Danish Maritime Accident Investigation Board

MARINE ACCIDENT REPORT
September 2014

SVENDBORG MÆRSK
Heavy weather damage on 14 February 2014

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This marine accident report is issued on 5 September 2014

Case number: 2013010519

Front page: SVENDBORG MÆRSK in the Bay of Biscay. **Source:** Maersk Line.

The marine accident report is available from the webpage of the Danish Maritime Accident Investigation Board www.dmaib.com.

The Danish Maritime Accident Investigation Board

The Danish Maritime Accident Investigation Board is an independent unit under the Ministry of Business and Growth that carries out investigations with a view to preventing accidents and promoting initiatives that will enhance safety at sea.

The Danish Maritime Accident Investigation Board is an impartial unit which is, organizationally and legally, independent of other parties

Purpose

The purpose of the Danish Maritime Accident Investigation Board is to investigate maritime accidents and to make recommendations for improving safety, and it forms part of a collaboration with similar investigation bodies in other countries. The Danish Maritime Accident Investigation Board investigates maritime accidents and accidents to seafarers on Danish and Greenlandic merchant and fishing ships as well as accidents on foreign merchant ships in Danish and Greenlandic waters.

The investigations of the Danish Maritime Accident Investigation Board procure information about the actual circumstances of accidents and clarify the sequence of events and reasons leading to these accidents.

The investigations are carried out separate from the criminal investigation. The criminal and/or liability aspects of accidents are not considered.

Marine accident reports and summary reports

The Danish Maritime Accident Investigation Board investigates about 140 accidents annually. In case of very serious accidents, such as deaths and losses, or in case of other special circumstances, either a marine accident report or a summary report is published depending on the extent and complexity of the events.

Contents

1. SUMMARY

On 13 February 2014 at 1530, the Danish container ship SVENDBORG MÆRSK departed from Rotterdam, the Netherlands. The ship was bound for the Suez Canal, and subsequently the Far East. The master expected to encounter adverse weather conditions on the route. However, the forecast did not cause any concern.

The following day, as the ship had left the Outer English Channel the weather conditions started deteriorating. In the afternoon, the ship suddenly and without warning rolled to extreme angles and a large number of cargo containers fell over board.

In the early evening, the ship again suddenly rolled violently, reaching an extreme angle of roll of 41° to port. Again a large number of containers were lost over board and the master considered the situation to threaten the safety of the ship. The master sounded the general alarm to muster the crew members. Later in the evening he assessed that the weather no longer posed an immediate danger to the ship.

The weather conditions encountered were more severe than the forecast had predicted.

SVENDBORG MÆRSK proceeded towards Malaga, Spain, for repairs of the ship and removal of damaged containers on board. The ship arrived alongside at 1715 on 17 February 2014.

In the analysis the DMAIB has addressed a number of topics, such as the master´s decision making and the information available to him, as well as the ship´s capability to withstand adverse weather conditions.

The report contains information, received from Maersk Line, about preventive actions taken.

2. FACTUAL INFORMATION

2.1 Photo of the ship

Figure 1: SVENDBORG MÆRSK after departure from Rotterdam on 13 February 2014
Source: Frans Sanderse/Shipspotting

2.2 Ship particulars

Name of vessel:	SVENDBORG MÆRSK
Type of vessel:	Container ship (fully cellular)
Nationality/flag:	Denmark (DIS)
Port of registry:	Svendborg
IMO number:	9146467
Call sign:	OZSK2
DOC company:	A.P. Møller-Mærsk A/S
IMO company no. (DOC):	0309317
Year built:	1998
Shipyard/yard number:	Odense Staalskibsværft A/S – Munkebo (Lindø Shipyard)164
Classification society:	American Bureau of Shipping (ABS)
Length overall:	346.980 m
Breadth overall:	42.8 m
Gross tonnage:	92,198
Deadweight:	110,387 t
Draught max.:	14.941 m
Engine rating:	54,835 kW
Service speed:	25.0 knots
Hull material:	Steel
Hull design:	Single hull

2.3 Voyage particulars

Port of departure:	Rotterdam, the Netherlands
Port of call:	Colombo, Sri Lanka
Type of voyage:	Merchant shipping, international
Cargo information:	General cargo in containers
Manning:	24
Pilot on board:	No
Number of passengers	0

2.4 Weather data

Wind – direction and speed:	Southwest – 25 m/s and gusts up to 33 m/s
Wave height:	10 metres and above
Visibility:	0,5 nm
Light/dark:	Light
Current:	Unknown

2.5 Marine casualty or incident information

Type of marine casualty/incident:	Loss of cargo
IMO classification	Serious casualty
Date, time:	14 February 2014 at 1543 & 1813 UTC
Location:	Atlantic Ocean, off Ushant Islands
Position:	48°42.4' N – 005°58.8' W & 48°22.3' N – 006°08.1' W
Ship's operation, voyage segment	In transit
Place on board:	Cargo deck
Human factor data:	Yes
Consequences:	517 containers lost over board and another 250 damaged. Damage to and loss of equipment stowed on deck and minor damage to the ship´s structure. No lost containers contained dangerous goods.

2.6 Shore authority involvement and emergency response

Involved parties:	C.R.O.S.S. Corsen (Ushant Traffic)
Resources used:	None
Speed of response:	N/A
Actions taken:	Navigational warning broadcast
Results achieved:	N/A

2.7 Key persons

Master:	Certificate of competency as master – STCW II/2. 57 years old. Has served on board since signing on 17 January 2014. Has previously served on board the sister ship SVEND MÆRSK. Employed by the company since 1999. Total time at sea is 42 years.
Chief officer:	Certificate of competency as master – STCW II/2. 40 years old. Has served on board for approx. one year. Employed by the company since 2002. Total time at sea is 13 years.

2.8 Scene of the incidents

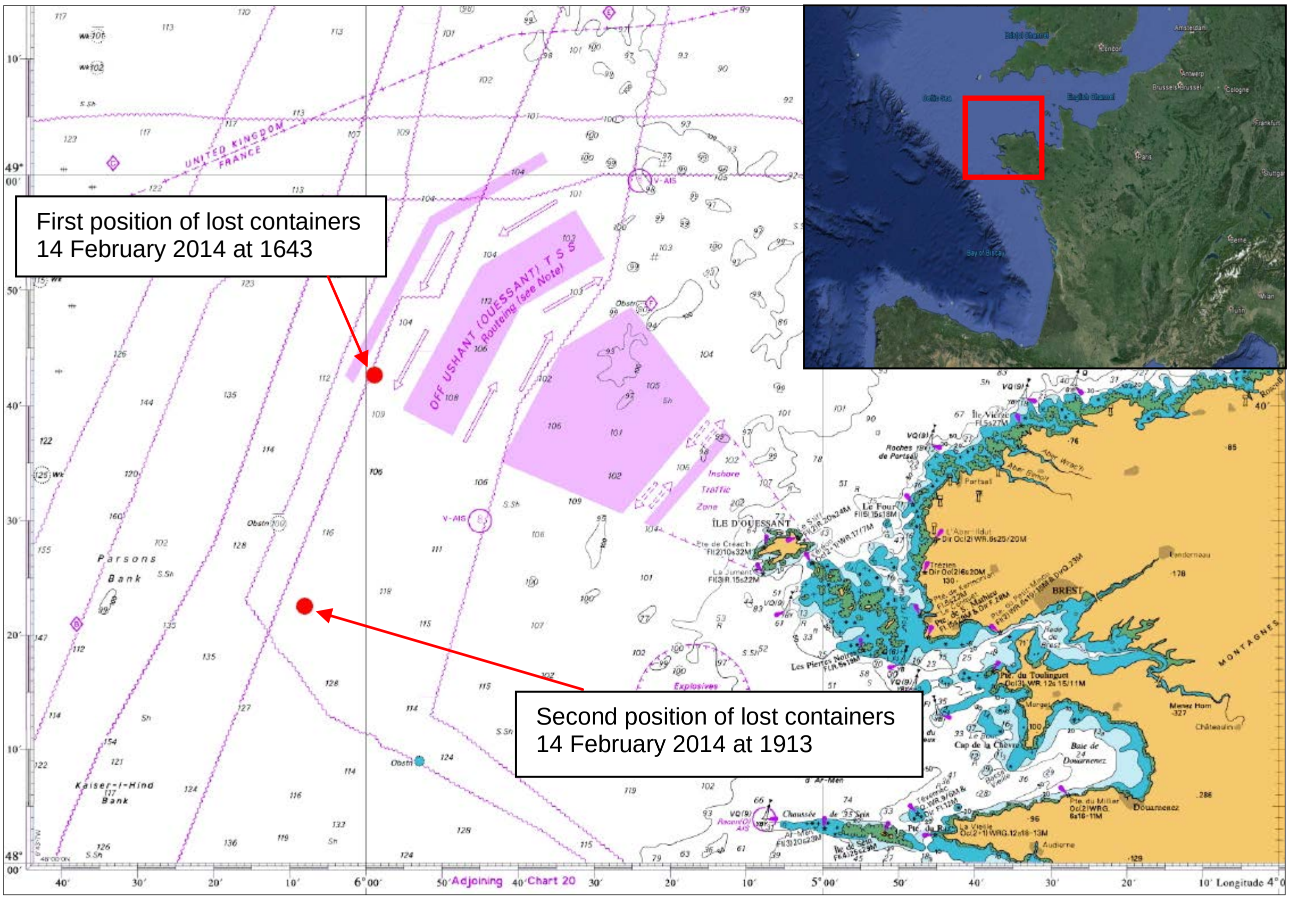


Figure 2: Scene of the accident. Atlantic Ocean (Bay of Biscay) off Ushant Island
Source: © Crown Copyright and/or database rights. Reproduced by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk) & Google Earth

3. NARRATIVE

3.1 Background

At the time of the incident, SVENDBORG MÆRSK was owned and operated by A.P. Møller-Mærsk A/S and registered in the Danish International Register of Shipping with its port of registry in Svendborg, Denmark.

