Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Bundesoberbehörde im Geschäftsbereich des Bundesministeriums
für Verkehr, Bau und Stadtentwicklung

## Investigation Report 45/04

**Very Serious Marine Casualty**

# Collision between CMV COSCO HAMBURG and CMV P&O NEDLLOYD FINLAND on 01 March 2004 on the Lower Elbe/off Buoy 91 with the Death of one Seaman

1 February 2006

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.

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

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

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# 1 Summary of the marine casualty

On 1 March 2004 at about 14.40 h CET[1] the Container Vessel P&O NEDLLOYD FINLAND[2] under German flag proceeding upstream on the river Elbe, bound for Hamburg, collided on the lower Elbe with the large Container Vessel COSCO HAMBURG also bound for Hamburg and sailing under the flag of the Hong Kong Special Administrative Region. COSCO HAMBURG had beforehand almost completely overtaken NEDLLOYD FINLAND that was working in feeder service, under good weather and visibility and its stern was just passing the fore ship area of the feeder vessel, when the latter suddenly lost its steerability on the basis of hydrodynamic interactions (suction effect) and turned very quickly with its bow towards the aft ship of COSCO HAMBURG. There was violent contact between the two vessels, both under pilot advice, in the said area. As a consequence of the impact NEDLLOYD FINLAND temporarily developed a list of between 30 and 40°. This led to several partly already unlashed containers on board the vessel being ripped out of their anchorages. One container went over board. However, both vessels remained afloat and were able to continue their voyage under their own power with damage above the water line in each case.

A short time after the collision a Philippine able bodied seaman[3] on board NEDLLOYD FINLAND was missed. At the time of the collision the seaman had been engaged in unlashing the containers on deck and must have lost his hold when NEDLLOYD FINLAND heeled over strongly as a result of the collision. The Captain issued a missing person notice at 14.53 h on VHF Channel 68. At the same time he initiated a person-over-board[4] manoeuvre. In addition several vessels belonging to public authorities (Waterway Police and Waterways and Shipping Directorate[5]) nearby participated in the search. At 15.36 h the unconscious seaman was recovered by the Sounding Vessel NIEDERELBE[6] between buoys 88 and 90 and subsequently brought ashore. The resuscitation attempts carried out were unsuccessful. At 16.02 h the rescue forces reported that the person had died.

The 40-foot container that went over board and was drifting towards Glückstadt with the ebb stream was secured by the vessels that had hurried to the scene of the accident and towed to Kollmar. As it did not contain any dangerous cargo and as no fuels or other oils and lubricants had spilled out during the collision of the vessels, the environment was not impaired by the marine casualty.

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[1] CET=Local Time=UTC+1h; this suffix is not repeated in the following.

[2] Hereinafter referred to briefly as "NEDLLOYD FINLAND“

[3] Able bodied seaman - this function designation is abrieviated in the following to "seaman"

[4] Correct designation for the traditional formulation "Man over board".

[5] Abbreviated to WSV

[6] Sounding vessel in the service of the Waterways and Shipping Office (WSA) Hamburg

## 2 Scene of the Accident

Nature of the incident: Very serious marine casualty
Date: 01 March 2004
Time: approx. 14:40 h
Location: Lower Elbe, off Buoy 91
Latitude/Longitude: φ 53°43‘N λ 009°28,4‘E

Section from Sea Chart 3010 Bl. 6 (Edition 2003); BSH

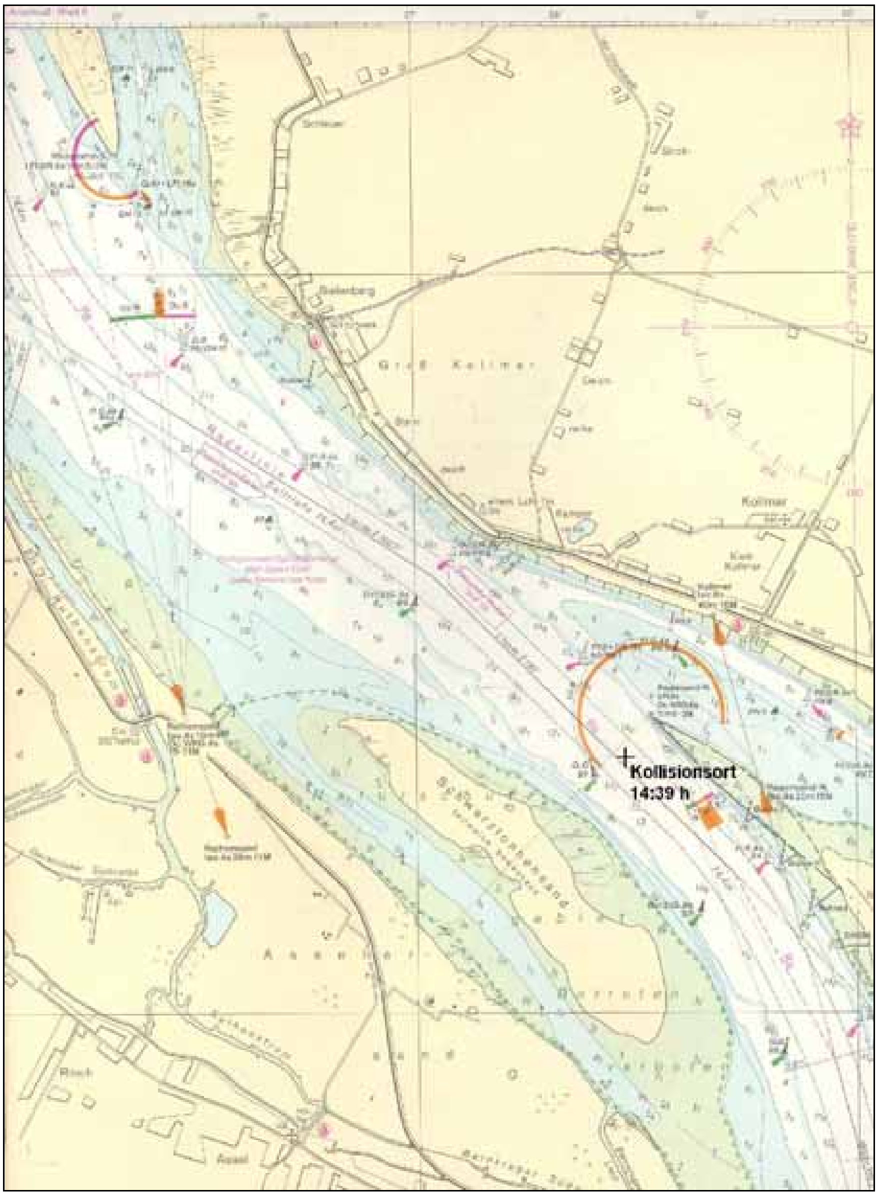

**Figure 1: Scene of the accident**

# 3 Vessel particulars

## 3.1 Photo CMV COSCO HAMBURG

Figure 2: CMV COSCO HAMBURG

## 3.2 Vessel particulars

| | |
|---|---|
| Name of vessel: | COSCO HAMBURG |
| IMO Number: | 9221085 |
| Type of vessel: | Container vessel |
| Nationality, flag | P.R. China, Hong Kong Special Administrative Region |
| Port of registry: | Hong Kong |
| Call sign: | VRXI3 |
| Operator: | COSCO MARITIME (UK) Ltd. |
| Year built: | 2001 |
| Building yard/building number: | KAWASAKI SHIPBUILDING CORPORATION/1503 |
| Classification Society: | American Bureau of Shipping |
| Class: | A1, Container Carrier, Ice Class D0, E, AMS, ACCU, OMBO |
| Length over all: | 280.00 m |
| Width over all: | 39.80 m |
| Max. draft: | 14.03 m |
| Gross tonnage: | 65,531 gt |
| Deadweight: | 69,193 t |
| Engine rating: | 43,716 kW |
| Main engine: | KAWASAKI MAN-B&W/10L90MC |
| Speed: | 24.5 kn |
| Number of crew: | 23 + 1 (Elbe pilot) |

## 3.3 Photo CMV P&O NEDLLOYD FINLAND

Figure 3: CMV P&O NEDLLOYD FINLAND

## 3.4 Vessel particulars

| | |
|---|---|
| Name of vessel: | P&O NEDLLOYD FINLAND |
| IMO Number: | 9129471 |
| Type of vessel: | Container vessel |
| Nationality/Flag | Federal Republic of Germany |
| Port of Registry: | Hamburg |
| Call letters: | DGSV |
| Operator: | MV "VERA" Wilfried Rambow KG |
| Year built/delivery: | 1995/1996 |
| Building yard/building number: | J. J. Sietas KG Schiffswerft GmbH & Co./1123 |
| Classification Society: | Germanischer Lloyd |
| Class: | 100A5 E3 SOLAS II-2-Container Ship, MC E3 AUT |
| Length over all: | 101. 10 m |
| Width over all: | 18. 20 m |
| Max draft: | 6. 55 m |
| Gross tonnage: | 3999 gt |
| Deadweight: | 5207 t |
| Engine rating: | 3825 kW |
| Main engine: | Deutz MWM/TBD 645 L 9 |
| Speed: | 15.5 kn |
| Number of crew: | 10 + 2 (Elbe pilot and passenger) |

# 4 Course of the accident

## 4.1 Voyage of CMV P&O NEDLLOYD FINLAND

NEDLLOYD FINLAND, built at the Sietas Yard, was on a voyage from Kotka, Finland, to Hamburg. The vessel was equipped in accordance with regulations and apart from two slight exceptions had remained without complaints during European Port State Control since it was commissioned.

NEDLLOYD FINLAND is equipped with a left-handed, variable pitch propeller installed in the middle at the stern as propulsion device. The manoeuvring unit consists of a Becker rudder (maximum rudder angle 45°), an automatic pilot (type Raytheon NautoPilot) that was in operation prior to the accident, and a bow thruster (type Jastram BV 60 F).

On the day of the accident the vessel was being navigated in particular with the aid of an electronic chart system (type Transas ECS Navi Sailor 2400), BA-Chart 3267, a GPS receiver (type Magnafox Mx 200), and two radar sets (type Kelvin Hughes Nucleus 5000 T). The radar screens were set to the Relative Motion North up mode on 1.5 sm and 3 sm range (in each case off-center).

At the time of the accident voyage[7] and manoeuvre data recorders were not part of the compulsory equipment for NEDLLOYD FINLAND and were not installed on board.

At the time of the accident the personnel on the bridge consisted of the Captain who was commanding the vessel from the starboard control console of the bridge control stand, the Chief Mate, the Chief Engineer and the Elbe Pilot advising the Captain, who had assumed a position at the port control console of the bridge control stand. In addition a passenger was on the bridge/in the wings. All persons were of German nationality.

### 4.1.1 Description of the course of the voyage by the Captain

In his testimony report submitted to the BSU the Captain described the course of the voyage and the accident as follows:

In the morning of 1 March 2004 the vessel had passed the Kiel Canal. He had taken over the watch from the Chief Mate in the Kiel Canal at about 11.30 h under good weather and visibility conditions. The vessel had left the Brunsbüttel Lock at approx. 13.10 h. The Elbe Pilot had come on board in the lock. The Captain had been able to see COSCO HAMBURG in the distance already on leaving the lock and had been informed by the Vessel Traffic Services (VTS) Brunsbüttel that the container vessel was also on its way to Hamburg. NEDLLOYD FINLAND had proceeded upstream at full speed under pilot advice. At a speed through the water of 15.5 kn and a tidal current running against the vessel of about 3 kn, the speed over ground had been 12.5 kn. Communications with the Vessel Traffic Services had been conducted throughout by the pilot via Channel 68 using the VHF set in the central console. A further VHF set had been uninterruptedly ready for reception on Channel 16.

During the time before the collision there had been only little shipping traffic and hardly any radio communication had been heard. The Captain had noticed that COSCO HAMBURG had come up slowly from aft. Its intention to overtake had been evident, but had not been notified via VHF or by other signals. There had been no

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[7] Schiffsdatenschreiber = Voyage Data Recorder (VDR).

radio communication between the vessels throughout the entire period. In order to facilitate the overtaking manoeuvre he had steered NEDLLOYD FINLAND further to the southern line of buoys[8]. The distance between the vessels had indicated that there would be a normal overtaking manoeuvre.

At about 14.30 h the overtaking manoeuvre had proceeded so far that the stern of COSCO HAMBURG had been on a level with the bridge. This had still been before Buoy 89. The passing distance at this time had still been about 70 to 80 metres, but was in any case distinctly less than one ship's length. NEDLLOYD FINLAND had steered a course of about 135° and kept at the outermost edge of the navigation channel close to the line of buoys. Shortly after passing Buoy 89, the superstructures of the overtaking vessel had been about midships with unchanged passing distance. Suddenly, at the same time, both the Pilot and the Captain had noticed a suction coming from COSCO HAMBURG and a swift increase in their own speed. The corresponding displays on the radar screens and in the electronic chart had shot up from 10 to 11 kn beforehand to now 13 kn. The lateral distance from COSCO HAMBURG had now been reduced too.

Immediately when the suction and increase in speed had become evident, the Pilot had issued instructions to put the helm hard to starboard, which the Captain executed by grasping the tiller on the middle console. The vessel had not reacted to this, neither at the beginning nor later. The speed indicator had now shown 14 kn and the distance between the vessels was decreasing rapidly. The Captain had gained the subjective impression that COSCO HAMBURG was changing its course towards NEDLLOYD FINLAND.

The Captain had thereupon set the propeller pitch directly to full astern. Despite this manoeuvre, speed had increased further and matched that of the overtaking vessel as the lateral distance between them decreased constantly. A few seconds later there had been a collision between the port shoulder of NEDLLOYD FINLAND and the aft ship of COSCO HAMBURG at an angle of about 20° at a level approx. 25 metres in front of the transom of COSCO HAMBURG. The Captain had noticed that the 40-foot container stowed on the outside portside in the top layer of Bay 2 had touched the ship’s wall of COSCO HAMBURG and been pushed over to starboard.

At the same time the whole vessel had been pushed over to starboard. He had been able to ascertain later with the aid of the clinometer[9] that the vessel had sustained a list of up to 40°.

Shortly before the vessel had uprighted itself again, the 40-foot container stowed on the outside starboard side in Bay 2 had tipped over the side of the vessel and the 20-foot container stowed beneath it in Bay 3 had fallen to starboard into the gangboard.[10]

After the vessel had come free of COSCO HAMBURG, it had abruptly lost speed, while the overtaking vessel had continued further without changing speed. Shortly afterwards the vessel had come to a stop crossways on the other side of the navigation channel with the propeller pitch still at full astern. After the vessel had been manoeuvred back onto the right-hand side of the navigation channel by running astern and had been stopped, the Pilot had informed the Vessel Traffic Services Brunsbüttel of the collision.

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[8] This is the imaginary connecting line between the starboard channel buoys.

[9] Measuring instrument installed on the bridge to display the list of the vessel.

[10] See here the graphic representation under Section 7.2.1.2.

Immediately after the collision the Captain had ordered the Chief Mate to the foreship to inspect the damage and ascertain whether the vessel could still float. After one seaman could not be found on board directly after the collision he had issued a missing person notice to the Vessel Traffic Services.

Shortly after this, at about 15.02 h, the Sounding Vessel BIENE[11] and the public authority vessel WEGA[12] had arrived at the scene of the accident. At the same time the vessel had manned and launched its own lifeboat. NEDLLOYD FINLAND itself had turned and joined in the search for the missing seaman, proceeding downstream on the Elbe.

At about 15.35 h the Sounding Vessel NIEDERELBE had reported that the seaman had been found and shortly after this the Vessel Traffic Services had declared the search action to be completed. The life-boat had been taken back on board and the voyage had been continued.

### 4.1.2 Testimony report by the Chief Mate

The Chief Mate confirmed and supplemented the statements made by the Captain.

After handing over the watch to the Captain he had initially left the bridge and had returned there at about 14.00 h in order to prepare the cargo plan for Hamburg. From the cargo computer in the aft bridge area he had been able to see COSCO HAMBURG, at this time still distant and coming up. Shortly before 14.30 h the Chief Engineer had come onto the bridge. The overtaking vessel had now no longer been visible from the cargo computer and had been in the dead angle behind the funnel cladding. In order to be able to observe the vessel the Chief Mate had positioned himself in the middle of the bridge in front of the middle column of the control position. The stern of COSCO HAMBURG had now been on a level with his vessel's own superstructures. According to his statement as well, the lateral passing distance at this time was about 60 to 80 metres.

The hull of the overtaking vessel had then pushed past NEDLLOYD FINLAND initially relatively quickly with a constant slight lateral distance. The Chief Mate had proceeded to the starboard side of the control position directly in front of the bridge window and had noticed that the lateral distance to COSCO HAMBURG was suddenly becoming less. He too had had the feeling that the overtaking vessel was turning towards NEDLLOYD FINLAND.

On glancing at the control position he had observed that the Captain had grasped the tiller of the manual rudder and put the rudder hard to starboard. A speed of 12.5 kn had been displayed on the monitor of the electronic chart.

The lateral distance to COSCO HAMBURG had continued to reduce quickly and his own vessel had not appeared to react to the hard to starboard rudder position.

The Captain had then grasped the control lever and shortly after this the vibrations in the vessel had indicated that the propeller pitch had been changed to reverse, but the vessel had not otherwise reacted. The lateral distance to COSCO HAMBURG had continued to decrease rapidly. The Chief Mate had now moved from the bridge window back to the starboard console of the bridge control position and had there experienced the collision in the manner described by the Captain. The list after the

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[11] Sounding vessel in the service of the Waterways and Shipping Office (WSA) Hamburg.

[12] Sounding, wreck-searching and research vessel in the service of the Federal Maritime and Hydrographic Agency (BSH).

collision had lasted about 20 to 25 seconds during the entire contact phase of the two vessels. NEDLLOYD FINLAND had initially been pulled along sideways over its port bow by COSCO HAMBURG and had then sagged slowly aft. The vessel had only uprighted itself again after it had come free.
At the instruction of the Captain he had inspected the damage to vessel and cargo on deck. On the way back to the bridge he had been informed that a seaman was missing. After passing this information on to the bridge he had participated in the search on the vessel and had then returned to the bridge. In the meantime the lifeboat had been cleared and launched.
After a report had been received that the seaman had been found he had supervised the hoisting in of the lifeboat. At about 15.52 h the voyage to Hamburg had been continued.

### 4.1.3 Report by the Elbe Pilot

The Pilot of NEDLLOYD FINLAND also describes the course of the accident in a manner similar to that of the Captain's description. However, as the Pilot's report contains additional or more specific remarks on some points, its content is reproduced below in essence and largely avoiding unnecessary repetitions.
According to his statement the Pilot knew the vessel and the vessel type very well. He stated that he had gone on board in the North Lock of the Kiel Canal in Brunsbüttel at about 13.05 h and had manned the port console of the bridge control stand during the passage up the river Elbe. He stressed that the Captain had commanded NEDLLOYD FINLAND with particular care, as at that time he was gathering experience to "run freely"[13] on the Elbe. The large container vessel COSCO HAMBURG had been running up the river and approaching with a speed surplus of approx. 4 to 5 kn. The Pilot's own vessel had been running at full service speed, though because of the strong ebb stream speed made good over the ground had only been between 10 and 13 kn, and later partly just under 10 kn. As there had been no oncoming traffic, COSCO HAMBURG had been able to overtake without any problem.
In order to facilitate the overtaking, NEDLLOYD FINLAND had steered a little further towards the direction of the southern line of buoys, while COSCO HAMBURG had been running just north of the radar line. The distance between the two vessels had appeared to the Pilot to be more than sufficient, and on the bridge of NEDLLOYD FINLAND they had expected a normal overtaking manoeuvre in the range of Buoy 91.[14]
When the overtaking manoeuvre had been almost completed, however, they had ascertained that their own vessel had developed a strong tendency to turn to port and at the same time to increase speed considerably (starting from the basis of 10.6 kn[15]).
At the Pilot's recommendation the Captain had therefore initially put the helm over to starboard 10, and immediately further hard to starboard, by taking over the rudder with the tiller (overriding function). At the same time the vessel had switched over to manual steering. The rudder had run hard to starboard without any time delay. It had

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[13] Acquiring experience in a river estuary in order to be able to gain exemption from the obligation to take on a pilot after a fixed number of voyages.
[14] Note: The Pilot's report does not contain any figures estimating the passing distance.
[15] Data according to GPS.

been assumed that the port turn could now be checked, especially as the propeller had been at maximum pitch. Contrary to expectations, however, nothing had changed in the tendency to turn to port. Despite the hard rudder position, the vessel had accelerated to 15 kn and had been sucked in by the stern of the overtaking vessel.
When they had noticed that the starboard rudder was ineffective, that speed was increasing and that a collision would thus be unavoidable, the variable pitch propeller had been set to full astern in order not to reinforce the pending collision impact with the vessel's own engine. The collision had occurred at 14.40 h.

The pilot had been extremely upset about the information reported to the bridge at about 14.50 by a crew member that a seaman was missing, as he had not assumed that any crew members had been on deck during the collision.
At 15.02 h the life-boat had been launched and NEDLLOYD FINLAND had been put on an opposite course on a level with Buoy 93. After that the vessel had proceeded down the river Elbe in the direction of Buoys 92 to 88.
Several people had been assigned on the bridge as lookouts and at about 15.20 h the passenger also searching over the water from the bridge had made out a garment of the missing seaman on a level with Buoy 90. The Pilot had immediately passed on this information to the Vessel Traffic Services over Channel 68. The Sounding Vessel NIEDERELBE that was closest to the missing seaman had finally recovered the seaman.
At 15.47 h the vessel had received a permit from the Vessel Traffic Services to continue the voyage to Hamburg.

### 4.1.4 Witness statement by the passenger

A few days after the accident the passenger was questioned by the Waterway Police Hamburg about her perceptions in connection with the accident. The information set out below is drawn from the corresponding record. The witness largely confirmed the statements by the Captain, the Chief Mate and the Pilot from the standpoint of an "impartial"[16] third party, but partly also described additional details. These especially are reproduced below.
The passenger stated that she had observed the course of the accident from changing positions inside the bridge where she had been in particular midships and on the port side. At the time of the overtaking manoeuvre the Captain had been sitting at the starboard console of the bridge control stand and the Pilot at the port side console. There had been no communication between the two vessels. In response to the question as to whether the Captain and the Pilot had left their places during the overtaking manoeuvre in order to make certain whether the manoeuvre was proceeding safely, the witness had replied literally that the Captain and the Pilot had remained sitting on their seats, the port wing had not been entered in order to follow the overtaking manoeuvre. In a later, written supplement to her statement, however, she relativised this answer and now stated that this only applied for the

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[16] Note: The term "Beteiligter" (involved person) has a legally defined meaning in the Seeamt proceedings that are to be separated strictly from the activities of the BSU, as the task of the former is to ascertain and if appropriate to sanction individual seamanly misconduct (cf. § 22 Para. 3 Maritime Safety Investigation Law (SUG)). Formulations such as "impartial" or "involved" in BSU reports, on the other hand, are not to be understood technically and are therefore not necessarily identical with the diction used by the Seeamt.

period directly before the collision. COSCO HAMBURG's intention to overtake had been known for some time on the bridge and the Pilot had also been "in the port wing (several times?)"[17].
As regards the passing distance between the vessels the witness states that this was reduced during the overtaking. The courses had been approx. 10° different. She had had the impression that the overtaking vessel was cutting the path of NEDLLOYD FINLAND. COSCO HAMBURG had retained its course unchanged during the overtaking manoeuvre. She had thought the passing distance was narrow.[18] She had not perceived any persons in the starboard wing of COSCO HAMBURG as the vessel passed. When asked whether the Captain or the Pilot had tried to prevent the collision by putting the helm about, changing the rate of speed and/or the course, the witness answered that the last manoeuvre prior to the collision had been "full astern". Before this the Pilot had issued two commands, one engine command and one hard rudder command[19]. At the time of the full astern manoeuvre it had been clear to her that a collision could occur, but she had only been certain of this a little time later when the vessels approached each other ever more closely. In response to the question as to when the witness had had the feeling that the vessel's command recognised the risk of collision, she replied that this would have been at the time of the Pilot's first command. At that moment the bow of COSCO HAMBURG had been ahead of NEDLLOYD FINLAND, but the stern had not yet been visible.
After the collision she had not observed any reactions on the part of COSCO HAMBURG. The vessel had simply continued its voyage.

The passenger also responded to the complex of questions regarding the seaman going over board.
From her standpoint on the bridge she had not been able to observe whether anyone had been working on the ship's deck. She had not registered any warnings addressed to crew members working on the deck prior to the collision. She had learned that a seaman was missing when about three minutes after the collision a seaman had come to the bridge and reported "Mr. P. is missing!". The Captain thereupon immediately had a call put out to the missing man, sent the seaman reporting this to look for him, and had the life-boat made clear.

## 4.2 Voyage of CMV COSCO HAMBURG

COSCO HAMBURG was on its way from Felixstowe, U.K., to Hamburg under pilot advice, per manual steering. The large container vessel (5,446 TEU) built in Japan in 2001 has modern bridge equipment. In particular the electronic track control system ATLAS-NACOS (SAM Electronics CHARTPILOT ATLAS 9320/30), a GPS receiver, the BA Chart 3267 and two radar sets (type: STN ATLAS 9600/9800) were available as navigation aids. The display modes selected had been Relativ Motion North up and Head up, both in the 3 sm range.
The vessel has a fixed-pitch propeller, a semi-balanced underhung rudder (maximum rudder angle 35°), an automatic pilot system and a bow thruster.

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[17] Original quotation.
[18] Note: The witness was unable to give a numerical estimate.
[19] The witness was unable to remember whether it was "hard right" or "hard left". However, the words port or starboard were not used.

In port state controls, the container vessel has so far only received isolated complaints for minor deficits. A VDR was not a part of the compulsory equipment and was not installed on board.

At the time of the accident the Master, the Second Officer, a helmsman, a lookout (all of Chinese nationality) and the German Pilot had been on board.

### 4.2.1 Particulars by the Captain regarding the course of the accident

The Master made a statement regarding the course of the accident to the Marine Accident Investigation Section of the Hong Kong Special Administrative Region (MAIS)[20] on 24 March 2004. The said authority has made the relevant statements available to the BSU.

The Master states that his own vessel had been running at a speed of 14 kn and had been steered manually with a course of 135°. The Elbe Pilot had been on board since 13.30 h. COSCO HAMBURG had passed the Buoys 62 to 90 at the following times:

- Buoy 62 at 13.42 h
- Buoy 76 at 14.09 h
- Buoy 84 at 14.24 h
- Buoy 86 at 14.29 h
- Buoy 90 at 14.35 h

The communications between the Pilot and the Vessel Traffic Services had been in German. The vessel had been running in the middle of the river. During the collision there had been no further traffic on the river in the relevant segment.

### 4.2.2 Particulars by the Pilot

The Pilot reported that the change of pilot had taken place off Brunsbüttel at about 13.15 h. The voyage had been continued at the rate of speed "Manoeuvre full ahead" with ebb stream as a stand-on vessel with a draft of 11.50 m. Before reaching Ruthenstrom the speed had been reduced briefly because of a sensitive installation on the river bank. On passing Buoy 87 the public authority vessel WEGA that had been carrying out work at Buoy 95 had been asked whether any considerateness was necessary, but this had not been the case.

No oncoming traffic had been evident up to Stadersand either visually or on the radar screens. At Buoy 89, the change of course point for the new radar line, NEDLLOYD FINLAND had been passed. At this time the leading light line Pagensand had been well open to the north. The passing distance had been "generously dimensioned"[21]. When the collision occurred, the overtaking manoeuvre had been considered completed.

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[20] Marine Accident Investigation Section.

[21] Original quotation; the report does not contain a numerical estimate of the distance.

## 4.3 Photo-documentation of the course of the collision

The passenger on NEDLLOYD FINLAND kindly made the photo series recorded with an analog viewfinder camera from the bridge of the vessel available to the BSU. This documents the course of the accident impressively in pictures.

**Figure 4: Positions of the vessels in relation to each other shortly before the collision**

**Figure 5: First contact of the vessels**

Figure 6: Last phase of the collision

Figure 7: Position of the vessels in relation to each other shortly after the collision

# 5 Consequences of the collision

The most serious consequence of the accident was the death of a Philippine seaman engaged in container lashing works on the deck of NEDLLOYD FINLAND, who had probably lost his hold during the list of the vessel triggered by the collision and fallen over board. Despite swift initiation of rescue measures he could only be recovered dead from the Elbe.

By contrast with this tragic death, the damage to the two vessels participating was relatively slight. NEDLLOYD FINLAND was deformed above the water line in the port fore ship area (known as the shoulder) between frames 124 and 135 over a length of approx. 10 metres as a result of the impact. In addition the container foundation Bay 1 on the port side was destroyed (see Fig. 9). As a consequence of the collision, four containers stowed in the foremost bays on deck were damaged. One 40-foot container that did not, however, contain any dangerous cargo went over board. There was no water ingress or any other impairment of floatability.

**Figure 8: Damage to NEDLLOYD FINLAND (1)**

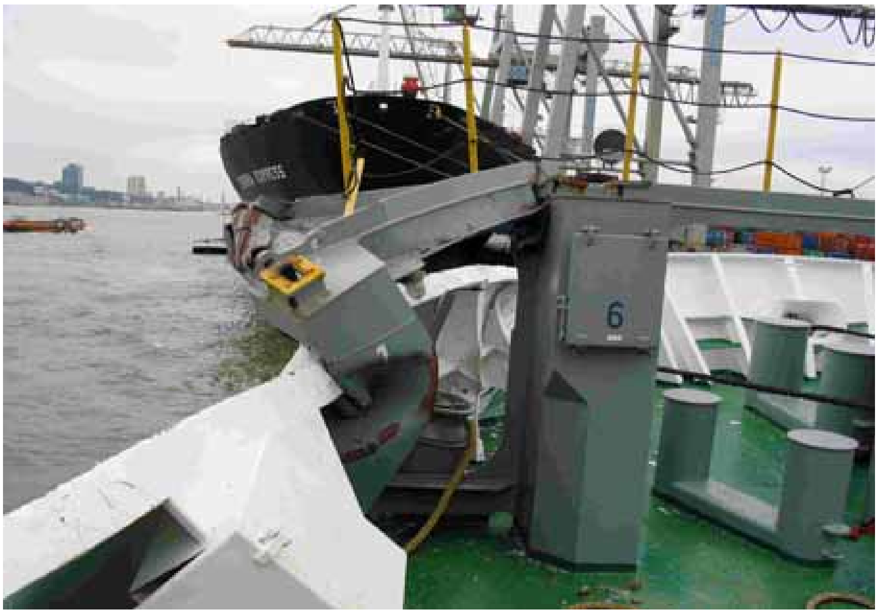

Figure 9: Damage to NEDLLOYD FINLAND (2)

The shell plating of COSCO HAMBURG was dent in at the stern on the starboard side (frames 8 to 14) above the water line (cf. marked area in Fig. 10) as a result of the contact with NEDLLOYD FINLAND, but the vessel remained otherwise undamaged and also unrestrictedly floatable.

Figure 10: Damage to COSCO HAMBURG

No damage to the environment was caused by the collision between the two vessels.

# 6 Accident investigation

## 6.1 Preliminary remarks

The starting point for the investigation of the accident occurrence was the reconstruction of the course of the passage of the two vessels. In this connection the evaluation of the data backup made from the electronic chart systems used on board was particularly important (cf. Section 6.2). The results found largely confirmed the initial presumption that ultimately hydrodynamic interactions between the two vessels must have caused the collision. The course of the collision was analysed both numerically and with the aid of model experiments via the extensive expert opinion commissioned by the BSU, in accordance with the current state of scientific knowledge[22] (6.3).

The factual and legal backgrounds to the fatal accident of the Philippine seaman engaged in lashing works were subjected to a separate examination. The corresponding remarks are summarised in Subsection 7.2 of the analysis part of the investigation report.

## 6.2 Reconstruction of the course of the voyage

### 6.2.1 Analysis of the statements by witnesses

Both the vessel command and the Pilot of NEDLLOYD FINLAND as well as the passenger have described the course of the accident in essentially the same manner (cf. above, Section 4.1.1 ff.). The feeder vessel was proceeding at maximum service speed and had been steered at the outermost edge of the navigation channel in order to give COSCO HAMBURG sufficient space. The latter vessel's intention to overtake was evident, and in view of the traffic situation that was classified as unproblematic it had not been discussed and agreed upon any further.

On the grounds of the largely coinciding and plausible statements by the witnesses, it is considered to be virtually certain that the two vessels had a lateral passing distance estimated at less than 100 metres when the post of COSCO HAMBURG was on a level with the bridge of NEDLLOYD FINLAND at about 14.30 h. Before the overtaking vessel had passed NEDLLOYD FINLAND completely, the latter suddenly lost its steerability and was caught in the suction of COSCO HAMBURG. At the same time the speed over ground increased constantly without the vessel doing anything to promote this. The Captain tried to counteract the said restrictions by executing a 10° to starboard manoeuvre at the recommendation of the Pilot, which was reportedly *immediately* extended to a hard to starboard manoeuvre. As this measure could not prevent the Captain's own vessel from turning towards the overtaking vessel and the increase in the vessel's own speed over ground, an attempt was finally made to at least mitigate the collision impact a little with a full astern manoeuvre. The time of collision was entered in the vessel's log as 14.40 h.

All in all, it is to be assumed that in accordance with the statements made by all the witnesses NEDLLOYD FINLAND behaved passively during the overtaking operation. A change in course and/or speed reportedly only took place when the suction action had already become evident. In this connection it should be noted that the

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[22] The scope of the scientific considerations was, however, limited for reasons of cost.

passenger, by contrast with the statements by the vessel's command and the Pilot, pointed out that there had been two manoeuvres prior to the final full-astern manoeuvre; in addition to a steering manoeuvre there had also been a further engine manoeuvre (cf. above Section 4.1.4). This inconsistency in the statements could not be clarified any more. As no manoeuvre printer is installed on board NEDLLOYD FINLAND, it was not possible for the BSU to reconstruct the manoeuvres described to avoid the collision on the basis of objective, technical records.

The testimony by the Captain and the Pilot on the course of the passage of COSCO HAMBURG up to the time of the collision (cf. Section 4.2.1 f. above) did not produce any findings concerning any evident navigational misconduct on the bridges of the two vessels either. There is no reason for any justified doubts as to the accuracy of the statements that the container vessel followed the course of the radar line under manual steering roughly in the middle of the navigation channel. In particular there are no objective indications or plausible potential explanations that sudden course changes having a negative influence on the accident occurrence were undertaken on the bridge. The witnesses on the bridge of NEDLLOYD FINLAND admittedly stated on the one hand that they had had the subjective impression that COSCO HAMBURG was turning towards their own vessel or cutting off their path. On the other hand, however, they all agreed that this was only a subjective perception of the relative ship movements in relation to each other.
Moreover the print-out of the manoeuvre printer confirms the statement by the Captain and the Pilot of COSCO HAMBURG, according to which their vessel had proceeded at manoeuvre rate of speed full ahead during the period relevant for the accident.

Interim results:

- The vessel commands and pilots on the two vessels involved in the overtaking operation conceded unanimously that express agreements in connection with the overtaking operation had not been conducted at any time.
- Both sides assumed that the overtaking manoeuvre would be managed without any problem and that in so far the relevant obligations existing had been sufficiently satisfied.
- According to the statements made by the Pilot and the command, NEDLLOYD FINLAND had supported the overtaking operation of COSCO HAMBURG by steering a course at the edge of the navigation channel (known as space-making manoeuvre), but had refrained from reducing speed, which would have shortened the duration of the overtaking operation.
- The Pilot of COSCO HAMBURG stresses that the passing distance to NEDLLOYD FINLAND had been "generously dimensioned" and that he had considered the overtaking operation as completed when the collision occurred. It was conceded that COSCO HAMBURG had overtaken at full manoeuvring speed (approx. 14 kn) and without changing the rate of speed.

The subjective but altogether plausible and credible statements and estimations of the course of the accident set out by the parties involved, taken by themselves, do not allow any reliable and adequate conclusions to be drawn regarding the causes of the accident.

### 6.2.2 Analysis of the electronically recorded track courses

To reconstruct the course of the voyage of the two vessels the BSU commissioned a situation analysis of the overtaking manoeuvre from the Department of Maritime Navigation Warnemünde of the University of Wismar[23].
Both vessels had recorded the course of their own voyage with the electronic chart system (ECS) installed on board and a backup of the relevant data had been made. It was now necessary to edit the stored information appropriately, to analyse and to visualise it in order to be able to reconstruct the passages of the two vessels in a manner approaching reality as far as possible. Specific difficulties resulted from the fact that sea chart systems of different manufacturers were used on the vessels. Accordingly the data backed up could not be related to each other without more ado. Moreover an isolated evaluation of the track course of *one* vessel simply with the aid of the proprietory reproduction software available for the relevant electronic chart system would only have been conditionally suitable for considering the speed and course of the individual vessel analytically, as there is here a lack of appropriate evaluation options within the relevant reproduction software.
The Department of Maritime Navigation with its human and technical resources succeeded in overcoming these difficulties. The final report of the Department of Maritime Navigation of 31 August 2004 is reproduced below in abbreviated form (but retaining the meaning), partly verbatim and thus forms the basis for the remarks and statements in the following subsections.[24]

#### 6.2.2.1 Methodology and scope of the investigation

The starting point for the data analysis by Department of Maritime Navigation was to transfer the ECS data available in the different manufacturer-specific formats into the relevant reproduction systems. After this the time segments of the data recorded relevant for the examination were extracted from the two reproduction systems and converted into a uniform ASCII data format. The time range to be investigated for the detailed evaluations to be carried out was defined as the **time segment between 14:31:24 h and 14:41:24 h** local time. The data available separately were finally transformed into one file and read into a program for detailed analysis.

