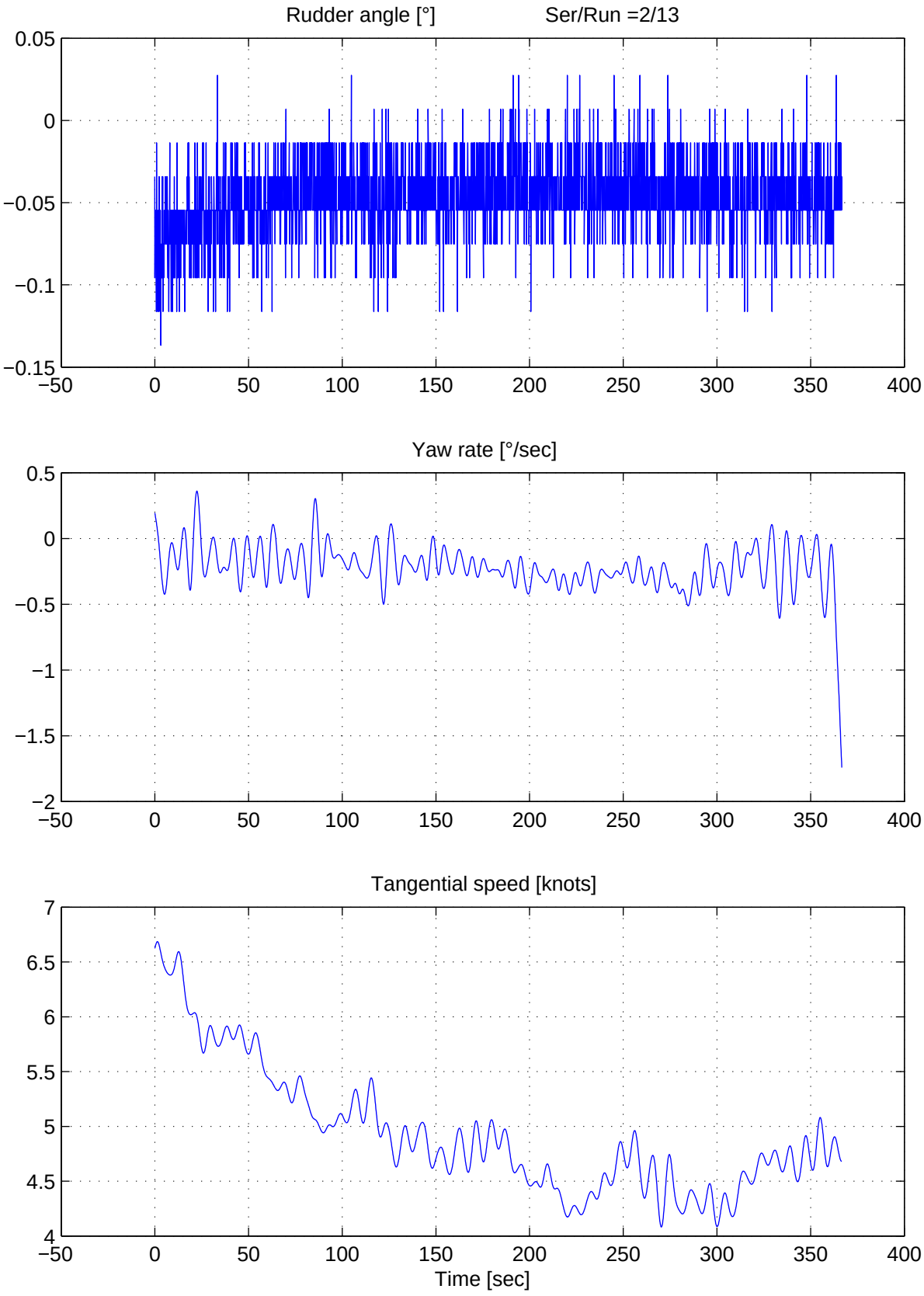


SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 11.1 Report 40064100−1

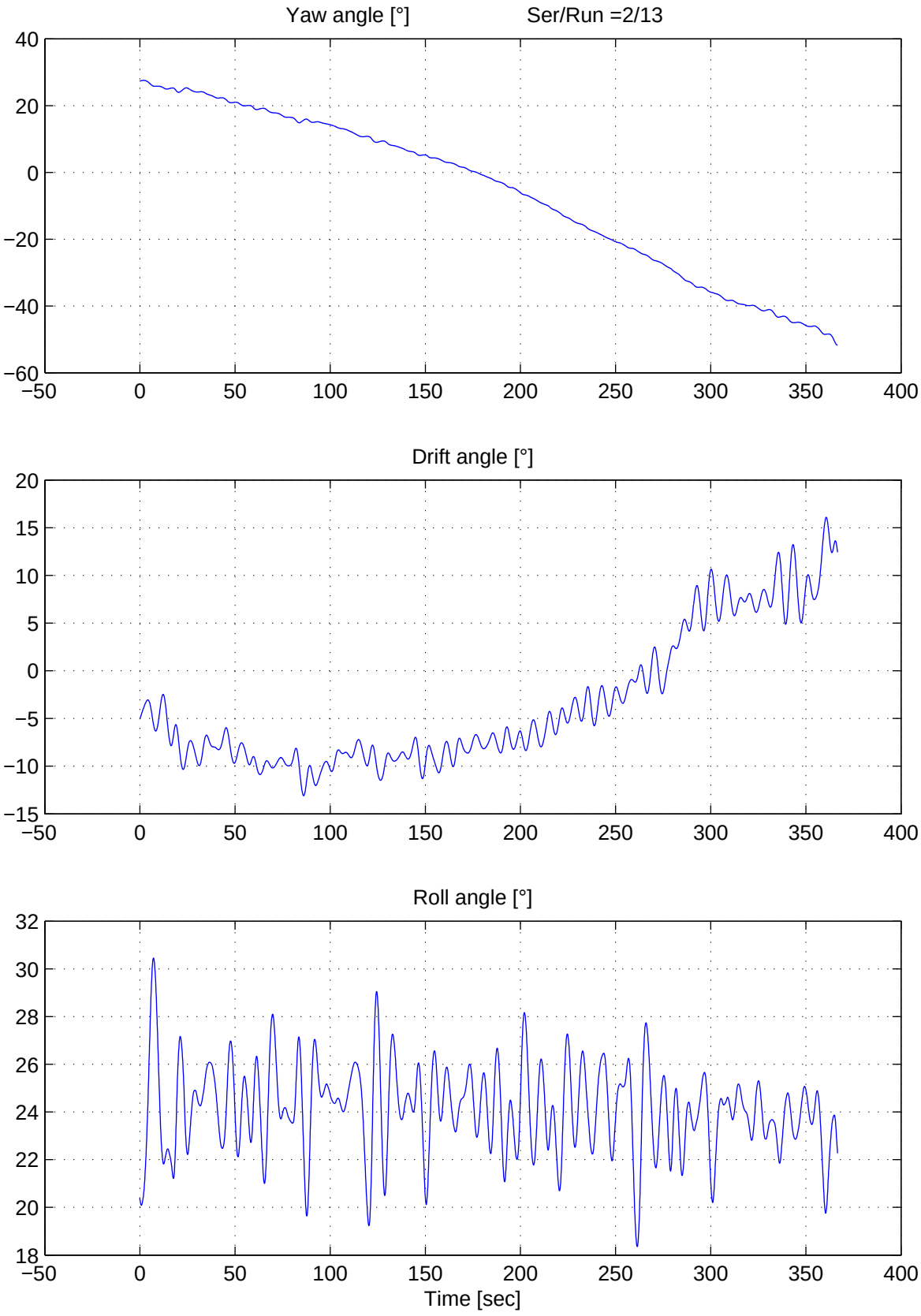


Time step between plots of ship	:	30	(sec)
Advance	:	0	(m) − 0 L_{pp}
Transfer	:	0	(m) − 0 L_{pp}
Tactical diameter	:	0	(m) − 0 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

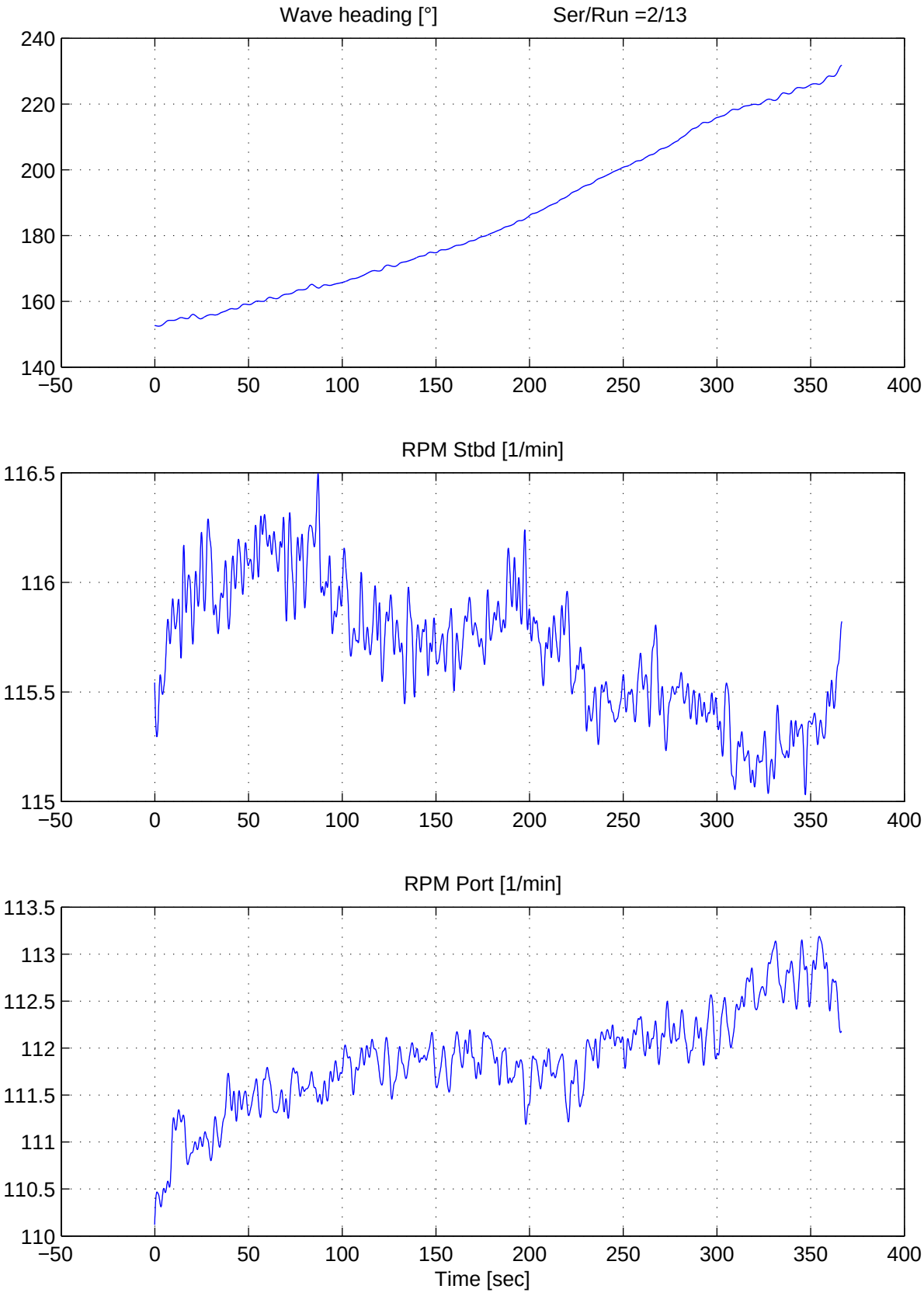
SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 11.2 Report 40064100−1



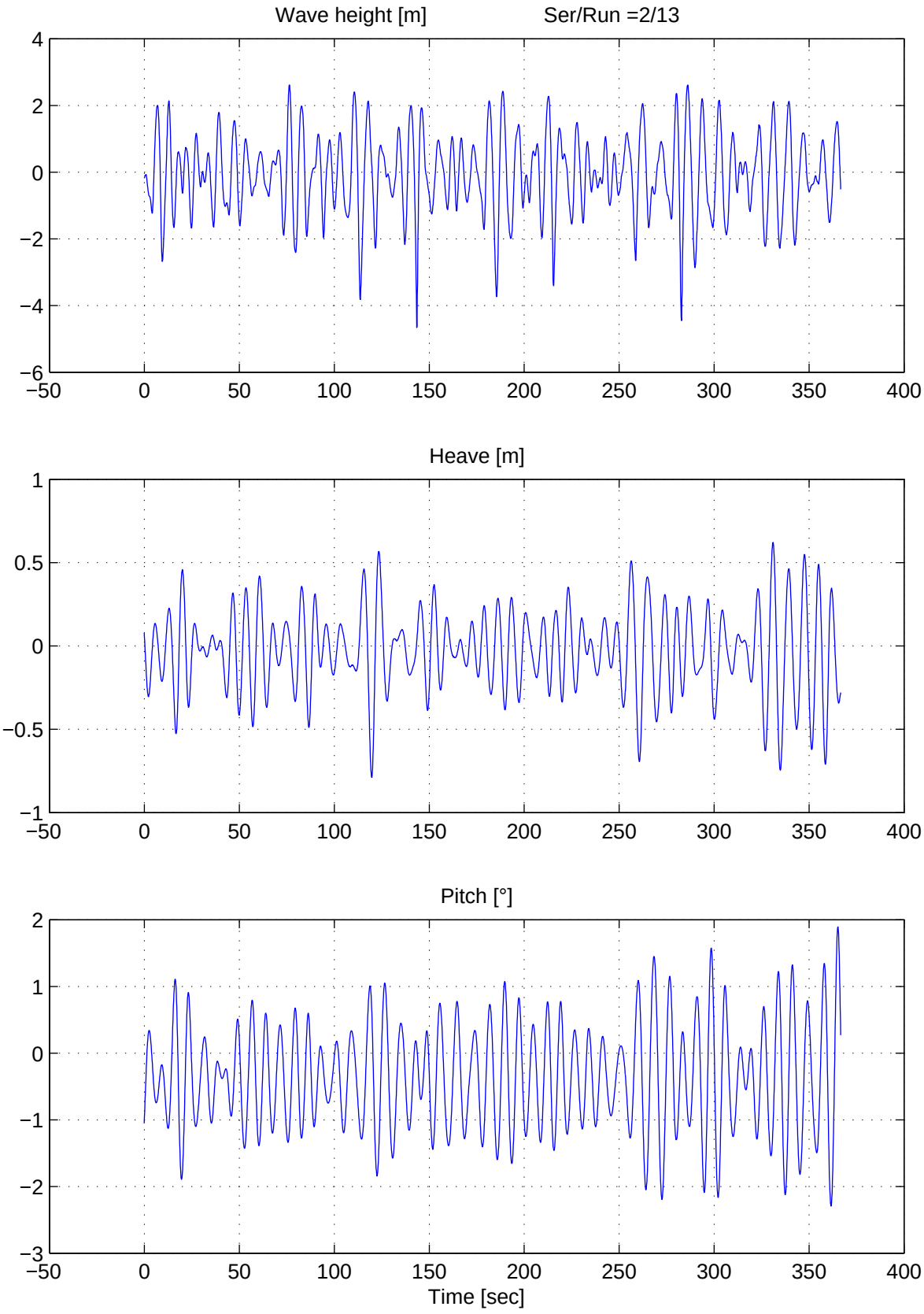
SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 11.3 Report 40064100−1



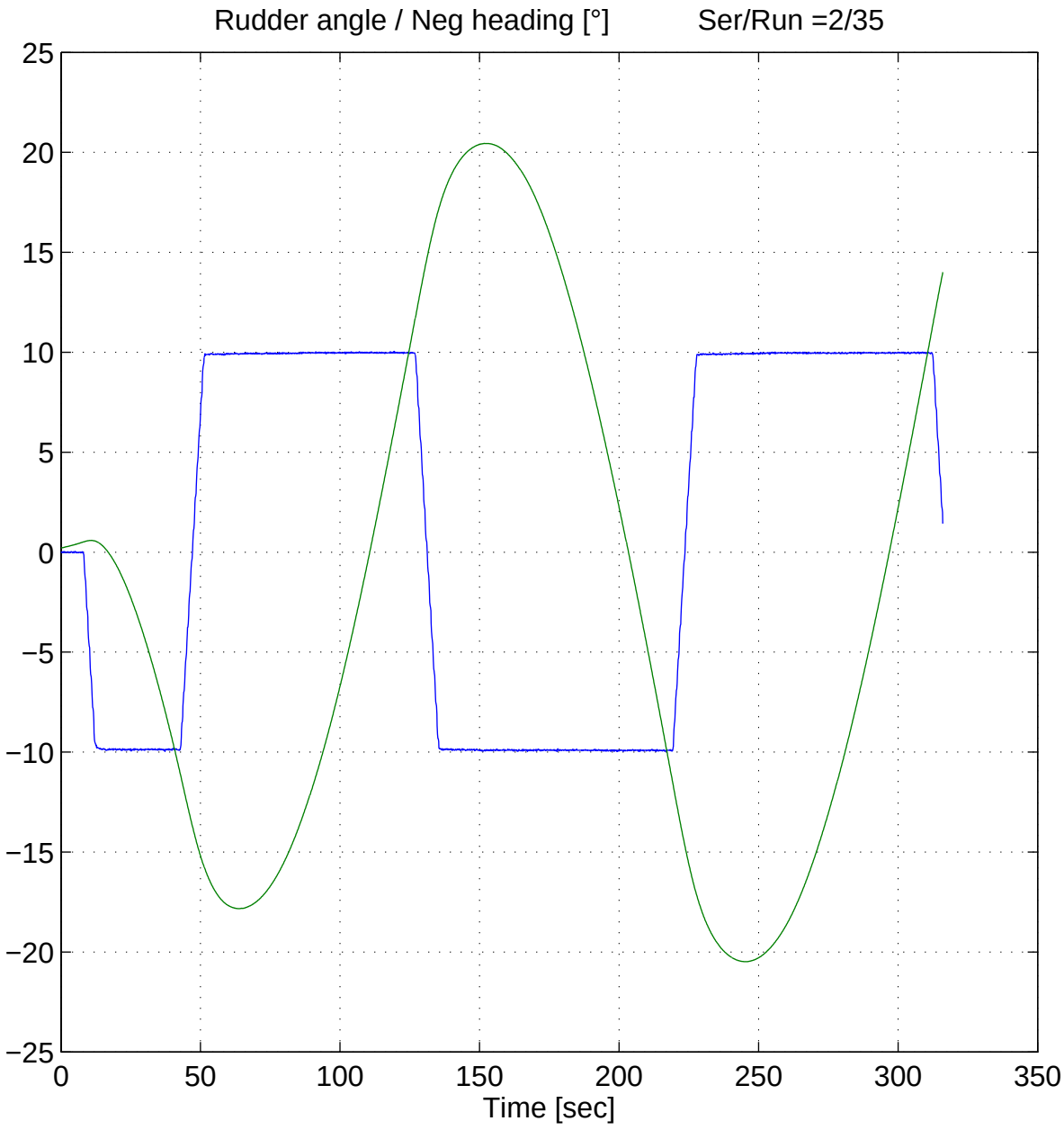
SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 11.4 Report 40064100−1



SSPA	MV Estonia Zero rudder tests in irregular waves Initial speed: 7 knots Draught Ta/Tf: 5.61/5.17 m	Figure 11.5 Report 40064100−1



SSPA	MV Estonia S 10°/10° Zig−zag test in calm water Initial speed: 14.5 knots Draught Ta/Tf 5.61/5.17 m	Figure 12.1 Report 40064100−1



First overshoot	:	8	(°)
Second overshoot	:	10.5	(°)
Sailed dist. to sec. execute/L	:	1.73	(−)
Period	:	186.3	(sec)
Time to second execute	:	32.5	(sec)
Time to check yaw	:	23	(sec)

MV Estonia

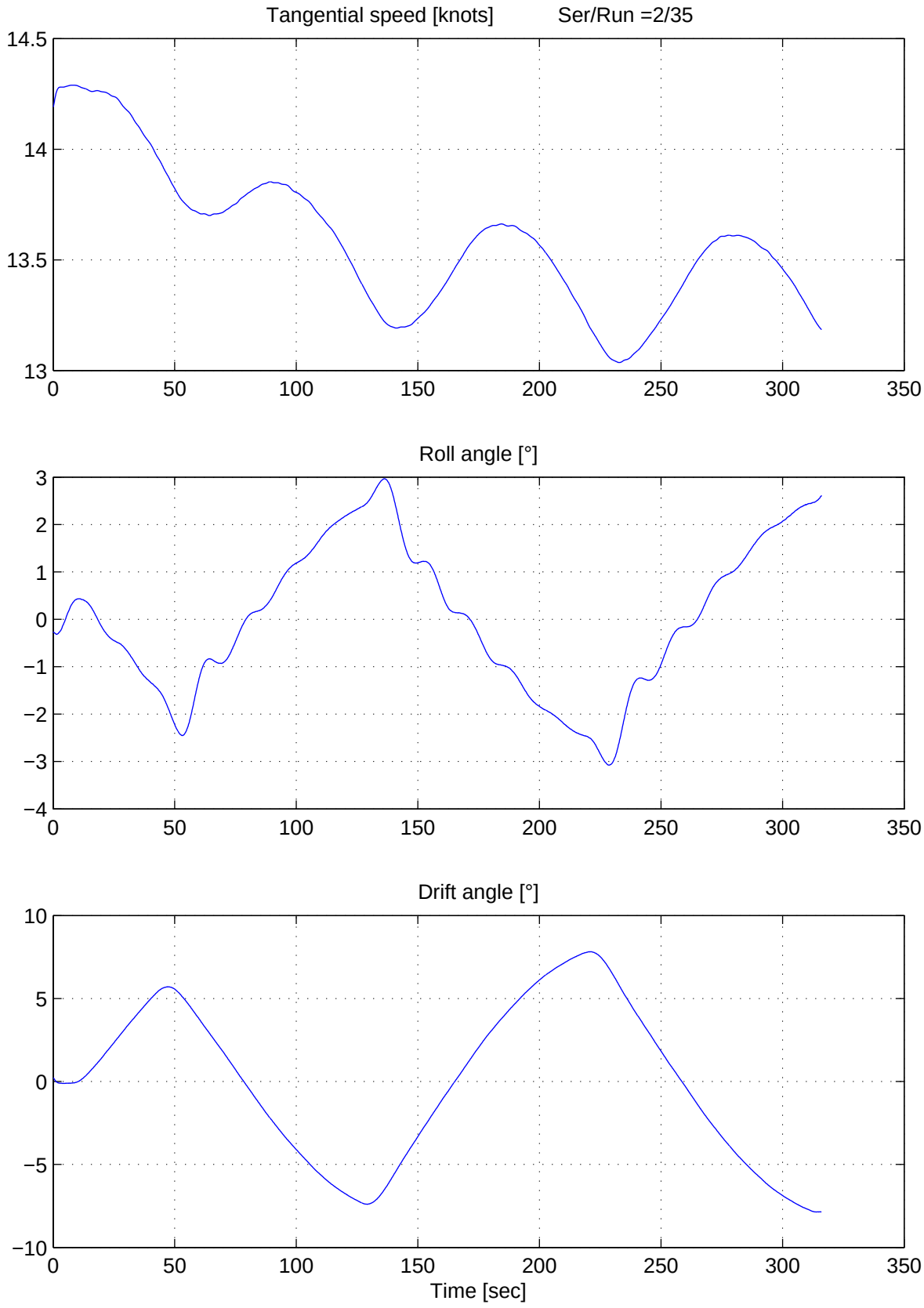
S 10°/10° Zig−zag test in calm water

Initial speed: 14.5 knots

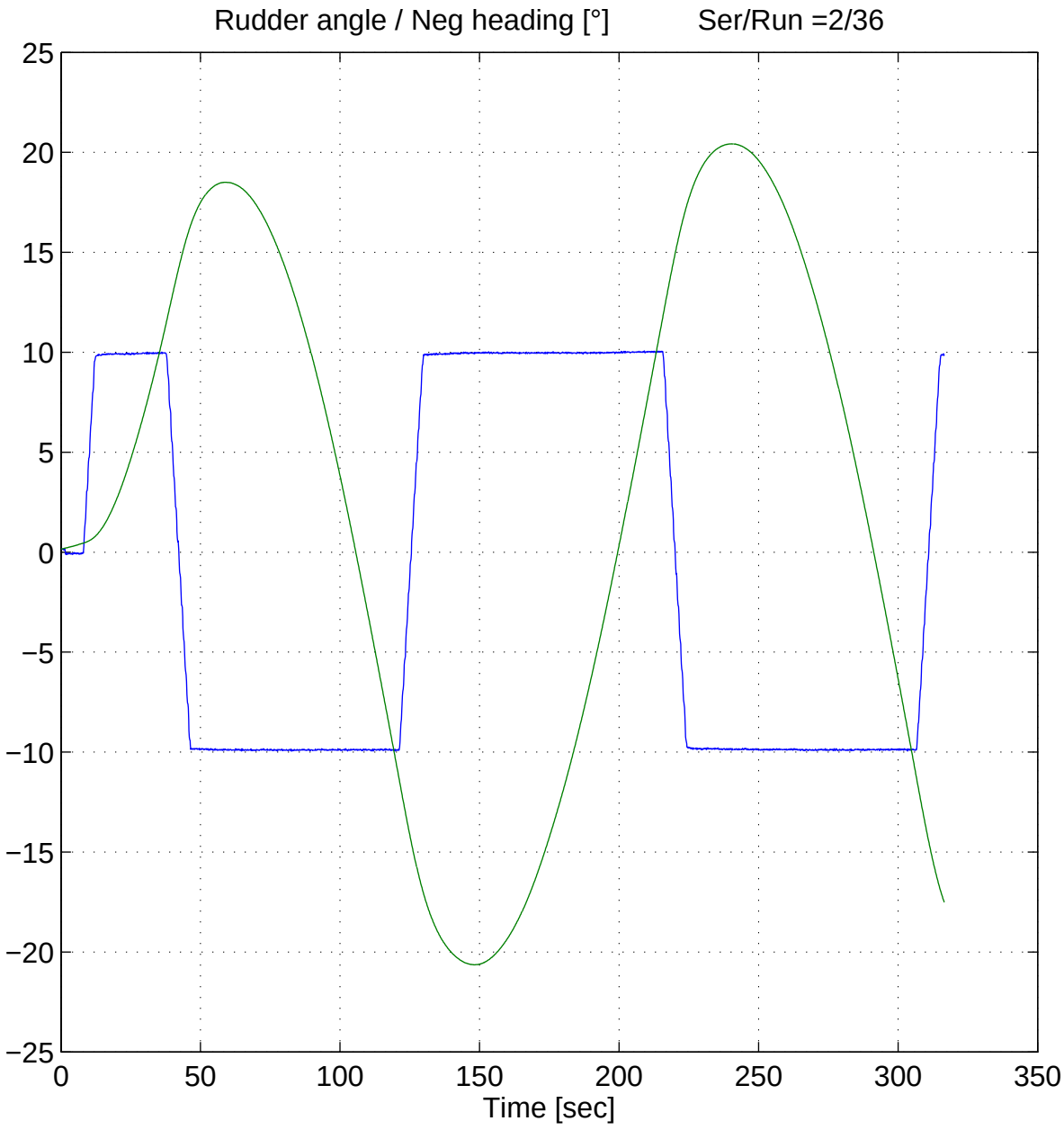
Draught Ta/Tf 5.61/5.17 m

Figure 12.2

Report 40064100−1

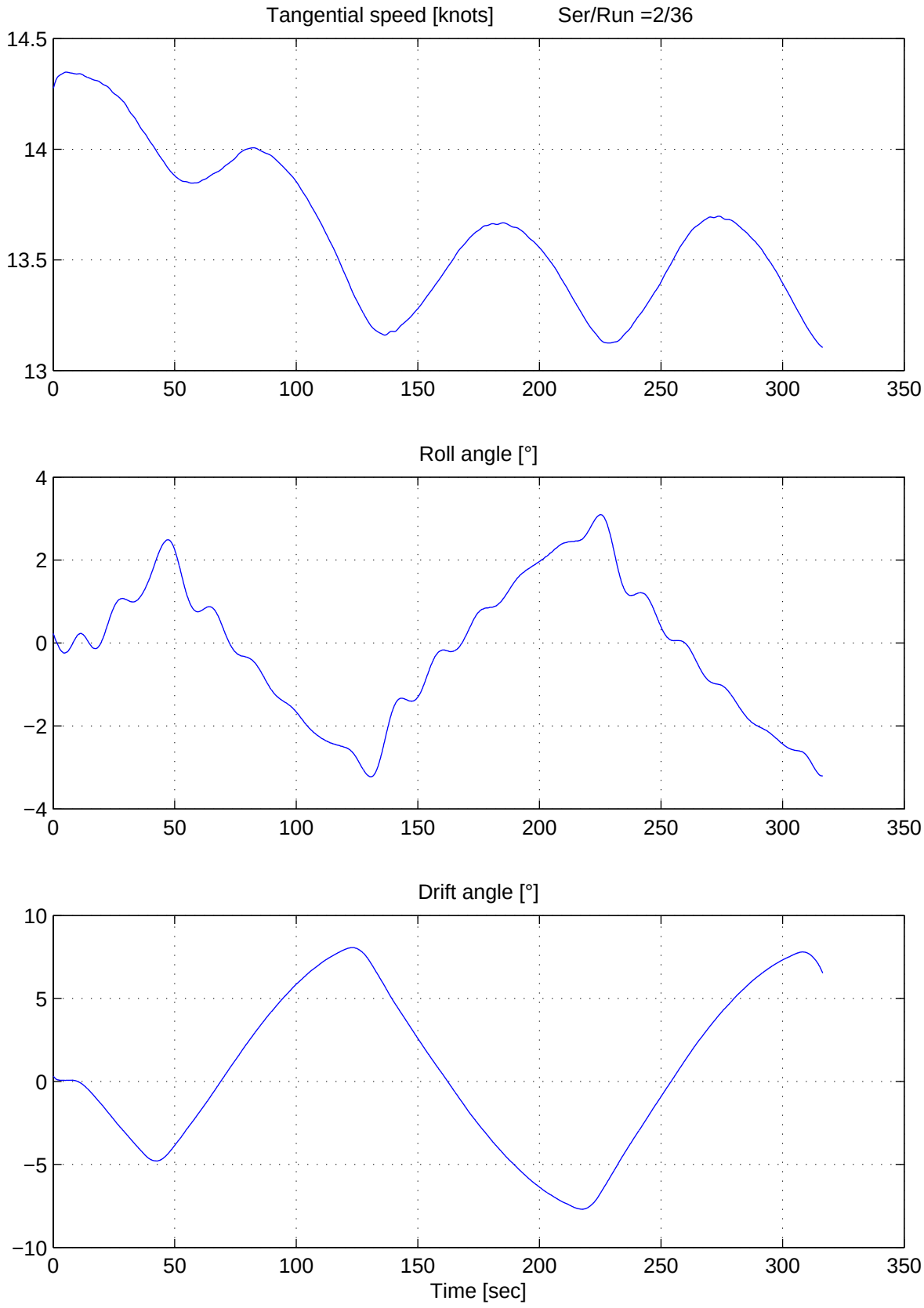


SSPA	MV Estonia P 10°/10° Zig−zag test in calm water Initial speed: 14.5 knots Draught Ta/Tf 5.61/5.17 m	Figure 13.1 Report 40064100−1

