Statens haverikommission
Swedish Accident Investigation Board

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Report RS 2008:03e

Loss of M/S FINNBIRCH between Öland and Gotland, 1 november 2006

Case S-130/06

Translated by V.J.Miller (B.E. Adelaide) from the original Swedish at the request of the Swedish Accident Investigation Board.

2008-12-01 S-130/06

Statens haverikommission
Swedish Accident Investigation Board

Sjöfartsverket
(The Swedish Maritime Administration)
601 78 NORRKÖPING

Report RS 2008:03e

The Swedish Accident Investigation Board has investigated the loss of M/S Finnbirch on 1 November 2006 in the Baltic Sea between Öland and Gotland. A representative of The Finnish Accident Investigation Board participated in the investigation.

The Swedish Accident Investigation Board presents herewith, in accordance with paragraph 14 of the relevant Ordinance (1990:717) its report on the investigation.

The Swedish Accident Investigation Board requests that reports of actions which have been taken on the basis of the recommendations included in the report be submitted on or before 1 June 2009.

Carin Hellner Ylva Bexell

This report has been submitted to the Swedish Civil Aviation Authority.

Appendices

1. Stowage plan
2. Stability Study Finnbirch
3. Calculations according to MSC.1/ Circ.1228
4. Balance equations for semitrailers
5. Calculation of maximum heeling moment due to a total cargo shift
6. Participating helicopter events in the rescue operation

Abbreviations and technical terminology

Abbreviation / term	Significance
ACO	*Aircraft co-ordinator*
AIS	*Automatic Identification System*
Duck tail	*Duck tail* Extension of the hull at the waterline of the stern for increased buoyancy and improved hydrodynamics.
ARCC	*Aeronautical Coordination Centre*
Auditing	Review of e.g. safety or quality control system.
Autopilot	A device by means of which the ship is steered automatically without the intervention of a helmsman.
Back	Forecastle deck where, inter alia, the anchor / mooring capstan is located.
Ballast	Heavy materials carried within a ship to increase its stability, permit trimming and to improve its hydrodynamic characteristics and the water flow around the propeller. Sea water stored as required in different ballast tanks is the most usual ballast.
BiS	*Beslut I Stort* – decisions made personally by the Rescue commander.
Bunker	Designation of the fuel used by the ship for propulsion.
Bunker port	Opening in the side of the hull for the entry of liquid fuel supply hoses.
Casing	Designation of enclosed stairways within a ship between decks
CS	Theoretical calculated tensile force in a lashing. May also be designated FL.
CSEC	*Cargo Ship Safety Equipment Certificate*
CSM	*Cargo Securing Manual*
CSS	*Code of Safe Practice for Cargo Stowage and Securing*
Displacement	The weight in (tonnes) of the ship and its contents. Calculated by dividing the volume of water displaced by the ship by the mean density of sea water.
DP	*Designated Person* Person allocated a particular responsibility in the safety organisation of a ship-owning company.
EPIRB	*Emergency Position Indicating Radio Beacon* Freely floating emergency radio transmitter broadcasting its location for further transmission via a satellite to rescuers. .
Fin stabilisers	Horizontal fins formed in the side of the hull intended to counter rolling of a ship due to motion of the sea.
Flag state	The state the flag of which is flown by the ship.
GA	*General Alarm* Internal lifeboat alarm

GM	The distance in metres between the centre of gravity of a ship and its metacentre.
GZ	The righting lever measured in metres at a given angle of heeling.
GZ-curves	*GZ-curve* Curve which shows the righting lever of a ship as a function of different angles of heeling.
Harbour state	The national state of the harbour where the ship is berthed.
HFO	*Heavy Fuel Oil* Designation of oil (not diesel fuel) used for propulsion of ships.
To hover	The capacity of a helicopter to remain under control at a fixed point in the air.
Hypothermia	Loss of body heat.
IFR	*Instrument Flight Rules* Rules for instrument flying.
IMC	*Instrument Meteorological Conditions* Designation of weather conditions requiring instrument flying.
IMO	*International Maritime Organization* The International Maritime Transport Organization affiliated with UN.
IOPP	International Oil Pollution Prevention Certificate Document certifying that the ship satisfies certain requirements to prevent the escape of oil.
ISM-code	*International Safety Management Code* International set of rules for safe operation of ships.
Classification society	Organisation which, inter alia, supervises the design and construction of ships and performs relevant inspections.
LSA-code	*Life-Saving Appliance Code* International specification of life-saving equipment to be provided on ships.
M	Abbreviation for nautical mile (1 M = 1852 m)
Marine Pollutant	Substance endangering the marine environment
MBL	*Minimum Break Load* The minimum breaking load on a lashing when new.
MRCC	*Maritime Rescue Coordination Centre* Centre at which a rescue operation at sea is managed.
MSL	*Maximum Securing Load* The maximum safe loading on cargo-securing equipment.
NVG	*Night Vision Goggles* Equipment which improves vision in the dark.
Emergency generator	*Emergency generator* Reserve generator for the supply of voltage, located outside the engine room.
Emergency –VHF	Portable VHF radio telephone
OSC	*On Scene Co-ordinator* Person appointed for comprehensive management of rescue operations at the site of the accident.

Poop	*Poop deck* Ships deck at the stern where the mooring capstan is located.
PSC	*Port State Control* Inspection of a ship on its arrival at a harbour.
Relative heeling angle	The angle between the resultant of the forces affecting the cargo and the normal to the deck of the ship.
RL	Rescue manager, director and coordinator of maritime rescue operations.
Roll-trailer	Cargo-carrying trailer without front axle, not intended for road transport.
Ro-Ro	*Roll-on/Roll-off* Ship designed for the transport of units which can be rolled on and rolled off the ship on their own wheels.
ROV	*Remotely Operated Vehicle* Vessel, for remotely controlled underwater operations.
SAR	*Search And Rescue* Search and rescue operations in a maritime environment.
Scupper port/valve	Opening through the side plating for drainage from the space on or under an open deck, provided with a spring-loaded back-valve.
Semi-trailer	Trailer without front axle, supported at the front and towed by a prime-mover for road transport of cargo.
SJÖFS	Designation of the collected Swedish national rules for ships and shipping published by Sjöverket.
Bulkhead	Vertical internal wall construction separating different spaces within a ship.
Bilge keel	Extra keels/strakes welded to the hull of a ship intended to counter rolling.
SMC	*Safety Management Certificate* Document certifying approval of a safety organisation
SOLAS	*International Convention for the Safety Of Life At Sea* The internationally accepted maritime safety convention.
Sponsons	Projections from the sides of the hull of a ship at the waterline for increased stability and buoyancy.
SSRS	Svenska Sjöräddningssällskapet – Swedish Sea Rescue Society. A voluntary organisation of persons active in the rescue of those in peril on the sea.
Static tipping angle	In this report, the listing angle reached by the supporting structure (one of the decks of a ship) at which a unit of cargo will overbalance.
STCW	*Standards of Training, Certification and Watchkeeping for Seafarers* International convention establishing standards for the training of seafarers, their certification and the performance of watchkeeping.
Sto-Ro	*Stowed cargo – Roll on/off* Cargo received on board on a wheeled vehicle, unloaded in units by forklift truck and stowed individually in the hold of the ship.
Swedish Maritime Inspectorate	*Sjöfartsinspektionen*
Swedish maritime Administration	*Sjöfartsverket*
Route	The travel pattern of a ship, e.g. a route traversed at regular intervals by the ship.

Trailer horse	A trestle to support the front end of a semi-trailer when it is separated from the prime-mover.
Trunk	Vertical access passage provided with a frame and closing hatch.
UNCLOS	*United Nations Convention on the Law of the Sea* A global UN convention specifying how the nations of the world are to make use of the seas of the world and their resources.
VDR	*Voyage Data Recorder* A device for recording the track of a ship.
Ventilator	Protection for ventilation openings which lead to dry spaces on board such as inredning, engineroom and holds for dry cargo.
VFR	*Visual Flight Rules* Rules for flying with visual contact with the environment.
VHF	*Very High Frequency* Radio communication making use of waves with very high frequency.
VMC	*Visual Meteorological Conditions* Meteorological conditions suitable for flying under Visual Flight Rules.
Walking board	Strong laminated plywood timber sheets which can be used for separation between different units of cargo.
WB tank	*Water Ballast tank* Tank in a ship for storage of ballast in the form of sea water..
WT-door	*Water Tight door* Door which can remain sealed against the water pressure to which it can be subjected.

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S-130/06
The report was completed on 2008-12-01

Ship; type, reg.designation. Signal letters	Ro-ro ship FINNBIRCH – SLNK IMO nr 7528609
Certificates	Valid
Owner/operator	Lindholm Shipping
Nationality/Flag state	Sweden
Class	Lloyd's Register
Time of occurrence	2006-11-01, 1539 hrs. In daylight (*Mayday)* *Note:* All times given are in Swedish standard time. (UTC + 1 hour)
Location	In international waters between Öland och Gotland (pos. Mayday: N57°01' E017°32') (pos. at disappearance from radar: N56°49' E017°13')
Type of voyage / activity	Ordinary voyage with cargo in Baltic Sea.
Weather and sea conditions	According to SMHI analysis: Wind approx. N, 20 m/s with appreciable gustiness 26-29 m/s, significant wave height 4m (increasing).
Number on board; Crew	14
Injuries to persons	Two deaths, one seriously injured
Damage to ship	Total loss
Damage to cargo	Total loss
Other damage (environ-mental)	Limited

SHK (the Swedish Accident Investigation Board) was informed on 2 November 2006 of an accident involving the merchant vessel Finnbirch in international waters between Öland and Gotland at 1539 hours on 1 November 2006.

The accident has been investigated by SHK personnel, Göran Rosvall until 2007-02-28 and subsequently Carin Hellner, Chair of the committee; Ylva Bexell, Investigation Manager; Thomas Milchert, Investigator, Naval engineering and Agne Widholm, Investigator, Rescue Services. SHK has been assisted by Peter Andersson, cargo-securing expert; Ronnie Larsen, Marine rescue expert; Per Stefenson, life saving equipment expert and Ulf Björnstig Medical expert. SHK has also been assisted by Risto Repo of the Finnish Accident Investigation Authority. Margareta Lützhöft and Jan Snöberg have participated by interviewing the crew in connection with the accident.

Sten Anderson of Sjöfartsverket (the Swedish Maritime Administration) has monitored the investigation.

Summary

The Swedish Ro-Ro ship Finnbirch left Helsinki on the evening of 31 October 2006 for a scheduled voyage with cargo to Århus, Denmark. The ship had a full load of roll-trailers and semi-trailers and a consignment of block-stowed paper reels. The weather was hard, with northerly winds at 20 m/s and gusts up to 26-29 m/s.

During the passage between Öland and Gotland, with a very heavy following sea, the ship heeled, suddenly and considerable, a couple of times to port. After these lurches, the ship remained stationary listing at 30-35 degrees to port with an almost complete cargo shift. The crew sent an immediate Mayday emergency call, this being the beginning of a long and complicated rescue operation. The crew assembled on the deck and dressed in survival suits. Rescue to ships in the vicinity was not possible and rescue attempts by helicopter were considered too risky in the circumstances and the crew therefore remained on board until the ship finally capsized and sank approximately four hours later.

One crew member was drawn down with the ship and drowned, another succumbed to hypothermia. The other crewmen were rescued from the sea by helicopter.

Causes of the accident were;

Finnbirch having unfavourable course and speed under sea conditions with high and long waves, which caused a reduction in stability with considerable but not exceptional heelings which resulted in the cargo shift. The securing of the cargo on board was inadequate.

Contributory factors were as follows:

- the ship's cargo-securing manual was neither complete nor was its instructions followed. The charterer used his own system for cargo-securing and did not request access to the ship's manual. The final cargo-securing level was mainly a result of verbal agreements between the charterer and different ship's officers on board, *and*

- the non conformity of the cargo-securing from the requirements in the ship's cargo-securing manual had not been reported to the shipowners. Neither the shipowners nor the relevant supervising authority had observed that the securing of the ship's cargo differed considerably from the stipulated requirements.

Recommendations

SHK recommend that the Swedish Maritime Administration

- propose that stability requirement for ships in following sea should be entered into the relevant international rules and regulations *(RS 2008:03R1),*

- review the present training of ship officers with respect to the handling of ships in heavy seas, to the different phenomena which can occur under such conditions and how these can be avoided or their effects can be minimized *(RS 2008:03 R2),*

- propose to international collaboration, that instructions for the dimensioning of cargo-securing systems in and on cargo transport units be added to the CSS code or other suitable code *(RS 2008:03 R3),*

- propose to international collaboration, the development of some form of obligatory code relating to the securing of cargo in and on cargo transport units. *(RS 2008:03 R4),*

- propose to international collaboration, an amendment to the STCW requirement for training of ship officers in cargo-securing so that it relates to all relevant ships and not only to ro-ro passenger ships. *(RS 2008:03 R5),*

- review the internal instructions for the approval of cargo-securing manuals to ensure that these manuals are checked with such methods that the results of the checking are credible *(RS 2008:03 R6),*

- increase the controls that the instructions for cargo-securing contained in cargo-securing manuals are observed in the practical work on board Swedish ships and in other ships entering Swedish ports *(RS 2008:03 R7),*

- draw attention, in international collaboration, to the problems relating to the size and fit of survival suits which emerged during the investigation and to the importance of the immediate availability of survival suits when required *(RS 2008:03 R8),*

- in its monitoring of the safety organisations of ship-owning companies, consider in particular the guidance developed by IMO regarding the qualifications a Designated Person (DP) should have *(RS 2008:03 R9),*

- in its monitoring of the safety organisations of ship-owning companies, consider in particular the guidance developed by IMO regarding their observation of the ISM code with respect to the authorities and resources granted to the Designated Person (DP) (RS 2008:3 R10),

- in its monitoring of the safety organisations of ship-owning companies, check in particular, their internal follow-up and investigation of accidents and other incidents on board with the objective of improving safety on their ships *(RS 2008:03 R11),*

- clarify, in consultation with the Swedish Civil Aviation Authority, the requirements for weather and other conditions under which off-shore SAR operations should or should not be performed *(RS 2008:03 R12), and*

- ensure that changes in SAR activities are analysed and as well as risk, and that measurements are taken to reduce any such risks identified *(RS 2008:03 R13).*

SHK recommend that the Civil Aviation Authority

- develop a national code of rules for requirements relating to and monitoring of SAR activities *(RS 2008:03 R14).*

1 FACTUAL INFORMATION

1.1 History of the voyage

The ship Finnbirch left the North harbour (Sumparn) Helsinki at approximately 2100 hrs, Swedish time, on the evening of 31 October 2006 for an regular voyage with cargo to Århus, Denmark. This was a route which the ship had performed during the last six years. The normal time for the voyage was approximately 36 hours and the departure of the ship had been delayed approximately 4 hours. At departure, the weather was calm but the forecast was for increasing winds to gale N-NE 14 – 20 m/s. The crew was informed of the weather forecast and the voyage plan was made with respect to the expected change in the weather. The ship was to pass relatively close to the south side of the island Gotska Sandön and then change to a course between the islands Öland and Gotland. Depending on the weather, it would then be decided whether to turn to starboard at the southern tip of Öland or to continue on a southerly course to pass east of the island of Bornholm.

The ship had a full cargo of sawn timber, paper reels, plywood, steel products and palleted goods. Most of the cargo was on semi-trailers or roll-trailers. Approximately 500 tonnes of paper reels were stowed furthest forward on the Main Deck, these being block-stowed by forklift truck.

As remembered by the Master, the draught aft was 7.05 m and the stern trim was 0.4 m. The Chief Officer had calculated the stability and determined the GM as 1.20 m, stating that all the requirements of the GZ curve were fulfilled. He informed the Master of this at the time of departure.

The weather experienced during the voyage was as forecast. The ship passed south of Gotska Sandön and continued, because of the weather, a further distance westward before changing course southwards between Öland and Gotland. At 1300 hours, the ship was abreast the town of Visby and on a course of 205° at a speed of 17.5 – 18.5 knots. At 1500 hours, the Second Mate marked a GPS position on the maritime chart. (Times referred to in this report are Swedish normal time. The ship used Finnish time as the ship's time, this meaning that the clocks on board showed 1600 hours at this point). Together with the Chief Officer, who happened to be on the bridge at the time, he also made weather observations which were entered into the log. As the Second remembered, these were "wind N 8-9 B, 6-4 2/3 [1]. According to the Second, the ship was proceeding in a wave system from the North with a certain proportion of other waves from NNE-NE. The ship rolled 7–10° and at times "surfed" on the following waves.

The First left the bridge soon after, leaving the Second on watch. The rolling increased soon to 12–15° and the Second accordingly changed course to port to 200° so that the waves followed the ship more directly from aft. This reduced the amplitude of the ship's movements. A standing order on board was that the ship was not permitted to roll more than 10–15° without action being taken to reduce the rolling. After a time, the Second tried to return the ship gradually to its earlier course (205°) but the rolling increased. At this time, two ships were observed on an opposing course at a distance of 20 M. Continuing on the 200° course appeared at the time as leading to a close quarter situation, bow to bow on opposing courses.

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[1] The figures are part of a numerical code system for recording weather observations in which the position of the figures is significant. The first figure relates to the seas and the figure 6 means that they were very rough, 4-6 m. The second figure star for the swell which in this case was of medium length and 2-4 m high. The third figure stands for the weather conditions, the figure 2 meaning that "the sky was more than half overcast". Finally, the fourth figure in the sequence stands for visibility which in this case was judged to be less than 0.3 M corresponding to less than 500 m.

It had already been considered that due to the weather, it might be preferable to continue southward and pass east of Bornholm instead of altering course at the southern tip of Öland. He decided therefore to call the Master for a consultation.

The Master reached the bridge quickly and commanded a return to the 200° course. Once again the ship's rolling was reduced and after that the course was step by step changed back to the original. When the course had almost reached 205° and the ship's motion appeared to be quieter, the Master decided to leave the bridge. At this point, a first violent heeling of the ship towards portside occurred according to the Master approximately 25° and according to the Second, 20 - 40°. The Master changed over to manual steering and, according to the Second, said "nu försöker vi gå upp i vind" ("lets try to head into the wind "). After the first heeling, the ship returned to an upright position, but was then subjected to a further two heelings towards portside. The second heeling was somewhat more severe than the first and the Master estimated the third to be 40–45°. After this, the ship did not return to an upright position, but remained with a severe list to portside. The Master, who believes that he turned the wheel hard towards portside but experienced no reaction, returned the steering to the automatic mode. He stood in a position from which he could not reach the engine controls. No change was made in the speed.

The Master decided to activate an immediate Mayday emergency call on the VHF radio, giving the Second the order to do this. According to MRCC, the first transmission was received and registered in their log at 1539 hrs.

The Master, who had been standing amidships at the central steering position, threw himself backward to reach the chart table and then left the bridge. He made his way to a cabin on the starboard side aft of the bridge where the survival suits were stored. Gathering as many as he could carry, he returned to the bridge with these. Several other members of the crew reached the bridge immediately and all there moved out onto the bridge deck on the starboard side, aft of the bridge. The remainder of the crew presently assembled there, was counted and donned the survival suits. No general emergency alarm was sounded but there could be no doubt as to the seriousness of the situation in which they found the ship. Several of the crew has said that it took about 5 minutes to get out from the interior of the ship and up to the assembly place on the deck on the starboard side aft of the bridge.

An estimated 30 minutes after the listing of the ship, black smoke came from the stack and it was assumed that the ship's engine had stopped. The sound of the start of the emergency generator was heard.

The rescue operation became long and dramatic. The Mayday signal was immediately acknowledged by MRCC in Gothenburg and the two ships nearby, the Dutch freighters Marneborg and Largo both set course for the ship in distress. Their crews had however little possibility of rescuing the crew of Finnbirch while they remained on board.

Finnbirch pitched and rolled considerably in the heavy seas which meant that on arrival, the crew of the rescue helicopters considered that it was impossible to hoist the crew directly from the ship if they could not reach a position more easily accessible to the rescue personnel, on the open deck at the bow. It was however impossible for the crew to reach this position without first returning inside and down into the ship and then clambering over the partly displaced cargo on the weather deck. This was judged to be both too difficult and dangerous under the prevailing circumstances. In addition, the crew found that they were hampered in their movements by the survival suits.

It soon became dark and vision was at times seriously affected by a snow storm and sleet. Ice accumulated on the deck which became very slippery. The list increased gradually. At about 1730 hours, the Master attempted to reach the life-saving rafts on the port side of the ship but even this was found to be too hazardous. He slipped and injured himself seriously in attempting to return to the crew. The Chief Officer then assumed the Master's position as commander.

The list continued to increase successively and at an increasing rate as time passed. The emergency lighting functioned to the end and light was cast out onto the deck from the galley. At 1924 hours, Marneborg advised MRCC that Finnbirch had finally capsized and 10 minutes later, that her radar echo had disappeared from their screen.

The crews jumped or were washed into the sea and pushed themselves away from the ship as it sank. The crews were separated and flotsam, including sawn timber released from the cargo, shot up to the surface like projectiles.

After the ship had sunk, 11 of the crew were winched from the sea by helicopter within the next hour. A further crew member was rescued at approximately 2115 hours and the last to be found was hoisted at 2217 hours. His survival suit was completely filled with water. The man, an AB seaman, showed no signs of life and was declared dead later. The Chief Officer was still missing and the search for him continued without success into the morning hours.

Three weeks after the sinking, the Coastguard recovered the body of the missing Chief Officer during an inspection of the wreck using a remotely controlled underwater vessel (ROV). His body was found near the starboard lifeboat, i.e. at the place where the crew had assembled before the ship sank. The body was recovered with the help of the ROV.

1.2 Consequences

1.2.1 Injuries to persons

All 12 survivors were admitted to hospital and 10 of these were discharged after 24 hours care. One remained for three days and one was transferred to his home hospital in Stockholm for continued treatment. One of the crew discharged after 24 hours, in addition to physical injuries, had suffered such a serious psychic trauma that a year after the sinking, he remained incapable of work.

Injuries	*Crew*	*Passengers*	*Others*	*Totalt*
Fatal	2	–	–	2
Serious	1	–	–	1
Moderate	2	–	–	2
Minor	8	–	–	8
None	1	–	–	1
Total	14	–	–	14

1.2.2 Damage to the environment

The ship had 441 m^3 HFO (Heavy Fuel Oil) and approximately 100 m^3 diesel fuel oil on board on departure from Helsinki. It is estimated that approximately 200 m^3 HFO has leaked from the ship in connection with the sinking. At the beginning of March 2007, 183 m^3 HFO and a negligible volume of diesel fuel oil were salvaged from the wreck under instructions from Swedish Maritime Administration. Approximately 100 m^3 of diesel fuel oil remain on board in a tank difficult to reach.

The ship's cargo also included a smaller quantity of dangerous material in packaged form which, to SHK's knowledge, has not been salvaged.

1.3 The ship

1.3.1 The ship's history

Finnbirch was delivered on 2 February 1978 from a shipyard in South Korea and introduced to service between Europe and Canada under the name Atlantic Prosper. The ship was one of a series of 10 ships built for Stena Container Line Ltd. in London. The year following the year of its delivery, the ship was provided with sponsons on the sides to improve its stability characteristics.

After several periods of use in charter traffic under different names, the ship was sold in 1985 to Rederi AB Concordia and renamed Stena Gothica. The ship was registered as Swedish on 3 January 1986 and during that year, a further deck was added, the Weather deck.

At the beginning of 1988 the ship was charted to Bore RoRo and renamed Bore Gothica. Before the end of the year, the ship was sold to August Lindholm Eftr AB in Stockholm, a subsidiary of Bore Lines AB. At the beginning of 1992, the ship was chartered to Finncarriers Oy AB (this being a trade name for Finnlines) and after some years in Baltic Sea traffic, was engaged in traffic between Finland and England. This continued until 2000 when the ship was employed in traffic between Helsinki and Århus – the route which it followed until the sinking.

The ownership situation changed during the 1990's as a result of different amalgamations and administrative rationalizations. Bore Gothica was reregistered to Bore Lines i Stockholm AB at the beginning of 1995. The name of the ship was changed the following year to Finnbirch. In 1999, it was transferred to Strömma Turism & Sjöfart AB which had been formed by an amalgamation of Bore Lines AB and Strömma Kanalbolaget AB. That year, most of the Swedish crew was replaced with Filipinos and the working language on board was changed to English. Strömma Turism & Sjöfart AB together with Bore, which operates a number of ships, most of which are ro-ro ships, is a company within the Rettig group.

1.3.2 The ship in general

The ship had four designated cargo decks; Weather Deck, Upper Deck, Main Deck and Tank Top. The cargo was taken on board via the stern ramp on to the Main Deck. It could then be lowered via a cargo lift to the Tank Top or could be transported up via a fixed ramp in the centre casing to the Upper Deck. From the Upper Deck, it could be conveyed to the Weather Deck via a retractable ramp which was hoisted and lashed in place at the level of the Weather Deck during voyages.

Finnbirch had been given special stability characteristics, recorded as data in the stability book, by the addition to the hull of sponsons and a so-called duck tail. The righting lever curve (the GZ curve) showed a dip at certain heeling angles, in this case between 20 and 40 degrees. The stability of the ship is discussed further in Chapter 1.9 below.

There was no stabilising system on board which could be used to minimize rolling due to sea conditions. When the ship was built, space was left empty in the hull in preparation for the possible future installation of fin stabilisers. This was never done. According to the shipping company, the bilge keels with which the ship had been equipped had successively disappeared when the ship had been operated in ice and, in principle, were all gone at the time of the sinking.

The ship had wing tanks for the correction of listing. Two of these could be operated from a position at the cargo office aft on the port side of the Main Deck and their contents were continuously adjusted during loading and discharge to correct listing. All ballasting operations were otherwise controlled from the engine control room.

1.3.3 Ship's data

Launching shipyard	Hyundai Heavy Industries Co. Ltd, South Korea
Class	Lloyd's Register of Shipping
Launching year	1978
Ship's registration	Swedish ship register
Type	Ro-ro-ship
Length overall	156 m
Length BP	137 m
Beam, max at sponsons	22.7 m
Beam moulded at Main deck	21.6 m
Beam, moulded below Main deck	19.9 m
Draught, max	7,30 m
Dead weight with max draught	8672 dwt
Gross tonnage	15396
Speed range	A
Motor type	Pielstick
Main engine, output	11482 kW
Speed	17 knop
IMO-number	7528609

Figur 1. Finnbirch during a voyage with a load of semitrailers on the Weather Deck. Openings in the ship's side at Upper Deck level are visible. The forward openings are closed with plywood (walking board). Toward the stern are openings under the poop deck. Sponsons welded to the hull at midships can be seen at the waterline.
Photo: www.faktaomfartyg

1.3.4 Certificate and inspection

Finnbirch had been subject to a 25 year classification some years previously and had been docked most recently in July 2005 at Örskovs shipyard in Fredrikshamn, Denmark. SHK has been provided with the docking report. The ship was classed with Lloyd's Register. There were no matters mentioned in the classification of significance for the sinking which remained unattended.

According to the owners, the ship was in good condition before the sinking. There had been no major problems with the hull during their years of ownership except with the welded connections of the Weather Deck to the original hull.

There had however been problems with the lashing points installed in the deck which had been underdimensioned from the beginning. These had been successively replaced with stronger fixings over the years. The tightening cups under the lashing points on the Tank Top had been damaged by rust which resulted in leakage and the escape of the contents of the tank to the cargo deck. At the time of the initial serious heeling, members of the crew were engaged in correcting such a minor leakage.

The ship was subjected to an inspection by Swedish Maritime Administration (SMA) in January 2006 in Helsinki, for approval according to four different certificates; Cargo Ship Safety Equipment Certificate (CSEC), Safety Management Certificate (SMC), International Oil Pollution Prevention Certificate (IOPP) and International Ship and Port Facility Security (ISPS) Certificate.

A total of nine defects on the ship were noted during this inspection. One of these related to defective lashing material, this being referred to later in this report.

The SMA also studied damage stability at water ingress and the operational readiness to counter this and observed that there were deficiencies with respect to appropriate routines, exercises and documentation.

At the time of the sinking, all of these defects had been reported as corrected and had been deleted from the list noted by the SMA.

In the report done by the SMA, after the control of the safety management system required for issue to the owners of the SMC certificate, this also in January 2006, it is stated that; “At the time of previous inspections, it was noted that no person on board had any training in cargo-securing. This appears not to have been corrected.” This was not registered as a formal deficiency as such training is not required by law and its provision is to be seen only as a recommendation.

The ship had also been inspected by relevant Finnish authorities in a port state control (PSC) approximately one month before the sinking. Five deficiencies were noted during this inspection, e.g. that the battery of one of the radio transponders was discharged. Beyond these, no shortcomings were found which could be related to the sinking or the rescue of the crew.

1.3.5 The ship’s bridge

The bridge was of an ordinary type with enclosed bridge wings and an exit to a bridge deck at the rear of each bridge wing. The operating controls, radar and electronic chart were widely separated on the instrument panel located parallel with the forward lights. This means that the bridge was particularly wide across the ship but not particularly deep. Finnbirch had not been equipped with a Voyage data recorder (VDR).

1.3.6 Life-saving equipment

There were two conventional life boats on board, located, one on each side, aft of and one deck below the bridge level. These were easily accessible from the bridge and the crew was able to use tools and equipment from the starboard life boat at the time of the accident.

Five inflatable rescue rafts were on board, two 20-person rafts of RFD type, two Viking 25-person and one Viking 12-person rafts. The 12-person raft was located on the Weather Deck under the foremast. The other rafts were located two on each side of the ship, on the deck below the lifeboat deck and behind the superstructure. On the starboard side, the rafts were stored in steel cradles bolted directly to the deck. On the port side, a framework had been built up from the deck so that the rafts lay, one on top of the other, in a rack almost at the level of the life boat deck. From films of the wreck lying on the bottom, it can be seen that the rafts on the starboard side are gone which suggests that they have been activated and floated up in the intended manner. The raft under the mast on the Weather Deck remains in its secured position. The wreck lies on its port side which is therefore impossible to film.

Life belts were available on both sides of the ship for all on board. These were stored in lockers on the deck adjacent to the life boat launching area. Survival suits (so-called 6 hour suits) were stored in a special cabin on the starboard side, aft of the bridge. Some suits were also stored in the engine control room. The survival suits are described in detail in section 1.13.2 below.

1.4 The crew, the owners and the charterer

1.4.1 Command

Master

The Master was 46 years of age at the time of the sinking and held a valid Sea Captain's certificate. He had been employed by the owners since 1998 as a ship's officer and on board ship for the first time, as Chief Officer in 1999. He became the regular Chief Officer on Finnbirch in 2000 and was promoted to Acting Master in August 2002. For several years he served as a replacement for one of the ordinary Masters on sick leave and became regular Master himself in the spring of 2006.

Chief Officer

The Chief Officer, who died in the sinking, was 49 years of age and had a valid Sea Captain's certificate. He had been at sea since 1974 and began his employment with the Owners in 1996 as Chief Officer on Finnbirch, an appointment which he held until his death.

Second Mate

The Second Mate was 26 years of age at the time of the sinking and had a certificate as Ship's Officer Class V. This voyage was his fifth appointment as Ship's Officer with the Owners and also as Mate.

Chief Engineer

The Chief Engineer was 58 years of age at the time of the sinking and had a certificate as Marine Engineer – Motor (IM). He had first gone to sea in 1965 and had been Chief Engineer with the then Bore lines AB since 1980 as Chief Engineer. He was appointed to Finnbirch as Chief Engineer in 1992.

Other Engineers

The First Engineer's Mate, aged 47 at the time of the sinking had been at sea since 1978 and joined the company in 1997, employed since then as First Engineer's Mate in Finnbirch.

The Second Engineer's Mate was aged 50 years at the time of the sinking. He had been at sea since 1980 and had been employed by the Owners in 2001, alternating as First and Second Engineer's mate on board Finnbirch.

Both Engineer Mates were Filipino citizens and were certificated for their positions on Swedish ships by a special Certificate Endorsement for non-EU nationals.

1.4.2 Crew

Furthermore, the crew on board consisted of three ordinary seamen, a boatswain, a motor man and an engine fitter. The galley crew consisted of a cook-steward and a mess boy. All of these crew members were Filipino citizens and were at the time of the sinking, between 42 and 47 years of age. Their service periods with the owners and on Finnbirch varied between 1 and 7 years.
One of the ordinary seamen did not survive the sinking.

1.4.3 The Owners

At the time of the sinking, Lindholm Shipping consisted of two companies, one which operated as ship-owners with the ships Finnbirch and Finnforest and the other as a shipping agency, acting, inter alia, as Agents for Finnlines in Sweden. The Ship-owning company ceased operations in December 2007 when the remaining ship was sold to Ireland.

The Ship-owning activity constituted a division of Strömma Turism & Sjöfart AB (Strömma) and was managed by its Managing Director. Strömma is, in turn, owned 100% by the Rettig Group, either directly or through different foundations controlled by the Group. The Rettig Group has a significant and long-term engagement in Finnish ro-ro shipping. Bore, which operates a number of ro-ro ships, is amalgamated with Strömma as a subsidiary of the Rettig Group. According to information received by SHK, there was however, no close collaboration between Bore and Strömma at the time of the sinking.

The Lindholm Shipping office employed two persons, one with the technical operation of the ships and one with manning/personnel and ISM issues. The Technical Manager in Lindholm Shipping who had a background as a marine Chief Engineer made regular visits to the ships when they were in port in Finland. The person responsible for ISM matters had undergone a two-day course in ISM in Mariehamn but had no practical experience of work at sea. He visited the ships less often, on an average 4 – 6 times a year and then primarily in connection with internal auditing.

There is a documented ISM system for the company and its ships. On a visit to Lindholm Shipping, this was found by SHK to be maintained in excellent order. Internal auditing in ships is performed at regular intervals but consisted mostly of an inspection of documents. A system for reporting non conformity appears to have been in use for a longer time and to function as intended.

The crew members interviewed by SHK considered in general that they were a closely knit team and that there was a good atmosphere on the ship and also within the company.

1.4.4. Charterer

Finnlines Oyj is a large Finnish shipping company with subsidiaries such as Finnlines AB in Sweden, Finnlines UK in England and Finnlines Deutschland GmbH in Germany. The company has specialized largely in regular services with ro-ro cargo vessels and ro-ro passenger ferries, primarily in North Sea and Baltic Sea traffic. The company operates both its own tonnage (ro-ro passenger ferries) and chartered ro-ro vessels. Finnlines also owns the Finnsteve stevedoring company with activities in Helsingfors, Kotka and Åbo. Finnbirch was chartered by the German Finnlines [2].

There was a contract between Lindholm Shipping and Finnlines for the chartering for a specified time of Finnbirch (and the sister ship Finnforest which traficked the same route). This contract had been arranged with the assistance of Thun Ship as brokers. Thun Ship and Strömma are wholly owned by the Rettig Group. According to the contract, the ship was available to

[2] BIMCO “LINERTIME” Deep Sea Time Charter

Finnlines for a specified time. As charterers, Finnlines managed and financed cargo booking, cargo planning and loading and discharging of the ship's cargo. Finnlines was also responsible for the bunkering of the ship, harbour and stevedoring costs including the costs of the securing of the cargo. It was also Finnlines who owned and supplied the cargo securing equipment on the ship. The ship's crew, however, were employed by Lindholm Shipping, they being also responsible for the technical operation of the ship.

Finnlines and Finnsteve have used a quality system[3] of SFS-EN ISO 9001:2000 type since 2005. Finnlines had previously been quality certificated but the quality assurance system had a period of degeneration at the beginning of the 2000's. Finnlines renewed its certificate in May 2005 and was audited in March 2006. Finnsteve, however, had its quality system certified during the degeneration period for Finnlines. The most recent auditing of Finnsteve before the sinking of Finnbirch was in August 2006. Manuals and handbooks which relate to the system are published in both Finnish and English. The quality assurance system also includes guidelines for the securing of cargo which embraces both the securing of cargo in and on cargo transport units and the securing of units of cargo and cargo transport units on board ship.

1.5 Meteorological information

1.5.1 Weather during the loading

During the loading in Helsinki, precipitation was rain and sleet during the entire day. The meteorological institute in Finland has provided a summary of the weather in Helsinki during the loading day.

