



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

Investigation Report 302/07

**Very serious marine casualty**

**Personal accident with stern line  
on the MS NORTHERN FAITH  
on 4 July 2007  
in port of Koper**

15. November 2008

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

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

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

Head: Jörg Kaufmann  
Phone: +49 40 31908300  
posteingang-bsu@bsh.de

Fax: +49 40 31908340  
[www.bsu-bund.de](http://www.bsu-bund.de)

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## 1 Summary of the marine casualty

On 4 July 2007 at 05:00<sup>1</sup> in the morning, the NORTHERN FAITH arrived at the container terminal in the port of Koper /Republic of Slovenia and moored with her starboard side. 3 fore and 3 stern lines as well as 2 springs each were put out forward and aft.

The mooring time was also to be used for maintenance work in the engine room. This is why neither the drive nor the bow thruster was available during the day.

At 12:00 the second nautical officer (NO) began his deck watch which was planned to last until 18:00. At 16:30 the wind grew increasingly more forceful until, within just a few minutes, it had reached 9 Bft. There was a high container stack behind the vessel's superstructure. This area exposed to the wind led to the stern of the NORTHERN FAITH being pushed very rapidly away from the pier.

The second NO responded immediately and sent a watchman forward to check the lines there while he ran to aft.

By chance, the first NO came on deck and noticed that the aftship was already 10-15 m away from the pier. He informed the master over VHF. The master ordered the crew to the manoeuvring stations forward and aft. At the same time, the first NO was to take command at the forward and the second NO was to take command at the aft.

At about 16:52 the master reached the bridge. He called the Koper pilot by VHF and requested tugs. He had just ordered the main engine and bow thruster to be started up in the engine room.

At this time the watchman positioned forward held the lines tight with winches until the first NO and the bosun reached him. They took over and sent the watchman to aft to support the second NO. When the seaman arrived at the aft manoeuvring station, he found the second NO severely injured and lying on the floor. He informed the bridge by telephone about the accident.

The master sent the first NO to aft and requested medical help by Koper pilot. The first NO tried to help the severely injured man.

The stern line on the middle winch had already broken relatively early. All other aft lines had run out.

The SIRIUS was the first tug to reach the drifting ship at 16:58; she tried to press the NORTHERN FAITH back into mooring position. Since the tug was unsuccessful in this, the master dropped the port anchor.

At 17:12 the WOTAN (second tug) reached the vessel and likewise applied pressure to the port side. The turning speed of the NORTHERN FAITH was reduced a little by using both tugs. At the same time a pilot came on board. The pilot had already been on the pier for several minutes advising the master by VHF. In the meantime, a medical rescue team had arrived by ambulance. The pilot sent the pilot's boat back to the pier to transport the medical team to the NORTHERN FAITH.

From 17:28 onwards the MAKS (as third tug) supported in pressing the NORTHERN FAITH back to the pier. Since they still did not manage to bring the vessel back to the pier against the force of the gale, the master decided to turn the ship further with the aim of berthing with the port side.

The main engine was ready to use at 17:34. Consequently they began to heave anchor shortly afterwards. The port anchor was on deck by 17:39. This was when the injured man was transported by pilot's boat to the pier where he was given into the charge of the ambulance. The ambulance took the second NO to a hospital where

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<sup>1</sup> All times in the report are CEST = UTC + 2h

they immediately carried out emergency surgery to save his right leg. The right arm had to be removed.

By 17:48 the starboard anchor was also on deck and the last lines were cast off. The NORTHERN FAITH turned far enough to start berthing with the port side. Meanwhile the mooring line handlers on the pier had pulled the lines ashore land that had run out of the ship and passed them back on board.

At 18:43 the NORTHERN FAITH was once again alongside against the port side with 2+1 forward and aft. At 19:30 the ship was secured: forward with 5 fore lines and 2 springs (5+2), aft with 4 stern lines and 3 spring lines (4+3).

## 2 Scene of the accident

Type of event: Very serious marine casualty  
 Date/time: 04. July 2007, 16:50  
 Location: Port of Koper / Slovenia  
 Latitude/longitude:  $\phi 45^{\circ}33.12'N \lambda 013^{\circ}44.05'E$

Section from the chart 1068, BSH (Federal Maritime and Hydrographic Agency)

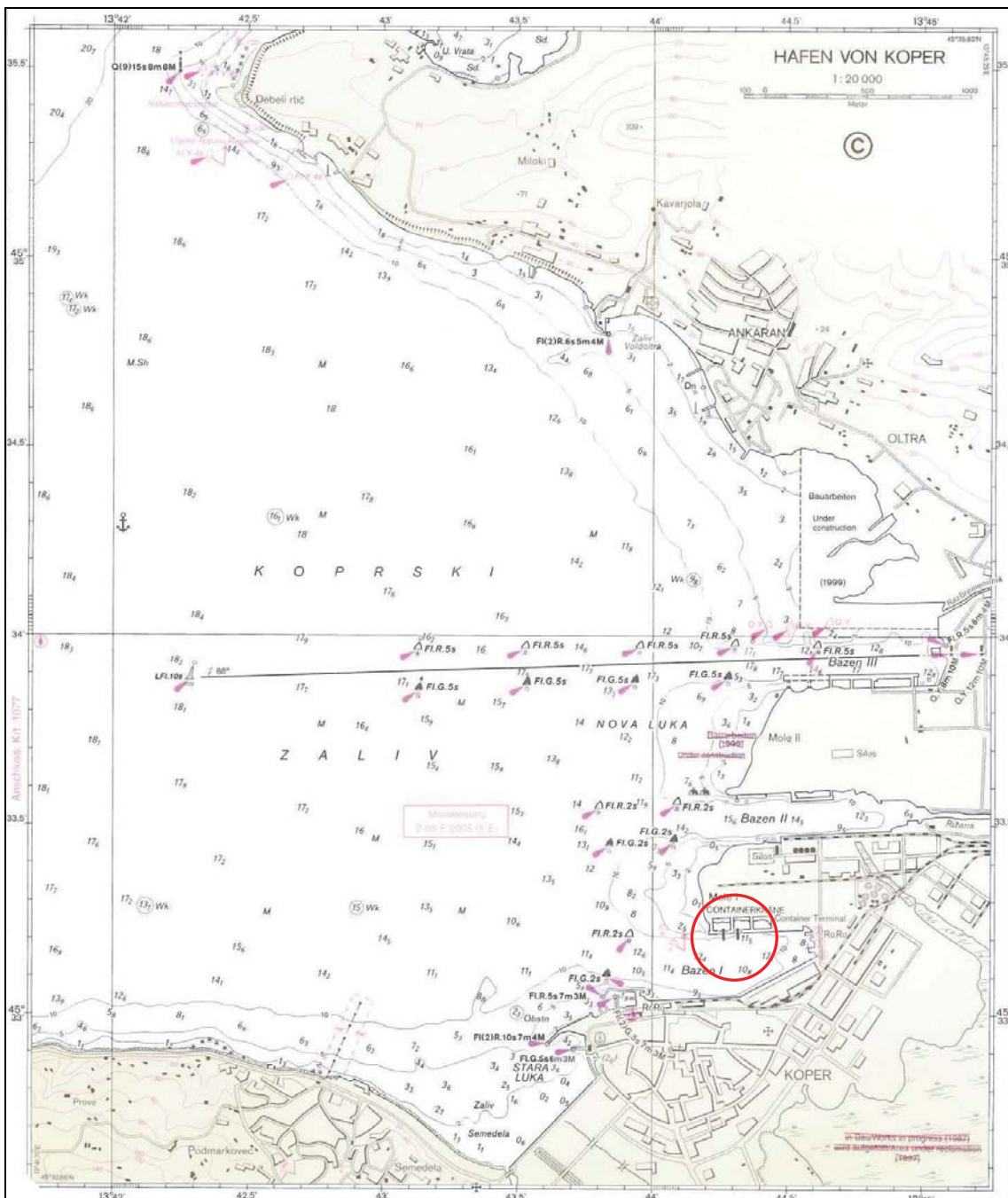


Figure 1: Chart

### 3 Vessel particulars

#### 3.1 Photo



Source: BSU

Figure 2: MV NORTHERN FAITH

#### 3.2 Particulars

Name of the vessel:	NORTHERN FAITH
Type of vessel:	Container ship
Nationality:	Germany
Port of registry:	Hamburg
IMO number:	9064877
Call sign:	DNFA
Vessel operator:	NSB Niederelbe Schiffahrtsgesellschaft mbH & Co. KG
Year built:	1994
Shipyard/yard number:	Hyundai Heavy Ind. Co. Ltd. / 847
Classification society:	German Lloyd
Length overall:	240.53 m
Breadth overall:	32.20 m
Gross tonnage:	35595
Deadweight:	42674 t
Max. draught:	11.70 m
Engine rating:	24010 kW
Main engine:	Hyundai Diesel 7 L 80 MC
Service speed:	22 kn
Hull material:	Steel
Hull construction:	Double bottom
Number of crew:	20



## 4 Course of the accident

On 4 July 2007 at 05:00 in the morning, the NORTHERN FAITH arrived at the container terminal in the port of Koper / Republic of Slovenia and moored with starboard side. 3 fore and 3 stern lines as well as 2 springs each were put out forward and aft<sup>2</sup>. The winches were switched to automatic at the aft station. The weather was good; the wind came from SSW with a force of 3 Bft. Handling operations began at 08:00.

The mooring time was also to be used for maintenance work in the engine room. This is why neither the drive nor the bow thruster was available during the day.

At 12:00 the second nautical officer (NO), who later sustained the injuries, began his deck watch which was planned to last until 18:00. At 16:45 a foreman for lashing the containers said there was a storm approaching which was why handling operations would be stopped now. The wind then very suddenly became much stronger until within just a few minutes it had risen to 9 Bft. At this point, the vessel only had minimum deck cargo in front of the superstructure. However, there was a high container stack behind the vessel's superstructure. This area was exposed to the wind and led to the stern end of the NORTHERN FAITH being pushed very rapidly away from the pier.

The second NO responded immediately and sent his watchman forward to check the lines there while he ran to aft.

By chance, the first NO came on deck and noticed that the ship's aft was already 10-15 m away from the pier. He immediately informed the master over VHF. The master ordered the crew to the manoeuvring stations forward and aft. At the same time, the first NO was to take command forward and the second NO was to take command aft. At about 16:52 the master reached the bridge and was able to establish that the fore lines still held the ship to the pier but that the aft had already drifted to a 40° angle away from the pier. The gale was already acting directly on the starboard side at approx. 45 kn. He called the Koper Traffic over VHF but did not receive an answer. Consequently he called the Koper pilot and requested tugs. He had just ordered the main engine and bow thruster to be started up in the engine room.

At this time the watchman at the forward end held the lines tight with winches until the first NO and bosun reached him. They took over the job and sent the watchman aft to support the second NO. When the seaman arrived at the aft manoeuvring station, he found the second NO severely injured and lying on the floor. The second NO was still conscious but was not responding. Since the seaman had no VHF unit with him and the second NO's unit lay destroyed on the deck, he ran to the superstructure to inform the bridge by telephone about the casualty.

The master received this call at 16:54 and immediately sent the first NO aft, informing him by VHF. He handed over control at the forward manoeuvring station to the bosun. Then he requested medical aid through the Koper pilot.

At 16:57 the forward manoeuvring station reported that the lines were under huge stress and there was a risk that they would break. In response, the anchor was made clear to drop.

The first NO reached the second NO and tried to help the man, severely injured on the right side of his body. Other crew members came aft over the following few minutes. This was partly to get the casualty ready to be transported off ship and

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<sup>2</sup> Usual maritime abbreviation: "3+2"

partly to get the vessel back against the pier. The stern line on the middle winch had already broken relatively early. All other aft lines had run out in the meantime.

The SIRIUS was the first tug to reach the drifting ship at 16:58; she tried to press the NORTHERN FAITH back into mooring position. Since the tug was unsuccessful in this, the master dropped the port anchor.

At 17:06 the master requested a second tug. Now the bow thruster was also ready to run. At 17:08 the vessel lay at an angle of 75° to the pier. The bulbous bow hit against the quay wall. The master let the starboard anchor drop.

At 17:12 the WOTAN (second tug) reached the vessel and likewise applied pressure to the port side. The rate of turn of NORTHERN FAITH was reduced a little by using both tugs. At the same time a pilot came on board by pilot boat. The pilot had already been on the pier for several minutes waiting for the pilot's boat. During this time he had already been advising the master by VHF. In the meantime, a medical team had arrived by ambulance. The pilot sent the pilot's back to the pier to transport the medical team to the NORTHERN FAITH. Consequently the rescue team arrived on board together with a policeman at 17:18.

From 17:28 onwards the MAKS (third tug) added its support in pressing the NORTHERN FAITH back to the pier. Since they were still unable to bring the vessel back to the pier against the force of the gale, the master decided (after consultation with the pilot) to turn the ship further in order to berth with the port side. The main engine was ready to use at 17:34. Consequently they began to heave anchor shortly afterwards. At 17:39 the port anchor was on deck and the first shackle of the starboard anchor was also on deck. The injured man was then taken on a stretcher by pilot's boat to the pier. He was taken into the care of the ambulance. The ambulance took the second NO to a hospital where they immediately carried out emergency surgery to save his right leg. The right arm had to be removed.

At 17:48 the starboard anchor was also on deck and the last lines were cast off. The NORTHERN FAITH turned far enough to start berthing with the port side. Meanwhile the mooring line handlers on the pier pulled the lines onto land that had slipped off the ship and passed them back on board. At this point, there was no longer any line at the aft manoeuvring station to establish a connection to the pier.

The gale had also turned and was just about to start brisking u. It therefore became necessary to throw the port anchor again to prevent the vessel being pushed back out. However, a few minutes later it was heaved back in and the first line connection was made.



Source: Shipping administration of the Republic of Slovenia

Figure 3: Photo of the turning NORTHERN FAITH (at about 17:23). A tug boat can be seen on the port side and the pilot's boat on the starboard side which had just brought the medical team on board and was waiting to transport the injured person to the pier.

At 18:43 the NORTHERN FAITH was once again alongside against the port side with 2+1 forward and aft and at 19:30 the ship was secured: forward with 5 fore lines and 2 springs (5+2), aft with 4 stern lines and 3 spring lines (4+3).

The tugs were released and the pilot disembarked. An investigation of the incident began directly after berthing by an employee of the shipping administration bureau for the Republic of Slovenia.

## 5 Consequences

The second NO had to be treated intensively over months. The amputated right arm was replaced by a prosthesis. Two fingers had to be removed from the left hand. The right leg recovered with minor limitations. The shipping company have provided him with a work place ashore.

Some mooring lines were destroyed on board the NORTHERN FAITH and two winches were damaged (see Fig. 4 and 5). There was also external damage from contact by the bow with the pier. There was also minor damage to the pier.

There was no damage to the cargo or environment.



Source: NSB shipping company

Figure 4: Bent brake rod on the port winch



Source: NSB shipping company

Figure 5: Ripped out bolt pin for holding the line end on the winch drum



## 6 Investigation

The investigation was complicated by the fact that there were no witnesses to the second NO's accident and he was unable to remember how he was injured. In order to be able to reconstruct the accident, all external circumstances had to be examined to illustrate the interplay of winches, lines and the forces affecting the ship itself.

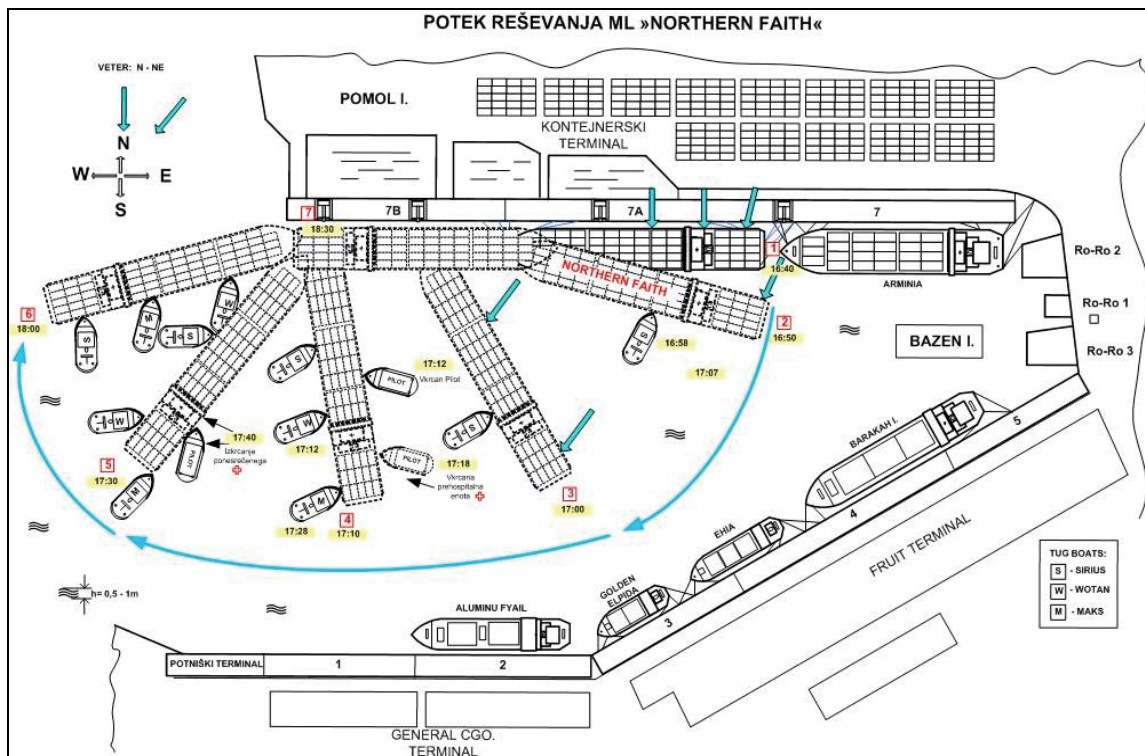
### 6.1 Investigation by the Slovenian authorities

Based on Slovenian law, the authority that also conducts the Port State Control is responsible for investigating marine casualties. During the accident investigation, the shipping inspector establishes all circumstances of the accident and draws up a report about the marine casualty.

In Slovenia, the aim of preparing this report is also to establish the causes and circumstances with the aim of improving safety at sea to avoid future marine casualties. As such, the purpose of the Slovenian report is not to determine guilt or to clarify issues of liability in the context of the incident.

This agreement of both Slovenian and German legal principles with the principles of the IMO code made collaboration between both parties considerably easier. In the course of the BSU investigation, numerous pieces of information were gathered on-site by the Slovenian inspector.

The investigating inspector had already arrived at the port during the turning manoeuvre by the NORTHERN FAITH and he documented the event (see Figure 6).

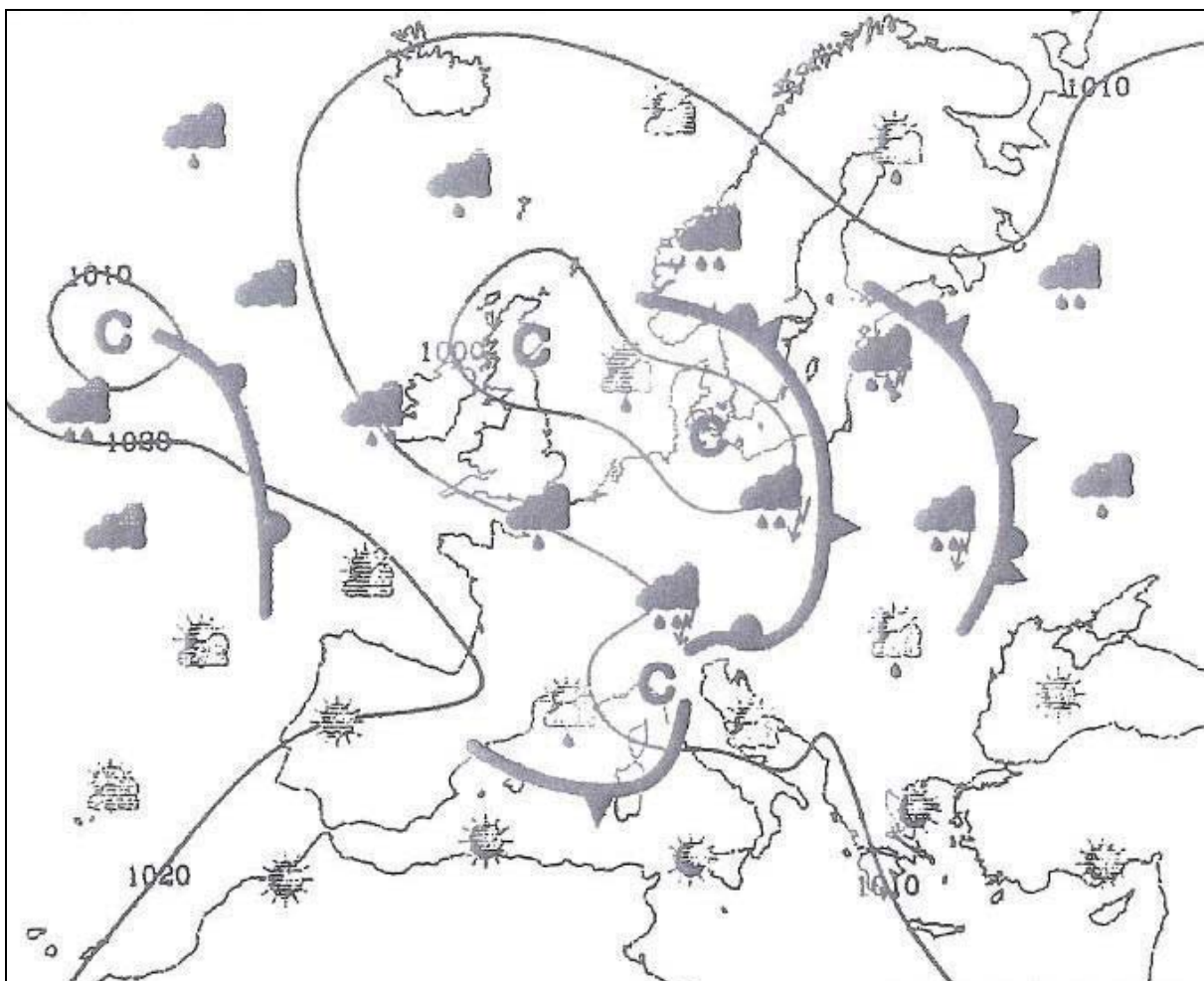


Source: Shipping administration of the Republic of Slovenia

Figure 6: Illustration of the turning movement by the NORTHERN FAITH

## 6.2 Environmental conditions

The published weather forecast for the northern Adriatic Sea clearly warned against the fall wind "Bora" which is well-known in that region. The wind was predicted to reach up to 45 kn on the afternoon of the day of the accident (see Figure 8). No one on board the NORTHERN FAITH knew about this warning. This appears believable as the vessel's command would have otherwise supposedly taken safety measures like the other crews in the port of Koper did.