The ship was a container ship with a capacity of 8,160 TEU, engaged in a regular trading service between ports in Asia and northern Europe via the Suez Canal. Port calls were according to a predetermined schedule. A round trip would typically consist of 18 port calls and take approx. two and a half months to complete.

The ship formed part of a series of 16 sister ships.

All times in this report are given as the ship's local time unless otherwise specified.

3.2 Sequence of events

On 13 February 2014 SVENDBORG MÆRSK was alongside the APM Terminals in Rotterdam loading and discharging cargo. Simultanously the ship bunkered and stores were taken on board by the crew members. Once all operations had been completed at 1530, the ship departed for the

Suez Canal, Port Said Anchorage. According to the voyage plan, the ship should arrive on 20 February at 1730 local time, requiring an average speed of 19.8 knots.

Prior to departure the master consulted the weather forecast and he concluded that there was a risk that the ship would encounter strong winds and high seas during the voyage. Therefore the crew members were instructed to prepare the ship for the expected heavy weather. The container lashings were checked visually, and where possible physically, to ensure the proper securing of the cargo when the cargo operations were complete. This was a routine procedure and when checks were completed, a note of this was entered into the logbook.

At 1500, the pilot arrived on board and the ship left the berth in Rotterdam at 1530, assisted by two tug boats. Once underway, the crew members stowed and secured the stores that were received during the port stay.

The following morning on 14 February 2014, the ship reached the southern part of the English Channel and around noon the weather conditions started to deteriorate.

At approx.1420, the weather conditions had worsenend and the master went to the bridge to assist the 2nd officer in the navigation of the ship. The master reduced the speed through the water to approx. 10 knots. The ship´s heading was changed from approx. 240° to 210° to have the predominant wind and sea direction straight on the bow to minimize the rolling of the ship.

At 1530, the chief officer came to the bridge where he took over the watch and relieved the 2nd officer. During the chief officer´s watch, the master frequently came to the bridge to assess the situation. At this time other crew members had also arrived on the bridge to observe the deterioating weather situation.

At 1559, the ship received a storm warning by EGC[1] forecasting violent storm, force 11 until 2100 for the area in which the ship was positioned.

The motions of the ship gradually became severer and the ship occasionally rolled heavily and the speed through the water was down to approx. three knots.

At 1643, in position 48°42´4 N 005°58´8 W (figure 2) the ship suddenly and without warning rolled to an extreme angle. Six to eight times the ship rolled, three to four times to each side, reaching an angle of 38° to starboard, before the ship once again resumed the more moderate motions experienced prior to the extreme rolling. The master took command of the ship assisted by the chief officer. During the extreme rolling, the crew members on the bridge observed that a large number of containers were lost over board from the bay just outside the front end windows of the wheelhouse and also from the aft part of the ship, on the aftermost bay.

Immediately after the extreme rolling, the vessel traffic service C.R.O.S.S. Corsen (Ushant Traffic) was informed by VHF radio about the loss of containers. A precise account of the loss could not be established due to the risk it would impose to send crew members on deck during the adverse weather conditions. A very rough estimate of the number of lost containers was given and Ushant Traffic subsequently broadcast a navigational warning to warn the shipping traffic in the area of the potential hazard imposed by floating containers. Furthermore, information about a point of contact with the ship owner was given upon request from Ushant Traffic.

As a result of the extreme rolling, two out of four steering gear pump units failed. Their function was quickly restored, and an able seaman (AB) was assigned to steer the ship by the helm. An additional auxiliary engine was started by the chief engineer, to provide backup and mitigate the risk of a blackout in the event that one would fail due to further violent motions of the ship. Bilge

[1] Enhanced Group Call is a system using Inmarsat C to receive maritime safety information (MSI).

alarms were activated, as water had entered the chainlocker, the port side engineer's passageways and the forward holds nos. 1 and 2 through openings in the deck and open firedampers. The water was removed by operating the ship´s bilge system from the engine control room.

After the violent rolling, the master and chief officer agreed that a two shift watch schedule should be implemented until the weather conditions had improved. The watch consisted of the master assisted by the 3rd officer and the chief officer assisted by the 2nd officer. However, as the events unfolded, this watch scheme was never implemented.

The chief officer left the bridge in order to rest until midnight, when he was to take over the watch on the bridge again. The master remained on the bridge assisted by the 2nd officer.

The master tried to call the company several times by the Iridium satellite telephone, but did not manage to get through to the designated emergency contact points. The 2nd officer continued to call the numbers provided and eventually contact was made and a company representative was informed about the situation on board.

At 1913, in position 48°32´3 N 006°08´1 W (figure 2) the ship again rolled over heavily, reaching an angle of 41° to port. A large amount of containers from the cargo deck were again observed falling overboard. The speed through the water was increased moderately to 4-5 knots to ensure effective steering and to mitigate parametric resonance, as this was suspected to be a possible cause of the extreme rolling. Again Ushant Traffic was notified about the additional loss of containers.

Following the second incident, the master became concerned not only about the cargo, but also about the overall safety of the ship and crew. He therefore sounded the general alarm and used the public address system to instruct the chief officer to come to the bridge. The chief officer collected his radio and crewlists as part of the muster routine and made his way from his cabin to the bridge. The situation was briefly discussed and the master informed that, due to his concerns about the present weather conditions, he wanted the crew members to muster to assure himself of where everybody was. The master did not consider it a favorable or safe option to turn the ship around and seek shelter as he was worried about the effect of the waves if the ship´s heading was changed substantially.

The chief officer left the bridge and went down to the ship control center on the A deck to count the crew members. The crew members had mustered there, and had brought their immersion suits. The chief engineer and the 2nd engineer had mustered in the engine control room.

Later in the evening, as the weather conditions improved slightly, the master decided to repeal the mustering and the crew members left the ship control center.

The master remained on the bridge during the rest of 14 February until 16 February 2014 at 0400.

As the weather slowly improved on 15 February 2014, the crew members started to clean up the ship. The chief officer carried out an estimated stability calculation to ascertain whether the condition of the ship remained favorable with some of the deck cargo lost over board. The ship had gained a slight forward trim as a result of the large amount of lost containers from the aft part of the deck.

At 0400 on 15 February 2014, the chief officer relieved the master on the bridge.

Preliminary assessments of the damages were carried out on board, in order to report to the company. The master was instructed to proceed to Malaga, Spain, for repair of minor damages to the ship and removal of the damaged containers still on board.

At 1715 on 17 February 2014, the ship arrived alongside in Malaga. After arrival a shared debriefing was held among the crew members, and a psychologist attended the ship to give support as needed. One crew member was sent to the local hospital for treatment of minor bruises originating from the incident. Four crew members signed off at their own request.

Final assessments of the damages to the ship and the loss of cargo were carried out in Malaga.

3.3 Cargo planning and securing

SVENDBORG MÆRSK was a fully cellular container ship configured for standardized cargo in the form of 20 ft. containers, 40 ft. containers and 45 ft. containers in holds and on deck. The position of a container was given according to a *bay, row and tier* system. The term bay meant a thwart ships section of the ship in its longitudinal direction and thus the container position longitudinally. The term row defined the thwarts ship container position in each bay and the term tier defined its lateral position in each horizontal layer (figure 3).