The weather on the 31th October 2006 in Helsinki was cloudy and rainy (also sleet).
There was no snow on the ground with observations at 06 and 18 UTC.
Rain and sleet has been observered during the day but no snowfall.
The winds were SE to ESE, in the morning 3-5 m/s, increasing to 7-10 m/s during the day and decreasing in the late evening to 3-5 m/s.
Air temperature was at 06 UTC -0.3 °C, at 09 UTC 2.9 °C, at 12 UTC 2.1 °C, at 15 UTC 2.2 °C, at 18 UTC 5.2 °C, at 21 UTC 4.6 °C

Precipitation events on the 31th October 2006 at Helsinki Kaisaniemi automatic weather station:
(the time is in UTC)

until 08:10	**no precipitation**
08:10 - 09:00	**weak rain, continuous**
09:00 - 12:20	**weak sleet, continuous**
12:20 - 12:40	**moderate or heavy sleet**
12:40 - 15:30	**weak sleet, continuous**
15:30 - 17:30	**moderate rain, continuous**
17:30 - 17:40	**heavy rain**
17:40 - 17:50	**moderate or heavy sleet**
17:50 - 18:30	**moderate rain, continuous**
18:30 - 19:30	**moderate or heavy sleet/rain, continuous**
19:30 - 21:50	**moderate and weak rain, continuous**

1.5.2 Weather forecast for the voyage

Before departure, the Master had obtained the Finnish weather forecasts and the forecasts from the websites of SMHI (Sweden) and DMI (Denmark). These forecasts stated that the wind would be N-NE 15-20 m/s during Wednesday 1 November. The Danish website also gave a broad but not particularly detailed forecast of wave conditions. The Master expected that there would be wave heights of approximately 5 m. Weather forecasts early on the Wednesday

[3] Audit, Finnlines 28/3/2006, Finnsteve 17/8/2006

morning, obtained during the voyage, as remembered by the Master, increased the winds to 22 m/s.

1.5.3 Weather at the accident site

At the request of SHK, The Swedish meteorological and hydrological Institute (SMHI) prepared a summary of the weather situation and the wave conditions at the site of the sinking during the afternoon and evening of 1 November 2006. Between 1530 hours and 1930 hours the wind was north with a mean speed of 20 m/s and appreciable gustiness 26-29 m/s. Visibility was limited to between 0.6 and 4 M because of showers of snow and sleet.

1.5.4 Wave conditions at the site of the sinking

There are observations of the conditions at the site from Finnbirch and from Marneborg which lay close to Finnbirch during the time before the sinking, as well as a calculation of the wave conditions performed by SMHI at the request of SHK. The estimates of the wave height made from the ships and the data from SMHI are in agreement.

Wave data for the area concerned are calculated by SMHI with the help of a model based on the actual wind conditions and adjusted with the help of wave data measured from a wave buoy ”Ost Huvudskär”,

The SMHI calculations of wave data for the site at the time gave the following results:

At 1500-1600 hours, the significant wave height in the area of the Mayday position was approximately 4 m (increasing) with a dominant wave period of 6.7 s (also increasing). The waves were from the direction of 002 degrees veering towards North. The estimated wave length was approximately 70 m. The calculated wave speed at the time of the accident was approximately 10.5 m/s. (20.4 knots).

SMHI considers that intersecting wave patterns could have developed in the area between Gotland and Öland. The maximum wave heights occurred, in accordance with the calculations, within the area of the accident. The highest individual waves can have had a height 1.8-2.0 times the significant wave height which at that time, there, was 4 m. Individual waves can therefore have reached a height of approximately 7-8 m.

In using this calculated data it must be considered that they represent estimations of typical conditions on the basis of a theoretical model. The actual conditions probably diverge from the calculated result and vary continually with respect to wave height, wave length, direction and speed. To further determine probable wave lengths, comparisons have been made with published measured wave data.

Published statistical wave data for the Baltic Sea according to BMT [4] for the period December to March show that significant wave heights of between 3 and 5 m occur with a probability of approximately 14% (percentage of the number of observations). These waves have typical periods concentrated in the range 6-8 s. This corresponds with calculated wave lengths between 56 and 100 m. See Appendix 3.

On the basis of this, SHK concludes that in the area at the time of the accident, individual waves with a wave length of at least 80 m and a height of approximately 7-8 m have occurred. These waves have travelled at a speed of 20-21 knots in the direction of the ship’s heading.

The maximum significant wave height in the area occurred at approximately 2200 hours, this being then, according to SMHI, 5 m, with wavelength 84 m.

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[4] Reference: Global wave statistics. British Maritime Technology Ltd.

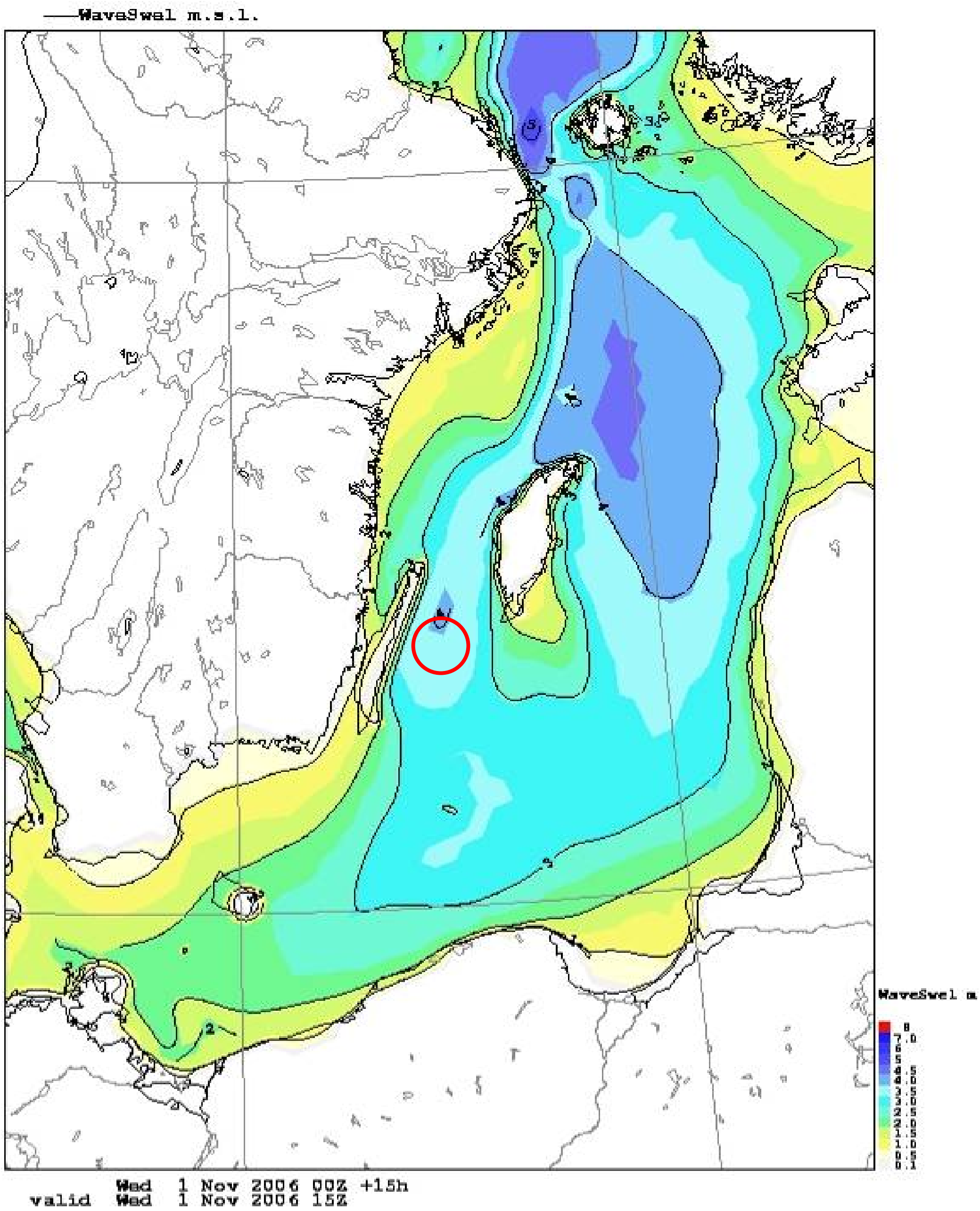


Fig. 2. The calculated significant wave heights according to SMHI at the approximate time of the accident. Note the area between Öland and Gotland with greater wave heights which coincides with the position of the accident (red circle indicates approximate position).

1.6 Loading

1.6.1 The harbour and stevedoring in Helsingfors

Norra hamnen a.k.a as Sumparn (The North Harbour) is exclusively a ro-ro harbour with seven berths, largely at the disposal of Finnlines and its subsidiary Finnsteve which conducts cargo loading and discharging operations. Finnsteve also performs the reloading of goods arriving by rail and road transport to different cargo transport units such as roll-trailers, cassettes, platforms and containers which are then loaded on board ships. Goods reloaded in this way are secured on the load carriers at separate cargo-securing stations before they leave the reloading terminal for loading on board.

About 13-14 forwarding agents and larger industrial firms are responsible for practically all the semi-trailer traffic to and from the harbour. Most of these companies book the transport via the Finnlines electronic booking system. It is relatively seldom that private persons or lesser industrial firms' book trailer space in the ships, these usually booked via a forwarding agent.

Approximately 250 persons are employed by Finnlines at Norra Hamnen, approximately 200 permanently, the remaining 50 persons being extra stevedores engaged from day to day according to the number of ships to be loaded or unloaded. To be eligible for employment as an extra stevedore, it is necessary to undergo a one day course for stevedores.

At the terminals, the majority at the load securing stations are permanent employees whereas on board the ships the case is the opposite, i.e. only a few are permanent employees. According to Finnlines, the personnel who performed the loading of Finnbirch on this occasion were experienced stevedores.

A typical cargo-securing gang on a ship's deck, loading semi-trailers and securing cargo with chains consists of two terminal tractor drivers who tow the trailers on board, a signal man who waves in the trailer and four lashing-men, one responsible for placing the trailer horses in position. If the cargo is secured with web lashings, one of the lashing-men is not required.

Finnsteve are well aware of the Finnlines instructions for securing cargo on board ships. According to representatives of Finnsteve, it is, however, the Master on board the ship who determines how the cargo is to be secured.

1.6.2 Cargo planning

The charterer, Finnlines' quality assurance system includes a manual designated "Fleet process"[5] for use in connection with cargo loading. The process charts in this manual state that the *Fleet Operation* department receives its booking information from its clients via *Customer Service* and that a preliminary loading plan is prepared on the basis of this information. This is then sent to the ship where a preliminary stability calculation is performed. If this appears to be satisfactory, the plan is returned to *Fleet Operations* and to the *Port Operator* (the stevedoring company) which begins the planning of the loading.

1.6.3 Loading into the ship

Finnbirch had four cargo decks. The cargo arrived on board via the stern ramp on the Main Deck and could then be lowered via a cargo lift down to the Tank Top or via a permanent ramp to the deck above, the Upper Deck, a partly covered deck. From the Upper Deck, the cargo could be transported via a retractable ramp up to the completely open Weather Deck.

In preparation for the voyage, the upper two decks were almost exclusively loaded with semi-trailers. On the Main Deck, roll-trailers were in the majority. Certain of these were block-stowed while others were arranged in traffic lanes. Forward on the Main Deck, approximately 500 tonnes of paper reels were loaded as sto-ro, the reels being carried in on platforms, lifted off and stowed closely with the help of fork lift trucks, several high, over the entire width of the hold. The remainder of the Main Deck was loaded with semi-trailers and the Tank Top mainly with roll-trailers.

Most of the semi-trailers were loaded with different kinds of forest products such as sawn timber, paper, plywood or different kinds of steel products. The cargo included a certain amount of goods on pallets. Most of the roll-trailers were loaded with paper reels, others with different kinds of fibreboard. A number of machinery was included in the cargo. The final cargo plan for the voyage is shown in Appendix 1.

[5] Binder 4, version 1.0 25.10.2005

On board the ship, one of the Mates and a seaman were on duty as the normal loading watch. When the ship had received and accepted the preliminary loading plan, the loading began. The mate checked off the cargo as it arrived on board, showed where it was to be finally placed and noted the weight of the unit in the stability programme. The weight of semi-trailers were accurate in many cases but were based on the information received from the client or the shipping agent and could therefore vary in accuracy. The weight given for goods reloaded to roll-trailers within the terminal was the actual weights.

An important responsibility of the supervising officer was to send lighter semi-trailers up to the Weather Deck and heavier units to the Tank Top and to the Main Deck, to ensure the stability of the ship on departure. A general limit of 550 tonnes of cargo on the Weather Deck of Finnbirch was set for reasons of stability. It had happened on board Finnbirch that loading of the Weather Deck was delayed until more cargo was available for the Tank Top and Main Deck to maintain stability at the berth.

The Mate also checked the units visually. If the load on a roll-trailer was judged to be inadequately secured, it was returned to land for corrective action. The contents of semi-trailers were much more difficult for the crew to check according to information from interviews and the subsequent maritime inquiry. According to the crew approximately a third of the semi-trailers were sealed. It took time, for example, to open the tarpaulin of the trailer to obtain an impression of how the cargo inside was secured. The Mate concerned said that they had insufficient time to check thoroughly. Approximately 30-40 units were being loaded per hour and, in addition to noting the arrival of each and entering it in the stability program, their work included controlling the pumping of ballast and operating the ramp and lift.

Finnlines state that the number of units per hour is less than the number given by the crew, varying between 2 and 27 units per hour during the loading day.

During the loading, it was the duty of the seamen to continuously check the securing of the cargo. One seaman, at times in company with the bosun, checked the securing continuously during the loading. The number of lashings of each unit was determined by the deck on which the cargo was located.

The wet weather during the loading probably lead to that an amount of water mixed with gravel and dirt arriving with the trailers, accumulated on the cargo decks.

Fig. 3 The above photo taken on board the sister ship M/V Finnforest in Helsingfors in December 2006 shows the collection of water on the Upper Deck following rain.

1.7 Securing of the cargo

1.7.1 Securing of the cargo on board the ship

It has not been possible to establish with absolute certainty how all parts of the cargo were secured on Finnbirch during its final voyage. It has, however, been possible to reconstruct largely the cargo-securing level by means of interviews with the crew and the stevedoring company, through visits by SHK to the sister ship Finnforest which used the same route as Finnbirch and through a visit to the reloading terminal in Norra hamnen. From interviews with crew members from both ships, Finnbirch and Finnforest, and personnel from Finnsteve, it has been learned that the cargo-securing level was the same on both ships and that it was only marginally changed after the accident.

Cargo securing equipment

The cargo securing equipment used on Finnbirch for securing trailers on the Upper Deck and the Weather Deck was mainly a 13 mm chain whereas web lashings were used on the Main Deck and on the Tank Top. The chains had a Minimum Breaking Load (MBL) of 20 tonnes and a Maximum Securing Load (MSL) of 10 tonnes. The web lashings had a MBL of 12 tonnes and a MSL of 6 tonnes.

It was the duty of the crew to keep stock of and to check the cargo securing equipment, remove defective equipment and order new equipment from Finnlines. This routine was documented within Finnlines. From receipts for material supplied to Finnbirch by Finnlines, it is seen that e.g. during the period between January 2006, when Swedish Maritime Administration drew attention to the failure to remove defective web lash equipment, forward to the time of the accident, a total of 429 web lashings were delivered to Finnbirch, distributed over 10 different occasions.

Stowage and securing of roll trailers on the ship

A large proportion of the roll-trailers were block-stowed. This means that across the ship, they were placed closely together along one long side of the ship or against another roll trailer placed there earlier. Even fore and aft the roll-trailers were backed closely against the previous row. They thus became packed together closely in both directions. As the width of the stowed trailers does not equal the width of the cargo hold, there will be a remaining empty space along one side of the ship.

The roll-trailers are manoeuvred on board with a terminal tractor. In this, the steering wheel is located on the left hand side so that the driver has a good view of the left hand side of the trailer when the unit is backed in against the ship's side or other trailers already in place. On the Tank Top, the roll-trailers are backed into place from the direction of the bow and are therefore parked close to the port side. On the Main Deck, they are backed from the direction of the stern and are parked close to the starboard side. SHK has been told the forward support of the roll-trailers was placed on a rubber mat.

According to the cargo plan from the voyage, (see Appendix 1) there were 17 roll- trailers with a length of 40 ft. (12.2 m) and 6 roll-trailers with a length of 20 ft. (6.1 m) on the Tank Top. These were probably block-stowed.

On the Main Deck were 28 roll-trailers of varying lengths 30-48 ft, mostly 40 ft. (12.2 m). Of these, according to the loading plan, half were block-stowed and half were lane stowed. As the units were parked in lanes there was space between the units both transversely and longitudinally. The total weight (cargo + cargo transport unit) of the roll-trailers varied between 20 and 53 tonnes with a mean weight of 33 tonnes. A roll-trailer was located on each of the Upper and Weather Decks. Both of these were parked in lanes as they were located together with semi-trailers.

It has not been possible to determine the number of lashings used on individual roll-trailers on the voyage as instructions in the cargo-securing manual and information provided by witnesses are in conflict. It has however been found that web lashings with MSL 6 tonnes were used on the 45 units on the Tank Top and Main Deck whereas 13 mm chains were used on the two units located on the Upper and Weather Decks respectively. The heaviest individual units on the Main Deck weighed approximately 44 tonnes each and were loaded with paper reels or with hardboard.

Although the cargo-securing manual required four to six chains, the Master considers that a lane stowed roll-trailer should be secured with eight lashings applied as shown in the following sketch.

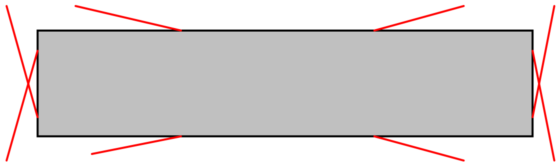


Fig. 4 Sketch showing how the Master considers the lashings should be applied on a lane stowed roll-trailer, as seen from above.

Roll-trailers stowed in a block should be secured, according to the Master, at the front end in accordance with the following sketch.

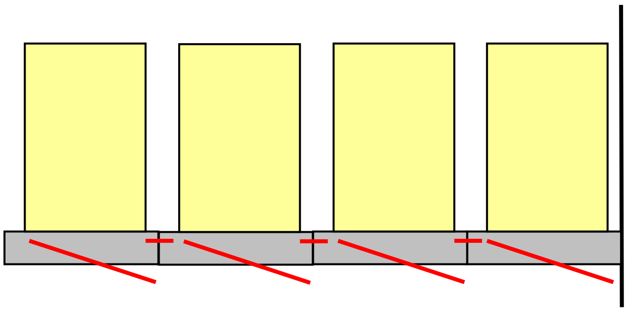


Fig 5 Sketch showing how the Master considers that block-stowed roll-trailers should be secured at the front.

He was less certain how the rear ends of the roll-trailers backed together should have been secured as it is difficult to reach these to perform the lashing. The heaviest block-stowed roll-trailers in the cargo were loaded with paper reels and weighed 50-54 tonnes.

When SHK visited the terminal in Helsinki in September 2007, it was observed that the block-stowed roll-trailers on the sister ship Finnforest were secured at the front, in principle, in the manner described by the Master. See the right-hand photo, Fig. 6. The rear ends were not secured.

The left-hand photo in Fig. 6 shows that in some cases, the securing was only applied in the form as a half cross as shown in Fig. 7 and there was no horizontal lashing holding the roll-trailers together. There were other examples in which block-stowed units were only secured to the adjacent unit, the outside unit being secured to the ship’s side with one lashing.

Fig. 6 The photo at the left shows roll-trailer 625 219 stowed on the Tank Top on board Finnforest and only secured with a half cross at the front of the unit. The Photo at the right shows roll-trailers on the Main Deck secured with a half cross plus one horizontal lashing.

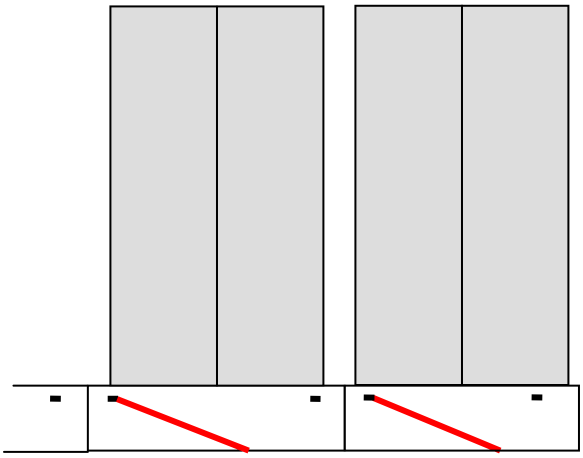


Fig. 7 Sketch showing how block-stowed roll-trailers in certain positions on board Finnforest in September 2007 were secured.

A separate explanation of the risk of sliding and tipping of roll-trailers with this type of securing is given in section 1.17.4 below.

When visiting Finnforest, SHK observed that roll-trailers on the Main Deck were block-stowed against the starboard side of the ship, as is normal practice when using terminal tractors.

Securing of semi-trailers

As shown in the load plan (Appendix 1), there were 4 semi-trailers on the Tank Top, 15 on the Main Deck, 42 on the Upper Deck and 30 on the Weather Deck.

When the semi-trailers were placed in position, they were supported on trailer horses and not on their own supporting legs. Two rubber chocks locked the wheels of each semi-trailer. A Finnsteve employee was detailed to release the air from the pneumatic suspension of the semi-trailers. That this was done was confirmed by the crew who heard the hissing noise of escaping compressed air.

The table on the next page shows the number, type and strength of the lashings for semi-trailers which the crew stated were used generally and in particular on the final voyage of Finnbirch.

Deck	Lashings used Number	Strength MSL (tonnes)
Tank Top	6 web lashings	6
Main Deck	6 web lashings	6
Upper Deck	6 chains*	10
Weather Deck	8 chains	10

** According to the Master, 8 chains should have been used per trailer on the Upper Deck in winter and 6 in summer. On the final voyage, only 6 chains were used per trailer on this deck.*

Most of the semi-trailers are used in a circulating transport system and reappearred regularly. According to information received at the port, only a small proportion, approximately 0.5% could be without secured fixings for lashings.

A separate explanation of the risk of sliding and tipping of semi-trailers with the relevant securing is given below in section 1.17.7.

Securing of sto-ro-cargo

For the final voyage of Finnbirch, approximately 500 tonnes of paper reels were stowed forward on the main Deck. The reels were stacked three or four high and each stack was approximately 3 m high, depending on the reel dimensions. According to the crew, the aft free face of this cargo was not secured. Walking boards, a type of laminated boards were placed vertically against the reels and roll-trailers were backed toward these. Finnline instructions are that roll-trailers should not be backed to make contact with sto-ro cargo. A space of at least 1 ft. should remain open, which means that the sto-ro cargo was not secured and the last row of the stacks of rolls was free to move. Shoring material or air bags were not used to fill any spaces between the reels. The ship's cargo-securing manual required the securing and shoring of sto-ro-cargo.

That the sto-ro cargo was transported unsecured and without shoring material was established practice on board both Finnbirch and Finnforest and was common also on other ships chartered by Finnlines.

Securing of cargo on roll-trailers.

SHK has received conflicting information about the number of lashings used for securing paper cargo on roll-trailers for transport on the Baltic Sea. Interviews with persons responsible for cargo handling at the terminal in Helsinki have elicited the information that paper reels on roll-trailers are secured either with 6 m long corner protections and two chains or with so-called WisaFix hoods.

Finnlines has however informed SHK that three chains are used for each corner protections for transport on the Baltic Sea and that WisaFix was not used on board Finnbirch on the final voyage. Finnlines also state that cargo on transport units is secured at six different levels of security, depending on the type of ship and that these security arrangements are documented. No such documentation for the final voyage of Finnbirch has been available.

During the maritime inquiry subsequent to the sinking, the Second mate of Finnbirch has stated that paper reels were stowed on roll-trailers two or three high, depending on the dimensions of the reels, held in place on the platform with corner protections and secured with a total of either three or four chains.

This means that either two or three chains were used per each long corner protections on a 40 ft. roll-trailer. All informants assert that other than the free height available between decks on the ship concerned, there is no specified limit to the stowage height on cargo transport units. Finnbirch had a free height of 5.8 m on the Main Deck.

An example is shown below, from discharge of cargo from M/V Antares at Rostock in September 2004, of how two chains per long corner protection have been used in Finnlines traffic on the Baltic Sea. Large paper reels, so-called jumbo reels were also in the cargo, completely unsecured, on roll-trailers. The Master of Finnbirch has been shown the picture below and is of the opinion that this level of securing of papers reels may not have been unlikely on Finnbirch.

Fig. 8 Paper reels on a roll-trailer during discharge of cargo from M/V Antares at Rostock in September 2004. Two chains per long corner protection secure this cargo.

Corner protections of both plastic and aluminium are used for securing cargo with corner protections and chains. No specification of the strength required of corner protections has been developed.

During the visit by SHK on board Finnforest during loading in Helsinki in September 2007, a number of observations with reference to cargo-securing of paper reels on roll-trailers were noted.

On each of the two roll-trailers (Fig. 46) located forward on the Main Deck, 110 reels were stowed in two lines and as 11 sections i.e. a total of 22 stacks with 5 reel in each stack. Each reel weighed approximately 460 kg.

Each stack had a height of approximately 3.3 m. The cargo was secured with WisaFix hoods with 8 straps on each long side and two on each short side. The straps were not tightened particularly and the pretension force S_{TF} was estimated to be approximately 1 kN (100 kg).

Fig. 9 Paper reels stowed on a cargo transport unit in the Helsinki terminal, a cargo section 5.25 m long secured with corner protection and two chains. Photo taken during visit by SHK in September 2007.

Fig. 10 Securing of large diameter reels on board the sistership Finnforest. A lashing has been placed over the midpoint of a long corner protection which holds two reels. At the left are palletted goods in the form of sheet paper. Photo taken during a visit by SHK in September 2007.

Securing of cargo in semi-trailers

How the cargo on board the approximately 90 semi-trailers on board Finnbirch on its final voyage was secured is unknown as this work in semi-trailers is mostly performed by individual truck drivers or terminal workers ashore.

In August 2007, the Finnish Accident Investigation Commission visited the despatch terminal at Rautaruukki in Järvepää, a firm which manufactures steel products which were often shipped via Finnbirch. The loading work was normally performed by a Rautaruukki truck driver under the supervision of the driver of the semi-trailer from the trucking/forwarding company.

The bed for the cargo is prepared by the driver of the semi-trailer who also performs the lashing work. He normally does this without specific instructions from Rautruukki but determines himself how the securing of the goods is to be done. A plastic-covered card, one example only, with illustrations and instructions in four languages explaining how the different products are to be secured for transport was available at the terminal. At the Rautaruukki despatch terminal, the personnel considered that they are not responsible for the securing of the cargo on the semi-trailer.

It was observed that the level of cargo securing and quality of lashing equipment varied between transport firms, some had a better standard than others.

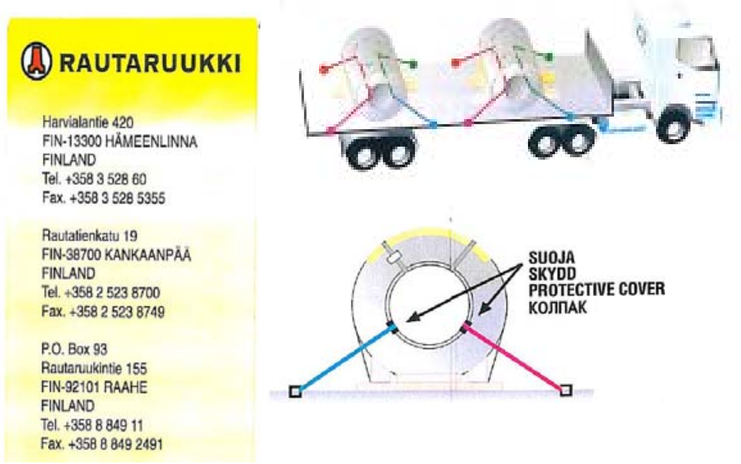


Fig. 11 Sketch showing the Rautaruukki securing instructions.

The Rautaruukki cargo-securing method is considered by SHK to be ineffective in preventing transverse movement and is radically different from recommendations for securing sheet steel coils in the European Best Practice Guidelines on Cargo Securing for Road Transport published by the EU Commission 2006 and Swedish guidelines on securing cargo published at the beginning of the 1990's. See the sketch below.

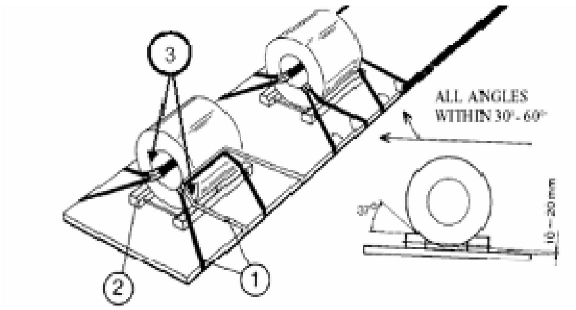


Fig.12 Instructions for securing steel coils from the European Best Practice Guidelines and the TFK guidelines.

The Finnish Accident Investigation Commission also visited the Schenker forwarding agency which manage the largest terminal in Helsinki. Approximately 700 semi-trailers leave the terminal each day. It is stated that within Schenker, the entire transport chain has received training in cargo-securing. The management and personnel have also participated in Finnlines information about cargo-securing. The cargo transported by Schenker consists of general cargo. The units to be transported are assembled in the terminal and secured on the semi-trailer by Schenker personnel. Supervisors at the site check the securing of the cargo. Web lashings with a breaking strength of 4 tonnes are the usual lashing material.

The major part of Schenker loads (approximately 70%) are however transported directly from the supplier as full semi-trailer loads to the harbour and on board. In such cases, the semi-trailer driver, mostly working for private trucking firms, secures the cargo. The semi-trailers and securing material are either owned by Schenker in Finland or in Denmark while the prime movers are owned and driven by sub-contractors.

Fig. 13 Schenker, import goods.

When the driver submits his log to Schenker, this includes the loading report in which the securing material used is specified and a sketch of the load distribution (full/partly full) in the unit.

The visit to Schenker also showed that the standard of securing of imported cargo was considerably lower than that of cargo secured at the terminal for export. Workers at the terminal stated that units from Spain and Italy in particular were often inadequately secured.

When visiting the terminal in Helsinki in September 2007, SHK judged that about a third of the units were sealed. The securing of cargo was examined in some units on board Finnforest which were not sealed.

Paper reels with a diameter of 1.30 m were seen in another semi-trailer, standing on end. These were secured with very long, longitudinal lashings. A number of transverse lashings over the top had been applied but because there was no long retaining angle, many of the lashings had fallen off. Some of the web lashings were in very poor condition and some were tangled. (Fig. 15)

Fig 14 6-tonnes steel coils from Rautaruukki loaded on semi-trailer in Finnforest. These are secured in accordance with the company's instructions.

Fig. 15 Paper reels in semi-trailer on board Finnforest in September 2007.

During 2007, Finnish authorities performed 23 inspections in different harbours in the Gulf of Finland on load-securing in and on cargo transport units and transport of dangerous materials. A total of 346 units were inspected of which 227 were semi-trailers and the remainder containers. Shortcomings with respect to the securing of cargo were noted in 44.5% of the units.

The Finnish Maritime Inspectorate participated in the inspections but as this authority has not developed its own national regulations in this field, approval of load-securing on transport units is largely based on the experience of its inspectors as seafarers. There is however a requirement for a maximum transverse acceleration forces of 0.5 g on cargo-securing for both road transport and marine transport on the Baltic Sea.

During the inspections, a difference between the level of cargo-securing in export and import cargo was observed. Of semi-trailers discharged, there were shortcomings in cargo-securing in 103 units (61%) of which 101 (60%) were so serious that further transport was inhibited. Of 58 semi-trailers to be loaded, shortcomings were found in 14 cases (24%) of which 12 (21%) were so serious that further transport was inhibited.

1.7.2 The cargo-securing manual on Finnbirch

According to SOLAS Chapter VI, all ships except for pure bulk-carriers and tankers should be provided with a ship-specific cargo-securing manual. The manual is to be approved by the relevant authority of the country of registration and the cargo is to be secured in accordance with the instructions in the manual. The manual is to be prepared in accordance with the guidelines in MSC/Circ 745 and is to contain information regarding the accelerations which can affect the cargo on board and the strengths/dimensions of the means of cargo securing required to withstanding these accelerations.

An approved cargo-securing manual designated ”M/S Bore Gothia SLNK Cargo securing Manual” was kept on board Finnbirch, and SHK has been provided with access to the copy submitted for approval to Swedish Maritime Administration, SMA, in Stockholm. The manual was dated 1996-06-26 and was received by SMA on that day. There was no stamp of approval on this copy but SMA has certified their approval. Copies of another manual which had not been submitted to SMA for approval were kept at the Owner's office and on board Finnbirch. The contents of this manual, apart from certain departures from the original manual, were largely in agreement with the one submitted to SMA but were translated into English.

The arrangement of chapters in the original manual differs somewhat from MSC/Cirk. 745. The manual also contained an example of the calculation of the listing of the ship caused by a hypothetic total cargo shift.

The manual further contained the rules which applied on Swedish ships for the securing of cargo in accordance with SJÖFS 1994:27. In addition, the manual referred to IMO Resolution A.489 (XII) with respect to layout.

The acceleration values given in the manual were calculated with the help of the Det Norske Veritas method and not in accordance with the Annex 13 to IMO Code of Safe Practice for Cargo Stowage and Securing (CSS).

In the introduction to the manual, it is stated that ”This cargo-securing manual specifies the arrangement and equipment for the securing of cargo on board the ship, for the correct placing and securing of cargo units, based on transverse, longitudinal and vertical forces which can be experienced under heavy weather and sea conditions.”

The manual, however, did not contain the warnings given in CSS Annex 13 which state that the accelerations given can be exceeded unless special caution is observed in certain circumstances such as a heavy head sea, resonance with beam seas or with heavy following seas.

The cargo securing was given schematically for each deck i.e. showing that the same number of lashings was specified for a certain type of cargo unit, irrespective of its weight and the location of its centre of gravity. The manual contained no calculations of the stresses these cargo securings were to withstand nor the weight of the secured unit assumed for this. Thus there was no relation between the calculated accelerations and the number and strength of the lashings in the different securing arrangements.

No instructions were provided nor examples given of how the strength and number of lashings required could be calculated on the basis of the accelerations specified.

Section 4.1 of the manual stated how different types of load; sto-ro, roll-trailers, semi-trailers, tractors/machinery, vehicles etc. should be stowed and secured on the different decks. Section 4.2 described the securing of these different types of load on an unspecified deck. This section was largely obtained from Finnlines' instructions for securing cargo on board ship (see below). There were no instructions regarding the angular placement of the lashings to effectively prevent sliding and/or tipping.

During interviews it was disclosed that the manual had been assembled by a group of ship's officers and its parts obtained from different sources. Much was copied from the guidelines used within Finnlines. Otherwise, the manual described approximately how the cargo was habitually secured in the ship. In the introduction to Chapter 4, it is stated that the description of how the cargo is to be secured is based on both calculations and experience.

The following instructions for the securing of different cargo types are given in the cargo-securing manual:

Securing of roll-trailers

According to the cargo-securing manual for Finnbirch, roll-trailers are to be secured with chains without the required strength of these being specified. The lightest chain to be used on board for cargo-securing was specified in Chapter 3 as 11 mm chain with minimum breaking load (MBL) 15 tonnes. With designation and safety factor according to CSS Annex 13, this gives a maximum permitted loading (MSL) of 7.5 tonnes.

For block-stowed roll-trailers, the manual states ”*If the ends of roll-trailers cannot be secured to the deck, they may be lashed together provided that a sufficient number of the roll-trailers in the block are properly secured to the deck*”. The sufficient number is not specified.

The following arrangement was shown in the manual for the securing of block-stowed roll-trailers.

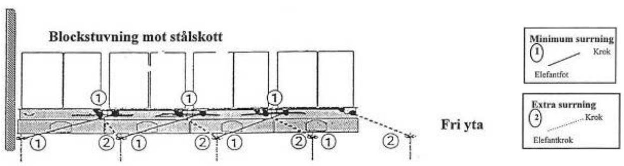


Fig. 16 Instructions in the cargo-securing manual for securing of block-stowed roll-trailers.

It was stated that lashings marked 1 were a minimum provision whereas those marked 2 were extra, without it being specified when the “extra” lashings were to be used.

According to section 4.1 of the manual, 40-foot roll-trailers stowed in lanes (not block-stowed) were to be secured to the deck with six chains, two on each end and one on each long side. In section 4.2.3 it is stated that four chains are to be used for basic securing, two per end which should be cross-lashed to the deck. There are no corresponding instructions for crossed lashing in Finnlines' guidelines in which it is specifically stated that cross-lashing is to be avoided.