The parameter-based analysis comprised the following data contents:
- Progress of the recorded speeds and courses over ground
- Calculation and diagrammatic representation of the distances of the sensor positions to the radar line.
- Calculation and diagrammatic representation of the distances between the sensor positions on both vessels
- Calculation and diagrammatic representation of the minimal distance between the vessels from side wall to side wall at the times delivered
- Calculation and diagrammatic representation of the minimal distance between the side wall and radar line at the times delivered

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[23] Hereinafter referred to briefly as "Department of Maritime Navigation".
[24] Note: The expert opinion of the Department of Maritime Navigation is available for downloading on the BSU's website.

### 6.2.2.2 Data bases

The BSU provided in particular the following information to Department of Maritime Navigation:

- Dimensions (length over all, width over all) of the participating vessels
- Sensor and system position of the GPS aerials on board the relevant vessels (from forward/aft; port/starboard)
- Geographical coordinates of the dredged channel, the radar and leading light lines, as well as the buoys and land contours in the estuary section under consideration[25]
- Photo material (cf. Fig. 4 to 7)
- ECS data[26]

Attention is drawn to the following specific features as regards the ECS data:
For the concrete marine casualty under review here, sensor data from various ship's own data of the vessels involved recorded with the electronic chart systems (ECS) of different manufacturers (TRANSAS and STN ATLAS) were available. The extents and contents of the data recorded differed from each other. There was only agreement as regards the standard data sets recorded of position, course and speed over ground, as well as headings. Data sets on the use of steering and propulsion facilities were only available for COSCO HAMBURG (rudder position, engine rpm and rate of turn). No comparable data were available for NEDLLOYD FINLAND.

### 6.2.2.3 Problem of time synchronisation

One essential difference in the ECS data sets recorded that was relevant for the investigation consisted in the absolute recording times. According to the time stamps in the files of NEDLLOYD FINLAND, the recording was carried out at 10-second intervals, always starting at 00:00:00. The data sets of COSCO HAMBURG did not show 10-second time steps throughout. The time intervals here varied between 9 and 11 seconds. Furthermore, the time stamp did not start at a full minute, but in some cases only 3 to 4 seconds later. As regards the precision of the accuracy of the time stamp of the data sets recorded, the manufacturer stated that in unfavourable cases time lags of at most 3 seconds are possible, in other words that in the worst case a position recorded could be 3 seconds "old".
According to the time stamps of the data sets recorded, this results in an absolute time difference between the data sets of the two vessels of at most three seconds. The relevant position data of NEDLLOYD FINLAND were extrapolated ahead to the corresponding times of COSCO HAMBURG using the course and speed measurements for the analysis to compensate for this time difference in the data sets.

### 6.2.2.4 Data analysis

#### 6.2.2.4.1 Marginal conditions

A detailed analysis was carried out with the evaluation files produced (fused track data) using the SimDat software specially applied by Department of Maritime

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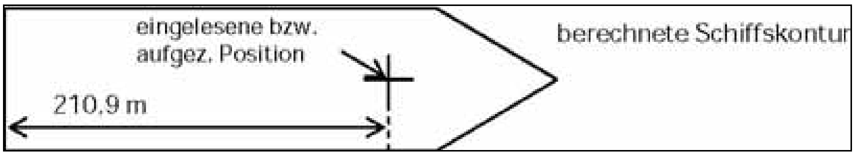
[25] The relevant information was kindly made available to the BSU by the Federal Maritime and Hydrographic Agency (BSH).
[26] Cf. preceding footnote.

Navigation. All the results below are based on evaluations of these data. The following circumstances are to be taken into account as regards the precision and reliability of the data recorded:

- The position data recorded consist of GPS position data according to the characterisation in the data sets, which are less precise by comparison with DGPS position data.
- Differing degrees of precision of the dilution of precision delivered by GPS receivers can furthermore occur as a result of the configuration. For example, the dilution of precisions in the differing operating modes "Auto", "3D" or "2D dilution of precision" can differ. All the configuration settings carried out manually also influence the quality of the position, such as for example setting the S/N ratio higher or lower, admitting signals from satellites with very small angles of elevation or higher PDOP values[27].
- The precision of the recorded positions can, moreover, deteriorate as a result of multiple reflections occurring on board, masking of the reception area or other ship-specific deflections.
- The position data of COSCO HAMBURG recorded are not direct GPS data. In the ECS system used, the so-called system position[28] is recorded instead. Here the position data transmitted by the GPS receiver connected to the ECS are converted to the system position stipulated by the manufacturer. According to the information supplied by the manufacturer, the system position of COSCO HAMBURG regarding the midships axis is +/- 4.14 m (depending on the use of position sensor GPS1 or GPS2) and 210.9 m away from the stern.

  Furthermore, the recorded position can be superimposed with an off-set that can be undertaken by the user as a manual adjustment.[29] In the data analysis carried out in this respect, however, no data on the magnitude of any setting of such an adjustment carried out during the accident period could be found. That is why in this connection it is assumed that no manual adjustment is to be considered.
- The recorded position data of NEDLLOYD FINLAND are position measurements recorded directly by the receiver. Any off-set would be apparent in the recorded data in addition to this, as all ECS actions are recorded.[30]
- Any information from recorded data of the steering and propulsion facilities that might be relevant for the course of the accident were only available to a partial extent. While for COSCO HAMBURG the rudder angle, actual engine speed and furthermore actual rates of turn are stored, the ECS system used by NEDLLOYD

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[27] PDOP = Position dilution of precision.

[28] The manufacturer has defined the system position as the position of the Doppler-Log oscillator in the vessel's bow.

[29] Cf. Operating Instructions Chartpilot 9330; ECDIS, Conning Displays. SAM Electronics Hamburg, 10.07.2003.

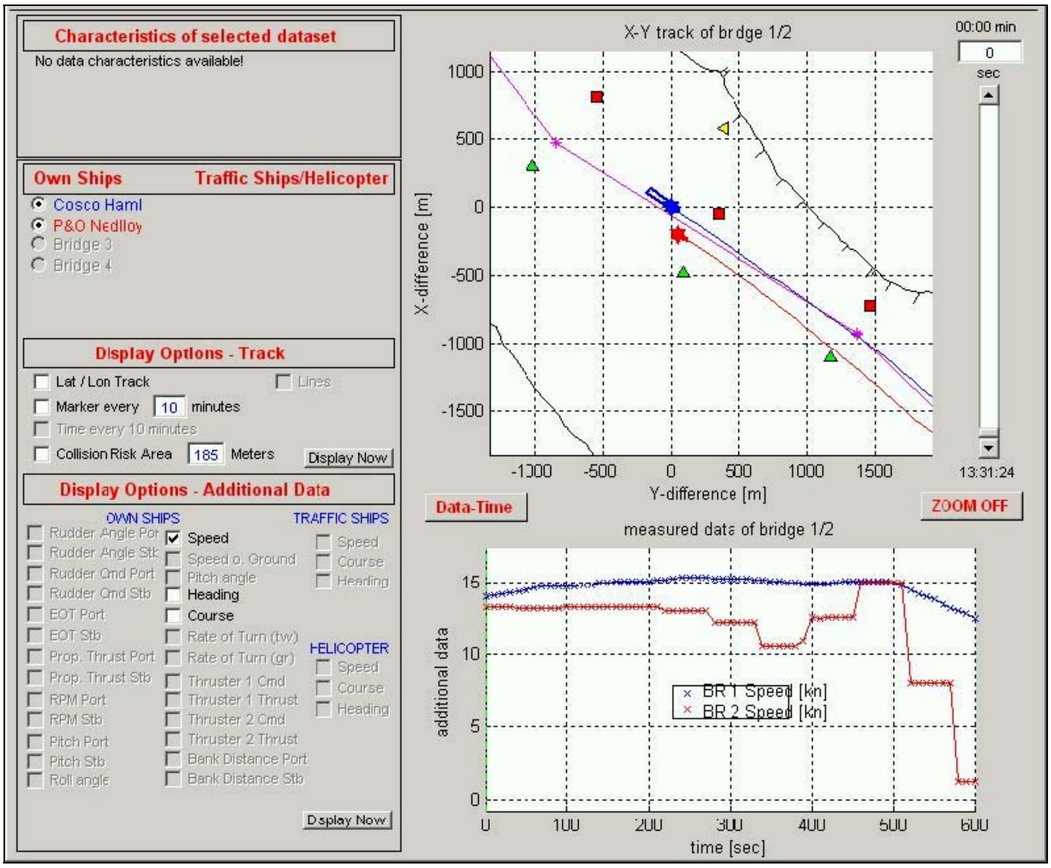
[30] Cf. Navi Sailor 3000 User Manual, TRANSAS Hamburg, May 2001.

FINLAND can only record engine speeds. In the case under consideration, however, the ECS system was not connected with the corresponding sensor.

- The synthetic radar data recorded by Vessel Traffic Services Brunsbüttel that were additionally made available to the Department of Maritime Navigation by the BSU could only be used, if at all, for a qualitative assessment in the meaning of a plausibility check of the position data recorded on board. On the one hand the synthetic data recorded are the position value extracted from the radar echo and calculated in accordance with a certain procedure (for example Leading Edge; Center of Gravity or the like), whose relation to the actual ship's contour is not deterministic. On the other hand, the recording interval of 60 seconds is too large to support the reconstruction of the course of the accident.

### 6.2.2.4.2 Results of the raw data analysis

The data edited were analysed with the aid of the SimDat software. The results obtained from the analysis are set out below in diagrammatic form.



**Characteristics of selected dataset**

No data characteristics available!

**Own Ships** **Traffic Ships/Helicopter**

● Cosco Haml
● P&O Nedlloy
○ Bridge 3
○ Bridge 4

**Display Options - Track**

☐ Lat / Lon Track ☐ Lines
☐ Marker every 10 minutes
☐ Time every 10 minutes
☐ Collision Risk Area 185 Meters

**Display Options - Additional Data**

OWN SHIPS

☐ Rudder Angle Por
☐ Rudder Angle Stb
☐ Rudder Cmd Port
☐ Rudder Cmd Stb
☐ EOT Port
☐ EOT Stb
☐ Prop. Thrust Port
☐ Prop. Thrust Stb
☐ RPM Port
☐ RPM Stb
☐ Pitch Port
☐ Pitch Stb
☐ Roll angle
☑ Speed
☐ Speed o. Ground
☐ Pitch angle
☐ Heading
☐ Course
☐ Rate of Turn (tw)
☐ Rate of Turn (gr)
☐ Thruster 1 Cmd
☐ Thruster 1 Thrust
☐ Thruster 2 Cmd
☐ Thruster 2 Thrust
☐ Bank Distance Port
☐ Bank Distance Stb

TRAFFIC SHIPS

☐ Speed
☐ Course
☐ Heading

HELICOPTER

☐ Speed
☐ Course
☐ Heading

00:00 min 0 sec

13:31:24

**Figure 11: Example of evaluation of the situation analysis of the overtaking manoeuvre**

Figure 11 shows the evaluation surface of the software used as an example. The diagrammatic representations in the right-hand part of the figure contain visualisations of the ECS data recorded.

In the upper diagram the tracks of the vessels involved (blue - COSCO HAMBURG; red – NEDLLOYD FINLAND) and their true-to-scale vessel contours at the position at the time 14:31:24 h together with selected chart objects (land contours (black), radar line (magenta) and navigation channel buoys) extracted from the ECS are shown in a cartesian X-Y-coordinate system (position data of the vessels transformed from Lat/Lon into Gauß/Krüger).

In the bottom diagram the speed tracks of the "speed over ground" values recorded for the two vessels are displayed over the entire analysis period observed. The green bars shown marks the time belonging to the situation set out above (here t= $t_0$ = 0 seconds).

The following figures contain enlarged diagram representations.

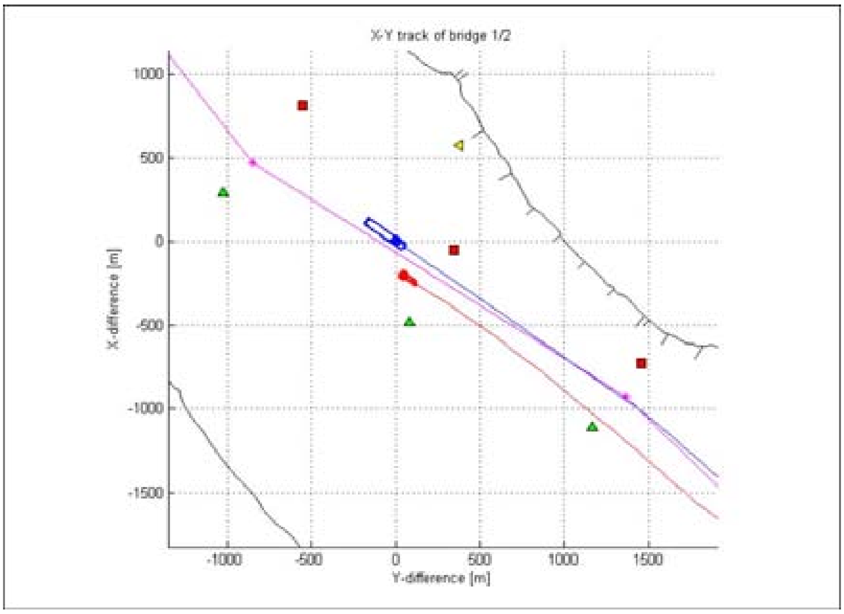


**Figure 12: Enlargement of excerpts from the visualised track courses at the start of the analysis period**

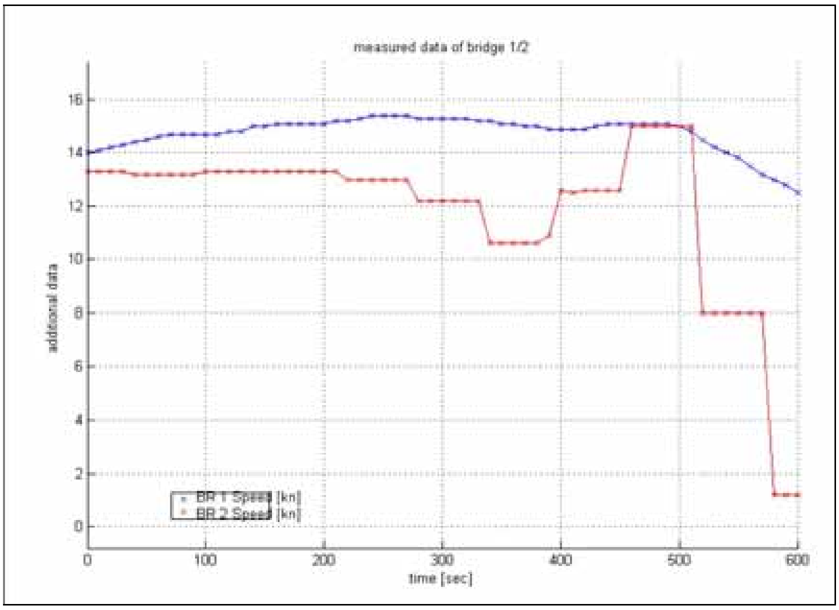


**Figure 13: Courses of speed over ground for the entire analysis period (blue – COSCO HAMBURG, red – NEDLLOYD FINLAND)**

The speed tracks recorded show the approximation of the speeds to each other clearly. The speed of COSCO HAMBURG initially appears to be constant, while the speed of NEDLLOYD FINLAND initially drops slightly up to about t = 390 s (approx. 14.38 h) from some 13.5 kn to less than 11 kn, and then rises to almost 15 kn in approx. 50 s. After contact between the vessel hulls (probably time t = 490…505 s; approx. 14.40 h), the speeds of the two vessels drop steeply.
In the following two figures the course tracks recorded through the water (Fig. 14 - heading) and over ground (Fig. 15) are shown. The heading of NEDLLOYD FINLAND is suddenly reduced shortly after t = 500 s from 130° to almost 90° and finally to 60°. At this time the vessel was lying almost crossways in the navigation channel.

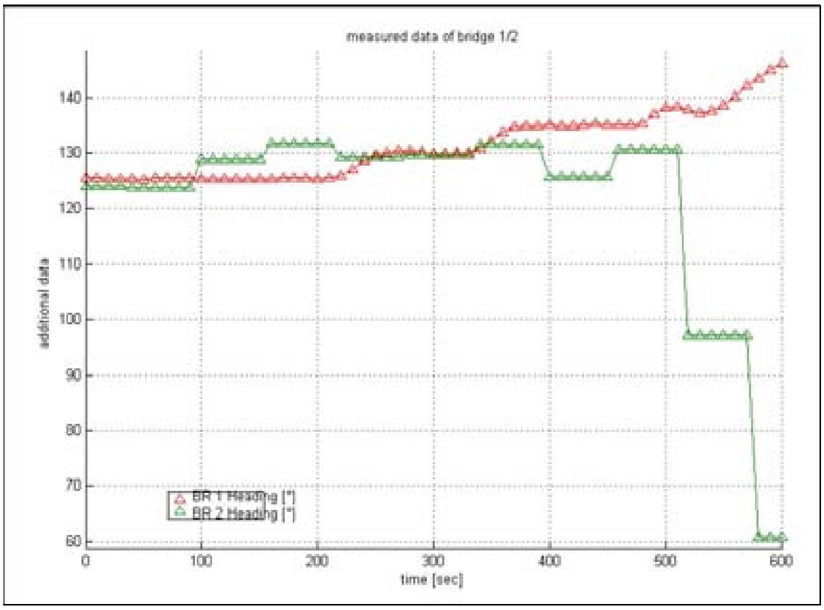


**Figure 14: Heading data**
**(green - NEDLLOYD FINLAND, red - COSCO HAMBURG)**

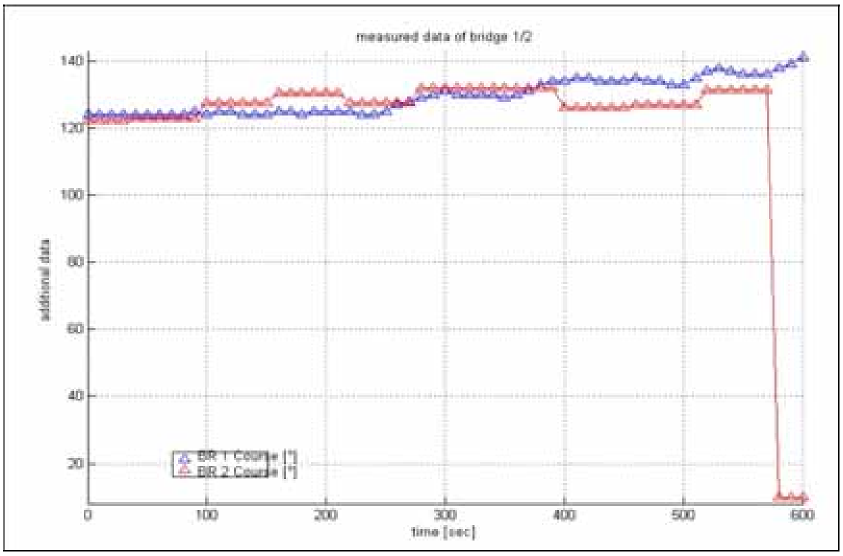


**Figure 15: Tracks of courses over ground**
**(blue COSCO HAMBURG, red NEDLLOYD FINLAND)**

The course over ground values recorded show that both vessels were largely proceeding on parallel courses. The course over ground of NEDLLOYD FINLAND only changes by almost 90° at the end of the period analysed. The additional off-set between the changes of the course values (over ground and heading) can be attributed to the fact that NEDLLOYD FINLAND, as evident on the photos of the accident, initially on still parallel courses approached COSCO HAMBURG and only turned crossways after touching the stern.

Figures 16 to 19 show further situation pictures of the overtaking manoeuvre on the basis of the data recorded.

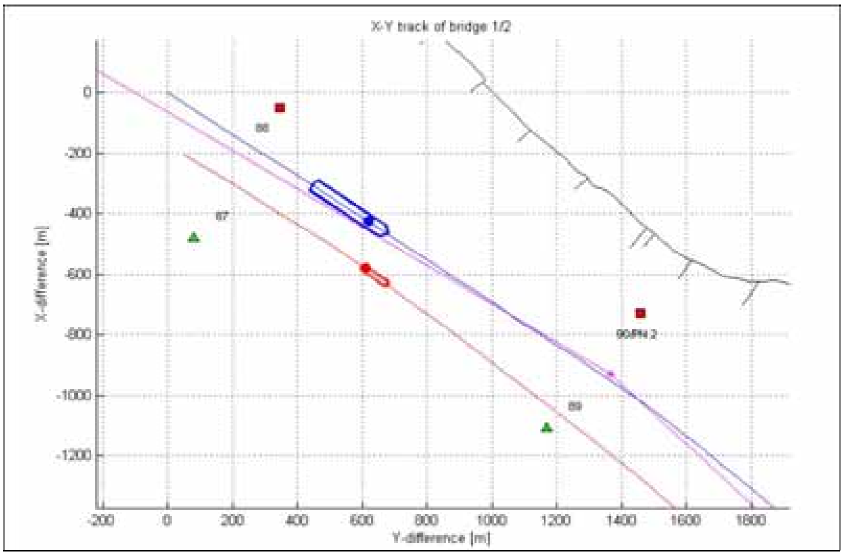


Figure 16: Snapshot of the overtaking operation; closest approach of the sensor positions (Gauß-Krüger Coordinates)

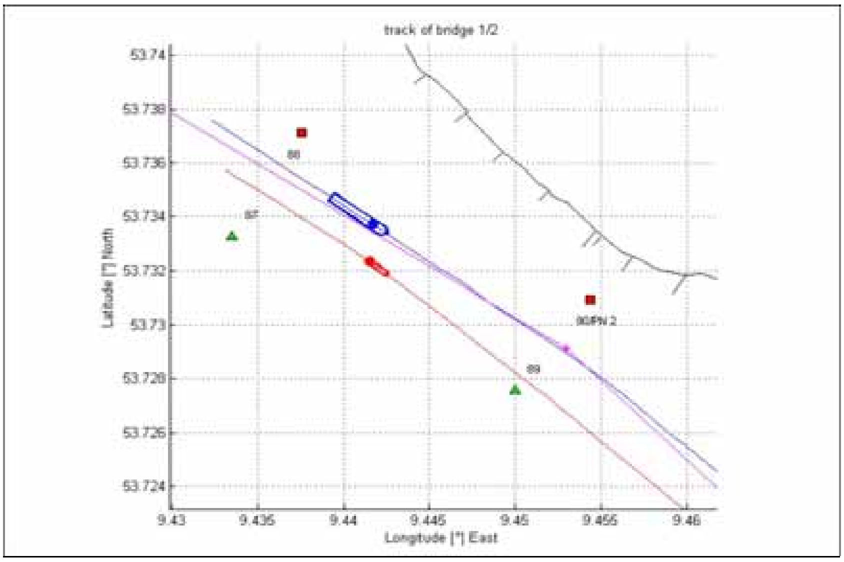


Figure 17: Snapshot of the overtaking operation; closest approach of the sensor positions (geographical coordinates)

In figures 16 and 17 the location of the vessels in relation to each other roughly at the start of the overtaking is shown. At this time the sensor positions are roughly on the same height and the current distance determined between the vessels reaches its minimum value (see here also the diagram in Fig. 21). The distance between the vessel hulls reaches a first minimum at time t ≈ 90 s or approx. 14.33 h (see here also the diagram in Fig. 20). After this closest approach the sensor positions move ever further away from each other. At the probable time of collision (t ≈ 390...450 s; 14.40 h) the distance between the sensor positions is roughly constant and then increases continuously.

In order to calculate the relevant minimal distance from ship's wall to ship's wall, an additional function was implemented in the analysis software that determines the smallest distance by "spot" considerations from the side wall of one vessel to that of the other. On the one hand the corner points of the vessel contours themselves and on the other hand three further points along the side wall at 25%, 50% and 75% of the ship's length were used as "measuring points". All corner point combinations were calculated and evaluated to determine the minimal distance for all measurement times.

The diagrams in Fig. 18 and 19 show the tracks of the last evaluation segment from directly before to after the contact between the vessels. The positions marked by the ship's contours are faded in for the time of the second closest approximation.

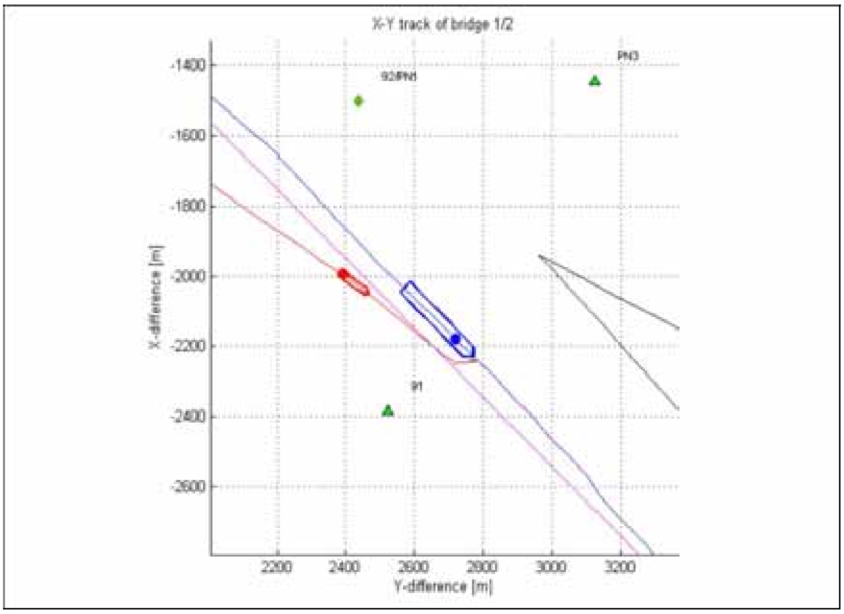


**Figure 18: Snapshot of the overtaking operation shortly before the collision (Gauß-Krüger Coordinates)**

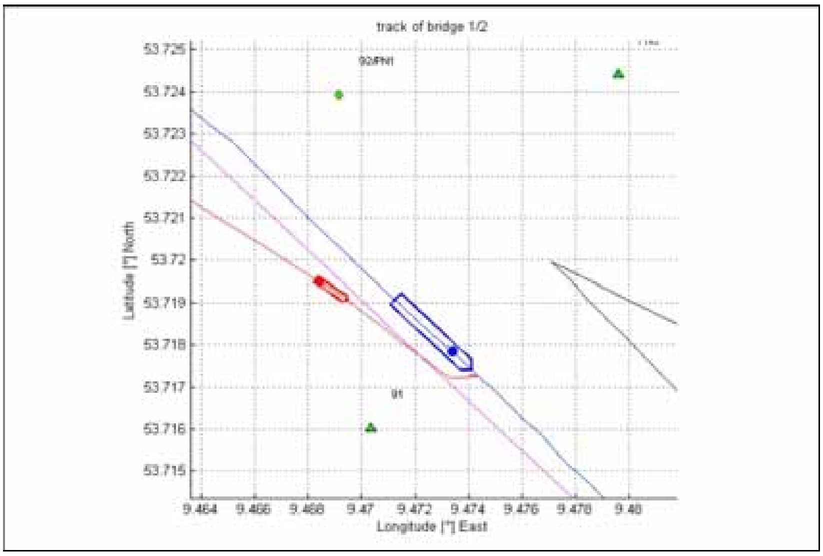


Figure 19: Snapshot of the overtaking operation shortly before the collision (geographical coordinates)

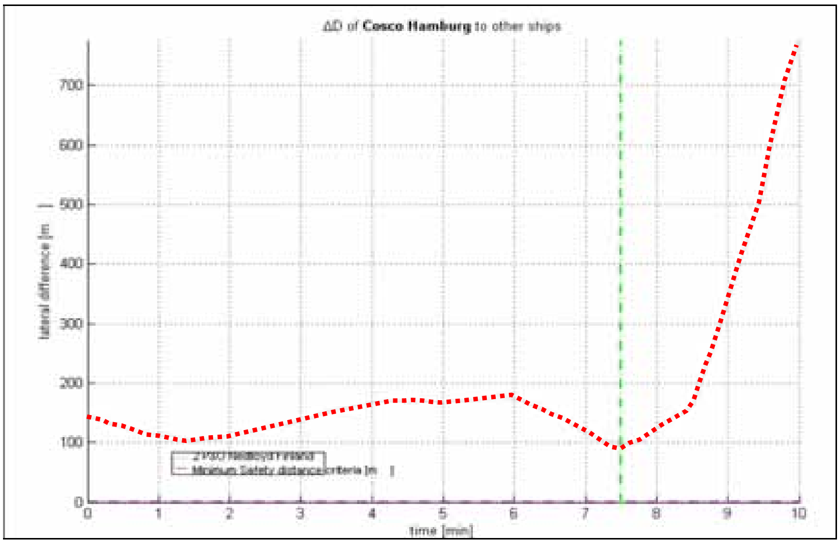


Figure 20: Closest distances between the vessel hulls of the vessels involved (minimal distance from ship's wall to ship's wall)

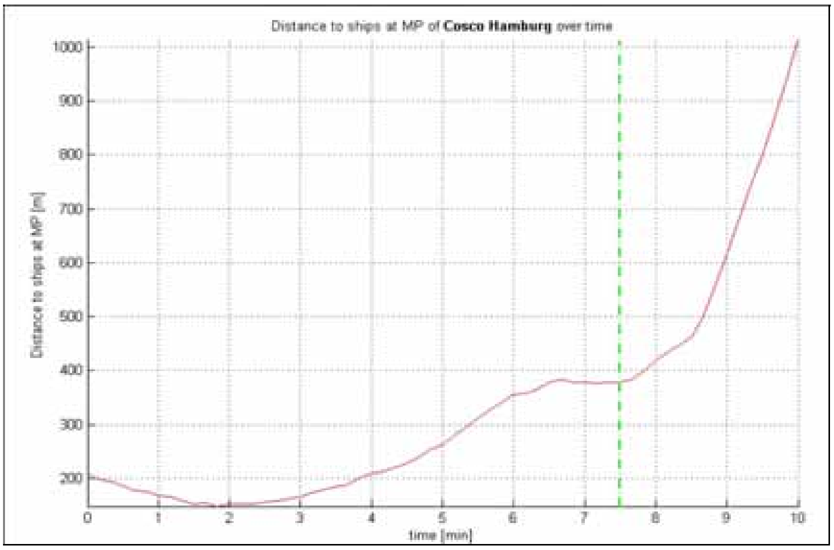


Figure 21: Closest distances between the sensor positions
(System position COSCO HAMBURG vs. GPS aerial NEDLLOYD FINLAND)

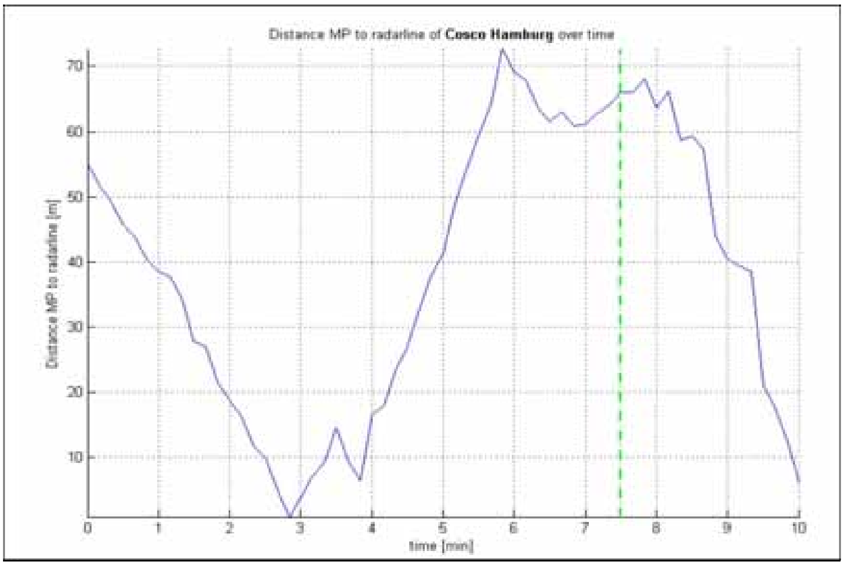


Figure 22: Absolute distances of the sensor position of COSCO HAMBURG to the radar line

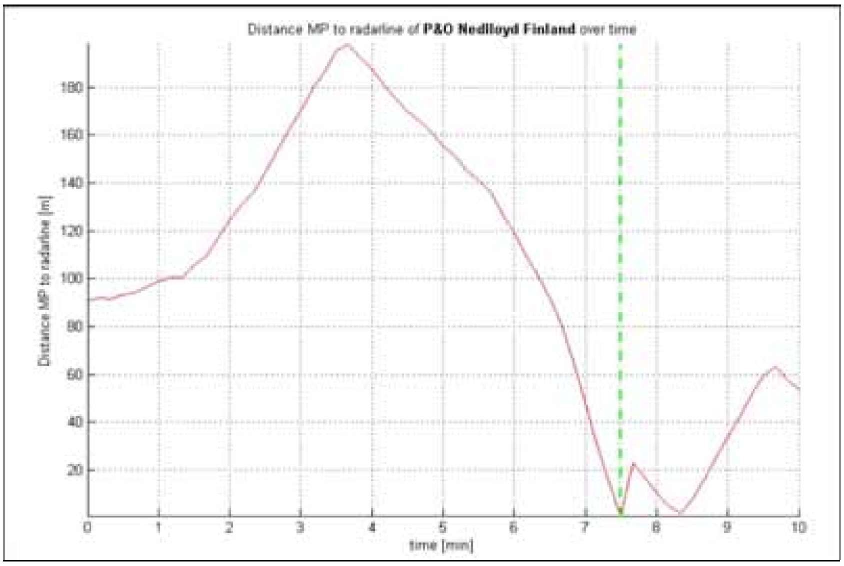


**Figure 23: Absolute distances of the sensor position of NEDLLOYD FINLAND to the radar line**

It becomes evident from the data analysis conducted and the relevant figures that the contact between the two vessel hulls occurred close to the radar line. The recorded track of NEDLLOYD FINLAND shows a clear tendency towards the radar line and the track of COSCO HAMBURG. The situation of the collision can be reconstructed in good quality from the tracks and analysis of the location of the vessels (heading) in relation to each other. As the detailed analyses of the time course of the distance of the vessels to the radar line (Fig. 22 and 23) shows, COSCO HAMBURG especially had a clear lateral distance from the radar line in the last minutes prior to the collision and was running on a roughly parallel course, while the approach of NEDLLOYD FINLAND to the radar line took place almost continuously and without any course correction evident in the data sets.

However, the representations (cf. in particular Fig. 18 and 19) also make it clear that the actual progress of the situation cannot be reconstructed exactly with the aid of the data recorded without any further corrections. The contact of the vessel hulls clearly visible on the photos of the accident series could not be reproduced in the analysis of the recorded data.

On the basis of the photo series available, for example, it could be assumed that the relative approximation to each other is correct. In this case either the positions of COSCO HAMBURG on its own track must be deferred further backwards in time, or the positions of NEDLLOYD FINLAND must be pushed further forward in time. Department of Maritime Navigation has carried out appropriate corrections by way of example. The following section contains explanations of these.

### 6.2.2.4.3 Subsequent time synchronising of the data sets

In order to be able to consider the probable course of the situation, Department of Maritime Navigation carried out synchronisation of the data sets on the basis of the photo series available. Figure 24 below shows a resulting snapshot shortly before the assumed time of the accident.

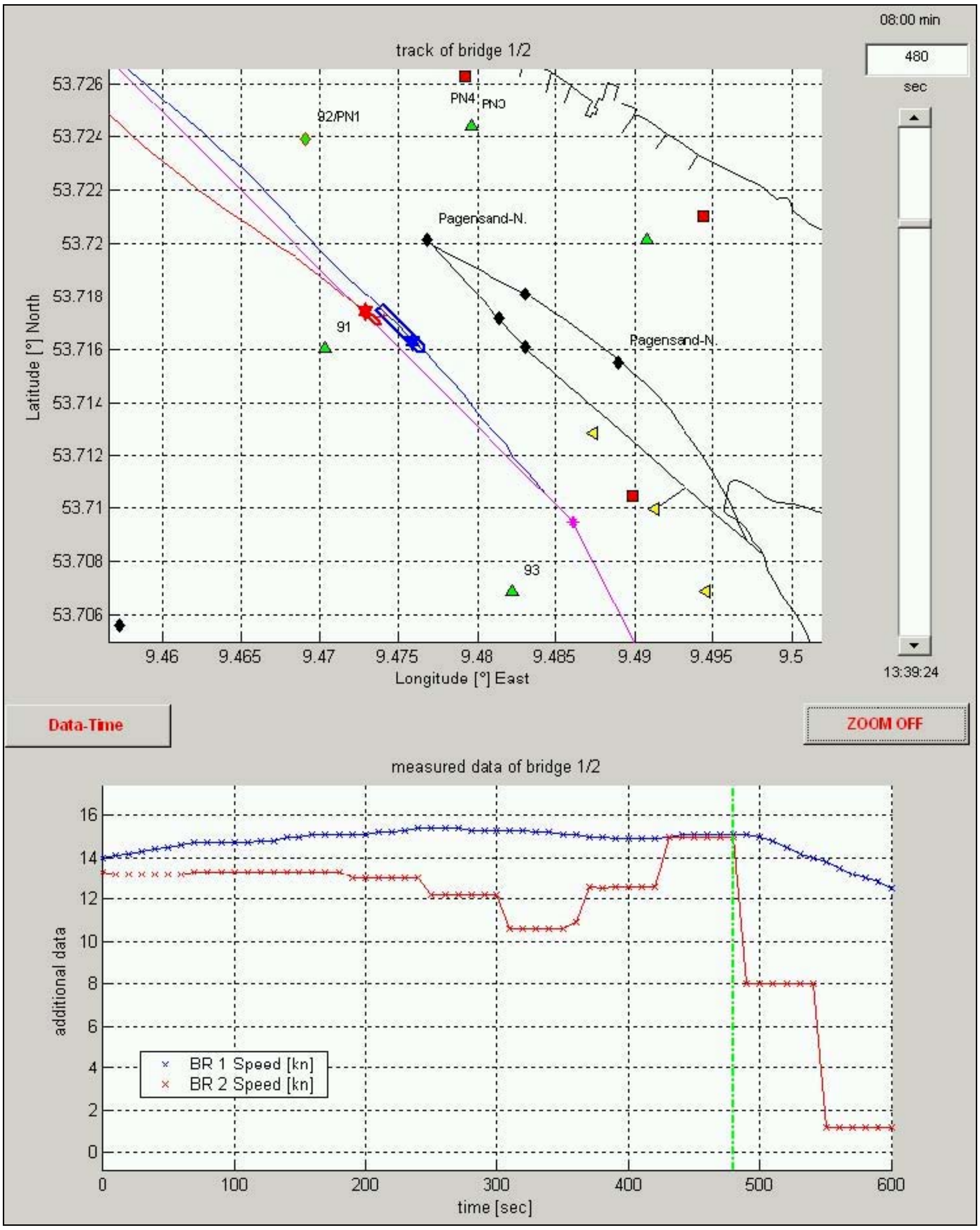


**Figure 24: Presentation of the probable situation shortly before the occurrence of the accident (time-synchronised data sets)**

Figure 24 shows the unchanged tracks of the two vessels and the hull contours for the time 14:39:24 in relation to the navigation channel limits and navigation marks taken from the BSH Database. While the position of NEDLLOYD FINLAND is still taken from the original data sets, the position of COSCO HAMBURG was set back by 30 seconds. The basis for this additional synchronisation is the position of the vessels documented in Fig. 7 directly after the collision. According to this, the navigation mark "Pagensand-Nord Front-Lt" was almost dead ahead viewed from NEDLLOYD FINLAND shortly after the collision, while the stern of COSCO HAMBURG had already moved further away. As GPS data are recorded without further conversion on NEDLLOYD FINLAND, it was assumed that the position and time of this recording roughly correspond to the actual time of the accident. Furthermore, it was assumed that the track of COSCO HAMBURG corresponds to the actual track, apart from the time allocation. It is further evident from the photos that the contact with the ship's bow of NEDLLOYD FINLAND occurred in the aft area roughly on a level with the last two 40-foot container bays. In order to reconstruct the collision, the data sets of COSCO HAMBURG were therefore set back in time in the available time steps recorded until the contact between the ships' hulls occurred. The further course of the situation reconstructed in this way is shown in the following figures.