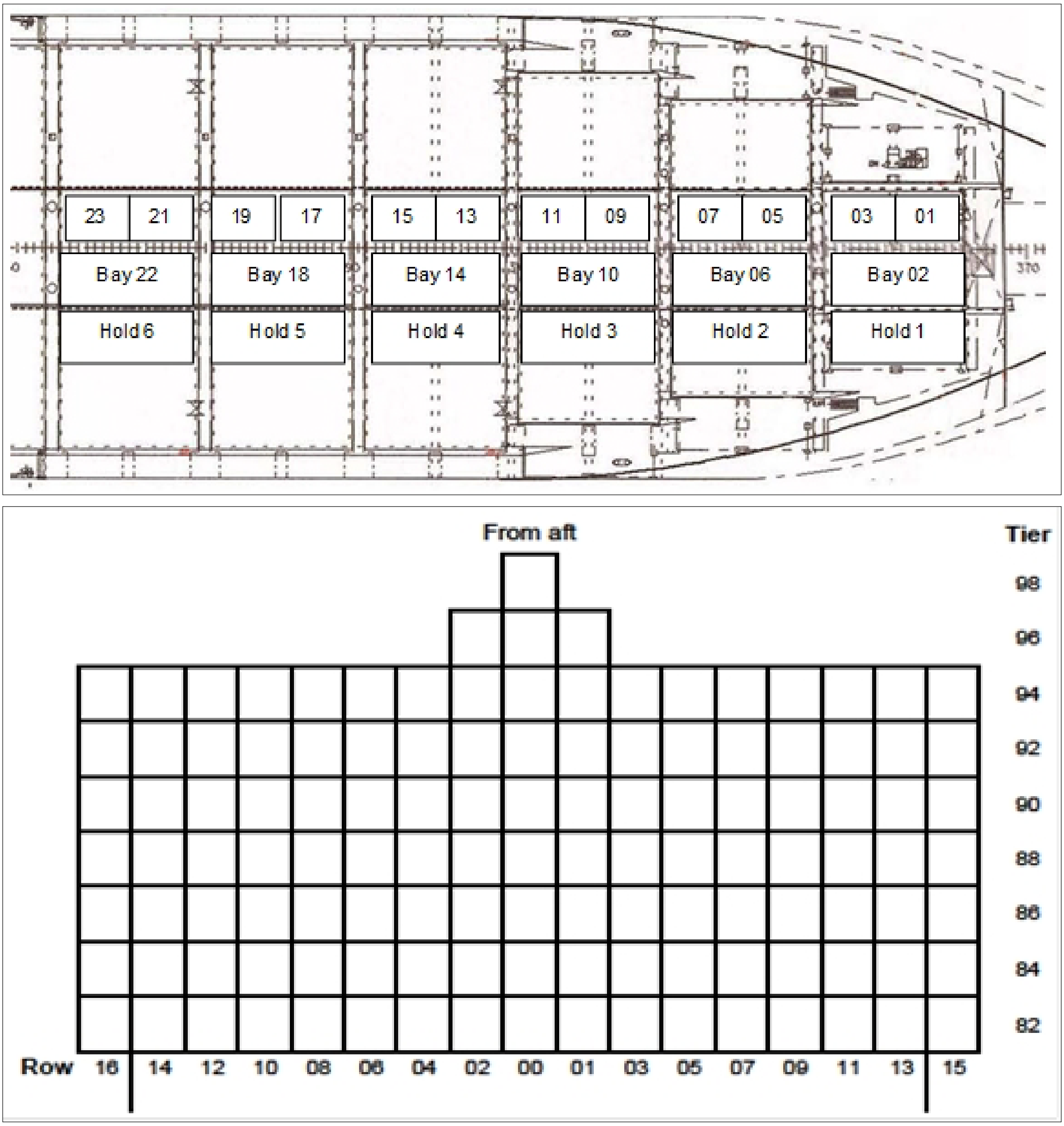


Figure 3: Principle of container stowage, bay, row & tier system
Source: DMAIB

3.3.1 Cargo planning

Prior to cargo operations, the ship received a preliminary loading condition for the cargo software application, LOADSTAR. The chief officer would then verify that all safety parameters were within limits, in relation to the ship´s stability, stress on the hull, and cargo stowage and cargo securing integrity. Prior to departure a new loading condition was received, reflecting the actual condition after loading, which again needed verification.

One calculated parameter that needed to be satisfied was the lashing roll angle. This was defined as the theoretic angle of roll to which the lashings would be able to withstand the dynamic forces from the ship´s roll motions acting on the cargo.

The lashing roll angle value to be applied in LOADSTAR was determined by the recently implemented company standard operating procedure (SOP) about dynamic lashing. This incorporated statistical wave data, hull particulars and voyage specific data to calculate the maximum roll angles, with a safety factor added that the vessel would be subject to on the voyage at the time of the year. The SOP allowed a reduction of the previous default lashing roll angle value of 20.06°.

According to the SOP, SVENDBORG MÆRSK was to apply a lashing roll angle of 17.1° on this voyage. However, the chief officer applied the default roll angle of 20.06° in LOADSTAR. Thereby, the ship could withstand roll angles larger than required by the SOP.

All calculated parameters in LOADSTAR, including the lashing roll angle, were satisfied upon departure from Rotterdam. There was a discrepancy between the calculated draught and the actual draught[2]. The calculated draught was 13.21 metres forward and 13.08 metres aft, and the observed draught was 13.40 metres forward and 13.20 metres aft.

3.3.2 Cargo securing

Securing of the cargo containers was carried out in accordance with the cargo securing manual, which was approved by the ship´s classification society. The securing system incorporated a number of types of lashing equipment to be applied, depending on the type of container and its position on board. Generally lashing rods/turnbuckles were used to secure the containers up to tier 88; either from the cargo hold hatches or the lashing bridges (figure 4). All containers were secured by twistlocks.

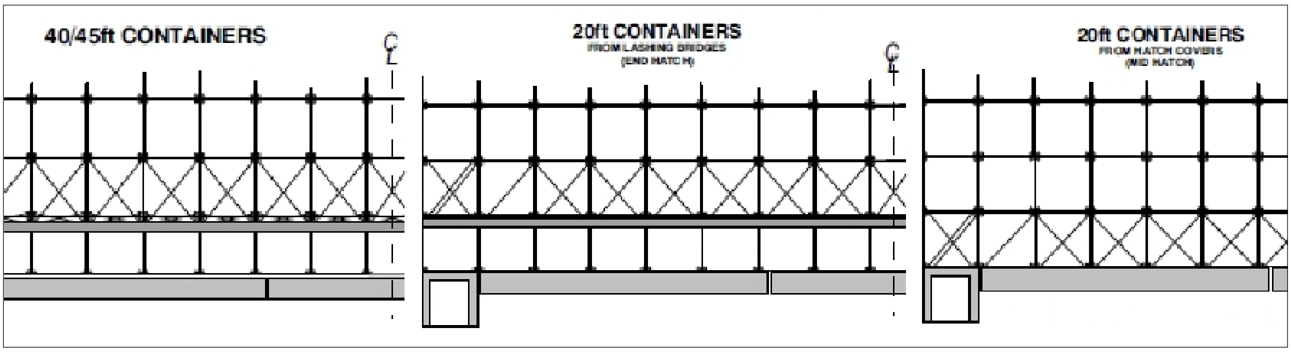


Figure 4: Securing of different cargo containers
Source: Maersk Line A/S

Fitting of all the lashing equipment was carried out by stevedores[3]. Instructions on how to secure the containers in the different positions on board were posted near the lashing bridges. The twistlocks were fitted on the containers by the stevedores on the quay. The cargo operations and securing of the cargo containers were supervised by the deck officers and final inspections were carried out prior to departure.

In general, many tasks needed attention during a busy port stay. Therefore, it was challenging for the deck officers to effectively check all the individual cargo lashings due to time constraints, accessibility, and priority of other duties to be carried out before departure.

Throughout a voyage, the lashings were normally inspected and tightened as appropriate. During this voyage, prior to the incidents, the lashings had not been attended to due to the short time elapsed since departure from Rotterdam. It was not found necessary since, at this stage, the lashings had not yet been exposed to any significant impact by dynamic forces on the ship, and when the weather deteriorated, the master decided that it was no longer safe to have crew members working on deck.

[2] Visually observed on the ship´s draught marks.
[3] Personnel employed in port to lash and unlash cargo on ships.

Throughout the cargo deck "Fully Automatic Twistlocks" (FATs) were used (figure 5). FATs were manually locked on containers positioned in tiers 82, 84 and 86. Above tier 86 the FATs were left in automatic mode. This type of twistlocks was designed to eliminate the time consuming task of un-locking twistlocks during cargo discharge operations in port, and to add an element of safety for the stevedores who did not need to climb ladders and container stacks etc.

The FATs was designed to enable automatic release of a container during cargo operations and at the same time securing the containers when exposed to the motions of the ship during transport.

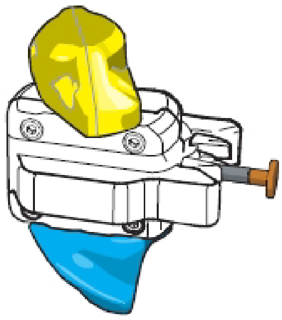
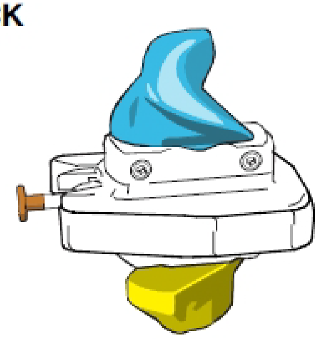
TYPE C8A-DF (APM 450998) SWL (LASHING) : 25 TONS SWL (LIFTING) : 10 TONS WEIGHT : 7.1 KG SUPPLIER : MACGREGOR	**TWISTLOCK** FULLY-AUTOMATIC  15.240 PCS
TYPE C8A-HC (APM 451001) SWL : 25 TONS WEIGHT : 8.5 KG SUPPLIER : MACGREGOR	**BASE TWISTLOCK** FULLY-AUTOMATIC  2.600 PCS

Figure 5: Fully Automatic Twistlocks (FATs)
Source: Maersk Line A/S

The design safety factor for FATs was lower than for conventional non-automatic twistlocks and semi-automatic twistlocks, allowing less force to act on them before reaching their minimum break-ing load. In addition, the design of FATs in automatic mode allowed container stacks to swing con-siderable due to a higher vertical tolerance.

Several pieces of lashing equipment, including FATs, were found damaged as a result of exces-sive forces induced by the severe rolling of the ship and impact from the seas (figure 6). Some of the lashing rods had failed in their function, indicating that the forces induced on the container stacks during the incident had found their way down to the bottom tiers.

