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

Investigation Report 422/11

Serious Marine Casualty

Accident involving a person on board

the tug

TAUCHER O. WULF 5

in Cuxhaven

on 28 September 2011

15 August 2013

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

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

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 19(4) SUG.

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

Issued by:
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1 Summary

At 0612[1] on 28 September 2011, the aft towing connection parted when a tug, TAUCHER O. WULF 5, was assisting a car carrier, BALTIC BREEZE, while she was making fast at Europakai 2 in Cuxhaven. A deckhand on the aft section in the area of the superstructure was struck by the parted line and suffered severe injuries to his legs. The casualty was given initial medical aid immediately after and transferred to the Hafenkaje tug station for transportation to hospital. The port towing gear, consisting of a three-part 50 m long towing connection and a gob rope, was made ready on the previous evening. It was (supposedly) configured for a breaking load of 50 t. The manoeuvre was discussed with the crew beforehand and particular hazards, as well as the use of personal protective equipment with protective jacket, were pointed out. The towing gear was visually inspected.

[1] Unless stated otherwise all times shown in this report are local = Central European Summer Time = UTC + 2

2 SHIP PARTICULARS

2.1 Photo

Figure 1: Photo of the vessel

2.2 Particulars

Name of vessel:	TAUCHER O. WULF 5
Type of vessel:	Tug
Nationality/Flag:	Germany
Port of registry:	Rostock
IMO number:	6907169
Call sign:	DGDA
Owner:	Otto Wulf GmbH & Co. KG
Year built:	1968
Shipyard/Yard number:	Mützelfeldtwerft/179
Classification society:	Germanischer Lloyd
Length overall:	29.60 m
Breadth overall:	7.92 m
Gross tonnage:	154
Deadweight:	99 t
Draught (max.):	3.20 m
Engine rating:	1,491 kW
Main engine:	Deutz SBV 8 M 545
(Service) Speed:	12 kts

Bollard pull	25 t
Minimum safe manning:	5

2.3 Voyage particulars

Port of departure:	Cuxhaven
Port of call:	Cuxhaven
Type of voyage:	Merchant shipping National
Cargo information:	None
Manning:	5
Draught at time of accident:	3.20 m
Pilot on board:	No
Number of passengers:	None

2.4 Marine casualty or incident information

Type of marine casualty/incident:	Serious marine casualty, accident involving a person
Date, time:	28/09/2011, 0612
Location:	Cuxhaven Europakai
Latitude/Longitude:	φ 53°51.7’ N 008° 43.5' E
Ship operation and voyage segment:	Making fast
Place on board:	Aft section, port side superstructure
Human factors:	Technical fault
Consequences (for people, vessel, cargo, the environment and other):	One casualty None

Excerpt from Nautical Chart 44, BSH map of Cuxhaven

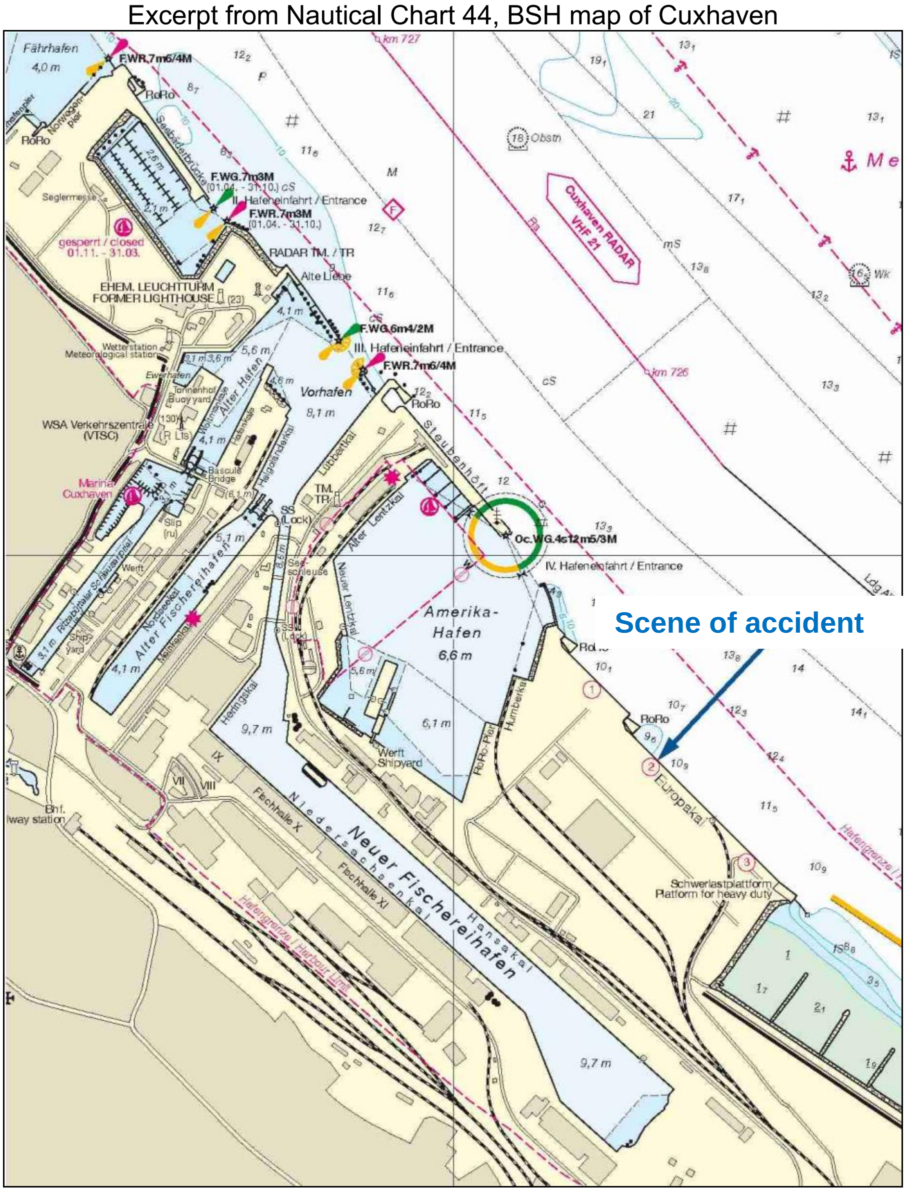

Figure 2: Nautical chart

2.5 Shore authority involvement and emergency response

Agencies involved:	Vessel Traffic Service
Resources used:	Ambulance, emergency physician
Action taken:	Medical treatment on board
Results achieved:	Transport to hospital

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident

At 0612 on 28 September 2011, the towing connection parted when an aft tug, TAUCHER O. WULF 5, was assisting a car carrier, BALTIC BREEZE, while she was making fast at Europakai 2 in Cuxhaven. A deckhand on the port side of the aft section in the area of the superstructure was struck by the parted line and suffered severe injuries to his legs. The port towing gear, consisting of a three-part 50 m long towing connection and a gob rope, was made ready on the previous evening. It was (supposedly) configured for a breaking load of 50 t. The crew was informed about the forthcoming work. In the process, the manoeuvre was discussed and particular hazards when tasked as an assisting tug, as well as the use of personal protective equipment with protective jacket, were pointed out. The towing gear was visually inspected. No deficiencies were discovered.

The tug and her five-member crew were made ready to sail at 0510 and cast off from the berth in the outer harbour at 0530 on the day of the accident. She sailed towards the BALTIC BREEZE, made her towline fast aft on the port side in accordance with the instructions of the pilot and accompanied the carrier. At the berth, the stern of the BALTIC BREEZE was to be kept clear of the quay. To achieve that, it was necessary to straighten the tug by hauling the towing connection tight and pull the car carrier away from the quay. The skipper steered the tug from the starboard control position. The watchkeeping officer was responsible for providing continuous updates on the condition of the towing connection. The engine room was manned and two deckhands were on deck at the aft section in the area of the superstructure (see Fig. 3). They were not visible from the bridge (see Fig. 4). Everything seemed to be going well when at 0612 the stretcher, about 20 m long, parted unexpectedly and struck a deckhand just in front of the port side companionway. The second deckhand was able to jump on to the port side companionway in time. The deckhand who was struck fell forward. In the process, his helmet came off. He was placed on his back and his work jacket opened to make it easier for him to breath. Following that, the bridge crew was informed of the accident and Vessel Traffic Service Cuxhaven notified. An ambulance was ordered to the outer harbour and first aid was rendered on deck by the engineer officer and the deckhand. The casualty was responsive and his feet were twisted. At 0620, the outer harbour was reached and medical treatment commenced. The casualty was then taken to a hospital.