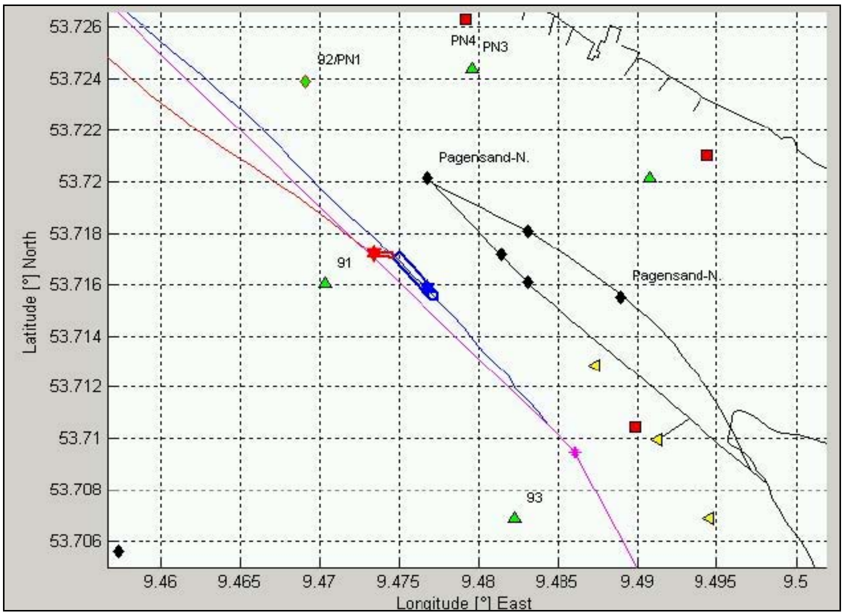


**Figure 25: Final phase of the contact between the vessels involved at approx. 14:39:34 h (time-sychronised data sets)**

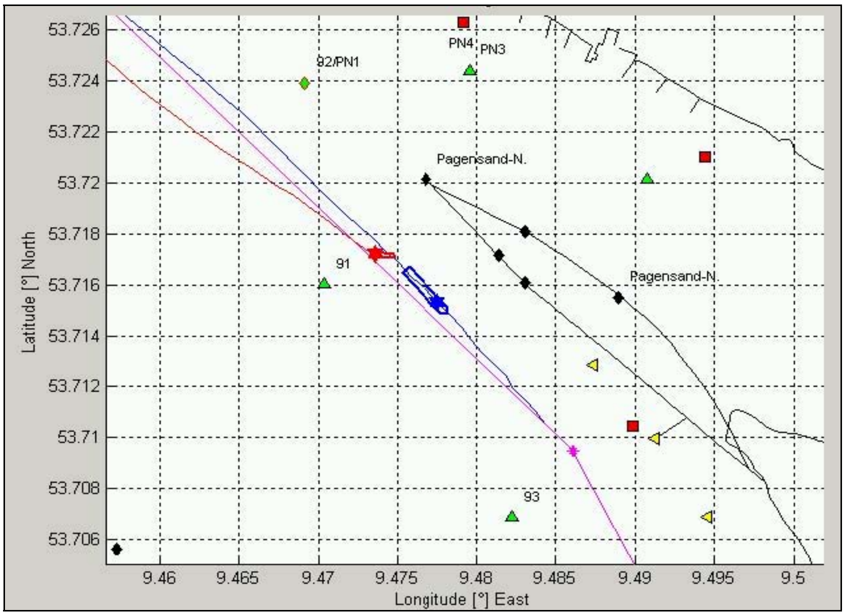


**Figure 26: Situation shortly after the collision (14:39:44) (time-synchronised data sets); NEDLLOYD FINLAND crossways in the navigation channel, navigation mark on the port side almost dead ahead)**

The constellations shown in the last two figures are similar to the heading of the vessels to each other shown in the photo (Fig. 7). If this time sychronisation is taken as a basis for the further data evaluation, the distance developments set out below result.

By comparison with the distance developments determined from the data recorded (cf. Fig. 20; minimum value approx. 100 metres!), considering the distance from ship's wall to ship's wall after the time synchronisation results in a minimum value of approximately 0 m at the time of the assumed collision.

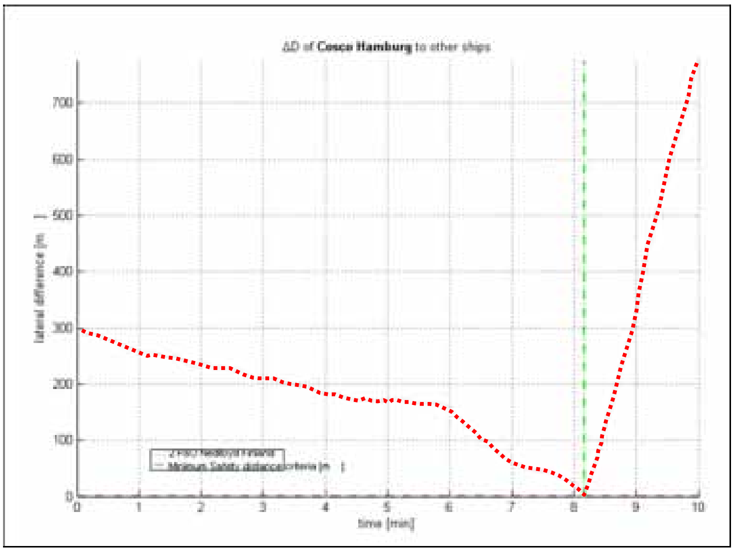


**Figure 27: Closest distances from ship's wall to ship's wall (time-synchronised data sets)**

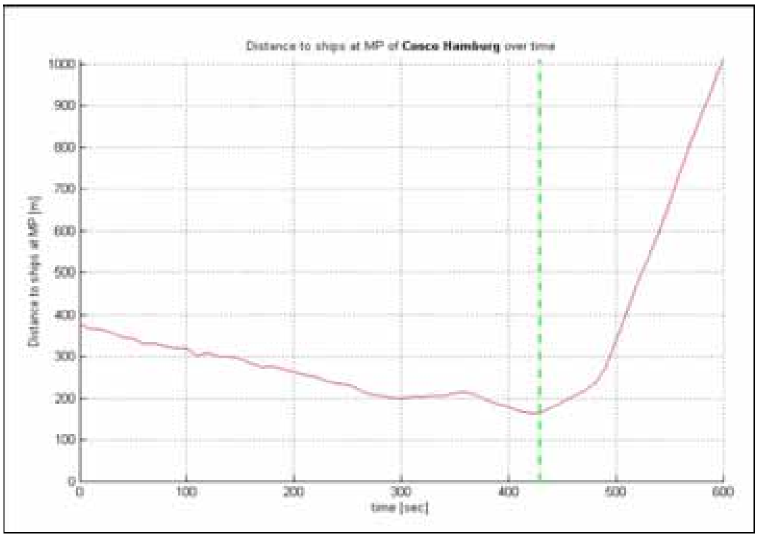


**Figure 28: Shortest distances between the sensor positions (System position COSCO HAMBURG vs. GPS aerial NEDLLOYD FINLAND) time-synchronised data sets**

### 6.2.2.5 Summary and conclusions

The situation of the collision could be reconstructed in good quality from the tracks and the evaluation of the position of the vessels (heading) in relation to each other. The evaluation of the recorded data has revealed, however, that the situation development could not be reconstructed exactly without further corrections. The contact between the vessel hulls clearly visible from the photos of the accident series could only be reconstructed following time synchronisation of the data available.
As regards the course of the accident, the results determined illustrate a continuous approach of the tracks, however, whereby COSCO HAMBURG followed a course almost parallel to the radar line, while NEDLLOYD FINLAND approached this ever more closely and finally passed it at the probable time of the accident. It is apparent from the evaluated speed data that the speed of the feeder vessel gradually approached the speed of the overtaking vessel. There was a very large leap in speed of around 4 kn within about one minute shortly before the probable time of the accident. A converging of the speeds can be seen clearly from the speed tracks.

With the time-synchronised position data (tracks) it was possible to reconstruct the collision approximately. Appropriate corrections for the probable time and scene of the accident can be determined from the movement tendencies. Department of Maritime Navigation carried out appropriate observations based on and stipulating assumptions and marginal conditions by way of example. In particular the photos of the accident provided were drawn on to correct the data sets. The situation analysis of this situation progress assumed to be probable clearly confirmed the tendencies determined so far.
However, as only the approach of speed made good over ground of NEDLLOYD FINLAND to the progress of COSCO HAMBURG was registered, the results obtained by the Department of Maritime Navigation support the hypothesis that the proven increase in speed is attributable to hydrodynamic interactions (suction effect). In particular the theory findings known from other investigations so far support this.

Furthermore, Department of Maritime Navigation also carried out simplifying simulator runs with similar vessels of comparable dimensions. These preliminary investigations into the reconstruction of the course of the situation on the Ship Handling Simulator showed good reproducibility of the suction effect with the position of COSCO HAMBURG being additionaly synchronised (cf. Fig. 29).

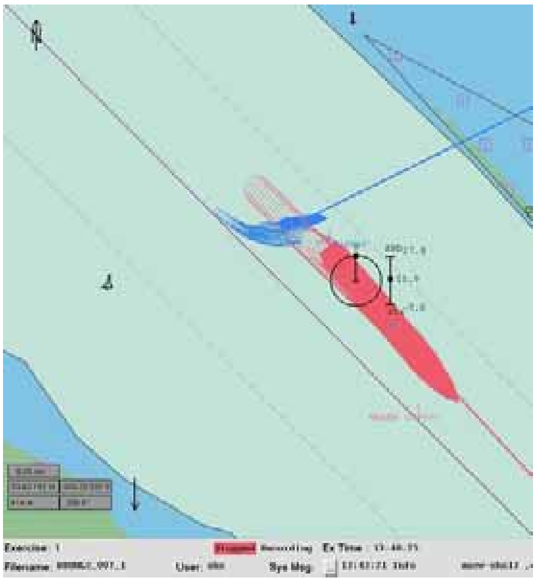


**Figure 29: Reconstruction of the marine casualty on the Ship Handling Simulator (Basis: time-synchronised data sets)**

## Table 1: Recorded data and associated analysis results

| Time (UTC) | Speed Cosco H. [kn] | Speed Nedlloyd F. [kn] | Course Cosco H. [°] | Course Nedlloyd F. [°] | Distance sensors [m] | Distances ship's wall [m] |
|---|---|---|---|---|---|---|
| 13:31:24 | 14.0 | 13.3 | 124.0 | 122.2 | 209.1 | 146.6 |
| 13:31:34 | 14.1 | 13.3 | 124.0 | 122.2 | 198.3 | 136.9 |
| 13:31:44 | 14.2 | 13.3 | 124.0 | 122.2 | 193.6 | 132.5 |
| 13:31:54 | 14.3 | 13.3 | 124.0 | 122.2 | 185.9 | 125.8 |
| 13:32:04 | 14.4 | 13.2 | 124.0 | 122.9 | 176.8 | 118.7 |
| 13:32:14 | 14.5 | 13.2 | 124.0 | 122.9 | 174.5 | 116.7 |
| 13:32:24 | 14.6 | 13.2 | 124.0 | 122.9 | 167.0 | 112.1 |
| 13:32:34 | 14.7 | 13.2 | 124.0 | 122.9 | 165.9 | 111.6 |
| 13:32:44 | 14.7 | 13.2 | 124.0 | 122.9 | 158.1 | 105.7 |
| 13:32:54 | 14.7 | 13.2 | 125.0 | 122.9 | 152.8 | 102.9 |
| 13:33:04 | 14.7 | 13.3 | 124.0 | 127.5 | 154.2 | 104.9 |
| 13:33:14 | 14.7 | 13.3 | 125.0 | 127.5 | 148.0 | 106.2 |
| 13:33:24 | 14.8 | 13.3 | 125.0 | 127.5 | 153.4 | 110.7 |
| 13:33:34 | 14.8 | 13.3 | 124.0 | 127.5 | 152.3 | 116.5 |
| 13:33:44 | 15.0 | 13.3 | 124.0 | 127.5 | 152.1 | 117.4 |
| 13:33:54 | 15.0 | 13.3 | 124.0 | 127.5 | 156.9 | 125.0 |
| 13:34:04 | 15.1 | 13.3 | 125.0 | 130.4 | 159.1 | 128.5 |
| 13:34:14 | 15.1 | 13.3 | 125.0 | 130.4 | 161.6 | 131.3 |
| 13:34:24 | 15.1 | 13.3 | 124.0 | 130.4 | 166.1 | 136.1 |
| 13:34:34 | 15.1 | 13.3 | 125.0 | 130.4 | 172.6 | 143.0 |
| 13:34:44 | 15.1 | 13.3 | 125.0 | 130.4 | 179.2 | 150.5 |
| 13:34:54 | 15.2 | 13.3 | 125.0 | 130.4 | 184.8 | 155.8 |
| 13:35:04 | 15.2 | 13.0 | 125.0 | 127.7 | 188.7 | 157.8 |
| 13:35:14 | 15.3 | 13.0 | 124.0 | 127.7 | 200.9 | 162.1 |
| 13:35:24 | 15.4 | 13.0 | 124.0 | 127.7 | 208.9 | 167.7 |
| 13:35:34 | 15.4 | 13.0 | 125.0 | 127.7 | 213.1 | 168.8 |
| 13:35:44 | 15.4 | 13.0 | 127.0 | 127.7 | 220.7 | 169.3 |
| 13:35:54 | 15.4 | 13.0 | 128.0 | 127.7 | 227.5 | 167.8 |
| 13:36:04 | 15.3 | 12.2 | 129.0 | 132.0 | 239.9 | 170.0 |
| 13:36:14 | 15.3 | 12.2 | 130.0 | 132.0 | 253.6 | 169.4 |
| 13:36:24 | 15.3 | 12.2 | 131.0 | 132.0 | 262.0 | 166.7 |
| 13:36:34 | 15.3 | 12.2 | 130.0 | 132.0 | 279.6 | 169.7 |
| 13:36:44 | 15.3 | 12.2 | 130.0 | 132.0 | 295.9 | 168.9 |
| 13:36:54 | 15.2 | 12.2 | 130.0 | 132.0 | 312.3 | 170.3 |
| 13:37:04 | 15.2 | 10.6 | 130.0 | 131.9 | 326.5 | 173.9 |
| 13:37:14 | 15.1 | 10.6 | 129.0 | 131.9 | 340.5 | 178.8 |
| 13:37:24 | 15.1 | 10.6 | 130.0 | 131.9 | 355.4 | 173.2 |
| 13:37:34 | 15.0 | 10.6 | 131.0 | 131.9 | 357.7 | 167.1 |
| 13:37:44 | 15.0 | 10.6 | 133.0 | 131.9 | 365.0 | 158.0 |
| 13:37:54 | 14.9 | 10.9 | 134.0 | 131.9 | 377.5 | 152.6 |
| 13:38:04 | 14.9 | 12.6 | 134.0 | 126.2 | 384.4 | 142.0 |

| Time (UTC | Speed Cosco H. [kn] | Speed Nedlloyd F. [kn] | Course Cosco H. [°] | Course Nedlloyd F. [°] | Distance sensors [m] | Distances ship's wall [m] |
|---|---|---|---|---|---|---|
| 13:38:14 | 14.9 | 12.5 | 135.0 | 126.2 | 378.0 | 126.5 |
| 13:38:24 | 14.9 | 12.6 | 135.0 | 126.2 | 377.3 | 115.7 |
| 13:38:34 | 15.0 | 12.6 | 134.0 | 126.2 | 376.3 | 107.5 |
| 13:38:44 | 15.1 | 12.6 | 134.0 | 126.2 | 377.1 | 101.4 |
| 13:38:54 | 15.1 | 12.6 | 134.0 | 126.2 | 378.2 | 94.4 |
| 13:39:04 | 15.1 | 15.0 | 135.0 | 127.0 | 383.9 | 96.7 |
| 13:39:14 | 15.1 | 15.0 | 134.0 | 127.0 | 398.9 | 107.1 |
| 13:39:24 | 15.1 | 15.0 | 134.0 | 127.0 | 418.5 | 121.7 |
| 13:39:34 | 15.1 | 15.0 | 133.0 | 127.0 | 434.9 | 138.3 |
| 13:39:44 | 15.0 | 15.0 | 133.0 | 127.0 | 448.1 | 149.3 |
| 13:39:54 | 14.8 | 15.0 | 135.0 | 127.0 | 462.8 | 163.0 |
| 13:40:04 | 14.5 | 8.0 | 137.0 | 131.4 | 497.6 | 213.8 |
| 13:40:14 | 14.2 | 8.0 | 138.0 | 131.4 | 553.6 | 272.2 |
| 13:40:24 | 14.0 | 8.0 | 137.0 | 131.4 | 615.1 | 334.5 |
| 13:40:34 | 13.8 | 8.0 | 136.0 | 131.4 | 679.1 | 399.3 |
| 13:40:44 | 13.5 | 8.0 | 136.0 | 131.4 | 742.8 | 463.9 |
| 13:40:54 | 13.2 | 8.0 | 136.0 | 131.4 | 800.5 | 522.8 |
| 13:41:04 | 13.0 | 1.2 | 138.0 | 10.0 | 867.2 | 632.8 |
| 13:41:14 | 12.8 | 1.2 | 139.0 | 10.0 | 939.7 | 704.0 |
| 13:41:24 | 12.5 | 1.2 | 141.0 | 10.0 | 1011.7 | 775.4 |

**Table 2: Data sets for the scenario additionally synchronised in time manually and associated analysis results**

| Time (UTC) | Speed Cosco H. [kn] | Speed Nedlloyd F. [kn] | Course Cosco H. [°] | Course Nedlloyd F. [°] | Distance sensors [m] | Distances ship's wall [m] |
|---|---|---|---|---|---|---|
| 13:31:24 | 14.0 | 13.3 | 124.0 | 122.2 | 380.1 | 303.1 |
| 13:31:34 | 14.1 | 13.2 | 124.0 | 122.9 | 365.6 | 288.8 |
| 13:31:44 | 14.2 | 13.2 | 124.0 | 122.9 | 365.6 | 288.8 |
| 13:31:54 | 14.3 | 13.2 | 124.0 | 122.9 | 357.3 | 280.7 |
| 13:32:04 | 14.4 | 13.2 | 124.0 | 122.9 | 346.3 | 270.2 |
| 13:32:14 | 14.5 | 13.2 | 124.0 | 122.9 | 342.5 | 266.3 |
| 13:32:24 | 14.6 | 13.2 | 124.0 | 122.9 | 331.7 | 256.1 |
| 13:32:34 | 14.7 | 13.3 | 124.0 | 127.5 | 331.0 | 255.9 |
| 13:32:44 | 14.7 | 13.3 | 124.0 | 127.5 | 325.3 | 251.0 |
| 13:32:54 | 14.7 | 13.3 | 125.0 | 127.5 | 320.5 | 246.6 |
| 13:33:04 | 14.7 | 13.3 | 124.0 | 127.5 | 320.6 | 247.5 |
| 13:33:14 | 14.7 | 13.3 | 125.0 | 127.5 | 303.2 | 231.4 |
| 13:33:24 | 14.8 | 13.3 | 125.0 | 127.5 | 309.3 | 237.7 |

| Time (UTC) | Speed Cosco H. [kn] | Speed Nedlloyd F. [kn] | Course Cosco H. [°] | Course Nedlloyd F. [°] | Distance sensors [m] | Distances ship's wall [m] |
|---|---|---|---|---|---|---|
| 13:33:34 | 14.8 | 13.3 | 124.0 | 130.4 | 299.2 | 229.8 |
| 13:33:44 | 15.0 | 13.3 | 124.0 | 130.4 | 299.5 | 230.8 |
| 13:33:54 | 15.0 | 13.3 | 124.0 | 130.4 | 292.6 | 225.8 |
| 13:34:04 | 15.1 | 13.3 | 125.0 | 130.4 | 283.6 | 219.3 |
| 13:34:14 | 15.1 | 13.3 | 125.0 | 130.4 | 273.8 | 210.4 |
| 13:34:24 | 15.1 | 13.3 | 124.0 | 130.4 | 275.6 | 212.7 |
| 13:34:34 | 15.1 | 13.0 | 125.0 | 127.7 | 270.0 | 207.9 |
| 13:34:44 | 15.1 | 13.0 | 125.0 | 127.7 | 262.5 | 202.3 |
| 13:34:54 | 15.2 | 13.0 | 125.0 | 127.7 | 256.5 | 198.3 |
| 13:35:04 | 15.2 | 13.0 | 125.0 | 127.7 | 251.6 | 195.0 |
| 13:35:14 | 15.3 | 13.0 | 124.0 | 127.7 | 240.5 | 187.8 |
| 13:35:24 | 15.4 | 13.0 | 124.0 | 127.7 | 233.6 | 183.0 |
| 13:35:34 | 15.4 | 12.2 | 125.0 | 132.0 | 231.3 | 182.4 |
| 13:35:44 | 15.4 | 12.2 | 127.0 | 132.0 | 220.9 | 176.9 |
| 13:35:54 | 15.4 | 12.2 | 128.0 | 132.0 | 210.0 | 171.8 |
| 13:36:04 | 15.3 | 12.2 | 129.0 | 132.0 | 205.4 | 172.6 |
| 13:36:14 | 15.3 | 12.2 | 130.0 | 132.0 | 201.2 | 171.5 |
| 13:36:24 | 15.3 | 12.2 | 131.0 | 132.0 | 200.0 | 171.2 |
| 13:36:34 | 15.3 | 10.6 | 130.0 | 131.9 | 204.2 | 174.2 |
| 13:36:44 | 15.3 | 10.6 | 130.0 | 131.9 | 204.2 | 169.8 |
| 13:36:54 | 15.2 | 10.6 | 130.0 | 131.9 | 206.7 | 167.0 |
| 13:37:04 | 15.2 | 10.6 | 130.0 | 131.9 | 206.4 | 164.0 |
| 13:37:14 | 15.1 | 10.6 | 129.0 | 131.9 | 212.6 | 165.5 |
| 13:37:24 | 15.1 | 10.9 | 130.0 | 131.9 | 214.2 | 155.3 |
| 13:37:34 | 15.0 | 12.6 | 131.0 | 126.2 | 207.0 | 137.7 |
| 13:37:44 | 15.0 | 12.5 | 133.0 | 126.2 | 195.1 | 120.4 |
| 13:37:54 | 14.9 | 12.6 | 134.0 | 126.2 | 186.6 | 102.3 |
| 13:38:04 | 14.9 | 12.6 | 134.0 | 126.2 | 179.6 | 89.0 |
| 13:38:14 | 14.9 | 12.6 | 135.0 | 126.2 | 168.7 | 73.0 |
| 13:38:24 | 14.9 | 12.6 | 135.0 | 126.2 | 163.6 | 58.4 |
| 13:38:34 | 15.0 | 15.0 | 134.0 | 127.0 | 163.5 | 52.8 |
| 13:38:44 | 15.1 | 15.0 | 134.0 | 127.0 | 176.0 | 47.0 |
| 13:38:54 | 15.1 | 15.0 | 134.0 | 127.0 | 189.9 | 45.9 |
| 13:39:04 | 15.1 | 15.0 | 135.0 | 127.0 | 204.4 | 40.3 |
| 13:39:14 | 15.1 | 15.0 | 134.0 | 127.0 | 217.3 | 32.9 |
| 13:39:24 | 15.1 | 15.0 | 134.0 | 127.0 | 235.1 | 23.2 |
| 13:39:34 | 15.1 | 8.0 | 133.0 | 131.4 | 272.0 | 3.5 |
| 13:39:44 | 15.0 | 8.0 | 133.0 | 131.4 | 340.1 | 57.2 |
| 13:39:54 | 14.8 | 8.0 | 135.0 | 131.4 | 406.9 | 125.2 |
| 13:40:04 | 14.5 | 8.0 | 137.0 | 131.4 | 474.2 | 193.2 |
| 13:40:14 | 14.2 | 8.0 | 138.0 | 131.4 | 531.5 | 252.2 |

| Time (UTC) | Speed Cosco H. [kn] | Speed Nedlloyd F. [kn] | Course Cosco H. [°] | Course Nedlloyd F. [°] | Distance sensors [m] | Distances ship's wall [°] |
|---|---|---|---|---|---|---|
| 13:40:24 | 14.0 | 8.0 | 137.0 | 131.4 | 594.4 | 315.7 |
| 13:40:34 | 13.8 | 1.2 | 136.0 | 10.0 | 665.0 | 429.4 |
| 13:40:44 | 13.5 | 1.2 | 136.0 | 10.0 | 741.6 | 505.2 |
| 13:40:54 | 13.2 | 1.2 | 136.0 | 10.0 | 813.9 | 578.7 |
| 13:41:04 | 13.0 | 1.2 | 138.0 | 10.0 | 881.2 | 645.5 |
| 13:41:14 | 12.8 | 1.2 | 139.0 | 10.0 | 947.1 | 710.9 |
| 13:41:24 | 12.5 | 1.2 | 141.0 | 10.0 | 1011.7 | 775.4 |

### 6.2.3 Results of the analysis of the course of the voyage

The analysis of the ECS data performed by Department of Maritime Navigation on behalf of BSU sustainably confirmed the supposition that it was hydrodynamic interactions between the vessels involved that brought about the collision incident, and not unilateral sudden changes in course and/or speed caused by technical or human failure.

Furthermore, the finding "merely" gained on the periphery of the calculations performed that at least one of the two electronic chart systems must have been fed faulty GPS data is also interesting. The fact that the collision could not be reconstructed analytically using solely the non-synchronised position data documents this impressively.

## 6.3 Hydrodynamic assessment

### 6.3.1 Introduction

The analysis of the recorded ECS data of the two vessels by Department of Maritime Navigation has revealed that the marine casualty was (co-)caused by hydrodynamic effects. Accordingly, on the occasion of the presentation of the analysis results by representatives of the Department of Maritime Navigation[31] at the offices of BSU on 15 September 2004, the BSU discussed the possibilities of more precise investigation of the hydrodynamic interactions. Prof. em. Dr.-Ing. Heinrich Söding, acknowledged as a proven expert in the field of hydrodynamics and who has already supplied valuable contributions for marine casualty investigations in Germany in the past through work as an expert in Seeamt proceedings also attended the discussion panel to advise the BSU on technical aspects.

The result of the meeting was that on the one hand, in other words before completion of the investigations, a safety recommendation on the hydrodynamic-related dangers in connection with overtaking manoeuvres in narrow channels should be published.[32] The main reason for the urgency of the recommendation to be published was the unanimous finding that the "historic" statements by Seeämter/courts that a passing distance of approx. 100 m was sufficient[33] to avoid suction effects, that had initially been taken from case to case but had then become increasingly generalised in public perception, required clarification. After all, in the case being examined here a dangerous suction effect had indubitably developed despite an at least initially much larger distance.

On the other hand, it was discussed whether and if so how a further hydrodynamic investigation into the marine casualty was to be carried out in order to finally be able to make (general) statements as far as possible about what passing distance must be observed during overtaking manoeuvres in order to avoid collision risks by suction.

Prof. Söding explained that for example Ship Model Basins were in a position to calculate the suction forces occurring. In order to be able to obtain reliable statements for the vessels concretely involved, it was necessary to provide the lines drawings, loading situations (loading cases) depths and navigation channel profiles.

The representatives of Department of Maritime Navigation pointed out that the Ship Handling Simulator in Warnemünde is able to map suction effects. It is possible to carry out calculations with vessel types already programmed on the simulator. Admittedly, it is also possible to model the two vessels concretely affected and then run them in the simulator. However, the latter variant would be connected with considerable (time-intensive and therefore cost-intensive) additional work.

Prof. Söding countered here that in his opinion the internal mathematical models of the simulators were no longer in line with the latest state of the art and that only

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[31] Dr.-Ing. M. Baldauf, Dipl.-Ing. M. Kirchhoff and Dipl.-Ing. S. Fischer.

[32] Note: The subject safety recommendation was published on 1 October 2004 and is repeated at the end of this investigation report.

[33] Cf. here for instance Higher Regional Court Hamburg, Judgement of 22 May 1986 (Ref. 6 U 225/84); Bundesoberseeamt, Decision on Objection on 16 December 1986 (BOSeeAE 7/87, P. 113 ff.); Administrative Court Hamburg, Judgement of 16 August 1988 (BOSeeAE 4/89, P. 76 ff.); Seeamt Hamburg, Findings of 25 February 1986 (BOSeeAE 8/86, P. 156 ff.) and 19 March 1996 (BOSeeAE 11/97, P. 419 ff.).

rough approximate values could probably be achieved with the formula used (not disclosed) by the simulator manufacturers.

As a result of the discussion it was considered expedient to conduct a further hydrodynamic examination that should be oriented to the concrete case, but also and in particular should serve the objective of developing generalised statements on the problem complex of "safe passing distance in narrow channels".

Prof. Söding gave the BSU valuable support in formulating the investigation orders to be issued. The Ship Model Basins to whom enquiries were addressed thereupon suggested carrying out calculations on the flow conditions round the two vessel hulls (1), and then calculating the relevant forces occurring with the (interim) results achieved (2) (important for determining the rudder angle and drift angle). It is possible to draw on different, partly very complex and costly/complicated calculating methods for the calculations (1) and (2) to be carried out. The processes used are subject to constant further development, as ever more powerful computer systems become available so that calculating inputs become possible that could not have been realised a few years ago.

A working meeting of the BSU's investigation team with scientists from various Ship Model Basins was held on 30 September 2004 on the fringes of the SMM[34], at which the BSU project was discussed extensively. The discussions were conducted at a very high scientific level; the participating scientists conducted an interesting dispute about the current scientific options and the pros and cons of the various potential solutions. The BSU's intention of taking the (continuously recurring and in future increasing) problems and difficulties within the framework of overtaking manoeuvres of ever larger vessels in narrow channels on the basis of the subject case under review as an occasion to conduct a more in-depth hydrodynamic investigation was unanimously welcomed. Admittedly it became clear that considering a single case would only offer very restricted opportunities for generally valid recommendations. Despite this, however, it was agreed that the more detailed examination of a single case could serve as an important impulse for thought and supply valuable findings at the preliminary stage for further hydrodynamic examinations.

Moreover, consensus was also achieved that both numerical approaches (pure calculations) and experiments were necessary for the hydrodynamic investigation to be conducted. The model experiments were to serve to validate and secure the calculations to be made.

All participants also agreed that the Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V. in Duisburg (Development Centre for Ship Technology and Transport Systems; hereinafter referred to briefly as DST) offered the best conditions for the experimental approach thanks to the unique technical resources there (possibility of reproducing two models and their interactions at the same time). Accordingly the DST was commissioned to execute the model experiments (cf. Section 6.3.3 below). The order for the numerical investigation was awarded to the Potsdam Model Basin (cf. also Section 6.3.2). It was possible to win over the Hamburgische Schiffbauversuchsanstalt (HSVA - Hamburg Ship Model Basin; cf. Section 6.3.4 below) for comparative considerations and evaluation of the results, and Prof. Söding as consultant to the BSU (cf. in particular Section 6.3.5).

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[34] SMM = Shipbuilding, Machinery and Marine Technology: international trade fair held every two years in Hamburg.

### 6.3.2 Numerical examination of the overtaking manoeuvre

The Shipbuilding Experimental Institute Potsdam[35] conducted a numerical study of an overtaking manoeuvre in restricted water on behalf of the BSU. This investigation was based largely on the available data material from the vessels involved. Where data necessary for the calculations were not available, the Potsdam Institute operated with approximate values. Altogether the forces and the yawing moment exerted on the vessel overtaken during the overtaking manoeuvre were calculated for seven situations considered in stationary terms. Furthermore, the rudder angle and the resulting drift angle necessary to keep to the straight line trajectory were determined.

The remarks in the following subsections reproduce the contents of the final report produced by the Potsdam Institute No. 3048 with the title "Numerical examination of an overtaking manoeuvre in restricted water" of 17 December 2004[36], in abbreviated form retaining the meaning and generally with the original wording.

#### 6.3.2.1 Preliminary theory considerations

When vessels move at a short distance from each other, they mutually influence the relevant flow fields. Considerable hydrodynamic forces and moments can develop here that impair the steerability of the vessels and can lead to collisions. This represents a major danger, especially in shallow water with a low ratio of water depth to draft (h/T). The most important reasons for collisions during an overtaking manoeuvre are insufficient distance between the vessels involved and the ship's speeds being too high, as this causes the forces and moments mentioned to increase, as well as insufficient speed differences as this means that the overtaking manoeuvre takes longer and the forces and moments can act longer.

The most important cause of the component force is the suction that develops because of the acceleration of the flow and reduction of the pressure between the two vessels. A further cause of the component force is the hydrofoil effect that leads to mainly the vessel in front experiencing a force that is oriented against the other vessel.

In the case of overtaking manoeuvres with small distances between the affected vessels the wave formation plays a minor role compared with the strong disturbance of the pressure field between the two vessels. However, the situation was different in the case of the collision between NEDLLOYD FINLAND and COSCO HAMBURG, where the initial side distance between the vessels was about four ship's widths of the large vessel. In this case the disturbance of the pressure field between the two vessels is much more moderate so that the slowly diminishing waves could play a larger role.

#### 6.3.2.2 Scope of tasks

As the difference in speed in overtaking manoeuvres is generally slight by contrast with encounters, and as the operations can last a long time, non-stationary effects could be neglected and the flow could be considered as stationary, so to speak. For the numerical considerations it was assumed that both vessels were proceeding on a parallel course at the same speed of 15 kn. For a lateral distance of 150 m between the centre lines of the vessels five positions of the two vessels in relation to each

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[35] Hereinafter referred to briefly as Potsdam Institute
[36] The original report can be downloaded from the BSU's website.

other in longitudinal direction were investigated (-0.2, 0, 0.3, 0.6 and 0.8 L[37]). In addition the lateral distances 100 m and 200 m were examined for the longitudinal off-set in which the numerically highest yawing moment is exerted on the overtaking vessel (0.6 L).

### 6.3.2.3 Procedure

6.3.2.3.1 Determining the forces and moments

The forces and moments on the overtaken vessel can be determined by calculating the flow round the two vessels. The potential-theory calculation procedure KELVIN developed by Prof. Söding (Technical University Hamburg Harburg) for the Potsdam Institute was used for this purpose. The influence of shallow water, the wave formation, as well as the dynamic lowering and trimming of the vessels involved are taken into account here. In the investigation it was not necessary to take the rudder of the overtaking vessel into account. The rudder of the overtaken vessel was significant for determining the yawing moment and was modelled as a fin (without thickness).

The river bottom was taken into account by way of approximation in the calculations. The information necessary for this was provided by DST Duisburg (cf. Fig. 30).

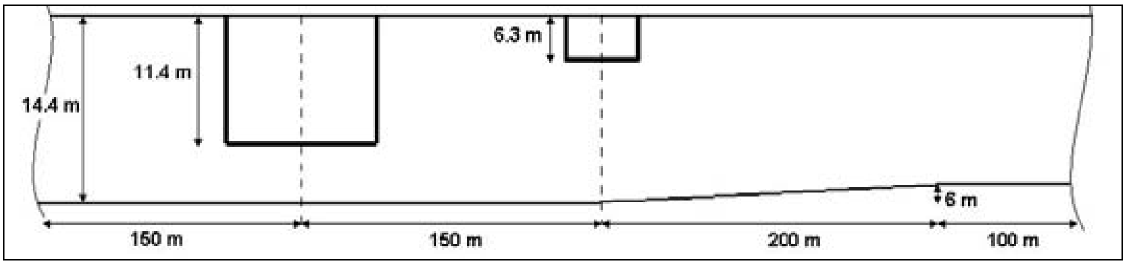

**Figure 30: Sketch of the cross section of the calculation area**

By contrast with a calculation of the viscous flow using a RANSE solver[38], the hydrofoil effect is not covered in the KELVIN calculations. This would probably only have had any notable influence on the calculated component force and yawing moment of the overtaken vessel in the approach phase. The (small) repellent component force in this phase would be somewhat larger if the hydrofoil effect were taken into account, and the yawing moment presumably a little smaller. KELVIN is currently being supplemented to take the hydrofoil effect into account so that this can be considered in future studies, which is expected to be increasingly important especially for investigations of strongly non-stationary cases (for example encounters).

