Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Ministry of Transport,
Building and Urban Development

Investigation Report 523/10

Serious Marine Casualty

Collision in the Kiel-Holtenau siding

at km 95.5 between the

CMV NATIONAL GLORY and

MV MALAGA

on 28 November 2010

Information as of: 22/08/2011

The investigation was conducted in conformity with the law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law - SUG) of 16 June 2002 in the version effective until 30 November 2011.

According to said act, the sole objective of this investigation is to prevent future accidents and malfunctions. This investigation does not serve to ascertain fault, liability or claims.

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to art. 19 para. 4 SUG in the aforementioned version.

The German text shall prevail in the interpretation of this Investigation Report.

Issued by:
Bundesstelle für Seeunfalluntersuchung - BSU
Federal Bureau of Maritime Casualty Investigation
Bernhard-Nocht-Str. 78
20359 Hamburg
Germany

Director: Jörg Kaufmann
Phone: +49 40 31908300 Fax: +49 40 31908340
posteingang-bsu@bsh.de www.bsu-bund.de

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1 Summary

At 0044 on 28 November 2010[1], the eastbound container vessel NATIONAL GLORY, which was entering the siding at Kiel-Holtenau Nordhafen (north harbour), collided in heavy fog with the westbound general cargo vessel MALAGA, which was waiting in the siding, in the Kiel Canal (NOK). The ro/ro vessel BALTICBORG was proceeding at a distance of 300 m ahead of the NATIONAL GLORY. About 4 minutes earlier, the NATIONAL GLORY had passed the oncoming container vessel SANDY RICKMERS. At about 0034, the MALAGA took up position behind the container vessel SANDY RICKMERS on the western row of dolphins in Nordhafen. The two vessels initially waited there until they were scheduled to proceed and then passed the gas tanker GAS CRYSTAL, which was moored in front of them at the dolphins. The SANDY RICKMERS was unable to maintain her position. Afterwards the SANDY RICKMERS sailed through the siding's stop signal. The oncoming BALTICBORG passed the SANDY RICKMERS between Projensdorf and the siding and after that the GAS CRYSTAL and the MALAGA at the same time in the siding. All vessels under way had pilots and canal helmsmen on board.

[1] Unless otherwise stated, all times shown in this report are local = Central European Time = UTC + 1

2 SHIP PARTICULARS

2.1 Photo

Figure 1: Photo of the NATIONAL GLORY

2.2 Particulars

Name of vessel:	NATIONAL GLORY
Type of vessel:	Container vessel
Nationality/flag:	United States of America
Port of registry:	Wilmington, DE
IMO number:	8302246
Call sign:	WDD4207
Owner:	R & D Investments Inc.
Year built:	1988
Shipyard/yard number:	Stocznia IM Gdynia/B354/06
Classification society:	American Bureau of Shipping (ABS)
Length overall:	149.1 m
Breadth overall:	22.0 m
Gross tonnage:	11,652
Deadweight:	20,738 t
Draught (max.):	9.11 m
Engine rating:	7,080 kW
Main engine:	Sulzer Direct Drive RTA S8
(Service) Speed:	14.2 kts
Hull material:	Steel
Hull design:	Double bottom
Manning:	25

2.3 Voyage particulars

Port of departure:	Bremerhaven
Port of call:	Muuga, Estonia
Type of voyage:	Merchant shipping/international
Cargo information:	Containers
Draught at time of accident:	7.70 m
Pilot on board:	Yes
Canal helmsman:	Yes
Number of passengers:	None

2.4 Photo

Figure 2: Photo of the MALAGA

2.5 Particulars

Name of vessel:	MALAGA
Type of vessel:	General cargo vessel
Nationality/flag:	St. Vincent & Grenadines
Port of registry:	Kingstown
IMO number:	751440
Call sign:	J8B3719
Owner:	Alga Chartering ApS
Year built:	1977
Shipyard/yard number:	Eid Verft, Naustdal/9
Classification society:	Germanischer Lloyd (GL)
Length overall:	82.21 m
Breadth overall:	13.30 m
Gross tonnage:	2,196
Deadweight:	4,034 t
Draught (max.):	6.5 m
Engine rating:	1,158 kW
Main engine:	Bergens Mekaniske Verksted AS
(Service) Speed:	12 kts
Hull material:	Steel
Hull design:	Double bottom
Manning:	No details

2.6 Voyage particulars

Port of departure:	Kaliningrad
Port of call:	Rotterdam
Type of voyage:	Merchant shipping/international
Cargo information:	Scrap
Manning:	No details
Draught at time of accident:	6.10 m
Pilot on board:	Yes
Canal helmsman:	Yes
Number of passengers:	None

2.7 Shore authority involvement and emergency response

Agencies involved:	Waterway Police Kiel and Brunsbüttel, Vessel Traffic Service
Resources used:	Tug for the MALAGA
Actions taken:	Vessels shifted to the pier
Results achieved:	Vessels were repaired

2.8 Marine casualty or incident information

Type of marine casualty/incident:	Serious marine casualty, collision
Date, time:	28/11/2010, 0044
Location:	Kiel Canal, km 95.5
Latitude/Longitude:	φ 54°22.3' N λ 010°06.1' E
Ship operation and voyage segment:	Harbour mode
Place on board:	Forecastles
Consequences (for people, vessel, cargo, the environment and other):	No injuries, bridge of the MALAGA torn open, no pollutants escaped

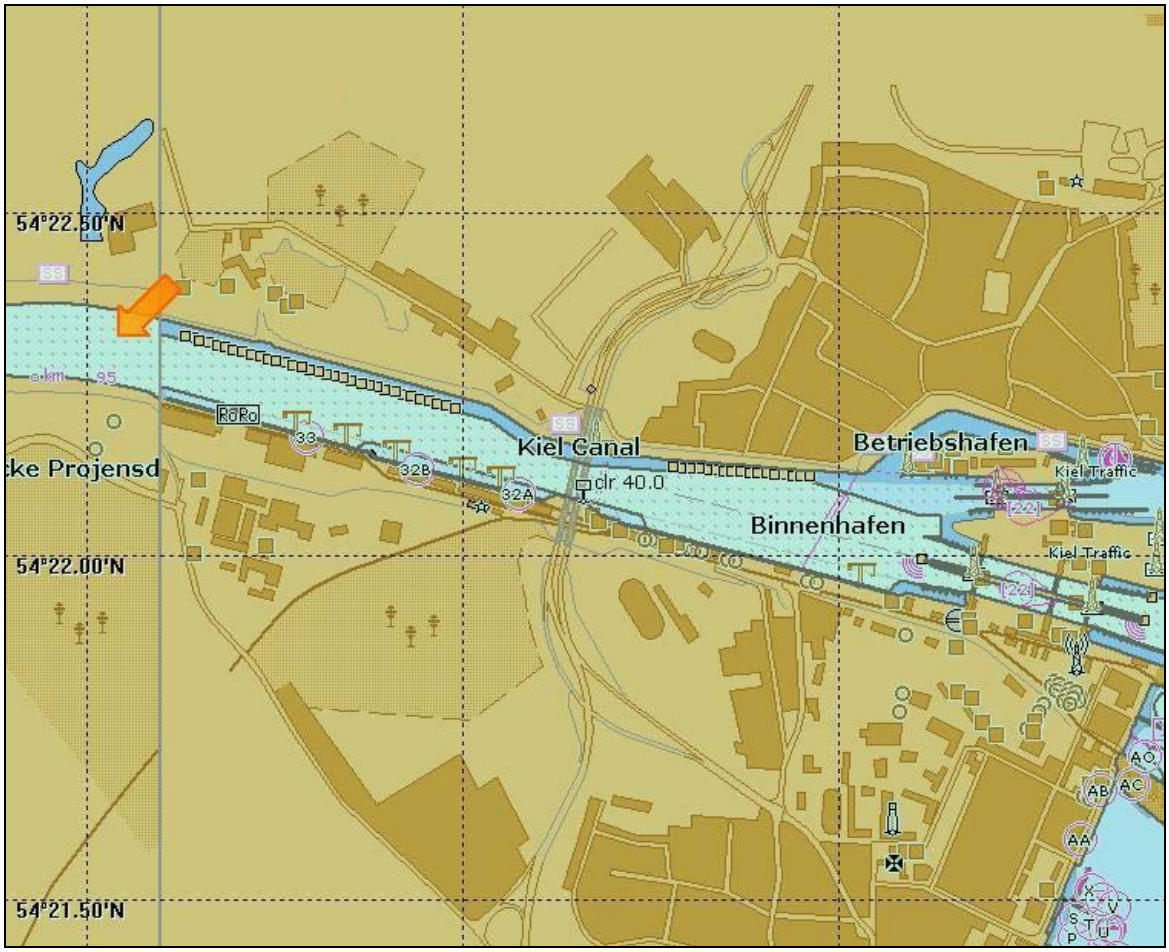

Figure 3: Scene of the accident, excerpt from ENC DE516200, DE421045, BSH

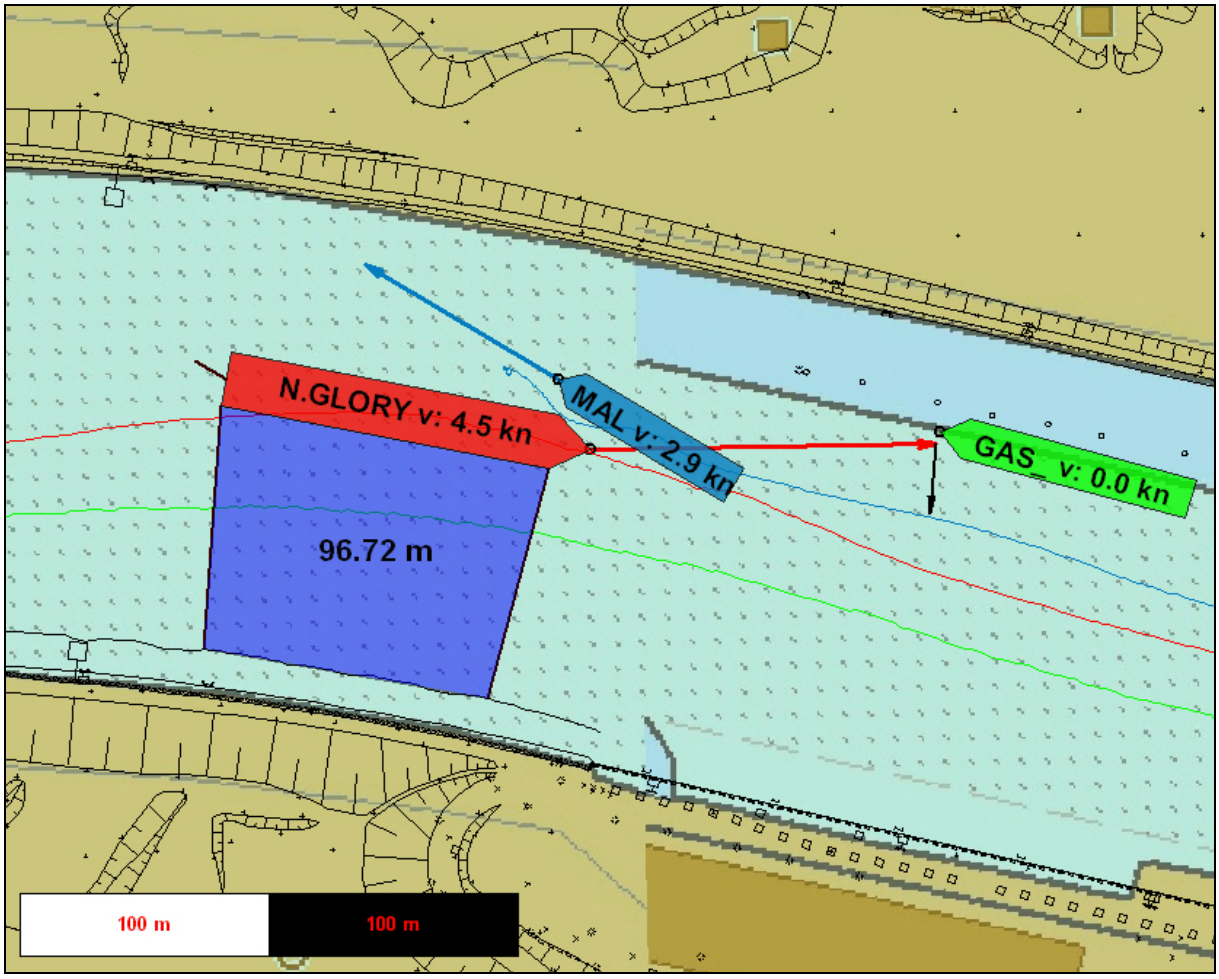

Figure 4: Collision at 004330 in Nordhafen, BAW Hamburg[2]

In Fig. 3, the collision is shown to scale. The vectors ahead of 1 min relate to the headings. The coloured lines in the fairway show the tracks of the vessels involved in the accident (Fig. 4). The black vector by the NATIONAL GLORY shows her drift to starboard and the line at her stern symbolises her rudder's angle to port. The lateral distance of 96.72 m relates to the 4 m contour line. The scene of the accident is situated north of the middle of the canal between the row of dolphins and the siding's exit signal mast.

[2] The figure stems from an animation of the Federal Waterways Engineering and Research Institute, Hamburg Department (BAW). The animation is available on the BSU website and shows the course of the accident. The chart in the background was assembled using ENC data of the BSH and Federal German waterway charts. The metadata for creating the 4 m contour line originate from a survey conducted between 23 August and 25 August 2010 relative to sea level.

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident

At 0044 on 28 November 2010, the eastbound container vessel NATIONAL GLORY, which was entering the siding at Kiel-Holtenau Nordhafen, collided in heavy fog with the westbound general cargo vessel MALAGA, which was waiting in the siding, at km 95.5 in the Kiel Canal (NOK). The ro/ro vessel BALTICBORG was proceeding at a distance of 300 m ahead of the NATIONAL GLORY. About 4 minutes earlier, the NATIONAL GLORY had passed the oncoming container vessel SANDY RICKMERS at the bunkering bridge at Projensdorf in the canal bend (Fig. 4). The MALAGA left the southern of the new locks at Kiel-Holtenau at 2357 and took up position behind the container vessel SANDY RICKMERS at 0034 at the row of dolphins in Nordhafen. The two vessels initially waited there until they were scheduled to proceed and then passed the gas tanker GAS CRYSTAL, which was moored in front of them at the dolphins. The SANDY RICKMERS was unable to maintain her position. Afterwards the SANDY RICKMERS sailed through the sidings stop signal. The oncoming BALTICBORG passed the SANDY RICKMERS between Projensdorf and the siding and after that the GAS CRYSTAL and MALAGA at the same time in the siding. All vessels under way had pilots and canal helmsmen on board.

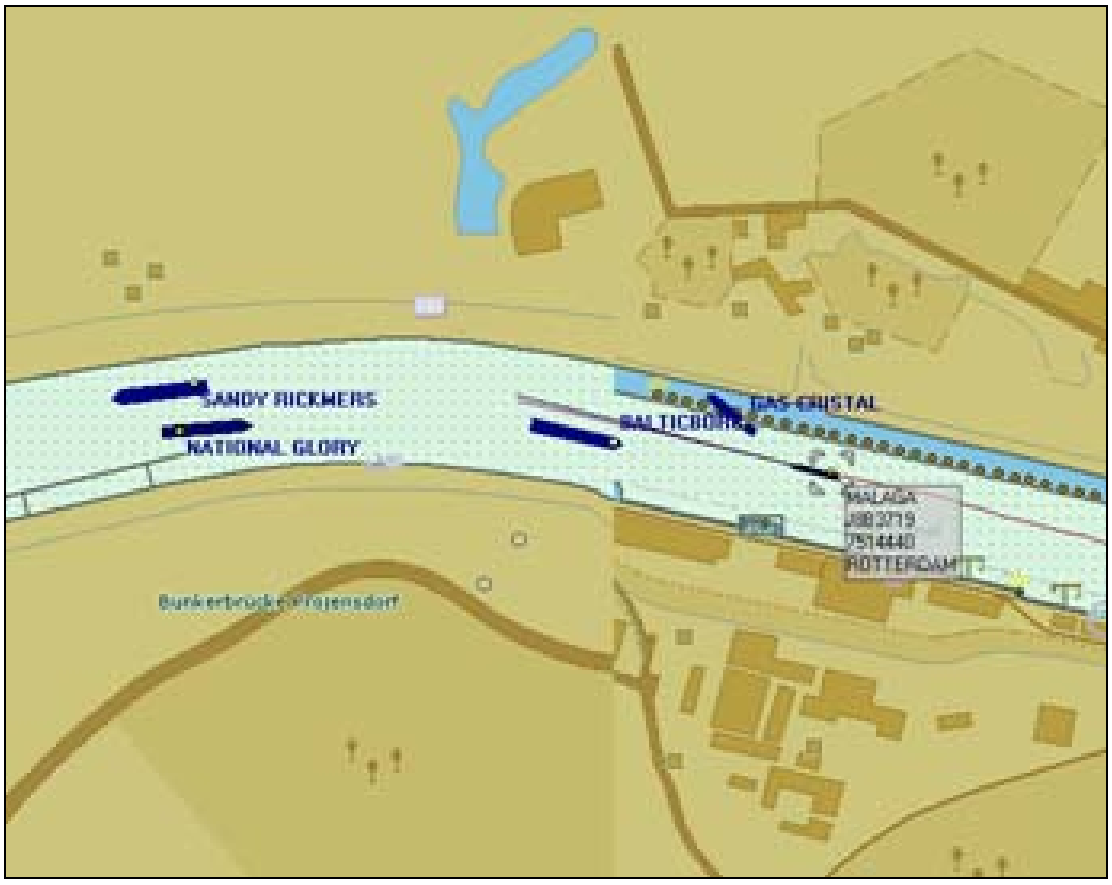

Figure 5: Traffic situation at 003803, AIS, WSP Kiel

3.2 Investigation

The NATIONAL GLORY cast off in Bremerhaven at 1018 on 27 November 2011 and was en route to Muuga in Estonia. The crew had already been woken before the siding at Kiel-Holtenau for entering and the master, a trainee, the pilot and the canal helmsman were on the bridge. The fog was very dense and visibility stood at 50 m according to measurements made independently using fixed points on board and ashore. Experience gained on previous voyages indicated that traffic volume on the NOK was reportedly very high. The pilot reportedly monitored the port radar image on the S-band system, which was set to a range of 0.5 nm, continuously; the helmsman was at the helm and the trainee stood at the starboard console to operate the engine telegraph and bow thruster.

