ACCIDENT REPORT

MAIB

MARINE ACCIDENT INVESTIGATION BRANCH

Report on the investigation of the capsize and sinking

of the cement carrier

Cemfjord

in the Pentland Firth, Scotland

with the loss of all eight crew

on 2 and 3 January 2015

VERY SERIOUS MARINE CASUALTY REPORT NO 8/2016 APRIL 2016

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2012 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

Front cover photograph courtesy of North Link Ferries

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

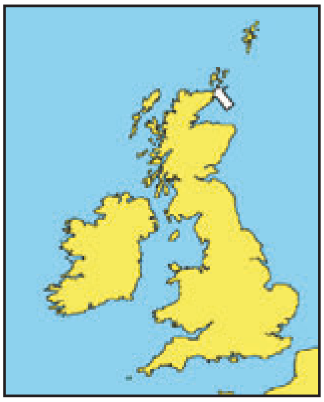
AB	-	Able seaman
AIS	-	Automatic Identification System
ALRS	-	Admiralty List of Radio Signals
BV	-	Bureau Veritas
CCTV	-	Closed Circuit Television
CoC	-	Certificate of Competency
COG	-	Course over the Ground
CRT	-	Coast Rescue Team
DMS	-	Department of Merchant Shipping, Republic of Cyprus
DNV-GL	-	Det Norske Veritas-Germanischer Lloyd
DoC	-	Document of Compliance
DP	-	Designated Person
DSC	-	Digital Selective Calling
EMEC	-	European Marine Energy Centre
EPIRB	-	Emergency Position Indicating Radio Beacon
GL	-	Germanischer Lloyd
GM	-	Metacentric Height
GMDSS	-	Global Maritime Distress and Safety System
gt	-	gross tonnage
GZ	-	Righting lever
HMS	-	Her Majesty's Ship
HRU	-	Hydrostatic Release Unit
HW	-	High Water
ILO	-	International Labour Organization
IMO	-	International Maritime Organization
IMSBC Code	-	International Maritime Solid Bulk Cargoes Code

ISM Code	-	International Safety Management Code
kg/m^3	-	kilogrammes per metre cubed
kts	-	knots
kW	-	kilowatt
LOA	-	Length overall
LR	-	Lloyd's Register
LRIT	-	Long Range Identification and Tracking
LSA	-	Life-Saving Appliances
LSA Code	-	International Life-Saving Appliance Code
LW	-	Low Water
m	-	metre
MAREP	-	Maritime Report
MCA	-	Maritime and Coastguard Agency
MRCC	-	Maritime Rescue Co-ordination Centre
Met Office	-	Meteorological Office
MGN	-	Marine Guidance Note
MoD	-	Ministry of Defence
MSC	-	Maritime Safety Committee (of the IMO)
NAVTEX	-	Navigational and Meteorological Warning Broadcast Service
NLB	-	Northern Lighthouse Board
nm	-	nautical mile
PSC	-	Port State Control
RO	-	Recognised organisation
ROV	-	Remotely Operated Vehicle
S3	-	Specialist Subsea Services
SAR	-	Search and Rescue
SART	-	Search and Rescue Transponder

SMC	-	Safety Management Certificate
SMS	-	Safety Management System
SOG	-	Speed over the Ground
SOLAS	-	International Convention for the Safety of Life at Sea 1974, as amended
STCW	-	International Convention on the Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended (STCW Convention)
t	-	tonne
UTC	-	Universal Co-ordinated Time
VCG	-	Vertical Centre of Gravity
VDR	-	Voyage Data Recorder
VHF	-	Very High Frequency
VTS	-	Vessel Traffic Services

TIMES: all times used in this report are UTC, unless otherwise stated.

SYNOPSIS



At 1316 on 2 January 2015, the Cyprus registered cement carrier *Cemfjord* capsized while transiting the Pentland Firth, Scotland; no distress message was transmitted. Twenty-five hours later, the alarm was raised when its upturned hull was sighted by a passing ferry. An extensive search followed but none of *Cemfjord*'s eight crew were found and they are all assumed to have perished. The vessel sank late in the evening on 3 January 2015.

The investigation found that *Cemfjord* capsized in extraordinarily violent sea conditions caused by gale force winds and a strong, opposing tidal stream. Such conditions are commonly experienced within the Pentland Firth, were predictable and could have been avoided by effective passage planning. The master's decision to take *Cemfjord* into the Pentland Firth at that time was probably influenced by actual or perceived commercial pressures and his personal determination to succeed. While it is likely that he had underestimated the environmental conditions, his decision to press on would almost certainly have been influenced by his recent experience of a dangerous cargo shift while attempting to abort an approach to the Firth in heavy seas.

The rapid nature of the capsize denied the crew the opportunity to broadcast a distress message or abandon their ship. The float-free emergency position indicating radio beacon did not work almost certainly because it became trapped in the upturned hull. The accident went unnoticed ashore because the vessel's progress through the Pentland Firth was not being monitored and Shetland Coastguard did not require vessels to report when exiting the voluntary reporting scheme area.

The investigation also established that *Cemfjord* was at sea with significant safety deficiencies relating to its rescue boat launching arrangements and bilge pumping system in the void spaces beneath the cement cargo holds. Both shortcomings were subject to Flag State approved exemptions from safety regulations; however, the exemption regarding the rescue boat was not applicable to the equipment on board. This resulted from misunderstandings caused by the imprecise nature of the communication between the vessel's managers, the Flag State and the Flag State's recognised organisation. The Flag State's process for managing requests for exemptions from international safety regulations was also found to lack rigour. Additionally, Flag State inspections of the vessel over many years in Poland were ineffective and did not deliver the intended levels of assurance.

Since the accident, *Cemfjord*'s managing company, Brise Bereederungs GmbH, has implemented several changes and initiatives aimed at improving the safe operation of its cement carrying vessels and the safety culture of its crews. The changes include enhancements to its vessels' stability management and weather forecasting capabilities in order to aid passage planning. The Department of Merchant Shipping for the Republic of Cyprus has introduced a new process for managing requests from shipping companies for Flag State exemptions from international safety regulations. Det Norske Veritas-Germanischer Lloyd has appointed designated Flag State liaison officers to improve dialogue and enhance mutual understanding between itself and Flag States.

Safety recommendations have been made to: Brise Bereederungs GmbH to further improve the safety of its fleet of cement carrying vessels; the Republic of Cyprus' Department of Merchant Shipping to enhance the management of its safety regulation exemption process; and to the UK Maritime and Coastguard Agency to review the arrangements for the safety of shipping in the Pentland Firth.

Photograph courtesy of Fotoflite.com

Cemfjord

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *CEMFJORD* AND ACCIDENT

SHIP PARTICULARS	
Vessel's name	*Cemfjord*
Flag	Republic of Cyprus
Classification society	Det Norske Veritas-Germanischer Lloyd
IMO number	8403569
Type	Cement carrier
Registered owner	Partenreederei Baltic Sun
Manager	Brise Bereederungs GmbH
Construction	Steel
Year of build	1984
Length overall	83.18m
Beam	11.34m
Gross tonnage	1850
Minimum safe manning	5
VOYAGE PARTICULARS	
Port of departure	Rordal, Denmark
Intended port of arrival	Runcorn, UK
Type of voyage	Short international
Cargo information	2084t of white cement in bulk
Manning	8
MARINE CASUALTY INFORMATION	
Date and time	2 January 2015 at 1316
Type of marine casualty	Very serious marine casualty
Location of incident	58º 43.2N - 003º09.0W
Fatalities	8
Damage/environmental impact	Vessel lost/No significant pollution
Ship operation	On passage
Voyage segment	Mid-water
External & internal environment	Wind: westerly, 40kts, gusting 56kts Tidal stream: 290º at 6kts Daylight Visibility: moderate in rain showers Sea temperature: 8ºC
Persons on board	8

1.2 NARRATIVE

At 2200 on 29 December 2014, the cement carrier *Cemfjord* berthed at Aalborg Portland's cement loading terminal in Rordal, Denmark. Once *Cemfjord* was secured alongside, the terminal's cement loading trunk was connected and the vessel's ballast system was configured in preparation for the loading operation. Loading cement commenced at 2250; at the same time, the vessel's port and starboard ballast pumps were started in order to simultaneously discharge water ballast.

During the loading, the port ballast pump was not working effectively, which caused the vessel to start listing to port. At 0139 (30 December), the loading operation was suspended by the shore workers because the vessel was listing to port by about 5° and there was concern about a risk of fracture to the loading trunk **(Figures 1a** and **b)**. Loading was resumed at 0430 but a further unplanned stop occurred at 0457 due to the persistent poor performance of the port ballast pump.

At about 0700, the master contacted the vessel's agent in Aalborg, Denmark and asked for the urgent supply of a portable, submersible pump to aid de-ballasting. The agent sourced a suitable pump from a local supplier and delivered it to the vessel; the crew then rigged it on board for pumping water out of the port ballast tanks. With this arrangement in place, loading restarted at 0959 and completed at 1234. The portable pump was then de-rigged and returned to the agent ashore.

At 1300, fully laden with 2084 tonnes (t) of cement, *Cemfjord* sailed **(Figure 2)**, bound for Runcorn, UK **(Figure 3)**. At 1542, the master sent a departure report to the vessel's charterer, Aalborg Portland, copied to the vessel's managers, Brise Bereederungs GmbH (Brise Bereederungs), which listed the timings of the intermittent loading events and a comment about the ballast problem that had been experienced.

During the passage from Rordal into the Skagerrak and onward towards the North Sea **(Figure 3)**, *Cemfjord*'s average speed over the ground (SOG) was 9.2 knots (kts). At 0715 on 31 December 2014, the master sent his daily report[1] to the charterer giving an estimated time of arrival at Liverpool Bar Buoy of 1400 on 4 January 2015.

Once clear of the Skagerrak, *Cemfjord* commenced a direct passage across the North Sea towards the Pentland Firth. At 0744 on 1 January 2015, having spent 24 hours heading into deteriorating weather and increasingly heavy seas the master reported to the charterer that there would be a 2 hour delay to the arrival time at Liverpool Bar Buoy, which was then estimated to be 1600 on 4 January 2015. The master's noon report to Brise Bereederungs stated that *Cemfjord*'s average SOG for the previous 24 hours had been 6.8kts.

At 0409 on 2 January 2015, when *Cemfjord* was approximately 43 nautical miles (nm) east of the entrance to the Pentland Firth, the initial detection of the vessel's automatic identification system (AIS) transmissions was made by the UK coastguard's land-based very high frequency (VHF) radio signal receivers **(Figure 4)**. At 0721, the master's morning report to the charterer stated that there would be a further 10 hours delay to the arrival time, which was then anticipated to be 0200 on 5 January 2015.

[1] The master was required to send a report at about 0800 local time each day to the charterer's logistics department, reporting position, weather and estimated arrival time at the next port of call. These reports were sent by email and copied to Brise Bereederungs. 'Noon reports' were also transmitted daily to the vessel's managers in accordance with International Maritime Organization's (IMO) Safety of Life at Sea (SOLAS) Chapter V, Regulation 28 (2).

In the eastern approaches to the Pentland Firth, at 1052 **(Figure 4)**, the master made voice contact with Shetland Coastguard on VHF radio in order to transmit a maritime report[2] (MAREP). Having established communications, the master advised

Image courtesy of Aalborg Portland A/S, Denmark

Figure 1a: CCTV image of *Cemfjord* alongside in Rordal at 0119, 30 December 2014. Vessel is upright, cement loading trunk is vertical

Image courtesy of Aalborg Portland A/S, Denmark

Figure 1b: CCTV image of *Cemfjord* alongside in Rordal at 0139, 30 December 2014. Vessel listing 5º to port, risk of fracture to loading trunk

[2] The maritime report was submitted to Shetland Coastguard in compliance with the requirements of the Pentland Firth voluntary reporting scheme. Details of the scheme are at **Annex A** and a full transcript of the master's conversation with the coastguard is at **Annex B**.

Image courtesy of Aalborg Portland A/S, Denmark

Figure 2: CCTV image of *Cemfjord* departing Rordal on 30 December 2014

Reproduced from Admiralty Chart BA 0002 and 4004 by permission of the Controller of HMSO and the UK Hydrographic Office

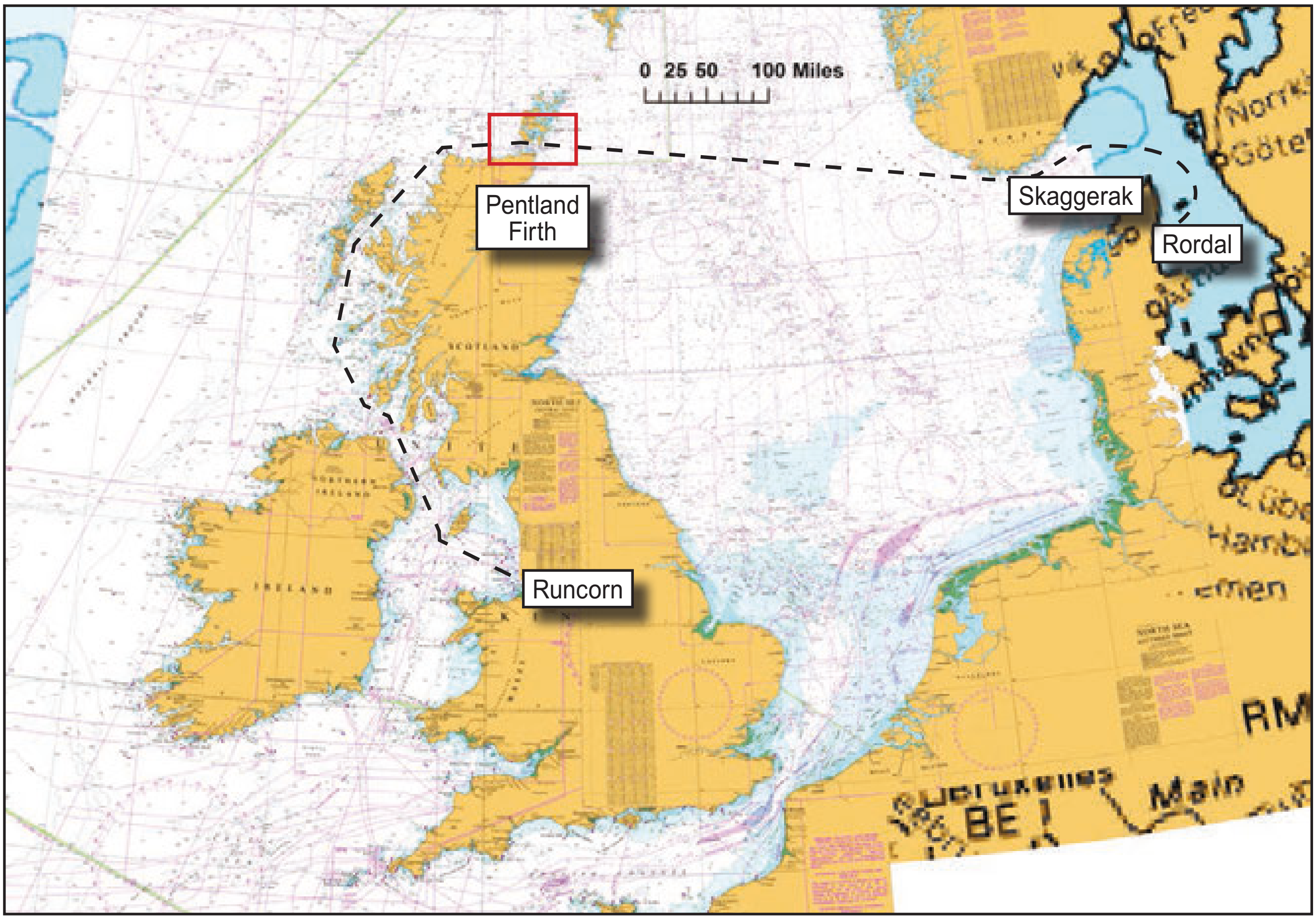


Figure 3: Overview of intended passage from Rordal, Denmark to Runcorn, UK via the Pentland Firth

Reproduced from Admiralty Chart BA 1942 by permission of the Controller of HMSO and the UK Hydrographic Office

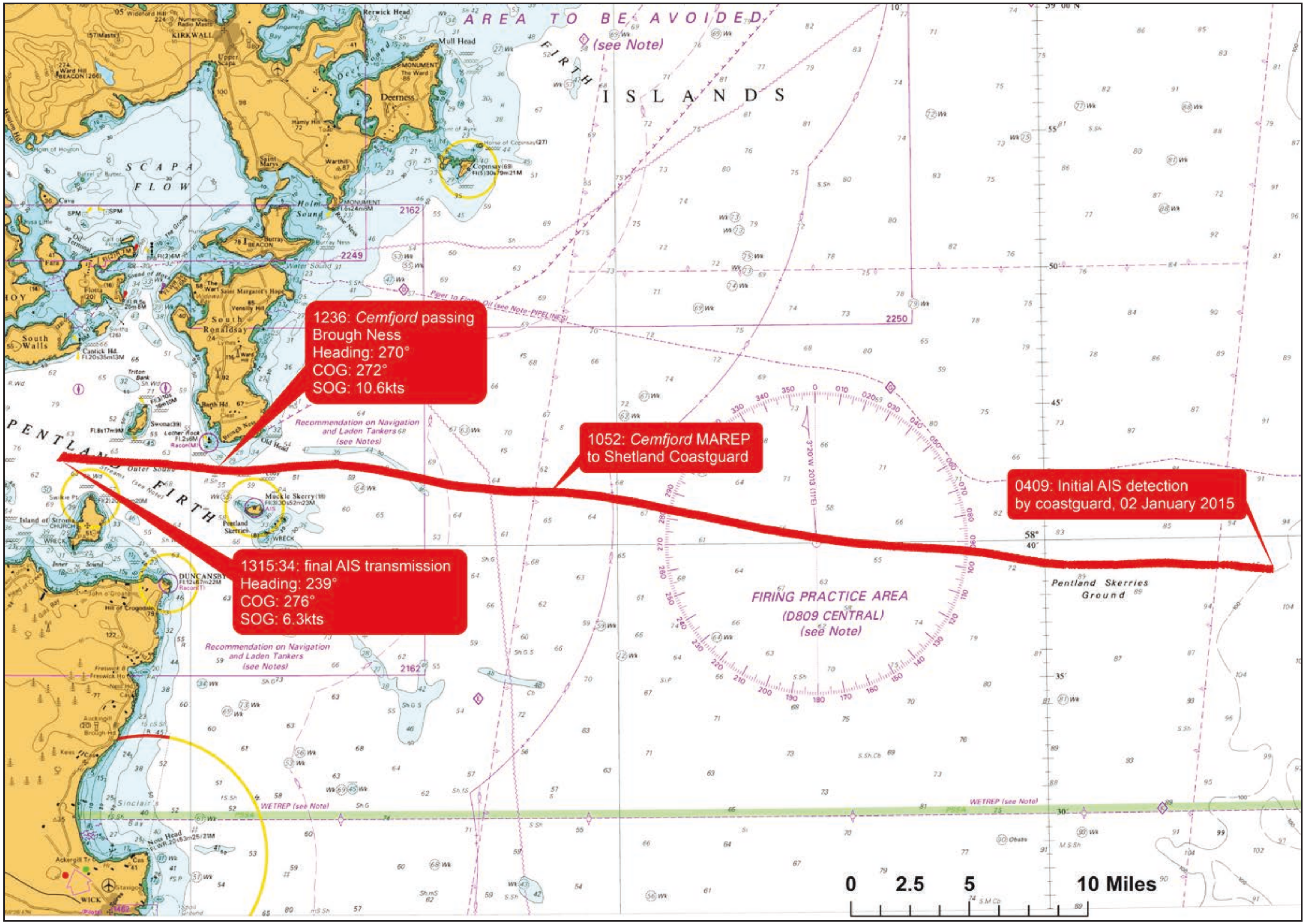


Figure 4: *Cemfjord*'s AIS track from 0409 on 2 January 2015 including MAREP reporting position, AIS data passing Brough Ness and final AIS information

the coastguard of *Cemfjord*'s previous and intended ports of call, as well as details of its cargo. He also confirmed that there were eight persons on board and that the vessel had no defects. The coastguard then advised the master that:

> *"as we can monitor your progress on AIS, there is no requirement to report in when you leave the Pentland Firth area."*

At 1100, the master sent his noon report to Brise Bereederungs, which gave an average SOG of 5.8kts for the previous 24 hours and reiterated his estimated arrival time at Liverpool Bar Buoy of 0200 on 5 January 2015. The master also reported experiencing a westerly gale at Beaufort Force 9[3] and very rough seas.

As *Cemfjord* approached the UK coastline, several members of the crew, including the master and chief officer, took advantage of the available mobile phone signal to call or send text messages home. At 1211, the chief officer tried to call his wife; she did not answer but rang him back immediately at 1212 and they spoke for about 3 minutes. The master called his wife at 1232 and they spoke for about 5 minutes.

As the vessel passed Brough Ness and entered the Firth **(Figure 4)**, it was on a heading of 270°, a course over the ground (COG) of 272° and SOG at 10.6kts. Once inside the Pentland Firth, *Cemfjord* was sighted by the crew of the ferry, *Pentalina*, which was on passage south from the Orkney Islands to mainland Scotland. The closest point of passing occurred at 1248 when *Pentalina* was just over 1nm ahead of *Cemfjord* **(Figure 5)**. At this point, *Cemfjord* appeared to be upright and making slow headway, pitching heavily into the large waves being encountered.

At 1315, *Cemfjord*'s AIS transmissions ceased. The data from the last received transmission showed a vessel heading of 239°, a COG of 276° and SOG at 6.3kts **(Figure 4)**.

Twenty-five hours later, at 1416 on 3 January 2015, the lookout on board the roll-on roll-off passenger ferry *Hrossey*, which was on passage from Lerwick to Aberdeen, spotted and reported an unusual object floating in the distance **(Figure 6)**. The ferry's master came to the bridge and decided to head towards the object and investigate it. As range reduced, it became apparent that the crew had sighted the hull of a capsized ship **(Figure 7)**; this was immediately reported by *Hrossey* to Shetland Coastguard using VHF radio. When closer in, the ferry crew was able to read the name '*Cemfjord'* **(Figure 8)** and report its position as 58°39.9'N - 002°33.1'W. *Hrossey*'s master ordered his crew to prepare the vessel's rescue boat and then commenced an expanding search of the area for survivors.

On receipt of the initial report from *Hrossey* at 1442, Shetland Coastguard initiated a search and rescue (SAR) operation, and tasked lifeboats from Wick, Thurso, Stromness and Long Hope to conduct searches of the Pentland Firth and the area around the upturned hull. SAR helicopters from Lossiemouth and Sumburgh launched to conduct searches of the area and additional coastguard officers were recalled to the Aberdeen Maritime Rescue and Co-ordination Centre (MRCC) in order to assist with the search planning effort. Other search assets activated included the UK warship, HMS *Somerset*, the emergency towing vessel *Heracles* and the environmental pollution control fixed wing aircraft *Watchdog*.

[3] Beaufort Force 9: strong gale, wind speed 41 - 47kts.

At about 1500, *Hrossey*'s bridge team observed *Cemfjord*'s bow move to a vertical position as its stern sank towards the seabed **(Figure 9)**. A short time later, with a lifeboat and helicopter on scene, *Hrossey* was released from the SAR effort and continued its passage south to Aberdeen.

On land, coast rescue teams (CRT) were tasked to search the coastline on both sides of the Pentland Firth. CRTs were also airlifted onto the uninhabited islands of Swona, Stroma and Muckle Skerry to search the shoreline. Areas searched by SAR assets are shown at **Figure 6**.

At 2120 on 3 January, the Thurso lifeboat crew observed *Cemfjord* as it sank out of sight. The multi-asset SAR operation continued until 1900 the following day when the search was terminated; none of the crew had been found.

On the morning of 4 January 2015, a CRT searching the southern coast of South Ronaldsay discovered the buoyancy tube from a Zodiac rigid-hulled inflatable boat **(Figure 10)**. This was passed to the local police for further investigation.

At 1455 on 5 January 2015, a liferaft was sighted in the North Sea by a passing ship, 70nm east of *Cemfjord*'s last recorded AIS position **(Figure 6)**. The sighting was reported to Shetland Coastguard and a SAR helicopter from Sumburgh was tasked to investigate **(Figure 11)**. There was no-one on board the liferaft and, having recovered its maintenance records, the helicopter's winchman punctured the buoyancy chambers in order that it would sink. The maintenance records recovered from the liferaft positively identified that it had come from *Cemfjord.*

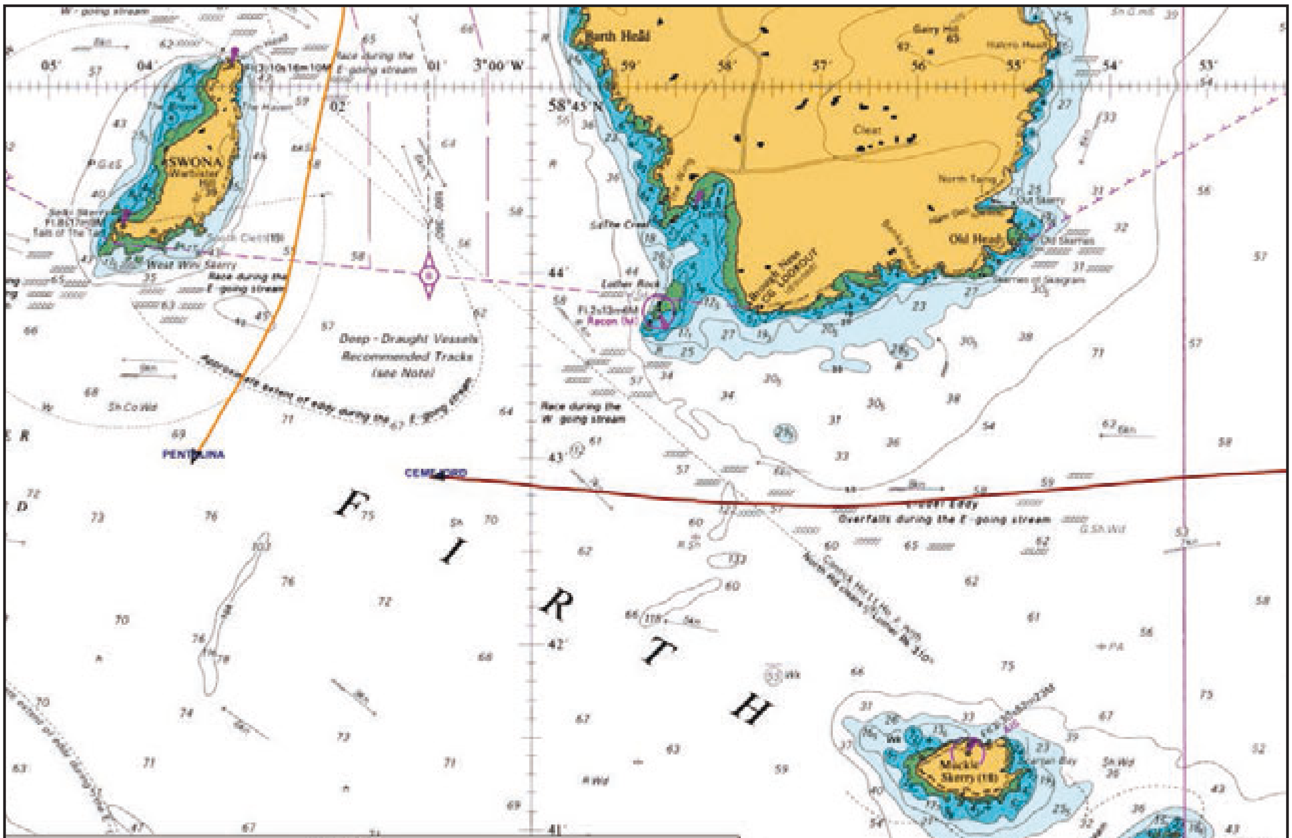


Figure 5: Tracks of *Cemfjord* and the ferry, *Pentalina*, passing in the eastern Pentland Firth

Reproduced from Admiralty Chart BA 0002 by permission of the Controller of HMSO and the UK Hydrographic Office

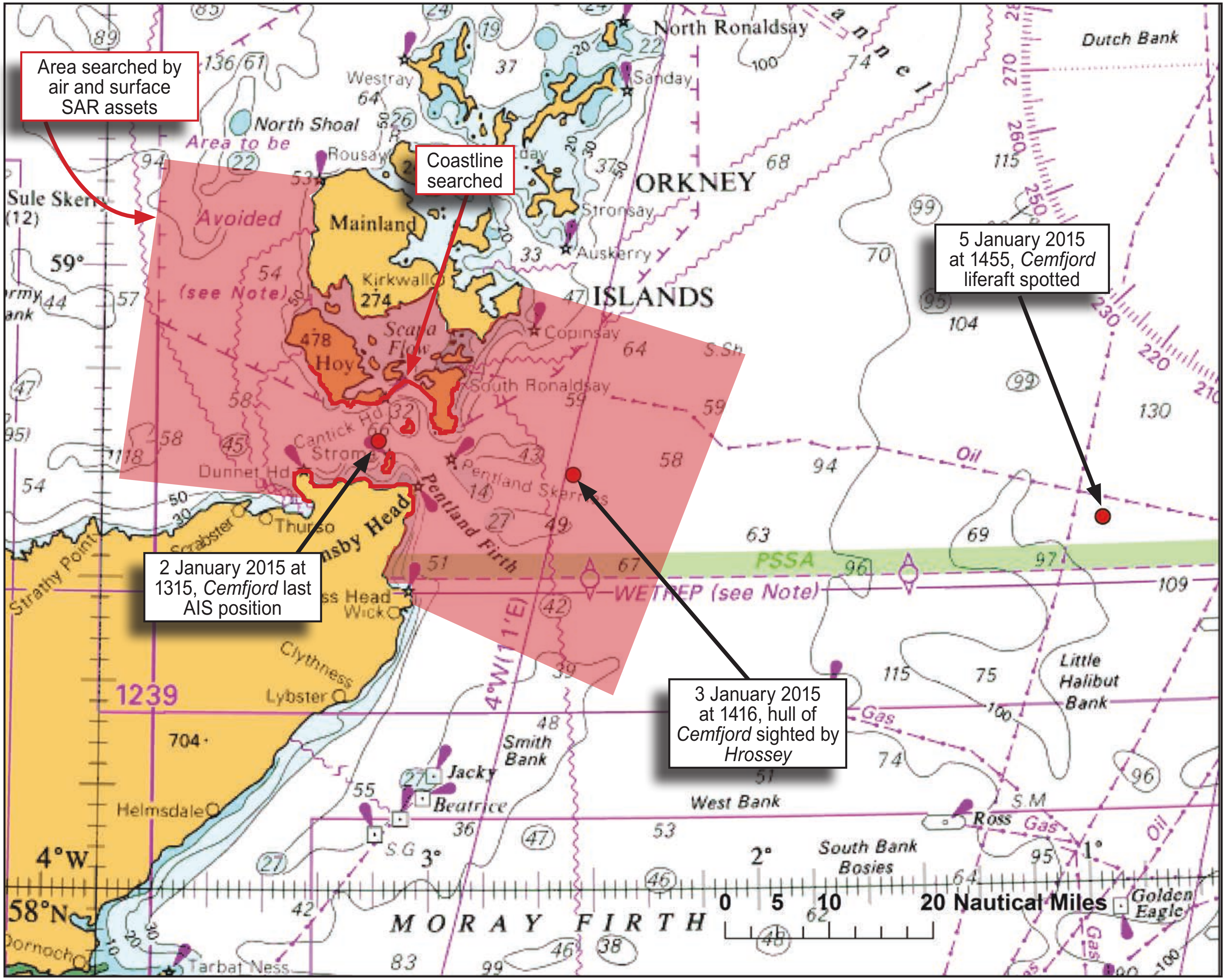


Figure 6: Chart showing the location of the sighting of *Cemfjord*'s hull by the crew of the ferry, *Hrossey*, areas searched by SAR assets and the location of the recovered liferaft

Image courtesy of North Link Ferries

Figure 7: *Cemfjord*'s capsized hull as seen from the bridge of the ferry, *Hrossey*

Image courtesy of North Link Ferries

Figure 8: *Cemfjord*'s capsized hull when the ferry, *Hrossey*, was close by

Image courtesy of North Link Ferries

Figure 9: *Cemfjord*'s hull after moving to a vertical position

Figure 10: Inflatable section of the Zodiac rescue boat found on South Ronaldsay on 4 January 2015

Image courtesy of Coastguard Rescue Helicopter Unit, Sumburgh

Figure 11: *Cemfjord*'s liferaft in the North Sea as seen from the SAR helicopter

1.3 ENVIRONMENTAL CONDITIONS

1.3.1 Weather forecasts

The UK Meteorological Office (Met Office) coastal forecast issued at 0500 on 1 January 2015, included:

General situation: a deepening area of low pressure will move northeastwards close to northwest Scotland bringing gales or severe gales to most areas.

Extended 'outlook' forecast for the period 0600 on 2 January 2015 to 0600 on 3 January 2015: Cape Wrath to Rattray Head including Pentland Firth:

Wind: *west 7 to severe gale 9, occasionally storm 10*

Sea state: *moderate or rough in east, very rough or high in north*

Weather: *squally wintry showers*

Visibility: *moderate or good, occasionally poor.*

The following day's forecast issued at 0500 on 2 January 2015 for the period 0600 on 2 January 2015 to 0600 on 3 January 2015 stated:

General situation: The very unsettled and at times very windy conditions will persist for the next couple of days.

Cape Wrath to Rattray Head including Pentland Firth:

Wind: *west 7 to severe gale 9, occasionally storm 10*

Sea state: *rough or very rough in east, very rough or high in north*

Weather: *squally showers*

Visibility: *moderate or good, occasionally poor.*

Cemfjord had the capability to receive this information via medium frequency and VHF radio, the Navigational and Meteorological Warning Broadcast Service (NAVTEX) and internet websites.

1.3.2 Recorded weather and Meteorological Office hindcast

According to *Pentalina*'s bridge log entry for 2 January 2015, the conditions on the eastern side of the Outer Sound at 1300 were: wind - west-north-west, force 7 to 8, swell - 2 to 3m and visibility moderate.

At the MAIB's request, the Met Office compiled a historical marine data report, or hindcast, using land observations and its climatic database. This included an analysis chart for 1200 on 2 January 2015 **(Figure 12)** that showed a succession of severe low pressure systems passing north of the UK, with associated high winds. For the accident location at 1300 on 2 January, the Met Office data modelling gave a calculated wind, at 10m elevation, of 269º at 40kts, gusting 56kts. This was corroborated by observed data from the nearby weather station at Sandy Hill[4] on South Ronaldsay **(Annex C)**, which recorded the wind as 252º at 51kts, gusting 63kts, at 1300 on 2 January 2015. In addition, just over an hour prior to the accident, the Sandy Hill weather station recorded a westerly gust of 74kts.

The Met Office hindcast model calculated a significant wave height of 5m in the position and time where *Cemfjord*'s AIS signal was lost. Actual wave heights vary around twice this average value, so the maximum wave height from this assessment was likely to have been in the order of 10m.