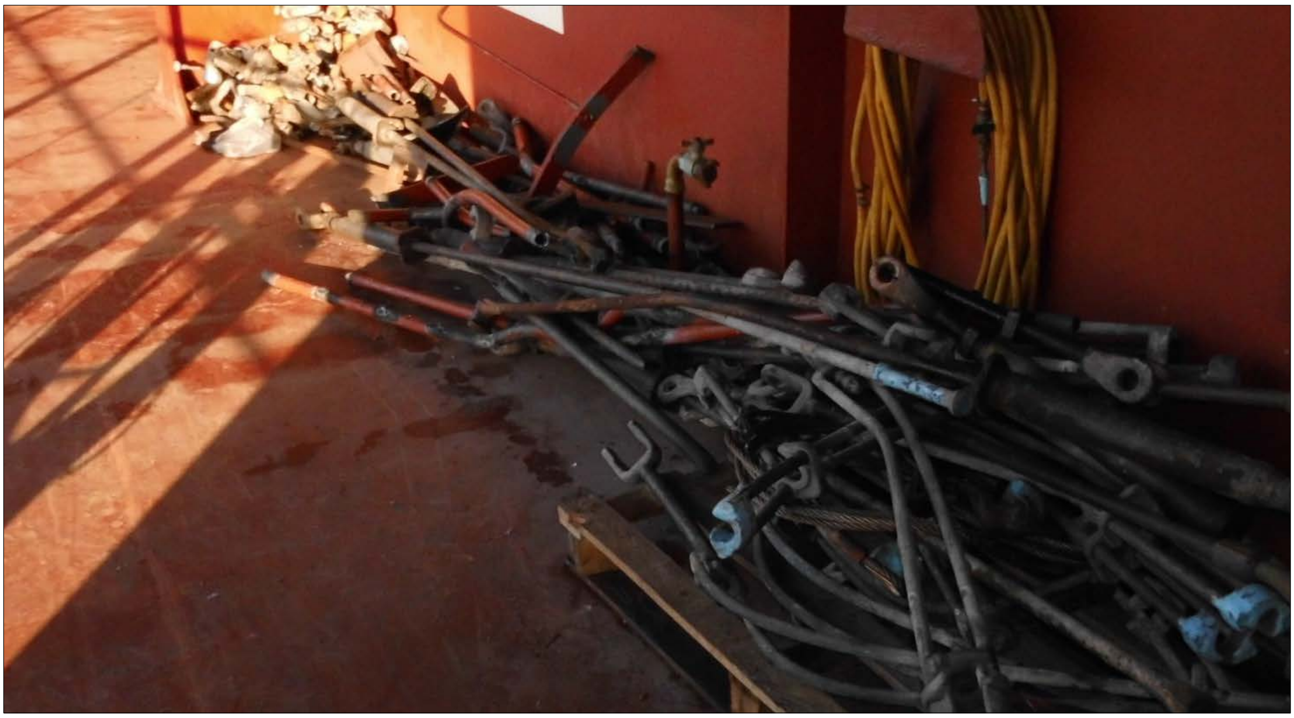


Figure 6: Damaged lashing equipment
Source: Maersk Line A/S

Some containers were found with structural damages confirming that their structural strength was lower than the lashing equipment (figure 7 & 8). The structural strength of the containers and lashing equipment depended on their individual condition and application. Therefore, the finding of damaged lashing equipment *and* containers indicated variations in their structural strength, and/or varying distribution of forces acting on them.

Figure 7: Damaged container
Source: Maersk Line A/S

Figure 8: Damaged containers
Source: Maersk Line A/S

3.4 Fin stabilizers

The ship was equipped with a retractable fin stabilizer system on starboard and port side. The system could be activated to reduce the rolling motions of the ship caused by wind and waves.

At the time of the incident, only the port side stabilizer fin was operational as the starboard fin had suffered a breakdown, which the company had decided not to repair. Several years before the heavy weather incidents, it was decided that new buildings should not be equipped with stabilizers. Later on, it was decided that existing stabilizers should be kept running, but taken out of service in case of breakdown. The company decision was based on the considerable speed loss that the stabilizers caused, not only when they were in use, but also from turbulence around the recesses when the fins were retracted.

The optimal operating parameters for fin stabilizers are uncertain as many variables affect their performance. Operating only one fin stabilizer may have approx. 80 % of the effect of using both fins depending on the actual forces acting on the hull. Fin stabilizers generally have a limited effect as the rolling forces increase. The effect will be further limited when a ship experiences the effect of parametric resonance as the roll inducing forces are quickly and significantly amplified leaving little time for the automatic adjustment of the fins. Low speed through the water will also limit the performance of the fin stabilizers.

Therefore, having one or two functioning stabilizer fins had little or no influence in limiting the severity of the rolling experienced by SVENDBORG MÆRSK during the incidents. They were not designed to be effective in countering the immense forces acting on the hull causing sudden extreme rolling.

3.5 Conversion of the ship

SVENDBORG MÆRSK was converted in 2012, being the 14th converted ship in a series of 16 container ships included in an optimization program. The scope of the conversion included:

- Elevation of the wheelhouse, by 8.4 metres.
- Replacement of the existing one-tier high lashing bridges with new two-tier high lashing bridges.
- Increase of scantling draught from 14.5 to 15.0 metres.
- Replacement of semi-automatic twistlocks with FATs.

The conversion made it possible to load an increased number of containers on deck by adding two or three layers; enabling stacking up to nine tiers high (figure 9).

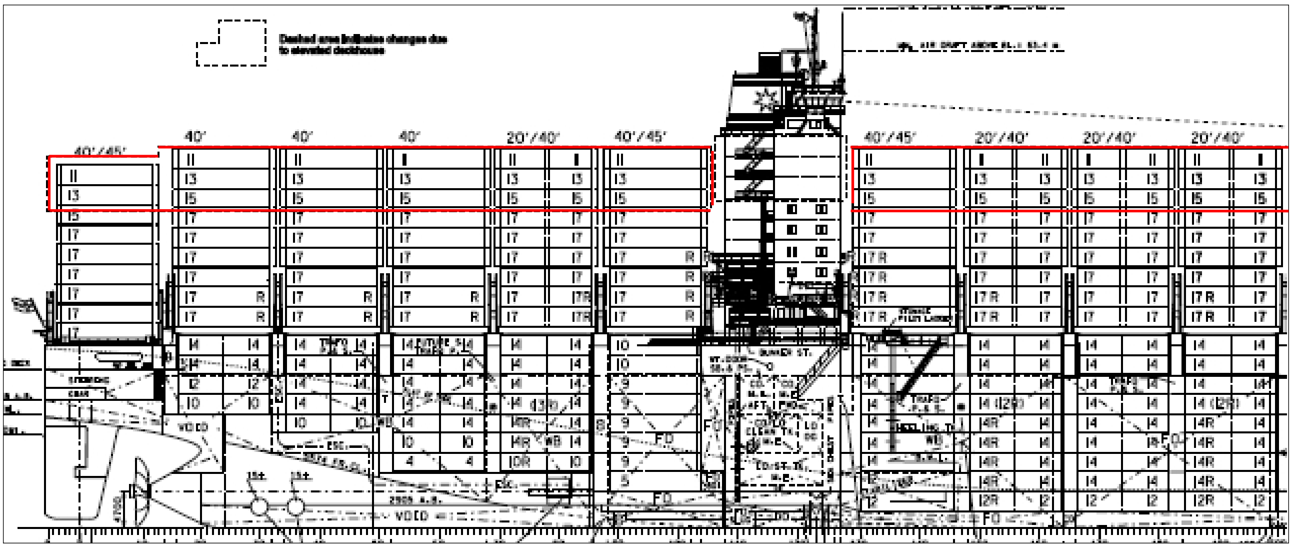


Figure 9: Excerpt from general arrangement of SVENDBORG MÆRSK after conversion. Boxed red area shows increase in container capacity.
Source: Maersk Line A/S

The modifications made during the conversion and the modified stability information and cargo loading computer system were subsequently approved by the ship´s classification society, American Bureau of Shipping.

The conversion updated the ship by utilizing changes to class rules, allowing higher limits when calculating forces. This enabled an increase of cargo capacity by approx. 3,000 TEU.

3.6 Weather

3.6.1 Weather forecast

SVENDBORG MÆRSK used SPOS[4] as its primary system for obtaining and analysing weather forecasts. The master usually studied the information received both prior to a voyage and during the voyage as regular updates were received. Additionally, weather information and maritime safety information was received by NAVTEX and EGC.

Before and during this particular voyage, the SPOS was configured to receive updated weather forecasting information four times a day.

[4] Ship Performance Optimisation System provided by MeteoGroup.

The SPOS weather forecasting application provided the master with information about the predicted barometric pressure, wind force, wind direction, and sea state. The development and movement of the weather systems were visually displayed to gain an overview of the expected sea and weather conditions in relation to the planned voyage.

Upon request by the Danish Maritime Accident Investigation Board, the provider of meteorological data to the SPOS application, MeteoGroup, has made a report showing what information was available to the master prior to departure from Rotterdam on 13 February 2014.

The data in the report were based on the updates provided to SVENDBORG MÆRSK on 13 February 2014 at 0000 UTC and 1200 UTC.

The sea state presented in the report as well as in the SPOS application was the significant wave height consisting of a total of swell and sea. Below is an excerpt from the conclusions in the report:

> "*SPOS forecast data as available on 13 February 2014 indicate that at the time and in the area of the incidents:*
>
> *Winds were expected to increase to 40-45 knots (8-9 Beaufort) from direction south to southwest.*
>
> *Total significant wave height would be 7.0-7.5 metres including 3.5-4.0 metres westerly swell"*

Below figures 10 - 15 show the forecasted weather on the day of the incidents which was available to the master of SVENDBORG MÆRSK in the SPOS application on 13 February 2014 – prior to departure from Rotterdam.

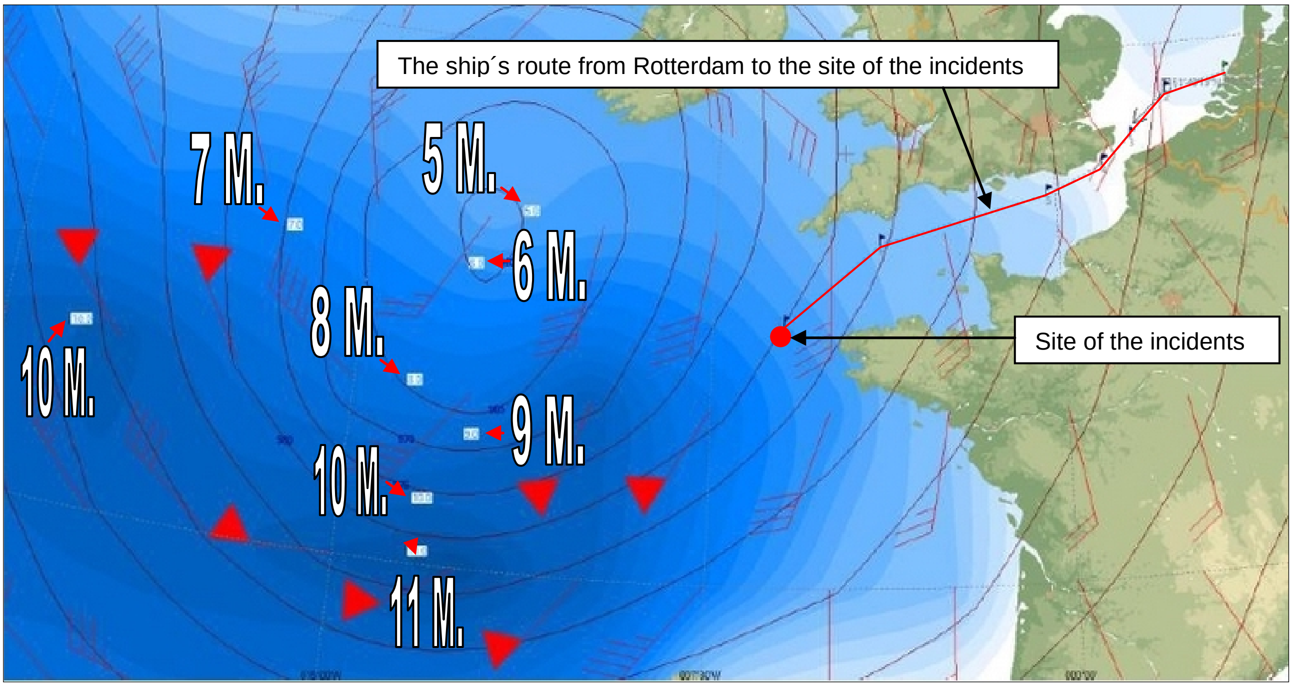


Figure 10: SPOS weather forecast for 14 February 2014 at 1200 UTC as forecasted on 13 February at 1200 UTC showing significant wave height (highlighted in large figures by DMAIB), air pressure isobars and wind speed/direction.
Source: MeteoGroup