Source: Shipping administration of the Republic of Slovenia

Figure 7: Weather chart for 4 July 2007 midday – published by the Slovenian Environment Agency

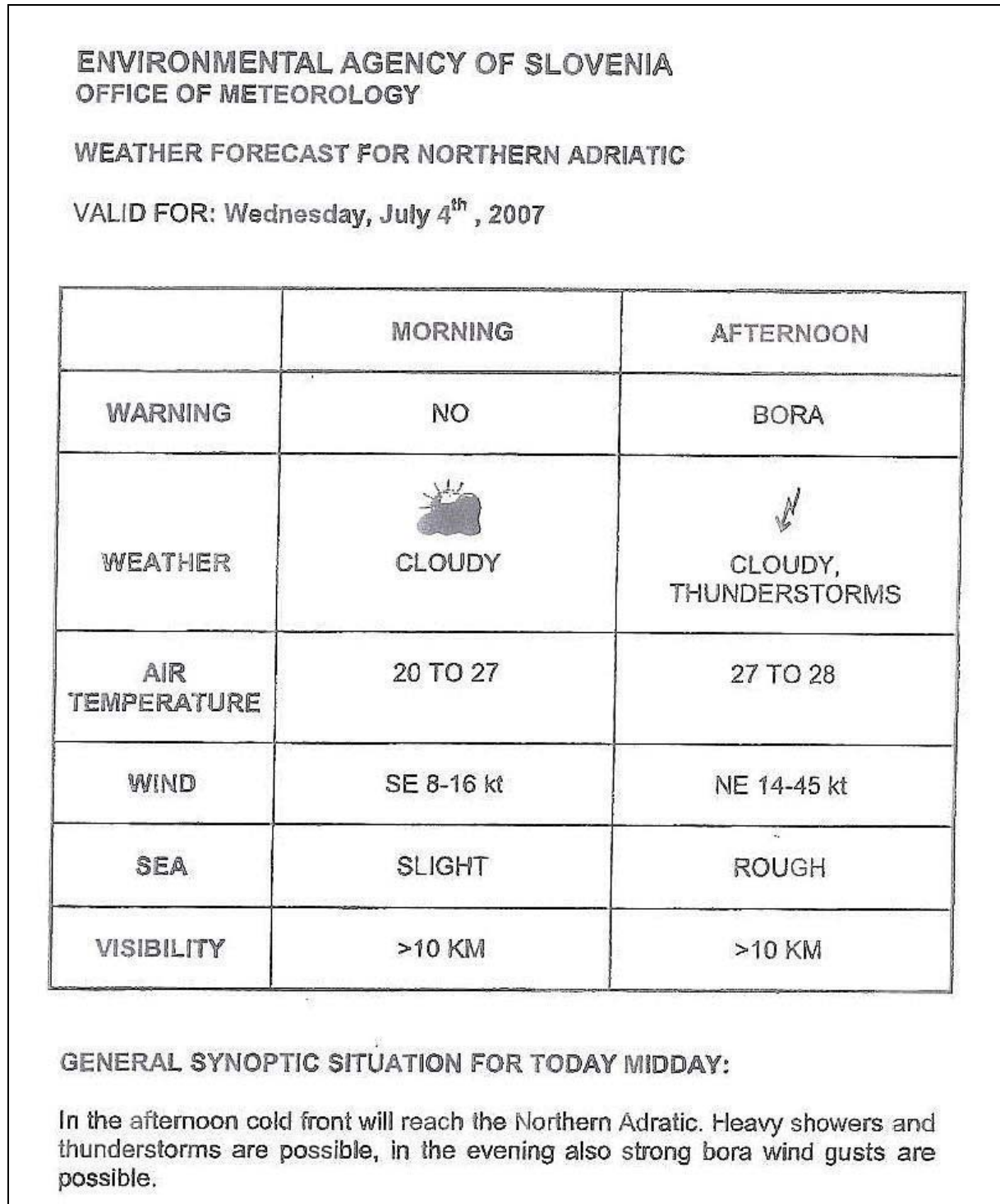


Figure 8: Weather forecast for 4 July 2007

*The Bora (Greek for "cold gust of wind") is a dry, cold fall wind (a katabatic wind)<sup>3</sup> that starts suddenly and with huge intensity from the NE to E (similar to the Mistral in*

<sup>3</sup> Katabatic wind: in contrast to the warm fall winds, the katabatic fall winds are cold and caused by gravitation: the Bora, glacier wind, the Mistral and Tramontana are katabatic fall winds.

the western Mediterranean). The Bora occurs as a result of air cooling in the Karst valleys of Croatia. This cold air drops down the slope of the Karst mountains as a fall wind. It can occur during any season, but is more frequent in winter when it often reaches gale force. It is not unusual for it to blow in May. However, in the summer it usually only lasts 2 days whereas in winter it can blow for up to 14 days with interruptions.

Bora is not bound to any particular time of day. However, it occurs more frequently in the afternoons than in the mornings. It reaches its greatest force between 7:00 and 11:00 and between 18:00 and 22:00.

It is characteristic for the Bora to blow in severe gusts and to start very suddenly. Its speed varies from a light breeze to a gale (80-100 km/h). The cold air masses, which are heavier than the air masses over the sea, drop down the mountain slopes and fall diagonally like water to the sea. Exceptionally severe gusts can be generated if an already forceful and gusty wind is reinforced by down gusts (as is the case on the Adriatic coast).<sup>4</sup>

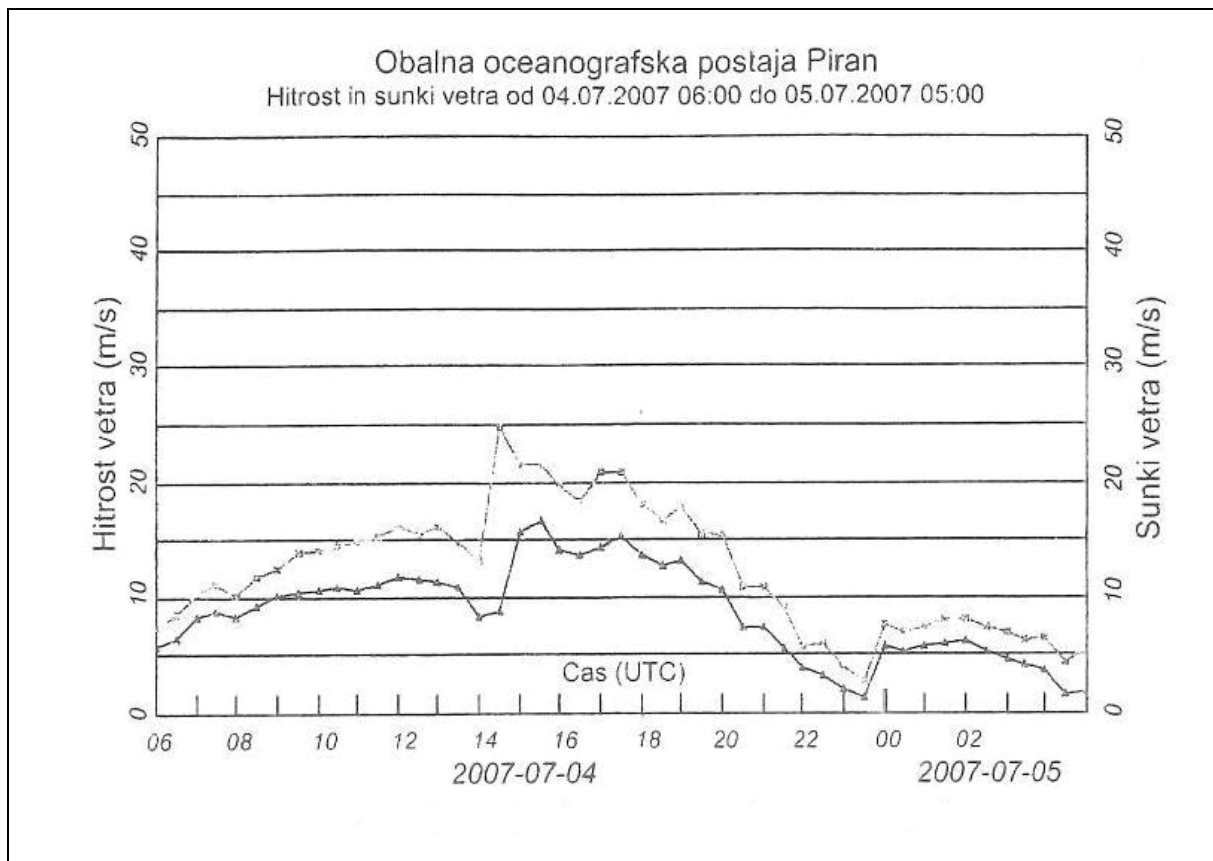


Figure 9: Measured wind speeds

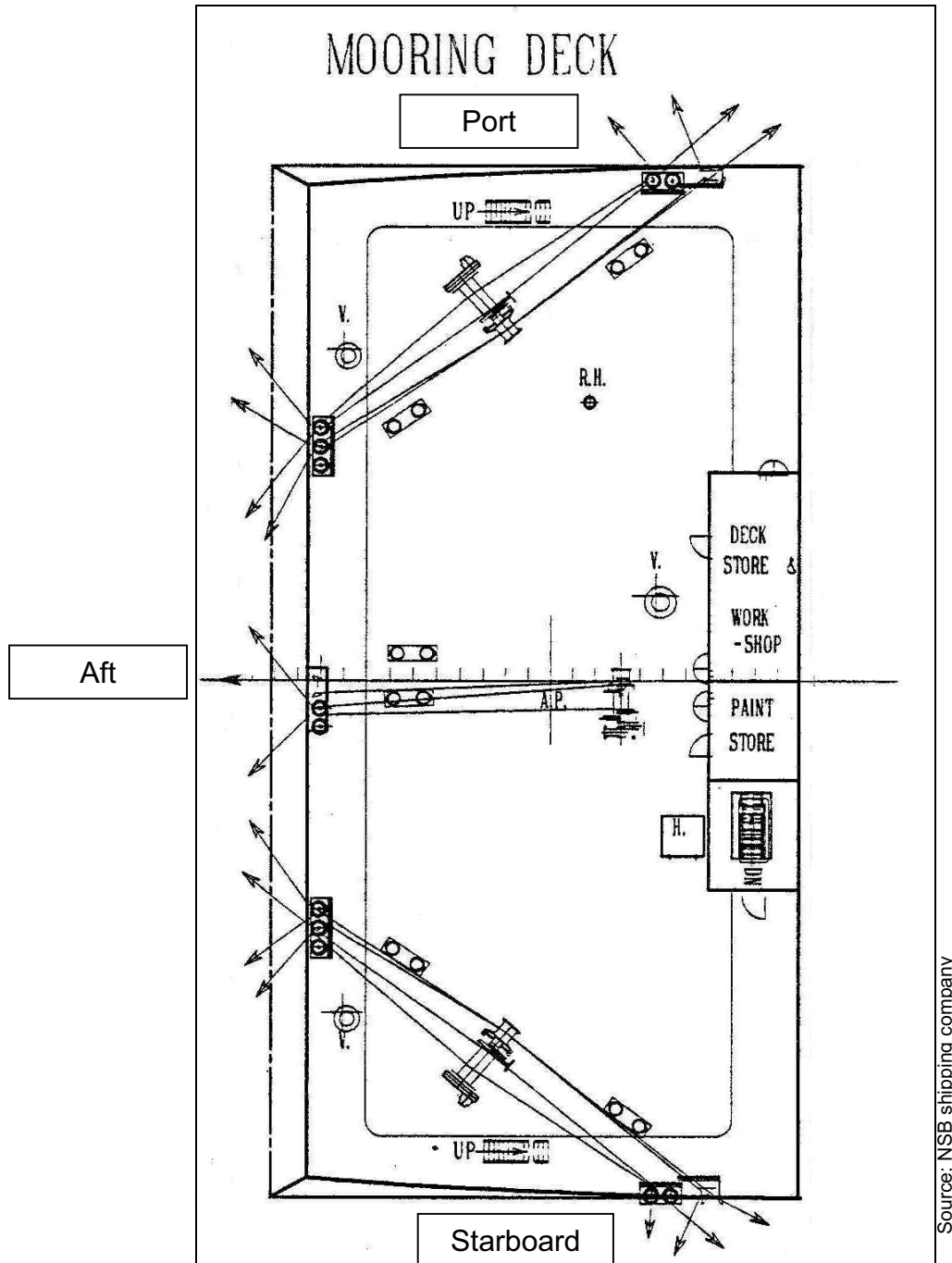
<sup>4</sup> Edited extract from explanations on the website:  
<http://www.esys.org/wetter/bora.html> with kind permission of the website owner.



### 6.3 On-site inspection by the BSU

On Wednesday the 29 August 2007, an investigation team from the BSU used the mooring time of the NORTHERN FAITH at port of Koper to carry out an investigation on-site. The vessel was at the same berth as at the time of the accident. Various crew members were questioned and the locality was viewed.

In particular the location of the injured man was confirmed by several crew members.



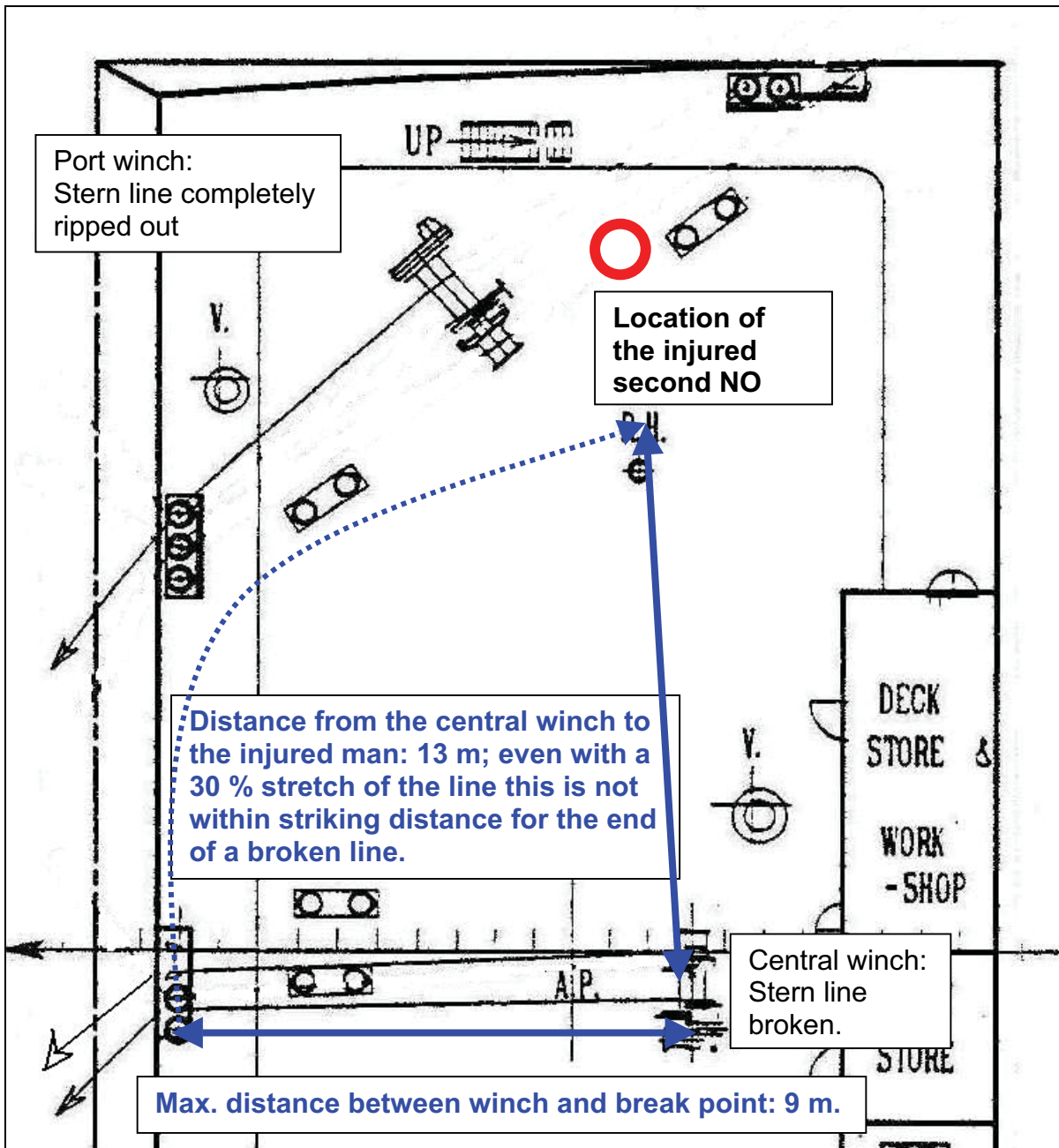
Source: NSB shipping company

Figure 10: Winch deck aft

**6.3.1 Position of the injured**

All those questioned indicated the same position on deck, independently of each other. According to them, the second NO lay about 2 - 3 m away from the port winch with his head towards the bollard. The distance from this position to the central winch was about 14 m. If the central line **on deck** was torn then it could **not** have reached him. If it broke outside the fairlead, then it would have been very unlikely to strike back on deck.

The following will examine whether he could have been hit by the port line.



Source: NSB shipping company

Figure 11: Position of the injured

### 6.3.2 Working hours

According to the work time sheets presented by the shipping company, the second NO carried out his normal cycle of watch duties during the days before the accident. On 4 July 2007 he worked from 00:00 to 07:00 and from 12:00 until the accident. In contradiction to this, there are statements saying that after the 00-04 watch he helped with berthing and then went to bed at 05:00. He was on deck again at 10:00 to work together with the attending nautical inspector. After a brief lunch break he took over deck watch from 12:00 onwards.

### 6.3.3 Log entries

The BSU was given copies of the log pages of the day of the accident. The left page (page 70) says:

"0600 ... vsl in Port of Koper stb. alongside **3/2**"

(long-hand: at 06:00 the vessel was fast in the port of Koper with 3 fore and 3 stern lines and 2 spring lines each.)

The right log page (page 71) of the same day says:

"0500 ... vsl fast with stb. side ... at Koper Cont Terminal (**4+2 F/A**)"

(long-hand: at 05:00 the vessel was fast with the starboard side at the Koper container terminal with 4 fore and 4 stern lines and 2 spring lines each.)

The copy of the bridge bell book had obviously been corrected. 4+2 was corrected from 3+2.

It was no longer possible to determine who had made the entries. Apart from this, the statements by crew members diverge as to whether 3 or 4 stern lines were used.

The general standing watch orders of the master (valid for the time of the accident) could not be provided. In particular, there were also no entries available relating to Koper port.

### 6.3.4 Replacement of the lines

In May 2007, two new mooring lines were delivered on board. No proof of delivery or the use of each line on board could be presented. Due to different statements, it is assumed that these lines were put forward and aft to be used as towing lines.

The mooring lines that were used and damaged during this accident had been in use on board since 2004.

#### 6.4 Structure and function of the winches

The winches located on board at the time of the accident were electrical hydraulic winches from the company of Friedrich Kocks GmbH Bremen. They were manufactured in 1993 and installed in 1994 on the newly built NORTHERN FAITH. One winch is arranged on the port side and on the starboard side as well as in the middle of the deck at both the forward and aft ends respectively. Each winch has a drum and a capstan head. The winches were approved by Germanischer Lloyd and since then have been regularly checked by this classification society.

Hydraulic pressures are generated using electric pumps; the pressures are used for the rotational movement of the winch. The active tensile load of these winches is max. 16 t. This can be stepless set using a lever valve.

The winches are designed in such a way that their force is lower than the breaking load values of the line used, i.e. the winch will give way before the line breaks.

The winches have an internal multi-disk brake for operation and an external band brake for passive holding of a line.



Source: BSU

Figure 12: Aft port winch with rigged line as spring

This band brake is constructed in such a way that it must hold approx. triple the winch tensile load: i.e. it will hold approx. 48 t tensile load from outside, then it will "slip". Already after 2 to 3 rotations against its own braking resistance, the brake

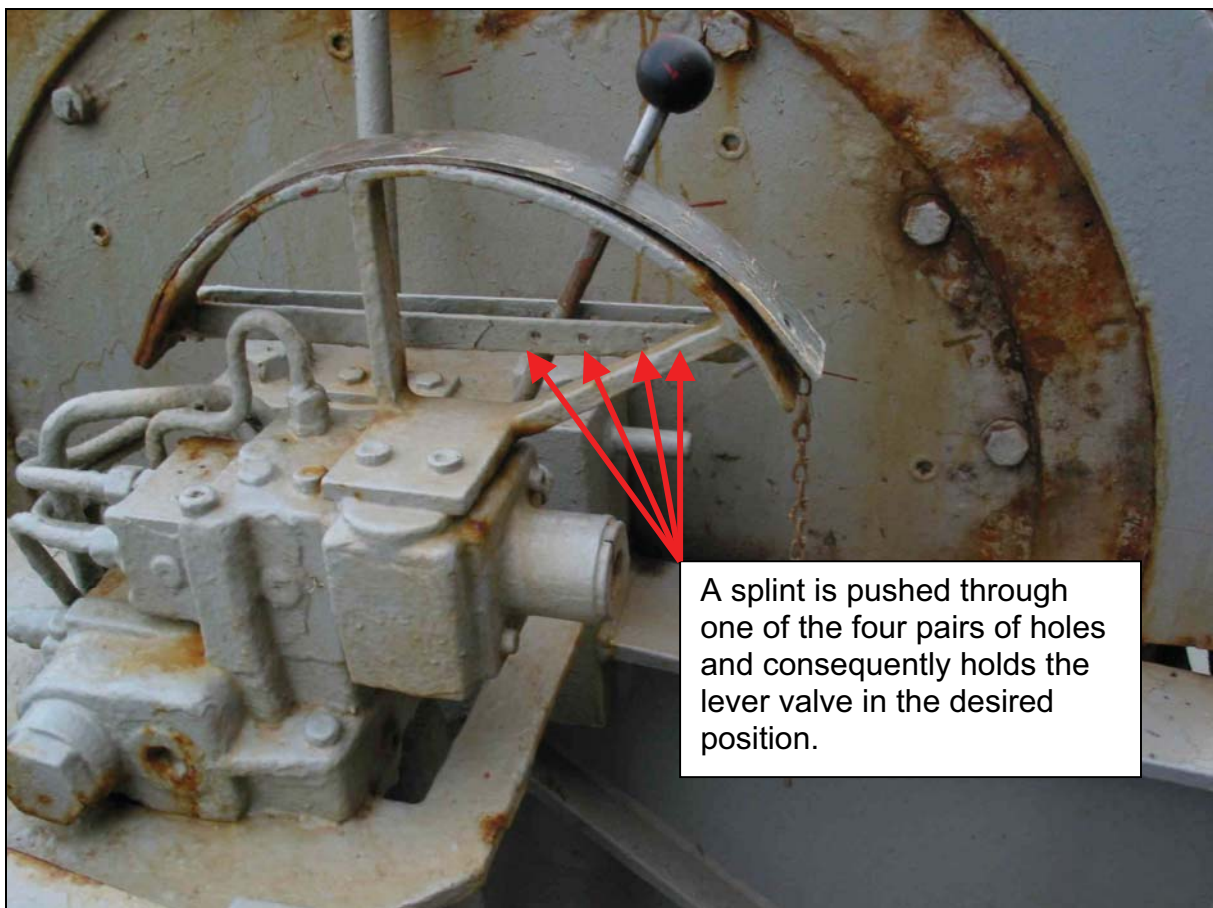


pad friction of the band brake has been reduced to such an extent that it practically does not hold any more.

The internal multi-disk brake works spring-loaded and hydraulically. This means it engages immediately when either the motor is not working or if the band brake is in use (tightening or releasing). This multi-disk brake holds max. 25 t tensile load. When the winch's electrical pumps are working, this brake holds:  $25\text{ t} + 48\text{ t} = 73\text{ t}$  total tensile load in addition to the engaged band brake.

These values are based on there being one layer of rope on the drum. If there are more layers then the braking resistance increases.