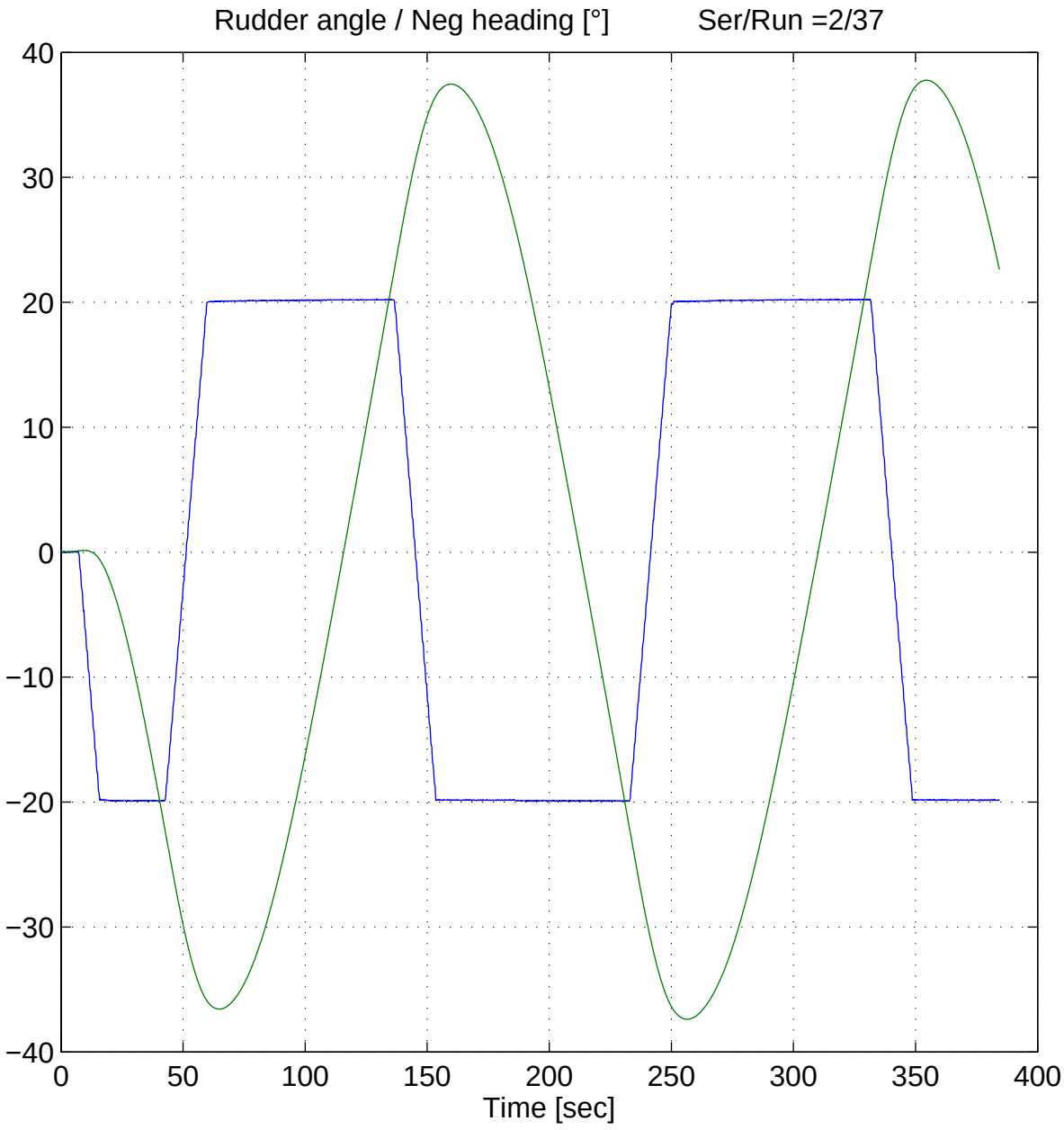


First overshoot	:	8.6	(°)
Second overshoot	:	10.7	(°)
Sailed dist. to sec. execute/L	:	1.45	(−)
Period	:	185.7	(sec)
Time to second execute	:	27.1	(sec)
Time to check yaw	:	23.4	(sec)

SSPA	MV Estonia P 10°/10° Zig−zag test in calm water Initial speed: 14.5 knots Draught Ta/Tf 5.61/5.17 m	Figure 13.2 Report 40064100−1



SSPA	MV Estonia S 20°/20° Zig−zag test in calm water Initial speed: 14.5 knots Draught Ta/Tf 5.61/5.17 m	Figure 14.1 Report 40064100−1



First overshoot	:	16.7	(°)
Second overshoot	:	17.3	(°)
Sailed dist. to sec. execute/L	:	1.73	(−)
Period	:	194.3	(sec)
Time to second execute	:	33	(sec)
Time to check yaw	:	24.3	(sec)

MV Estonia

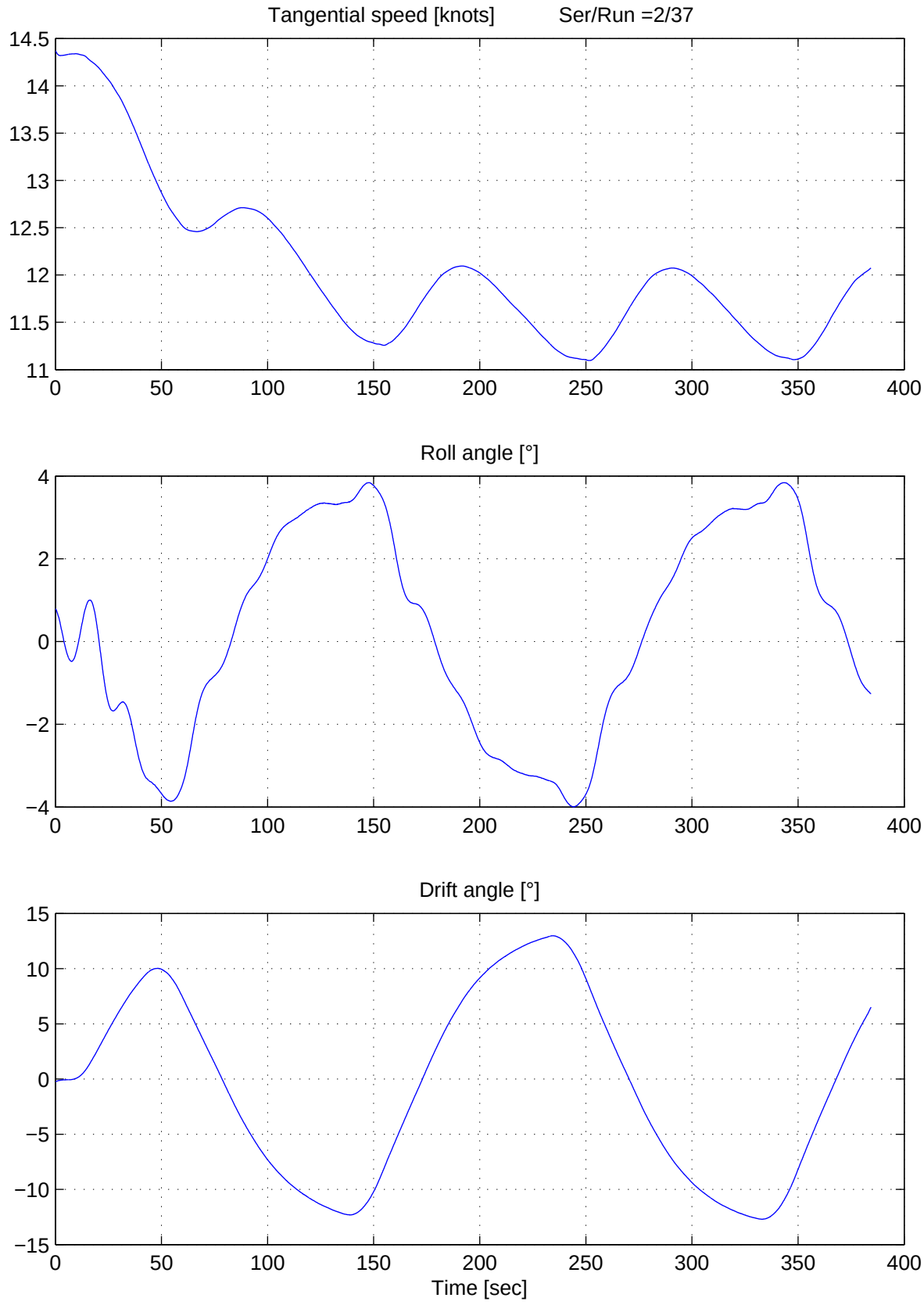
S 20°/20° Zig−zag test in calm water

Initial speed: 14.5 knots

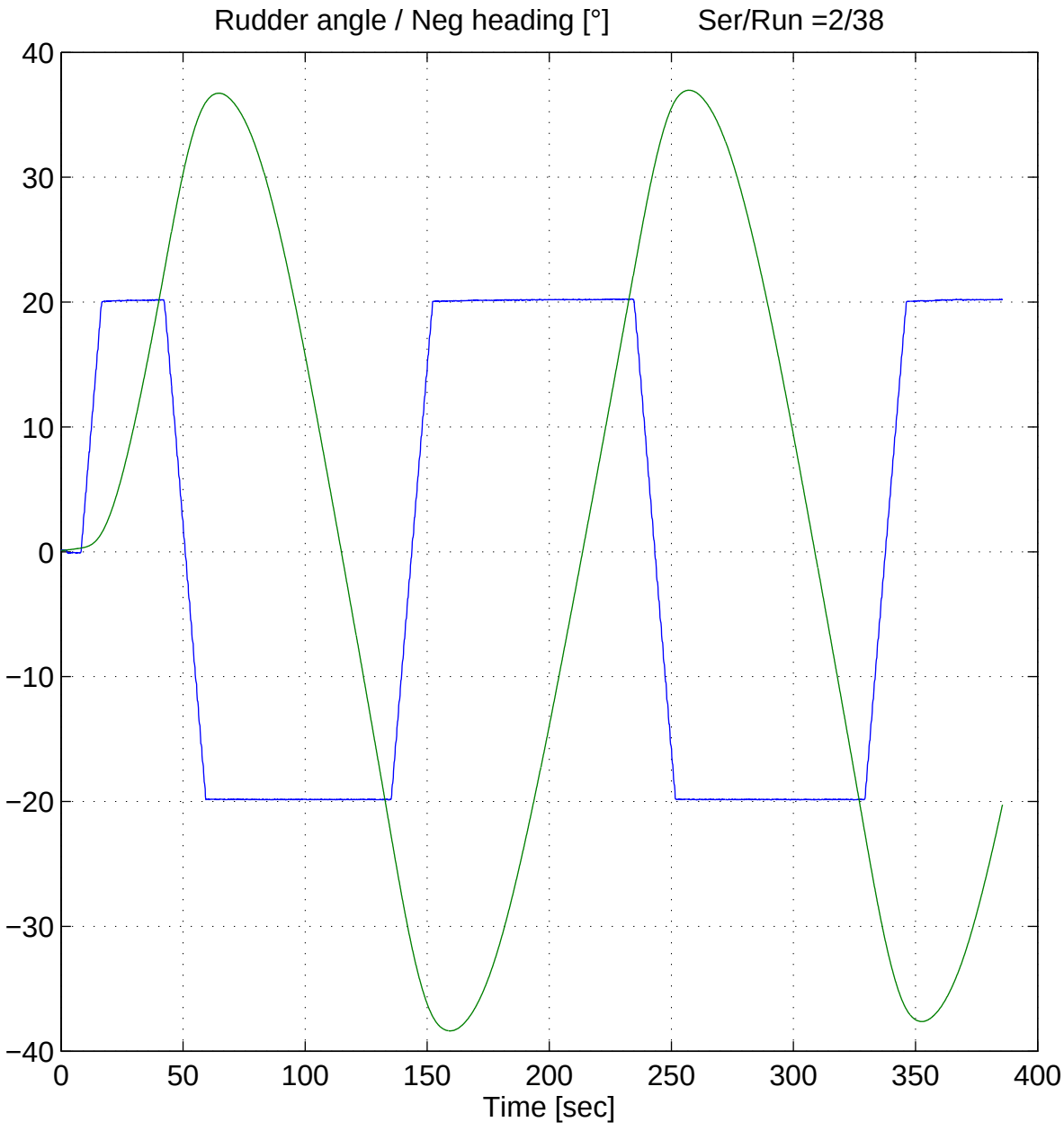
Draught Ta/Tf 5.61/5.17 m

Figure 14.2

Report 40064100−1



SSPA	MV Estonia P 20°/20° Zig−zag test in calm water Initial speed: 14.5 knots Draught Ta/Tf 5.61/5.17 m	Figure 15.1 Report 40064100−1



First overshoot	:	16.6	(°)
Second overshoot	:	18.5	(°)
Sailed dist. to sec. execute/L	:	1.67	(−)
Period	:	193.9	(sec)
Time to second execute	:	31.9	(sec)
Time to check yaw	:	24.7	(sec)

MV Estonia

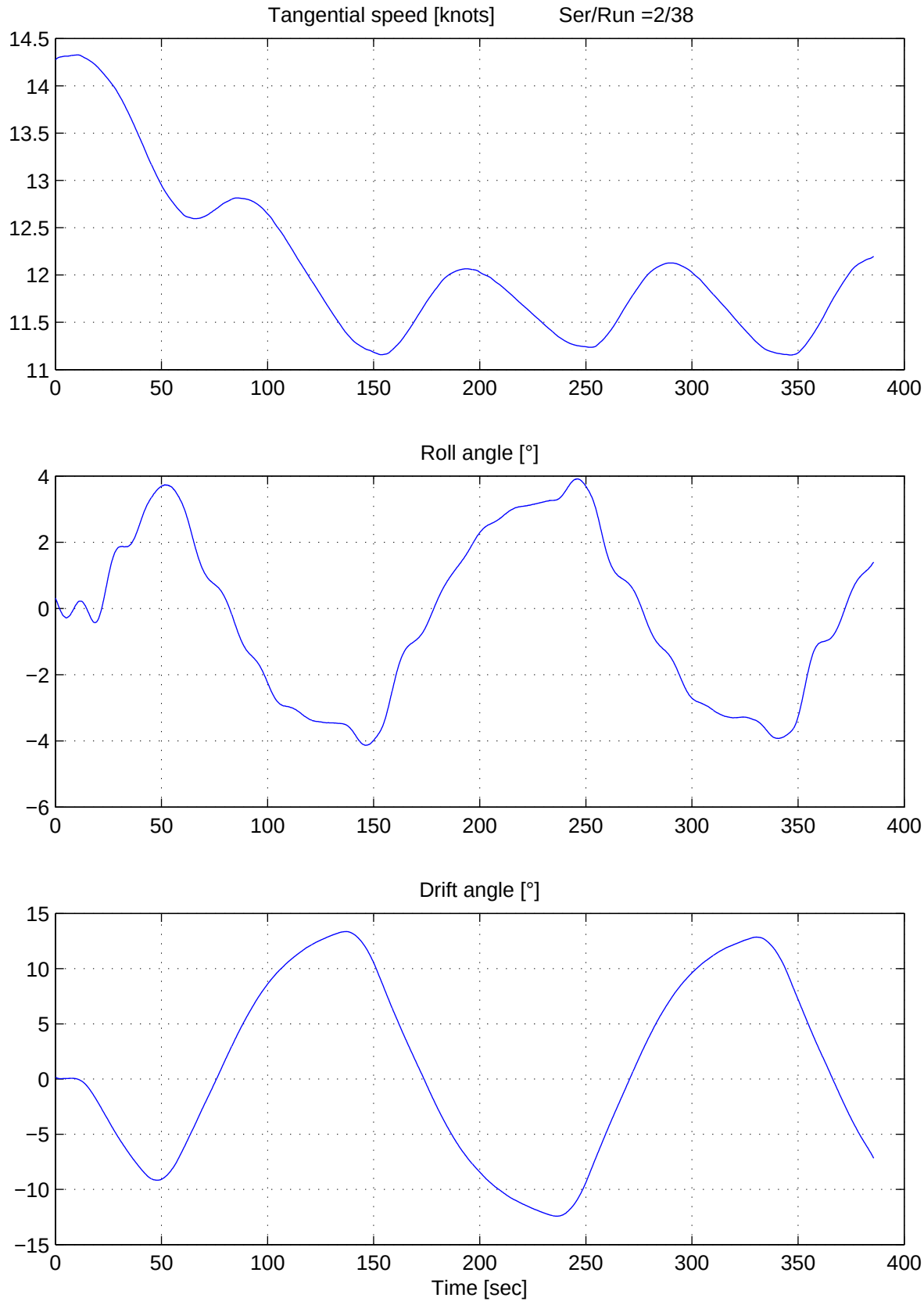
P 20°/20° Zig−zag test in calm water

Initial speed: 14.5 knots

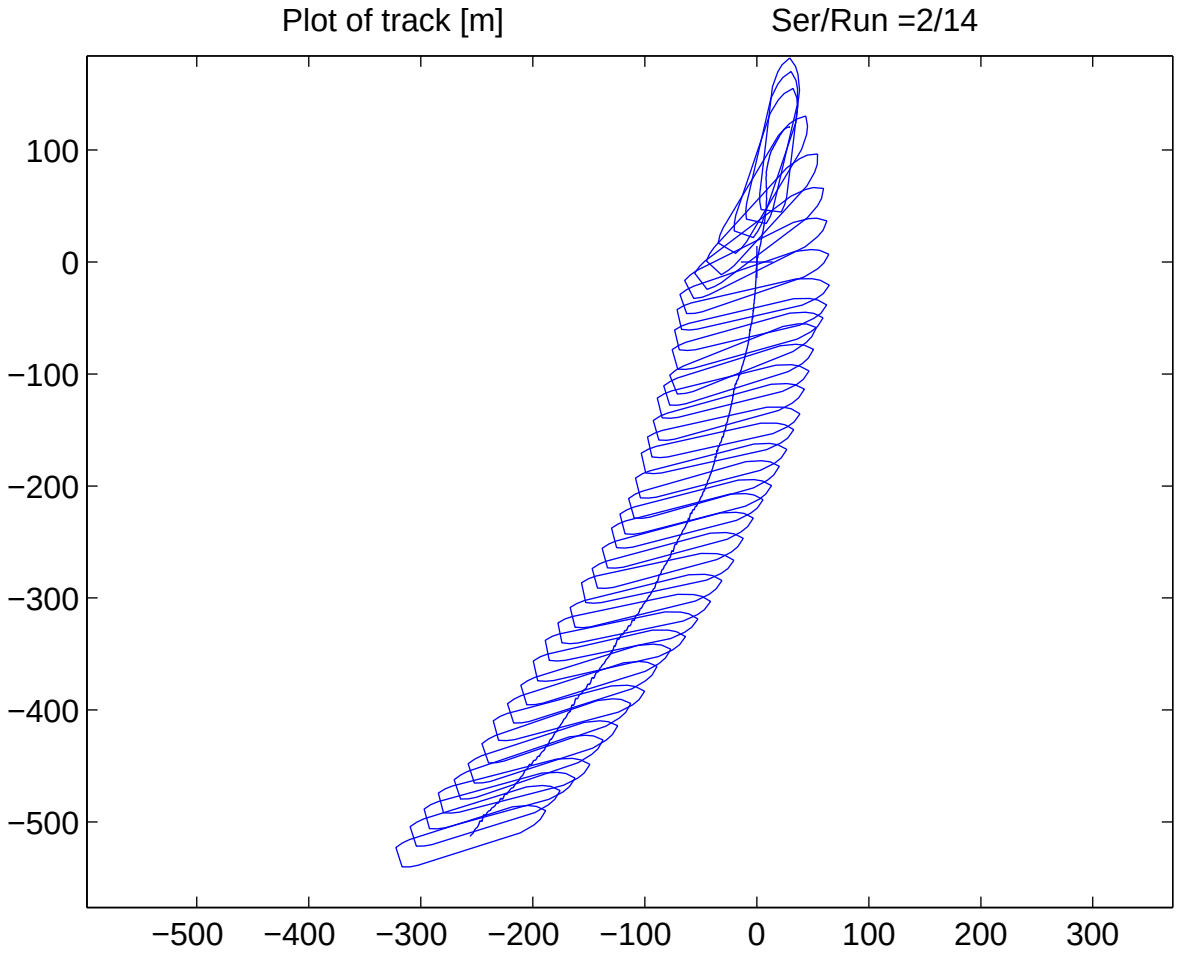
Draught Ta/Tf 5.61/5.17 m

Figure 15.2

Report 40064100−1

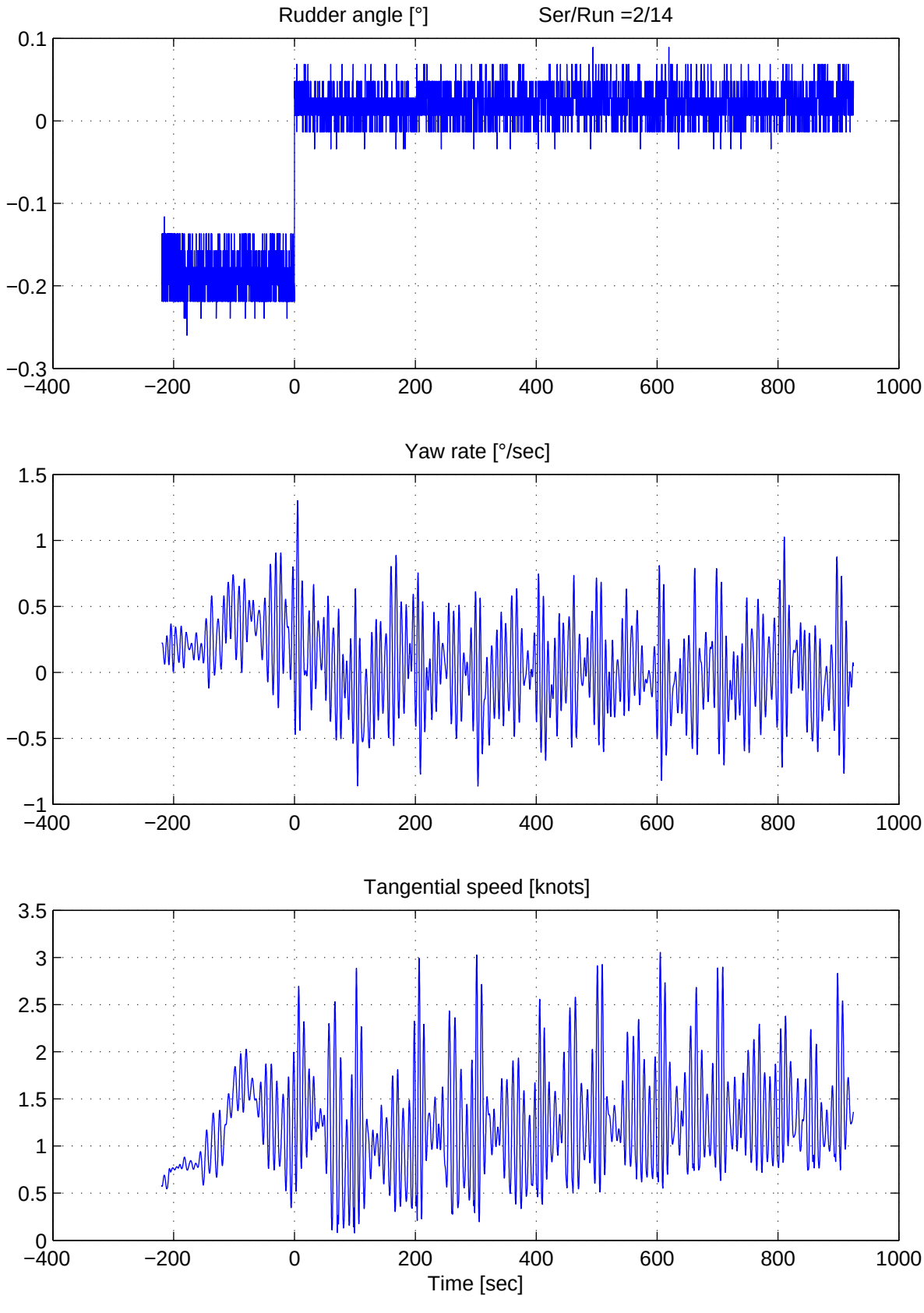


SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 16.1 Report 40064100−1

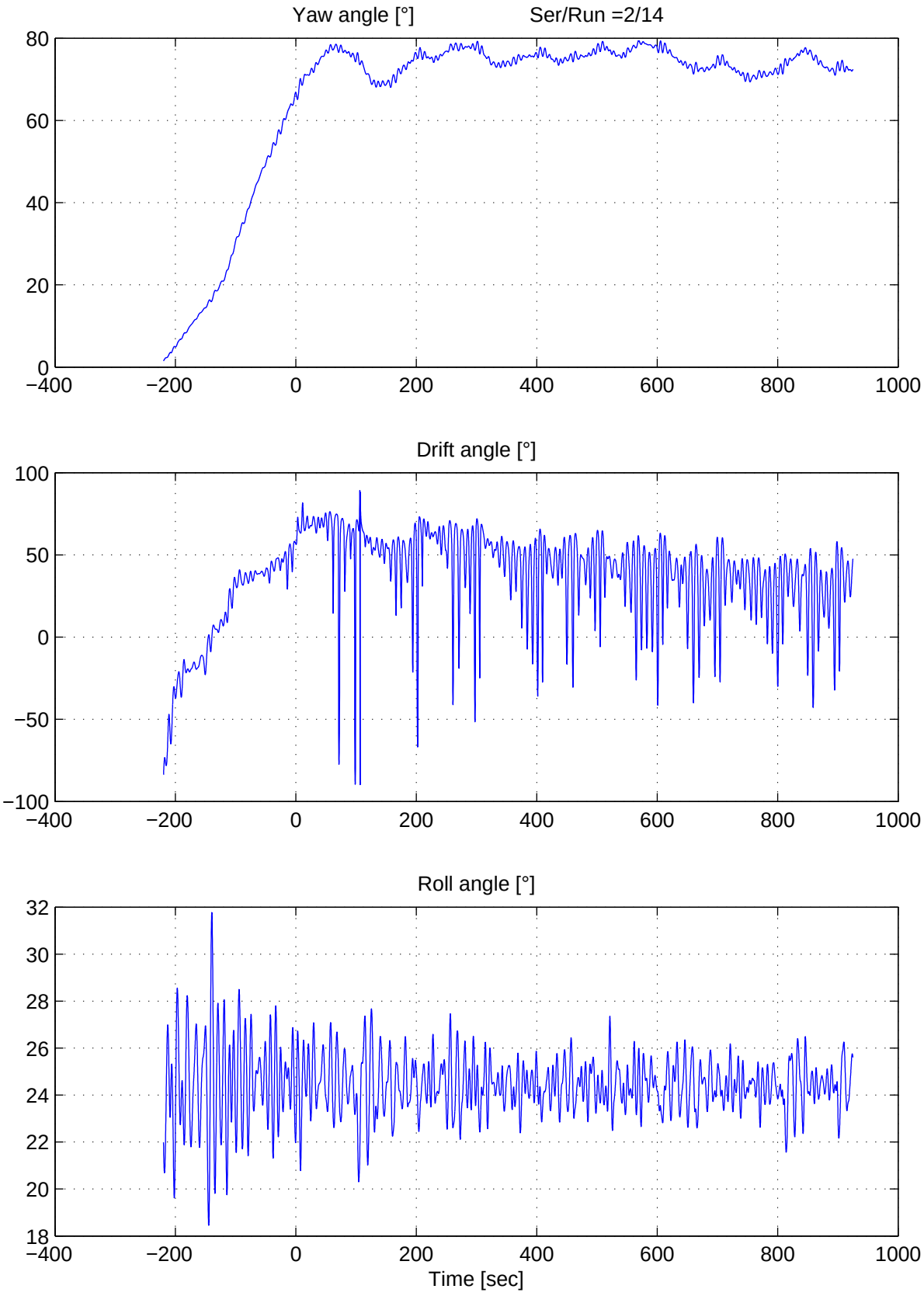


Time step between plots of ship	:	30	(sec)
Advance	:	0	(m) − 0 L_{pp}
Transfer	:	0	(m) − 0 L_{pp}
Tactical diameter	:	0	(m) − 0 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