1.3.3 Tidal stream

The Admiralty Tidal Stream Atlas predictions for the area (NP209) are based on high water (HW) at Dover, which is similar in time to Muckle Skerry in the eastern approach to the Pentland Firth. Tide times for Dover on 2 January 2015 were:

- High water: 0851
- Low water: 1610
- High water: 2124

[4] Sandy Hill weather station has an altitude of 92m and this observation data has not been corrected for altitude; however, the wind at sea level in the same position would be slightly less.

This tidal range was 38% of the full spring range, therefore the predicted stream at 1315, interpolated between the tidal atlas data for 1251 and 1351 **(Annex D)** for the location where the AIS was lost, was approximately 5kts in a direction of 290°.

1.3.4 European Marine Energy Centre data

The MAIB also obtained hindcast modelling data after the accident from the European Marine Energy Centre (EMEC). This analysis was based on tidal energy fieldwork studies in the area, conducted for the renewable energy business sector. The tidal current data from this analysis for 1300 on 2 January 2015 **(Figure 13)** shows a 5.8 to 6.8kts[5] north-westerly stream at the location where *Cemfjord*'s AIS signal was lost. The EMEC data also included wave height analysis; this showed an assessed significant wave height in the area of lost AIS signal of 6-6.5m **(Figure 14)**.

Image courtesy of UK Meteorological Office

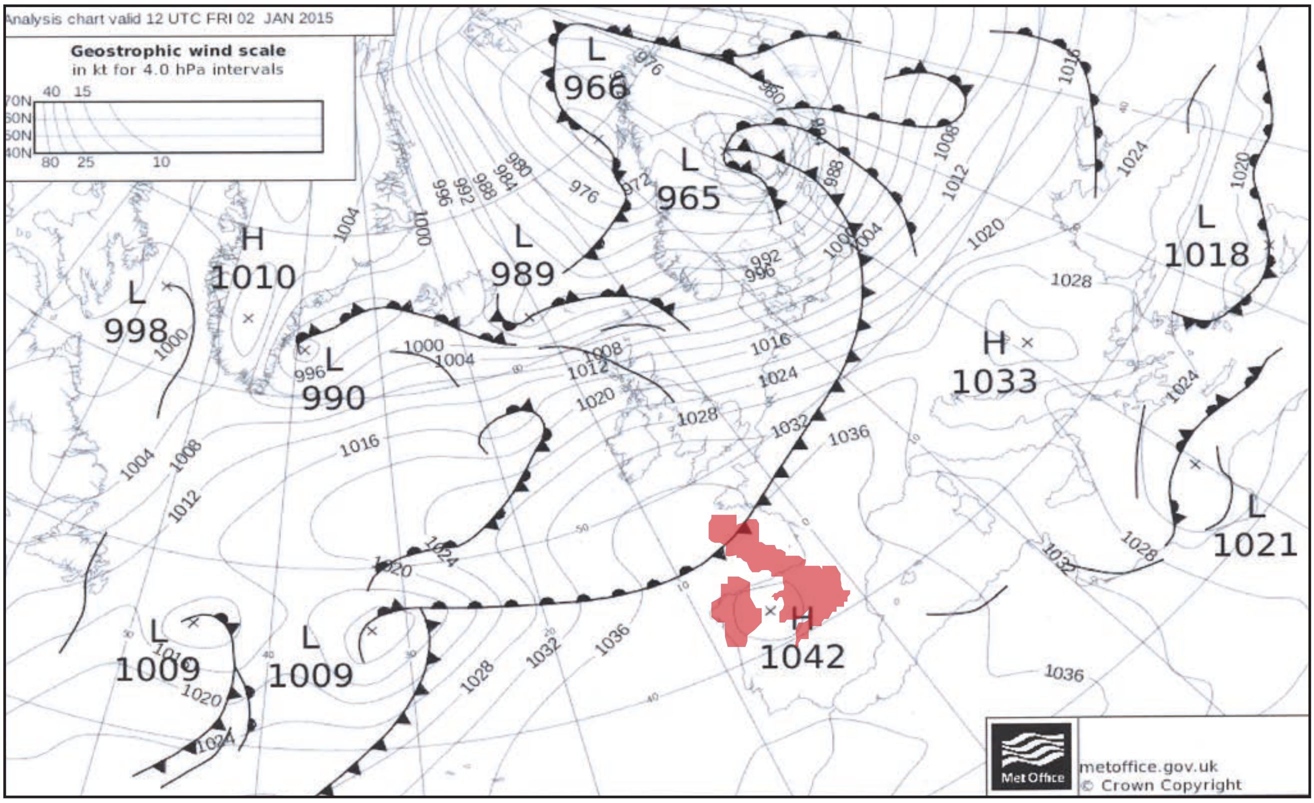


Figure 12: UK Meteorological Office Analysis chart for 1200, 2 January 2015 showing succession of low pressure systems west and north of UK

[5] Current values on the EMEC chart **(Figure 13)** are given in meters per second.

Images courtesy of European Marine Energy Centre

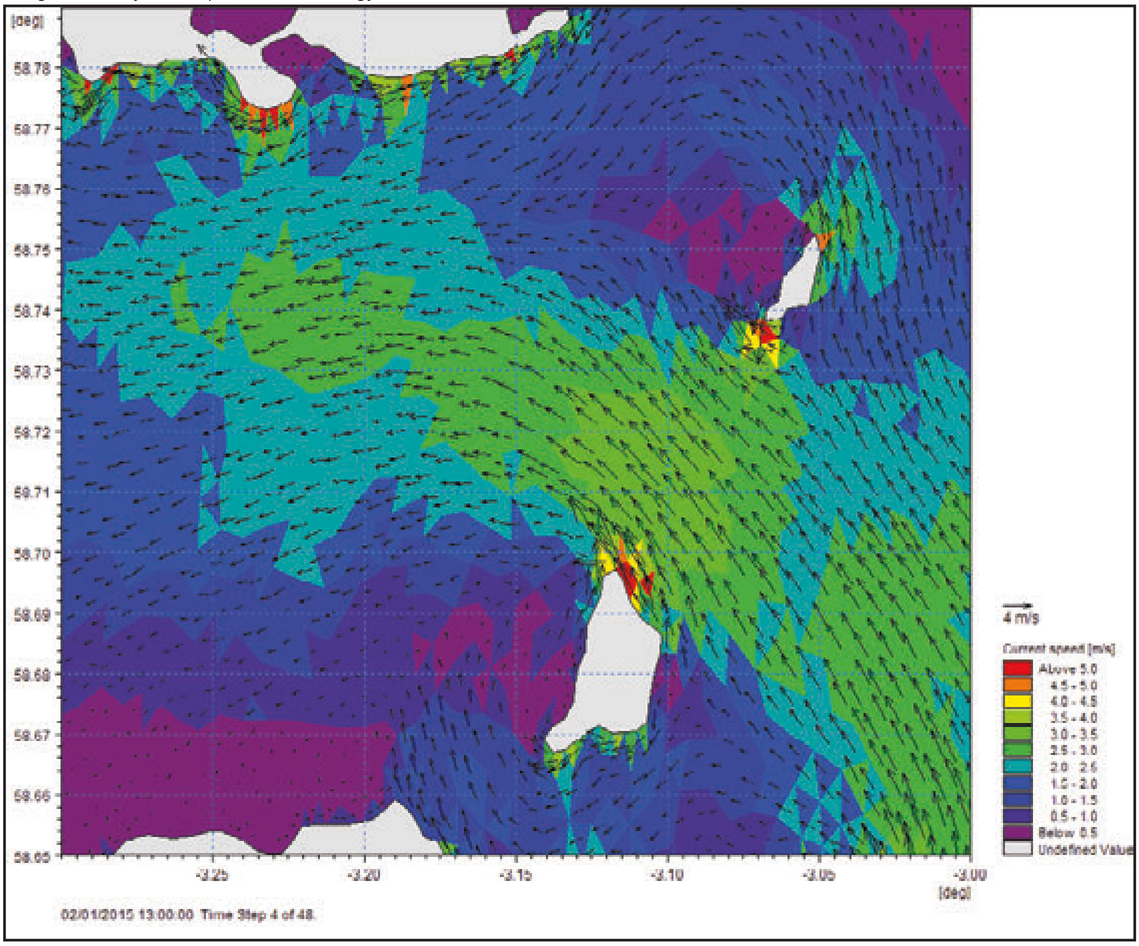


Figure 13: European Marine Energy Centre: tidal stream analysis for the Pentland Firth, Outer Sound at 1300 on 2 January 2015

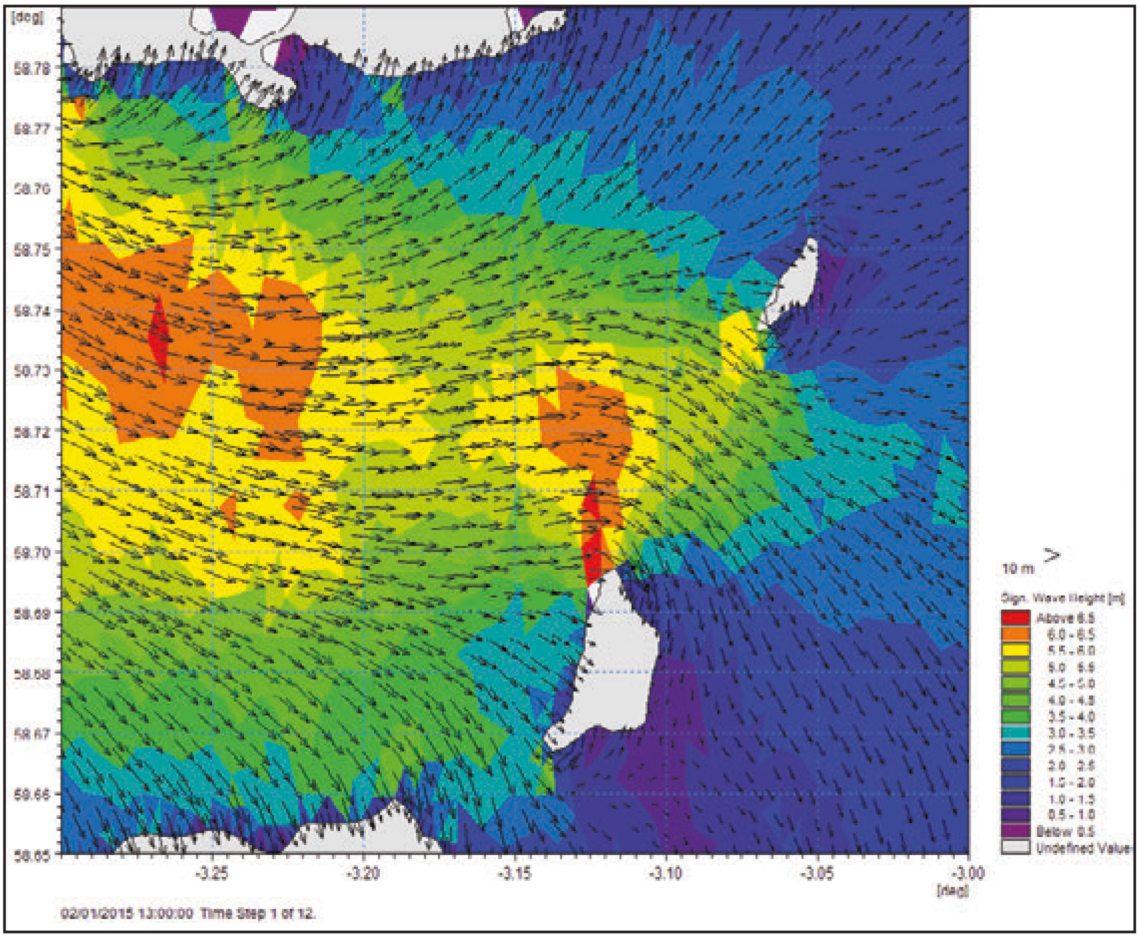


Figure 14: European Marine Energy Centre: significant wave height analysis for the Pentland Firth, Outer Sound at 1300 on 2 January 2015

1.4 CREW

Cemfjord's crew consisted of seven Polish nationals and one Filipino national; all were employed through the crewing agency, A&A Shipping Limited.

The master, Pawel Chruscinski, was 43 years old. He held an International Convention on the Standards of Training, Certification and Watchkeepers (STCW) II/2 master's Certificate of Competency (CoC). As a career mariner he had worked his way from able seaman (AB) to master and had gained a reputation within Brise Bereederungs as a hard-working, confident captain who was passionate about his ship. He had extensive experience of cement carriers and had been the chief officer of *Cemstar* and *Cemsol* prior to becoming the master of *Cemfjord* in 2008. As *Cemfjord*'s regular master, he routinely spent 8 months a year on board the vessel. He had a detailed knowledge of *Cemfjord*'s machinery systems and often assisted his crew with maintenance and engineering tasks.

The chief officer, Jaroslaw Orlow, was 45 years old and held an STCW II/2 master's CoC. He joined *Cemfjord* on 11 October 2014 on his first contract with Brise Bereederungs. His previous seagoing experience was predominantly in passenger ferries and general cargo ships.

The chief engineer, Roman Tamas, was 56 years old and held an STCW III/3 engineering CoC. He joined *Cemfjord* on 25 November 2014 on his first contract. His previous experience was in bulk carriers and general cargo vessels.

The second engineer, Jerome Narvasa, was 32 years old and a Filipino national. His previous experience was on container ships and a car carrier. He joined the vessel on 1 October 2014 on his first contract on board.

The first AB, Henryk Dubanowski, was 55 years old and held an STCW II/4 CoC. He had been a regular crewman on *Cemfjord* since 2007.

The second AB, Tomasz Kwiatkowski, was 32 years old and joined the vessel on 10 December 2014 on his first contract on board.

The first ordinary seaman, Artur Wegorek, who was also the ship's cook, was 24 years old and joined the vessel on 1 October 2014 on his first contract on board.

The second ordinary seaman, Artur Podrazka, was 24 years old and joined on 8 December 2014, also on his first contract on board.

1.5 BRIDGE WATCHKEEPING ROUTINES

At sea, the master and chief officer kept the following routine navigational watches on the bridge using the local time on board, which was UTC + 1 hour:

- 0000-0600 and 1200-1800: chief officer
- 0600-1200 and 1800-0000: master

Irrespective of the watchkeeping routine, the master was usually on the bridge whenever *Cemfjord* was in pilotage waters and during the vessel's passage through the Pentland Firth. At sea, the presence of a rating for bridge lookout duties was only required during the hours of darkness. In harbour, the chief officer was required to supervise cargo loading and discharge.

1.6 THE VESSEL

1.6.1 General

Cemfjord (originally named *Margarita*) was built in 1984 in Bremen, Germany as a general cargo vessel. Its length overall was 83.18m and its gross tonnage (gt) was 1,850. Main propulsion was provided by a Deutz 441 kilowatt (kW) main engine, providing a maximum service speed of 9.5kts; it was also fitted with a 136kW bow thruster.

Cemfjord was owned by the investment group Partenreederei Baltic Sun. Technical and safety management was provided by Brise Bereederungs, which managed a fleet of over 20 vessels, primarily container ships and cement carriers. The chartering arrangement for Brise Bereederungs' cement carriers was managed by Baltrader Schifffahrtsgesellschaft GmbH. Brise Bereederungs and Baltrader Schifffahrtsgesellschaft GmbH were both part of the Brise Schiffahrt Group that was originally founded in 1984, and operated from its offices in Hamburg, Germany.

In 1998, *Cemfjord* was converted to become a dedicated cement carrier. This significant alteration involved reshaping the cargo hold and the installation of a pneumatic system for discharge of cement in bulk **(Figure 15)**.

1.6.2 Flag State and its recognised organisation

Cemfjord was registered in Limassol, Cyprus. The Government of Cyprus' shipping register was administered by its Department of Merchant Shipping (DMS). In addition to its head office in Limassol, DMS had consuls situated in the UK, Germany, Belgium, Netherlands and the USA. The DMS consul in Germany was based in Hamburg and acted as a regional link for owners and operators of Cyprus flagged vessels.

The Cyprus registry had appointed Det Norske Veritas-Germanischer Lloyd (DNV-GL) to act as its recognised organisation (RO) for *Cemfjord*. Flag States routinely employ and authorise ROs to conduct surveys and issue certificates on their behalf, and guidance for the responsibilities and conduct of ROs is set out in the International Maritime Organization's (IMO) Resolution MSC.349(92) *Code for Recognized Organizations*.

1.6.3 Time charter and passages

Cemfjord was operated in accordance with a charter agreement between Baltrader Schifffahrtsgesellschaft GmbH, on behalf of the owner, and Aalborg Portland, the charterer. Under the terms of the charter, *Cemfjord* was required to transport cement in bulk between Aalborg Portland's manufacturing plant in Rordal, Denmark, and remote storage silos located in various ports around Europe. Aalborg Portland's cement silos in the UK were located in Runcorn, Goole and Londonderry; *Cemfjord* regularly visited all these ports to discharge cement before returning to Denmark to reload.

The vessel's schedule allowed 8 hours berthed in Rordal for each loading operation and the charter agreement required a passage speed of '*about 9 knots'.* On 30 December 2014, Aalborg Portland's cement loading berth in Rordal had been assigned to *Cemfjord* from midnight to 0800. The vessel arrived in Rordal about 2 hours earlier than planned but sailed 5 hours later than expected.

Image courtesy of Brise Bereederungs

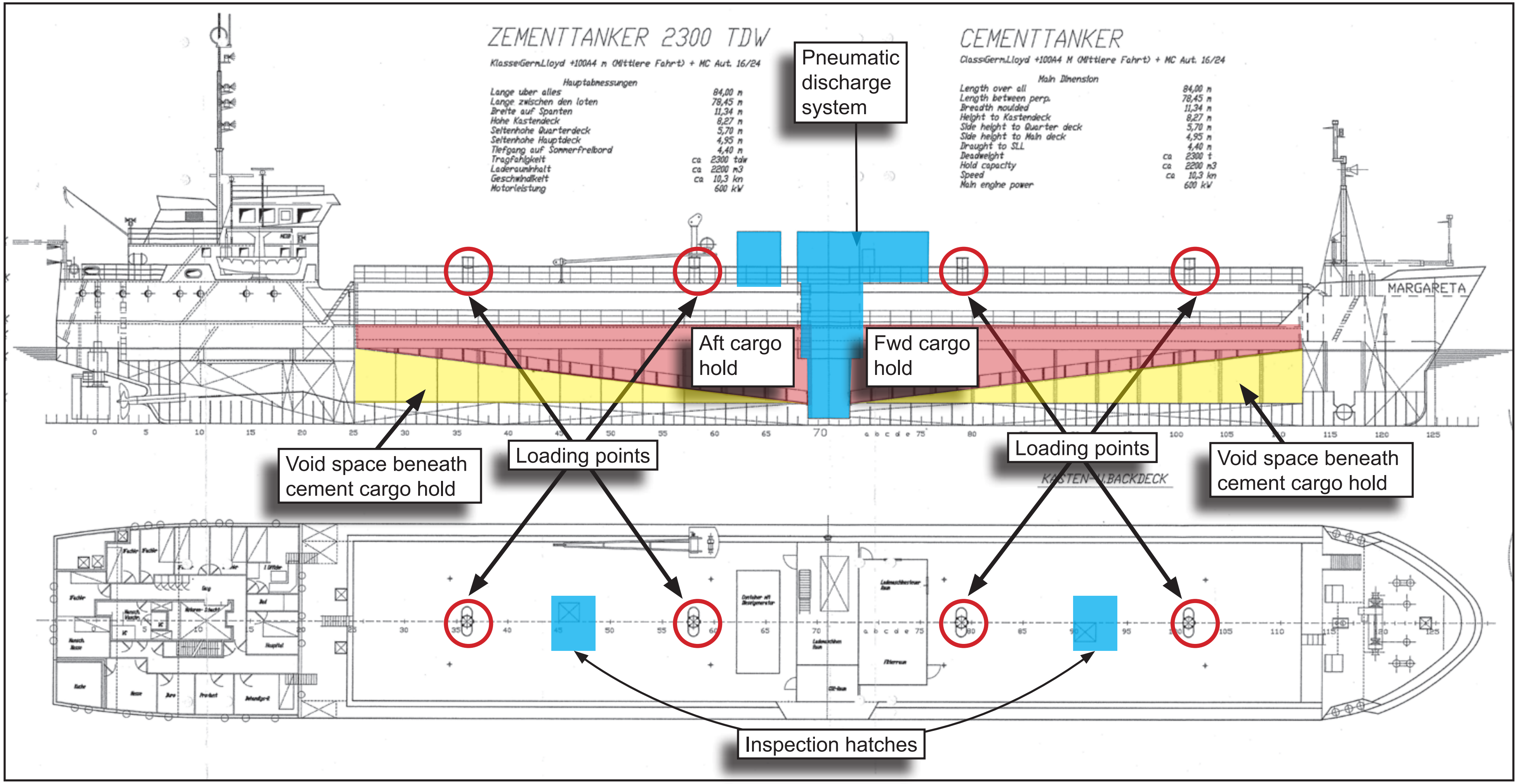


Figure 15: *Cemfjord* - general arrangement showing cement cargo holds and pneumatic discharge system

1.6.4 Navigation and distress alerting equipment

Cemfjord's primary means of navigation was paper charts; there was no electronic navigation chart plotter on board. The vessel was equipped with an up to date folio of navigation charts and publications covering all its areas of operation. This included the Admiralty Sailing Directions (North Coast of Scotland Pilot)(NP 52), which contained guidance on navigation in the Pentland Firth.

The Global Maritime Distress and Safety System (GMDSS) regulations set out in Chapter IV of the International Convention for the Safety of Life at Sea 1974 (SOLAS), as amended, require all commercial vessels of 300gt and above, engaged on international voyages to be suitably equipped with radio equipment for distress alerting. *Cemfjord* complied with the GMDSS regulations and was equipped with:

- Two VHF radios with digital selective calling[6] (DSC) capability
- Furuno FS2571C high and medium frequency radiotelephone
- ICOM and Jotron TR20 handheld VHF radios
- Two Jotron Tronsart radar search and rescue transponders (SART), stored internally
- Saab R4 Class A[7] AIS transponder
- Satpro long range identification and tracking (LRIT) system
- Inmarsat 'C' satellite communications
- Sirius 3 Navigational telex system (NAVTEX)
- Flares

The GMDSS regulations also required the installation of an automatic release (float-free) Emergency Position Indicating Radio Beacon (EPIRB). *Cemfjord* carried a Sailor SE406 II EPIRB that was housed in a plastic enclosure mounted on the port bridge wing bulwark **(Figure 16)**. The enclosure included a hydrostatic release switch and loaded spring for lid ejection. The manufacturer's installation instructions **(Annex E)** stated that the unit should be mounted upright against a vertical surface in an obstruction-free area, but also stated that mounting it horizontally on a flat surface such as a cabin roof was an acceptable alternative. The installation instructions also stated that it was critical that the unit should be mounted in *'a position where the released EPIRB will not get trapped by overhangings, rigging, antennas etc, should the vessel ever sink'.*

The GMDSS regulations required vessel operators to ensure that EPIRBs are examined and tested annually. The unit on board *Cemfjord* had been subject to its annual test by a surveyor from DNV-GL on 8 December 2014. This test included confirmation that its position was checked for float-free operation and that it had been properly maintained by an approved maintenance provider.

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6 In an emergency, a DSC distress call allows the operator to transmit a substantial amount of information, including the vessel's position, to the coastguard and nearby vessels without the need for voice communication.

7 Data transmitted from a 'Class A' AIS transponder includes the vessel's position, course and speed over the ground as well as heading through the water.

Image courtesy of Brise Bereederungs

Figure 16: *Cemfjord* - EPIRB mounting arrangements on port bridge wing bulwark

1.6.5 Life-saving appliances

Cemfjord was fitted with three 12-man inflatable liferafts and a davit launched rescue boat. One liferaft was located on the port side of the accommodation block at deck level and two were on the starboard side; one at deck level and the other mounted on top of the bulwark **(Figure 17)**.

The rescue boat was located beneath the bridge wing on the starboard side of the vessel. *Cemfjord* also carried eight lifebuoys that were stowed in various locations on the upper deck. The crew's abandon ship lifejackets (8) and immersion suits (8) were stored externally in a box aft of the starboard bridge wing **(Figure 17)**.

Cemfjord's liferafts were manufactured by Viking and each contained a sealed pack of additional safety equipment complying with the 'SOLAS A' standard. The pack's contents included a sea anchor, flares, water and food rations, sea sickness tablets and other safety stores. The liferafts were also fitted with a throw-recovery line and quoit, which was attached to one of the liferaft's buoyancy tubes and stowed close to one of its canopy doors.

Image courtesy of Brise Bereederungs

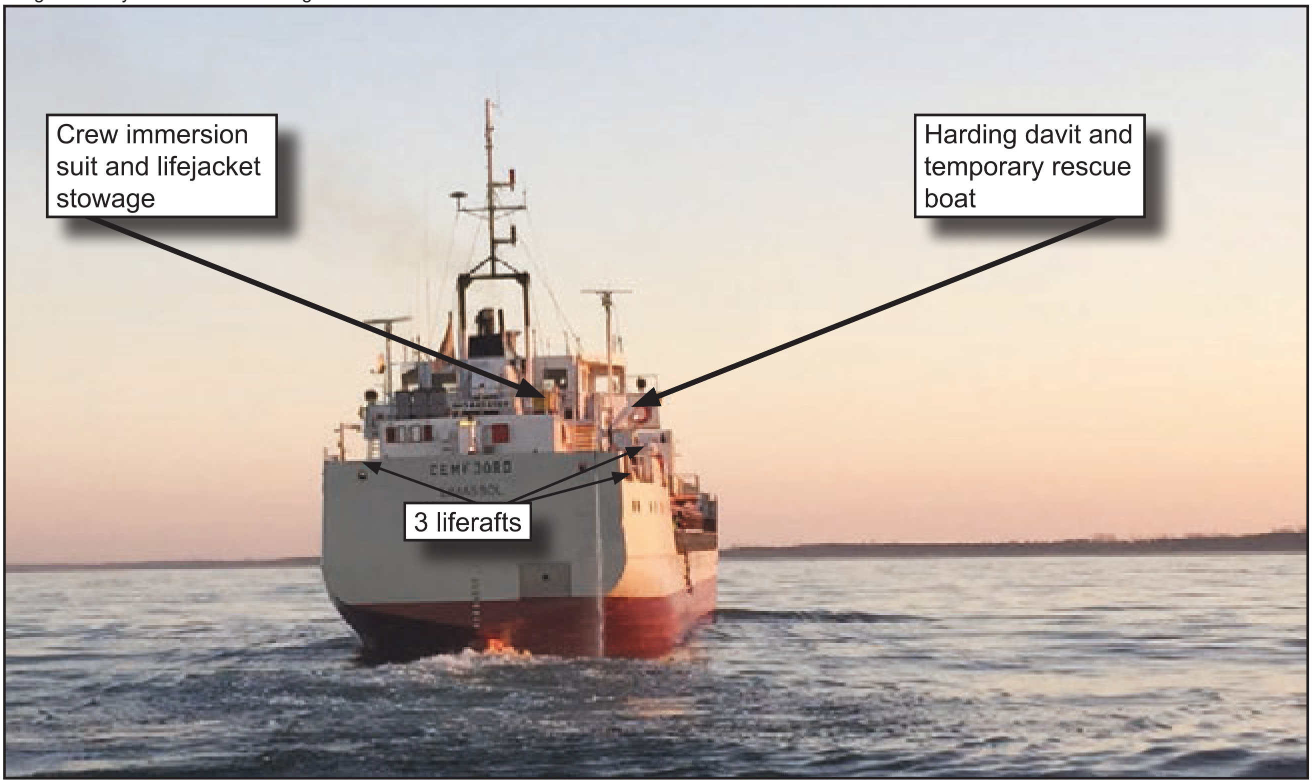


Figure 17: *Cemfjord* underway with locations of life-saving equipment shown

Two of the liferafts (one on the port side, one on the starboard) were secured in tip-over cradles by a lashing arrangement and a hydrostatic release unit (HRU). The tip-over cradles were mounted at deck level and formed part of the ship's side guardrails. If released manually, by removal of the deck locking pin **(Figure 18)**, the cradle and guardrail section would tip over the vessel's side and release the liferaft into the sea. The third liferaft, which had been fitted as a temporary measure, was mounted in a cradle at the top of the ship's side guardrail aft of the starboard bridge wing.

The securing arrangements and the liferaft painters were rigged so that, had the ship capsized or sunk before the crew were able to launch a liferaft, the following sequence of events **(Figure 19)** should have occurred:

- At a depth of about 2m to 4m the water pressure acting on the HRUs should activate its spring tensioned knife, which would cut through the HRU strong rope and release the liferaft canister lashing arrangement.
- This would allow the liferaft(s) to float towards the surface, pulling the painter line from the canister.
- Once fully extended, the painter should activate the liferaft's inflation mechanism.
- As the liferaft(s) inflates the buoyant forces generated should cause the HRU's weak link to break, allowing the liferaft(s) to float-free of the sinking vessel.

Image courtesy of Brise Bereederungs

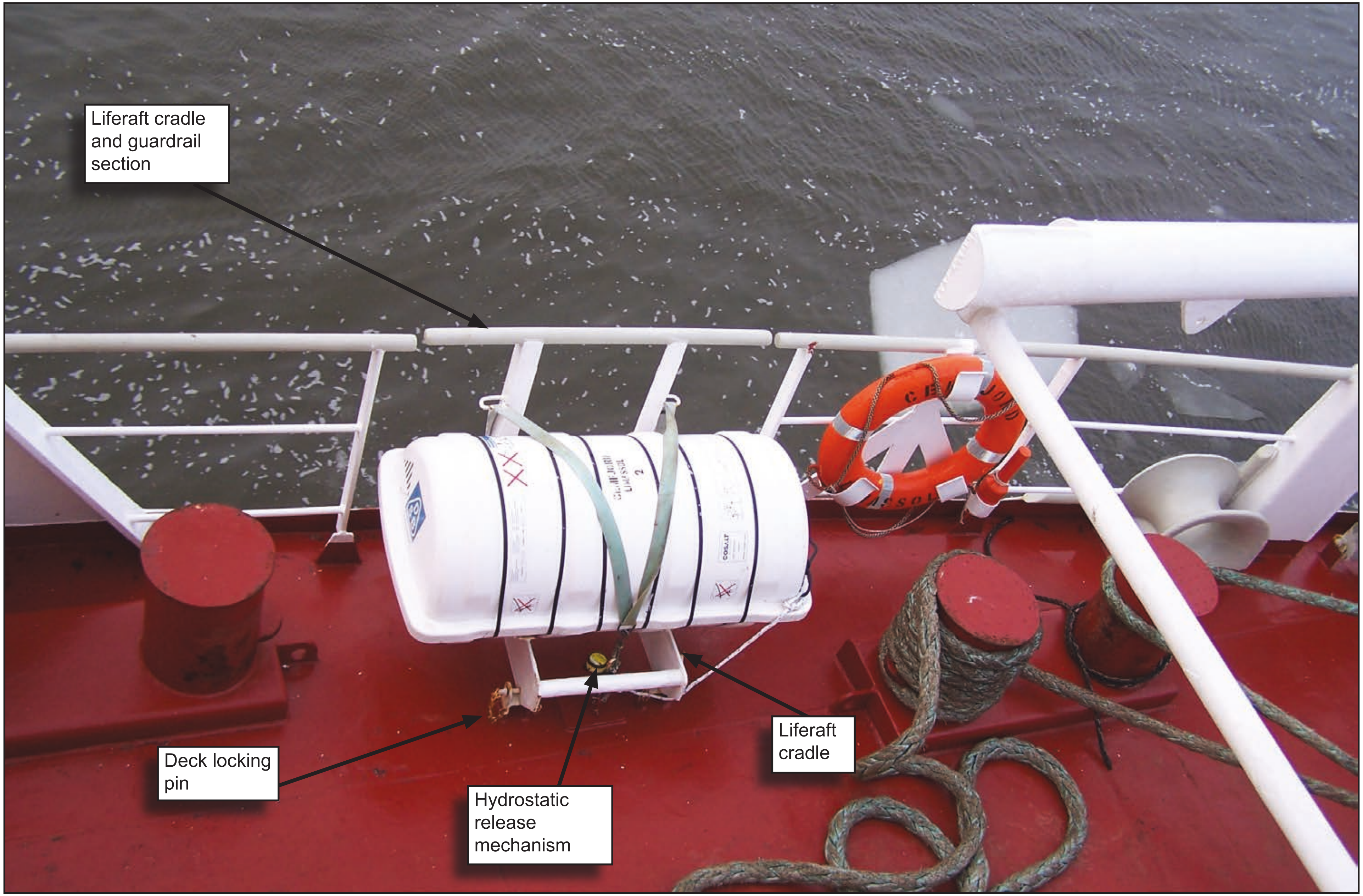


Figure 18: *Cemfjord* - image taken prior to accident showing starboard deck level liferaft stowage

Images courtesy of CM Hammar website instructional video

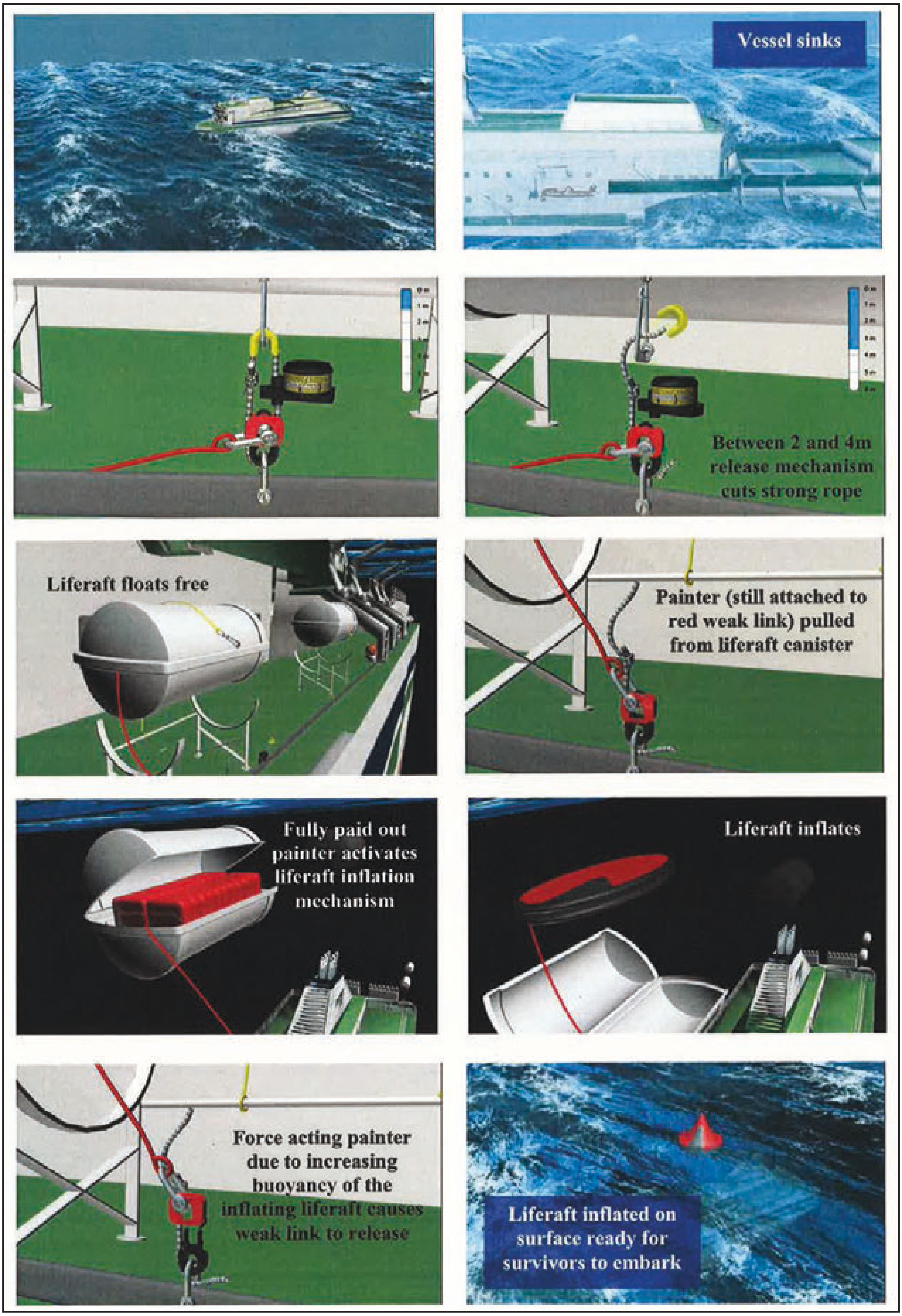


Figure 19: Generic automatic liferaft deployment and inflation process

The rescue boat davit was manufactured and supplied by Harding Safety, and was fitted during *Cemfjord*'s refit, approximately 1 month before the accident. It was a remotely operated hydraulic pivoting 'NOREQ NPDS 1300 H' davit and was fitted with a Harding type RRH15 off-load/on-load single fall release hook. The davit was designed to launch and recover rescue boats or lifeboats and could be operated from inside the boat or a remote position on deck. An extract of the davit's user manual is at **Figure 20**. A Harding rigid rescue boat Type 425 had been ordered at the same time as the replacement davit but it was not delivered during the refit and a temporary rescue boat was sourced and carried instead.