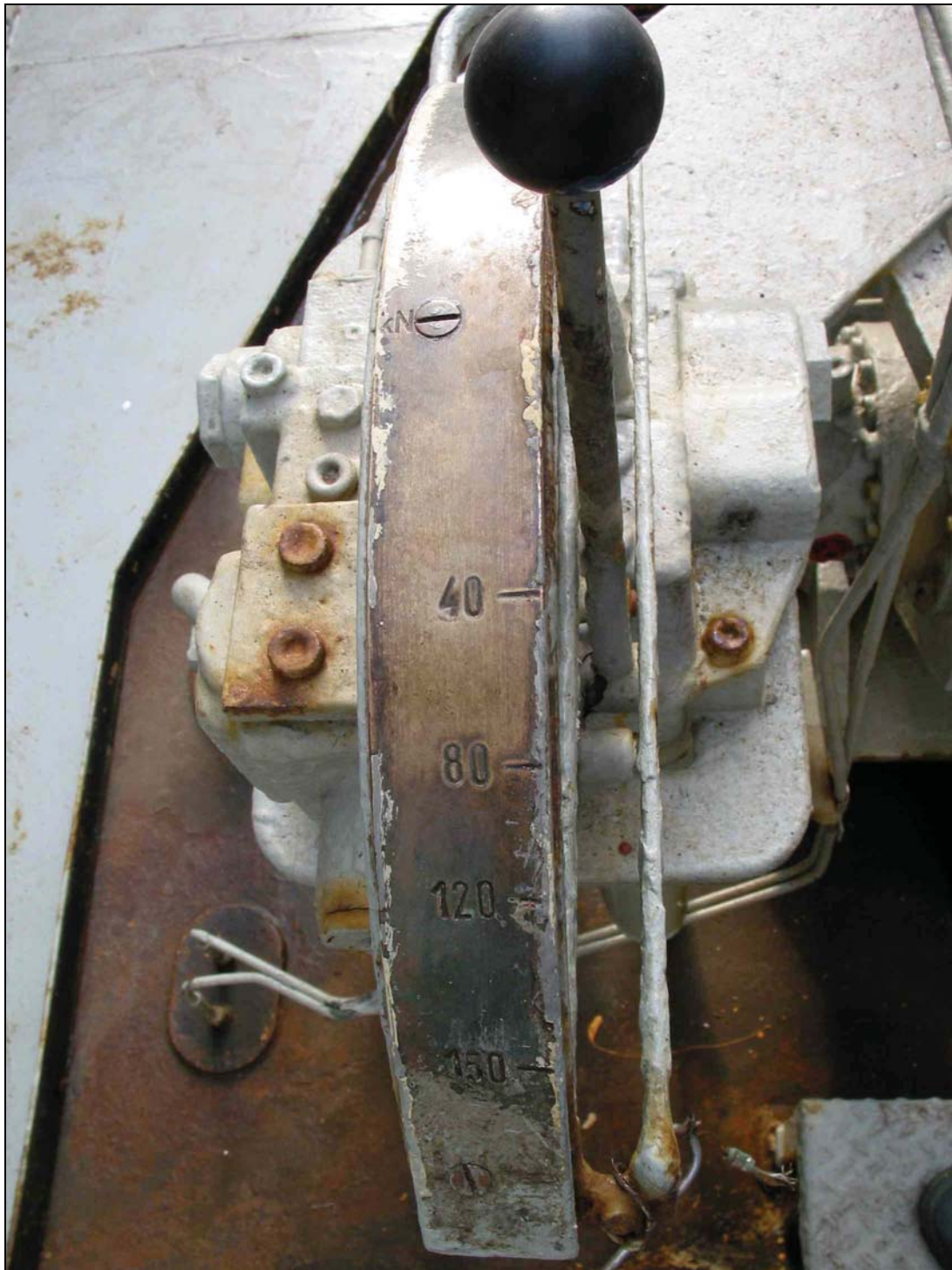
If the winch is running on "automatic", four load ranges are possible: from min. 3 t to max. 16 t tensile load. According to the winch manufacturer, there is also a reserve meaning that the winch will give way at the latest when there is a 20 t tractive force from outside. "Automatic" on these winches means that the lever valve is set to one of the four preset positions thus holding the desired hydraulic pressure roughly steady. If the line is slackened, the winch tightens as far as the set pressure allows. However, if the vessel is pushed away from the pier too strongly, the line will wind off the drum against the pressure of the winch.



Source: BSU

Figure 13: Lever valve for automatic operation of the winch

The winch manufacturer has a test department to adjust and test newly built winches. Repeatedly in such tests a line tears off the drum when a continuous pulling force is applied to it. It is worth noting that the line already tears off the drum when there are still 3 or 4 turns on it. A drum diameter of approx. 0.5 m gives a circumference of approx. 1.5 m. Accordingly, an end of a line measuring up to 6 m long can strike through the area around the winch like a whip.



Source: BSU

Figure 14: Lever valve scale

It could no longer be substantiated how the winches were set. Statements from crew members were widely divergent. The most probable setting is the generally applied type: using all winches in "automatic" mode on a medium load.

### **6.5 Structure and function of the mooring lines**

6-strand DURA winch lines (formerly known as Atlas rope) with a 60 mm diameter and a 70 t tensile load were used on the NORTHERN FAITH winches. All other mooring lines were polypropylene 8-strand mooring lines.

Atlas ropes are synthetic wire ropes that combine the properties of wires and fibre ropes. They keep their shape, are flexible, maintenance-free, and resistant to corrosion and sea water. Their stretch parameters set them somewhere between wire and polyamide.

On the day of the accident, both types of mooring lines were used together. This means that the tensile load on all lines was of varying degrees due to the different levels of stretch behaviour; consequently the loads could not be spread over all lines. The central winch line slipped from out of the bottom of the winch while being used as a stern line.

### **6.6 Line test in Hamburg**

The supplier company for the NORTHERN FAITH mooring lines declared itself willing to carry out two load tests.

A structurally identical piece of new Atlas line was torn as the first test. The prescribed load values of 70 t were easily exceeded.

The second test took place on Wednesday, 5 September 2007. A piece of the line that ripped on board was flown in extra and used to determine the existing breaking load.

The line broke on reaching a tensile load of just over 50 t. At the same time it was established that two strands remained intact and all others broke at different lengths. This is probably due to different wear on the individual strands. The similarity with the break appearance on board indicates that there must have been minimal recoil force due to the delayed breaking of individual strands when compared with a complete break of the line.

On the other hand this presupposes that this broken line did not hit the second NO as it would not have been able to injure him as severely as it actually did. In addition to this, the impact would have had to throw him several metres to where he was ultimately found.

However, an important factor arising from this test for the BSU investigation is that it is impossible to draw conclusions about the condition of the line before the final load strain from such a load test. Consequently a load test of this type is unsuitable when looking at establishing the cause of a line break.

### **6.7 TTI report**

Following extensive research, only one company could be found to prepare a report on why the line broke.

Tension Technology International Ltd. (TTI) (based in the United Kingdom) was commissioned to draw up a report in which the following questions were addressed:

- 1) Why did the stern line break?
- 2) Could the broken end of this stern line have hit the second NO? If yes, how? Or can this be excluded as a cause once and for all?
- 3) Are there possibilities of avoiding these kinds of accidents in future, i.e. are there possibilities of having the lines checked regularly and easily for their ultimate breaking load? And are there technical aids (software) that could support the vessel's command in berthing a ship in a way that takes account of the extant circumstances?

These questions are answered in the two following chapters. The complete report is attached in the appendix.

### **6.7.1 Report part 1: Visual examination and strand test of the failure**

A prerequisite for the work conducted by TTI was that samples of the broken line be obtained. A request was issued for both ends of the break and for a reference piece as far away from the break as possible. This request was passed to the shipping company. Once the pieces of line supplied by the shipping company were passed on to TTI, they were able to make the following statements after appropriate testing:

The main focus was on the obvious fragment of the line.

The mooring line under examination broke in an area of the line where there is obvious external wear. By examining and analysing the break, they were unable to establish whether this wear occurred before or during the accident. The photographic evidence presented to Tension Technology suggests that the area of damage in the clear length of the mooring line was between the pier bollard and the deck fairlead. If this is correct, then the fail zone of the line was not in contact with anything else when it broke and consequently the wear must have occurred prior to the incident.

The blue and red discolourations on the fail zone of the line appear to be paint residue that matches the colour of the ship. If this is the case, then it is proof that the line rebounded off the ship after breaking.

The load capacity of the line in the abraded region is estimated at 60 % (with 400 kN) of the load of the same line in a new condition. At another area of failure where the wear was less severe, the line had an estimated residual load of 75 % of a new line, about 500 kN.

These load-bearing values are based on "dry" tensile testing. In wet condition, the actual load of the abraded zone had to be reduced by 10 %, from 400 kN to 360 kN.

**The other sample pieces presented to the TTI (the apparent counterpiece to the broken end and the reference piece) were different lines.** Values from the tensile tests for these lines were used for comparative purposes in this report but have to be viewed from the perspective of their different makes.

**It is therefore not possible to make any statement about whether the damage occurred during use in the mooring process or beforehand.** Irrespective of this, TTI has identified from this incident the necessity to have the condition of each line checked regularly by a responsible person on the vessel. If there should be any



doubts as to the condition of the lines, then the line in question should not be used any more until it has been fully examined. There are several instructions and recommendations in respect of examining lines (listed in the appendix for reference), but experience, common sense and an awareness of the consequences of insufficient examination of a line will always reduce the danger of such an incident occurring.

### **6.7.2 Report part 2: Mooring analysis using simulation software**

The simulation of conditions at the time the ship moored up at the pier, specifically for those decisive 20 minutes from 16:40 to 17:00, illustrates the considerable external influences from stern yawing. The vessel yawed 35 m away from the pier as the (later broken) stern line had given way; the stern line had dropped to only 60 % of the prescribed minimum breaking load (MBL) of a new line and the braking force of the winches had dropped to 30 t.<sup>5</sup>

If line 3 (i.e. the broken stern line) had maintained its original manufactured minimum breaking load, this influence would have been just 12.8 m. This shows that the reduced breaking load of line 3 had a far-reaching effect on the ship drifting away. This line broke within 3-4 minutes after starting the simulation.

**If all lines had the MBL value of a new line, then none of them would have broken.**

The winch brake giving way was also a decisive factor. The external influence was doubled since the braking value of the winch provided was reduced from 42 to 30 t.<sup>6</sup>

Furthermore, the vessel had a huge area exposed to the wind due to the superstructure and high load on one side. This had a major influence on the stern of the ship and specifically caused this end to yaw outwards.

### **6.8 Medical expertise**

Since there were no witnesses to the actual injury, the intention of the medical report was to at least limit the causes. The BSU consequently commissioned the Institute for Forensic Medicine at the University of Hamburg to pursue the question of how the injuries could have occurred to the second NO. In addition to this, the second NO was examined and his hospital files were assessed.

Extracts of the report are included here and are presented in edited form:

*The pattern of injuries indicates that there was massive, abrasive, blunt-force trauma to the right side of the body. His left hand was obviously also within range of this source of trauma at the time of the accident.*

*If we take into account the situation on the stern deck, the only affecting force that comes under consideration is that of a ship's line hitting the right side of the body with high impact.*

---

<sup>5</sup>The complete report is attached in the appendix.

<sup>6</sup> See attached report too

*There is absolutely no way that these injuries are due to a fall. It was also most certainly not a consequence of any physical dispute, or the effect of flying objects, or such like.*

*The severely injured second NO was apparently found near a ship's winch on the stern deck. There were only blood traces in close proximity to the injured man; for example there were no blood traces on the lines.*

*If we assume that he wore tough work clothing, then there would have been no blood transfer onto the trauma-inducing object from his severe injuries. Consequently, the ship's line could have injured him without leaving blood traces.*

*Based on all investigative results so far, it is ultimately assumed that the second NO was very probably near the port winch when the wound ship's line released very quickly from this winch and hit the right side of his body moving with a whip-like force from bottom to top. This direction of injury is confirmed by the fact that the right arm was partially torn off and that the right side of the torso also suffered a decollement<sup>7</sup>, which would not have happened if the vessel's line had hit the upper arm first moving from top to bottom.*

*In view of the tremendous forces at work here, it is inconceivable that special work clothing, for example, could provide sufficient protection. The only precaution that a person can take in the face of such forces it to remain outside of the range of the vessel's line which can act like a whip.*


## **6.9 Occupational Safety and Health Administration (AfA)**

As a consequence of researching possibilities of avoiding accidents with mooring lines, an intensive dialogue developed between the BSU and the Occupation Safety and Health Administration for the Free and Hanseatic City of Hamburg. For example, an accident occurred mid-October 2007 on the wharf at the Hamburg port. In this instance, an eleven-year old boy and his mother were hit by a breaking mooring line of a cruise vessel. This and other accidents at the Hamburg port fall under the jurisdiction of the AfA. Consequently, the following criteria were published from this party in respect of replacing fibre lines:

---

<sup>7</sup> Decollement occurs from a crushing trauma with simultaneous displacement of the sub-layer of the skin. Consequently the subcutaneous fatty tissue is overstretched until it tears internally from the skin; as a result of this the blood supply and nerve connections to the skin are lost in the affected area. Decollement is often an injury accompanying fractures of the extremities. However it also occurs as a separate injury and is occasionally underestimated in its severity.  
(Source: <http://de.wikipedia.org/wiki/Decollement>)

Criteria for Withdraw of Ropes  
according EN ISO 9554:2005

  
**Hamburg**  
 Stand: 12/2008

Ropes must be checked before use. The user must take regard that even carefully used ropes will wear out if receive sufficient use. Care should be taken to withdraw them from service before this time is reached rather than allowing them to continue in use until they fail.  
Following you will find the most important criteria for withdraw of ropes.  
Please keep in mind that there are different criteria for slinging ropes.

**All Ropes**

- Rope suspected of shock loaded.
- Exposure to excess temperature as specified for type of fibre.
- Burns or melting visible for a length of over four rope diameters.
- Abrasion on inside radius of eye, with bulk of surface yarns and strands reduced by 50% or more.
- Bulk of surface yarns or strands reduced by 50% or more for a linear distance equal to the rope diameter.
- Heavy surface fuzz-progressive.
- UV degradation, splinters on yarn surface.
- Rust on nylon. (May indicate chemical damage)

**For Braided Cover and Core Ropes**

- More than four consecutive pulled cover strands (which cannot be reincorporated into cover braid).
- More than 3 cut cover strands.
- Multiple cut yarns or filaments within distance of one pitch length.
- Core visible through cover, because of cover damage.
- Core damage-pulled, cut, abraded, powdered, or melted strands.
- Hemiation-core pokes through cover (sheath).

**For 3-Strand and 8-Strand (braided) Ropes**

- 5% of yarns cut or badly abraded in score between strands.
- Cover yarns cut or abraded more than 50% on one or more crowns on rope.
- Strand cut to 5% of diameter within one lay length.
- Powdering between adjacent strand contact surfaces.
- Hockle or backturn.
- 10% abrasion of one strand within one lay length.

**Thermal Damage**

- The rope may show up as a hard, melted, flattened area which can seriously damage the rope.
- Melting or fusing affecting 20% or more of rope yarns if over more than one lay length.

**Short term exposure to temperature above fibre working temperature**

- Polyolefin over 65 °C
- Polyamide over 100 °C
- Polyester over 100 °C
- Manila over 100 °C
- Sisal over 100 °C
- Hemp over 150 °C

**Impressum**  
 Herausgeber: Behörde für Soziales, Familie, Gesundheit und Verbraucherschutz (BSG)  
 Amt für Arbeitsschutz, Billstraße 80, 20539 Hamburg,  
 Arbeitsschutztelefon 040 / 428 37 -2112, Fax 040 / 428 37 -3100  
[arbeitsschutztelefon@bsg.hamburg.de](mailto:arbeitsschutztelefon@bsg.hamburg.de), <http://www.hamburg.de/portisafety>





Figure 15: Criteria for when a line should be withdrawn from use, Page 1

**General Guidance of the Yarns for Man-Made and Natural Fibres according EN ISO 9554:2005**


  
**Hamburg**  
 Stand 12/2008

Yarns of fibre ropes have specific characteristics. Proper choice, care and inspection of the rope are essential for reasonably safe use of the rope.  
The most important characteristics are:

<b>Polyamide</b>	
Corresponding Rope Standard:	ISO 1140
Environmental Resistance:	excellent
Sunlight Resistance:	very good
Effects of Chemical Exposure:	Resistant to weak acids, alkalis and organic solvents. Decomposed by strong mineral acids. Soluble in phenols and formic acid.
<b>Polyester</b>	
Corresponding Rope Standard:	ISO 1141
Environmental Resistance:	excellent
Sunlight Resistance:	excellent
Effects of Chemical Exposure:	Resistant to mineral acids and organic solvents. Decomposed by strong sulphuric acids and strong alkalis at high temperature. Soluble in phenols.
<b>Polypropylene</b>	
Corresponding Rope Standard:	ISO 1346
Environmental Resistance:	good
Sunlight Resistance:	fair
Effects of Chemical Exposure:	Resistant to acids, alkalis, organic solvents. Soluble in chlorinated hydrocarbons.
<b>Polyethylene</b>	
Corresponding Rope Standard:	ISO 1969
Environmental Resistance:	very good to excellent
Sunlight Resistance:	very good
Effects of Chemical Exposure:	Resistant to acids, alkalis, organic solvents. Soluble in chlorinated hydrocarbons.
<b>Mixed Polyolefin</b>	
Corresponding Rope Standard:	EN 14687
Environmental Resistance:	good to very good
Sunlight Resistance:	fair to good
Effects of Chemical Exposure:	Resistant to acids, alkalis, organic solvents. Soluble in chlorinated hydrocarbons.
<b>Sisal</b>	
Corresponding Rope Standard:	ISO 1181
Environmental Resistance:	poor
Sunlight Resistance:	good to very good
Effects of Chemical Exposure:	Resistant to alkalis and organic solvents. Degradation by acids in high concentration or high temperature.
<b>Manila</b>	
Corresponding Rope Standard:	ISO 1181
Environmental Resistance:	poor to fair
Sunlight Resistance:	good to very good
Effects of Chemical Exposure:	Resistant to organic solvents. Degradation by organic solvents, acids in high concentration or high temperature.
<b>Hemp</b>	
Corresponding Rope Standard:	EN 1261
Environmental Resistance:	poor to fair
Sunlight Resistance:	good to very good
Effects of Chemical Exposure:	Resistant to organic solvents. Degradation by organic solvents, acids in high concentration or high temperature.

**Impressum**  
 Herausgeber Behörde für Soziales, Familie, Gesundheit und Verbraucherschutz (BSG)  
 Amt für Arbeitsschutz, Billstraße 80, 20539 Hamburg,  
 Arbeitsschutztelefon 040 / 428 37 -2112, Fax 040 / 42837 -3100  
[arbeitschutztelefon@bsg.hamburg.de](mailto:arbeitschutztelefon@bsg.hamburg.de), <http://www.hamburg.de/portsafety>




Figure 16: Criteria for when a line should be withdrawn from use, Page 2

## 6.10 Considerations for avoiding line breaks

Although lines are the most conventional method for mooring ships, there is currently no technical option available to check a line quickly and easily. Of course there are experienced ropemakers and seamen who can assess the condition with a visual examination.

However, there are no scientifically established test methods available.

There are two types of ideas under continuous development:

The first type continues to deal with the lines themselves. The second type aims at indirectly avoiding accidents with lines.

### The following will touch on a few ideas relating to the first type:

In 1989 already, a proposal was submitted to the patent office of the GDR (former German Democratic Republic) to manufacture a mooring line with a safety marker. According to this proposal, a strand was to be integrated into the line that was distinguished from the other strands by its colour and by having a lower expansion coefficient than the other actual strands. This so-called "nominal fail point" could show when a line has already reached the limits of its load capacity. Of course, a line will still break immediately if the affecting forces are major and sudden.

This patent was accepted by the German Patent and Trade Mark Office on the reunification of Germany. However, the industrial property rights expired in 1994.

The reason for why this patent was not acted on for 20 years is explained as follows by a renowned rope manufacturer:

Often the idea was unknown or there were doubts as to whether it was technically feasible. If such a "nominal break strand" were to be integrated into a line, then the overall load capacity would be lower than desired. In addition to this, such a rope would no longer "run circularly". The issue of liability also arose as the contract would have to be legally formulated with great care and precision if a rope manufacturer was to market a line with such a safety marker.

Only one manufacturer declared that he had manufactured such a rope once on request by a customer. During the use of this rope, it was noted that the "nominal break strand" (which was naturally of a different material to the rest of the rope) had cut into the other strands, consequently doing more harm than good!

Another idea was to manufacture a coloured strand or even to have the entire line coloured. This colour would then change under the influence of UV radiation and salt water so that it would be apparent when the line had to be replaced purely for this reason.

During its research, the BSU was unable to find any reference to the development of technical devices to "screen" ropes.

### Ideas of the second type:

These ideas are intended to indirectly avoid such accidents. In the case of the accident with the boy and his mother, there is the admittedly impracticable suggestion of cordoning off access areas to the wharf, at least during berthing and casting off of vessels.

In principle, there is the possibility of setting up appropriate protective walls to protect people both on board and on the pier against lines.

Other mooring methods are also conceivable: There are already technical means to moor vessels without using ropes. For example, vacuum systems have been in use for several years now. According to the manufacturer's instructions, docking is completed in 12 seconds. Bollard systems, mooring lines and winches are no longer required for the procedure. Equally few personnel are required on shore and on board. Only one worker is needed to monitor berthing and casting off of vessels from the pier. There is no longer a need to interrupt rest times of crew; no need to wait for mooring line handlers and there is no longer a risk of injury from lines!

### **6.11 Dangerous accidents involving lines**

Accidents with mooring lines occur more frequently than generally assumed. At about the same time as the tragic accident in Koper, the MSC MARTHA was berthing in Bremerhaven. The vessel, which was sailing under the Panama flag, already had 3 fore lines and 2 spring lines on shore and the crew was working on hauling in the slack of the lines. For no explicable reason, one fore line suddenly broke and injured the bosun very severely on his leg.

One current case is the incident where the MS PUCON drifted away. On 7 August 2008, the vessel lay in Hamburg harbour when a sudden gale kicked up around 20:00 from the southwest reaching wind forces of up to 10 Bft; these winds pushed the vessel away from the pier. At the same time, all mooring lines broke and the PUCON broached against the current. With the help of 5 tugs the vessel managed to return to its berth.

After carrying out preliminary investigations, the BSU decided to present the investigative findings of the accidents using the example of the incident on board the NORTHERN FAITH.

## 7 Analysis

### 7.1 Environmental conditions

BSU established that a weather warning was issued in good time by the National Meteorological Service. It could not be established why this warning did not reach the vessel's command of the NORTHERN FAITH, or why for example it was neither conveyed by the pilot nor by technical means. It is conspicuous however that other vessels in the port were warned and rigged more mooring lines in response, and they kept the main engines on standby. Instead of taking measures, the crew of the NORTHERN FAITH conducted routine maintenance of the engine lasting several hours which meant that it could not be used at the time of the accident.

It was obvious that no one on board was aware of the gale warning.

### 7.2 Position of the injured

The location of the second NO, which was described by several people, is viewed as reliable. There is merely the question of whether he was thrown there by the central stern line breaking, or whether he was already at the position and was hit by the port stern line when it ripped out. If he was hit by the central stern line, he would have had to be thrown a distance of more than 10 m. Apart from this, all personal property (mobile, VHF unit ...) was also found in direct proximity to the man. Consequently, the BSU assumes that he was very probably hit by the port line as the tail end of it was torn from the drum.

### 7.3 Medical examination

The medical examination of the second NO was to give an indication of how he was injured. It was possible to exclude a fall, physical dispute or the impact of flying objects. The medical consultant concluded that the second NO was very probably hit by a mooring line grazing him from bottom to top.

### 7.4 Fatigue

The available working time sheets do not indicate that the second NO would have been overtired. He may have only had 3 to 4 hours sleep in the recreational hours before the accident, but this can be viewed as an exception. Furthermore, the BSU found no indication that he committed any error due to being overtired.

### 7.5 Documentation

There were no problems in collaborating with the shipping company. There were no complaints regarding the certificates and vessel papers submitted to the BSU. The only point to note is that there were contradictions in the copies of the logbook. In particular the corrected information on the number of mooring lines used leaves room for various interpretations.

### 7.6 Condition of the lines

The mooring lines on board had been in use since the end of 2004 / beginning of 2005. Since there are no practicable methods for testing lines, the general idea is that mooring lines are to be replaced every two years. The lines would have had to be replaced just based on this prerequisite. However, there is a "rule of fist" based on

empirical values. Each practitioner is aware that a new line is potentially already severely compromised in its load capacity after its first use; and yet on the other hand, a line can maintain a load capacity "as good as new" after more than 2 years. The hawser lines that were replaced in May show that the vessel's command and the shipping company are aware of the need to replace mooring lines regularly.

## 7.7 Winches

No technical deficiencies that might have contributed to the accident were identified on the winches. The fact that the last turn tore out of the drum was established as a generally unknown effect. Up to now it was assumed that only the last turn on the drum had released and that accordingly the end of the line had a range of about one metre. This report in particular draws attention to the fact that it is very possible for more than one turn to have ripped off the drum with continuously applied tractive forces to a winch. Consequently a greater safety distance should be maintained.

Due to the fact that the area exposed to the wind increases strongly on container ships ever growing larger and their high deck cargo compared with current ship dimensions a safe mooring in port during gale-force cross winds grew more complicated.

If ropes are subjected to heavy load mooring winches should by no means be switched to automatic operation. The ship is able to shift on her own in longitudinal direction by heaving on one side and giving way by the winches on the other side.

It should be checked if new builded large container ships require the installation of more than usual 3 winches on forecastle and after deck. It would also be conceivable to install double mooring winches each with a bearing and working drum. Professional working methods would allow for the Atlas ropes not to be jammed in the drum anymore and therefore be protected. The retention force of the individual mooring winch would be increased by only one layer on the working drum. The crucial advantage would be that more similar ropes could be rigged. This ropes can take up the steady influencing forces due to the same strain of the lines. Furthermore guide pulleys should be installed in such a way that the respective rope does not touch the ship hull. In doing so damages at the ships shell plating caused by welding seams can be avoided.