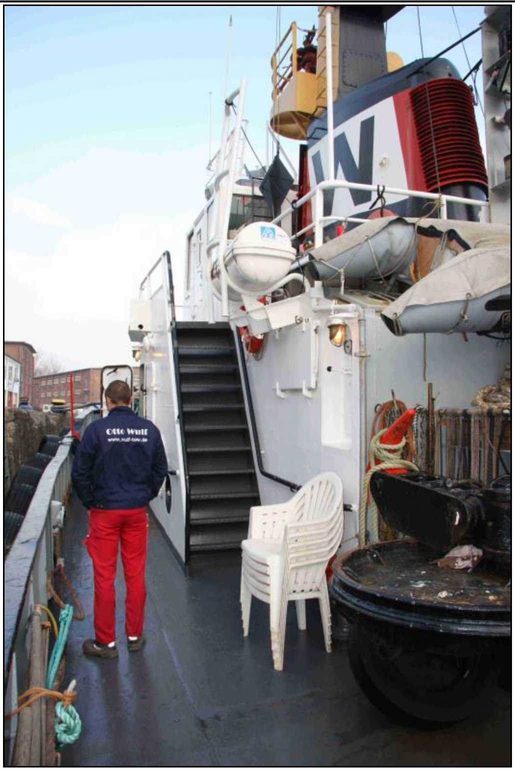

Figure 3: Port side companionway

Figure 4: Bridge, starboard aft

3.2 Investigation

The BSU surveyed the TAUCHER O. WULF 5 on 25 October 2011. The accident was reconstructed and the towing connection explained (see Fig. 5). According to the crew, its length was 50 m, it was configured for a breaking load of 50 t and guided by the towing hook and a gob rope, which was controlled aft by means of a winch and attached to the towline via a roller (see Fig. 6) using a round pin anchor shackle, to the towing hook (see Fig. 7). The towline consisted of three parts: 10 m bridle to seagoing ship, 28 mm cable (62 t), connected with round pin anchor shackle (35 t), 20 m stretcher (supposedly) polypropylene (64 mm, 49.8 t), parted towards the middle, 20 m UHMWPE[2] rope (84.3 t), mated eye to eye, as well as a 28 mm tricing cable (62 t), which was attached to the towline using a round pin anchor shackle and controlled by means of a tricing winch. The tug assisted at the stern at an angle of approximately 90° and was reportedly straightening herself when the stretcher parted.

[2] Ultra high molecular weight polyethylene (Dyneema, Spectra)

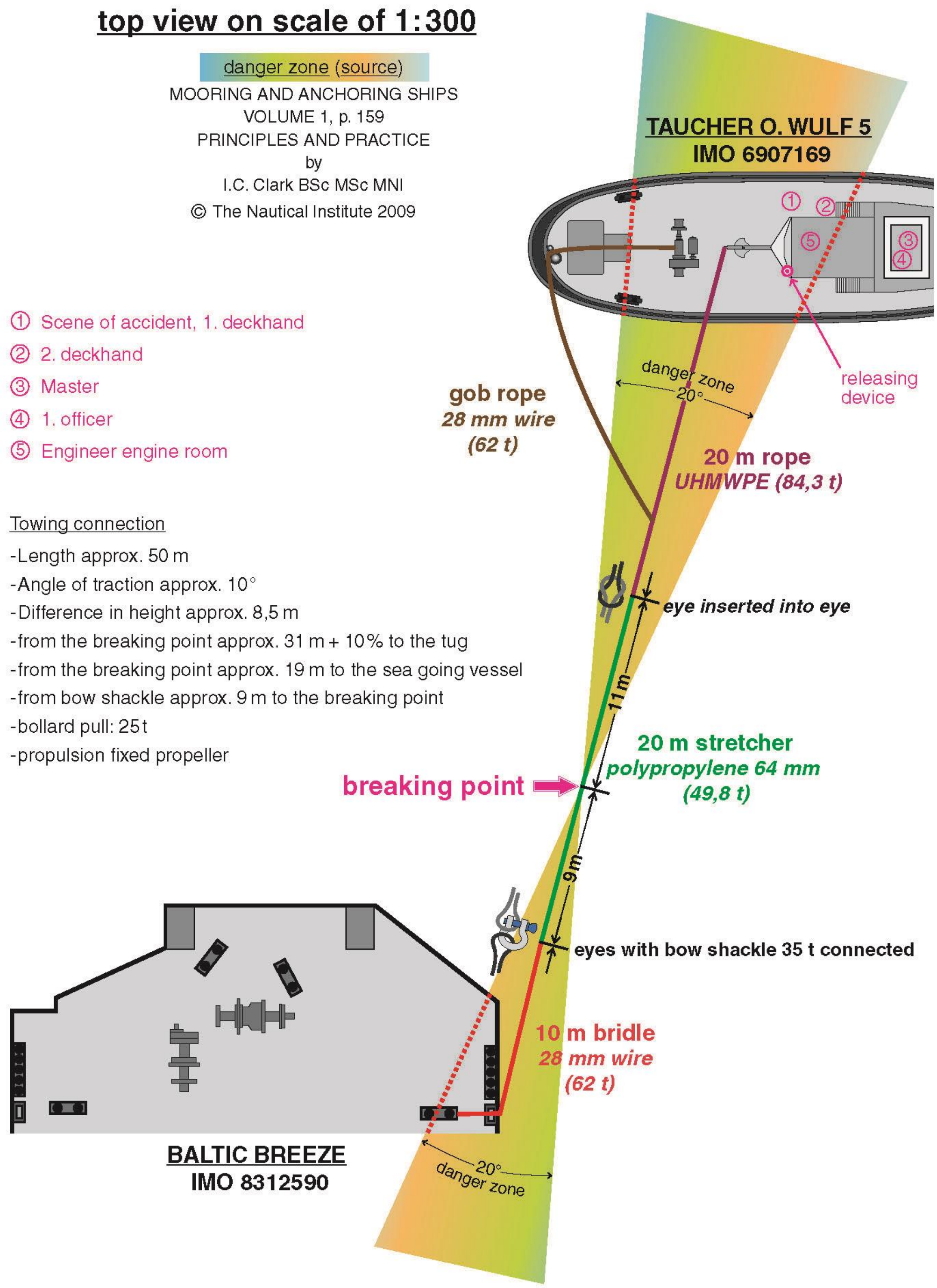

Figure 5: Towing connection, drawn in accordance with statements and certificates (Figures reproduced with kind permission from Tug Use in Port, published by the Nautical Institute, written by Henk Hensen FNI)

Figure 6: Gob rope roller

Figure 7: Towing hook and angle

As can be seen in Fig. 5 (towing connection), the deckhands were within the snap back zone. While one of the deckhands managed to jump on to the port side companionway, the other was struck by the towline as it snapped back. The casualty was experienced and has worked on the tug since March 2000. His safety area by the companionways has reportedly already been tried and tested. The only other possible safety area on the deck of an aft tug would be the forward edge of the bridge (see Fig. 9). However, the towing connection cannot be controlled from there, e.g. to trigger the slip device (see Fig. 8) with a lever. A second set of towing gear is available for the event of the towing connection breaking. A parted towline is unpredictable in that when it snaps back it moves faster than the speed of sound. In the present case, this means that the accident had already happened before the bang was heard on the aft deck and the deckhands could not move to safety if they were still within the danger area. The best protection is located in the superstructure. At the same time, it should be noted that there is room for only two people on the bridge while towing because the entire stern is only controllable by continuously moving backward and forward and more people would interfere with each other. The funnel obstructs the view astern due to a large blind spot. In this situation, the skipper usually steers the tug and the chief officer monitors the towing connection. The procedures of the owner's quality management system do not define safety areas for the crew. During the task, the doors must be closed and crew members wear protective clothing.

Figure 8: Slip device

Figure 9: Possible safety area

The towing gear used on board was documented and certificates were present. However, in the cable-tier it was only possible to correlate the material used to a certain degree. In some cases, the synthetic lines from an ordered cable length of 220 m are cut to the correct length and spliced on board. To connect synthetic lines, the eyes (line ends) are mated using cow hitches (square knot). Round pin anchor shackles[3] are used for connecting cable and synthetic material. So-called fairlead shackles[4] equipped with a roller are not used.

[3] A round pin anchor shackle is shaped like an eye and locked using a pin.
[4] In the case of a fairlead shackle, the synthetic rope is guided over a roller on a pin without any appreciable build-up of friction that could damage the eye.

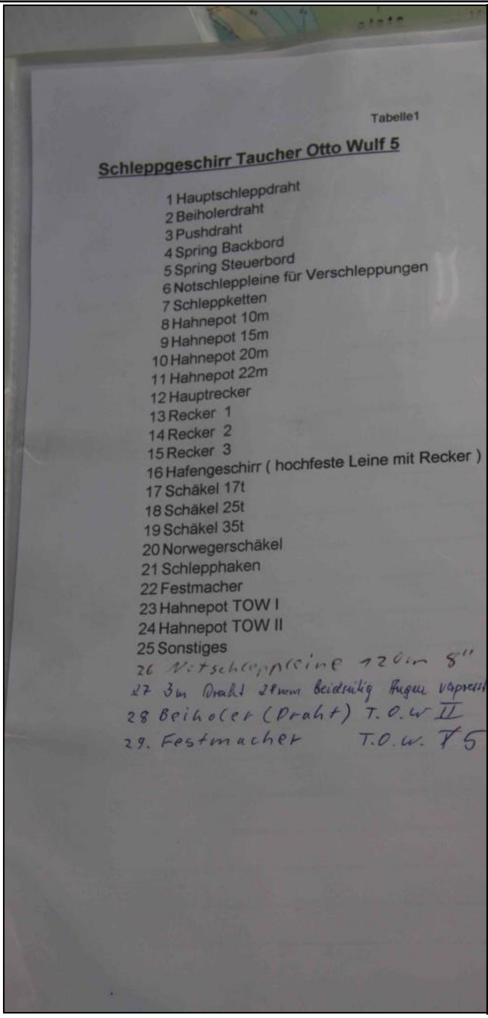
Tabelle1

Schleppgeschirr Taucher Otto Wulf 5

1 Hauptschleppdraht
2 Beiholerdraht
3 Pushdraht
4 Spring Backbord
5 Spring Steuerbord
6 Notschleppleine für Verschleppungen
7 Schleppketten
8 Hahnepot 10m
9 Hahnepot 15m
10 Hahnepot 20m
11 Hahnepot 22m
12 Hauptrecker
13 Recker 1
14 Recker 2
15 Recker 3
16 Hafengeschirr (hochfeste Leine mit Recker)
17 Schäkel 17t
18 Schäkel 25t
19 Schäkel 35t
20 Norwegerschäkel
21 Schlepphaken
22 Festmacher
23 Hahnepot TOW I
24 Hahnepot TOW II
25 Sonstiges
26 Notschleppleine 120cm 8"
27 3m Draht 28mm Beidseitig Augen verpresst
28 Beiholer (Draht) T.O.W II
29. Festmacher T.O.W. T5