The master was behind the starboard X-band radar system and reportedly switched between a range of 0.25 and 0.5 nm. Both radars were said to have been set to off-centre head-up with fixed range rings. The variable range rings were reportedly at about 0.3 nm. An AIS overlay was reportedly not made use of on the radar screens. The resolution of the radar screens was reportedly good and the lubber line set correctly. No deviation was reportedly indicated by the gyro compass. The engine was a start/stop engine with fixed pitch propeller and conventional rates of speed. 'Dead slow ahead' (DSA) is the lowest rate of speed at which it is possible to retain the ability to steer. Allowing for the canal section, at DSA the vessel would achieve a speed of 3-4 kts, at SA about 5 kts (in a narrow section about 4 kts) and at FA about 7.9 kts (in a narrow section about 6.5 kts). Both steering gears were in operation.

The NATIONAL GLORY was proceeding in convoy behind the BALTICBORG; both vessels were traffic group 5 (VG5). The required distance of between 1,200 m and 1,400 m was maintained outside the siding areas. After the pilot transfer at Rüsterbergen, the eastbound passage passed uneventfully. There was a stay of about 45 minutes at the Audorf-Rade siding. Visibility reportedly deteriorated to 50-100 m at the western side of the Großnordsee siding. Following that, the speed was reportedly reduced and the lookout posted. By all accounts, visibility did not improve until the subsequent collision and was announced in the traffic situation report. Both anchors were reportedly ready to drop. Seven oncoming vessels were reportedly passed in the Großnordsee siding. There was no wind and the NATIONAL GLORY reportedly kept to the dolphins in the siding by using rudder and engine manoeuvres. The stopping times between manoeuvres were reportedly about 15 minutes. The vessel proceeded at SA and 4 kts from km 90.5. She reportedly halted at km 91.0 (Schwartenbek siding) in order to maintain the distance to the BALTICBORG and allow two oncoming vessels to pass. The siding was passed in about 10 minutes. The narrow section below the Levensau Bridge was reportedly passed at 4 kts in the middle of the canal. The lights on the two embankments were reportedly just possible to make out. Due to the situation report, it was known that the slow moving SANDY RICKMERS, VG5 with a draught of 9.4 m, and the MALAGA, VG3, had to wait in the Kiel-Holtenau Nordhafen siding. In addition, the GAS CRYSTAL, a tanker classified to VG4, was moored at the dolphins waiting for better visibility. On VHF channel 73, it was reportedly heard that the SANDY RICKMERS was reportedly in the middle of the Nordhafen and the BALTICBORG was reportedly slowly encountering.

This message was unexpected because the SANDY RICKMERS was apparently unable to maintain her position and would reportedly leave the siding despite the stop signal. Therefore, use of the middle of the canal was discontinued after passing the Levensau Bridge in favour of proceeding cautiously in the southern half of the fairway.

The master and pilot observed the passage of the oncoming SANDY RICKMERS on the radar screen. Additionally, distance also had to be maintained to the bunkering bridge at Projensdorf. The pilot of the SANDY RICKMERS reportedly commented on VHF channel 73 that there was no other option. The navigation lights were reportedly barely visible and it was just possible to see the first two container bays. The passing distance to the bunkering bridge was reportedly 15-20 m and aft about 5 m in the case of the SANDY RICKMERS. When the SANDY RICKMERS was passed, the NATIONAL GLORY reportedly turned back to port; however, hard to starboard rudder angles were reportedly implemented to counter the hydrodynamic interactions between vessel/vessel and vessel/bank.

The master and pilot then saw on the radar that the NATIONAL GLORY was still just south of the middle of the canal and steering directly towards the oncoming MALAGA. The engine telegraph was reportedly set to dead slow ahead at a speed of 3.5 kts and the rudder to hard to starboard. It could be seen on the radar screens that the echo of MALAGA was reportedly clearly separated from the northern row of dolphins and the gas tanker moored there. The lights of the Knierim shipyard were reportedly visible and on a bearing of 3 points ahead on the starboard side. The MALAGA reportedly called on VHF channel 73 and requested a turn to starboard. The reply was reportedly that the NATIONAL GLORY was already turning to starboard. Shortly after, at 0044, two impacts were reportedly felt and the engine was stopped. Neither an astern manoeuvre nor an increase in speed to improve the rudder effect was reportedly justifiable in this situation.

As the masthead light of the MALAGA was just visible on the port side, the forecastle struck the MALAGA and presumably tore open the superstructure with the anchor. After the collision, the accident was reported and the vessel inspected. There were no casualties, no water ingress and no escape of pollutants on the NATIONAL GLORY. The Kiel Canal was closed and the NATIONAL GLORY was able to continue her voyage. At 0150, she made fast with port side in the new north lock and then proceeded to Kiel for further investigations.

At 2245 on 27 November 2010, the MALAGA took the pilot on board at the Kiel-Holtenau roads, proceeded to the new south lock with a cargo of 2,790 t of scrap and then made fast behind the SANDY RICKMERS. Since visibility was 50-70 m, the master decided to request a canal helmsman in addition to the pilot. The MALAGA left the lock at 2357. The master operated the engine controls, the officer on watch monitored the electronic chart system (ECS) with displayed AIS targets and the pilot was at the X-band radar system and maintained radio contact with the traffic control. The canal helmsman was at the helm and received helm commands from the pilot in German. Both steering gear pumps were switched on.

A lookout was on the forecastle and the engine room was manned. The bridges at Holtenau were passed at a speed of 2.8 kts at 0020. Sailing ahead, the SANDY RICKMERS and the MALAGA were to wait in the Nordhafen siding for the BALTICBORG and NATIONAL GLORY to pass. The MALAGA stayed behind the SANDY RICKMERS and passed the tanker GAS CRYSTAL, which was moored at the dolphins, at a crawl. It could be heard over VHF that the pilots of the SANDY RICKMERS and BALTICBORG were coordinating and the SANDY RICKMERS was reportedly slowly encountering. At 0037, the BALTICBORG passed the MALAGA in the siding area parallel to the GAS CRYSTAL. A short time later, at 0042, the pilot called the NATIONAL GLORY and requested that she turn further to starboard. The reply was that they could not move any faster. The red signal light of the siding was reportedly still visible when the two vessels collided on a heading of 289° immediately after the VHF call. Everyone on the bridge moved to safety on the starboard side. There were no injuries. The NATIONAL GLORY first struck the foredeck, then amidships on the port side and finally the deck superstructure and the life-boat. The master stopped with a full astern manoeuvre and let the port side anchor go by 1 shackle. The pilot informed the Vessel Traffic Service. There was no visible underwater damage to the MALAGA and no pollutants escaped. The tug Holtenau arrived at the scene of the accident at 0120. After that, the MALAGA was shifted to the south side of the Nordhafen with tug assistance, where she made fast at 0135.

At buoy 7 west of the bunkering bridge at Projensdorf, the pilot of the BALTICBORG was informed by his colleague on the SANDY RICKMERS in visibility of less than 20 m that they would now encounter, even though a displayed stop signal meant they would have to wait in the Nordhafen siding. Since there was no other option, the BALTICBORG assisted the announced pass by keeping as far to the south as possible. The two vessels then reportedly passed safely in the canal bend at km 95. When the eastbound BALTICBORG entered the Nordhafen siding, she reportedly had a radar echo ahead to begin with. Here, it was initially thought that this concerned the tanker GAS CRYSTAL, which was moored at the row of dolphins. The echo of the westbound MALAGA emerged from that. In the process, the passing distance between the aft sections of the two vessels was reportedly 5 m.

3.3 Analysis

VDR recordings of the NATIONAL GLORY

The traffic situation is announced in the collective calls every half hour over Kiel Canal 3. At 0020, it is broadcast that the BALTICBORG and NATIONAL GLORY of traffic group 5 are leaving the Schwartenbek siding eastbound; in the Nordhafen siding, the SANDY RICKMERS of VG5 and the MALAGA of VG3 are lying in front of the signal and the GAS CRYSTAL is waiting for better visibility on the western side of the dolphins. It is announced that the SANDY RICKMERS and the MALAGA would proceed at about 0040.

At 0032, the BALTICBORG is called by the SANDY RICKMERS; she is informed that they are positioned centrally and approaching slowly. The message is acknowledged at buoy 7. At 0038, the SANDY RICKMERS is called by the NATIONAL GLORY. The NATIONAL GLORY is informed that there is no other option and she reportedly had to continue. At 0040, the two vessels encounter at the bunkering station at Projensdorf. The helmsman of the NATIONAL GLORY notes that she is quite far to the south and there is a possibility she will be 'pushed away' by the bank[3]. In fact, the NATIONAL GLORY starts to turn to port. At dead slow ahead and hard to starboard, the pilot asks whether they are turning at 0041. The question was affirmed. At 0042, the echoes of the MALAGA emerge from the GAS CRYSTAL on the recorded radar image of the NATIONAL GLORY in the area ahead. After that, both vessels are passed by the BALTICBORG. At 0043, the NATIONAL GLORY is proceeding in the middle of the canal and is requested to turn to starboard by the MALAGA. The reply is that they are unable to move any faster. The engine of the NATIONAL GLORY is stopped. The two vessels collide at 0044.

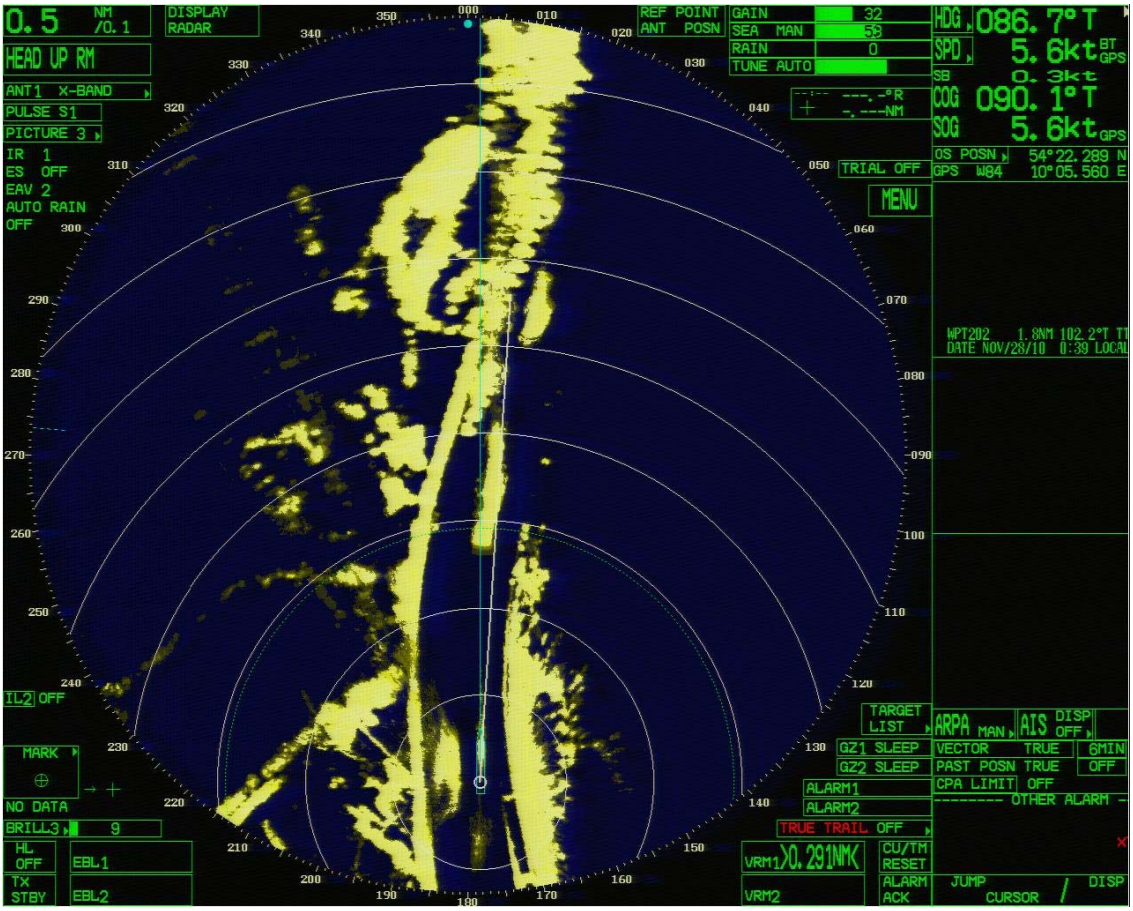

Figure 6: NATIONAL GLORY, 004000 system time

The radar image (s. fig. 6) at 004000 shows the passage of the NATIONAL GLORY at the bunkering bridge at Projensdorf and the SANDY RICKMERS. The X-band radar system is set to off-centre in relative head-up display mode at a range of 0.5 nm. One range ring represents 0.1 nm.

[3] By 'pushed away' the pilots and helmsmen on the NOK mean a movement of the vessel caused by the bank effect, which cannot be controlled by the rudder and controls.

The variable range ring is set to 0.29 nm as a measure for turning during a change of course. The heading (HDG) is 086.7°. The speed ahead over ground (SPD) with GPS as a sensor is 5.6 kts. The transverse speed (SB) to starboard is displayed as being 0.3 kt. Located ahead are the vessels BALTICBORG at a distance of 0.27 nm, the GAS CRYSTAL merged with the echo of the forward row of dolphins at 0.45 nm and behind her the MALAGA at 0.5 nm. Corresponding sensor readings apply for the following radar images. The direction of the transverse speed subsequently switches to port (-) and the differences between HDG and course over ground (COG) increase. SPD and speed over ground (SOG) always have the same values. The HDG is shown on the PPI (plan position indicator) as a blue line and the COG as a white line.