## 7.8 Determining causes for the broken line

Since it had initially been assumed that the second NO was hit by the breaking central stern line, this came under increasing focus for the investigation. The shipping company offered to have load tests carried out on the broken line. These tests clearly showed that they were not appropriate for determining the cause of a break. A load test merely shows what tractive force the line can hold at that moment. The test does not show what the line would have held beforehand or what it could sustain in future. This kind of break test can only be used to check a newly manufactured line for its load capacity by separating a piece which is then subjected to tractive strain.

The British company Tension Technology International Ltd. (TTI) considered itself capable of establishing prior damage to a line. In order to do this, they required both ends of the break as well as a piece of line at least 20 m away from the fail zone as a reference piece. Unfortunately, the shipping company supplied broken line pieces that obviously all originated from other lines (different thicknesses of strands,



different number of strands). Consequently it was impossible for TTI to prove or exclude prior damage to the broken central stern line.

## 7.9 Mooring software

TTI has developed mooring software and is marketing it globally. With the help of this software, vessel commands can relatively easily calculate what line connections they need to moor their ship at the targeted pier. To do this, you need to enter not only the vessel's parameters but also all environmental factors such as wind, waves, current and pier structure into the software.

Four scenarios were calculated:

1. **All lines maintain their minimum breaking load values (MBL) and all winches achieve 60 % of the MBL; this is the optimum scenario.**
2. As 1. with the exception of having the broken stern line; the reduced value determined in report part 1 (60 % of the MBL) is assumed for this.
3. As 1., only the winch performance is reduced to 60 %.
4. **As 3., however with the reduced line performance of 2.**

**Nothing would have happened in scenario 1. The lines would not have broken and the winches would have held the ship against the pier.**

In scenario 2, the line on the central winch would have broken.

In scenario 3, no lines would have broken but the ship would have been driven further and further away from the pier.

**In scenario 4 the central stern line would have already broken after 2 to 4 minutes, and the vessel would have been driven very quickly away from the pier, especially the stern of the ship.**

**This last simulation shows a very great similarity to the reality.**

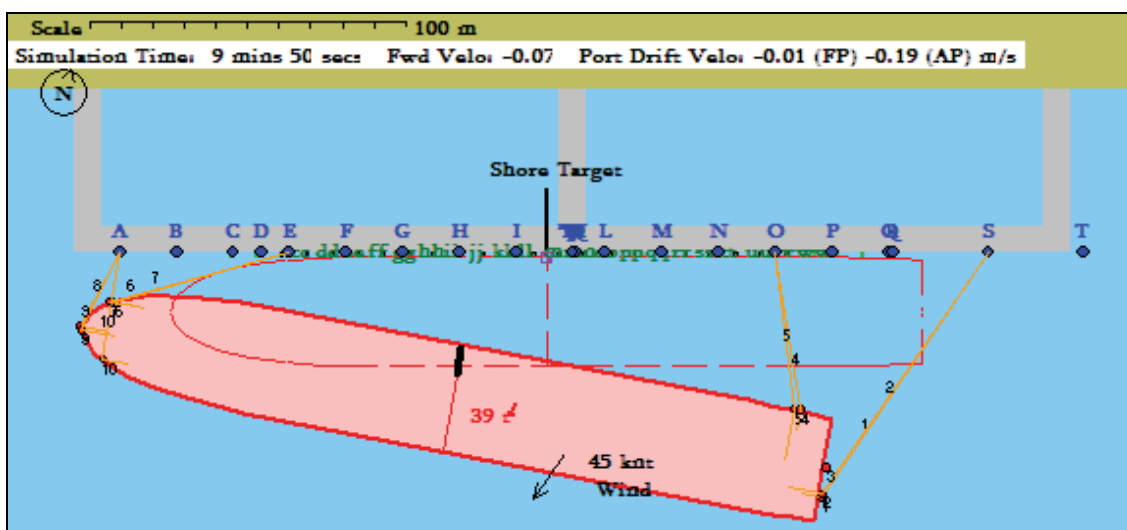


Figure 17: Simulation scenario 4 after 10 mins of wind impact

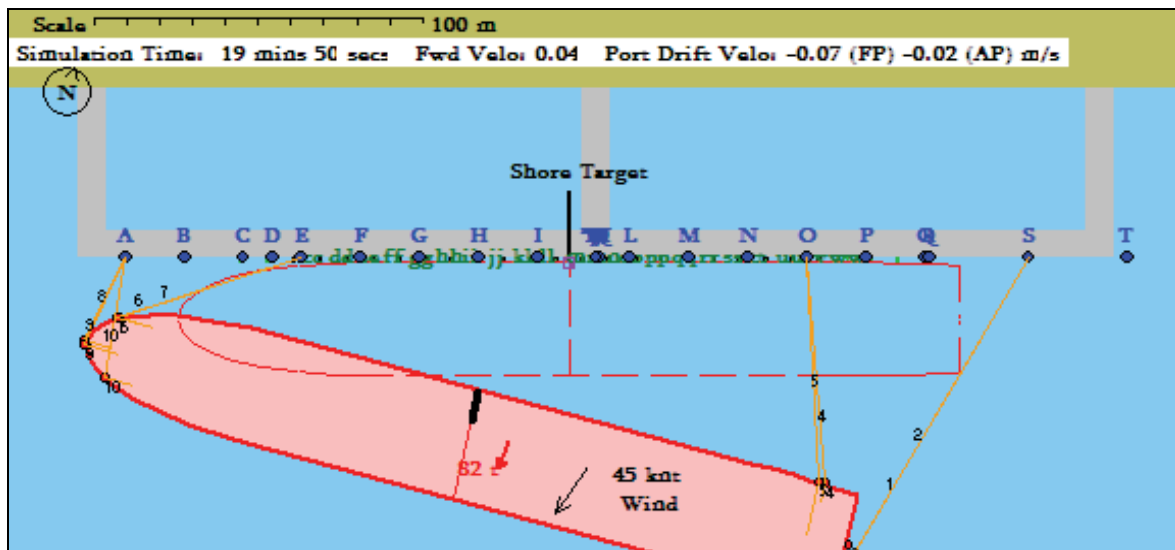


Figure 18: Simulation scenario 4 after 20 mins of wind impact

### In summary we can state the following:

If the lines and winchs had not had limitations to their performance, then the NORTHERN FAITH would have most probably not swung away from the pier.

### 7.10 Summary

Accidents with mooring lines usually cause severe injuries. Up to now, there has been no possibility of reliably identifying the load carrying strength of a line. Vessel lines should at least be inspected according to the criteria of the ISO 9554:2005(D) (see Figure 15).

When rigging mooring lines, attention should in particular be paid to ensuring that only lines with a similar expansion behaviour in the same direction are rigged, e.g. that only Atlas lines are used as stern lines and only polypropylene lines are used as spring lines. This is the only way for the applied forces to be distributed evenly over several lines.

One modern support for berthing is so-called "Mooring Software". Even line-free holding systems should continue to be developed further.

Particular caution should be used if a line is torn violently from a winch drum. An unexpectedly long line end can become a sudden hazard for people nearby.

Vessel commands must also inform themselves regularly in port about environmental conditions such as wind and current.

## 8 Action taken

The NSB shipping company arranged in December 2007 for the mooring decks on the ships of their fleet at al. to be painted with an anti-slip paint. In this respect, they referred to § 94b of the accident prevention regulations for shipping enterprises (UVV-See) of the Marine Insurance and Safety Association (See-BG)<sup>8</sup>.

### **§ 94 b Accessible Floor Surfaces and Floor Coverings**

**(1) Accessible floor surfaces and floor coverings shall have an antiskid effect.**

**(2) Floor coverings shall be manufactured, laid out and affixed such that sufficient protection is provided against personal hazard through stumbling, slipping or falling.**

**(3) If a danger of slipping can be expected in accommodation and working areas as well as in passageways, special requirements apply to accessible floor surfaces and floor coverings with respect to their anti-skid effect; if there is an increased danger of slipping, more stringent requirements shall apply.**

This regulation is considered fulfilled for accessible floor surfaces in service spaces if smooth surfaces are covered with welding naps or with an anti-skid coating or covering.

Accessible floor surfaces are e.g. steel decks, pinned plates and metal gratings. Floor coverings are e.g. elastic coverings of rubber and plastic, carpeting as well as ceramic tiles and plates.

Furthermore, the management referred to § 30 UVV-See to promote how to handle lines correctly and responsibly.

### **§ 30 Ropes and Running Rigging**

**Insured persons shall take into account the physical properties of the ropes and running rigging they are working with, and the dangers to which they can give rise - in particular, breaking or whipping back. They shall further take care not to step in fakes.**

F 5 Instruction Sheet on the Selection, Use and Maintenance of Synthetic Fibre Ropes<sup>9</sup>, dated 21st September 1989 provides information about the particular dangers associated with operations involving synthetic fibre ropes.

In addition to this, the shipping company's management commissioned their crews with securing the winch control position on board. Different approaches were developed that are to be implemented on board. (see Figure 19)

<sup>8</sup> see appendix

<sup>9</sup> No official translation available

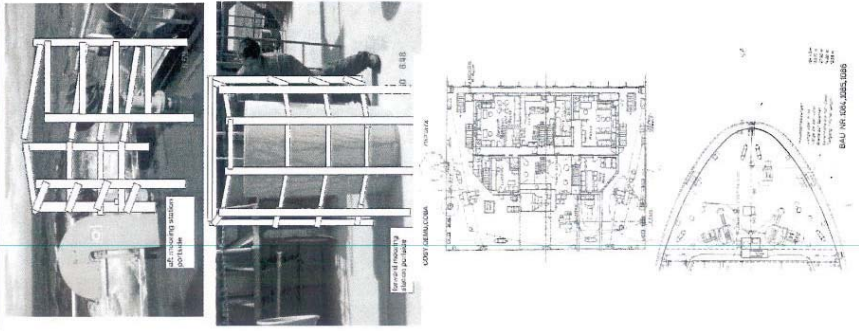
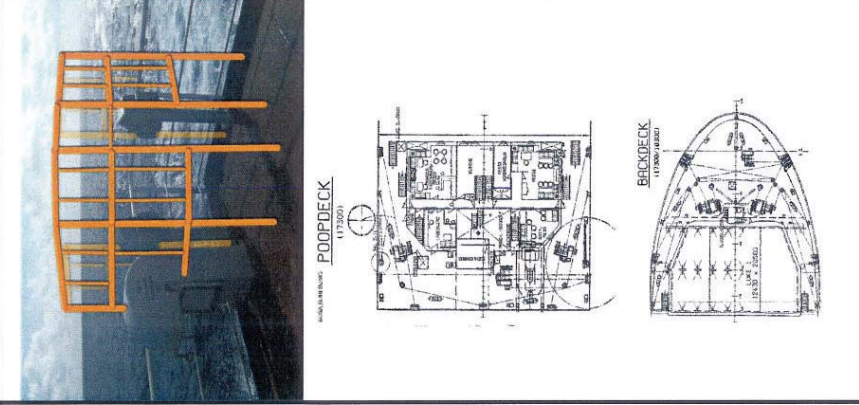
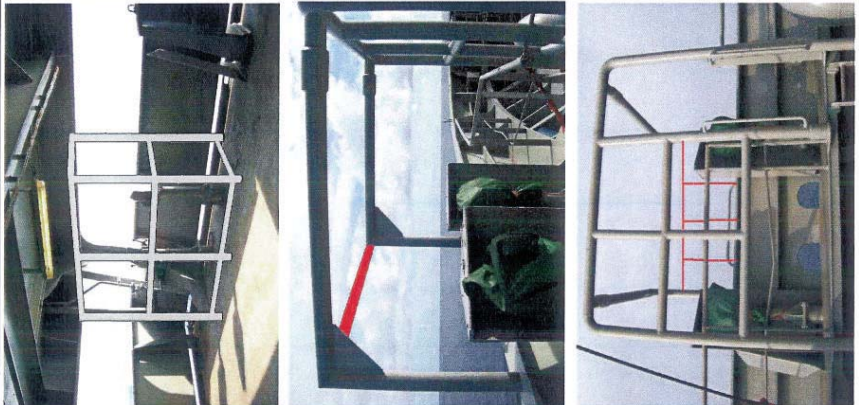

Proposals for rope protection T12			
<b>Conti Sydney (20)</b>	<b>Buxmoon (48)</b>	<b>YM Ibiza (62)</b>	<b>San Pedro Bridge (53)</b>
			
anwendbar auf, materialverbrauch Oel Mumbai (21) 150m Conti Barcelona (22) =84m Conti Sydney (20) =54m Buxhill (49) =75m Buxsailor (31) =	anwendbar auf, materialverbrauch Buxhill (49) =75m Buxsailor (31) Oel Mumbai (21) =150 m Conti Barcelona (22) =84m Cont Sydney (20) =54m + material an bord	anwendbar auf, materialverbrauch Conti Esperance (58), Käfig nicht vorhanden CMA CGM Alabama (61) Emirates Spring (63) YM Ibiza (62) = 65m	anwendbar auf, materialverbrauch MOL Wish (52) Ville de Taurus (67) San Pedro Bridge (53) = 120m

Figure 19: Suggestions for securing winch control positions

## 9 Safety recommendations

The following safety recommendations shall not create a presumption of blame or liability, neither by form, number nor order.

### 9.1 Vessel operators – responsible handling of lines

The Federal Bureau of Maritime Casualty Investigation recommends that **operators of maritime vessels** regularly promote the correct and responsible handling of lines in terms of § 30 UVV-See.

### 9.2 Vessel operators, classification societies, shipyards, winch manufacturers - safety measures on winches and winch control positions

The Federal Bureau of Maritime Casualty Investigation recommend that **operators of maritime vessels** continue improving the safety of winches and their control positions on board in collaboration with classification societies, shipyards and winch manufacturers using appropriate structural safety measures.

### 9.3 Operators - mooring software

The Federal Bureau of Maritime Casualty Investigation recommends that **operators of maritime vessels** examine the use of so-called "Mooring Software" and if necessary make it available to their vessel commands to increase the safety of the vessel at its berth.

### 9.4 Vessel's command – use of mooring lines

The Federal Bureau of Maritime Casualty Investigation recommends that **vessel commands** use only mooring lines of the same type for berthing their vessels. If this is not possible, then the lines running in the same direction should be of the same type.

If the rope is subjected to strong load the mooring winch should not be switched to automatic operation.

### 9.5 Vessel's command - distance from lines that are running out

The Federal Bureau of Maritime Casualty Investigation recommends that **vessel commands** point out the danger to their crew that more than just one turn on the drum could be torn out when continuous tractive forces are applied to the winch. Consequently a greater safety distance should be maintained.

### 9.6 Vessel's command – observing environmental conditions in port

The Federal Bureau of Maritime Casualty Investigation recommends that **vessel commands** regularly inform themselves about the environmental conditions such as wind and current.

### **9.7 Scientific maritime institutions and rope manufacturers, Marine Insurance and Safety Association and the Federal Ministry of Transport, Building and Urban Affairs**

The Federal Bureau of Maritime Casualty Investigation recommends that **scientific maritime institutions and rope manufacturers** expedite the development of lines and/or systems that make it possible for vessel commands to determine the existing load capacity of a line in a practicable way.

The Federal Bureau of Maritime Casualty Investigation recommends that **Marine Insurance and Safety Association** continue to lend support to the development of such systems and if necessary to update guidelines for the use of these systems.

We recommend that the **Federal Ministry of Transport, Building and Urban Affairs** promotes the research and development of such systems.

## 10 Sources

- Written statements
  - Vessel's command
  - Shipping company/owner
  - Classification society
  - Rope manufacturer
  - Winch manufacturer
- Witness accounts
- Report by Tension Technology International Ltd.
- Report from the Forensic Medical Institute Hamburg
- Section from nautical chart 1068 and vessel data from the Bundesamt für Seeschifffahrt und Hydrographie (BSH - Federal Maritime and Hydrographic Agency)
- Assistance from the shipping administration of the Slovenian Republic
- Explanations from the website: <http://www.esys.org/wetter/bora.html> with kind permission of the website owner.
- Reports on the properties of different mooring lines from Capt. Kurt A.v. Ziegner
- MAIB Safety Digest 2/2007: "Mooring arrangement"
- Schiff & Hafen – May 2008 – No.5 Page 20:  
"Effizienzsteigerung durch automatische Festmachsysteme" (Increasing efficiency with automatic mooring systems)
- Occupational Safety and Health Administration (AfA) Hamburg
- German Patent and Trade Mark Office
- Documents from the Marine Insurance and Safety Association (See-BG)
  - Accident prevention regulations for shipping enterprises (UVV-See)
  - Guidelines and codes of practice
  - Ship's documents

## 11 Appendix



## 11.1 Accident prevention regulations for shipping enterprises (UVV-See):

### **§ 30 Ropes and Running Rigging**

**Insured persons shall take into account the physical properties of the ropes and running rigging they are working with, and the dangers to which they can give rise - in particular, breaking or whipping back. They shall further take care not to step in fakes.**

F 5 Instruction Sheet on the Selection, Use and Maintenance of Synthetic Fibre Ropes<sup>10</sup>, dated 21st September 1989 provides information about the particular dangers associated with operations involving synthetic fibre ropes.

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<sup>10</sup> No official translation available

See-Berufsgenossenschaft  
Hamburg

21. September 1989  
i. d. F. vom 23. September 2004

## F 5 MERKBLATT

### über Auswahl, Gebrauch und Pflege von Chemiefaserseilen

#### 1. Allgemeines

Beim Gebrauch von Chemiefaserseilen (Leinen und Tauwerk aus Chemiefasern) an Bord von Seeschiffen ereignen sich immer wieder schwere Unfälle. Einige dieser Unfälle sind darauf zurückzuführen, weil der Besatzung die Eigenschaften dieser Seile nicht genügend bekannt waren oder ungeeignetes Material verwendet wurde.

Zur Zeit sind hauptsächlich folgende Chemiefaserseile in Gebrauch:

Material	Handelsnamen	Kennstreifen
Polyamid	Perlon, Nylon	grün
Polyester	Trevira, Diolen, Terylene, Tergal, Dacron	blau
Polypropylen	Polyprop, Tipto, Powerflote	braun
div. Mischseile (teilweise mit Polyethylen)	Powerplait, Cruiser	zweifarbige; in den Farben der beiden prozentualen Haupttraganteile

Chemiefaserseile, die Fasern enthalten, welche ausschließlich aus Polyethylen(PE)-Granulat hergestellt worden sind, dürfen an Bord nicht verwendet werden. Chemiefaserseile mit Fasern, welche aus einem Granulat-Mix mit PE-Anteilen erschmolzen wurden, dürfen an Bord verwendet werden, wenn sie vom Germanischen Lloyd oder einer anderen anerkannten Klassifikationsgesellschaft typgeprüft und zugelassen wurden.

Der Einsatz von Chemiefaserseilen in Maschinenräumen ist nicht zulässig (siehe § 151 Abs. 10 UVV See).

An Bord verwendete Seile aus Polypropylen müssen aus lichtstabilisiertem Material hergestellt sein.

An Bord dürfen nur Seile mit Kennstreifen und Prüfbescheinigungen verwendet werden. Prüfbescheinigungen sind während der Gebrauchszeit der Seile an Bord aufzubewahren.

Für Sicherheitsgeschirre aus Chemiefaserseilen gelten besondere Bestimmungen.

#### 2. Auswahl von Chemiefaserseilen

Bei der Auswahl von Chemiefaserseilen ist zu beachten:

- Großer Reck (Seil-Dehnung)<sup>1)</sup> bis zu 40%
- Geringe Dichte

**F5**

- Verrottungsfestigkeit
- Geringe Alterungsneigung
- Geringe Wasseraufnahme (5 bis 15% bei Polyamidseilen) und dadurch leichte Handhabung
- Festigkeitsverlust durch Wärme und Reibung (Hohe Festigkeitsverluste treten bereits bei Temperaturen von ca. 150°C auf. Überdehnung führt zu Wärmestau, der nicht abgeführt wird.)
- Verkürzung der Lebensdauer von Polyamidseilen durch Wasseraufnahme.
- Schlechte Griffigkeit bei neuen Seilen

Die schwersten Unfälle haben sich beim Brechen nicht ausreichend bemessener Chemiefaserseile ereignet. Das Brechen kündigt sich nicht an. Die Seile schnellen wegen des hohen Recks<sup>1)</sup> mit großer Energie zurück.

**3. Festmachertrossen**

Für die Bemessung der Festmachertrossen gilt beispielhaft die nachstehende Tabelle (die erforderliche Trossenbruchlast ist abhängig von Schiffstyp und Schiffsgröße und kann dem Anhang der „G3 Richtlinie für Festmacher- und Verhol-einrichtungen“ entnommen werden, bei abweichenden Schiffsgrößen ist entsprechend zu interpolieren).

Minstdurchmesser von Festmachertrossen auf Seeschiffen

Ausrüstungs- Register-Nr. <sup>2)</sup>	Bruchlast kN <sup>3)</sup>	Stahldrahtseil nach DIN 3068 oder gleichwertig Ø (mm)	Chemiefaserseile			
			Polyamid nach DIN EN 696 Ø (mm)	Polyamid (vergütet) Ø (mm)	Polyester nach DIN EN 697 Ø (mm)	Polypropylen nach DIN EN 699 Ø (mm)
bis						
110	72,8	12	30	30	30	30
112	85,4	13	32	32	32	32
114	99,1	14	36	36	36	36
117	129,0	16	40	40	40	40
120	164,0	18	44	44	44	44
122	202,0	20	48	44	48	48
125	245,0	22	48	44	48	52
128	291,0	24	52	48	52	56
132	342,0	26	60	56	60	64
134	396,0	28	64	62	64	72
141	518,0	32	72	68	72	80
147	655,0	36	80	78	80	88
155	809,0	40	88	84	88	96
168	979,0	44	96	90	96	-

F5

In dieser Tabelle sind Bruchlastverluste berücksichtigt, die unter normalen Betriebsverhältnissen entstehen können durch:

- Spleißen (ca. 10%)
- Sonneneinstrahlung
- Innere Erwärmung bei Arbeitsaufnahme
- Äußere Erwärmung durch Reibung (Klüse, Spillkopf usw.)
- Abrieb und Verschleiß bei sachgemäßem Gebrauch

Werden Leinen geknotet, ist mit einem weiteren Bruchlastverlust von 50% zu rechnen, der in der Tabelle nicht berücksichtigt wurde.

Chemiefaserseile, die nach den Mindestmaßen der Tabelle ausgewählt sind, werden beim sachgemäßen Gebrauch nicht überbeansprucht.

In Verbindung mit Drahtseilen haben sich Vorläufer aus Polyamidfaser am besten bewährt.

#### 4. Gebrauch von Trossen aus Chemiefaserseilen

- Oberflächen von Spillköpfen, Klüsen, Umlenkrollen oder Pollem müssen glatt und frei von Rost sein
- Bewegliche Teile sind gut gangbar zu halten
- Rollen- und Walzenklüsen sind zu bevorzugen
- Trossen nicht über scharfe Kanten ziehen
- Zutschen möglichst vermeiden (dadurch Auftreten von Kleben und unkontrolliertem Anschmelzen und Entstehen glatter Oberflächen mit plötzlichem Rutschen, verbunden mit erhöhter Unfallgefahr. Fiert man die Trossen mit der Winde auf, wird die Unfallgefahr vermindert)
- Jedes Schamfielen vermeiden
- Bei Verwendung als Vorläufer Kauschen einspleißen
- Stopper aus Chemiefaserseilen mit großem Reck<sup>1)</sup> verwenden
- Niemals in Richtung einer unter Kraft stehenden Trosse aufhalten
- Zum Festmachen des Schiffes möglichst nur Trossen gleichen Recks<sup>1)</sup> verwenden, also nicht gleichzeitig nebeneinander Trossen aus Stahldraht- und Chemiefaserseilen

#### 5. Pflege von Chemiefaserseilen

- Nach Antritt der Seereise unter Deck verstauen oder mit Persenningen abdecken (Schutz gegen Sonneneinstrahlung und Nässe)
- Nicht in der Nähe von Wärmequellen lagern
- Nicht mit Chemikalien (z.B. Lösungsmitteln und Farben) in Berührung bringen
- Beschädigte Kauschen erneuern, lose Kauschen neu einspleißen
- Regelmäßige Kontrollen durchführen (von Zeit zu Zeit sind die Seile sorgfältig auf innere und äußere Schäden zu untersuchen. Die Seile unterliegen auch ohne

3

**F5**

Beanspruchung einer gewissen Alterung, die insbesondere von der Stärke der ultravioletten Strahlung sowie von klimatischen und anderen Umwelteinflüssen abhängig ist. Deshalb können genauere Angaben über die Lebensdauer nicht gemacht werden. Nach den bisherigen Erfahrungen beträgt sie ca. 3 Jahre)

**6. Besondere Empfehlungen für Tanker**

Für Tanker können besondere Empfehlungen in der Ausrüstung mit Festmacherleinen erforderlich sein, da Chemiefaserseile bei bestimmter Zusammensetzung beim Schamfielen dazu neigen, sich elektrisch aufzuladen.