However, as a digitised description of the hull form was only available for NEDLLOYD FINLAND, while only the lines drawing was available for COSCO HAMBURG, COSCO HAMBURG was first digitised. After this, calculation grids were generated on both vessel hulls using IGES data.

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[37] L = Length of the overtaking vessel. The length off-set is zero if the forward perpendiculars of both vessels are at the same level. A positive length off-set means that the bow of the overtaking vessel is in front of that of the overtaken vessel

[38] Solution of the "***R**eynolds-**A**veraged **N**avier-**S**tokes **E**quations".*

In addition to the seven cases commissioned as mentioned above, Potsdam Institute conducted many calculations in order to check the quality of the results. For example calculations for both vessels in deep water, and for NEDLLOYD FINLAND alone in deep and shallow water were conducted. All the calculations were repeated with different grid resolutions. The finest grid resolution contained 120x60 cells for the free water surface. In addition the influence of the bottom rising towards the banks was examined by comparing calculations with and without an embankment. In order to be able to assess the course of the quantities examined during the overtaking manoeuvre, a large number of additional positions of the overtaking vessel in the longitudinal direction were examined as well.

It was ascertained that all test calculations backed up the results achieved. The calculated developments were smooth and plausible. The influence of the (very slight) rise of the river bed towards the bank on the calculated forces and moments at the overtaken vessel is small, but not negligible. As of a resolution of 90x45 cells, in other words 90 cells in the longitudinal direction and 45 cells in the lateral direction, the results of the KELVIN calculations did not show any more notable changes.

#### 6.3.2.3.2 Determination of the necessary rudder angle and drift angle

The values calculated for "stationary" applications using KELVIN for the forces and yawing moment on NEDLLOYD FINLAND in the various situations during the overtaking operation subsequently served to predict the rudder angle to be set in each case and the resulting drift angle in order to achieve the dynamic balance to maintain the straight line trajectory. This was done in two different ways.

In the first approach drift passages of the force-guided vessel with helm set were simulated numerically for various combinations of drift and rudder angles using the SIMBEL simulation program, and the combination that compensates the previously calculated component force and calculated yawing moment was determined for each case examined. The second method consisted in determining a set of hydrodynamic coefficients with the aid of empirical formulae and data from similar vessels that describe the dependencies of the component force and the yawing moment on drift and rudder angle. By equating the approaches formed with these coefficients for the component force and yawing moment with the values previously calculated using KELVIN, it was possible to determine the rudder angle and drift angle for each situation considered.

The main particulars of the vessels involved in the overtaking manoeuvre under examination that were used in the calculations are set out in the following table. Figure 31 shows the propeller and rudder arrangement of NEDLLOYD FINLAND taken as a basis.

**Table 3: Vessel data used for the numerical examination:**

| | | COSCO HAMBURG | NEDLLOYD FINLAND |
|---|---|---|---|
| Length between perpendiculars | $L_{pp}$ | 264.00 m | 96.00 m |
| Length over all | L | 280.00 m | 101.00 m |
| Width | B | 39.90 m | 18.40 m |
| Draft forward | $T_v$ | 11.30 m | 6.00 m |
| Draft aft | $T_h$ | 11.50 m | 6.57 m |
| Block coefficient | $C_B$ | 0.59 | 0.652 |
| Speed | v | 15 kn | 15 kn |
| Froude number | $F_n$ | 0.152 | 0.251 |
| Froude depth number | $F_{nh}$ | 0.64 | 0.64 |
| Water/Draft | $2h / (T_v + T_h)$ | 1.26 | 2.30 |

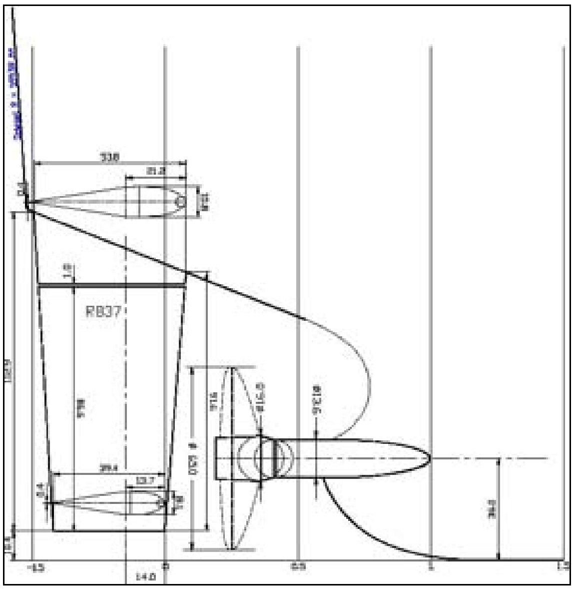

Figure 31: Propeller and rudder arrangement on NEDLLOYD FINLAND

### 6.3.2.4 Forces and moments on the vessel overtaken

The forces and yawing moments on the overtaken vessel at a lateral distance of 150 m calculated with KELVIN are set out in Figure 32. The position/the dimensionless longitudinal off-set of the overtaking vessel in relation to the overtaken vessel was shown as abscissa. L=280 m was used as a reference length.[39] The coordinate system used on the overtaken vessel originates at the main frame on the water line. The longitudinal coordinate x points forward, y to starboard and z downwards. The positive directions of the Forward force X, the component force Y and the yawing moment N are defined accordingly.

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[39] Cf. the remarks above under Section 6.3.2.2. for a definition of the quantity L

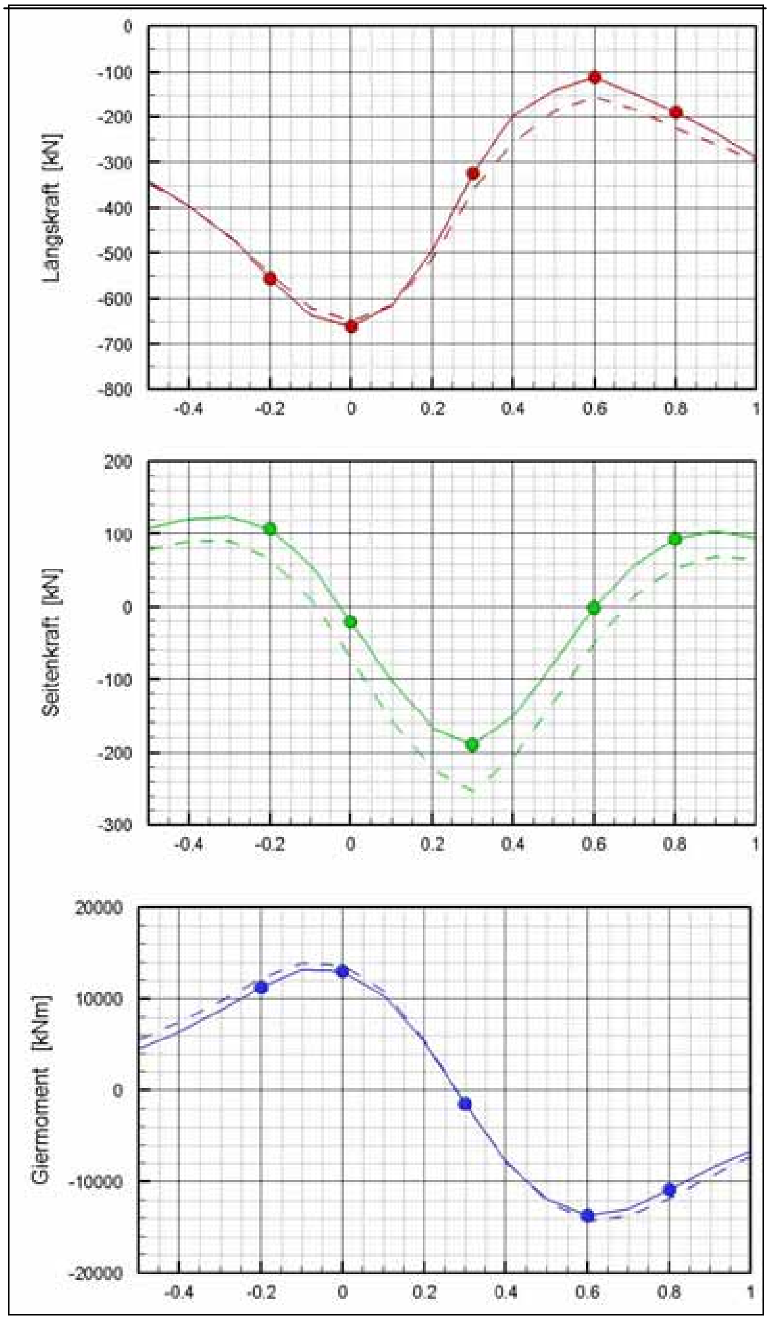

Figure 32: Forward force, component force and yawing moment on the vessel overtaken

At a lateral distance of 150 m during the overtaking operation, the overtaken vessel experiences a small component force that is largely directed towards the passing vessel. The yawing moment changes the prefix during the operation and assumes roughly equally large positive and negative maximum values. During the approach phase the overtaken vessel experiences a yawing moment that tries to turn its own bow away from the overtaking vessel. When both main frames lie roughly next to one another, the yawing moment disappears. During the distancing phase a yawing moment that tries to turn the overtaken vessel's own bow towards the overtaking vessel is experienced by the overtaken vessel. The longitudinal component of the suction force on the overtaken vessel also changes the prefix during the operation.[40] This is dangerous because initially a *short* overtaking process is simulated, but then the operation is strongly delayed by the acceleration of the overtaken vessel. As can be seen in Figure 32, the forward force (the resistance) assumes numerically much lower values in the distancing phase.

Even without the hydrofoil effect the component force, especially in the approach phase, assumes positive values. Potsdam Institute could not clarify the reason for this (small) repellent force on the overtaken vessel completely, but it is probably attributable to the building up of the flow in front of the overtaking vessel and the corresponding increase of pressure on the port side of the overtaken vessel.
In Figure 32 the tracks for the case of a horizontal bottom at h/T=2.3 are additionally shown in an interrupted line as an approximation to the real bottom geometry. The differences between these results and those taking into account the embankment (uninterrupted lines) are low for the lateral distance considered. The slight asymmetry of the cross section of the flow area did not have any major influence on the results. As test calculations showed, the component force is increased to an extent roughly corresponding to the amount of the force acting towards the shore on the overtaken vessel in the absence of the overtaking vessel.

The developments of the lowering and trimming of the overtaken vessel for various positions of the overtaking vessel between -0.5 L and 1 L at the lateral distance of 150 m displayed at the bottom in Figure 33 show a somewhat stronger change in the dynamic position afloat when the embankment is taken into account. The test calculations of the Potsdam Institute for NEDLLOYD FINLAND alone showed a moderate increase in the vessel lowering of about 0.30 m to 0.55 m for deep water and for shallow water at h/T=2.30. By contrast the lowering varies strongly during the overtaking manoeuvre and reaches values of around one metre. The trimming always remains relatively low here.
Both the component force and the yawing moment increase strongly in shallow water. Figure 34 shows the calculated course of the yawing moment on the overtaken vessel for the overtaking operation in deep water by way of example. The maximum values are one order of magnitude smaller here than in the case examined, cf. Figure 32.

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[40] Note: The *calculated (!)* forward force shows the course described, but does not change its prefix (cf. Fig. 32). The reason for this is solely the fact that in Fig. 32 the propeller thrust was not taken into account.

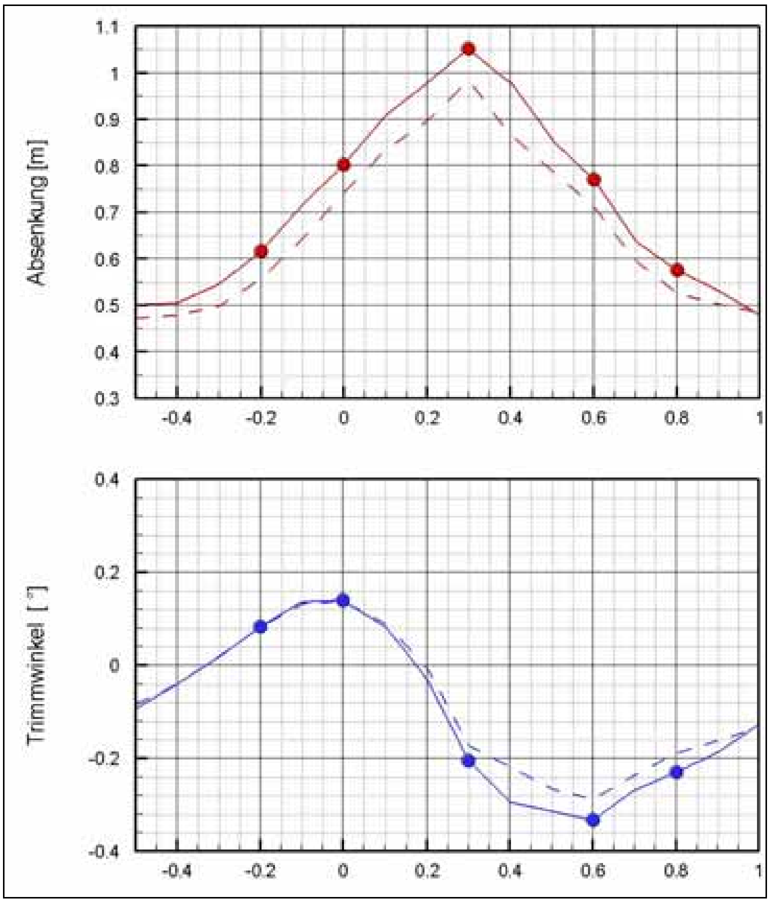

Figure 33: Vessel lowering and trimming on the vessel overtaken

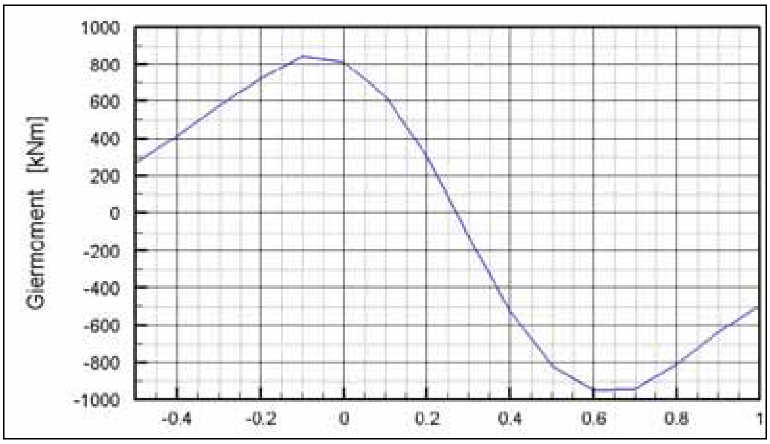

Figure 34: Yawing moment on the vessel overtaken in deep water

The repetition of the calculations for all the interesting cases with the higher resolution of 120x60 cells on the water surface grid did not show any notable change in the component forces and yawing moments. Differences could only be ascertained in the forward force. The course of the forward force with the medium (interrupted line) and finer (uninterrupted line) resolution is shown in Figure 35.

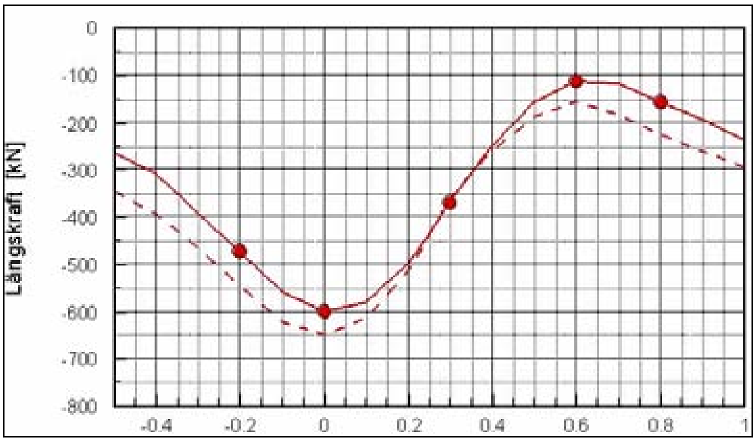

Figure 35: Forward force on the vessel overtaken, medium and fine grid resolution

#### 6.3.2.5 Speed course of NEDLLOYD FINLAND during the overtaking manoeuvre

On the basis of the course of the forward force calculated and shown in Figure 35, Potsdam Institute conducted a rough estimation of the actual course of the speed of NEDLLOYD FINLAND during the overtaking manoeuvre. It was assumed that the overtaking vessel passed at a constant speed of 15 kn and that the initial speed of the overtaken vessel was 13.5 kn.

Figure 36 shows the result of the time simulation resulting from solving the impulse equation in the longitudinal direction. The time calculation starts at the moment at which the bow of the overtaking vessel has reached the stern of the overtaken vessel (longitudinal off-set approx. -0.35 L) and ends after the overtaking vessel has passed (longitudinal off-set 1L). The course of the speed shows a strong decline in speed to about 10.5 kn and subsequently a drastic increase to almost 15 kn.

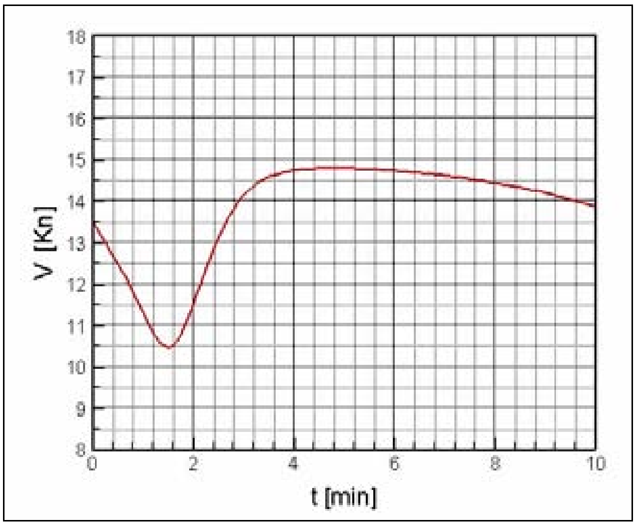

Figure 36: Speed course of NEDLLOYD FINLAND

#### 6.3.2.6 dder angle to be set and associated drift angle

The most reliable way of determining the rudder angle to be set and the resulting drift angle for each situation considered would be to calculate the viscosity-affected flow around the overtaken vessel on a real scale for a variation of drift angle and rudder angle, taking into account the wave formation, the real bottom condition and the corresponding propeller load. However, as this would have expanded the scope of the study too far, two different conventional strategies were pursued to determine the rudder angle to be set and the associated drift angle on the overtaken vessel (cf. Section 6.3.2.3.2). RANSE calculations were carried out for some selected cases to verify the results achieved by this. The path via the hydrodynamic coefficients proved to be more precise here.

The RANSE calculations were carried out for the flow around the model instead of around the large version and without taking into account the free water surface, as they were only of a supporting nature here and were thus less expensive. With regard to determining the necessary rudder angle and corresponding drift angle, however, scale effects can play a larger role than in determining the component force and yawing moment on the overtaken vessel. This is primarily attributable to the strongly overdrawn boundary layer and stronger propeller load in the model. If these two effects do not mutually cancel each other out, a different rudder inflow develops on the model than occurs in the large version.

The RANSE simulations were carried out for different stationary drift passages with the helm put to the middle and to one side. The (axial) propeller effect was simulated by specifying a distribution of forces in the propeller plane (corresponding to the thrust of the propeller). The influence of the direction of rotation of the propeller was not taken into account, but probably was not very important for the question being considered here.

In the case under review the depth froude number Fnh=0.64, so that shallow water effects would not have been very pronounced. Nevertheless, this was taken into account when determining the rudder angle and drift angle via corrections of the hydrodynamic coefficients for shallow water. In order to check these empirical corrections that were not always reliable, the RANSE calculations were carried out both for deep water and for the case of water depth limitation by a horizontal bottom corresponding to the ratio h/T=2.3 and were used to prepare the set of coefficients. As it turned out that the linear hydrodynamic coefficients were sufficient to predict the rudder angle and the drift angle, the hydrodynamic coefficients determined with RANSE were finally used for this purpose.

The rudder angles and angles of drift calculated using the process described in Section 6.3.2.3.2 for the seven situations examined are listed in the last two columns of Tables 4 and 5 of this report (cf. Section 6.3.2.7 further below). Figure 37 shows the calculated rudder angle and the resulting drift angle on the overtaken vessel for various positions of the overtaking vessel between -0.5 L and 1 L for the lateral distance of 150 m. The calculations taking into account the embankment (uninterrupted line) revealed only slight changes by comparison with the calculations using a horizontal bottom (h/T=2.30; interrupted line) here too. Altogether only relatively small rudder angles were necessary to compensate the previously calculated component forces and yawing moments.

The values determined in the accompanying calculations for deep water for rudder angles and angles of drift were somewhat higher than for the case of restricted water considered. The turning ability and steerability of the vessel generally decrease steeply in shallow water as the rudder action decreases altogether. This is attributable to the fact that the hull forces increase relatively much more strongly than the rudder force. On the other hand, however, the yawing stability and initial turning capability of the vessel in shallow water increase, which in turn benefits the ability to keep course.

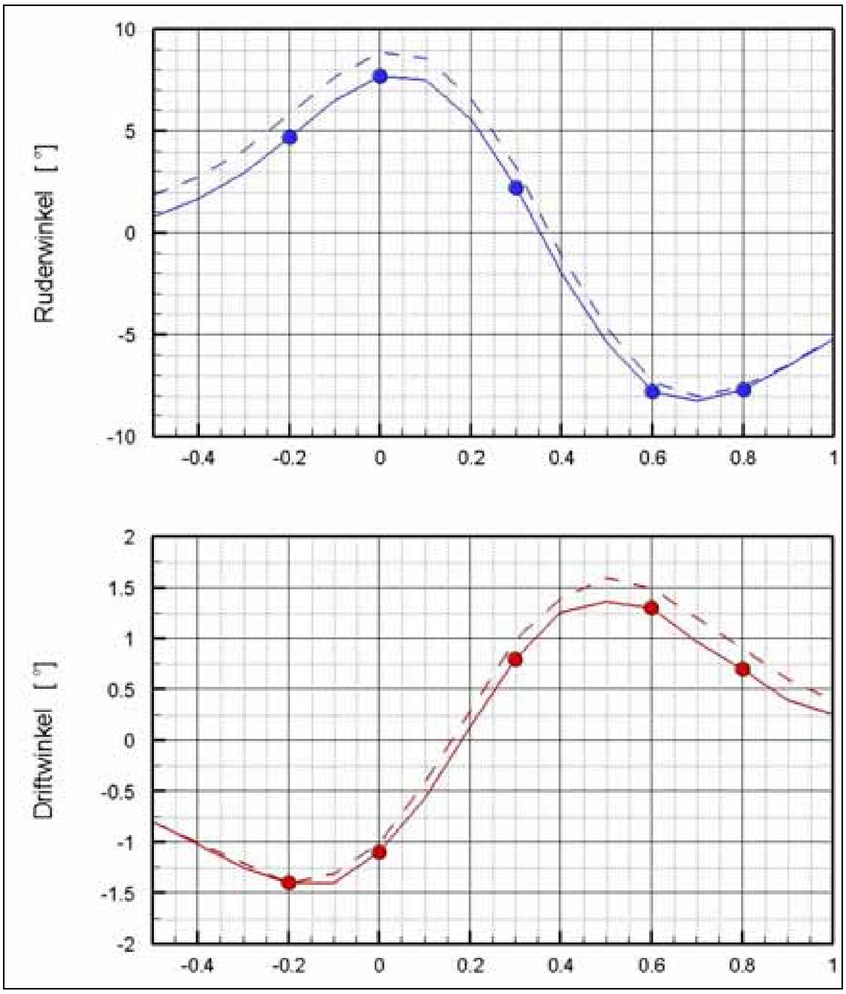

Figure 37: Rudder angle and drift angle on the vessel overtaken

### 6.3.2.7 Summary of the numerical achieved results

According to the calculations of Potsdam Institute, only small rudder angles are necessary to hold the trajectory for the lateral distance of 150 m chiefly examined. However, the respective necessary rudder angle changes strongly with the longitudinal off-set between the overtaking and overtaken vessel. The resulting angles of drift are very small. Somewhat larger rudder angles only resulted for the case with a lateral distance of 100 m. The reason for this small angles is the relatively large lateral distance between the vessels involved, the moderate ship's speed and the not extremely shallow water ratio in the case under investigation. As a result of the restricted scope of the order, it was not possible to investigate all aspects of the overtaking operation in this study. In particular a more comprehensive variation of parameters would have been necessary to derive criteria to be observed for minimum distances, maximum speed and speed difference. In the opinion of Potsdam Institute, these examinations should be conducted on the basis of RANSE and possibly also cover non-stationary effects.

The results with and without consideration of the embankment are summarised in the following tables. The results of the calculations with the lateral distances 100 and 200 m for the longitudinal off-set of 0.6 L, at which according to the Potsdam Institute calculations the largest yawing moment occurs, can also be seen from the tables. As expected the yawing moment on the overtaken vessel is magnified strongly at the transition from 200 to 100 m. On the other hand, the component force hardly changes. The explanation for this is probably that the change in prefix of the component force occurring at roughly longitudinal off-set 0.6 L is not very dependent on the distance considered.

**Table 4: Results of the 7 cases investigated, horizontal bottom at h/T=2.3**

| **Longi-tudinal off-set L** | **Lateral distance [m]** | **For-ward force X [kN]** | **Compo nent force Y [kN]** | **Yawing moment N [kNm]** | **Draft change $\Delta T$ [m]** | **Trim angle $\theta$ [°]** | **Rudder angle $\delta$ [°]** | **Drift angle $\beta$ [°]** |
|---|---|---|---|---|---|---|---|---|
| -0.2 | 150 | -546 | 66 | 12307 | 0.56 | 0.083 | 5.9 | -1.4 |
| 0. | 150 | -648 | -71 | 13680 | 0.744 | 0.138 | 8.9 | -1.0 |
| 0.3 | 150 | -358 | -252 | -1429 | 0.985 | -0.172 | 3.2 | 1.0 |
| 0.6 | 150 | -154 | -50 | -14243 | 0.712 | -0.286 | -7.2 | 1.5 |
| 0.8 | 150 | -225 | 54 | -11805 | 0.526 | -0.188 | -7.5 | 0.9 |
| 0.6 | 100 | 55 | -43 | -24724 | 0.750 | -0.471 | -13.3 | 2.4 |
| 0.6 | 200 | -256 | -42 | -8497 | 0.654 | -0.183 | -4.1 | 0.9 |

**Table 5: Results of the 7 cases investigated, bottom with embankment**

| **Longi-tudinal off-set L** | **Lateral distance [m]** | **For-ward force X [kN]** | **Compo nent force Y [kN]** | **Yawing moment N [kNm]** | **Draft change $\Delta T$ [m]** | **Trim angle $\theta$ [°]** | **Rudder angle $\delta$ [°]** | **Drift angle $\beta$ [°]** |
|---|---|---|---|---|---|---|---|---|
| -0.2 | 150 | -556 | 107 | 11279 | 0.617 | 0.084 | 4.7 | -1.4 |
| 0. | 150 | -660 | -21 | 12968 | 0.803 | 0.140 | 7.7 | -1.1 |
| 0.3 | 150 | -324 | -189 | -1499 | 1.053 | -0.205 | 2.2 | 0.8 |
| 0.6 | 150 | -111 | -1 | -13756 | 0.770 | -0.332 | -7.8 | 1.3 |
| 0.8 | 150 | -190 | 93 | -10921 | 0.576 | -0.230 | -7.7 | 0.7 |
| 0.6 | 100 | 116 | 10 | -23912 | 0.816 | -0.534 | -13.7 | 2.1 |
| 0.6 | 200 | -224 | 2 | -8133 | 0.725 | -0.227 | -4.7 | 0.7 |

The following representations of the calculated isolines of the wave elevation serve to illustrate the mutual influencing of the two vessels further.[41]

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[41] Wave elevation between -1.2 m and 1.2 m with intervals of 0.10 m; horizontal bottom at h/T=2.3.

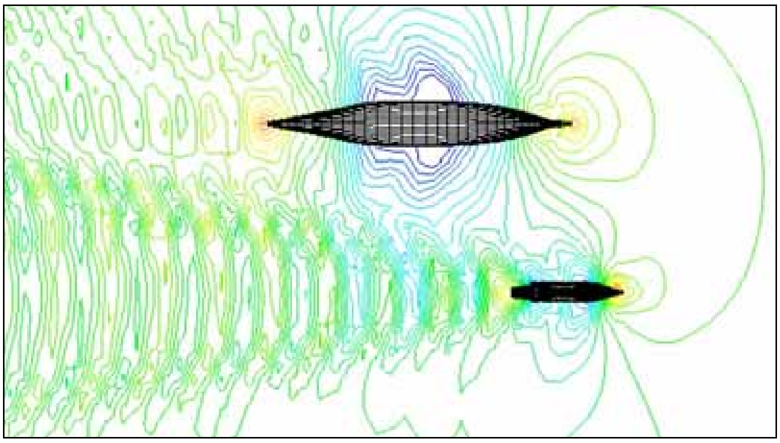

Figure 38: Isolines of the wave elevation (L –0.2; side distance 150 m)

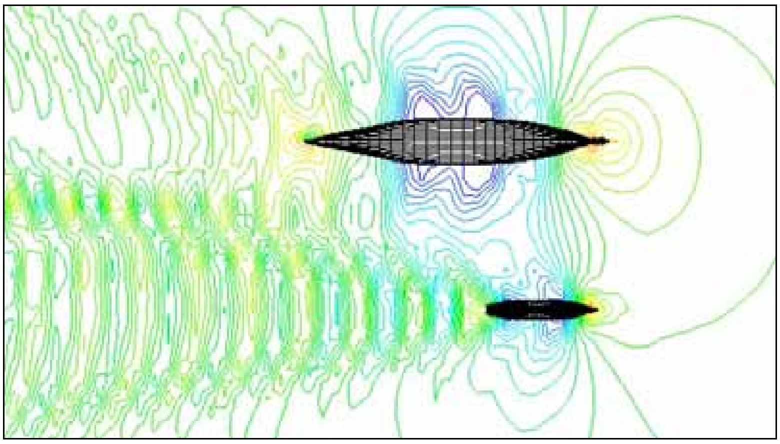

Figure 39: Isolines of the wave elevation (L 0; side distance 150 m)

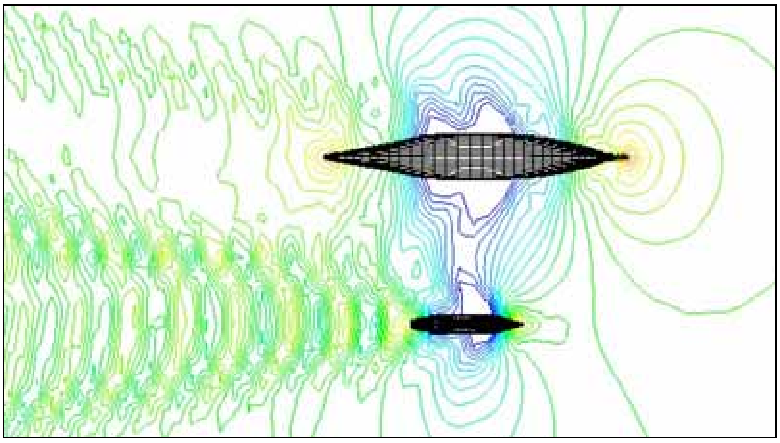

Figure 40: Isolines of the wave elevation (L 0.3; side distance 150 m)

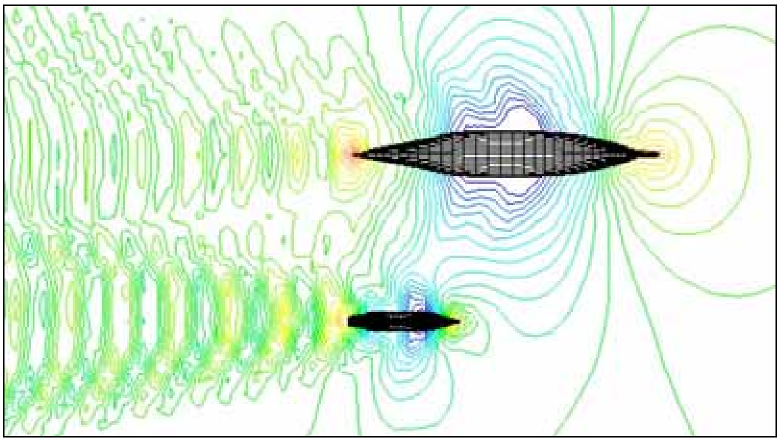

Figure 41: Isolines of the wave elevation (L 0.6; side distance 150 m)

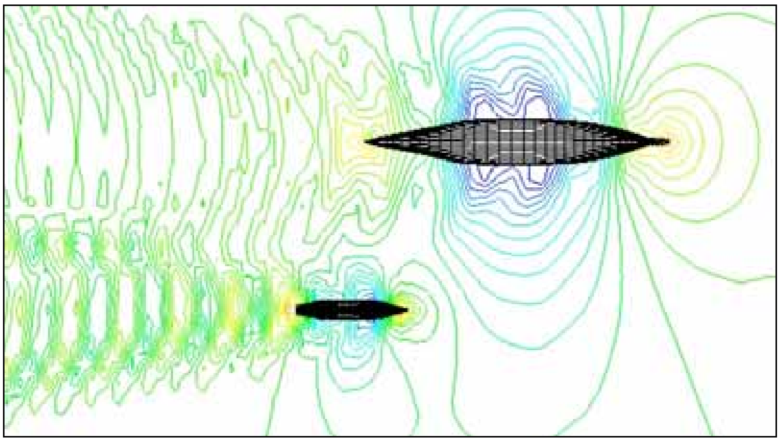

Figure 42: Isolines of the wave elevation (L 0.8; side distance 150 m)

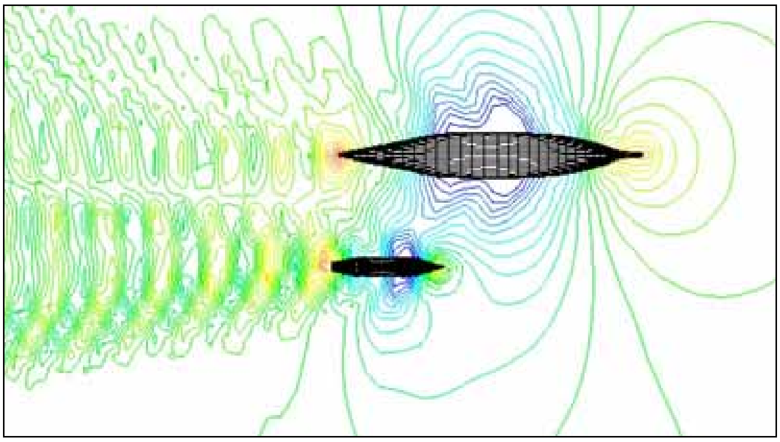

Figure 43: Isolines of the wave elevation (L 0.6; side distance 100m)

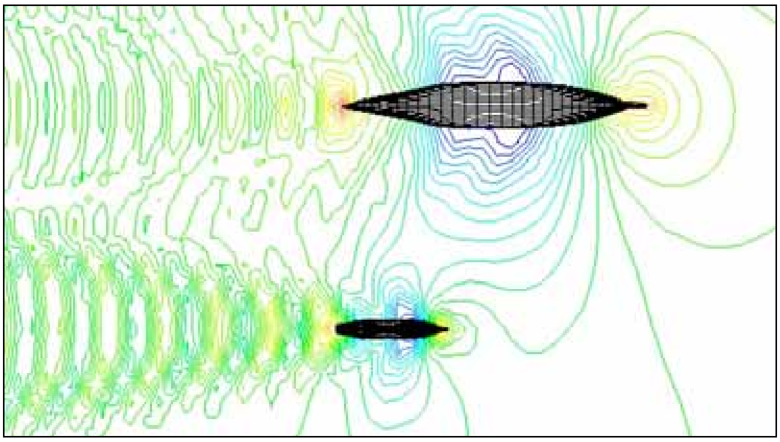

**Figure 44: Isolines of the wave elevation (L 0.6; side distance 200 m)**

### 6.3.3 Experimental examination of the overtaking manoeuvre

The Entwicklungszentrum für Schiffstechnik und Transportsysteme e.V. in Duisburg (Development Centre for Ship Technology and Transport Systems; hereinafter referred to briefly as DST) was commissioned to examine the overtaking operation between COSCO HAMBURG and NEDLLOYD FINLAND by means of model experiments. These experiments in shallow water comprised both stationary parallel passage and also the actual non-stationary overtaking operation. For this the longitudinal and transverse positions of the vessels in relation to each other and the speed of the overtaken vessel were varied. The measured bottom pressures, forces and moments on the smaller vessel and its position afloat were evaluated and set out and explained vis-à-vis the variation parameters. The following remarks reproduce the content of the final report No. 1759 entitled "Examination of the overtaking operation between two vessels in shallow waters" of 12 May 2005 in abbreviated form and largely with the original wording.[42]

#### 6.3.3.1 Scope of order

The order from the BSU comprised

- Reproducing the shore embankment of the navigation channel in the model tank
- Constructing 2 models of the vessel involved to scale 1:50,
- Performing overtaking experiments with fettered models (non-stationary) with different vessel speeds and lateral distances,
- Conducting parallel passages (stationary) with fettered models in 7 positions (longitudinal and transverse position)
- Estimating the necessary rudder angle and resulting drift angle to compensate the measured component force and yawing moment on the small vessel.

In addition to documents on the two vessels involved, the Department of Maritime Navigation's "Situation analysis of the overtaking manoeuvre" (see above Section 6.2.2) was made available to the DST so that it could define the parameters for the model experiments.

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[42] The complete original expert opinion can be downloaded from the BSU Internet Page as a pdf file.