TAUCHER OTTO WULF 5 towing gear

1 Main towline
2 Gob rope
3 Push cable
4 Port spring
5 Starboard spring
6 Emergency towline for towing operations
7 Drag chains
8 Bridle 10 m
9 Bridle 15 m
10 Bridle 20 m
11 Bridle 22 m
12 Main stretcher
13 Stretcher 1
14 Stretcher 2
15 Stretcher 3
16 Port towing gear (high-tenacity line with stretcher)
17 Shackle 17 t
18 Shackle 25 t
19 Shackle 35 t
20 Norwegian shackle
21 Towing hook
22 Mooring line
23 Bridle TOW I
24 Bridle TOW II
25 Miscellaneous
26 Emergency towline 120 cm 8"
27 3 m cable 28 mm wrought eyes on both sides
28 Tricing cable T.O.W. II
29 Mooring line T.O.W. 5

Figure 10: Towing gear

Figure 11: Port towing gear, cable-tier

The BSU visited the owner of the tug on 1 November 2011. The tug operating procedures are documented in the owner's quality management system and certified in accordance with ISO 9001. Inter alia, the following is stated in section A5 of the QM Ship instructions: "Due to the forces that act on the towline and hazard caused by the towline (e.g. if it parts), the area of deck near the towline guides should be entered only in an emergency (e.g. problem with the towline) during a manoeuvre.

The towline must be monitored continuously when on the tow deck and personal safety considered." Section A5, Connecting lines, was amended by Revision No 1 after the accident. The following sentences were added: "Crew members are required to move away from the danger area of the towline after the towing connection has been established. This comprises a corridor running parallel to the towline, which exists about three metres to its right and left in the direction of pull." The following sentence was added to section A5, Towline: "The towline used should be checked for damaged or fragile points before and after the manoeuvre." Statements regarding the materials to be used and type of towing connections have not been made.

While looking through the certificates and surveying the storage facility, it was noted that the line materials were marked by labels but could not be correlated with the certificates.

Figure 12: Company's premises in Cuxhaven

The stretcher was seized by WSP Cuxhaven. It was reported that the point of failure was roughly in the middle. The operator submitted a certificate for the line from the supplier Canel & Sohn, which indicated a breaking load of 49.8 t at a diameter of 64 mm. The stated material is polypropylene.

A copy of the certificate and photos of the point of failure were shown to the manager when WSP Cuxhaven and the BSU visited Canel & Sohn on 8 November 2011 in Hamburg. He claimed that such a delivery had not taken place and that the specified material was not polypropylene. An inspection of the accounts revealed that such line had reportedly never been delivered, meaning the certificate reportedly did not come from Canel & Sohn, either. According to the standards DIN EN 701 and DIN EN 1261, a green tracer must be present to identify the rope material and for rope diameters of 16 mm and above, identification threads. The identification threads contain the name of the manufacturer, year of manufacture, number of the standard DIN EN 1261 and the approval number of a classification society. The label for each delivery (cable length) must also contain corresponding particulars and the year of manufacture in addition to DIN EN 701.

The parted stretcher evidently represents non-certified material from an unknown manufacturer that cannot be correlated.

Figure 13: Point of failure on the stretcher

4 ANALYSIS

Expert appraisal by R. K. Consulting

An analysis of the point of failure on the rope revealed that regardless of the tractive forces exerted, the rope failed due to being severely damaged at the point of failure (see characteristic representations of the point of failure in Figs. 14 and 15).

Figure 14: Damage before the break

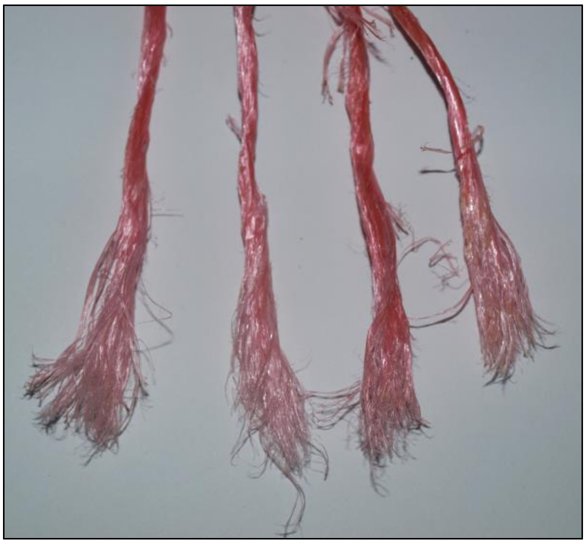

Figure 15: Damage after the break

The examination of each individual strand and the respective strand fibres at the point of failure on the rope revealed that at least 73 fibres of the total of 456 fibres in the eight-strand square plait were completely or partially frayed. That corresponds to damage to 16% of the total number of fibres. Here, at a total of 20 damaged fibres the most damage to a strand stood at 36%.

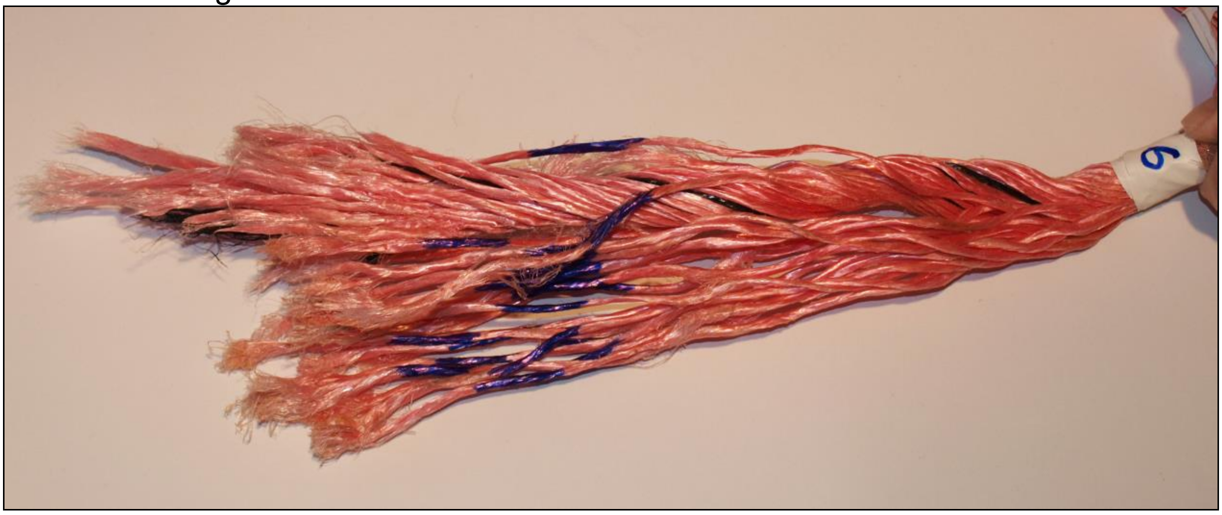

Figure 16: Most damage to a strand

The fibre breakage at the point of failure on the rope was spread over a length of 0.50 m. The point of failure of the damaged fibres displayed mainly brown discolouration and contamination possibly due to rust. When rope is damaged in this manner the tractive force introduced can no longer be evenly absorbed by the strands. This inevitably leads to a shift in the rope's structure with the negative impact of sharply decreasing tensile strength.

The heavily damaged fibres at the point of failure, as well as the damage at other points along the stretcher, display the same picture with regard to the characteristics of the tear, the damage, and the contamination. Consequently, it can be regarded as a fact that the condition of the stretcher was inadequate and the ensuing significant loss in its tensile strength inevitably led to the failure. However, since a visual inspection was carried out when the towing gear was assembled, the possibility of the damage occurring as the towing connection was established is something that cannot be ruled out with any certainty.

In the case of the material used for the stretcher, the known man-made fibres were of the lowest quality grade. Such 'polypropylene split film' material is normally used for mooring lines.

The fact that the rope was manufactured according to an unknown standard and delivered without any threads identifying the company or standard clearly shows that the level of quality fell short of international standards. Unfortunately, it is not possible to establish the manufacturer or the country of manufacture.