The temporary rescue boat was a SOLAS approved 4.2m length overall Survitec Zodiac RIBO 420. It had a rigid glass re-enforced plastic hull and a five chamber inflatable buoyancy tube. It was certified to carry up to six persons and was powered by a 25 horsepower (hp) tiller operated outboard engine. The temporary rescue boat was supplied with its own hoisting sling arrangement **(Figure 21)**. The hoisting slings were too long for the davit, which meant the boat could not be launched or recovered from the Harding davit.

1.6.6 Abandon ship procedures

SOLAS Chapter III, Regulation 19 mandated the requirements for emergency training and drills. It required every crew member to be familiar with their duties prior to undertaking a voyage and, as a minimum, abandon ship drills to be conducted monthly. In addition, rescue boats should, so far as reasonably practicable, be launched monthly with the designated crew embarked and operated in the water. SOLAS Chapter III, Regulation 35 required a training manual to be provided on board, which should explain in detail the methods for operating safety equipment. This should include instructions for use of lifejackets, launch and recovery of safety craft, and use of all survival equipment.

Cemfjord's safety management system (SMS) provided a generic abandon ship procedure **(Annex F)** that set out the principal duties of each of the crew and an outline procedure to be followed. *Cemfjord*'s crew also had local procedures for abandoning ship, which were specific to the equipment on board. Copies of these procedures were not held ashore and therefore have not been examined.

During a controlled abandonment of *Cemfjord* its crew would have been required to take the following steps:

- Muster at their assembly point (the bridge).
- Don their lifejackets and immersion suits.
- Rig a liferaft embarkation ladder.
- Ensure the liferaft painter was secured to the vessel's structure.
- Release the liferaft canister securing straps.
- Remove the cradle locking pins and tip the liferaft over the side (or throw the liferaft overboard).
- Pull in on the liferaft's painter to activate its inflation mechanism.

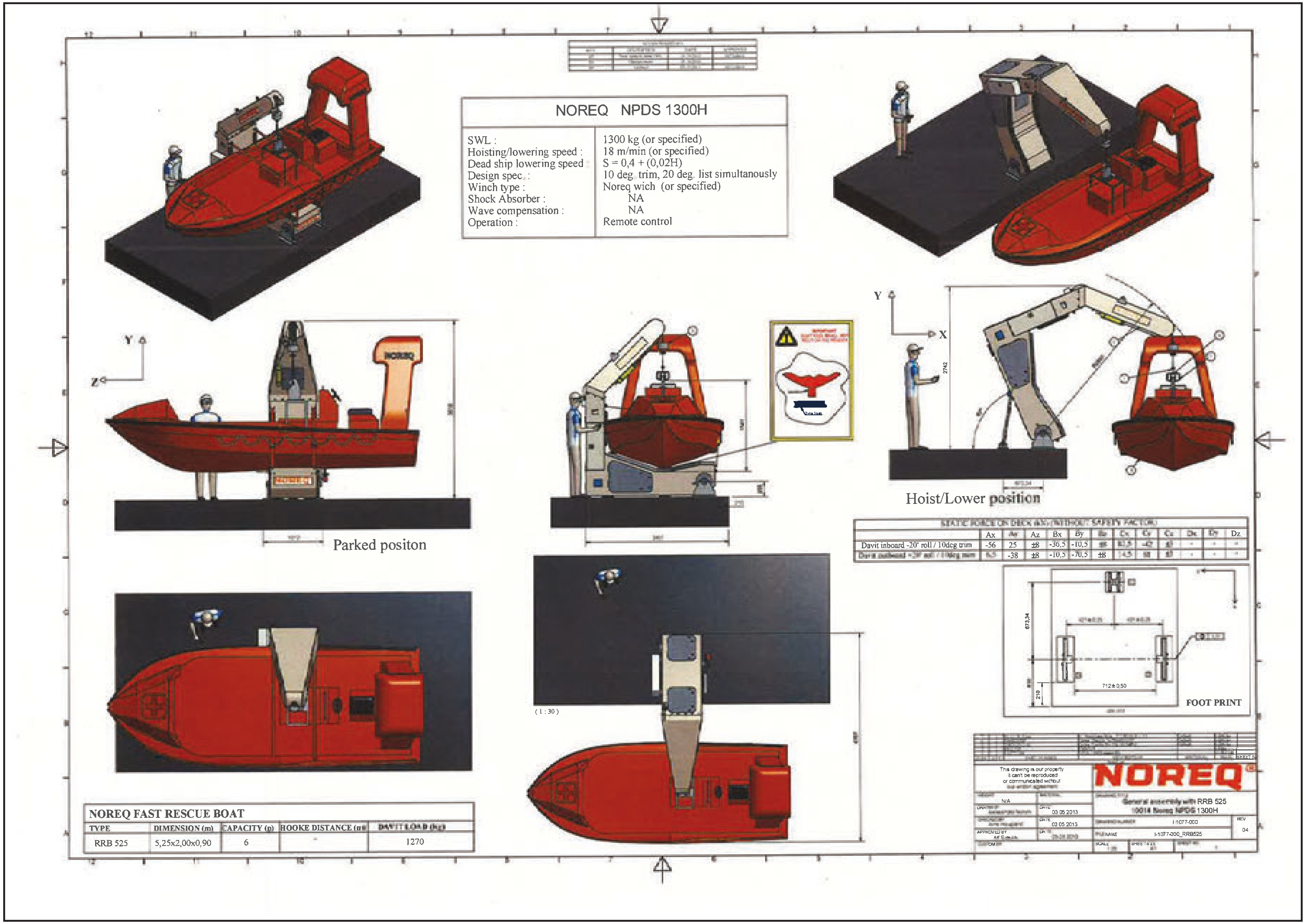


Figure 20: Harding davit NOREQ NPDS 1300H: extract of user manual

- Pull the inflated liferaft alongside the vessel.

- Climb down the embarkation ladder into the liferaft.

- Cut the painter (from within the liferaft).

- Paddle clear of the vessel (the vessel's rescue boat might be used to assist this process and marshal the liferafts).

- Close down the liferaft canopy.

There was no evidence to show whether the crew of *Cemfjord* had conducted any abandon ship drills or updated the local procedures on board between leaving Gdynia and the accident.

Image courtesy of Brise Bereederungs.

Figure 21: Zodiac temporary rescue boat in replacement Harding davit

1.6.7 Heavy weather ship handling

Previous masters of *Cemfjord* indicated that their preferred policy when encountering heavy weather, especially when the vessel was in a loaded condition, was to place the approaching seas fine on the port or starboard bow and reduce speed. This allowed *Cemfjord* to ride over larger waves and reduced the risk of heavy pitching and pounding. The policy was also designed to minimise the extent to which the vessel shipped large volumes of water over its main deck, thus limiting any adverse effects the weight of the entrained water might have on *Cemfjord*'s stability.

1.6.8 Bilge and void space pumping

SOLAS Chapter II-1, as amended, requires that all cargo vessels are provided with an efficient bilge pump capable of pumping from and draining any watertight compartment on board under all practical conditions.

Cemfjord was originally constructed as a general cargo ship with a bilge pumping system that included suctions in the main cargo hold. On conversion to a dedicated cement carrier in 1998, the insertion of the new holds resulted in the creation of large void spaces beneath the cement holds **(Figure 15)**. The bilge pumping suctions associated with the original cargo hold bilges remained in place after the conversion; this was in order that the vessel retained a capability to pump out the void spaces beneath the cement holds.

1.7 POST-ACCIDENT EVIDENCE RECOVERY

1.7.1 Crew and recovered equipment

During the search and rescue efforts, none of the crew were found and very little debris or equipment was recovered. The only safety equipment found was the liferaft that was discovered 70nm east of *Cemfjord*'s last AIS transmission **(Figure 6)**, and the inflatable buoyancy tube that was found on the southern coast of South Ronaldsay **(Figure 10)**, and later confirmed to have come from the vessel's temporary rescue boat.

The liferaft's canopy had been torn and was no longer covering the raft **(Figure 11)**; its SOLAS A pack had gone; the full length throw recovery line and its quoit were trailing in the sea. The sea anchor had not been streamed and the liferaft painter was not visible on the SAR helicopter's video recordings.

The rescue boat's buoyancy tube had deflated and two of its wooden bench seats were still attached to the tube. The forward bench seat had snapped in two and the buoyancy tube's outer grab rope had been torn off.

1.7.2 Underwater surveys

Following the sinking, the MAIB commissioned two underwater surveys of *Cemfjord*'s wreck. The first survey was conducted by the UK Ministry of Defence (MoD) from the Northern Lighthouse Board vessel *Pharos,* the second was conducted by Specialist Subsea Services (S3) from the offshore support vessel *EDT Hercules*. A representative from Brise Bereederungs was in attendance at both surveys and provided additional technical advice to the MAIB investigation team.

The wreck was located on the seabed in position 58°40.198N - 002°32.811W by *Pharos* on 5 January 2015. It was lying in approximately 70m of water in an east-west orientation. The initial survey using an MoD underwater remotely operated vehicle (ROV) was undertaken on 18 and 19 January 2015. This survey positively identified that the wreck was *Cemfjord*, and that it was lying on its port side at an angle of approximately 120° from upright **(Figure 22)**. However, this survey was cut short due to deteriorating weather conditions and strong tidal streams.

The second survey, using S3 ROVs was conducted between 8 and 10 February 2015. A multi-beam echo sounding survey **(Figure 23)** confirmed that the vessel was intact and there was no evidence of structural failure of the hull. The key observations made during this survey were:

- The wooden, hinged starboard bridge door was missing **(Figure 24)**.
- The main superstructure was significantly distorted and the port bridge wing area was partially buried in the seabed **(Figure 25)**.
- All the bridge windows were broken and missing **(Figure 26)**.
- The starboard side door beneath the bridge wing, accessing the accommodation spaces, was closed **(Figure 27)**.
- The stern door between the poop deck and internal fan space was open **(Figure 28)**.
- The rescue boat was missing.
- The rescue boat davit was in its fully stowed position and the davit fall wire had not been lowered **(Figure 29)**.
- The starboard liferafts were missing; the cradle for the starboard deck mounted liferaft was in the stowed position but its guardrail section had broken away **(Figure 30)**. The port liferaft stowage was not accessible.
- The lifebuoys had gone from the stowages observed.
- The deck stowage for the crew lifejackets and immersion suits was missing **(Figure 31)**.
- All four of the cement loading ports were shut and secured **(Figure 32)**.
- The forward cargo hold loading hatch was slightly buckled and partially open **(Figure 33)**.
- The rudder was set approximately 10° to port **(Figure 34)**.
- The starboard side liferaft embarkation ladders had not been rigged and no sightings of crew bodies were made.

Image courtesy of Ministry of Defence

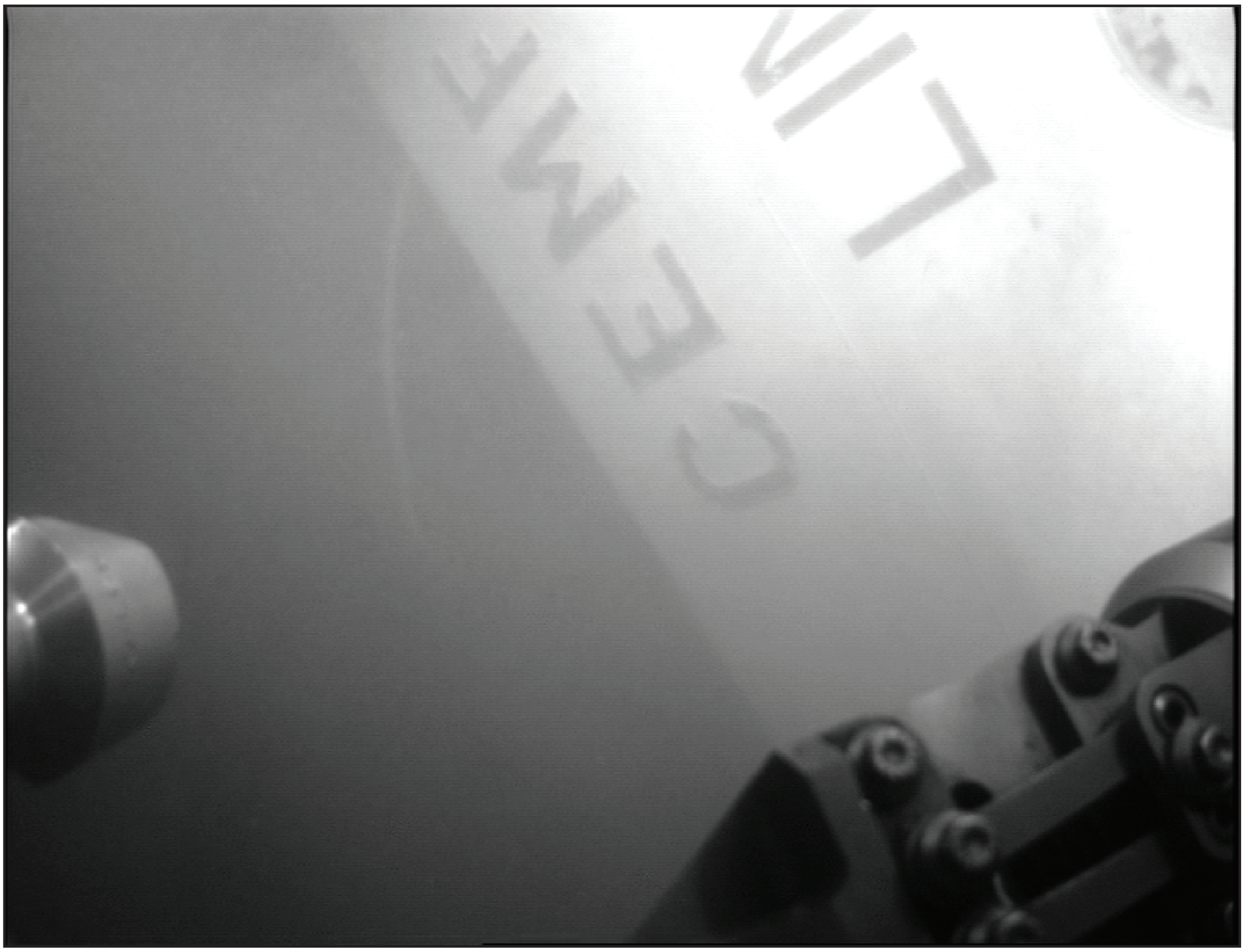


Figure 22: Wreck of *Cemfjord* - initial identification and angle of heel from Ministry of Defence remotely operated vehicle

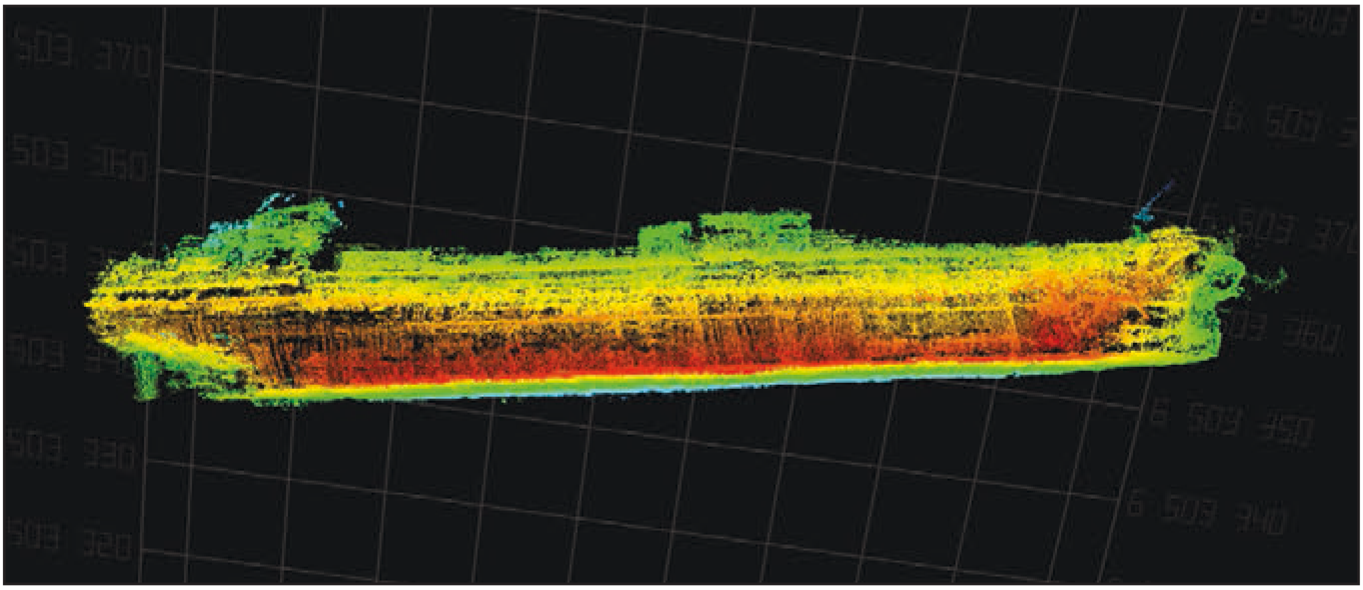


Figure 23: Wreck of *Cemfjord* - multi-beam echo sounding image of entire vessel

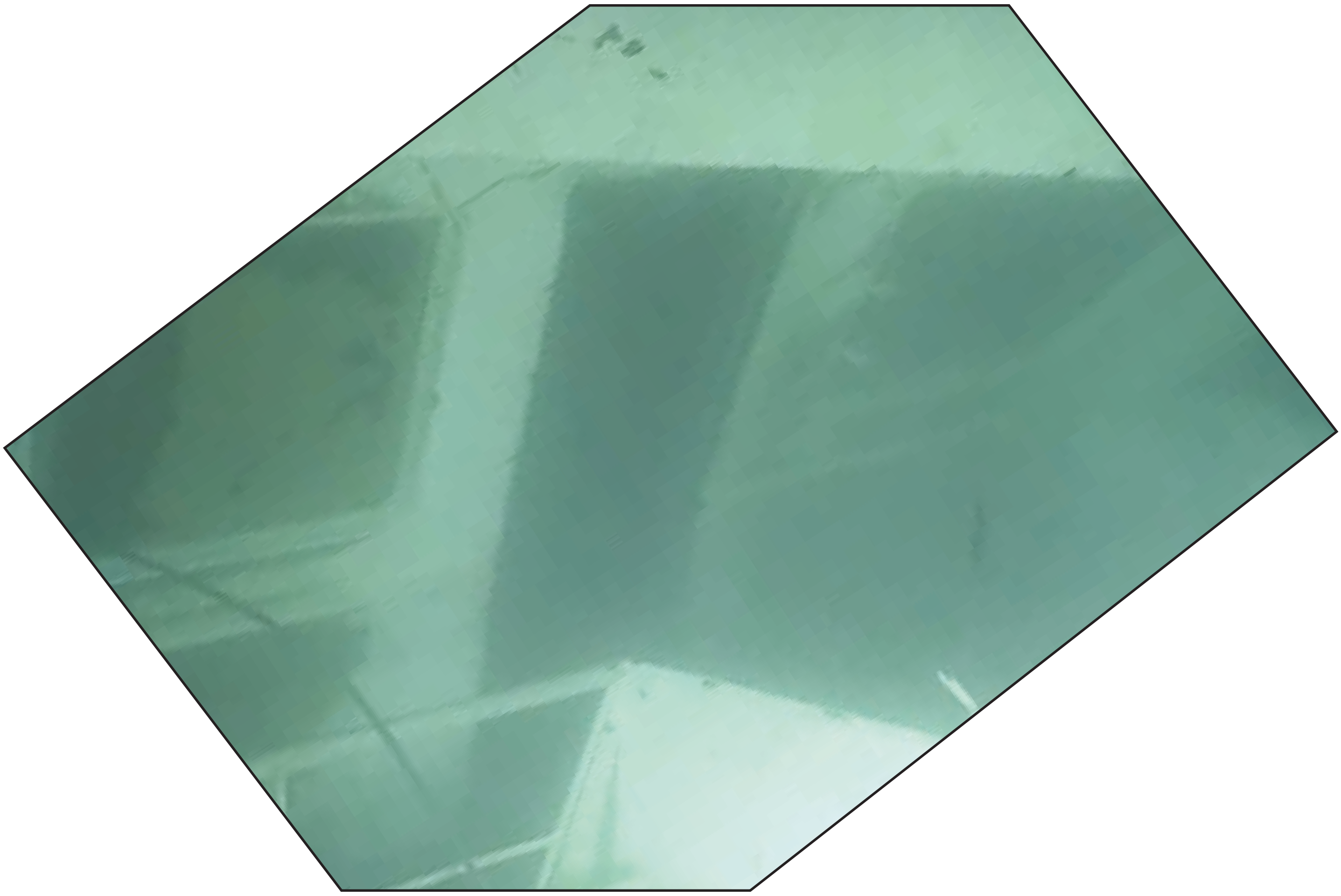


Figure 24: Wreck of *Cemfjord* - starboard bridge wing door area (image inverted)

Figure 25: Wreck of *Cemfjord* - port bridge wing and superstructure impacted on seabed

Figure 26: Wreck of *Cemfjord* - bridge windows detail


Figure 27: Wreck of *Cemfjord* - starboard side accommodation door closed (image inverted)

Figure 28: Wreck of *Cemfjord* - poop deck door to fan space open

Figure 29: Wreck of *Cemfjord* - Harding davit on starboard side in stowed position with fall wire not lowered (image inverted)

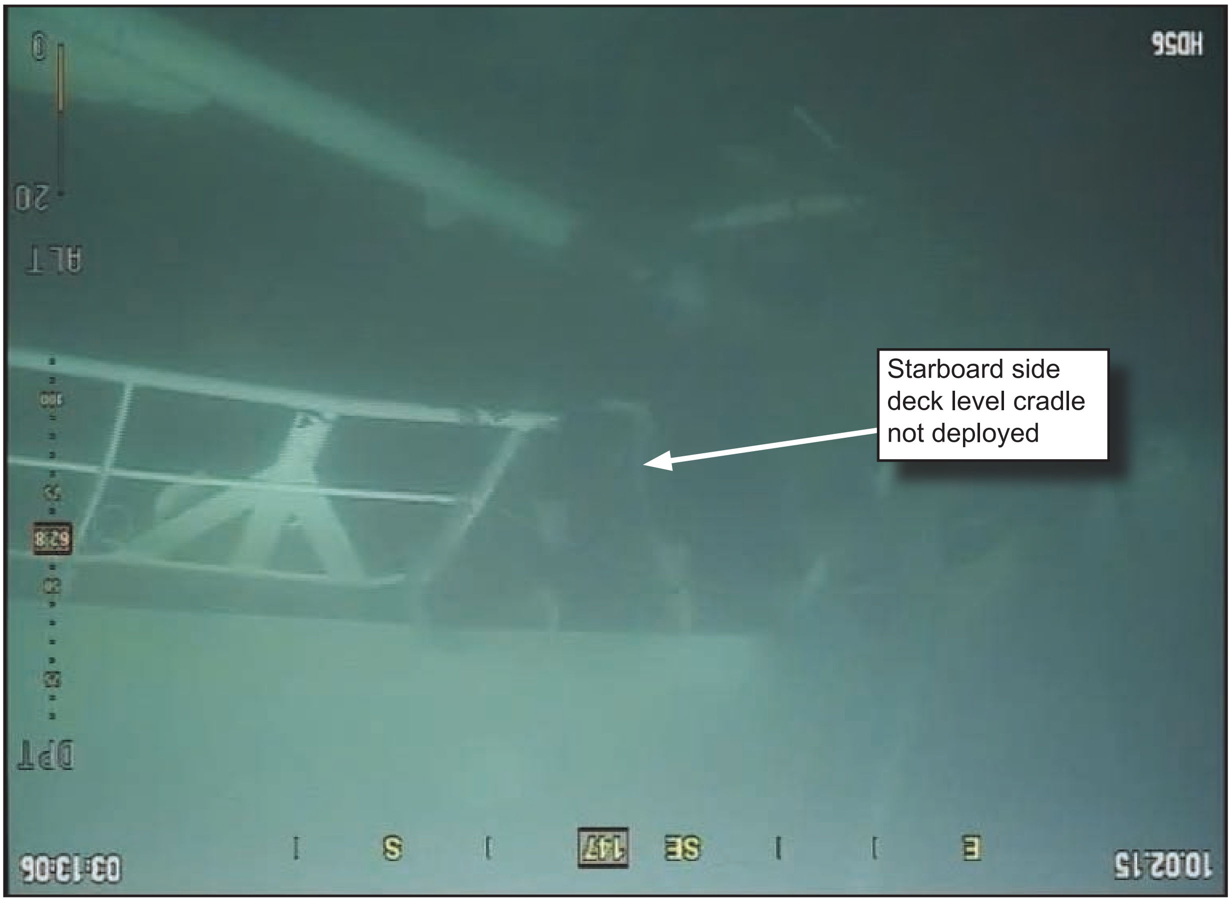


Figure 30: Wreck of *Cemfjord* - starboard deck level liferaft cradle empty and guardrails missing (image inverted)

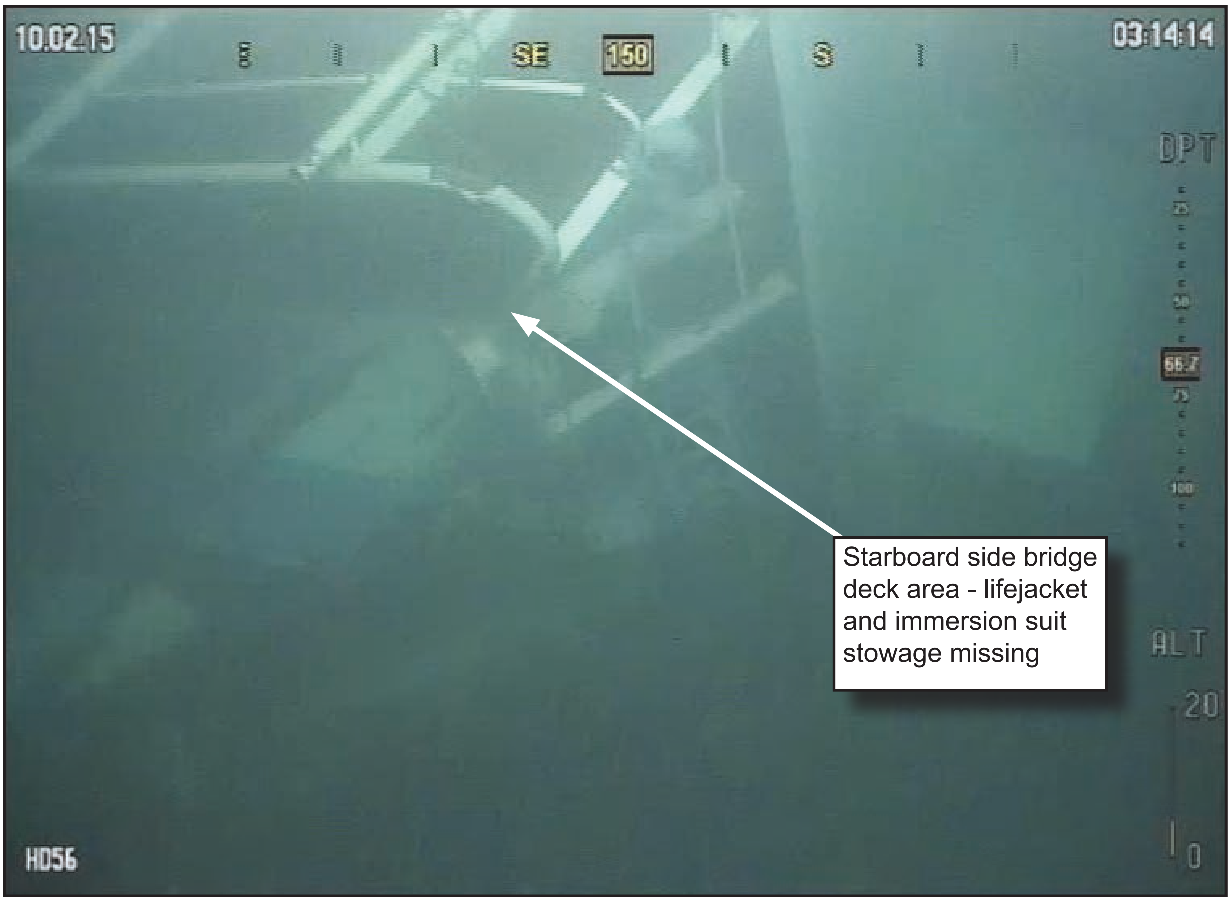


Figure 31: Wreck of *Cemfjord* - starboard bridge deck area showing that crew immersion suit and lifejacket stowage was missing

Figure 32: Wreck of *Cemfjord* - closed cement loading port

Figure 33: Wreck of *Cemfjord* - forward cargo loading hatch

Figure 34: Wreck of *Cemfjord* - propeller with rudder set to approximately 10º to port

1.8 PASSAGE PLANNING

1.8.1 International requirement

SOLAS Regulation 34 requires that, prior to proceeding to sea, the master is to ensure that the intended voyage has been planned taking into account the guidance in IMO Resolution A.893(21) '*Guidelines for Voyage Planning*', which explains that:

> *'The development of a plan for voyage or passage, as well as the close and continuous monitoring of the vessel's progress and position during the execution of such a plan, are of essential importance for safety of life at sea, safety and efficiency of navigation and protection of the marine environment.'*

The guidance sub-divides passage planning into four key stages: appraisal, planning, execution and monitoring. The initial voyage planning **appraisal** stage involves the gathering of all information relevant to the intended voyage. The next stage requires the detailed **planning** of the whole voyage from berth-to-berth. The third and fourth stages are the effective **execution** of the plan and **monitoring** the progress of the vessel during the implementation of the plan.

1.8.2 Company direction

Cemfjord's SMS contained passage planning guidance that mirrored the IMO requirement for a methodical, staged approach to identifying and avoiding navigational hazards. The SMS included the following guidance:

At least the following should be plotted on charts…

- *<u>Indication of hazards</u> such as shallow waters, rocks, wrecks*
- *<u>Abort points / points of no return</u>*
- *Areas of danger…*

The shortest route is not always the quickest route and the most safe therefore the following should be taken into account:

- *Ship's condition such as draught, trim, manoeuvrability*
- *Prevailing weather conditions*
- *Cargo and possibility of damage likely to be sustained*
- *Proximity to navigational hazards*
- *Advice and recommendation from routing services*
- *Recommendation from Ocean Passages of the World (when applicable)*

1.8.3 Responsibility for passage planning

Cemfjord's SMS required the chief officer to fulfil the role of the ship's navigation officer. As such, he was expected to prepare the passage plan in accordance with the company's *voyage planning and performance procedure*. Specifically, he was required to:

- *'Carry out appraisal of all available pertinent information for preparing voyage plan from navigational publications, instructions from Master, Owner, Charterer, weather and navigational radio bulleting, international and local regulations and data/experience from previous voyages,*
- *Establish route, calculate distances and draw courses on smaller scale charts and analyse with the Master voyage details to <u>identify hazards</u> and set margins meeting voyage parameters,*
- *Lay out true courses, distances, waypoints and all other necessary information on charts selected for the voyage,*
- *Issue a written voyage plan and submits it for Masters approval.'* [sic]

The master was responsible for ensuring the necessary charts and publications were on board as well as providing guidance and instructions to the chief officer for preparation of the passage plan. The master was also required to monitor the passage to establish that it was being executed safely.

1.9 THE PENTLAND FIRTH

1.9.1 Background

The Pentland Firth is a sea passage between the Scottish mainland and the Orkney Islands **(Figure 35)**. It is used by shipping traffic passing in both directions between the Atlantic Ocean and North Sea, as well as by vessels proceeding in and out of Scapa Flow. A report[8] published by the Scottish Government in 2012 identified a daily average of 76 vessel movements in the Firth during winter months.

The area is notorious for extreme tidal and sea conditions that must be taken into account by all vessels when planning their passages. The Pentland Firth is within Shetland Coastguard's area of responsibility and is also the subject of an IMO approved voluntary reporting scheme.

1.9.2 Risk assessment for use of the Pentland Firth by shipping

An independent marine consultancy conducted a risk assessment[9] of the Pentland Firth area on behalf of the Maritime and Coastguard Agency (MCA) that was published in 2001. Although the primary function of the coastguard was identified in the report as SAR, it was established that it would be advantageous for the coastguard to have better situational awareness of shipping movements in the area. The report anticipated heavy reliance on AIS, rather than radar, for such future surveillance requirements.

Evidence in the report also suggested that significant levels of shipping traffic did not participate in the voluntary reporting scheme. As a result, the report indicated that, should the Pentland Firth voluntary reporting scheme become compulsory, this would improve vessels' participation. In addition, the report identified increased risks associated with '*sub-standard'* ships using the Firth. The Paris Memorandum of Understanding, Port State Control (PSC) inspection regime was identified in the report as mitigating this risk.