### 6.3.3.2 Models

#### 6.3.3.2.1 Cosco Hamburg

As the lines drawing of the large Container Vessel COSCO HAMBURG could not be procured promptly, the DST designed a comparable vessel with the principal dimensions of the overtaking vessel and built this to scale 1:50 in wood. It was assumed that the influence of the precise ship's lines by comparison with realising the important parameters of length, width, draft, displacement and water depth is slight. In agreement with the BSU, the model was executed without any drive of its own as it was assumed that the main influence on the overtaken vessel resulted from the pressure distribution in the area surrounding the overtaking vessel.

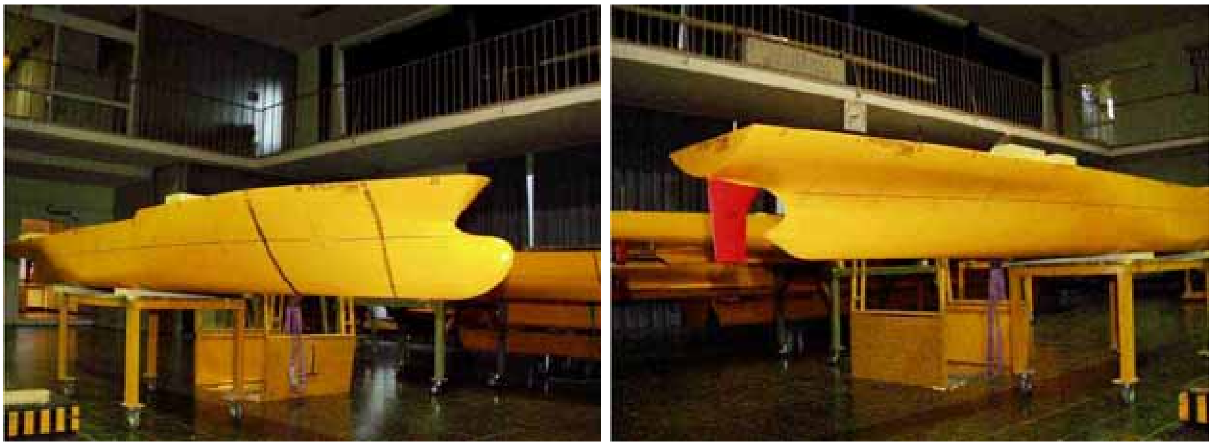

Figure 45: Model COSCO HAMBURG

#### 6.3.3.2.2 Nedlloyd Finland

The lines drawings of the smaller vessel were available so that it could be reconstructed precisely (also to scale 1:50). The model has its own propulsion and an adjustable rudder.

Figure 46: Model NEDLLOYD FINLAND

#### 6.3.3.2.3 Speeds

The evaluation of the ECS data of Department of Maritime Navigation Warnemünde (cf. Section 6.2.2. above) contains the speed developments of the two vessels during the overtaking manoeuvre. While COSCO HAMBURG proceeded approximately constantly at 15 kn, the speed of NEDLLOYD FINLAND varied between values below 11 kn and at most 15 kn. Based on this, the speed was fixed at 15 kn for the stationary parallel passage, while by contrast speeds of 11, 12 and 13 kn were taken as examination speeds for the non-stationary overtaking manoeuvre. A higher speed for the overtaken vessel was not possible because of the ever lower speed differential and the limited length of the tank, as otherwise the overtaking process could not have been fully realised from the "start of approach" to "completion of the overtaking manoeuvre".

### 6.3.3.3 Performance of experiments

#### 6.3.3.3.1 Arrangement in the model tank

The scale 1:50 is good for reproducing the surroundings of the overtaking manoeuvre as with a tank width of almost 10 m it covers the natural width of the waterway (over 500 m), leaves sufficient space at the outer sides to be able to neglect wall influences, and at the same time still allows the use of models of a size that lead us to espect realistic results.

The track of the large vessel COSCO HAMBURG was fixed at 3 m from the left wall in the DST tank, in other words at approx. 1/3 of the tank width. The various tracks (lateral distances of 50 m to 200 m in the large version) of the overtaken vessel NEDLLOYD FINLAND were in the centre third, and the last (right-hand) third was taken up by a reconstructed shore embankment.

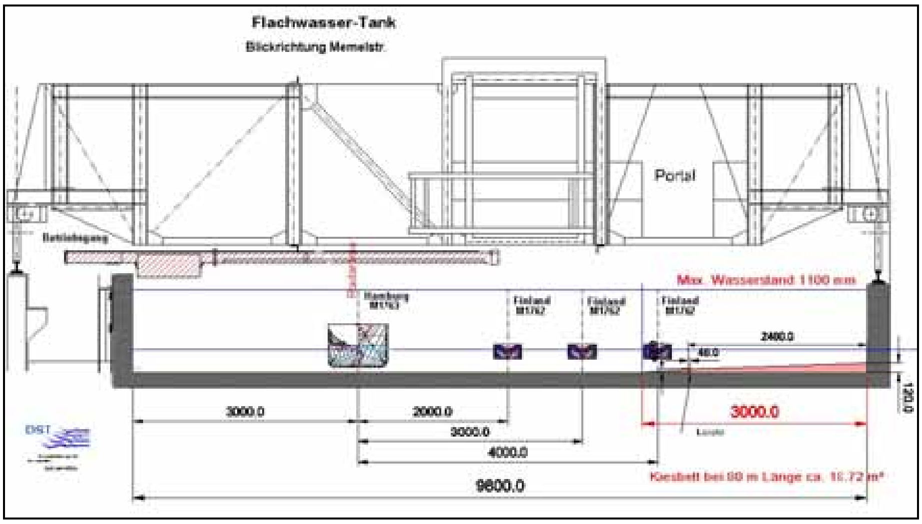

Figure 47: Experimental arrangement, cross section

This embankment was reconstructed in accordance with the mean depth data on the waterway chart and in consultation with the BSU. Over a length of approx. 85 m battens were inserted at the bottom on the right hand tank wall, between which fine gravel was filled and smoothed. The transition to the tank middle and the ramps at both ends were modelled by hand.

To implement the parallel passages both models were secured under the large towing carriage, while for the overtaking manoeuvres the quick towing system (a carriage that proceeds unmanned and can pass beneath the large towing carriage) was used. The track of the large vessel remained unchanged here, only the guiding of the model was changed.

In both cases, because of the necessary space requirement, the small model was fastened crossways in front of the actual measuring platform in such a way that it could be displaced sideways on existing transverse struts to examine the various transverse distances. The representation of the positions of the models for the overtaking manoeuvre is reproduced qualitatively in the following figure.

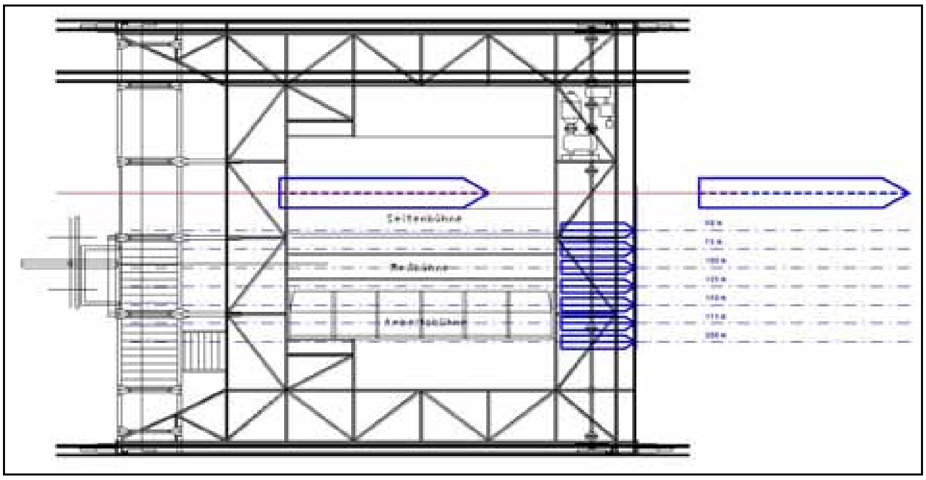

Figure 48: Experimental arrangement with the various tracks, top view

### 6.3.3.3.2 Experimental programme

The following table shows the programme implemented for the stationary and non-stationary experiments.

| | | small model (towing carriage) | | | | large model (fast towing system) | | |
|---|---|---|---|---|---|---|---|---|
| Vers. No. | Type | V [kn] | y-distance | DltR [°] | Beta [°] | V [kn] | x-Position | Remark |
| 2 | stationary | | | | | 15 | 0.6 | Only large vessel |
| 10 | stationary | 15 | 150 | 0 | 0 | | | Only small vessel |
| 5 | stationary | 15 | 150 | 0 | 0 | 15 | 0.6 | Both together |
| 8 | stationary | 15 | 150 | 0 | 0 | 15 | -0.2 | Variation longitudinal distance |
| 7 | stationary | 15 | 150 | 0 | 0 | 15 | 0 | Variation longitudinal distance |
| 6 | stationary | 15 | 150 | 0 | 0 | 15 | 0.3 | Variation longitudinal distance |
| 5 | stationary | 15 | 150 | 0 | 0 | 15 | 0.6 | Variation longitudinal distance |
| 9 | stationary | 15 | 150 | 0 | 0 | 15 | 0.8 | Variation longitudinal distance |
| 14 | stationary | 15 | 100 | 0 | 0 | | | Variation transverse, only small vessel |
| 10 | stationary | 15 | 150 | 0 | 0 | | | Variation transverse, only small vessel |
| 17 | stationary | 15 | 200 | 0 | 0 | | | Variation transverse, only small vessel |
| 15 | stationary | 15 | 100 | 0 | 0 | 15 | 0.8 | Variation transverse, both vessels |
| 9 | stationary | 15 | 150 | 0 | 0 | 15 | 0.8 | Variation transverse, both vessels |
| 16 | stationary | 15 | 200 | 0 | 0 | 15 | 0.8 | Variation transverse, both vessels |
| 11 | Drift+rudder | 12 | 150 | 0, 10, 20 | 0 | | | |
| 12 | Drift+rudder | 12 | 150 | 0, 10, 20 | -5 | | | |
| 13 | Drift+rudder | 12 | 150 | 0, 10, 20 | -10 | | | |
| 18 | non-stationary | 11 | 200 | 0 | 0 | 15 | over-taking | |
| 19 | non-stationary | 12 | " | " | " | " | over-taking | |
| 20 | non-stationary | 13 | " | " | " | " | over-taking | |
| 21 | non-stationary | 11 | 175 | 0 | 0 | " | over-taking | |
| 22 | non-stationary | 12 | " | " | " | " | over-taking | |
| 23 | non-stationary | 13 | " | " | " | " | over-taking | |
| 24 | non-stationary | 11 | 150 | 0 | 0 | " | over-taking | |
| 25 | non-stationary | 12 | " | " | " | " | over-taking | |
| 26 | non-stationary | 13 | " | " | " | " | over-taking | |
| 27 | non-stationary | 11 | 125 | 0 | 0 | " | over-taking | |
| 28 | non-stationary | 12 | " | " | " | " | over-taking | |
| 29 | non-stationary | 13 | " | " | " | " | over-taking | |
| 30 | non-stationary | 11 | 100 | 0 | 0 | " | over-taking | |
| 31 | non-stationary | 12 | " | " | " | " | over-taking | |
| 32 | non-stationary | 13 | " | " | " | " | over-taking | |
| 33 | non-stationary | 11 | 75 | 0 | 0 | " | over-taking | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 34 | non-stationary | 12 | " | " | " | " | over-taking | |
| 35 | non-stationary | 13 | " | " | " | " | over-taking | |
| 36 | non-stationary | 11 | 50 | 0 | 0 | " | over-taking | |
| 37 | non-stationary | 12 | " | " | " | " | over-taking | |
| 38 | non-stationary | 13 | " | " | " | " | over-taking | |

The dimensions concerning transverse position y are stated in metres of the large version related to the centre lines of the two vessels. The data stated for the longitudinal position x are relative data relating to the length between perpendiculars ($L_{pp}$) of the large vessel. Here "zero" is the position "bow to bow" and positive values describe a position in which the bow of the overtaking vessel is in front of that of the overtaken vessel.[43]

#### 6.3.3.3.3 Measurement quantities

During the experiments various measurement quantities were registered in both the stationary and non-stationary experiments, although not all data were always evaluated.

In the parallel passages the bottom pressure field is a direct indicator for the wave pattern (the primary, not the secondary wave system). As the experimental situation is "stationary", a path scale can be calculated from the time series of the pressure measurements with velocity V and so the pressure field in the x direction can also be represented with a fixed probe arrangement in the y direction. The time recording of the other measurement quantities were averaged and so the data for the forces and moments were determined.

In the non-stationary experiments it is not expedient to form an average value as the situation changes at every point in time. For this reason it is not appropriate to evaluate the bottom pressure sensors, as a different overtaking situation $\Delta x$ occurs for each time t, but the pressure sockets are firmly fitted in the tank bottom.

No measurements were taken over from the large model and from the quick towing installation, as only the reactions of the overtaken vessel were of interest and the position of the overtaking vessel can be reconstructed exactly from the light barrier passages. The information concerning the forces and moments from the model of the small vessel were transmitted from three force measuring limbs X, $Y_v$ and $Y_h$ that were arranged via joints, ball bearings and ball bushings in such a way that all distorsion was avoided and the two degrees of freedom trim and lowering were released. The list had to be blocked because of the high centre of gravity of the model, as otherwise unnatural angles of roll or rolling oscillations could have occurred.

---

[43] It should be noted that this definition was only used for planning and stating the positions in the stationary experiments. The evaluations of the non-stationary experiments showed that the zero position "main frame to main frame" was much easier to handle, as the events behaved point-symmetrically or mirror-symmetrically in relation to this newly defined zero.

The total component force Y was calculated by addition from the two quantities $Y_v$ and $Y_h$, and the turning moment N about the reference point (main frame) was calculated from the difference taking into account the lever arms.
The two types of motion released, trim and lowering, were recorded with laser distance meters. Here too the mean lowering at the main frame and the angle of trim were determined by addition and subtraction, taking into account the lever arms.

### 6.3.3.3.4 Stationary experiments

The arrangement of the models in the stationary experiments (both models guided by the large towing carriage) is shown schematically below. Here COSCO HAMBURG was displaced lengthways and NEDLLOYD FINLAND crossways under the towing carriage.

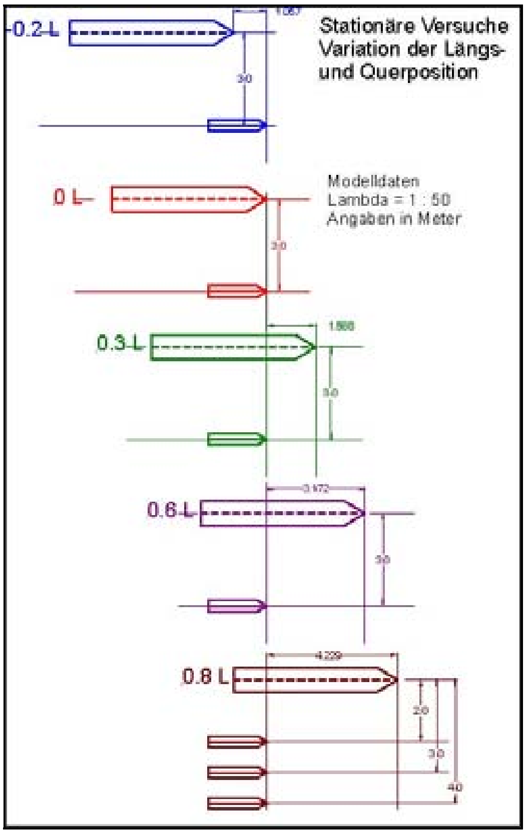

**Figure 49: Variation of the model arrangement (stationary experiments)**

### 6.3.3.3.5 Rudder and slanted towing experiments

Force measurements with the helm put at an angle and with drift angles were carried out on the "150 m" track in the same arrangement as for the stationary experiments. The large model was extended for this. These measurements served to determine the dimension-related linear hydrodynamic coefficients $Y_d$, Nd, $Y_v$ and $N_v$.[44]

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[44] These are the slopes of the straight lines of the measurement quantities component force Y and turning moment N via the converted set quantities rudder angle d and drift angle v.

6.3.3.3.6 Non-stationary experiments

Both towing carriages of the DST were used for the overtaking manoeuvres at different speeds: the large towing carriage and the fast towing system. The special feature here is that not only can they operate independently of one another, but can also be used for overtaking and encounter experiments.
The relevant overtaking situation was determined by registering four light barrier signals. The situations and resulting intermediate positions are set out in the following figure.
However, it should be pointed out once again that related to the diagram shown, a different "zero position" was used in the non-stationary experiments (cf. remarks above under Section 6.3.3.3.2)

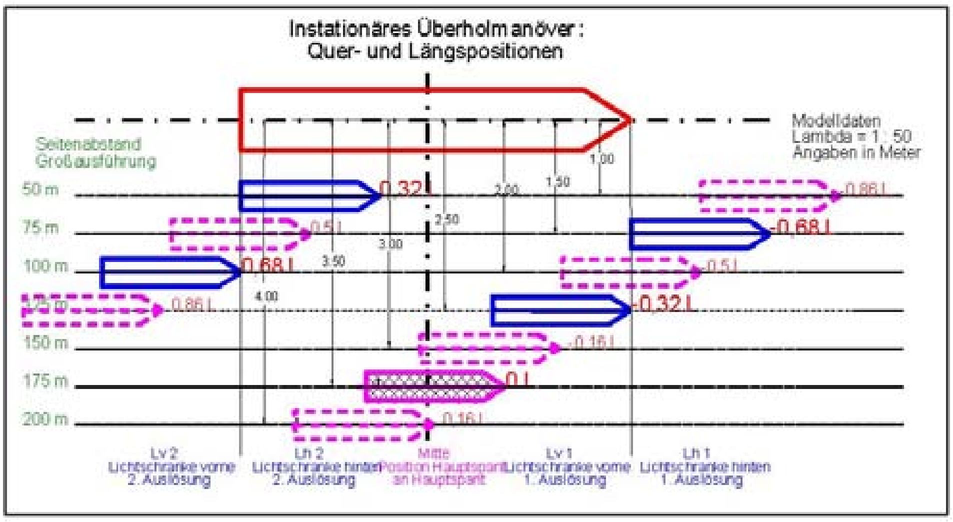


**Figure 50: Variation of the model arrangement (non-stationary experiments)**

## 6.3.3.4 Results

6.3.3.4.1 Stationary experiments

As the small vessel was equipped with its own propulsion, an abbreviated propulsion experiment had to be conducted in addition to the planned measurements in order to define the propeller speed of NEDLLOYD FINLAND for the model experiments. The actual rate of revolution is not relevant in this respect, as it depends on the type of propeller used, but what is primarily important is to define the propulsion point at which thrust and resistance are in balance.

A speed of 12 kn was fixed as reference speed for the overtaken vessel. This is the mean speed in the non-stationary experiments. According to the results obtained by Department of Maritime Navigation, it could be used as an expedient assumption for the initial speed. The ordinates of the following diagram, displaced by subtracting the friction deduction, result in the value of the propeller rpm for the propulsion point of the model via the regression degrees. Taking into account the (unknown) thrust-deduction coefficient, the resistance of the model can be inferred from the thrust data.

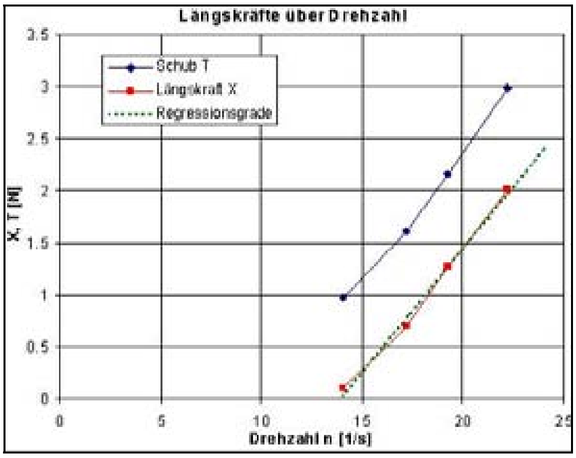


**Figure 51: Simplified propulsion experiment**

The propeller speed of the small model of n = 19.6 1/s for 12 kn of the large version defined in this way was set for all experiments, as it can be assumed that in the overtaking manoeuvre reproduced the rate of revolution was not changed.

6.3.3.4.1.1 Influence of the embankment

In order to determine the influence of the embankment (that by contrast with the smooth tank bottom was executed with a "rough" bottom), force measurements in addition to the agreed scope of the experiment were only conducted with the model NEDLLOYD FINLAND. At position y = 200 m the model is over the foot of the embankment and thus has a slightly reduced water depth, but above all it has a "rough bottom". The forces and moments measured in the variation of the lateral distance are reproduced in the figure below.

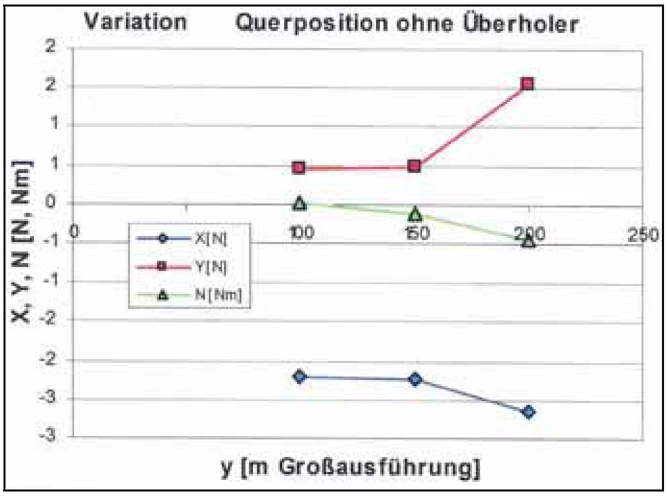


**Figure 52: Forces and moments in the stationary experiment (only NEDLLOYD FINLAND)**

The fluctuations of the moment N move in the range of measuring accuracy, which can be explained by the fact that this is an average value formed from the forces only in the area of the embankment. The component forces Y and the forward forces X (distinctly different from zero, as examined at 15 kn in the self-propulsion point for 12 kn), however, show an influence if the model is over the rough bottom with embankment. This was to be expected, as an increase in resistance (larger negative forward forces) is known from DST's experience and an unsymmetrical bottom topography must also show an influence.

Outside the embankment (y = 150 m and y = 100 m) both the longitudinal and component force are proximately constant. This indicates that the influence of the embankment is negligible for the relevant area from y = 150 to 50 m.[45]

### 6.3.3.4.1.2 Bottom pressure distribution

Stationary measurements are suitable for recording a two-dimensional status picture through constant speed over time with a limited number of probes arranged in the transverse direction. To record the bottom pressure field below the vessels, six pressure probes were secured in a rail flush with the tank bottom. Starting from the track of the overtaking vessel, these were arranged at intervals of 75 cm and extended up to the embankment.

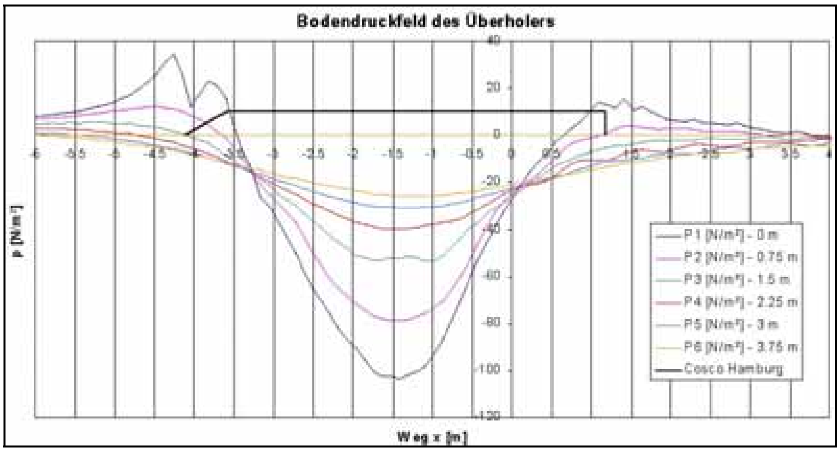


**Figure 53: Longitudinal section through the bottom pressure field (COSCO HAMBURG)**

The time series recorded (see example above) for each individual pressure socket were summarised to form a matrix to which the coordinates of the pressure sockets/the longitudinal positions of the measurements were allocated. These data fields were processed further with an isoline program.

In the following subpoints a) to d) the pressure fields of the stationary experiments are compared under different aspects. The bottom pressures form a very good indicator for the lowering of the water level by the moving vessel.

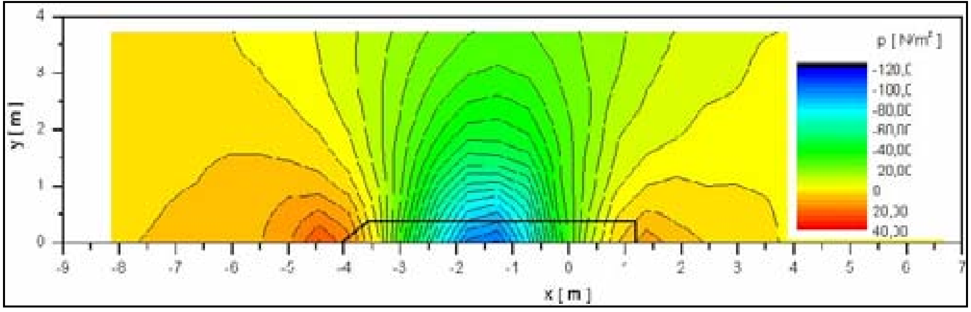
---

[45] Note: For later investigations into this theme, the DST therefore recommends refraining from the costly construction of an embankment to this (relatively) slight extent.

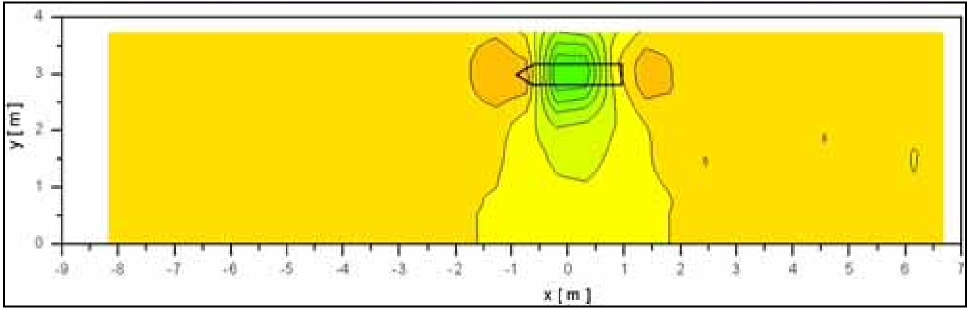
a) Variation of the vessels

The pressure fields for the cases "large vessel only", "small vessel only" and "both vessels" for positions x = 0.6 L (0 = bow to bow) and y = 150 m are shown in the three representations below. It could have been suspected that Fig. No. 3 for both vessels is shown as a superimposition of the two individual pressure fields. In order to check this the individual pressure fields were added together and the result is shown in Fig. No. 4. The supposition was only conditionally confirmed, as the underpressure field under the smaller vessel with genuine parallel travel is more strongly structured than by simply adding the individual measurement values.

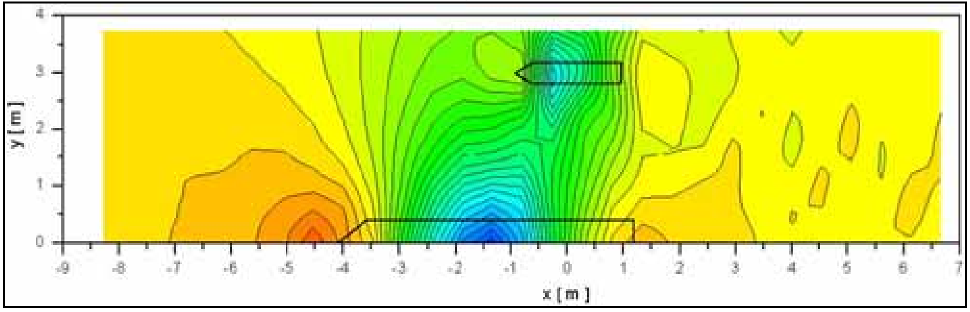
**No. 1: Only Cosco Hamburg, y = 150 m**



**No. 2: Only Nedlloyd Finland, y = 150 m**



**No. 3: Both vessels together, y = 150 m, x = 0,6L**



**No. 4: Individual data added, y = 150 m, x = 0,6L**

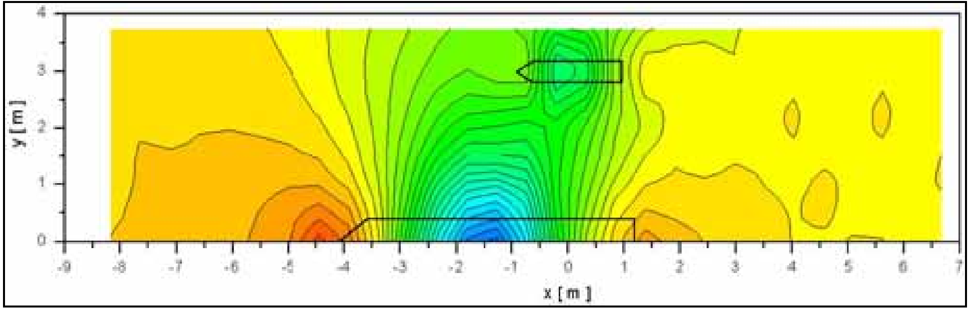


Figure 54: Variation of the vessels

b) Variation of the longitudinal position x

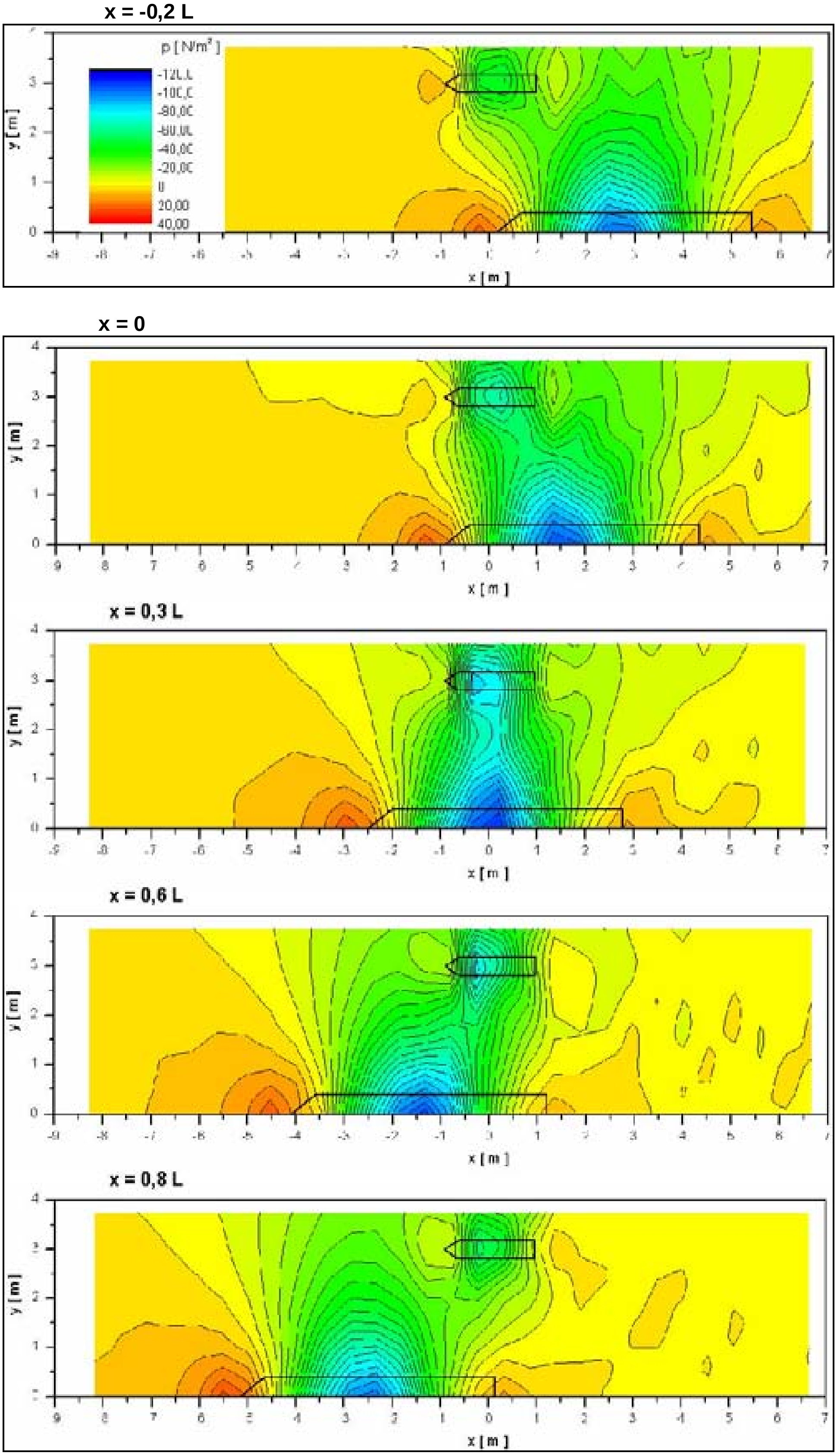
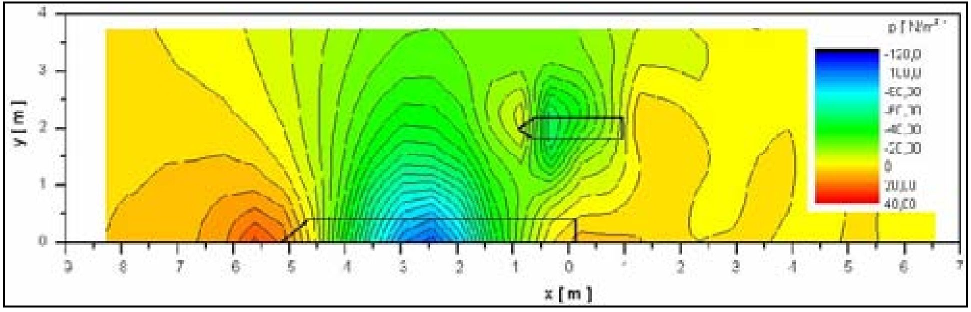


Figure 55: Variation longitudinal distance

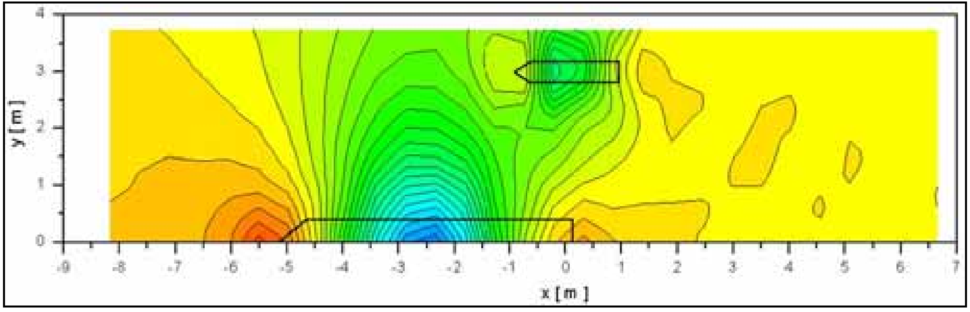
The variation of the longitudinal position x of the overtaking vessel shown above in Fig. 55 in five steps (between –0.2 L and 0.8 L) at a constant transverse distance of y = 150 m shows how the two individual pressure fields of the vessels fuse together and intersperse with each other. It becomes clear above all that the dominance lies distinctly with the overtaking vessel. This is partly due to the fact that it is proceeding with substantially less moving water and is therefore subject to a clearer shallow water effect.

c) Variation of the transverse position y (both vessels)
The next figure illustrates in three representations the influence of the lateral distance on the bottom pressure distribution. It can be seen that the pressure field of the overtaking vessel is only very slightly influenced by the overtaken vessel. This confirms the assumption that the overtaking vessel with a mass over 10 times larger is hardly influenced at all by the smaller vessel and validates the decision to refrain from force-measuring elements in the large model.