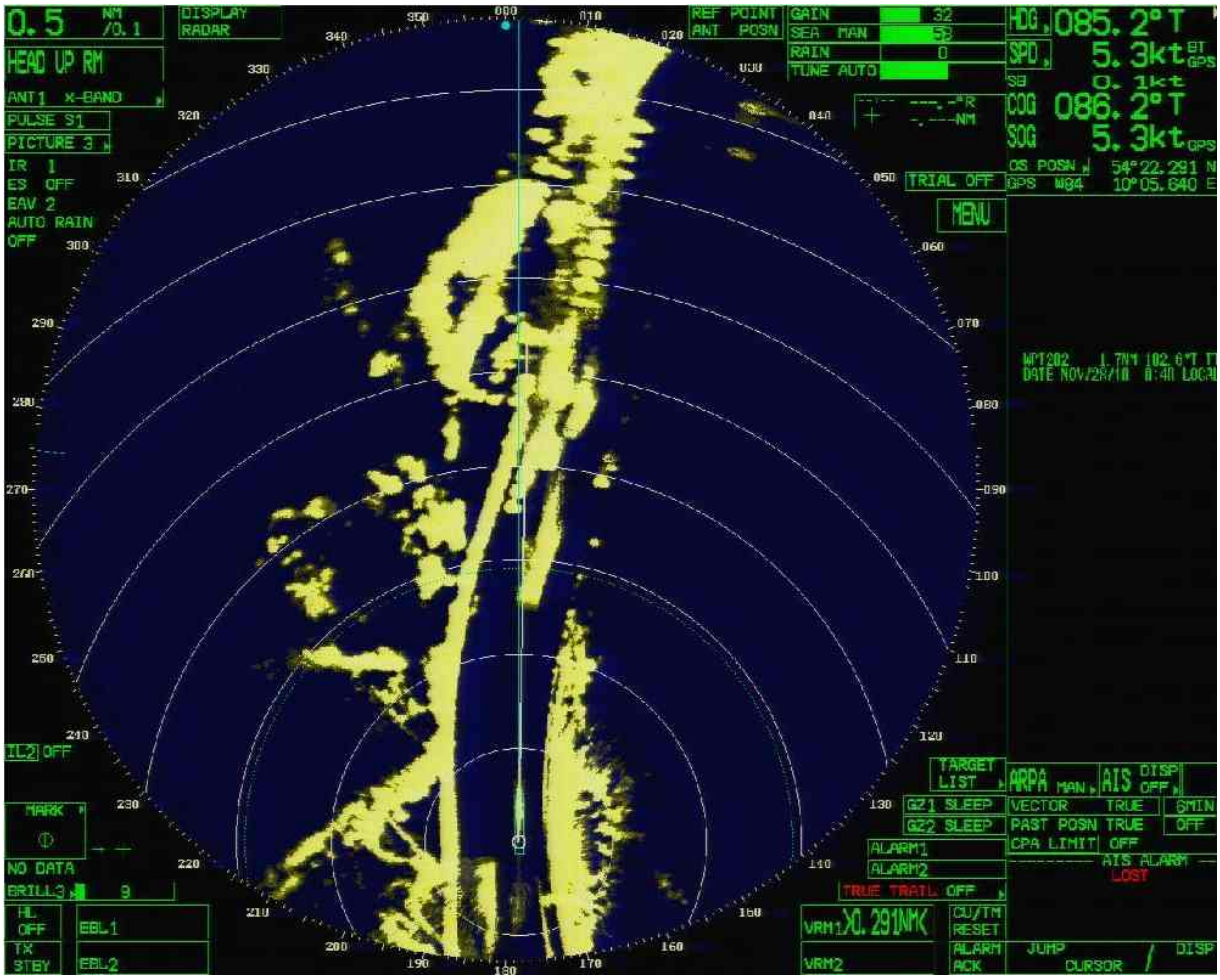

Figure 7: NATIONAL GLORY, 004100 system time

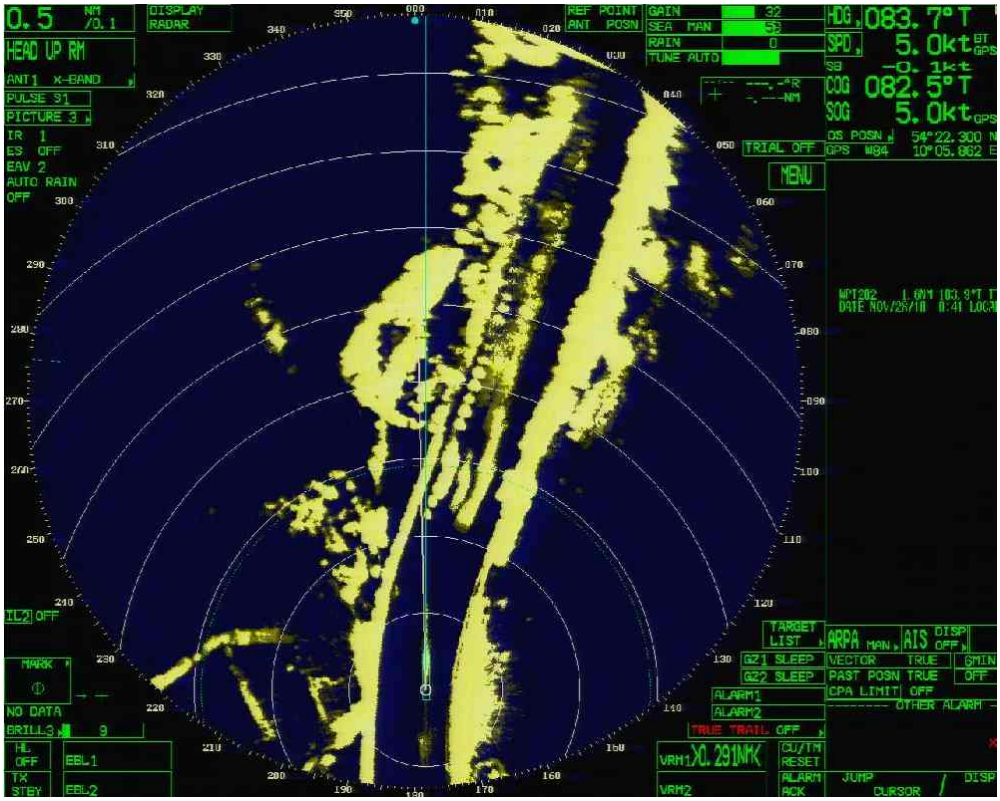

Figure 8: NATIONAL GLORY, 004200 system time

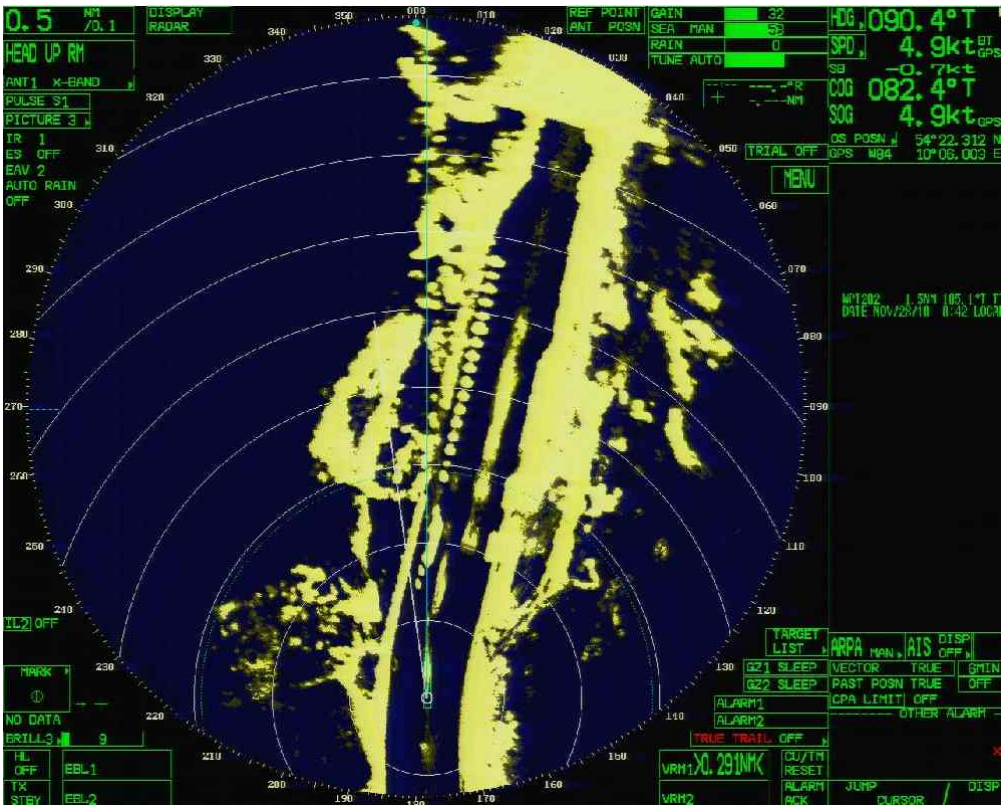

Figure 9: NATIONAL GLORY, 004300 system time

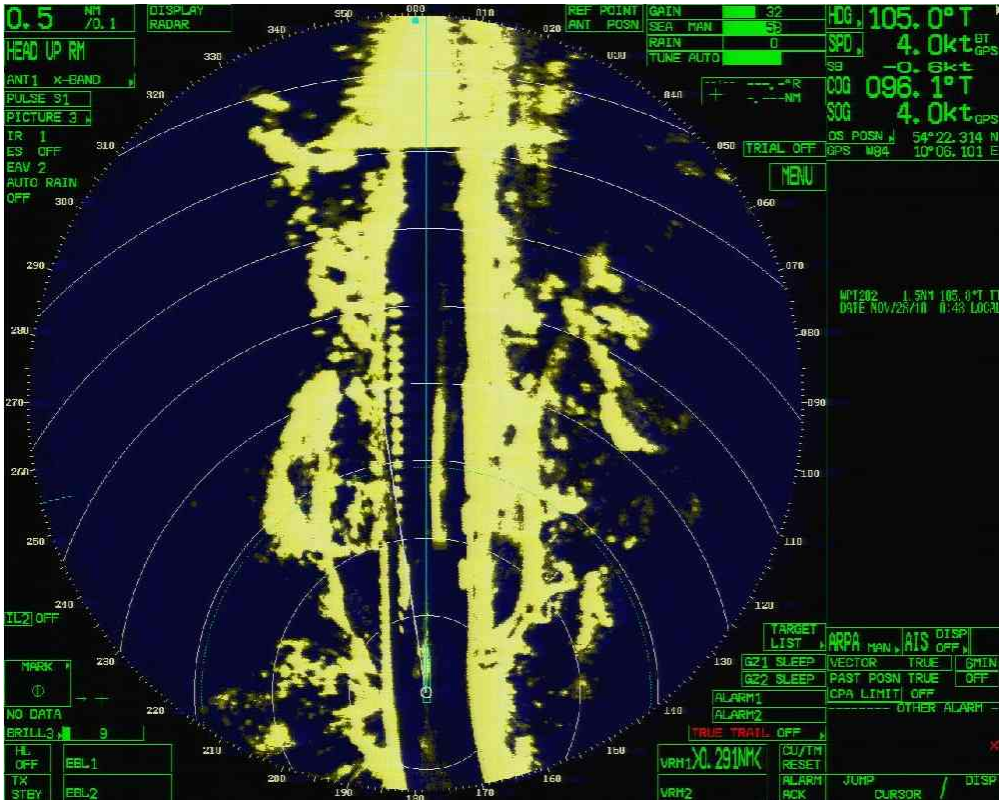

Figure 10: NATIONAL GLORY, 004345 system time (collision)

VDR recordings of the SANDY RICKMERS

Use of the recordings was only limited due to the VDR being improperly installed. The radar images of the port radar system were not fully recorded and are distorted. The area around the radar antenna is absent. For the most part, the audio recordings are incomprehensible. Helm commands cannot be heard. The rate of turn (ROT) was neither recorded in the VDR data nor in the AIS data. The following images show how the SANDY RICKMERS enters the siding at about 3.5 kts and then at first, at a speed of 0.1 kt, first of all stops 1 cbl behind the GAS CRYSTAL and then veers with a drift of 0.5 kt (s. radar fig. 14 “SB”). GPS was chosen for the speed sensor. It can be deduced from the audio recordings that the planned overtaking manoeuvre of the MALAGA is abandoned at 0012 and it becomes apparent that the CRYSTAL GAS is remaining at the forward row of dolphins. At 0014, the searchlight on the starboard wing is made ready. At 0017, the pilot inquires as to the functioning of the bow thruster, which reportedly did not respond when operated at the conning position. At 0018, the controls of the bow thruster are changed from the starboard wing, where the controls were switched before the lock manoeuvre, to the conning position. During this procedure, the SANDY RICKMERS veers to port and the pilot decides to pass the GAS CRYSTAL (Fig. 13). At 0026, he obtains information from the Vessel Traffic Service (VTS) about the oncoming vessels that could be expected. Following that, the SANDY RICKMERS steers towards the signal mast. The speed at 0031 is 0.1 kt. The BALTICBORG is called and informed that the SANDY RICKMERS was getting under way and converging.

The two vessels pass at 0035. At 0038, the NATIONAL GLORY calls the SANDY RICKMERS on VHF and asks what the intentions of the pilot are. The two vessels pass at the bunkering bridge at Projensdorf shortly after. The pilot then orders a lookout to the forecastle for the Schwartenbek siding.

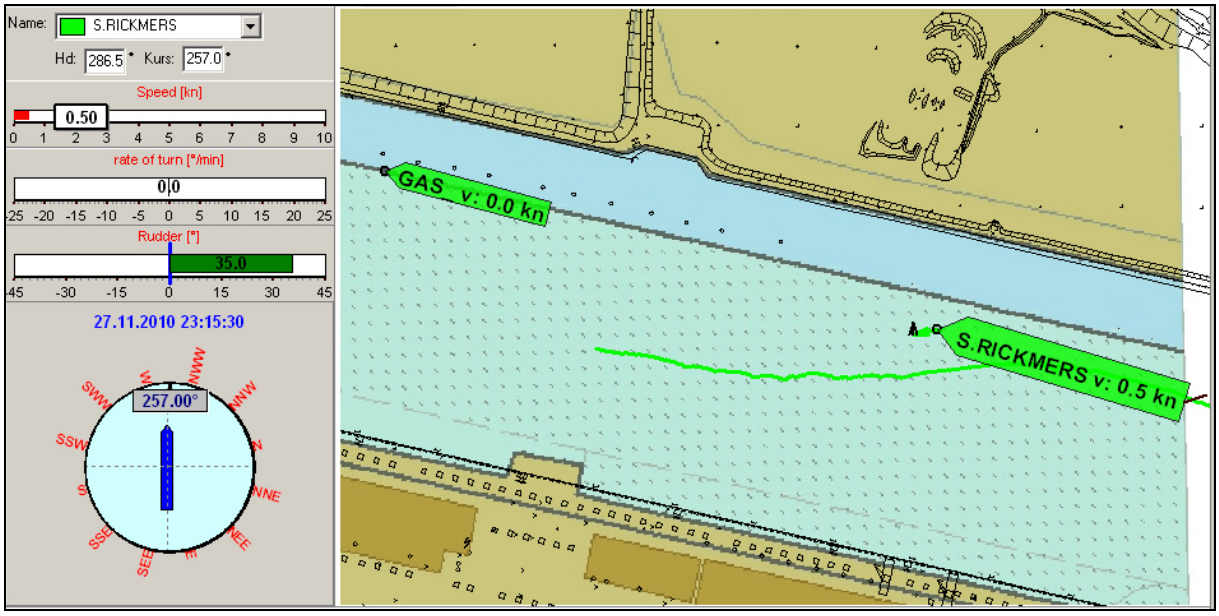

Figure 11: SANDY RICKMERS at 0015, row of dolphins in Nordhafen

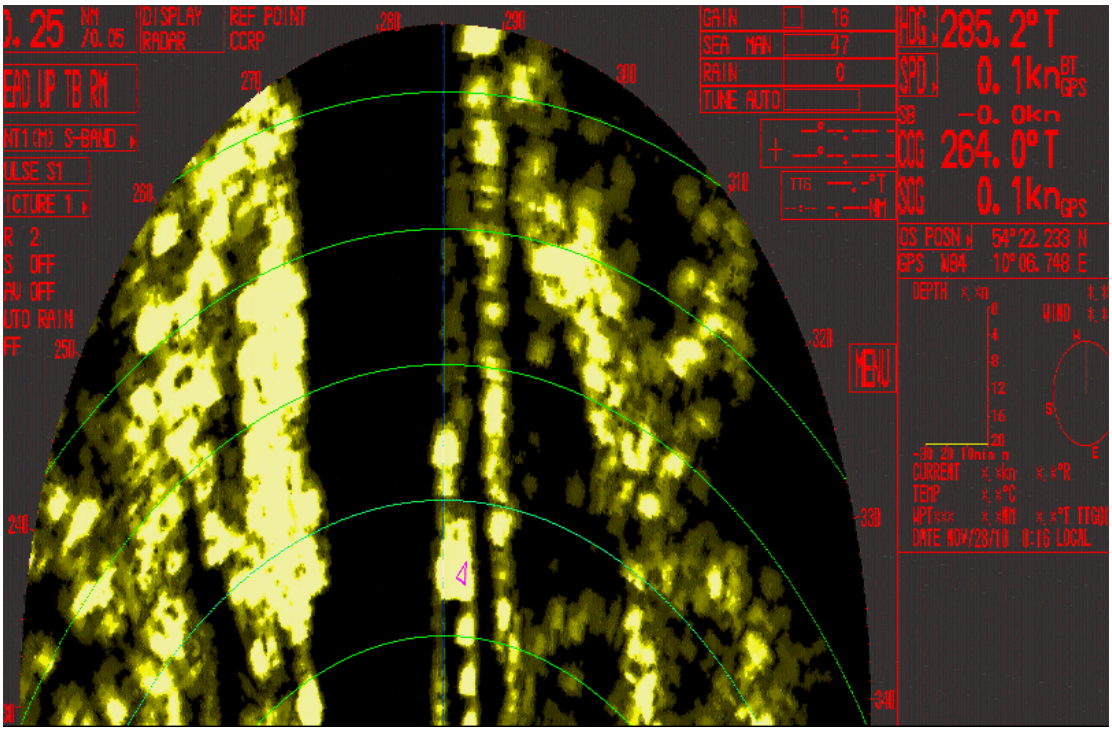

Figure 12: SANDY RICKMERS at 0016, GAS CRYSTAL ahead[4]

[4] The distortion and missing areas on the radar image are caused by the faulty installation of the VDR on the SANDY RICKMERS.