1.9.3 Sailing directions

For vessels planning a passage through the Pentland Firth, Admiralty Sailing Directions (North Coast of Scotland Pilot) (NP 52) contains detailed guidance on safe navigation. Key extracts include:

> ***Tidal information***
>
> ***3.108 General information**.*
>
> *Tidal streams are highly significant to the mariner navigating in or through Pentland Firth and need to be considered at all times. They encounter a number of obstructions, which give rise to eddies and races, which, in several areas of the Firth, can be very strong and extremely violent.*
>
> ***Rates.** Tidal streams run with great strength, rates up to 16 kn have been reported close W of Pentland Skerries.*

[8] Shipping Study of the Pentland Firth and Orkney waters

[9] MCA Project MSA 10/6/159: 'Pentland Firth - a systematic and rational assessment of risk and risk control measured in the Pentland Firth arising out of the use of the Pentland Firth by shipping'.

Reproduced from Admiralty Chart BA 0002 and 1954 by permission of the Controller of HMSO and the UK Hydrographic Office

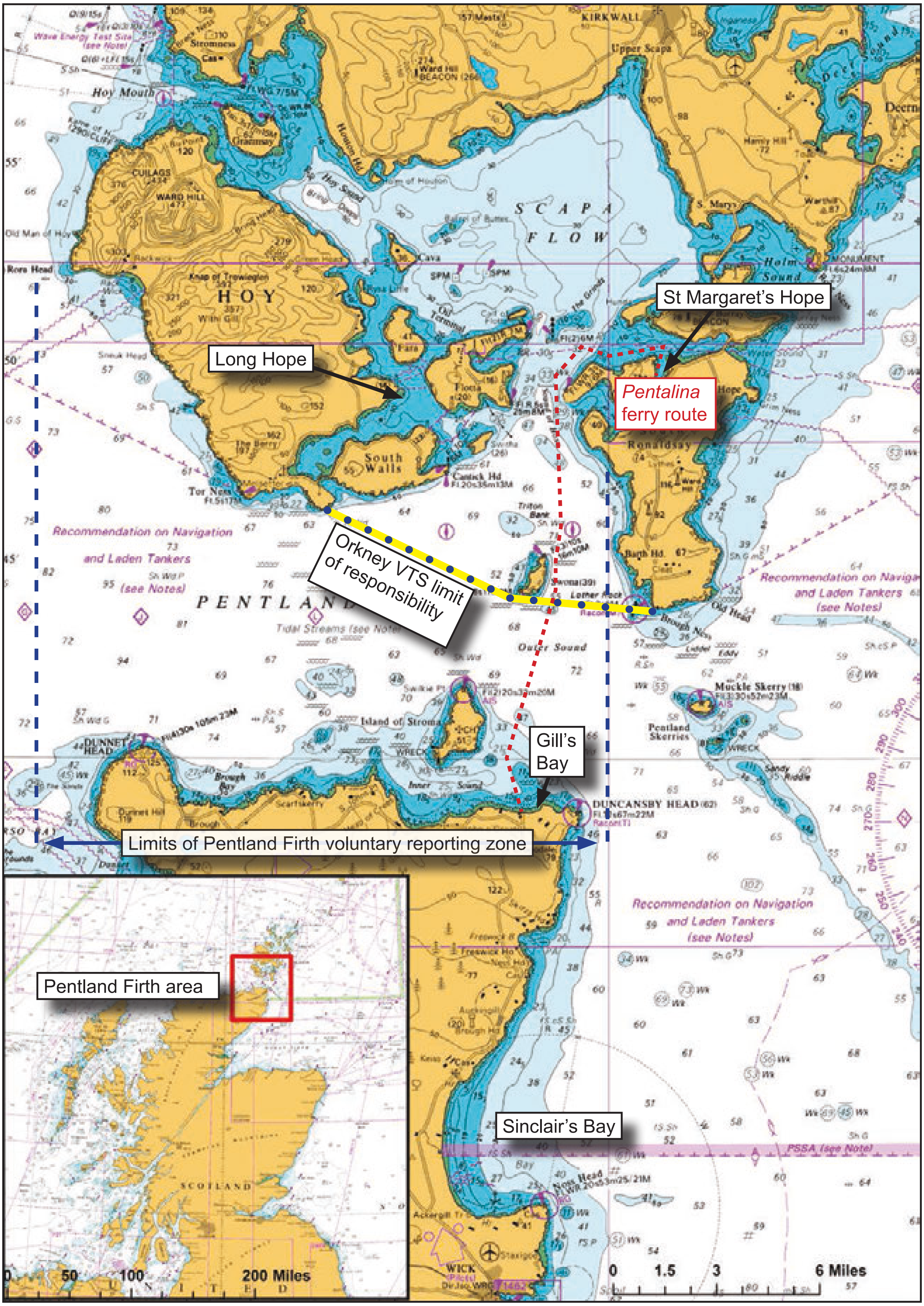


Figure 35: The Pentland Firth showing Orkney VTS area of responsibility, boundaries of the voluntary reporting area, *Pentalina* ferry route and potential weather avoidance areas

Races. *Even in calm conditions there can be heavy turbulence in the races; in disturbed conditions, particularly when the tidal streams are opposed by strong winds or a swell, the sea in the races can become extraordinarily violent and confused, and extremely dangerous to smaller vessels which may become unmanageable.*

3.110 Tide race: Merry Men of Mey*.*

The most extensive and dangerous race in Pentland Firth, known as Merry Men of Mey, forms off Saint John's Point during the W-going tidal stream and, when fully established, extends NNW the whole way across the firth to Tor Ness. With a W sea or swell the entire race becomes very violent: large waves form suddenly and from varying directions, making them difficult to anticipate or counter.

The race forms a natural breakwater across the firth…mariners, particularly those in small, low-powered or sailing vessels, are advised to remember that the W-going tidal stream emerging through Outer Sound can be very strong, rates in excess of 10 kn have been recorded, and the danger of being swept into the race is very real.

The race forms in the following sequence:

Interval from HW Dover	**Remarks**
30 minutes after HW Dover	*Race forms off Men of Mey Rocks and extends initially west towards Dunnet Head. As the W-going tidal stream gains strength the race begins to extend …in a NNW direction.*
4 hours 20 minutes after HW Dover	***When the W-going stream has attained its full strength heavy breaking seas extend the whole way across the firth…***
5 hours 35 minutes after HW Dover	*The SW end of the race becomes detached from Men of Mey Rocks leaving a clear passage*
5 hours 30 minutes before HW Dover	*The NW end of the race begins to subside*
4 hours 50 minutes before HW Dover	*The race subsides in mid-channel with the beginning of the E-going tidal stream*

General precautionary measures and navigational advice

3.119 Passage planning*.*

Because of the very strong tidal streams, the eddies and races to which these give rise and the extraordinarily violent and confused seas which occur at times, particularly in some of the races, navigation in Pentland Firth requires careful preparation and is attended by special problems.

These are such that some mariners may find it advantageous to adjust their arrival at the firth so as to pass through under favourable tidal conditions…

3.122 Steerage*.*

Difficulties in maintaining course and speed can be encountered when transiting either with or against the tidal stream. Masters should therefore ensure that a close watch is kept at all times on the course and speed of their vessels.

3.123 Power*.*

Another factor in safe navigation of Pentland Firth is availability of sufficient power to overcome the strengths of the tidal streams.

Low powered vessels, small vessels, and vessels under sail, *whatever the weather, should avoid at all costs being drawn into any race which is at strength, in particular taking care to avoid Merry Men of Mey during the W-going stream…*

Directions: Outer Sound westbound

Swona to Dunnet Head

3.135 Caution*.*

When the W-going tidal stream is opposed by strong W or NW winds there is a heavy breaking sea, which can be dangerous to small coasters, in mid-firth W of Swona and Stroma. In these conditions passage through the firth ***should not be attempted*** *and mariners are advised to proceed E of Swona and await favourable conditions in Long Hope.*

1.9.4 Safe tidal window planning

The primary reference on board for the master’s situational awareness of the tidal streams was the Admiralty Tidal Stream Atlas for the area. This shows that slack water (low tide) was about 5 hours 30 minutes before HW Dover and slack water (high tide) was about 30 minutes after HW Dover.

Using this information, *Cemfjord*’s masters typically planned westbound passages at slack water with either the first or last of a westerly (ebb) current. This routine would avoid the easterly (flood) tide, which would make progress in a westerly direction impossible and, critically, would avoid the dangerous tidal race, peaking at 4 hours 20 minutes after HW Dover.

Using this information, the key tidal planning considerations for *Cemfjord*'s passage of the Pentland Firth on a westerly heading on 2 January 2015 are shown at **Table 1:**

Time (UTC, 2 January 2015)	The Pentland Firth tidal situation
0820	Easterly flow subsiding
0850	HW Dover
0921	Slack water (HW) Tidal race starts to form at southern side of Firth
1100	West going steam gains strength Tidal race reaches across Firth
1311	Tidal race gains full strength Heavy breaking seas across entire Firth
1426	South east of the race subsides leaving a clear passage
1554	Slack water (LW) North west of the race begins to subside
1700	Tidal race subsides Easterly flow begins

Table 1: Times of tidal events for the Pentland Firth on 2 January 2015

Taking this information into account, the estimated windows for westerly passage through the Pentland Firth on 2 January 2015 (excluding other planning factors), were approximately:

- High water window: 0820-1100
- Low water window: 1426-1700

1.9.5 Alternative routes and shelter options

For vessels passaging from Rordal, Denmark to Runcorn, UK, the most direct route is 981nm via the Pentland Firth. A passage via the English Channel, avoiding the Pentland Firth, is 1,187nm **(Figure 36)**.

On 18 November 2014, the Brise Bereederungs cement carrier, *Cemisle*, was laden and on passage from Brunsbuttel, Germany to Glasgow, UK via the English Channel. The vessel's managers sent an email to the master (who had recently taken command) asking about the choice of route and whether it was for weather avoidance. The master's reply stated that he had chosen the southerly route to avoid predicted stormy weather north of the UK.

Weather avoiding options east of the Pentland Firth were also available in Sinclair's Bay or Long Hope in accordance with the Admiralty Sailing Directions **(Figure 35)**.

Reproduced from Admiralty Chart BA 0002 and 4004 by permission of the Controller of HMSO and the UK Hydrographic Office

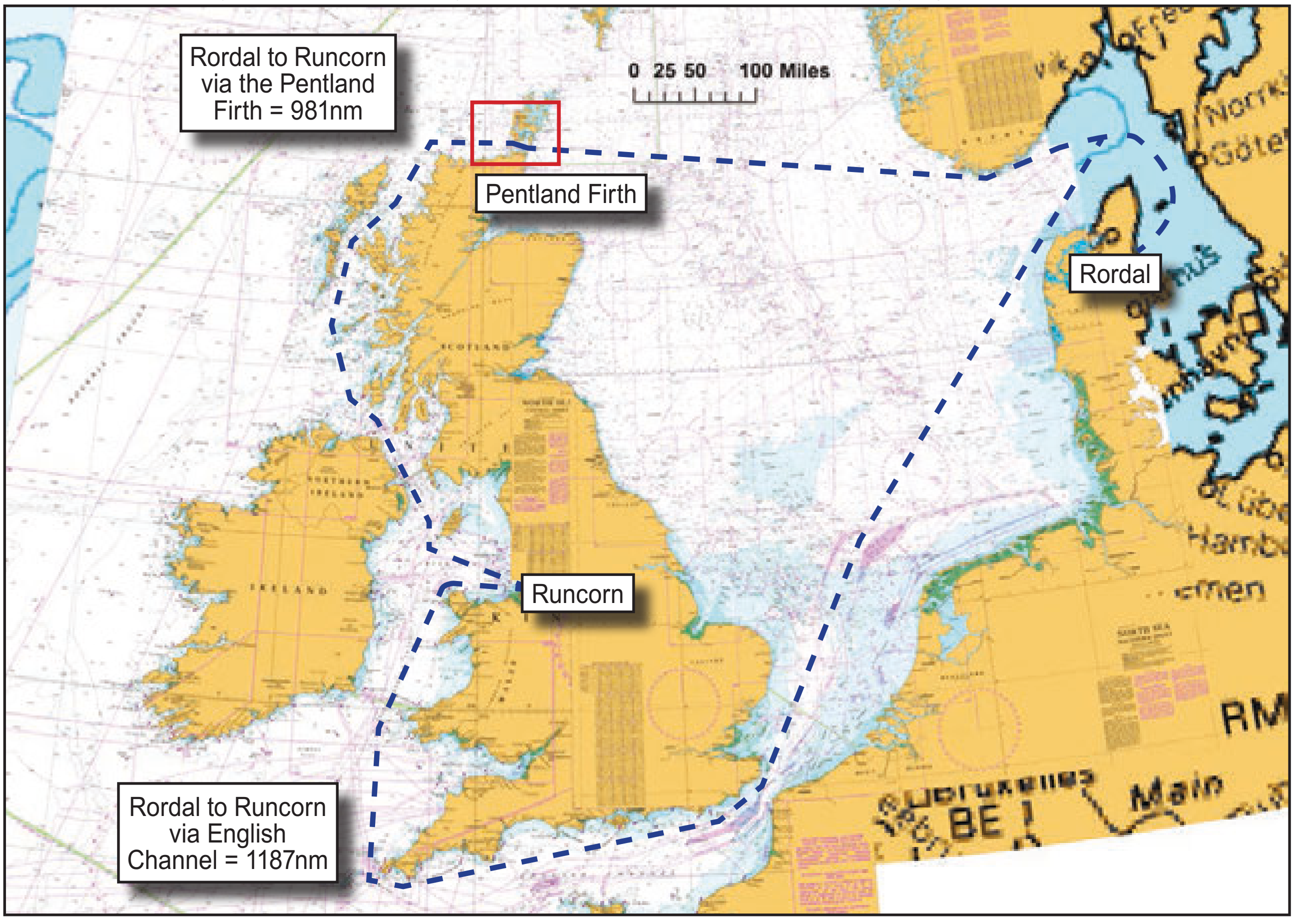


Figure 36: Comparison of the Pentland Firth and English Channel routeing options between Rordal and Runcorn

1.9.6 Weather avoiding actions taken by other vessels on 2 January 2015

At the time of the accident, no other vessels were attempting transit passage east or west through the Pentland Firth, no vessels were moving in or out of Scapa Flow and the ferry, *Hrossey,* delayed its departure from Lerwick for weather avoidance.

Pentland Ferries Limited operated the ferry *Pentalina*, which provided an all year round service between Gills Bay on mainland Scotland and St Margaret's Hope in the Orkney Islands **(Figure 35)**. During the winter, *Pentalina* made three return passages across the Firth, departing St Margaret's Hope at 0745, 1150 and 1650 daily. Due to the severe weather and sea conditions on 2 January 2015, *Pentalina*'s 0745 and 1650 scheduled sailings were cancelled. The 1150 sailing was delayed but went ahead and it was during this passage that the ferry passed ahead of *Cemfjord.*

A review of AIS data identified 11 vessels that passed through the Pentland Firth area during the 25-hour period that elapsed between the loss of *Cemfjord*'s AIS signal, and the sighting of its upturned hull by the crew of *Hrossey*. No sightings of *Cemfjord* or its upturned hull were reported by any vessels during that period.

1.10 AUTOMATIC IDENTIFICATION SYSTEM DATA FOR *CEMFJORD*

In the calendar year 2014, *Cemfjord* made eight return passages from Rordal to UK ports via the Pentland Firth. A review of the vessel's AIS tracks for the westbound passages through the Pentland Firth in 2014 identified that, when Captain Chruscinski was in command the following events occurred:

- At 1209 on 6 March 2014, *Cemfjord* made a 180° course reversal to delay entry into the Pentland Firth. Having turned, the vessel proceeded on an easterly heading until 1400, before reversing course again and proceeding through the Firth **(Figure 37)**. This action delayed the vessel's entry into the Firth by 2 hours and 7 minutes.

- From 0658 until 0929 on 31 March 2014, *Cemfjord* was almost stationary in the eastern side of the Pentland Firth. During this time, the vessel was stemming an easterly tidal flow. Having manoeuvred in the same position for 2½ hours, the vessel then made very slow headway against the tidal stream; at 1000, it was on a heading of 287° and SOG of 1.3kts **(Figure 38)**.

- At 0748 on 17 May 2014, *Cemfjord* made an alteration of course to port when approximately 9 miles east of the entrance to the Pentland Firth. The vessel then held its position south east of Pentland Skerries before heading into the Firth at approximately 1230 **(Figure 39)**.

- At 0700 on 7 October 2014, the vessel altered course to avoid entering the Pentland Firth **(Figure 40)**. This action resulted in a cement cargo shift [para 1.20.1].

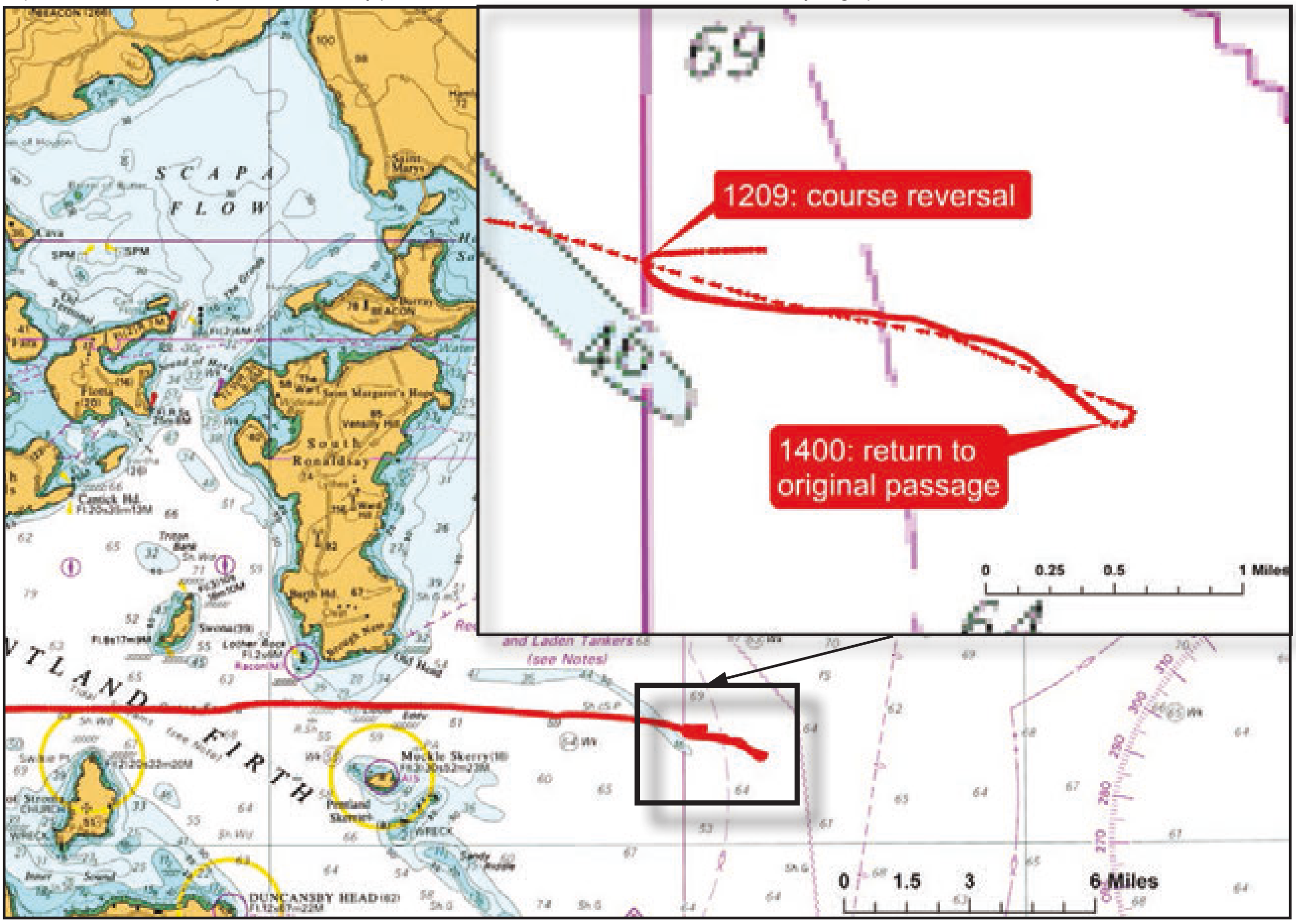


Figure 37: *Cemfjord* - AIS track on 6 March 2014

Reproduced from Admiralty Chart BA 2162 by permission of the Controller of HMSO and the UK Hydrographic Office.

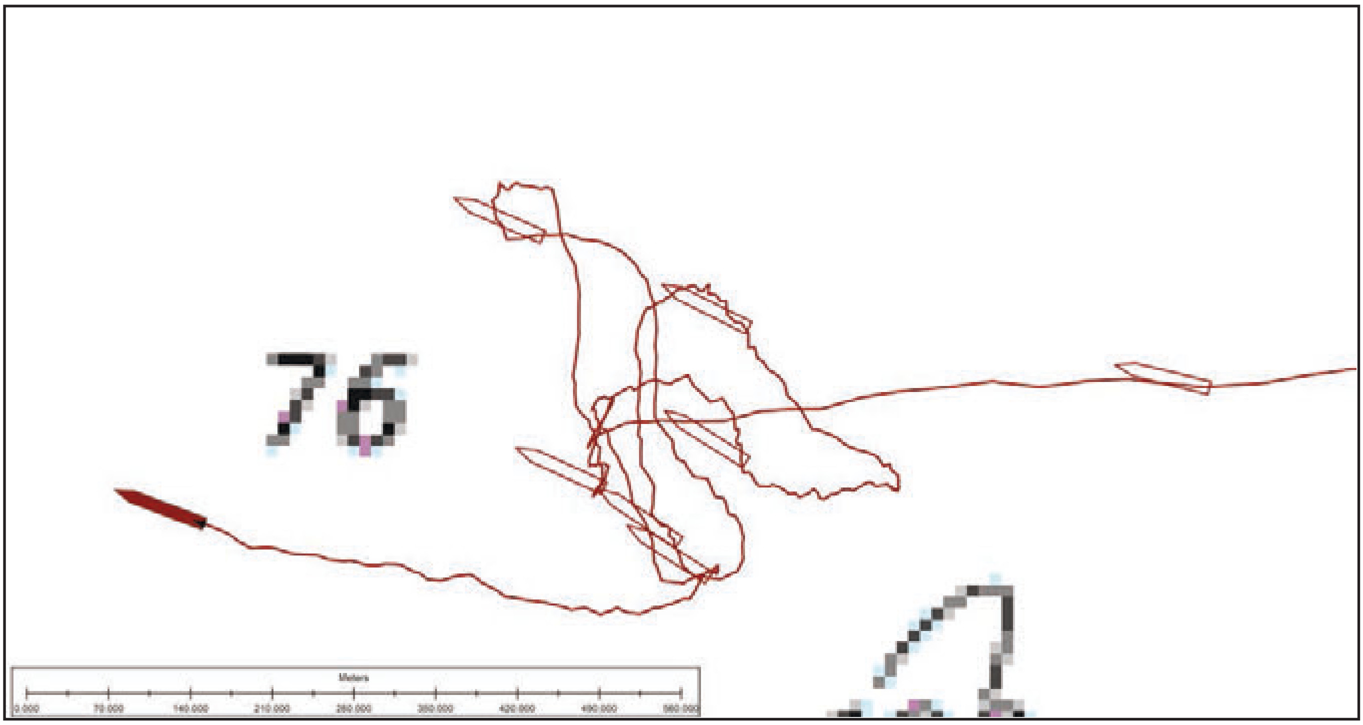


Figure 38: *Cemfjord* - AIS track on 31 March 2014

Reproduced from Admiralty Chart BA 1942s by permission of the Controller of HMSO and the UK Hydrographic Office.

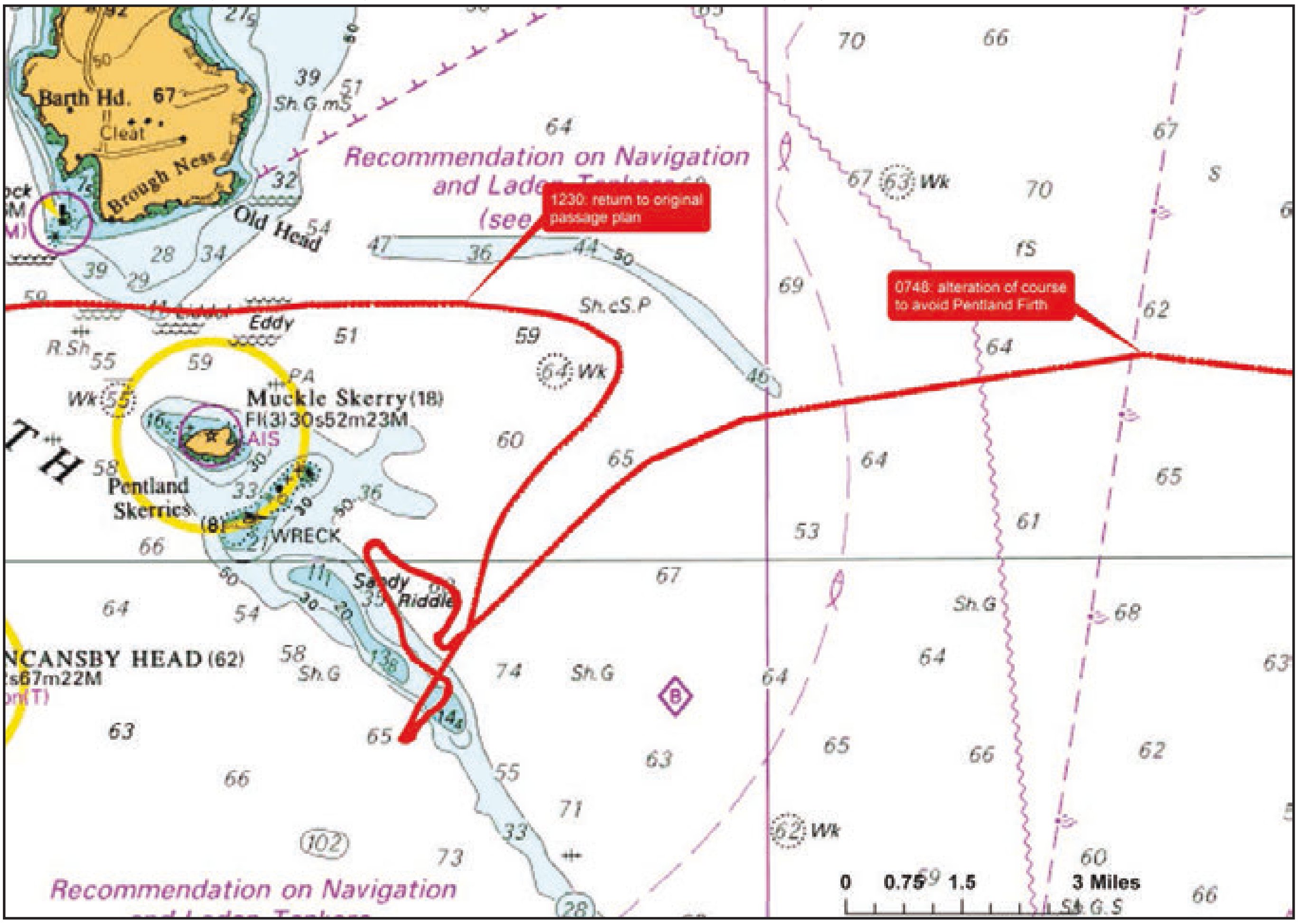


Figure 39: *Cemfjord* - AIS track on 17 May 2014

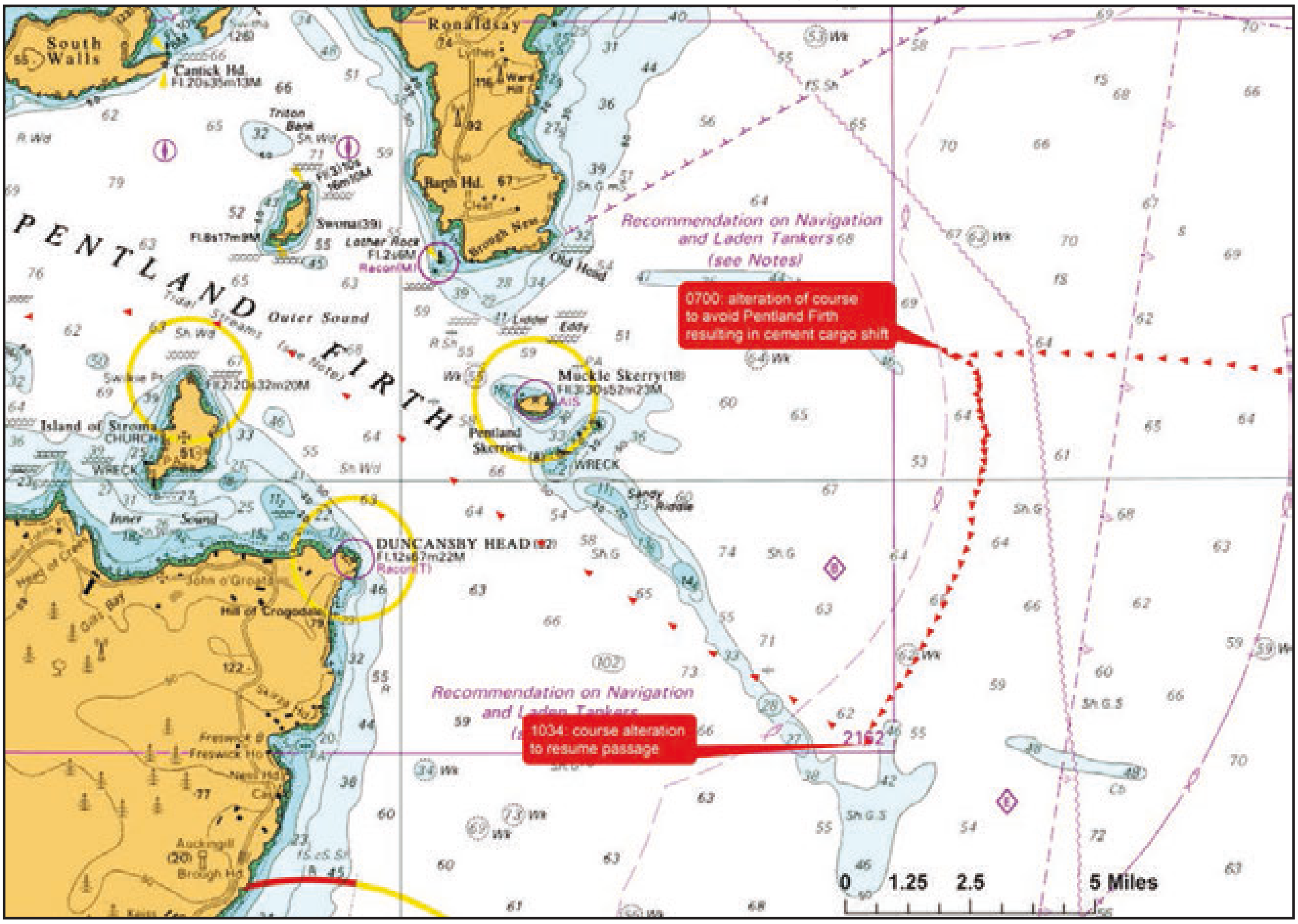


Figure 40: *Cemfjord* - AIS track on 7 October 2014

Data from *Cemfjord*'s AIS for the passage in the period prior to the accident was recovered from 0409[10] on 2 January 2015, until it ceased at 1315:34 **(Figure 4)**. The vessel's headings, COG and SOG, at approximately 1-minute intervals for the 10 minutes prior to the transmissions ceasing, are at **Table 2.**

Time (UTC) (hours, minutes, seconds)	Heading (degrees)	COG (degrees)	SOG (knots)
1305:34	245	275.9	9.7
1306:34	249	277.3	9.3
1307:34	247	279.5	8.9
1308:34	242	276.2	8.7
1309:34	244	273.1	8.5
1310:34	246	272.6	8.9
1311:42	246	273.9	7.7
1312:31	255	274.3	7.4
1313:35	249	278.5	7.8
1314:35	240	278.1	6.6
1315:04	238	267.9	5.2
1315:34	239	276.0	6.3

Table 2: AIS data transmitted by *Cemfjord* prior to capsizing

[10] This was the time when the vessel's AIS transmissions were first received by a UK based aerial.

1.11 SHIP REPORTING SYSTEMS

In co-operation with French authorities, the UK exercises jurisdiction over three IMO adopted mandatory ship reporting systems: Dover Strait, Les Casquets and Ushant. In addition, the UK operates five voluntary reporting schemes including the Pentland Firth. Details of these schemes are promulgated in the Admiralty List of Radio Signals (ALRS) Volume 6 (NP 286(1)) **(Annex A)**. These details include the definition of the area covered by the scheme **(Figure 35)** and the procedure for ships to report at least 1 hour before entering the scheme and again on final departure.

The general principles of a ship reporting system are defined in IMO Resolution A.851(20), adopted by the organisation on 27 November 1997. The obligations for vessels and coastal states are promulgated in SOLAS Chapter V, Regulation 11. Ship reporting systems are used to gather information using radio reports between vessels and the coastal state. The information gathered can then be used to provide data for multiple purposes including search and rescue, vessel traffic management and pollution prevention. Reports should be kept to a minimum and contain only the information essential for the objectives of the scheme.

The purpose of ship reporting schemes should be clearly defined, and governments establishing such systems should notify mariners of the requirements to be met and procedures to be followed. Neither the SOLAS Regulation nor the IMO Resolution regarding ship reporting systems offered any distinction between mandatory or voluntary schemes.

1.11.1 The Pentland Firth voluntary reporting scheme

The Pentland Firth voluntary reporting scheme was managed by Shetland Coastguard. The relevant ALRS instructions included the MAREP format for the scheme, but its purpose was not defined and there was no obligation on the shore authority to monitor the positions of vessels in the scheme.

Based in Lerwick, Shetland Coastguard's operations room **(Figure 41)** was continuously manned with a watch supervisor, watch officer and watch assistant. All the operations room staff had access to VHF radios and display screens, which were used for operations and planning management. Live AIS tracks were fed to the operators' display screens. At the time of the accident, the two display screens used by the watch supervisor were not showing AIS information due to a fault with the operations room data distribution system.

The coastguard watch officer was assigned the task of monitoring VHF radio traffic and responding to vessels' MAREPs. Information received from these reports was recorded in a database. Where a vessel making a MAREP on entering the scheme was positively identified on AIS by the watch officer, there was a procedure in place allowing the operator to inform the vessel that an exit report was not required. This was a local procedure that was intended to reduce levels of VHF voice radio traffic; it had not been endorsed by MCA headquarters.

Coastguard staff did not routinely monitor vessels' progress through the voluntary reporting scheme. If AIS transmissions from a vessel in the scheme ceased, there was no alarm system to alert the watch officers and there was also no operator procedure to follow for such an event.

Figure 41: Shetland Coastguard operations room

The coastguard MAREP database for 2014 contained seven reports made by *Cemfjord* prior to entering the Pentland Firth on a westerly heading and eight prior to entering on an easterly heading. There was no MAREP recorded for the vessel's passage from Rordal to Runcorn between 14 and 18 May 2014. This is either because no MAREP report was made by the vessel, or a report was made but not recorded in the coastguard database; this was also one of the occasions the master had taken deliberate action to delay his entry into the Pentland Firth [paragraph 1.10].