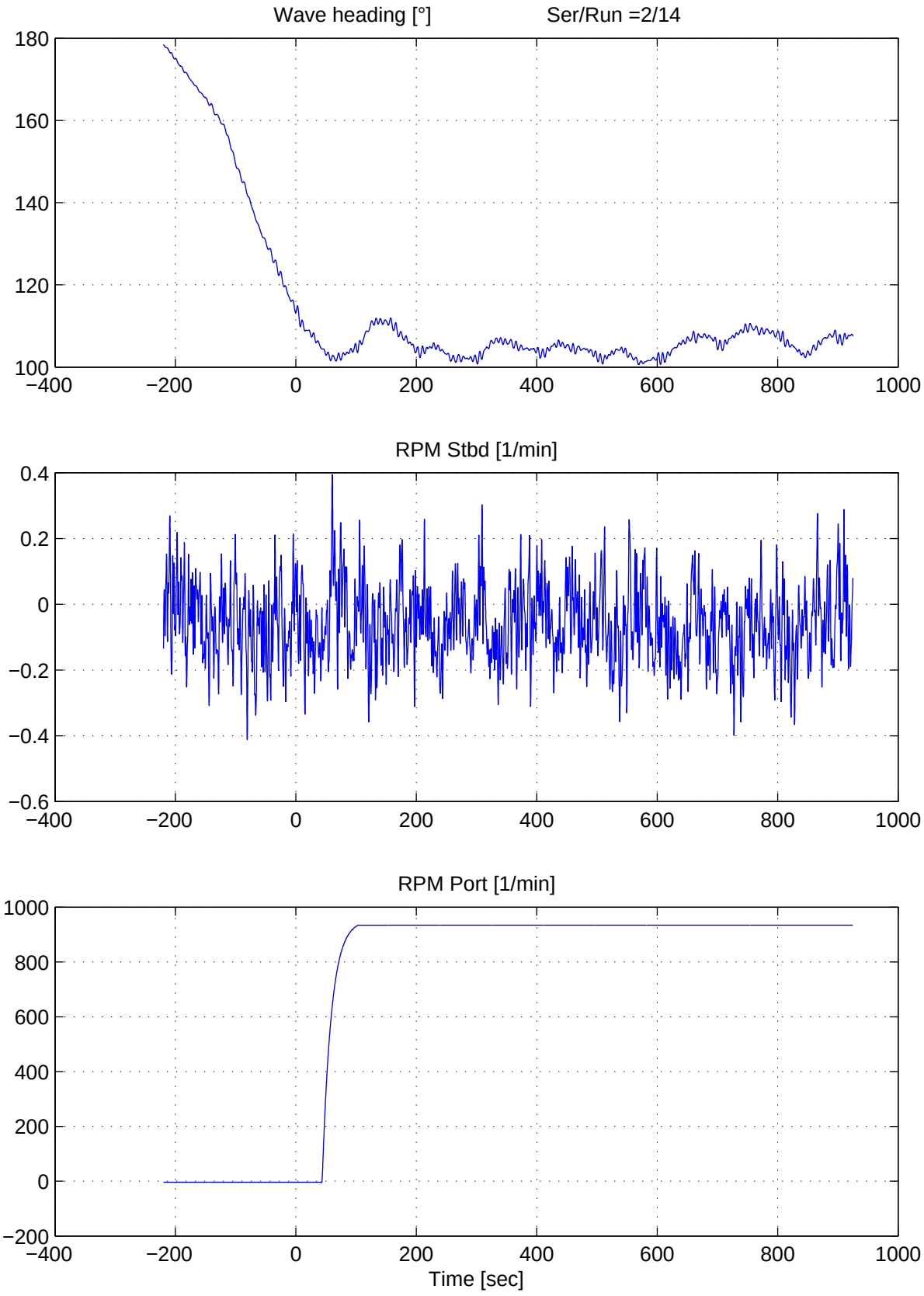
SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 16.2 Report 40064100−1



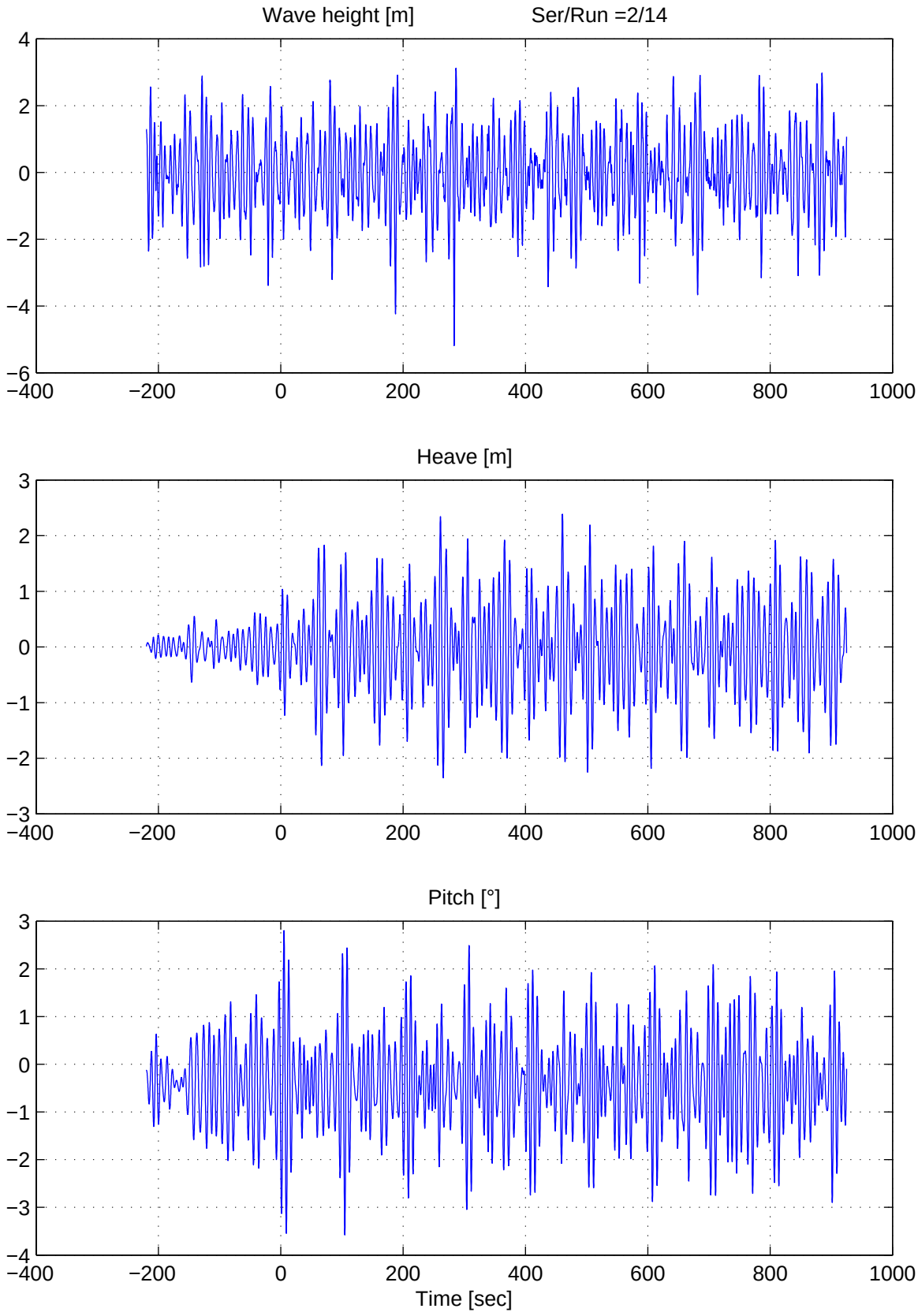
SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 16.3 Report 40064100−1



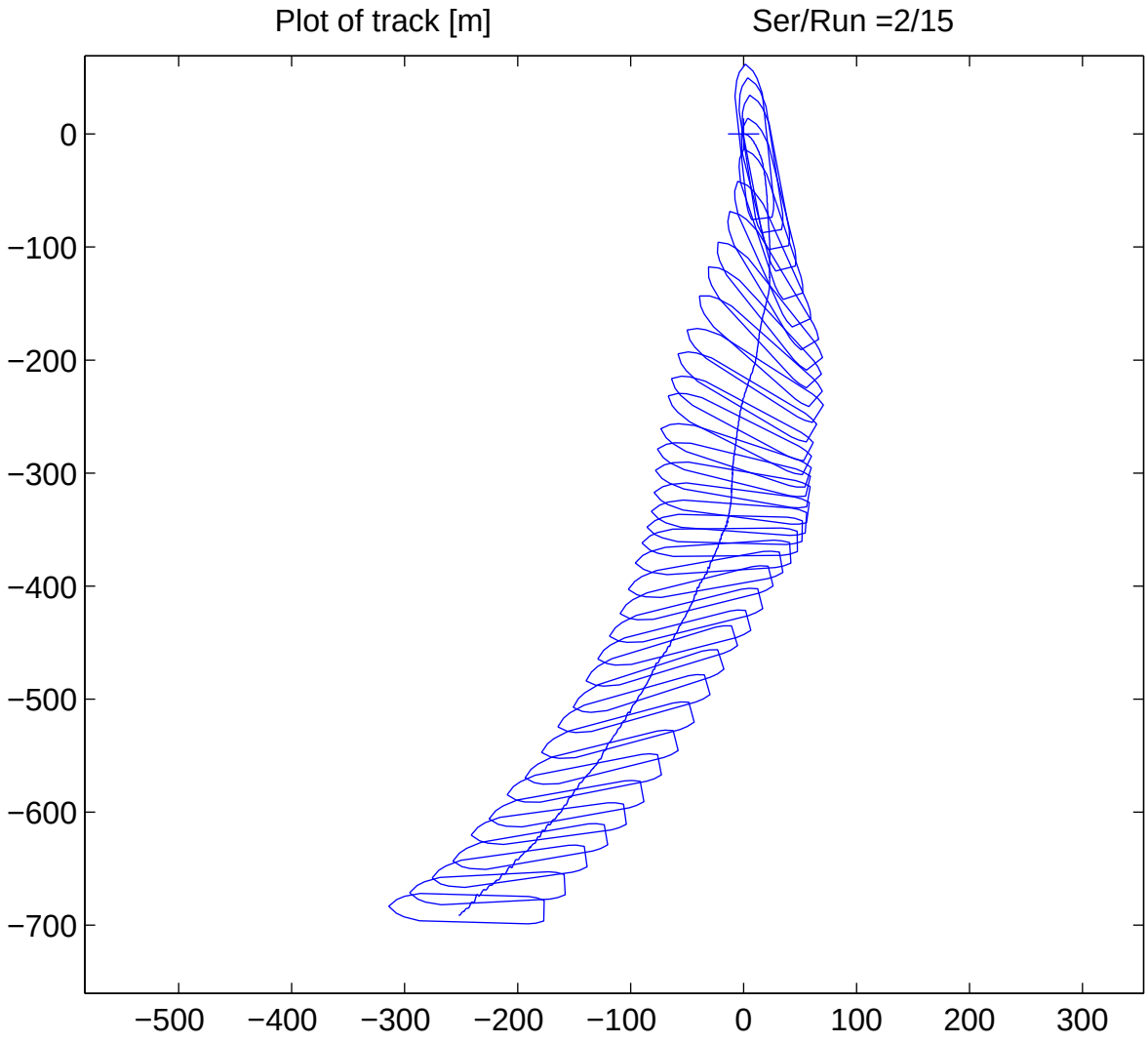
SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 16.4 Report 40064100−1



SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 16.5 Report 40064100−1

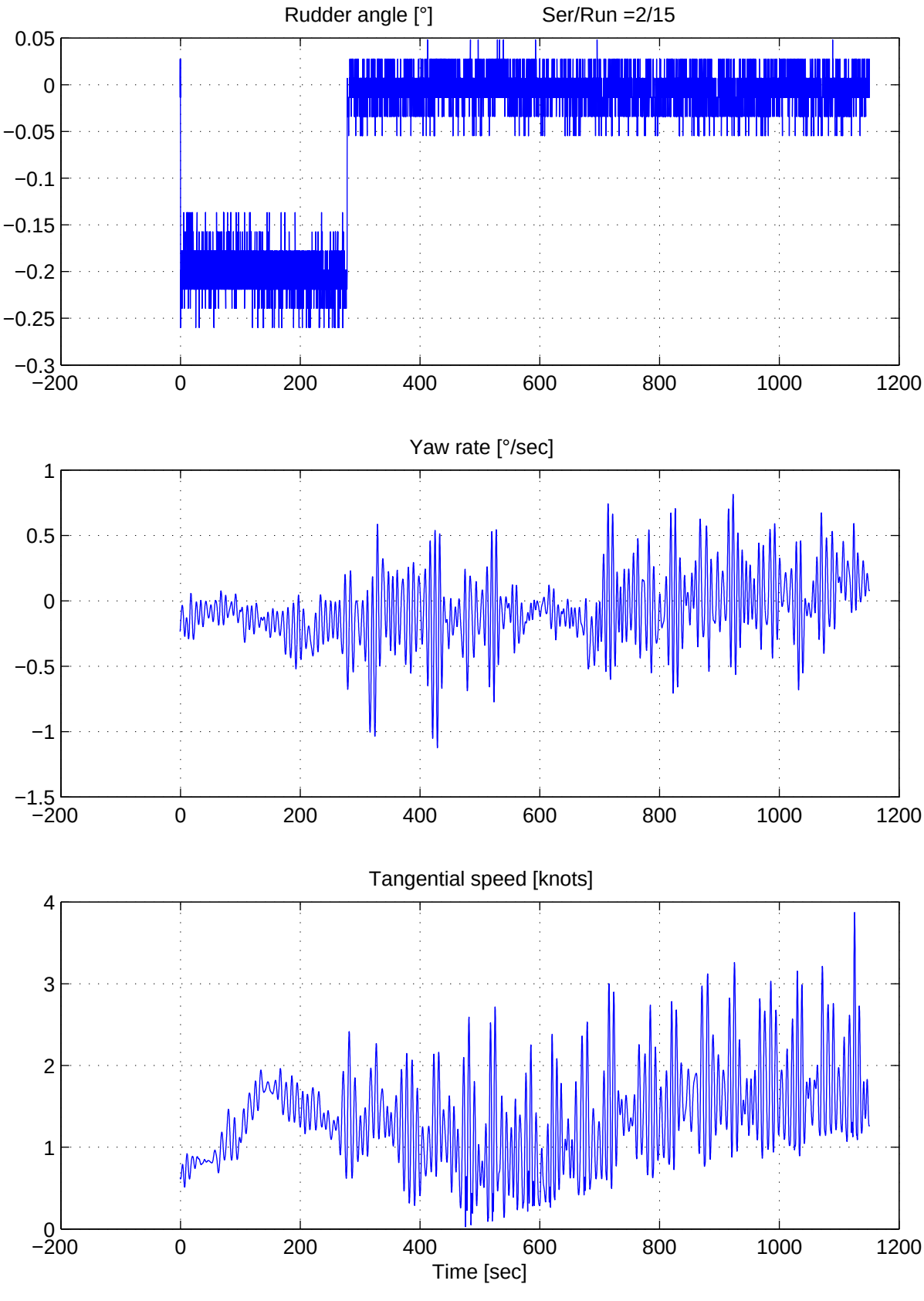


SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 17.1 Report 40064100−1



Time step between plots of ship	:	30	(sec)
Advance	:	383	(m) − 2.79 L_{pp}
Transfer	:	38	(m) − 0.277 L_{pp}
Tactical diameter	:	0	(m) − 0 L_{pp}
Steady turning diameter	:	0	(m) − 0 L_{pp}

SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 17.2 Report 40064100−1



MV Estonia

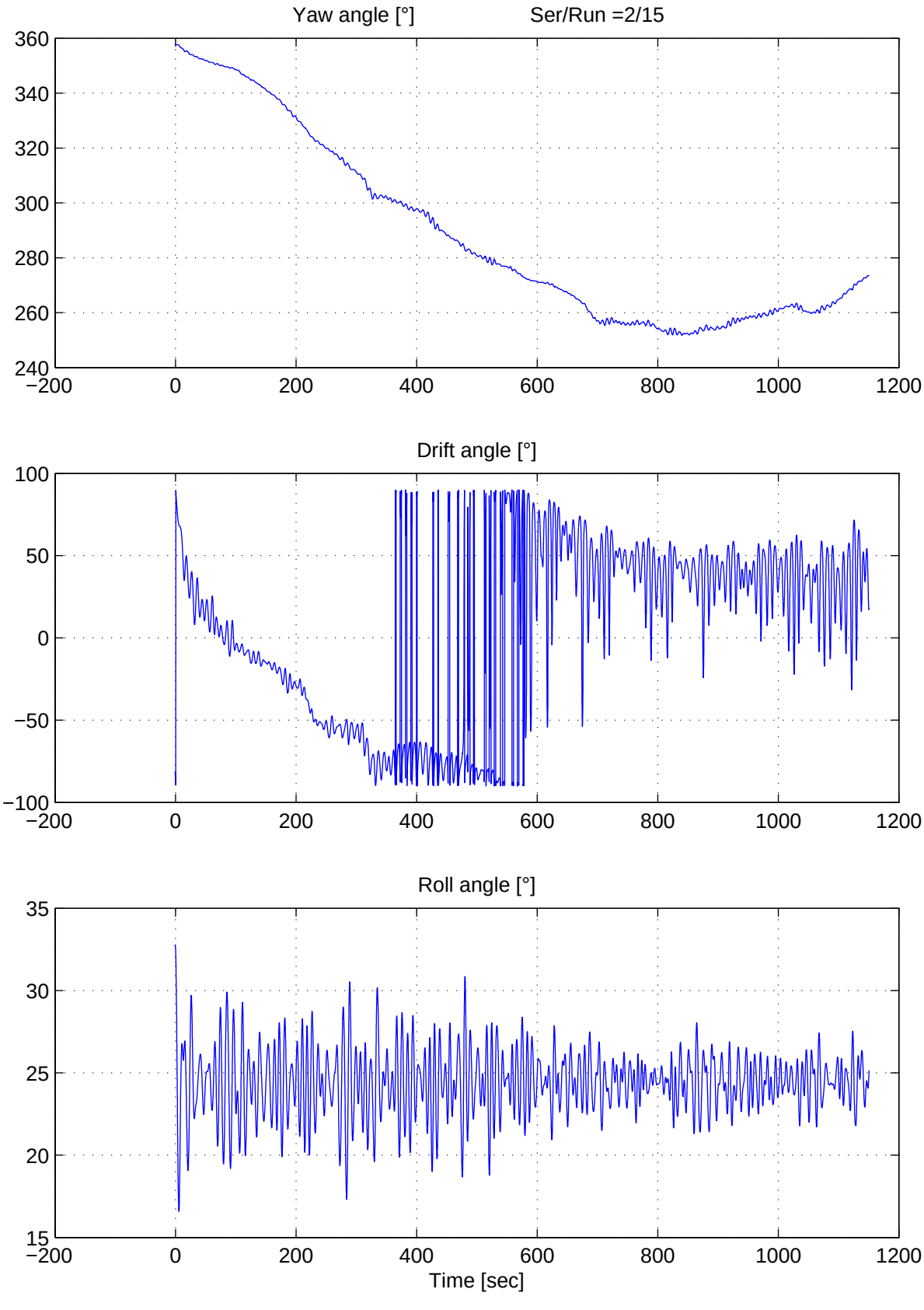
Drift tests in irregular waves

Initial speed: 0.1 knots

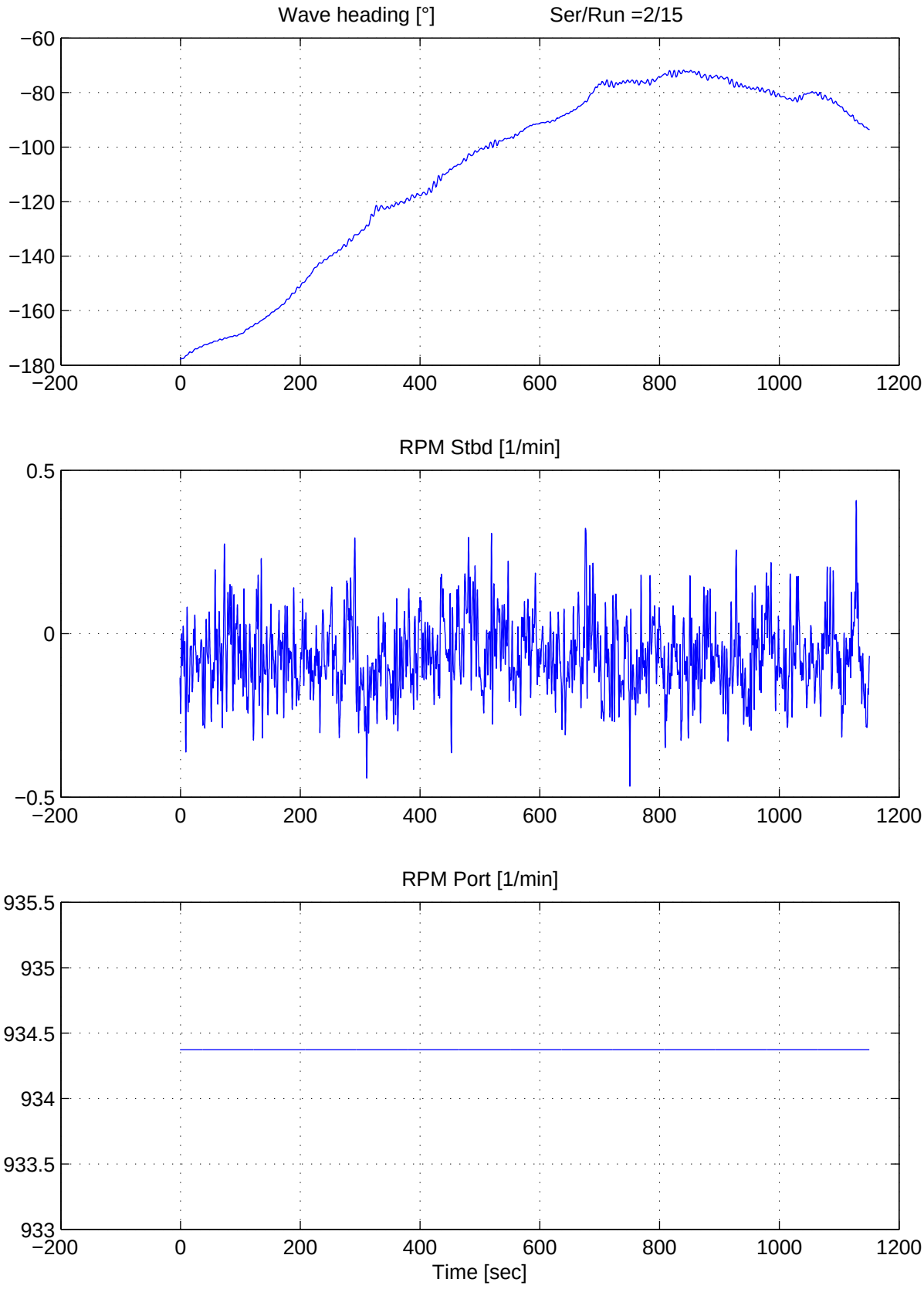
Draught Ta/Tf: 5.61/5.17 m

Figure 17.3

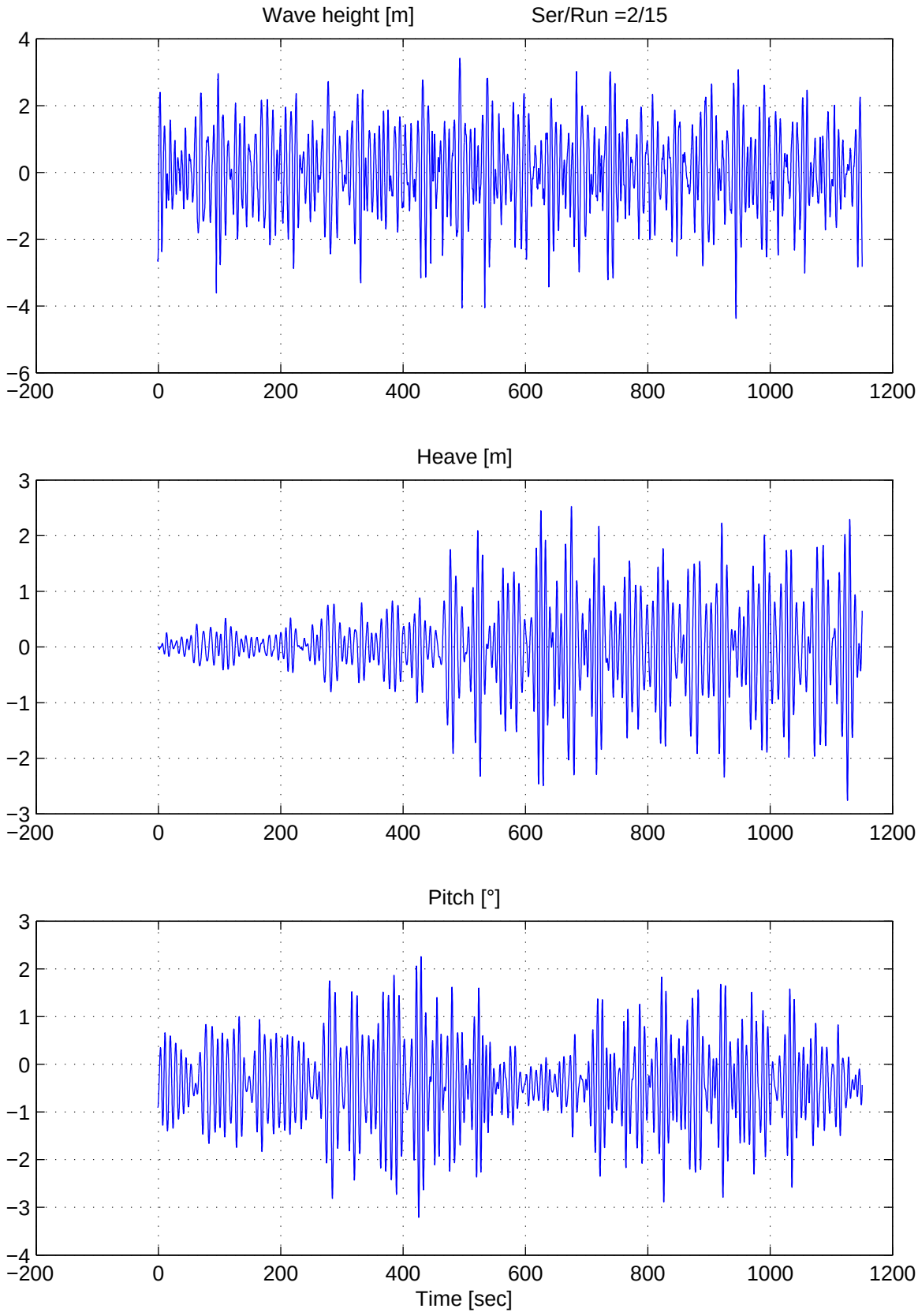
Report 40064100−1



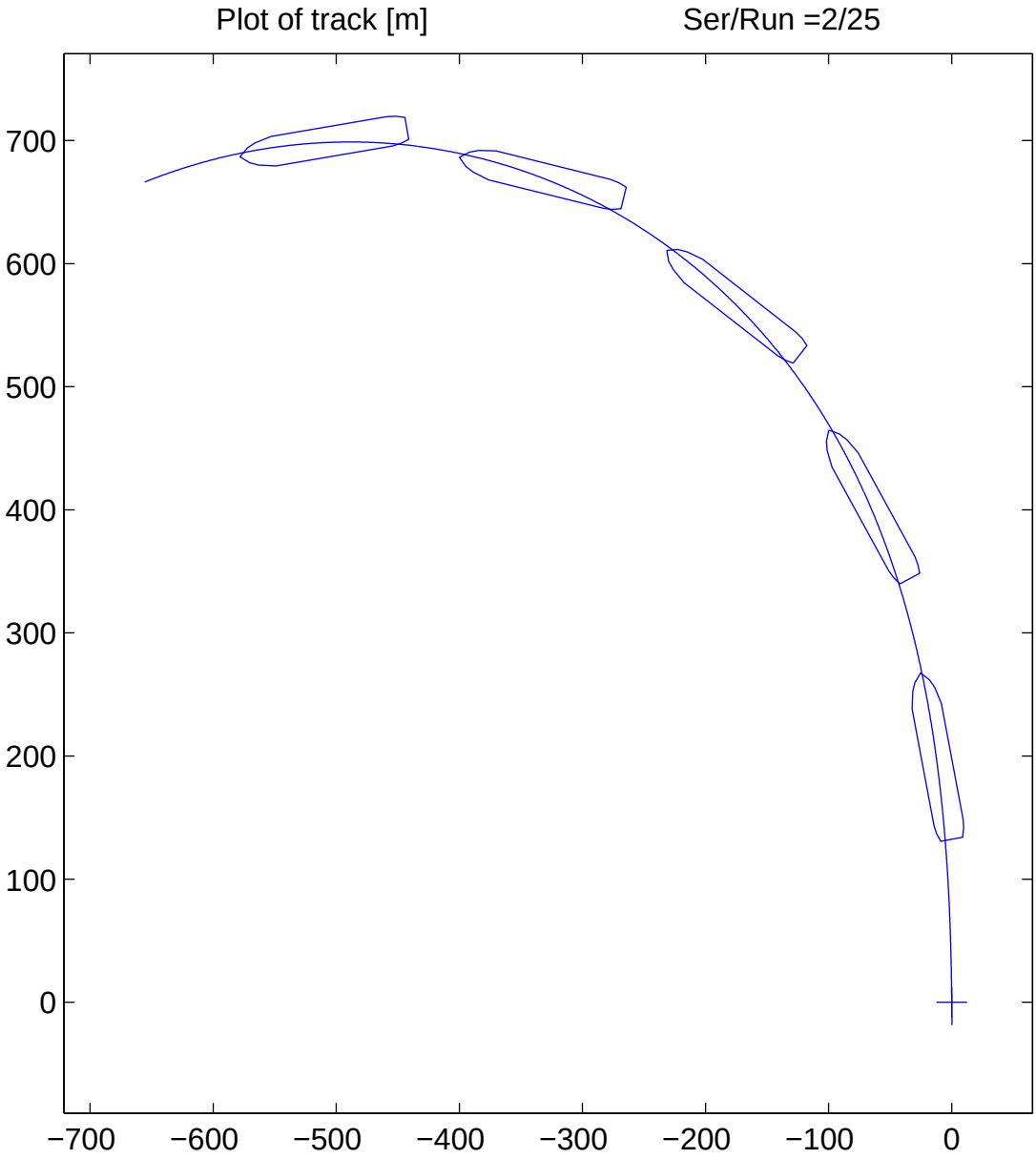
SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 17.4 Report 40064100−1



SSPA	MV Estonia Drift tests in irregular waves Initial speed: 0.1 knots Draught Ta/Tf: 5.61/5.17 m	Figure 17.5 Report 40064100−1

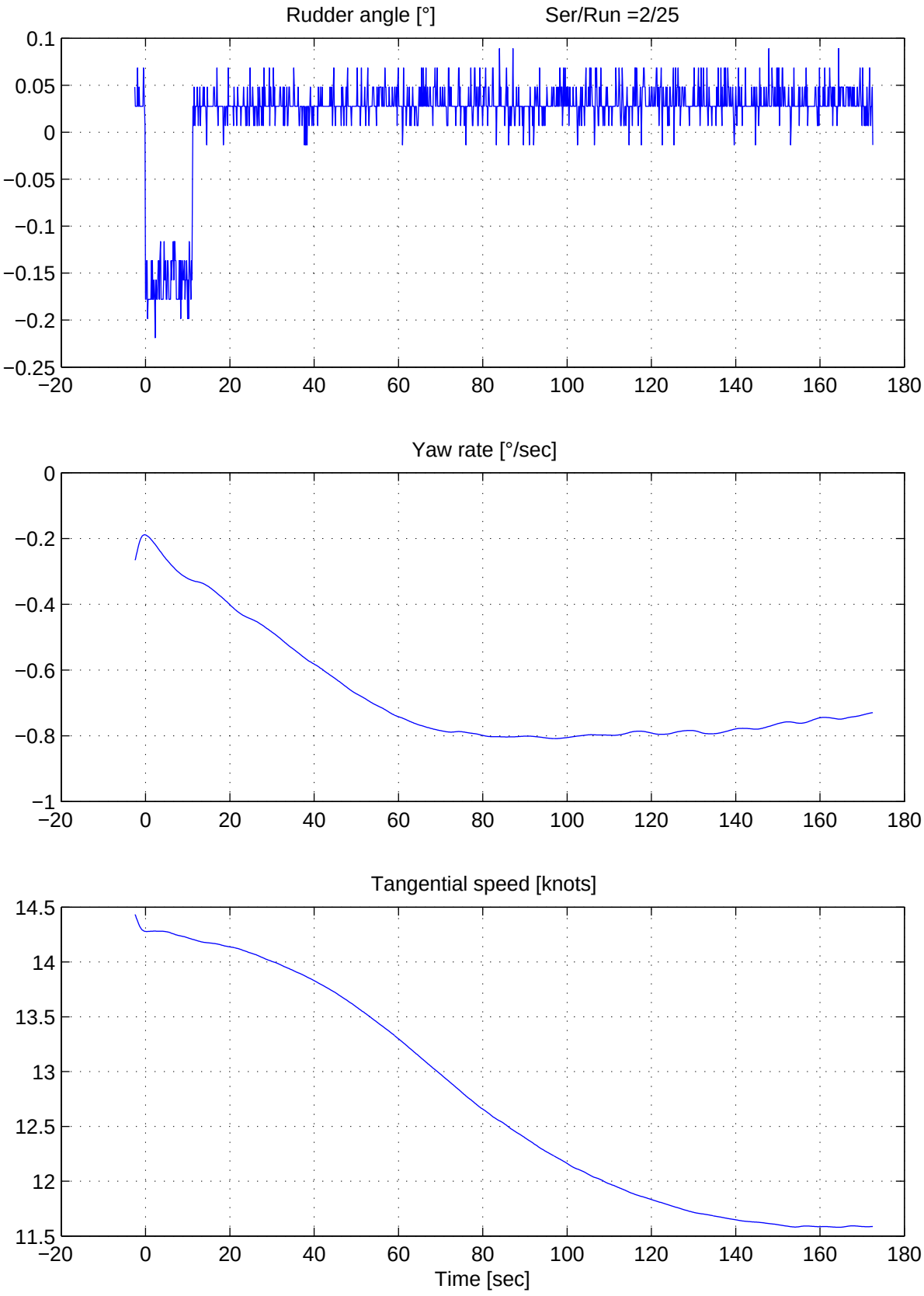


SSPA	MV Estonia Straight course test in calm water with heel Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 18.1 Report 40064100−1

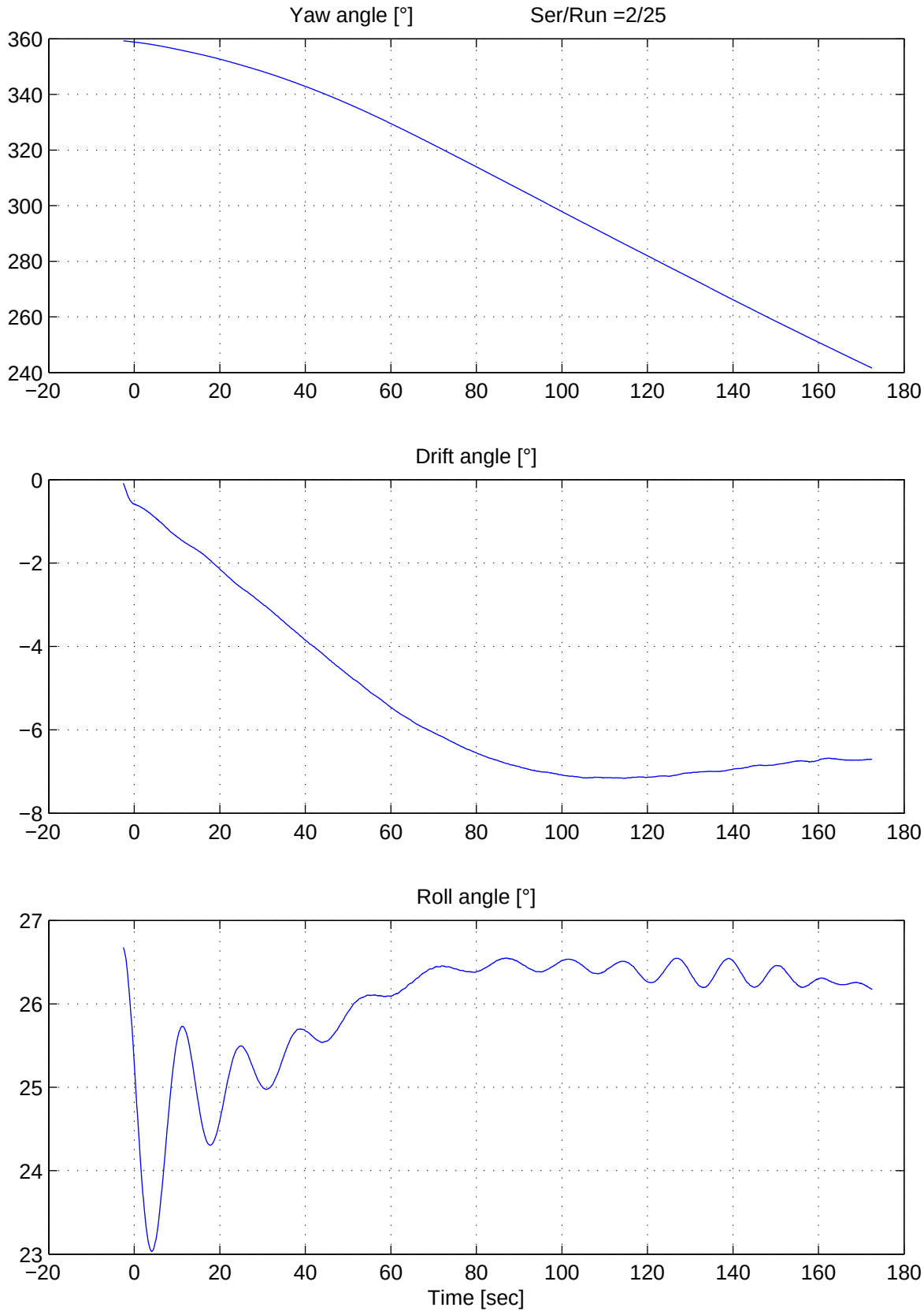


Time step between plots of ship	:	30	(sec)	
Advance	:	696	(m)	− 5.07 L_{pp}
Transfer	:	437	(m)	− 3.18 L_{pp}
Tactical diameter	:	0	(m)	− 0 L_{pp}
Steady turning diameter	:	0	(m)	− 0 L_{pp}

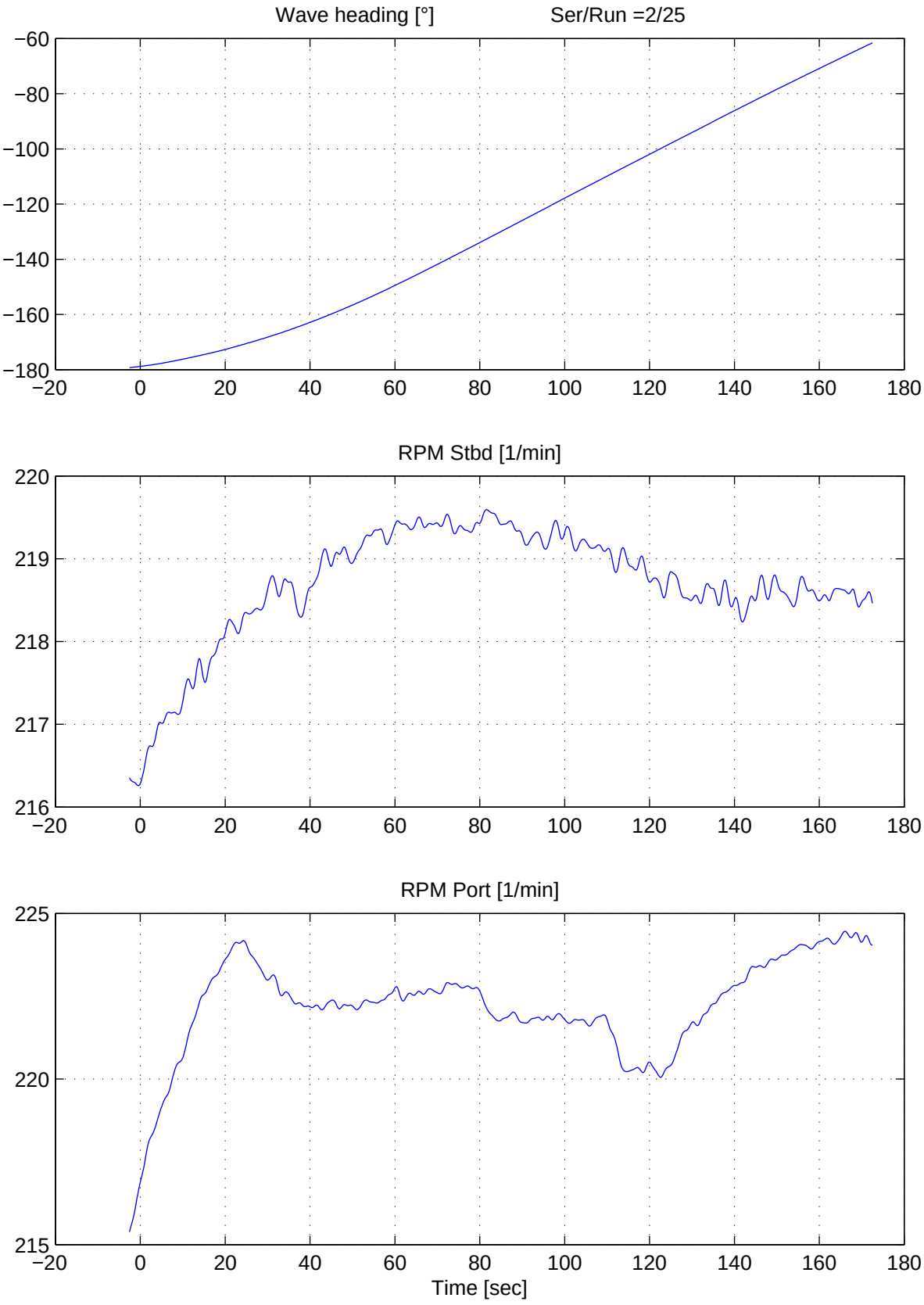
SSPA	MV Estonia Straight course test in calm water with heel Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 18.2 Report 40064100−1



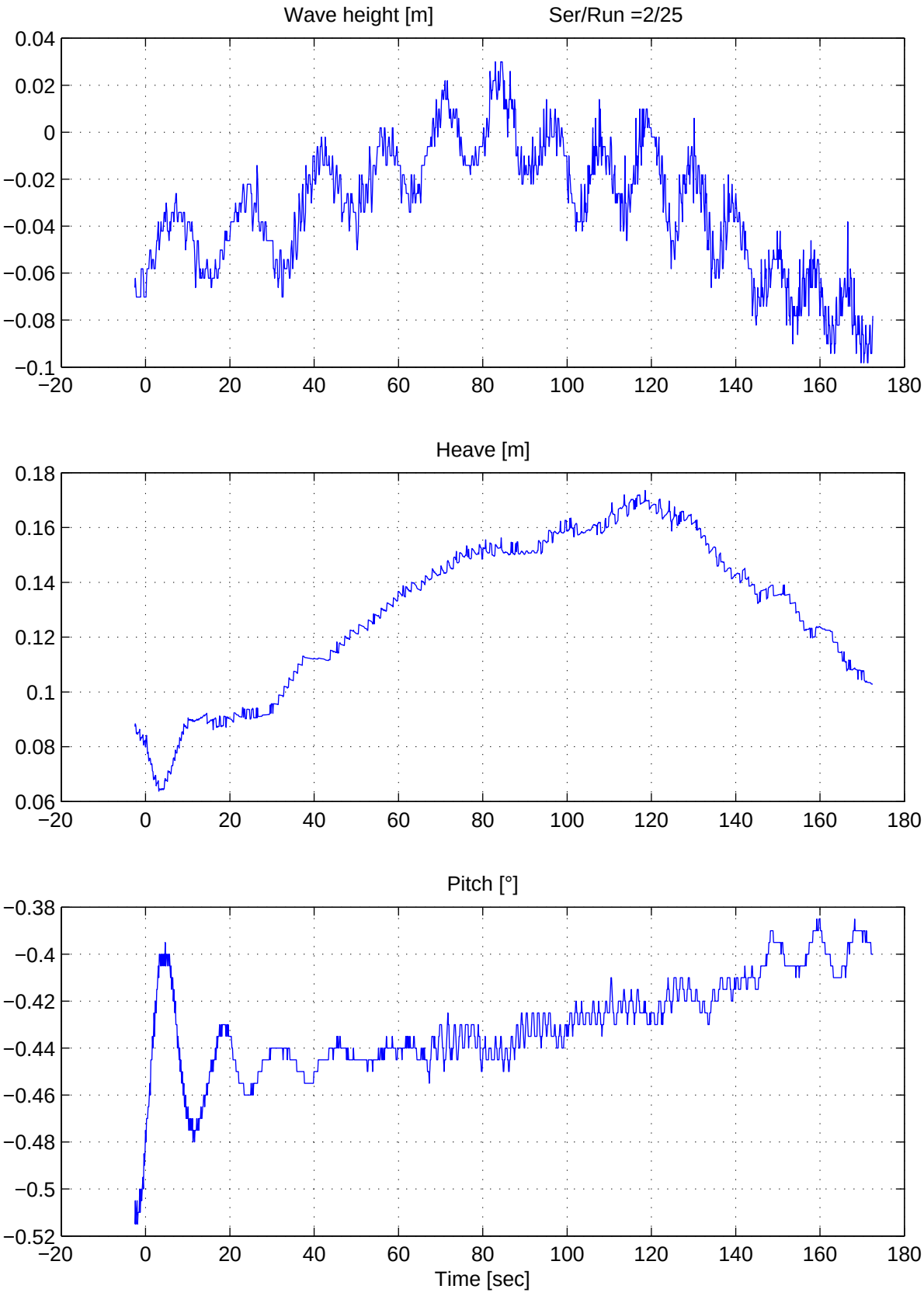
SSPA	MV Estonia Straight course test in calm water with heel Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 18.3 Report 40064100−1



SSPA	MV Estonia Straight course test in calm water with heel Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 18.4 Report 40064100−1



SSPA	MV Estonia Straight course test in calm water with heel Initial speed: 14.5 knots Draught Ta/Tf: 5.61/5.17 m	Figure 18.5 Report 40064100−1



Appendix B

Statistical result tables from seakeeping tests
in irregular seas

List of figures

Figure		
1	Wave direction: 180°; 12 knots - 25° heel	Ser/Run: 2/28,29
2	Wave direction: 150°; 12 knots - 25° heel	Ser/Run: 2/30,31
3	Wave direction: 120°; 12 knots - 25° heel	Ser/Run: 2/32,33
4	Wave direction: 180°; 14.5 knots - No heel	Ser/Run: 2/43
5	Wave direction: 150°; 14.5 knots - No heel	Ser/Run: 2/44-47
6	Wave direction: 120°; 14.5 knots - No heel	Ser/Run: 2/48
7	Wave direction: 180°; 10 knots - No heel	Ser/Run: 3/3,5
8	Wave direction: 165°; 10 knots - No heel	Ser/Run: 3/7
9	Wave direction: 150°; 10 knots - No heel	Ser/Run: 3/9
10	Wave direction: 150°; 5 knots - No heel	Ser/Run: 3/11
11	Wave direction: 150°; 14.5 knots - No heel	Ser/Run: 3/13
12	Wave direction: 180°; 10 knots - No heel	Ser/Run: 3/15,19
13	Wave direction: 165°; 10 knots - No heel	Ser/Run: 3/22,24
14	Wave direction: 150°; 10 knots - No heel	Ser/Run: 3/26,28
15	Wave direction: 150°; 5 knots - No heel	Ser/Run: 3/30,34
16	Wave direction: 150°; 12 knots - No heel	Ser/Run: 3/32
17	Wave direction: 150°; 10 knots - No heel – 1m trim by bow	Ser/Run: 3/42
18	Wave direction: 150°; 5 knots - No heel – 1m trim by bow	Ser/Run: 3/44
19	Wave direction: 150°; 5 knots - No heel – 1m trim by stern	Ser/Run: 3/48
20	Wave direction: 180°; 5 knots - 25° heel	Ser/Run: 3/51
21	Wave direction: 180°; 10 knots - 25° heel	Ser/Run: 3/53,55
22	Wave direction: 165°; 8.5 knots - 25° heel	Ser/Run: 3/57
23	Wave direction: 150°; 8.5 knots - 25° heel	Ser/Run: 3/59,61

Ser no	:	2
Run no	:	28 29
Scale factor	:	40.000
Measurement time	:	11 min 58 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	150 -
Ship speed (Nominal)	:	12.00 knots
Ship length	:	137.40 m
Wave heading	:	180.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.81	-0.03	3.42	4.41*	4.79
Wave heading	[deg]	177.18	181.76	192.57	4.95	34.41
Speed	[knots]	10.92	11.87	13.29	0.61	37.98
Prop revs stbd	[rpm]	210.78	219.62	227.24	1.79	27.74
Prop revs port	[rpm]	205.31	217.99	229.92	3.83	17.99
Rudder angle	[deg]	-29.24	-7.31	4.35	10.04	15.58
Surge	[m]	-0.44	0.00	0.35	0.20	10.71
Sway	[m]	-0.38	0.00	0.49	0.22	7.17
Heave	[m]	-0.64	0.08	0.71	0.42	6.65
Roll	[deg]	18.02	23.66	28.57	3.74	12.51
Pitch	[deg]	-1.90	-0.38	1.41	1.10	6.67
Yaw	[deg]	-0.65	-0.01	0.55	0.35	6.92

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	2
Run no	:	30 31
Scale factor	:	40.000
Measurement time	:	7 min 21 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	87 -
Ship speed (Nominal)	:	12.00 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.70	-0.08	3.45	4.41*	5.07
Wave heading	[deg]	145.46	151.70	154.64	3.25	36.83
Speed	[knots]	10.26	11.23	13.33	1.23	15.64
Prop revs stbd	[rpm]	211.83	216.52	221.35	1.81	8.66
Prop revs port	[rpm]	203.66	217.47	226.65	4.16	29.91
Rudder angle	[deg]	-16.02	-8.46	6.96	7.84	12.31
Surge	[m]	-0.27	0.03	0.45	0.25	8.91
Sway	[m]	-0.57	0.00	0.45	0.32	8.03
Heave	[m]	-0.92	0.06	0.83	0.63	6.51
Roll	[deg]	16.52	23.94	30.11	4.93	12.56
Pitch	[deg]	-2.28	-0.38	1.60	1.49	6.54
Yaw	[deg]	-1.59	-0.02	0.97	0.71	7.85

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	2
Run no	:	32 33
Scale factor	:	40.000
Measurement time	:	7 min 1 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	78 -
Ship speed (Nominal)	:	12.00 knots
Ship length	:	137.40 m
Wave heading	:	120.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.76	-0.08	2.57	4.30*	5.41
Wave heading	[deg]	114.58	122.03	126.30	4.21	13.15
Speed	[knots]	10.97	11.58	12.63	0.75	21.41
Prop revs stbd	[rpm]	219.37	223.68	226.46	1.71	6.93
Prop revs port	[rpm]	218.74	224.77	230.97	3.13	24.44
Rudder angle	[deg]	-19.84	-9.37	8.01	9.49	9.21
Surge	[m]	-0.36	0.01	0.40	0.26	7.78
Sway	[m]	-0.68	0.01	0.58	0.53	8.11
Heave	[m]	-1.45	0.05	1.48	1.13	6.80
Roll	[deg]	20.47	24.20	27.80	2.83	9.93
Pitch	[deg]	-2.96	-0.40	2.25	1.99	6.82
Yaw	[deg]	-1.47	0.01	1.41	1.04	7.22

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	2
Run no	:	43
Scale factor	:	40.000
Measurement time	:	4 min 55 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	65 -
Ship speed (Nominal)	:	14.49 knots
Ship length	:	137.40 m
Wave heading	:	180.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.83	-0.02	2.76	4.55*	4.52
Wave heading	[deg]	179.29	180.10	180.85	0.67	30.75
Speed	[knots]	13.52	14.05	14.53	0.34	22.92
Prop revs stbd	[rpm]	196.81	197.82	198.97	0.97	11.96
Prop revs port	[rpm]	193.02	195.92	199.07	2.87	18.66
Rudder angle	[deg]	-2.01	0.31	3.08	1.98	16.24
Surge	[m]	-0.21	0.00	0.30	0.18	9.50
Sway	[m]	-0.13	0.00	0.14	0.10	7.63
Heave	[m]	-0.87	0.13	0.86	0.54	6.22
Roll	[deg]	-0.96	-0.01	1.22	0.89	14.77
Pitch	[deg]	-1.52	0.00	1.68	1.19	6.65
Yaw	[deg]	-0.40	0.00	0.49	0.28	11.22