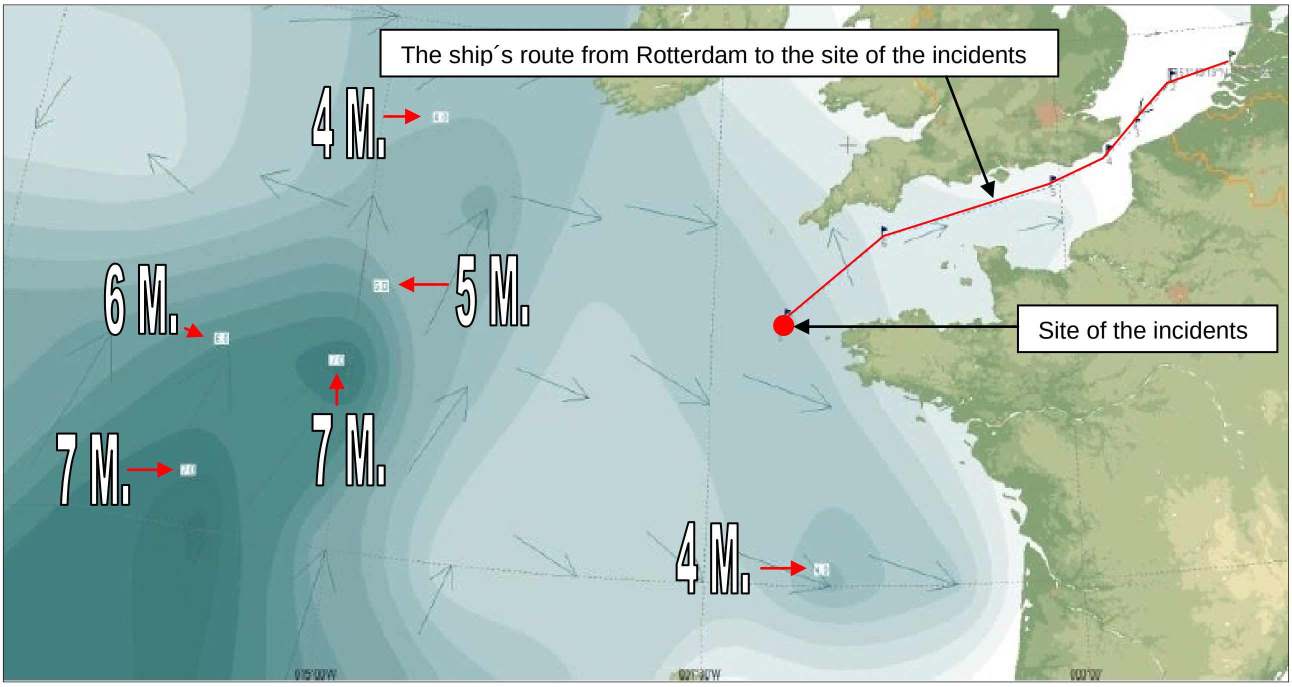


Figure 11: SPOS weather forecast for 14 February 2014 at 1200 UTC as forecasted on 13 February 2014 at 1200 UTC showing swell height (highlighted in large figures by DMAIB) and direction.
Source: MeteoGroup

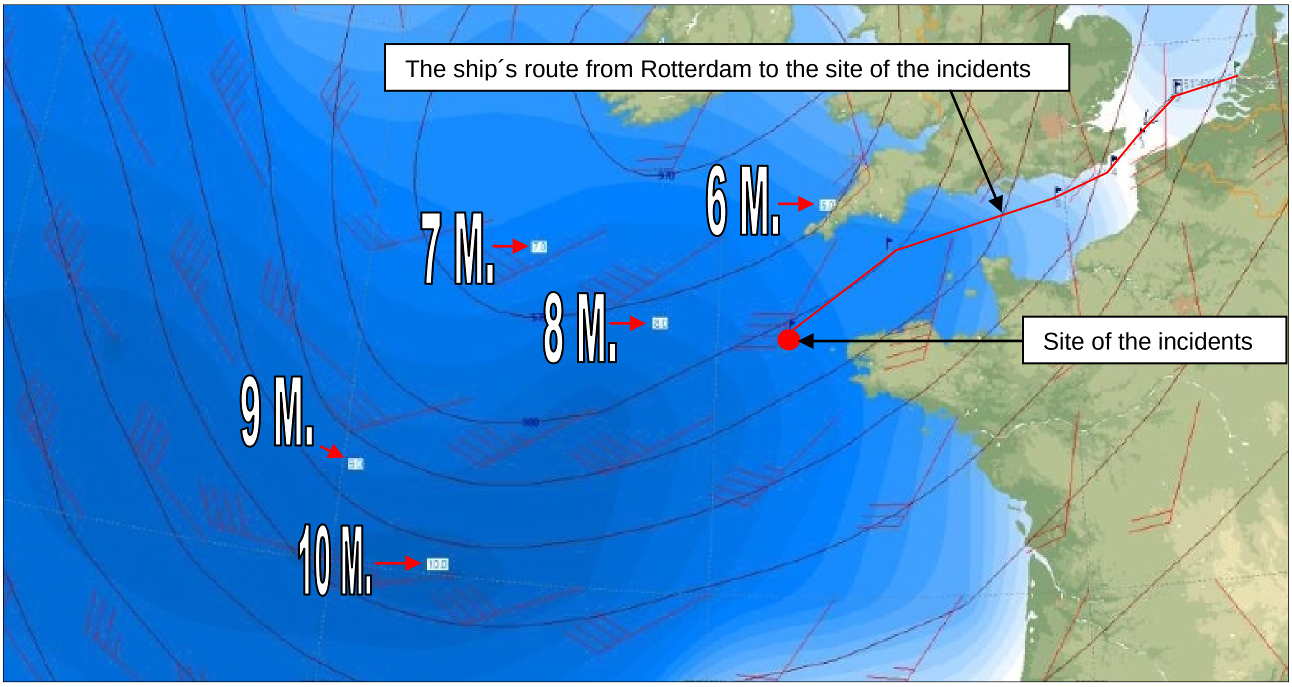


Figure 12: SPOS weather forecast for 14 February 2014 at 1800 UTC as forecasted on 13 February 2014 at 1200 UTC showing significant wave height (highlighted in large figures by DMAIB), air pressure isobars and wind speed/direction.
Source: MeteoGroup

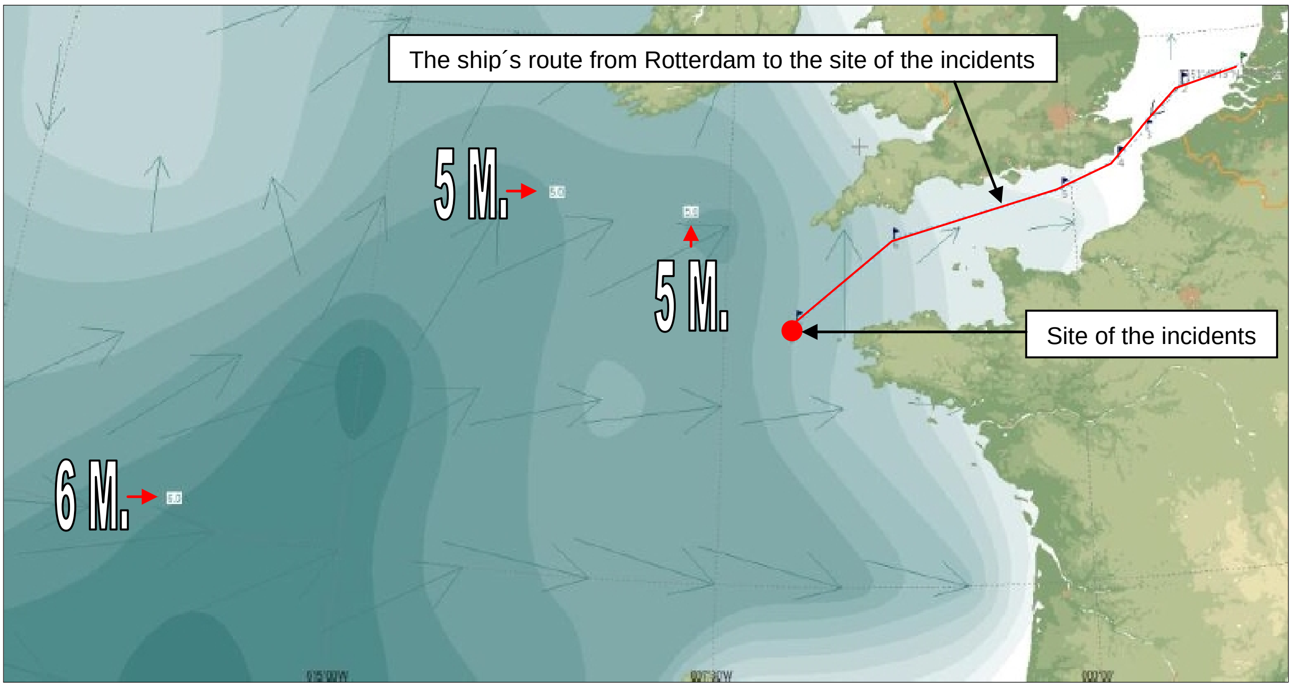


Figure 13: SPOS weather forecast for 14 February 2014 at 1800 UTC as forecasted on 13 February 2014 at 1200 UTC showing swell height (highlighted in large figures by DMAIB) and direction.
Source: MeteoGroup