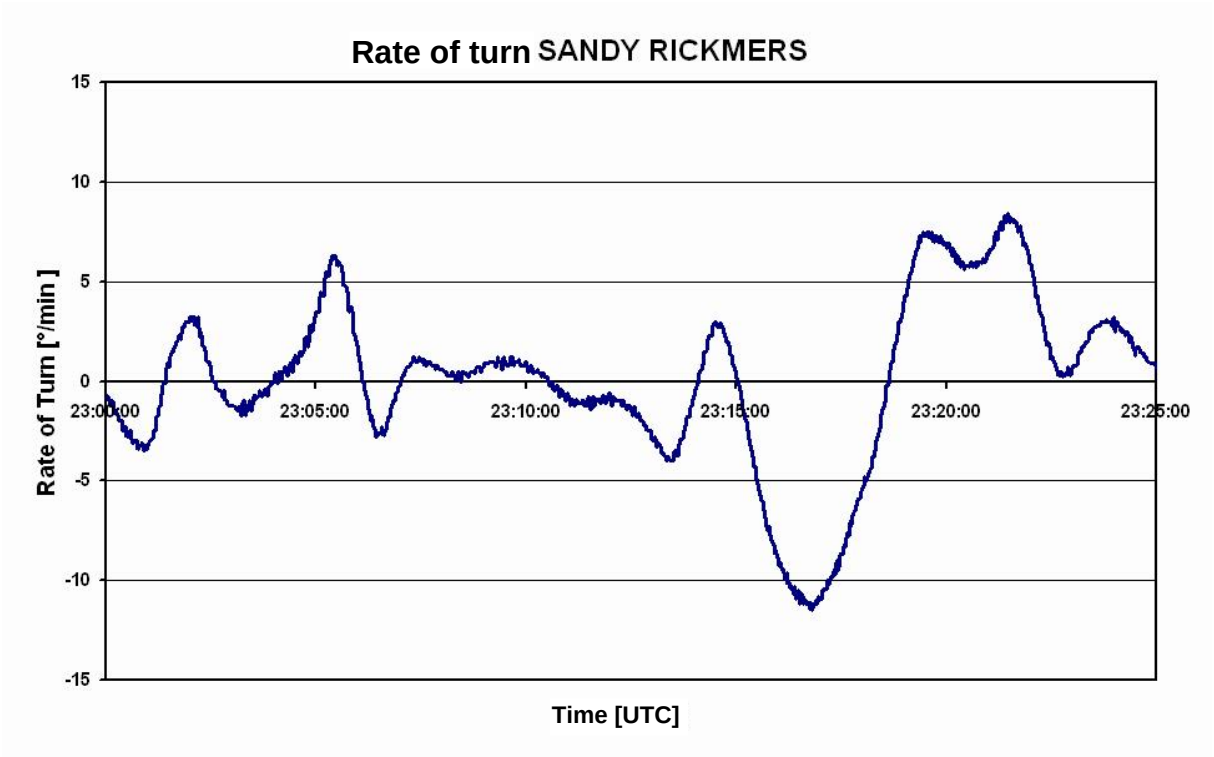

Figure 13: Rate of turn/min, calculated and derived from the gyro compass, BAW

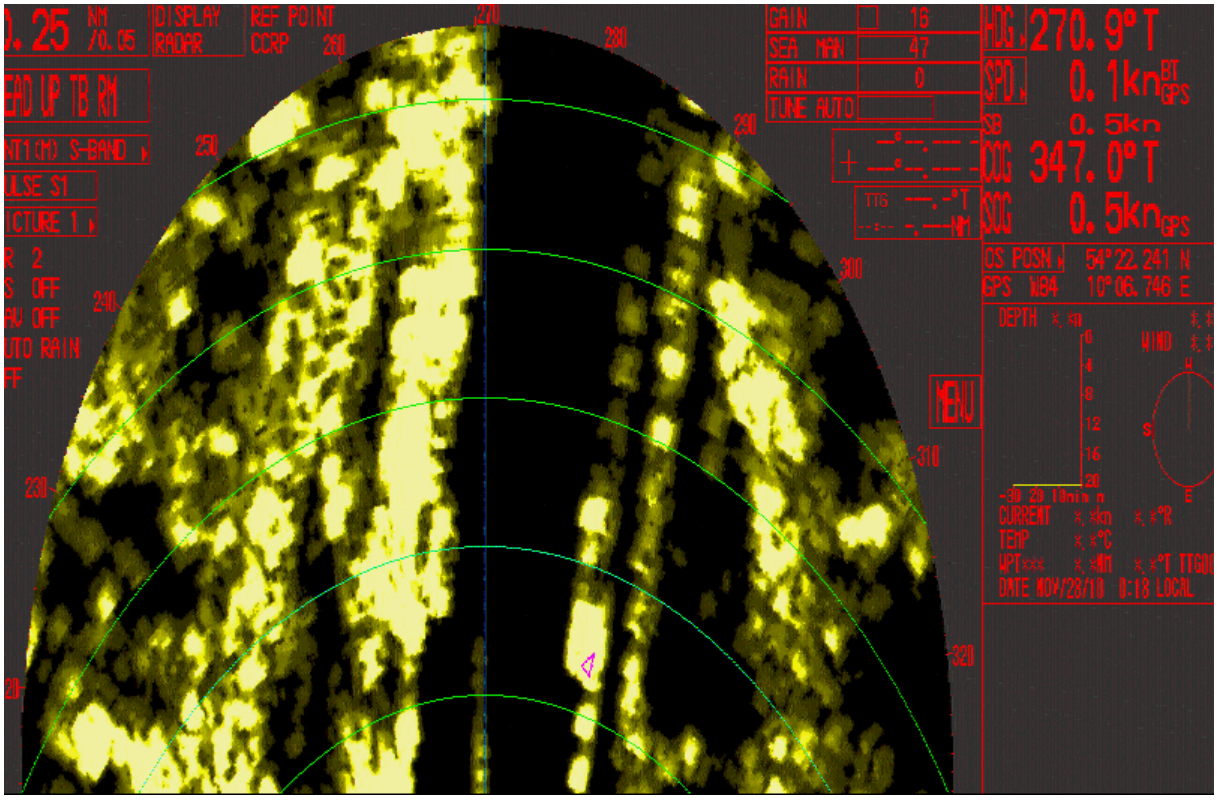

Figure 14: SANDY RICKMERS at 0018, GAS CRYSTAL ahead

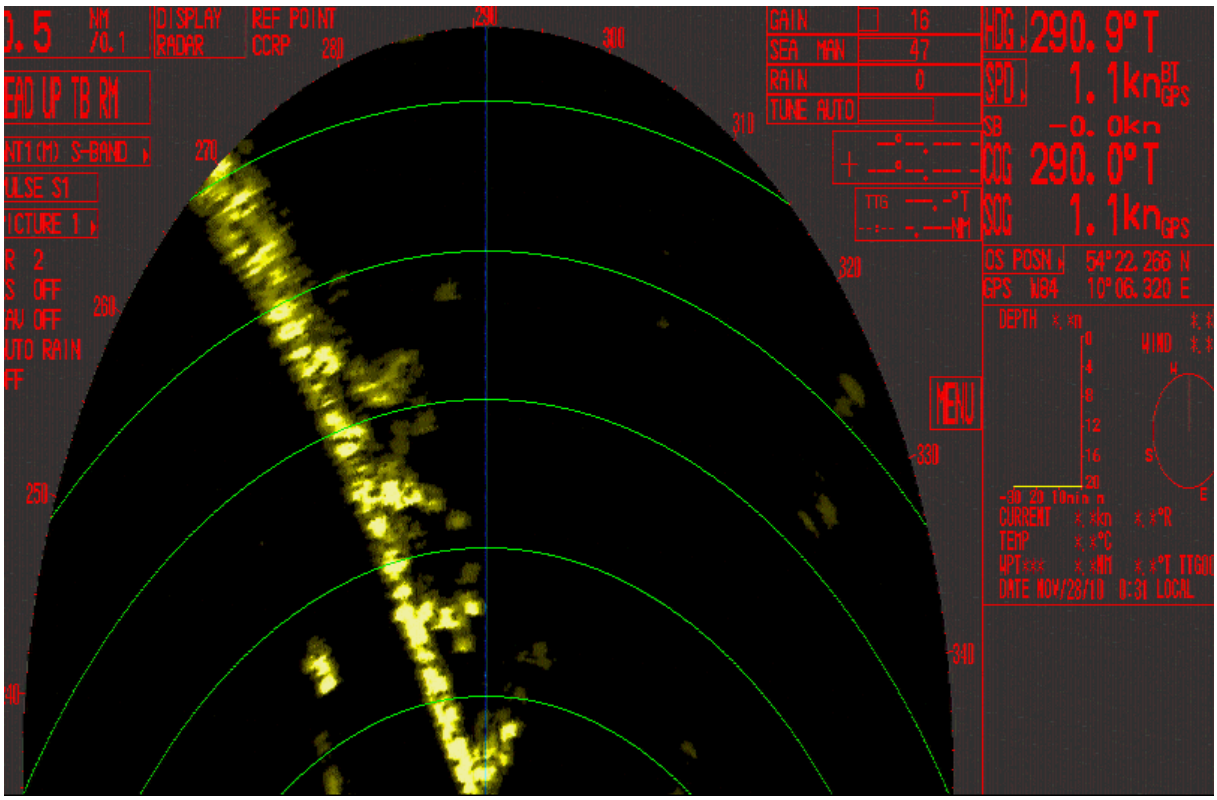

Figure 15: SANDY RICKMERS at 0031, end of the siding

ECS recordings and navigation equipment on the MALAGA

On the MALAGA, it was possible to reproduce the course made good up to the collision on her ECS. The photos of the ECS screen show the track of the MALAGA up to the collision. The red line shows the plotted chart course. The positions are plotted at 1 minute intervals and after passing the bridges at Holtenau are continuously to the right of the plotted course line. Other vessels and thus the traffic situation are not displayed. A voyage data recorder was not installed on the MALAGA[5]. Therefore, it was not possible to reproduce any other data on the vessel.

When the survey was carried out by the BSU after the accident, the port radar system was destroyed. The starboard radar system was still intact and yielded a clear image (Fig. 15). The lubber line was well configured. The radar antenna is located in front of the funnel amidships on the signal mast.

[5] A carriage requirement applies only from 3,000 GT onwards.

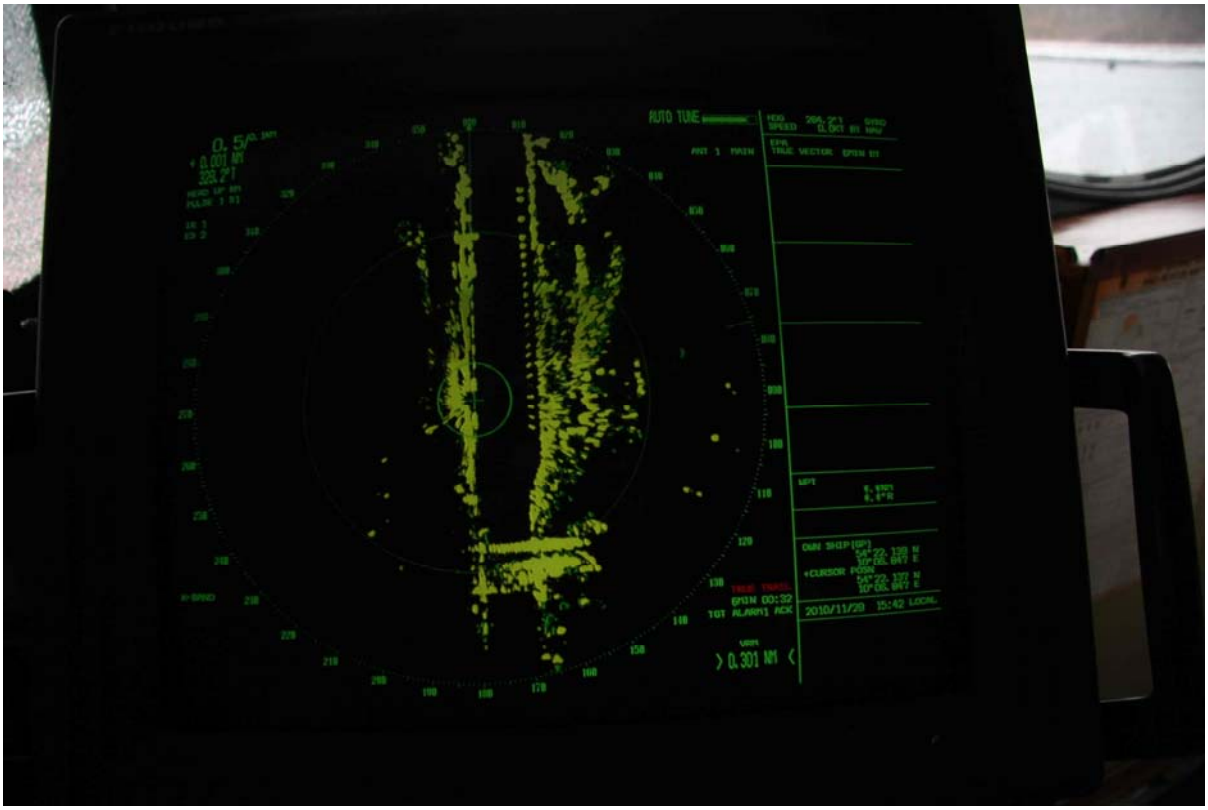

Figure 16: Starboard radar image on the MALAGA

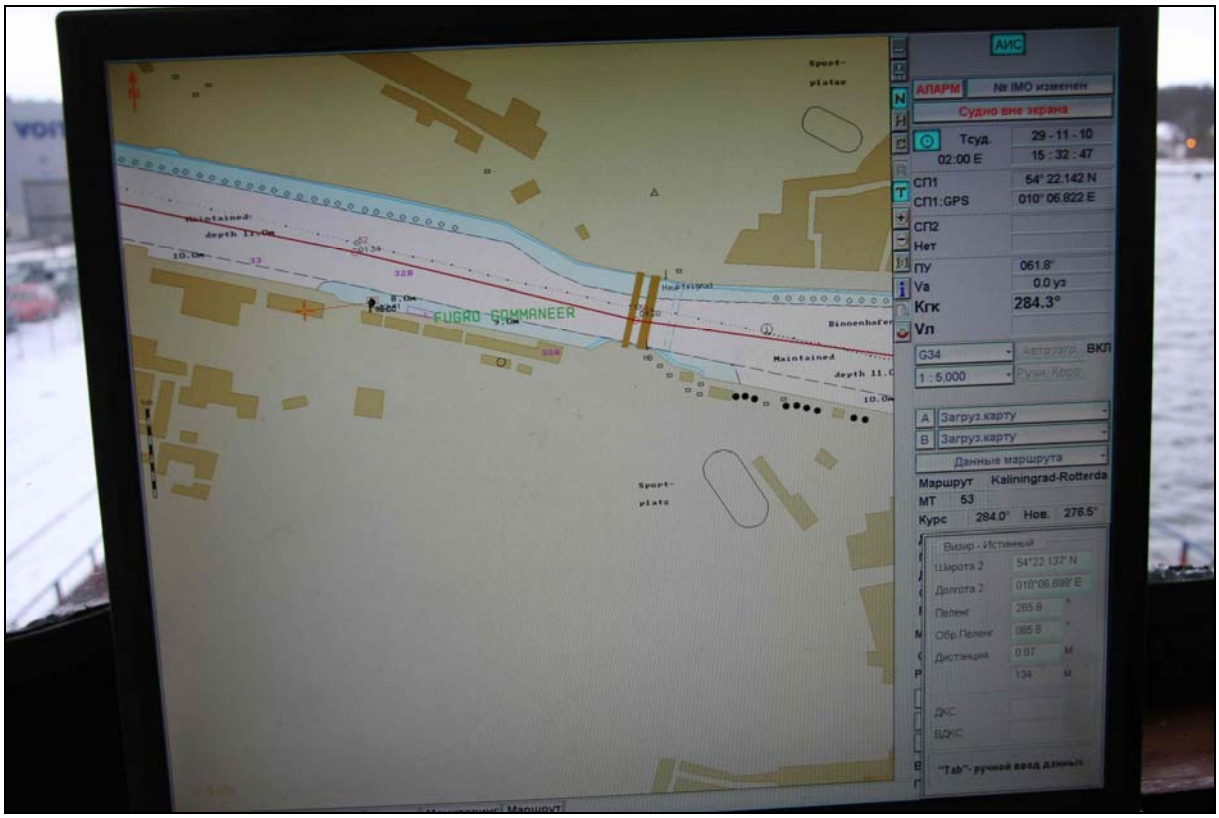

Figure 17: ECS on the MALAGA, bridges at Holtenau

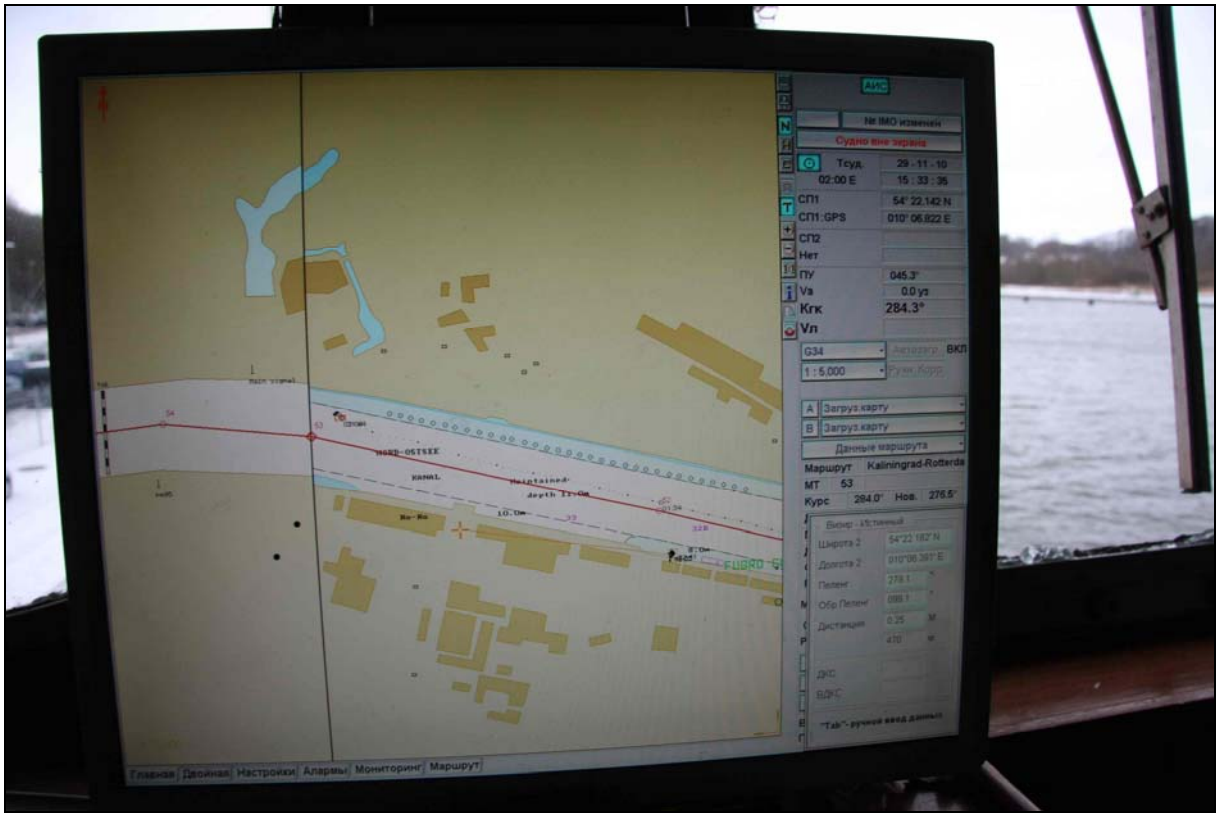

Figure 18: ECS on the MALAGA, row of dolphins at Nordhafen

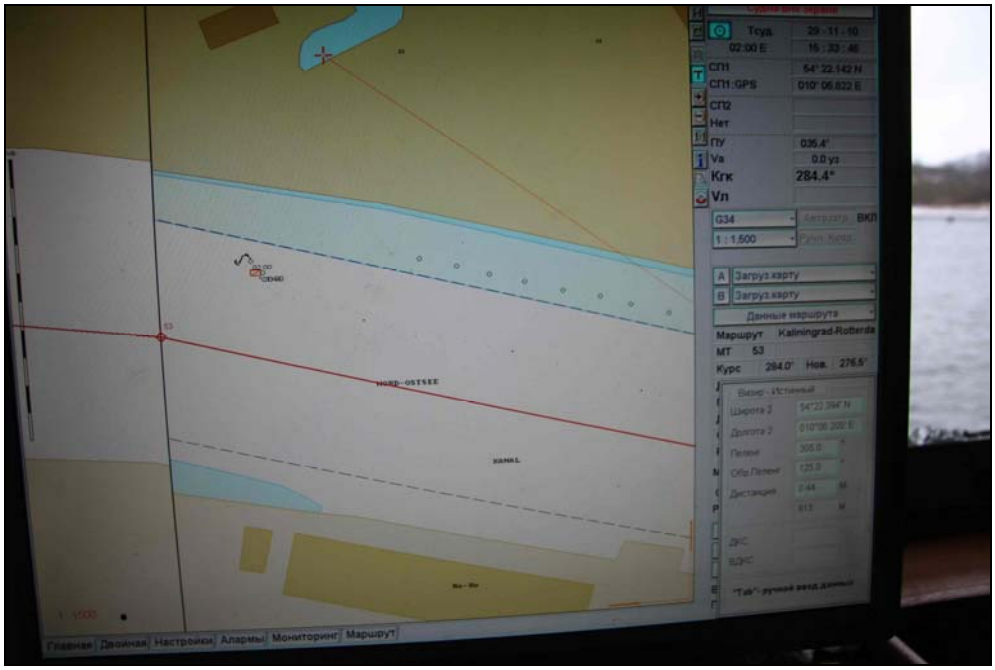

Figure 19: ECS on the MALAGA, collision

With ECS and two radar systems, the navigation equipment and systems installed on the MALAGA exceed the carriage requirements for a vessel measured at 2,196 GT. The automatic identification system was a standalone device and showed the targets

in addition to the starboard radar system on a minimum keyboard display (MKD). The GPS position is centred on the ECS, but displayed about 20 m too far forward (Fig. 19). The antenna is entered correctly in the AIS configuration with a location of A = 70m, B = 12m, C = 10m and D = 2m.