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	2
Run no	:	44 45 46 47
Scale factor	:	40.000
Measurement time	:	10 min 46 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	136 -
Ship speed (Nominal)	:	14.49 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.40	-0.07	3.30	4.50*	4.73
Wave heading	[deg]	147.35	149.82	151.63	1.47	17.54
Speed	[knots]	13.40	14.35	15.12	0.48	21.30
Prop revs stbd	[rpm]	200.96	208.74	216.38	1.46	14.36
Prop revs port	[rpm]	198.49	210.46	220.20	4.03	11.27
Rudder angle	[deg]	-4.31	0.81	9.01	4.44	12.52
Surge	[m]	-0.34	-0.00	0.48	0.23	10.07
Sway	[m]	-0.60	0.00	0.35	0.28	9.94
Heave	[m]	-1.28	0.11	1.18	0.76	6.37
Roll	[deg]	-1.86	0.64	3.53	1.94	11.38
Pitch	[deg]	-2.38	0.02	2.59	1.61	6.46
Yaw	[deg]	-0.77	0.00	0.87	0.54	9.79

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	2
Run no	:	48
Scale factor	:	40.000
Measurement time	:	2 min 43 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	31 -
Ship speed (Nominal)	:	14.49 knots
Ship length	:	137.40 m
Wave heading	:	120.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-2.79	-0.08	2.46	4.29*	5.31
Wave heading	[deg]	117.39	119.57	121.93	2.00	14.00
Speed	[knots]	13.81	14.32	15.13	0.63	22.29
Prop revs stbd	[rpm]	198.60	200.96	203.36	2.76	4.81
Prop revs port	[rpm]	202.86	205.46	208.94	3.32	11.38
Rudder angle	[deg]	-5.05	1.12	8.58	5.78	8.17
Surge	[m]	-0.26	0.01	0.39	0.24	10.60
Sway	[m]	-0.75	-0.01	0.54	0.53	7.52
Heave	[m]	-1.66	0.11	1.80	1.37	6.63
Roll	[deg]	-2.49	0.83	4.67	2.56	9.34
Pitch	[deg]	-2.54	0.00	2.46	1.99	6.31
Yaw	[deg]	-1.13	0.01	0.99	0.85	7.24

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	3 5
Scale factor	:	40.000
Measurement time	:	15 min 7 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	175 -
Ship speed (Nominal)	:	9.99 knots
Ship length	:	137.40 m
Wave heading	:	180.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.47	0.07	2.88	4.50*	5.19
Wave heading	[deg]	179.29	180.01	180.80	0.52	19.01
Speed	[knots]	8.68	10.02	11.51	0.62	42.77
Prop revs stbd	[rpm]	138.28	151.14	161.47	2.17	42.38
Prop revs port	[rpm]	147.60	155.85	163.87	3.22	9.31
Rudder angle	[deg]	-1.89	0.50	2.92	1.47	11.00
Surge	[m]	-0.33	0.00	0.43	0.22	10.05
Sway	[m]	-0.19	0.00	0.18	0.10	7.01
Heave	[m]	-0.75	0.06	0.81	0.55	6.42
Roll	[deg]	-1.79	-0.14	1.47	1.03	12.91
Pitch	[deg]	-1.90	-0.02	2.04	1.22	6.90
Yaw	[deg]	-0.33	0.00	0.39	0.22	9.54

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	7
Scale factor	:	40.000
Measurement time	:	7 min 8 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	81 -
Ship speed (Nominal)	:	9.99 knots
Ship length	:	137.40 m
Wave heading	:	165.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.84	0.05	3.32	4.34*	5.28
Wave heading	[deg]	162.59	164.87	165.92	1.10	20.70
Speed	[knots]	9.07	9.60	10.17	0.47	26.31
Prop revs stbd	[rpm]	150.83	153.99	155.84	2.20	6.07
Prop revs port	[rpm]	147.60	152.94	155.88	3.62	0.00
Rudder angle	[deg]	-2.77	0.72	7.82	3.00	15.22
Surge	[m]	-1.12	-0.01	0.41	0.27	9.14
Sway	[m]	-0.19	0.00	0.19	0.13	8.02
Heave	[m]	-0.77	0.03	0.89	0.62	6.78
Roll	[deg]	-1.66	0.32	3.00	1.40	14.14
Pitch	[deg]	-1.98	-0.01	1.94	1.40	7.02
Yaw	[deg]	-0.72	-0.01	0.77	0.39	10.76

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	9
Scale factor	:	40.000
Measurement time	:	4 min 19 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	46 -
Ship speed (Nominal)	:	9.99 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.31	0.04	2.75	4.42*	5.65
Wave heading	[deg]	147.05	149.81	152.25	2.06	28.01
Speed	[knots]	8.93	9.63	10.29	0.56	22.88
Prop revs stbd	[rpm]	152.68	157.26	158.50	2.17	9.92
Prop revs port	[rpm]	150.70	155.41	157.58	2.85	20.83
Rudder angle	[deg]	-4.97	0.84	9.20	5.40	14.19
Surge	[m]	-0.34	0.00	0.39	0.25	10.10
Sway	[m]	-0.35	0.00	0.30	0.25	10.05
Heave	[m]	-0.99	0.02	1.06	0.75	6.77
Roll	[deg]	-1.79	0.56	3.12	2.07	11.06
Pitch	[deg]	-2.16	-0.01	2.36	1.73	6.97
Yaw	[deg]	-0.71	0.00	0.82	0.57	9.03

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	11
Scale factor	:	40.000
Measurement time	:	8 min 25 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	75 -
Ship speed (Nominal)	:	5.00 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.84	0.01	3.02	4.65*	6.72
Wave heading	[deg]	142.92	146.77	150.83	3.23	39.62
Speed	[knots]	3.56	4.13	4.87	0.55	14.98
Prop revs stbd	[rpm]	83.92	86.69	89.17	2.76	21.47
Prop revs port	[rpm]	84.96	86.78	88.11	1.54	35.26
Rudder angle	[deg]	-2.51	7.07	18.21	7.46	17.09
Surge	[m]	-0.46	0.01	0.52	0.34	9.03
Sway	[m]	-0.58	-0.01	0.48	0.30	8.00
Heave	[m]	-0.96	-0.01	0.81	0.63	7.68
Roll	[deg]	-3.15	0.44	5.26	3.02	14.26
Pitch	[deg]	-2.75	-0.03	2.38	1.88	7.84
Yaw	[deg]	-0.99	0.00	0.85	0.63	7.96

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	13
Scale factor	:	40.000
Measurement time	:	3 min 3 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	36 -
Ship speed (Nominal)	:	14.49 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.09	-0.08	2.35	4.40*	5.05
Wave heading	[deg]	147.86	149.96	151.55	1.48	18.43
Speed	[knots]	12.74	13.39	14.51	0.72	22.20
Prop revs stbd	[rpm]	196.79	200.05	201.93	2.77	0.00
Prop revs port	[rpm]	192.76	195.54	199.79	4.03	0.00
Rudder angle	[deg]	-4.07	0.47	6.82	4.14	10.76
Surge	[m]	-0.23	0.02	0.44	0.25	12.23
Sway	[m]	-0.44	0.00	0.29	0.24	9.02
Heave	[m]	-0.75	0.09	0.93	0.68	6.59
Roll	[deg]	-1.29	0.74	2.67	1.81	14.06
Pitch	[deg]	-1.58	-0.04	1.75	1.47	6.54
Yaw	[deg]	-0.53	0.01	0.55	0.44	10.16

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	15 19
Scale factor	:	40.000
Measurement time	:	14 min 59 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	182 -
Ship speed (Nominal)	:	9.99 knots
Ship length	:	137.40 m
Wave heading	:	180.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.92	-0.01	3.04	4.45*	4.92
Wave heading	[deg]	178.64	179.93	181.03	0.84	36.06
Speed	[knots]	9.21	10.11	10.97	0.60	37.63
Prop revs stbd	[rpm]	155.01	161.33	164.42	2.95	15.09
Prop revs port	[rpm]	-5.66	77.76	168.00	5.76	3.42
Rudder angle	[deg]	-2.26	0.55	3.86	2.13	13.97
Surge	[m]	-0.29	0.00	0.36	0.22	8.82
Sway	[m]	-0.18	0.00	0.20	0.10	6.95
Heave	[m]	-0.64	0.13	0.82	0.50	6.46
Roll	[deg]	-2.32	-0.31	1.78	1.05	13.39
Pitch	[deg]	-1.85	-0.13	1.65	1.11	7.05
Yaw	[deg]	-0.45	0.00	0.39	0.24	9.64

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	22 24
Scale factor	:	40.000
Measurement time	:	14 min 5 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	159 -
Ship speed (Nominal)	:	9.99 knots
Ship length	:	137.40 m
Wave heading	:	165.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli- tude	Period of enc. (s)
Wave height	[m]	-3.83	-0.04	3.37	4.31*	5.30
Wave heading	[deg]	163.37	164.94	166.22	0.99	29.81
Speed	[knots]	9.02	9.79	10.51	0.58	29.33
Prop revs stbd	[rpm]	157.12	160.37	161.84	1.22	14.98
Prop revs port	[rpm]	-5.85	-3.61	-1.50	2.64	78.04
Rudder angle	[deg]	-3.57	0.54	5.30	2.82	11.53
Surge	[m]	-0.35	0.00	0.42	0.24	11.59
Sway	[m]	-0.40	0.00	0.24	0.16	8.13
Heave	[m]	-0.80	0.11	1.05	0.58	6.89
Roll	[deg]	-2.73	0.07	2.48	1.41	12.59
Pitch	[deg]	-1.91	-0.13	1.74	1.27	6.98
Yaw	[deg]	-0.69	0.00	0.50	0.34	9.06

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

```
Ser no                :         3
Run no                :     26 28
Scale factor          :    40.000
Measurement time      :   8 min 30 sec
Sampling frequency    :     7.906 Hz
Number of wave enc.   :        97 -
Ship speed (Nominal)  :      9.99 knots
Ship length           :    137.40 m
Wave heading          :    150.00 deg
Water depth           :    102.00 m
Nominal wave height   :      4.30 m
Nominal wave period   :      8.30 sec
```

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.91	-0.09	2.94	4.38*	5.26
Wave heading	[deg]	146.55	149.80	152.25	1.97	23.34
Speed	[knots]	9.10	9.77	10.47	0.60	22.97
Prop revs stbd	[rpm]	160.09	162.39	163.40	0.88	15.35
Prop revs port	[rpm]	-5.82	-4.88	-2.97	1.20	35.70
Rudder angle	[deg]	-6.78	0.84	10.99	5.28	10.61
Surge	[m]	-0.88	0.01	0.49	0.28	11.78
Sway	[m]	-0.44	-0.01	0.47	0.26	9.21
Heave	[m]	-0.85	0.13	1.03	0.65	7.20
Roll	[deg]	-2.40	0.42	2.88	1.83	10.51
Pitch	[deg]	-2.22	-0.16	2.00	1.56	6.96
Yaw	[deg]	-1.18	-0.01	0.82	0.58	7.88

```
      Significant single amplitude = 2*standard deviation
    * Significant wave height      = 4*standard deviation
```

Ser no	:	3
Run no	:	30 34
Scale factor	:	40.000
Measurement time	:	14 min 10 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	133 -
Ship speed (Nominal)	:	5.00 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-5.01	-0.09	2.96	4.28*	6.41
Wave heading	[deg]	144.27	148.29	151.35	2.95	39.09
Speed	[knots]	4.74	5.47	6.91	0.53	18.56
Prop revs stbd	[rpm]	97.86	111.53	114.99	7.09	12.36
Prop revs port	[rpm]	-5.89	-2.96	-1.43	1.89	53.84
Rudder angle	[deg]	-3.96	3.92	15.65	7.08	16.95
Surge	[m]	-0.40	-0.01	0.47	0.28	8.91
Sway	[m]	-0.46	-0.01	0.37	0.26	9.28
Heave	[m]	-0.94	0.04	1.03	0.62	7.74
Roll	[deg]	-2.50	0.21	2.73	1.83	11.07
Pitch	[deg]	-2.13	-0.09	1.98	1.64	7.61
Yaw	[deg]	-0.89	0.01	0.89	0.61	7.84

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	32
Scale factor	:	40.000
Measurement time	:	3 min 46 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	44 -
Ship speed (Nominal)	:	12.00 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.86	-0.08	2.62	4.45*	5.06
Wave heading	[deg]	148.58	150.41	151.90	1.50	29.44
Speed	[knots]	10.39	11.36	12.36	0.87	18.25
Prop revs stbd	[rpm]	179.83	182.38	183.36	0.96	22.21
Prop revs port	[rpm]	-5.75	-4.24	-1.61	2.63	0.00
Rudder angle	[deg]	-5.71	-0.39	5.77	4.47	12.94
Surge	[m]	-1.12	0.01	0.41	0.31	10.47
Sway	[m]	-0.38	0.00	0.77	0.27	9.34
Heave	[m]	-0.68	0.30	1.21	0.68	6.94
Roll	[deg]	-2.01	0.56	3.26	1.90	11.82
Pitch	[deg]	-2.83	-0.40	1.63	1.53	6.83
Yaw	[deg]	-0.68	-0.01	0.73	0.52	8.71

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	42
Scale factor	:	40.000
Measurement time	:	2 min 25 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	26 -
Ship speed (Nominal)	:	9.99 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-5.35	-0.04	2.69	4.24*	5.60
Wave heading	[deg]	147.50	149.96	151.82	1.85	15.24
Speed	[knots]	8.30	9.28	10.05	0.93	12.27
Prop revs stbd	[rpm]	159.41	160.47	162.44	1.21	17.71
Prop revs port	[rpm]	-5.96	-3.70	-1.51	2.71	0.00
Rudder angle	[deg]	-5.83	0.38	8.25	5.27	8.92
Surge	[m]	-0.28	0.02	0.39	0.27	11.92
Sway	[m]	-0.36	0.00	0.22	0.22	9.86
Heave	[m]	-0.83	0.28	1.04	0.63	8.22
Roll	[deg]	-2.34	0.89	2.91	2.12	12.41
Pitch	[deg]	-2.80	-0.77	1.11	1.59	7.30
Yaw	[deg]	-0.76	0.00	0.68	0.60	8.94

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	44
Scale factor	:	40.000
Measurement time	:	6 min 50 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	65 -
Ship speed (Nominal)	:	5.00 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.88	-0.05	2.99	4.38*	6.25
Wave heading	[deg]	146.18	149.04	151.77	1.94	23.97
Speed	[knots]	4.90	5.56	6.30	0.55	17.79
Prop revs stbd	[rpm]	109.07	112.03	113.40	1.96	18.69
Prop revs port	[rpm]	-5.82	-4.09	-1.53	2.42	85.48
Rudder angle	[deg]	-4.48	2.43	10.23	5.21	10.86
Surge	[m]	-0.36	-0.01	0.38	0.27	8.65
Sway	[m]	-0.36	0.00	0.86	0.25	8.89
Heave	[m]	-0.98	0.08	0.92	0.60	8.17
Roll	[deg]	-2.51	0.50	3.65	1.91	11.83
Pitch	[deg]	-2.71	-0.54	1.26	1.63	7.83
Yaw	[deg]	-0.97	0.00	0.73	0.58	7.85

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	48
Scale factor	:	40.000
Measurement time	:	6 min 33 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	60 -
Ship speed (Nominal)	:	5.00 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.82	-0.05	3.26	4.25*	6.51
Wave heading	[deg]	145.37	147.93	150.47	2.11	56.92
Speed	[knots]	4.92	5.56	6.18	0.45	15.37
Prop revs stbd	[rpm]	107.20	109.19	112.45	3.12	0.00
Prop revs port	[rpm]	-6.17	-3.55	-1.77	2.45	127.69
Rudder angle	[deg]	-2.83	4.60	13.08	5.51	12.89
Surge	[m]	-0.36	0.00	0.42	0.27	7.60
Sway	[m]	-0.37	-0.01	0.33	0.25	8.51
Heave	[m]	-0.88	-0.02	0.84	0.59	7.67
Roll	[deg]	-2.92	0.23	3.03	1.62	10.24
Pitch	[deg]	-1.78	0.31	2.15	1.62	7.66
Yaw	[deg]	-0.90	0.00	0.76	0.55	8.63

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	51
Scale factor	:	40.000
Measurement time	:	14 min 59 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	146 -
Ship speed (Nominal)	:	5.00 knots
Ship length	:	137.40 m
Wave heading	:	180.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.85	0.00	3.13	4.72*	6.14
Wave heading	[deg]	174.85	180.55	184.50	3.59	113.34
Speed	[knots]	4.28	5.35	6.45	0.99	31.16
Prop revs stbd	[rpm]	125.82	128.31	130.44	2.44	52.20
Prop revs port	[rpm]	128.74	130.21	131.64	1.27	47.90
Rudder angle	[deg]	-12.16	-2.63	10.33	7.50	36.48
Surge	[m]	-0.41	-0.01	0.43	0.24	9.51
Sway	[m]	-0.29	0.00	0.26	0.14	7.30
Heave	[m]	-0.67	0.02	0.71	0.39	7.35
Roll	[deg]	18.07	23.97	30.37	3.63	9.09
Pitch	[deg]	-2.44	-0.39	1.66	1.21	7.86
Yaw	[deg]	-0.51	0.00	0.42	0.31	7.34

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	53 55
Scale factor	:	40.000
Measurement time	:	18 min 17 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	206 -
Ship speed (Nominal)	:	9.99 knots
Ship length	:	137.40 m
Wave heading	:	180.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-6.04	-0.01	3.23	4.62*	5.33
Wave heading	[deg]	178.53	181.80	186.55	2.51	47.56
Speed	[knots]	7.27	8.37	9.77	0.65	28.63
Prop revs stbd	[rpm]	168.89	176.95	185.76	1.23	23.84
Prop revs port	[rpm]	166.54	178.20	187.47	4.37	15.86
Rudder angle	[deg]	-15.63	-5.05	3.00	5.52	18.45
Surge	[m]	-0.31	0.01	0.66	0.23	8.88
Sway	[m]	-0.22	0.00	0.22	0.15	7.00
Heave	[m]	-0.56	0.07	0.71	0.40	6.92
Roll	[deg]	17.23	24.23	29.67	4.33	10.39
Pitch	[deg]	-2.19	-0.46	1.19	1.08	7.38
Yaw	[deg]	-0.69	0.00	0.59	0.33	6.88

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	57
Scale factor	:	40.000
Measurement time	:	9 min 2 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	108 -
Ship speed (Nominal)	:	8.50 knots
Ship length	:	137.40 m
Wave heading	:	165.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-3.50	0.00	2.72	4.19*	5.01
Wave heading	[deg]	165.44	167.27	168.76	1.25	19.65
Speed	[knots]	7.94	8.70	9.35	0.58	26.20
Prop revs stbd	[rpm]	184.78	188.05	189.59	1.59	7.96
Prop revs port	[rpm]	182.91	189.64	193.02	4.70	21.68
Rudder angle	[deg]	-12.01	-6.01	-0.21	3.75	9.74
Surge	[m]	-0.29	0.00	0.40	0.24	10.31
Sway	[m]	-0.25	0.00	0.26	0.17	7.28
Heave	[m]	-0.64	0.09	0.74	0.45	7.14
Roll	[deg]	17.74	24.40	30.75	4.59	10.36
Pitch	[deg]	-2.11	-0.46	1.18	1.14	7.11
Yaw	[deg]	-0.73	0.00	0.60	0.45	7.22

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Ser no	:	3
Run no	:	59 61
Scale factor	:	40.000
Measurement time	:	11 min 6 sec
Sampling frequency	:	7.906 Hz
Number of wave enc.	:	118 -
Ship speed (Nominal)	:	8.50 knots
Ship length	:	137.40 m
Wave heading	:	150.00 deg
Water depth	:	102.00 m
Nominal wave height	:	4.30 m
Nominal wave period	:	8.30 sec

		Minimum Value	Mean Value	Maximum Value	Signif. single ampli-tude	Period of enc. (s)
Wave height	[m]	-4.36	-0.01	3.23	4.35*	5.64
Wave heading	[deg]	145.43	152.97	156.74	3.86	22.52
Speed	[knots]	8.00	8.66	9.54	0.52	23.20
Prop revs stbd	[rpm]	186.54	189.88	191.50	1.53	19.81
Prop revs port	[rpm]	184.90	191.19	194.41	3.57	12.29
Rudder angle	[deg]	-17.80	-7.51	10.92	8.65	12.90
Surge	[m]	-1.12	0.00	0.45	0.28	9.07
Sway	[m]	-0.52	0.01	0.31	0.25	9.45
Heave	[m]	-0.73	0.07	0.78	0.53	6.88
Roll	[deg]	18.92	24.40	31.36	4.48	10.78
Pitch	[deg]	-2.44	-0.46	1.61	1.36	7.10
Yaw	[deg]	-0.90	0.00	0.99	0.61	7.48

Significant single amplitude = 2*standard deviation
* Significant wave height = 4*standard deviation

Appendix C

Photos of model and from seakeeping tests
in irregular seas

List of photos

Figure

1	Photos of model from bow and astern before launching
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6	Model in calm water with 25° heel
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9	Tests in irregular bow seas – Bow ramp completely opened
10	Tests in irregular bow seas – Bow ramp completely opened
11	Tests in irregular bow seas – Bow ramp completely opened
12	Tests in irregular bow seas – Bow ramp completely opened
13	Tests in irregular head seas – Bow ramp completely opened - 25° heel
14	Tests in irregular head seas – Bow ramp completely opened - 25° heel
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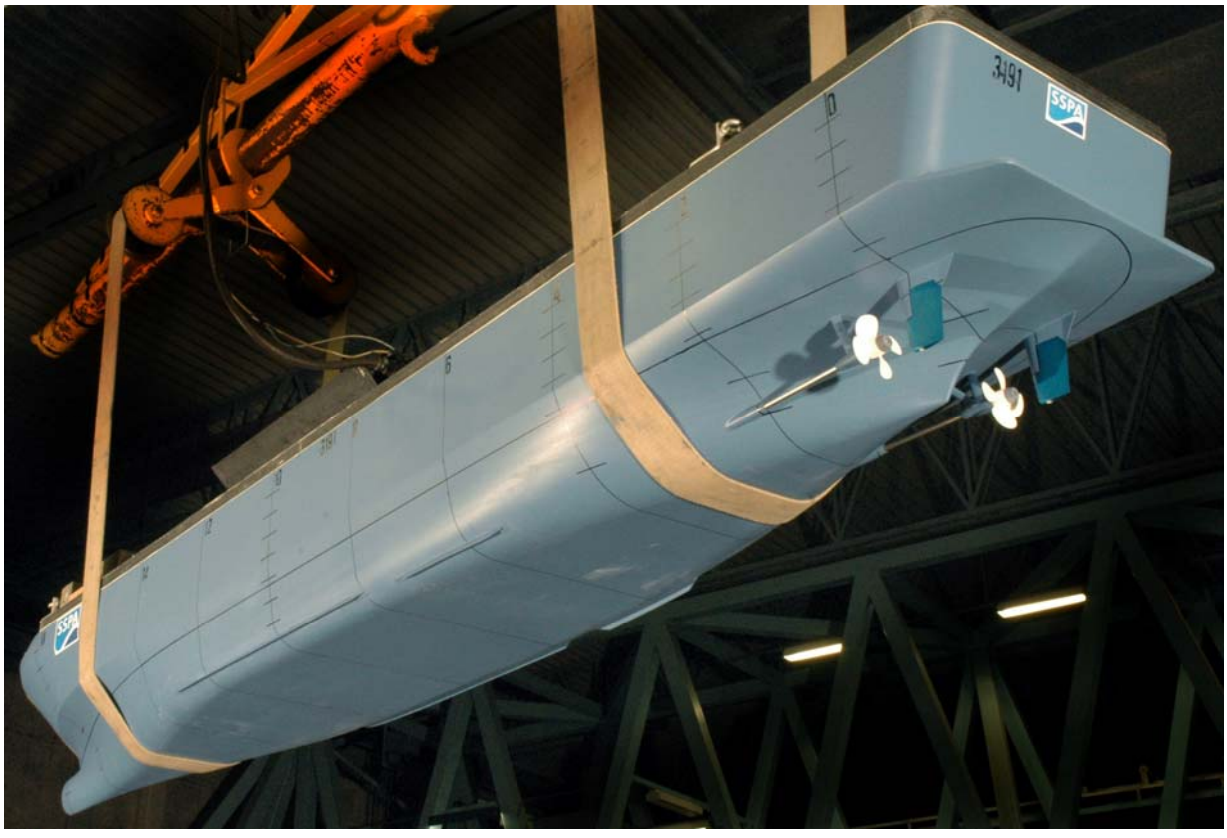
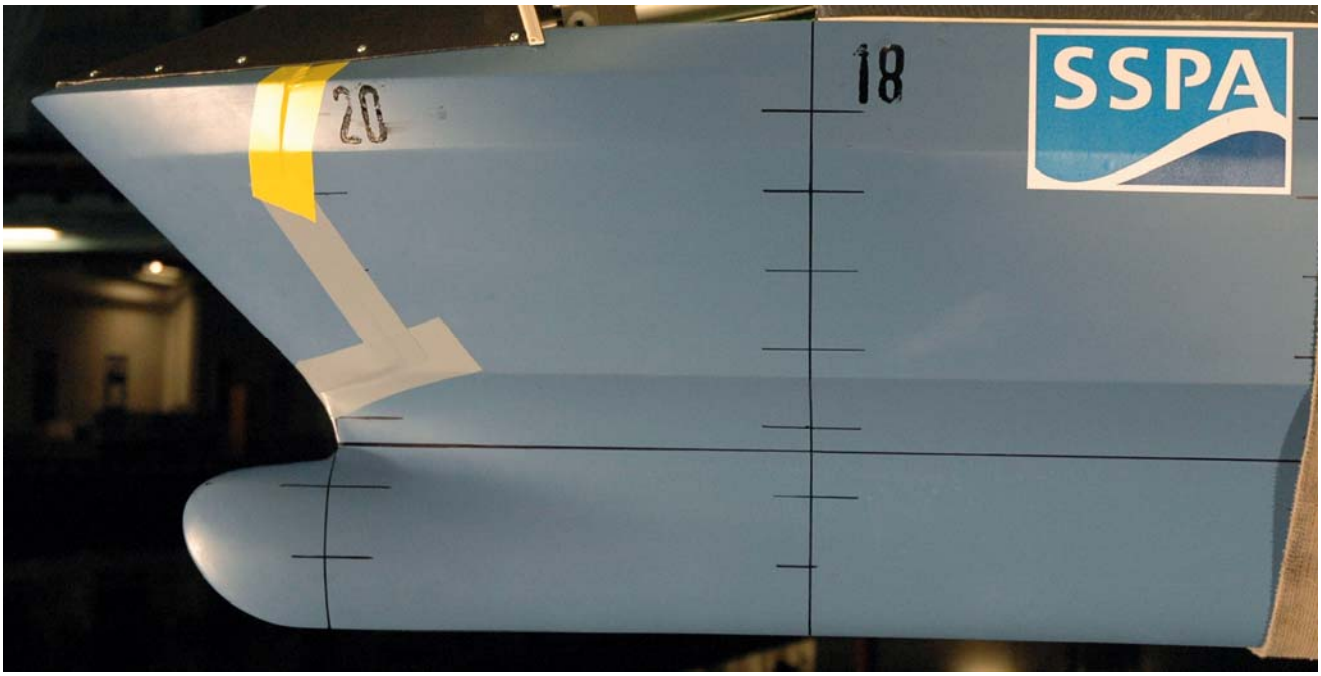
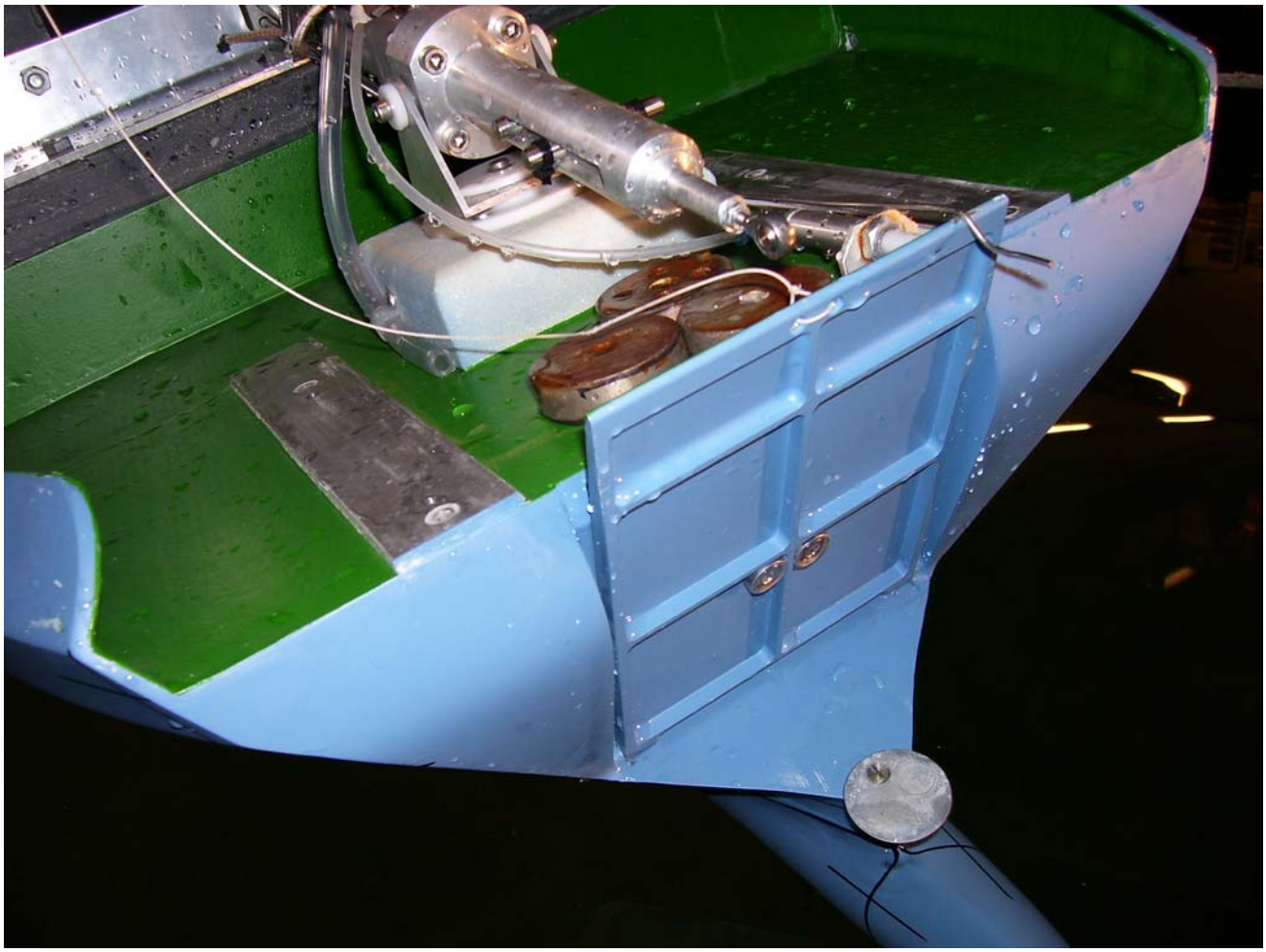
17	Close-ups of bow ramp at tests in irregular head seas