**Transverse variation, both vessels, y = 100 m, x = 0.8L**



**Transverse variation, both vessels, y = 150 m, x = 0.8L**



**Transverse variation, both vessels, y = 200 m, x = 0.8L**

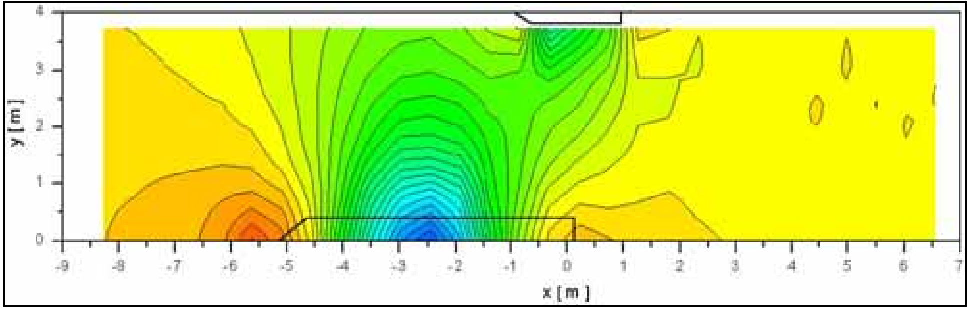
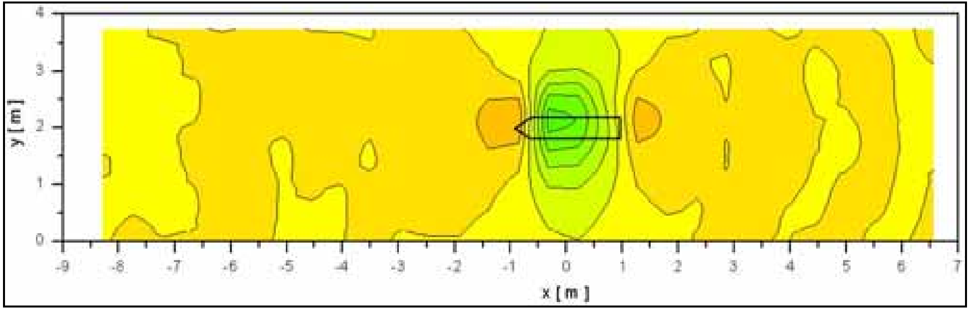


**Figure 56: Variation of the transverse position (both vessels)**

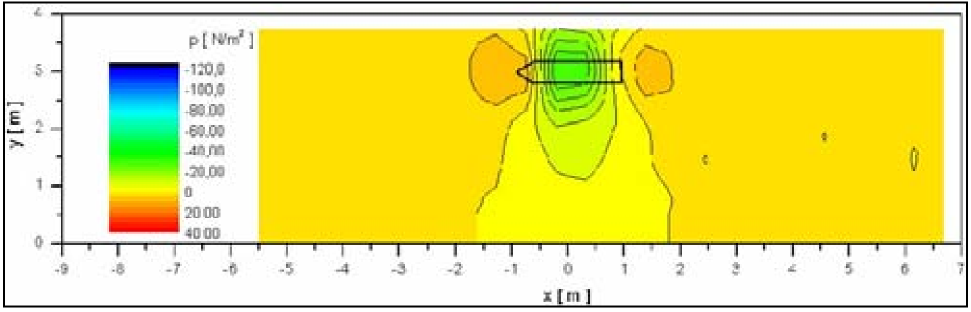
d) Variation of the transverse position y (only the smaller vessel)

The presentation of the pressure fields for the overtaken vessel without the overtaking vessel originates from an additional examination conducted that was to provide information about the influence of the embankment on the small vessel. Unfortunately no pressure could be measured in the embankment so that the informative nature of these presentations is relatively low. For the sake of completeness, however, they are included here after all.

**Transverse variation, only Nedlloyd Finland, y = 100 m**



**Transverse variation, only Nedlloyd Finland, y = 150 m**



**Transverse variation, only Nedlloyd Finland, y = 150 m**

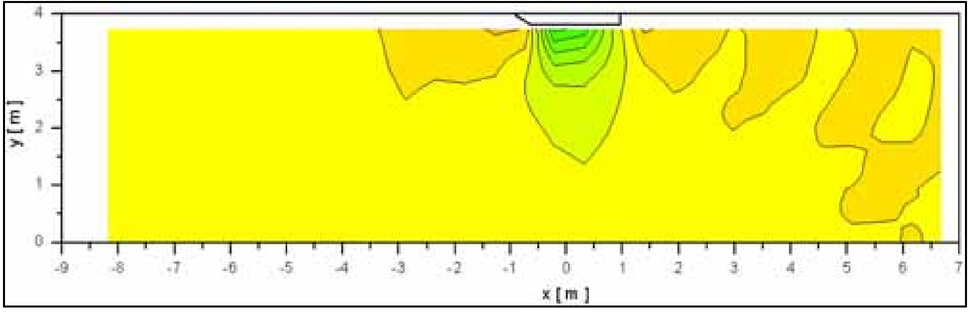


**Figure 57: Variation of the transverse position (only NEDLLOYD FINLAND)**

### 6.3.3.4.1.3 Forces and positions afloat

The results of the experiments for the stationary measurements (averaged values) are reproduced without any comment here, as these are above all validation data for numerical calculations. However, these data are inserted in the diagrams in the representation of the non-stationary measurements and are thus compared with the "genuine" values.

The forward forces that are *negative* over the whole course are due solely to the self-propulsion point for V = 12 kn at an experimental speed of 15 kn.[46] The non-stationary measurements, on the other hand, document that the forward force actually does change its prefix (cf. under Section 6.3.3.4.2.1 and Fig. 61).

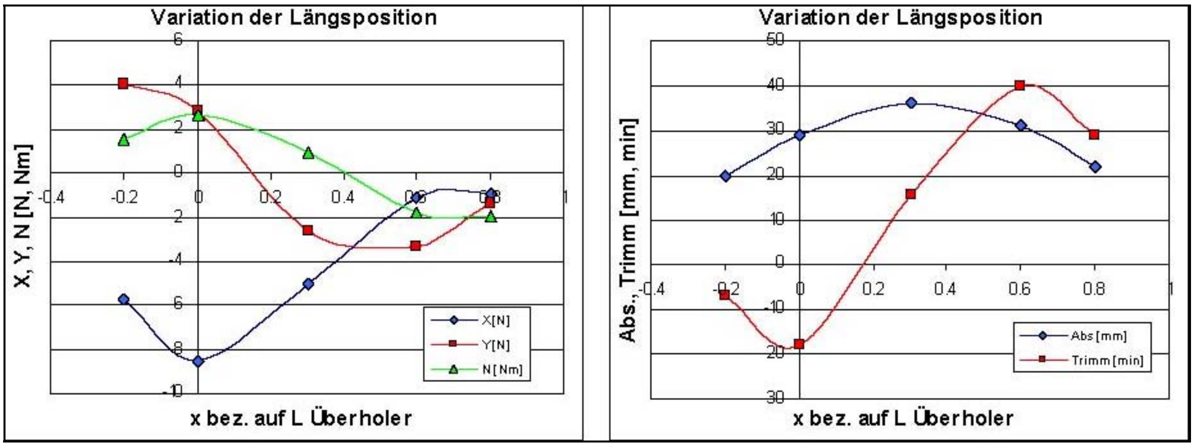


**Figure 58: Forces, moments and positions afloat in the stationary experiment (variation longitudinal position)**

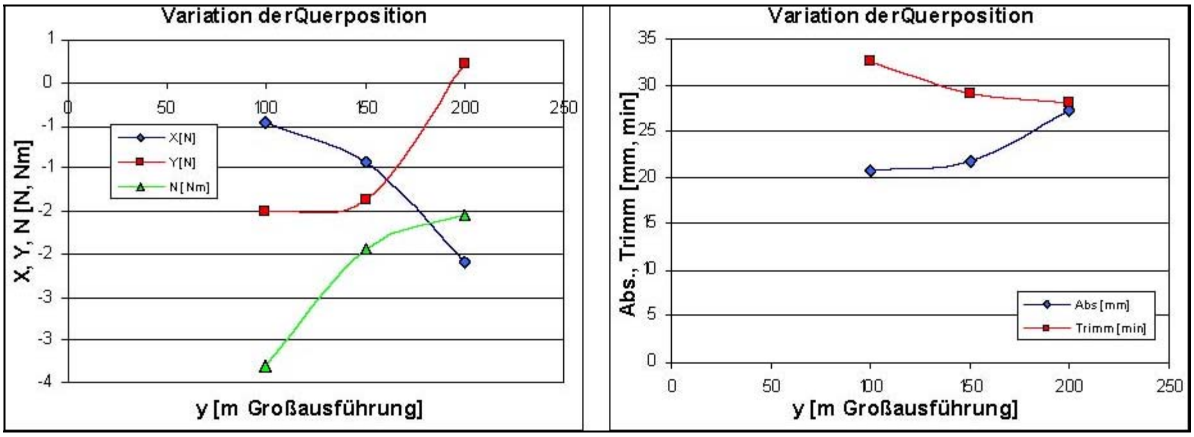


**Figure 59: Forces, moments and positions afloat in the stationary experiment (variation transverse position)**

#### 6.3.3.4.1.4 Rudder and drift angle experiments

The measurements of the forces and moments on the small model at rudder positions and drift angles were carried our for rudder positions 0°, 10° and 20° and for drift angles 0°, 5° and 10°. The rudder angles are in the linear range (that is left as of approx. 30°), while with the angles of drift the linear range is already left slightly for Beta = 10°. The following figures reproduce the results of these experiments.

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[46] Note: Here zero point for x = condition "bow to bow"

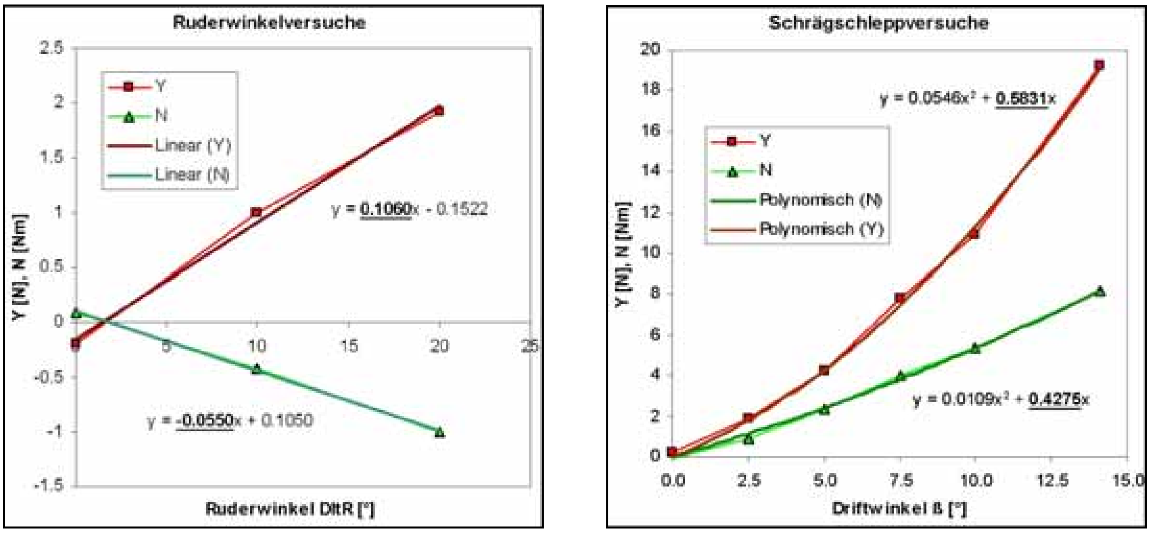


**Figure 60: Results of the rudder and drift angle experiments**

The slopes of the straight lines shown here represent the dimension-related hydrodynamic coefficients $Y_d$, $N_d$, $Y_v$ and $N_v$. When multiplied by the rudder angle and drift angle of the experiment (in degrees), they give the component force Y and the moment N measured at the model via $Y_v$ and $Y_h$.
The component force and moment at the vessel can be determined in a purely linear consideration by the hydrodynamic coefficients determined here specifying the rudder angle and drift angle.

In the further evaluations of the non-stationary experiments the calculated rudder and drift angles are also given consistently without any checking for plausibility.
It is to be noted that for rudder angles above approx. 30° and drift angles above 10° there is clear non-linear behaviour. For the rudder this is due to the fact that as of about 30° the flow breaks down and the forces and moments no longer run proportionally to the rudder angle, but instead collapse. Moreover substantially larger rudder angles can no longer be set. For the drift angle the non-linearity means that for angles as of approx. 10° or below the increase in growth rises - with larger angles of drift higher forces and moments occur than according to the linear approach.

In conclusion it can be noted that from approx. 10° the calculated drift angle for compensation/generation is higher than that actually necessary, but the theoretically determined rudder angles stated can no longer be used above a value of approx. 35°!

### 6.3.3.4.2 Non-stationary experiments

Both the stationary and non-stationary experiments were evaluated with an Excel application that automatically re-scales all data copied in (that have previously been reduced from a tact rate of 100 Hz to 10 Hz with a special program and converted from mm water column to N/m² for the bottom pressures) as regards the sychronisation signals, filters these and produces averaged values for the relevant x-coordinates. These "significant results" were then edited in further Excel applications to provide the results diagrams.

#### 6.3.3.4.2.1 Comparison with the stationary experiments

The results of the stationary experiments on the track y = 150 m were compared with the non-stationary measurements from passage 25 (overtaken vessel V = 12 kn). Here the relative x-coordinates were converted to the new reference system "0 = main frame to main frame".

For better understanding of the following representations it must be noted that the light barrier signals for the incidents explained above in Section 6.3.3.3.6 are presented here as vertical strokes. The abbreviations introduced there were used. The scale of the x-axis is always related to Lpp of the large vessel, in other words the range from –0.5 to +0.5 extends from situations "bow of the overtaking vessel at main frame of small vessel" to "stern of overtaking vessel at main frame of small vessel". The latter relative position roughly corresponds to the definition "0.8 L" from the stationary experiments.

For the forces and moments the comparison in the diagram below provides good agreement for Y and N, but shows clear offsetting for X. This is due to the fact that in the stationary experiments the small model also proceeded at a speed of 15 kn, but the propeller speed was set for 12 kn. The lacking thrust is shown as a residual resistance in negative offsetting of the blue lozenge shapes by comparison with the course of the forward forces.

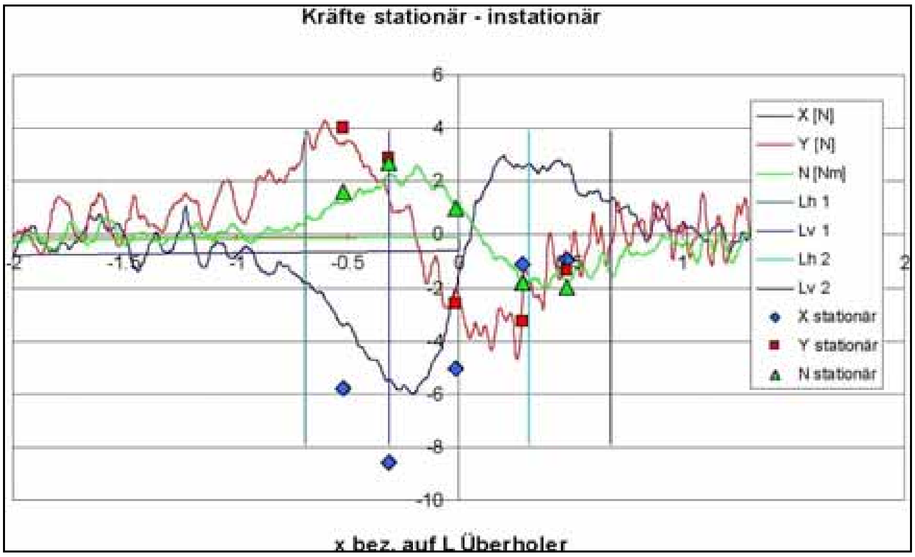


Figure 61: Comparison X, Y and N stationary and non-stationary

The same applies for the position afloat of the small vessel. As a result of the lower speed in the non-stationary experiment the lowering and to a certain extent the trim too are less than in the case of 15 kn with stationary measurements.

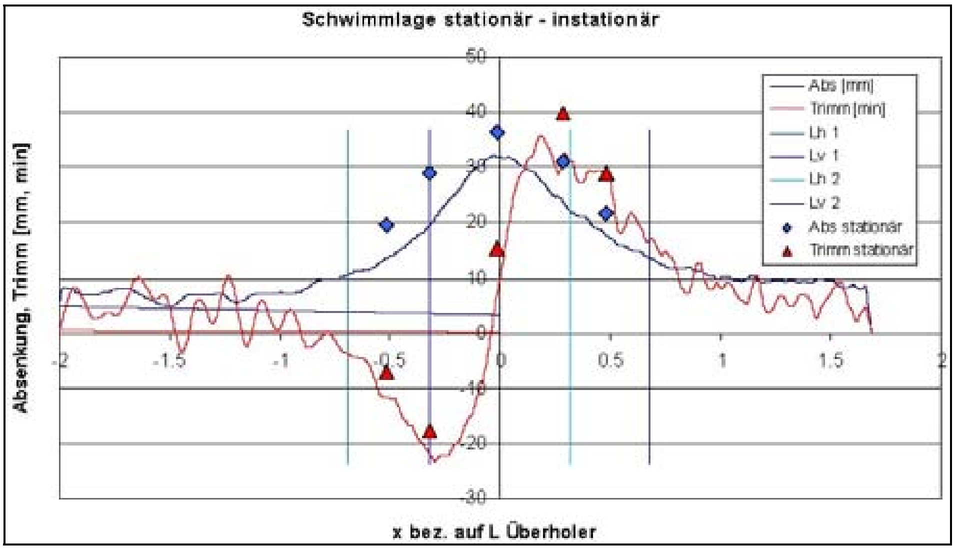


Figure 62: Comparison between lowering and trim stationary and non-stationary

The rudder angle and drift angle for generating/compensating the forces and moments measured provide relatively good agreement of the extrapolation from the stationary measured data with the non-stationary results. However, it should be noted that these are not real settings for a compensation manoeuvre, but instead only the calculated implementation of the linear connection between the combination of Y and N with the motion and steering quantities v and d.

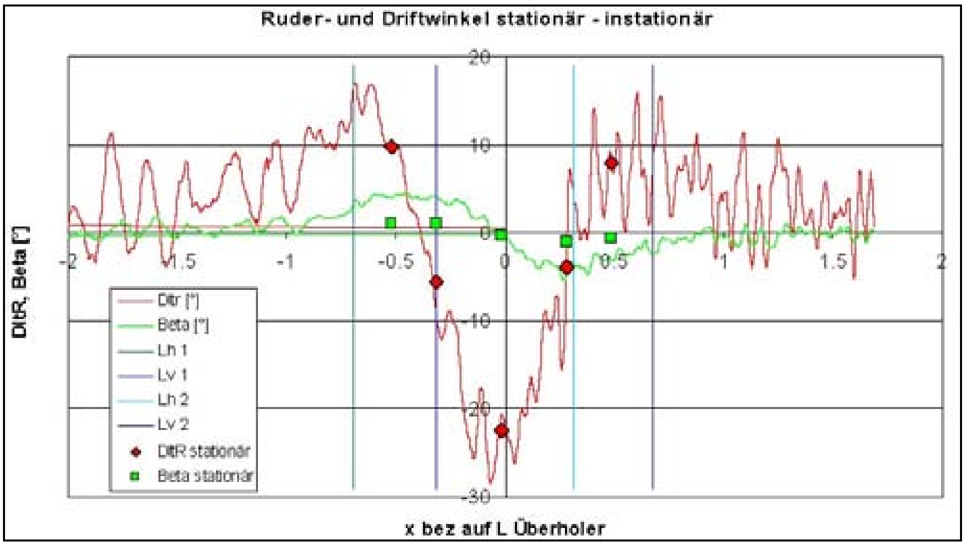
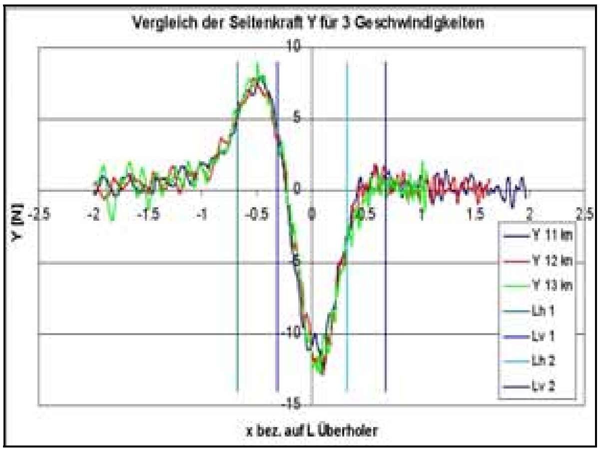
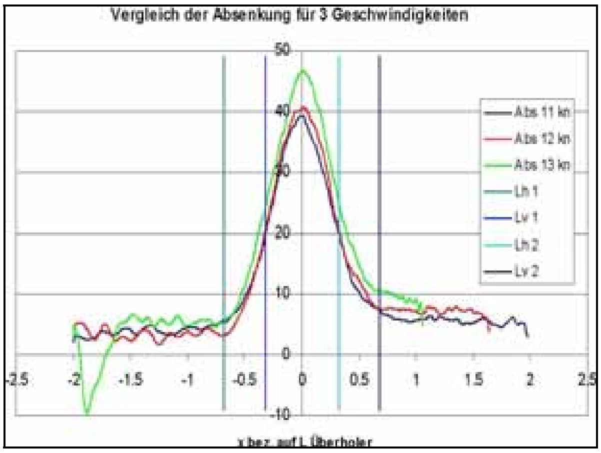


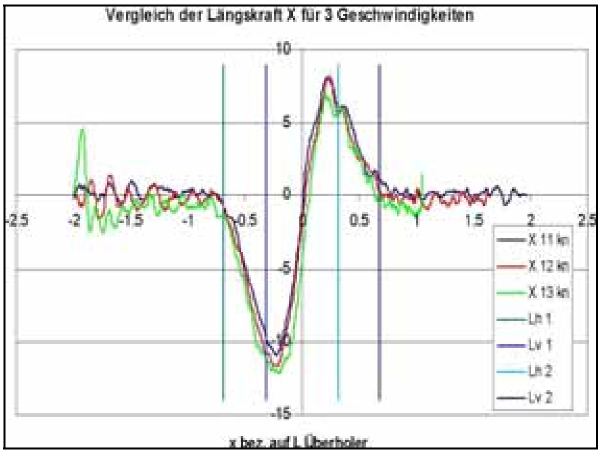
Figure 63: Comparison of rudder and drift angle stationary and non-stationary

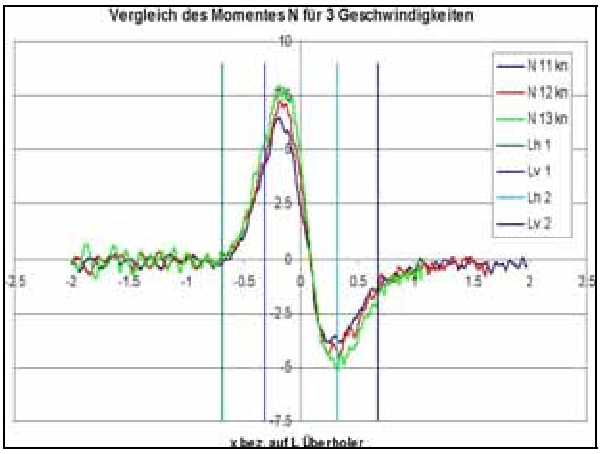
### 6.3.3.4.2.2 Comparison of the different speeds

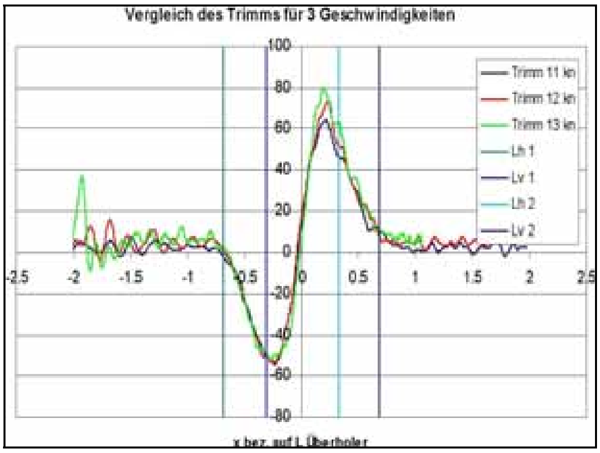
An important question for evaluating the examinations conducted as well as for planning subsequent research is that of the influence of speed on the overtaking manoeuvre. It is relevant here, how fast the overtaken vessel was proceeding at constant speed of the overtaking vessel. Diagrams of the component force, forward force, lowering, moment, trim, rudder angle and drift angle are shown from the many passages with differing speed of the small vessel for the lateral passing distance of y = 75 m.

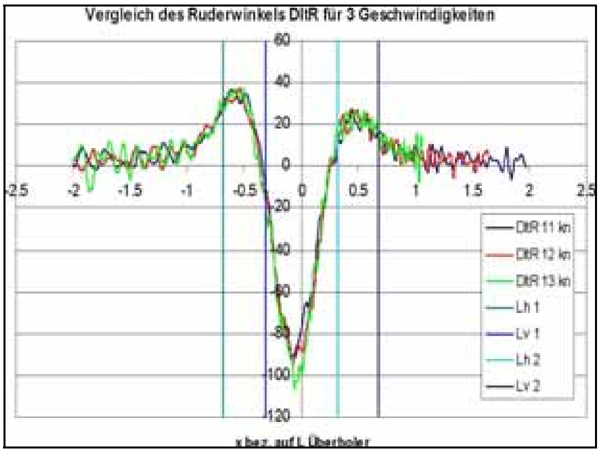












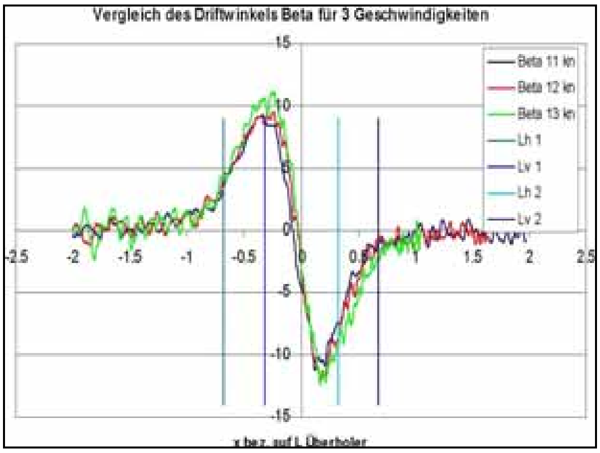


Figure 64: Comparison of the differing speeds

It becomes apparent that after rescaling the abscissa on the synchronisation signals an almost identical course of the component forces results. It is only during lowering (and to a slight extent for trim) that the influence of speed is seen again, as the smaller vessel generates its own underpressure field dependent on speed due to the limited water depth. It can be concluded from this for subsequent investigations that the difference in speed in overtaking manoeuvres in this combination of vessel sizes, lateral distances and water depth can be neglected for determining the forces and moments that act on the overtaken vessel.[47] The difference in speed is important, however, for compensating these forces by drift and rudder angles of the overtaken vessel and for changes in track that these forces exert on the overtaken vessel.

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[47] This does not mean that it can be generally neglected as the data are not comprehensive enough to be able to make such a statement.

### 6.3.3.4.2.3 Comparison in variations of the longitudinal position

The data recorded in the overtaking manoeuvres were filtered numerically and the significant values averaged at the light barrier positions and further intermediate values were determined (data reduction).

In the figure below originating from the overtaking manoeuvre at y = 50 m lateral distance for 12 kn of the small vessel (passage No. 37), the filtered forces and moments and the calculated significant values are shown by way of example for all passages. For reasons of space we have refrained from a complete reproduction of all time recordings.

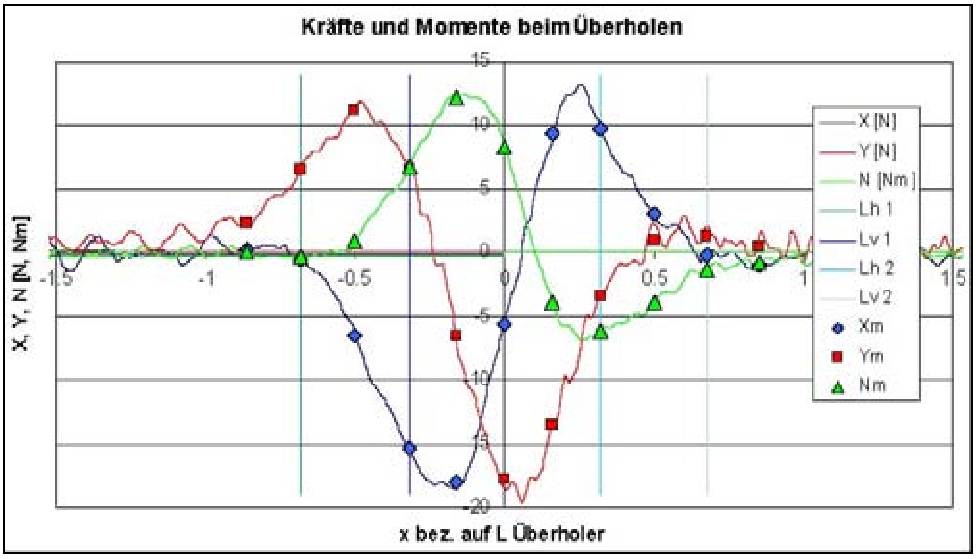

Figure 65: Averaged data for non-stationary experiments at selected positions

These average values for X, Y, N, lowering and trim were summarised in the result lines in order to be able to apply them over other parameters, such as for example the lateral distance. By way of illustration the representation of the forces and positions afloat for the case "relative longitudinal position x = -0.5 L" is reproduced here.

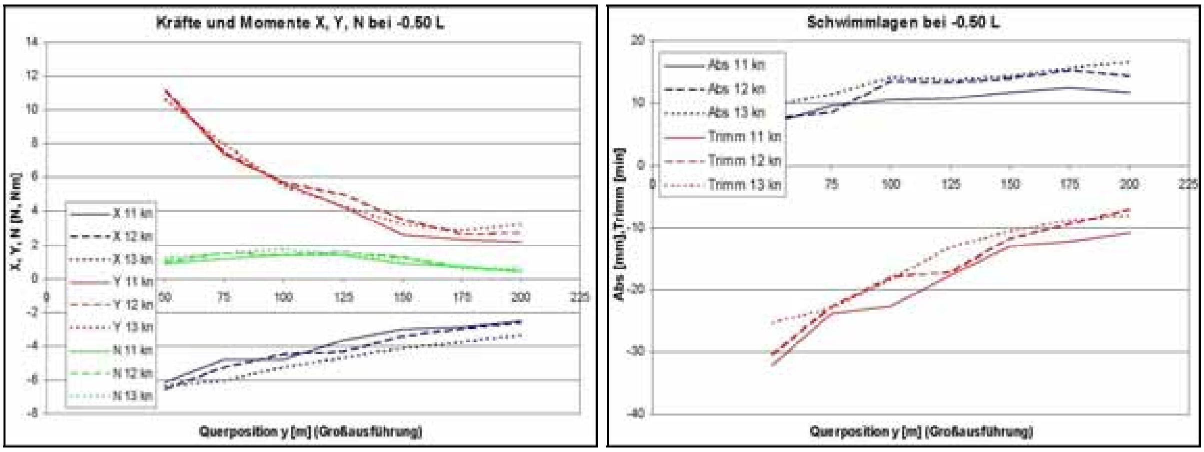

Figure 66: Forces, moments and positions afloat at 3 different speeds

In this representation too the relatively slight dependence on the speed of the overtaken vessel is shown again. This is not always so clear in other positions, as the data are scattered somewhat over the lateral distance application parameter. However, a staggering of the curves about the variation parameter V can be ascertained, but this recedes into the background through the dominating influence of the lateral distance.

One very informative representation is the application of the rudder and drift angles necessary for generating/compensation (cf. Fig. 67). These are the maximum values DltR and Beta determined during the overtaking manoeuvre. They are not simultaneous, but instead an absolute maximum value for DltR occurs roughly at the relative position 0 L, while the largest absolute angles of drift are to be found close to ±0.2 L.

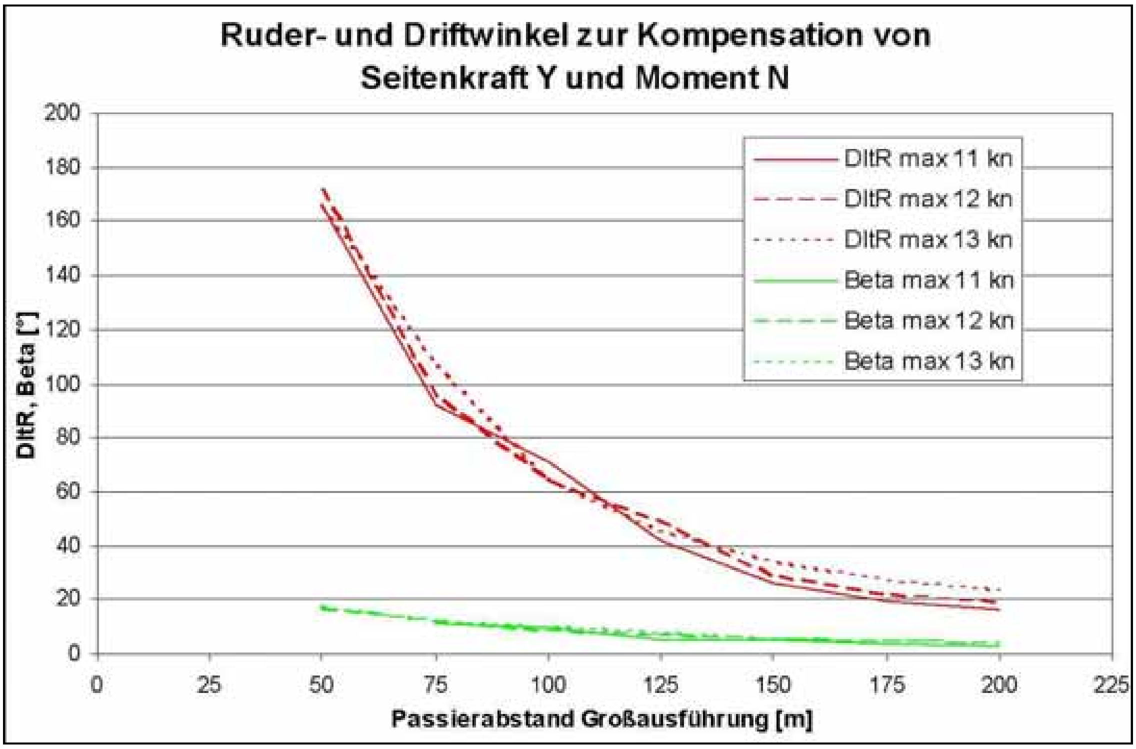

**Figure 67: Theoretically calculated rudder and drift angles at 3 different speeds**

From a lateral distance of about 170 m the linear range of the rudder forces is left and the maximum rudder position of normally 35° to 40° is exceeded already before the distance 130 m is reached.[48] The angles of drift are unproblematic at these lateral distances, as firstly they are still approximately linear, and secondly they are not limited like the rudder position.

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[48] Cf. here also the remarks below under Section 6.3.3.5.

#### 6.3.3.4.2.4 Comparison in variation of the transverse position

In order to be able to reproduce the time course of the quantities X, Y, N, lowering, trim, DltR and Beta shown approximately, the significant average values explained above were applied over the relative positions x as curves. This form of representation no longer reproduces the course of the measurement quantities exactly, as it is a reduction to 11 points per measurement for the entire overtaking manoeuvre. However, on the other hand a clear representation is possible, for example of the forces for each longitudinal and lateral position.
It must be pointed out that use has been made here of the fact that it was determined that the measurements are independent of the speed of the overtaken vessel. This concerns the data of the speed relations 15 kn / 11 kn. The results for other speeds look almost the same.

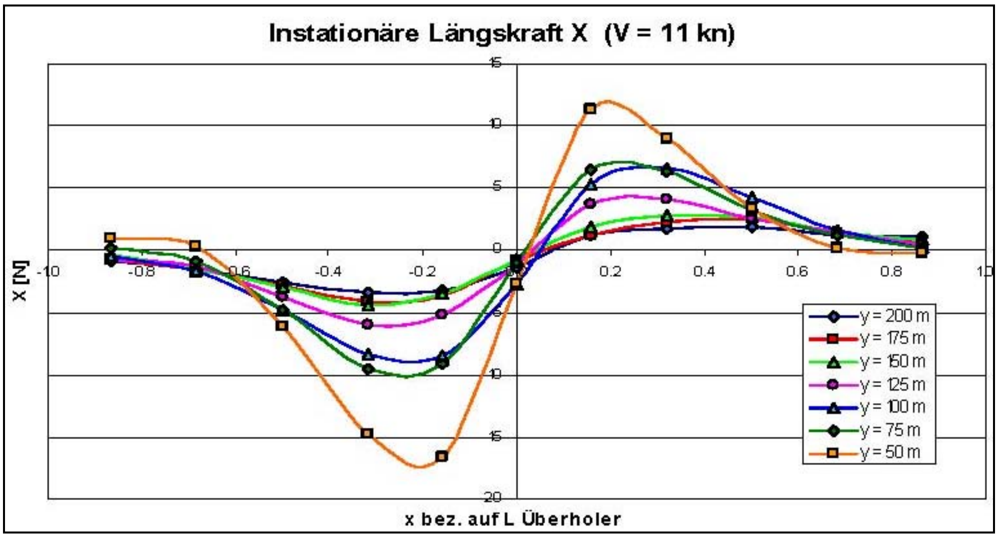

**Figure 68: Forward force at the non-stationary experiments at selected positions**

The Forward force X shows approximately point-symmetrical behaviour related to the zero point. At the start of the overtaking manoeuvre it becomes clearly negative, passes roughly through zero at the position main frame to main frame, and then assumes a positive value (force ahead!). These changes in force are not caused by the propeller, as it supplies a constant thrust. A comparison with the trim further below indicates a possible explanation. The trim curves have a course virtually identical with that of the forward force curves, which lead one to suspect that this is at least partly a slope take-off force. A rough calculation with a maximum trim of 2° (120’) and a mass of 50 kg supplies F = m x g x sin (α) ≈ 17 N! This corresponds relatively well to the maximum values for the forward forces measured in the vicinity of ±0.2 L and supplies a possible explanation for the lag and the following acceleration of the overtaken vessel. This gradient effect is only to be expected with a distinct difference in length between the vessels involved (here 1:2.5), as only then can the small vessel follow the trough of the larger vessel.