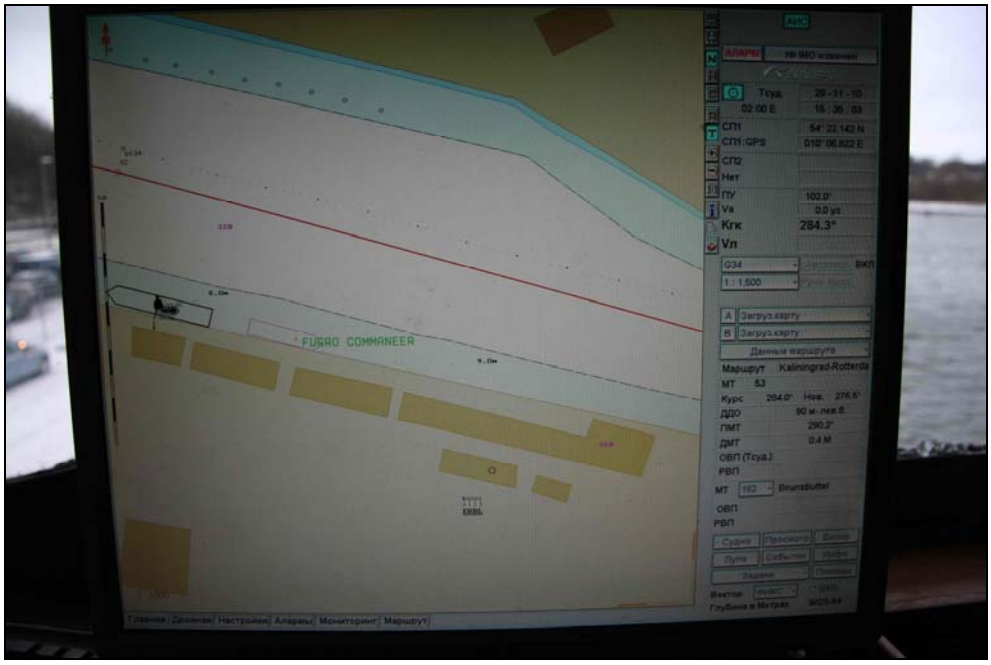

Figure 20: Antenna position of the ECS on the MALAGA

Navigation equipment on the NATIONAL GLORY

The navigation equipment on the NATIONAL GLORY corresponds to the current state of the art. Beyond the carriage requirements, she has 2 x AIS installed, the targets of which can be superimposed with both radar systems. The antenna position transmitted is configured properly: A = 117m, B = 32m, 14m and C = D = 8m. Inter alia, the navigation equipment consists of 1 Furuno VR-5020 SVDR, 2 Furuno GP-150 GPS, 2 Furuno FA-150 AIS, Furuno FAR-2837S S-band radar system, Furuno FAR-2827 X-band radar system, Yokogawa Denshikiki CMZ700S gyro compass, Yokogawa Denshikiki PM 208 steering stand, Saura Keiki Seisakusho SR-165 magnetic compass. An ECS is not installed.

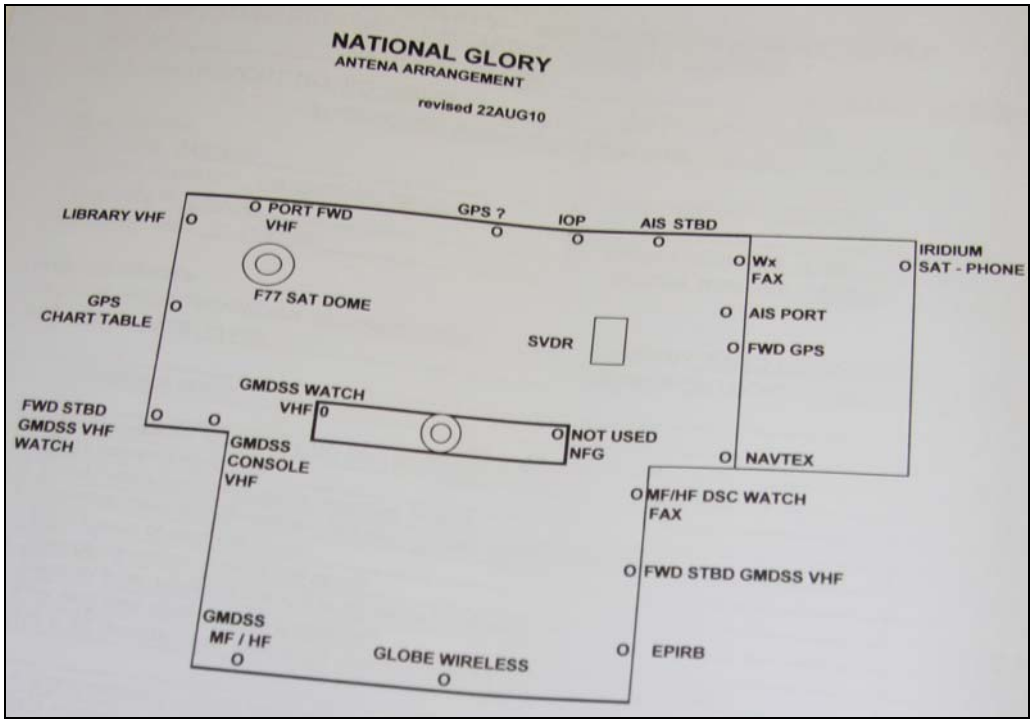

Figure 21: Antenna arrangement on the NATIONAL GLORY

Figure 22: Bridge of the NATIONAL GLORY

The NATIONAL GLORY has a well documented safety management system (SMS) and comprehensive route planning. The NOK passage is documented with 37 waypoints, chart courses and a distance of 67 nm. The bell book contains a handwritten record of all engine manoeuvres and special events, such as waking the crew, tug assistance and docking manoeuvres. Charts of the British Hydrographic Service were used for navigation, which were updated.

The chart for the NOK, BA 2469, contained the revision status 2010-3849-4915. At 0036 on the day of the accident, it was noted in the log book that there was reportedly a high volume of traffic on the NOK and the pilot was using radar as a basis for issuing his helm and engine commands. For AIS, it was defined in the SMS that the starboard system continuously sends updated data and the port system is used only as a receiver and fall-back option. AIS data should be constantly superimposed only on the port radar system and on the starboard radar system when needed, i.e. to identify a specific target. At no time should AIS be used as an aid for preventing collisions because the data received are reportedly often confusing and unreliable for this purpose, e.g. in connection with the use of ARPA, bearings by sight, radar bearings at distance and manual plotting with relative display of the radar image.

Damage

After being requested to do so by its shipping agent in Kiel-Holtenau and the classification society, the owner of the MALAGA did not provide the BSU with any data beyond the statements of the crew and the photos taken on board by the BSU. To that extent, it is not possible to make further statements about operation and equipment or the damage on the MALAGA. It can be seen on the photos that the NATIONAL GLORY first struck the forecastle of the MALAGA on her port side, scraped along the hull and hit the superstructure. In the process, the bow and the bridge were pushed in and the life-boat and davit positioned behind as well as the port side radar system and antenna were damaged. No longer seaworthy, the MALAGA was shifted to the Nordhafen in the NOK after the accident with tug assistance, where she was surveyed by the authorities and the classification society (GL). The MALAGA arrived at the Rendsburg Nobiskrug shipyard on 21 December and was repaired there. 11 tonnes of steel had to be replaced on the superstructure and forecastle. She left the shipyard on 25 January 2011 with her cargo of 2,000 t of scrap in the direction of Brunsbüttel and the port of destination, Rotterdam.

Figure 23: Bow of the MALAGA

Figure 24: Superstructure of the MALAGA

Figure 25: Bridge of the MALAGA

The classification society, American Bureau of Shipping (ABS), noted in its damage report for the NATIONAL GLORY that the rudder angle indicator on the bridge displayed 2-3° less than that shown on the indicator in the steering gear compartment. The rudder's midship position is displayed correctly and the error is reportedly < 1° for rudder angles of < 15°. The steering gear with two pumps and emergency steering were tested and operable. The rudder feedback unit was properly aligned and the master was informed about the errors of the rudder angle indicator on the bridge at full rudder angles.
The propeller was ground and smoothed on blade 2 on 1 November 2010 in Muuga, Estonia due to a fracture of 20 mm on the suction side. On 3 November 2010, it was tested at half load together with the steering gear in forward and reverse travel. The test was successful and no unusual vibrations were detected. A fracture of 220 mm was found on blade 2 of the propeller during a subsequent inspection on 10

November 2010. In zone C, 2,450 mm was measured on the suction side and 3,500 mm on the pressure side. It is reported that the damage had been repaired provisionally until the next inspection in dry dock by divers of the Tuukritoode Ou diving company during cleaning work in agreement with ABS. This led to an improvement of 20 mm on the suction side. The bow had damage to the cover of the Suez Canal searchlight and scrapes on the shell plating due to the collision.

Figure 26: Bow of the NATIONAL GLORY

Animation and technical paper of the BAW

The Federal Waterways Engineering and Research Institute, Hamburg Department (BAW), was commissioned by the BSU to reconstruct the situation with all involved vessels in an animation in order to assess it in hydrodynamic terms. Masses, distances and speeds have a significant impact on vessel/vessel interaction, respectively, the bank effect. Here, the effects increase proportionally by a factor of about four when distances reduce and with increasing speed by two. Rudder and drift angle must be able to compensate for transverse forces and yaw-moments, otherwise an accident will inevitably occur.

The effects that develop in a spatially limited canal during encounters and at the bank are unique in different situations; therefore, no universally valid statements are possible. The VDR recordings of the NATIONAL GLORY and SANDY RICKMERS, the AIS recordings of the VTS, and AIS raw data of the WSD-N were used as parameters for the vessels' movements.

Operating area effects

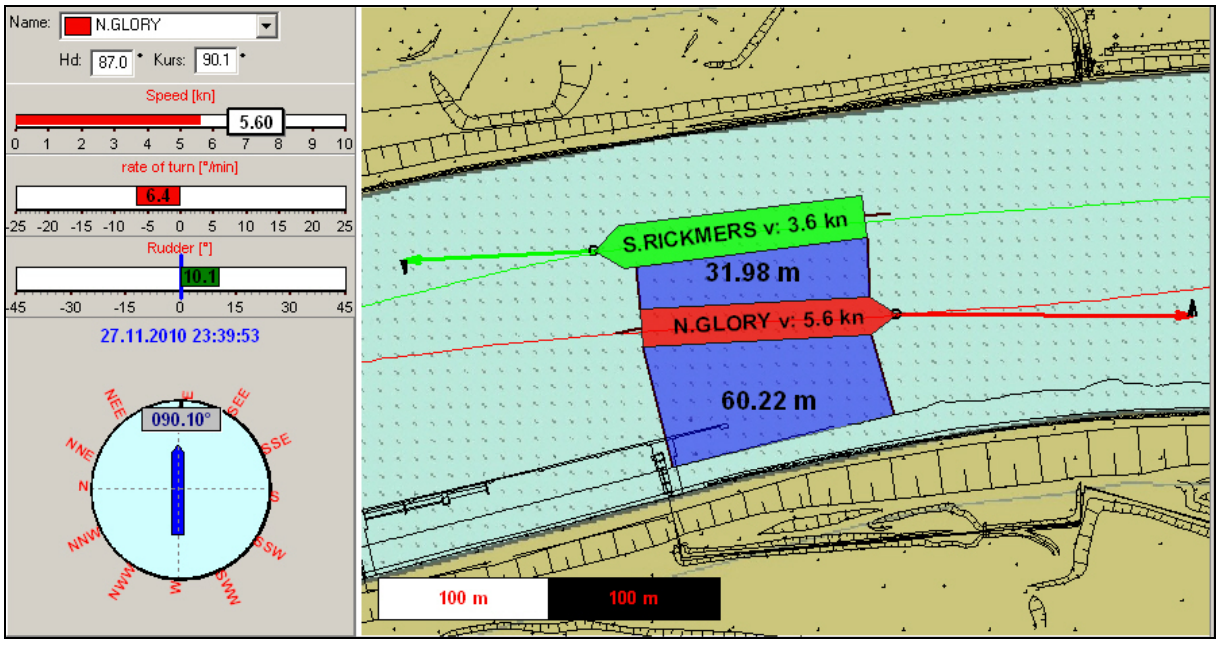

Figure 27: Encounter at 003953

Based on the rudder manoeuvres and changing ROT data of the NATIONAL GLORY, interaction between the vessels during the encounter of the SANDY RICKMERS and NATIONAL GLORY at the bunkering bridge at Projensdorf is detectable. This is to be expected because at amidships the passing distance is just 32 m at a speed of about 5.6 kts. A slight misalignment of the significantly slower oncoming vessel is discernible. The passing distance to the bank during the period of the encounter is about 60 m. This reduces to about 48 m as the sterns pass and is therefore considerably larger than the passing distance of the vessels. At this stage, the bank effect is not a decisive factor.

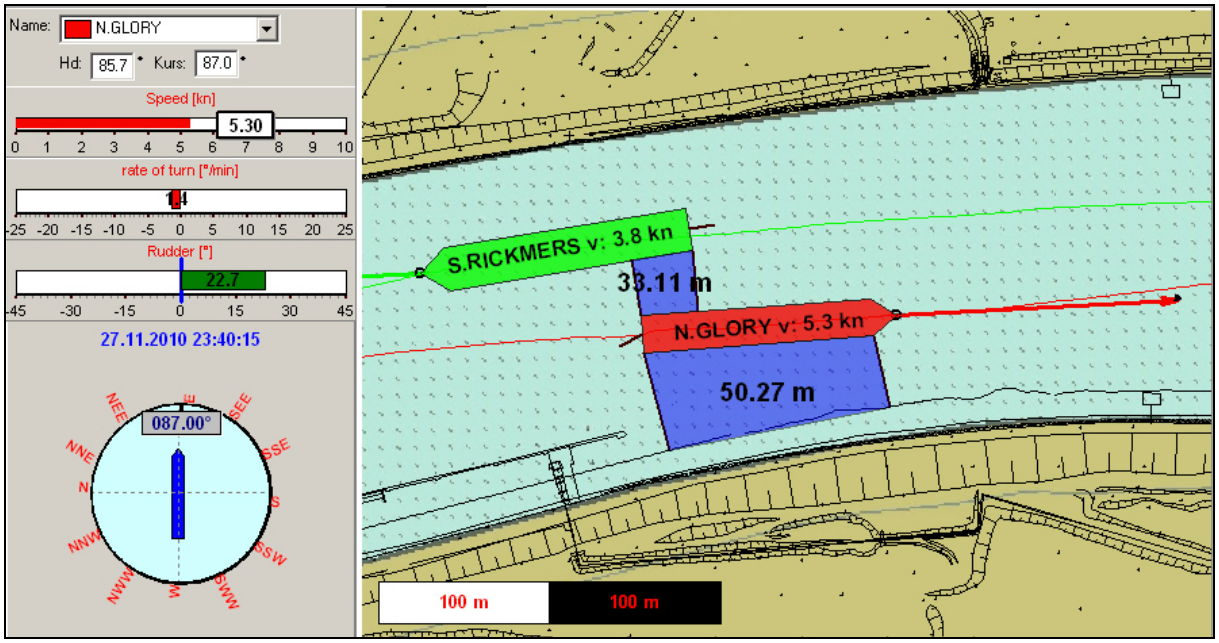

Figure 28: Encounter at 004015

Towards the end of the encounter, the vessel/vessel interaction is stronger than the bank effect (about 004015), but this is compensated by an appropriate helm setting on the NATIONAL GLORY.