SSPA	**MV Estonia** Photos of model on shore	Figure 1 Report 4006 4100-1 Appendix C



SSPA	**MV Estonia** Photos of model on shore	Figure 2 Report 4006 4100-1 Appendix C



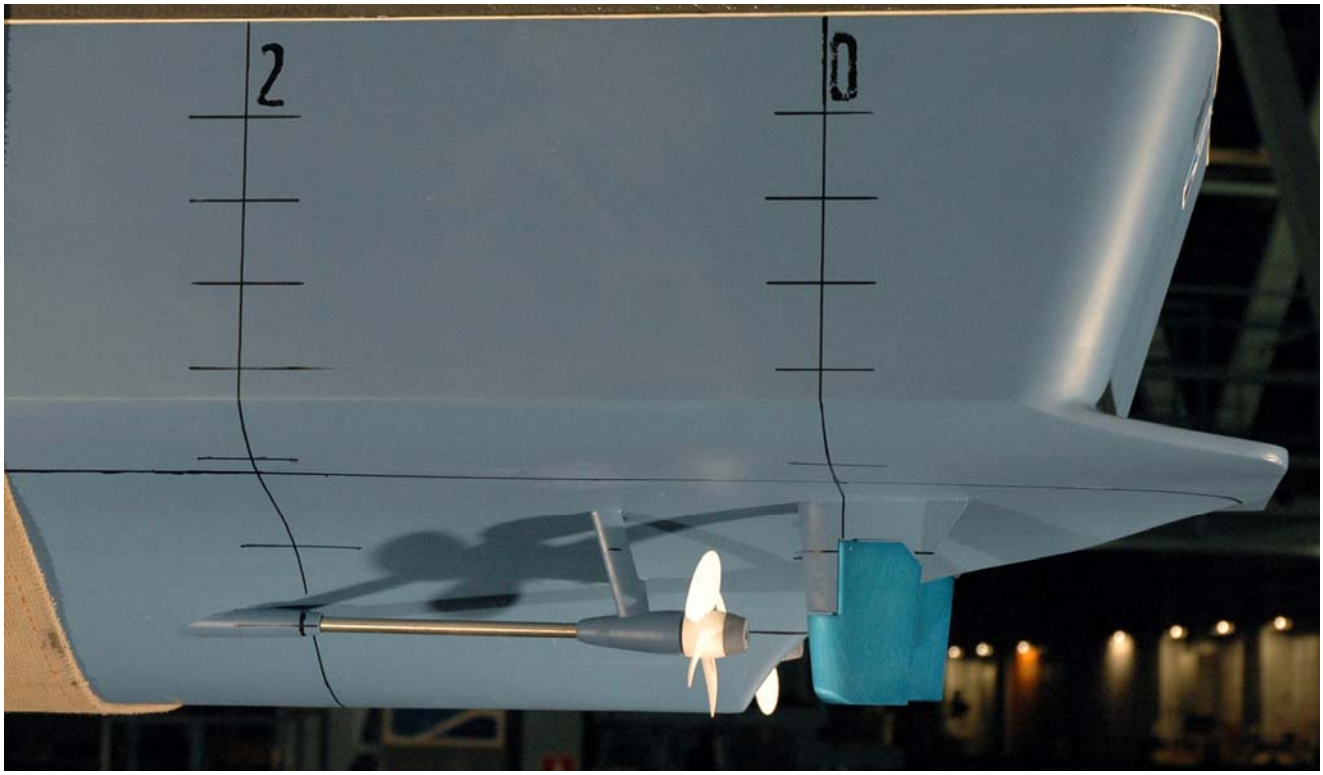


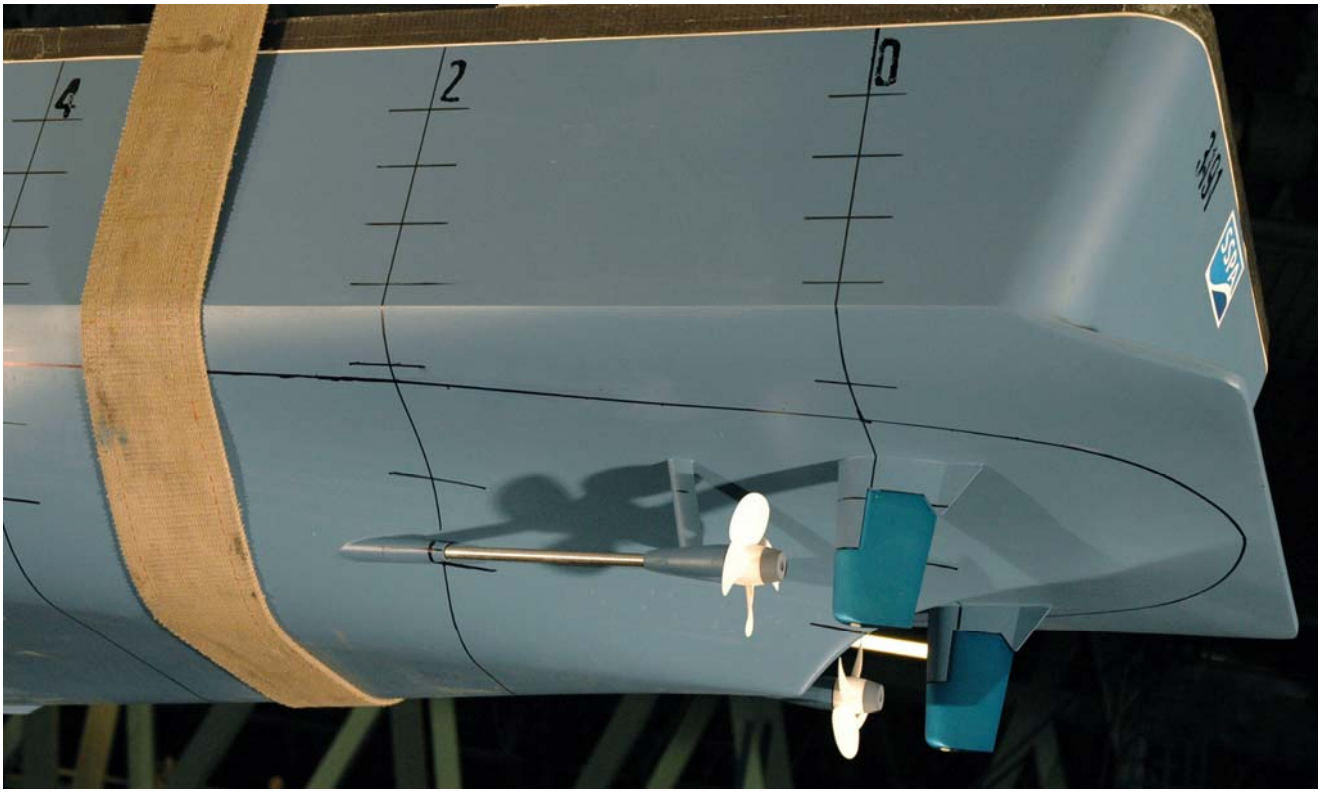
Bow ramp closed

Bow ramp opened 1 m

Bow ramp completely open

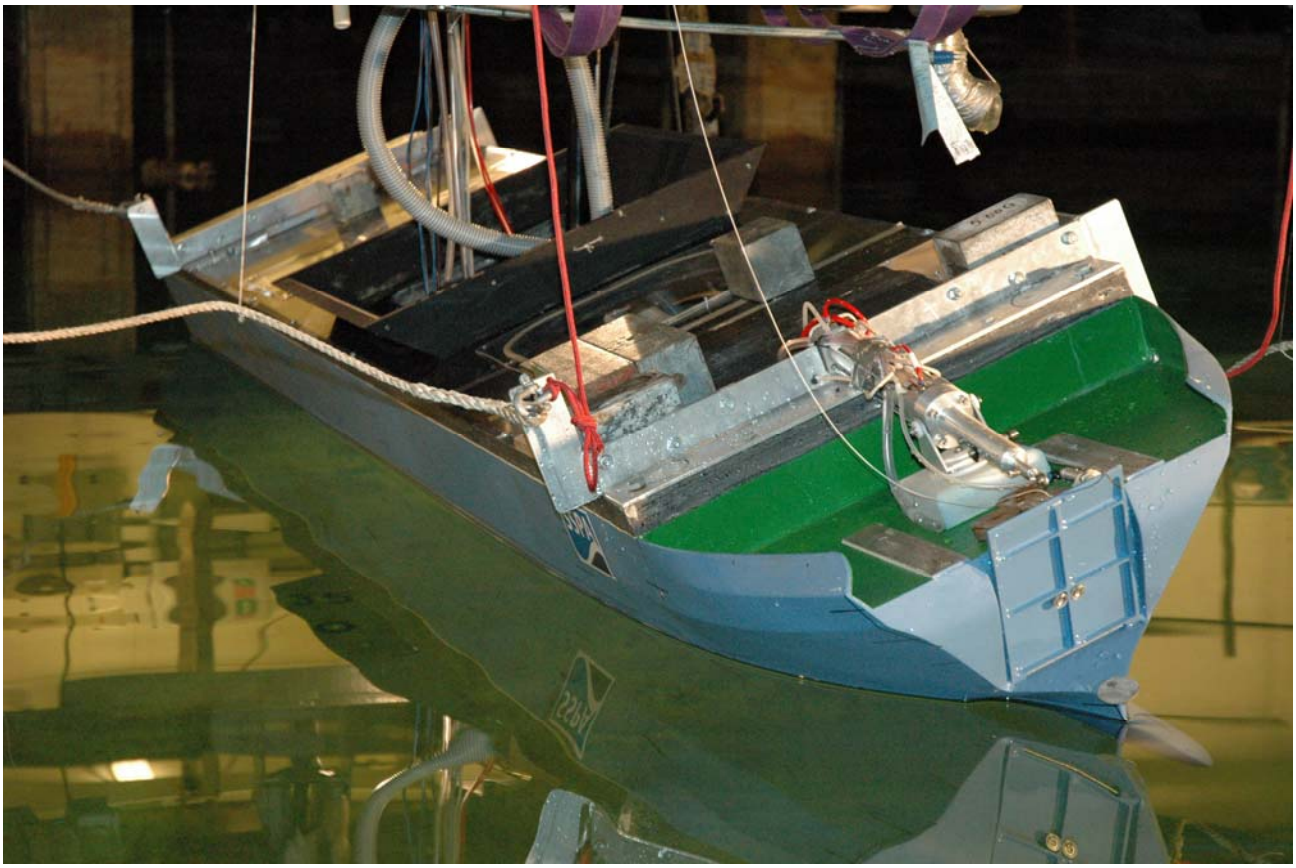
SSPA	**MV Estonia** Photos of model on shore	Figure 4 Report 4006 4100-1 Appendix C

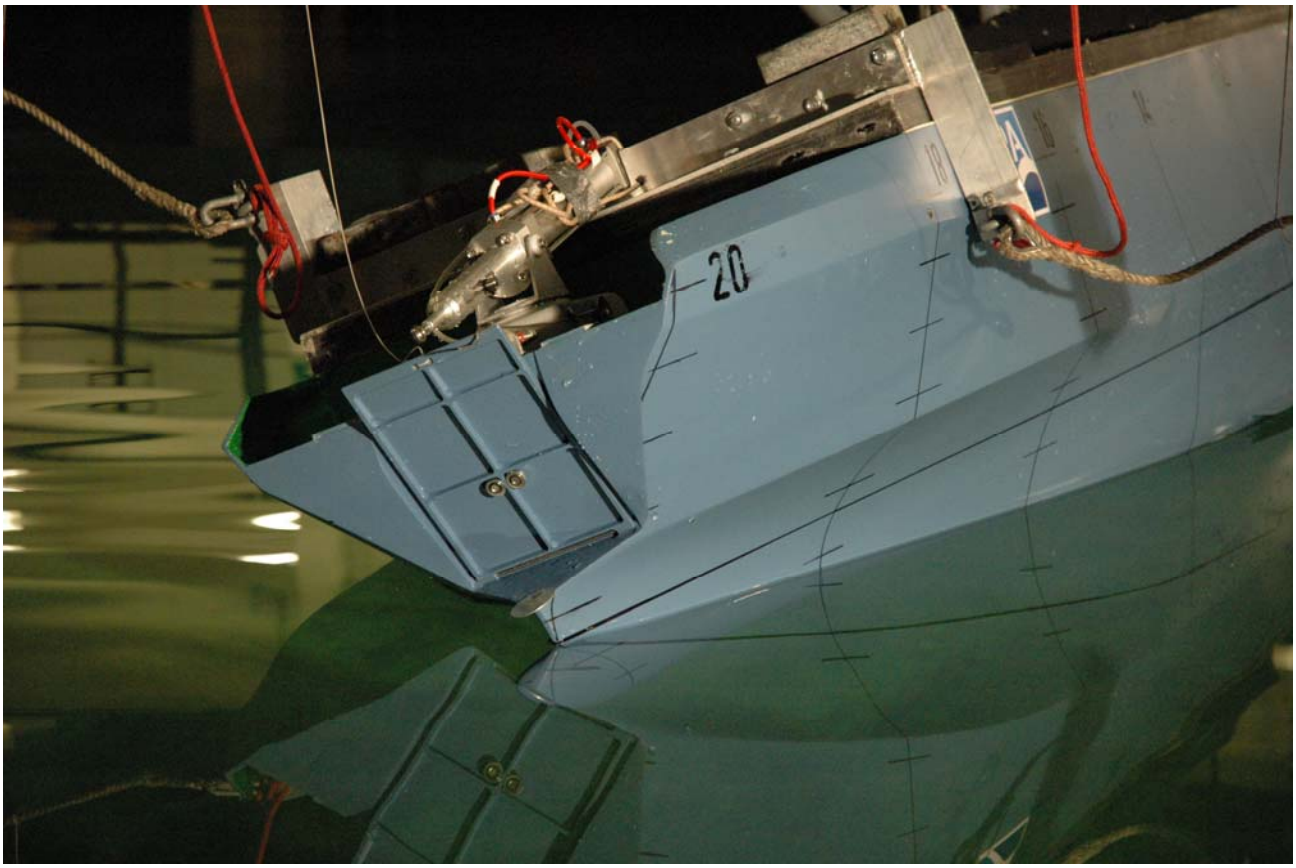




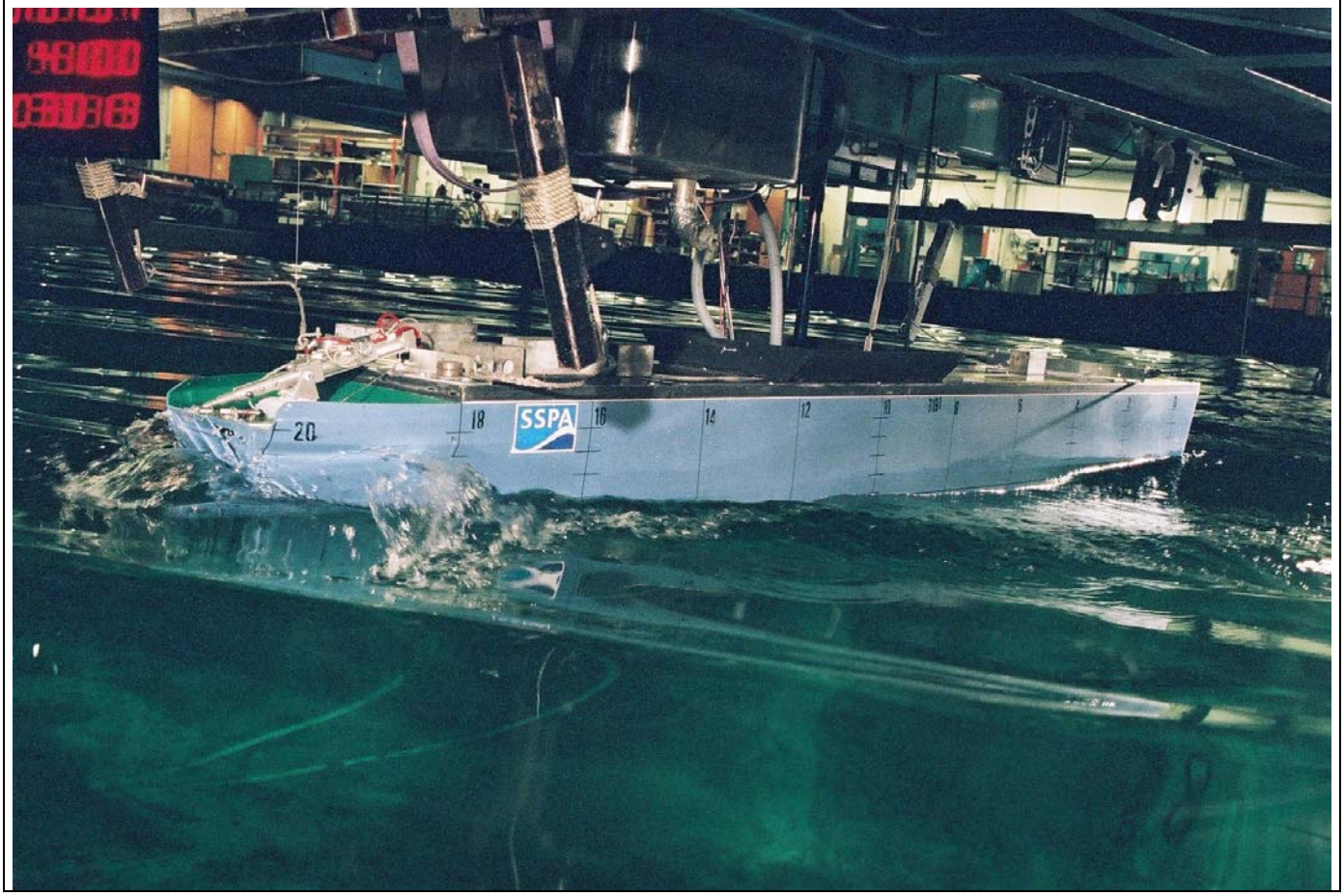
SSPA	**MV Estonia** Model with SB 25° heel	Figure 5 Report 4006 4100-1 Appendix C

SSPA	**MV Estonia** Model with SB 25° heel	Figure 6 Report 4006 4100-1 Appendix C

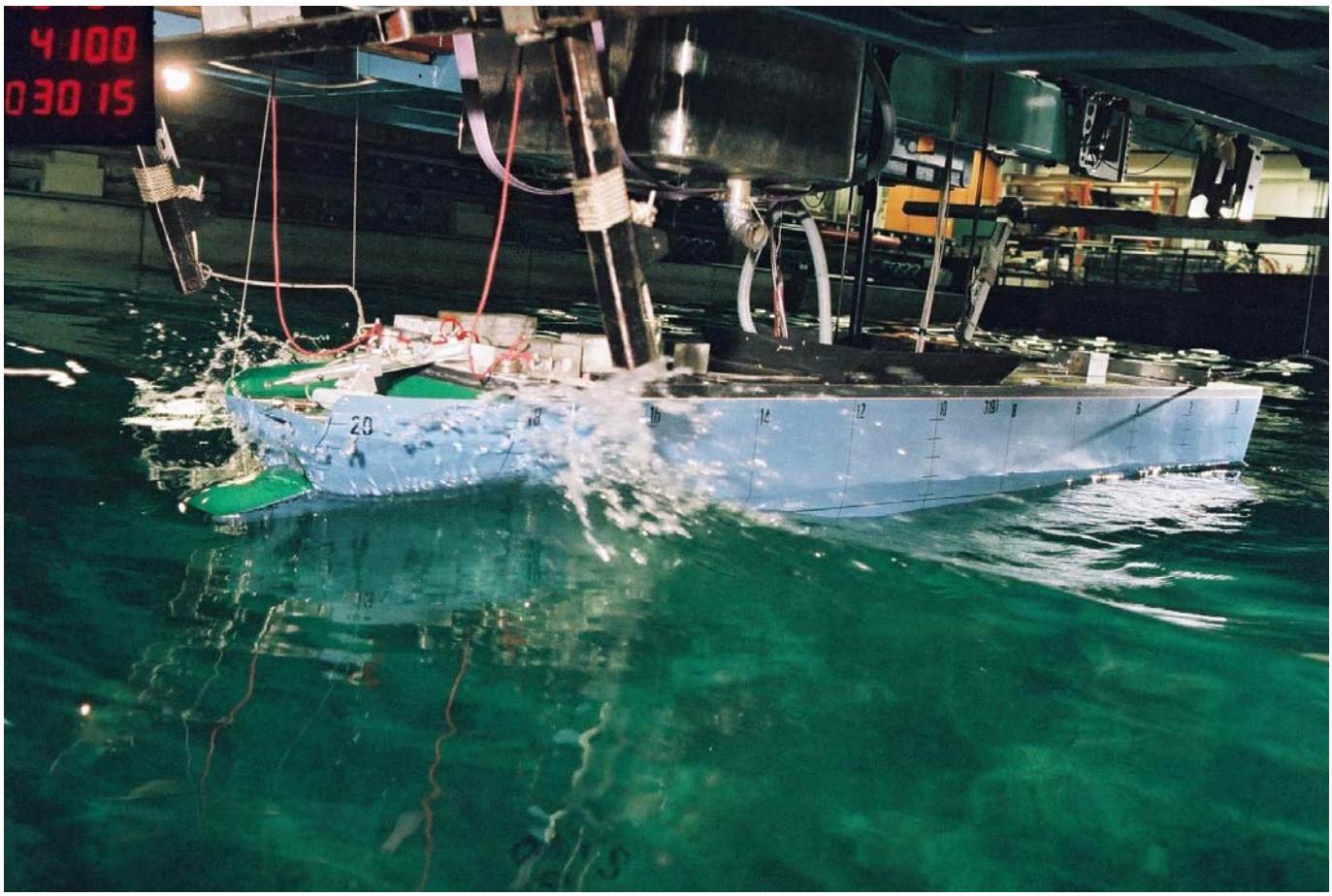


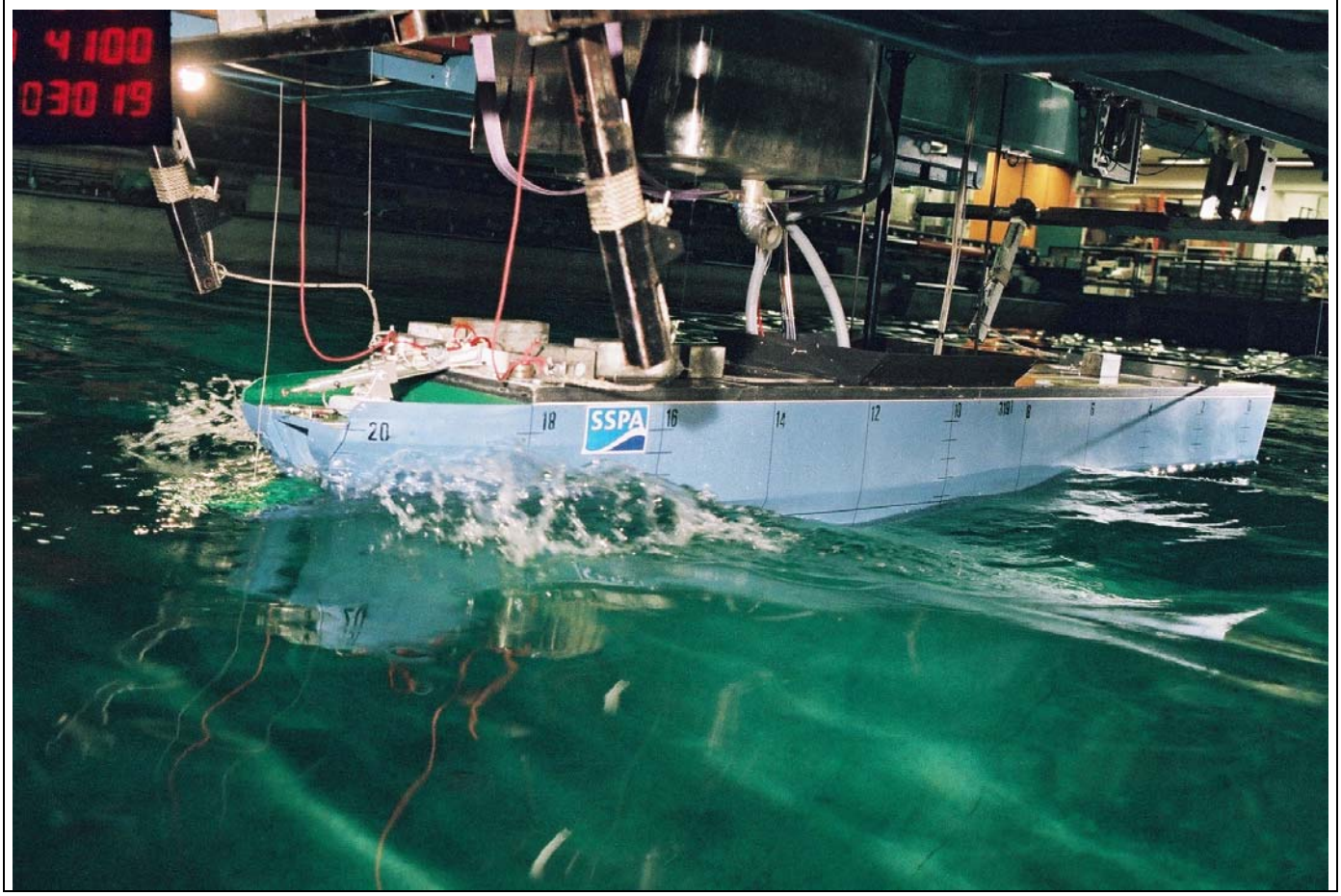


SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 150° (bow sea) – 14.5 knots – No heel No bow visor; Bow ramp open 1 m	Figure 7 Report 4006 4100-1 Appendix C