1.12 ORKNEY VESSEL TRAFFIC SERVICES

Orkney Islands Council's Marine Services Department operated an information level[11] vessel traffic service (VTS) from its operations room at Scapa Flow. This service was provided to vessels in or approaching the Scapa Flow VTS area **(Figure 35)**. An information level service does not involve the direction of shipping movements but provides essential and timely information which may include traffic updates, weather forecasts, notices to mariners and the status of aids to navigation.

The Orkney VTS operations room was continuously manned and situational awareness was delivered using radar and AIS surveillance as well as VHF radio. Shipping traffic transiting through the Pentland Firth did not cross into the Orkney VTS area; nevertheless, such vessels were usually detected and displayed on the VTS operator's display.

Cemfjord's passage into the Pentland Firth was detected and tracked by the Orkney VTS system. Good quality, continuous radar contact was held as *Cemfjord* headed west in the eastern Firth. This radar echo was also correlated by the VTS computer with *Cemfjord*'s AIS data and shown on the watchkeeper's display screen **(Figure 42)**. As *Cemfjord* was on passage through the Firth and was not approaching the VTS area, there was no requirement for the VTS watchkeeper to monitor or assess *Cemfjord*'s track.

[11] The UK definition of an information level service is in the MCA Marine Guidance Notice 401 (M+F) - Navigation: Vessel Traffic Services (VTS) and Local Port Services (LPS).

Image courtesy of Orkney Island Council, Marine Services

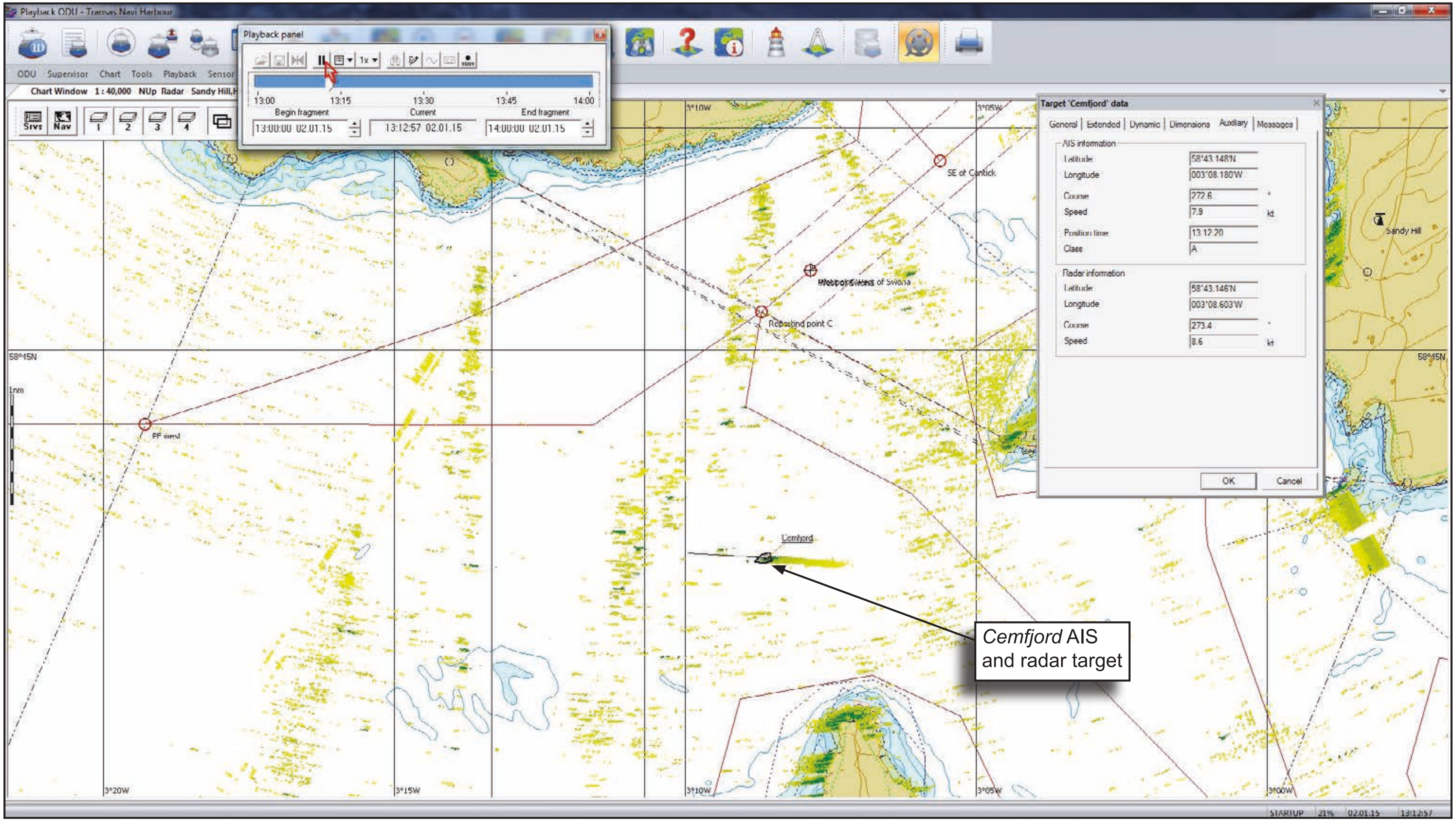


Figure 42: Orkney VTS operator's display showing *Cemfjord*'s correlated radar and AIS track

Orkney VTS radar and AIS contacts on *Cemfjord* were lost abruptly at 1316:12 on 2 January 2015 **(Figures 43** and **44)**. A brief radar detection was subsequently made from 1317:58 until 1318:45; however, this was insufficient time for the radar system to form a track and no further radar detections were made of *Cemfjord* **(Figure 45)**.

In addition to the radar detection of *Cemfjord*, clutter returns from large waves can also be observed; some of these waves were sufficiently large radar targets for the VTS system to form tracks **(Figure 46)**.

1.13 VESSEL STABILITY

1.13.1 Responsibility

Stability of the vessel was the responsibility of the master. The SMS stated that the master was required to '*verify and approve stability calculations'*.

The chief officer, as *Cemfjord*'s cargo officer, was required to plan, manage and supervise cargo operations. This included the preparation of cargo loading plans, the conduct of stability calculations and monitoring the condition and quantity of cargo. The chief officer was also responsible for planning and managing ballasting operations.

Image courtesy of Orkney Island Council, Marine Services

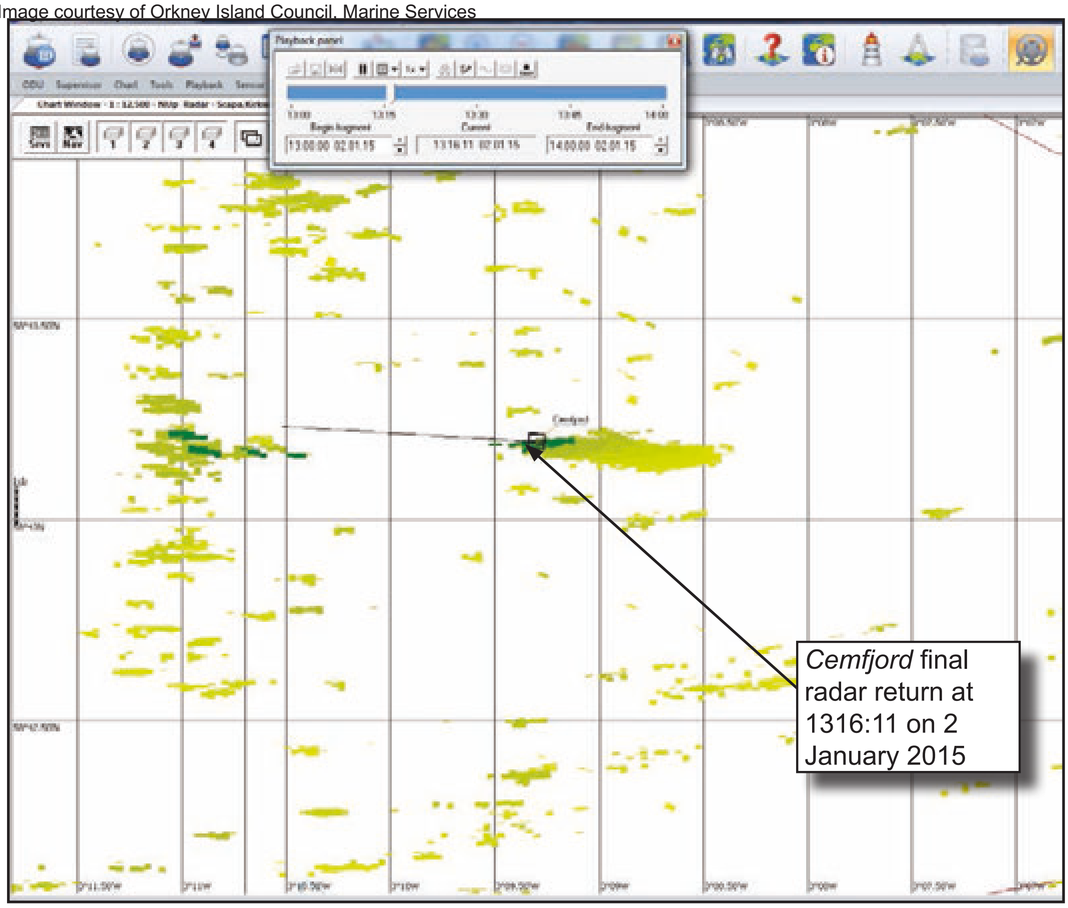


Figure 43: Orkney VTS final radar detection of *Cemfjord* at 1316:11

Image courtesy of Orkney Island Council, Marine Services

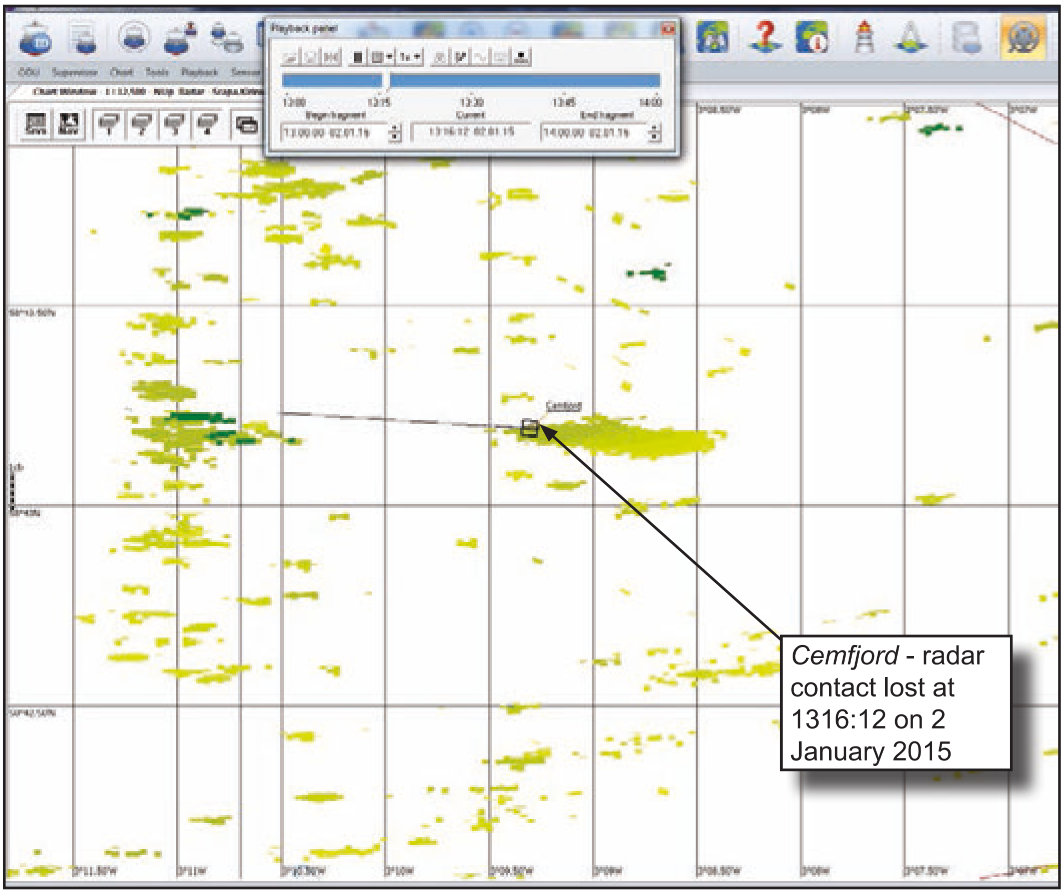


Figure 44 Orkney VTS picture at 1316:12 after loss of radar contact

Image courtesy of Orkney Island Council, Marine Services

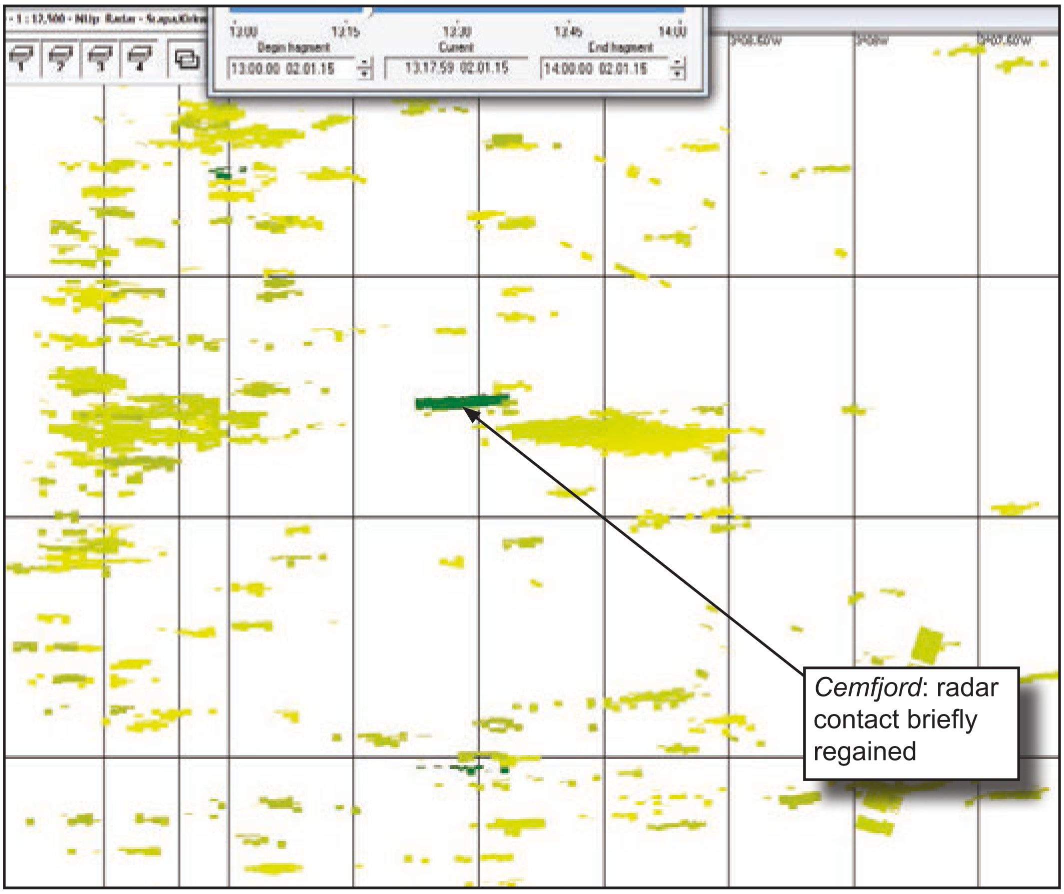


Figure 45: Orkney VTS picture showing brief regain of radar contact at 1317:58

Image courtesy of Orkney Island Council, Marine Services

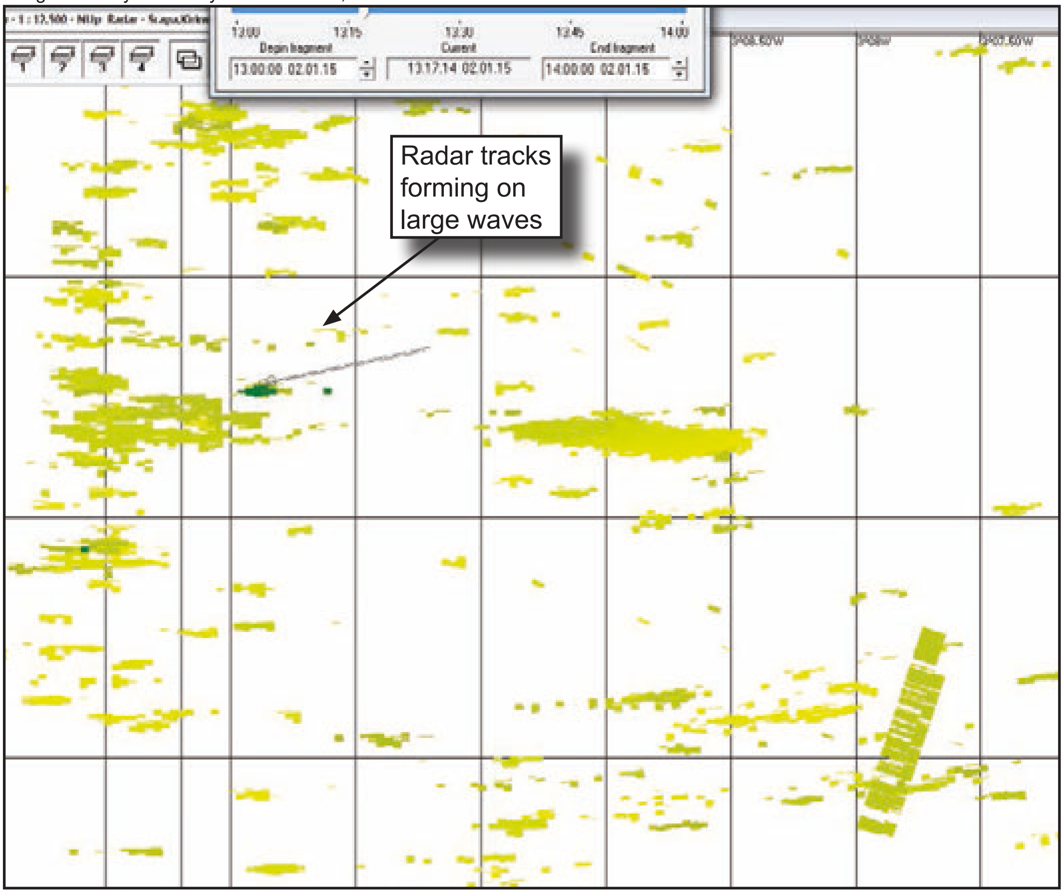


Figure 46: Orkney VTS picture showing radar tracks forming on very large waves

1.13.2 Regulations and guidance

The minimum stability criteria **(Figure 47)** that applied to *Cemfjord* was set out in the Intact Stability Code[12] for Passenger and Cargo Ships under 100m in length (The Stability Code). This required:

1. The area under the righting lever[13] (GZ) curve up to an angle of heel of 30° should not be less than 0.055 metre-radians (m-rad).

2. The area under the GZ curve should not be less than 0.09m-rad up to an angle of heel of 40° or the angle of downflooding if this is less than 40°.

3. The area under the GZ curve between the angles of heel of 30° and 40° or between 30° and the angle of downflooding, if this is less than 40°, should be not less than 0.03m-rad.

4. The GZ should be at least 0.2m at an angle of heel of greater or equal to 30°.

5. The maximum GZ should occur at an angle of heel preferably exceeding 30° but not less than 25°.

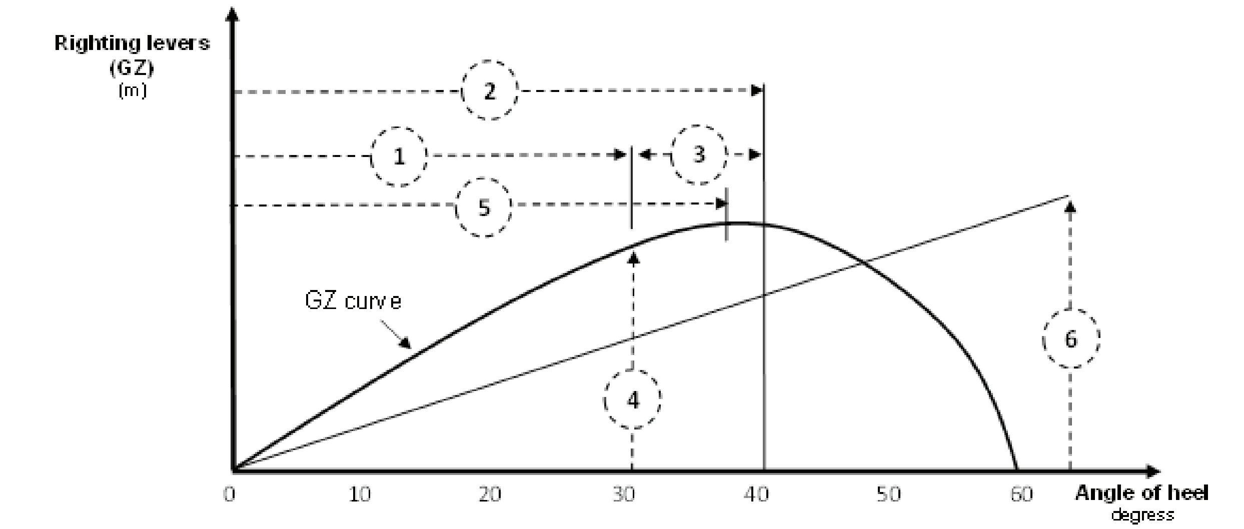
6. The initial metacentric height[14] (GM) should not be less than 0.15m.

---

[12] IMO Resolution A749, as amended by MSC.75(69)

[13] The righting lever, usually measured in metres, is the horizontal distance from the centre of gravity of a heeled vessel and the vertical line from its centre of buoyancy. The righting lever is often referred to as the righting arm.

[14] The metacentric height (GM) is a measurement of a vessel's initial static stability. It is calculated as a distance between the centre of gravity of a ship and its metacentre. A larger GM implies greater initial stability.



1 - Area under the righting lever (GZ) curve up to 30 degrees to be not less than 0.055 metre-radian (m-rad).
2 - Area under GZ curve up to 40 degrees or flood to be less than 0.09m-rad.
3 - Area between 30 and 40 degrees or flood to be not less than 0.03m-rad.
4 - GZ to be at least 0.2m at an angle of heel equal to or greater than 30 degrees.
5 - Angle from 0 degrees to maximum GZ to be not less than 25 degrees.
6 - Initial GM (corrected for free surfaces) not to be less than 0.15m

Figure 47: IMO requirement for intact stability of cargo vessels less than 100m in length

The International Maritime Solid Bulk Cargoes Code (IMSBC Code) was adopted by the IMO's Maritime Safety Committee (MSC) Resolution 268(85) and entered into force on 1 January 2011. Irrespective of the date the vessel's keel was laid, all vessels carrying solid bulk cargoes are required to comply with this Code. The purpose of the Code is to facilitate the safe loading, unloading and safety management of solid bulk cargoes.

Appendix 1 to the IMSBC Code provides individual schedules for common solid bulk cargoes; key points from the schedule for cement **(Annex G)** include:

- Cement is a finely ground powder which becomes almost fluid in nature when aeriated or significantly disturbed thereby creating a very minimal angle of repose[15].
- The ship shall be kept upright during the loading of this cargo.
- After the settlement, shifting of the cargo is not liable to occur unless the angle of the surface with the horizontal plane exceeds 30 degrees.

1.13.3 Stability data

The IMO SOLAS Regulations require that masters are provided with the necessary information for *rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service.*

[15] The angle of repose is maximum slope angle of free-flowing granular material. Thus, for cement, the loaded cargo will settle with an almost flat top surface, similar to the behaviour of a liquid.

Following *Cemfjord*'s conversion to a cement carrier in 1998, the vessel was subject to an inclining experiment. Data from the experiment was used to prepare a cargo loading manual **(Annex H)**. The inclining data and associated stability documents were reviewed and certified as compliant with the IMO Stability Code by Germanischer Lloyd[16] (GL) on 7 May 2012. GL's approval letter **(Annex H)** stated that:

> *our approval should not be considered as relieving the master in any way of the responsibility for the safe and proper loading and ballasting of the vessel.*

GL also explained that stability criteria would only be met when the cement was sufficiently settled.

Cemfjord's loading manual was held on board the vessel in hard copy and was the primary reference for the crew when assessing stability. In addition to general stability data, the loading manual contained eight stability calculations based on typical conditions for the vessel; four of these related to the vessel in a laden condition with a settled cement cargo:

- Cement cargo settled +100% stores short voyage - departure
- Cement cargo settled +10% stores short voyage - arrival
- Cement cargo settled +100% stores long voyage - departure
- Cement cargo settled +10% stores long voyage - arrival

The calculated stability criteria for *Cemfjord* in each of these conditions are at **Table 3**. This shows that, when the vessel was loaded in accordance with parameters set out in the loading manual for any of these four conditions, the IMO's minimum stability criteria would be met.

Minimum stability criteria recommended in the Intact Stability Code for cargo ships under 100m in length		***Cemfjord* loading manual**			
		Short voyage		**Long voyage**	
		Departure 100% stores	**Arrival 10% stores**	**Departure 100% stores**	**Arrival 10% stores**
Area under GZ curve from 0 to 30	≥0.055m-rad	0.057	0.058	0.061	0.055
Area under GZ curve from 0 to 40 or flood	≥0.09m-rad	0.110	0.111	0.116	0.107
Area under GZ curve from 30 to 40 or flood	≥0.03m-rad	0.053	0.053	0.055	0.52
GZ at 30	≥0.2m	0.217	0.221	0.23	0.213
Angle from 0 to Max GZ	≥25	47.6	47.69	47.76	47.55
Initial GM	≥0.15m	0.452	0.444	0.477	0.412

Table 3: *Cemfjord*'s stability criteria from the vessel's loading manual

[16] The classification societies Det Norske Veritas (DNV) and Germanischer Lloyd (GL) merged on 12 September 2013 and were rebranded as Det Norske Veritas-Germanischer Lloyd (DNV-GL).

Cemfjord's loading manual also contained a limiting vertical centre of gravity (VCG) curve **(Annex H)**. This graph could be used by the crew to assess whether the IMO stability criteria was met based on two known conditions: the vessel's displacement and its VCG. It would be possible for the crew to identify both values; displacement from the draught marks and VCG values using data contained in the loading manual.

Cemfjord typically carried sufficient levels of stores, fuel and fresh water to meet its short voyage stability conditions. The loading manual displacement and VCG values for the *Cement cargo settled +100% short voyage - departure* were:

- Displacement: 3420t
- VCG: 4.477m

Figure 48 shows this data plotted on the limiting VCG curve from the loading manual. Any VCG value below the limiting curve (green area) would comply with the IMO's stability requirements.

In addition to the loading manual, the investigation has established that *Cemfjord*'s previous chief officers had developed and used a locally produced spreadsheet to help calculate the vessel's GM. It is unknown if this spreadsheet was used by the chief officer on board at the time of the accident, but examples of the spreadsheet calculations for voyages conducted in 2004, were provided to the MAIB by Brise Bereederungs. A review of the data contained in the spreadsheet identified that the vessel often put to sea on short voyages fully loaded with cement with its ballast tanks almost empty.

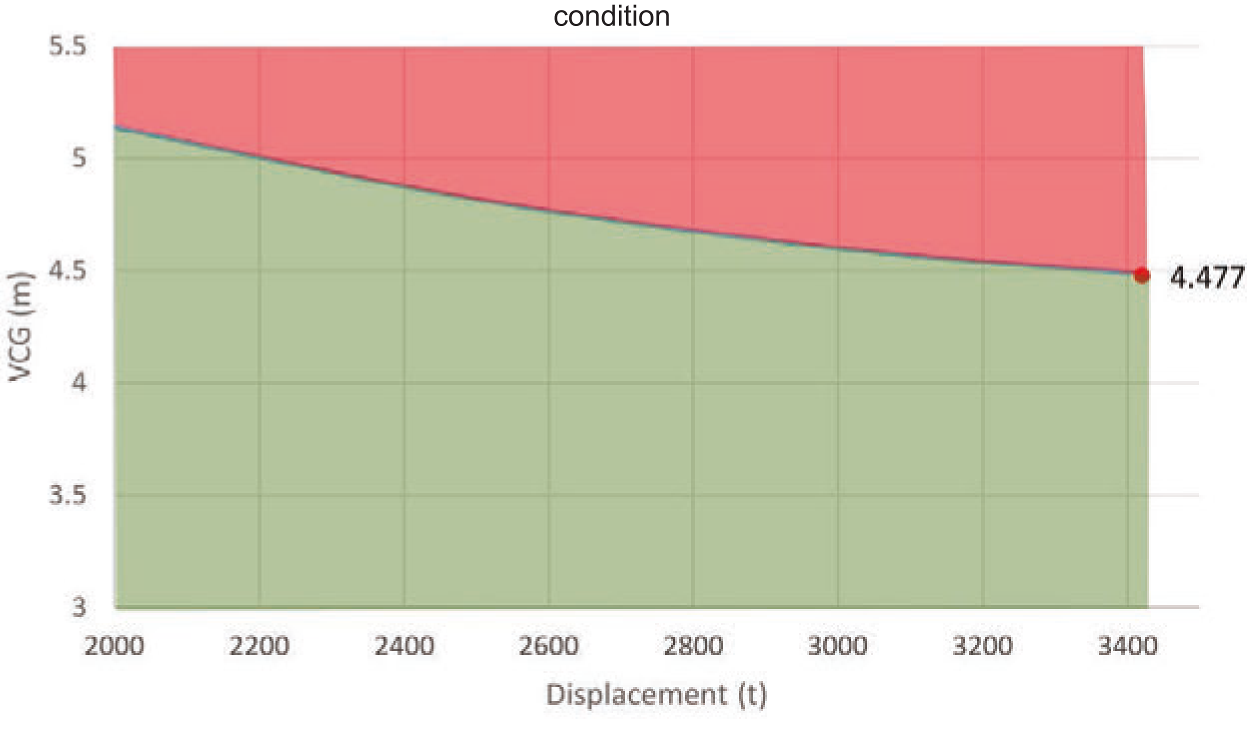


Figure 48: *Cemfjord*'s approved vertical centre of gravity limiting curve showing data point for known condition for vessel (short voyage - departure)

1.13.4 Cargo bulk density

According to the cement manufacturer's technical datasheet, the cargo loaded on board *Cemfjord* had a bulk density of 1100kg/m³. The IMSBC Code provides a density spectrum of 1000 to 1493kg/m³ for bulk cement and the data contained within *Cemfjord*'s loading manual were derived from calculations that used a bulk density figure of 1350kg/m³. The locally developed stability spreadsheet calculated the vessel's GM using a density range of 1560 to 1640kg/m³.

1.13.5 Post-accident stability assessment

As part of its own investigation, Brise Bereederungs commissioned a stability study to ascertain the likely stability characteristics of *Cemfjord* at departure Rordal and at sea. Given the unknown condition of the vessel's ballast tanks or cargo distribution at the time of the accident, the company's independent stability assessment was based on a number of assumptions. Nevertheless, stability calculations were carried out using cargo densities of 1300, 1180 and 1100kg/m³.

The stability analysis report concluded that the IMO's minimum criteria for GM was met for all conditions, but most of the other stability criteria were not met when using densities of 1180 and 1100 kg/m³. The results for a cement cargo of 1100kg/m³ are given in **Table 4**; values that do not meet the IMO criteria in these calculations are shown in red.

Minimum stability criteria recommended in the Intact Stability Code for cargo ships under 100m in length		Stability analysis results for cement density of 1.1t/m³	
		Departure	At sea
Area under GZ curve from 0 to 30°	≥0.055m-rad	0.0365	0.0358
Area under GZ curve from 0 to 40° or flood	≥0.09m-rad	0.0697	0.0688
Area under GZ curve from 30° to 40° or flood	≥0.03m-rad	0.00332	0.0330
GZ at 30°	≥0.2m	0.1340	0.1315
Angle from 0 to Max GZ	≥25	42	42
Initial GM	≥0.15m	0.2580	0.2431

Table 4: post-accident stability calculations from the company's report

1.14 CARGO LOADING PROCEDURE

Cargo loading was required to be undertaken in accordance with the loading procedure set out in *Cemfjord*'s SMS **(Annex I)**. This required the chief officer to prepare a plan with the cement terminal's loading team prior to loading of cement.

The chief officer's loading plan agreed with the shore loading team for 29-30 December 2015 has not been found but an example of a previous plan, dated 20 August 2010, is at **Annex J**.

Each of *Cemfjord*'s four loading ports was fitted with a diverter flap **(Figure 49)** that was used to direct the flow of cement to the selected side of the hold. The diverter flap was used by the crew to keep the vessel upright during loading. The loading procedures stated that the crew were required to *keep the vessel always without list by operating dividers*. The procedure also stated that lists above 2° should be avoided.

De-ballasting was carried out simultaneously with the loading of cargo, and the ballast discharge rate was balanced to allow the uninterrupted flow of cement. However, as the cement loading trunk was in a fixed position ashore, the vessel was required to be moved along the quay when loading was switched from one cargo loading port to another. In order to minimise the requirement to move the vessel, the crew typically used three of the four loading ports available. Initially, cargo was loaded into the aft hold through its forward port; then the forward hold was loaded through its aft port; and finally the vessel was trimmed by loading cement into the aft hold through its aft port.

Due to the problems with the port ballast pump on 30 December 2014, *Cemfjord* assumed a list of 5° during the loading operation; closed circuit television (CCTV) footage of *Cemfjord* leaving the terminal **(Figure 2)** indicated that the vessel was upright on departure.

Figure 49: *Cemfjord* - cement loading cargo ports showing the diverter flap used by the crew to keep vessel upright during loading

Even though the crew were required to undertake stability calculations to assess the condition of the vessel prior to departure, it is understood that the vessel was typically loaded to its draught marks with its ballast tanks fully pumped out. The extent of the stability calculations carried out prior to departure Rordal on 30 December 2014 is unknown. Furthermore, as there was no requirement to send copies of the vessel's stability records ashore, the extent of stability calculations routinely undertaken by previous crews is also unknown.

1.15 SURVIVAL CRAFT AND RESCUE BOAT

1.15.1 SOLAS requirements

The 1974 SOLAS Regulations, Chapter III (Lifesaving Appliances), Regulation 35, unamended, required that:

> *every cargo ship…shall carry lifeboats on each side of the ship of such aggregate capacity as will accommodate all persons on board, and in addition shall carry liferafts to accommodate half that number.*

Regulation 8 of the same chapter required that, for cargo vessels of 1600gt and upwards, at least one of the lifeboats should be motorised.

The lifesaving appliances chapter of SOLAS was completely rewritten and published in the 1983 amendments that came into force on 1 July 1986, under IMO Resolution MSC.6(48). These changes included the introduction of a requirement for a rescue boat to be carried in vessels with keels laid after 1 July 1986. For ships constructed before this date (*Cemfjord* was built in 1984), the 1983 amendments encouraged flag administrations to ensure that the revised lifesaving regulations were adopted where '*reasonable and practicable*'.