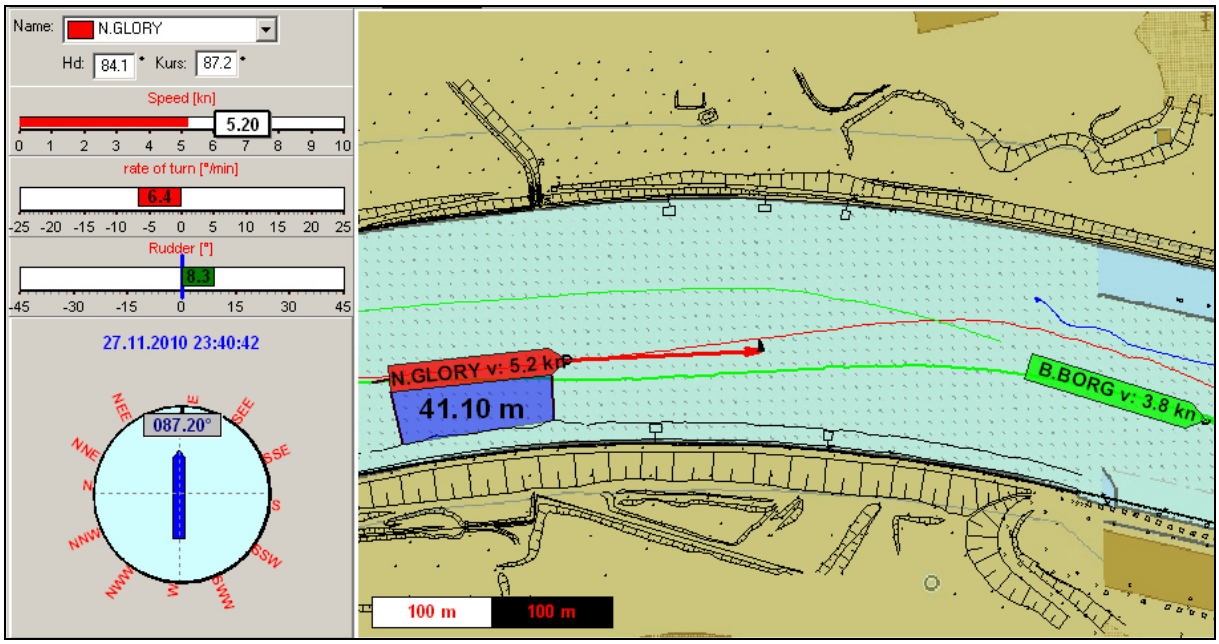

Figure 29: Situation at 004042

After the encounter, from approximately 004042, the distance of the underwater hull to the 4 m contour line is only about 41 m, which, in contrast to the BALTICBORG sailing ahead (about 4 kts), may have led to the NATIONAL GLORY (speed about > 5 kts) being influenced significantly by the bank effect with her stern being sucked in (ROT to port up to about 6.4°/min). From a hydrodynamic perspective, after the

encounter it seems more likely that the bank effect caused the NATIONAL GLORY to change course to port rather than the vessel/vessel interaction with the SANDY RICKMERS.

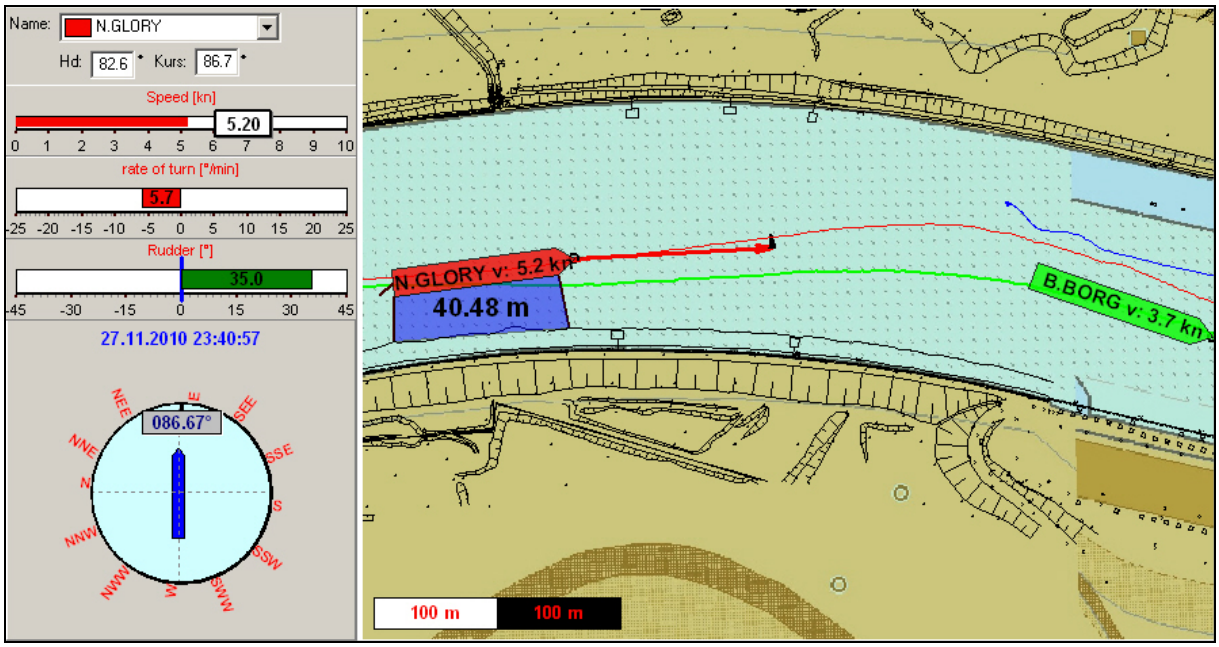

Figure 30: Situation at 004057

At 004057, the NATIONAL GLORY attempts to counteract the bank effect with a full rudder angle. Here, the rate of turn is indicated at 5.7°/min to port.

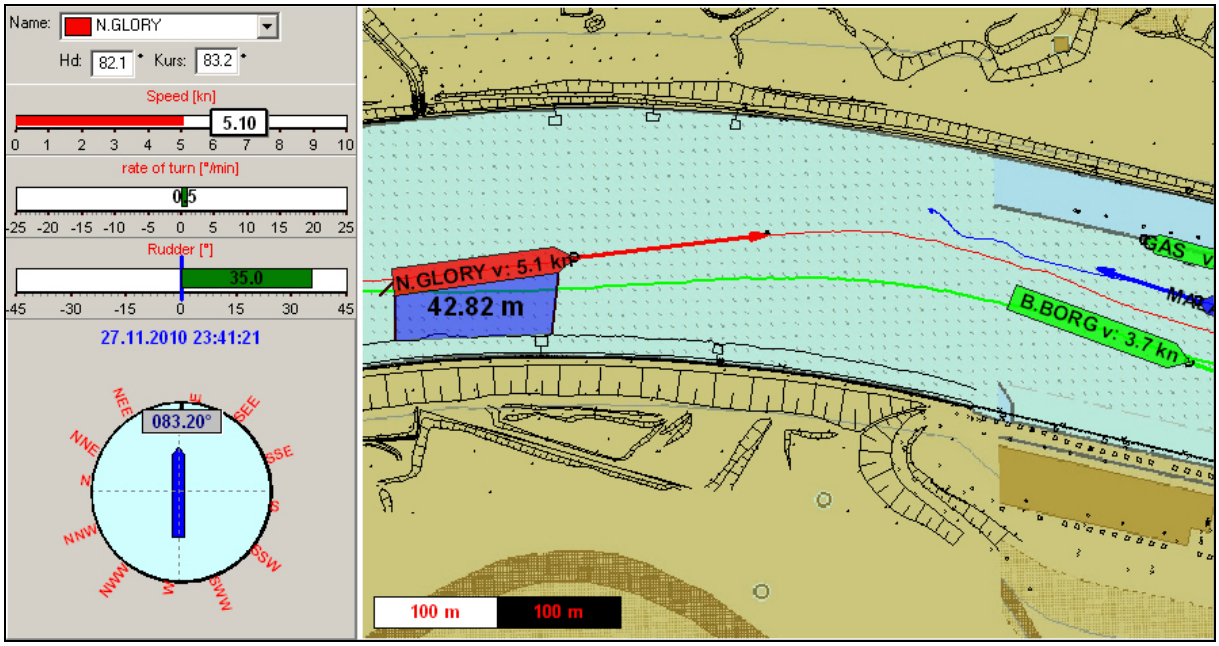

Figure 31: Situation at 004121

It was possible to stop the turn to port at 004121. The rudder is set at hard to starboard. In terms of hydrodynamics and ship flow (wake and/or propeller wash), due to the distance between the vessels as well as the low and decreasing speed of

the BALTICBORG, the NATIONAL GLORY is not subjected to any effective flow-induced influences by the SANDY RICKMERS or the BALTICBORG.

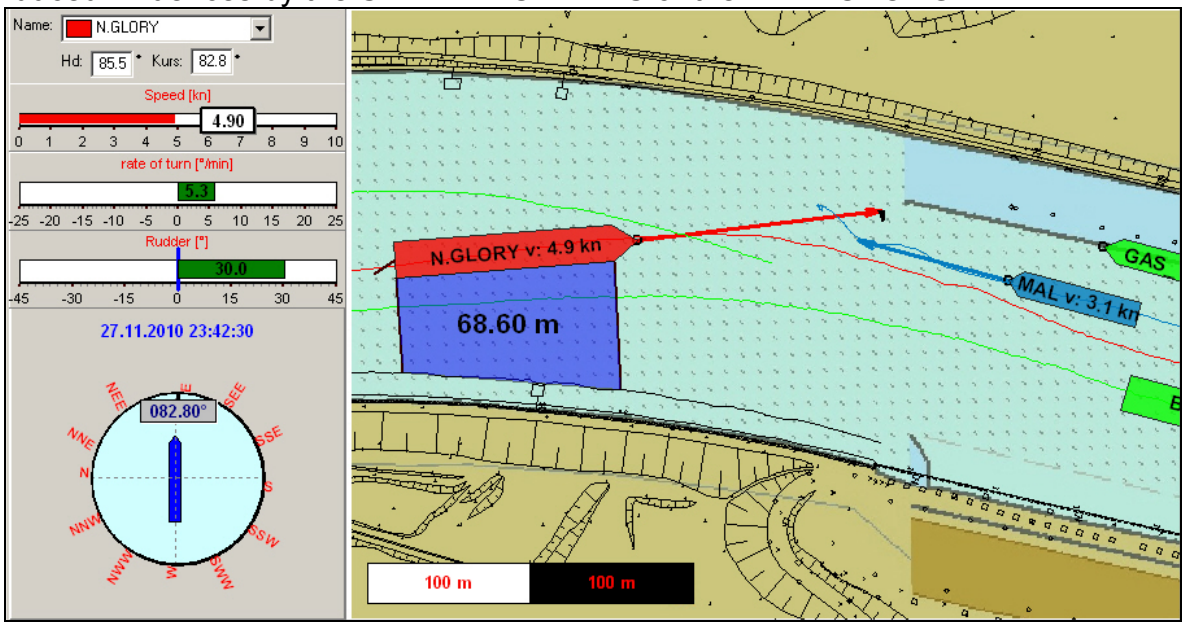

Figure 32: Situation at 004230

Although it was only acted with starboard rudder angles in the final 2 minutes up to 004230 and then up to the collision at 004330, no sufficient rate of turn was developed to pass through the canal bend at Projensdorf without entering the northern side of the fairway. This would, depending on track and selected radius, require a rate of turn of about 10°/min.

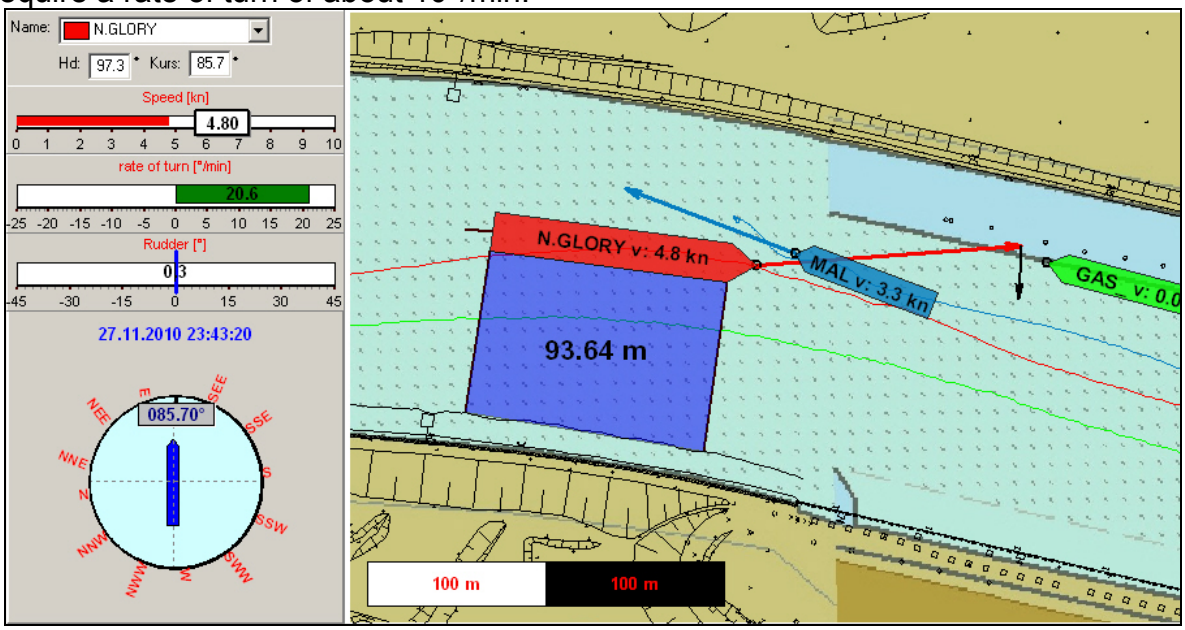

Figure 33: Situation at 004320

At 004320, 10 seconds before the collision with the MALAGA, the NATIONAL GLORY has developed a rate of turn of 20.6°/min and rising. This rate of turn would have probably been enough to just pass the GAS CRYSTAL had the MALAGA not been there.

CET	RUD	ROT	HDG	COG	SOG	DIST
003900	-1	5	86.3	83.3	5.8	1092
003901	-1	4	86.4	83.3	5.8	1088
003902	-1	4	86.4	83.3	5.8	1084
003903	-1	4	86.5	83.5	5.8	1079
003904	-1	4	86.5	83.7	5.7	1075
003905	1	4	86.6	84.0	5.7	1071
003906	1	4	86.7	84.3	5.7	1067
003907	1	4	86.8	84.3	5.7	1062
003908	1	4	86.8	84.3	5.7	1058
003909	1	4	86.9	84.5	5.7	1054
003910	1	4	86.9	84.6	5.7	1050
003911	0	4	86.9	84.7	5.7	1046
003912	-2	4	86.9	84.7	5.7	1042
003913	-2	4	87.0	84.7	5.7	1037
003914	4	4	87.1	84.9	5.7	1033
003915	6	4	87.2	84.9	5.7	1029
003916	7	4	87.3	85.1	5.7	1020
003917	7	4	87.4	85.3	5.7	1016
003918	3	4	87.5	85.3	5.7	1012
003919	1	4	87.6	85.6	5.7	1008
003920	1	4	87.7	85.7	5.7	1003
003921	1	4	87.7	85.8	5.7	999
003922	1	4	87.8	85.8	5.7	995
003923	1	4	87.8	85.8	5.7	991
003924	0	4	87.9	85.9	5.7	986
003925	-1	4	87.9	86.0	5.7	982
003926	-3	4	88.0	86.1	5.7	978
003927	-8	4	88.1	86.3	5.7	974
003928	-8	4	88.2	86.3	5.7	970
003929	-8	4	88.2	86.3	5.7	965
003930	-9	4	88.3	86.4	5.7	961
003931	-11	3	88.3	86.5	5.7	957
003932	-11	3	88.3	86.5	5.7	953
003933	-11	3	88.3	86.5	5.7	949
003934	-11	3	88.4	86.7	5.7	944
003935	-11	2	88.4	87.4	5.6	940
003936	-11	2	88.4	87.4	5.6	936
003937	-11	1	88.4	87.4	5.6	932
003938	-11	1	88.4	87.9	5.6	927
003939	-11	1	88.4	88.4	5.6	923
003940	-16	-1	88.3	88.4	5.6	919
003941	-18	-2	88.2	88.8	5.6	914
003942	-16	-2	88.2	88.8	5.6	910
003943	-15	-3	88.1	88.8	5.6	906
003944	-13	-3	88.0	89.2	5.6	902
003945	-11	-4	87.9	89.5	5.6	897
003946	-8	-5	87.9	89.6	5.6	893
003947	-5	-5	87.8	89.6	5.6	889
003948	-2	-6	87.6	89.6	5.6	885
003949	3	-6	87.4	89.8	5.6	881
003950	6	-6	87.3	89.8	5.6	877
003951	9	-6	87.2	89.8	5.6	873
003952	9	-6	87.1	90.0	5.6	869
003953	10	-6	87.0	90.1	5.6	865
003954	16	-6	86.9	90.1	5.6	861
003955	17	-6	86.7	90.2	5.6	857
003956	17	-6	86.6	90.2	5.6	853
003957	17	-6	86.5	90.2	5.6	849
003958	17	-6	86.5	90.1	5.6	844
003959	17	-6	86.4	90.0	5.5	840
004000	17	-6	86.4	89.9	5.5	836
004001	17	-6	86.3	89.7	5.5	832
004002	21	-5	86.1	89.5	5.5	828
004003	25	-5	86.1	88.8	5.5	824
004004	25	-4	86.1	88.8	5.5	820
004005	25	-4	86.0	88.8	5.5	816
004006	25	-4	86.0	87.9	5.4	812
004007	24	-4	85.9	87.0	5.3	808
004008	21	-3	85.9	87.0	5.3	805
004009	17	-3	85.9	87.0	5.3	802
004010	19	-3	85.8	87.1	5.3	798
004011	23	-2	85.8	87.2	5.3	791
004012	23	-2	85.8	87.2	5.3	787
004013	23	-2	85.8	87.2	5.3	783
004014	23	-2	85.8	87.1	5.3	779
004015	23	-1	85.7	87.0	5.3	775
004016	17	-1	85.7	87.0	5.3	771
004017	15	-1	85.7	86.8	5.3	766
004018	15	-1	85.7	86.8	5.3	762
004019	14	-1	85.6	86.8	5.3	758
004020	14	-1	85.6	86.6	5.3	754
004021	14	-1	85.6	86.3	5.3	750
004022	14	-1	85.6	86.3	5.3	746
004023	14	-1	85.6	86.3	5.3	741
004024	13	-1	85.6	86.3	5.3	737
004025	7	-1	85.5	86.2	5.3	733
004026	4	-1	85.5	86.2	5.3	729
004027	2	-2	85.5	86.2	5.3	725
004028	1	-2	85.5	86.4	5.3	721
004029	0	-2	85.4	86.5	5.3	717
004030	-4	-2	85.3	86.5	5.3	712
004031	-6	-3	85.2	86.6	5.3	708
004032	-8	-3	85.2	86.6	5.3	704
004033	-9	-3	85.1	86.6	5.3	700
004034	-9	-4	85.0	86.7	5.3	696