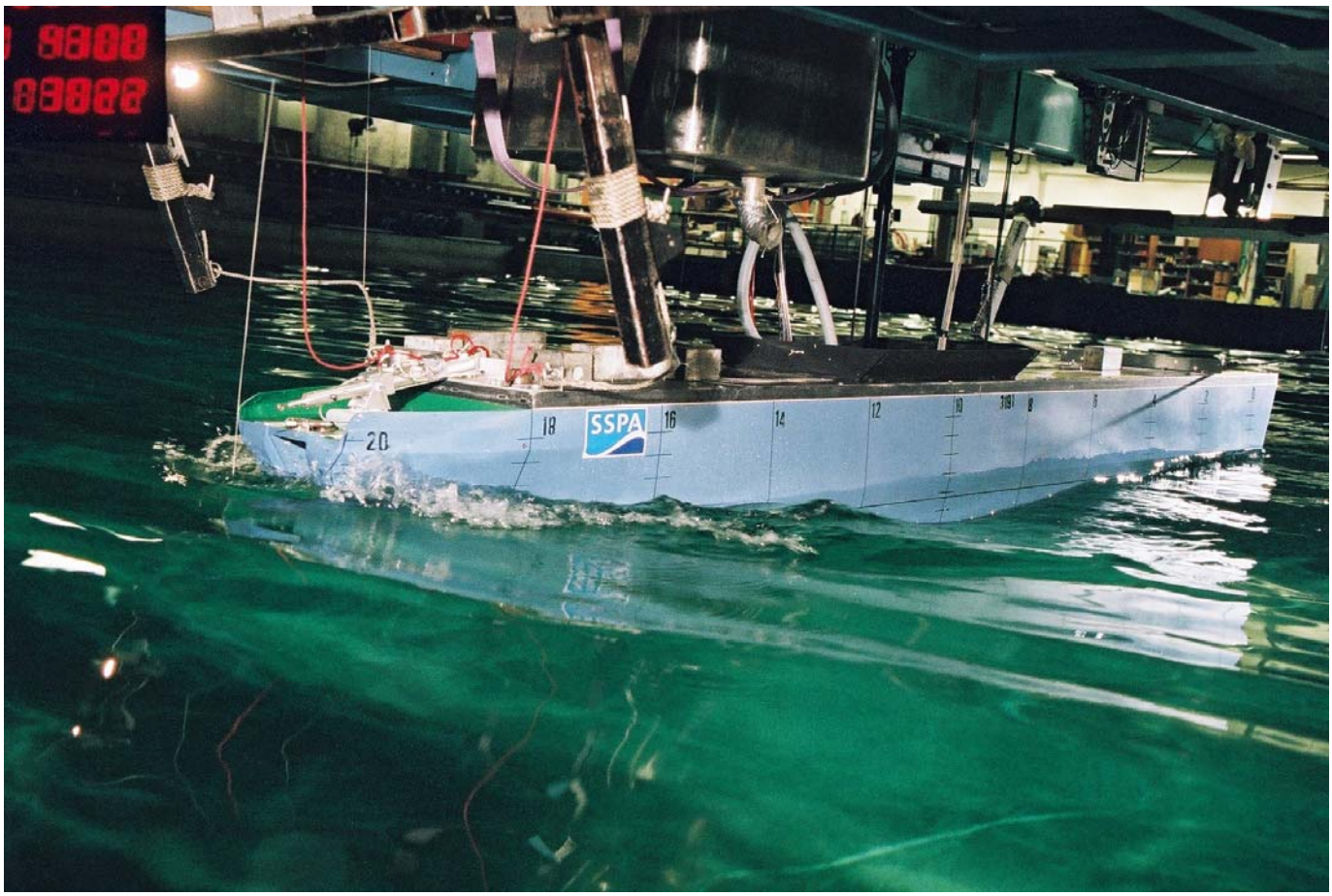


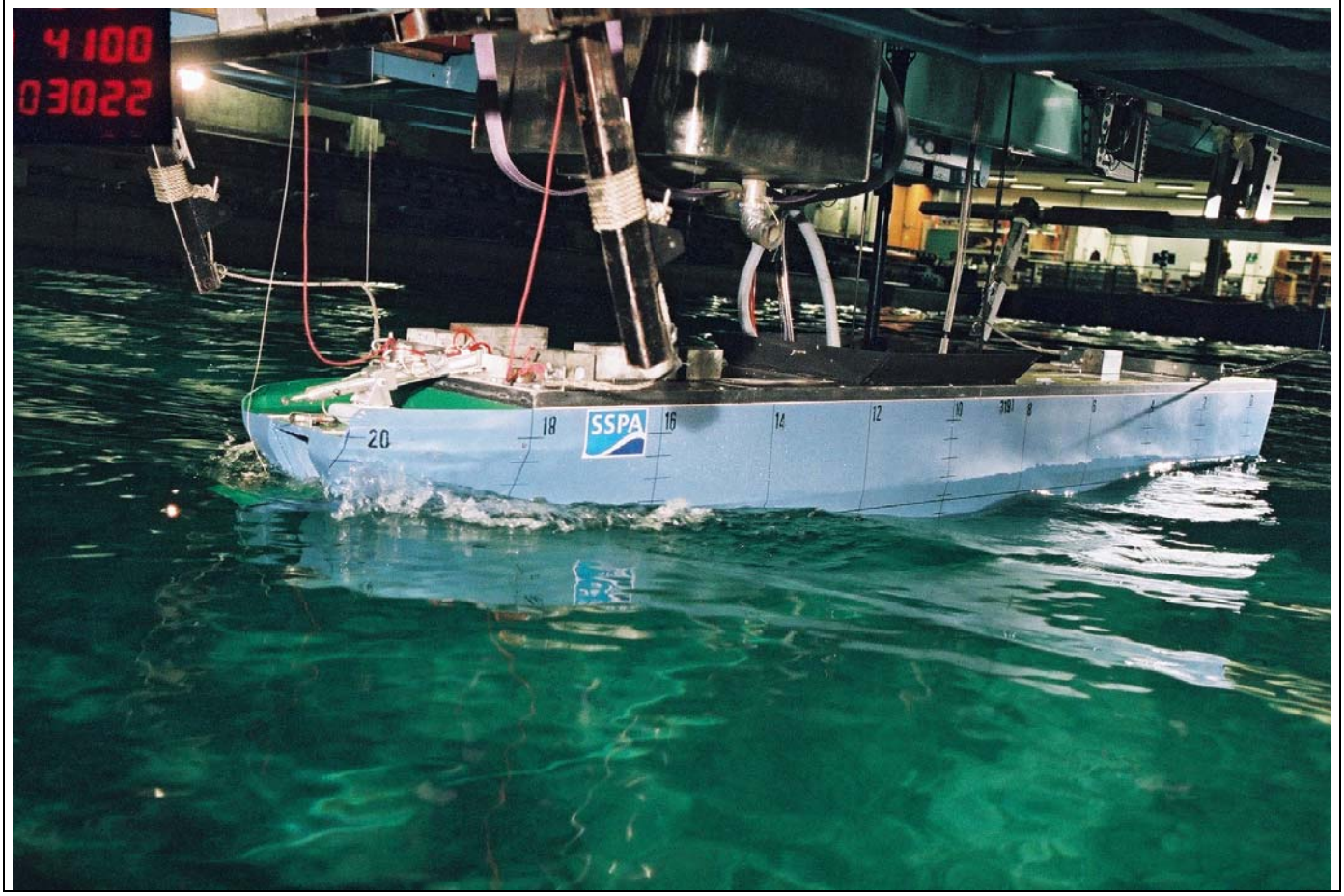
SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 180° (head sea) – 10 knots – No heel No bow visor; Bow ramp completely open	Figure 8 Report 4006 4100-1 Appendix C



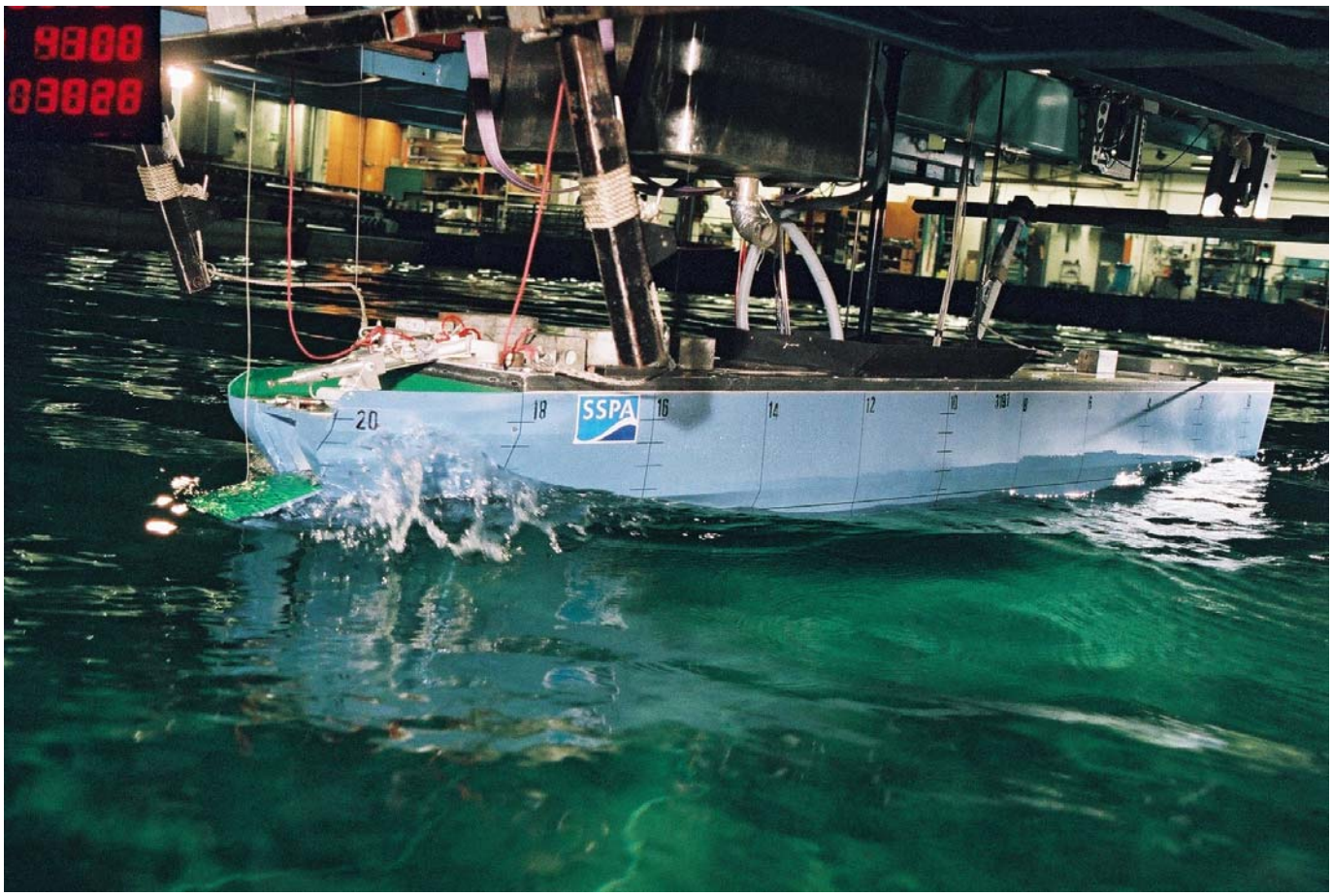


SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 165° (bow sea) – 10 knots – No heel No bow visor; Bow ramp completely open	Figure 9 Report 4006 4100-1 Appendix C

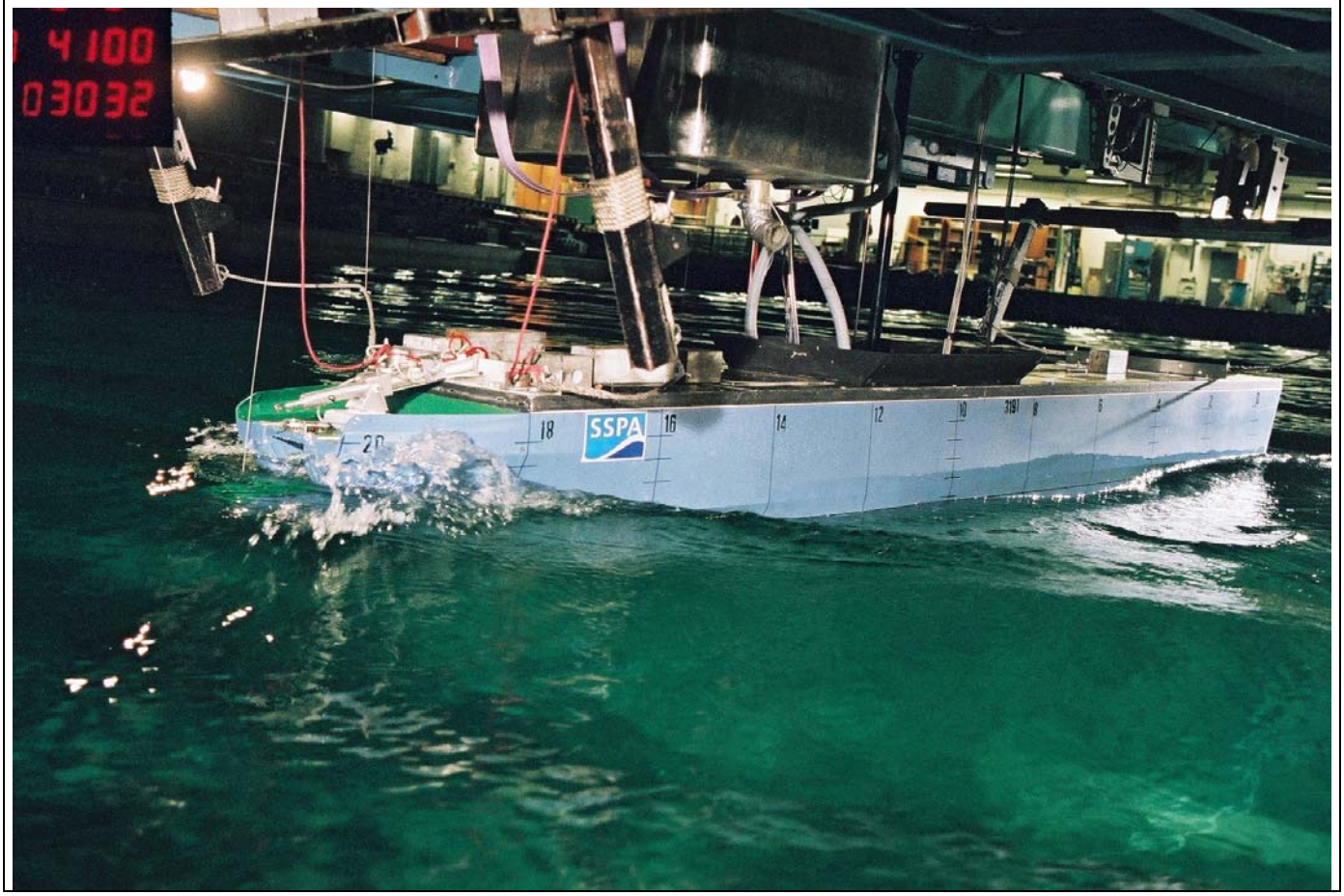




SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 150° (bow sea) – 8.5 knots – No heel No bow visor; Bow ramp completely open	Figure 10 Report 4006 4100-1 Appendix C

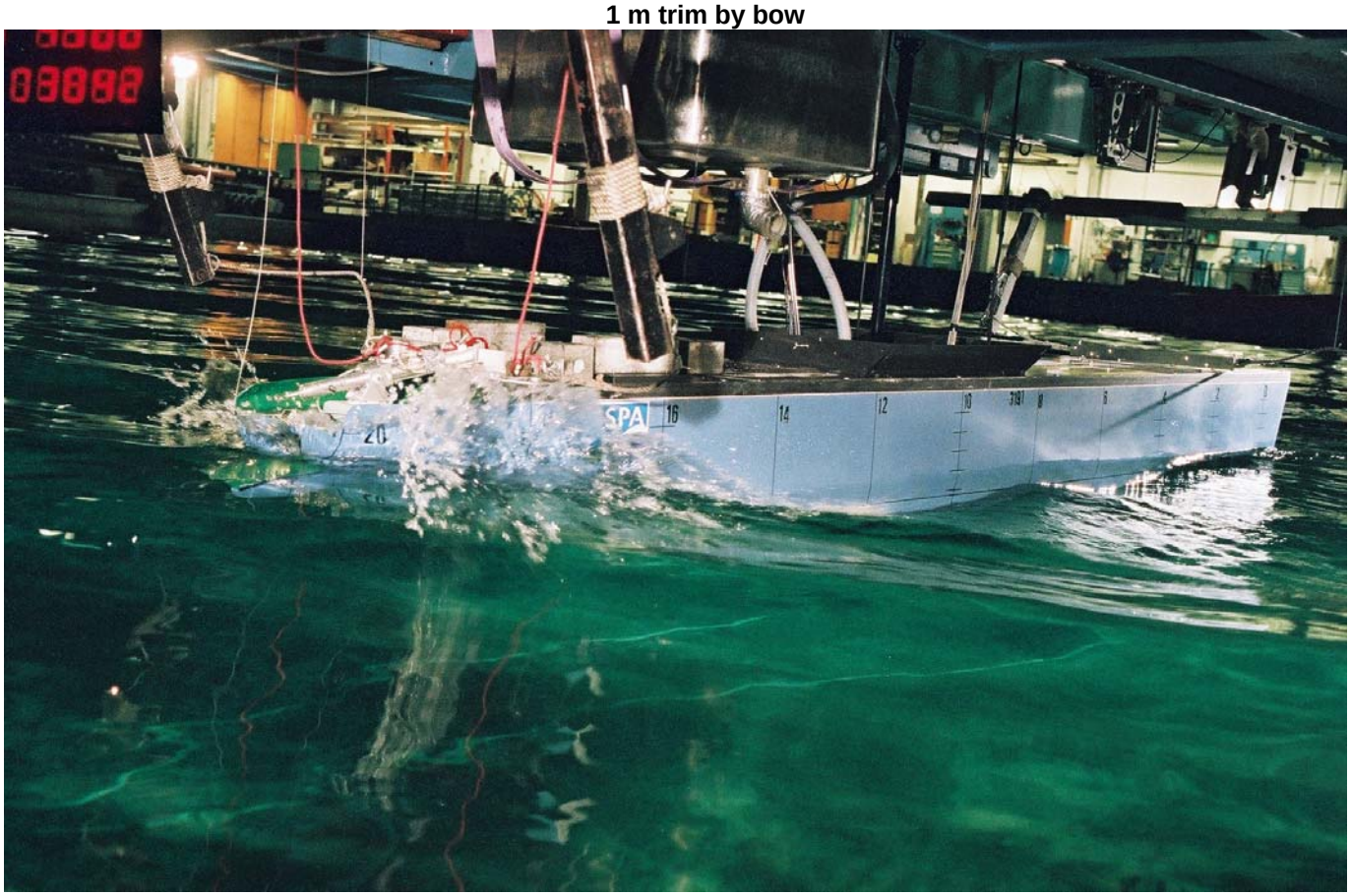


SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 150° (bow sea) – 12 knots - No heel No bow visor; Bow ramp completely open	Figure 11 Report 4006 4100-1 Appendix C

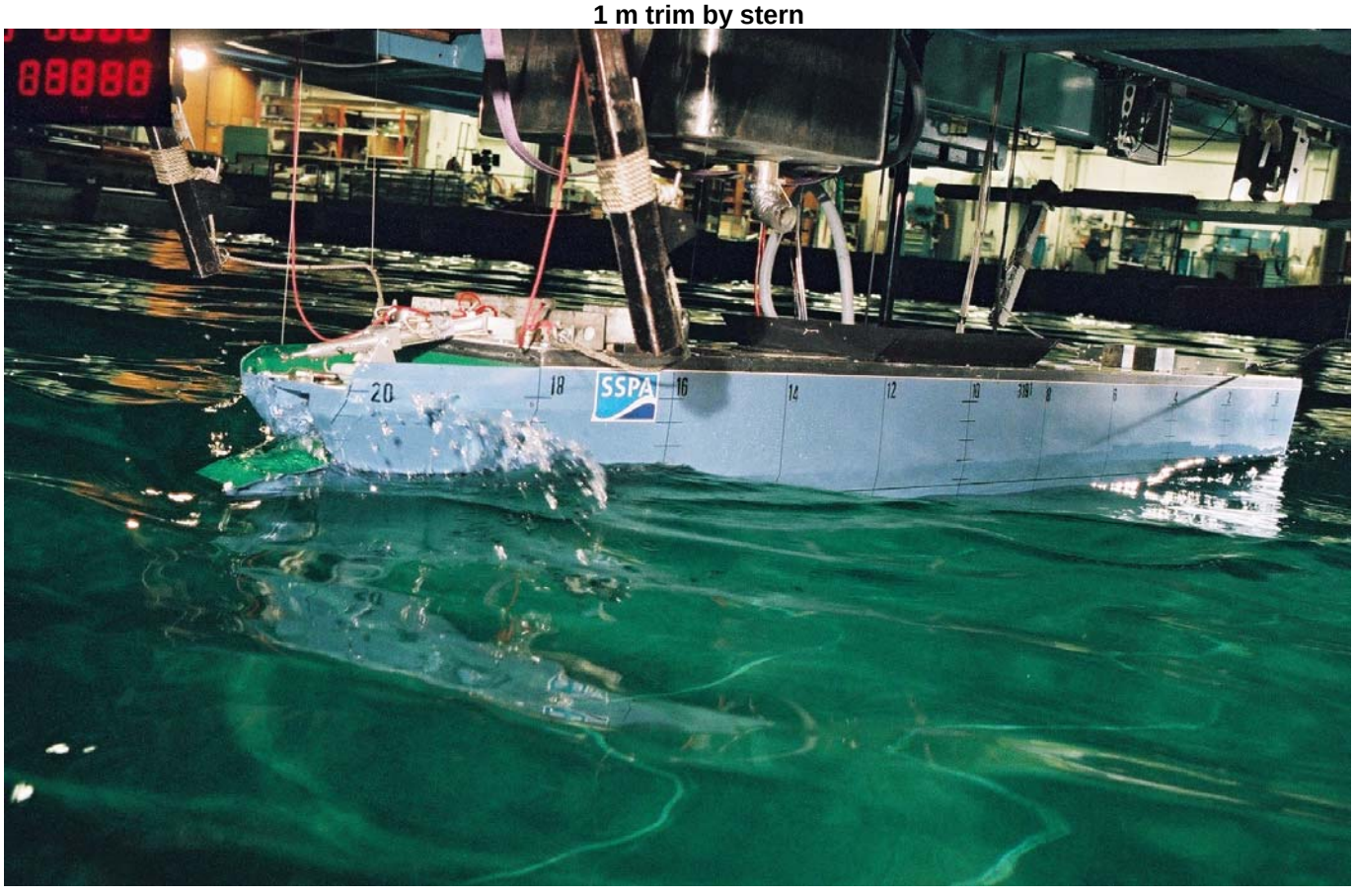


SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 150° (bow sea) – 5 knots - No heel No bow visor; Bow ramp completely open	Figure 12 Report 4006 4100-1 Appendix C