All of the roll-trailers shown in the manual have low loads *(Fig. 16)*, and no maximum height or weight for which the lashings specified are applicable is given.

Securing of semi-trailers

According to the cargo-securing manual for Finnbirch, semi-trailers are to be secured on the Tank Top and Main Deck with chains, without the required strength of these being given, and it is therefore not certain if the arrangement requires the use of a 11 or 13 mm chain. The use of 13 mm chains are specified for securing semi-trailers on the Upper Deck and Weather Deck. The number of chains for securing semi-trailers on the different decks was specified in the manual and the requirements can be summarized by the following table.

Deck	*Specified lashings (CSM)*	
	Number	*Strength MSL (tonnes)*
Tank Top	*6*	*7,5–10*
Main Deck	*8*	*7,5–10*
Upper Deck	*8*	*10*
Weather Deck	*8*	*10*

According to the instructions in the manual approved by the Swedish Maritime Administration, the landing legs should be wound down on semitrailers and a rubber mat placed under the feet of the legs after the trailer has been located on the supporting trailer horse.

Securing of sto-ro-cargo

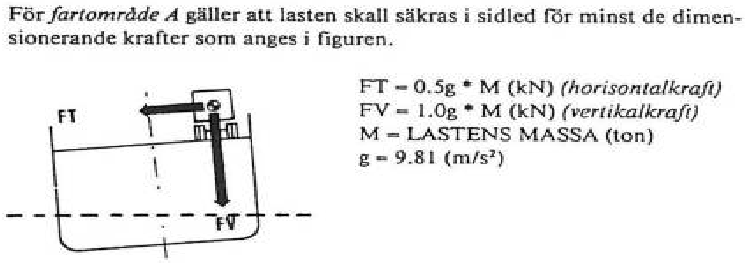
According to the cargo-securing manual for Finnbirch, the free end of Sto-ro cargo should be secured with lashings from the deck above, over an aluminium corner protection and down to the lashing points in the deck on which the cargo is placed. The lashings may be either web lashings or chains.

Air bags or similar should be used to fill the spaces between the units of the sto-ro cargo.

Cargo securing in and on cargo transport units

According to the cargo-securing manual for Finnbirch, cargo on cargo transport units should be secured to withstand at least the dimensioning forces for the route concerned in accordance with SJÖFS 1994:27 §§ 7 and 8. An extract from this regulation was attached to the manual and from this it appears that for transport on the Baltic Sea, cargo on cargo transport units should be secured transversely to withstand a force equivalent to half the weight of the cargo; 0.5 g or 5 m/s^2, for transport on the Baltic Sea, in combination with gravitational forces according to Fig. 17.

For trade area A, the cargo shall be secured transversely to withstand at least the dimensioning forces given in the figure.



FT = 0.5g * M (kN)
horizontal force
FV = 1.0g * M (kN)
vertical force
M = MASS OF THE CARGO (tonnes)
$g = 9.81\ (m/s^2)$

Fig. 17 Extract from SJÖFS 1994:27.

Listing after cargo shift

The cargo-securing manual for Finnbirch also contained calculations for the listing of the ship resulting from the shift of the cargo. The cases considered were a full load of units stowed in lanes and secured individually and a load consisting of several units on the Main Deck and on the Tank Top, block-stowed as usually.
The results obtained are shown e.g. in the diagram below showing the righting and heeling lever.

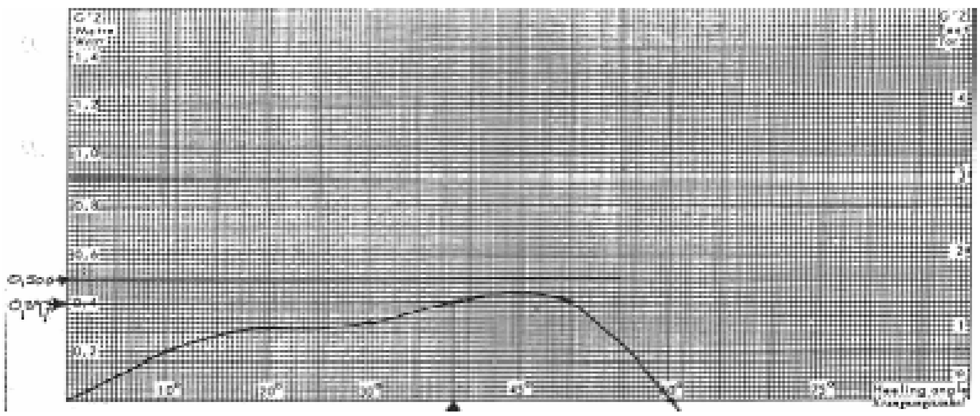


Fig. 18 The calculated righting and heeling lever at a total cargo shift. The larger heeling moment applies for the loading case with completely free-standing units.

The diagram shows that the ship would capsize if a total shift of completely free-standing units occurred. The lower value of the heeling moment applies with a corresponding loading situation but where parts of the load on the Main Deck are block-stowed. The heeling angle is judged in this case to reach 38.5 degrees with a very small stability margin remaining.
The following was noted further in this chapter: ”*With heeling angles of this order of magnitude, the scupper openings on the Main Deck would be under sea level and all of these should be closed as soon as possible (if accessible under the shifted cargo) to reduce the risk of water entering the Main Deck (non-return valves are fitted).* ” It was also pointed out that the poop decks (the aft berthing decks) would also be under water at such considerable heeling angles and therefore important to keep the hatches to trunks from these decks and the spaces underneath closed.

Amendments made in cargo-securing and in the cargo-securing manual with the passage of time

From interviews, it has been elicited that cargo-securing practices on board Finnbirch changed over the years, not least when the ship entered into Baltic Sea traffic in 2000. Inter alia, web lashings were used instead of lashings of chain on the Main Deck and the Tank Top. This change followed an agreement between the Finnlines cargo-securing department, who supplied the cargo-securing equipment, and the Masters of both sister ships. This was known to the ship's owners even if they had not been engaged in the discussions which led to the decision. In October 2002, Finnbirch reported a non conformity to the ship owner that the cargo-securing equipment was not in accordance with the requirements of the cargo-securing manual, this having been pointed out during a PSC in Denmark. It was also noted at this time that no information about the strength of the cargo-securing equipment was available on board. It was requested that the relevant information should be obtained from Finnlines to permit subsequent correction of the manual. This has been done and is confirmed by notes on the non conformity report.

The cargo-securing manual was a part of the documented safety system (ISM) in use by the ship owner. The proposed amendments in the manual requested from the ship were entered into the system and a new document was prepared and sent to the ship to be signed by the Master for filing in the manual on board. A copy of the new document was also filed with the ship owner's copy of the manual.

The copy of the manual held at the owner's office is the English translation/revision of the manual approved by the company's managing director in November 2003. It contains the following differences as compared with the manual approved by Swedish Maritime Administration:

1. A sketch showing the location of the fixed cargo-securing equipment has been included in Chapter 2.
2. In the inventory of loose securing equipment in Chapter 3, the breaking load of the equipment has been given as Safe Working Load.
3. 9 mm chain intended for securing sto-ro cargo has been deleted from the list of loose lashing material.
4. Web lashings 2,5 m long have been added to Chapter 3 with the comment that they are intended for securing semi-trailers, roll-trailers and other vehicles. The instructions for securing these cargo units with chains remain unchanged in Chapter 4.
5. Instructions for use of tension levers in Chapter 3 have been deleted.
6. The requirement in Chapter 4 that the supporting legs of semi-trailers is to be wined down before transportation has been deleted.

None of the amendments made to the cargo-securing manual have however been submitted to Swedish Maritime Administration. According to the ship's officers, this is something which should be attended to by the ship owner's personnel who are not aware of any such responsibility.

Approval of the cargo-securing manual

According to the guidelines which the head office of Swedish Maritime Administration has prepared for the checking of manuals, the calculations in the cargo-securing manual were not to be checked by Swedish Maritime Administration, but it was incumbent on the ship owners to present correct calculations. The duty of the person checking the manuals was to primarily ensure the manual contained largely the sections and chapters included in the international guidelines. No estimate of the strength of the cargo-securing arrangements in relation to the accelerations specified was therefore done. The manual was approved on the basis of the calculations which showed that a complete cargo shift would lead to an immediate capsizing.

These internal guidelines for checking and approving cargo-securing manuals have been and remain in effect at Swedish Maritime Administration where relevant knowledge is not formally required of the inspectors checking and approving cargo-securing manuals. The employee who approved the cargo-securing manual for Finnbirch had received a short period of training in securing of cargo but admitted that he was not certain how the calculations on which the manual was based should be performed.

1.7.3 Finnlines' guidelines for cargo-securing

"Guidelines for Cargo Handling" are included in the Finnlines' quality system. These include instructions for both the securing of cargo on cargo transport units and the securing of cargo and cargo transport units on board a ship. Finnlines' instructions have been developed over long time and are based on practical experience rather than on theoretical calculations. The company has an internal group working on the follow-up of cargo damage and cargo damage statistics. Damage to cargo in the event of major casualties such as the sinking of Finnbirch is however not included in the statistics and are therefore not subject to closer analysis.

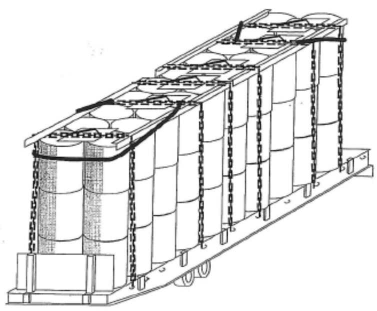
No calculations have been performed regarding cargo-securing arrangements presented in the manual to determine which acceleration stresses they withstand. Nor have calculations been performed to verify that the cargo-securing arrangements specified withstand the acceleration stresses specified in the IMO guidelines for securing cargo in and on cargo transport units. No practical tests have been performed to verify that the cargo-securing arrangements are in accordance with international recommendations.

Finnlines has, however, performed a series of tests at the beginning of 1987 which demonstrated that high stacks of paper reels secured on roll-trailers tipped over with approximately 20 degrees of static heeling. These tests were supplemented with a new series of tests during autumn 2007. See section 1.17.5 below.

Guidelines for securing cargo on roll-trailers

The Finnlines guidelines include the following instruction for securing small reels of paper on roll-trailers.

Small reels



- In the North Sea Services, three chains for each long aluminium profile
- In the Baltic service, two chains for each long aluminium or plastic profile

Fig. 19 Finnlines' instruction for securing small reels on roll trailers.

The guidelines show that on the Baltic Sea, two chain lashings are placed over each long (6 m) corner protection.

The guidelines are however general and do not take into account the constituents of the load, its height and the dimensions of the goods. As an alternative to long corner protection and chains, WisaFix-hoods with straps sewn in may be used for securing paper reels on roll-trailers as shown below:

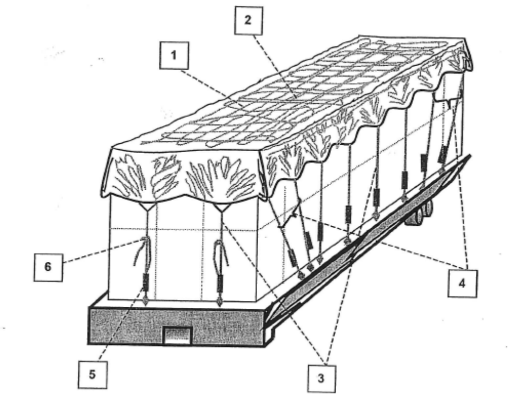


Fig. 20 Extract from Finnlines' guidelines for securing cargo with WisaFix-hoods.

In addition to these guidelines, there is a Finnlines instruction used at the reloading terminal which gives, on six different levels, more precise directions for the securing of cargo depending on the type of vessel to be loaded. For example, on one ship type, certain cargo (so-called jumbo reels) may be loaded on the cargo transport unit without lashing. According to Finnlines, WisaFix was not used on Finnbirch on its final voyage.

Guidelines for securing cargo on semi-trailers

Finnlines' guidelines for cargo-securing contain no instructions for securing cargo on semi-trailers. Finnlines has however used the manual "Kuormansidontakäsikirja" prepared by the Finnish ICHCA 1998 for information to its clients describing how cargo should be secured on cargo transport units for transport on board a ship.

Guidelines for securing roll-trailers on board a ship

Finnlines' guidelines state that roll-trailers may be secured to each other if no suitable lashing points in the ship's deck are available and if a sufficient number of roll-trailers in a block are secured to the ship.

At least four lashings are required to secure a free-standing roll-trailer. Lashings at the ends of roll-trailers are not to be crossed except as a supplement to straight lashings as shown below.

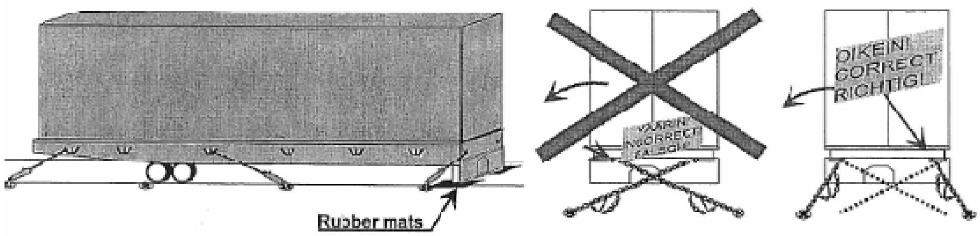
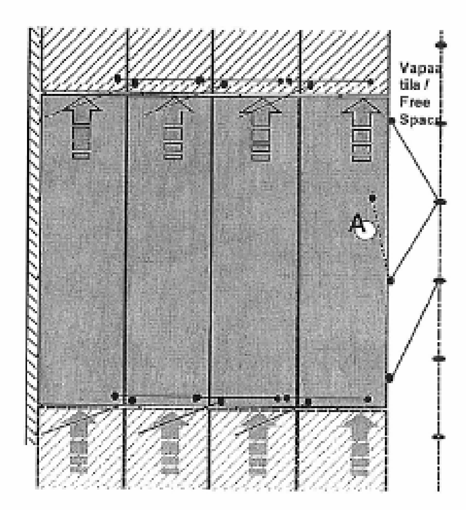
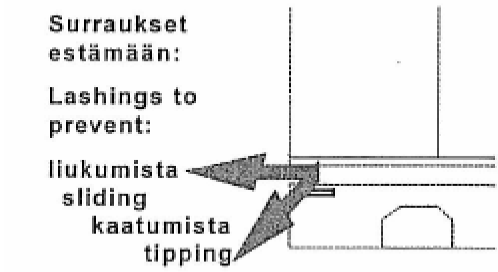


Fig. 21 Finnlines' instruction for securing free-standing roll-trailers.

An example of how roll-trailers stowed in blocks are to be secured is shown in Fig. 22 below. The units are to be stowed closely together both transversely and longitudinally and secured to the deck and each other at the free end only. The end which has been backed toward a trailer already stowed is not lashed.





It is stated that the lashings must be used to prevent both sliding and tipping.

Fig. 22 Finnlines' instructions for securing block-stowed roll-trailers.

Guidelines for securing semi-trailers on board ships

Finnlines' guidelines require e.g. that the securing shall be so performed that it prevents movement of the units in any direction and in particular, tipping sideways. It is pointed out that cross-lashing does not effectively prevent tipping sideways. (See Fig. 21).

They do not state the number of lashings nor the type of lashing equipment which is to be used otherwise than for semi-trailers loaded with dangerous goods. These are to be secured with at least six chains without the strength of these being specified.

Guidelines for securing sto-ro cargo on board ship

The free end of paper reels stowed by truck and other sto-ro cargo, see figure below, is to be lashed in place with horizontal and vertical lashings. No exceptions from the securing of the cargo with lashings were documented.

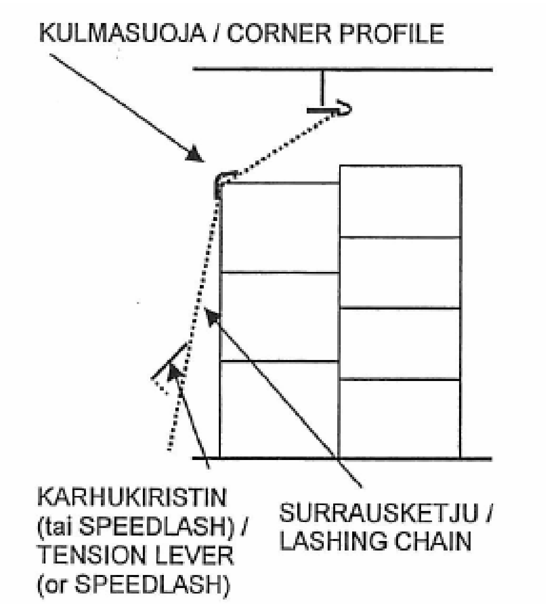


Fig. 23 Finnlines' instruction for securing of sto-ro cargo.

If roll-railers are backed against the free end of sto-ro cargo, the instructions require a space of at least 1 foot to remain free to avoid damage to reels when the roll-trailers are lifted by the terminal tractor.

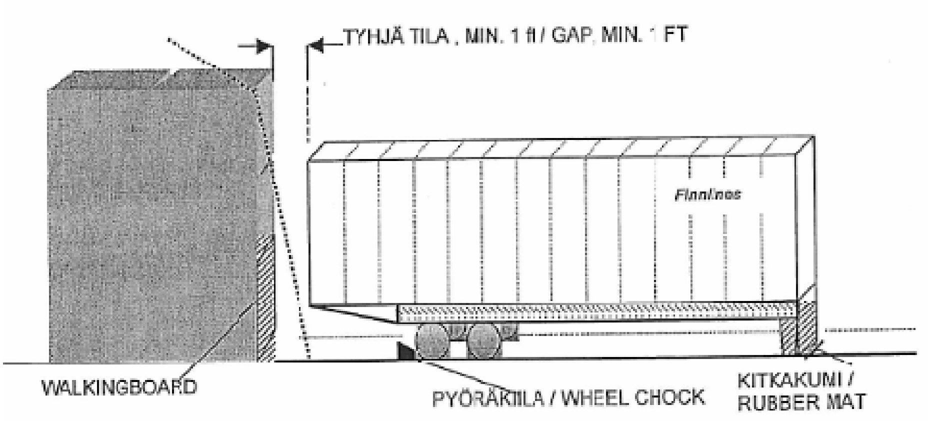


Fig. 24 Finnlines' instruction for minimum distance between roll-trailer and sto-ro cargo.

According to Finnlines' instructions, spaces in sto-ro cargo are to be filled completely with air bags to minimize the risk of cargo shifting.

1.7.4 Distribution of responsibilty for loading and cargo-securing

Contacts and agreements relating to the day-to-day operation of Finnbirch and Finnforest have been primarily arranged between Finnlines and the crew on board the ships and between Finnlines and the technical inspector employed by the Owners. The Finnlines Traffic Manager for the Baltic Sea made regular visits to both ships in Helsinki. There is however no formalised collaboration of the parties in, for example, the form of regular meetings between Finnlines and Lindholmen Shipping or between Finnlines and the Masters. The Master of Finnbirch states that he has neither been invited to, nor on his own initiative, visited Finnlines or Finnsteve offices.

With respect to cargo-securing matters, Lindholmen Shipping referred to Finnlines on whom they relied in this connection. The Owners agreed that they did not discuss with Finnlines the change from chain lashings to web lashings on the Main Deck and Tank Top when the ships began their voyage between Helsingfors and Århus but were aware that this had been decided on. Being without in-house competence in cargo-securing matters, Lindholmen Shipping understood and agreed that agreements were made directly between Finnlines and the ship's officers without their direct involvement.

Regarding the securing of cargo, the Master stated that he was well aware of his comprehensive responsibility for the securing of the cargo on the ship but was of the opinion that the accepted practice was to follow the advice of Finnlines "you are to do it this way". He knew that Finnlines had a cargo-securing department and he saw no reason to question their judgement. With respect to his own employers, the owners of the ship, he understood that they considered that "if Finnlines has said so, you are to do it so".

None of the three Masters employed by the Owners interviewed by SHK considered that they could make independent decisions regarding cargo-securing in general on board their ships. One expressed it thus, "we can stop the loading of individual units with cargo that is not properly secured, and we do so, but we cannot tell Finnlines how they are to perform their cargo-securing work".

The Masters all expressed dissatisfaction with the standard of cargo-securing on semi-trailers. They felt the same way about the securing of cargo on roll-trailers and above all, when these were loaded with paper reels. One of the Masters remembered that he had raised this subject with a representative of Finnlines but the response received was that the arrangement was in accordance with the Finnlines cargo-securing instructions.

According to the ship's cargo-securing manual, cargo in, or on cargo transport units on board the ship is to be secured in accordance with the basic requirements according to SJÖFS 1994:27.

Whether the Finnlines cargo-securing system satisfies this requirement has not, to the knowledge of SHK, been discussed internally by the Owners nor have the owners raised the subject with Finnlines.

The Owners were not aware of the special stability characteristics of the ship. Nor did they know that the routine for cargo-securing on board the ship deviated in several ways from the requirements of the cargo-securing manual. It has been difficult to clarify completely the status of the Finnlines guidelines in relation to the chartered ship. The standard clauses attached to the charter-contract require that the securing of cargo is to be to the Master's approval. This has also been stressed by Finnlines.

The Finnlines quality system includes the manual "Guidelines for Cargo Handling", and according to the person responsible for the quality assurance system, suppliers of, for example, chartered tonnage, shall satisfy Finnlines' quality standards.

A lowering of the level of the Finnlines guidelines for cargo-securing on board could be agreed upon between the Traffic Manager and the ship. This type of non conformity was not documented.

Finnlines also explained that when a ship is chartered, Finnlines visit the Master on board, present their cargo-securing instructions and obtain his acceptance of these. Finnlines however do not request a copy of the ship's own cargo-securing manual or otherwise obtain information about the contents of this manual.

1.7.5 Training of the crew in the securing of cargo

Several of the ship's officers in Lindholm Shipping, including the Master of Finnbirch, had requested to the Owners to receive training in securing of cargo. Swedish Maritime Administration, in connection with inspections over several years, had recommended the officers being given such training. Training of ship's officers in the securing of cargo is not a statutory requirement but should be viewed as desirable. The Owners had not sent any of its employees to such a course before the sinking of Finnbirch, the motivation for this being that the company policy was "to follow statutory requirements of the relevant authority". This view of the Owner's policy was expressed at several levels in the organisation, both on board and on land and is confirmed by company documentation of its safety and environmental policies as expressed in its safety management system. There is however, a note in the minutes of the Swedish Maritime Administration auditing of the Owner's company activities in May 2006 that the Owners planned to budget for some form of cargo-securing training. After the sinking of Finnbirch, the Chief Officer of the sister ship Finnforest has received training in cargo-securing.

1.7.6 Monitoring and follow-up of cargo-securing in the ship

In connection with a PSC control in Denmark in 2002, it was pointed out that web lashings were used for securing cargo on the Main Deck and the Tank Top despite this not being expressed by the ship's cargo-securing manual which specified the use of chains. The Master wrote a non conformity report to the Owners and the manual was supplemented, from what can be read in the report, with a data sheet relating to the relevant lashings.

Swedish Maritime Administration (SMA) had not been informed of this nor of other changes in the cargo-securing manual introduced during the years as these had not been submitted by the owners to the authority. Nor had the SMA at any time checked that the actual cargo-securing standard on board was in agreement with the manual as approved.

During the SMA inspection of the ship in January 2006, attention was drawn to shortcomings in the work of the crew in not checking for and discarding defective lashing material. According to the Master, this was related to web lashings only and was due to there being no instructions on board for determining when web lashings should be considered to be worn out. Finnlines had prepared instructions for the discarding of defective lashings but these did not apply, as far as SHK could determine, to the type of lashings used on board. This was remedied by SMA sending photographs showing the state of wear at which the relevant straps should be discarded. A manual was then prepared and made available in the deck office.

As far as SHK is aware, no non conformity report has been written - apart from the report written in October 2002 after the PSC in Denmark – from the ship to the Owners, informing that the actual practical cargo-securing work on board was not in accordance with the instructions in the ship's cargo-securing manual. Nor have the shortcomings been observed in connection with the owner's own internal ISM auditing of the ship and Finnlines has not reported any non conformity from their own quality requirements.

1.8 The Voyage

1.8.1 The Route

Finnbirch and its sister ship Finnforest had been engaged in regular traffic between Helsinki and Århus since 2000. The route involved 36 hours at sea and 3 callings at port per week. Each second week, the ships alternately remained an extra day in Helsinki. It was after such an extra day in harbour that Finnbirch departed on its final voyage, delayed approximately four hours.

Delays were frequent on the route. The ships had difficulty in keeping to the timetable, to a degree because the time at sea according to the timetable was limited but mostly because loading and discharging cargo occupied more time than was allowed for. The volume of cargo on the route had increased over the years. The Master has stated that initially he had felt stressed in keeping to the timetable but had gradually become adjusted to the conditions. He has stated that he did not experience direct pressure from the owners or from Finnlines with respect to choice of course or delays resulting from difficult weather.

1.8.2 The voyage prior to the accident

The course followed was east and south of Gotska Sandön. The ship then continued for a time on a westerly course, partly to remain in the lee of Gotska Sandön to permit a more detailed check of the securing of the cargo, partly to obtain waves more directly from astern when the turn was made down between the islands of Öland and Gotland. An alternative, if the weather became harder, was to take a north-westerly course to presently come under the lee of the Swedish coast. A further alternative, when the ship arrived between Öland and Gotland, and depending on the sea conditions, was to continue on a southerly course and pass east of Bornholm instead of altering course at Ölands södra udde. One reason for choosing the course between Öland and Gotland instead of a course east of Gotland was to remain within coverage for mobile telephone.

Because of the weather, the shaft generator was not engaged, electrical power being supplied by two emergency power plants.

During the day, the crew had been employed in checking the securing of the cargo on the different decks, this being routine with heavy weather. The Upper and Main Decks were checked before lunch and the Tank Top after lunch.

During the check of the Tank Top, a minor leak of fuel oil from a double bottom tank was detected. Part of the crew were then detailed to attend to this leak, both on the Tank Top and in the engine room from which they pumped oil from the tank at the time when the ship heeled over.

The ship was not equipped with a Voyage Data Recorder (VDR). It was however equipped with an Automatic Identification System (AIS) by means of which the voyage could be traced from the Swedish Maritime Administration AIS recordings along the Swedish coast. The voyage could be followed forward until the minutes before the ship finally capsized and sank.

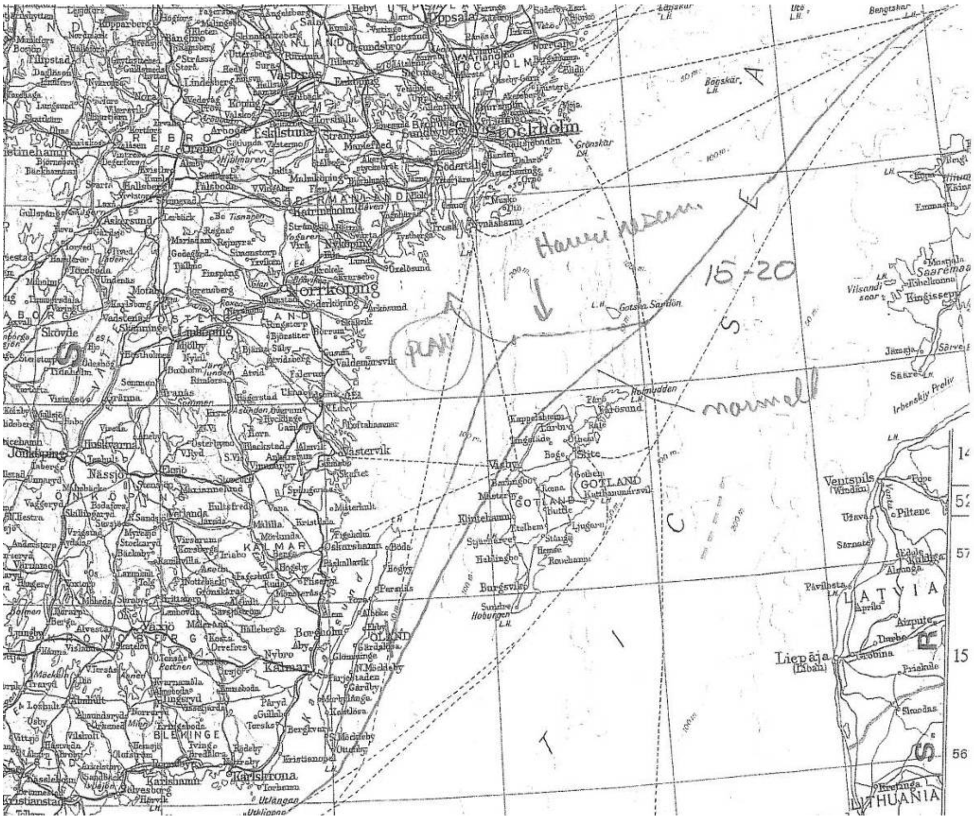


Fig. 25 Rough sketch of the final voyage of Finnbirch drawn for SHK by the Master.

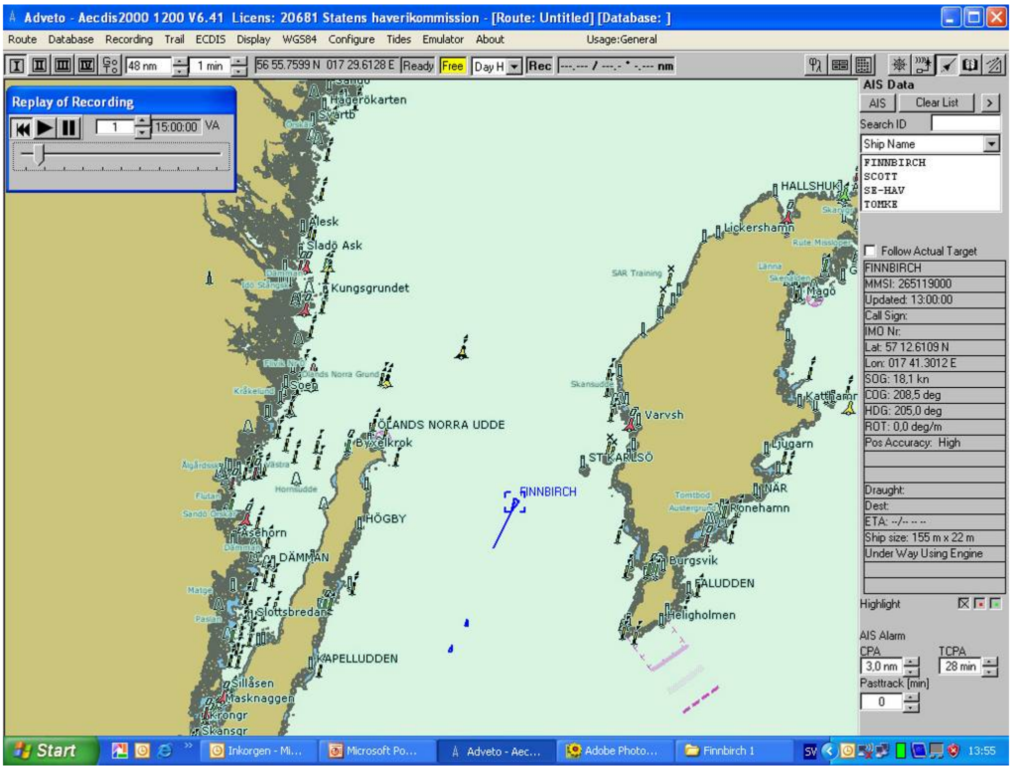


Fig. 26 Finnbirch at 1500 hours at the time of the last weather observations. The approaching ships Marneborg and Tomke which later took part in the life-saving operation can also be seen in the picture.

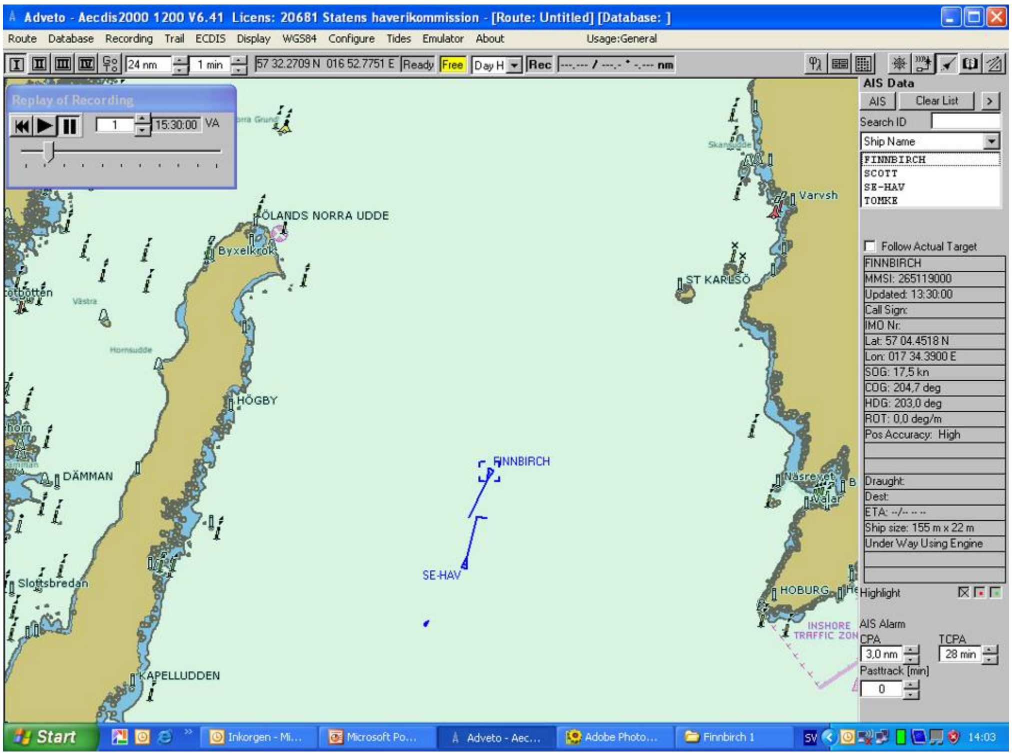


Fig. 27 Finnbirch at 1530 hours, approximately 10 min. before the sudden heeling of the ship. Finnbirch had begun its return to course 205. The ship with designation SE-HAV is Marneborg followed by Tomke.

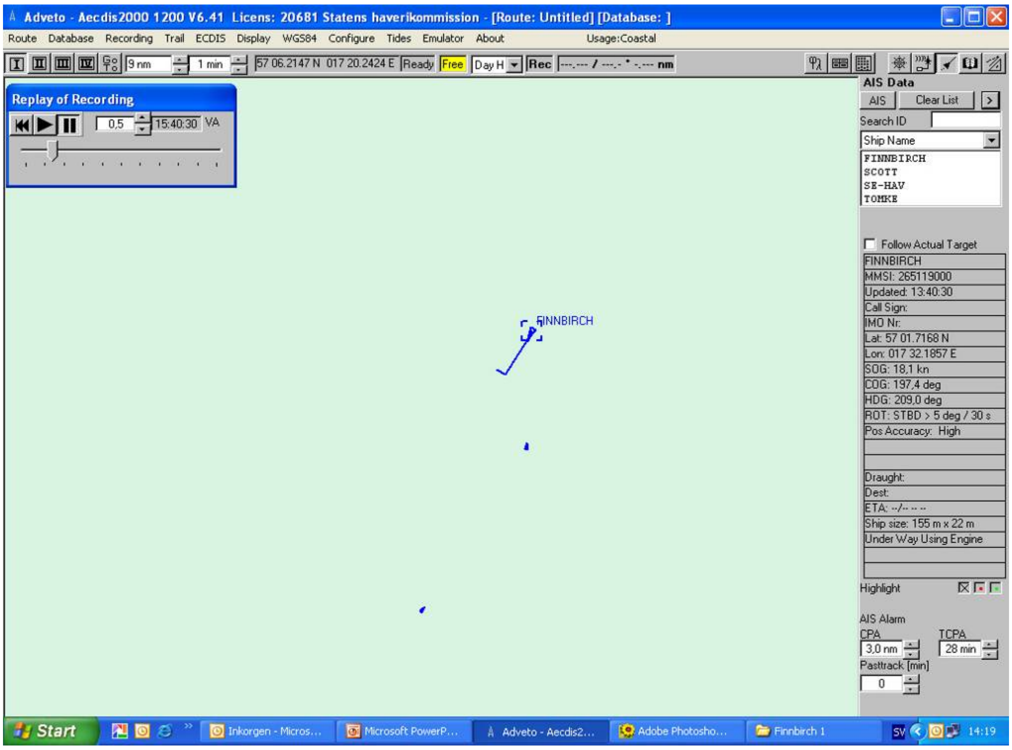


Fig. 28 Finnbirch at 1540 hours, at the time of the cargo shifting. The vector shows the beginning of the tendency to sheer to starboard. The speed remains unchanged. Marneborg is at a distance of approximately 2.3 M.