The particulars of the rope on the dubious certificate already discussed are also questionable. The diameter specified cannot be right. A diameter of 64 mm has a weight of 185.00 kg/100 m. The weight determined is 126.00 kg/100 m. On the assumption that the original weight was 142.00 kg/100 m, the diameter could not have been more than 56 mm even if the stretcher is fully elongated and thus a reduction in weight taken into account. This rope diameter results in a tensile strength of 381 kN according to the standard, which is about 100 kN or about 20% less than the 488 kN specified.

Since the rope's condition is virtually new in terms of its internal and low wear and it reveals no other traces of a continuously high load, the actual rope diameter is confirmed at 381 kN (splice), correspondingly 419 kN in the rope, by means of the value determined by a tensile test on an intact part of the rope.

Questions arise due to the rope diameter and corresponding tensile strength, as well as the length of the rope and corresponding ability to absorb kinetic energy. Although there are no mandatory provisions for the dimensioning of towing gear, the stretcher should never be the weakest of the components that make up the towing connection. Only then is it possible to prevent the energy stored from being released, the rope ends from snapping back, and generally, as in this case, too, serious injuries being caused to members of the crew if it suddenly fails.

The potential to absorb kinetic energy is determined by the material, such as polyamide or polyester, and the rope's structure. In the present case, the low specific energy absorption capacity per running metre should be compensated by an excess length of 20 m. The effects are known: rope parts in the free length towards the middle and the parted rope lengths snap back with their stored energy.

Even according to the certificate submitted the user was sold a mooring line. The user has a duty of care in terms of employing the product as intended. In the present case, the material used, the actual diameter, and the length used were not suitable for a stretcher.

For the towing connection configurations the expert has referred, inter alia, to the documents Guidelines for Marine Transportations | GL Noble Denton, as well as Rules and Recommendations | GL Group, Service/Rules of Germanischer Lloyd.

Here, the dimensioning of diameters and thus determination of the tensile strength of each of the towing connection components are based on the specified maximum bollard pull of the deployed tug.

With the exception of the used stretcher, it is generally recommended that the dimensioning of connecting components be set at the twice the tug's maximum bollard pull.

Due to the expected currents, the dimensioning of connecting components is often set at the three times the tug's maximum bollard pull.

Since a failure of the stretcher must be ruled out with the greatest possible certainty in the event of the towing connection failing, this is oversized at 1.5 times the maximum tensile strength/connecting component.

Example for the TAUCHER O. WULF 5:

Maximum tug bollard pull = 25 tonnes

Minimum tensile strength of the cables = 2.0 times x 25 tonnes = 50 tonnes
Maximum tensile strength of the cables = 3.0 times x 25 tonnes = 75 tonnes

The dimensioning of the stretcher is thus:

Minimum tensile strength of the stretcher = 1.5 times x 50 tonnes = 75 tonnes
Maximum tensile strength of the stretcher = 1.5 times x 75 tonnes = 112.5 tonnes

The length of the stretcher should be no less than 5.00 m and no more than 10.00 m for port towing connections.

Nothing other than fairlead shackles should be used for connecting individual components of the towing gear.

As a general rule, individual components should be discarded after three years or their period of operation is three years.

A test report (certificate) with detailed specification of and stating the international standard should be issued for all components.

Expert appraisal by the Federal Waterways Engineering and Research Institute (BAW)

Account of the accident situation

Based on the AIS data, the account of the accident situation essentially focuses on a not entirely reliable interpolation of individual data as very slow acting vessels transmit correspondingly few AIS signals. This should be considered when interpreting and judging the data and diagrams. In the AIS data animations, the vessel positions substantiated by means of data are blackened while interpolated ship positions are highlighted. This is illustrated by the sequence of the diagrams in Fig. 17:

- A: Position report for the BALTIC BREEZE at 061057 (e.g. t_0 = 0 s)
- B: Position report for the TAUCHER WULF 5 at 061106 (t_1 = t_0 + 9 s)
- C: Position report for the BALTIC BREEZE at 061108 (t_2 = t_0 + 11 s)
- D: Position report for the TAUCHER WULF 5 at 061353 (t_3 = t_0 + 187 s)

During the period under consideration, position data substantiated roughly every 10 s are available for the BALTIC BREEZE (e.g. Fig. 17, A and C).

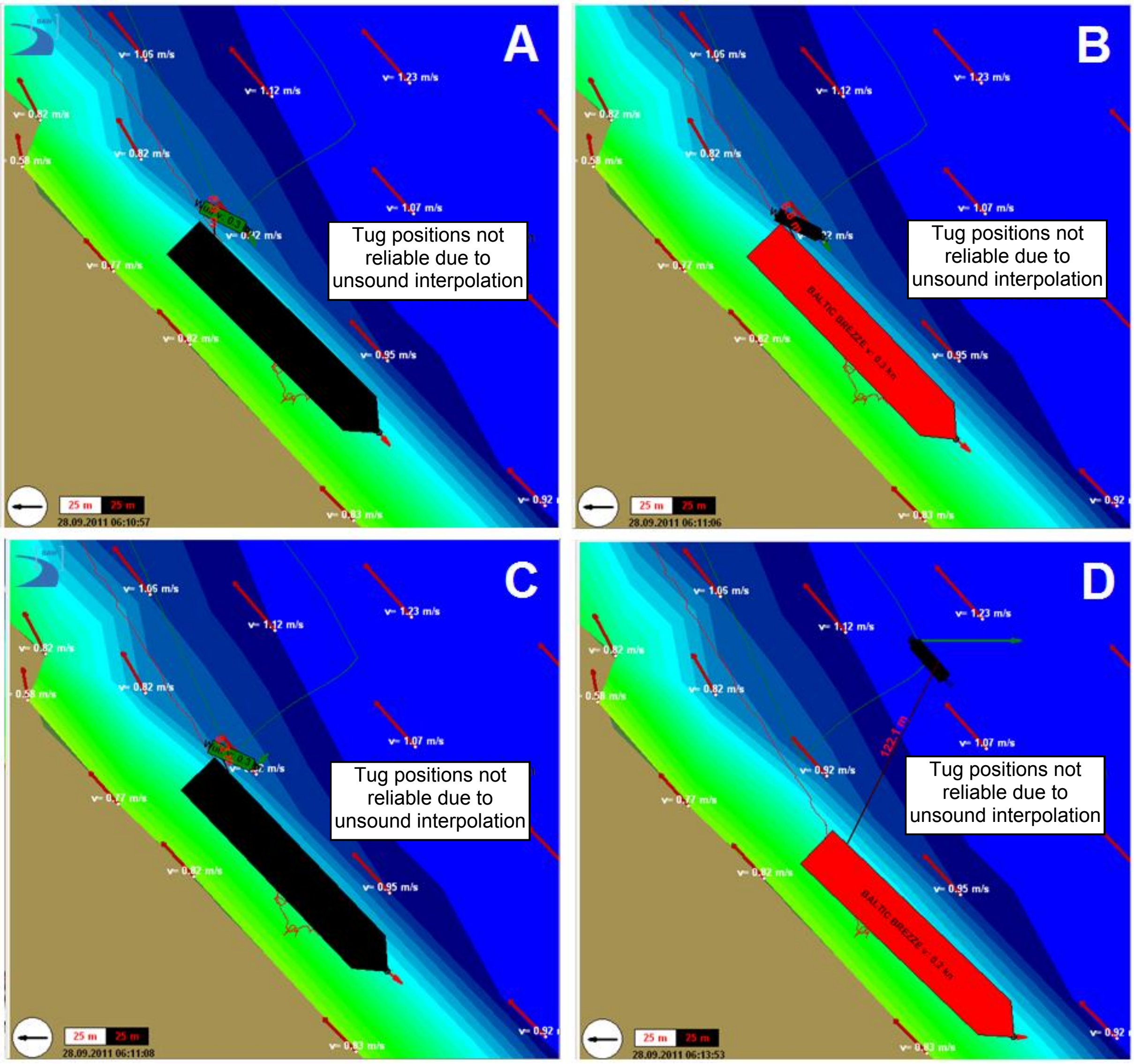

Figure 17: AIS positions

Substantiated by means of AIS data are positions of the BALTIC BREEZE (061057, A), the TAUCHER WULF 5 (061106, B), following that the BALTIC BREEZE (061108, C), as well as the next substantiated position of the TAUCHER WULF 5 (061353, D).

At the time of the accident, the positions of the TAUCHER WULF 5 substantiated by means of AIS data are 167 s apart (e.g. Fig. 17, B and D). The linear interpolation in terms of time between the substantiated positions of the TAUCHER WULF 5 (Fig. 17, B and D) is based only on assumptions because no additional manoeuvring information (e.g. rudder angle, rated speed, heading) is available. Therefore, the TAUCHER WULF 5's direction of turn to port between 061106 and 061353 based on the substantiated AIS data should be seen only as a presumption.

The length of the towline was 50 m in total. At a difference in height of 8.5 m between the anchor point of the BALTIC BREEZE (BBR: stern bollard, port, about 10.5 m above the waterline) and the anchor point on the TAUCHER WULF 5 (TW5: towing hook with tricing cable, starboard, about 2 m above the waterline), the resulting distance calculated for the elongated line between the vessels (should be 50 m) is about 49.3 m (horizontal distance without slack: BBR anchor stern bollard about 12 m from aft/TW5 anchor with tricing cable about 10 m from aft).

Local sea conditions

To estimate the wave motion during the period of the accident, the BAW was provided the 'Official report on the weather conditions at 0614 CEST on 28 September 2011 in the area of Europakai Cuxhaven' by Germany's National Meteorological Service (DWD, 23/11/2011, WV SB/64.30.16-20/110_11).