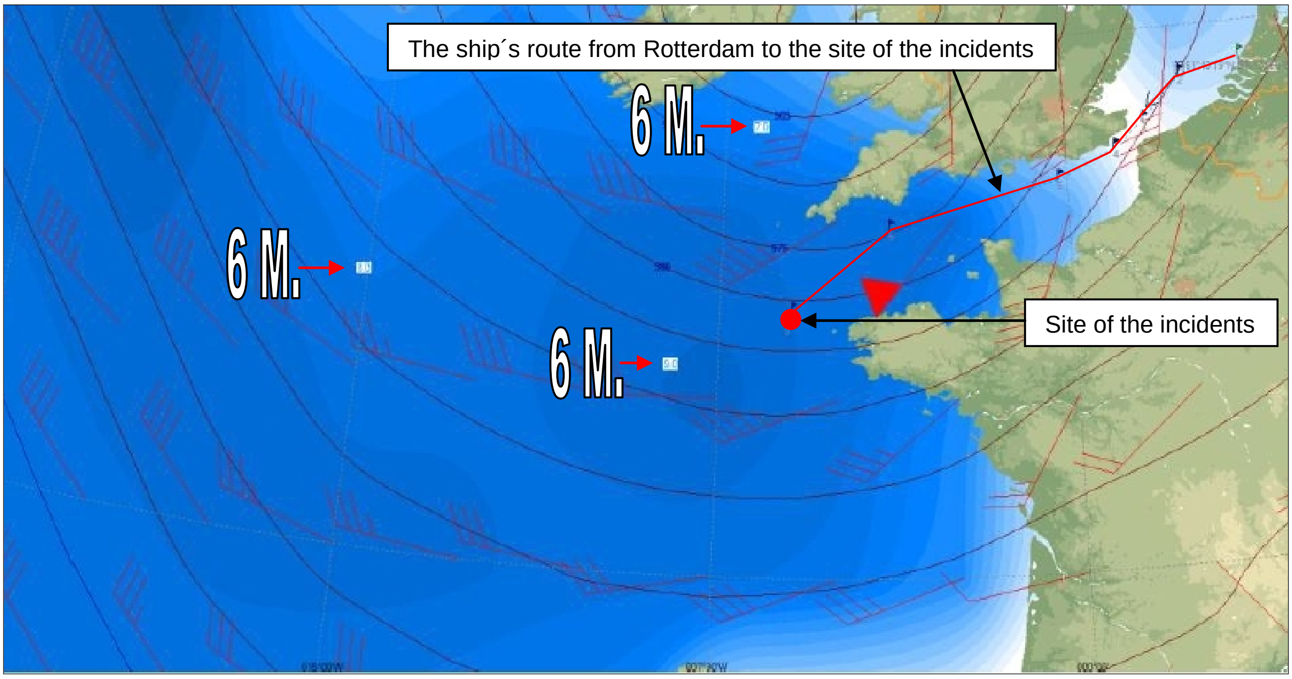


Figure 14: SPOS weather forecast for 15 February 2014 at 0000 UTC as forecasted on 13 February 2014 at 1200 UTC showing significant wave height (highlighted in large figures by DMAIB), air pressure isobars and wind speed/direction.
Source: MeteoGroup

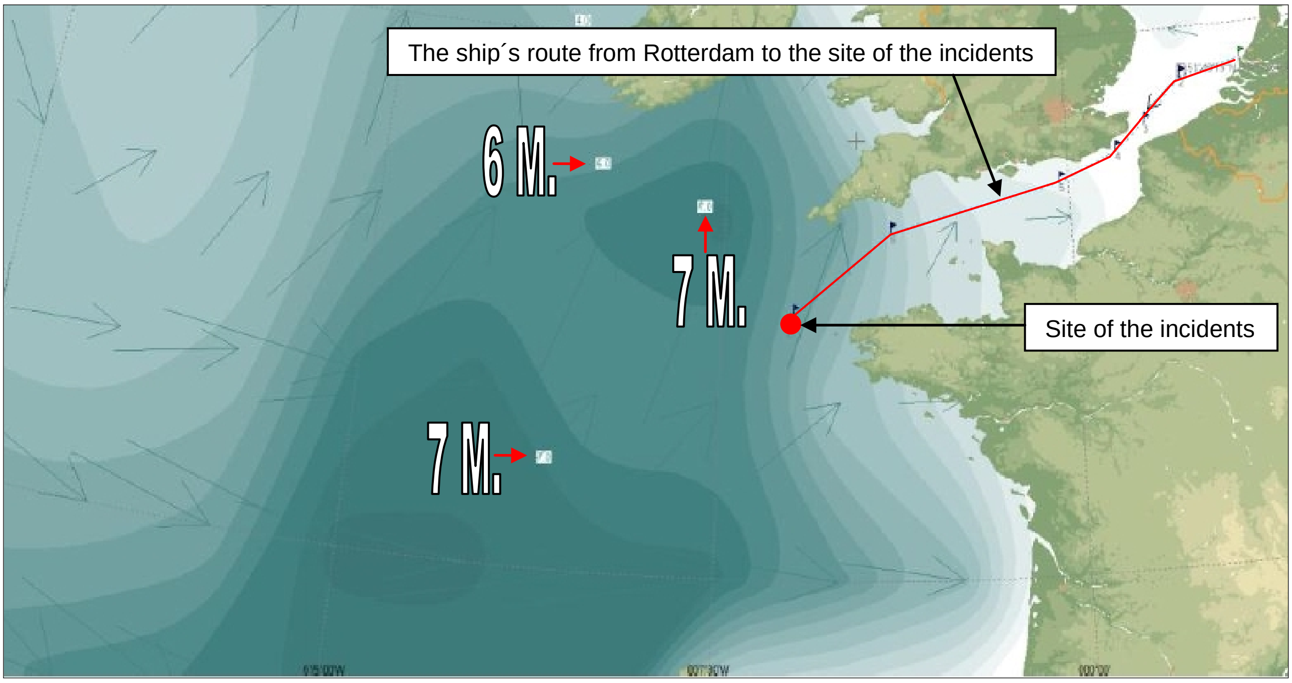


Figure 15: SPOS weather forecast for 15 February 2014 at 0000 UTC as forecasted on 13 February 2014 at 1200 UTC showing swell height (highlighted in large figures by DMAIB) and direction.
Source: MeteoGroup

The report data largely substantiated the master´s conception of the weather situation on the forthcoming voyage, prior to departure from Rotterdam, on the day before the incidents. Based on the master´s experience with heavy weather, and the ship type, the forecasted conditions did not concern him. They were not unusual for the area at the time of the year.

3.6.2 Weather observations in the area

The North Atlantic area had experienced some extreme weather during the last two weeks prior to the accident. Below is an excerpt from a text issued by the UK Met Office[5] on its website giving an impression of the nature of the weather conditions:

"Winter storms, January to February 2014

The UK experienced a spell of extreme weather from late January to mid-February as a succession of major storms brought widespread impacts and damage to the UK.

Around 6 major storms hit through this period, separated by intervals of 2 to 3 days. The sequence of storms followed an earlier stormy period from mid-December 2013 to early January 2014. Taken individually, the first two storms were notable but not exceptional for the winter period. However, the later storms from early to mid-February were much more severe. Overall, the period from mid-December 2013 to mid-February 2014 saw at least 12 major winter storms, and, when considered overall, this was the stormiest period of weather the UK has experienced for at least 20 years.

Strong winds and huge waves made conditions extremely dangerous around exposed coastlines – particularly in the south and west, and caused widespread transport disruption."

[5] United Kingdom National Weather Service.
Source: http://www.metoffice.gov.uk/climate/uk/interesting/2014-janwind

The ship's crew members made observations of the weather conditions on February 14 2014 and these were entered into the log book. At 1400 the wind was observed to be at a direction south-westerly force 10 on the Beaufort scale and the corresponding sea state was 9 on the Beaufort scale. At 1800 the wind was observed to be at a direction south-westerly force 10 and the sea state had increased to 10. At 2200 the wind was observed to be at a direction south-westerly force 12 and the sea state 10.

Furthermore, subsequent to the incidents, weather observations were obtained and analysed by meteorological sources:

Excerpt from "Weather and ocean conditions Svendborg Maersk February 2014 Preliminary report" by the Danish Meteorological Institute[6]:

> *"Evaluation of weather and ocean conditions:*
> *Prior to the heavy weather event, several weeks of enhanced and strong low activity had been taking place. The North Atlantic track of winter lows, had since early January in general positioned from off Eastern seaboard towards the British Isles and the waters south of Iceland. Most of these lows were either of strong gale force- or frequently storm force, with associated very high seas occurring over a large area, in particular south- and west of the individual lows.*
>
> *Conditions in the Bay of Biscay February 14th 2014:*
> *This was also the case when Svendborg Maersk left Rotterdam February 13th afternoon. One of the mentioned strong lows was developing rapidly west-southwest of Ireland. Several days ahead this weather development had been well forecasted with only minor deviations of the exact center position and with even higher probabilities for more than 10m high waves to occur over a larger area of especially the northwest- and northerly parts of Bay of Biscay.*
>
> *The 14th/0000 UTC a storm low located west of the Bay of Biscay was moving towards northeast, with an associated significant wave field of 10m or more, covering an area from outer English Channel towards northwest- and northern parts of Bay of Biscay. This coincides with Svendborg Maersk exiting the English Channel and meeting the heavy weather just after.*
>
> *Measured wave heights and periods in the Bay of Biscay:*
> *A wave rider[7] positioned at 47-30 N / 008-24 W measured a peak in significant wave of 13.40m at the measurement time 1500 UTC and again at 1600 UTC. It is likely that the vessel met similar conditions when leaving Outer English Channel."*

Winds gusting up to 33 m/s were measured at Ushant Island on 14 February 2014 between 1500 and 1800 UTC[8].