Regulation 47 of the 1983 amendments required a rescue boat to be capable of:

> *'1.2.1: carrying at least five seated persons and a person lying down*
>
> *1.6: having sufficient mobility and manoeuvrability in a seaway to enable persons to be retrieved from the water, marshal liferafts and tow the largest liferaft carried on the ship when loaded with its full complement of persons and equipment…at a speed of at least 2 knots.'*

The IMO Code for ROs requires non-compliance with statutory regulations to be referred to the Flag State. In such cases, Flag States may grant an exemption from the regulation in order that a vessel can operate at sea pending rectification of the shortcoming. Alternatively, Flag States may promulgate a permanently acceptable equivalence arrangement to safety regulations. **Annex K** is a summary of the exemptions from safety regulations issued by the Flag State for *Cemfjord* from 16 December 2013 until the accident.

On 7 April 1986, DMS Cyprus issued a notice **(Annex L)** to all its ship owners stating that the administration would accept the following equivalent arrangement to the SOLAS regulations for Cyprus flagged ships:

> *Cargo ships of less than 1600gt, or less than 85m in length…may carry the following equipment:*

1. *on each side of the ship one or more liferafts of sufficient aggregate capacity to accommodate the total number of persons on board:*

4. *A rescue boat, or a lifeboat which complies with the requirements for a rescue boat of the 1983 Amendments to the Convention on one side of the ship as to accommodate all persons on board. The rescue boat or lifeboat shall be provided with an approved launching device capable of launching and recovering the boat.*

In accepting this equivalence arrangement, the Government of the Republic of Cyprus has taken into account the experience gained up to now and the 1983 relevant amendments to the Convention.

This DMS Cyprus equivalence arrangement statement was also published to DNV-GL surveyors in its *'Additional Statutory Requirements for Cyprus'* **(Annex M)**.

1.15.2 *Cemfjord*'s original survival craft arrangements

From build in 1984, *Cemfjord* was fitted with two open lifeboats **(Figure 50)**, launched by davits on either side of the superstructure below the bridge; the starboard lifeboat was engine powered and the port was propelled by oars. This original installation complied with the SOLAS requirements at the time of build. In accordance with the 1983 SOLAS amendments and *Cemfjord*'s man-overboard recovery procedure **(Annex N)**, the starboard lifeboat was the vessel's designated rescue boat. In addition, *Cemfjord* was also fitted with two deck-mounted 12-man liferafts.

Image courtesy of Marine Traffic

Figure 50: *Cemfjord* - original open lifeboat installation

1.15.3 The circumstances leading to the removal of *Cemfjord*'s lifeboats

On 15 December 2013 and just prior to sailing, *Cemfjord* was subject to a PSC inspection after the Liverpool Pilot Station had reported to the MCA that significant, repeated difficulties, had been experienced communicating with the vessel by VHF radio.

The MCA PSC inspector required *Cemfjord*'s crew to lower the starboard lifeboat into the water. During the lowering of the lifeboat, the davit's hydraulic control unit failed, resulting in a spill of hydraulic oil on the deck and the lifeboat left hanging over the water without control. The crew were unable to repair the unit and Brise Bereederungs arranged for a specialist davit contractor to attend the vessel and assess the situation. The vessel's technical superintendent also arrived from Germany to supervise repairs and rectification of other deficiencies identified in the PSC report.

The davit could not be repaired immediately so Brise Bereederungs applied to the Flag State for an exemption from the SOLAS regulation in order to release the vessel from detention. The Flag State agreed and issued a written exemption stating that the vessel could sail without a functioning starboard lifeboat provided that the port lifeboat was fully functional and that an additional liferaft was provided on the starboard side. The exemption was also time limited to 1 month. After a further 3 days in Runcorn with the crew, contractor and technical superintendent attending to the PSC deficiencies, *Cemfjord* sailed on 18 December 2013 to return to Rordal.

Following the vessel's release, the Flag State instructed Brise Bereederungs to submit an investigation report into the circumstances that led to the detention. The master's report, submitted to Brise Bereederungs as part of its investigation, concluded that the failure of the starboard lifeboat davit was the result of a lack of regular drills and maintenance. In his report the master stated his opinion that:

> *there are two parts of that: insufficient numbers of drills with use of davit and the policy "running of the equipment" till it's broken.*

The defect on the starboard davit hydraulics was finally reported as rectified on 8 March 2014 and the Flag State exemption had been extended to cover this period.

During 2014, the vessel experienced further significant difficulties with its lifeboats and associated equipment. From 23 September until 30 October 2014, the winch brake on the port lifeboat davit was defective, preventing launch, and from 29 October until 15 November 2014 the starboard lifeboat's engine was defective. Both these defects required further Flag State exemptions from SOLAS to allow the vessel to remain in service without fully functioning lifeboats.

As a result of the ongoing problems being experienced with *Cemfjord*'s lifeboats and davits, Brise Bereederungs started to consider options for their removal and replacement. On 20 October 2014, Brise Bereederungs sent an email to the Flag State stating:

> *We would like to replace the lifeboat at portside during vessel's next docking in November against a liferaft incl. hook and davit, because condition of portside lifeboat is decreasing also due to age of equipment. Please advise, if from flag state side there are any objections to the exchange of LSA.*

On 22 October 2014, a representative from DMS Cyprus replied by email stating that the proposed alterations were not in line with the SOLAS 1974 requirement, and therefore were not acceptable to the Administration. The following day, Brise Bereederungs emailed DNV-GL explaining its desire to replace the port lifeboat with a liferaft and davit, and asked if this would be in compliance with SOLAS regulations. DNV-GL's reply stated that the Cyprus equivalence arrangement could not be applied because *Cemfjord*'s gross tonnage was 1850 and therefore exceeded the 1600gt limit. However, once Brise Bereederungs had pointed out that the arrangements also applied to ships less than 85m in length, DNV-GL agreed that the equivalence arrangement could be applied.

On 5 November 2014, Brise Bereederungs sought further clarification from DNV-GL and explained that its intention had changed, and it wanted to remove both lifeboats, stating:

> *We need to consider possibility of installation of new davit and new rescue boat on this vessel and remove the present arrangements (2 lifeboats and davits each side). Please kindly advice if the following arrangements for this vessel will be acceptable by the class and the flag:*
>
> 1. *New rescue boat that can accommodate whole crew and new davit.*
>
> 2. *liferaft that can accommodate 150% persons on board on each ship side.*

DNV-GL replied stating that the proposal was:

> *from a technical and classification point of view acceptable as long as the current SOLAS requirements are complied with…*

Brise Bereederungs then placed an order for a Harding NOREQ NPDS 1300 H davit and a Harding rigid rescue boat in preparation for *Cemfjord*'s refit.

1.15.4 Removal of the lifeboats and the installation of the rescue boat davit

Cemfjord's refit period began on 26 November 2014 in Gdynia, Poland and ended 14 December 2014. During this period the port and starboard lifeboats and their davits were removed and the new Harding rescue boat davit was installed **(Figure 51)**. In addition, a significant programme of work was undertaken, including an overhaul of the main engine and the replacement of the upper deck crane.

Although Brise Bereederungs had ordered the davit and a compatible rescue boat at the same time and from the same manufacturer, Harding could not supply the rescue boat until January 2015. Recognising that this situation had the potential to prevent *Cemfjord* from sailing from Gdynia as planned, Brise Bereederungs (on 28 November 2014) contacted the Cyprus Administration's consul in Hamburg to request an exemption from SOLAS to allow *Cemfjord* to leave the port with only a lifeboat fitted to its port side. Brise Bereederungs' email stated:

> *'We finally decided to install a complete new boat incl. new davit installation on stbd side, because unfortunately the motor is not repairable anymore. Unfortunately, suppliers just informed us that the boat is still under production and will be delivered in week 2 in 2015. Due to these circumstances we kindly ask you to extend the exemption for my Cemfjord until 12.01.2014* [sic]*. Vessel's lifeboat on ps*[17] *is still in good and full workable condition.'*

[17] 'ps' understood to mean port side

On the same day, the Hamburg Office of the Cyprus Administration issued an exemption from SOLAS regulations, addressed to DNV-GL Hamburg, permitting the vessel to sail until 12 January 2015 pending the installation of a '*new davit and lifeboat on the starboard side'*. The exemption included the following two conditions:

1. *The port side lifeboat is in good working condition and the 2 x 12 persons liferafts are in good condition*
2. *There will be an addition of a liferaft of minimum 6 persons at the starboard side.*

Notwithstanding its request for a SOLAS exemption, Brise Bereederungs arranged for a temporary rescue boat to be supplied to the vessel for use in the interim period before the proper rescue boat arrived.

When the temporary rescue boat arrived in Poland, it was load tested on the quayside in the presence of the DNV-GL surveyor with seven persons embarked **(Figure 52)**. When it was put in the davit it became apparent that it was not compatible as the rescue boat slings were too long. This prevented the crew from launching and recovering the boat using the hydraulic pivoting davit as designed.

1.16 SAFETY CONSTRUCTION AND SAFETY EQUIPMENT SURVEYS

On 12 December 2014[18], *Cemfjord* was inspected by a DNV-GL surveyor in order to complete the pre-sailing safety surveys and certification. During this survey, the DNV-GL surveyor rejected the temporary rescue boat arrangements due to its incompatibility with the newly installed Harding davit. He also identified that the vessel's bilge pumping system was defective and was unable to pump water from the void spaces beneath both the forward and after cargo holds. Unresolved, these deficiencies would prevent the issue of the vessel's safety construction and safety equipment certification and therefore prevent *Cemfjord* sailing.

In response, Brise Bereederungs contacted the DMS consul in Hamburg, seeking Flag State exemptions for both SOLAS related shortcomings, in order to allow the vessel to sail on schedule. On the same day, the DMS consul issued a further exemption letter **(Annex O)** addressed to DNV-GL that agreed to the vessel sailing *'pending the installation of a new davit and lifeboat'*. This exemption was valid until 12 January 2015 and required the provision of an additional liferaft.

The following day, 13 December 2014, the DMS consul in Hamburg issued another exemption letter **(Annex P)** stating that *Cemfjord* could sail '*pending the repair of her bilge suction system*'. This exemption was valid until 28 January 2015 and required the provision of two portable, submersible pumps and restricted the vessel to remain within 150 miles of a safe haven.

Having received the Flag State SOLAS exemption letters, DNV-GL issued the following safety certificates:

- Interim Cargo Ship Safety Equipment Certificate **(Annex Q)** valid until 12 January 2015, certifying that the vessel's life-saving, navigation and fire-fighting equipment complied with the relevant sections of SOLAS. It stated that an exemption certificate had not been issued but included the comment:

  Rescue boat to be placed on board. Initial test to be carried out in presence of DNV-GL.

[18] 12 December 2014 was a Friday

Image courtesy of Brise Bereederungs

Figure 51: Replacement Harding davit (starboard side)

Image courtesy of Brise Bereederungs

Figure 52: Temporary rescue boat load test with seven persons embarked during refit period in Poland

The associated record of equipment **(Annex R)** stated that the total number of persons for which life-saving appliances were provided was 7[19].

- Interim Cargo Ship Safety Construction Certificate **(Annex S)**, valid until 12 January 2015, certifying that the vessel had been surveyed and its structure, machinery and equipment met the requirements of SOLAS Chapters II-1 and II-2. It also stated that an Exemption Certificate had not been issued, but recorded the following deficiency:

  The bilge pumping system in watertight compartments below Cargo Hold no:1 and 2 is to be repaired.

Cemfjord completed its refit and sailed from Gdynia as planned on 14 December 2014.

1.17 TECHNICAL AND SAFETY MANAGEMENT

The International Safety Management Code (ISM Code) places responsibilities for safety and environmental protection on vessel owners and operators as well as its crews. Section 1.2 of the ISM Code sets out safety management objectives and states that the company should:

- *provide for safe practices in ship operation and a safe working environment;*
- *assess all identified risks to its ships, personnel and the environment and establish appropriate safeguards; and*
- *continuously improve safety management skills of personnel ashore and aboard ships, including preparing for emergencies related both to safety and environmental protection.*

Section 10 of the ISM Code sets out the maintenance management requirements for ships and ships' equipment. It requires managers to establish procedures to ensure that vessels are maintained in conformity with the provisions of any relevant rules and regulations. In meeting these requirements, the company should ensure that:

- *inspections are held at appropriate intervals;*
- *any non-conformity*[20] *is reported, with its possible cause, if known;*
- *appropriate corrective action is taken; and*
- *records of these activities are maintained.*

---

[19] Although this certificate stated that the maximum number of persons for whom life-saving appliances was provided, there were, in fact, sufficient liferaft capacity and personal lifesaving appliances for eight crew (and there were eight crew on board at the time of the accident).

[20] A non-conformity means an observed situation where objective evidence indicates the non-fulfilment of a specified requirement of the ISM Code. A non-conformity should normally be closed out within 3 months of the date of the audit.

Technical management of Brise Bereederungs' vessels was overseen by the company's technical director, who led a team of managers providing support and advice to masters and chief engineers. The technical manager assigned to *Cemfjord* was Polish and had a good working knowledge of the vessel's equipment and procedures. He had also recently supervised the vessel's refit period in Poland. Safety and security management was delivered by Brise Bereederungs' designated person[21] (DP) who was also familiar with *Cemfjord*'s equipment and safety procedures.

Equipment maintenance in the Brise Bereederungs fleet was managed using its electronic *Mainstar* system. The *Mainstar* system contained a database of routine maintenance procedures for each item of equipment on each of Brise Bereederungs' vessels. Each maintenance procedure had a job description and was allocated a periodicity. Once the work had been completed, comments were entered onto the database and the job closed out. Records of the maintenance were held on board and in Brise Bereederungs' offices in Hamburg. The routine maintenance reports submitted by the crew were reviewed by Brise Bereederungs technical staff.

1.18 COMPANY DOCUMENT OF COMPLIANCE AUDITS

Lloyd's Register (LR) had been appointed on behalf of the Cyprus Registry to audit Brise Bereederungs' compliance with the International Safety Management Code (ISM Code). LR issued a Document of Compliance (DoC) stating that the company's safety management procedures complied with the ISM Code, which was valid until 22 October 2015.

During the annual ISM Code audit of Brise Bereederungs on 17 December 2013, LR raised four non-conformities that highlighted shortcomings in its management; specifically, the lack of effective procedures for routine maintenance and document control, as well as insufficient resources for the DP. This audit also commented on difficulties that Brise Bereederungs had been experiencing with its electronic maintenance management system. As a result, an additional DoC audit inspection was undertaken on 13 March 2014. At this audit, Brise Bereederungs provided evidence of corrective action that was intended to be taken and the audit concluded that significant improvements were underway and the maintenance management system non-conformities were closed.

At the next annual audit on 22 October 2014, four further ISM Code non-conformities were raised. Similar to the previous annual audit, these non-conformities highlighted issues with Brise Bereederungs' management of maintenance and the resources available for safety and technical managers ashore. The audit report concluded with an agreement between the LR auditor and Brise Bereederungs that future office audits would take place at more frequent intervals to verify that the necessary improvements were being made.

[21] Designated person - the person based ashore having direct access to the highest level of management and whose influence and responsibilities should significantly affect the development and implementation of a safety culture within the company, as required by the ISM Code

1.19 VESSEL AUDITS AND INSPECTIONS

1.19.1 Internal company audits

Cemfjord had been subject to annual internal company audits. An audit conducted on 22 February 2013 identified eight non-conformities and four observations relating to poor standards of safety management on board. The audit report included evidence that safety rules and masters' orders were being ignored on board and that risk assessments were incomplete. The annual internal audit conducted on 22 February 2014 raised one non-conformity regarding inadequate emergency preparedness. The evidence provided for this included a comment that two of the crew were unaware of the liferaft launching procedure.

The last internal audit conducted prior to the accident was carried out by the vessel's technical superintendent from 27 to 30 October 2014 during passage from Gdynia to Rordal. The audit report identified a number of issues on board, categorised as 'poor[22]'; including:

- The bilge system for the void spaces beneath the cement cargo holds was found to be defective. The audit report indicated that the emergency portable fire pump should be used in case of emergency and the system would be repaired in the forthcoming refit.

- The starboard lifeboat engine was found to be in poor condition and its starting device was defective. The report noted that spare parts were no longer available and stated that the vessel's managers were investigating the possibility of a new rescue boat or new diesel engine for the lifeboat.

The audit report's summary stated that the vessel was found in fair condition but this could be spoilt by stores being kept in unsuitable areas and the standards of crew accommodation suffering from age. The crew had commented to the auditor that the requirement to keep lookout watches on the bridge at night was '*lost'* time, which had a significant impact on the hours available to keep up with the high maintenance burden on board. Indeed, evidence was presented to the auditor that showed the constant disruption of short sea trade activity meant that International Labour Organization (ILO) regulations for hours of work and rest were being broken. This led to an agreement on board that crew hours of work and rest would be monitored closely for the following month with results reported to the company. The audit report finished with a comment from the auditor stating '*I see the crew very much motivated and responding to the problems immediately - master is the lead and the spirit of the ship-team'.*

1.19.2 External audits

Prior to LR[23] being tasked to conduct Brise Bereederungs' ISM Code audits, *Cemfjord*'s external audits had been undertaken by Bureau Veritas (BV). In addition to routine audits under this regime, the vessel was subject to two additional audits

[22] The company report assigned a score of Good, Fair or Poor for each aspect of the audit. 'Poor' was defined as '*below acceptable standard and requiring immediate attention*'.

[23] The inspection by LR instead of BV was a result of Brise Bereederungs' strategy to transition all office and vessel audits to LR.

imposed by the Flag State as a result of the high number of deficiencies identified by the PSC inspection in Poland on 14 January 2013 and the detention in the UK on 15 December 2013 (see 1.19.3 and 1.19.4).

The additional audit conducted by BV on 17 December 2013 included a non-conformity that highlighted a lack of procedures, guidance or instructions for passage planning. An observation was also raised suggesting that Brise Bereederungs *may wish to consider a more rigorous testing and inspection regime* of davits and associated equipment.

The last external audit prior to the accident was a Safety Management Certificate (SMC) renewal audit conducted by LR on 14 May 2014. The report from this audit concluded that the vessel's SMS complied with the ISM Code, no non-conformities were raised and a full term SMC was issued, valid until 15 May 2019.

1.19.3 Flag State inspections

DMS Cyprus employed a network of surveyors worldwide to conduct Flag State inspections of vessels on its registry. The surveyors were a mix of dedicated DMS employees and non-exclusive[24] surveyors. The non-exclusive surveyors had a degree of freedom to choose which vessels to inspect, and undertook two inspection types: either a full vessel inspection[25] or a documentation verification inspection.

DMS utilised the 'MARCOS' maritime control survey system, which was used to record all inspection reports, including deficiency reports per vessel and per surveyor. Analysis of this data by DMS Cyprus showed that non-exclusive surveyors tended to focus on document verification inspections of newer vessels. This led DMS Cyprus, in August 2014, to terminate document verification inspections and restrict Flag State inspections by non-exclusive surveyors to vessels that were either more than 10 years old or on its target list (based on previous low performance).

Between February 2006 and April 2013, *Cemfjord* was inspected in Gdynia, Poland 14 times by the same non-exclusive surveyor; seven were full inspections and seven were documentation verifications. None of these 14 inspections identified any deficiencies with the vessel and, according to his inspection reports, the surveyor never witnessed a lifeboat launch drill.

The same non-exclusive surveyor conducted a full inspection of the vessel on 20 February 2014; this inspection was the first such check on the vessel by a representative of the Flag State since the detention in the UK in December 2013. The report from this inspection noted that '*PSC report deficiencies dated 15-12-13 rectified'*. This statement was incorrect as the repair to the starboard lifeboat davit was not reported as complete until 8 March 2014.

[24] The non-exclusive surveyors were normally self-employed and contracted to inspect Cyprus flagged vessels; they were paid per inspection conducted.

[25] Full inspections were also referred to as entry inspections.

1.19.4 Port state control inspections

Between 2004 and 2015, *Cemfjord* was subject to 24 PSC inspections in accordance with the Paris Memorandum of Understanding, during which a total of 91 deficiencies were raised; of note:

- On 25 November 2004, a PSC inspection in Germany identified that the launch arrangements for survival craft had not been properly maintained.

- On 14 January 2013, a PSC inspection in Poland identified 23 deficiencies that included shortcomings with the vessel's charts, passage planning and lack of familiarity with GMDSS equipment.

- On 22 April 2013 a PSC inspection in Poland reported that the vessel's lifebuoys were not ready for use.

- In addition to the lifeboat davit issues [para 1.15.3] identified during the MCA PSC inspection in Runcorn on 15 December 2013, a total of 11 deficiencies were identified. These included the passage plan not being marked on the chart.

1.20 PREVIOUS OR SIMILAR INCIDENTS

1.20.1 *Cemfjord* - cement cargo shift

At 0700 on 7 October 2014, when fully loaded with cement and in the eastern approaches to the Pentland Firth, *Cemfjord* reversed course to abort further passage. The decision to abort was made because of unfavourable sea and tidal conditions in the Pentland Firth. During the alteration of course across the sea, *Cemfjord* heeled excessively and suffered a cement cargo shift, resulting in a significant list to port. The crew were mustered at their emergency stations and the master managed to bring the vessel back upright by flooding water into the starboard wing ballast tanks.

In his phone call to Brise Bereederungs explaining the incident at the time, the master said that he had to alter course to avoid the Firth as a further speed reduction would be ineffective and also risk loss of steerage. During the phone call, the master was advised that the vessel should remain heading slowly into sea until the weather improved. However, contrary to this advice, the master made a further substantial alteration of course across the sea and proceeded through the Pentland Firth. The coastguard was not alerted to the situation on board and the incident was not reported to the Flag State or the MAIB.

This significant cargo shift incident was investigated by Brise Bereederungs and a number of recommendations were made to masters of its cement carrying vessels. This included fresh advice on passage planning, weather avoidance, cargo management and stability. These recommendations were issued by Brise Bereederungs on 5 January 2015.

1.20.2 *Cemfjord* - groundings

On 12 June 2006, *Cemfjord* ran aground in the approaches to Goole docks, UK. The vessel was under pilotage and at mooring stations when it suffered a loss of main engine control that resulted in a heavy grounding and damage to the rudder stock. MAIB inspectors attended the accident and the investigation established that the accident happened after a failure of the engine control system.

The vessel suffered further groundings in Goole on 19 March 2009 and in the Skagerrak on 29 July 2014. After the Skagerrak grounding, the Russian master who was in command at the time was prosecuted by the Danish authorities for alcohol consumption offences while at sea.

1.20.3 *Flag Theofano*

On 29 January 1990, the Greece registered bulk cement carrier *Flag Theofano* was on passage from Le Havre, France, to Southampton, UK when it and its crew were lost in gale force winds and heavy seas. The vessel had been in contact with Southampton VTS during the afternoon and early evening and had stated an intention to anchor east of the Isle of Wight. The vessel's loss was not noticed until the following day when bodies and wreckage were washed up on a nearby beach. Although it was not possible to determine with certainty exactly why the vessel was lost, the MAIB investigation concluded that the most likely cause was that the cement cargo shifted in the poor weather resulting in a rapid capsize and sinking.

1.20.4 *Multitank Ascania* - MAIB Report 22/2000

On 19 March 1999, the Tuvalu registered chemical tanker *Multitank Ascania* suffered a machinery space fire during passage of the Pentland Firth. The crew reacted promptly by attacking the fire with fixed and portable fire-fighting systems. However, without power, the vessel started drifting towards the shore, but was eventually towed to safety and the crew airlifted off.

The coastguard was initially unaware of the presence of the tanker in the Pentland Firth as no report of entering the voluntary reporting scheme had been made. The MAIB report of the investigation made a recommendation to the MCA to *'consider making compulsory the voluntary reporting scheme for vessels transiting the Pentland Firth, particularly with respect to vessels carrying hazardous cargoes'.*

This recommendation was considered by the MCA in its risk assessment of shipping in the Pentland Firth [paragraph 1.9.2]. This assessment, published in 2001, also identified the potential for improved participation in the reporting scheme if it were to become compulsory. However, participation in the Pentland Firth reporting scheme remained voluntary.

1.20.5 *Karin Schepers* - MAIB Report 10/2012

At 0535 on 3 August 2011, the Antigua and Barbuda registered container vessel *Karin Schepers* grounded in Cornwall, UK after the master, who was the only person on the bridge, fell asleep. Prior to the grounding, the vessel had crossed the Land's End traffic separation scheme and, 2 miles offshore, the coastguard attempted unsuccessfully to alert the vessel to danger. No-one was injured and the vessel refloated successfully on the next high tide.

The MAIB investigation identified that, had the coastguard been monitoring AIS tracks, it would have been possible to identify the risk of grounding at an earlier stage. As a result, a recommendation (2012/115) was made to the MCA to:

> *Assess the desirability of, and, where appropriate, develop operational guidelines for using Automatic Identification System (AIS) data to monitor marine traffic movements. Special consideration should be given to using AIS data to monitor marine traffic movements in areas of high traffic concentrations, including traffic separation schemes, where there is limited or no radar coverage.*

The MCA accepted the recommendation and reported that it intended to take appropriate action by 31 December 2015. However, the MAIB recommendation remains open at the time of publication of this report.

1.20.6 *Danio* - MAIB Report 8/2014

On 16 March 2013, the Antigua and Barbuda registered cargo vessel, *Danio*, ran aground in the Farne Islands, UK after the chief officer, who was the officer of the watch and alone at night on the bridge, fell asleep. Fatigue was identified as a significant factor as the chief officer and the master worked a 6 hours on / 6 hours off watchkeeping regime at sea and were the only two deck officers on board. The investigation identified that this arrangement was typical of many near coastal vessels trading in European waters.

In response to an MAIB recommendation made in its 2004 Bridge Watchkeeping Study, the UK attempted to secure an international mandate for a minimum of three bridge watchkeepers on commercially operated cargo vessels. However, this initiative did not succeed due to lack of support from international partners. Consequently, a recommendation (2014/110) in the report into the *Danio* grounding was made to the MCA to work closely with European partners to propose to the IMO that a minimum of two navigational watchkeepers were required, in addition to the master, on vessels engaged in short sea trade passages.

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 OVERVIEW

The investigation into the circumstances of this accident focused on four key areas:

- Where and when *Cemfjord* capsized.
- How and why it capsized.
- Why a distress alert was not transmitted and the alarm was not raised until 25 hours after its AIS transmissions ceased; and
- Whether the crew had an opportunity to abandon ship.

In addition to explaining the factors that almost certainly contributed to the loss of *Cemfjord* and its crew, the underlying causes that allowed these circumstances to develop will also be discussed in this section.

As there were no survivors from the accident and no other primary sources of evidence, such as a distress report or eye witness account, it has not been possible to determine with absolute certainty the exact circumstances that led to the loss of *Cemfjord*. However, analysis of the electronic data, documentary evidence and footage from the external examination of the wreck, allowed the investigation to establish, with a high degree of probability, the accident's causes. Furthermore, the retrospective evidence gathered relating to the oversight and management of the vessel and its operations, its material condition and the normal working practices of its master and crew, allowed the investigation to identify the likely underlying contributory factors.

2.3 THE CAPSIZE

In order to determine what caused the accident, it was first necessary to establish when and where the capsize occurred. *Cemfjord*'s upturned hull was discovered in the North Sea by the crew of *Hrossey* in position 58°39.9'N - 002°33.1'W, initially sighted at 1416 on 3 January 2015. However, *Cemfjord*'s AIS ceased transmitting and the Orkney VTS radar target was lost abruptly 19 miles west in the Pentland Firth, Outer Sound; position 58° 43.2'N - 003° 09.0'W at 1316 on 2 January 2015. There were no communications between ship and shore during that 25-hour period.

Cemfjord's AIS signal and radar contact were lost 4 hours 25 minutes after HW Dover when the Merry Men of Mey tidal race would have been at maximum strength. This alone would make the Firth extremely hazardous for small vessels. But the magnitude of the tidal races in the Firth would have been severely exacerbated by the opposing gale force winds creating extremely violent and confused seas with large breaking waves. The waters subjected to these treacherous conditions would have reached right across the Firth from south to north including, from east to west, the Outer Sound and Merry Men of Mey areas **(Figure 35)**. The Orkney VTS radar imagery showed extreme wave conditions reaching across the Firth in *Cemfjord*'s path at the time of the loss **(Figure 46)**. Furthermore, the position where *Cemfjord*'s radar and AIS contacts were lost was, critically, in the Outer Sound, west of the islands of Swona and Stroma where the Admiralty Sailing Directions specifically offer an unambiguous caution for westbound vessels, stating that, in the conditions that would have been present at that time, *passage through the firth should not be attempted*. It is also an area of peak wave heights, as shown by the EMEC analysis **(Figure 53)**.

Given these extremely hazardous seas, it is concluded that *Cemfjord* succumbed to the conditions and capsized at 1316 on 2 January 2015 in the Pentland Firth, Outer Sound. Furthermore, the abrupt nature of the loss of the Orkney VTS radar contact on *Cemfjord* and the absence of any distress transmissions from the vessel, indicate that the capsize event itself was extremely rapid in nature. Post-capsize, the upturned hull's subsequent movement would have been determined by the tidal stream. This means that the upturned hull would have continued in a westerly direction until about 1600, then drifted back through the Firth in an easterly direction with the tidal stream from about 1700 until approximately 2200. The dominant easterly flow of the tidal streams would have led to the vessel drifting out of the Firth into the North Sea.

Image courtesy of European Marine Energy Centre

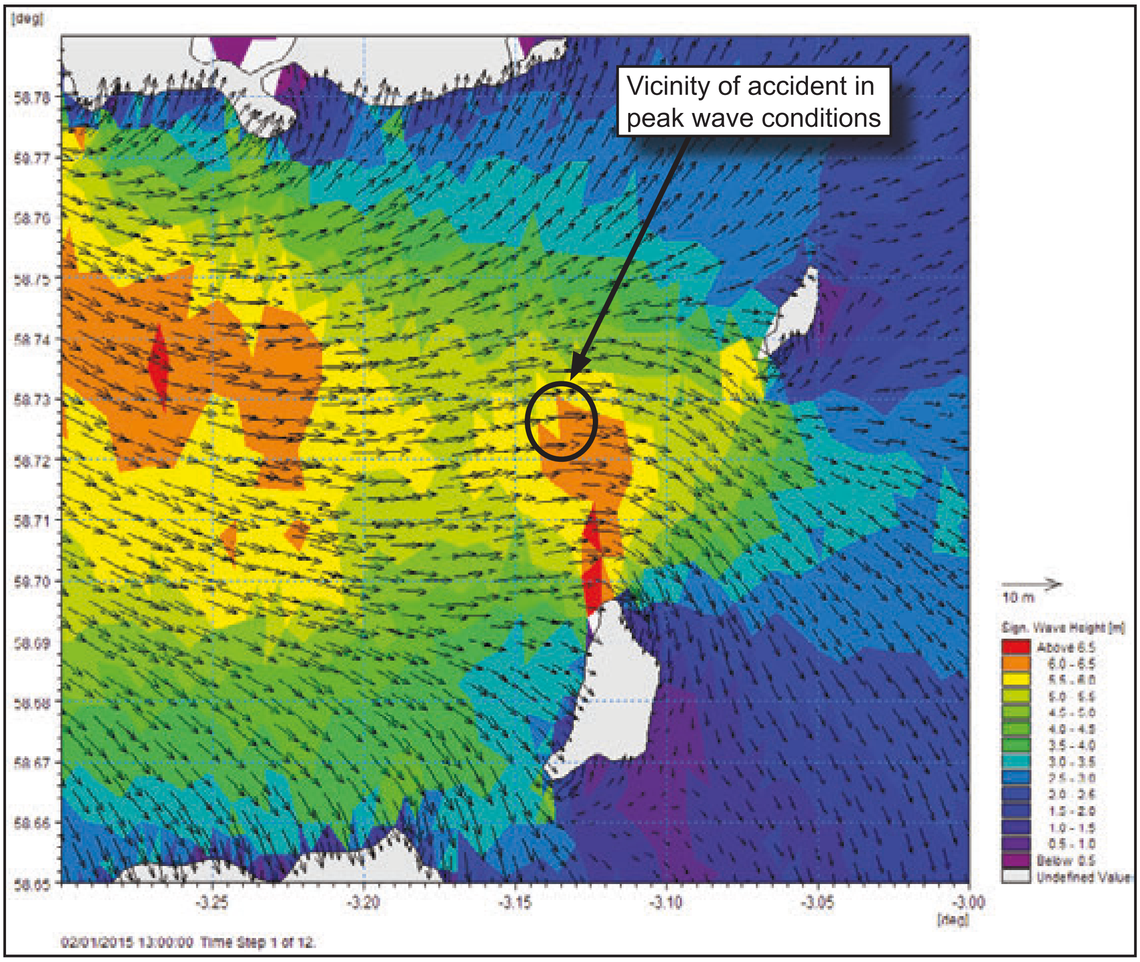


Figure 53: European Marine Energy Centre: significant wave height analysis for the Pentland Firth showing area of peak wave height in vicinity of the capsize

2.4 THE MECHANISM OF THE CAPSIZE

When *Cemfjord* entered the Pentland Firth, passing Brough Ness at 1235, its SOG was 10.6kts **(Figure 54)**. At this point, there was a following tidal stream of approximately 3.5kts, which meant that the vessel's speed through the water was about 7kts. The final SOG transmitted by *Cemfjord*'s AIS was 6.3kts at 1315, but by this time the vessel was experiencing a 6kts ebb current in a north-westerly direction. Thus, in the 40 minutes prior to the accident, *Cemfjord*'s speed through the water reduced from about 7kts to less than 1kt.

Cemfjord's reduction in speed through the water is assessed to have been an action taken by the master and/or chief officer to reduce the risk of excessive pitching or ploughing as the vessel continued west into severely deteriorating sea conditions. However, the reduction in speed to less than 1kt through the water in the confused sea conditions would have resulted in a loss of flow of water over the rudder and a consequent loss of steerage.

The combined effects of the ebb tidal stream setting the vessel to the north-west and the vessel's speed reductions also meant that alterations of course to port became necessary to maintain the intended navigational track over the ground **(Figure 54)**. Such course alterations to port will have put the prevailing sea at about 30° on the starboard bow, but this angle would have been increasing significantly as the vessel turned further to port.

Thus, the combined factors of reducing speed to avoid pitching and incrementally making small course alterations to port resulted in the situation where the vessel was without steerage and the violent seas were increasingly on the starboard beam. Once *Cemfjord* entered the breaking seas it would have taken a large amount of water on deck and quickly been forced beam onto the waves. As a result, it is highly likely that the capsize was to port.

The damage observed to *Cemfjord*'s foremast **(Figure 9)** a few hours before it sank, was consistent with the vessel experiencing heavy wave strikes over its bow and indicates the magnitude of the forces encountered just prior to its capsize.

2.5 OTHER POTENTIAL CAUSAL AND CONTRIBUTORY FACTORS

It is clear that the magnitude of the breaking sea alone was sufficient to cause the loss of a vessel of *Cemfjord*'s size; however, the investigation explored a variety of other potential causal and contributory factors. These included: loss of power, propulsion or steering control, and loss of intact stability due to flooding or a cargo shift.