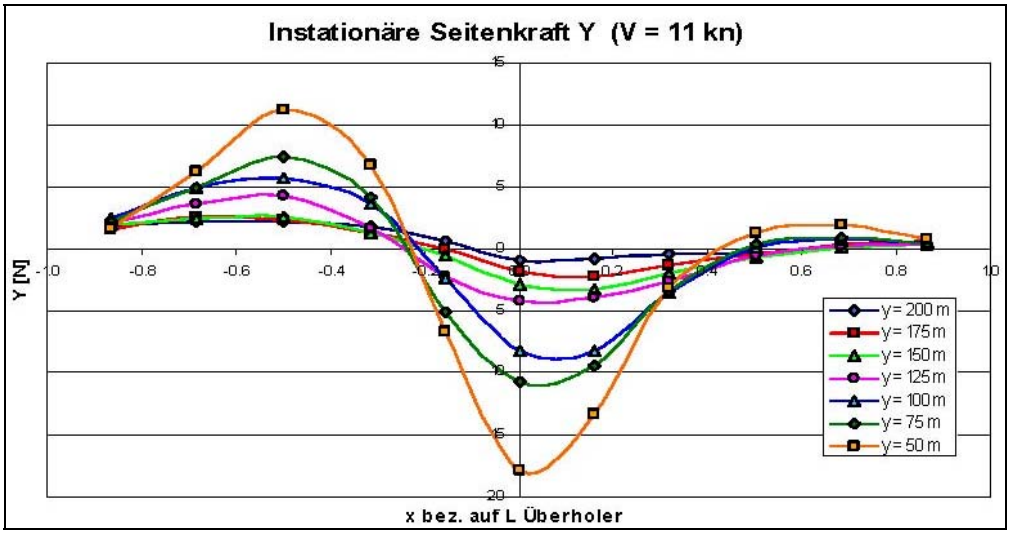

**Figure 69: Component force in the non-stationary experiments at selected positions**

The component force Y looks almost symmetrical to the Y-axis, even though a little off-set in x. At the start of the overtaking there is repulsion (positively to starboard) with a force roughly corresponding to about 1/50 of the mass of the model (weight force of the model ≈ 500 N). The following suction in roughly the same order of magnitude would bring the vessel back to the initial track. In the third phase (overtaking vessel passes the stern) the component force action is slight.
As the surface inclination in the transverse direction is very small, it is chiefly hydrodynamic effects that are responsible for this force effect.

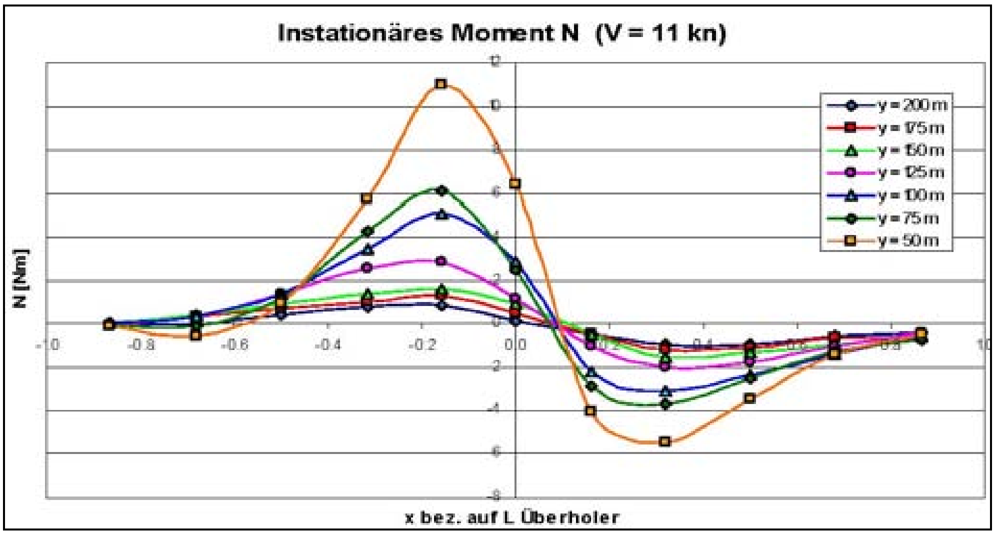

**Figure 70: Turning moment at the non-stationary experiments at selected positions**

At the start of the overtaking operation a positive (right-hand) moment N acts on the small vessel. This turns it out of the initial course away from the overtaking vessel. After the middle position the moment of turn reverses and the vessel is forced towards the overtaking vessel again.

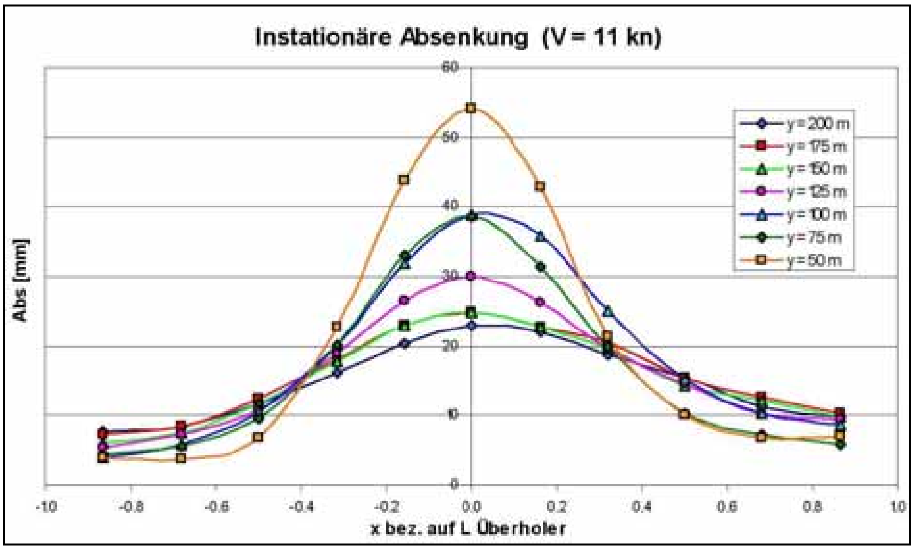

Figure 71: Lowering at the non-stationary experiments at selected positions

The lowering is mirror-symmetrical to the middle position. The model is in the trough caused by the flow surrounding the large vessel (lowering of water level) and follows it down. A comparison with the bottom pressure measurements in chapter 6.3.3.4.1.2 confirms this.

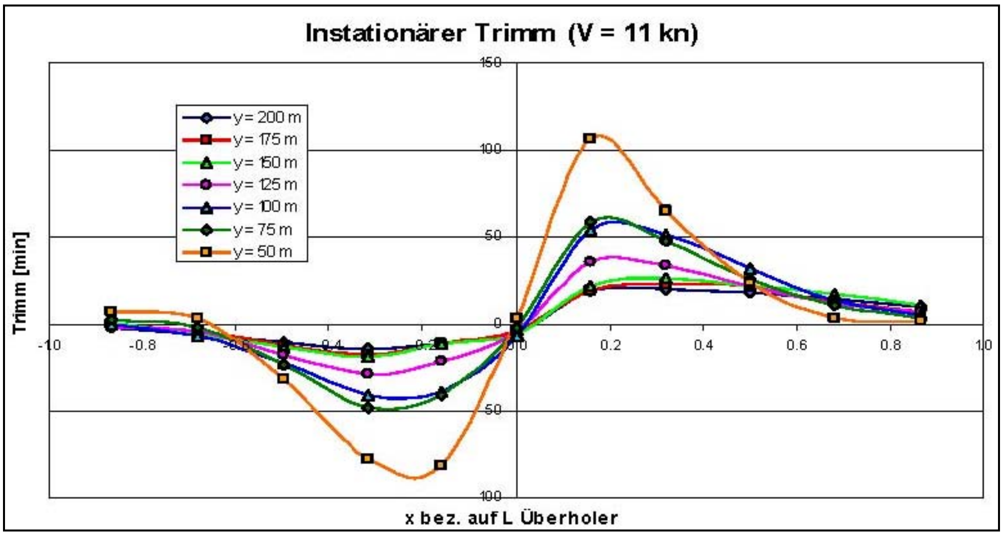

Figure 72: Trim at the non-stationary experiments at selected positions

Like the lowering, the trim that has already been compared with the forward force is caused by the trough generated by the overtaking vessel in that the model follows this sloping water surface. A comparison with surfing is indicated here, where the propulsion force as well as the braking force of the surfboard is caused solely by the slope of the waves.

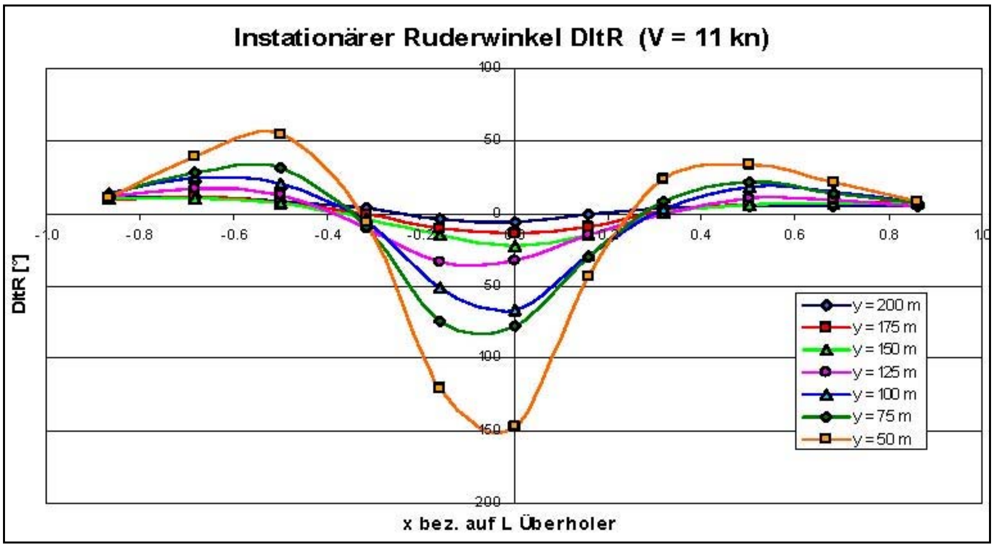

**Figure 73: Theoretical rudder angle at the non-stationary experiments at selected positions**

The course of the compensating rudder angle DltR is also mirror-symmetrical, but by contrast with lowering has 3 maxima and/or minima. As it is calculated purely theoretically from the combination of the measured component force Y and the moment N, it is not directly possible to trace this back to the overtaking manoeuvre.

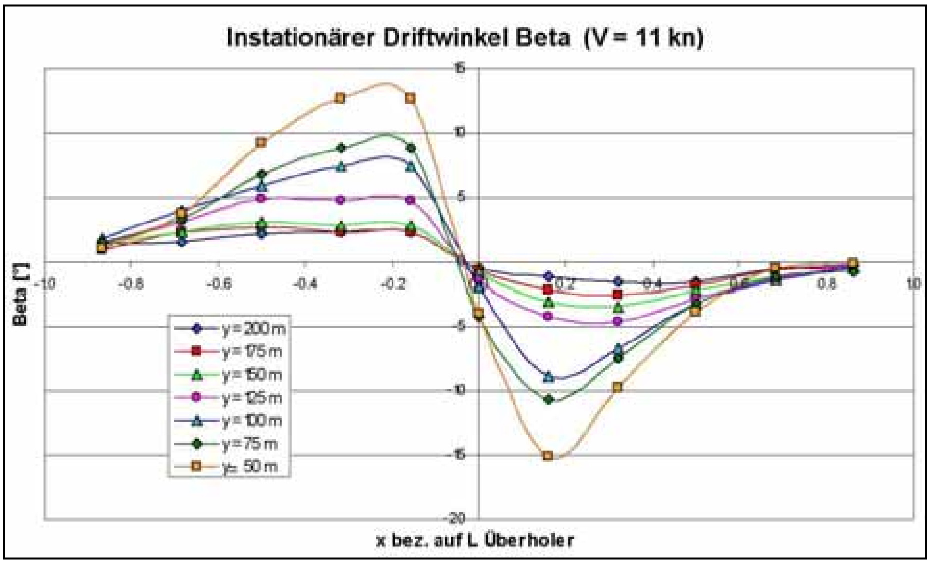

**Figure 74: Theoretical drift angle of the non-stationary experiments at selected positions**

The same applies for the compensating drift angle Beta, that here behaves point-symmetrically again (with x-displacement).

### 6.3.3.5 Final remarks on the experiments

The influence of the embankment on the right shore is not considerable for the investigation range of the passing distance that is of interest here.

By comparison with the influence of the lateral distance, the influence on the effects of the speed of the overtaken vessel at constant speed of the overtaking vessel is slight.

The stationary measurements can certainly be compared with the non-stationary data, taking into account the physical differences.

With a lateral approach of less than approx. 130 m, the rudder position theoretically calculated as necessary to generate/compensate the forces and moments occurring in accordance with a linear approach lies outside the valid rudder angle range. However, this statement should not be overrated, as calculating these angles is a rough aid and the simultaneous setting of a certain combination of rudder and drift angles is hardly possible in practice.

Alongside the forces and moments acting hydrodynamically on the level, the dominant incident when vessels overtake in shallow water is the deformation of the water surface (chiefly primary wave system) by the vessels involved.

The gradient force caused by the primary wave system of the overtaking vessel is at least partially responsible for the change in forward forces during the overtaking operation.

### 6.3.3.6 Prospects

The experiments conducted within the investigation for the BSU comprised a minimal program for assessing the hydrodynamic effects on overtaking in shallow water. Despite this they provide clear indications towards possible simplifications and details that are worth a deeper examination. Furthermore, further studies can be suggested that are appropriate for investigating the problem complex of overtaking in more detail and may provide better foundations and tools for future evaluations.

- The suction of a working propeller has an influence that should not be neglected on the pressure field and the water surface deformation at low lateral distances. It is recommended that this be checked quantitatively with the aid of overtaking experiments where the overtaking vessel is equipped with its own propulsion.
- The force measurements carried out with fettered models are suitable for theoretical examination of the physics of the overtaking operation. The actual reaction of the overtaken vessel can only be considered through freely run (remote controlled or regulated with an automatic pilot) model experiments. DST possesses facilities for conducting such experiments.
- Hydrodynamic coefficients (dimension-related linear derivatives regarding the rudder and drift forces and moments) were determined to a very slight extent. For a reality-related simulation of the movement behaviour, Planar-Motion experiments (force measurements on moved fettered models) are necessary. These provide a complete non-linear set of coefficients with which simulation calculations can be carried out. This is possible at DST, but it is advisable to select a larger scale for the model of the overtaking vessel (1:16 to 1:20).
- In simulations of an overtaking manoeuvre it is necessary to provide the external forces and moments acting on the vessel examined that are generated by the overtaking vessel via a corresponding mathematical formulation. A basis for the mathematical forces model of the influence of the overtaking vessel could be

supplied by the diagrams shown in 6.3.3.4.2.4 (X, Y, N as a function of x and y). In a research project for the Federal Ministry for Education and Research (BMBF) the DST has already carried out similar modelling assignments by simulating the passage of an inline vessel under the influence of a groyne field.

### 6.3.3.7 List of symbols

| Qty. | Unit | Explanation |
|---|---|---|
| Abs | m | Mean lowering z (positively downwards) |
| Beta | ° | Drift angle (used here instead of the lettering β ) |
| Büa | m | Breadth over all |
| d | ° | Rudder angle (actually dimensionless in rad) |
| Dlt R | ° | Rudder angle (used here instead of the lettering δR )<br>(positive prefix to port) |
| L | m | Used here as an abbreviated form for Lpp |
| Lüa | m | Length over all |
| Lpp | m | Length between perpendiculars |
| m | kg | Mass/weight |
| N | Nm | Moment of turn (positive clock-wise from above) |
| Nd | N/° | Slope of the moment curve over the rudder angle |
| Nv | N/° | Slope of the moment curve over the drift angle |
| p | N/m² | Pressure |
| Q | Nm | Torque of the propeller shaft |
| t | s | Time |
| T | N | Thrust |
| T | m | Draft |
| Tv | m | Draft forward |
| Th | m | Draft aft |
| Trimm | min | Angle of trim of the vessel (down by head, positive)<br>(used here instead of the lettering Θ ) |
| v | ° | Drift angle (actually dimensionless transverse speed) |
| V | m/s | Speed in the model experiment |
| V | kn | Speed in the large version |
| x | m | Longitudinal coordinates |
| X | N | Forward force (positive forwards) |
| y | m | Transverse coordinates |
| Y | N | Component force (positive to starboard) |
| Yd | N/° | Slope of the component force curve over the rudder angle |
| Yh | N | Aft component force |
| Yv | N | Forward component force |
| Yv | N/° | Slope of the component force curve over the drift angle |

| | | |
|---|---|---|
| z | m | Height coordinates, also lowering |
| V | m³ | Displacement (in fresh water equal to the mass/weight in t) |
| $\Delta x$ | m | Path difference |

### 6.3.4 Comparative considerations by HSVA

On the basis of the numerical investigation conducted by the Potsdam Institute and the (initally) provisional results of the DST achieved experimentally (status: December 2004), the Hamburgische Schiffbau-Versuchsanstalt (Hamburg Ship Model Basin - HSVA) carried out a comparative consideration of the investigation results available on behalf of the BSU and presented the report Man198/05 on this entitled "Hydrodynamic analysis of the overtaking manoeuvre in narrow navigation channels" in February 2005. The objective of the considerations was to compare and assess the expert opinions submitted by the scientists involved. Building on this, the HSVA was subsequently to review the possibilities of formulating generalising safety recommendations on the problem complex of a safe passing distance and to elaborate such recommendations if this review proved positive.

Within the framework of the comparison considerations by the HSVA, however, it quickly became apparent that the DST results and the Potsdam Institute results did not coincide to the extent that would have been necessary for a final reliable assessment of the hydrodynamic occurrences in connection with the collision of NEDLLOYD FINLAND and COSCO HAMBURG. As in so far no safe result could be achieved even for the concrete case under review, it was understandably not possible to make any generalising statement in the manner set out above.

The originally very large discrepancies between the calculated and experimentally gained forces and moments was subsequently reduced by additional calculations and experiments. However, because of the still excessive differences, it was not possible to elaborate generalising recommendations on the problem of overtaking that were targeted by the contract with HSVA.

# 7 Analysis

## 7.1 Appraisement of the collision

### 7.1.1 Analysis of the track according to ECS data evaluation[49]

| Time (UTC) | Speed Cosco H. [kn] | Speed Nedlloyd F. [kn] | Course Cosco H. [°] | Course Nedlloyd F. [°] | Distance sensors [m] | Distances ship's wall [m] |
|---|---|---|---|---|---|---|
| 13:34:24 | 15.1 | 13.3 | 124.0 | 130.4 | 275.6 | 212.7 |
| 13:34:34 | 15.1 | 13.0 | 125.0 | 127.7 | 270.0 | 207.9 |
| 13:34:44 | 15.1 | 13.0 | 125.0 | 127.7 | 262.5 | 202.3 |
| 13:34:54 | 15.2 | 13.0 | 125.0 | 127.7 | 256.5 | 198.3 |
| 13:35:04 | 15.2 | 13.0 | 125.0 | 127.7 | 251.6 | 195.0 |
| 13:35:14 | 15.3 | 13.0 | 124.0 | 127.7 | 240.5 | 187.8 |
| 13:35:24 | 15.4 | 13.0 | 124.0 | 127.7 | 233.6 | 183.0 |
| 13:35:34 | 15.4 | 12.2 | 125.0 | 132.0 | 231.3 | 182.4 |
| 13:35:44 | 15.4 | 12.2 | 127.0 | 132.0 | 220.9 | 176.9 |
| 13:35:54 | 15.4 | 12.2 | 128.0 | 132.0 | 210.0 | 171.8 |
| 13:36:04 | 15.3 | 12.2 | 129.0 | 132.0 | 205.4 | 172.6 |
| 13:36:14 | 15.3 | 12.2 | 130.0 | 132.0 | 201.2 | 171.5 |
| 13:36:24 | 15.3 | 12.2 | 131.0 | 132.0 | 200.0 | 171.2 |
| 13:36:34 | 15.3 | 10.6 | 130.0 | 131.9 | 204.2 | 174.2 |
| 13:36:44 | 15.3 | 10.6 | 130.0 | 131.9 | 204.2 | 169.8 |
| 13:36:54 | 15.2 | 10.6 | 130.0 | 131.9 | 206.7 | 167.0 |
| 13:37:04 | 15.2 | 10.6 | 130.0 | 131.9 | 206.4 | 164.0 |
| 13:37:14 | 15.1 | 10.6 | 129.0 | 131.9 | 212.6 | 165.5 |
| 13:37:24 | 15.1 | 10.9 | 130.0 | 131.9 | 214.2 | 155.3 |
| 13:37:34 | 15.0 | 12.6 | 131.0 | 126.2 | 207.0 | 137.7 |
| 13:37:44 | 15.0 | 12.5 | 133.0 | 126.2 | 195.1 | 120.4 |
| 13:37:54 | 14.9 | 12.6 | 134.0 | 126.2 | 186.6 | 102.3 |
| 13:38:04 | 14.9 | 12.6 | 134.0 | 126.2 | 179.6 | 89.0 |
| 13:38:14 | 14.9 | 12.6 | 135.0 | 126.2 | 168.7 | 73.0 |
| 13:38:24 | 14.9 | 12.6 | 135.0 | 126.2 | 163.6 | 58.4 |
| 13:38:34 | 15.0 | 15.0 | 134.0 | 127.0 | 163.5 | 52.8 |
| 13:38:44 | 15.1 | 15.0 | 134.0 | 127.0 | 176.0 | 47.0 |
| 13:38:54 | 15.1 | 15.0 | 134.0 | 127.0 | 189.9 | 45.9 |
| 13:39:04 | 15.1 | 15.0 | 135.0 | 127.0 | 204.4 | 40.3 |
| 13:39:14 | 15.1 | 15.0 | 134.0 | 127.0 | 217.3 | 32.9 |
| 13:39:24 | 15.1 | 15.0 | 134.0 | 127.0 | 235.1 | 23.2 |
| 13:39:34 | 15.1 | 8.0 | 133.0 | 131.4 | 272.0 | 3.5 |
| 13:39:44 | 15.0 | 8.0 | 133.0 | 131.4 | 340.1 | 57.2 |
| 13:39:54 | 14.8 | 8.0 | 135.0 | 131.4 | 406.9 | 125.2 |

**Excerpt from Table 2 (cf. Section 6.2.2.5)**

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[49] Source: Department of Maritime Navigation.

The values contained in the table excerpt with grey backing roughly characterise the time periods ultimately crucial for the collision. It is to be taken into account here that this is the result of distances determined on a time-synchronised basis. However, this does not alter anything about the fact that the otherwise relatively safe data basis shows a clear tendency and allows the following conclusions to be drawn.

The approach of the two vessels that - due to the lack of any other indications - in all probability was determined solely hydrodynamically started at a time when the lowest distance between the ship's walls of the vessels was still more than 170 metres and the bow of COSCO HAMBURG was roughly on the same level as the stern of NEDLLOYD FINLAND.[50] With a meantime increasing speed difference (up to approx. 4.5 kn), COSCO HAMBURG subsequently moved past NEDLLOYD FINLAND at a speed of about 140 metres a minute. The bridges of the two vessels were accordingly on the same level about one to two minutes later.[51] The lateral distance between the ship's walls of NEDLLOYD FINLAND and COSCO HAMBURG was now - at first glance still apparently sufficient - approx. 90 metres, but continued to decline continuously as shown impressively in Table 2.

### 7.1.2 Hydrodynamic considerations

As indicated already above, a comparison of the results of the numerical study (Potsdam Institute) with those of the experimental examination (DST) reveals that although the forces and moments determined for the hydrodynamic aspect of the collision development tend to show a same or similar course, they diverge numerically quite clearly in some parts. In this respect it was particularly important that the participating scientists from Potsdam, Duisburg and Hamburg maintained regular contact and shared experience during the production of their expert opinions. It was thus assured that all the experts participating were able to carry out their scientific examinations on the basis of a largely uniform database.

While the calculations of Potsdam Institute ultimately led to the result that for the passing distance of 150 metres chiefly considered only relatively small rudder angles - although changing with the longitudinal off-set of the vessels - were necessary to master the suction effects occurring, the DST experiments showed that already at a lateral distance of approx. 130 metres rudder angles become necessary that are practically no longer available in this order of magnitude.

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[50] The relevant "bow to stern - time" can probably be classified within the (time-synchronised) range between 13:35:44 h UTC and 13:36:34 h UTC.

[51] (Synchronised) time "bridge next to bridge" approx. 13:38 h UTC.

### 7.1.3 Conclusions

An inventory of the investigation results achieved was conducted at the BSU offices on 21 February 2005. The scientists of the institutes[52] commissioned attended the discussion round as guests and an experienced master mariner[53] participated as expert for the BSU.
Within the framework of the meeting it became clear that the results of the experiments and calculations available were not sufficient to be able to conduct a final evaluation of the hydrodynamic aspects of the accident. There was also an insufficient basis for formulating generally valid safety recommendations.
Especially because of the evident discrepancies in the examination results, after this both DST and Potsdam Institute made efforts extending partly well beyond the original investigation order to disclose any errors within the framework of their own considerations. Despite all these efforts, however, apart from clarification of a few differences, the diverging results described above were ultimately retained.

Prof. Söding, who carried out a final evaluation of all the results obtained for the BSU, tends in his assessment to the opinion that the results obtained numerically were more reliable. In detail he included the following remarks in his written comments: "*...I fear that the results* (those of the DST are meant here; the author) *are not wrong, but are imprecise as regards the horizontal transverse force, perhaps also as regards the forward force. In my opinion the agreement regarding the yawing moment shows that the calculations are correct and very precise. In the experiments it appears to be certainly possible that the moment was measured correctly and the forces imprecisely; this can for example be related to imprecise orientation of the model in the longitudinal direction. For calculations, however, it is extremely improbable that the moments are correct in all cases and the forces wrong ...*"

A comparison of the forces measured by DST and moments on the model of NEDLLOYD FINLAND depending solely on the angles of rudder and drift ( = direction of movement relative to the longitudinal axis of the vessel) with the corresponding results of the Potsdam calculations conducted by Prof. Söding revealed the following discrepancies:

1. Component force dependent on drift angle:
   Measuring result = 85% of the calculated result
2. Component force dependent on the rudder angle:
   Measuring result = 92% of the calculated result
3. Yawing moment dependent on the drift angle:
   Measuring result = 89% of the calculated result
4. Yawing moment dependent on the rudder angle:
   Measuring result = 50% of the calculated result

In the first three values, measurement and calculation thus agree usefully. For value No. 4, however, this does not apply. Prof. Söding considers the calculated value to be more credible as the relation between yawing moment and component force (both

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[52] PD Dr.-Ing. T. Jiang, Dr.-Ing. A. Gronarz (both for DST), Dr.-Ing. H. Weede (HSVA), Dr.-Ing. A. Cura Hochbaum (Potsdam Institute), Prof. em. Dr.-Ing. H. Söding (Advisor BSU)
[53] Captain W. Heppner (Yard Captain at the Sietas-Werft)

dependent on the rudder angle) is about 42% of the ship's length in the calculation as expected, while in the measurement an unexpectedly (for the water depth present) smaller value of 22% of the ship's length results.

The discrepancy of the values for No. 4 was particularly important because it was specifically the size of the yawing moment dependent on the rudder angle that is crucial for what rudder angle is necessary to hold the small vessel on its course.

In the following diagrams Prof. Söding has graphically superimposed the experimentally and numerically achieved values for the Forward force X, the transverse force Y and the yawing moment N to illustrate the differences in the results achieved.

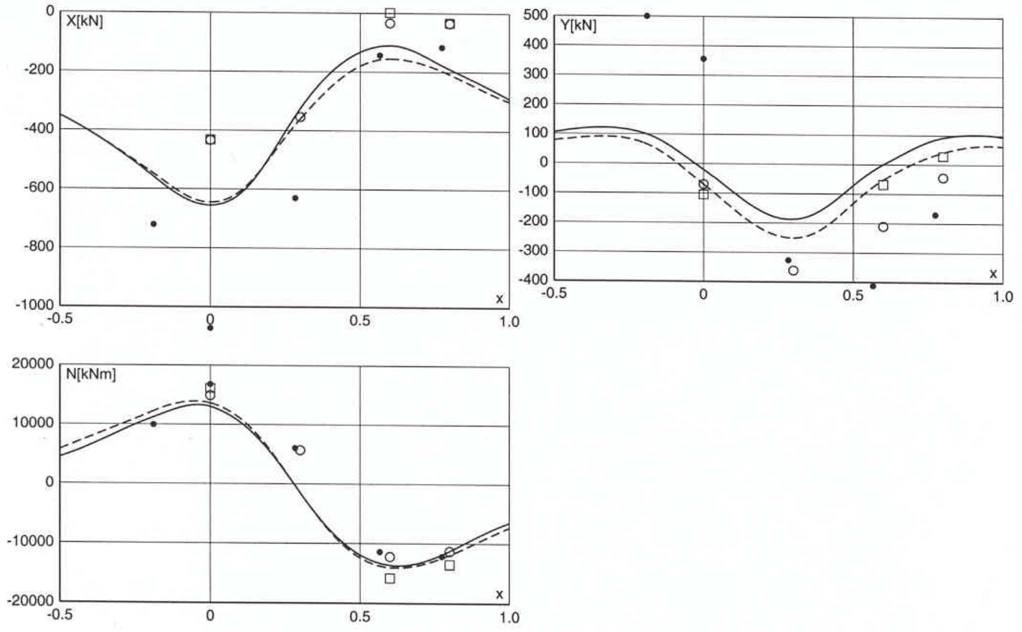

Fig. 2. Forward force $X$, starboard force $Y$ and bow-to-starboard moment $N$ on the feeder ship depending on the relative longitudinal position $x \cdot 280$m of the two ships' bows. Broken line: Kelvin, constant water depth; continuous line: Kelvin, bottom profile; •: DST experiments; ○: Unopam results, with vortices; □: Unopam results, without vortices.

**Figure 75: Comparison of the different calculated and measurement results**[54]

At different relative positions of the two vessels[55] Figure 75 shows the Forward force X[56], the transverse force Y[57] and the yawing moment N[58] acting on NEDLLOYD FINLAND at a lateral distance of 150 metres and a speed of 15 kn.

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[54] Source: Prof. Söding for BSU, at the same time manuscript Söding/Conrad: "Analysis of overtaking manoeuvres in a narrow waterway" (Contribution to the Hydman Conference in Poland in September 2005)

[55] Lon^^gitudinal off-set x (cf. abscissa) is zero when the bow tips of both vessels are at the same level; x is 1.0 when the bow of NEDLLOYD FINLAND is 280 metres (= approximate Loa of COSCO HAMBURG) behind the bow of the overtaking vessel.

For the calculating methods used it should be noted that the KELVIN program used by the Potsdam Institute uses non-linear source methods, whereby the kinetic and dynamic marginal conditions at the deformed water surface are fulfilled. The calculations completed were carried out without taking into account eddy effects and neglecting the Kutta conditions on the flow separation at the aft ends and the rudder blades of both vessels. Nor were propeller influences included in the calculation. The friction forces at the vessel hulls were estimated with the aid of the ITTC Guidelines.
Prof. Söding carried out additional calculations using the UNOPAM[59] program. In this calculating model a different non-linear Rankine source method based on the Patch method is applied that differs in many details from "Kelvin". Here calculations were conducted with and without taking eddy influences at the hull of NEDLLOYD FINLAND into account.

As a conclusion from the experiments conducted and sundry calculations it is thus evident that a clear, indubitable derivation of the causes of the accident and in particular a precise picture of the hydrodynamic interactions accompanying the collision occurrences between COSCO HAMBURG and NEDLLOYD FINLAND were not possible. Admittedly the calculations of Potsdam Institute and their evaluation by Prof. Söding indicate that for an initial lateral distance of about 150 metres the steerability of NEDLLOYD FINLAND to avoid the collision should still have sufficed to avoid threatening suction effects. On the other hand the results of the DST coincide largely with the plausible statements of eye witnesses regarding the accident occurrence and with the evaluations of Department of Maritime Navigation, according to which NEDLLOYD FINLAND ran towards the stern of COSCO HAMBURG, without this ultimately being avoidable for NEDLLOYD FINLAND.

Furthermore, the finding that changing rudder angles had to be set for the "theoretical" holding of a minimised, safe passing distance during the course of the overtaking operation is of importance. In this connection reference is made to the results of the calculations by Potsdam Institute. Independently of the fact that the values calculated cannot be correlated with the measuring results of DST and the track courses determined by Department of Maritime Navigation, as well as the testimonies, the rudder angles - excerpts from which are set out below - confirm the known theses according to which the smaller vessel first has to steer (moderately) towards the overtaking vessel in order to keep its track and a minimum distance, and basically may only turn away from it in the last phase of the overtaking operation.

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[56]. Positive prefix means force directed ahead. Positive values for X are not achieved here solely because the thrust force of the propeller of NEDLLOYD FINLAND was neglected in the calculations (quasi-stationary consideration method).
[57] Positive prefix means force directed to starboard
[58] Positive prefix means direction of turning of the bow away from the overtaking vessel.
[59] UNOPAM= Unsteady Nolinear Panel Method.

| Longi-tudinal off-set L | Lateral distance [m] | Rudder angle δ [°] |
|---|---|---|
| -0.2 | 150 | 4.7 |
| 0. | 150 | 7.7 |
| 0.3 | 150 | 2.2 |
| 0.6 | 150 | -7.8 |
| 0.8 | 150 | -7.7 |
| 0.6 | 100 | -13.7 |
| 0.6 | 200 | -4.7 |

**Excerpt from Table 5 (cf. Point 6.3.2.7)**

However, such a theoretically optimal procedure can seldom be implemented in practice. The BSU expert Captain Heppner pointed out the difficulties that practitioners naturally have in determining the forces and moments acting between the vessels at the above mentioned discussion panel on 21 February 2005. The corresponding characteristic quantities on board are not known or cannot be determined quickly. At present the most important way of avoiding danger in the area of overtaking operations is therefore timely and comprehensive communication between the participating vessel commands and pilots. Moreover the vessel to be overtaken must play an active role in the overtaking operation.

The fact that it is not possible to make any sound statements about the lateral distance at which the steerability of NEDLLOYD FINLAND was practically suspended in the concrete marine casualty under review here, despite the presence of nearly all important relevant data, shows that it is not possible to make the generally valid statement originally targeted by the BSU about the question of safe passing distances in limited navigation channels.
However, the findings gained totally support the safety recommendation on the problem of safe passing distances published already on 1 October 2004.[60] It was pointed out already in this recommendation that generally valid recommendations on the overall problem complex hardly appear possible at the present time. This fear has regrettably now been confirmed. Critical comments on the recommendation[61] that in particular did not consider the general statements made by the BSU to be very helpful must be countered by pointing out that the current state of the art concerning the extremely important and complicated problem complex of safe passing distances during overtaking is indeed unsatisfactory. Despite this, the BSU saw and sees it as its obligation to draw attention to the high danger potential of suction effects within the framework of overtaking manoeuvres and in this connection considers a "generalising" safety recommendation to be as any rate better than disregarding the necessary discussion of the problem altogether.

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[60] Cf. here the original text of the recommendation printed at the end of the report.
[61] Cf. as representation Prof. W. Huth, in Schiff & Hafen, December 2004, P. 57 f.

To summarise the following findings can be made:[62]

- The investigations conducted so far do not make it possible to provide improved (in other words more concrete) recommendations on overtaking of seagoing ships in limited navigation channels.
- In consideration of the growing size of vessels, improved recommendations are absolutely necessary.
- The publications that have appeared to date chiefly examined the forces crossways to the track and yawing moment that the vessels exert on each other. However, it appears equally important to take into account the forward-directed forward force on the overtaken vessel towards the end of the overtaking operation. (The bow of the overtaken vessel is then in a "trough" that the overtaking vessel generates alongside itself, while the stern floats in less disturbed water or even at a water level raised above the level of rest behind the "trough". The "slope take-off force" thus acting on the overtaken vessel, directed forwards, reduces this vessel's propeller load and thus its rudder effectiveness. Furthermore, it can accelerate the initially slower vessel up to the speed of the overtaking vessel and thus make an overtaking operation actually impossible due to the resulting "surfing effect". There is then a danger that the vessel’s command will reduce the pitch/speed of the propeller with a view to ending the "surfing along", which in turn will reduce the effectiveness of the rudder even further. This necessarily increases the risk that it is no longer possible to compensate the turning of the bow towards the stern of the overtaking vessel (yawing moment).)
- The difference in speed during overtaking is just as important as sufficient transverse distance. (At the start of the overtaking operation the difference in speed between the vessels must be so great that the overtaken vessel is not accelerated to the speed of the overtaking vessel if the speed/propeller pitch on the overtaken vessel are kept constant.)
- Safe distances presuppose that the overtaken vessel remains steerable, in other words the rudder angle necessary to hold a course is less than the maximum rudder angle.
- When elaborating generally valid recommendations on determining safe passing distances, unrestricted suitability for practice has top priority. When specifying safe distances, a passive course behaviour of the overtaking vessel should therefore mainly be presumed. Instructions concerning various rudder manoeuvres to be carried out at various phases of the overtaking operation, for instance, would not be very practicable and would not mean any perceptible gain in safety.
- Generally valid recommendations providing information, for instance, for certain estuaries depending on the vessels involved (with distinctions on the basis of dimensions, fullness, draft), the navigation channel widths and depths available and the vessel speeds, on what passing distances and/or speed differences are to be observed in order to ensure a safe overtaking manoeuvre require extensive investigations into many cases with a widely scattered variation of the above and other parameters (e.g. construction of the steering and propulsion facility, bottom topography).

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[62] The contents of the following findings was partly taken from a comment by Prof. Söding for BSU. The information supplied by the Expert Captain Heppner was also taken into account.

- Training in overtaking operations on vessel command simulators is extremely important. However, in this respect it must be ensured that the corresponding systems map the forces and moments actually occurring at the relevant situations very close to reality. The objective of scientific investigations must therefore primarily be to optimise the computing programs for the simulation facilities in this respect.