3.6.3 Waves

The SPOS weather forecasting application displayed the significant wave height, commonly referred to as seas in the marine forecast, and their direction.

[6] The Danish Meteorological Institute (DMI) is an institution under the Danish Ministry of Climate, Energy and Building.
[7] Brittany Buoy (62163) owned by UK Met Office. Wind speed measured by anemometer and sea surface measured by intake.
[8] Source: from "Weather and ocean conditions Svendborg Maersk February 2014 Preliminary report" by the Danish Meteorological Institute.

Below is an excerpt from the American National Weather Service defining significant wave height[9]:

"Significant wave height is an average measurement of the largest 33% of waves. We measure it because in many applications of wave data, larger waves are more "significant" (important) than smaller waves. For example, the larger waves in a storm cause the most erosion on a beach.

Significant wave height measured by a wave buoy corresponds well to visual estimates of wave height. Most human observers tend to overestimate the real height of waves. As the significant wave height is an average of the largest waves over a recording period it should be noted that some individual waves might be much larger than this.

On average, about 15% of waves will equal or exceed the significant wave height. The highest 10% of waves could be 25-30% higher than the significant wave height. And on occasion (about one per hour) one can expect to see a wave nearly twice the significant wave height."

Therefore, it is probable that the wave heights encountered by SVENDBORG MÆRSK, over a period of time, would vary substantially from the wave height values given in the weather forecast.

3.7 Parametric roll resonance

Parametric roll resonance is a phenomenon that can be observed as a significant amplification of roll motion, which can endanger the ship. This phenomenon occurs as the ship´s stability is changed periodically when the ship´s speed enables a wave encounter frequency approx. twice the ship´s natural rolling frequency. The damping of the ship may then not be sufficient to eliminate the parametric roll energy and avoid a resonant condition.

The ship´s susceptibility to parametric roll resonance is determined by its design parameters along with the environment the ship encounters.

When a ship is susceptible to parametric roll resonance, the most effective preventive measures are a change of speed and/or a change of course.

The SOP about dynamic lashing prescribed the installation of an additional module to SPOS: a seakeeping module to enable the master to make a qualified assessment of the ship's motions during a forthcoming voyage. The seakeeping module should be able to forecast the roll motions of the ship and warn against risks, i.e. parametric rolling, based on specific ship data. The sea keeping module had been supplied to the ship but was not yet been implemented on board.

The textbook on marine technology[10] used in the training of navigators in Denmark recommended that the master avoided large parametric roll, which is described as: encounter frequency (T_e) ≈ rolling period (T_n) / 2. The operational guidance is stated as follows:

1. *Determine T_e (encounter frequency) and T_n (rolling period)*
2. *If $T_e \approx T_n / 2$, the speed is reduced further, while ensuring the manoeuvring speed.*

The encounter frequency can be established by measuring the ship´s pitch period with a stop watch, or by application of knowledge of the actual wave data, the expected encounter frequency can be calculated:

$$T_e = \frac{\lambda * 3600}{(Vb - Vs * \cos\chi) * 1852} \ (seconds)$$

[9] Source: http://www.srh.weather.gov/mfl/?n=waves
[10] "Skibsteknik 2", 3rd edition, published 2002.

λ = wave length, V_b = wave speed, V_s = Ship´s speed, χ = angle between the ship´s course and the wave´s direction of propagation.

The ship´s natural rolling period is dependent on its actual loading condition. Hence this should be determined by use of stop watch in calm seas at each departure, after completing cargo operations, or an approximate value can be calculated:

$$T_n = \frac{2*C*B}{\sqrt{GM}} \quad (seconds)$$

*C = 0.373 + 0.023 * B/d – 0.043 * L /100, B = breadth, d = draught, GM = metacentre height, L = length between perpendiculars.*

Excerpt from “Weather and ocean conditions Svendborg Maersk February 2014 Preliminary report” by the Danish Meteorological Institute:

> *“Dependent on the actual wave spectrum and the vessel’s dimension, speed and loading conditions, these conditions can result in a risk of experiencing parametric roll. Even though the weather situation was well forecasted and conditions like the described occur yearly/regularly, situations with risk of experiencing parametric roll are difficult to predict. This is due to the many variables involved, such as the actual composition of the wave spectrum at a given location and the vessel speed, heading and loading condition.”*

During the years 2001 to 2003, the masters employed by the company attended a course in heavy weather damage avoidance. During this course, the principles of parametric rolling were presented along with precautions and response to it. The presentations were subsequently laid down on a training CD and distributed to the company´s existing fleet and it was put on board all new buildings. The intention was that members of the bridge teams should familiarize themselves with the contents. The CD formed part of the training CD library on board SVENDBORG MÆRSK. However, not much focus had been put on the contents for some years, neither by the ship´s crew members nor by the company in general, because parametric rolling had not been identified as a cause of incidents or accidents for several years. Therefore the awareness of the contents was limited in the daily operations on board the ship.

3.8 The safety management system (SMS) and heavy weather precautions

A procedure for navigation in adverse weather was included in the ship´s SMS. The procedure instructed that when encountering rough weather, heavy seas or swell, care should be taken to avoid damage to the ship and her cargo. The primary precautions suggested by the procedure to avoid the risk of damage to the ship and cargo were an alteration of speed or change of course, or a combination of the two. Furthermore, measures to alter the ship´s stability to suit the circumstances were suggested.

A checklist for heavy weather navigation was included in the ship´s SMS. This was intended as a guide to fulfil all necessary steps to avoid incidents or damage when used prior to a heavy weather encounter. The heavy weather checklist was completed on the day of the incident.

According to the instructions in the company´s SMS, the masters should order weather routing when the regular weather forecasting means were found to be insufficient. The company preferred the Danish Meteorological Institute (DMI) with which the company had a service agreement for the delivery of weather routing service. The company´s ships were able to contact the DMI when found necessary for the purpose of getting a second opinion on the given weather situation, as DMI used a different meteorological model.

3.9 Consequences of the heavy weather encounter

After the arrival in Malaga, the results of the heavy weather encounter of the ship were determined to include the loss over board of some lifesaving appliances stored on deck and damage to others. Some other equipment fitted on deck was found missing and some damaged, including one pilot combination ladder and related fittings. Furthermore, the ship had suffered minor structural damage including stanchions and railings, and shell plating indents.

Lashing gear for 600-700 containers was found to have been damaged during the incidents. The counting of the cargo containers showed that 517 units had been lost over board. From the cargo documentation it was established that of these, 75 units contained cargo and the additional 442 units were empty. Another 250 units were found to be damaged (figure 16).

17 floating containers were recovered from the area of the incidents.

Figure 16: SVENDBORG MÆRSK, aft deck at arrival in Malaga
Source: Maersk Line A/S

A large number of the lost containers were placed in stacks of eight to nine tiers' height. These comprised bays 46, 50, 58, 62, 74, 78 and 82. Where the containers were stacked seven tiers high, containers were lost over board in some bays. These comprised bays 10, 14 and 66 (Figure 17).

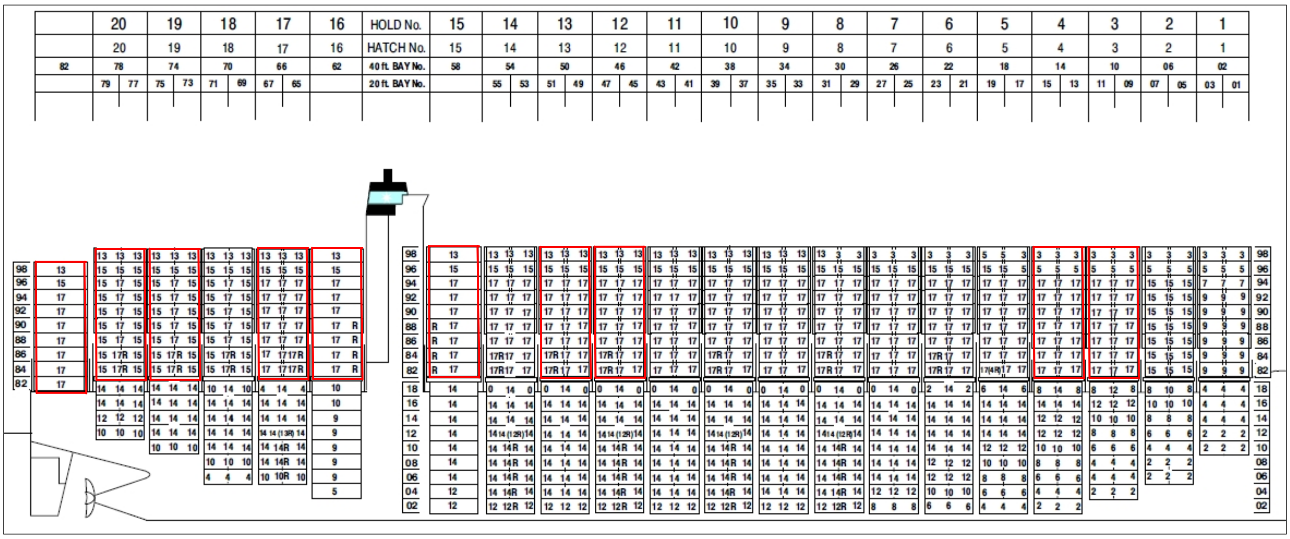


Figure 17: SVENDBORG MÆRSK, bays with lost containers are boxed in red
Source: Maersk Line A/S

3.10 Ship traffic in the area at the time of the incident

Numerous ships passed the TSS[11] off Ushant during the adverse weather conditions experienced in the area by SVENDBORG MÆRSK. Between 1000 UTC on 14 February and 1000 UTC on 15 February 2014, 46 ships including SVENDBORG MÆRSK are known to have passed a line north of the TSS. The south-bound ships were all on similar south-westerly courses.