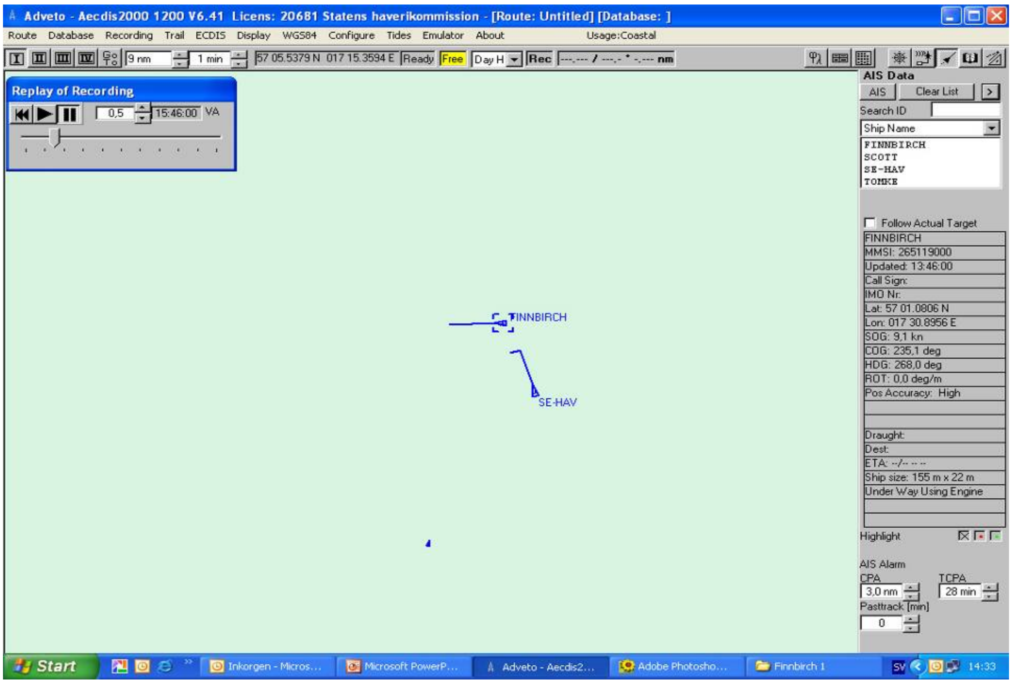


Fig. 29 Finnbirch at 1546 hours. The ship has changed course and the speed has dropped to 9.1 knots. The ship Marneborg (SE-HAV) has begun to alter course to head toward Finnbirch.

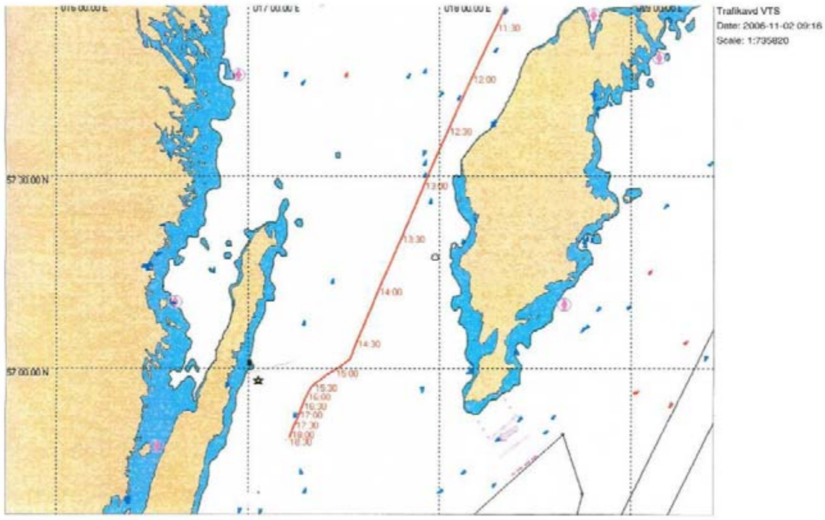


Fig. 30 The picture shows the track of the ship before and at the time of the shifting of the cargo. The first abrupt change of course between 1530 and 1600 hours (in the picture, between 1430 and 1500 hours GMT) indicates the location of the sudden heeling of the ship and the shifting of the cargo. The second and less abrupt change of course occurs when the engine has stopped after a further half hour. The last stage of the track shows how the ship drifted at approximately 2.5 knots to the position where the ship sunk at which the track ended.

1.9 The stability characteristics of the ship

1.9.1 The stability of ships in general

The stability of a ship is described and characterized by the so-called static lever curve, the GZ curve. GZ(m) is the so-called righting lever. The appearance of the lever-curve depends, inter alia, on the hull form, lightweight distribution and actual loading condition. It is affected by any cargo shifting and any external influences such as wind forces.
A GZ curve must be calculated for each particular loading case. The appearance of the GZ curve varies with the draught of the ship (or displacement) and the position of the centre of gravity. Consideration must be given to the effects of free fluid surfaces on board the ship such as in different bunkers and/or ballast tanks. A GZ curve with an appearance typical of a conventional cargo ship with vertical sides is shown in Swedish Maritime Administration Rules for The Stability of Ships. See Fig. 31.

The righting moment (M) at a certain heeling angle is calculated according to:

$$M = GZ \bullet \text{Shifting (tm)},$$

where the value of GZ is read on the y-axis and the heeling angle on the x-axis.

The area under the lever curve multiplied by the displacement gives a measure of the so-called dynamic stability, i.e. the static energy accumulated by the ship when heeling. This is the energy which will return the ship to its normal upright position.

As appears in the text and Fig. 31 from the relevant set of rules, a rising GZ curve is normally assumed from upright position to relatively large heeling angles. Such a GZ curve is obtained with a normal hull form i.e. with vertical ship sides. When the ship heels, the width of the waterline area increases, this in turn adding stability. When the ship's deck goes down under the waterline or the bilge is lifted up out of the water with extreme heeling angles, the waterline area decreases and the stability is reduced.

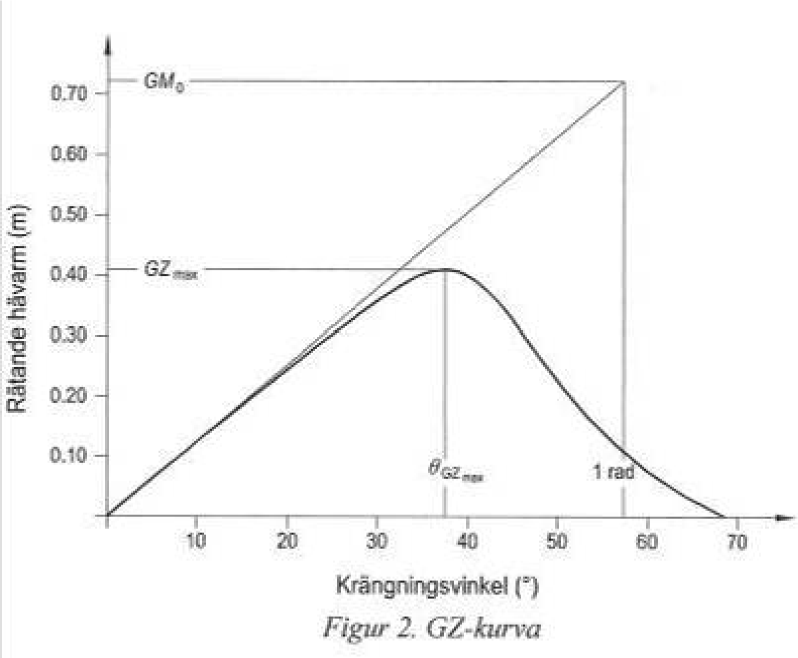


Fig. 31 Diagram from SJÖFS 2006:1.
Krängningsvinkel = Heeling angle, Rätande hävarm = Righting lever

1.9.2 Stability characteristics of Finnbirch

As shown in the ship's stability book, Finnbirch has been given special stability characteristics by the addition of sponsons and a so-called duck's tail. See below.

The addition of sponsons which increase the beam of the ship at the waterline gave the ship a different hull form (Fig. 32). With small heeling angles, the increased waterline beam gives the ship increased stability. With larger heeling angles, this positive effect is reduced as the water line rises over the sponsons on the one side and under on the other. This gives a GZ curve characterized by a dip at certain heeling angles, in this case, between approximately 20 and 40 degrees.

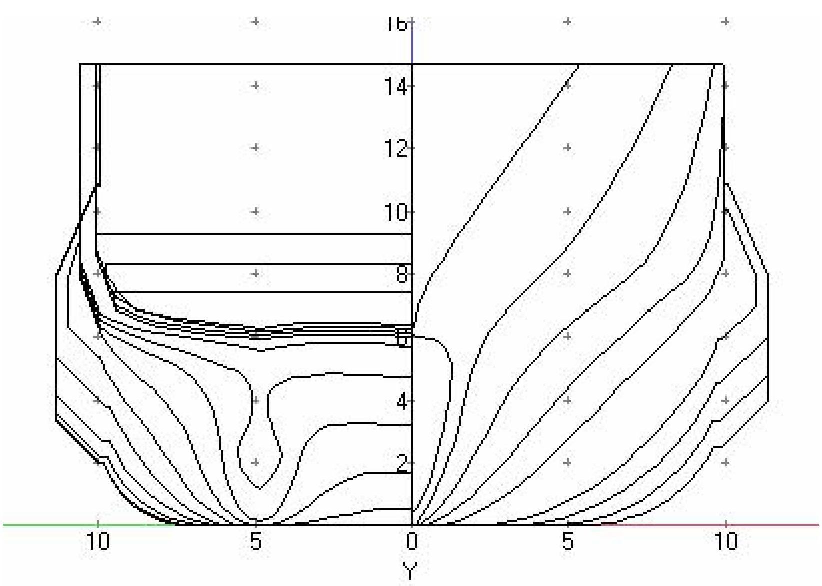


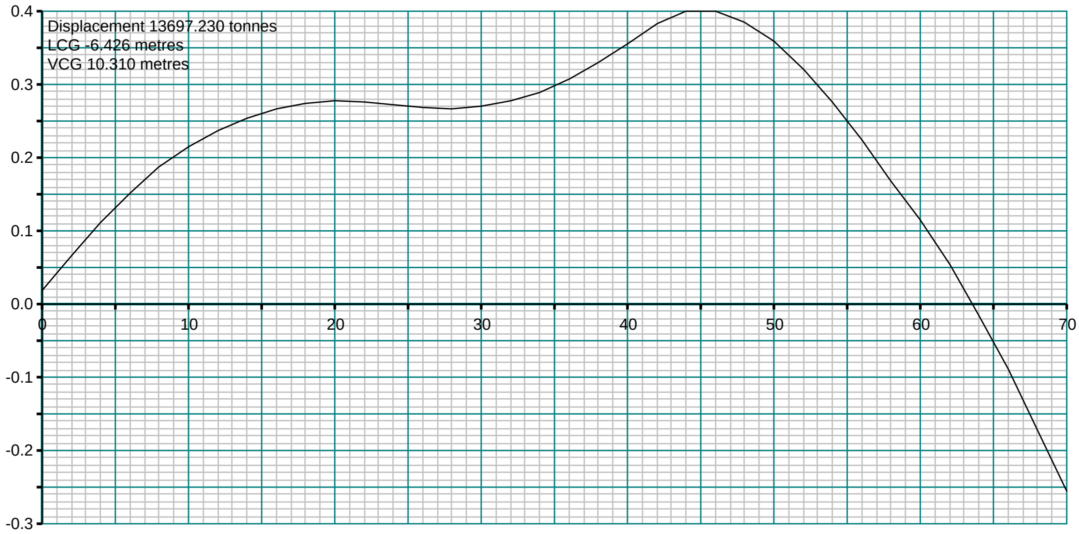
Fig. 32 Form of the ship's hull with sponsons.

The effect of the sponsons on the ship's stability is also reduced in high waves as the waterline then appears partly over and partly under the sponsons.

The extension of the stern, the so-called duck's tail, (not shown in Fig. 32) only adds to the stability with a draught at which it intersects the waterline and then only with smaller heeling angles.

To be able to calculate the stability characteristics of Finnbirch at the time of the sinking, the stability data has been recalculated and the loading conditions reconstructed. These calculations are presented in more detail in Appendix 2. The description in this section is based on the reconstruction and data from the Appendix.

The figure below shows the calculated GZ curve at departure from Helsingfors with a shifting of approximately 13700 tonnes and a GM of approximately 1.36 m.



Figur 33 Calculated GZ-curve for Finnbirch at departure from Helsingfors.

As shown by the curve, there is no, or only an insignificant increase in the righting moment in the range between 20 and 35 degrees. This means that a larger heeling, trigged by a heeling moment, is first stopped at approximately 35 degrees, at which the righting moment increases again. A rolling exceeding 20 degrees can thus have considerable consequences for the safety of the ship. The situation improves first with higher GM-values as shown in the trim and stability book.

1.9.3 The ship's trim and stability book

The ship's trim and stability book which applied until the sinking was prepared after the rebuilding in 1985/86 and was in English. Its contents were in accordance with the normal requirements and it had been approved by Swedish Maritime Administration.

The dip in the GZ curve which appears with certain loading cases and is described above, appears clearly in the cases calculated (Fig. 34).

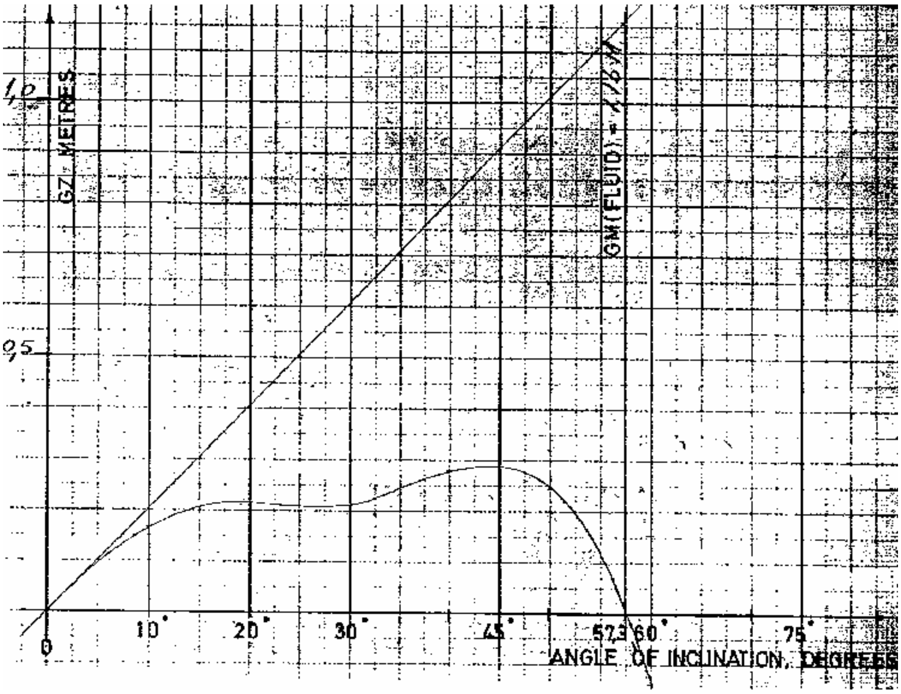


Fig. 34 Extract from the stability book. Lever curve for loading case 4 with a displacement of 13110 ton and GM=1,16 m.

1.9.4 Stability calculations on board

Stability calculations were performed on board Finnbirch during the loading in Helsingfors with the help of a PC computer located in a loading office on the main deck near the stern ramp.

Before departure from Helsinki, the Chief Officer established the metacentre height (GM) as 1.2 m and all values for the GZ curve satisfied the requirements. He reported this to the Master on the bridge. According to the requirements in the trim and stability book, the GM for the draught concerned should be at least 1.07 m.

The least permissible GM and the highest permissible centre of gravity with different draughts are given in a table and a diagram in the stability book. The diagram, (Fig. 35) shows that the area around a draught between 6.5 and 7.0 m is particularly sensitive with respect to stability. This draught corresponds with the draught on departure from Helsinki and was usual for the ship.

Calculations performed by SHK (see Appendix 2) show a somewhat better stability than that calculated on board. The loading conditions on departure from Helsinki and the influence of free fluid surfaces are shown by the calculations in Appendix 2. The total correction of the GM for the influence of free fluid surfaces was 0.3 m.

An Excel calculation sheet programmed by one of the company's ship's officers was used for the calculations on board the ship. The weight and the centre of gravity of the units of cargo loaded and the current contents of the different tanks in the ship were entered into the program. The preliminary information in the booking list was used in entering cargo weights. The heights of the centres of gravity of the different cargo units were not those of the true centres of gravity but were an assumed standard value obtained from the calculated loading case in the stability book. An automatic correction for free fluid surfaces in the different ballast and bunker tanks was made in the calculation sheet.

The program calculated only the transverse stability and thus not the fore and aft trim of the ship.

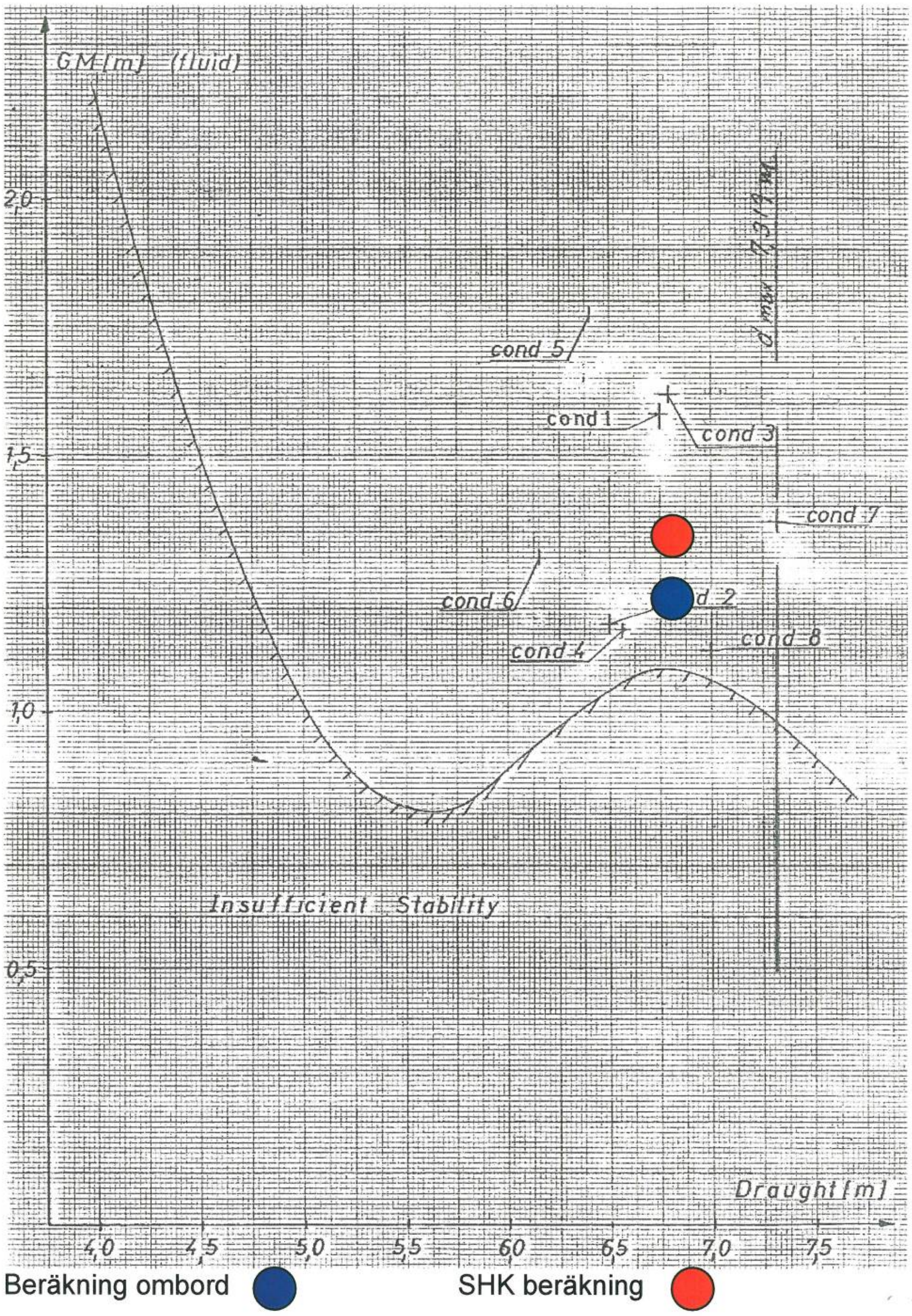


Fig 35 The curve shows the requirement for metacentre height, GM, with different draughts. The calculated GM for the loading condition on departure are shown on the diagram. (Blue dot shows onboard calculations and red dot shows SHK calculations.)

The calculations resulted e.g. in a graphic presentation of the GZ curve of the ship during its final voyage. SKH has had access to this calculation sheet from the sister ship Finnforest and have performed their own calculations with this sheet. See Appendix 2.

1.9.5 Ballast and bunkers

The trim- and stability book contains particular references to the ballasting of the ship. The loading condition on departure are calculated with full ballast tanks no. 1 (bow), no.2 (deep tank), 5, 8, 9 portside and starboard to give the ship a suitable trim and stability. The calculated loading case assumed that the ship was loaded with a homogeneous load of trailers or containers. On departure from Helsinki, a considerable part of the cargo on the Main Deck consisted however of block-stowed paper reels and block-stowed roll-trailers with very heavy loads. This cargo was stowed far forward and had a large trimming effect. As a result, filling the forward ballast tanks, under these loading conditions, would have given the ship a considerable forward trim.

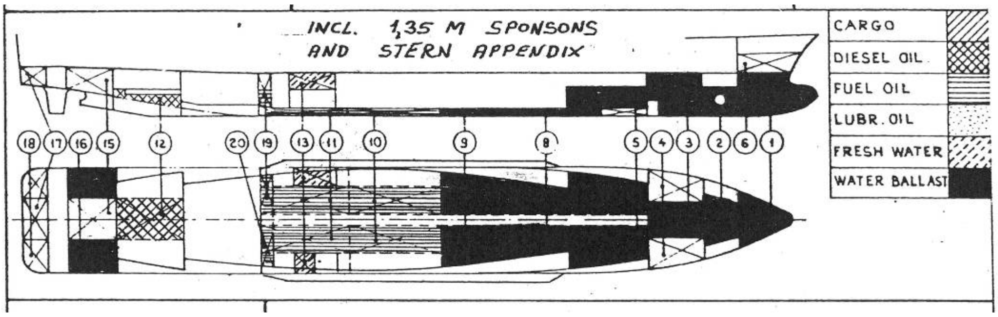


Fig. 36 Location of the ballast tanks (black) in the ship.

According to the trim and stability book, it is necessary, under certain conditions, to fill the ballast tanks to compensate for the consumption of fuel and fresh water. It is important to avoid free fluid surfaces in more than one fuel tank at any one time and also to top-up ballast tanks from time to time. After the departure from Helsinki, no special measures were taken to avoid there being free fluid surfaces.

1.10 Stability with a following sea

With a following sea, a number of stability phenomena develop which affect the stability characteristics of a ship and in certain conditions can lead to problems which can cause heeling. These stability phenomena with a following sea are well known and have been described in professional journals for several decades. The designations of the different phenomena vary and they are described in different ways.

SHK has observed that a reference to these phenomena is included in e.g. the cargo-securing instructions in the CSS code.

In 1995, IMO published an MSC-circular 707 with the title “Guidance to the master for avoiding dangerous situations in following and quartering seas”. This circular was reviewed in circular 1228 published in January 2007. The phenomena are usually distinguished in the following way (here according to IMO MSC/Circ. 1228):

- Surfing and broaching is a phenomenon which results in loss of steering capacity and course stability in following seas at relatively high ship speed.
- Reduction of stability when the ship rides on a wave with the top amidships. Referred to in the literature as “pure loss of stability” or “(quasi-)static loss of stability”.
- Successive attack in high seas. The phenomenon is not completely clearly described in the references but can partly coincide with the other phenomena described. It is characterised by a successively increasing rolling and pitching.
- Synchronized (parametric) rolling which can occur when the encountering period of the waves, which hit the ship, is close to the ship’s natural period in rolling or close to half that period.

1.10.1 The handling of the ship by the crew with a following sea

The crew was well aware that the ship could be difficult to handle with a following sea and in particular with a quartering sea. None of the masters interviewed by SHK in connection with the sinking of Finnbirch knew, however, that there were guidelines issued by IMO for the handling of ships in heavy weather with following seas. Nor was the existence of this document known at the Owner's office. The Master of Finnbirch could not remember that the phenomena which can develop with following seas had been presented during his training at the ship officer's school. According to the minutes of the maritime inquiry following the sinking, he was of the opinion that it was advantageous to proceed at full speed in a following sea and thereby pass the waves and reach a condition which corresponded with meeting a head sea.

It also became evident during interviews that he was not aware of the ship's rather special stability characteristics with larger heeling angles under certain cargo conditions nor how the stability curve of the ship should be interpreted. He was not alone among the masters in this respect. He had experienced single heelings which he estimated to be in the range of 25-30 degrees during the years he had trafficked the Baltic and his opinion was that the cargo should withstand heeling up to 20 degrees but not constant rolling of this order of magnitude.

From his own experience of following seas, the Master could relate that the ship behaved well with a sea from directly astern but that a quartering sea was considerably more problematic. When the seas approached from astern at an angle of 15 degrees or more, the ship became difficult to control. This applied also to the sister ship and the phenomenon was also well-known to other masters in the company interviewed by SHK. Whilst turning through quarterly sea the ship could also lean over considerably.

As mentioned above, a standing order issued by the Master called for action if the ship began to roll between 10-15 degrees. This rule was based partly on an estimate of which rolling the ship could accept without risking any shifting of the cargo, partly on the recommendation of experienced colleagues not to allow the ship to heel more than 20 degrees. A similar order had been issued by the master of the sister ship Finnforest.

The masters interviewed by SHK have all stated that they make considerable efforts to obtain weather forecasts and planning a voyage to avoid unfavourable conditions. The masters say that they must always have one or more reserve plans available for alternative routes to allow for unfavourable developments in weather conditions and must see that it is possible to execute such a plan.

1.11 The accident sequence

1.11.1 The sudden heelings

The interviewed crew members described the rolling which preceded the listing as unexpected and particularly violent but not directly exceptional. A few of the crew have stated that after the first severe roll motion, they had begun to pick up objects from the deck and/or had intended to resume their work. With the second roll over, they had however begun to feel that all was not as it should be. Several crewmen have described how the ship returned to an upright position but did not roll further to starboard as it would naturally. Some of the crew stated that they had decided to, and in some cases already had begun to move upward in the ship before the third and final roll over after which the ship did not recover.

The Master and the Second Mate, both on the bridge, describe the movements of the ship in slightly different ways. While the Master experienced the ship as being thrown to starboard (broached), the Second, who observed the gyro repeater, believes that the ship came only some degrees to starboard with the first roll. It has not been possible to clarify if or not they refer here to the same rolling.

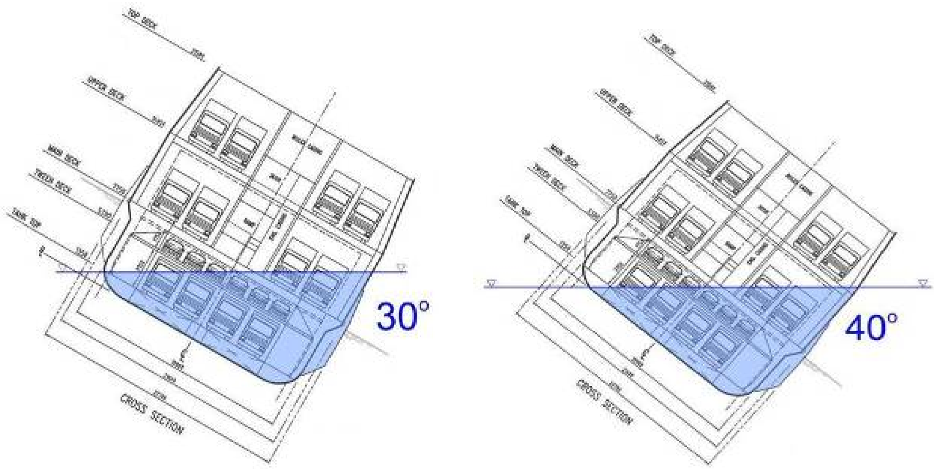
The considerable rolling of Finnbirch was also observed from Marneborg, the ship on a meeting course which was then at a distance of approximately 2 M. From Marneborg, it appeared as if the rolling of Finnbirch was surprisingly slow. Finnbirch was seen to change direction in the waves to both starboard and port.

1.11.2 The list

SHK has requested an analysis by the Swedish Defence Forces Intelligence and Security Centre of a video recording made from the first helicopter to arrive at the site. The following is extracted from their report:

"The list of Finnbirch is within the interval port 22˚and port 45˚. The value of the ship's list is not completely reliable as the horizon could not be used as a horizontal reference and the measurements have only been made when the ship was close to the target-angle zero degrees. No consideration has been given to the altitude of the helicopter over the surface or when the target angle has varied from zero degrees. No mean value of the list is presented as Finnbirch was pitching and rolling continuously with a periodicity of approximately 13 seconds with seas in a direction from the starboard quarter."

On the basis of the report, SHK has calculated the mean value of all the observations of the starboard list as 32.3 degrees.



Figur 37 Simplified sketches, from forward, of when the water level reached the Upper Deck with different heeling angles.

1.11.3 Observations of cargo shifting

The crew made only few observations of the cargo in the hold at the time of the heeling or afterward. Two seamen were on the Tank Top when the ship rolled over. They noticed no cargo shifting at the stern end of the deck while they remained there but could hear a rattling noise and objects sliding on the deck above, the Main Deck. They rushed up and out from the superstructure via the center case without stopping to look into any of the cargo decks and heard both sliding and rattling sounds as they passed.

The machine-repairer, who was working in the engine room workshop at the time of the rollings, also took the stairs in the center case, but stopped and opened the door out to the Upper Deck. Through the door, he saw two covered trailers which leaned to port and which moved (in a twisted motion). One of the trailers was damaged.

From the bridge, it could be seen down to the Weather Deck, that a cargo shifting had occurred there. This shifting is also clearly visible on the photo from a rescue helicopter arriving early. From the picture, it can be seen that several of the trailers have been distorted which suggests that the cargo within these has shifted. A comparison with the cargo list indicates that in the first place, it is units with a total weight exceeding approximately 22 tonnes which have loosened on the Weather Deck.

Fig. 38 Photograph of the Weather Deck after cargo shifting (Swedish Maritime Administration*).*

From his position on the lifeboat deck, the Second Mate could also see the open part of the Upper Deck aft of the superstructure. During the Maritime inquiry into the sinking, he has witnessed that the five semi-trailers stowed there remained in position up to a listing angle of 60-70 degrees before the lashings broke and these also slid away. Several of these units were loaded with steel products and weighed up to 37 tonnes each. The trailers stood on a friction-enhancing surface, 10 mm high square-section rod being welded in a fish-bone pattern to the deck, this radically reducing the risk of the trailers sliding across the deck.

1.12 The sinking sequence

1.12.1 Observations in connection with the sinking sequence

According to the MRCC rescue log, approximately four hours passed between the first heeling and the final capsizing and sinking. There are not many observations recorded of the sinking sequence, either from on board or from surrounding ships. From the position on the starboard side, aft of the bridge and later on the lifeboat deck, the crew could appreciate the gradual increase in the list and that the heeling accelerated towards the end. From their position, they could not see if the ship changed trim. There are no observations of any entry of water into the ship.

Finnbirch was filmed from a rescue helicopter which arrived approximately 40 minutes after the shifting of the cargo. The film shows that water washed over the forecastle with the more extreme rolling. Finnbirch was difficult to observe in the dark and vision was reduced considerably because of rain and sleet.

1.12.2 Water tightness

According to information from the crew, there were routines for closing hatches on the deck and for certain of the air intakes to fans in the hold. It was the duty of the bosun to check the proper closing on departure and report to the bridge. The Master confirms that this was done on departure from

Helsinki. It has not been possible after the event, to check whether necessary watertight doors, hatches and fan intakes actually were closed, battened down and sealed.

A bunker door was located on the Main Deck on the port side. There were also so-called scupper valves along both sides, the whole length of the cargo deck. Their function is to drain any water from the cargo deck. The valves are operated manually from the deck above, the Upper Deck. The scupper valves normally remained open during voyages according to the crew, confirming that this was also the case on the voyage. The valves were provided with a non-return valve intended to prevent the entry of water from outside. Routine checks of the function of valves vas performed but it has not been possible to establish when the non-return function was most recently checked.

A mooring station on a Poop Deck was located aft, at a level between the Main Deck and the Upper Deck, on both sides of the ship. From this station on the port side, it was possible, via a trunk, to climb down to the hydraulic pump room located on the Main Deck. From this space, access was available via a watertight door to the cargo deck or via another trunk down to the steering gear room. A ventilator in connection with the hydraulic pump room and with the steering gear room was probably on the port Poop Deck. There was also a larger, closable hatch in to an earlier fan intake for the Main Deck. This space, in direct connection with the hold was said to be used for the storage of mooring lines.

On the Upper Deck, along the sides, at midships, were air intakes for ventilation of the Main Deck. These were housed in closable trunks and were closed as a routine procedure on departure. Forward, on the outside of the ship, on both sides and just aft of the forecastle, were large fan intakes for the Main Deck and the Tank Top. These could not be closed against the entry of water.

1.13 The evacuation

1.13.1 Evacuation

All of the crew was awake and active at the time of the sudden heavy rolls. Some were in the galley collecting food and about to sit down to eat. Two of these were injured when pitched down a 9 m long transverse corridor. Others were in the engine room. One has mentioned the difficulty in opening the engine room door which became too heavy to open with the extreme list. He escaped through an emergency exit. As mentioned previously, there were men working on the Tank Top. Some have stated that it was difficult, in the stressing circumstances, to unlock the door in the center case which was provided with a coded lock. (Locking or guarding of doors is required by the ISPS code as protection against terrorists). Most of the crew reached the bridge deck via the interior of the ship and then forward into the bridge or aft to the cabin on the starboard side, a spare cabin were the survival suits were stored.

The Master, immediately after the Mayday call had been transmitted, had gone aft from the bridge to the spare cabin returning to the bridge with as many survival suits as he could carry. Further crewmen soon arrived and then went out on the deck on the starboard side, aft of the bridge. As others arrived at the bridge, these were drawn up to the bridge door on the high side of the ship with the help of a boat hook taken from the lifeboat on the starboard side. The three who had reached the spare cabin were trapped in that cabin when the door suddenly swung closed and falling objects fell over them. The Master, standing out on the deck, then took an axe from the lifeboat, smashed the porthole to the cabin and helped the crewmen out with a boats hook. All men without survival suits were then provided with these from the spare cabin. Lifebelts stored in a locker on the lifeboat deck were distributed soon after. The deck was very slippery because of ice and slush. After about a half hour, black smoke issued from the stack and the start-up of the emergency generator was heard.

With the help of a harness stored in the spare cabin for use in lifeboat training exercises, one of the seamen was lowered into the bridge to fetch the portable VHF transceivers stored in the battery charger on the aft bulkhead approximately midships. He returned with two of these and it was then possible to communicate by radio with other ships standing by and helicopters which had arrived on the scene. The Master used one of the transceivers and the Second the other one.

It became evident that the helicopters could not hoist them in their present position and that the crew must try to move to the open forecastle deck. This was deemed to be impossible under the circumstances. The dropping of rafts from the helicopters and the ships was considered to be pointless as these would in all probability drift away. The crew presently moved down one deck to the lifeboat deck. It became dark and snowstorms considerably reduced visibility.

At approximately 1730 hours, the Master made an attempt to reach the rafts on the port side to see if it might be possible to launch these and evacuate the crew on these. He realized that it was too risky even to attempt to climb down to these and he therefore abandoned his attempt. During his return, he slipped on the deck, sliding almost 20 m down to the port side and suffered injuries to his head, ribs and a knee. Despite his injuries, he was able to contact the crew via the VHF transceiver and these were able, after a time, to lower a line and hoist him up to the starboard side again. Considerably shaken, he handed the transceiver and the command over to the Chief Officer. The Master was placed in the angle formed between the deck and the deckhouse with crew members sitting side by side, backs against the deck and feet against the bulkhead as the list increased, forming a "tunnel" under their knees in which the Master was given some degree of protection from the weather.