**Note: In his comment on the draft of this investigation report Prof. Söding drew attention to the fact that both the DST experiments and the Potsdam Institute calculations were conducted on the assumption that COSCO HAMBURG was proceeding at a speed of 15 kn. However, under the present findings this speed represented the hydrodynamically irrelevant speed over ground. By contrast, it was to be noted that in view of the strong ebb current prevailing at the time of the accident (approx. 2 kn[63]), COSCO HAMBURG must have been proceeding through the water at a crucial speed for the forces occurring of approx. 17 kn. At such a speed the forces acting on NEDLLOYD FINLAND and necessary rudder angles could be 1.5 to 2 times as high as for a passage through the water of 15 kn.**
**Potsdam Institute also stressed in its comment that forces and moments acting on the overtaken vessel depend very strongly on the speed of the overtaking vessel through the water.**

**The aspect commented on does not change anything in the basic statement of the results ascertained, in particular the fact that the calculated and experimentally determined rudder angles do not coincide despite the same initial data. The reference that a speed through the water approx. 2 kn faster leads to a strong increase in the forces and moments and hence the necessary rudder angles is particularly important, however, because at the very least this relativises the great discrepancy between the witness testimonies and the results of Department of Maritime Navigation on the one hand (suction effects already with a lateral distance of 170 metres) and the Potsdam Institute values predicted by calculation (the situation can be managed even at a lateral distance of 100 metres) on the other hand.**

The above considerations lead to the following aspects for vessel commands and pilots of overtaking vessels:

- When specifying a safe overtaking speed, the speed *through* water is particularly relevant, as in addition to the lateral distance, the forces and moments between the vessels are critically determined by this "type of speed".
- GPS-based speed data that are regularly very important for navigation as so-called speed *over ground* (made good) do not provide a sufficient basis for selecting the safe overtaking speed when considered in isolation, but must first of all be adjusted for any current and wind effects.
- When proceeding against the current, one particular difficulty is that on the one hand a sufficient difference in speed is necessary between the vessels in order to reduce the time required for the overtaking operation. On the other hand the

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[63] According to the technical records of the Local Office for Waterways and Shipping (WSA) Hamburg and the Federal Maritime and Hydrographic Agency (BSH) available to the BSU the ebb current in the area of the scene of the accident prevailing at the time of the accident was about 1.65 to 1.75 knots.

forces arising are exponentiated when the speed through water is increased and thus promote the development of unmanagable situations.

Dr. Ing. Andreas Gronarz from DST informed BSU of the following considerations in a final comment on the necessary demand for research:
*"...As a result of experimental and numerical examinations it is possible to make statements about the forces and moments acting from both the overtaking vessel and the overtaken vessel. It is possible to draw conclusions regarding the controllability indirectly from the results if the steering properties (hydrodynamic coefficients) are known.*
*However, it is not possible to determine the time course of an overtaking operation. This is only possible by using numerical movement simulation. For this the complete hydrodynamic coefficients of the vessel considered are necessary and in addition a mathematical formulation of the forces and moments acting on the vessel as a result of the interaction with the other vessel. Here as many as possible of the parameters indicated above should be taken into account in order to be able to examine a large number of possible cases with the means of simulation.*
*So far such simulation has not been possible as there is no mathematical description of the interaction forces. Various investigations have been published, but the results are not sufficient to simulate overtaking manoeuvres in a manner close to reality. A simulation on a Ship Handling Simulator would be desirable. These facilities that provide not only a calculation of the movement of one's own vessel but also a realistic representation of the surroundings are supplied by commercial manufacturers and very rarely allow intervention into the simulation software. However, this is just what is needed in order to implement an interaction model and take into account the effect of the forces and moments acting in addition to the overtaking operation.*
*An alternative would be to waive visualisation of a bridge and simulate on a PC with special software that is open to access by the programmers. However, cooperation with the manufacturer who allows intervention into software and cooperates in simulating overtaking operations would also be conceivable. Possible partners in a joint research project could be experimental institutions or other research facilities, as well as operators/manufacturers of simulators, provided that they allow the necessary intervention into the software...."*

Finally, it can be ascertained that the discussions between the BSU and the various research facilities with participation by their most important scientific capacities have revealed that there are indeed different opinions on details of whether, how and (current) limits of specifying/specifiability of generally valid recommendations on safe passing distances of vessels in limited navigation channels. However, it was agreed that further considerations are indispensable in order to effectively improve safety of shipping in the subject area.

For this it is necessary to initiate appropriate research projects. In view of the (qualitatively and quantitatively increasing) dangers and possible economic and ecological consequences as a result of hydrodynamic interactions within the framework of overtaking manoeuvres, these have a very high degree of macroeconomic importance.

## 7.2 Admissibility of lashing works on travelling container vessels

As already set out above, as a consequence of the collision between the two vessels the Philippine seaman (P.) working on the deck of NEDLLOYD FINLAND fell over board and could subsequently only be recovered dead. This tragic accident has occasioned the BSU to look further in the spirit of a comprehensive analysis into the question of whether or under what conditions lashing works on moving container vessels are admissible.

This question is particularly important in feeder service, as here

- special value is attached to minimising berth and port through-put times,
- the number of containers to be moved at the relevant place of transhipment is generally relatively low,
- the vessel dimensions and in particular the height of the stacks[64] make it possible to climb onto the deck container cargo for lashing work to an extent that regularly does not enter into consideration on large container vessels.

The fact that *regular* lashing work[65] on board feeder vessels during sailing, for example on the Rivers Elbe or Weser, is carried out regularly, that seaman work without any special safety provisions, and that these are consequently by no means isolated cases, is generally known.[66]

The work on board NEDLLOYD FINLAND was carried out no more and no less as part of this customary practice. That is why, following on from the description of the subject happenings on the day of the accident (Section 7.2.1) a general inventory of the important rules and regulations is conducted (7.2.2), before finally answering the initial questions raised regarding the admissibility of lashing work (Section 7.2.3).

### 7.2.1 Context

#### 7.2.1.1 Statement by witness

At about 14.30 h the later victim of the accident, P., had been assigned by the Chief Mate together with a further Philippine seaman to unlash containers. One day after the accident this seaman was asked by the Waterway Police Hamburg what he had seen.

He reported that he himself had started unlashing work in Bay 1[67], and P. in Bays 3/5. They had worked aft together. When the witness had passed by Bays 7/9, P.

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[64] stack = Stapel (in German)

[65] Note: The BSU's considerations do not relate to cases in which unscheduled measures to safeguard cargo have to be taken on board at short notice in emergency situations (known as after-lashing)

[66] Cf. in connection with the overall problem complex the essay by Prof. W. Huth "Lascharbeiten auf Feederschiffen auf der Elbe bzw. Weser“( Lashing work on feeder vessels on the Elbe/Weser), Schiff & Hafen 2/2005, P. 59 f.

[67] "Bay" = a row of containers (complete stack) crossways on the vessel from ship’s wall to ship’s wall; these are counted from forward to aft, whereby the transverse stacks of the 20-foot containers are numbered with uneven numbers (1, 3, 5, ...) while those of the 40-foot containers are marked with even numbers (2, 4, 6, ...). This method of counting described here means that Bay 2 corresponds location-wise to Bays 1 and 3 (in brief 1/3).

had just loosened the lashings of about the third container from starboard there. The witness himself had intended to carry on at Bays 11/13. He had perceived that their own vessel was approaching the stern of COSCO HAMBURG and called out to P. to watch out. He had not received any answer from P., who was not in his line of vision. The witness had observed what would happen and had held himself fast. At the collision the containers had swayed. It was only some time later that the vessel had come free again and returned to its old position. The witness had proceeded to Bays 7/9 but could not find P. After other crew members could not provide him with any information concerning the whereabouts of P. he had immediately informed the vessel command.

In response to the question as to whether safety belts and inflatable working jackets were used for such lashing work, the witness answered that this was normally not the case. Safety belts were only worn at high sea when lashings were tightened in bad weather. Life jackets were not customary during such work.

### 7.2.1.2 Container stowage on deck NEDLLOYD FINLAND on the day of the accident

The representation below shows the arrangement of the container cargo above the main deck of NEDLLOYD FINLAND on the day of the accident. The containers were stowed up to a maximum level of four tiers[68] on deck.

(For better illustration of the relevant cargo unit, the 40-foot containers and special sizes are shown in blue or green. The 20-foot containers are shown in red and yellow. The vacant items are colourless.)

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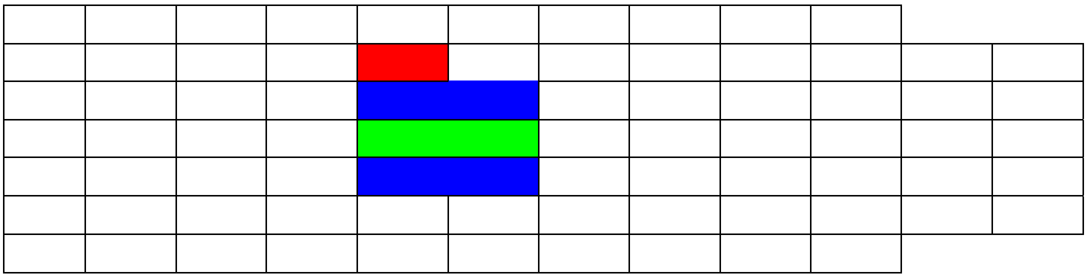
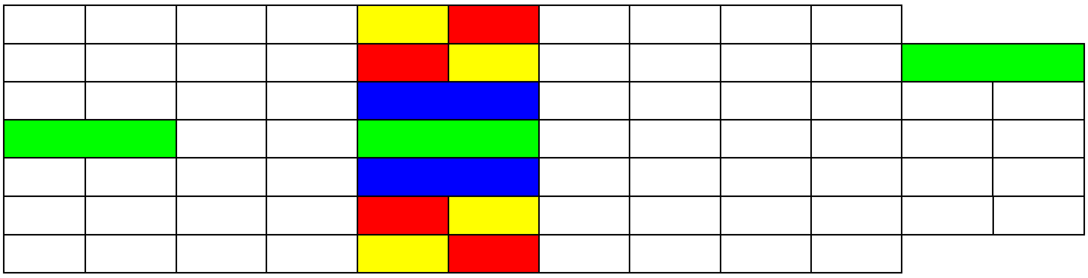
[68] The technical English term for a layer of containers is "tier"

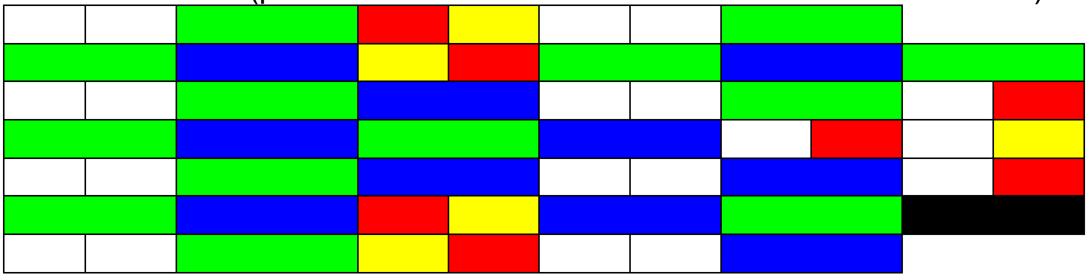
## 4th container tier



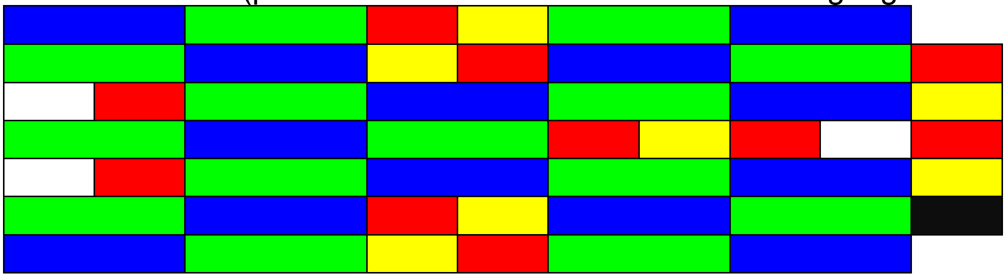
## 3rd container tier



## 2nd container tier (position of the containers that went over board in black)



## 1st container tier (position of the container that fell into the gangboard in black)



| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **23** | **21** | **19** | **17** | **15** | **13** | **11** | **9** | **7** | **5** | **3** | **1** |
| **12** | | **10** | | **8** | | **6** | | **4** | | **2** | |

**Way in which bays are counted (last known area in which P. was seen shown in grey)**

### 7.2.2 Legal stipulations

Standards, that (also) impinge on the legal assessment of lashing problems on moving container vessels are to be found in Chapter VI SOLAS 74/88[69] and in the Accident Prevention Regulations of the Berufsgenossenschaft.

#### 7.2.2.1 SOLAS Convention

7.2.2.1.1 General Regulations

In Regulation *5* (Stowage and securing) of *Chapter VI* (Carriage of cargoes), Paragraph 1 states:

***"Cargo, cargo units and cargo transport units carried on or under deck shall be so loaded, stowed and secured as to prevent as far as is practicable, throughout the voyage, damage or hazard to the ship and the persons on board, and loss of cargo overboard. "[70]***

For the implementation of this obligation proper lashing, in other words securing cargo for the voyage, is necessarily one of the most important measures. In particular, however, the lashing work itself as a working process on board is subject to the protective scope of the SOLAS Regulation cited. In this respect too it must be ensured that perils for the vessel and the persons on board are prevented as far as possible.
It can be concluded from this that both unjustified risks within the framework of the lashing work as well as unlashing of cargo before reaching the berth, in other words premature removal of safety measures, must in every case be considered as infringements of the requirements of the above cited Rule 5 Para. 1. Consequently the unlashing of containers on board NEDLLOYD FINLAND during the voyage to the berth in the port of Hamburg indubitably infringed the said SOLAS Rule.
The norm content of Para. 6 of the subject Rule 5 does not alter anything in this basic finding either. This states literally:

***"All cargoes, other than solid and liquid bulk cargoes, cargo units and cargo transport units, shall be loaded, stowed and secured throughout the voyage in accordance with the Cargo Securing Manual approved by the Administration. In ships with ro-ro spaces, as defined in regulation II-2/3.41, all securing of such cargoes, cargo units, and cargo transport units, in accordance with the Cargo Securing Manual, shall be completed before the ship leaves the berth. The Cargo Securing Manual shall be drawn up to a standard at least equivalent to relevant guidelines developed by the Organization.[71]***

The latter provision, that in Sentence 2 expressly requires for Ro-Ro cargo that securing must be completed prior to sailing of the vessel may not be misunderstood to mean that the general requirement issued for all (other) types of cargo calling for safe loading and stowage throughout the entire voyage only need be observed less

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[69] International Convention of 1974 for the protection of human life at sea, amended by the Protocol of 1988 (in Germany binding in conjunction with § 1 Para. 2 Ship's Safety Act, Federal Law Gazette I 1998, 2860; last amended by Art. 3 Law of 25. 6. 2004 Federal Law Gazette I 1389).
[70] Underlining by the author of the report.
[71] Cf. Footnote 69 f.

strictly in the spirit of Rule 5 Para. 1. In particular it cannot be concluded conversely from the specification in Para. 6 Sentence 2 that apart from Ro-Ro cargo, it is possible in principle to refrain from comprehensive securing of the cargo at the beginning of the voyage or - going even further - already before the end of the voyage.

The accident to be investigated here has shown clearly that the specific perils of a sea voyage connected with incorrectly loaded, stowed or secured (other) cargo can occur at any time between leaving the old berth and reaching the new berth, in other words even directly before berthing or shortly after casting off. The obligation set out separately in Rule 5 Para. 6 Sentence 2 that the securing of Ro-Ro cargo must have been completed prior to sailing only takes into account the particularly high peril potential of "moving" cargo. However, it cannot under any circumstances be concluded in a generalising manner from this that the safety requirements for other cargo are secondary.

Furthermore, it is for the rest doubtful whether it can basically be concluded at all from the special instruction that securing "moving" cargo must be completed prior to sailing that the final securing of other cargo can <u>regularly</u> be continued after sailing too. On the contrary, an interpretation in accordance with the meaning and purpose of the entire Rule 5 shows that the special emphasis on safety requirements for "moving" cargo was issued above all in order to make it clear for this sensitive cargo from the very start that <u>completing</u> the lashing work only after the vessel has sailed is always inadmissible (in other words even by way of exception). The express mention of this prohibition should thus primarily make it clear and serve as a demarcation against the historically developed, divergent practice on board relating to conventional general cargo passages. However, there is no supportable reason that can be derived from the fact that on board vessels, in view of practical requirements, it was customary especially in the past to continue or complete the partly time-consuming lashing work for various items of general cargo after the vessel had sailed, to mean that it can generally be refrained from standardised lashing of containers when a vessel is lying at berth. Furthermore, it should be remembered that in the present case we are dealing not with the <u>completion</u> of lashing work that is fundamentally admissible in exceptional cases after the vessel has cast off, but instead about premature <u>suspension</u> of securing measures already before the vessel berths. For this reason alone it is inadmissible to draw the converse conclusion in the spirit of the manner described above as the relevant circumstances are not comparable.

The following instruction deriving fundamentally from SOLAS Chapter VI Rule 5 Para. 1 that the cargo be secured during the <u>entire</u> voyage is thus not weakened by the special emphasis where this concerns securing of Ro-Ro cargo (Rule 5 Para. 6 Sentence 2).

**<u>Note:</u> The See-Berufsgenossenschaft (See-BG) has informed us in its comment on the draft of this investigation report that the (extensive) interpretation of Rule 5 Para. 1 SOLAS set out is in its opinion not tenable. No danger had emanated from the cargo for persons on board. Moreover the cargo on NEDLLOYD FINLAND had "*probably been sufficiently secured in order to be able to proceed along a waterway with it, here the River Elbe, on which a sea swell is ruled out*". The interpretation of Rule 5 Para. 6**

**Sentence 2 was also not plausible as it contradicted the idea behind the SOLAS Convention of aiming to make a special ruling exclusively for Ro-Ro cargo.**

**The BSU has reviewed the arguments put forward, but retains its opinion as set out in full. In the opinion of the BSU, there is no reasonable doubt that great dangers for persons on deck can emanate from unsecured cargo as a result of it falling down. The fact that independently of this dangers can emanate from cargo items becoming loose when a peaceful waterway like the River Elbe is being sailed is documented convincingly by the accident under review here. The fact that in the accident being investigated exceptional but not remote circumstances were additionally involved to realise these specific dangers does not alter anything in this fundamental finding. The protective area of Rule 5 Para. 1 SOLAS cannot be restricted when considering the meaning and purpose of the Regulation, to mean that sufficient securing throughout the (entire!) voyage aims to provide protection solely against dangers resulting from "regular" sea swell.**

**Furthermore, the BSU does not fail to realise that Rule 5 Para. 6 Sentence 2 of SOLAS represents a regulation issued specifically for Ro-Ro cargo. On the contrary, the considerations set out in this respect serve solely to prevent that addressees of the norm drawing premature, inadmissible (converse) conclusions for other cargo from the existence of this special ruling.**

#### 7.2.2.1.2 Cargo-securing Manual of NEDLLOYD FINLAND

The requirements made of cargo securing on moving container vessels set out above, initially on the basis of general legal and actual considerations, are explicitly confirmed for NEDLLOYD FINLAND by the specifications of the Cargo-securing Manual approved for this vessel by the administration in the meaning of Rule 5 Para. 6 Sentence 1 SOLAS. It is stated on page 13 of the manual in Chapter 3 (heading: "Stowage and Securing of Containers") in sub-section 3.1 (heading: "Handling and safety instructions") in addition to other instructions: "*Any securing or unsecuring of containers must be carried out during the ship´s stay at a berth."*

### 7.2.2.2 Accident Prevention Regulations

The question as to whether or under what conditions lashing work is admissible on moving (container) vessels is not specially regulated within the Accident Prevention Regulations of the See-Berufsgenossenschaft (German acronym UVV See). In addition to the very generally formulated ruling in § 9 UVV See that obliges the employer to take all the necessary safety measures for dangerous work called for according to the requirements from case to case, however, the See-BG has written and published the Pamphlet E2 that contains important instructions for lashing of containers by the ship's crew:

***"E 2 - Pamphlet on Lashing Containers by the Ship's Crew***

***To protect the insured on container vessels the See-Berufsgenossenschaft issues the following pamphlet on lashing of containers by the ship's crew.***

1. ***It must be possible to walk safely through lashing aisles even after all the lashing rods provided for in the cargo-securing manual have been set (cf. UVV See § 92).***

2. ***In hours of darkness sufficient lighting must be provided. The lighting may not dazzle (cf. UVV See § 139).***

3. ***During lashing work the appropriate personal protective equipment such as protective shoes, helmet and gloves must be worn (cf. UVV See § 19).***

4. ***Lashing bars may only be set or removed with the assistance of a second person.***

5. ***Safety gear is to be worn when working on the first tier of containers or higher.***

6. ***Use of a spreader to transport people is not permitted, unless the spreader has a secured platform provided for this purpose (cf. UVV See § 20).***

7. ***When using a ladder, this must be secured. The danger of the ladder slipping on wet hatches or containers must be considered. Climbing onto containers without a ladder is not allowed. (cf. UVV See § 9 and Pamphlet F 8).***

8. ***Lashing work during loading or discharge in the same or adjacent bays is not permitted due to the danger of items falling down (cf. UVV See § 22). The supervising officer shall be responsible for coordination.***

9. ***At sea container lashings must be checked and where necessary post-lashing is to be carried out, especially when approaching or in bad weather areas. Post-lashing on containers is to be avoided and should only be instructed in urgent cases.***

10. ***During post-lashing at sea the movements of the vessel are to be restricted to a minimum by a suitable selection of course and speed. Post-lashing during heavy motion of the vessel in a sea swell is to be carried out with maximum caution in order to avoid contusions and similar injuries.***

    ***When working on the outer stacks safety gear must be worn. The same applies when unavoidable securing work is to be carried out on the containers.***

11. ***UVV See § 9 (4) on re-stowing of cargo at sea with ship-side equipment must be observed.*** [72]***"***

The question as to whether lashing/unlashing on moving container vessels is admissible under labour-law aspects is not answered directly by the pamphlet, however. Yet important indications are provided under Points 9 and 10 (post-lashing at sea) that support the aforementioned extensive interpretation of SOLAS Chapter VI Rule 5 Para. 1. In this respect the fact that the aspect of cargo securing at sea is addressed solely in connection with any post-lashing work that becomes necessary,

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[72] Will be added after § 9 Para. 4 UVV See enters into force.

in other words is considered to need regulating, is significant. This "restriction" of Pamphlet E 2 can only be explained expediently by the fact that in contrast to <u>necessary post-lashing</u> work, lashing and unlashing work on moving vessels that is not necessary as a result of special circumstances but solely due to economic factors is basically inadmissible.

The fundamental prohibition of lashing/unlashing work on moving container vessels can also only be derived indirectly, but despite this convincingly, from the fact that the safeguarding specified for the crew member instructed to carry out this work can practically hardly be provided by the ship's staff. Point 5 of Pamphlet E 2 requires the use of safety gear for work on the first tier of containers or higher. However, use of this presumes that the relevant securing equipment can in turn be fixed effectively without endangering the seaman to be charged with this. Yet such safeguarding measures can generally not be carried out with ship-side equipment on moving vessels.

The high demands made of securing the staff charged with container lashing work are, moreover, also documented by § 11 of the Accident Prevention Regulation Port Work[73]. It is stated there under the heading *Periods spent on stacks and cargo:*

*"(1) The employer must ensure that <u>safeguards</u> are provided <u>against falling</u> when*

1. *<u>the fall height is higher than one container height when staff are on containers,</u>*
2. *during periods of stay on stacks or on the cargo of vessels or vehicles when the fall height is more than 2 m.*[74]

*(2) Insured persons may only step on containers, stacks or cargo once safeguards against falling have been taken in accordance with Para. 1. This does not apply for the performance of this securing work if stepping on containers, stacks or cargo is necessary for this and this work is carried out by technically qualified insured persons under instruction and under supervision.*

*(3) The stability of stacks or cargo may not be impaired by people spending time on them.*
*(4) Objects may not be thrown down from containers, stacks or cargo."*

As a supplement § 43 Para. 6 of the cited UVV for work places on vessels requires:

> *"The employer must ensure that protective measures are taken against insured persons falling down if the fall height is more than 2 m. In the case of containers proteive measures are to be taken if containers are stacked more than one high or if the fall height is more than one container height."*

The validity of these regulations in shipping businesses too results from § 3 Para. 1 UVV See. According to this norm the employer must take measures to prevent

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[73] Cf. Berufsgenossenschaft Regulation for Safety and Health at Work BGV C21 (previously VBG 75) of 1 October 1995 in the version of 1 April 2001.
[74] Underlining by the author of this report.

accidents at work, occupational illnesses and work-related health risks and to ensure effective first aid. In particular the employer shall provide facilities and make arrangements conforming with the provisions of the UVV See, *other accident-prevention regulations applying for him,* and for the rest in accordance with generally recognised rules of safety engineering and industrial health. In the implementing provision of this regulation it is pointed out that generally recognised safety engineering rules are set out in particular in the accident prevention regulations issued in agreement by other Berufsgenossenschaften. These accident-prevention regulations should be consulted on board if the UVV See does not contain any rulings of its own.

Since as set out above the industrial safety requirements connected with cargo-securing works within the UVV See are defined relatively generally, but at any rate not conclusively, the requirements under §§ 11 and 43 Para. 6 UVV Port Work apply as a supplement. Consideration in a manner that would apply other and in cases of doubt lower safety standards for ships personnel is inadmissible. The purpose in norm §§ 11 and 43 of lowering the risk of falling for port workers connected with their stay on stacks and cargo is equally - if not even more - relevant for seamen on board. This becomes particularly clear when one takes into account that the existing dangers of falling are additionally increased by the movements of a vessel in motion that can only be partly calculated in advance.

### 7.2.3 Summary

The lashing activities on board moving container vessels practiced in particular in the field of feeder shipping, and on the day of the accident on board NEDLLOYD FINLAND too, infringe both the general internationally binding legal specifications set out in SOLAS Chapter VI Rule 5 and against the express provisions of the cargo-securing manual of NEDLLOYD FINLAND in as far as they extend beyond the measure that is for instance indispensable due to weather conditions. Furthermore, they also represent an infringement of the German Accident Prevention Regulations UVV See (§ 9; Pamphlet E 2) and Port Work (§§ 11, 43 in conjunction with § 3 Para. 1 UVV See).

However, the Federal Bureau of Maritime Casualty Investigation expressly does not connect the conclusion that the said infringements and accompanying dangers (due to the cargo coming loose or due to unsecured stay at a higher level) must have been responsible for the accidental death of the seaman P. with this finding. It was not possible to furnish appropriate evidence as the precise position of the seaman P. at the time of his fall over board could not longer be determined. Accordingly the possibility that at the time of the collision P. was on the main deck (in an area possibly between containers that were still secured) cannot be ruled out. In this case special personal safeguards would not have been necessary.

However, this does not alter anything about the basic finding that releasing (unlashing) containers on a moving vessel is contrary to the rules in the meaning of the provisions cited above.

# 8 Safety recommendations

## 8.1 Safety recommendations of 1 October 2004

In view of the special danger in delaying, the BSU has already issued a safety recommendation during the extensive ongoing investigations to prevent future accidents occurring for the same or similar reasons. This recommendation still stands in full after completion of the investigation and is therefore repeated again here:

***"In accordance with § 9 Para. 2 No. 2; § 15 Para. 1 and 10 of the Maritime Safety Investigation Law (SUG) of 16 June 2002 in conjunction with § 19 Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (FlUUG) of 26 August 1998, the BSU issues the following safety recommendations:***

*The BSU is investigating the collision between a container vessel registered in Hong Kong and a German feeder vessel at Buoy 91 on the river Elbe on 1 March 2004 in the course of which a Philippine sailor lost his life. The investigation of the marine casualty has not yet been completed. According to the current status of investigations, however, it is to be assumed that the feeder vessel (length over all: 101 m) was caught in the wash suction during an overtaking manoeuvre by the container vessel (length over all: 280 m). The hydrodynamic suction effect was so strong that the bow of the feeder vessel touched the starboard aft part of the container vessel.*

***The accident occurrence prompts us to draw the attention of ship commands and pilots to the following:***

***Hydrodynamically conditioned suction effects that act during overtaking, especially when large vessels overtake smaller vessels, may not under any circumstances be underestimated. Passing distances during overtaking or encounters must always be dimensioned in such a way that no dangerous suction results. In this connection the Federal Bureau of Maritime Casualty Investigation (BSU) draws attention to the fact that it is no longer fundamentally possible to maintain the opinion held in the past by the German Seeämter (maritime casualty investigation authorities), the Bundesoberseeamt (higher maritime casualty investigation authority) and a few courts that no suction effect occurs any more at a passing distance of 100 m, or that at any rate such a suction effect can be mastered,.***

*Taking today's traffic situation as a basis (increasingly larger, faster vessels with a greater draft), it is to be assumed that dangerous suction effects cannot be ruled out even at passing distances of well over 150 m.*

*The BSU is currently checking whether concrete quantity recommendations can be issued in future for safe passing distances. However, it is to be considered that such recommendations will be dependent on many factors (size, draft, speed and manoeuvring properties of the vessels, water depth, navigation channel effects) and accordingly it appears very difficult to stipulate these generally, at any rate at present.*
*That is why in view of the lack of concrete standard values for passing distances during overtaking communication between the participating vessel commands and in particular support of the overtaking manoeuvre by the vessel to be overtaken are extremely important in avoiding suction effects. In this connection the BSU reminds participants of the statutory obligation in federal German waterways for the vessel to be overtaken to facilitate the*

*overtaking process as far as possible (cf. § 23 Para. 2 SeeSchStrO). Under international aspects too there is a legally binding rule that the overtaken vessel must take measures for safe passage (cf. Rule 9 Letter e Collision Prevention Regulations).*

***That is why it should also be noted when selecting the appropriate measures in the spirit of the above remarks that***

- ***during encountering and overtaking between a large and a small vessel (e.g. length ratio 2:1) the large vessel does not sheer substantially from its course, while the small vessel is at risk of running out of the rudder,***
- ***the forces that occur affecting a small vessel during the passing operation depend primarily on the speed of the larger vessel through the water and only slightly on the speed of the smaller vessel,***
- ***the speed difference between the vessels is not crucial as regards the forces acting.***

***All this leads to a need for the overtaken vessel to reduce speed prior to the start of an overtaking manoeuvre if the probable (or possible) passing distance is such that occurrence of suction forces cannot be ruled out safely. On the one hand this has the advantage that the effective duration of the suction forces building up between the vessel hulls can be minimised. Furthermore the vessel to be overtaken will thus be enabled to increase its steerability during a later phase of the passing operation by briefly increasing its rate of speed to counteract any suction effects occurring effectively.***

***However, it is to be stressed that the small vessel should definitely avoid reducing speed at a time at which a suction effect is already starting to make itself noticeable, since reducing speed basically has a negative influence on steerability. Furthermore, depending on the execution of the vessel screw(s) (fixed/variable pitch propeller, left-hand/right-hand) the direct and indirect steering effects, especially during reverse manoeuvres, can promote turning towards the potential other party in a collision.***

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*The analysis of the marine casualty also revealed that a collision of the vessels could not be reconstructed with the GPS positions processed from the electronic sea chart systems in each case. Accordingly as regards the recording/processing of GPS signals there must have been a system and/or configuration-related error in at least one of the two ships. However, this was not the cause of the accident.*

***The BSU draws attention to the fact that it must be ensured that the vessel operators, the manufacturers of the relevant systems, the supervisory organs and the vessel commands can intervene and monitor in accordance with their relevant scope of tasks that the vessels are being operated internally with the correct parameters. This requirement gains additional weight when one takes into account the fact that in adverse circumstances false data may be disseminated via the automatic ship identification systems (AIS). This could lead to incorrect assessments of the traffic situation by the recipients of the data.***

*Finally, the BSU stresses that this safety recommendation may not under any circumstances be misunderstood as anticipating the results of the investigation into the accident of 1 March 2004. It is expressly not connected with an assessment of the collision happenings. On the contrary, the recommendation solely serves the legally allocated purpose of preventing future accidents caused by the same or similar reasons.*

*For an assessment of the accident reference is made to the complete investigation report which the BSU will publish on completion."*[75]

## 8.2 Further recommendations

1. As a supplement to the reference contained in Recommendation 8.1 that the safe passing distance depends crucially on the speed of the overtaking vessel *through* the water, the attention of **vessel commands and pilots** of sea-going vessels is drawn to the fact that GPS-based speed information on board that map the speed *over ground* do not form any sufficient basis for determining a safe overtaking speed when considered in isolation. Instead the relevant data must be adjusted for the influences - that may be significant - of current and wind.

2. The attention of **vessel commands and pilots** of sea-going vessels is drawn to the fact that overtaking manoeuvres in (narrow) navigation channels that need the collaboration of the vessel being overtaken for safety reasons are only admissible if the vessel to be overtaken has previously clearly consented to the overtaking manoeuvre in response to a corresponding request by the overtaking vessel (cf. § 23 Para. 4 Sentence 1 Seeschifffahrtsstraßen-Ordnung (Traffic Regulation for Navigable Waterways) for the national area and Rule 9 Letter e Number (i) for the international area).
   Accordingly the **vessel command and pilots** of the vessel to be overtaken have the right and obligation to refuse the overtaking manoeuvre from case to case if they come to the conclusion that despite utilising all reasonable collaboration contributions safe implementation of the overtaking operation cannot be ensured beyond doubt.

3. The **vessel commands** and **pilots**, especially of large vessels (**to be defined in more detail by the relevant responsible Waterways and Shipping Office (WSA)**) are urgently recommended to report any intended overtaking manoeuvre to the responsible Vessel Traffic Services in good time. In addition to direct communication between the vessels involved (cf. No. 2 above), coordination with the Vessel Traffic Services regarding the traffic situation and the local and actual features is advisable for the intended manoeuvre. The coordination by the Vessel Traffic Services is indispensable above all in the interest of safety of other shipping too, when for instance one or both of the participating vessels are considering overstepping the given navigation channel briefly in order to achieve a safe passing distance.

4. The **Federal Ministries for Transport, Building and Urban Development** (BMVBS) and **for Economics and Technology** (BMWi) are called upon with regard to effective improvement of the safety and ease of shipping traffic to review the possibilities of awarding reseach funds in order to have currently lacking, reliable and as generally valid as possible recommendations on the problem complex of "**safe passing distance during approaches of vessels in restricted navigation channels**" elaborated by Ship Model Basins and other

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[75] The text printed in grey is no longer applicable.

suitable scientific institutions (for example **shipping academies, research and development departments of manufacturers and operators of vessel command simulators**).
The objective of corresponding research orders must be to provide vessel commands and pilots on board with **practicable sets of instruments** for the relevant river estuaries, for example in the form of tables or computing programs in order to identify hydrodynamically conditioned dangers in connection with overtaking and encounter situations effectively and be able to take appropriate action in good time.
A first important step in this direction that would particularly cater to the requirements of practice and could probably be implemented already in the medium term would be to provide improved computing programs for existing vessel command simulators and new ones to be installed. Vessel commands and pilots could thus "experience" and train for hydrodynamically conditioned borderline situations better than so far.
The demand for research outlined here is of high macroeconomic importance due to the dangers threatening for humans and the environment regularly connected with shipping accidents. It is made particularly important by the fact that the risks of serious accidents due to dangerous and no longer manageable approaches will increase significantly in future in view of the fact that vessel units are becoming ever larger.

**5.** The currently available vessel command simulators are partly in a position to map hydrodynamic effects at least to a certain degree. Despite their existing technical limits and independently of the demand for research outlined under No. 4, they thus already provide valuable opportunities for training in close encounter situations. The **supervisory authorities** responsible for **piloting** and **operators** of **sea-going vessels** are recommended to provide the pilots and vessel commands operating in their spheres of responsibility with sufficient training facilities on the simulation facilities available.

**6.** The attention of **owners and operators** as **commands** of sea-going vessels is drawn to the fact that any kind of lashing and unlashing work on board moving vessels that exceeds, for example, the measure indispensable due to weather conditions (known as post-lashing) infringes both the internationally binding legal regulations set out in SOLAS Chapter VI Rule 5 and the German Accident Prevention Regulations UVV See (§ 9; Pamphlet E 2) and Port Work (§§ 11, 43 in conjunction with § 3 Para. 1 UVV See). **Vessel commands** are accordingly called upon not to charge seamen on board *moving* vessels with such work.

**7.** The attention of **charterers** and **parties chartering out** feeder vessels is drawn to the fact that clauses in charter parties stating that vessels must arrive at the terminal with unlashed containers infringe mandatory national and international law (cf. No. 6) and are therefore invalid.

**8.** The **See-Berufsgenossenschaft** and **water police of the Laender (German states)** are called upon to foster observation of the legal regulations cited under No. 6 within their spheres of responsibility and their legal and actual potentials.
In this connection it is recommended that the **See-Berufsgenossenschaft** add a note clarifying the prohibition of lashing/unlashing work on board moving vessels, to its Pamphlet E 2.

# 9 Sources

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  - Captain MV P&O NEDLLOYD FINLAND
  - Chief Mate MV P&O NEDLLOYD FINLAND
  - Pilot MV P&O NEDLLOYD FINLAND
  - Passenger MV P&O NEDLLOYD FINLAND
  - Vessel operator COSCO MARITIME
  - Captain MV COSCO HAMBURG
  - Pilot MV COSCO HAMBURG

- Photo series of the collision occurrence, taken with an analog viewfinder camera (Type: RICOH TF-900; 35/70 mm) published by kind approval of the photographer Dr. Brigitte Karin Becker, 69190 Walldorf

- Photos of the vessels by Hasenpusch Photo-Productions Hamburg

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  - Charts and data sets of the electronic chart of the scene of the accident
  - Current calculations
  - Technical processing of lines draawings

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- Records of the Vessel Traffic Services (VTS) Brunsbüttel

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- Investigation results/records by the Waterway Police Hamburg

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- Report Man198/05 "Hydrodynamic analysis of the overtaking manoeuvre in restricted waters", February 2005, Hamburgische Schiffbau-Versuchsanstalt, Dr.-Ing. H. Weede

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- "Lashing works on feeder vessels on the Elbe and Weser“, Prof. Capt. W. Huth, Hamburg, in Schiff & Hafen 2/2005, p. 59 f.

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- Contact with the Office for Industrial Protection Hamburg (Capt. D. Boels, Capt. O. Ulrich); cf. also Komnet-database (accessible via www.komnet.hamburg.de), Category "Sicherer Transport", article on the subject of cargo securing on container vessels