004035	-9	-4	84.9	86.7	5.3	692
004036	-9	-5	84.9	86.8	5.3	688
004037	-8	-5	84.8	86.8	5.3	683
004038	-5	-6	84.6	86.8	5.3	679
004039	0	-6	84.4	87.0	5.2	675
004040	4	-6	84.3	87.0	5.2	671
004041	7	-6	84.2	87.0	5.2	667
004042	8	-6	84.1	87.2	5.2	663
004043	10	-7	84.0	87.4	5.2	659
004044	16	-7	83.9	87.4	5.2	655
004045	17	-7	83.7	87.7	5.2	651
004046	20	-7	83.6	87.7	5.2	647
004047	22	-7	83.5	87.7	5.2	643
004048	24	-7	83.4	87.8	5.2	639
004049	25	-7	83.3	87.8	5.2	635
004050	26	-7	83.2	87.8	5.2	630
004051	27	-7	83.1	87.7	5.2	626
004052	32	-7	83.0	87.7	5.2	622
004053	34	-6	82.8	87.2	5.2	618
004054	35	-6	82.8	87.2	5.2	614
004055	35	-6	82.7	87.2	5.2	610
004056	35	-6	82.7	86.9	5.2	606
004057	35	-6	82.6	86.7	5.2	603
004058	35	-6	82.6	86.4	5.2	600
004059	35	-5	82.6	86.4	5.2	597
004100	35	-5	82.5	86.4	5.2	594
004101	35	-5	82.4	86.0	5.2	587
004102	35	-4	82.3	85.8	5.1	583
004103	35	-4	82.3	85.8	5.1	579
004104	35	-3	82.2	85.8	5.1	575
004105	35	-3	82.2	85.6	5.1	571
004106	35	-3	82.2	85.3	5.1	568
004107	35	-3	82.1	85.3	5.1	564
004108	35	-2	82.1	84.9	5.1	560
004109	35	-2	82.1	84.9	5.1	557
004110	35	-2	82.1	84.9	5.1	553
004111	35	-2	82.1	84.5	5.1	549
004112	35	-2	82.0	84.1	5.1	545
004113	35	-1	82.0	84.1	5.1	541
004114	35	-1	82.0	84.1	5.1	536
004115	35	-1	82.0	83.7	5.1	532
004116	35	-1	82.0	83.4	5.1	528
004117	35	-1	82.0	83.4	5.1	524
004118	35	0	82.0	83.4	5.1	520
004119	35	0	82.0	83.3	5.1	516
004120	35	0	82.0	83.2	5.1	513
004121	35	1	82.1	83.2	5.1	509
004122	35	1	82.1	83.1	5.0	505
004123	34	1	82.1	83.1	5.0	501
004124	33	1	82.1	83.1	5.0	496
004125	31	1	82.2	83.1	5.0	492
004126	28	1	82.2	83.1	5.0	488
004127	26	1	82.2	83.0	5.0	484
004128	24	1	82.2	82.8	5.0	481
004129	25	1	82.2	82.8	5.0	476
004130	25	2	82.3	82.5	5.0	472
004131	27	2	82.3	82.5	5.0	468
004132	29	2	82.3	82.5	5.0	464
004133	31	2	82.4	82.4	5.0	460
004134	33	2	82.4	82.3	5.0	456
004135	35	2	82.5	82.3	5.0	452
004136	35	3	82.6	82.4	5.0	448
004137	35	3	82.6	82.5	5.0	444
004138	35	3	82.6	82.5	5.0	440
004139	34	3	82.7	82.5	5.0	436
004140	33	3	82.7	82.5	5.0	432
004141	30	3	82.8	82.5	5.0	427
004142	26	3	82.8	82.5	5.0	423
004143	22	3	82.9	82.5	5.0	419
004144	18	3	83.0	82.2	5.0	415
004145	17	3	83.1	82.2	5.0	411
004146	15	3	83.1	82.2	5.0	406
004147	15	3	83.2	82.0	5.0	402
004148	14	3	83.2	81.8	5.0	398
004149	15	3	83.2	81.8	5.0	394
004150	15	3	83.2	81.8	5.0	390
004151	19	3	83.3	81.8	5.0	387
004152	19	3	83.4	82.0	5.0	383
004153	19	3	83.5	82.0	5.0	379
004154	19	3	83.5	82.0	5.0	375
004155	19	3	83.6	82.3	5.0	371
004156	19	3	83.6	82.5	5.0	367
004157	19	3	83.7	82.5	5.0	363
004158	16	3	83.8	82.7	5.0	360
004159	14	3	83.9	82.7	5.0	355
004200	11	3	83.9	82.7	5.0	351
004201	10	3	83.9	82.7	5.0	347
004202	10	3	83.9	82.6	5.0	343
004203	10	3	84.0	82.6	5.0	339
004204	10	3	84.0	82.5	5.0	335
004205	6	3	84.1	82.5	5.0	331
004206	1	3	84.1	82.4	5.0	327
004207	2	3	84.2	82.4	5.0	323
004208	4	3	84.2	82.4	5.0	319
004209	4	2	84.3	82.5	5.0	315
004210	4	2	84.3	82.6	4.9	311

004211	10	2	84.3	82.6	4.9	307
004212	14	2	84.4	83.0	4.9	303
004213	17	2	84.4	83.0	4.9	299
004214	20	2	84.4	83.0	4.9	294
004215	22	2	84.5	83.2	4.9	290
004216	23	2	84.5	83.3	4.9	286
004217	26	2	84.6	83.5	4.9	282
004218	29	2	84.6	83.6	4.9	278
004219	30	3	84.6	83.6	4.9	274
004220	30	3	84.7	83.5	4.9	270
004221	30	3	84.8	83.5	4.9	266
004222	30	3	84.8	83.5	4.9	262
004223	30	3	84.9	83.3	4.9	257
004224	30	4	84.9	83.0	4.9	253
004225	30	4	85.1	83.0	4.9	249
004226	30	4	85.2	83.0	4.9	246
004227	30	4	85.2	82.9	4.9	244
004228	30	5	85.3	82.8	4.9	237
004229	30	5	85.4	82.8	4.9	233
004230	30	5	85.5	82.8	4.9	229
004231	27	6	85.6	82.8	4.9	225
004232	23	6	85.7	82.8	4.9	221
004233	22	6	85.9	82.8	4.9	217
004234	22	6	86.0	82.7	4.9	212
004235	22	7	86.2	82.7	4.9	204
004236	24	7	86.3	82.6	4.9	200
004237	26	7	86.4	82.5	4.9	196
004238	27	7	86.5	82.5	4.9	192
004239	27	7	86.6	82.5	4.9	188
004240	26	8	86.9	82.5	4.9	184
004241	22	9	87.1	82.4	4.9	179
004242	22	9	87.2	82.4	4.9	175
004243	22	9	87.3	82.4	4.9	171
004244	25	9	87.5	82.4	4.9	167
004245	28	9	87.6	82.4	4.9	163
004246	35	10	87.9	82.4	4.9	159
004247	35	11	88.2	82.4	4.9	154
004248	35	11	88.4	82.4	4.9	150
004249	35	11	88.6	82.4	4.9	145
004250	35	11	88.7	82.5	4.9	141
004251	35	12	88.8	82.5	4.9	137
004252	35	12	89.0	82.5	4.9	133
004253	35	12	89.2	82.5	4.9	129
004254	35	13	89.6	82.5	4.9	125
004255	35	13	89.9	82.4	4.9	120
004256	35	13	90.1	82.4	4.9	116
004257	35	14	90.3	82.4	4.9	112
004258	35	14	90.6	82.3	4.9	108
004259	35	15	90.8	82.2	4.8	104
004300	35	15	91.2	82.2	4.8	100
004301	35	16	91.6	82.2	4.8	96
004302	35	16	91.9	82.3	4.8	92
004303	35	17	92.1	82.4	4.8	88
004304	33	17	92.4	82.4	4.8	84
004305	32	17	92.6	82.4	4.8	80
004306	29	17	92.9	82.6	4.8	76
004307	26	18	93.1	82.7	4.8	72
004308	24	18	93.5	82.7	4.8	68
004309	20	18	94.0	83.2	4.8	64
004310	17	18	94.3	83.2	4.8	60
004311	15	18	94.5	83.2	4.8	56
004312	14	18	94.8	83.5	4.8	52
004313	13	18	95.0	83.8	4.8	48
004314	11	18	95.3	83.8	4.8	46
004315	9	18	95.5	83.8	4.8	43
004316	7	18	96.0	84.1	4.8	39
004317	3	18	96.4	84.1	4.8	33
004318	2	19	96.7	84.7	4.8	29
004319	1	19	96.9	85.3	4.8	26
004320	0	21	97.3	85.7	4.8	23
004321	-2	22	97.7	86.1	4.8	21
004322	-6	23	98.4	86.1	4.8	20
004323	-9	23	99.0	87.2	4.7	20
004324	-11	23	99.3	87.2	4.7	19
004325	-13	23	99.5	87.2	4.7	20
004326	-14	22	99.8	88.2	4.6	23
004327	-15	21	100.0	89.1	4.5	24
004328	-17	20	100.2	89.1	4.5	25
004329	-19	19	100.4	89.0	4.5	28
004330	-21	18	100.8	89.0	4.5	30
004331	-16	16	101.1	88.2	4.4	33
004332	-15	16	101.3	88.2	4.4	36
004333	-13	16	101.5	88.2	4.4	40
004334	-10	17	101.9	88.9	4.4	43
004335	-7	19	102.2	89.6	4.3	46
004336	-3	19	102.7	89.6	4.3	49
004337	-3	21	103.5	91.2	4.3	53
004338	-3	21	103.8	91.2	4.3	56
004339	-3	21	104.0	91.2	4.3	60
004340	-5	21	104.3	93.7	4.2	63
004341	-6	20	104.5	96.1	4.0	66
004342	-8	20	104.7	96.5	4.0	69
004343	-10	19	104.9	96.9	4.0	71
004344	-10	18	105	96.9	4.0	74
004345	-11	15	106	96.7	3.9	77
004346	-11	15	106	96.7	3.9	80

Legend:

CET = Central European Time, RUD = Rudder Angle (port), ROT = Rate of Turn/min (port), COG = Course Over Ground, SOG = Speed Over Ground, DIST = Distance (bow/bow in metres between the NATIONAL GLORY and MALAGA); source: VDR on the NATIONAL GLORY, data rounded for presentation and if necessary interpolated, Federal Waterways Engineering and Research Institute, Hamburg Department

After analysing the tables and animation, the BSU has decided not to commission further hydrodynamic studies, e.g. at shipbuilding research institutes. The BSU is of the view that on the MALAGA and the NATIONAL GLORY no manoeuvring errors were made by the crews, the pilots or the canal helmsmen. With regard to the rudder angles, it is important to remember that the canal pilots generally issue course commands in 1-5° increments. This is something that the canal helmsmen adapt to. If the desired direction of turn is not effected by any change, then the only option is to respond with full rudder angles and possibly increases in speed.

3.4 Meeting at the Lotsenbrüderschaft NOK II (Brotherhood of NOK II Pilots [sic]) / Kiel / Lübeck / Flensburg on 26 May 2011 between the pilots involved, WSV and BSU

Using the animation, it was possible to demonstrate at the meeting on the lock island that the bank effect in the bend at Projensdorf was the determining factor in the collision between the MALAGA and NATIONAL GLORY. It was not possible for the NATIONAL GLORY to develop a rate of turn (ROT) sufficient enough to avoid the collision.

In the opinion of a pilot and the representatives of the Waterways and Shipping Directorate North as well as the Waterways and Shipping Office Kiel-Holtenau, the NATIONAL GLORY's insufficient rate of turn could have been intensified at any time with a short engine manoeuvre. The NATIONAL GLORY is said to have constantly proceeded at the lowest rate of speed. When manoeuvring in tight spaces (and also during encounters) on the NOK, it is very common to enhance the effect of the rudder with engine manoeuvres. This is also conveyed to trainee pilots and free-running vessels. A brief increase in the revolutions of the main engine would have led to a higher rate of turn. The vessel's speed is likely to have increased slightly, but would have remained at an acceptable level.

Without the presence of the MALAGA, a passage north of the track of the BALTICBORG sailing ahead would have been possible. The rate of turn that had developed would also have been sufficient to pass the gas tanker GAS CRYSTAL, which was moored at the dolphins in Nordhafen. The GAS CRYSTAL was about 330 metres in front of the signal mast. At this point, the dredged channel is 135 m wide and has a depth of 11 m.

According to the testimony of the pilots, it was originally intended that the SANDY RICKMERS would remain behind the GAS CRYSTAL, and the MALAGA behind the SANDY RICKMERS. After consultation with his colleague the pilot of the MALAGA started to overtake the SANDY RICKMERS in the siding, but abandoned his plan when the SANDY RICKMERS was unable to keep her position behind the GAS CRYSTAL. There were problems on the SANDY RICKMERS. The bow thruster was not available in time and the pilot only had about 10 engine starts at his disposal on the slow-moving vessel. When the SANDY RICKMERS veered off of the row of dolphins, the pilot decided to pass the GAS CRYSTAL and sail through the stop signal. An astern manoeuvre or dropping anchor could have resulted in the SANDY RICKMERS turning transverse into the canal and impeding the upcoming traffic. The starting-air of the main engine might not have been sufficient. Moreover there was a risk of the stern moving between the dolphins. Therefore the ability to manoeuvre had to be maintained by taking into account minmal stop and start manoeuvres.
The MALAGA passed the GAS CRYSTAL due to her aborted overtaking manoeuvre and waited between the dolphins and the signal mast to allow the passage of the BALTICBORG and NATIONAL GLORY.

As regards assessing the risk of this sequence of events, different factors come together, which ultimately led to the collision. Three vessels of traffic group 5 and one of traffic group 3 were operating in a confined space. A traffic group 4 gas tanker was moored at the dolphins in Nordhafen. According to the planning and the distance/time graph of the Vessel Traffic Service (VTS), an encounter should not have taken place between the sidings at Schwartenbek and Kiel-Holtenau. The last traffic situation report before the collision was transmitted at 0020. After that, the VTS did not report again until after the collision at 0044. During this period, organisation in the inner harbour and Nordhafen was left to the pilots. The VTS was neither informed about the intentions of the pilots nor the problems on the SANDY RICKMERS and therefore was unable to intervene in time.

The SeeSchStrO requires the notification of deviations to the traffic planning and any problems, delays, stops, etc. Measures by the navigational authorities must be resolutely implemented. Procedural instructions are already in place and updated on an ongoing basis. Tugs are permanently stationed at the ends of the NOK in Brunsbüttel and Kiel-Holtenau; in the middle of the NOK smaller tugs are available in the area of Rendsburg to both the WSV and local shipyards for emergencies. The latter must be manned with personnel if needed. Mooring services are available in the ports of Brunsbüttel, Rendsburg and Kiel; if required, vessels are made fast by the crews on the dolphin rows in the sidings, where a mooring service is not available.

To minimise the permanent risk of collision in the very confined spaces on the NOK, vessels are divided into traffic groups. The traffic signals in the sidings are switched according to this system, which has been in operation for some 40 years. First in/first out (FIFO) applies in principle. This means that the NOK can be transited in both directions in about 8 hours. Waiting times can be controlled only in the sidings, where dolphin rows are in place to facilitate such periods. They do not serve as fixed berthing facilities. While mooring facilities exist, there is no organised mooring

service. The options for action in unusual events are very limited. The whole of the canal is monitored by AIS. Radar monitoring is installed at the locks.

Over the last 40 years, vessel sizes have changed dramatically and hydrodynamic forces are increasing concomitantly (longitudinal/transverse forces and yaw-moments). These forces are caused by hydrodynamic actions (vessel/vessel, vessel/bank). If the rudder moments of a vessel are not sufficient, then the planned track cannot be maintained. A rate of turn of 10°/min, depending on the selected radius, has to be developed in many of the canal bends in order to pass through them. The VTS does not have so-called ship domains with comprehensive information like turning circle, navigation equipment, propulsion and rudder on hand. Vessels are currently recorded only in traffic groups, which are based solely on length, breadth and draught.

The performance of a risk analysis has reportedly already been discussed by the WSV. The catalyst for these considerations is the sharp rise in the size of vessels operating on the NOK. The introduction of ship domains is part of this discussion process. Here, extensive bases for the determination of these domains need to be developed, however. The concept of basing traffic control and at the same time the permissible encounter options on a planned development of ship domains, or at least to use this to assist the process, can certainly be useful in the future.