The listing accelerated toward the end and when the ship began to sink, the Chief Officer helped the Master to his feet. None of the crew saw what happened to the Mate after this. The crew was separated when the ship sank. The emergency lighting functioned to the end and extinguished immediately before the porthole broke under pressure from inside the ship as it filled with water. The Master was caught in the ship's railings and was close to being drawn down with the ship when, with a final effort he managed to free himself. When the ship sank, the deck load of e.g. planks and boards began to float up, almost as projectiles, with large sheets of plywood being blown around over the surface at high speed. Several of the crew has said that it felt warmer in the water compared to when they sat on the bridge deck.

Two of the crewmen managed to board one of the rafts. A third clung to the raft but was unable to climb on board via the rope ladder. The two on board attempted to help but had difficulty in getting a grip of the third because of the stiffness of the gloves. They noticed that the suit of the third man was open approximately 10 cm. He had previously, on board the ship, complained several times of difficulty in breathing in the suit and asked for help in opening it over his face, his shipmates attempting to dissuade him. Presently, the third man lost his grip on the raft and drifted away. When found later, his suit was open down to his chest and filled with water. On arrival at hospital, his body temperature was 15.9 degrees and he was declared dead from hypothermia.

1.13.2 Survival suits

Most of the crew was lightly dressed in shirt or T-shirt, trousers and socks when they assembled on the bridge deck. The survival suits were therefore their only protection against the cold, both in the open air (+1 °C) during the four hours they remained on the listing ship and later in the water (+10 °C). All had lifebelts outside the suits but these gave little thermal protection.

Two of the survival suits came from the engine control room and were brought by the crewmen when they left this space. The other suits were obtained from the spare cabin aft of the bridge.

Inspection of the survival suits

All of the suits worn by the crew were recovered and could be inspected after the sinking. The suits are of two types, both approved in accordance with SOLAS and according to the regulations, shall "give such thermal protection that the internal body temperature of the bearer shall not fall more than 2 °C if the suit is worn for 6 hours in quietly circulating water at a temperature between 0°C and 2 °C".[6]

Of the fourteen suits, three have been slashed. The material of one of these has been compressed to approximately 3 mm as compared with the normal original thickness of 5 mm. It is assumed that this suit is that worn by the Chief Officer whose body was found on the wreck at 7o m depth, three weeks after the sinking.

The suit worn by the dead seaman had also been cut open to release the water it contained, to reduce the weight to be winched into the helicopter.

A further suit had been cut open. During an interview with the Master, he explained that this was his suit which had been cut open when he was rescued to permit attention to his injuries. The other suits were intact.

Eight of the suits are newer than the others but on inspection, the materials of all have been found to be of equal value. During interviews after the sinking, some of the crew stated that they experienced the gloves as inflexible because the material had aged and had become stiff. Differences between the older and newer suits in this respect have not been detected but there are differences in their design. For example, the newer gloves now have five fingers instead of the earlier three.

The function of survival suits

All of the suits have the same size, adult universal, for adult persons with weight 50-150 kg and height 150 – 190 cm. In interviews with the crew, after the sinking, several of the crew pointed out that the suits were too large for many of the crew. The majority of the Filipino crewmen were relatively short, between 160 and 170 cm tall, which meant that the suits did not fit them as well as the taller members. The Filipino crewman who died had complained on several occasions that the suit covered his mouth and made breathing difficult. Despite his shipmates' advice to keep the suit closed, he opened it to be able to breathe. A further two crewmen have witnessed during interviews that they were unable to close the suit because of difficulty in breathing. The design of the suit is such that the mouth is intended to be covered with the zip-fastener and a face flap which is located over jaw and mouth.

The suits being too large may have resulted in the face flap and zipfastener being higher on the face than intended, which may have hampered the breathing of the crewmen through both nose and mouth.

When the deceased crewman was to be hoisted into the helicopter, his suit was found to be open down to the chest and it was necessary to cut the suit open to drain the water with which it had filled. At the hospital, he was judged to have died of hypothermia.

The other suits were intact. Some contained small quantities of water which indicates some form of leakage even with closed suits. Some of the crew has reported some leakage at the level of the hood.

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[6] LSA-code 2.3.2.2

All suits have been polluted with oil to varying degrees indicating clearly that the survivors had been swimming in oil-covered water. The medical report states that one crewman vomited an oil-water mixture.

The suits were not damaged externally. While in the water, the survivors were surrounded by large quantities of floating timber and other flotsam and several have reported contact with this. The medical report says that most had bruises and minor injuries but there were only a few serious injuries. The 5 mm thick rubber material appears to have provided a certain degree of protection against floating wreckage.

Fig. 39 The survival suits on board were of two types, Imperial at left and Stearn at right.

1.13.3 Hypothermia and personal injuries generally

Thirteen persons were transported by helicopter to Kalmar airport where the survivors were allocated individual priority. They were then carried by ambulance to the County Hospital in Kalmar. Helicopter Lifeguard 992 landed at Kalmar airport at 2038 hours with seven crewmen. Helicopter Y67 landed at 2135 with three crewmen and helicopter Y63 landed at 2250 hours with three crewmen. One of these was dead. All the 12 survivors were suffering from hypothermia on arrival at hospital. Accidental hypothermia is the condition where a body temperature is 35 degrees or lower.

One person had been close to drowning, this being classified as a serious injury. (AIS3) [7]. Additionally, he had a body temperature of 33.3 degrees. Two of the crewmen had moderate injuries (AIS2), fractured ribs, a knee injury and a fractured elbow. Eight persons were slightly injured, (AIS1), mostly hypothermia and bruises. One person was classified as uninjured (AIS0). His body temperature was 35.7 degrees but otherwise he had no physical injuries.

It has been reported that one person suffered a severe and persistent psychic trauma as a result of the sinking.

1.14 Rescue operation

1.14.1 Rescue services with accidents at sea

Rescue operations at sea are regulated internationally via the SOLAS convention (Safety of Life at Sea) and the SAR-convention (International Convention on Maritime Search and Rescue), both of which have been adopted by Sweden. In Sweden, Swedish Maritime Administration is the authority which according

[7] AIS (Abbreviated Injury Scale) indicates the degree of injury where every individual injury is classified according to a grade from 0-6, where 0 is uninjured and 6 almost fatally wounded.

to the statute 2003:778 relating to protection against accidents is responsible for rescue operations at sea.

The MRCC, (Maritime Rescue Coordination Centre) in Sweden is located in Gothenburg together with the ARCC (Aeronautical Rescue Coordination Centre) which organises aerial rescue, the Coastguard regional direction and the defence forces marine monitoring central.

MRCC is responsible for maritime rescue services with search and rescue of people who are in, or may be feared to be in danger at sea and for the transport of patients from ships.

Different maritime rescue operations are directed by a Rescue Leader (RL) at the central. As an assistant, the RL can appoint an OSC (On Scene Coordinator). The OSC is subordinate to the RL and is present at the site of the accident or nearby. The OSC coordinates and directs the rescue operations there in accordance with the intentions and directives of the RL. For help with staff work during a rescue operation, the RL has access to personnel of the associated authorities in Gothenburg.

The resources available for maritime rescue operations consist of Swedish Maritime Administration own ships, the ships and general resources of the Coastguard and the ships of SSRS (The Sea Rescue Society). For support of the civilian community, the defence forces can contribute certain resources in the event of a serious accident. By agreement, certain helicopter support is on-call for marine rescue operations.

In accordance with the law relating to protection against accidents, other suitable units may be used in a rescue operation. Civilian ships are also obliged to assist in rescue operations in the event of a maritime accident in accordance with the UNCLOS [8] article 98 and Chapter 6 of Swedish maritime law.

Maritime rescue operation involving helicopters are normally managed by ARCC. When a function is required for coordinating the helicopter activities in the area, the rescue manager at ARCC can appoint a suitable person/flying unit to be ACO, (Aircraft Coordinator). ACO is a function for the coordination of the activities of several flying units in a rescue operation.

1.14.2 The sequence of events in the rescue operation

The sequence of events is described below broadly and in chronological order. The times given in the different reports are corrected as necessary in accordance with the radio traffic records.

Time	***Event***
2006-11-01	
15:39	MRCC receives the emergency Mayday call from Finnbirch on channel 16 informing that they have a severe list at position N 57° 01’, E 017° 32’. The two Dutch ships nearby, Marneborg in visual contact with Finnbirch and Largo acknowledge the emergency call and set course toward the ship in distress.
15:42	ARCC alerts Visby helicopter base (LG 997)
15:43	Finnbirch no longer answers on channel 16. The Rescue Leader (RL) makes a BiS decision; *Classifying the incident as an Emergency and to alert helicopters with rafts and surface units for rescue of the crew, to prepare for environment monitoring and to prepare for provision of medical assistance and disembarkation on land.* Staff work is allocated to different persons in the rescue centre.
15:45	ARCC alerts Ronneby helicopter base (Y 67)

[8] United Nations Law on the Sea Convention

15:54 MRCC alerts SSRS Visby. MRCC has now received information from the Owners that the cargo consists of paper products and trailers and that the ship is on a voyage from Helsingfors to Århus and that there are 14-15 persons on board. After this point in time, Marneborg begins, in practice, to act as OSC without a formal decision being made by RL.

15:55 Hcp Y 67 take off from Ronneby.

15:57 Hcp LG 997 take off from Visby. At the same time, another two ships, Finnhansa and Tomke have acknowledged the emergency call and RL requests them to proceed toward Finnbirch.

16:00 MRCC alerts KBV 281 in harbour at Kalmar.

16:04 MRCC alerts SSRS Böda, but they cannot leave harbour because of the prevailing weather conditions.
The weather in the area reported by Marneborg is north half-gale strength 9–10 Beaufort[9]. Wave-height 4.5 m. Visby airport has wind 360 degrees strength 27 knots, gusts to 42 knots.

16:09 Marneborg has arrived at Finnbirch but cannot approach too closely because of the hard weather.

16:11 SSRS Visby is ready to go to sea to check the weather

16:12 KBV 281 is 7 hours distant from the position but remains at standby in harbour.

16:22 LG 997 has arrived at Finnbirch with a strong tailwind and it is still light. They have no radio contact with the crew but can count 13-14 persons sitting on the starboard side at the level of the bridge. It is decided that winching is not possible because of the ship's pitching and rolling and no winching is attempted. It is decided to await events nearby.

16:28 Telephone contact between LG 997 and RL. It is reported that at times, the entire side of the ship is under, that 13-14 persons in red survival suits can be counted and that it impossible to launch rafts.

16:31 Y 67 abeam Färjestaden with ETA at the ship within 20 minutes.

16:36 ARCC orders LG 992 at Arlanda to fly to Visby to have an extra helicopter in the vicinity.

16:44 SSRS Visby returns to Visby because of the weather and the seas.

16:47 MRCC orders KBV 281 to proceed to the Finnbirch to have an extra smaller unit nearby.

16:54 Y 67 has arrived at Finnbirch after 60 minutes flight against strong headwinds. They have been advised that Marneborg is OSC and they have made contact with LG997 who have reported that they cannot winch. They have made several attempts to reach a winching position but consider that the turbulence is too severe to permit a safe winching and no attempt has been made. Y67 have also decided not to attempt winching but to wait until further notice nearby.

16:54 KBV 202 Take off from Åhus.

17:10 LG 992 has started from Arlanda to relocate at Visby airport.

17:15– Communication has been established between Marneborg, Finnbirch and LG997.

17:27 The crew on Finnbirch cannot reach their rafts. The risks of attempting to reach a raft from the sea are discussed. Finnbirch in communication by means of two portable VHF- radios. LG 997 considers the launching of its 20 man raft.

RL decides that the Finnbirch crew should remain on board until further notice and that LG 997 should not launch its raft because of the risk of it drifting out of range. .

17:30 Y 67 informs RL that a member of the crew has fallen and broken a leg. It is the Master who is now alone on the port side. The other crew members on the starboard side attempt a rescue using a line. Y67 remains in the vicinity and can remain a further 2 hours.

17:35 ARCC investigates the availability of other helicopters.

17:36 LG 997 leaves for Kalmar for refueling.

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[9] Beaufort Wind Scale (9–10 Beaufort motsvarar halv storm till storm)

17:43 KBV 281 decide to return to Kalmar, one of the crew has injured his back in the heavy seas.
17:52 LG 997 lands at Kalmar.
18:01 ARCC requests of MRCC Turku/Åbo a helicopter from Åbo/Turku to standby at Visby.
18:02 The Master of Finnbirch who broke a leg in a fall is now reunited with the crew on the starboard side.
18:02 LG 992 lands at Visby.
18:05 Finnbirch confirms to Marneborg that they are 14 persons on board and that they are all on the starboard side under the bridge.
18:14 KBV 281 is at sea again and will arrive at the accident within 6 hours.
18:22 Y 67 reports that it can remain over Finnbirch another hour.
RL's intention is to have at least one helicopter over Finnbirch at all times.
18:27 A further helicopter is reported available, Y 63 at Ronneby, which is alerted.
18:34 MRCC Turku has alerted the Finnish Super Puman OH-HVI which leaves from Åbo to fly to Visby to be on standby.
18:47 LG 997in Kalmar is alerted.

Marneborg reports that the list of the Finnbirch is increasing.
RL and ARCC intend now to start all available helicopters.

18:50 LG 992 receives order to take off from Visby.
18:51 The Dutch ship Largo intends to attempt to launch a raft.
19:02 LG 992 take off from Visby.
19:05 LG 997 take off from Kalmar. They have a faulty compass which is corrected during the flight.
19:18 Y 67 leaves for Kalmar. The bridge of Finnbirch is now in the water.

19:24 ***Marneborg reports that Finnbirch has capsized at pos. N5649,4/E01713,15***

19:30 LG 992 has arrived and sees the ship, which has capsized, the crew in the water and their emergency lights. They fly past all the swimmers, drop their raft and begin the winching.
19:34 Marneborg reports that the Finnbirch radar echo has disappeared.
19:36 KBV 181 departs from Slite.
19:45 LG 997 has arrived and is in contact with LG 992 which is 300 m ahead and winching. They see two persons on a raft and two outside the raft.They make repeated efforts to winch from the water and conclude that there is a technical fault in the hover height function of the automatic control system.
19:49 Y 67 now at Kalmar has loaded a 20-man raft and report their intention to start a.s.a.p.
19:50 Y 63 take off from Ronneby with two 20-man rafts and is on the way to Kalmar to standby.
19:58 LG 992 is winching and has rescued 6 persons.
19:59 Largo moves away to avoid interfering with the helicopters and does not drop its raft.
20:05 Y 63 is ordered to fly directly to the site as Y67 has a faulty control gyro.
20:10 LG 997 retire without having succeeded in winching and fly toward Visby.
20:10 Y 67 take off from Kalmar.
20:15 LG 992 has winched 7 persons and sets course for Kalmar.
20:19 OH-HVI is ordered to fly directly to the rescue area instead of Visby.
20:25 Y 63 will arrive in 7 minutes and heads for a raft with two persons illuminated by Largo.
20:31 Y 63 and Y67 arrive at the rescue area at the same time and begin winching different persons. Y67 heads for persons in the water left there by LG 992 in which the rescueman is now exhausted and which is now fully loaded.
20:33 Y 67 begins winching two persons clinging to a larger piece of timber.
20:38 LG 992 lands at Kalmar where medical personnel and ambulances take care of the 7 persons.
20:47 Y 63 has winched up the two persons from the raft.

20:50 OH-HVI is soon at the area. Y 63 and Y 67 are ordered to search for persons in the water north of the rescue position.
21:15 Y 67 has observed one person in the water and makes a short approach for winching.
21:00– 21:20 *The Rescue Centre has no contact with the helicopters during this time. This depends partly on inadequate radio coverage, partly on the preoccupation of the crews with e.g. the winching. They do not respond via channel 16 or telephone. In addition, the Finnbirch EPIRB (Emergency Position-Indicating Radio Beacon) "jams" channel 67 for Y 63 and Y 67.*
21:20 Y 67 sets course for Kalmar with 3 rescued on board.
21:35 Y 67 lands at Kalmar.
21:45 Y 63 and OH-HVI will be able to remain in the rescue area for another hour.
22:00 RL orders LG 992 and Y 67 to relieve Y 63 and OH-HVI by 2245 hours.
22:17 Y 63 has found one person in the water and begun winching.
22:32 Y 63 sets course for Kalmar with 3 rescued on board, the one most recently rescued in serious condition.
22:34 LG 992 starts from Kalmar to continue, with Y 67, the search for the 14th person on board Finnbirch.
22:30 OH-HVI lands at Kalmar.
22:35 Y 67 take off from Kalmar for continued searching.
22:50 Y 63 lands at Kalmar.

The searches by LG 992 and Y 67 are to be "square searches" with start positions N564572/E171446 and N564914/E171290 respectively. They are given responsibility for their mutual separation.

22:52 LG 992 cannot perform a "square search" because of the heavy wind but begins instead a search up wind.
23:18 KBV 281 gives midnight as ETA at the search area. Marneborg is thanked for its efforts and advised to continue to its destination.

2006-11-02

00:24 LG 992 picks up and disables EPIRB at pos. N564430/E0171432 after homing by Radio Direction Finding.

LG 992 and Y 67 continue searching 2235 to 0115 hours without result.

00:47 LG 992 leaves the area for Kalmar.
01:06 LG 992 lands at Kalmar and is relieved of search duty. Refuels for return to Arlanda.
01:15 Y 67 leaves the area and sets course for Kalmar.
01:30 Y 63 take off from Kalmar to continue searching together with OH-HVI.
01:40 Y 67 lands at Kalmar and is relieved of search duty.
01:41 OH-HVI take off from Kalmar for continued searching.
01:54 KBV 281 has found something which may be a person.
02:11 Y 63 report that the find is an empty survival suit.
02:48 OH-HVI discontinues its search and sets course for Visby for refuelling.
03:59 Y 63 discontinues its search and returns to Ronneby.
06:43 The Rescue Centre closed the rescue operation and those concerned stand down. .

1.14.3 Direction of the rescue operation

MRCC has reported that an unusually large number of its personnel were available at the beginning of the operation when a large proportion of the staff were present and could be allocated different duties. When the Mayday call from Finnbirch was broadcast, it was received by several ships as the accident had occurred in a relatively busy sea lane. MRCC directed the rescue operation and four ships were asked to set course to the position of the ship in distress. Other ships offered help but were advised to continue their voyages. The following merchant ships in the vicinity were directed to the position.

Marneborg/PDHZ general cargo ship, length 150 m.
Tomke/ZDEC9 general cargo ship, length 108 m.
Largo/PFNC ro-ro ship, length 91 m.
Finnhansa/OJFG ro-ro passenger ship, length 183 m.

The situation of the ship, its position and the weather in the area led to the decision that the most suitable means of rescue were helicopters. The Rescue Leader's "BIS" meant that the operation was classified as an emergency and helicopters with 20-man rafts and different surface units should be alerted to rescue the crew. The following units took part in the rescue operation;

SAR rescue units participating

Name	Type	Alerted	Arrival	Discontinued	Based at
Lifeguard 997	Hcp Sikorsky S-76	15:42	16:22	20:10	Visby
Y 67	Hcp Vertol 107	15:45	16:54	01:40	Ronneby
Lifeguard 992	Hcp Sikorsky S-76	16:36	19:30	01:06	Arlanda
KBV 281	Ship	16:47	23:57	04:47	Kalmar
KBV 202	Ship	16:50	04:48	06:00	Åhus
KBV 181	Ship	16:50	05:51	06:00	Slite
Y 63	Hcp Vertol 107	18:27	20:31	03:59	Ronneby
OH-HVI	Hcp Super Puma	18:34	20:55	02:48	Åbo Finland

The surface SAR units of the Kustbevakningen (Coastguard Service) and SSRS which were alerted and able to participate were at a distance from the position of the accident and thereby became a secondary resource in the rescue operation. Two units, the Coastguard ship KBV 281 and the SSRS Marine Rescue ships in Visby were forced to abandon their participation because of the weather. KBV 281 returned because of injury to one of the crew caused by the heavy seas. After having disembarked this crewman, KBV 281 again set course for the accident location. The Marine Rescue ship in harbour at Böda, the surface unit closest to the Finnbirch could not leave harbour because of the weather.

Merchant ships in the vicinity were unable to rescue the crew as long as they were on board and – because of the high seas, their own high freeboard and their limited manoeuvrability – were much less able than the helicopters to rescue the crew from the sea. The ships at the site could, however, contribute by launching their own life-saving rafts, illuminating the sea with their searchlights and possibly providing accommodation for those of the rescued not in need of immediate professional medical care.

The Marneborg was the ship closest to and had visual contact with the ship in distress. It was Marneborg which, in practice, assumed the role of OSC.

In the first place, two helicopters were to partake in an operation which the Rescue Leader anticipated would permit evacuation of the crew of the ship without problem. The two closest helicopter bases, Visby and Ronneby were alerted immediately. The first helicopter, LG 997 from Visby, arrived approximately 40 minutes after the Mayday signal but reported difficulties in performing a winching. The second helicopter, Y 67 from Ronneby arrived 30 minutes later and also reported winching difficulties.

When it was appreciated that the helicopters were unable to immediately evacuate the crew from the ship, which was listing considerably, the strategy adopted was to await further developments and ensure that there was a helicopter above the ship at all times, ready to intervene if the situation deteriorated or if a winching should become possible. At the same time, all available helicopters in the area were alerted. At the most, five helicopters were engaged in the rescue operation.

After the crew on Finnbirch had succeeded in entering the bridge and fetching the mobile VHF transceivers, communication was possible with the helicopters and the ships. Proposals for dropping a raft from a helicopter or for the crew to move to a part of the ship more readibly accessible to the helicopters were discussed. The Master of Finnbirch attempted unsuccessfully to reach the ship's own inflatable rafts on the port side but fell and was injured severely. The Rescue Leader then decided that it was best not to drop the raft from the helicopter and for the crew to remain on board Finnbirch while awaiting further developments.

When it was reported that the ship had listed further and that the bridge had almost reached the water, it became obvious to the Rescue Leader that the ship would soon capsize. All available helicopters were then given take off orders or were directed to the scene.

The rescue of persons in the sea after the ship had capsized and sunk was performed autonomously by all the helicopters on their own initiative, without awaiting orders. No ACO for coordinating at the scene was issued. There have been no reports of any collision incident or incipient collisions between the helicopters nor have any such been referred to despite the helicopters manoeuvring in a limited space in darkness with reduced vision. The proximity of other helicopters in the operation was a source of concern for the helicopter commanders.

During the operation, the helicopters communicated on frequency 123.10 MHz. ARCC had no coverage in the area on this frequency and could therefore not receive the radio traffic in the vicinity of Finnbirch. The possibility of ARCC following other radio traffic in the area was periodically somewhat limited and contact between ARCC and above all, hovering helicopters, which because of their low altitude had limited radio range, was broken at times. ARCC could, however, communicate with the helicopters equipped with airborne mobile telephones. Marneborg played an important role in reporting search work to the rescue centre when radio traffic on channel 67 between ARCC and some of the helicopters was "jammed" by the interference of transmissions from the Finnbirch EPIRB which was activated when the ship sank. The helicopter crews also gave priority to the winching work in preference to reporting to the rescue centre. The rescue centre gave instructions for the performance of a "square search" in which helicopters were to search for survivors in a pattern expanding from a given point. The crews considered this unsuitable in the hard wind which considerably distorted the tracks of the helicopters during each leg of the search. The helicopters then recommended to the Rescue Leader and performed an "in-line search" against the wind with a geographic separation between the helicopters.

1.14.4 Participating units

Helicopter Lifeguard 997 (Sikorsky S-76)

Lifeguard (LG) 997, owned by Norrlandsflyg AB, was at stand-by at Visby airport when informed of the listing of Finnbirch. The helicopter commander, who had begun his SAR training in April 2006, approximately seven months before, was at the time under the operative restrictions applied to all Norrlandsflyg commanders during their first year of engagement in SAR activities. He was thereby nominally limited to flying under VFR rules with visibility at least 2500 m and cloud-base at least 1000 ft. Under IFR rules, the least altitude permitted was 100 ft. and obstacles should be visible at a minimum distance of 0.25 M. The commander has informed SHK that this was his first SAR operation.

LG 997 was the first helicopter to arrive at the ship. It was still daylight. After sighting the crew, realizing their inability to move to another location and studying the movements of the ship and the obstacles presented, it was decided that winching was not then a practical proposition and the best alternative was to remain in position, approximately 150 ft above the ship, with no turbulence problem, and await events.

Preparations were made to drop the 20-man raft to make this available to the Finnbirch crew. This was cancelled when the Rescue Leader decided that the crew should remain on board. It was considered that the risks in leaving the ship were too great and the possibilities of holding the raft in position with the hard wind were minimal.

After hovering over, or near the ship for 1 hr. 14 min. LG 997 departed for Kalmar for refuelling. LG 997 returned to the rescue during the evening leaving Kalmar at 1905 hours, 20 minutes before Finnbirch capsized. LG 997 made a long approach from the south at low speed as LG 992 was in the area and visibility was reduced at times by heavy falls of snow. The approach took a total of 40 minutes and LG 997 arrived 20 minutes after Finnbirch had capsized. On arrival, the helicopter crew observed persons in a raft and began preparations for winching.

This winching attempt began from a height of 100 ft. with the help of the automatic height and position-holding control system. Because of the heavy sea, the system gave excessive rudder and was automatically disconnected, generating a collective warning signal. The commander experienced this as a technical fault in the control system.

After further attempts with the same result, the commander attempted a winching from the same height, 100 ft, with manual height and position-holding.

The commander decided that the risks to his own crew were too great in consideration of the difficulties he had in holding the helicopter in the winching position and decided to abandon these attempts after 25 minutes.

LG 997 discontinued its efforts at 2010 hours and landed at Visby at 2052 hours.

Helicopter Y 67 (Vertol 107)

Y 67 – a military helicopter based at Ronneby – was at stand-by for sea rescue when alerted. Y 67 was soon airborne and, after consultation with ARCC, without its 20 man raft which would take 20 minutes take on board.

Y 67 flew against a head wind and was at the site of the accident after an hour as darkness set in. The crew had learned, during their approach, that LG 997 had decided not to winch the crew from Finnbirch and that Marneborg was, in effect, OSC.

On arrival, the crew experienced very strong turbulence while hovering at 150 ft. They made repeated unsuccessful attempts to reach a winching position. It appeared to them that there were somewhat better winching conditions at the bow of the ship (forecastle deck) but learned that the ship's crew could not get to this position. NVG (Night Vision Goggles) were used in attempting to approach for winching but the movements of the ship and the turbulence still made this inadvisable.

Y 67 remained in the vicinity of Finnbirch for approximately two hours and learned that the ship's Master had been injured but could do nothing but observe and await developments.

When Y 67 left Finnbirch at 1918 hours for refuelling at Kalmar, MRCC was advised that the listing of the ship had increased and that the structure of the bridge had reached the water.

Finnbirch capsized six minutes after Y 67 left the area.

At Kalmar air port, Y67 was loaded with a 20-man raft transported from Ronneby. The helicopter was airborne again after 25 minutes and within another 25 minutes, was back at the scene of the rescue. It was then 1 hour 10 minutes since Finnbirch had capsized. They knew that LG 997 had left the area that LG 992 had winched seven survivors and recently left the area and that Y 63 had arrived at the same time as Y 67.

The crew of Y 67 quickly discovered two persons supported by a larger piece of timber and began manual winching from 40 ft. The winching was successful, the second pilot flying with NVG and the first without.

The two winched from the sea were in such sufficiently good condition that searching could continue. After a further half hour, another person was found and winched in the same way. This survivor was in such poor condition that it was decided to return to Kalmar.

After an hour at Kalmar, Y 67 began its return to the rescue location, learning at the same time that Y 63 was incoming with three persons. It was then known that one person was still missing. Further searching was to be coordinated with LG 992. There were no results from this and the operation was called off, Y 67 landing at Kalmar at 0140 hours

The crew has reported that NVG were of great assistance in holding the helicopters safely separated during both the winching and the searching. The interference with VHF channel 67 from the transmissions from the ship's EPIRB was also remarked upon. It was considered by the crew that the OSC had performed its duties in a praiseworthy manner.

Helicopter Lifeguard 992 (Sikorsky S-76)

Lifeguard (LG) 992 from Norrlandsflyg AB was at standby at Arlanda when the crew was informed by ARCC that a rescue operation involving Finnbirch had begun. They were also advised that LG 997 and Y 67 were alerted and had been instructed to fly to the ship. LG 992 was instructed to proceed to a new base at Visby Airport to be closer to the area of the rescue. LG 992 landed at Visby immediately after 1800 hours. Approximately 50 minutes later, LG 992 was given order to take off as the listing of Finnbirch had worsened. LG 992 was airborne immediately after 1900 hours with a 20-man raft on board.

During the approach, experiencing periodic snow squalls, LG 992 learned via the communication radio that Y 67 had left the area of the accident for refuelling at Kalmar. It was also learned that the ship Largo had reported that Finnbirch had capsized. It was then 1924 hours and the ship was to be reached in 6 minutes. On arrival, Finnbirch could be seen on its beam ends or with its keel upward. After 4 minutes, at 1934 hours, the ship sank.

LG 992 hovered/drifted past the location of the sinking of the ship and dropped its raft upwind of the survivors in the water to remove its bulk from within the helicopter and thereby obtain space in the helicopter for those to be rescued. The raft was dropped without activating its inflation. The helicopter was backed and began winching, attempting the use of the automatic hovering holding system. The heavy seas prevented this and several collective warning signals were generated. The commander then decided to attempt again, hovering at 50 ft. under manual control. 3-4 persons were winched; the crew waited 4 minutes during a heavy snow storm and was then able to rescue a further 3-4, making 7 survivors on board. It was noticed that some of the survival suits were too large for those wearing them and in some cases, the zip-fasteners had not been fully closed. The winching occupied 45 minutes and LG 992 then returned to Kalmar where ambulances waited.

At 2234 hours, LG 992 started again to continue the search together with Y 67.

The continued searching gave no results but at 0024 hours, the Finnbirch EPIRB was winched up from the sea and disabled. This had earlier interfered with radio traffic for Y 67 and Y 63.

LG 992 landed at Kalmar at 0106 hours and discontinued operations. The crew has reported that there was no problem keeping enough separation between the helicopters.

Helicopter Y 63 (Vertol 107)

Y 63 – a military helicopter was not at standby when the alarm was raised. On request from ARCC, the helicopter squadron at Ronneby assembled a crew for Y 63 which started at 1950 hours, carrying two 20-man rafts. The initial instructions were to fly to Kalmar to wait, at standby, for further instructions. Finnbirch capsized while Y 63 flew to Kalmar and as the departure of Y 67 from Kalmar had been delayed, Y 63 was instructed to fly directly to the rescue area. En route, Y 63 contacted OSC Marneborg. Largo had sighted and illuminated a raft with survivors on board. Y 63 and Y 67 entered the rescue area at the same time.

Y 63 approached the illuminated raft and Y 67 towards the persons sighted in the water. Y 63 winched from 30 ft. using NVG. The two persons winched from the raft by Y 63 were in relatively good condition. On arrival in the helicopter, these reported that there had been further survivors at the raft.

A search track was begun upwind, from the position of the raft, to where the ship had sunk. After almost an hour and a half, a person was discovered floating. The crew winched as before until the person was at the level of the door, to be taken into the helicopter. He fastened there because the survival suit was filled with water and the legs of the suit, distended with water as balloons, had been caught under the helicopter. After considerable difficulty, the crews were able to puncture the suit with a knife and could then draw the person into the helicopter. He was found to be dead. The crew decided to return to Kalmar with the three persons on board, landing at the airport at 2250 hours. After two and a half hours at Kalmar, Y 63 restarted to return to search, together with the Finnish helicopter OH HVI, for the 14th person still missing. Except for an empty survival suit, nothing further was found during the next two hours of searching.

The crew discontinued their search at 0359 hours and returned to Ronneby.

The crew considered that the rescue had been directed effectively and felt that the crew were in good “flying trim” and worked well together. They had been aware of the interference from the ship’s EPIRB in the same way as Y 67.

They had the same positive impression of the use of NVG as the Y 67 crew.

Helicopter OH-HVI (AS 332 Super Puma)

The Finnish helicopter OH-HVI was based at Åbo at the time of the accident to Finnbirch.

At the request of the Swedish rescue centre, MRCC Turku (Åbo) alerted OH-HVI at 1834 hours. After collecting all the information available regarding the proposed operation, weather etc. OH-HVI started an hour later to fly to Visby to stand by. During the flight to Visby, OH-HVI was redirected to the location of the accident. OH-HVI could utilize its de-icing system for the rotor blades, which this type of helicopter is provided with and could therefore fly at an altitude where the tail wind was at maximum, despite the risk of icing. They arrived in the area after a flight of 1 hour 20 minutes.

On arrival, OH-HVI had certain difficulties in obtaining information because of communication problems. Radio connection with the rescue centre was lost at times; other units were engaged in their own rescue activities and were too busy to take the time to explain the situation to OH-HVI. After making radio contact with the helicopters at lower altitudes, OH-HVI descended with visual contact and began its efforts, which despite these problems were not delayed. At this time, seven persons remained missing. The area search was between the position of the sinking and the EPIRB. Much debris from the ship was visible but no persons. After searching for one and a half hours, OH-HVI set course for Kalmar for refuelling. After almost three hours at Kalmar, OH-HVI returned to the rescue together with Y 63. No further results were obtained and OH-HVI discontinued at 02.48 hours its efforts and flew to Visby.

1.14.5 General comments

The automatic controls in all the three helicopter types used in the rescue operations have technical limitations when winching from a water surface with a heavy sea. The system, which is intended to hold the helicopter steady at a chosen position and a chosen height, measures e.g. the height of the helicopter above the surface of the water. This is done with a radar altimeter. With a heavy sea, the system attempts to follow the waves and maintain the helicopter at the same height above both wave crest and wave trough. This leads to different phenomena. If the difference between the pre-selected hovering height and the measured hovering height is too great, the system warns with a so-called "collective warning" and is automatically disabled and the pilot must return to manual control. The efforts of the system to hold the pre-selected altitude mean that the variations in the power output of the engines become excessive and the pilot is forced to return to manual control. The limitations in the operative capacity of the automatic control system are a function of the wave height, the wave length and the hovering altitude selected.

When winching from the ship which rolled and pitched, it was not possible to make use of the automatic control system as the reading of the radar altimeter is a parameter of the function of the automatic control system. The radar altimeter measures the helicopter's altitude, at times above different parts of the ship, at times above the waves, with considerable altitude measurement differences. The rolling of the ship also causes variations in the height of the winching area. The higher in the ship the winching area is, the greater is its transverse movement when the ship pitches and rolls.

All of the Swedish helicopter crews had flying time according to the norm during the preceding 12 months. Manual flying in darkness i.e. flying at night without automatic control had however been trained relatively seldom. This was because only a few flights could be performed in darkness and it was recommended that such flights and/or flights under IMC (Instrument Meteorological Conditions) should be performed, as far as possible, using the automatic control system, as specified in the Defence Forces Flight Instruction no. 06 2006-02-16 and Norrlandsflygs FOM 14.2.7 and 14.4.1.

The commander of LG 992 was placed under operative limitations by the company's flying manager. These limitations had not been reported to ARCC.

On the arrival of the helicopters at the position of the sinking, there was oil and fuel on the surface. This could cause injury to the inner organs and/eyes of the survivors and the search and rescue (SAR) divers.

Flotsam on and in the water was also dangerous for the search and rescue (SAR) divers. There have however, been no reports of injuries to the search and rescue (SAR) divers.

Communication with search and rescue (SAR) divers in the water was by means of sign language. These were difficult to interpret because of the darkness, the hard weather with reduced visibility and high hovering height.

Operational reports after the accident vary between the different units with respect to volume and presentation. There were no standard forms in which they were presented

The two helicopters LG 992 and Y 67 had a problem with incorrect indication of the gyro-compass when parked at Kalmar airport. It is known by several pilots that this can occur when starting from parking place 2 at the airport.

The helicopter bases at Arlanda, Visby and Ronneby respectively, operate with two different helicopter types with different operational capacities which were not known in detail to the rescue centre. These differences include flight time capacity, load capacity, weather limitations, performance under icing conditions, and darkness capacity with NVG.