A weak southerly wind of 4 to 8 knots (2-3 Bft) with a wave height calculated by the DWD of 0.5 m, mainly due to swell from the northwest, prevailed at the time of the accident. According to the DWD, a significant steepening of the waves due to a crossing sea was not expected in the area of the accident; however, the uncertainty of the information especially when waves and wind events are low was referred to explicitly.

The wave-induced orbital flow due to the swell from the northwest acted with its oscillating flow components both in and against the direction of the tidal current (overlay effects), which was aligned roughly northwest at the time of the accident.

Assessment of the accident situation

The prepared and interpolated position data of the BALTIC BREEZE and the largely unsafe (linear interpolated) position and course data of the TAUCHER WULF 5 give rise to the following assessment vis-à-vis accident situation:

Fig. 18 illustrates the positions of the BALTIC BREEZE substantiated by AIS data at an interpolated distance to the TAUCHER WULF 5 of 30.0 m (061138, A), of 38.9 m (061147, B), of 45.4 m (061157, C), and of 50.6 m (061208, D).

Based on the substantiated positions of the BALTIC BREEZE and her direction of movement at the bow, as well as the distance calculations between the BALTIC BREEZE and interpolated positions of the TAUCHER WULF 5, the following sequence of events may be assumed on the basis of Fig. 18:

- at about 061138, the distance between the vessels is about 30.0 m (angle of pull tug/tow about 16°). The BALTIC BREEZE turns to starboard (Image A) presumably because of tractive forces from the tug on the bow, inter alia;
- at a distance of about 38.9 m (angle of pull about 12°), tractive forces are presumably still acting via the towline at 061147 because the bow of the BALTIC BREEZE continues her starboard turn towards the quay (Image B).

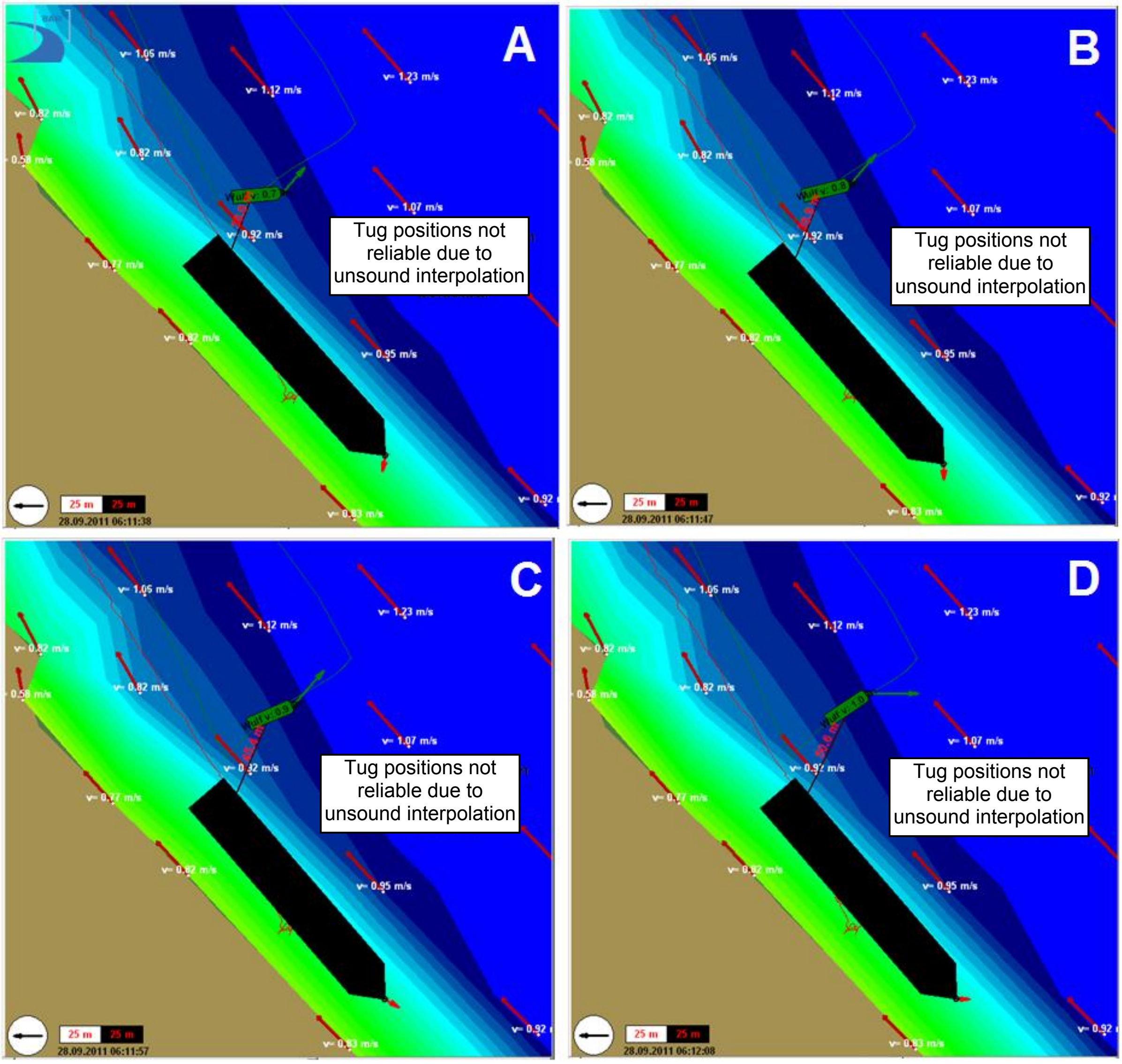

Figure 18: Analysis, interpolated towing connection distance

Substantiated positions of the BALTIC BREEZE at an interpolated distance to the TAUCHER WULF 5 of 30.0 m (061138, A), of 38.9 m (061147, B), of 45.4 m (061157, C), and of 50.6 m (061208, D):

- the distance between the vessels at 061157 is presumably about 45.4 m (angle of pull about 11°) and it is likely that as before the tug is still turning to port (Image C). Since the bow of the BALTIC BREEZE is now also turning slightly to port (substantiated AIS data), it is assumed that tractive force from the tug is no longer acting on the BALTIC BREEZE;
- at this point, the tug is presumably at an angle of 80° to the tidal flow of about 0.9 m/s to 1.0 m/s, where this inclination may have caused a further force component in addition to the propeller thrust (dynamic stagnation pressure at oblique inflow; see notes below);

- the tug straightened herself after the line parted (presumably between Images B and C), which permits the conclusion that a roll and pitch moment acted previously due to tractive forces from the propeller thrust and oblique inflow;
- the turn to port of the BALTIC BREEZE after the presumed failure of the line connection becomes even more evident on the basis of the substantiated AIS data at 061208 (tow/tug distance about 50.6 m and angle of pull about 10°, Image D).

Evaluation of the flow and sea conditions

Above and beyond the report of the DWD and on the basis of the analyses of the tidal current, as well as the underwater bathymetry (Image 3), the following is noted by the BAW:

- the accident occurred at a water level of about msl 0.8 m in an almost fully developed ebb current estimated at roughly 0.9 m/s to 1.0 m/s in the area between the tug and tow. Considerable simplification (rectangular, lateral underwater profile of tug at $l \cdot t = 30\ m \cdot 3\ m = 90\ m^2$, slight oblique inflow 80°, water density $\rho = 1{,}000\ kg/m^3$, inflow velocity $v = 1\ m/s$) results in dynamic stagnation pressure according to BERNOULLI of about $p \approx 37\ kN$ ($p = 0.5 \cdot \rho \cdot v^2$), which would presumably have to be absorbed by the line proportionally in addition to the propeller-induced tensile load;
- the light swell from the northwest calculated by the DWD ran against the tidal current during this period. This means that in the light of the opposing flow effects (about 2 kts), as well as additionally due to the localised shoaling and refraction effects on the rising underwater embankment (gradient about 1:10), a slight steepening of the swell waves could not be ruled out. Although, in our opinion, the long wavelengths of swell did not lead to sudden, spasmodic increases in tractive force on the towline, they could have increased the effect of the northwesterly tidal current further because of the seaward facing orbital flow component on the windward side of the wave crest;
- in our opinion, localised swell due to the weak southerly wind and very low fetch length from a southerly direction, thus also wave reflections on the side of the BALTIC BREEZE or their superimposition, did not have a material effect on the movements of the tug.