- 1) Reck (-oder Seil-Dehnung-) ist die bei Zugbeanspruchung auftretende prozentuale Vergrößerung der Seillänge.
- 2) Die Ausrüstungs-Register Nr. in der Tabelle ergibt sich aus den Unified Requirements der IACS. Mittels dieser kann auf die für dieses Schiff gemäß seiner Größe, Lateralfläche, Windangriffsfläche etc. (=Ausrüstungsleitzahl) erforderliche Bruchlast der Festmachertrosse geschlussfolgert werden.
- 3) 10 kN entsprechen der Gewichtskraft von etwa 1 Tonne.



**§ 94 b Accessible Floor Surfaces and Floor Coverings**

**(1) Accessible floor surfaces and floor coverings shall have an antiskid effect.**

**(2) Floor coverings shall be manufactured, laid out and affixed such that sufficient protection is provided against personal hazard through stumbling, slipping or falling.**

**(3) If a danger of slipping can be expected in accommodation and working areas as well as in passageways, special requirements apply to accessible floor surfaces and floor coverings with respect to their anti-skid effect; if there is an increased danger of slipping, more stringent requirements shall apply.**

This regulation is considered fulfilled for accessible floor surfaces in service spaces if smooth surfaces are covered with welding naps or with an anti-skid coating or covering.

Accessible floor surfaces are e.g. steel decks, pinned plates and metal gratings. Floor coverings are e.g. elastic coverings of rubber and plastic, carpeting as well as ceramic tiles and plates.

## 11.2 TTI report



Tension Technology International Ltd

# **VISUAL EXAMINATION AND TENSILE TESTING OF A FAILED MOORING LINE TO ESTABLISH THE CAUSE OF FAILURE**

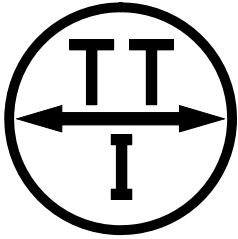
**And**

**OPTIMOOR MOORING ANALYSIS**

**SIMULATION OF NORTHERN FAITH BREAK AWAY  
AT KOPER TERMINAL ON 4 JULY 2007**

**for**

**Federal Bureau of Investigation of Maritime Casualty  
Investigation**



**Tension Technology International Ltd**

**REPORT**

**‘MV NORTHERN FAITH’**

**VISUAL EXAMINATION AND TENSILE TESTING OF  
A FAILED MOORING LINE TO ESTABLISH THE  
CAUSE OF FAILURE**

**For**

**Federal Bureau of Investigation of Maritime Casualty  
Investigation**

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## EXECUTIVE SUMMARY

**The mooring line has failed at a region where external abrasion is very evident. From inspection and analysis of the failure, it is not possible to say if this abrasion had occurred at some time before the accident or if it happened during the accident. Photographic evidence supplied to Tension Technology suggests that the zone of damage was in the free length of the mooring line, between the pier bollard and deck winch/fairlead. If this is true, then the rope at its fail zone was not in contact with anything when it failed and thus the damage must have occurred before the accident.**

**Areas of blue and red staining to the rope of the fail zone appear to be paint residue, matching the colours of the vessel. If this is the case, then this is evidence of recoil of the rope against the vessel after it had failed.**

**It is estimated that the rope had a residual strength in the abraded region as low as 60% of the strength of the same rope in new condition at about 400 kN. Elsewhere within the failure zone, where abrasion damage was less severe, the rope had an estimated residual strength of 75% of new strength, about 500 kN.**

**These percent residual strengths are estimates based on 'dry' tensile testing. In wet conditions, the actual strength of the abraded zone could be reduced by about 10%, from about 400 kN to 360 kN.**

**Other samples submitted to TTI for examination had different constructions. Data from tensile testing of these ropes has been used for comparison purposes in this report, but need to be understood in the light of these constructional differences.**

**It has not been possible to say if the damage occurred during its deployment on this particular mooring or if it had occurred previously. However this accident highlights the necessity of regular monitoring of the condition of any rope by a responsible person on a vessel and that if there is any doubt as to the condition of the rope then it should be removed from service until a full inspection has been carried out. There are several published sets of guidance and recommendations on the subject of rope inspection [listed as references], but experience, common sense and an awareness of the consequences of not taking a cautious approach to rope condition will always reduce the chances of an accident.**

### Terms and Definitions

<b>Filament</b>	Fundamental textile component from which ropes are constructed
<b>Textile yarn</b>	Assembly of filaments, typically 100-200 filaments per textile yarn
<b>Rope Yarn</b>	Assembly of textile yarns
<b>Monofilament</b>	The rope samples had 4 mm diameter polyamide components, referred to as 'monofilament' for the purposes of this report.
<b>Core</b>	Inner structure of rope
<b>Strand</b>	Conventionally, a strand is an assembly of rope yarns.  The 'failed' Atlas rope sample sent to TTI for investigation had outer strands consisting of rope yarns and large diameter monofilaments. Other samples, remote from and adjacent to the failure, had outer strands consisting of monofilaments, rope yarns and textile yarns.
<b>Polyamide</b>	Synthetic polymer material from which the present rope is made. Commonly known as 'Nylon'. Ropes made from polyamide yarn are characterised by having the highest extensions at break of all the synthetic materials commonly used in marine rope applications. Also, the breaking strength of polyamide material is reduced when it is wet, by at least 10% of its dry breaking strength.
<b>MBL</b>	Minimum breaking load, in kN, as specified by manufacturer.
<b>Residual Strength</b>	Estimated strength of a rope, expressed as a percentage of MBL
<b>Linear density</b>	The weight in grams of 1000 metres of material. The unit is called 'tex'
<b>Melding</b>	A term used to describe bonding between rope elements that is a combination of mechanical entanglement and fusing of the thermoplastic polyamide material.. This is evidence that heat and/or pressure had been generated during the failure.
<b>Realisation Factor</b>	A factor, when multiplied with the summed strengths of the rope elements, that is used to estimate the rope strength. It is always less than 1 and has different values for different rope types and diameters.  In this investigation, the Realisation Factor was calculated by dividing the aggregated strengths of the rope elements by the breaking strength of a rope sample tested by others for FBMCI



## 1. INTRODUCTION

This report is submitted to Bundesstelle für Seeunfalluntersuchung, [Federal Bureau of Maritime Casualty Investigation, FBMCI] in response to their request to investigate the failure of an Atlas rope mooring line. The accident resulted in injury to an officer on deck of the MV Northern Faith.

FBMCI requested the following:

- a. Visual examination to establish the cause of failure
- b. Determination of the rope residual strength by yarn realisation
- c. Scanning Electron Microscopy of rope filaments
- d. An analysis of the mooring system using TTI software, 'Optimoor' to establish probable line loads at the time of the accident
- e. An analysis of the energy and lashback characteristics at the time of failure
- f. Recommendations for the avoidance of future accidents

This report covers items 'a', 'b' and 'f'. Items 'c' was considered not to be necessary at this stage. Item 'd' is the subject of a second report and item 'e' remains to be completed.

## 2. DETAILED REPORT

### 2.1 Visual examination and tensile testing of fail zone

Visual examination of the hawser in accordance with OCIMF, ACI and CMI guidelines. Three samples were submitted for examination as follows:

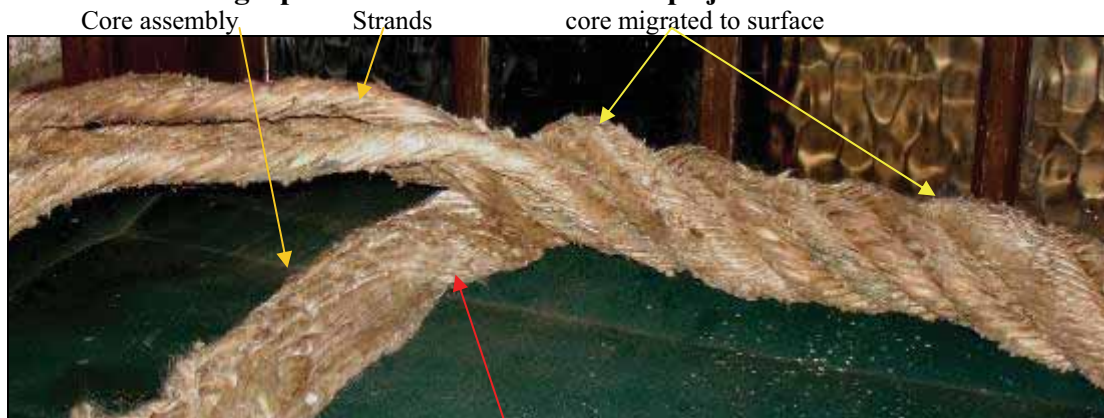
1. One half of the fail zone of the rope
2. One short section of rope labeled 'adjacent to failure'
3. One short section of rope sampled from about 20 metres from the failure

#### 2.1.1 Initial visual examination of Fail Zone

Photograph 1 shows a general view of the rope just behind the fail zone. Figure 1 is a sketch of the main features of the failure and Table 1 gives the details of the construction. It consists of a central core of textile-based rope yarns, around which are 6 strands, helically wound, normally referred to as a '6 round 1' construction.

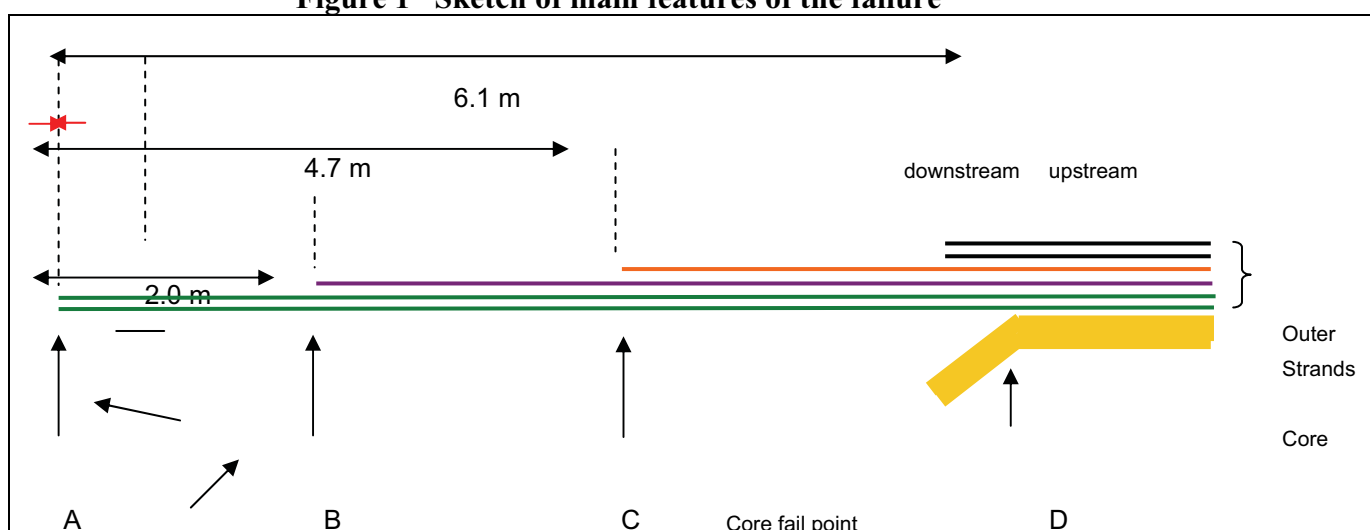
Each strand consists of a core of rope yarns around which is wound a combination of thick monofilaments and textile-based rope yarns. These particular rope yarns will make some contribution to strength, but also have a function of making the rope easier to handle. Once the rope yarns begin to abrade, the rope is softer to the hand.

**Photograph 1 General view of the rope just behind the fail zone**



Position D of Figure 1

**Figure 1 Sketch of main features of the failure**



**Table 1 Rope construction of rope in fail zone**

Rope Component	Construction
Core, one assembly	Outer layer: 21 rope yarns, approx lin density 11000 Tex
	Inner layer: 33 rope yarns, approx lin density 11000 Tex
	1 rope yarn, approx lin density 2300 Tex
Outer strand, x 6	Outer layer: 9 monofilaments, diameter 4.2 mm
	9 rope yarns, approx lin density 5033 Tex
	Inner layer: 20 rope yarns, approx lin density 2300 Tex
	5 rope yarns, approx lin density 4600 Tex
	<i>NB A second strand was analysed and the inner layer had a different construction, having 16 thin rope yarns and 4 thicker rope yarns</i>

It was not possible to measure the linear densities [tex or g/1000metres] of the various elements of the rope accurately. This was due to their overall condition.

Any differences in strand construction should not affect rope performance as long as they have been properly specified and controlled within a Quality Assurance procedure.

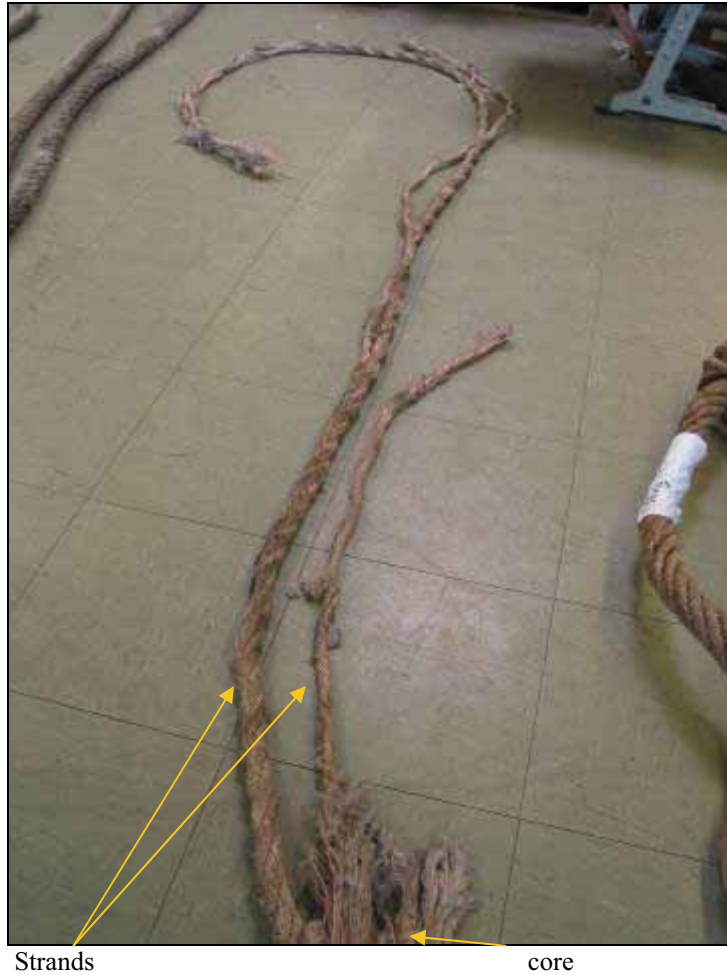
Photographs 2 and 3 give general views of the failure. The images were supplied by FBMCI

**Photograph 2** General view of failure, looking towards pier bollard eye



The failure is located about 20 metres from the pier bollard eye and thus would probably have been located within the 'free length' of the line, between the pier bollard and deck winch/ fairlead at the time of the accident.

**Photograph 3 General view of one half of the fail zone**



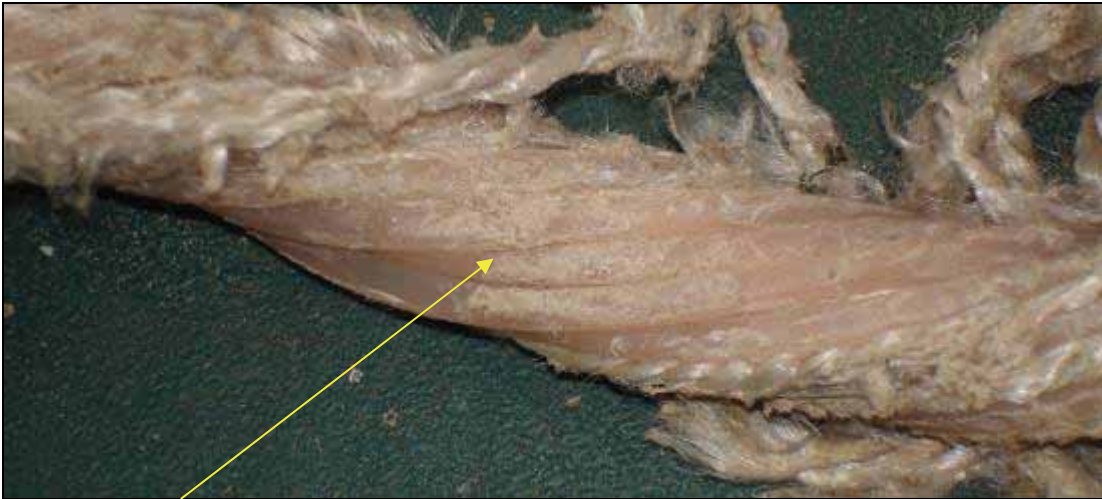
The following part of the report starts with the findings of the investigation of the rope condition downstream of position D of figure 1, where the majority of the rope component failures occurred. Further findings about the rope condition upstream of D are then discussed.

### 2.1.2 Detailed examination, downstream of position D

Photographs 4 and 5 shows a view of the condition of strands within the fail zone.

#### Photograph 4

Condition of a strand in fail zone, 1 metre behind position A of figure 1



External abrasion

#### Photograph 5

Condition of a strand 1 metre downstream of position D of figure 1



Fused rope yarn material

Both images reveal that the rope yarns of the strands had been subjected to severe external abrasion, resulting in either complete removal [photo 4] or fused material [photo 5]. Inspection of all the strands revealed that a general melding of the textile and monofilament components had occurred, indicating a failure under elevated temperature and/or pressure conditions.

In photograph 4, abrasion to the monofilament material is also clearly seen.

Photograph 6 shows about 1.2 metres of an outer strand core assembly of rope yarns, behind its fail point.



**Photograph 6**



Fail point

The rope yarns are relatively clean and in reasonable condition up to about 400 mm from the actual fail point. As the fail point is approached, contamination increases and the overall condition declines rapidly. These are indications of external abrasion having occurred.

Photograph 7 shows an optical microscopy image of filaments from the core fail point.

**Photograph 7      Fused filaments from core fail point of figure 1**



A cluster of fused filaments is seen in the centre of the image. Darker spots are also seen which could be charred material or contamination. The image is evidence of excessive heat being present at the time of failure.



### 2.1.3 Detailed examination, upstream of position D

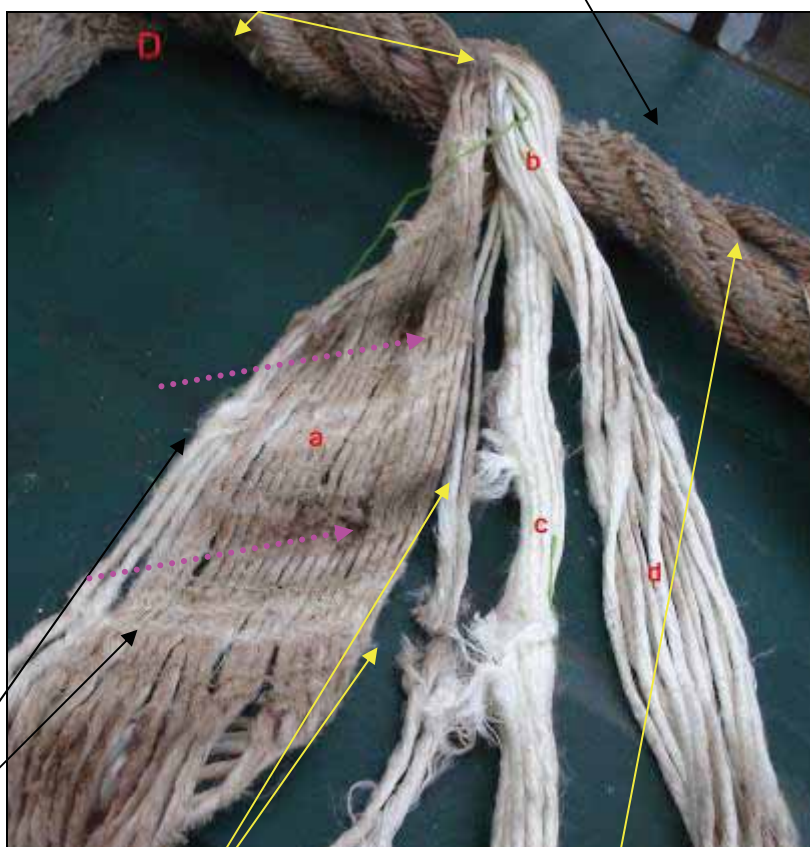
General melding of the rope components was found. Photograph 8 shows the rope core assembly, opened up to reveal the condition of the elements. At 'a', the outer rope yarns are seen. The view is of their inner faces. The yarns have been 'melded' together but could be separated by pulling them apart. The outer faces of these yarns show evidence of damage that is consistent with the effects of heat and pressure.

Above and below 'a', two zones of excessive damage are seen running in the line of the purple arrows across the image. These have been caused by pressure from the two strands, coloured black in figure 1, repeated below for convenience. During the investigation, these two strands were found to be severely melded to the outer rope yarns of the core and could only be separated by exerting considerable force

**Photograph 8 Unraveled core, upstream of position D**

Core assembly, helically arranged around rope axis

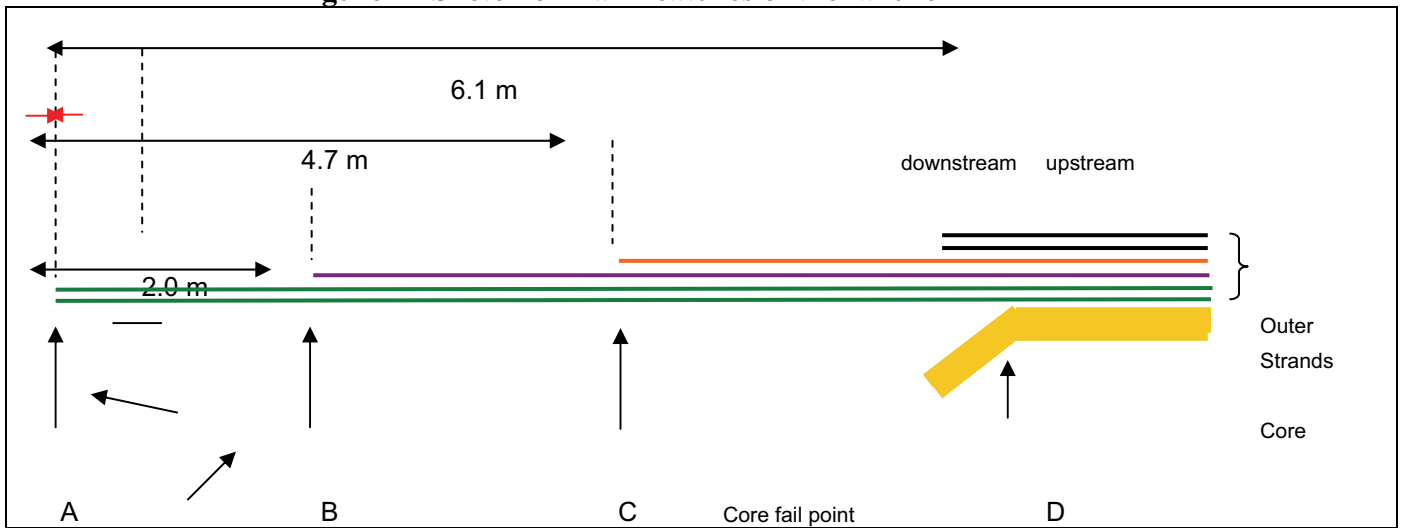
melded cluster of 4 strands



Localised compression

localised failure

one of two strands not melded with 4-strand c

**Figure 1 Sketch of main features of the failure**

The rope yarns of the inner layer are seen at 'b'. They divide into two separate groups 'c' and 'd'. Group 'd' are loose and are in reasonable condition. Group 'c' show evidence of two clusters of localised failure and also melding. The melding is found between the upper and lower clusters of damage, suggesting a short zone where internal structure of the rope had been subjected to excess pressure. These clusters of localised failure are in line with the localised distortion seen at 'a'.