Three weeks after the accident, the Coastguard found the body of the missing Chief Officer when investigating the wreck with a remotely controlled underwater robot (ROV). He was found near the starboard life boat i.e. where the crew were assembled when the ship sank. The body was recovered with the help of the ROV.

1.14.6 Helicopters in marine rescue operations

Helicopters have been used in Sweden since the 1960's for rescue operations on land and at sea. The defence forces have previously maintained readiness for these but since 2000 have modified their activity. The defence plans for 2004 required that certain bases be abandoned. After these organizational changes, the Defence Forces have successively chosen to withdraw from their responsibility for readiness for marine rescue operations. At the time of the accident, however, the rescue activity at Ronneby was still operational.

Swedish Maritime Administration has since then, engaged a civilian contractor, Norrlandsflyg AB to provide a helicopter readiness service for marine rescue operations. From 2002, Norrlandsflyg established readiness helicopter services first at Sundsvall and then at Visby airport. In February 2006, operations were begun at Arlanda and later, at Gothenburg and in the spring of 2007, after the accident, at Ronneby.

In connection with the negotiations for SAR helicopter services, Swedish Maritime Administration specified its requirements in an operational duty specification. This states that rescues are to be possible in heavy weather without this being specified in more detail. The agreement with the defence forces also included a document dated 1998-11-20 with designation "Guidelines for the planning and execution of contracted helicopter services". This document contains no declaration of any level of ambition and under which circumstances a recue are to be performed.

Neither the Defence Forces nor Norrlandsflyg have, in their Flight or other Operation Manuals, established in detail their operational objectives. In connection with interviews with helicopter crews, SHK has observed that at crew level, there are different opinions regarding limits within which rescues may or may not be performed.

The Defence Forces have been phasing out their activities to provide helicopter readiness for SAR operations during recent years. Ronneby base, for example, had no marine or aeronautical rescue readiness from October 2005 until August 2006 and, before the accident, had only been operational for seven weeks

During the years 2002 forward to 2007, Norrlandsflyg built up its experience and competence in marine rescue operations. This has resulted in the need for 15 new crews, approximately 60 persons in different crew positions in the helicopters, these to be trained in SAR duties.

Formal requirements for commanders in SAR service are given in FOM 14.12.2.1. A training program is also specified in FOM 14.12.6. There are however no requirements that commanders on board a helicopter are to have previous experience of SAR activity.

There were no civilian statutes governing SAR activity at the time Norrlandsflyg began such operations as there had previously been no such activity in civil aviation in Sweden. Instead, approval of the company and its proposals for operational instructions has been approved, for which Luftfartsstyrelsen (The Civil Aviation Authority) is responsible.

1.15 Relevant actions taken following the accident

1.15.1 The Owners

Lindholm Shipping has not itself formally investigated the circumstances of the loss of Finnbirch, this being required of them by the ISM code, but has interviewed the crew. No actions were taken with respect to their remaining activity. When SHK visited the Owners in September 2007, they considered that, irrespective of the results of such an investigation, their small company is not able to make demands on such a large actor in their market as Finnlines. Approximately a year after the accident, the Owners commissioned a calculation of the effectiveness of the cargo-securing on board the sister ship Finnforest. Their conclusion was that the level of cargo securing was acceptable in relation to the calculated accelerations of the ship to which it could be exposed.

1.15.2 The charterer

The non conformity reporting system is mainly handled locally within Finnlines. It is only repeated non conformities indicating more systematic problems which are taken up by the management for analysis. Those non conformities which relate to cargo-securing, and are taken up, are handled by a special working group for such matters. The group has not been convened to investigate the accident to Finnbirch as the company considers that this was an isolated occurrence and not repeated non conformities.

Finnlines has taken certain actions after the accident. In January 2007, an internal auditing was performed of the cargo-securing stations at the reloading terminals. Certain non conformities from requirements such as the incorrect application of tension levers were detected by this. These failings were corrected according to Finnlines, this being confirmed by crewmen on the sister ship Finnforest. Approximately 11 months after the accident, in October 2007, the possible tipping of roll-trailers loaded with paper reels was investigated by testing. No relevant shortcomings of significance in the operational procedures were detected which called for major changes. Finnlines has reported that further tipping tests have been performed.

1.15.3 The Inspecting Authority

At the request of SHK, the inspecting authority went on board the sister ship Finnforest in Helsinki during late autumn 2007 to check the cargo-securing. Shortcomings in relation to the cargo-securing manual were observed. This led to the replacement of the web lashings used on board with 13 mm chains.

1.16 Current Statutory Requirements

1.16.1 Stability and freeboard

The current requirements for stability and freeboard for Swedish ships, which in all important respects applied at the time of the sinking of Finnbirch, are contained in the statute SJÖFS 2006:1.

The stability characteristics of a ship and data for calculating its stability are to be documented in a stability book which is also to contain typical loading conditions, inter alia, limiting values for the vertical location of the center of gravity of the ship and cargo. This book is to be submitted to Swedish Maritime Administration for approval. This had been done for Finnbirch.

1.16.2 Cargo-securing on board ships

The international set of rules for the securing of cargo on board ships is clear, and SOLAS Chapter VI, rule 5, paragraph 6, includes the following:

1. All ships except those for bulk cargo are to be provided with an individual cargo-securing manual.
2. The manual shall contain instructions for stowing and securing cargo in accordance with MSC/Circ. 745.
3. The cargo-securing manual is to be approved by the administration.
4. The cargo is to be secured in accordance with the instructions in the cargo-securing manual.
5. The cargo on ro-ro-ships is to be secured in accordance with the instructions before the ship leaves harbour.

According to the instructions in MSC/Circ. 745, the cargo-securing manual is to specify how the cargo-securing equipment is to be used, how different types of cargo and cargo units are to be secured, giving the number of lashings, lashing angles, requirements for friction increasing material etc. Examples are to be given of the forces affecting the cargo units and limiting values of rolling angles and GM values where the permitted loadings on lashing are exceeded. Examples are also to be given of how the number and strength of the lashings are to be calculated and the safety factors which are then to be used.
In addition to the international set of rules the IMO Code of Safe Practice for Cargo Stowage and Securing (the CSS-code) exists. This code contains e.g. in Annex 13, clear dimensioning criteria for cargo-securing arrangements. This annex also contains the information that with rolling resonance in a beam sea with rolling angles larger than 30 degrees, the specified values for transverse acceleration can be exceeded and that effective measures are to be taken to avoid such situations, also that in high following seas, with low reserves of stability, large rolling angles can develop with transverse accelerations exceeding the specified values and that a suitable change of course should then be considered.

At the time of the loss of Finnbirch, SJÖFS 2001:2, the Swedish Maritime Administration regulations for cargo-securing applied on Swedish ships. This document legitimized the above international requirement for Swedish ships and for ships calling at Swedish ports. Swedish Maritime Administration has since issued new assembled regulations in SJÖFS 2008:4, Swedish Maritime Administration regulations and general recommendations for transport of cargo which replace the previous regulations.

In the international set of rules, SOLAS chapter VI, rule 5, states e.g. the following;

"5.1. Cargo, cargo units and cargo transport units carried on or under deck shall be so loaded, stowed and secured as to prevent as far as is practicable , throughout the voyage, damage or hazards to the ship and the persons onboard, and loss of cargo overboard."

"5.3 Appropriate precautions shall be taken during loading and transport of cargo transport units onboard ro-ro ships, especially with regard to the securing arrangements on board such ships and on the cargo units and cargo transport units and with regard to the strength of the fixing points and the lashings."

1.16.3 Securing of goods in and on cargo transport units

SOLAS chapter VI, rule 5 in reference to the securing of goods in and on cargo transport units, contains the following;

"5.2 Cargo, cargo units and cargo transport units shall be so packed and secured within the unit as to prevent, throughout the voyage, damage or hazard to the ship and the persons onboard. "

IMO/ILO/UN ECE Guidelines for packing of Cargo Transport Units (CTUs) contain general recommendations and instructions for the stowing and securing of cargo in and on cargo transport units. Detailed instructions for the dimensioning of cargo-securing arrangements contained in the training material for IMO model course 3.18 developed in addition to these guidlines. Observation of these is not internationally obligatory.

At the time of the accident Sweden had ratified parts of these Guidelines for goods transported on Swedish ships or goods loaded in Swedish ports through Swedish Maritime Administration's regulations and general recommendations (SJÖFS 2003:14) relating to securing cargo in cargo transport units on ships. This document has also been replaced by the assembled regulations for the transport of cargo which were issued during 2008. There is no corresponding requirement in regulations in Finland.

The Maritime law (SFS 1994:1009), chapter 13 relating to general cargo, states the following:

"Delivery of the goods

5 § The shipper shall deliver the goods at the place and within the time specified by the carrier. It shall be delivered in such a manner and in such condition that it can be conveniently and safely received, stowed, transported and discharged

Inspection of the packing

6 § The carrier shall, to a reasonable degree, inspect the goods to confirm that they are packed in such a manner that they are not damaged or can cause injury to persons or property. If the goods are delivered in a container or similar means of transport, the carrier is not required to inspect the contents of the container unless there is reason to suspect that the container is not packed correctly.

The carrier shall inform the shipper of such shortcomings he has discovered. He is not required to transport the goods if he cannot, by taking reasonable precautions, make the consignment suitable for transport.

1.16.4 The responsibility of the Master and the safety organisation of the Owners

The responsibilities of the Master of a ship are regulated by the Maritime law (SFS 1994:1009), chapter 6. These include ensuring that the ship is seaworthy on departure and during a voyage. He is also required to inform the Owners of any loss of seaworthiness which cannot be corrected immediately. The concept of seaworthiness to which the paragraph refers and which is described in more detail in Chap 1 § 9, includes the ship being *"so loaded and ballasted that the security of the ship, persons and goods is not prejudiced".*

The responsibility of the Owner is described in the Maritime Safety act (SFS 2003:364): According to Chapter 2:

"9 § The activities of ship owners shall be performed in such a manner that safety at sea is maintained and that persons, the environment and property are protected."

To control and ensure security within the Owners' activities and on board ship, the law relating to ship security states further that the Owners shall institute an approved safety management system (SMS) in accordance with the International ISM-code (International Safety Management code). The code is incorporated in a Swedish regulation (SJÖFS 2002:8) relating to the safety organisation of ship owning companies and ships. The objectives of such a safety management system are described in Chapter 1.2 of the code. It is said there, for example;

"The safety management system should ensure;

.1 compliance with mandatory rules and regulations; and

.2 that applicable codes, guidelines and standards, recommended by the Organization, Administration, classification societies and maritime industry organizations are taken into account.

To ensure that the Owners are capable of achieving the specified objectives, certain functional requirements of the safety management system must be satisfied as stated in Chapter 1.4.
These include;

".3 defined levels of authority and lines of communication between and amongst shore and shipboard personnel;

.4 procedures for reporting accidents an non-conformities with provisions of this code;

.5 procedures for prepare and respond to emergency situations; and

.6 procedures for intended audits and management reviews."

To ensure the safe operation of all ships and to establish a connection between the ship owner's company and the personnel on board, the ISM code recommends that the Owners have one or more persons employed on land with certain allocated responsibilities, so-called Designated Persons (DP). These persons are to have direct contact with the management at the highest level.

The responsibilities and authority of these persons are to include the following:

"monitoring the safety and pollution-prevention aspects of the operation of each ship and ensuring that adequate resources and shore-based support are applied, as required."

The ISM system also requires the Master to report non-conformities to the management on land, and the management on land to support the Master to enable him to perform his duties in a reassuring manner;

"5.1.5 reviewing the SMS and reporting its deficiencies to the shore-based management.

"5.2 The company should ensure that the SMS operating onboard the ship contains a clear statement emphasizing the master's authority. The Company should establish in the SMS that the master has the overriding authority and the responsibility to make decisions with respect to safety and pollution prevention and to request the Company's assistance as may be necessary.

"6.1 The Company should ensure that the master is"….

".3 given the necessary support so that the master's duties can be safely performed."

In an appendix to the IMO code, IMO (International Maritime Organization) has developed guidelines for Owners in the operative application of the ISM code, (MSC-MEPC.7/Circ.5), dated 19 October 2007. In these guidelines IMO has presented the basic principles for e.g. internal audition of the ISM system, reporting and analysis of accidents, incidents and deviations from the norm as well as the important role which a DP has in the company's safety work and which resources and authorities he should be allocated. IMO has also prepared a special guide specifying which background, qualifications and training a DP should have. (MSC-MEPC.7/Circ.6, dated 10 October 2007).

1.17 Special tests and investigations

SHK has commissioned an investigation in accordance with IMO MSC/Circ. 1228 into the performance of ships in a following sea to determine if such could have influenced the unexpected heavy rolls of Finnbirch.

SHK has also commissioned an analysis of the risks of tipping and sliding of the relevant units with different types of cargo-securing arangements. A possible scenario for cargo-shifting has then been developed on the basis of these calculations, the cargo plan and observations made. The Ship's EPIRB has also been examined at the request of SHK.

1.17.1 Stability phenomena in following sea

In 1995, IMO published an MSC-circular 707 with the title "Guidance to the master for avoiding dangerous situations in following and quartering seas". This circular was revised in MSC/Circ. 1228 issued in January 2007. The calculations for Finnbirch according to this recommendation are shown in Appendix 3.

The calculations show that the speed of Finnbirch was lower than that required to satisfy the speed criteria for broaching. On the other hand, the ship satisfied the criteria for reduction of stability when ships ride on a wave with the crest amidships, "pure loss of stability" or "(quasi-) static loss of stability. This quasistatic phenomenon can occur with wavelengths between 0.6 and 2.3 times the waterline length of a ship and then in particular, when the ship's speed is close to that of the waves, this being the case here. The static stability can be very low and even negative under unfavourable circumstances.

For the phenomenon "successive attack in high seas" the speed criterion does not coincide with the ship's speed according to the calculations performed. Nor are the criteria for synchronized (parametric) rolling satisfied. From neither interviews with the crew nor other witnesses has any evidence been obtained of successively increasing rolling or heeling in time with the waves.

A number of research institutions have, worldwide, studied the phenomenon and also attempted to improve the hull form of different types of ship. The risk of capsizing in a following sea is given by this research as probabilities calculated through simulation of ships' movements in waves. At greatest risk are ro-ro ships and container ships in heavy seas with a wave length somewhat over half the ship length and greater. The speed of the ship is of great importance and the risk can be reduced by adjustment of the speed. There is however more than one which gives an increased risk range of speed.

In these and other studies, attention has been drawn to the quasistatistic stability loss which occurs when the wave crest in a long following sea is close to the midpoint of the ship's length, or with the increase in the righting moment with wave crests tops at the quarter lengths.

This phenomenon has been studied for the case of Finnbirch. In high waves with wavelengths over 70 m and with the wave top amidships, a considerable reduction in the GZ value occurs in relation to the value in still water while a large increase occurs with the crests at the quarter lengths. Low GZ values can lead to capsize with only a moderate heeling angle. Large variation in the righting lever with wave passage gives a considerable heeling effect with rolling. (See Appendix 2).

1.17.2 Examination of the EPIRB

During the rescue work, the helicopter crews in Vertol 107 reported that VHF channel 67 was subject to interference ("jammed") by the emergency transmitter EPIRB. SHK requested FOI (The Defence Research Institute) to examine the Finnbirch EPIRB. The FOI examination has not been able to show that it transmits on channel 67. No fault was found in the EPIRB which functioned in accordance with its specification.

When testing on board the Vertol 107 with the EPIRB concerned, it was found that the radio on board the helicopter has a function to permit reception of transmissions on 121.5 MHz (EPIRB) irrespective of the frequency set. If an EPIRB transmits, this sound is superimposed on the sound which is received from the frequency set. The radio on the helicopter has a switch to enable or disable this alarm function. If this function had been utilized, the interference on channel 67 would have been eliminated.

1.17.3 Basic data for the dimensioning of cargo-securing arrangements

The cargo-securing arrangements are to prevent cargo from sliding and tipping. The following basic parameters must be known to correctly dimension the arrangements for the securing of cargo on board a specific ship: accelerations which affect the cargo, the friction between the cargo and the deck surface and the weight and position of the centre of gravity of the cargo/cargo unit.

To be able to determine the amount of lashing equipment required, the following parameters must also be known; the strength of the lashings, the lashing angles and the points of application of the lashings on the goods and the safety factors to be used in the calculations.

Accelerations in the ship

SHK has calculated the ship accelerations for Finnbirch in accordance with the CSS code. These values are somewhat higher than those shown in the ship's cargo-securing manual which was calculated following formulae developed by the classification society Det Norske Veritas (DNV). Before the introduction of the CSS code, it was common for the DNV acceleration values to be used as a basis for the dimensioning. The acceleration values calculated according to these methods assume however that those responsible on board the ship are observant and take measures to ensure that, in certain situations, the accelerations are not exceeded.

To obtain an impression of the order of magnitude of the forces which affects the cargo with the transverse accelerations, the relative heeling angle can be calculated as ;

$V = arctan\ (a_t/g)$.

For Finnbirch, the following relative heeling angles are obtained at different positions on board the ship. The relative heeling angle corresponds with the angle which an inclinometer on board would show with the accelerations given.

Relative heeling angles at different positions on board. The bold type figures indicate cargo positions

	Relative heeling angle [°], for M/V Finnbirch										
	Transverse										
Long. position:	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
Wheel house	-	-	**35,3**	-	-	-	-	-	-	-	-
Weather deck	34,3	33,2	32,4	**32,0**	**31,7**	**31,7**	**32,0**	**32,4**	**33,2**	**34,3**	35,7
Upper deck	**31,7**	**30,9**	**30,1**	**29,3**	**29,3**	**29,3**	**29,3**	**30,1**	**30,9**	**31,7**	32,8
Main deck	**29,7**	**28,5**	**27,3**	**26,9**	**26,4**	**26,4**	**26,9**	**27,3**	**28,5**	**29,7**	31,3
Lower hold	28,5	26,9	26,0	**25,1**	**24,7**	**24,7**	**25,1**	**26,0**	**26,9**	**28,5**	30,1

Friction between cargo and ship's deck

According to CSS Annex 13, the following coefficients of friction are to be used when dimensioning cargo-securing arrangements:

Friction coefficients.

Materials in contact	*Friction coefficient (μ)*
Timber–timber, wet or dry	0,4
Steel–timber or steel–rubber	0,3
Steel–Steel, dry	0,1
Steel–steel, wet	0,0

Safety factors

Two different safety factors are used when dimensioning cargo-securing arrangements. One is to allow for possible defects in the lashing equipment such as wear. The maximum permissible load on a lashing is designated Maximum Securing Load (MSL). This is given as a certain percentage of the Minimum Breaking Load (MBL) of the lashing. See the table below.

MSL (Maximum securing load) on the basis of MBL (Minimum Breaking Load)

Material	*MSL*
Shackles, rings, deckeyes, turnbuckles of mild steel	50% of breaking strength
Fibre rope	33% of breaking strength
Web lashing	50% of breaking strength
Wire rope (single use)	80% of breaking strength
Wire rope (re-useable)	30% of breaking strength
Steel band (single use)	70% of breaking strength
Chains	50% of breaking strength

A further safety factor is to be used e.g. to compensate for uneven distribution of forces among the different lashings of the same unit. When dimensioning a cargo-securing arrangement, the maximum theoretical calculated value of the force in a lashing, Calculated Strength (CS) may be:

CS ≤ MBL × SF1 / SF2, where

MBL = Minimum breaking Load on the lashing
SF1 = safety factor according to the table above
SF2 = 1,35

1.17.4 Calculated Tipping and Sliding angles for roll-trailers

As described above, according to the instructions in the cargo-securing manual for Finnbirch and from Finnlines, block-stowed roll-trailers need only be lashed at the front end, (the end near the terminal tractor). It was learned during the SHK visit to the sister ship Finnforest in September, these lashings were applied in such a way that they largely prevented sliding but had a limited effect in preventing tipping. It can be assumed with a high degree of probability that the roll-trailers on Finnbirch on its final voyage were not lashed at the back and in principle, only lashed against sliding at the front.

With a coefficient of friction of 0.3 between the wheels of the roll-trailers and the ship's deck, sliding on the deck has begun with a relative heeling angle of 16.7 degrees. That a coefficient of friction of this order of magnitude can occur on a wet deck has been confirmed by tests performed by Finnlines on board Finnforest.

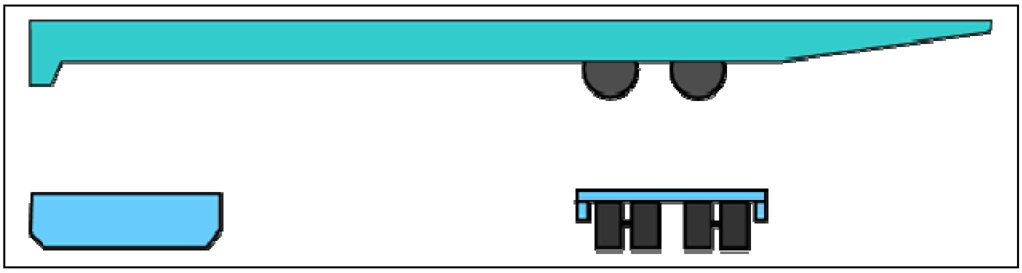


Fig. 40 Typical 40-ft. roll- trailer.

Roll-trailers which have a high load are particularly sensitive to tipping and this tendency depends on the following parameters.

- The height of the load
- The weight of the load
- The height of the roll-trailer platform
- The tare weight of the roll-trailer and the positon of its center of gravity
- The distribution of the weight carried between the front support and the boggie
- The width of the supports at the front of the roll-trailer and at the boggie
- The height up to the centre of the boggie

In the following diagram the tipping angle as a function of the height of the load with 30 and 50 tonnes total load (tare weight + load weight) respectively is shown.

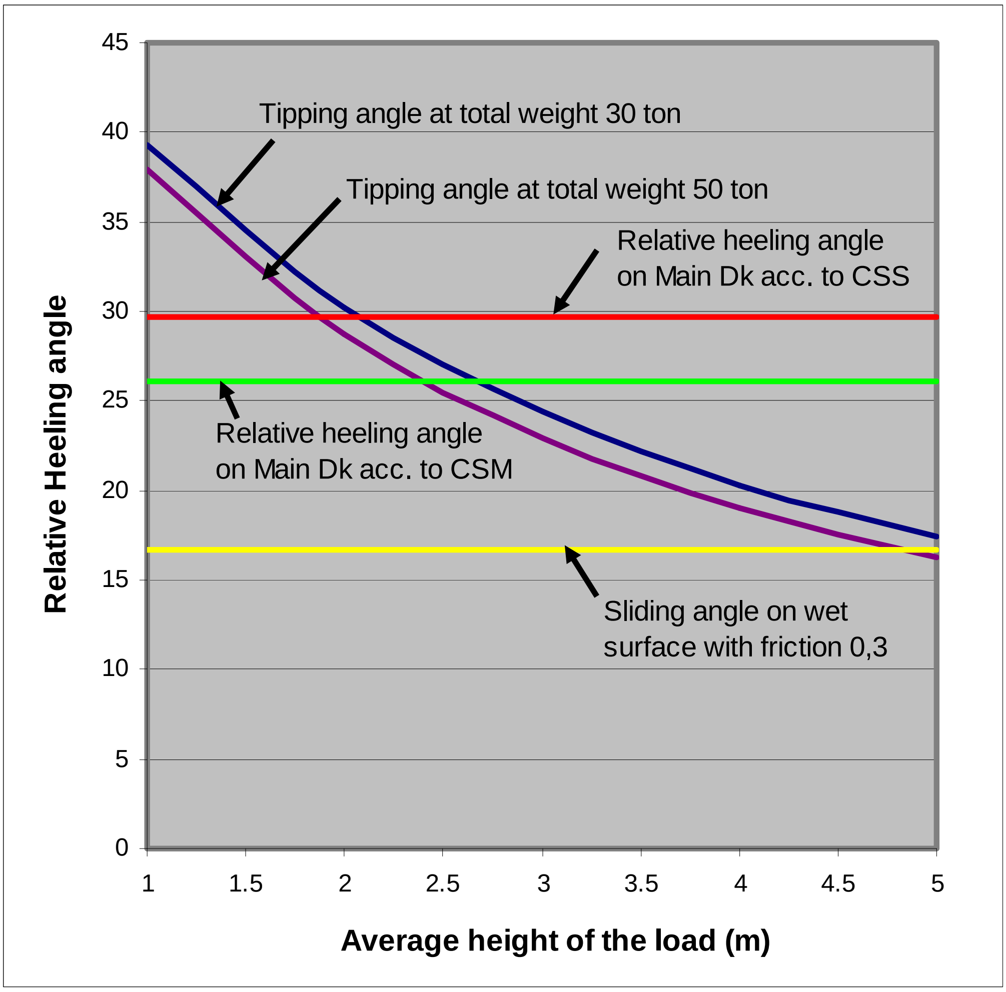


Fig. 41 Tipping angles for roll-trailers with total weight 30-50 tonnes as a function of the height of the load.

From the diagram above, it can be seen that a roll-trailer which has a total weight of 50 tonnes and is loaded to 3.5 m height without lashing to prevent tipping, will tip at a heeling angle just over 20 degrees. For these calculations, parameter values for a roll-trailer according to the below have been used. The range of the parameter values for Finnlines 40 ft roll-trailers are given in brackets.

Height of roll-trailer platform:	780 mm	(750–810 mm)
Tare weight of the roll-trailer:	5,5 tonnes	(4,6–6,7 tonnes)
Height of the C.of G. of the roll-trailer:	70 % of the height to the platform	
Distribution of weight between the front end of the roll-trailer and the boggie:	1/3 and 2/3 respectively	
Width of support at the front end of the roll-trailer:	2.3 m	(2,2–2,5 m)
Width of support at the roll-trailer boggie:	1,35 m	(1,35–1,45 m)
Height of the boggie centre:	0,2 m	(ca 0,2 m)

The diagram also shows the relative heeling angle when there is sliding risk at the rear of a roll-trailer without lashings and the expected relative heeling angles on the Main Deck on board Finnbirch calculated in accordance with the CSS Annex 13 method and the accelerations given in the cargo-securing manual. With accelerations according to CSS Annex 13, there is tipping risk with load heights larger than approximately 2 m, and, with accelerations according to the cargo-securing manual, with loads higher than approximately 2.5 m.

1.17.5 Practical tipping tests with roll-trailers.

That roll-trailers are sensitive to tripping depends primarily on the main part of the load being carried by the boggie and that this has a relatively small support width.

At the boggie end, the roll-trailer tips around the support points of the boggie package. The transverse distance between these is approximately 1.35 - 1.45 m which should be compared with the total width of the trailer, approximately 2.5 m.

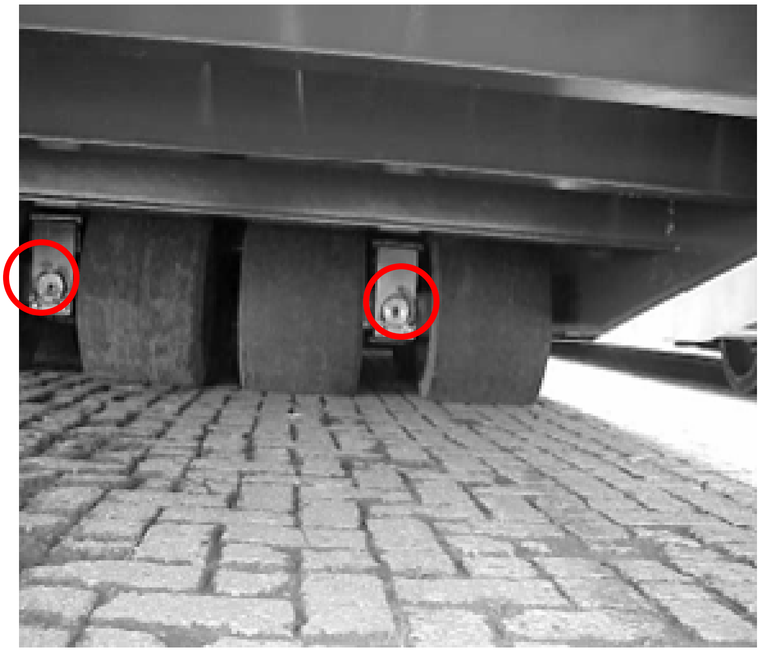


Fig. 42 Tipping points at the boggie end of a normal 40 ft. roll-trailer.

The inherent tendency of roll-trailers to tip is confirmed by heeling tests performed by Finnlines. The photo below illustrates tests performed during Autumn 2007. When the heeling angle exceeded approximately 20 degrees, the tipping was prevented by two chains coupled to heavy fork-lift trucks. Corresponding tests were performed by Finnlines in 1987. Restraining trucks were not used and in some tests, the roll-trailers tipped at heeling angles of approximately 20 degrees.

Fig. 43 Heeling tests showing that roll-trailers with high load are very likely to tip.

In certain heeling tests performed in 1987, the load tipped and slid from the roll-trailer before the trailer itself tipped. During tests performed in November 2007, the load remained on the roll-trailer until the heeling angle had reached approximately 45 degrees as shown by the photo below.

Fig. 44 Heeling test, Finnlines, October 2007.

The documentation from the tests in 2007 relate only to arrangements with three lashings per corner protection. Tests were not performed with two lashings per corner protection as permitted by Finnlines' guidelines for transport on the Baltic. Finnlines' report that heeling tests were performed later with two chains per corner protection and that the cargo slid off the cargo transport unit with a 30 degree static heeling angle. SHK has not studied these later tests nor the circumstances under which they were performed.

1.17.6 Calculation of the tipping angle for the relevant roll-trailer cargo.

The tally reports from Finnsteve, Finnlines stevedors in the terminal at Helsinki are fully detailed. With their help, it has been possible to reconstruct which paper reels, with weight and dimensions were loaded on which roll-trailer.
The cargo plan is also detailed and shows where on board the different units were stowed.

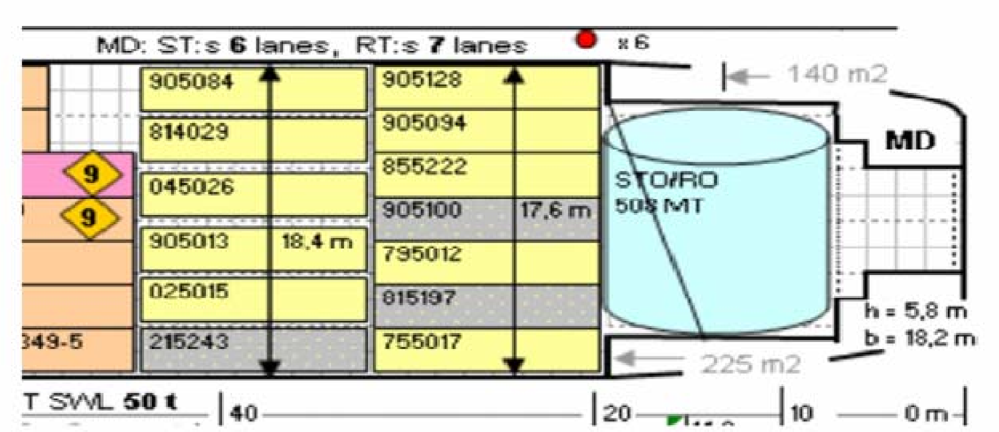


Fig. 45 Extract from cargo plan for the final voyage of Finnbirch showing the cargo units at the forward end of the Main Deck.

The static tipping angle has been calculated for a number of the roll-trailers stowed forward on the Main Deck. The parameter values from Finnlines for the different roll-trailers have been used in the calculations. Calculations have been performed for stowing patterns in which the entire area of the platform of the roll-trailer have been used and for patterns in which a margin of some centimetres has remained free. The following tipping angles were obtained for the roll-trailers stowed forward on the Main Deck.

Static tipping angle for some of the roll-trailers stowed forward on the Main Deck.

Roll-trailer No	***Total weight (tonnes)***	***Stowage height (m)***	***Static tipping angle (degrees)***
215243	*36,2*	*3,57–4,10*	*20,0–22,0*
855222	*35,5*	*3,00–3,41*	*23,1–24,9*
905128	*36,8*	*3,30–3,75*	*20,4–22,2*
755017	*46,6*	*2,63–2,79*	*24,4–25,3*
815197	*50,0*	*1,89–2,18*	*27,3–29,3*
905100	*48,0*	*2,86–2,88*	*23,5–23,6*

The above static tipping angles are calculated for completely rigid roll-trailers with center of gravity at the centre line. When the ship heels over and the load begins to lean, there is a compression effect on the lower side of the roll-trailers rubberwheels, as well as on the rubber mat under foremost support of the roll-trailer. The tipping width of the boggie is also less. As a result, the rear of the roll-trailer begins to tip at an angle 3-4 degrees less than the values given in the table. Because a roll-trailer is relatively weak in torsion, the rear section will tip first and draw with it the rest of the unit. In practice, it is also, in principle, impossible to load a roll-trailer completely symmetrically. For these reasons it is reasonable to assume that in practice, a roll-trailer will tip somewhat earlier than theoretical calculations show.

From the table above, it can be seen that several of the roll-trailers tipped with a theoretical static heeling angle between 20 and 25 degrees.

The second row of roll-trailers from the front contained a number of units loaded with approximately 90 m^3 of board with a loading height approximately 3 m. The total weight of these units was 40-45 tonnes. These units have also tipped with a theoretical heeling angle of 20-25 degrees.

Calculations have also been performed to determine the efficiency of the cargo-securing on the two roll-trailers which, when SHK visited Finnforest in September 2007 were stowed on the Main Deck.

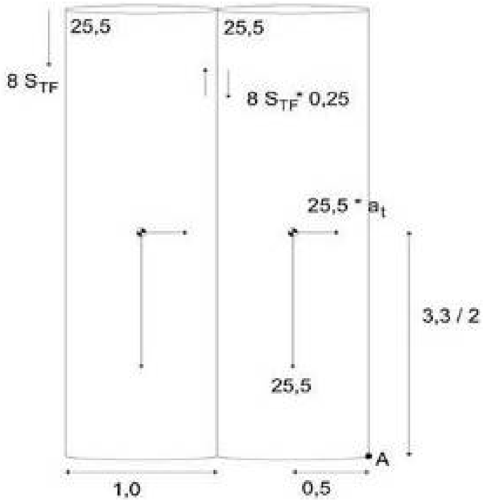
Fig. 46 Roll-trailers stowed on the Main Deck on board Finnforest. The load is secured with WisaFix hoods.

Each of the two roll-trailers was loaded with 110 reels in two lines of 11 sections i.e. a total of 22 stacks with 5 reels in each stack. The reels had a diameter of 999 mm and a width (height) of 660 mm. Each reel weighed approximately 460 kg.

Each stack thus had a height of approximately 3.3 m. The load was secured with WisaFix hoods with 8 straps per side.

The straps were not tensioned adequately, the tension being estimated to be approximately 100 kg or 0.1 tonne.

The calculations below show that the reel stacks began to tip at a heeling angle of approximately 17.5 degrees with tension force S_{TF} 0.1 ton and immediately the entire load tipped because of the elasticity of the straps and hood. In the calculations it has been assumed that the internal friction between the reel stacks is 0.25. If the tension in the straps had been approximately 0.5 tonne, the tipping would have instead begun at approximately 20 degrees relative heeling angle. Finnlines has reported that there were no units secured with WisaFix hoods on board Finnbirch on its final voyage.



$$Heeling\ moment: 25{,}5 \cdot \frac{3{,}3}{2} \cdot a_t$$

$$Righting\ moment: 2 \cdot 25{,}5 \cdot 0{,}5 + 8 \cdot S_{TF} \cdot 1 + 8 \cdot S_{TF} \cdot 0{,}25 \cdot 1$$

$$a_t = \frac{25{,}5 + 10 \cdot S_{TF}}{84{,}15}$$

$$S_{TF} = 0{,}1 \Rightarrow a_t = 0{,}32 \approx 17{,}5^\circ$$

$$S_{TF} = 0{,}5 \Rightarrow a_t = 0{,}36 \approx 20^\circ$$

1.17.7 Calculated Tipping and Sliding risks of semi-trailers

The semi-trailers on board Finnbirch were in all probability secured in accordance with the evidence given at the Maritime inquiry and in interviews and as summarized in the following table;

Deck	Lashings used		Lashing type
	Number	Strength MSL (tonnes)	
Tank Top	6	6	Web
Main Deck	6	6	Web
Upper Deck	6	10	Chain
Weather Deck	8	10	Chain

On the basis of this table, calculations have been performed to determine at which transverse accelerations a trailer slides or tips sideways at front or rear with different trailer weights.