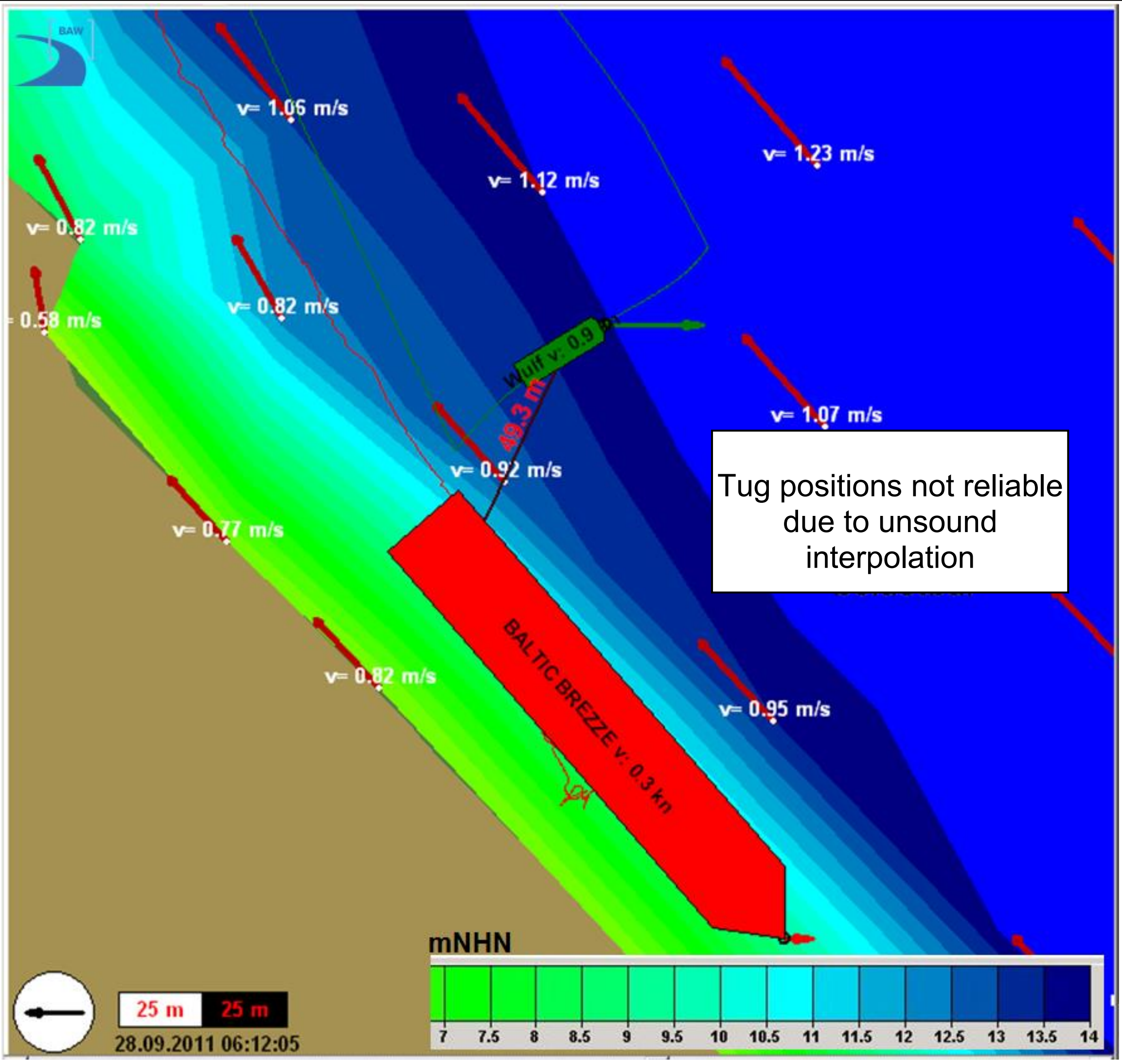

Figure 19: Accident situation

Fig. 19: calculated positions, flows and underwater bathymetry (2010) at the presumed time of the failure of the line connection between the TAUCHER WULF 5 and the BALTIC BREEZE (presumed distance about 49.3 m, 061205). In the table below, the information between the verified AIS data highlighted yellow is interpolated. The distances and angles relate to the space between the towline anchor points. The time of the accident is highlighted red. At this point, the towing connection specified at about 50 m in length was fully elongated and parted. The course of the accident can be obtained as an animation on the BSU website. Due to the low data density vis-à-vis AIS information, the tug positions are uncertain and the headings displayed should be rated only as an indication. VDR data were not available to the BSU.

	Measured AIS positions							
	BALTIC BREEZE			TAUCHER O.WULF 5				
Time	Course	SOG	COG	Course	SOG	COG	Distance	Angle
061132	137	0.31	191	91	0.59	40	24.4	19.2
061133	137	0.31	192	90	0.60	41	25.6	18.4
061134	138	0.31	191	89	0.61	40	25.0	18.8
061135	138	0.31	192	88	0.62	41	26.2	17.9
061136	138	0.31	191	87	0.63	41	27.4	17.2
061137	138	0.31	192	86	0.64	40	28.8	16.5
061138	138	0.31	191	85	0.65	41	30.0	15.8
061139	138	0.31	191	84	0.66	40	31.1	15.3
061140	138	0.31	191	83	0.68	41	32.3	14.7
061141	138	0.31	191	82	0.69	41	33.6	14.2
061142	138	0.31	191	81	0.70	40	34.8	13.7
061143	139	0.31	191	80	0.71	41	34.1	14.0
061144	139	0.31	191	79	0.72	41	35.3	13.5
061145	139	0.31	181	78	0.73	41	36.5	13.1
061146	139	0.31	180	77	0.74	41	37.7	12.7
061147	139	0.31	180	76	0.75	40	38.9	12.3
061148	139	0.31	120	76	0.76	41	39.5	12.1
061149	139	0.31	120	75	0.77	41	40.2	11.9
061150	139	0.31	119	74	0.78	41	40.8	11.8
061151	139	0.31	120	73	0.79	40	41.5	11.6
061152	139	0.31	120	72	0.80	41	42.2	11.4
061153	139	0.31	119	71	0.82	41	42.8	11.2
061154	139	0.31	120	70	0.83	41	43.4	11.1
061155	139	0.31	121	69	0.84	41	44.1	10.9
061156	139	0.31	119	68	0.85	40	44.8	10.8
061157	139	0.31	120	67	0.86	41	45.4	10.6
061158	139	0.30	120	66	0.87	90	45.9	10.5
061159	139	0.30	121	65	0.88	90	46.3	10.4
061200	139	0.29	121	64	0.89	90	46.9	10.3
061201	139	0.29	122	63	0.90	40	47.3	10.2
061202	139	0.29	122	62	0.91	90	47.8	10.1
061203	139	0.28	123	61	0.92	90	48.3	10.0
061204	139	0.28	123	60	0.93	90	48.8	9.9
061205	139	0.27	124	59	0.94	90	49.2	9.8
061206	139	0.27	124	58	0.96	90	49.7	9.7
061207	139	0.26	125	57	0.97	90	50.2	9.6
061208	139	0.26	125	56	0.98	90	50.6	9.5
061209	139	0.27	126	55	0.99	40	51.8	9.3
061210	139	0.28	126	54	1.00	41	52.9	9.1
061211	138	0.29	127	53	1.01	41	56.0	8.6
061212	138	0.30	127	52	1.02	40	57.2	8.5
061213	138	0.31	128	51	1.03	41	58.3	8.3

Figure 20: AIS data

Weather report by Germany's National Meteorological Service

On 28 September 2011, northern Germany was affected by the strong high-pressure system, SEPIDEH, the centre of which shifted roughly from the lower Elbe to southwest Poland as the day progressed. In generally light winds, there was no rainfall in the area of the accident throughout the day; however, at times it was quite cloudy or even hazy. In the area of the aforementioned high-pressure system, a weak southerly wind of 4 to 8 knots (2-3 Bft) prevailed at the time and in the area of the accident. Essentially due to swell which came from the northwest, the calculated significant wave height stood at or below 0.5 m. At the time of the accident, wave heights of around 0.5 m were measured in the area of the German Bight. A significant wave split due to crossing sea is not expected in the weak wind sea in the area of the accident. It should be noted that in the light winds and low wave heights, in particular, it is only possible to reproduce the swell within the area of the port with a degree of uncertainty.

Load on the towing connection

The forces and/or loads acting on the towing connection consist of the static and dynamic element. The static element can be calculated from the bollard pull and the angle of the towing connection to the seagoing ship. A bollard pull of 25 t and a reconstructed angle of 10° results in a proportion of 25 * factor 1 = 25 t. Here, the slope of the towline is relevant. At an angle of about 60°, the load already equals twice the bollard pull. The expert appraisal of the BAW indicates a dynamic load of 3.5 t due to the existing weather and flow conditions. Consequently, theoretically the total load on the towing connection should not have exceeded 28.5 t.