The pilots have internal information at their disposal. They also share this knowledge with each other orally. They are aware of the physical effects experienced on the canal, as are the canal helmsmen. Due to the FIFO system, they must accept the traffic situation as they find it and can only organise and coordinate independently in the NOK. Sometimes the simplest equipment is missing, such as an absent analogue 10 degree dial on the compass display. Even better would be a real time rate of turn/min (ROT) indicator. Neither the VTS nor the pilots have any control over a vessel's equipment. Therefore, prior information about this is all the more important.

The traffic group system is very generalised and applies to all situations. With respect to particular situations, the VTS has little opportunity to intervene in the planning. As the discussion has shown, in the case of this accident all the actions taken were legally defensible. This even includes passing through stop signals if doing so is required from a nautical perspective. However, this increases – and accepts – the risk of accidents. In the short-term, these situations can be defused only if the safety barriers are raised. For example, the gas tanker could have been instructed by the VTS to leave her mooring at the dolphins and possibly directed to the roads at Holtenau outside the NOK.

At the same time, it must be remembered that the berth possibly represents a lower risk than continuing the voyage with partially inoperable radar systems, such as on the GAS CRYSTAL. In an age of older radar systems, the siding areas of the NOK have reportedly been used all the time for laying up in fog or at night. An instruction by the VTS to move to another berth or turn in the NOK and return to the lock was reportedly always associated with higher risks than mooring at the row of dolphins in Nordhafen. Mooring at the beginning of the row of dolphins would possibly have been

somewhat more favourable because this would have meant that the entire width was available in the area at the end of the Nordhafen siding.

In this respect, raising the awareness of the advising pilots on the Kiel Firth, who guide vessels to the locks of the NOK, could lead to vessels that are expected to experience difficulties owing to their equipment, e.g. while proceeding in fog, possibly being taken to the roads in Kiel Firth rather than the locks. This could be achieved with a recommendation of the pilot to the ship's command. If this recommendation is not complied with, then the VTS can be contacted at any time with a request for an official decision on entering the NOK following an explanation of the facts. Reportedly, this is also the norm for derogations from the requirements of art. 42 SeeSchStrO for transiting the NOK.

In fog, traffic could be reduced and traffic between the sidings only allowed in one direction. In view of the efficiency of the maritime traffic, ship domains would be essential for the nautical supervisor in the long-term in order to be able to respond flexibly, e.g. to fog, via a more differentiated basis for decision making at as early as the planning stage. The BISS database of the BSH contains vessel particulars from German operators, which also include navigation equipment.

Measures to raise the safety barriers, especially in fog, could also be modifications to the encounter options of shipping. If necessary, this could be limited to the stretches affected by fog as experience shows that fog generally occurs sporadically on the NOK. The NOK is reportedly rarely affected by fog along its entire length. A reduction in shipping is reportedly critical since a build-up of vessels could occur in the areas adjacent to the NOK (Kiel Firth and the Elbe), which could lead to heightened risk there. Subsequently, the dispersal of a build-up of vessels on the Elbe or Kiel Firth would, in turn, lead to an increased burden on the NOK (both in the locks and along the route of the canal) with corresponding risks for the shipping in tight manoeuvring spaces. Furthermore, significant delays due to waiting times could be expected together with the implications of that for the NOK.

Distance/time graph of the VTS

The graph shows the NATIONAL GLORY/SANDY RICKMERS and NATIONAL GLORY/MALAGA encounters at 0040 and 0044 between the sidings at Kiel and Schwartenbek outlined in red. The graph is based on AIS and is available to the VTS more or less in real time. Therefore, it was informed about encounters between sidings that did not conform to the standards. It did not step in during the sequence of events in the Kiel siding and only took action after the collision. The GAS CRYSTAL is not shown.

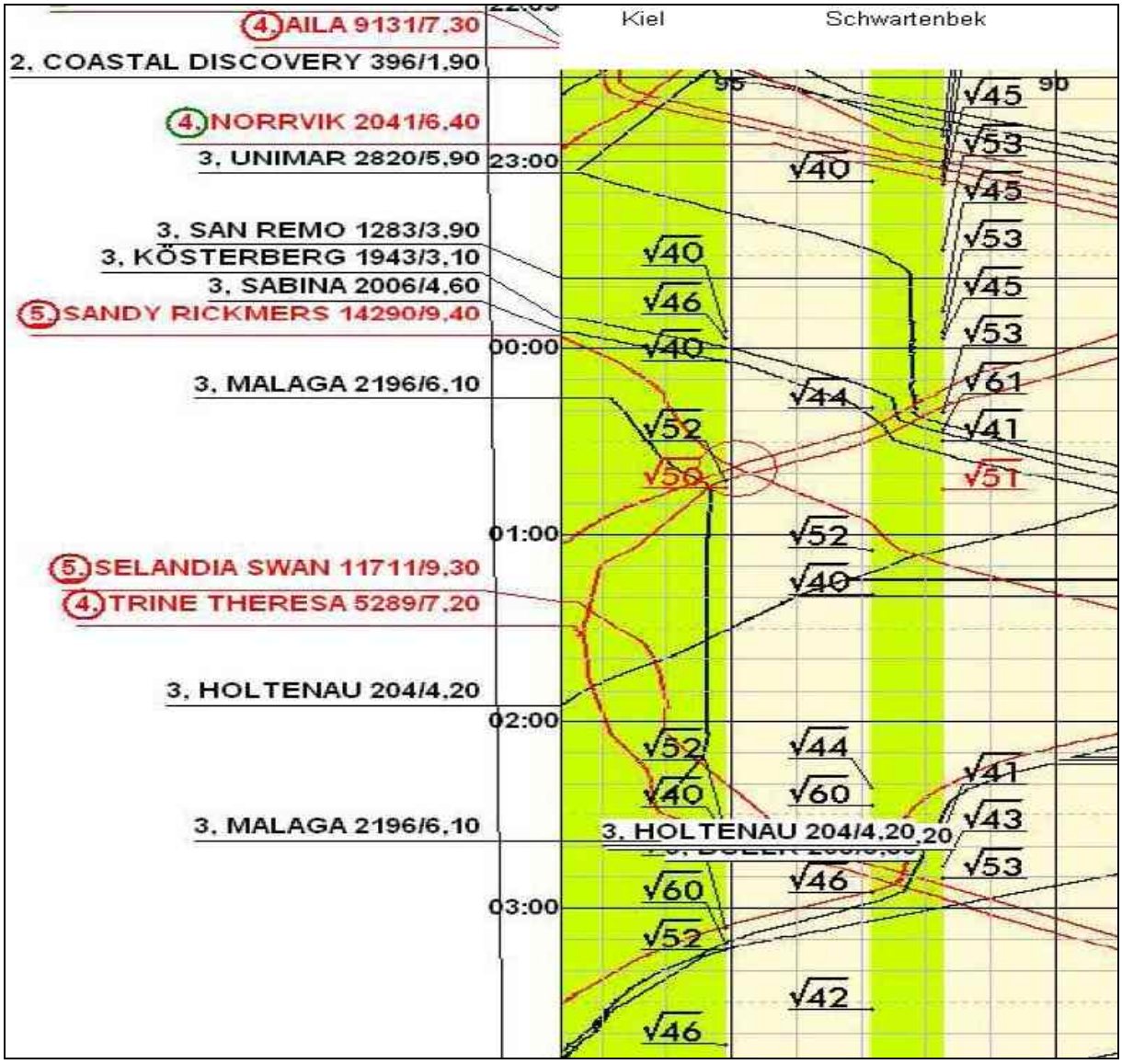

Figure 34: Excerpt from the distance/time graph

The rows in the graph denote the times in increments of 10 minutes and the columns the distance in increments of 1 km. The sidings can be seen on the green bars. The even numbers denote the signals for westbound traffic heading for Brunsbüttel and the odd numbers the signals for eastbound traffic heading for Kiel. Signals 40 and 41 mean it is prohibited to set sail; the boundary of the siding area may not be crossed by vessels of traffic group 2 and higher. Signals 50 and 51 mean it is prohibited to set sail; the boundary of the siding area may not be crossed by any vessel. Signals 52 and 53 mean set sail for all vessels. The other signals provide additional subdivisions according to traffic group. The signals are program-controlled. Traffic groups > 3 are identifiable by the circled numbers. The name of the vessel, GT and draught are next to them.

4 CONCLUSIONS

The accident is attributable to several factors, which were not detected and dealt with by the VTS or the pilots involved in due time. The collision between the NATIONAL GLORY and MALAGA was the outcome of the problems encountered.

To begin with, there was fog with visibility of less than 100 m. The gas tanker GAS CRYSTAL was moored at the front of the row of dolphins, just 330 m away from the signal mast, in her waiting position. Thus, until the traffic that was following could proceed, it was compelled to wait behind the gas tanker. Moreover, all the traffic had less room to navigate the bend at Projensdorf in both directions in a specified radius. Here, the tracks and the specified distance/time graph must be strictly adhered to so that traffic can be kept fluid. If problems occur during implementation of the planning, then the sidings should serve as buffers.

No readily available tug and mooring service is in place in the sidings. Hence, the GAS CRYSTAL was laid up at the dolphins with anchor and stern rope for the whole night because of problems with the navigation equipment and visibility. During this period, the ever-present risk of collisions in the very confined spaces on the NOK was increased further. Here, the VTS should have reacted, especially since an additional risk factor was posed by the fog. It should have instructed the GAS CRYSTAL to leave her berth, possibly with tug assistance, and either make fast further to the east on the row of dolphins or leave the NOK again via the locks in order to move to an anchorage.

According to the traffic planning, which was last transmitted to shipping on VHF at 0020, the SANDY RICKMERS (VG 5) and the MALAGA (VG 3) should have waited behind the GAS CRYSTAL (VG 4) as per the FIFO principle until the oncoming traffic, the BALTICBORG (VG 5) and the NATIONAL GLORY (VG 5), had passed in the Kiel-Holtenau Nordhafen siding. It was not possible for the pilots of the SANDY RICKMERS and the MALAGA to adhere to this planning. According to the arrangements made between the two pilots, the MALAGA intended to overtake the SANDY RICKMERS while still in the siding to achieve a faster passage through the NOK as VG5 vessel encounters are not permitted between the sidings. This plan was discarded due to problems in switching over the bow thruster on the SANDY RICKMERS. In the process, the SANDY RICKMERS veered out from her waiting position behind the GAS CRYSTAL towards the middle of the canal and the pilot decided to sail past the GAS CRYSTAL. After that, the 330 m to the signal mast was no longer sufficient to keep the SANDY RICKMERS in a waiting position at the row of dolphins. The pilot announced to the oncoming traffic that he was getting under way even though it was still prohibited to set sail.

The MALAGA had already built-up too much speed to stop behind the GAS CRYSTAL.

She passed between the vessels GAS CRYSTAL and BALTICBORG and waited for the oncoming traffic on the right-hand side of the fairway in front of the signal mast. The VTS was not informed about the intentions and problems on board the two vessels in the sidings. While the SANDY RICKMERS informed the BALTICBORG and NATIONAL GLORY, that she was coming up, the MALAGA remained silent. She did not announce that she intended to first pass the GAS CHRYSTAL and then wait in front of the stop signal in the siding. It would also have been too late to make organisational interventions, though the distance/time graph displays the vessels fitted with AIS almost in real-time. The time window from 0018, when the SANDY RICKMERS veered out, to 0035, when the SANDY RICKMERS left the siding, was too short to intervene and provide support. Even if the pilots had informed the VTS about their problems, there would have been no room for action. An immediate tug and mooring service was not available. The oncoming traffic was already under way and could no longer be stopped. The NATIONAL GLORY left the Schwartenbek siding at 0029.

At 0035 and 0040, the SANDY RICKMERS passed the oncoming traffic in the bend between the signal mast of the siding and the bunkering bridge at Projensdorf. While these passing manoeuvres unfolded smoothly with due care and the knowledge the pilots and canal helmsmen have regarding hydrodynamic effects, the NATIONAL GLORY was unable to maintain her planned track in the bend up to the collision at 0044. Despite starboard rudder angles, she turned across the middle of the canal and struck the MALAGA on the bow and superstructure at the end of the canal bend. The echo on the radar screen parted from the merged echo with the GAS CRYSTAL just shortly before that at 0042. It is possible that the pilot on the NATIONAL GLORY expected the MALAGA to wait behind the GAS CRYSTAL. However, the BSU considers that overall this had no influence on her manoeuvring on the required track. At 20°/min, the rate of turn that had developed by 0044 would have been sufficient to pass the GAS CRYSTAL without the presence of the MALAGA.

When the SANDY RICKMERS was unable to maintain her waiting position due to the fact that the GAS CHRYSTAL veered uncontrollable the decision was made to deviate from the initial planning. The pilots reacted to the new situation by the manoeuvres described in the report. As regards the pilot advice it should be noted that the helm commands of the pilots are generally issued in 1-5° increments. Here, depending on the manoeuvring behaviour of the vessel, the radar system's variable range ring is set at 0.25-0.35 nm. This is a measure used by the pilots to keep to the radius of the bend. Here, the accuracy of the distance measurement needs to be considered. According to the performance standards, radar systems must demonstrate precision of ≤ 30 m. Other aids include the rate of turn of the repeater compass dial, which in cases is graduated in tenths of a degree, or an analogue rate of turn indicator. At any event, depending on the planned track and selected radius, a rate of turn of 10°/min must be maintained in the bend at Projensdorf to sail through the bend..At the same time, rudder moments and drift angle must be sufficient for counteracting vessel/vessel and vessel/bank hydrodynamic effects. In the case of the NATIONAL GLORY, the bank effect was greater than the manoeuvre made to compensate for it.

The representatives of the Waterways and Shipping Directorate North and the Waterways and Shipping Office Kiel-Holtenau as well as the operator of the SANDY RICKMERS are of the opinion that the collision could have been avoided had the NATIONAL GLORY manoeuvred in a better way. An appraisal of this thesis would have required extensive hydrographic examinations. However, the findings resulting from that would only apply to this single case. The BSU had refrained from this since no other behaviour pattern of the pilots, canal helmsmen and watch officers are to be expected for the Kiel Canal. The BSU could not determine crucial manoeuvre errors of the involved pilots, canal helmsmen and crews.

Although the NOK pilots and helmsmen are highly qualified and have a profound knowledge of the operating area, navigating on precise tracks is something that cannot be expected in all circumstances. The international convention for the safety of life at sea, SOLAS, prescribes minimum standards for the equipment of vessels. This is outside the control of the VTS and pilots. They have to cope with conditions as they find them. Here, NOK pilots complain about the fact that important tools like an analogue gyro compass dial with 10-degree graduation and a rate of turn indicator are absent, for example. Precision inadequate for their tasks in terms of distance measurement and a lack of information about the manoeuvring behaviour from the masters they are advising are additional factors. The VTS does not possess such information, either. Given these shortcomings and in conjunction with the total traffic of 16,501 vessels in the first six months of 2011 as well as the increasing size of the vessels that transit the NOK, the BSU considers that management of the NOK must be improved by localised measures in order to reduce the risk of collision.

Classification to traffic groups, which only take the length, breadth and draught into account, is not enough. It must also address determinants such as hydrodynamics, the weather as well as the manoeuvring behaviour and equipment of vessels in order for tracks to be maintained. The VTS, pilots and canal helmsmen are dependent on such information in advance.

Pilots on German operating areas and in many other countries are already being equipped with mobile information systems, so-called portable pilot units (PPU). Amongst other things, the PPU is able to display vessel positions in the official ECDIS S-57 format, current sounding data and other information specific to the area of operation. These information systems need to be continuously enhanced to meet the particular needs of the pilots. Vessel-specific parameters, which include human and physical factors, can be developed in so-called ship domains, which go back to Toyoda / Fuji and Goodwin[6]. For the NOK in particular, the experience of pilots, hydrodynamic canal effects, weather conditions, navigation equipment, manoeuvring aids (e.g. rudder type and bow thruster) should be included in the pool of data. Next to GPS and AIS, rates of turn and distances with accuracy < 10 m to the bank and vessels could also be displayed. As regards sensor data, it is important to remember that this conforms to the performance requirements for navigation equipment at minimum and should have a high level of reliability with probability of at least 95%.

[6] See Seiji Toyoda/Yahei Fuji, Journal of Navigation, 1971, Vol. 24 No. 1, Marine Traffic Engineering Elisabeth M. Goodwin, Journal of Navigation,1975, Vol. 28, No. 3 A Statistical Study of Ship Domains

5 SAFETY RECOMMENDATIONS

5.1 Waterways and Shipping Directorate North, Waterways and Shipping Offices Kiel-Holtenau and Brunsbüttel

The BSU recommends that a risk analysis on the space requirement of shipping on the Kiel Canal to be conducted to reduce the risk of collision and that the system of traffic groups be overhauled with due regard to ship domains. The ship domains should include human and physical factors such as the experience of pilots, hydrodynamic canal effects, weather conditions, navigation equipment and manoeuvring aids (e.g. type of propulsion and rudder, bow thruster).

Information from the ship domains should be made accessible to pilots and the Vessel Traffic Service via the introduction of a mobile information system, the so-called portable pilot unit (PPU). Next to the electronic chart system, sounding plans, GPS and AIS, it should also be possible to display rates of turn/min and distances with accuracy < 10 m to the bank as well as vessels.

Based on the experience gained regarding accidents in fog, safety barriers should be raised in the short-term, e.g. by revising the provisions for prohibiting encounters in the SeeSchStrO.

6 SOURCES

- Investigations by Waterway Police (WSP) Kiel, Brunsbüttel, and the BSU

- Written statements
  - Shipping companies, Ship's commands, pilots
  - Waterways and Shipping Directorate North (WSD-N) and Waterways and Shipping Office Kiel-Holtenau

- Testimony of the crews

- Technical paper
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