As a basis for the calculations, parameters for some typical semi-trailers have been measured and heights, widths and distances according to the sketches below have been used in the calculations. The tare weight of the semi-trailers has been assumed to be 7 tonnes and the height of the C.of G. of the tare weight has been assumed to be 70% of the height to the platform which has been set at 1.15 m. The maximum total weight is approximately 37 tonnes.

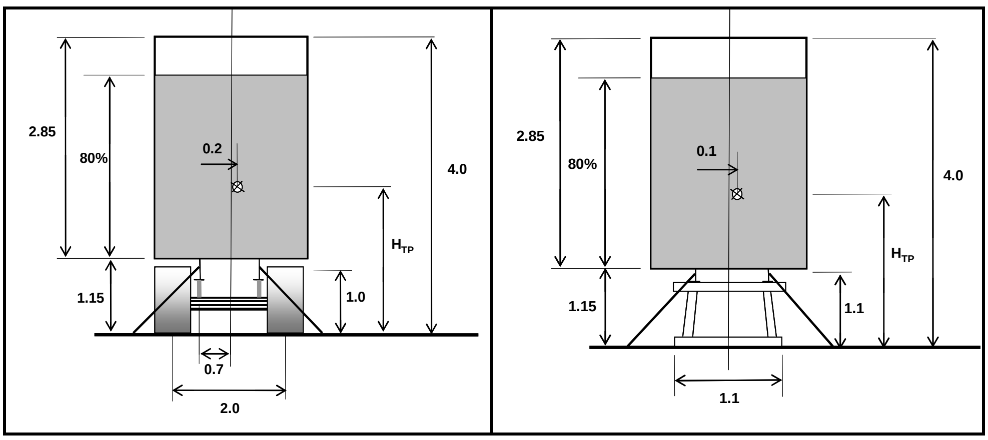


Fig. 47 Typical parameter values for semi-trailers.

Coefficients of friction, safety factors and wind pressure according to CS Annex 13 have been used and the angle between the lashings and the ship's deck has been assumed to be between 30 and 60 degrees.

Fig. 48 Semi-trailers on board Finnforest.

Fig. 49 Arrangement in which the longitudinal lashing angle is small.

In consideration of the situation in the above photo from the cargo-securing on board Finnforest, it is seen that the angle between the longitudinal axis of the ship and the lashings may be small in some cases. Calculations have therefore been performed with longitudinal angles of both 30 and 15 degrees.

In the calculations it has been assumed that the lashings have been located symmetrically. In arrangements with six lashings, it is assumed that four have been placed at the front of the trailer around the trestle and two behind the wheels. In arrangements with eight lashings, four have been placed at the front and four at the rear in accordance with the sketches below. Half of the trailer's weight has been assumed to rest on the boggie and half on the trestle. Because of the trailers' lack of torsion strength, separate calculations have been performed for the rear and front ends of the trailers.

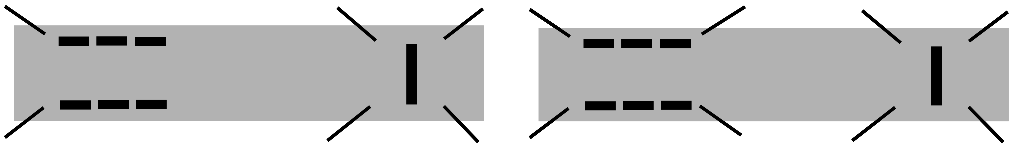


Fig. 50 Arrangements with six and eight lashings respectively.

In the table below, it is seen at which trailer weight sliding and tipping risks develop on the different decks with 30 and 15 degrees longitudinal angle on the lashings with parameter values according to the description above and accelerations according to the ship's cargo-securing manual.

	Longitudinal lashing angle	
Deck	*30 degrees*	*15 degrees*
Tank Top	*25 tonnes*	*18 tonnes*
Main Deck	*25 tonnes*	*18 tonnes*
Upper Deck	*32 tonnes*	*23 tonnes*
Weather Deck	*33 tonnes*	*25 tonnes*

The maximum weights of the trailers loaded on the different decks on board Finnbirch on its final voyage are shown in the following table together with the acceleration with which a risk of sliding develops with the relevant cargo-securing and corresponding relative heeling angle.

		Longitudinal lashing angle			
		30 degrees		*15 degrees*	
Deck	*Max trailer weight on board Finnbirch (tonnes)*	*Acc m/s^2*	*Rel angle degrees*	*Acc m/s^2*	*Rel angle degrees*
Tank Top	*37,3*	*4,1*	*22,9*	*3,8*	*21,3*
Main Deck	*36,5*	*4,2*	*23,0*	*3,8*	*21,4*
Upper Deck	*37,0*	*4,9*	*26,5*	*4,4*	*24,2*
Weather Deck	*29,5*	*6,6*	*33,9*	*5,2*	*28,1*

Corresponding accelerations and relative heeling angles when there is a tipping risk with the relevant cargo-securing are given in the following table.

		Longitudinal lashing angle			
		30 degrees		*15 degrees*	
Däck	*Max trailer weight on board Finnbirch (tonnes)*	*Acc m/s^2*	*Rel angle degrees*	*Acc m/s^2*	*Rel angle degrees*
Tank Top	*37,3*	*4,8*	*26,3*	*4,3*	*23,7*
Main Deck	*36,5*	*4,9*	*26,6*	*4,4*	*24,0*
Upper Deck	*37,0*	*6,6*	*33,9*	*5,7*	*30,1*
Weather Deck	*29,5*	*6,2*	*32,4*	*5,0*	*27,2*

It can thus be said that with the lashing angles used, there was considerable risk of shifting of the heavier semi-trailers on all decks except the Weather Deck with rolling angles under 25 degrees.

(*See Appendix 4*)

1.17.8 Securing of semi-trailers in accordance with current rules

Calculations have been performed to determine which cargo-securing arrangements would have been required to withstand the accelerations which, according to the cargo-securing manual, could be expected on board Finnbirch.

With parameter values according to the preceding section, the required strengths in MSL of the lashings for 6 and 8 lashings respectively per trailer are obtained according to the following table.

Deck	Trans-verse . acc (m/s^2)	Max Trailer Weight (ton-nes)	Longitudinal lashing angle			
			30 degrees		15 degrees	
			Number of lashngs	Strength MSL (tonnes)	Number of la-shings	Strength MSL (tonnes)
Tank Top	4,71	37	6	8,5	6	12,0
			8	5,5	8	7,0
Main Deck	4,68	37	6	8,5	6	12,0
			8	5,5	8	7,0
Upper Deck	5,26	37	6	11,5	6	15,5
			8	7,0	8	8,5
Weather Deck	5,63*	30	6	16,0	6	22,0
			8	9,0	8	11,5

* Wind load 1 kN/m^2 to be added

1.17.9 Calculation of tipping angle for sto-ro caro without lashing

The truck-stowed cargo of paper reels on board Finnbirch was stowed forward on the MainDeck. There was no securing of this part of the cargo but walking boards had been placed against the reels and roll-trailers were backed toward these, leaving a space approximately 30 cm. free.

Fig. 51 Sto-ro cargo on board Finnforest in December 2007.

The photo above from sto-ro loading on board Finnforest shows the reels crotch stowed. Alternate reels then project out from the remainder. It is possible that these might tip sideways with any considerable rolling. If the outermost row has tipped, the following row might well follow.

Number of reels reelsr	Width (height) Mm	Total width (height) Mm	Weight kg
56	1 100	61 600	52 316
48	1 428	68 544	76 132
29	952	27 608	30 476
14	872	12 208	10 374
19	990	18 810	16 065
101	1 384	139 784	126 527
56	1 214	67 984	61 555
45	1 038	46 710	42 223
26	865	22 490	20 315
28	860	24 080	35 780
6	600	3 600	1 436
		493 418	473 199

Acording to the cargo plan, the above cargo was loaded as sto-ro cargo on board Finnbirch on its final voyage. According to the cargo plan, this cargo occupied 225 $m^{2.}$ All of the reels had diameter of 1.25 m. The nominal area of each reel stack is thus 1,23 m^2 . With the reels crotch stowed, it can be assumed that the stowing factor becomes 1.15 which means that each stack occupies an area of 1.15 x 1.23 = 1.41 m^2.

The total number of stacks becomes: 225/1.41 = 160 stacks.

The total height of all the reels was 493 m. The height of each stack is then 493/160 = 3.08 m

A free-standing stack of paper reels with diameter 1.25m and height 3.08 m tips with an angle of approximately 22 degrees.

1.17.10 Heeling moment due to a total cargo shifting

The Swedish Maritime Administration regulations SJÖFS 1993:3 and 2006:1 relating to stability require that the survival capability, after total cargo shift, of ships with known risks of cargo shift is to be presented. However, no method for calculating the heeling moment is given nor which criteria are to be satisfied for the survival capability to be considered acceptable.

Appendix 5 contains calculations of the moment obtained from each unit if they are packed closely to port against the side of the ship, a bulkhead or other unit. The assumptions made for the calculations are given in the right hand column in the tables. For example, it has been assumed that only a sector of approximately 25 degrees of sto-ro cargo on the Main Deck has shifted and that only the top layer of the three layer high stowed paper reels in this sector have been shifted.

For the Weather Deck, as far as possible, the actual cargo shifting, as shown in the photographs taken from the helicopters, has been used in the calculations.

With the above calculations, a heeling moment is obtained as below. It is considered improbable that 100% of the units have been packed closely to port. There is evidence that e.g. the semi-trailers furthest aft on the Upper Deck remained in their positions long after the initial lurching of the ship. Considering that many of the semi-trailers on the Weather deck, according to photos from the rescue helicopters, have remained lashed in place, it has been assumed that also a part of the trailer cargo on the Upper deck has remained lashed in place. It has therefore been assumed that only approximately 60% of the cargo on this deck has been shifted in the initial stage on this deck.

It has been assumed that a realistic cargo shifting of the units on the Tank Top and Main Deck is approximately 90% of the maximum possible i.e. without including the units which were already stowed to port.

Deck	*Totalt moment (tonne.m)*	*Assumed cargo Shifting , %*	*Probable moment (tonne.m)*
Tank Top	349	90	314
Main Deck	2290	90	2061
Upper Deck	2247	60	1348
Weather Deck	628	Actual according to photo.	628
Totalt moment (tonne m)	5514		4352

Calculations show that a heeling moment of 4352–5514 tonne meter has developed with an almost total cargo shifting. *(See Appendix 5).*

1.17.11 Heeling angle at a total cargo shifting

With a heeling moment according to the preceding section and a shifting and a righting arm curve according to the stability calculations in Appendix 2, a static list of 30-37 degrees is obtained.

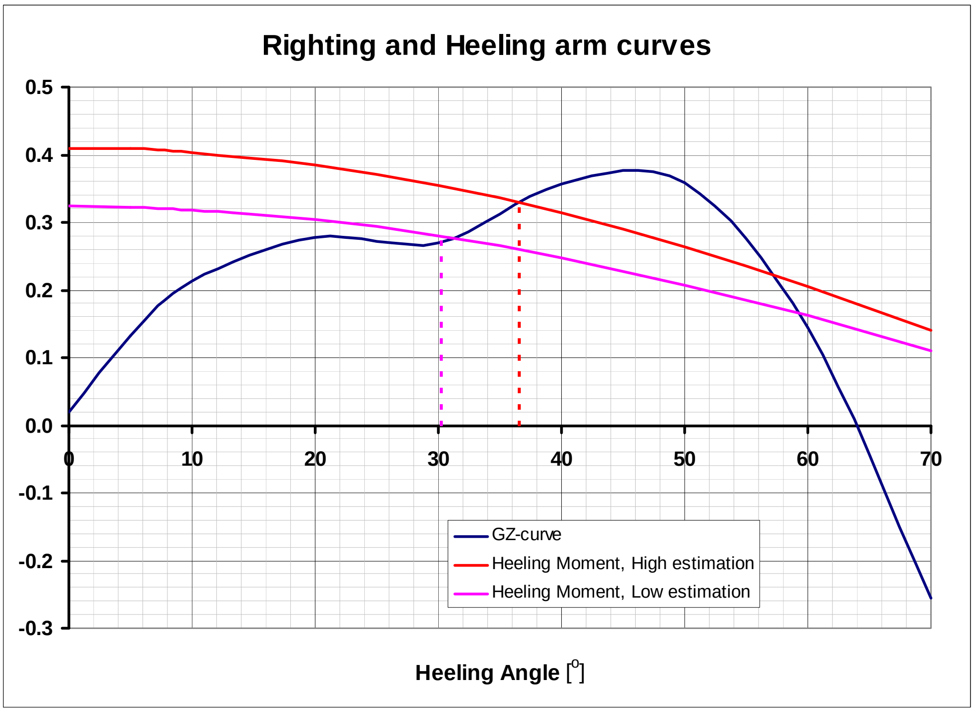


Fig. 52 The list is read on the x-axis as a function of the heeling moment where this intersects the GZ curve

This list is close to the values which, based on video-films from the helicopters were calculated by the Swedish Defence Forces Intelligence and Security Centre.

1.17.12 Previous shifting of cargo in ships carrying forrest products

Shifting of forest product cargo from Finnish and Swedish ports has occurred on several previous occasions. In 1988 M/V Vinca Gorthon was subjected to a total cargo shift, the list reaching approximately 35 degrees and the completely new ship sinking within 12 hours.

Fig. 53 Vinca Gorthon with large list following shifting of forest products cargo loaded on roll-trailers.

Fig. 54 Examples of shifted forest products cargo loaded on roll-trailers and cassettes.

Bore Lines have also experienced cargo shifting with serious consequences. The Finnish ro-ro ship Karelia listed considerably off Gotska Sandön in 1986. The ship was abandoned by its crew and several seamen lost their lives in the accident.

Finnlines state that serious cargo shifting have occurred on a number of occasions in ships they have chartered. Some of these have resulted in considerable listing but the situations have been corrected at sea and the ships have reached harbour.

1.17.13 Environmental aspects

SHK has not investigated the environmental aspects of the accident.

2 ANALYSIS

2.1 Stability conditions and cargo-securing

SHK has investigated two main technical problems in connection with the sinking of Finnbirch. One relates to the stability characteristics of the ship and the heeling phenomena which can develop with a following sea. The other relates to the securing of cargo on board the ship and the securing of cargo on and in cargo transport units.

2.1.1 Stability conditions and the sudden heeling

By the addition of sponsons, the ship was given stability characteristics which differ from the normal and which demand special consideration. The appearance of the GZ-curve for the relevant cargo conditions indicates that the heelings could easily become very large if a critical value of approximately 20 degrees was exceeded.

The GM-value of the ship on departure had been calculated on board as 1.2 m. Calculations performed by SHK give a somewhat higher value. That calculated GM-value on board was near the limit of the stability requirement in the stability book while the check calculation value exceeded this limit by a margin of approximately 0.2-0.3 m., ignoring uncertainties in the calculation which can approach a decimetre. The stability book shows that the stability is particularly sensitive at the draught of the ship on departure. The stability margin proved itself to be inadequate for the ship in high following seas.

The stability could have been improved with a higher GM-value obtained with less cargo on the highest deck, more ballast or a combination of appropriate measures. Such loading conditions would have appreciably improved the form of the GZ-curve and thereby the capacity of the ship to resist large heeling moments and also the effects of reduced stability in waves.

To ballast the ship entirely in accordance with the recommendations in the stability book – considering the distribution of the cargo in the ship – was not possible without this resulting in an unacceptable forward trim. All the ballast tanks aft were full on departure while those forward were empty.

When long waves passed in the high following seas, the stability of the ship was reduced. However, high and, under Baltic sea conditions, very long waves, with wavelengths over 70 m, are necessary to significantly affect the stability of a ship of this size.

From calculations performed, and from wave statistics, SHK has concluded that individual waves 7-8 m high with wavelengths over 80 m were probable at the place and time of the accident.

The ship was at high speed, over 18 knots in the following sea, i.e. relatively close to the calculated wave speed of approximately 20 knots which resulted in the ship being on a wave crest amidships for a relatively long time. Under such conditions, a large and extended loss of stability develops with attendant risk of severe heeling.

According to the minutes of the maritime inquiry, the Master considered that the ship should maintain a high speed in the following sea. With long and high following waves, however, a ship's speed should be adjusted so that the waves pass the ship rapidly to avoid protracted loss of stability and also to reduce the risk of temporary loss of steering.

SHK point out that phenomena such as broaching and parametric rolling are well-known to seafarers. Loss of stability in following seas, however, appears to be relatively unknown. Several IMO documents refer to these different phenomena and include explanations and recommendations. These documents were not known to the Owners or on board the ship.

There was therefore no detailed knowledge of the above mentioned phenomena and of the criteria to avoid the problems involved, either on board Finnbirch or at the Owners. There was certain awareness that quartering seas could cause larger problems with rolling than other wave conditions, but there was no deeper knowledge of the risks involved nor of which measures were suitable to avoid critical situations, by, for example, in good time, performing a large, protracted change of course and/or a considerable reduction in speed.

Stability and rolling conditions in a following sea are complicated phenomena which can be difficult to distinguish one from the other. Many different parameters must be considered in a risk-evaluation e.g. a judgement of which phenomenon or phenomena can be expected to appear and if such involve serious risks. It can be difficult to estimate wave lengths, wave speeds and wave direction from a ship’s bridge, not least when different wave systems intersect or in darkness or conditions of poor or no visibility due to snow or rain.

The traffic situation, in this case, the meeting ships, can also, at least psychologically, prevent the taking of adequate preventive measures, even in situations where the risk of serious heeling is known to the ship’s officers. A more detailed knowledge of the heeling phenomenon in a following sea and of the effects of a suitable reduction of speed in the developing situation would have given the officers better grounds for taking suitable action.

Unfavourable wave conditions in a following sea, the high speed, the inherent stability characteristics of the ship and its limited stability margin, in addition to the limited awareness of the officers of the significance of these factors contributed to the lurching of the ship which led to cargo shifting and finally capsizing.

2.1.2 Cargo-securing in the ship

Taken together, the heelings to which the ship was subjected were considerable but not exceptional. The level of cargo-securing in the ship was, however, in many respects lower than the standard specified in international and national requirements and recommendations.

The original cargo-securing manual was unsatisfactory in many ways. Additionally, departures from the original manual in the actual cargo-securing were extensive and of decisive significance for the consequences of the accident.

Added to the inadequate cargo-securing was the reduced friction on the wet decks of the ship during the voyage, a result of the rainy weather during the loading.

If the cargo had been secured in accordance with the instructions in the ship’s cargo-securing manual, the risk of an extensive cargo shifting would have been considerably less and the survival capability of the ship correspondingly larger.

It is the opinion of SHK that the safety of a ship and its crew must be based on a sufficient stability and a sufficient level of cargo-securing and not on the capacity of the crew, in all sea conditions, to foresee and compensate for different types of stability and rolling phenomena.

It has not been possible to determine how all parts of the cargo were secured on board. SHK has, however, performed calculations, based on the evidence of the crew and observations and interviews made during visits to the sister-ship Finnforest and the Finnlines terminal in Helsinki. These calculations show a considerable difference between the accelerations, for which the cargo should have been secured, according to the calculated values, specific to the ship, in the cargo-securing manual and the accelerations to which the cargo-securing was subjected. The calculations show that there was the risk of shifting of different parts of the cargo at the following heeling angles.

Cargo section	*Heeling angle degrees*
Sto-ro cargo	22
Roll-trailers, sliding risk at unlashed end [1)]	17
Roll-trailers, tipping risk [2)]	20–25
Semi trailers – Tank Top [3)]	21–23
Semi-trailers – Main Deck [3)]	22–23
Semi trailers – Upper Deck [3)]	25–27
Semi-trailers – Weather Deck [3)]	29–34
Cargo in Semi-trailers [4)]	17–20

[1)] with a friction of 0,3
[2)] Units most likely to tip
[3)] Gliding risk for the heaviest unit on the relevant deck with longitudinal lashing angles, 15–30 degrees
[4)] With wet and soiled platforms with a friction of 0,3

This summary shows that there were on board a number of cargo units with risk of shifting at approximately 20 degrees static heeling angle.
It is therefore probable that these units were already shifted by the first lurching. With the following lurchings, the list successively increased until most of the cargo had shifted and the ship adopted a new stable state with a list of 30-35 degrees.

Securing of semi-trailers

The calculations performed show that the original cargo-securing arrangements for the securing of semi-trailers on board, described in the cargo-securing manual approved by the inspecting authority, satisfy largely the dimensioning requirements with the accelerations calculated in the manual. The actual cargo-securing level, with respect to number and strength of the lashings was below the requirements on most of the decks on departure from Helsinki. It was only on the Weather Deck that the cargo-securing of semi-trailers was on a par with the requirements of the cargo-securing manual.

Deck	*Lashings used/unit*		*Specified lashings (CSM)*	
	Number	*Strength MSL (tonnes)*	*Number*	*Strength MSL (tonnes)*
Tank Top	*6*	*6*	*6*	*7,5–10*
Main Deck	*6*	*6*	*8*	*7,5–10*
Upper Deck	*6*	*10*	*8*	*10*
Weather Deck	*8*	*10*	*8*	*10*

An appreciable difference resulted from the change from chain lashings to web lashings on two of the decks. The web lashings had a lower breaking strength than the chains used previously. They also had a certain degree of elasticity which gives a more uneven load distribution than with chains, and, under wear, they lose their breaking strength much faster. In addition, the number of lashings had been reduced on the Main and Upper Decks.

Securing of sto-ro cargo

The securing of sto-ro cargo also departed from that stipulated in the cargo-securing manual. On departure, it was neither stepped down, lashed nor blocked but was stowed with the outer row standing free. According to the manual, sto-ro cargo should be lashed on the free side with lashings from the deck head, over corner protection down to deck eyes in the deck on which it is stowed. According to the manual, air bags or equal are to be used to fill the spaces between the units of sto-ro cargo.

Securing of roll-trailers

According to the cargo-securing manual, block-stowed roll-trailers were to be secured to the deck with lashings preventing tipping and sliding and the units are to be lashed together. From a visit to Finnforest, it was learned that roll-trailers were only lashed at the front end. In certain cases, the lashings were applied as a half cross-lashing and could therefore only prevent sliding. In other cases, the lashing to the deck was supplemented with a horizontal lashing between the roll-trailers. These lashings also had very limited effects in preventing tipping. The lashing arrangement used could not prevent the rear end of the roll-trailer from tipping or sliding. It is probable that the same arrangement was used on Finnbirch on its final voyage. The units were presumably only lashed at the one short end in accordance with both the cargo-securing manual and the Finnlines guidelines but these lashings were insufficient to withstand the loads with the acceleration levels for which the cargo should be secured according to the cargo-securing manual.

It has not been possible to determine how many lashings were applied to free-standing roll-trailers but according to the cargo-securing manual and the Master, these should have been cross-lashed at the ends. This is a very unsuitable securing arrangement to prevent tipping of cargo units. Units with high loads therefore probably tipped at an early stage of the cargo shifting.

The minor oil leakage on the Tank Top is judged not to have played any role in the shifting of cargo as the roll-trailers stowed there had been block-stowed against the port side and were therefore incapable of further movement to port.

Securing of cargo on and in cargo transport units

SHK consider that the level of cargo-securing in semi-trailers and on roll-trailers had a significant effect on the sequence of events, partly because shifting of cargo on a cargo transport unit can cause movement of the centre of gravity of the unit so that the unit tips more readily, and partly because cargo breaking away from the cargo transport unit can damage lashings holding other cargo nearby.

Statistics from inspections of cargo-securing in semi-trailers by different authorities in Finland indicate extensive and serious shortcomings. International statistics also show that the problem of cargo-securing in semi-trailers is wide-spread.

The securing of cargo on roll-trailers has been difficult to assess as the information about the normal appearance of the securing varies between reports. It can be that the level of cargo-securing varied between the different units. On a visit to the sister-ship Finnforest about a year after the loss of Finnbirch, SHK could observe that the cargo-securing on certain units was obviously under the recommended international level whereas the cargo on others appeared to be secured more effectively.

Sweden is today one of the few countries regulating the securing of cargo on and in cargo transport units for transport by ship. Finland has not developed comparable requirements for marine transport. An obligatory, common international or European statute could be a way to solve the problem, at least regionally, if it were also combined with organized campaign/inspections in harbours.

2.1.3 Operative preconditions

It has not been possible to determine if cargo-securing generally, on Finnbirch and its sister ship Finnforest has been on the same low level since the ships were introduced to traffic in the Baltic – or if there has been a successive degeneration over the years. The cargo-securing has however been inadequate for a longer time, probably several years, following well developed practices based on verbal agreements between representatives of Finnlines and individual crewmembers on board.

According to the relevant marine laws, the securing of cargo on board his ship is the responsibility of the Master. This responsibility is also included in the charter contract which contains a clause which states that the cargo shall be secured to the approval of the Master. The Ship Safety Law in turn, places a clear responsibility on the ship's owner to operate ships safely in accordance with current laws and regulations. In support of this, the laws contain a requirement that the Owners shall have an approved safety management system.

A legal requirement is also that the cargo shall be secured in accordance with the relevant cargo-securing manual. There is thus a clear responsibility placed on the Master and the Owners to ensure that the manual is followed on board. The requirements of the manual have however, had a marginal effect on the actual cargo-securing level in the ship. One of the probable reasons is that the instructions in the manual are of a general nature, and in parts, very vague, for example with respect to the number and type of cargo lashings to be applied to different units. A very serious deviation from the regulations was that the manual lacked precise instructions for how necessary cargo lashings should be calculated or evaluated on the basis of given values of cargo weight, centre of gravity and accelerations. The manual could therefore not be used to perform checking calculations, to check the lashing angles used or as support in achieving a specified cargo-securing level. The limited knowledge of the Master and Chief Officer of cargo-securing together with the deficiencies of the manual, made it difficult for the officers to judge which loading the cargo-securing arrangements should withstand and thereby to question the level of cargo-securing.

The officers on Finnbirch and Finnforest made considerable efforts in planning and executing voyages to minimize rolling and to avoid damage to their cargo as they were well aware that parts of the cargo would not withstand more than 20 degrees rolling before their displacement could begin. This was particularly the case with cargoes on semi-trailers and roll-trailers. However they have probably not understood that such a large part of the cargo, including units which appeared to be well secured could be involved in a total cargo shifting. It is rather difficult, without very good knowledge of cargo-securing to decide visually what stresses different cargoes will withstand.

Lindholm Shipping

At the office of the Owners, Lindholm Shipping, there was no real knowledge of cargo-securing, they relied upon the cargo-securing system of the charterers and refrained from involving themselves in such matters. That the Owners avoided involvement in cargo-securing matters, had no own knowledge thereof and had expressed an almost unreserved trust in the charterer in this question probably influenced the Masters' attitude toward the Owners with respect to the failure to report that the cargo-securing manual was not being followed. The way the contents of the manual had been amended, through the non-conformity reporting system, had probably given the officers a feeling that the Owners were aware of the current cargo-securing level. These conditions do not however, absolve the Masters from the duty to report the serious divergences occurring in relation to the manual.

The Ship Safety Law and the ISM code clearly make the Owners responsible for ensuring that their activity is in accordance with the current laws. In this case, that cargo-securing on board is performed in accordance with the relevant regulations and that the Master is supported in his efforts to perform his duties in a satisfactory manner.

That the Owners did not observe that the cargo-securing in the ship departed considerably from the requirements in the cargo-securing manual suggests that there are shortcomings in the Owners' ISM system. So obvious and serious departures as, for example, that sto-ro cargos were transported in both ships without blocking and without restraining lashings on the exposed sides should have been reported by the Masters but should also have been observed by one of the Owners' internal auditings. These internal inspections were performed by a person with only a two-day training in ISM and had no professionl seafaring experience. SHK point out that marine transport, as distinct from air traffic, has no official competence requirement for certain essential functions of importance for safety, in their organisation on land. This has today been observed by IMO who have prepared guidelines for establishing what is suitable competence for a DP.

The officers had reported to the Owners that they felt that they had inadequate knowledge of cargo-securing and requested appropriate training. The use of arrangements with low cross-lashing on free-standing roll-trailers, thereby creating extreme risks of tipping indicate ignorance of basic cargo-securing techniques. The Swedish Maritime Administration had also remarked on the lack of cargo-securing training during several auditings of Lindholm Shipping. In this respect, the management of the company had consciously refrained from taking action.

The low level of competence within several fields of ship operation at the Owners' office together with the low level of ambition which the management had expressed verbally, and even in writing in its ISM policy, were insufficient to create an organisation which could in an effective manner identify and correct the particular risks which are associated with ro-ro shipping operations. This attitude meant that the Masters were left without support from their Owners in dealing with cargo-securing matters.

Lindholm Shipping has stated that their position in relation to their contract partners Finnlines is too weak for them to be able to make demands on Finnlines with respect to cargo-securing matters. Irrespective of their size in the market, a ship-owning company cannot divest itself of the responsibility to operate their ships safely. SHK notes that Strömma Turism & Sjöfart, in which Lindholm Shipping is incorporated, is wholly-owned by the Rettig group which in turn has large interests in Finnish ro-ro shipping.

A natural way, with such a small land organisation, to exert more control over the actual conditions, could have been to employ an external instance with more professional competence for the internal auditing of both the ships and the shipping company, or to engage competence from Bore which was a company in the same concern. Regular safety meetings within the company between, for example, administrative staff, Masters and Chief engineers, could have broadened the knowledge of the very limited land-based organisation. The absence of more general safety discussions between the crews and the land organisation probably contributed to cargo-securing questions not being given the attention they deserved within the Owners' company.

Finnlines

The charterer Finnlines had no specific responsibility for the cargo-securing on board Finnbirch. They had however, an extensive interest in questions relating to both the loading and securing of cargo by being the instance which received its revenue from the freight charges and by being responsible for the costs of both loading and securing the load. Finnlines also had an interest in minimizing damage to the cargo.

Fore and aft block-stowing of roll-trailers is a method by means of which it is possible to increase the loading of a ship but which results in it being impossible to lash both ends of the unit to the ship. The Finnlines cargo-securing instructions which are a part of the company quality assurance system contain e.g. examples of fore and aft block-stowage of roll-trailers. These instructions are included in the cargo-securing manual for Finnbirch and had probably been obtained directly from the charterer. If cargo-securing of semi-trailers were performed with straps instead of with chains, one stevedore in each cargo-securing gang would become redundant. Finnbirch and Finnforest suffered chronically from delays, primarily because the loadings had increased during the years and times in port became longer.

The arrangements specified in the charterer's cargo-securing instructions for securing goods on roll-trailers were not associated with any particular acceleration level which made it very difficult for the Masters, objectively, to decide if the cargo-securing on the roll-trailers would withstand the stresses which could be anticipated on the voyage. To the knowledge of SHK, no calculations of the cargo-securing arrangements have ever been performed. A series of practical trials were however performed at the beginning of 1987 which showed that some of the secured high loads on roll-trailers tipped with approximately 20 degrees static heeling angle. This state of affairs has apparently been accepted by the company.

The Masters interviewed by SHK agreed that with rolling angles greater than 20 degrees, shifting of and damage to cargos of roll-trailers could be expected. The charterer's cargo-securing instructions, the SHK calculations and the Masters' evidence, taken together, show a cargo-securing system and practices which in several ways do not satisfy international requirements and recommendations. A precondition for ensuring that the cargo-securing system functioned was for the Master to keep the movements of the ship in heavy sea conditions within a very moderate rolling range.

The charterer's own statistics over cargo damage show a low frequency of damage which indicates that the Masters were, most often, able to control the movements of their ships in heavy sea conditions. The statistics did not include cargo damage which occurred with larger cargo-shifting despite there being several such accidents with their own and chartered ships, occasionally with considerable resultant listing. SHK concludes that the Finnlines concept for minimizing cargo damage was successful but that this is not the same as the cargo-securing concept being adequate from the aspect of ship safety.

It has not been possible to establish to what degree it depended on the influence of the charterer that the sto-ro cargo was stowed on the ship without lashings – this being contrary to the charterer's own quality instructions. It has, however, been found that there were agreements on a local level about deviations from the cargo-securing instructions which were not documented. The use of straps on the Main Deck and on the Tank Top for securing semi-trailers and roll-trailers on board Finnbirch, instead of chains is an example of such local agreements being made between the charterer directly with the Master or the Chief Officer.

The fact that the cargo-securing level was determined by different verbal agreements probably contributed to an uncertainty among the officers about which agreements had been entered into by his colleagues and made it considerably more difficult for individual officers to question the general cargo-securing level. That other chartered ships carried sto-ro cargo without lashings indicates that it was not an isolated occurrence at Norra Hamnen that the cargo-securing manuals were not followed.

The routine described by Finnlines was to visit ships when chartered to obtain a verbal acceptance from the officer on duty of their proposed cargo-securing level. According to SHK, this routine has had a direct and unfortunate effect on the cargo-securing level on board Finnbirch. If Finnlines, instead of requiring the use of their own instructions and proposals had requested the ship's approved cargo-securing manual and loaded the cargo in accordance with this, the level of cargo-securing on Finnbirch would have been considerably higher.

The Finnlines fleet is relatively modern and the ships are provided with fin stabilizers which e.g. effectively reduce rolling in a following sea. This in turn may have affected Finnlines in their judgement of what is an acceptable cargo-securing level.

Finnbirch and Finnforest are older and simpler ships than Finnlines own ships. They were without systems for minimizing rolling in heavy seas and had documented limited possibilities of surviving a serious cargo shifting.

One way for the charterer to solve the problem of influence over the cargo-securing in a more responsible way, without jeopardizing safety on board chartered tonnage, would be to determine values of the accelerations and rolling angles which their own proposed cargo-securing arrangements could withstand. This would make it easier Masters and Owners to evaluate the proposed arrangements. The parties could then together adapt the arrangements in accordance with the calculated acceleration forces in the ship's cargo-securing manual to ensure that they are at a level equivalent to those in international and national requirements and recommendations. Such an adaptation of the cargo-securing arrangements should naturally be well documented and established at management level within the Owner's company concerned and not remain as a verbal agreement with an individual officer on board the ship. For Swedish ships, it would also be required that the supervising authority be provided with copies of such new cargo-securing agreements.

2.1.4 Inspection of cargo-securing

The ship's cargo-securing manual

The cargo-securing manual contains several examples of directly unsuitable lashing arrangements such as cross-lashing at the ends of free-standing roll-trailers and the lashing of roll-trailers to each other instead of to the ship.

The manual contains no specification of how high stacks of paper reels should be secured on roll-trailers or for which accelerations and heeling angles the cargo-securing arrangements were dimensioned.

Despite serious shortcomings, the manual was approved by the inspecting authority. In the directive issued by the head office of Swedish Maritime Administration for the checking of manuals, only the layout of the chapters was to be checked. SHK considers that this level of checking is inadequate for the approval of an authority. SHK also considers that it is reasonable that the checking of manuals by the Maritime Inspectorate should be performed by persons who can make a qualified judgement of the calculations and the lashing arrangements presented. As the inadequacies in the checking and approval of the manual must primarily be attributed to shortcomings in the management of the Maritime Inspectorate it can be assumed that the cargo-securing manuals of other ships have been approved in the same way.

Cargo-securing on the ship

The non conformities in the actual cargo-securing from the instructions indicate shortcomings in the work of the authorities in the inspection of the ship. The SMA noted that the routines for discarding defective web lashings was unsatisfactory but did not observe that the use of these lashings was in contradiction to the requirements of the cargo-securing manual which had been approved by the authority.

For the manual to be guaranteed a real influence over the cargo-securing level on board the ship – which is a national and international requirement – it should be unequivocal and usable by the crew and respected by all the parties concerned as a document of significance for their activity.

The investigation of the accident by SHK has exposed a considerable lack of balance in the distribution of responsibility and interest between the different parties involved when it comes to cargo-securing.

The control by the inspecting authority that the cargo-securing manual is complete and that its requirements are met is a very important factor in ensuring safety in ro-ro shipping operations and can, according to SHK, be given a much higher priority than at present.

2.1.5 The ship after the cargo shifting

During interviews, the Master has stated that he attempted to steer the ship to port, in connection with the heeling, both manually and with the automatic control, with no apparent results. Films of the wreck also show that the rudder is hard towards portside. The course of the ship after the listing consists probably of the resultant of the turning tendency to starboard, primarily generated by the considerable listing but also by the wind and the seas, opposed by the rudder and propeller effects which remained until the engines stopped.

After the cargo-shifting occurred, there was little the crew could do to oppose the listing. The calculations in the trim and stability book show that, under the loading conditions similar to the condition during the voyage, the ship would capsize immediately with a complete cargo shifting. There was no possibility of the crew reaching and closing the port side scupper valves under the displaced cargo, this being pointed out in connection with the above calculations. Heeling tanks could not be controlled from the bridge, only from the engine control room and the cargo control room on the Main Deck. It was too risky for the crew to return inside the ship. Altogether, Finnbirch had very small chances of surviving the cargo-shifting which had developed.