The rope yarn failures found at 'c' are unusual as they have occurred on inner rope yarns whilst their partner outer rope yarns [at 'a'] have only been severely compressed. The damage to both sets of rope yarns has probably been caused by the two strands, black in figure 1. This evidence suggests that at the time of failure, there was excess load and that the load distribution between the elements within the core was poor. The inner rope yarns were strained to a higher extent than the outer rope yarns. The pressure from the outer strands would have resulted in localised restraint of the material lying beneath them, further complicating the load distribution. Due to the excess strain on the inner rope yarns, some have failed whilst the outer rope yarns, under less strain, have been able to withstand the strand pressure more successfully.

Photograph 9 shows an optical microscopy image of failed filaments from the localised failure 'c'

**Photo 9 Failed filaments from inner rope yarns of core assembly**



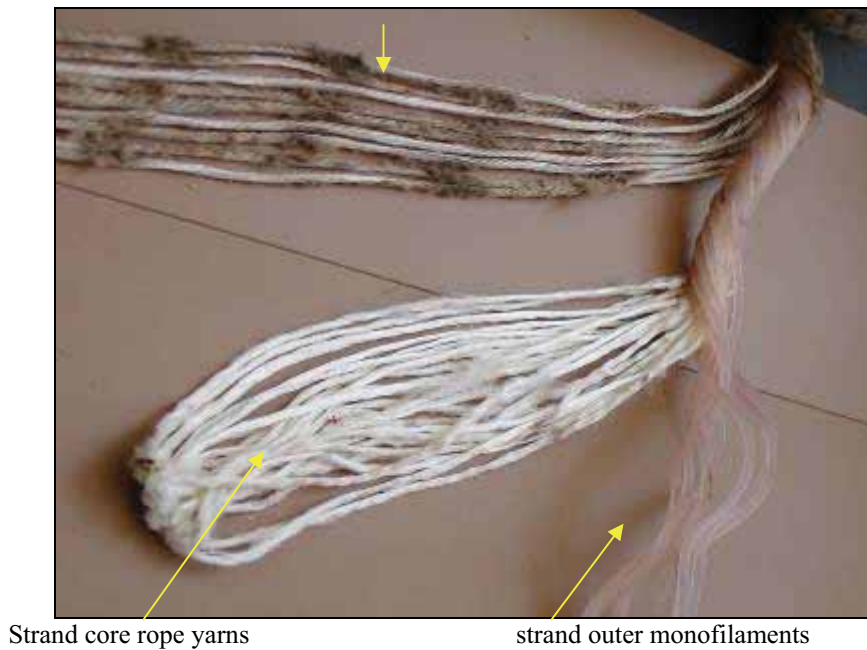
At 'A', the failed ends have a shape that is typical of ductile tensile failure. At B, folding and flattening of filaments is seen [ the image is slightly out of focus]. This indicates that pressure has been a factor in these failures of the internal rope yarns

Investigation of the remaining four strands revealed that they were melded firmly together as a cluster of four, coloured orange, purple and green in figure 1.

The core assembly was found to be arranged in a helical fashion around the rope axis and this must have happened as a result of the failure when the rope recoiled following the release of strain energy. This is shown in photograph 1

Photograph 10 shows one of the strands upstream of D, unraveled. The outer rope yarns are abraded, but retain some structure. Also, the yarns had a soft 'feel' to the hand, in contrast to the harder 'feel' found on surviving rope yarn material downstream of D. In addition, examination of the monofilaments failed to reveal the same degree of external abrasion as that found on monofilaments downstream of D.

**Photograph 10 Unraveled strand, upstream of D**  
Strand outer rope yarns



Small areas of rope both upstream and downstream of D were seen to have coloured contamination, dark blue and red. These were examined under optical microscopy and photograph 11 is an example of part of a red stained area. A particle of red material can be seen embedded in an area of fused rope filaments

**Photograph 11 Red particle embedded in fused matrix of rope filaments**



It was concluded that these areas of contamination were most likely to be paint that had contaminated the rope when the rope had made high energy contact with the vessel during the recoil after the failure.

### 2.1.4 Comparison of tensile strengths of the rope components upstream and downstream of position D

Table 2 shows the results of tensile tests on the elements that it was possible to test upstream of D. Table 3 shows the results for elements downstream of D

**Table 2**

Fail zone, upstream of position D					
		number	BL kN	sum kN	
<b>Core, x 1</b>					
<b>Outer layer</b>					
Rope yarn	11000 tex	21	3.162	66.402	
<b>Core</b>					
rope yarn	11000 tex	33	3.162	104.346	
Rope yarn	2300 tex	1	1.562	1.562	
				Sum	172.31 kN
<b>Strand, x 6</b>					
<b>Outer layer</b>					
Monofilament		9	4.713	254.502	
Rope yarn	5033 tex	9	1.386	74.844	
<b>Core</b>					
Rope yarn	2300 tex	20	1.562	187.44	
	4600 tex	5	3.162	94.86	
				Sum	611.65 kN
<b>Grand sum</b>				<b>783.96</b>	<b>kN</b>

Manufacturer's data for the minimum breaking load of a new rope, 60 mm diameter, is 686.70 kN.

From information received from FBMCI, whole-rope tensile testing from another rope sample resulted in a fail load of 514.54 kN. This suggests a Realisation Factor of

0.66 [514.54/783.96] for used rope of this particular specification.

Thus, the estimated Residual Strength of the rope, upstream of Position D, is 517 kN, 75% of new Minimum Breaking Load.

**Table 3**

Fail zone, downstream of position D					
		number	BL kN	sum kN	
<b>Strand, x 6</b>					
<b>Outer layer</b>					
Monofilament		9	4.411	238.194	
Rope yarn	5033 tex	9	0.563	30.402	
<b>Core</b>					
Rope yarn	2300 tex	20	1.241	148.92	
	4600 tex	5	2.729	81.87	
				Sum	499.39 kN

It was not possible to perform tensile tests on the surviving downstream core rope yarns and only data from the testing of the elements of an outer strand is shown in table 3. Comparing this strand data, it can be seen that upstream of position D, the summed strength of all the elements of the outer strand is 611.65 kN, whilst downstream of D it is only 499.39 kN. This represents a 19% reduction of the strength of a strand and agrees with the visual assessment of the failure sample, i.e. there was a greater degree of damage to the strands downstream of

position D. It is therefore reasonable to assume that the residual rope strength downstream of D would be lower than that estimated for upstream of D because of the additional abrasion damage and a percent residual strength of 60% is used.

After considering all of these separate observations, the following is a reasonable explanation of the progression of the failure:

1. The rope had been weakened by localised external abrasion damage. It is estimated that the rope had a residual strength of about 60% of its new Minimum Breaking Load in the damaged zone. It is not possible to determine if this damage happened at the time of the incident or had occurred as a result of a previous incident. However, the location of the damage is very likely to be between the pier bollard and the deck winch and fairlead and could not have been in contact with anything at the time of failure. It is therefore likely that the damage had occurred before the actual failure.
2. The rope was subjected to severe load, possibly of a very localised nature and this load caused the failure at the abrasion damaged zone.
3. Position D of figure 1 is a transition point in terms of visible damage. Damage is greater downstream of D than upstream of D.
4. The two black coloured strands of figure 1 failed initially. During the course of their failure, the strands exerted extreme pressure on the core structure of the rope. This resulted in the damage seen to the rope yarns of the core, photograph 8.
5. The failure of these two strands created an instantaneous increase in load on the surviving 4 outer strands and the core.
6. The remainder of the rope failed and the rapid contraction of the rope resulted in the migration of the core assembly to the surface of the rope, filling the gap left by the failure of the first two strands.
7. This also resulted in the four strands remaining after the initial failure becoming melded together due to the higher energy involved in the final phase of the failure.
8. Red and blue contamination on the failure sample is likely to be paint from the vessel, transferred when the rope recoiled into it under high energy, following failure.



## 2.2 Visual examination and tensile testing of sample adjacent to fail zone

Table 4 shows the analysis of the rope construction.

**Table 4 Rope construction of rope sample ‘adjacent to fail zone’**

Rope Component	Construction
Core, one assembly	91 rope yarns, approx lin density 6300 Tex
	8 rope yarn, approx lin density 5067 Tex
Outer strand, x 6 assemblies	Outer layer: 9 monofilaments, diameter 4.2 mm
	9 rope yarns, approx lin density 5033 Tex
	Core : 378 textile yarns, approx lin density 217 Tex

**Table 1 Rope construction of rope in fail zone**

Rope Component	Construction
Core, one assembly	Outer layer: 21 rope yarns, approx lin density 11000 Tex
	Inner layer: 33 rope yarns, approx lin density 11000 Tex
	1 rope yarn, approx lin density 2300 Tex
Outer strand, x 6	Outer layer: 9 monofilaments, diameter 4.2 mm
	9 rope yarns, approx lin density 5033 Tex
	Inner layer: 20 rope yarns, approx lin density 2300 Tex
	5 rope yarns, approx lin density 4600 Tex
	<i>NB A second strand was analysed and the inner layer had a different construction, having 16 thin rope yarns and 4 thicker rope yarns</i>

When compared to table 1, reproduced above, it can be seen that there are differences in the way the rope has been constructed. Firstly, the core of the strands of the ‘adjacent’ sample is made up of textile yarns whilst for the fail zone rope, the inner layer of a strand is made up of rope yarns, these in turn being made of a cluster of textile yarns. Thus, for the ‘adjacent’ sample, the intermediate manufacturing process of producing rope yarns has not been conducted.

A second difference is in the core construction. Both rope samples have cores made from assemblies of rope yarns, but the number of rope yarns and their linear densities are different.

Summing up the total tex involved in each rope sample revealed that there was a small difference between them but this is probably due to inaccuracy in measurement of linear density. Thus there is no reason to believe that rope performance has been compromised by these differences in construction, but TTI can offer no explanation as to how they can appear in what should be the same rope.

A further difference is seen in the monofilament material. In the failed sample. It has a pink colour whilst in the ‘adjacent’ sample it is milky white.

Photograph 12 shows the adjacent zone, unraveled to reveal core rope yarns and photograph is an unraveled strand, showing the textile yarn assembly of the core.

**Photo 12 Unraveled ‘adjacent’ sample showing core rope yarns**



Severe damage to cluster of core rope yarns

Photograph 13 shows an unraveled strand, to reveal the textile yarns of the core assembly

**Photo 13 Unraveled strand showing core textile yarns**



Textile yarns of core assembly

Severe damage was found to some of the rope yarns in the core assembly, photograph 12, but with little evidence of similar damage to the outer strands in the that region. This is similar to damage found in the ‘failure’ sample, upstream of D, where damage to the core was not matched by comparable damage to the outer strands. However, in this case, the cause may have been a previous compression incident, not related to the rope failure. The outer strands, with the tough monofilaments, were able to withstand the compression, whilst the softer core rope yarns could not.

As the ‘failure’ rope and the ‘adjacent’ rope are of different constructions a comparison of their tensile performances is not going to be very useful. However, table 5 shows the results of the testing.

**Table 5 Breaking strengths of rope elements ‘adjacent to fail’**

Rope segment adjacent to fail					
			number	BL kN	Sum kN
<b>Core x 1</b>					
Rope yarn	6300 tex	good	26	3.872	100.672
		mild	13	3.263	42.419
		modest	24	2.125	51
		severe	25	0.912	22.8
		broken	3	0	0
Rope yarn	5067 tex		8	1.637	13.096
					229.987 kN
<b>Strand</b>					
<b>Outer layer</b>					
Monofilament			9	4.632	250.128
Rope yarn	5033 tex		9	0.296	15.984
<b>Core</b>					
Textile yarn	217 tex	good	125	0.134	100.5
		poor	253	0.078	118.404
					485.016 kN
<b>Grand sum</b>					<b>715.003 kN</b>

Because of the damage found to the rope elements, the elements were visually categorized by their degree of damage. A representative group of yarns from each category was tensile tested to calculate the average breaking load for the damage category. This value was then used to estimate the summed strengths for each category. The core rope yarns, 6300 tex, were separated into 5 categories; good, mild damage, modest damage, severe damage and broken. The strand core textile yarns were divided into just two categories, good and poor.

The summed breaking load for the ‘failure’ sample, upstream of D, is 784 kN. For the ‘adjacent’ sample it is 715 kN, a reduction of 9%. Thus, if the two samples are from the same mooring line, then the ‘adjacent’ sample is in a worse condition than the ‘failure’ sample.

By taking the best individual results of the tensile tests of table 5, it is possible to estimate the strength of a rope without the degrees of damage found. Table 6 shows the calculation.

**Table 6 Estimate of summed strengths of rope elements for rope in good condition**

Estimate of good condition rope					
			number	BL kN	Sum kN
<b>Core x1</b>					
Rope yarn	6300 tex		91	3.872	352.352
Rope yarn	5067 tex		8	2.000	16.000
					368.352 kN
<b>Strand x6</b>					
<b>Outer layer</b>					
monofilament			9	5.15	278.1
Rope yarn	5033 tex		9	2.000	108
<b>Core</b>					
Textile yarn	217 tex		378	0.134	303.912
					690.012 kN
<b>Grand sum</b>					<b>1058.364 kN</b>

If the realization Factor of 0.66 is applied to this summed strength, then the estimate of a 'good condition' rope strength is 698 kN. This compares well with the manufacturer's MBL of 687 kN and suggests that the rope as delivered to the customer was up to specification.

## 2.3 Visual examination of sample clear of fail zone

The structure of this sample appears to be the same as for the 'adjacent' sample, but both are different from the 'failure' sample.

Photograph 14 shows the sample 'clear of fail zone'. This was sampled about 20 metres from the fail zone.

**Photograph 14** 'Clear of fail zone' sample unraveled to expose core rope yarns



Broken small diameter rope yarns

contaminated and damaged large diameter rope yarns

**Photograph 15**  
**Strand from 'clear' sample, unraveled to core reveal textile yarns**



Damage to the rope yarns and textile yarns were seen, but it was thought not to be of much use for the present investigation to perform further tensile testing.

**Note:**

A further sample was sent to TTI for investigation, taken from the whole-rope tensile test mentioned in 2.1.1.3. An initial examination revealed a difference in the diameter of the monofilament used in strands of this rope as opposed to the samples already delivered to TTI. No further investigation was conducted.



### 3. CONCLUSIONS

Samples were examined visually and tested for their tensile properties. They were identified as follows:

One half of the failure  
Adjacent to fail zone [parted end]  
Clear of fail zone [parted end]

1. The rope sample from the failure zone of the line had been severely abraded, though the monofilaments of the outer strands had given some protection to the textile elements of the rope.
2. It is not possible to say from inspection of the failure, if this abrasion had occurred before the failure or was created during the failure. However, photographic evidence supplied by FBMC I show the fail zone to be about 20 metres from the pier bollard eye and it is thus likely that the damage was located between the vessel and the pier at the time of the accident. Thus, if this is correct, the abrasion damage could not have occurred at the time of the accident as the rope could not have been in contact with anything. Therefore the damage must have occurred at some time before the failure.
3. Either way it would have represented a weakened zone within the mooring line.
4. In the fail zone of the rope, it is estimated that the rope had a strength of about 75% of its new strength before the failure. However, tensile tests made on surviving elements of the rope where abrasion damage was very evident showed that they had a combined strength 19% less than the same elements within the fail zone where abrasion damage was less evident.
5. Therefore, from the observations of item 4 it is entirely possible that the abraded rope just before failure would have had a strength of less than 60% of its new MBL at about 400 kN.
6. From the visual inspection of the failure sample, it is possible to construct a sequence of events that occurred during the failure.
7. The two samples 'adjacent to' and 'clear of' the fail zone were of a different construction though appear to be of the same general specification.
8. Tensile testing of the 'adjacent' sample suggests an estimated residual strength of 69% when compared to the new MBL of the rope. It must be remembered that this was a rope of a different construction from the fail rope, however.
9. It has not been possible to say if the damage occurred during its deployment on this particular mooring or if it had occurred previously. However this accident highlights the necessity of regular monitoring of the condition of any rope by a responsible person on a vessel and that if there is any doubt as to the condition of the rope then it should be removed from service until a full inspection has been carried out. There are



several published sets of guidance and recommendations on the subject of rope inspection [references 1-5 ], but experience, common sense and an awareness of the consequences of not taking a cautious approach to rope condition will always reduce the chances of an accident.

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## References

1. "The selection, use, care, inspection and maintenance of non-metallic ropes and cords"  
United Kingdom Defence Standard DEF STAN 40-7/1.
2. "Mooring Equipment Guidelines", 2<sup>nd</sup> Edition, Oil Companies International Marine Forum 1997.
3. "Admiralty Manual of Seamanship' III 1983
4. "The selection, use and care of man-made-fibre ropes in Marine applications". British Standard BS 4128 1967 : Now lapsed, not replaced.
5. Cordage Manufacturers Institute, Recommendations for Rope Safety, 1984.



**Tension Technology International Ltd**

# **OPTIMOOR MOORING ANALYSIS**

**SIMULATION OF NORTHERN FAITH BREAK AWAY  
AT KOPER TERMINAL ON 4 JULY 2007**

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## **Executive Summary**

Simulating the conditions of the vessel moored at the berth for the key 20 minutes period from 1640 to 1700 demonstrated significant outward sway through aft yawing. The vessel yawed 35 m when stern line 3 had a reduced break load of 60% of new MBL as found in the TTI Report TTI-JN-2008-469 and the brakes on the winches had faded to 30 tf.

If line 3 had its new MBL this sway would have been 12.8 m. This demonstrates that the reduced break load of stern line 3 had a dramatic effect on the excursion of the vessel. This line broke within 3 to 4 minutes of the start of the simulations.

When all lines have their as new MBL - none of them break.

Fading of winch brakes was also an important issue as the outward sway doubled when the winch rendering threshold force was reduced from 42 to 30 tf.

Further the vessel side wind area was biased towards the vessel aft due to the position of the above main deck accommodation, control rooms etc causing the wind when blowing beam-on to create an outward sway yawing moment.

## **1. INTRODUCTION**

On 4<sup>th</sup> July 2007 the Northern Faith Containership when moored at Koper terminal, Slovenia broke a stern line during 45 knot winds. As a result the mooring became unsafe and the vessel stern yawed outwards causing the winches to render excessively. The vessel was out of control until port tugs came to assist and the vessel was remoored and made fast. During this incident one of the vessel's crew was seriously injured.

## **2. SCOPE OF WORK**

The object of the Optimoor analysis is to simulate the early part of the incident where one of the mooring lines broke and the excessive aft yawing that consequently occurred.

Four scenarios were modelled using dynamic analysis:

- (i) Assuming all ropes still had their certified minimum break loads (MBL) and all winches rendered at 60% of rope MBL.
- (ii) As (i) except the stern line that broke was assumed to have a reduced break load determined through failed rope investigation by TTI (Report: TTI-JN-2008-469)
- (iii) As (i) except the winches after initially rendering at 60% of rope MBL (42 tf) did subsequently render at a lower load (30 tf) due to brake fading.
- (iv) As (iii) but using the lower rope break load from (ii).

In dynamic mode of analysis, the short-term behaviour is governed by forces which change over seconds and minutes such as the varying wind gusts which may give increased loads over the mean wind speed due to the short term force and inertial effects.

The output data used for discussion and conclusions were maximum surge and sway, highest line loads, highest line slippage and time of line breaks where applicable.

### **3. DATA SOURCES**

Input data for Optimoor was rather scarce and sometimes contradictory. In the absence of necessary data, generic data from within TTI was used. For example, in the case of missing vessel data, estimations were made from similar vessels.

The input data came in e-mails from Captain Dirk Dietrich of the Federal Bureau of Maritime Casualty Investigation, Zoper terminal, Google Earth, TTI and various other internet sites.

### **4. BERTH DATA**

The berth data used by Optimoor is shown in Appendix A.

### **5. VESSEL DATA**

Optimoor assumes that the winch brakes retain their specified holding power in all circumstances. In practice, they will fade by an unknown factor as soon as they start slipping. This is a common defect in winch design, which the OCIMF mooring guidelines warn against. The effect is not serious so long as the brakes serve their primary purpose of levelling out inequalities in tensions of lines within a particular service. However, if brakes slip more than, say, about a metre, their capability is likely to be significantly degraded. As we are modelling an instance of winches rendering then two different vessel files were created representing an example of winch brake fade. One file assumes the winches render at 60% of rope MBL which is 42 tf and the other assumes that they render at 30 tf to represent fading.

The other two variants that go to make a total of four vessel files are the assumption that all the ropes were capable of their certified MBL and that one stern line had only 60% of its new MBL – 42 tf as indicated in the failed rope investigation report by TTI.

The vessel was only partly loaded at the stern and this combined with the above main deck accommodation, control rooms etc produced a longitudinal centre of area that is biased towards the stern of the vessel causing the wind when blowing beam-on to create a significant outward sway yawing moment.

The vessel data files used by Optimoor are shown in Appendix B.



## 6. MOORING ARRANGEMENT

The mooring arrangement is shown in figure 1.

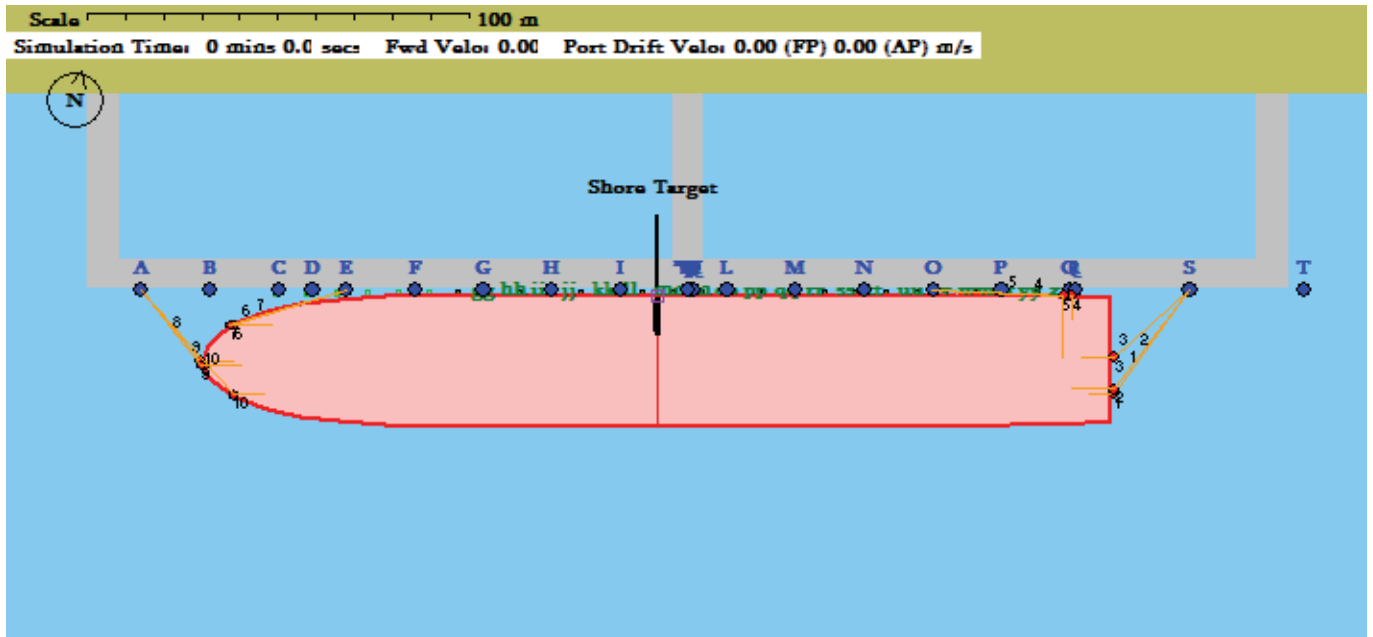


Figure 1: Mooring Arrangement

Two of the three head lines are 6-strand nylon wire laid construction of 70 tf MBL when new, the third is 8-strand plaited polypropylene of 79 tf MBL when new. One of each rope type is used for the forward and aft springs. The three stern lines like the head lines comprise two 6-strand nylons and one 8-strand polypropylene. The nylon lines use winches and the polypropylene lines use warping drums secured on bitts. The pre-tension aim for the winch ropes was 10 tf and for the bitt secured ropes zero tf. The brake limit for the winches was discussed in the Vessel Data – Section 5. The load at which the bitt secured lines slipped was set at 1 tf for all cases.