Main engine or steering gear failures have been discounted as alternative explanations for the heading changes and speed reduction. This is because the engine had been recently overhauled and had not suffered any failures since, and the vessel reported to the coastguard that there were no defects prior to entering the Firth. In addition, it is highly likely that the crew would have immediately reported a main engine failure had this occurred in the Pentland Firth. Crew members had made phone calls home in the hour before the accident and no reports of machinery or equipment defects have emerged.

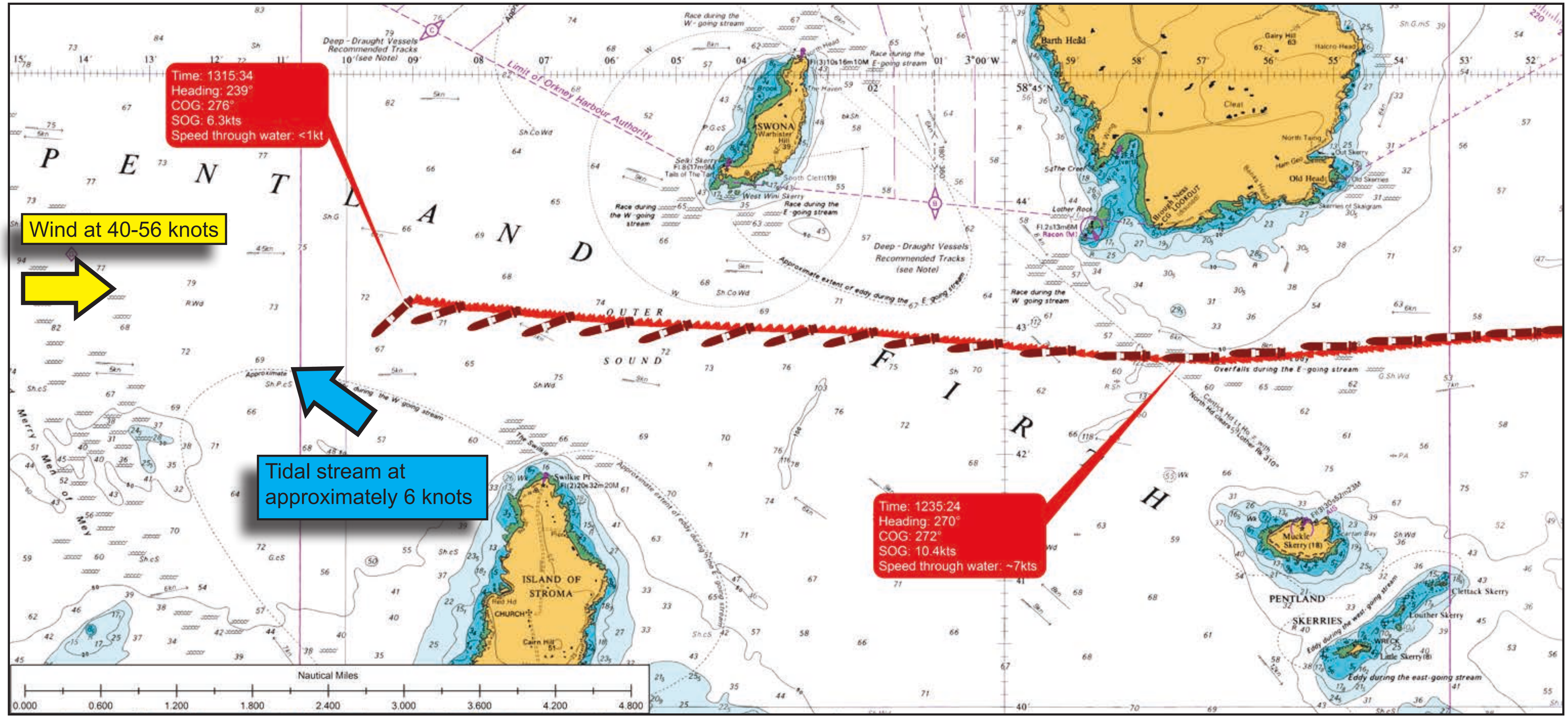


Figure 54: *Cemfjord*'s track based on AIS data up until the accident showing headings through the water (vessel shown 10 times actual size)

The multi-beam sonar survey **(Figure 23)** identified that the hull was intact and, therefore, did not break up or suffer a structural failure. It is also evident from the fact that the vessel floated for about 34 hours after the capsize, including when in violent sea conditions, that it retained sufficient buoyancy not to sink. This indicates that there was not a catastrophic flooding incident. The damage to the superstructure and the open inspection hatch to the forward hold area observed during the ROV survey were assessed to have occurred when the vessel hit the seabed.

There was insufficient information available to this investigation to conduct a detailed assessment of *Cemfjord*'s actual stability condition on departure from Rordal. However, if loaded exactly in accordance with its loading manual, *Cemfjord* would have met the minimum stability criteria prescribed in the IMO Stability Code for cargo vessels under 100m in length. Although based on significant assumptions, an independent assessment conducted for the company concluded that *Cemfjord*'s stability fell short of the IMO's minimum criteria when it departed Rordal and arrived at the Pentland Firth. In particular, this analysis indicated that the vessel's GZ values for given angles of heel had been reduced. This would mean that the vessel's ability to right itself in heavy seas would have been diminished. This reduction in stability would have exacerbated the accident in the Pentland Firth, but is not assessed to have been the initial cause of the capsize.

There is a well-documented, high risk of a cement cargo shifting when a vessel's angle of heel exceeds 30°. A cargo shift would cause the vessel's centre of gravity to move, leading to the ship listing. This had happened only 3 months earlier on board *Cemfjord* during a turn in the eastern approaches to the Pentland Firth. There is no evidence to indicate that the vessel suffered such an event prior to entering the Pentland Firth or reaching the breaking waves in the Outer Sound. The master's MAREP to Shetland coastguard made no mention of any difficulty with the cargo or the vessel's stability, and no problems were reported to the Brise Bereederungs Hamburg office. Furthermore, when sighted in the Pentland Firth by the bridge team on board the passenger ferry *Pentalina, Cemfjord* appeared to be upright.

It is without doubt that *Cemfjord*'s cargo shifted during its capsize. The extreme and violent seas acting on the vessel's starboard beam would have caused *Cemfjord* to heel heavily to the point where the cargo would have shifted. These events would almost certainly have developed instantaneously and would have contributed significantly to the rapid nature of the capsize.

2.6 PASSAGE PLANNING

2.6.1 Appraisal and planning stages

Irrespective of the nature of a vessel's operations, it is imperative that every voyage is properly planned taking into account the factors necessary to ensure that all hazards are identified and avoided, including aborting the plan if necessary. *Cemfjord*'s SMS required the chief officer to prepare the vessel's passage plans in accordance with the IMO's *Guidelines for Voyage Planning*. In order to do this, he was expected to gather all relevant information and develop a detailed berth to berth plan for the voyage between Rordal and Runcorn. It was the role of the master to provide guidance to the chief officer, to assess and approve his plans and to monitor the progress of the vessel during the implementation of the plan.

Cemfjord was equipped with the charts and publications, as well as external information sources, necessary to gather all the information required to prepare an effective passage plan. Furthermore, the master was experienced and had undertaken the passage between Rordal and Runcorn many times.

A critical planning factor on this route was the timing of the vessel's arrival at and entry into the Pentland Firth. The Admiralty Sailing Directions warn of the extraordinarily violent and confused seas that occur at times in the Firth and advises mariners to adjust arrival times so as to pass through under favourable tidal conditions.

The extent of the passage planning process conducted by the chief officer and master prior to departing the berth in Rordal is unknown. However, the initial planning would have been based on *Cemfjord* departing on time at 0800 on 30 December 2014 and achieving an average passage speed of about 9kts.

2.6.2 Execution and monitoring of the plan

Having already departed later than anticipated, *Cemfjord*'s progress across the North Sea was hampered by heavy sea conditions. As the vessel headed west into the deteriorating weather, its speed made good reduced, resulting in the master having to report delays to the anticipated arrival time at Runcorn.

Again, the extent of passage monitoring and forward planning conducted by the master and his chief officer during this stage of the voyage is unknown. When *Cemfjord* arrived at the eastern approaches to the Pentland Firth the master made his MAREP to the coastguard and proceeded straight into the Firth.

Once in the Firth, the master continued on his westerly passage in moderate visibility and a heavy swell through the Outer Sound, towards the Merry Men of Mey tidal race. *Cemfjord* approached the capsize position at the worst possible time with the maximum westerly current being opposed by westerly gale force winds. Had proper consideration been given to all the passage planning factors, in particular the tide and wind, then it would have been apparent that such a situation should have been avoided and an alternative plan executed.

2.6.3 Abort option planning

Guidance in the Admiralty Sailing Directions on when to transit the Pentland Firth is forthright and uncompromising especially regarding small coasters or low powered vessels. The violence of the tidal races is described as '*extraordinary*' and the Sailing Directions specifically advise that a westbound passage through the Outer Sound should not be attempted by small coasters when '*the W-going tidal stream is opposed by strong W or NW winds*.'

Identifying the pre-conditions for aborting a passage or taking an alternative route should form part of the navigational plan. A decision to abort or divert would be necessary where significant danger was apparent, typically untenable weather or sea conditions. Once *Cemfjord* departed Rordal the master had a number of options including diverting via the English Channel, slowing down, or seeking shelter.

2.6.4 Previous westbound passages through the Pentland Firth

During 2014, *Cemfjord* made eight westbound passages of the Pentland Firth. It is evident from analysis of the AIS data for these passages **(Annex T)** that they were timed to avoid dangerous tidal conditions in the Pentland Firth. This is illustrated at **Figure 55**, which shows the time, relative to HW Dover, that the vessel passed the accident location on these eight occasions, avoiding dangerous ebb and flood streams.

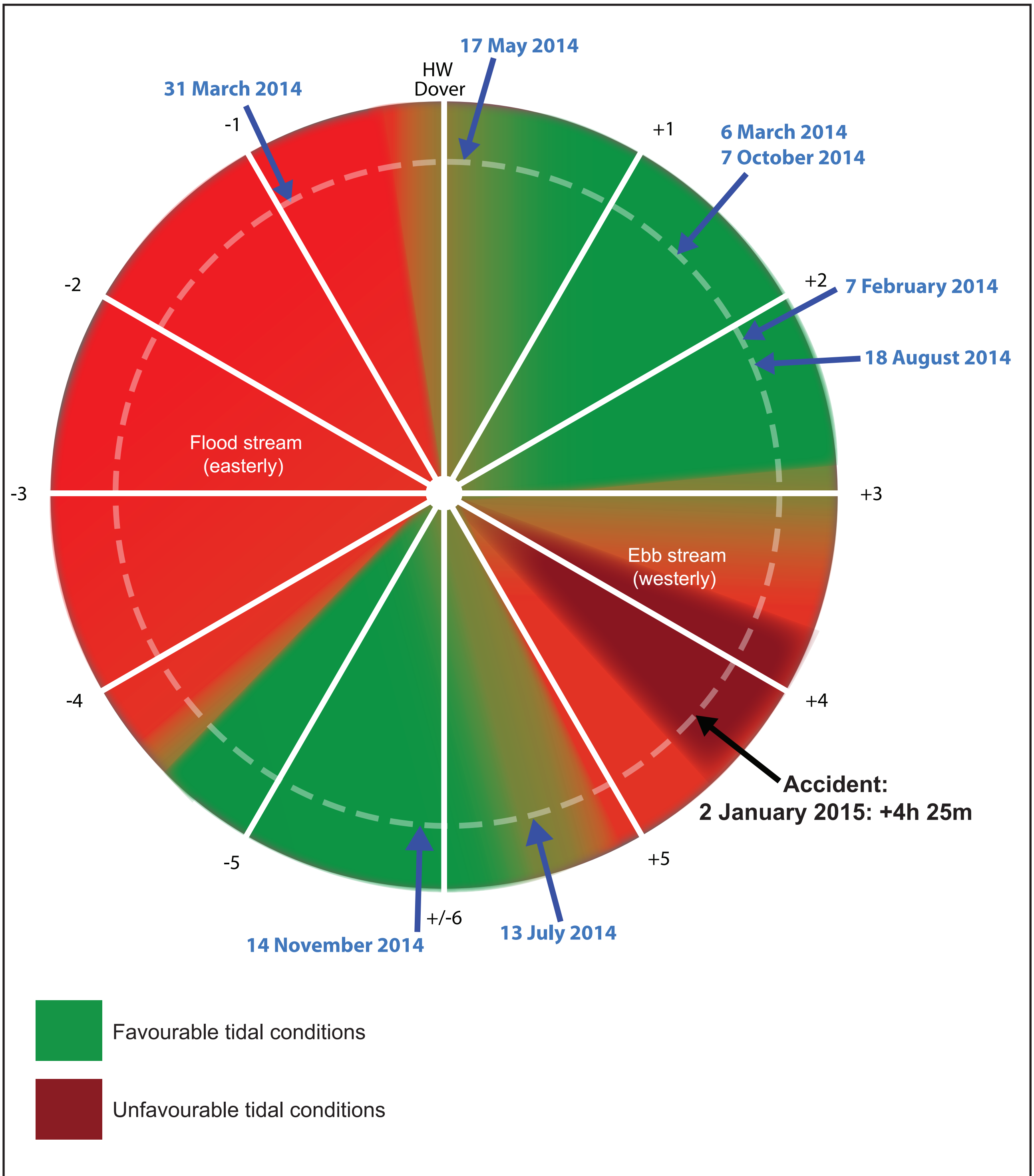


Figure 55: Clockface diagram showing the times of *Cemfjord*'s westbound passages through the Pentland Firth relative to HW Dover

On three occasions (6 March 2014, 17 May 2014 and 7 October 2014) *Cemfjord*'s bridge team[26] took positive action by making a significant course alteration to avoid entering the Firth during adverse tidal conditions. On one occasion when the vessel entered the Firth with an opposing flood tide (31 March 2014), the master held position by stemming the stream, and waited for it to ease.

It was also apparent from the historical AIS tracks that, irrespective of when the decision was made on board, any action taken to delay entry into the Firth occurred between 1 and 2[27] hours' passage time from its entrance **(Figure 56)**. This suggests that the master's planning strategy was to achieve the best overall speed across the North Sea, then deal with the Pentland Firth tidal issue in the hours before entering the area. What is clear from this analysis was that the tidal risks were understood by the master and actions were normally taken to abort or avoid the unfavourable tidal conditions. Therefore, the master's decision to proceed into the Firth on 2 January 2015, at the very worst possible time was inconsistent with his previous actions **(Figure 55)**.

2.7 THE DECISION TO ENTER THE PENTLAND FIRTH

The master's decision to enter the Pentland Firth and then attempt to negotiate its extraordinarily hazardous tidal races during the worst possible environmental conditions proved to be catastrophic for the ship and its crew. The master and chief officer might have miscalculated the vessel's arrival time at the Outer Sound tidal race or underestimated the magnitude of the hazard. Regardless, given the master's experience and his previous avoiding actions, factors other than competence are likely to have strongly influenced his decision-making process.

Early opportunities to avoid the poor weather being forecast for north-west Scotland would have been available as the vessel was crossing the North Sea. This could have included diverting south through the English Channel **(Figure 36)** or seeking shelter east of mainland Scotland. Although such a decision to divert via the English Channel had previously been made by another master on board *Cemisle*, there is no evidence that this was a course of action previously taken by *Cemfjord*'s master. This route is at least an extra day's passage and would incur other significant hazards, particularly the high volume of shipping. It is, therefore, unlikely that the master would have considered this option.

Cemfjord's charter required a passage speed of '*about 9 knots',* in good weather, which was only slightly less than the vessel's maximum speed. As *Cemfjord* headed west into the deteriorating weather, the speed made good reduced, resulting in the master having to report delays to the anticipated arrival time at the next port. The master was the driving force behind the ship and had a reputation as a hardworking, task focused and determined leader. Having already incurred a delay in departure from Rordal, these further delays to the passage time might have resulted in the master adding pressure on himself to press ahead and make up the lost time. In such circumstances the master is unlikely to have considered a speed reduction during the North Sea passage or an early decision to seek shelter east of mainland Scotland.

[26] Captain Chruscinski was in command on each of these three occasions.

[27] On the three occasions in 2014 that action was taken, it occurred between 7.5nm and 13nm from the entrance to the Firth.

Reproduced from Admiralty Chart BA 1942 by permission of the Controller of HMSO and the UK Hydrographic Office.

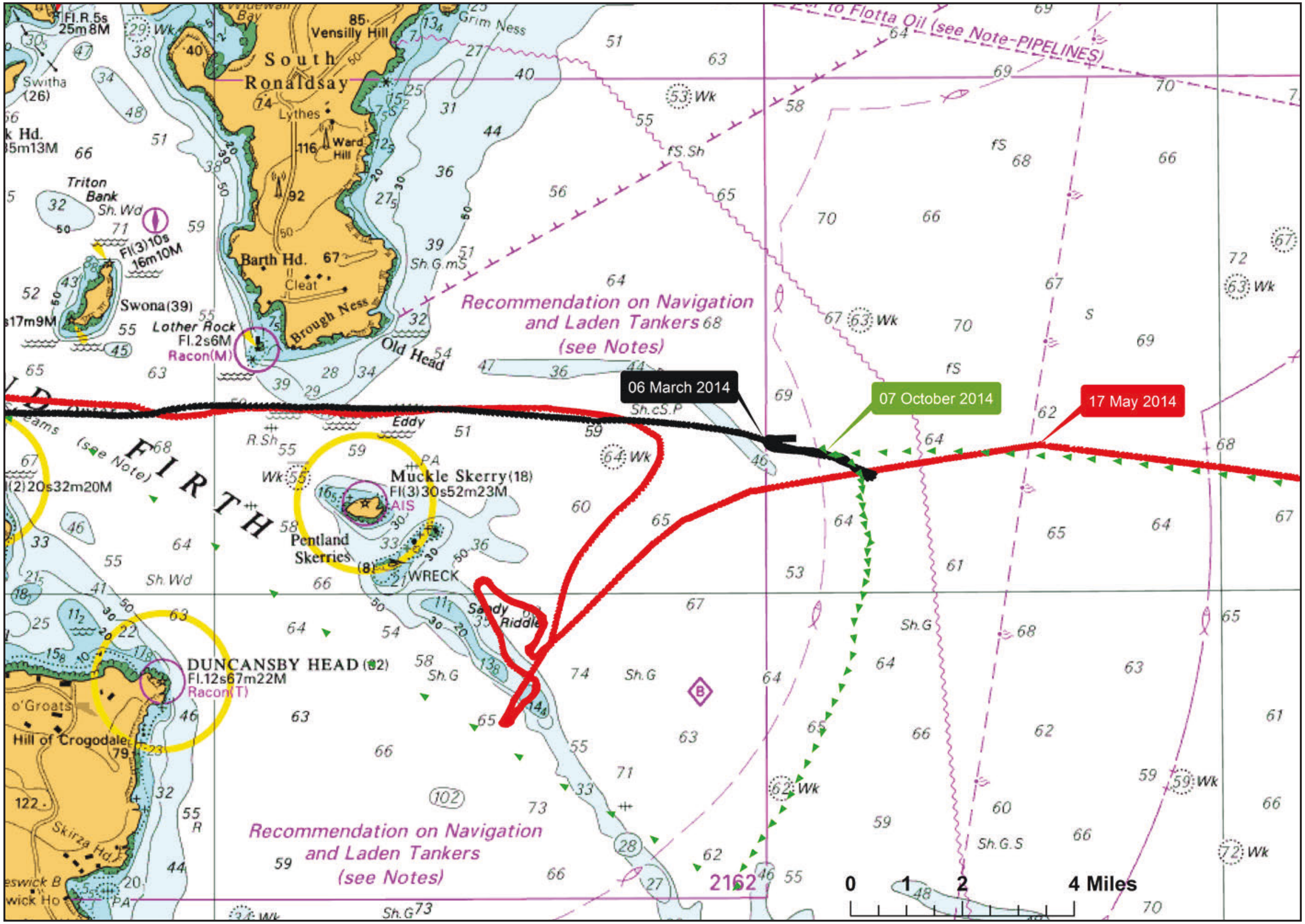


Figure 56: Chart showing where action was taken by *Cemfjord* to avoid the Pentland Firth on three occasions

When previously facing potentially untenable conditions ahead, the master took late avoiding action by reversing course or holding position to await more favourable conditions. However, on the most recent occasion, just under 3 months prior to the accident, the master had experienced a cargo shift as he altered course across a heavy sea. This event would have been a terrible experience for the master and his crew, and one he would not have wanted to repeat. The master's subsequent actions to correct the list by pumping in ballast water and, contrary to company advice, making a further alteration across the sea, illustrated his determination to press-on and complete each voyage. This recent previous experience was likely to have had a significant influence on the master's willingness to alter course across a heavy sea.

At the start of the master's 0600[28] to 1200 watch on the morning of 2 January 2015, *Cemfjord*'s SOG was less than 5kts. Had he or the chief officer used this average speed to project ahead, the predicted arrival time at the Pentland Firth, Outer Sound would have been approximately 1415 later that day **(Figure 57)**. If this calculation was made, it would have acted as a positive factor, reinforcing the decision to press ahead, because the time (1415) coincided with the tidal race subsiding and the afternoon tidal 'window' opening. However, as the vessel approached the Firth, the westerly tidal flow started to take significant effect, sweeping *Cemfjord* along; on passing Brough Ness, the SOG was about 11kts. This had the effect of bringing the vessel into the Outer Sound about an hour sooner than might have been predicted earlier in the day.

Having entered the Firth the last avoidance strategy, other than attempting to turn the vessel around and head into the westerly tidal stream, was to head towards Scapa Flow, seeking shelter in Long Hope **(Figure 35)**, a course of action advised by the Admiralty Sailing Directions. Like the English Channel diversion, there is no evidence to suggest the master had previously adopted this course of action, and it is unlikely that a navigational plan was prepared for such an eventuality. It is therefore highly unlikely that this option would have been considered.

The master's decision to press ahead into the Firth was also probably reinforced by his confidence in the vessel and the fact that the tidal stream was westerly. Although the master almost certainly understood the hazards associated with the Pentland Firth's tidal races, he might not have fully appreciated the severity of the conditions, particularly the severe compounding factor of the westerly gale.

It is clear that, given the weather forecasts and the prevailing tidal conditions, an early decision should have been made to divert south and seek shelter, ideally in the lee of Sinclair's Bay, and to wait for more favourable conditions.

The decision to proceed through the Pentland Firth was almost certainly the result of poor passage planning, inaccurate calculations, an under estimation of the environmental conditions, over-confidence in the vessel's handling characteristics and, critically, an unwillingness to alter course in heavy seas. Such a decision to press on with the voyage would have been influenced by the master's determination to succeed, actual or perceived commercial pressures and his recent experience of a near miss when the cement cargo shifted during a turn in heavy seas.

[28] 0600 local time on board and the start of the master's bridge watch was 0500 UTC.

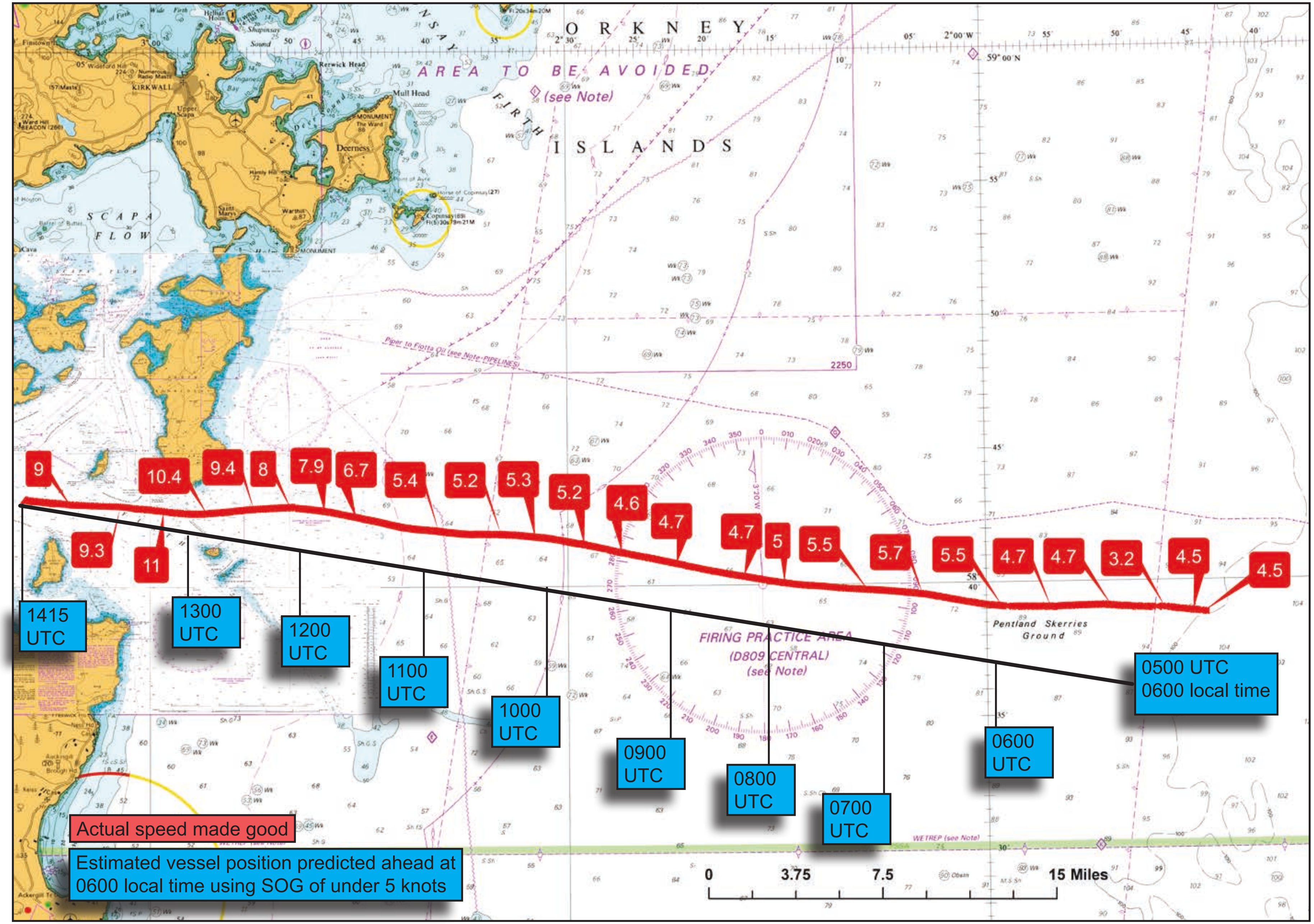


Figure 57: Chart showing speeds made good in the approach to the Pentland Firth (red) and estimated arrival time in the Firth using a speed of 5 knots (blue)

2.8 OTHER FACTORS AFFECTING THE MASTER'S DECISION-MAKING

A person's actions and decision-making can be seriously affected by tiredness and fatigue. Previous accident investigations have shown that a 6 hours on / 6 hours off watchkeeping routine in short coastal trading cargo vessels can generate high levels of fatigue, particularly when the sea watchkeeping is persistently disrupted by duties in harbour.

The cargo loading problems experienced in Rordal would almost certainly have increased the hours worked by all the crew and disrupted their normal working routines. In the 72-hour period prior to the accident the master and his chief officer would have worked to a 6 on / 6 off watchkeeping routine. The extent of any additional work undertaken by either watchkeeper outside this routine is unknown. However, the deteriorating sea conditions in the North Sea would have made the crew's hours of rest uncomfortable and adversely affected their quality of sleep. Taking these factors into account, it is almost inevitable that both the master and chief officer would have been feeling very tired when *Cemfjord* arrived at the approaches to the Pentland Firth. Thus, there was a significant risk of one or both of them suffering the effects of fatigue.

Six of the eight crewmen were serving on board *Cemfjord* on their first contract; only the master and one of the ABs had sailed on board for any significant period of time previously. The chief officer had joined on 11 October 2014 so would have experienced one previous westbound passage of the Pentland Firth on 14 November 2014. The chief officer also had no previous experience of cement carrying vessels. As a result, the collective experience of the crew lacked depth. This would have increased the master's operational burden and reduced the level of support available to him. It would also have made it more difficult for any of the crew, especially those on their first contracts, to challenge his decisions regarding the operational conduct of the vessel.

2.9 THE LOADING OPERATION

Cemfjord departed Rordal with 2084t of cement on board and 49t of fuel, but as no loading plan or records of *Cemfjord*'s stability condition were held ashore, it has not been possible to determine the exact distribution of the cargo or the status of the vessel's ballast tanks. In order to achieve the correct trim, *Cemfjord*'s aft cargo hold would have contained more cement than its forward hold and, as indicated on CCTV footage from the cement loading terminal, *Cemfjord* departed on an even keel.

According to *Cemfjord*'s loading procedures and the IMSBC Code, the vessel should have been kept upright throughout loading. Keeping a vessel upright is a critical factor in the safe loading of bulk cement carriers. This is to ensure that the settled cement is level in the holds on departure. However, as a result of the ballast pump problems experienced during loading, *Cemfjord* listed to port by about 5° before the terminal workers intervened and ceased the loading operation. This was despite *Cemfjord*'s loading plan **(Annex J)** stating that lists greater than 2° should be avoided. By this time, the crew had been loading cement into the aft hold, through its forward loading port, for over 3 hours.

Even though *Cemfjord* appeared to be upright on departure, the settled attitude of the cement in the holds is unknown. What is clear, however, is that the best practice given in the loading procedures and the IMSBC Code were not followed and this introduced a very high risk of the cargo settling unevenly. In this case, ballast water might have been used to compensate for the list.

Had the cargo settled unevenly in the holds, the risk of a cargo shift would have been significantly increased. In order to avoid this hazardous condition, the master and/or his chief officer should have ceased cargo operations as soon as it became apparent that there was a ballasting problem and the vessel could not be kept upright. Similarly, the shore terminal operators should have intervened and stopped the loading when its 2° limit had been reached. The situation on board regarding loading and de-ballasting could then have been properly assessed before loading more cargo.

2.10 CARGO BULK DENSITY AND ITS POTENTIAL EFFECT ON VESSEL STABILITY

When cargo is carried in bulk, its density value is critical in assessing a vessel's stability. For a given weight of bulk cement, the lower its density the greater the volume it will occupy in a vessel's cargo hold. Therefore, reducing the bulk density of a vessel's cargo will have the effect of raising its overall VCG for a given weight and, therefore, reduce stability. Equally, a higher cargo density value will lower the VCG and increase stability.

The data contained in *Cemfjord*'s loading manual was based on calculations conducted using a bulk density value of 1350kg/m³, which falls within the recognised spectrum for cement in the IMSBC Code **(Annex G)**. However, the manufacturer's stated bulk density value for the 'white' cement product that was loaded into *Cemfjord* was 1100 kg/m³. This means that, when fully loaded to its draught marks with the 'white' cement product, the vessel's VCG would have been higher than that stipulated in the loading manual, and the vessel would have had less stability, making it more vulnerable to capsize when in a heeling situation.

This effect can be illustrated by applying the manufacturer's bulk density figure of 1100kg/m³ to the limiting VCG curve for the loading manual's *Cement cargo settled +100% short voyage - departure* conditions. This calculation uses the same displacement value (3420t) but a modified VCG of 4.73m based on the lighter bulk density value that was applicable to *Cemfjord*'s cargo. When plotted next to the data from the loading manual **(Figure 58)**, it is apparent that this calculation has the effect of increasing the VCG value above the VCG limiting line. In other words, the loading manual short voyage departure condition would only meet the IMO stability criteria if the cargo density value was 1350kg/m³, or higher.

The even higher bulk cargo density values of 1560-1640kg/m³ that appeared to be used in the chief officers' unauthorised spreadsheet would have made matters even worse. The origin of these values is unknown, but they fall outside the parameters set out in the IMSBC Code and would have potentially offered an even greater distortion from the reality of the vessel's stability.

Thus, the bulk density value is critical in assessing the stability of a vessel with bulk cargoes embarked; incorrectly high values introduce a very high risk of a false impression of the vessel's stability. This is particularly relevant in the case of *Cemfjord*, where the vessel was typically loaded to its draught marks, and there is little evidence of further detailed pre-departure calculations on board. Such a situation is likely to have been exacerbated by the lack of detailed stability information, the absence of a stability computer as well as the repetitive nature of *Cemfjord*'s operations.

2.11 RAISING THE ALARM

2.11.1 Distress call or alert from the vessel

Cemfjord was equipped with two DSC capable VHF radios, an externally mounted float-free EPIRB, and an outfit of distress flares. All were understood to be in full working condition. Despite this, no distress alerts were received from the crew or the vessel's electronic distress signalling equipment.

The fastest method of the crew raising the alarm would have been to use the DSC alert function of one of the bridge VHF radios. This action would have required the operator to hold the DSC button depressed for approximately 5 seconds. The system would then have transmitted a distress message that would have included the vessel's identity and position. Equally, a voice "Mayday" message could have been transmitted. Had power been lost to the GMDSS equipment, the crew could have manually activated the vessel's SART or EPIRB. However, no such distress reporting was made. As it is highly likely that both the master and chief officer were on the bridge at the time of the accident, and both would have been familiar with the GMDSS equipment, the lack of a crew initiated distress call is strong supporting evidence of the rapid nature of *Cemfjord*'s capsize.

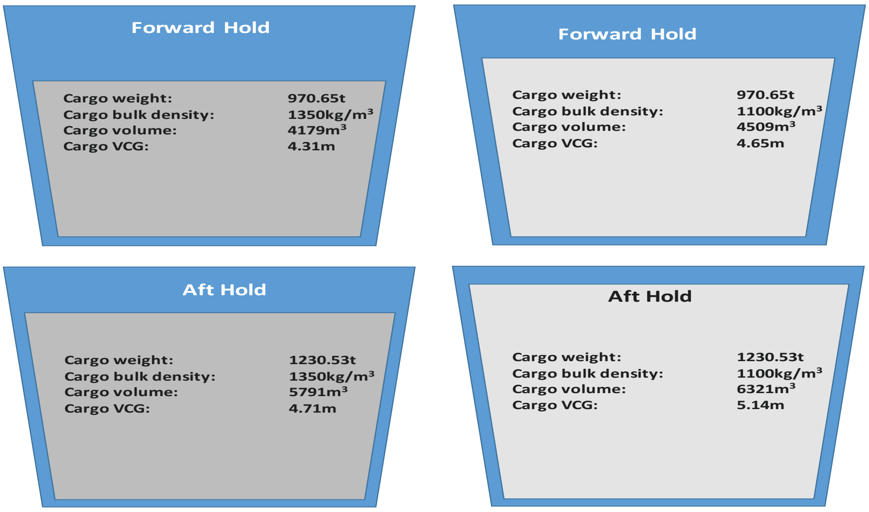
Having capsized, *Cemfjord*'s EPIRB, which was horizontally mounted on the port bridge wing **(Figure 16)**, should have been automatically released and activated. However, no transmissions were received from *Cemfjord*'s EPIRB. As the EPIRB and its float-free arrangements had recently been inspected and serviced, the likelihood of it not being released when its HRU was submerged and it failing to transmit when it reached the surface would have been very low.