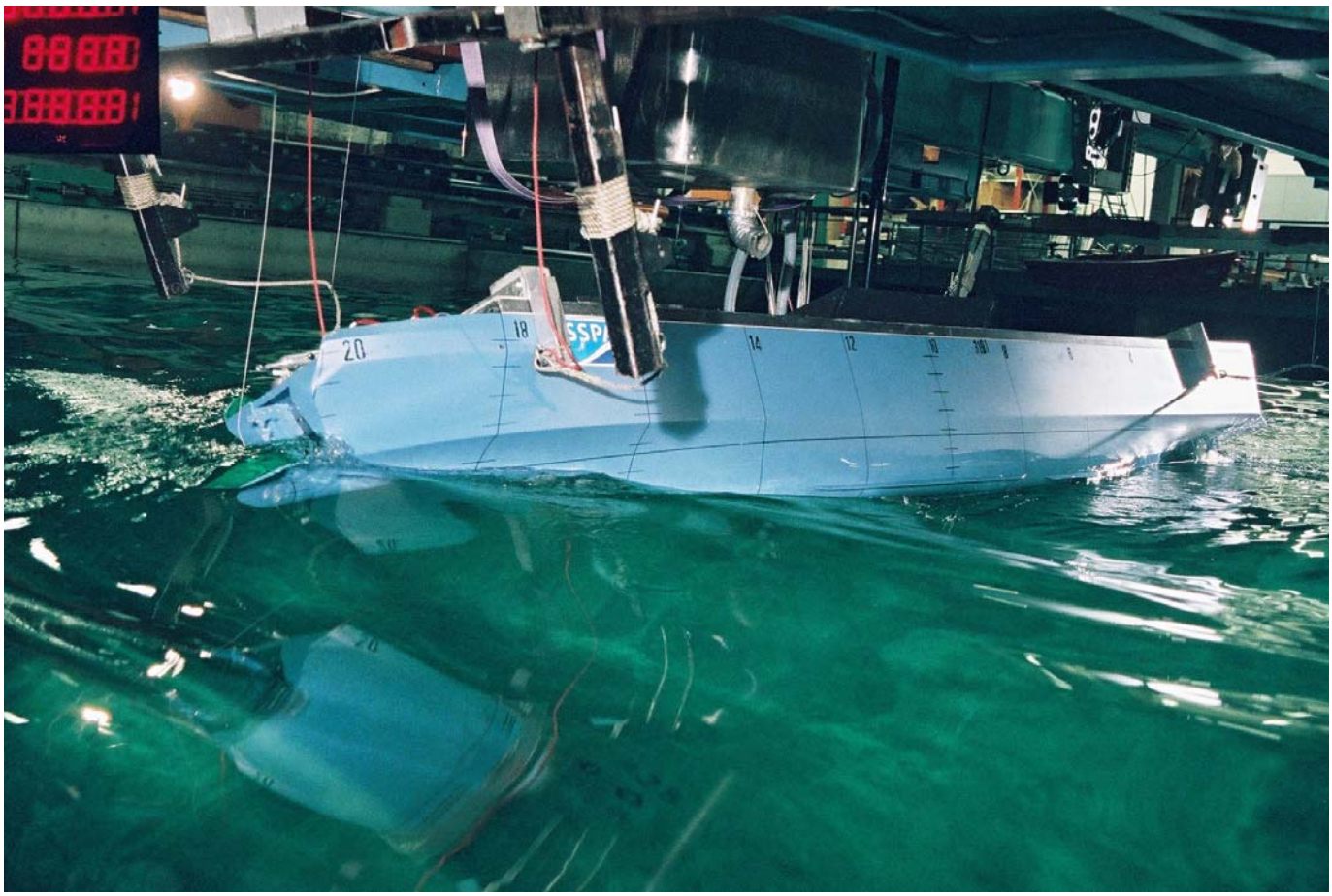
1 m trim by bow

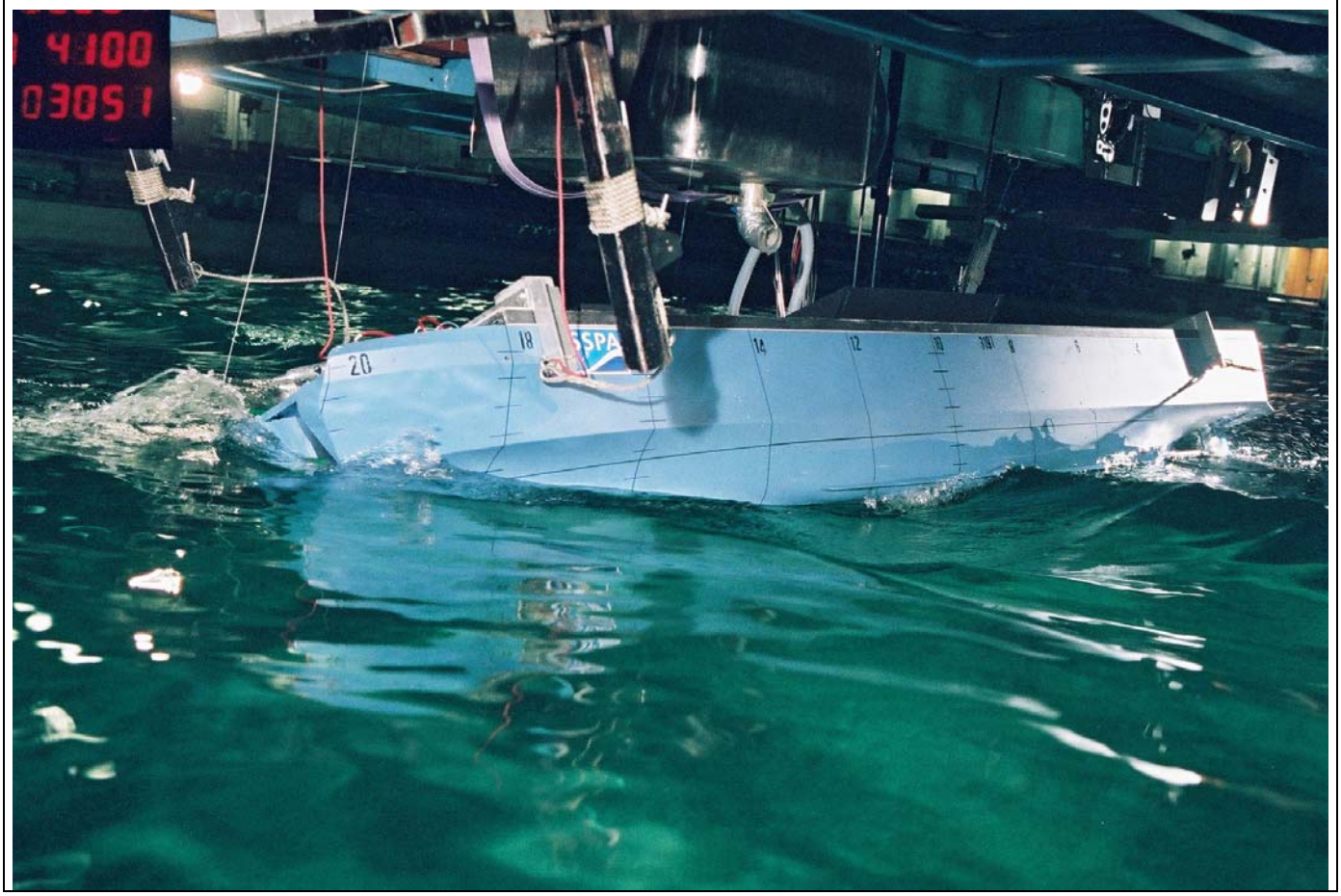


1 m trim by stern

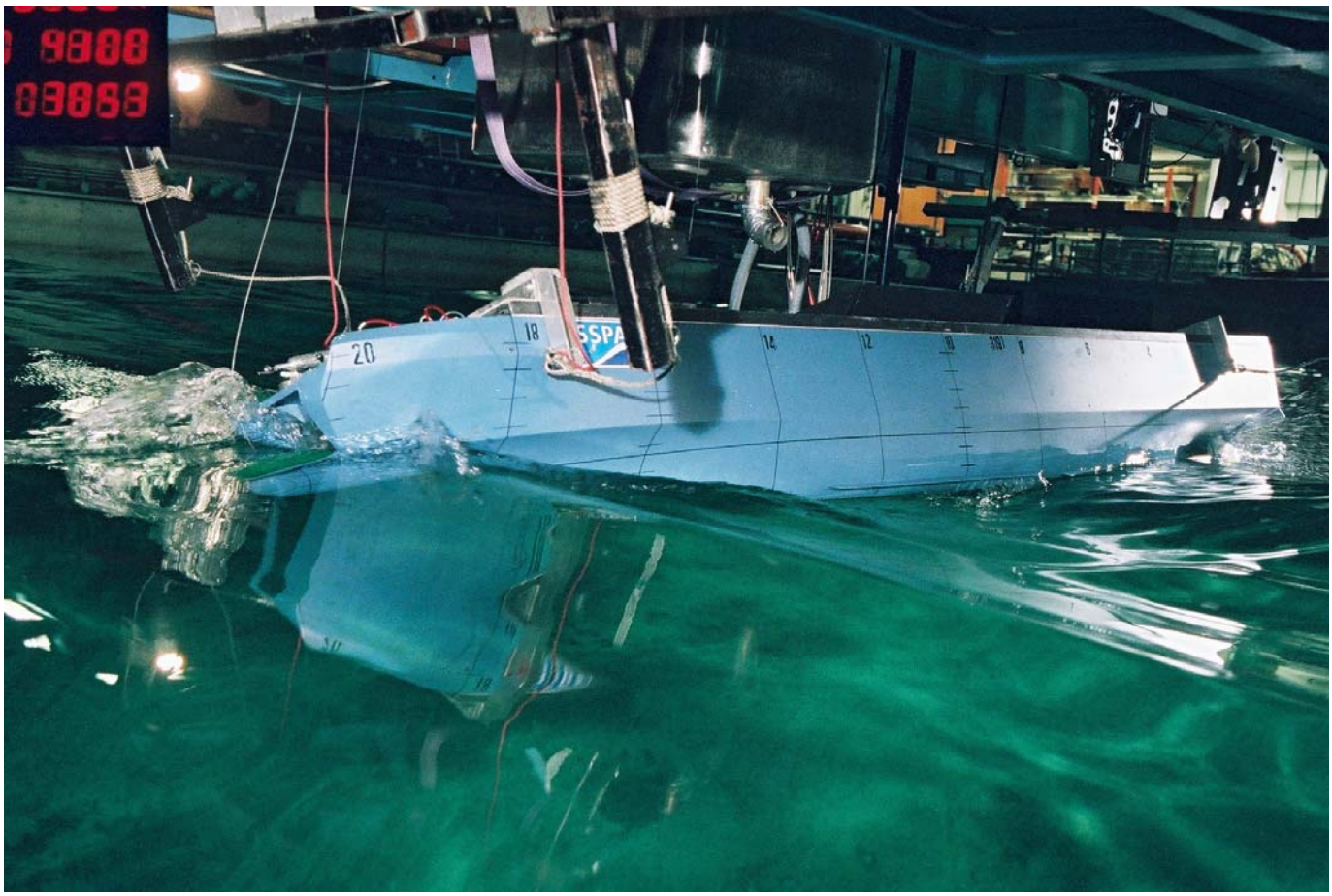


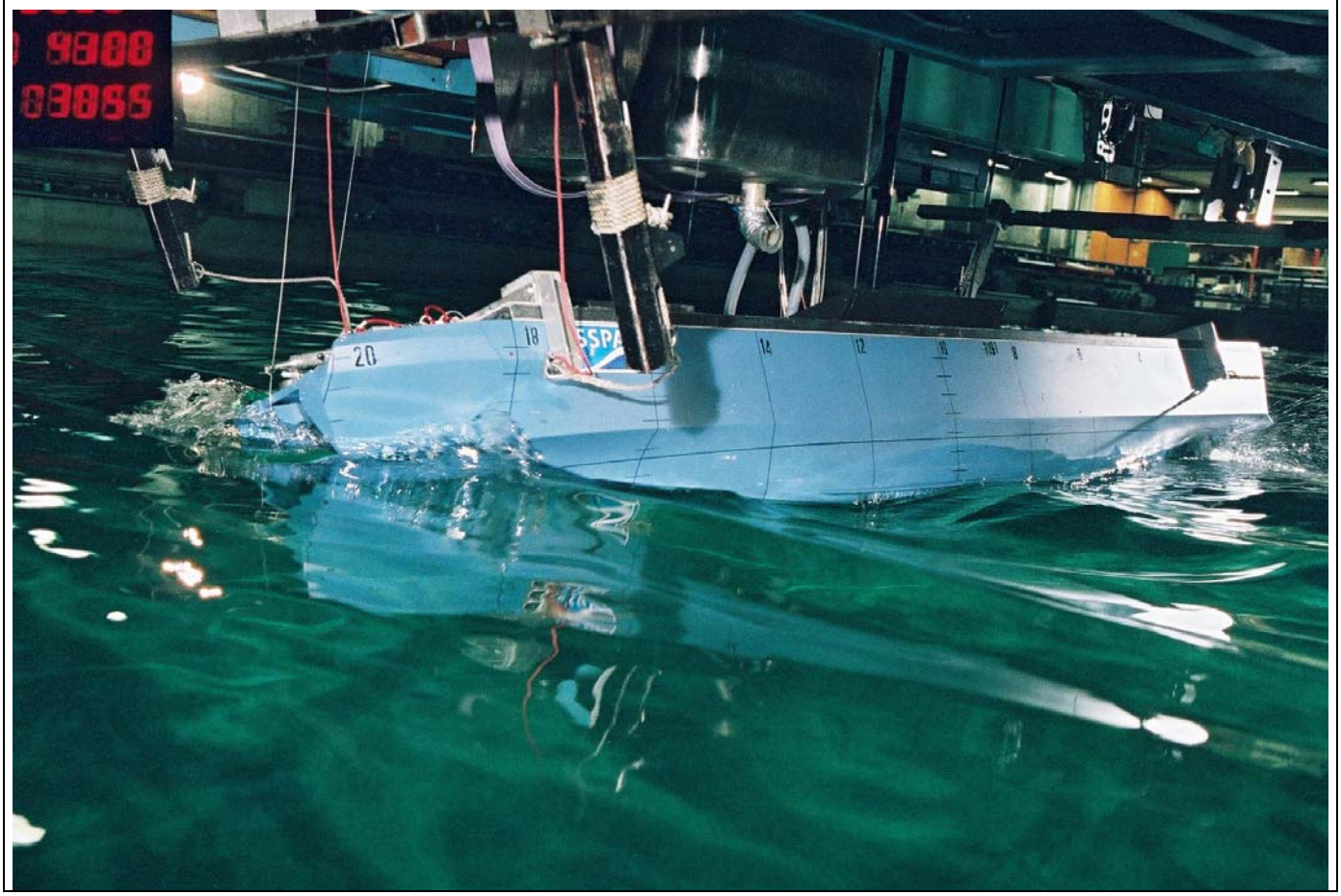
SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 180° (head sea) – 5 knots - 25° heel No bow visor; Bow ramp completely open	Figure 13 Report 4006 4100-1 Appendix C



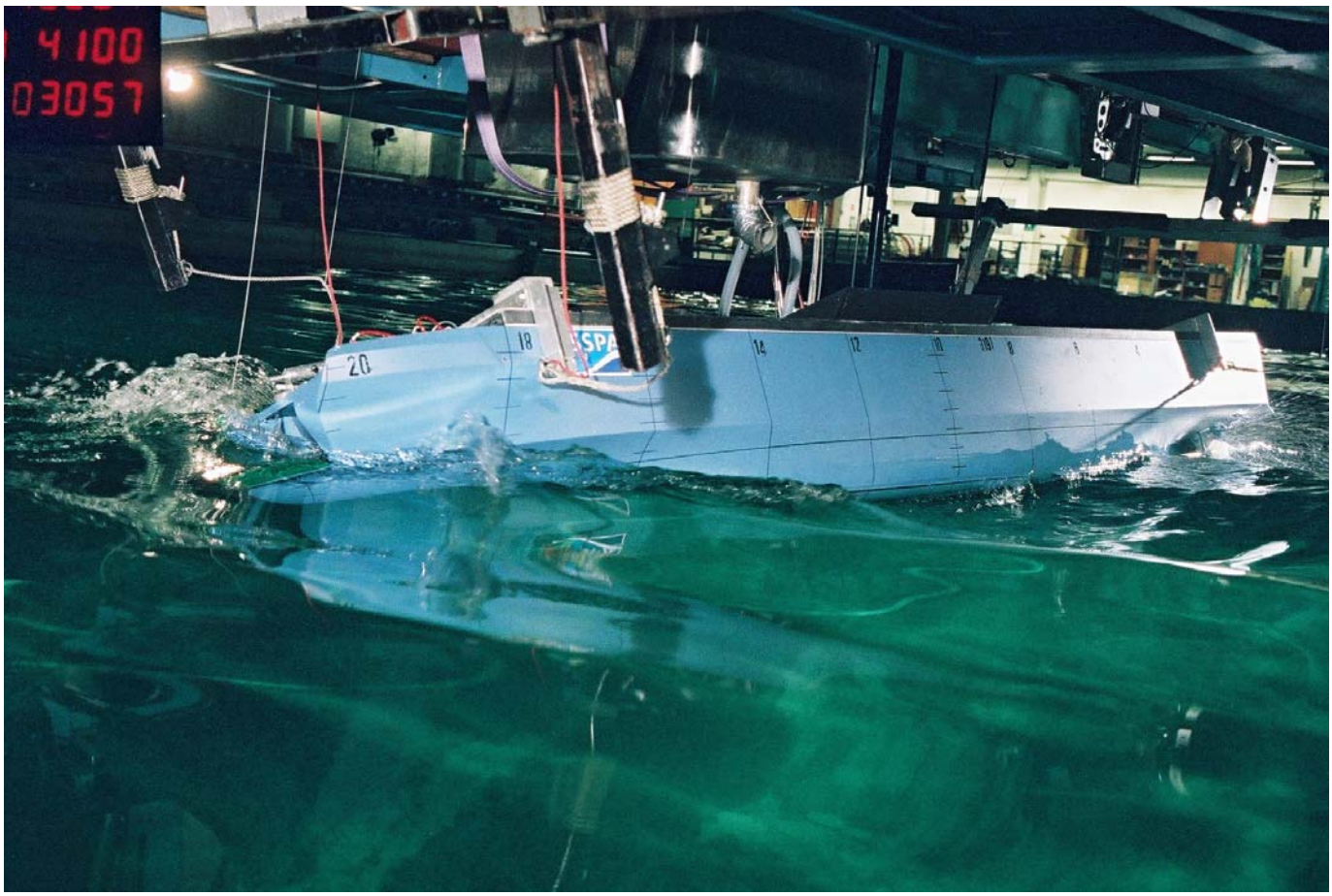


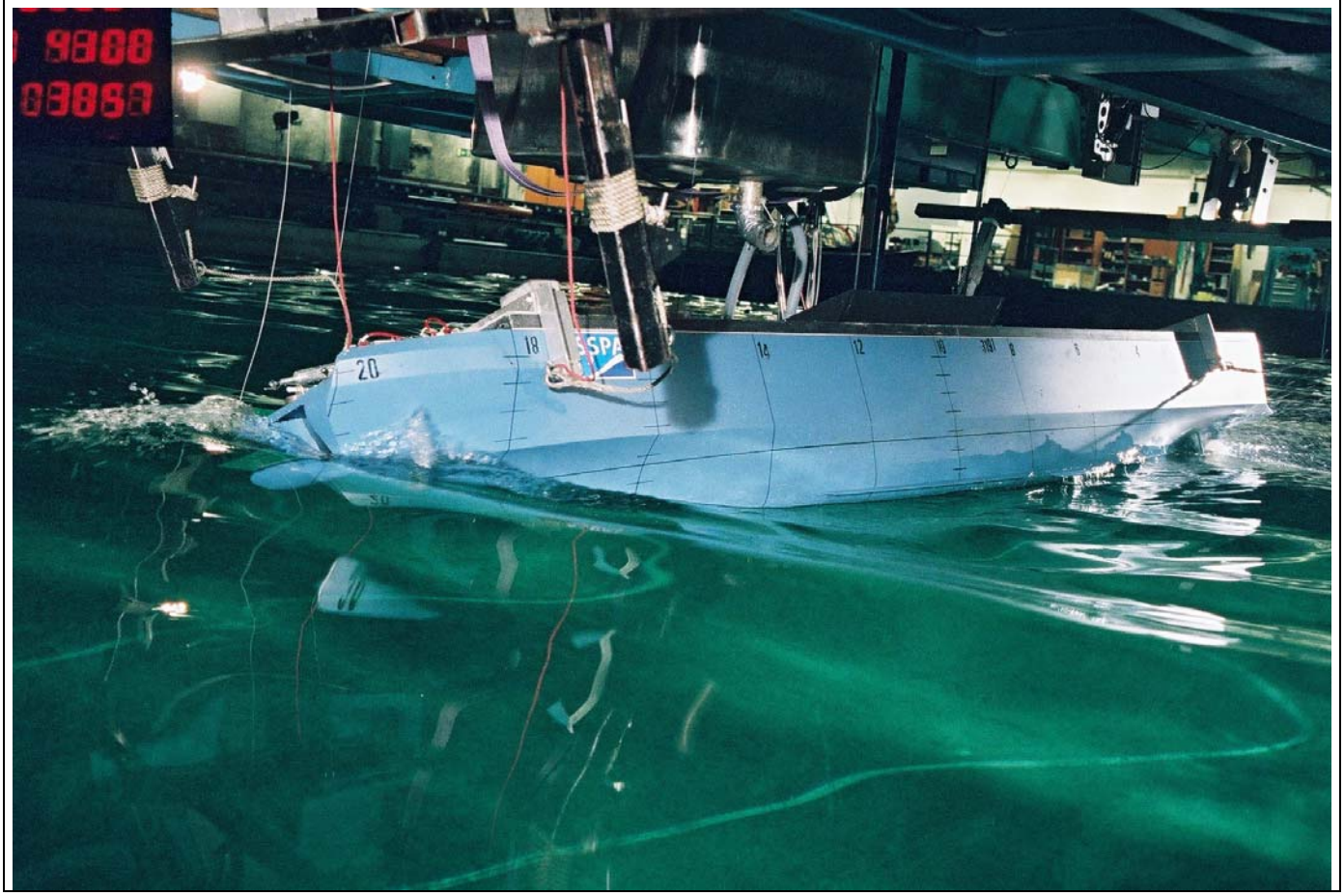
SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 180° (head sea) – 10 knots - 25° heel No bow visor; Bow ramp completely open	Figure 14 Report 4006 4100-1 Appendix C



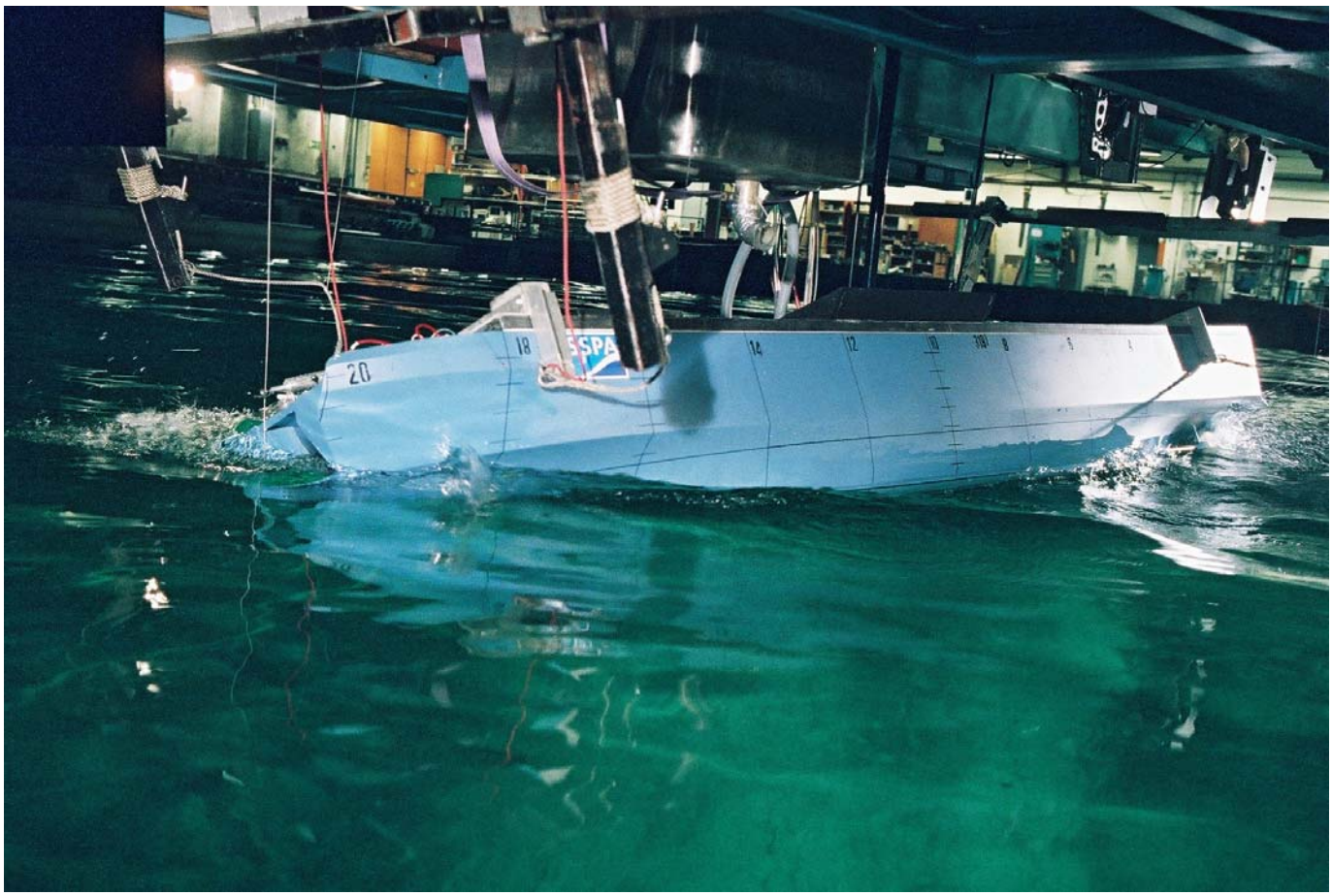


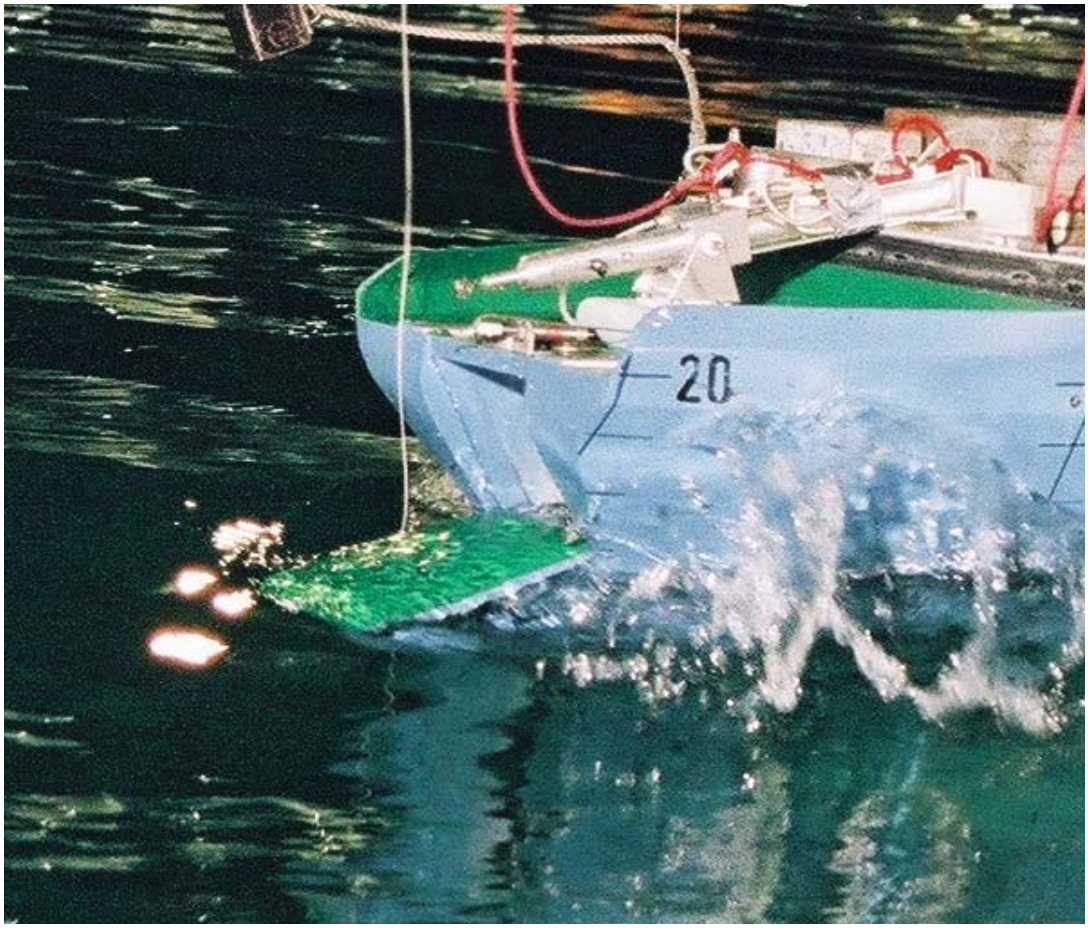
SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 165° (bow sea) – 8.5 knots - 25° heel No bow visor; Bow ramp completely open	Figure 15 Report 4006 4100-1 Appendix C





SSPA	**MV Estonia** Model tests in irregular waves ($H_{1/3}$: 4.3 m; T_P=8.3 s) Wave direction: 150° (bow sea) – 8.5 knots - 25° heel No bow visor; Bow ramp completely open	Figure 16 Report 4006 4100-1 Appendix C

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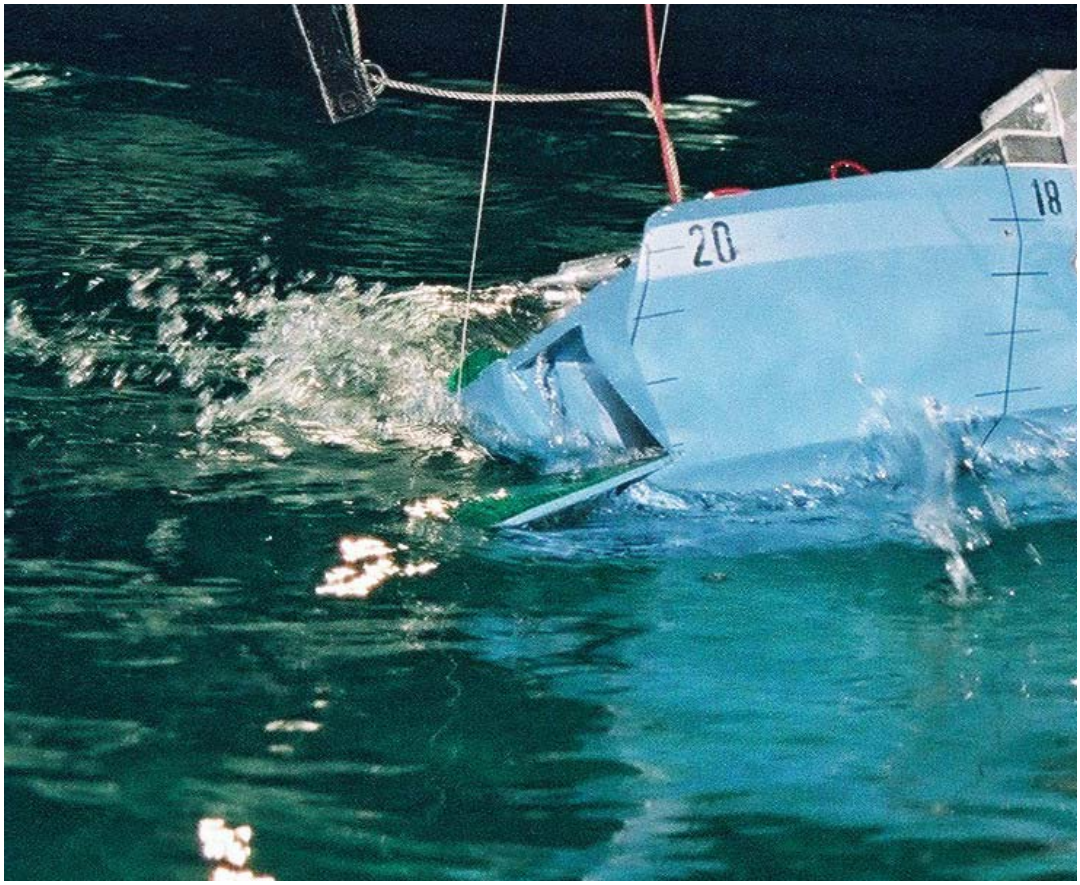
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