## 7. ENVIRONMENTAL DATA

The berth position is along the middle of the jetty as indicated in figure 2.



Figure 2: Koper Container Jetty

The surrounding area to Koper terminal is shown in figure 3.



Figure 3: Surrounding Area to Koper Terminal

Forty-five knot mean wind speeds were blowing on to the terminal from a North to North-Easterly direction. No wave, swell or current data was provided. As the terminal is in a sheltered bay and there are no significant fetches to generate wind blown waves then the only environment applied to the vessel was wind.

A mean wind direction of 20 degrees was chosen as representing the North to North-Easterly directions.

A Davenport Gusting Coefficient,  $k$  of 0.01 was used. Davenport (ref. 2) gives the following definitions for roughness parameter  $k$ :-

- 0.005 open unobstructed country e.g. prairie-type grassland, tundra, desert
- 0.015 to 0.020 country broken by low clustered obstructions such as trees and houses (below 10 metres)
- 0.050 heavily built-up urban centres with tall buildings

The appropriate  $k$  value for the surrounding area is not known, so 0.01 is an approximation. A coefficient of 0.01 is equal to a gusting ratio of approximately 1.4, which is the peak gust wind speed over the mean wind speed.

Figure 4 shows a diagram of the vessel being securely moored at 1640 through to it being controlled by assistant tugs at 1800. As no data was available for the tugs and the initial activity is the most important since this dictates the later excursion of the vessel then the dynamic analysis was conducted from 1640 to 1700.

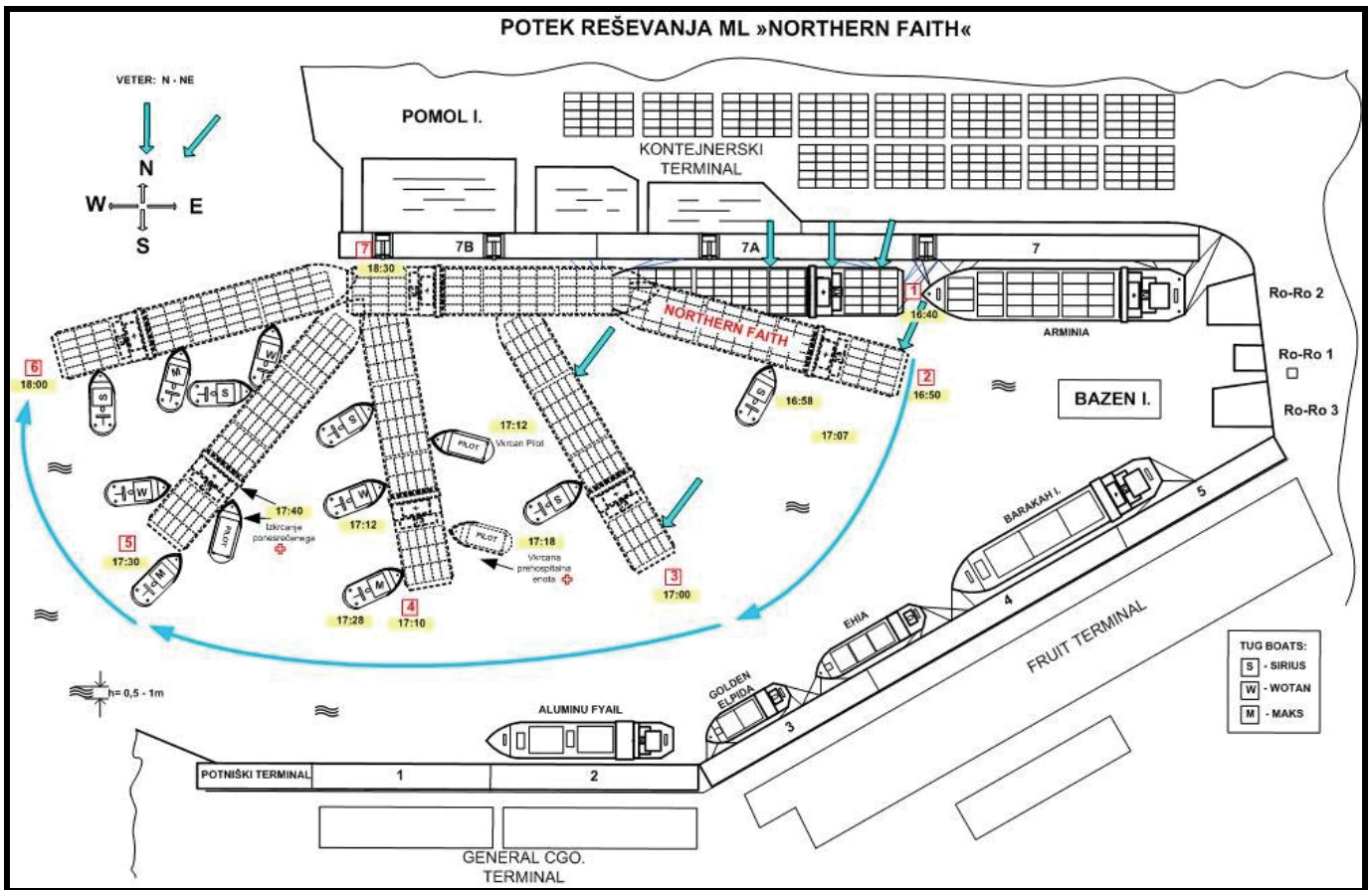


Figure 4: Northern Faith Movement

## 8. PROPOSED RUNS

Each of the four cases was run under the same conditions except for the differences shown in table 1 as follows:

Wind Speed:	45 knots
Direction:	20 degrees true
Davenport Gusting coefficient:	0.01
Duration:	20 minutes (1640 – 1700)
Current:	None
Waves/Swell:	None

**Table 1: Difference Between the Four Cases**

Case No.	Centre Aft Line Break Load	Winch Brake Limit (tf)
1	70 tf (MBL)	42 tf (60% of MBL)
2	60% of MBL	42 tf (60% of MBL)
3	70 tf (MBL)	30 tf (43% of MBL)
4	60% of MBL	30 tf (43% of MBL)

The line that broke during the mooring and 45 knot wind was the centre aft line, therefore Case 1 was run with that line having its new certified MBL of 70 tf and the winch brake limit set at 60% of this (42 tf).

Case 2 assumes the same winch brake limit but the break load of this rope was reduced to 42 tf consistent with the post-mortem estimation of this rope’s break load. The winch brake load remains at 42 tf. For practical reasons the winch brake load was adjusted to be just above the line break load otherwise the winch would render just below the line’s break load.

Case 3 assumes new certified rope MBL and that the winch brakes fade to 30 tf from initially and momentarily being 42 tf.

Case 4 assumes both the reduced rope break load and reduced winch brake load.

## 9. RESULTS

The dynamic analysis performs calculations at the rate of ten per second for these runs over the twenty minute duration. Snapshots were displayed every 10 seconds and from this data I have taken the most relevant at the 10 and 20 minute intervals. Key data is shown in table 2 and vessel positions relative to the berth are shown in figures 5 to 12.

**Table 2: Results Summary**

Case No.	Broken Lines	After 10 Minutes				After 20 Minutes			
		Surge (m)	Sway (m)	Highest Loaded Line	Maximum Line Slippage (m)	Surge (m)	Sway (m)	Highest Loaded Line	Maximum Line Slippage (m)
1	None	1.6 fwd	0.8 out	Fwd sprg (7-E) 36%	Stern (2-S) 5.3 m	2.4 fwd	5.6 out	Fwd sprg (7-E) 32%	Stern (2-S) 10.9 m
2	Stern Line 3 – S between 200 and 210 secs	6.8 fwd	13.4 out	Fwd sprg (7-E) 34%	Stern (2-S) 26.7 m	12.5 fwd	18.0 out	Aft sprg (4-O) 32%	Stern (2-S) 37.2 m
3	None	2.4 fwd	6.1 out	Fwd sprg (7-E) 19%	Stern (2-S) 13.2 m	5.5 fwd	12.8 out	Stern Line (1-S) 30%	Stern (2-S) 22.0 m
4	Stern Line 3 – S between 190 and 200 secs	25.7 fwd	24.7 out	Fwd sprg (7-E) 31%	Stern (2-S) 58.6 m	27.4 fwd	35.1 out	Stern Line (1-S) 40%	Stern (2-S) 74.1 m



## 9.1 Case 1

Case 1 has all ropes with new certified break load and winch brakes set at 42 tf. After 10 minutes there are no broken lines, acceptable vessel excursion, a highest loaded line of 36% MBL and maximum rendered line of 5.3 m. In the circumstances of a mean wind speed of 45 knots beam on blowing off the jetty this is an acceptable position. Figure 5 depicts this position.

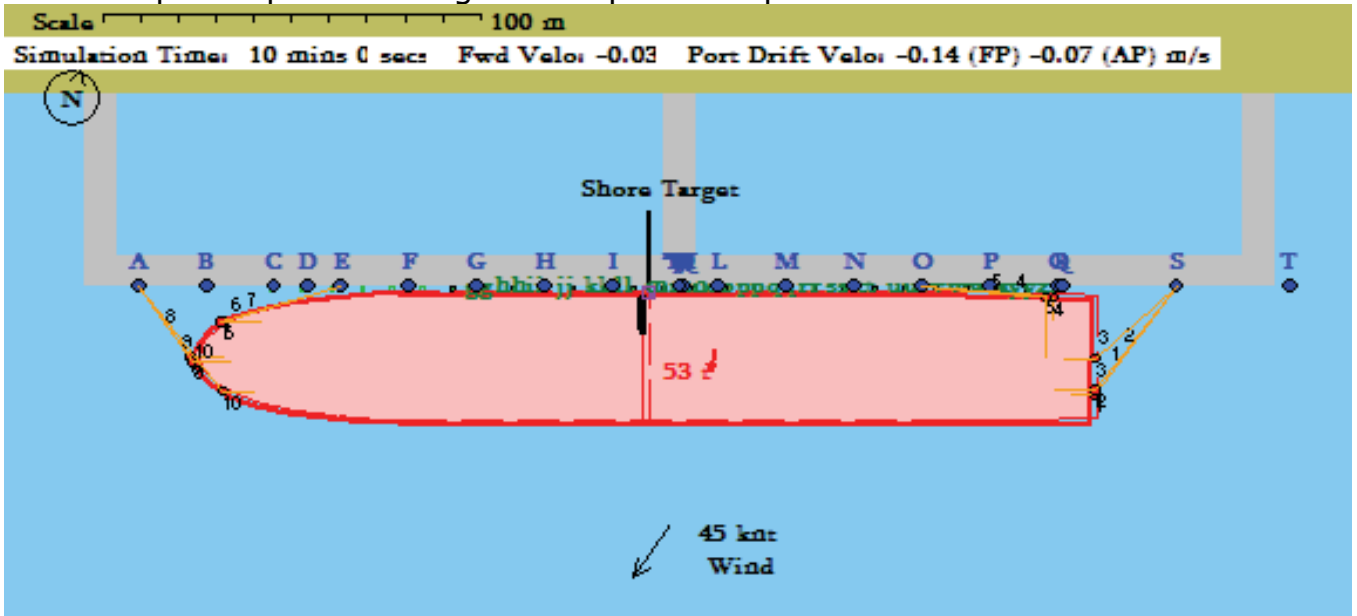


Figure 5: Case 1 After 10 Minutes

After 20 minutes, there are still no broken lines, vessel excursion is high at 2.4 m forward surge and 5.6 m outwards sway. Highest loaded line 32% MBL and maximum rendered line length is 10.9 m. Again in the circumstances of a mean wind speed of 45 knots beam on blowing off the jetty this maybe an expected position but the vessel is not out of control and does not bear resemblance to the Northern Faith's position after the same time interval depicted in figure 4.

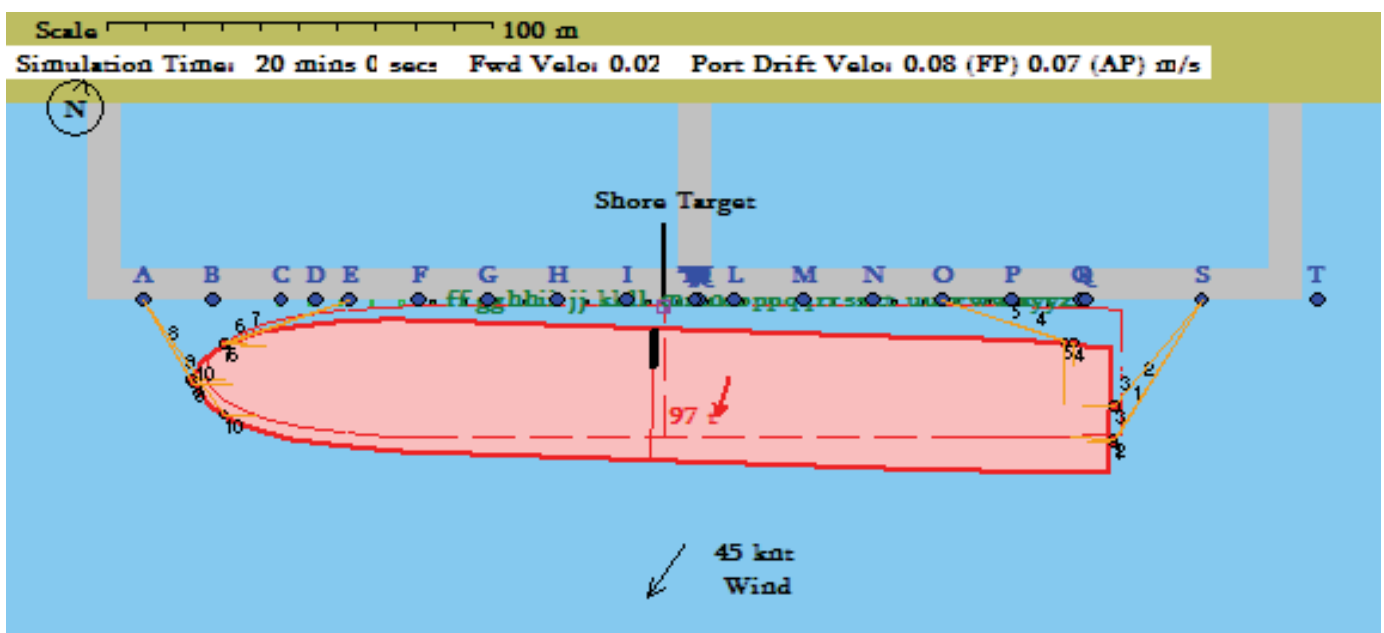


Figure 6: Case 1 After 20 Minutes

## 9.2 Case 2

Case 2 has all ropes with new certified break load and winch brakes set at 42 tf except line 3 which has a breaking load of 42 tf. Between 3 and 4 minutes line 3 has broken because the line loads were too high. After 10 minutes there is unacceptable vessel excursion of 6.8 m forward surge and 13.4 m outwards sway, a highest loaded line of 34% MBL and maximum rendered line of 26.7 m. In these circumstances of a mean wind speed of 45 knots beam on blowing off the jetty the vessel is no longer securely moored with only one winch stern line and one on bits. Figure 7 depicts this position and it is noted that it is not dissimilar to the actual displacement of the Northern faith shown in figure 4 after 10 minutes.

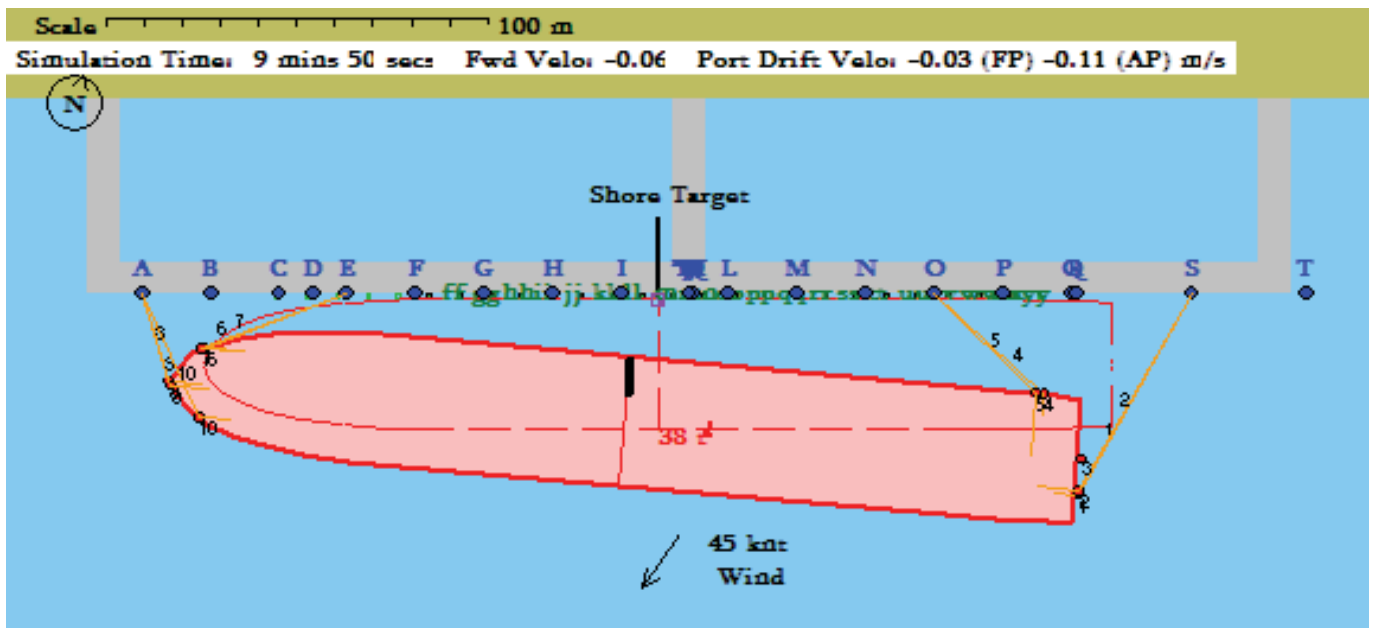


Figure 7: Case 2 After 10 Minutes

After 20 minutes things have got progressively worse with vessel excursion of 12.5 m forward surge and 18.0 m outwards sway, a highest loaded line of 32% MBL and maximum rendered line of 37.2 m. Figure 8 depicts this position. The actual displacement of the Northern Faith shown in figure 4 after 20 minutes is worse than this case 2 simulation after 20 minutes.

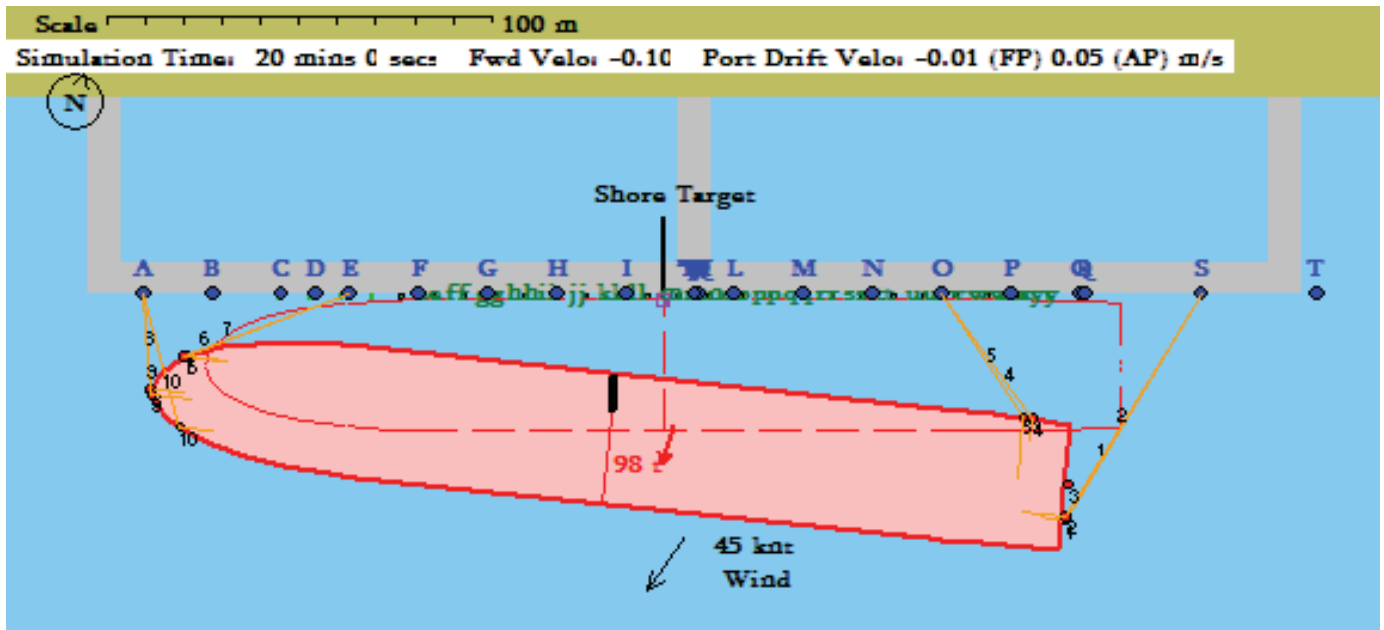


Figure 8: Case 2 After 20 Minutes

### 9.3 Case 3

Case 3 has all ropes with new certified break load but winch brakes set at 30 tf as an example of brake fade occurring as discussed earlier. After 10 minutes there are no broken lines, 2.4 m forward vessel surge and 6.1 m outwards sway, a highest loaded line of 19% MBL and maximum rendered line of 13.2 m. Case 3 is similar to Case 1 with the exception of lower winch load rendering and therefore the additional vessel excursion is consistent with this. Figure 9 depicts this position.

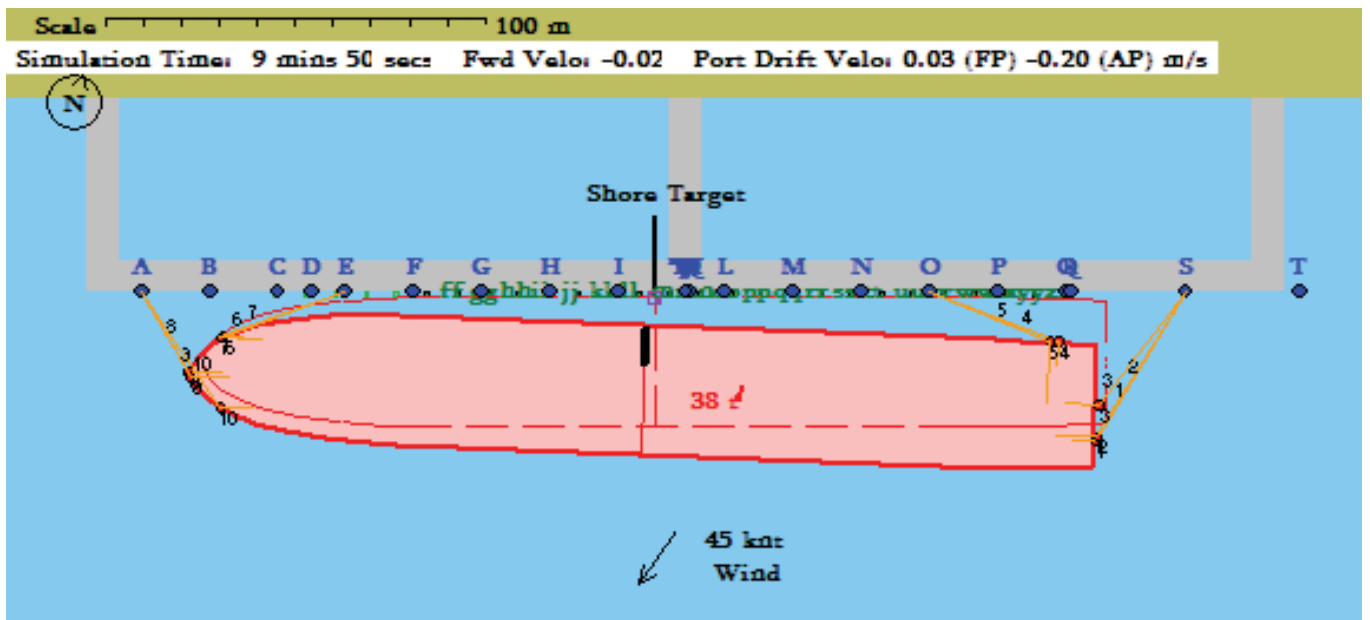


Figure 9: Case 3 After 10 Minutes

After 20 minutes there are still no broken lines but surge and outwards sway have increased to 5.5 and 12.8 m respectively, highest loaded line is 30% MBL and maximum rendered line of 22.0 m. Again with Case 3 being similar to Case 1 bar

the reduced rendering load the additional vessel excursion is consistent with this but the vessel displacement is not as severe as that experienced by the Northern Faith from the figure 4 diagram.