The EPIRB manufacturer's instructions stated that, if mounted horizontally, it should be placed on an obstruction free, flat surface such as a cabin roof. Critically, it should be located away from any risk of entrapment by obstructions such as overhangs or rigging. *Cemfjord*'s EPIRB was mounted on top of the port bridge wing's aft bulwark below the level of the bridge roof overhang, which increased the risk of it becoming entrapped when the vessel was submerged.

The ROV survey was unable to observe this area of the wreck as the port bridge wing was distorted and largely buried in sand. Given the rapid nature of the capsize and the location the EPIRB mounting, there is a very high probability that the EPIRB was released, but rather than floating free to the surface it became trapped in the upturned bridge wing. The assessment that the vessel capsized to port, very significantly increased this risk of entrapment.

2.11.2 Loss of AIS transmissions

The master's MAREP report to Shetland Coastguard as *Cemfjord* approached the scheme was acknowledged by the coastguard. The conversation ended with the coastguard watch officer advising the master that, as *Cemfjord*'s AIS track could



	Weight (t)	VCG (m)	Vmom
Displacement- cargo 100% (density 1.35) short voyage	3420	4.48	15311
Cargo aft hold 1.35 density	1230.53	4.71	5791
Cargo fwd hold 1.35 density	970.65	4.31	4179
Cargo total 1.35 density	2201.18	4.53	9970
Short voyage displacement- less cargo	1218.82	**4.38**	5342
Cargo aft hold 1.1 density	1230.53	5.14	6321
Cargo fwd hold 1.1 density	970.65	4.65	4509
	2201.18	4.92	10830
Displacement- cargo 100% (density 1.1) short voyage	3420	**4.73**	16172
Cargo VCG rise		0.39	
Overall VCG rise		0.25	

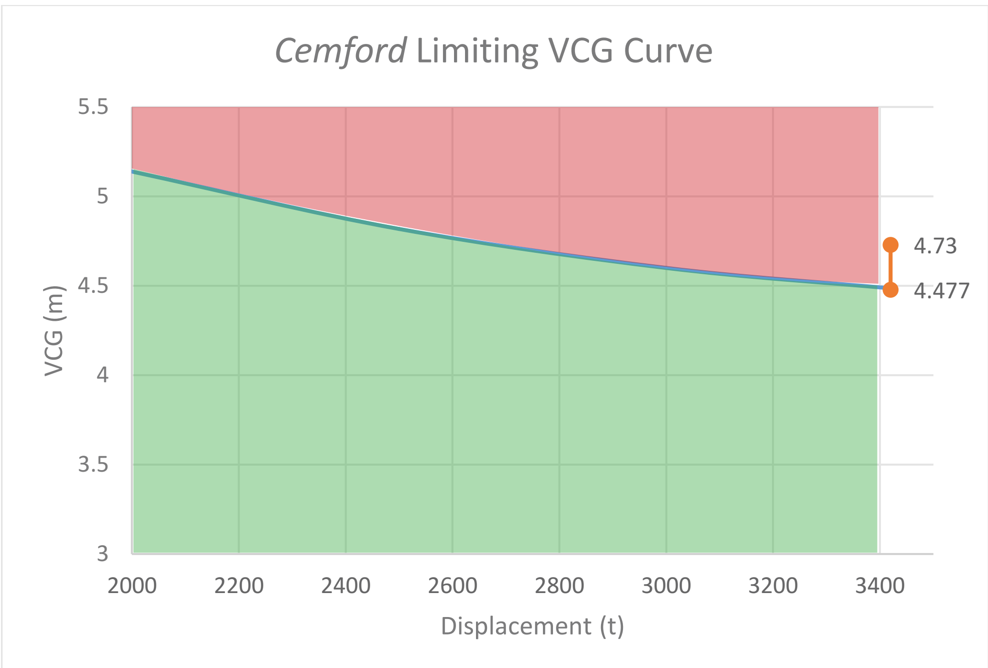


Figure 58: *Cemfjord*'s approved vertical centre of gravity limiting curve showing data points for 1350kg/m³ and 1100kg/m³

be monitored, there was no requirement for him to make an exit report on departing the scheme. Despite this comment, *Cemfjord*'s progress through the Firth was not monitored by the coastguard watchkeepers and the loss of the vessel's AIS transmissions was not noticed.

Whilst it was unhelpful that 50% of the computer display screens in Shetland Coastguard's operations room were not showing AIS tracks, the watchkeepers still had the capability to monitor *Cemfjord*'s passage. The vessel's AIS track was being received and there were three watchkeepers present. Indeed, at the time of the accident, *Cemfjord* was the only vessel on passage through the Pentland Firth, so monitoring the AIS track would have been a very straightforward task for the coastguard team. However, there was no requirement for them to monitor vessels' progress through the voluntary reporting scheme, and it was uncommon to do so.

Had the Shetland Coastguard watchkeepers been actively monitoring their AIS picture, then there is a very high probability that, when *Cemfjord*'s AIS transmissions ceased and the track vanished from the screen, this would have been observed. Equally, had the vessel been obliged to make an exit report from the voluntary reporting scheme, the absence of such a report would have been noticed. In the case of either the AIS transmissions ceasing or the absence of an expected exit report, it is likely that the coastguard watchkeepers would have investigated the matter further and identified that the vessel was missing, potentially leading to an earlier commencement of the SAR effort.

2.11.3 Loss of radar contact

Cemfjord's radar target was also being displayed on the Orkney VTS operators' computer screens. Similar to the coastguard, the vessel's progress was not being monitored and the loss of its radar contact was not observed. This was because *Cemfjord* was not in Orkney VTS's pilotage area, and there was no requirement for the vessel to make contact with the VTS operators, or for the VTS to acquire or monitor the vessel's radar target.

2.11.4 Absence of sightings by other vessels

Cemfjord's upturned hull was spotted and the alarm raised by the crew of the roll-on roll-off passenger ferry, *Hrossey,* 25 hours after it capsized. During this period, *Cemfjord* would have been floating, upturned, with a significant proportion of its hull visible above the surface; probably similar to when first sighted **(Figure 7)**. In this state, the upturned hull would have been a very significant hazard to other shipping.

Analysis of AIS records for the 25 hours between the capsize and *Hrossey*'s sighting has identified that 11 vessels passed through the area, none of which reported seeing the upturned hull.

It was fortuitous that the ferry's lookout spotted the upturned hull, and its bridge team should be commended for its vigilance and its subsequent actions. Given the position and the depth of water[29] where *Cemfjord* sank, had its hull not been spotted in the distance and investigated, *Cemfjord*'s wreck might never have been found.

[29] The charted depth where this occurred was 70m.

2.11.5 Reports to shore management

When underway, *Cemfjord* made daily reports to the charterer and company, normally at about 0800 and 1200 respectively. On the day following the capsize, the absence of the daily reports went unnoticed.

In the case of the charterer, Aalborg Portland, it had no direct responsibility for the vessel's safety and did not provide out-of-hours coverage. This is significant because the accident happened during the Christmas and New Year holiday period. Equally, whilst Brise Bereederungs operated an emergency response organisation, emails were not routinely monitored out of working hours, which meant that the absence of the 'noon' report on Saturday 3 January was not spotted.

Had the absence of either daily report been identified, at best the alarm might have been raised an hour or two earlier. If this had been the case, it would have made little or no difference to the search and rescue effort.

2.12 PURPOSE OF THE PENTLAND FIRTH VOLUNTARY REPORTING SCHEME

In its report into the fire on board the chemical tanker *Multitank Ascania*, which occurred in 1999, the MAIB made a recommendation to the MCA [paragraph 1.20.4] to "…*consider making compulsory the voluntary reporting scheme for vessels transiting the Pentland Firth,* …". The MCA took this recommendation into consideration in its 2001 risk assessment of shipping in the Firth, and identified that surveillance in Pentland Firth was a priority. However, the MCA concluded that the calls for mandatory reporting could not be supported due to the imminent phased introduction of shipboard AIS.

While the ALRS instructed vessels utilising the Pentland Firth voluntary reporting scheme to make reports using the MAREP format, the purpose of the scheme was not defined. Consequently, Shetland coastguard felt able, on the one hand, to dispense with the requirement for those vessels transmitting on AIS to make exit reports on leaving the reporting area while, on the other hand, deciding not to actively monitor the AIS transmissions of such vessels. The result was that *Cemfjord* was able to report on entering the scheme, and subsequently vanish until its upturned hull was spotted by a passing ferry 25 hours later. During this time the wreck posed a significant hazard to passing vessels and, had it been driven ashore or broken up, there could have been pollution. Importantly, because the coastguard had not identified that *Cemfjord* was no longer transmitting on AIS, it made no attempt to contact the vessel to establish its status or initiate any other action.

While the Pentland Firth reporting scheme is not an IMO mandatory reporting scheme it is, nevertheless, necessary that the purpose of the system is clearly defined. This would identify the hazards being mitigated, and would help inform decisions on whether or not to provide warning to vessels before they attempt to transit the Firth in hazardous conditions. Furthermore, as is clear from this accident, there is a compelling case for procedures to be put in place to monitor vessels transiting or operating in the Pentland Firth, and to note their safe departure from this hazardous area. Such action would ensure that the coastguard is able to respond promptly to emergencies while also providing it with up to date information on traffic levels, ship types and hazardous cargoes, enabling it to better prepare for emergency situations.

2.13 SHIP ABANDONMENT AND CREW SURVIVABILITY

The investigation attempted to establish if there was any indication that *Cemfjord*'s crew had attempted to escape from the vessel and launch its liferafts and/or the rescue boat. At the time of the capsize, the vessel should have been prepared for heavy weather with all watertight doors closed. It is most probable that all crew members would have been inside as working on the upper deck would not have been tenable in the prevailing weather conditions. *Cemfjord* was equipped with sufficient lifejackets and immersion suits for all the crew; these were stored externally. It would have required several minutes, with the vessel upright, for the crew to assemble, don their personal safety equipment and launch a liferaft and/or the rescue boat.

The ROV examination of the wreck searched for any evidence of crew escape. The watertight door into accommodation on the starboard weather deck was closed; the watertight door at the poop deck was open; and the starboard bridge wing's wooden door was missing. The watertight door on the poop deck was the means of access to a fan room and did not lead to the accommodation spaces. It is possible that the bridge wing door had been opened by the crew prior to or during the capsize event, particularly as that would have been the obvious route to the lifejackets. However, there was no clear evidence to support this. The wooden bridge wing door was more likely torn from its hinges by the underwater currents in the Outer Sound or on impact with the seabed.

The ROV survey identified that the two starboard liferafts and the temporary rescue boat were no longer in their cradles or davit. The tip-over liferaft cradle for the liferaft furthest away from the bridge wing door was in its housed position on deck but its section of guardrail had broken away. The rescue boat davit was in its housed position and its fall wire had not been lowered **(Figure 29)**. This indicates that no attempt had been made to use the rescue boat.

The rescue boat must have been torn from its davit by the turbulent currents of the Outer Sound tidal races after *Cemfjord* capsized. The inflatable section of the rescue boat that was found ashore must have torn from its rigid hull.

The only liferaft found from *Cemfjord* was discovered 70nm east of the capsize position. Its canopy was torn and its throw-recovery line was trailing in the sea. There was no evidence that the sea anchor had been streamed and the sealed 'SOLAS A' survival pack was missing. It would have required human intervention to remove the sea anchor from the survival canister and stream it, but the throw-recovery line, which was attached to the liferaft buoyancy tube, could easily have self-deployed.

There was no evidence to indicate that the crew had made any attempt to launch a liferaft or the rescue boat. Had the master ordered the crew to prepare for or carry out a vessel abandonment they would have initially assembled on the bridge. It is unknown if this had happened or if any of the crew managed to escape the vessel before or during the capsize. The rapid nature of the capsize and the fact that no bodies have been recovered is a strong indication that all the crew were trapped in the upturned hull. Had crew members entered the cold, turbulent water without lifejackets on, their survival time would have been measured in seconds or minutes, rather than hours. Had crew members entered the water wearing lifejackets, their survival time would still have been limited given the sea conditions and temperature, but the likelihood of their bodies being recovered would have been high.

The coastguard search and rescue effort was extensive once the alarm had been raised, but it would not have been feasible to take *Cemfjord* under tow or access its accommodation spaces before it sank. Had a distress alert been transmitted or the loss of the vessel's AIS transmission or radar target been observed and acted upon, the outcome for the crew and its vessel would almost certainly have been the same.

2.14 EMERGENCY PREPAREDNESS

In order to minimise the consequences of a marine accident, a vessel and its crew need to be prepared to deal with a variety of emergency situations. Vessels are prepared for this through design and the provision of LSA and other safety equipment. Vessel owners and operators prepare their crews by providing them with guidance and procedures, and through the delivery of training. To ensure that the emergency equipment remains in an operational state, the crew training has been effective, and the vessel's emergency procedures are fully understood, ships' crews are required to conduct realistic emergency response drills on a regular periodic basis.

Prior to *Cemfjord*'s detention in Runcorn on 15 December 2013 its LSA had not been properly maintained, its crew did not fully understand how to operate some of its key safety equipment and regular lifeboat drills had not been carried out. Furthermore, inadequacy of emergency preparedness was identified by the company in an internal audit in February 2014, when it was discovered that crew members were unaware of the vessel's liferaft launching procedures. The number of problems experienced with the lifeboats during 2014 might have been the result of the implementation of a regular drill regime following the lessons learnt from the PSC detention and internal audit.

Post-refit, *Cemfjord* returned to service with a functioning rescue boat that could not be launched or recovered because the lifting slings were too long. This meant that the crew had no means of recovering a person from the water, and could not practise the vessel's manoverboard procedure. Additionally, contrary to SOLAS requirements, without the rescue boat they could not marshal the liferafts and tow them clear of danger. In the persistently cruel conditions of the North Sea, and even with UK SAR helicopters and RNLI lifeboats close at hand, such a capability is vital for the safe operation of a ship.

SOLAS also requires that vessels should have abandon ship procedures and that the crew should be prepared for such an emergency by the conduct of frequent drills. Brise Bereederungs' SMS for *Cemfjord* contained only a generic abandon ship procedure **(Annex F)** as it was company policy that each vessel in the fleet should have its own procedure, unique to the crew and equipment fit on board. There was no evidence to indicate that the onboard abandon ship procedures were rewritten by the crew of *Cemfjord* following the changes made to the safety arrangements in Poland, but in any event the procedures could not have been practised as the rescue boat could not be launched. It is, therefore, unlikely that the crew were adequately equipped to deal with emergency situations, including abandonment, when *Cemfjord* sailed from Rordal on 30 December 2014.

Cemfjord also sailed with an adhoc means of pumping out the void spaces beneath the cement cargo holds. The ability to pump water from such a large internal space is also critical for the safe operation of the vessel at sea.

Given the evidence of safety equipment shortcomings, instead of sailing, a more appropriate course of action would have been to extend *Cemfjord*'s refit period in Poland, rectify the safety equipment defects and ensure that crew training for all emergencies was complete.

2.15 SAFETY EQUIPMENT MANAGEMENT

2.15.1 Miscommunication and misunderstandings

Prior to *Cemfjord*'s refit in Poland, the vessel was equipped with two davit-launched open lifeboats and three 12-man throw-over liferafts. As a result of the escalating problems experienced with the elderly and poorly maintained lifeboats, Brise Bereederungs started planning to replace both lifeboats with a rescue boat. According to its 1986 memorandum **(Annex L)**, the Flag State accepted liferafts and a rescue boat as an equivalent arrangement to lifeboats on cargo vessels of less than 85m in length. However, Brise Bereederungs' initial request to the Flag State for approval to modify *Cemfjord* in accordance with this equivalent arrangement was denied. Nevertheless, Brise Bereederungs pressed ahead with plans for the removal of *Cemfjord*'s lifeboats and installation of a rescue boat, in combination with the liferafts. The planned modifications to the vessel were approved by DNV-GL, applying the guidance held regarding the Flag State's requirement, but at no point in the transition did the Flag State (Cyprus or Hamburg offices) specifically approve the changes.

The Flag State's awareness of the situation was not helped by Brise Bereederungs' language in its correspondence. On 28 November 2014, when requesting a SOLAS exemption due to the delay in delivery of the new rescue boat, Brise Bereederungs stated in an email that it had decided to install a complete '*new boat*' on the starboard side and that the port side lifeboat was still in good working condition. This was misleading: by 28 November 2014 the decision had already been taken to remove both lifeboats. Indeed, *Cemfjord* was already in dock in Poland and modification work was underway.

When Brise Bereederungs was told that the DNV-GL surveyor had rejected the new rescue boat arrangements it contacted the Flag State consul in Hamburg to update the SOLAS exemption to account for this change of circumstance. Almost immediately, the Flag State updated the exemption, but this still referred to the vessel's lifeboats, rather than the inadequate rescue boat arrangements. The exemption letter from the Flag State **(Annex O)** reinforced the assessment that it never fully comprehended the state of the vessel's safety equipment. This happened because Brise Bereederungs' request was misleading and the Flag State did not subsequently scrutinise the request effectively. Equally, when the Flag State's exemption letter, still referring to '*lifeboats*', was received by DNV-GL and the company, this should have alerted them to the misunderstanding that existed, and prompted them to clarify the situation.

At the completion of the refit work in Poland, the principal understanding of the key agencies was:

- Brise Bereederungs understood that the changes had been approved by DNV-GL and that the Flag State had approved the vessel's return to operation without a functional rescue boat launching arrangement.
- DNV-GL had approved the changes from a technical point of view, and considered that they met the Flag State's written guidance regarding SOLAS equivalence arrangements.
- DMS Cyprus' consul in Hamburg had been informed by the company of some changes to the vessel but did not have a detailed understanding or any documentary evidence of approvals for changes.
- DMS Cyprus' head office in Limassol was unaware of the nature of the work that had been undertaken and believed that *Cemfjord* was still fitted with two lifeboats.

Thus, each of these key agencies had a different view of the situation on board. This happened because the management of information between each of these agencies was predominantly by phone call or email, and the information passed was potentially ambiguous and misleading or incomplete. As the authority approving the exemptions to safety shortcomings, DMS Cyprus did not thoroughly scrutinise all the information relating to safety of a vessel on its register. This lack of rigour allowed the misunderstandings to develop and not be clarified.

2.15.2 Use of Flag State exemptions and management of risk

When a Flag State issues an exemption from a safety regulation, it is effectively accepting a level of risk for the vessel's safety shortcomings. In doing so, it is vital that the Flag State's administrators assure themselves that the risk being adopted is fully understood. To achieve this, it is necessary for vessel operators' requests for SOLAS exemptions to be properly scrutinised, in particular an understanding should be developed regarding the specific regulation being exempted and the additional mitigation required.

Analysis of the exemptions issued by the Cyprus Flag State for *Cemfjord* in the 13 months prior to the accident **(Annex K)** showed that the vessel spent 54% of this time with exemptions from safety regulations and 40% of this related to lifeboat defects. Thus, it is evident that *Cemfjord* was often at sea with SOLAS related shortcomings and little consideration appears to have been given to preventing the vessel from trading until reported deficiences were resolved.

In order to ensure that a Flag State has a clear understanding of the level of risk it is endorsing when it issues regulatory exemptions, it needs to be in possession of adequate information. Key to this, the vessel operators should be asked to submit details of the regulations from which it wants to be exempt. Had DMS Cyprus been fully aware of the situation on board *Cemfjord* it might well have refused to allow the vessel to sail. The predictable manner in which the Flag State was willing to issue such exemptions effectively normalised the company's deviance from the well-founded SOLAS regulations.

2.15.3 Rescue boat capacity

Confusion over *Cemfjord*'s safety equipment was further compounded by the matter of the rescue boat's carrying capacity. An IMO LSA compliant rescue boat needs to be able to accommodate six persons. In its email to DNV-GL on 5 November 2014, Brise Bereederungs stated that it was intending to provide a rescue boat *capable of accommodating all persons on board*. This suggests that Brise Bereederungs' understanding at the time was that a rescue boat should be able to accommodate the whole crew, in this case eight persons. This is reinforced by the evidence of a load test in Poland **(Figure 52)** where there were seven persons on board a boat that was certified to carry only six.

2.16 MAINTENANCE MANAGEMENT

Brise Bereederungs used a computerised system to help manage planned and defect maintenance on board its vessels. Recent external DoC audits had highlighted maintenance management shortcomings and a lack of resources available to the company's DP. *Cemfjord* entered refit with long term LSA problems and a defective void space bilge pumping system, and finished the refit with SOLAS exemptions for both.

Cemfjord was an elderly and hard-working cement carrier conducting frequent passages across the North Sea, routinely in poor weather conditions. The charterer's schedule was unrelenting and the vessel's programme was managed to the nearest hour. In these circumstances, finding time to conduct routine maintenance would have provided a significant challenge for the master and his crew. This point had been identified by *Cemfjord*'s technical superintendent during his last audit, which he had conducted at sea between 27 and 30 October 2014. His report reflected the comments of the deck crew, who argued that they had been unable to meet their obligations to maintain a bridge lookout during the hours of darkness and keep on top of vessel maintenance. The master's own attempts to repair the starboard lifeboat davit during the 2013 PSC inspection in Runcorn, and his reaction to the defective ballast pump during loading in Rordal demonstrated his desire to find work-rounds and a commitment to meet *Cemfjord*'s operational schedule.

It was apparent that Brise Bereederungs had taken steps prior to the accident to improve its management of maintenance and also to ensure that the DP and the technical manager had the right resources available for safety management. However, the numerous deficiencies identified during PSC inspections indicates that *Cemfjord*'s general condition was often poor. These difficulties were summarised by the master in his comments in the post-detention report to Brise Bereederungs, where he indicated that the root cause of the problems were insufficient drills and the policy of running equipment until it failed. As a result, it is evident that Brise Bereederungs needs to invest significant resources to ensure the swift delivery of improvements in its, and its ships' crews', management of maintenance.

2.17 EFFECTIVENESS OF FLAG STATE INSPECTIONS

DMS Cyprus employed a global network of non-exclusive surveyors to provide additional assurance, through the conduct of regular full or document verification Flag State inspections, that Cyprus flagged vessels were being manned and operated safely. Under this regime, *Cemfjord* had been inspected by the same non-exclusive surveyor twice a year for the previous 7 years, during which time he had carried out seven full inspections and seven documentary verification inspections with no deficiencies ever having been noted.

Given the extent of deficiencies identified by PSC inspectors during the same period, it is not credible for the non-exclusive surveyor to have found no shortcomings during his visits to *Cemfjord*. As a result, the Flag State's inspections of *Cemfjord* did not provide the levels of assurance required.

Copies of the non-exclusive surveyor's inspection reports had been forwarded to DMS Cyprus and added to the vessel's Flag State file. However, there was not an effective mechanism in place within the administration to identify anomalies such as a significant difference of opinion between PSC and Flag State inspection reports. The repeated lack of observations, deficiencies and non-conformities in the non-exclusive surveyor's reports should have caused concern and triggered an intervention.

2.18 SAFETY CULTURE AND LESSONS LEARNT FROM PREVIOUS INCIDENTS

As discussed throughout this report, the master was hard working and was recognised as a driving force for *Cemfjord* and his crew. It was also apparent that the master had a task-based approach and was prepared to accept a high degree of risk to achieve his aims. This approach, coupled with high levels of commercial pressure, can adversely affect safety culture.

Safety culture defines the ways in which safety is managed on board vessels and is reflected in the shared attitudes, beliefs, perceptions and values of a company and its crews in relation to safety. Safety culture can be difficult to measure or quantify, however it can be summed up as *"the way we do things here"*. Owners and masters have the pivotal role of embedding and driving a strong safety culture among their crews. If they do not portray a positive approach towards safety management, then it is likely their crew will adopt similar attitudes, and a poor safety culture will result. Learning lessons from less serious marine incidents or near misses can significantly improve safety awareness and help promote safety culture.

The cargo shift incident on board *Cemfjord* on 7 October 2014 was a very significant event and the vessel was in serious danger until the situation was resolved. It is a requirement of the ISM Code that hazardous situations are properly investigated and appropriate corrective actions are taken. In its investigation of *Cemfjord*'s cargo shift, Brise Bereederungs identified significant lessons regarding passage planning, loading operations and vessel stability. Although company staff discussed the issue with the master at the time, these lessons were not promulgated by Brise Bereederungs to its ships' crews until 5 January 2015, after the *Cemfjord* accident. Had the lessons from the incident been more promptly established and promulgated, it might have had an impact on the circumstances leading up to the master's decision to enter the Firth.

2.19 INDUSTRY AND COMMERCIAL PRESSURES

The investigation into the circumstances of this accident identified that industry and commercial pressures at all levels in the management and oversight of the vessel, almost certainly had an impact on the vessel's operations. Of note:

- The charterer's planning schedule was challenging and allowed very limited flexibility for delays in loading, unloading or on passage. The 8-hour period allocated for loading cement and *Cemfjord*'s maximum speed of 9.5kts provided little time to deal with unexpected problems during loading and limited opportunity for the master to recover time during passage.

- Brise Bereederungs' willingness to repeatedly seek SOLAS exemptions and put *Cemfjord* to sea with significant safety shortcomings is an indication of the level of commercial pressure it was experiencing.

- The manner in which the Cyprus administration was willing to issue SOLAS exemptions, without a real understanding of the situation on board or the impact on crew safety, is also indicative of the level of global industry pressures applied to Flag States and ROs.

These factors would have inevitably had an effect on the master's decision-making and his willingness to accept higher levels of risk to achieve his goals.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT THAT HAVE BEEN ADDRESSED OR RESULTED IN RECOMMENDATIONS

1. It is concluded that *Cemfjord* capsized suddenly and rapidly at 1316 on 2 January 2015 when it encountered extraordinarily violent, breaking seas in the Pentland Firth, Outer Sound. The rapid nature of the capsize would have been exacerbated by a shift in the cement cargo as the vessel heeled beyond 30°. [2.3]

2. It is assessed that, in order to reduce the risk of heavy pitching while maintaining *Cemfjord*'s navigational course over the ground, the master made a succession of speed reductions and course alterations. These actions led to a loss of steerage and placed the sea increasingly on the starboard beam, leading to a probable capsize to port. [2.4]

3. The extraordinarily violent sea conditions were created by gale force winds opposing a strong ebb tidal stream. Such conditions were predictable and passage through the Pentland Firth should not have been attempted. [2.6.2]

4. The master's decision to enter the Pentland Firth and then attempt to negotiate its notoriously hazardous tidal races during the worst possible environmental conditions, rather than divert or seek shelter, proved to be catastrophic for the ship and its crew. His decision was almost certainly the result of poor passage planning, an under-estimation of the environmental factors and an unwillingness to turn across the sea. [2.7]

5. It is possible that the vessel arrived in the Pentland Firth, Outer Sound about an hour sooner than might have been calculated earlier in the day. If this was the case, it would have been a result of the vessel's unexpected increase in speed over the ground as it was swept into the Firth by the strong tidal stream. [2.7]

6. The master's decision-making process was probably influenced by his personal determination to succeed, actual or perceived commercial pressures and his recent experience of a cargo shift during an attempted turn across heavy seas in the eastern approaches to the Pentland Firth. [2.7]

7. The bridge team's decision-making on board was probably degraded through fatigue or tiredness. [2.8]

8. The rapid nature of the capsize prevented the crew from making a distress radio call. [2.11.1]

9. Assuming a rapid capsize to port, *Cemfjord*'s EPIRB was probably released from its housing but then became trapped in the upturned hull and, therefore, did not float free to the surface or transmit. [2.11.1]

10. Despite the master reporting his intent to enter the Pentland Firth, *Cemfjord*'s capsize went unnoticed ashore because its passage through the voluntary reporting scheme was not being monitored by the coastguard and there was no requirement for an exit report. [2.11.2]

11. The absence of a distress alert from the vessel combined with the accident not being observed ashore meant that the search for survivors did not start until 25 hours after the accident. In that period, the upturned hull presented a very significant hazard to other shipping. [2.11.4]

12. There was no evidence to indicate that the crew had attempted a controlled abandonment from the vessel. No bodies have been recovered, and it is most likely that the crew were trapped within *Cemfjord*'s upturned hull. [2.13]

13. Had any of the crew escaped from the vessel, their survivability in the ferocious sea conditions would have been measured in minutes and seconds, rather than hours. [2.13]

14. Even had the alarm been raised at the time of the capsize, the outcome for the vessel and its crew would almost certainly have been the same. [2.13]

3.2 SAFETY ISSUES NOT DIRECTLY CONTRIBUTING TO THE ACCIDENT THAT HAVE BEEN ADDRESSED OR RESULTED IN RECOMMENDATIONS

1. *Cemfjord* was allowed to develop a significant list during the loading operation. This introduced the possibility that the cement had settled unevenly in the hold and subsequently increased the risk of the cargo shifting in heavy seas. [2.9]

2. *Cemfjord* was loaded to its draught marks and the density of its bulk cargo was not properly considered. As a result it is likely that its stability did not meet the minimum criteria set by the IMO. Potential reductions in its righting levers, would have made *Cemfjord* more vulnerable to capsize when in a heeling situation. [2.10]

3. The purpose of the Pentland Firth voluntary reporting scheme was not well defined, exit reports were not required from vessels transmitting AIS, yet the coastguard had no means of identifying AIS transmission failures and was therefore ill-prepared to respond to emergency situations. [2.12]

4. It is likely that *Cemfjord* and its crew had not been adequately prepared to deal with emergency situations. [2.14]

5. *Cemfjord* was authorised to proceed to sea with significant safety deficiencies relating to its rescue boat launching arrangements and cargo hold bilge pumping system. [2.15]

6. The company, Flag State and RO did not share a common understanding of the situation on board regarding the replacement of the vessel's lifeboats by a rescue boat. This resulted in the Flag State's exemption from safety regulation regarding the rescue boat not being applicable to the equipment on board because the lines of communication between the three organisations was poor and the Flag State's process for managing safety regulation exemptions lacked rigour. [2.15]

7. In the 13 months prior to the accident, *Cemfjord* spent 54% of the time with shortcomings in safety related equipment; 40% of this time, the defects related to the vessel's lifeboats. This was made possible by the Flag State's willingness to repeatedly approve exemptions from the SOLAS regulations. [2.15.2]

8. Inspections of the vessel, conducted in Poland on behalf of the Flag State over many years, were inconsistent with Port State Control inspections in the same timeframe and did not provide the level of assurance required. This happened because the Flag State did not have an effective mechanism to identify weaknesses in its inspection regime. [2.17]

9. Lessons identified from Brise Bereederungs' investigation into the cement cargo shift incident on board *Cemfjord* on 7 October 2014 should have been promulgated to its cement carrying vessels more promptly. [2.18]

10. This investigation has highlighted that industrial and commercial pressures existed at all levels in the management and oversight of *Cemfjord.* [2.19]

SECTION 4 - ACTIONS TAKEN

Brise Bereederungs GmbH has:

- Conducted an investigation into the causes of the accident. The investigation was undertaken by an independent marine consultant and identified that inadequate passage planning, uncertainties regarding stability and poor decision-making were the root causes.

- Introduced a dedicated stability and draught survey computer program for use on board its cement carrying vessels. Titled 'Cemload', the system has technical approval from the classification society Bureau Veritas.

- Introduced a computer-based training (CBT) system for continuation training on board its vessels; this includes stability CBT that is mandatory for masters and chief officers.

- Introduced the 'Chartco' passage planning system for preparation of voyage plans in all its vessels.

- Established a system for the provision of dedicated meteorological services, including tailored weather advice.

- Installed voyage data recorders on all vessels including those under 3000gt.

- Introduced a cargo density sampling tool for use on all cement carrying vessels. Instructions have also been issued for cargo density measurements to be taken during loading and discharge operations.

- Produced documentary and video training material for crews of cement carrying vessels on cargo density measurement, cargo levelling and settling.

- Provided its safety staff with improved e-mail connectivity for ease of monitoring ship to shore communications, particularly out of working hours.

- Reviewed processes for safety dispensations, extensions and exemptions with all flag administrations and recognised organisations.

- Reviewed loading procedures for cement carriers including updated safety instructions to ensure compliance with stability criteria.

- Introduced additional watchkeeping officers on all vessels between October and April to reduce the risk of fatigue caused by 6-on, 6-off routines.

- Upgraded the 'Mainstar' planned maintenance software to include an incident reporting facility to be used to record accidents, inspections, employee suggestions and to monitor actions / due dates.

DNV-GL has:

- Appointed Flag State liaison officers, responsible for:
    - Maintaining relationships between DNV-GL and flag administrations
    - Delivering advice and support for Flag State agreements and subsequent amendments
    - Acting as a single point of contact for flag administrations
    - Requesting clarification from Flag States for specific cases
    - Keeping records of all communications with flag administrations.

The **Government of the Republic of Cyprus** has:

- Introduced a new process for its management of applications that it receives for exemptions from safety regulations. Under the revised process, vessel owners and managers are required to list the regulation(s) from which they are seeking to be exempt and explain any mitigation they intend to put in place to control the risk. All applications will be scrutinised by subject matter experts within the administration before being approved or denied.
- Reviewed its Flag State inspection regime and identified weaknesses in the way it monitored the performance of its non-exclusive surveyors and analysed their inspection reports. As a result, the administation has developed a revised Flag State inspection regime.

The **Maritime and Coastguard Agency** has:

- Conducted an internal investigation into the accident that concluded the matter was professionally handled by the coastguard team in Shetland Coastguard.

Shetland Coastguard has:

- Ceased the local practice of informing vessels in the voluntary reporting scheme that exit reports are not required to be submitted.

SECTION 5 - RECOMMENDATIONS

Brise Bereederungs GmbH is recommended to:

2016/113 Ensure that its masters and chief officers receive training in their vessels' newly installed stability and cargo management tools and are familiar with the company's revised cargo loading and passage planning procedures.

2016/114 Take robust measures to improve the safety culture on board its vessels and within the company as a whole. In particular, monitor the use and effectiveness of its upgraded accident reporting and information sharing software system.

The **Maritime and Coastguard Agency** is recommended to:

2016/115 Review the arrangements for the safety of shipping in the Pentland Firth, giving particular consideration to:

- Defining the purpose of the Pentland Firth voluntary reporting scheme. This should include the information to be provided by vessels in the area and the subsequent use of that information by the coastguard.
- The potential benefits of making the Pentland Firth voluntary reporting scheme compulsory.
- Identifying the level of surveillance and monitoring required of vessels operating in the Pentland Firth. In particular, establishing operational routines for the use of AIS information and operator procedures to monitor AIS tracks and respond to loss of AIS contact.
- Whether, given the frequent and extreme local sea conditions, advisory information should be broadcast to ships in addition to routine maritime safety information.

The **Cyprus Department of Merchant Shipping** is recommended to:

2016/116 Undertake a thorough review of its revised processes for the managment of regulatory exemptions and the conduct of Flag State inspections. In particular, assure itself that:

- Vessel owners and managers are providing the levels of information required to allow exemptions to be issued based on reliable assessments of risk; and
- The training provided to, and the supervision of, its non-exclusive surveyors is effective.

Safety recommendations shall in no case create a presumption of blame or liability

Marine Accident Report