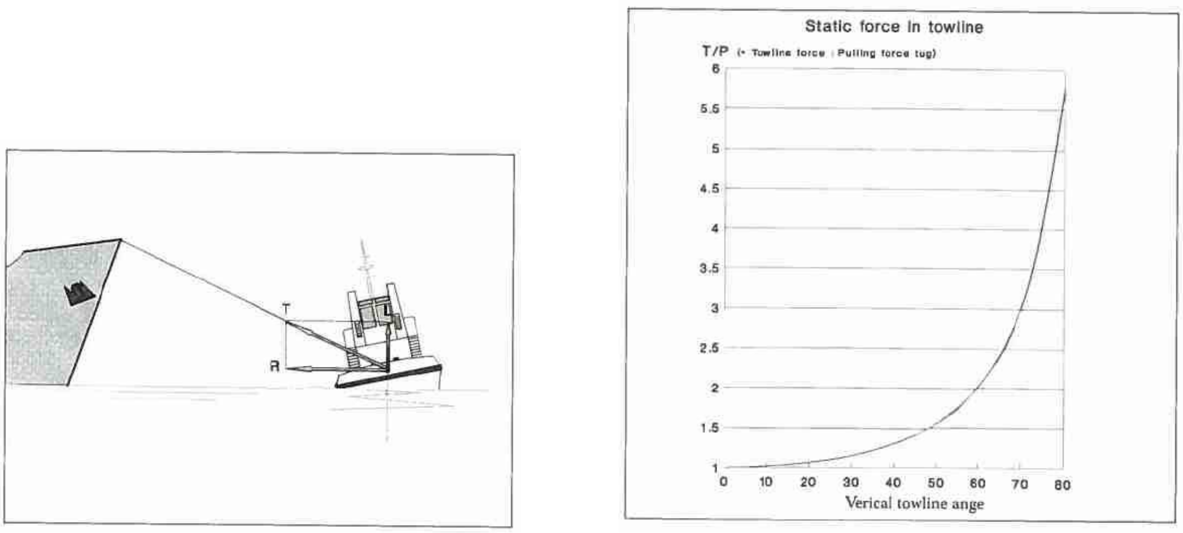

Figure 21: Load on towing connection[5]

(Figures reproduced with kind permission from Tug Use in Port, published by the Nautical Institute, written by Henk Hensen FNI)

[5] Source, The Nautical Institute, Tug Use in Port, 2nd Edition, 2008, p. 109

Breaking load test on the stretcher by Messrs Seil Hering

On 21 August 2012, the seized, failed stretcher, with a total length of 8 m and an additional eye spliced at the point of failure, was clamped into a tractive unit so as to measure the breaking load in Hamburg. A visual inspection indicated that the sample was a polypropylene line (PP) from an unknown manufacturer with a diameter of 56 mm and a four x two strand square plait. The theoretical breaking load would be 38.9 t. The expert emphasised that the sample does not meet the requirements of a stretcher and therefore, should not be so identified. The reported purpose of a stretcher is to absorb shock loads. Neither the original length of about 20 m nor the material and specified breaking load are reportedly fit for that. The submitted certificate for a polypropylene line of 64 mm in diameter and a breaking load of 49.8 t reportedly does not correspond to the sample.

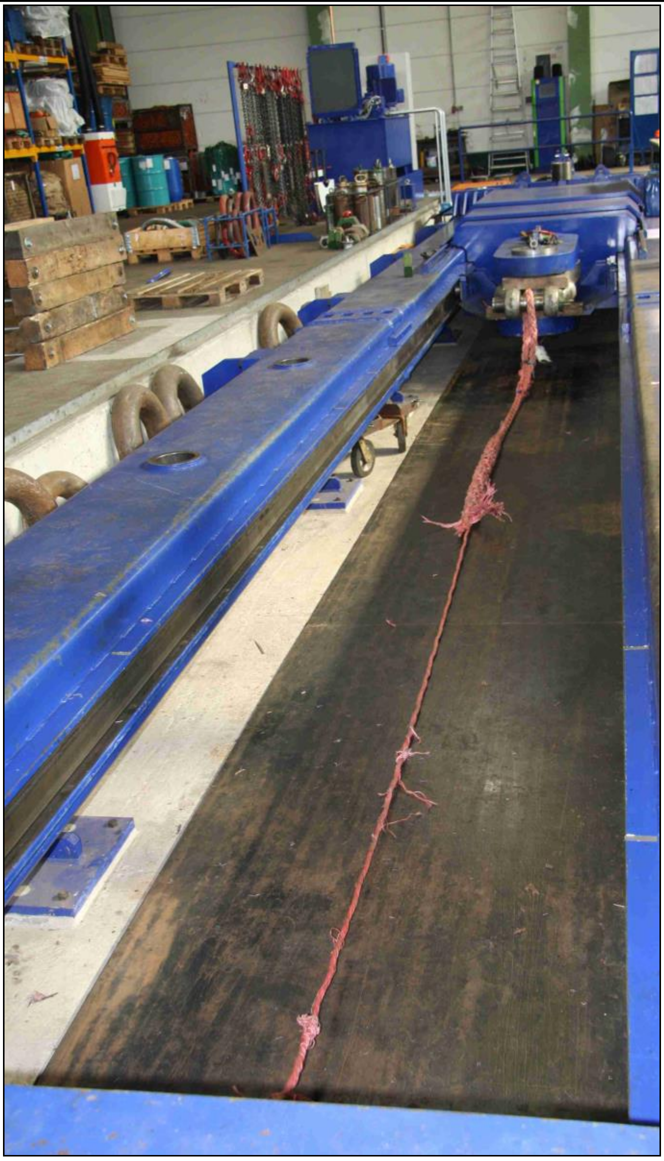

Figure 22: Breaking load test by Messrs Seil Hering

The breaking load test revealed a tensile strength of 224.2 kN (22.9 t) and elongation of 1,041.8 mm, i.e. 13%. The elongation at break in the case of polypropylene is reportedly 12%[6], depending on the frequency of use and wear on the line.

[6] Source: The Nautical Institute, Mooring and Anchoring Ships Vol. 1, 1st Edition, 2009, p.65