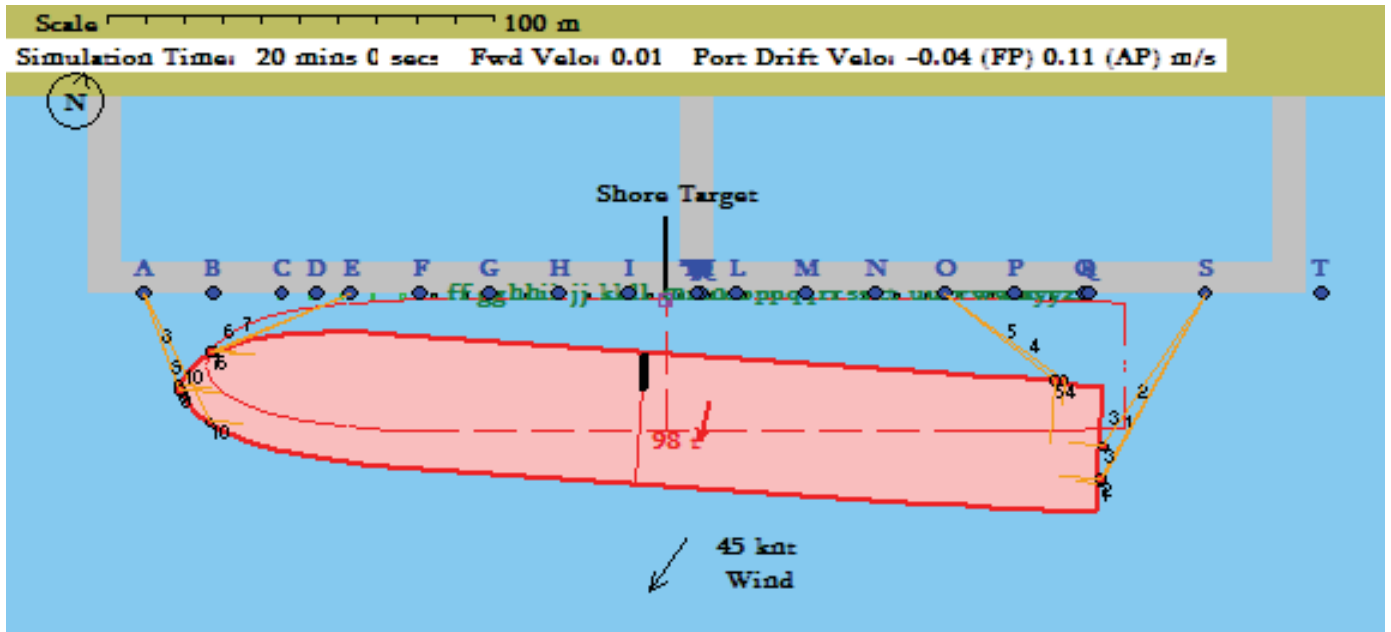


Figure 10: Case 3 After 20 Minutes

## 9.4 Case 4

Case 4 has all ropes with new certified break load except line 3 which has a breaking load of 42 tf and winch brakes set at 30 tf. Between 3 and 4 minutes line 3 has broken because the line loads were too high. After 10 minutes there is unacceptable vessel excursion of 25.7 m forward surge and 24.7 m outwards sway, a highest loaded line of 31% MBL and maximum rendered line of 58.6 m. Clearly a desperate situation and the worst of the four cases investigated at the 10 minute time interval and very similar to the Northern Faith graphic at the same time interval (see figure 4).

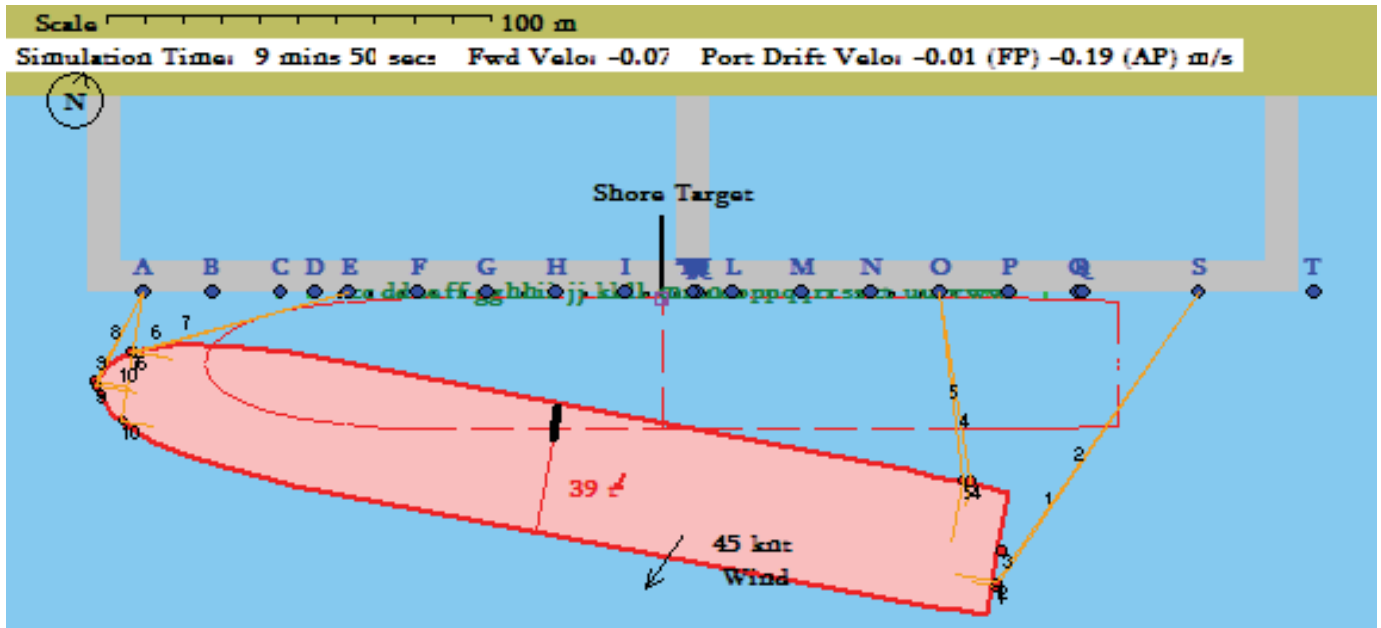


Figure 11: Case 4 After 10 Minutes

After 20 minutes things have got progressively worse with vessel excursion of 27.4 m forward surge and 35.1 m outwards sway, a highest loaded line of 40% MBL and maximum rendered line of 74.1 m. Figure 12 depicts this position. The actual displacement of the Northern Faith (fig. 4) after 20 minutes is similar to this Case 4 after 20 minutes.

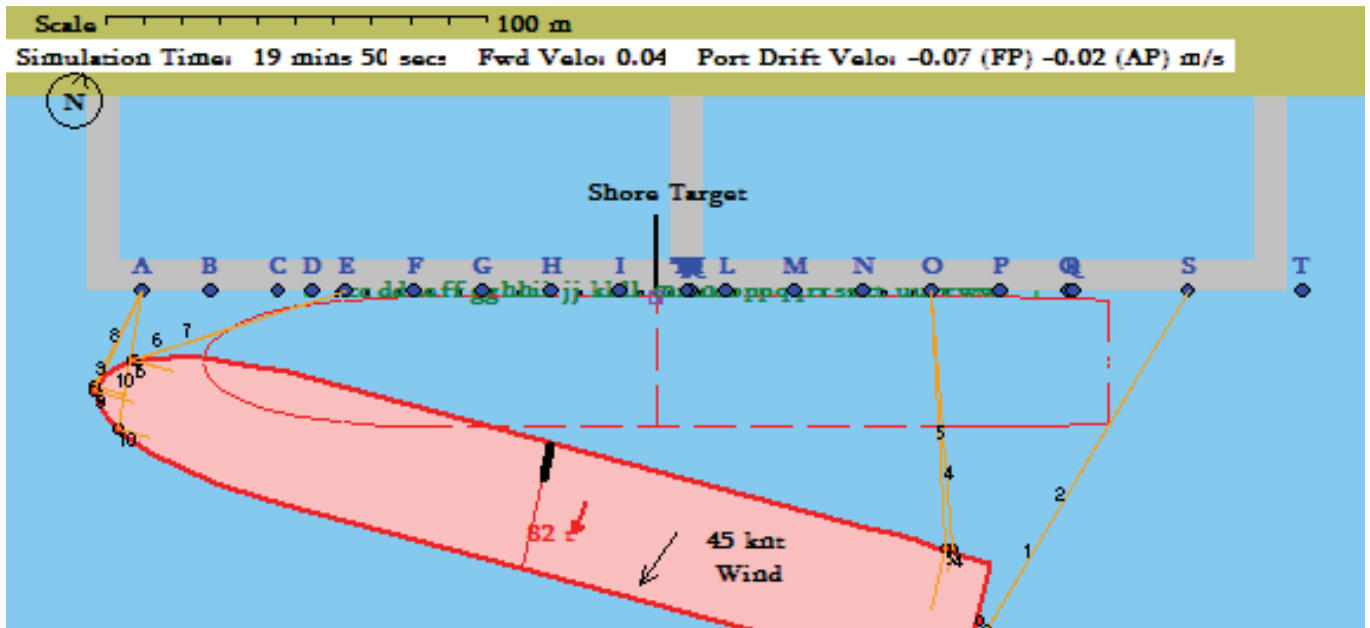


Figure 12: Case 4 After 20 Minutes

## 10. DISCUSSION

The case that most closely represents the movement of the Northern Faith is Case 4 where stern line number 3 has a reduced break load of 42 tf consistent with post-mortem analysis on this rope by TTI and where the winch brakes fade to 30 tf after initially having a rendering load threshold of 42 tf.

Comparing Cases 1 and 2 with 3 and 4 it is shown that reducing the load at which the rope renders from the winch has a bigger effect on vessel excursion than the reduction in one of the stern lines from 70 to 42 tf.

If stern line 3 had its new certified break load then with winches rendering at either 42 or 30 tf (Cases 1 and 3) then after 20 minutes the vessel would not have swayed outwards to the point of being out of control although tugs would still have being required to keep the vessel close to the berth.

No current, waves or swell were included in this analysis. Such data may have had an affect on the results.



## **11. REFERENCES**

1. OPTIMOOR, mooring analyses software for tankers and gas carriers by Tension Technology International, version 5.3.0, Feb 6, 2008
2. Davenport A.G., The spectrum of horizontal gustiness near the ground in high winds, Dept of Civil Engineering, Univ. Bristol, 1960.

**APPENDIX A.                      BERTH DATA**

Optimoor Jobs\Northern Faith Accident\Case Files\Koper.bth)  
 Units in m & tonnes  
 Solid Pier Shields wind

Permissible Surge Excursion Fwd/Aft: ± 1.50  
 Permissible Sway Excursion Port/Stbd: ± 1.50  
 Dist of Berth Target to Right of Origin: -8.0  
 Wind Speed Specified at Height: 10.0  
 Current Specified at Depth: mean

Hook/ Bollard	X-Dist to Origin	Dist to Fender Line	Ht above Berth
A	-143.5	1.5	0.0
B	-125.4	1.5	0.0
C	-107.5	1.5	0.0
D	-98.6	1.5	0.0
E	-89.7	1.5	0.0
F	-71.6	1.5	0.0
G	-53.7	1.5	0.0
H	-35.7	1.5	0.0
I	-17.7	1.5	0.0
J	0.0	1.5	0.0
K	1.3	1.5	0.0
L	10.3	1.5	0.0
M	28.3	1.5	0.0
N	46.4	1.5	0.0
O	64.5	1.5	0.0
P	82.4	1.5	0.0
Q	100.4	1.5	0.0
R	101.7	1.5	0.0
S	131.8	1.5	0.0
T	161.8	1.5	0.0
U	0.0	1.5	0.0
V	0.0	1.5	0.0
W	0.0	1.5	0.0
X	0.0	1.5	0.0
Y	0.0	1.5	0.0
Z	0.0	1.5	0.0
*A	0.0	1.5	0.0
*B	0.0	1.5	0.0
*C	0.0	1.5	0.0
*D	0.0	1.5	0.0
*E	0.0	1.5	0.0
*F	0.0	1.5	0.0
*G	0.0	1.5	0.0
*H	0.0	1.5	0.0
*I	0.0	1.5	0.0
*J	0.0	1.5	0.0
*K	0.0	1.5	0.0
*L	0.0	1.5	0.0
*M	0.0	1.5	0.0
*N	0.0	1.5	0.0
*O	0.0	1.5	0.0
*P	0.0	1.5	0.0
*Q	0.0	1.5	0.0
*R	0.0	1.5	0.0
*S	0.0	1.5	0.0
*T	0.0	1.5	0.0
*U	0.0	1.5	0.0
*V	0.0	1.5	0.0
*W	0.0	1.5	0.0
*X	0.0	1.5	0.0
*Y	0.0	1.5	0.0
*Z	0.0	1.5	0.0

Fender	X-Dist to Origin	Ht above Datum	width Along Side	Face Contact Area (m <sup>2</sup> )
aa	-108.0	7.5	1.0	1.8
bb	-100.0	7.5	1.0	1.8
cc	-92.0	7.5	1.0	1.8

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dd	-84.0	7.5	1.0	1.8
ee	-76.0	7.5	1.0	1.8
ff	-68.0	7.5	1.0	1.8
gg	-60.0	7.5	1.0	1.8
hh	-52.0	7.5	1.0	1.8
ii	-44.0	7.5	1.0	1.8
jj	-36.0	7.5	1.0	1.8
kk	-28.0	7.5	1.0	1.8
ll	-20.0	7.5	1.0	1.8
mm	-12.0	7.5	1.0	1.8
nn	-4.0	7.5	1.0	1.8
oo	4.0	7.5	1.0	1.8
pp	12.0	7.5	1.0	1.8
qq	20.0	7.5	1.0	1.8
rr	28.0	7.5	1.0	1.8
ss	36.0	7.5	1.0	1.8
tt	44.0	7.5	1.0	1.8
uu	52.0	7.5	1.0	1.8
vv	60.0	7.5	1.0	1.8
ww	68.0	7.5	1.0	1.8
xx	76.0	7.5	1.0	1.8
yy	84.0	7.5	1.0	1.8
zz	92.0	7.5	1.0	1.8

Fender Load-Compression Data

aa	7	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
bb	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
cc	200	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
dd	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
ee	200	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
ff	200	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
gg	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
hh	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
ii	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
jj	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
kk	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
ll	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
mm	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
nn	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
oo	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
pp	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
qq	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
rr	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m

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ss	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
tt	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
uu	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
vv	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
ww	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
xx	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
yy	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m
zz	0	13	20	27	34	40	47	54	61	67 tonnes
	0.02	0.08	0.21	0.30	0.38	0.44	0.50	0.54	0.58	0.60 m

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APPENDIX B. VESSEL DATA

**VESSEL DATA CASE 1**

**Vessel Data for Northern Faith**

(file G:\TTI\Optimoor Jobs\Northern Faith Accident\Case Files\Northern Faith - Line new BL - 42 t  
brake.vsl)

Units in m, mm, & tonnes  
Longitudinal datum at Midship

LBP: 225.2  
Breadth: 32.2  
Depth: 19.0  
Target: 0.0 fwd from midship and 0.0 above deck at side  
End-on projected windage area: 794 above deck level  
Side projected windage area: 1784 above deck level  
Longitudinal Centroid: -0.5 fwd midship  
Fendering possible from: 0.480 LBP aft of midship  
to: 0.257 LBP fwd of midship  
Current drag data based on: OCIMF (Conventional Bow)  
Wind drag data based on: Container Ship (L/B = 6.4)  
Wave motion data based on: Post-Panamax Containership  
Roll Damping Coeff: 5% of Critical  
Cb: 0.55

Flatside Contour

x-dist -108.0 57.8  
Depth 14.3 14.3

Line No.	Fair- Lead X	Fair- Lead Y	Ht on Deck	Dist to Winch	Brake Limit	Pre-Tension	Line Size-Type-BL	Tail Segment-1 Lgth-Size-Type-BL
1	-120.0	-8.0	0.5	7.0	42	10	60 ATw 70	
2	-120.0	-7.0	0.5	11.5	1	0	64 ppw 79	
3	-120.0	0.9	0.5	9.0	42	10	60 ATw 70	
4	-108.9	16.1	0.5	6.1	42	10	60 ATw 70	
5	-106.7	16.1	0.5	15.8	1	0	64 ppw 79	
6	111.2	8.9	-2.5	10.7	1	0	64 ppw 79	
7	112.0	8.8	-2.5	9.2	42	10	60 ATw 70	
8	120.0	0.0	-2.5	9.2	42	10	60 ATw 70	
9	119.6	-1.1	-2.5	11.0	1	0	64 ppw 79	
10	111.3	-8.4	-2.5	8.8	42	10	60 ATw 70	

Codes for Types of Line:  
pp: polypropylene dry (broken-in)  
ppw: polypropylene wet (broken-in)  
ATw: Atlas 6-Strand Nylon Multi/Mono

**VESSEL DATA CASE 2**

**Vessel Data for Northern Faith**

(file G:\TTI\Optimoor Jobs\Northern Faith Accident\Case Files\Northern Faith - Line new BL - 42 t  
brake.vsl)

Units in m, mm, & tonnes  
Longitudinal datum at Midship

LBP: 225.2  
Breadth: 32.2  
Depth: 19.0  
Target: 0.0 fwd from midship and 0.0 above deck at side  
End-on projected windage area: 794 above deck level  
Side projected windage area: 1784 above deck level  
Longitudinal centroid: -0.5 fwd midship  
Fendering possible from: 0.480 LBP aft of midship  
to: 0.257 LBP fwd of midship  
Current drag data based on: OCIMF (Conventional Bow)  
wind drag data based on: Container Ship (L/B = 6.4)  
Wave motion data based on: Post-Panamax Containership  
Roll Damping Coeff: 5% of Critical  
Cb: 0.55

Flatside Contour

X-dist -108.0 57.8  
Depth 14.3 14.3

Line No.	Fair- Lead X	Fair- Lead Y	Ht on Deck	Dist to Winch	Brake Limit	Pre-Tension	Line Size-Type-BL	Tail Segment-1 Lgth-Size-Type-BL
1	-120.0	-8.0	0.5	7.0	42	10	60 ATw 70	
2	-120.0	-7.0	0.5	11.5	1	0	64 ppw 79	
3	-120.0	0.9	0.5	9.0	42	10	60 ATw 41	
4	-108.9	16.1	0.5	6.1	42	10	60 ATw 70	
5	-106.7	16.1	0.5	15.8	1	0	64 ppw 79	
6	111.2	8.9	-2.5	10.7	1	0	64 ppw 79	
7	112.0	8.8	-2.5	9.2	42	10	60 ATw 70	
8	120.0	0.0	-2.5	9.2	42	10	60 ATw 70	
9	119.6	-1.1	-2.5	11.0	1	0	64 ppw 79	
10	111.3	-8.4	-2.5	8.8	42	10	60 ATw 70	

Codes for Types of Line:  
pp: polypropylene dry (broken-in)  
ppw: polypropylene wet (broken-in)  
ATw: Atlas 6-Strand Nylon Multi/Mono



**VESSEL DATA CASE 3**

**Vessel Data for Northern Faith**

(file G:\TTI\Optimoor Jobs\Northern Faith Accident\Case Files\Northern Faith - Line 60% BL - 30 t  
brake.vsl)

Units in m, mm, & tonnes  
Longitudinal datum at Midship

LBP: 225.2  
Breadth: 32.2  
Depth: 19.0  
Target: 0.0 fwd from midship and 0.0 above deck at side  
End-on projected windage area: 794 above deck level  
Side projected windage area: 1784 above deck level  
Longitudinal Centroid: -0.5 fwd midship  
Fendering possible from: 0.480 LBP aft of midship  
to: 0.257 LBP fwd of midship  
Current drag data based on: OCIMF (Conventional Bow)  
Wind drag data based on: Container Ship (L/B = 6.4)  
Wave motion data based on: Post-Panamax Containership  
Roll Damping Coeff: 5% of Critical  
Cb: 0.55

Flatside Contour

X-dist -108.0 57.8  
Depth 14.3 14.3

Line No.	Fair- Lead X	Fair- Lead Y	Ht on Deck	Dist to Winch	Brake Limit	Pre-Tension	Line Size-Type-BL	Tail Segment-1 Lgth-Size-Type-BL
1	-120.0	-8.0	0.5	7.0	30	10	60 ATw 70	
2	-120.0	-7.0	0.5	11.5	1	0	64 ppw 79	
3	-120.0	0.9	0.5	9.0	30	10	60 ATw 70	
4	-108.9	16.1	0.5	6.1	30	10	60 ATw 70	
5	-106.7	16.1	0.5	15.8	1	0	64 ppw 79	
6	111.2	8.9	-2.5	10.7	1	0	64 ppw 79	
7	112.0	8.8	-2.5	9.2	30	10	60 ATw 70	
8	120.0	0.0	-2.5	9.2	30	10	60 ATw 70	
9	119.6	-1.1	-2.5	11.0	1	0	64 ppw 79	
10	111.3	-8.4	-2.5	8.8	30	10	60 ATw 70	

Codes for Types of Line:

pp: polypropylene dry (broken-in)  
ppw: polypropylene wet (broken-in)  
ATw: Atlas 6-Strand Nylon Multi/Mono

**VESSEL DATA CASE 4**

**Vessel Data for Northern Faith**

(file G:\TTI\Optimoor Jobs\Northern Faith Accident\Case Files\Northern Faith - Line 60% BL - 30 t  
brake.vsl)

Units in m, mm, & tonnes  
Longitudinal datum at Midship

LBP: 225.2  
Breadth: 32.2  
Depth: 19.0  
Target: 0.0 fwd from midship and 0.0 above deck at side  
End-on projected windage area: 794 above deck level  
Side projected windage area: 1784 above deck level  
Longitudinal centroid: -0.5 fwd midship  
Fendering possible from: 0.480 LBP aft of midship  
to: 0.257 LBP fwd of midship  
Current drag data based on: OCIMF (Conventional Bow)  
wind drag data based on: Container Ship (L/B = 6.4)  
Wave motion data based on: Post-Panamax Containership  
Roll Damping Coeff: 5% of Critical  
Cb: 0.55

Flatside Contour

X-dist -108.0 57.8  
Depth 14.3 14.3

Line No.	Fair- Lead X	Fair- Lead Y	Ht on Deck	Dist to Winch	Brake Limit	Pre-Tension	Line Size-Type-BL	Tail Segment-1 Lgth-Size-Type-BL
1	-120.0	-8.0	0.5	7.0	30	10	60 ATw 70	
2	-120.0	-7.0	0.5	11.5	1	0	64 ppw 79	
3	-120.0	0.9	0.5	9.0	42	10	60 ATw 41	
4	-108.9	16.1	0.5	6.1	30	10	60 ATw 70	
5	-106.7	16.1	0.5	15.8	1	0	64 ppw 79	
6	111.2	8.9	-2.5	10.7	1	0	64 ppw 79	
7	112.0	8.8	-2.5	9.2	30	10	60 ATw 70	
8	120.0	0.0	-2.5	9.2	30	10	60 ATw 70	
9	119.6	-1.1	-2.5	11.0	1	0	64 ppw 79	
10	111.3	-8.4	-2.5	8.8	30	10	60 ATw 70	

Codes for Types of Line:  
pp: polypropylene dry (broken-in)  
ppw: polypropylene wet (broken-in)  
ATw: Atlas 6-Strand Nylon Multi/Mono