Two of these ships are known to have suffered damages resulting from the adverse weather conditions in the area. The container ship SEAGO ANTWERP suffered only material damage, while the passenger ship MARCO POLO suffered a passenger fatality.

4. ANALYSIS

The heavy weather incidents occurred when SVENDBORG MÆRSK encountered adverse weather conditions off the Island of Ushant on 14 February 2014. The severity of the incidents was caused by the weather conditions in combination with the ship´s particulars, cargo loading and cargo securing configuration, which resulted in the loss of a large number of containers as the structural strength of the containers and the cargo securing equipment could not withstand the forces induced by the extreme heavy rolling of the ship.

When the ship departed the port of Rotterdam, the master expected that heavy weather conditions would be encountered during the forthcoming voyage. The ship was prepared in accordance with the crew members´ experience and the company´s heavy weather checklist. However, the encountered weather conditions were more adverse than forecasted in SPOS. The decision to depart or continue the voyage was based on the forecasted weather conditions.

4.1 Ship design and cargo securing

The ship’s robustness to withstand adverse weather conditions without compromising the safety of the cargo had been reduced following the optimization of the cargo capacity.

[11] Traffic Separation Scheme Off Ushant.

The majority of the containers lost over board were from positions where the containers were stacked up to tier 98. The high stacking of containers may have contributed to the severity of the consequences. However, the lashings had never been calculated or designed to withstand roll angles as those encountered by SVENDBORG MÆRSK on 14 February 2014.

Some uncertainty about the properties of the securing of the cargo can be expected, as it is difficult for the crew members to effectively assure the proper securing and settings of all lashing equipment under the constraints imposed by the conditions of a busy sailing schedule, and the environmental factors such as rain and darkness.

Calculating the correct dynamic forces acting on the cargo containers would require the container weight entered in LOADSTAR to be accurate. It has not been possible to establish whether the discrepancy between the calculated and the observed draught was the result of discrepancies in container weights on deck. However, discrepancies can affect the actual forces acting on the container stacks, adding to the uncertainty about the properties of the ship and the cargo capability in adverse weather conditions.

The IMO is in the process of implementing amendments to SOLAS making verification of container weights mandatory prior to loading containers on board ships.

Having one or two functioning stabilizer fins had little or no influence in limiting the severity of the rolling experienced by SVENDBORG MÆRSK during the two incidents. The fins were not designed to be effective with those immense forces acting on the hull, causing rolling to an angle of 41° - in particular at low speed.

4.2 Ship and weather

It has not been possible to establish whether the extreme rolling motions of the ship were caused by parametric resonance or single waves that were different from the predominant wave pattern in size and/or direction – or a combination of both.

Actual wave heights encountered by SVENDBORG MÆRSK, over a period of time, could vary substantially from the wave height value given in the weather forecast. On occasion (about one per hour), one can expect to see a wave nearly twice the significant wave height. Furthermore, the wave pattern was also unpredictable due to westerly swell from other weather systems.

The data presented in the report from MeteoGroup showing which weather information had been available to the master in SPOS largely substantiated the master´s perception of the weather situation on the forthcoming voyage.

The report concluded that the weather forecasted in SPOS predicted a total significant wave height of 7.0-7.5 metres, including 3.5-4.0 metres westerly swell. This was consistent with the master´s perception of the weather, following his consultation of the SPOS weather forecast, prior to departure from Rotterdam on 13 February 2014. Observations of the actual sea state near the site of the incidents reported a significant wave height of up to 13.40 metres at the time of the incidents. It is probable that SVENDBORG MÆRSK encountered similar conditions when exiting the English Channel.

The crew members did not at any time establish that the ship was subject to parametric resonance. The sea keeping module in the SPOS application that should have been in place to assist the master in his assessment of the ship´s risk of being exposed to parametric resonance was not utilized, as it had not yet been implemented by the crew members. If the module had been implemented and was to be effective, it would rely on the forecasted weather conditions being similar to the observed weather conditions encountered by the ship. The forecasted and observed conditions varied on 14 February 2014. The many variables related to the prediction of parametric resonance can make calculations, as suggested by the marine technology textbook uncertain and thus it may not have any preventive effect. Therefore a ship may well experience the effect of parametric resonance without warning.

4.3 Decision making before and during the adverse weather encounter

From the weather information readily available to the master in the SPOS application prior to departure, there were no indications that the conditions on the voyage would exceed the ship´s capability to operate safely without immediate danger to the crew members, ship and cargo. Based on the master's experience, there were no indications in the available weather information to encourage a decision to take weather routing advice on the forthcoming voyage. In practice, without any knowledge of the future unfolding events, it was difficult for the master to assess whether the weather forecasting data were insufficient, and weather routing should be taken as instructed by the company procedure. Therefore, such a procedure presented little operational support, as it was under-specified in relation to when to do what. The evaluation of how the forthcoming weather would affect the ship was therefore subject to the experience of the master.

Once the ship was in a situation with such adverse weather conditions, the possibilities of acting effectively to escape the situation were narrow. The options available in procedural guidelines were too generic and difficult to operationalize during the changing operational conditions in the dynamic environment.

The procedure for navigation in adverse weather was descriptive and offered little support in negotiating operational decisions for avoiding heavy weather damages, for example "*Also parametric- and/or synchronous-rolling should be taken into account*"[12]*.* The heavy weather checklist offered advice on specific items such as "*ventilation for bow thruster closed*"[13]*,* but in relation to the loading condition no specific advice was provided. In this adverse weather situation, the master and the crew members relied on the knowledge gained through experience.

In general, the commercial objectives related to ships' activities will not promote a cautious approach to voyage planning and to any decision to proceed with the voyage in adverse weather, which later would be questioned if other ships passed the area of adverse weather safely. These objectives will have an influence on the master's decision-making. However, commercial considerations were of little relevance when the conditions for the forthcoming voyage did not present themselves as hazardous to the ship.

5. CONCLUSIONS

The accident happened when SVENDBORG MÆRSK, on two separate occasions, encountered extremities in an adverse weather situation in the northern part of the Bay of Biscay. The extremities caused sudden heavy rolling of the ship that led to the loss of 517 cargo containers and damage to approx. 250 cargo containers. A number of factors coincided and caused the incidents and subsequent consequences.

An adverse weather situation was forecasted in SPOS and the ship had prepared for this. However, the weather as a combination of dynamic forces and the extremities encountered by SVENDBORG MÆRSK was not expected by the master and crew members. It was inherently challenging, beforehand, by the means available, to gain a mental overview depicting the exact weather and wave situation the ship encountered during the incidents, including the ship´s motional behaviour, as many variables were involved.

[12] GSMS procedure 4.6, Navigation in adverse weather.
[13] Checklist – Heavy Weather ID 416.

The master´s decision-making prior to the heavy weather navigation was largely reliant on his personal experience with heavy weather and the ship he commanded. Decision-making was challenged during uncertain and dynamic conditions with limited data at hand, or a limited recognition of their meaning in combination with the generic SMS procedures available, that will inherently have a deviance in work as described and how work is carried out, which provided poor decision-making support for the master. The quality of the master´s decisions would therefore only be obvious afterwards, when the outcome was known.

A number of initiatives affecting the operation of SVENDBORG MAERSK had been initiated by the company, starting with a conversion in 2012. The initiatives ensured an increased cargo capacity on board the ship by modifications made according to changed class rules. The initiatives may have affected the ship´s ability to operate safely in adverse weather conditions, and it is likely to have been a determinant for the extent of the consequences of the incidents. However, the ship had never been designed or configured for operation in weather extremities as those encountered on 14 February 2014.

6. PREVENTIVE MEASURES TAKEN

In relation to the incidents with SVENDBORG MÆRSK on 14 February 2014 Maersk Line has informed the DMAIB about preventive measures:

For more than a decade Maersk Line has installed and subscribed for the SPOS program, which provides vessels with computer based weather routing, based on two daily weather forecasts.

Since November 2013 Maersk Line has installed and subscribed for a SPOS See Keeping Module on board 106 of the most exposed vessels. This module provides an automatic pre-calculation of vessel's behaviour in the forecasted wind and wave pattern – sparing the master for the complex pre-calculation and likewise complex risk assessment of parametric roll, synchronic roll, pitching, etc. – In the early months of 2014 Maersk Line found reason to emphasize and positively confirm that this Sea Keeping Module is indeed being utilized.

By Fleet Circular 009/2014 Maersk Line enhanced the already existing requirement for the masters to supplement the SPOS program with Weather Routing from DMI and, to the extent possible, deviate or postpone the passage whenever the forecasted wind exceeds BF 9.

By the same Fleet Circular Maersk Line removed the generic Heavy Weather Checklist from their Safety Management System and instructed the vessels to use the more dynamic version included in the SPOS program.

Since 2004 Maersk Line provided their senior officers with Heavy Weather Training, covering wave theories, vessel response patterns, precautionary measures, etc. Until 2007 the courses were conducted by class room training, but when all had passed, the contents were compiled into a Heavy Weather Training CD which was made available to all vessels through their formal Training Library. Through the mentioned Fleet Circular all vessels were reminded of this Training CD and a new set of CDs were distributed to ensure 100% availability.

Within Maersk Line all container lashing equipment is dimensioned with Minimum Breaking Load double of the Safe Working Load – except for the Fully Automatic Twist Locks, which have a considerably lower safety factor when in "automatic mode". The recent container losses prompted Maersk Line to initiate Final Element Calculations of the captioned twist locks and their influence on the whole stowage behaviour during various scenarios.