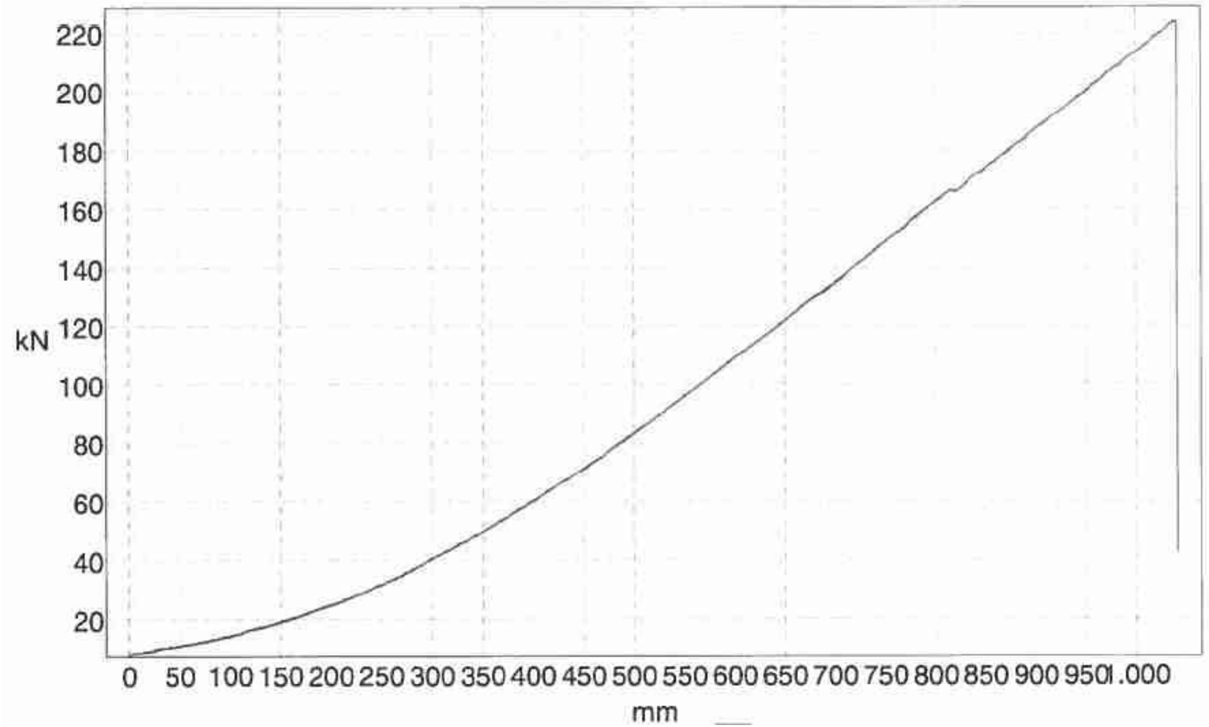

Figure 23: Measurement of tensile strength and elongation, Messrs Seil Hering

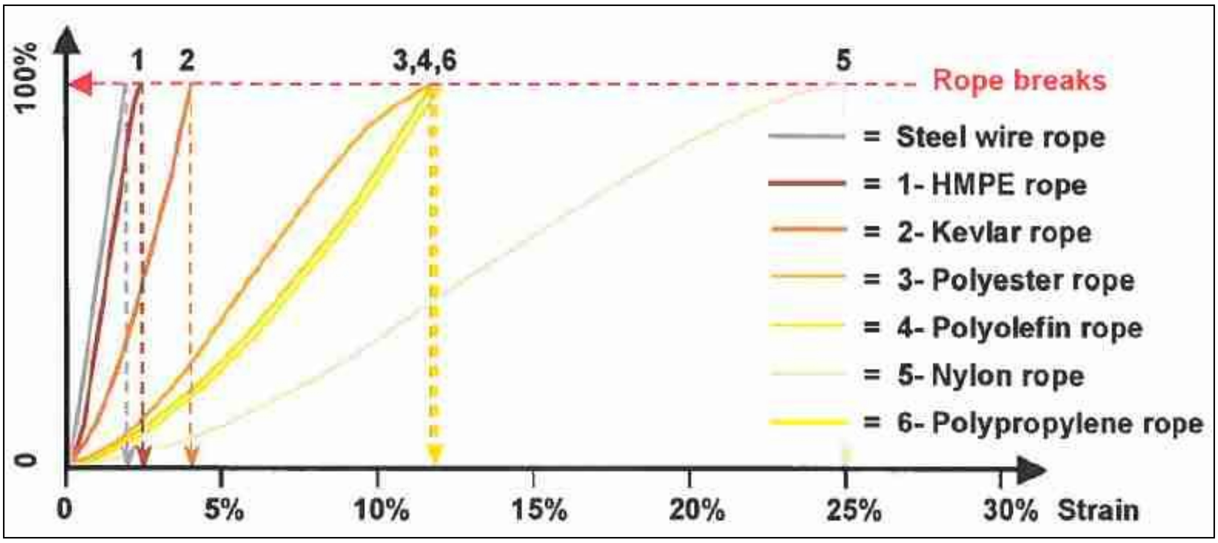

Figure 24: Rope elongation curves

5 CONCLUSIONS

Consisting of three parts, the 50 m long towing connection, the actual breaking load of which was, contrary to the statements and submitted certificates, measured at 40 t at the weakest point, should not have failed due to the arising static and dynamic loads of 28.5 t on the day of the accident. Here, a 20 m long polypropylene line used as a stretcher parted at roughly the middle. The BSU arranged for the point of failure to be examined. This involved the performance of a breaking load test on seized remnants of the line, which at a line length of 8 m resulted in a load of about 22 t and elongation of 13%. This value is significantly lower than the expected minimum breaking load of 38.9 t at a line diameter of 56 mm. At the same time, it should be noted that an already parted line would most likely no longer achieve the minimum breaking load in the area of the point of failure and that experience gained during such tests reveals that the measured value is reportedly quite realistic. The visual inspection of the point of failure showed that it was a PP line in good condition externally and about two years old according to the certificate. However, ultimately it was not possible to correlate the material with a specific certificate, meaning it is very likely that the line was not certified. A corresponding identifier for this, e.g. by means of a continuous woven colour code which would make clear identification possible, was absent. The fibres evaluated during the breaking load test revealed that prior to use 73 of the total of 456 fibres were already completely or partially frayed. The failure of the rope was caused by this heavy damage.

The type of towing connection is left to the operator. For port operations the towing connection could consist of a single cable or synthetic rope or several parts of different materials with a stretcher of about 5-10 m fitted between them, which can absorb the shock loads. To absorb shock loads and protect the structural fabric, towing hooks with integrated absorbers (shock absorbers) that are capable of controlling the elongation of a towing connection are also available.

The configuration of the towing connection is determined based on the tug's bollard pull, type of task, sea area, and safety factors. In the case of a port tug, the towing connection is configured to be up to three times the bollard pull, depending on which dynamic loads are expected due to swell, for example. Slightly higher forces can occur when escorting a seagoing ship than the bollard pull itself due to the indirect towing effect of the tug with its mass. During this task, the tug was operating as an aft tug in Cuxhaven. The aim was to ensure that the stern of the car carrier did not strike the pier in an uncontrolled manner while berthing. Car carriers have a large lateral windage area because of their design.

Environmental conditions on the day of the accident were good. There was hardly any swell or wind. The dynamic forces calculated by the BAW stood at 36 kN. Inasmuch, the configuration of the towing connection would have been sufficient in relation to the tug's 25 t bollard pull and the small angle of about 10° – which applied no additional static forces on the towing connection – due to the 50 m long tug attachment. However, it should be noted that the elongation length of polypropylene when fully operational is only 12%, while nylon, for example, can elongate up to 25%.

At 20 m, the dimension of the stretcher was twice as long as the recommended elongation length of 10 m. Inasmuch, the stretcher used could elongate by about 2 m. However, it parted towards the middle and not just behind the splice as to be expected.

Compared to the other lines used (10 m bridle, 28 mm cable, breaking load 62 t, 20 m UHMWPE, breaking load 84.3 t), with a breaking load of 40 t the capacity of the stretcher was too low. This combination is unusual and does not conform to the recommendations of the OCIMF (Oil Companies International Marine Forum), amongst other things. According to that, a forerunner should be no more than 11 m (6 fathoms) long and have a 25% higher breaking load than the cable because synthetic fibres wear faster than cable. Moreover, the line ends should be mated with a fairlead shackle. Instead of fairlead shackles, which, for example, develop less friction due to a built-in roller, round pin anchor shackles were used. The two synthetic lines were mated eye to eye at their ends in the form of cow hitches (square knot). This connection between synthetic lines is quite common and any weakness as compared to the fairlead shackle connection insignificant. The advantage is in the handling of the connection – on fairleads, for example. Cow hitch connections should not be used for aramid (Kevlar) and between cable and synthetic material.

Consequently, the polypropylene line used as a stretcher was not used properly. It was of the lowest quality grade in terms of known man-made fibres. Such material (PP split film) is normally used for mooring lines. It was too weak and because of low elongation unsuitable for absorbing shock loads. Based on the lower wearing bridle cable with a breaking load of 62 t and the good weather conditions, as well as according to the state of today's traffic engineering, nylon or at least polyester with elongation of 12% and a breaking load of about 80 t should have been the material used.

For a tug with fixed pitch propeller, the applied method of working with a gob rope is very effective and does not merit any criticism. However, it is more labour intensive as compared to pod and tractor propulsion systems because the gob rope winch is used and operated to control the towing point. Consequently, it may be necessary for deckhands to be situated in the area of the winch and monitor the towing connection so as to take action on the towing winch or towing hook's slip device if necessary. Here, the deckhands must avoid the danger areas which change and depend on the angle of the towing connection to the seagoing ship. It cannot be ruled out that the towline will fail at an unfavourable moment. With that in mind, it is all the more important to ensure that material is used properly. As a general rule, the employer is responsible for occupational safety and must assess the risk at working stations, as well as take action to prevent accidents.

Although the operator has a documented QMS and is certified according to ISO 9001, unsuitable material was used in the towing connection. Furthermore, it was not possible to prove that the equipment conformed to the certificates submitted. Correlation was also largely impossible in the storage facility at the owner's premises in Cuxhaven. The certificates available to the BSU for the used stretcher were dubious because the distributor did not issue them in this form. The parted line with a diameter of 56 mm was not consistent with the diameter of 64 mm specified in the certificate.

During another casualty involving the same owner on 14 September 2011, the towing cable on the forward tug, TOW 4, parted as the VIKING ODESSA was towed into the Amerikahafen in force 6-7 Bft wind from the west. According to investigations of WSP Cuxhaven, it was not possible to submit a certificate for the towing cable immediately after this accident, either. Here, the pilot expressed doubts as to the quality of the cable used. According to the supplier's statement of compliance with the order, at a rope diameter of 30 mm the tensile strength of the cable should have been at least 628 kN.

The procedures of the QMS will be revised by the owner. At present, specific statements as to danger areas, safety areas in tug operation, as well as type of towing connections and material used for them are absent. The certificate according to EN ISO 9001, issued for the first time on 6 April 2004 by Lloyd's Register Quality Assurance GmbH, is valid until 5 April 2013. After that re-examination and evaluation is necessary. The certification is voluntary. According to the QM manual, the crew should be familiarised with all the safety equipment on board by means of the monthly safety drills and exercises. The skipper is responsible for implementing and documenting the drills and exercises.

6 SAFETY RECOMMENDATIONS

6.1 Owners, operators, and skipper of the tug

Owners, operators and skippers must ensure that test certificates are kept on their tugs for individual components of the towing connection on board and that the material used is consistent with the recognised test standards. It must be verifiable that certified material is used. Moreover, based on the task and the expected static and dynamic forces, as well as according to recognised procedures, the type of towing connection chosen must be verifiable. The voluntarily implemented quality management system should be revised accordingly.

In the risk assessment for occupational safety, the danger area and safety areas in different work situations should be defined specifically for every crew member, e.g. by means of drawings.

7 SOURCES

- Investigations by Waterway Police (WSP) Cuxhaven

- Written statements
  - Ship's command
  - Owner

- Witness accounts

- Reports and technical paper
  - Canel & Sohn, Hamburg
  - Seil Hering, Hamburg
  - R. K. Consulting, Rudolf F. Kirst, Bremen
  - Federal Waterways Engineering and Research Institute, Hamburg, Dr. Ing. Klemens Uliczka, Dipl. Ing. Martin Wezel
  - Figures 5, 21 and information as per figure 22 reproduced with kind permission from Tug Use in Port, published by The Nautical Institute, Mooring and Anchoring Ships, Vol. 1, 2009, Captain I.C. Clark, Tug Use in Port, 2nd Edition, 2008, written by Captain Henk Hensen FNI
  - DIN EN ISO 9554, Fibre ropes – General specifications, DIN EN ISO 1346 Fibre ropes – Polypropylene split film, monofilament and multifilament (PP2) and polypropylene high-tenacity multifilament (PP3), VG 84544-1 Towing gear, as well as other applicable VG standards

- Nautical charts, towing connection drawing, and ship particulars, Federal Maritime and Hydrographic Agency (BSH)

- Official weather report by Germany's National Meteorological Service (DWD)

- AIS recordings, ship safety services and vessel traffic services (VTS)

- Documentation, Ship Safety Division (BG Verkehr)
  - Accident Prevention Regulations for Shipping Enterprises (UVV-See)
  - Guidelines and codes of practice
  - Ship files

- Photos
  - Photo of vessel, Hasenpusch
  - Owner
  - BSU