The ship remained with a list of 30-35 degrees and with rolling, approximately 45 degrees. Water probably entered the Upper Deck through the large openings in the ships side and collected on the port side where it could only drain slowly.

With this list, the scupper valves on the Main Deck and the bunker port came under the water line. The poop deck on the port side was periodically under water. The ventilation trunks on the Upper Deck which lead down to the Main Deck were also under water at an early stage as the ship rolled.

SHK has judged, inter alia, against the background of the lack of reliable information about the actual status of different water-tight doors and hatches at the time of the accident, that it is impossible, in detail, to explain the capsize and sinking process. A reasonable assumption, according to SHK, is that the water began to enter the ship, partly through possibly leaking non-return valves in the scupper valves, partly through a gooseneck ventilator on the poop deck which led down to the hydraulic room on the Main Deck and then into the steering gear room. This space was in turn connected through different doors, to the engine room. If, in addition, adjacent trunk hatches on the poop deck and steering gear room were open for some reason, or if the ventilation trunks on the Upper Deck were not closed or were not sealed, the entry of water would have been accelerated. According to the crew, the closing of these trunk hatches on the poop-deck and the Upper Deck was included in the normal closing routine and had been reported to the bridge on departure.

As the list increased, partly because of the entry of water, partly by further shifting of the cargo, more vents, ventilators and other openings in the hull came near or under the surrounding water level.

A large ventilation intake, in direct connection with both Main Deck and Tank Top was located on the outside of the hull, immediately aft of the forecastle deck and level with the Upper Deck. It was not possible to close this against the entry of water. Aerial photographs taken an hour after the accident show the ship taking individual seas over the forecastle deck on the port side. It is conceivable that water entered the ship through this ventilation shaft at an early stage even if in small volumes only. When water began to enter more continuously through this shaft, the rate of listing and the sinking of the ship were accelerated.

2.1.6 Actions taken after the accident.

Immediately after the sinking of Finnbirch, theories were advanced that the cause was inadequate cargo-securing. Despite this, neither the Owners, the Maritime Inspectorate nor the charterer discovered that the cargo-securing on board the sister ship Finnforest did not follow the instructions in the cargo-securing manual, prepared by the Owners and approved by Swedish Maritime Administration.

The ISM-code states that an Owner is required to perform investigations to ascertain the causes of relevant accidents and abnormalities with the purpose of improving safety on ships. The Owners have not made such an investigation nor did they take concrete measures after the loss of Finnbirch to check the level of cargo-securing quality on the sister ship Finnforest until a year after the sinking.

Soon after the accident, the charterer performed a check of the cargo-securing on roll-trailers which left the terminal but undertook no other investigation with reference to cargo-securing action related to the accident. Action was first taken in October 2007, almost a year after the accident.

The anomalies on board Finnforest were not observed before September 2007, 10 months after the accident, when SHK visited Finnforest and advised the Maritime Inspectorate of the shortcomings in cargo-securing on board.

2.2 Survival aspects

The launching and entering of lifesaving rafts was impossible in the prevailing weather with the ship listing severely. It would have been very risky for the crew to jump into the sea. The listing ship drifted with a speed approximately 2.5 knots, and rolled and heaved approximately 4 m in the waves. The crew had difficulty in moving surely and freely on the slippery, snow-covered deck, being hampered by the survival suits.

The survival suits, despite certain shortcomings, were of decisive importance for the survival of most of the crew. In the hard wind and showers of snow, the suits protected the crew from hypothermia during the time they were out on the deck. The wearing of survival suits gave the rescue services time to await a more favourable opportunity for a helicopter rescue. When the ship sank and the crew entered the water (temperature 10 degrees), the suits were the essential factor in their survival.

The location of survival suit stores adjacent to the bridge and in the machinery control room was decisive for these being accessible.

The long delay in the wind and cold on deck, water which leaked into the suits and the struggle for life in the stormy sea may have contributed to a certain loss of body heat in a time shorter than the six hours for which the suits should protect the wearer according to international requirements. Poor fit of the suits made movement more difficult for some of the crew.

Poor fit, particularly around the face also contributed to increased leakage and breathing difficulty with the suit completely closed around the face. In one case, a crewman felt forced to open the suit around his face and neck to be able to breathe. As a result, when he entered the sea, the water filled the suit and he died of hypothermia. The poor fitting was primarily a problem for the more slightly built Philippine members of the crew.

SHK is of the opinion that the function of the survival suits “one size for all”, a so-called *adult universal 50 to 100 kg. 150 to 190 cm*, is not satisfactory for persons of size close to the lower limit. Certification of suits of a size for such a wide range of personal physiques is questionable and the certification requirements should be reviewed.

2.3 Rescue efforts

2.3.1 Direction of the rescue efforts

Marneborg was the ship closest to Finnbirch at the time of the accident and was then in visual contact. It was Marneborg which de facto assumed the role of OSC and performed this duty in a professional manner according to the helicopter crew.

LG 997 had an inexperienced commander with limited operative ability, this not being reported to the Rescue Centre. If technical differences or differences with respect to the operative ability of the personnel had been known, the Rescue Leader would have had better grounds for making his decisions when alerting rescuers.

LG 992 was first alerted one hour after the Mayday call – the Finnish helicopter OH-HVI and Y63 from Ronneby almost three hours after the Mayday call. These units could have been alerted or redirected earlier when it became apparent that rescue from the ship (Finnbirch) was not was possible and capsizing was to be expected. Winching from the sea would then be necessary.

The helicopter crew’s interpretation of the Rescue Leader’s decision that the ship’s crew should remain on board was that the Rescue Centre did not expect the ship to capsize immediately. This probably meant that the helicopter crew then refrained from continuing their winching efforts.

The Rescue Leader, in his position, understood that winching from the ship was not possible and that the crew could not board their lifesaving rafts. There was no other alternative for the ship’s crew than to remain on board.

After immediate winching from the ship was no longer considered feasible, the helicopter resources successively built up until five were available. The strategy of having at least one helicopter over the ship in case the situation should deteriorate must be considered to be appropriate.

Y 67 had left the area six minutes before the ship capsized and LG 992 arrived six minutes after. The change of helicopter over the ship could have been organized by ARCC with overlapping so that the relieving helicopter had time to appreciate the situation before the departing helicopter had left. This had probably no effect on the rescue as several minutes must pass after a capsize before the situation can stabilize sufficiently for a rescue to begin.

The rescue was performed by the helicopters in the area without the guidance of an ACO.

It is possible, when it was evident that LG997 could not winch, that it should have functioned as ACO instead, particularly as the roles of rescuer and ACO may be conflicting.

With the number of helicopters involved and under conditions of low visibility, storm and darkness, ARCC could have organized a traffic separation system with approach and departure points, possibly with height separation.

Under the prevailing conditions, the helicopter commanders were concerned for their safety because of the proximity of others. There have however been no reports from the helicopter crews of any such danger despite the number of helicopters engaged in the operation in the same area in darkness and with reduced visibility.

When the first phase of the rescue was completed and two persons remained missing, the operation changed from a rescue to a search.

The choice of search pattern made by the Rescue Centre was unsuitable for the helicopters in the weather experienced but this choice was amended on the recommendation of the helicopter crews. At this stage, the visibility had improved and more than two helicopters could have been employed but in the opinion of SHK, this was not motivated because of the relatively limited area to be searched.

SHK considers that the rescue efforts were directed from the Rescue Centre in a calm and controlled manner with adequate supporting personnel. The alerting of all available helicopter resources was an appropriate action in view of the weather and the limited possibilities surface units had of participation within a reasonable time.

The Rescue Leader made the major decisions but was also active in controlling the details of the rescue operation. Decisions about the details of the activities of the rescue units should be delegated to the unit commanders.

SHK considers that knowledge, at the Rescue Centre, of the technical performance of helicopters and the capabilities and limitations of the crews should be improved

2.3.2 Helicopter activities before the capsizing

LG 997 was the first helicopter to arrive at the ship. It was then daylight and under the light, wind and sea conditions then prevailing, it is normally possible to perform winching from a ship of the size of Finnbirch. From the safety point of view, winching without search and rescue (SAR) divers could have been performed, those to be rescued seating themselves in the winching harness or equivalent. Small differences in winching height may have considerable effects on this possibility. It may require several attempts to determine if winching is possible. It was known that it would be dark within 30 minutes and the possibilities would then be even more limited.

Y 67, which arrived 30 minutes later, when the light was failing, reported that it had difficulty in winching due to the movement of the ship and extreme turbulence. Y 67 made no attempts at winching. The degree of difficulty had increased considerably as the darkness deepened. It is also possible that Y 67 was influenced by the decision made by the first helicopter and the later decision of the Rescue Leader that the crew should remain on board the ship.

SHK considers that winching of the crew from the ship in daylight should have been possible. The commander of LG 997 had little experience of SAR operations and this lack of experience has probably influenced his decision not to continue the winching attempts. Both of the helicopter commanders have, however, on the basis of the situation, their own experience and capability, made a well-balanced and correct decision when refraining from attempting to winch. SHK however, considers that it is not out of the question that if the commander and the crew had had more training and experience, the commander would have made a different decision.

2.3.3 Helicopter activities after he capsizing

LG 992 which arrived from Arlanda via Visby was the first helicopter to arrive, six minutes after the ship capsized. The 2o-man raft was dropped without being activated – probably a correct and a necessary action in consideration of the gain in time it meant and the low degree of probability that the crew could reach and board the raft.

The fact that seven persons had been winched up after 45 minutes must be considered satisfactory in view of the prevailing conditions.

LG 997 was the second helicopter to arrive, approximately 20 minutes after the capsizing. The approach took approximately 20 minutes longer than was motivated by the distance to the scene. This delay was due to the poor visibility and the low speed required because of the presence of another helicopter in the area. If traffic control had been organized through ACO, it is possible that the approach time could have been reduced.

After attempting winching for 25 minutes, LG 997 concluded its efforts and flew toward Visby. The winching height chosen (100 ft) provided inadequate visual references in the weather conditions.

Y 67 and Y 63 arrived at the same time, as the third and fourth helicopters engaged, approximately one hour ten minutes after the capsizing. Y67 which came from Kalmar began the winching of two persons in the water from 40 ft. with manually controlled hovering. The winching was felt to be difficult but was completed successfully when the second pilot used NVG and the first pilot flew without. Searching then began and after 30 minutes, a single person was found in the water and winched aboard in the same way.

Y 63 performed the winching of two persons from a raft from a hovering altitude of 30 ft without problem. The conditions were judged to be severe and winching with coupled search and rescue (SAR) divers was chosen, i.e. the rescuer and rescued were winched together. Y 63 then continued searching for approximately 1.5 hours when a third person lying lifeless in the water was discovered. The body was winched to the helicopter.

SHK consider that when winching in darkness with reduced visibility and above all, with snowfall, a low winching height should be chosen to give sufficient references on the water surface to be able to notice the movements of the helicopter. With heavy seas, as in this case, it is inadvisable to use the hovering function of the automatic controls during winching as it attempts to follow the profile of the waves which results in excessive oscillation in both altitude and engine power output.

The operation demonstrated that winching from the sea surface under these weather conditions is possible even at night if the correct tactics are used. Three of the helicopters have used a suitable tactic and could perform successful winching.

The commander of LG 997 made a decision to discontinue the operation which can be seen as judicious and correct. The high winching height chosen and his limited experience, in particular in training in flying manually at night can be seen as the reasons why winching could not be performed.

SHK considers that the helicopter operators (Norrlandsflyg) have allowed a commander with insufficient training and experience to attempt a task beyond his capabilities at the time.

After LG 992 had winched seven persons and LG 997 had returned to base, it was 18 minutes before Y 63 and Y 67 arrived. The survivors had then been in the sea approximately one hour. It is not impossible that the rescue operation would have been more successful if a helicopter had been active during this important time.

2.3.4 Capability of the helicopter crews

The capability of the helicopter crews to perform rescue operations during any season, day or night, in darkness or heavy weather is a product of training, and their flying trim and experience. The most important factor is training. Training must be continuous and aimed at achieving and maintaining a correct and clearly defined requirement.

In negotiations for the supply of SAR helicopter services Swedish Maritime Administration required that rescue was to be possible under ”svårt väder” (heavy weather conditions). The concept is not precise but 20 m/s with 26–29 m/s in gusts and significant wave height about 4 m i the Baltic Sea Östersjön, as experienced at the time, may be considered to occur relatively frequently and be within a definition of “svårt väder”.

The automatic controls can only be used to a limited degree in such weather and the crews must be trained thoroughly in manual flying and winching.

Flying trim is ephemeral, i.e. flying trim can be achieved by flying and training intensively for some weeks but relatively quickly lost after any longer period of inactivity.

Experience in general is something accumulated during a longer period of continuous engagement in some activity. SHK considers that in rescue activity in particular, a long period is required before a crew member can be considered to be experienced. Experience shows that expertise can be quickly lost by the organisation if experienced crews leave or if the organisation is disbanded or its activities restricted. The commander on board a rescue helicopter should be very experienced because of the wide range of rescue operations and the nature of these so varied that many difficult decisions must be made by the commander. The impulse to rescue persons in difficulty can be so strong that it can involve taking dangerous risks if the commander is not sufficiently experienced.

SHK considers that all the crews had flying times as required by norms and they have themselves stated that they were in good flying trim and well-trained as a team.

SHK considers that the requirements of Swedish Maritime Administration for operational rescue capability are unclear with respect to the weather (wind speed, wave height and visibility, day and night) in which rescue is to be possible. This has created a somewhat diffuse objective for the helicopter operators and the opinions of the crews regarding acceptable weather conditions vary. The decision to discontinue an operation is always to be made by the commander. This is necessary as each rescue operation is unique and the conditions can vary considerably, but to be able to carry on education and training in an appropriate manner there should be a distinct objective with requirements for limits for rescue operations.

2.3.5 Change of SAR-operator of helicopter services

The operator of helicopter services for maritime rescue was changed in 2002. The helicopters operated by the defence forces were previously the only resource available. Their participation has successively been replaced by that of the civilian aviation company Norrlandsflyg AB which had no previous experience of SAR activity. By the spring of 2007, the company had established five bases which must be seen as a very short time in which to create an organisation with capability and experience of rescue operations at so many places. During the Norrlandsflyg’s build-up time, it was natural that capability and experience has drained from the defence forces as their involvement declined, particularly as the crews concerned at Ronneby were no longer kept at a state of readiness for SAR activity. The experience of the military system has only to a degree been transferred, because, for example, with the helicopter types concerned, military and civilian, certain experience was not compatible.

Swedish Maritime Administration has not informed SHK of any risk analysis of how the change of operator of SAR helicopter activity should be performed, of the time it would take or of its consequences.

SHK considers that at the time, because of the change of operator within SAR activity then in progress, there was a lesser operative capability within both operators’ organisations.

2.3.6 Set of Rules for SAR

There is at present no international set of rules for civilian SAR activity or such a national set of rules in Sweden. The European aviation safety authority EASA has advised the EU commission not to develop a European SAR set of rules as this is considered to be a national concern. SHK considers that a national set of rules for SAR activity should be developed when the requirements of civil aviation authority, from the point of view of aviation safety become clear.

3 CONCLUSIONS

3.1 Findings

- The ship was classified, had the required certificates and had no uncorrected documented shortcomings.
- The ship was properly manned and the crew was experienced and worked well as a team.
- The ship's GM was sufficient according to the stability book but the stability calculated on board was close to the limits of the stability requirement.
- The ship's stability, because of the hull form, was particularly sensitive at the draught at the time.
- Calculations, taking into consideration the ship's course and speed and the sea conditions at the place of the accident, show that the ship probably on several occasions, rode on a long and high wave with the wave crest amidships under which condition, the static stability can have been very low.
- The ship made one and then two very pronounced heelings to port. The later, according to crew estimates, about 40-45 degrees.
- The ship suffered an extensive shifting of the cargo as a result of the heelings and gained a list to port at 30-35 degrees.
- The cargo on board Finnbirch was not satisfactorily secured, not only on the final voyage but as a matter of routine.
- The cargo-securing manual was approved by the inspecting authority despite several serious deviates from the relevant set of rules.
- The cargo-securing on the ship was below the standard, in extensive and important parts, of the requirements of the cargo-securing manual.
- The requirements of the cargo-securing manual had been successively put out of the running by verbal agreements between the charterer and different officers on the ship.
- Deviations from the cargo-securing manual had not been reported to the Owners.
- The Owners' routines for checking the observance of the safety management system on board, in respect of cargo-securing, were unsatisfactory.
- The ship's Master and several colleagues had requested to the Owners, for training in cargo-securing. The inspecting authority had, during several inspections advised the Owners of the need for training in cargo-securing for the crew.
- The charterer, responsible for the loading, cargo-securing and cargo-securing equipment on board had its´ own system for cargo-securing and did not request access to the ship's cargo-securing manual.
- The charterer's management of its quality assurance system, with respect to cargo-securing on board chartered tonnage left too much latitude for undocumented deviations.

- Flag- and port state controls that the ship followed the cargo-securing manual were largely non-existent.
- It has not been possible to determine the securing of cargo on roll-trailers which has probably varied between the vehicles. Examples were observed aboard the sister ship of cargo-securing arrangements which were clearly short of the international recommendations.
- As distinct from Sweden, Finland has no national rules for the securing of cargo in and on cargo transport units to be transported by ship.
- The securing of cargo in semi-trailers varied. Statistics from controls of cargo-securing of dangerous goods in Finnish harbours are evidence of extensive shortcomings.
- The checking of the cargo-securing in semitrailers, both on board and on land was sporadic.
- On all levels of all instances involved, there has been evidence of inadequate theoretic knowledge of cargo-securing techniques.
- The officers on the ship and the sister ship were well aware that problems could develop for ships in following seas and planned voyages carefully to avoid quartering seas and large heeling angles.
- The officers had no detailed knowledge of the problems which can develop in following seas and they were unaware of published international guidelines to avoid these problems.
- The parties involved had no real knowledge of the behaviour neither of ships in following seas nor of the special stability characteristics of the ship concerned.
- In the prevailing weather, rescue by helicopter was the only possible.
- The crew of helicopters which arrived before the ship capsized judged that the winching of the ship’s crew was not possible when it remained on board the ship.
- Norrlandsflyg had rostered a commander on standby duty who had insufficient experience of SAR operations. His operational limitations were not known to MRCC or ARCC.
- No Aircraft Coordinator (ACO) was appointed.
- Winching from the water was performed with manual piloting as the high seas prevented hovering under automatic control.
- The change of helicopter operator for SAR activity has resulted in a temporary reduction in capability in the event of difficult rescue operations.
- The survival suits were of decisive significance for the survival of most of the crew and the location of the survival suit storage adjacent to the bridge was decisive for the accessibility of these.
- The poor fit of the survival suits, in particular for smaller persons, resulted, inter alia, in leakage around the hood and difficulty in breathing with the suit closed. One person succumbed to hypothermia after opening the suit to permit breathing.

3.2 Causes

Finnbirch was on an unfavourable course at an unfavourable speed in a sea with high and long waves which resulted in a loss of stability with considerable but not exceptional heelings and a subsequent shifting of the cargo. The securing of the cargo on board was unsatisfactory.

Contributory factors included

- the ship's cargo-securing manual being neither complete nor followed. The charterer had his own system for cargo-securing and did not request access to the ship's cargo-securing manual. The actual level of cargo-securing was mainly a result of verbal agreements between the charterer and different officers on board.

- the failure to report to the Owner that the cargo-securing departed from the requirements of the ship's cargo-securing manual. Neither the Owners nor the inspecting authority observed that the cargo-securing on the ship deviated essentially from the specified requirements.

4 RECOMMENDATIONS

SHK recommend that the Swedish Maritime Administration

- propose that stability requirements for ships with a following sea should be entered into the relevant international rules and regulations *(RS 2008:03R1),*

- review the present training of ship's officers with respect to the handling of ships in heavy seas, to the different phenomena which can occur under such conditions and how these can be avoided or their effects minimized *(RS 2008:03 R2),*

- propose, in international collaboration, that instructions for the dimensioning of cargo-securing systems in and on cargo transport units be added to the CSS code or other suitable code*(RS 2008:03 R3),*

- propose, in international collaboration, the development of some form of obligatory code relating to the securing of cargo in and on cargo transport units. *(RS 2008:03 R4),*

- propose, in international collaboration, an amendment to the STCW requirement for training of ship's officers in cargo-securing so that it relates to all relevant ships and not only to ro-ro passenger ships. *(RS 2008:03 R5),*

- review the internal instructions for the checking of cargo-securing manuals to ensure that these manuals are checked with such methods that the results of the checking are credible *(RS 2008:03 R6),*

- increase the checks that the instructions for cargo-securing contained in cargo-securing manuals are followed in the practical work on board Swedish ships and in other ships entering Swedish ports *(RS 2008:03 R7),*

- draw attention, in international collaboration, to the problems relating to the sizes and fit of survival suits which emerged during the investigation and to the importance of the immediate availability of survival suits when required*(RS 2008:03 R8),*

- in its monitoring of the safety organisations of ship-owning companies, consider in particular the guidance developed by IMO regarding the qualifications a Designated Person (DP) should have*(RS 2008:03 R9),*

- in its monitoring of the safety organisations of ship-owning companies, consider in particular the guidance developed by IMO regarding their observation of the ISM code with respect to the authorities and resources granted Designated Persons (DP) *(RS 2008:03 R10)*

- in its monitoring of the safety organisations of ship-owning companies, check in particular, their internal follow-up and investigation of accidents and other incidents on board with the objective of improving safety on their ships *(RS 2008:03 R11),*

- clarify, in consultation with the Swedish Civil Aviation Authority, the requirements for weather and other conditions under which off-shore SAR operations should or should not be performed, *(RS 2008:03 R12), and*

- ensure that changes in SAR activity are analysed and that the risks they involve are evaluated and that measures are taken to reduce any such risks identified *(RS 2008:03 R13)*.

SHK recommend that the Civil Aviation Authority

- develop a national code of rules for requirements relating to and monitoring SAR activity *(RS 2008:03 R14)*.

Finnlines cargo services

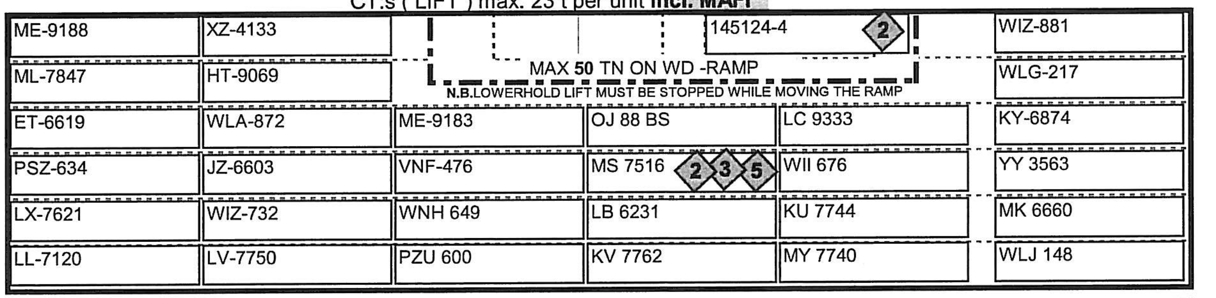
m/s FINNBIRCH

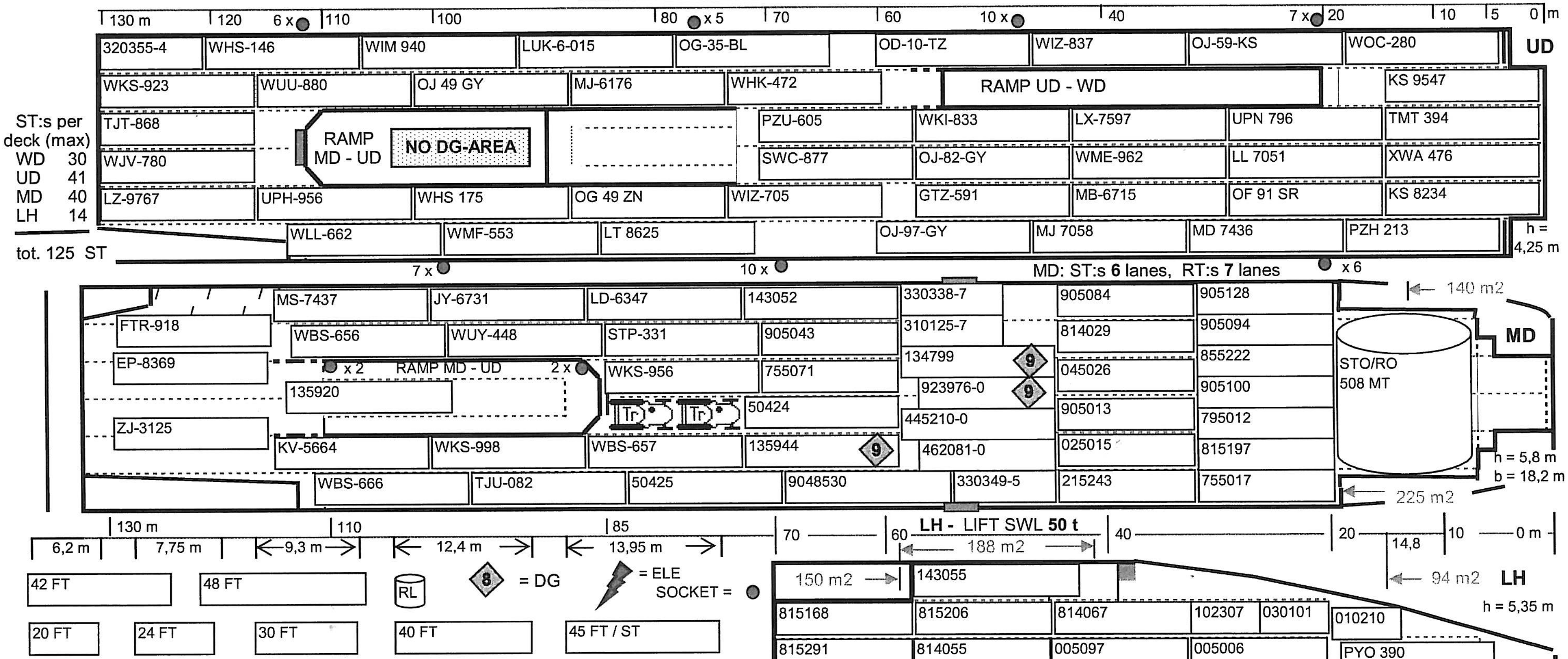
STOWAGE PLAN @ 2008-07-24 09:17

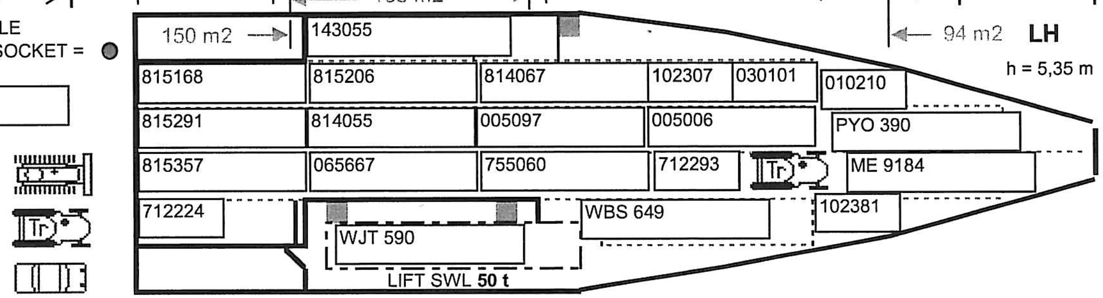
WD ST:s **6** lanes RT:s / LoLo **7** lanes, 81 TEU
CT:s (LIFT) max. 23 t per unit **incl. MAFI**

WD

DATE	**31-10-06.**	**VOY No**	**130.**
FROM	**HELSINKI.**	**LOADING COMPL.**	**31-2145.**
TO	**AARHUS.**	**DEP.**	**31-2205.**
VIA		**ETA**	**02-1200.**







	UNITS				WEIGHT				
	ST	RT's	VCL	TOTAL	ST	RT's	VCL	Sto-Ro	TOTAL
WD	30	1		31				-	573
UD	42	1		43				-	1423
MD	15	28	2	45				508	1958
LH	4	17	1	22	135	483	3		621
Total	*91*	*47*	*3*	**141**	*135*	*483*	*3*	*508*	**4575**

SALTECH

Dok No:
APPENDIX 2

Project/Object/Client:

SHK – Accident Investigation FINNBIRCH

Document title:

Stability Study FINNBIRCH

Abstract:

Stability study with reconstructed loading condition and for ship in following waves.

Checked:	Sorting code:	Rev. date:
T. Milchert		**2008-09-11** Translation Feb. 2009/TM
Author:	Document No:	
Sara Hedberg		

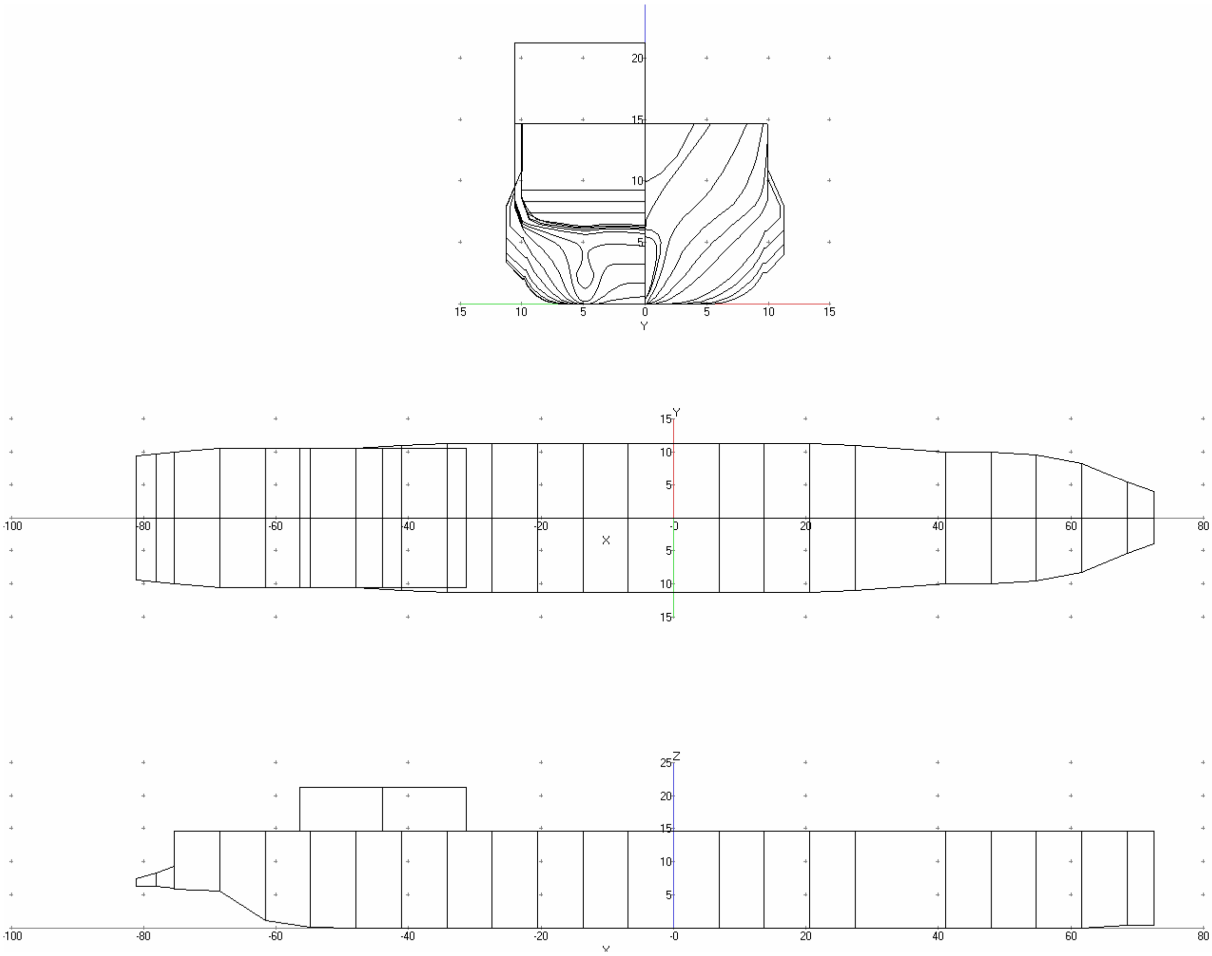
Contents

1. Ship geometry

The calculations were carried out with software HST by av Wolfson Unit Marine Technology and Industrial Aerodynamics, University of Southampton, England.

1.1. The model

The superstructure was modelled simplified as a cubicle as this would not influence the ship's stability in this study.



1.2. Hydrostatic data

The below hydrostatic data of the ship were calculated in the vicinity of the actual draught only. Data is calculated without trim and for freshwater density 1,00 ton/m^3.
The shell thickness is set equal to 10 mm.

Trim Between Marks 0.000 metres

Draught at Mid Marks metres	Moulded Draught metres	Moulded Displacement tonnes	Full Displacement tonnes	LCB metres	LCF metres	Moulded VCB metres	Moulded HCB metres	Immersion tonnes/cm	WSA metres²
6.000	6.000	10251.400	10280.680	-1.937	-3.284	3.756	0.000	20.368	2927.89
6.200	6.200	10660.340	10690.340	-1.985	-3.271	3.840	0.000	20.537	3000.25
6.400	6.400	11074.000	11104.990	-2.041	-4.267	3.925	0.000	20.962	3099.33
6.600	6.600	11497.260	11529.210	-2.137	-5.053	4.011	0.000	21.358	3195.43
6.800	6.800	11934.110	11967.550	-2.288	-7.344	4.098	0.000	22.271	3344.04
7.000	7.000	12379.220	12413.880	-2.456	-7.233	4.186	0.000	22.406	3465.46

Draught at Mid Marks metres	Moulded KMT metres	GMT metres	Moulded KML metres	MCT tonnes-metres/cm	LCG metres	LWL metres	BWL metres	CB	CP	CM	CW
6.000	10.250	10.250	182.053	136.226	-1.937	147.850	22.619	0.511	0.361	1.414	0.609
6.200	10.138	10.138	179.943	140.019	-1.985	147.850	22.619	0.514	0.367	1.399	0.614
6.400	10.053	10.053	191.449	154.752	-2.041	147.850	22.619	0.517	0.374	1.385	0.627
6.600	9.974	9.974	197.385	165.649	-2.137	147.850	22.619	0.521	0.380	1.372	0.639
6.800	9.961	9.961	219.133	190.888	-2.288	147.850	22.619	0.525	0.386	1.359	0.666
7.000	9.872	9.872	213.377	192.806	-2.456	147.850	22.619	0.529	0.393	1.346	0.670

2. Loading condition

The loading condition at departure from Helsinki on 31 November 2006 was reconstructed from available information on cargo, content of tanks, draught and trim. The loading conditions was calculated in fresh water with density 1,00 ton/m^3.

2.1. *Tanks, stores and miscellaneous*

Here, the content in tanks etc. at departure from Helsinki is reproduced. The item Stores Extra was adjusted in order to obtain reported draught and trim.

Note: Correction for free fluid surfaces was made in principle for all tanks which are not empty.
The free fluid surface in Bunker Tank No. 11 P yields a GM-correction of max. 2 cm.

Ballast Water

Tank name	Weight[ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]	FSM [t m]
1 FP Tank	0.00	63.96	4.84	0.00	0.00
2 Deep Tk C	0.00	55.84	3.32	0.00	0.00
3 Deep Tk C	415.00	47.94	4.37	0.00	340.00
5 Wing DB Tk P	0.00	34.61	3.35	0.00	0.00
5 Wing DB Tk S	0.00	34.55	3.35	0.00	0.00
6 Upper FP Tk	0.00	63.81	9.92	0.00	0.00
8 DB Tk P+S	149.70	25.95	0.73	0.00	375.00
9 DB Tk P+S	279.40	10.51	0.71	0.00	1104.00
16 Wing TkP+S	212.00	-62.22	7.03	0.00	486.60
17 Deep Tk C	98.70	-72.83	7.46	0.00	132.00
18 Wing TkP+S	156.40	-72.79	7.55	0.00	183.20
Totalt	1311.20	-3.85	4.22	0.00	2620.80

Fresh Water

Tank name	Weight[ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]	FSM [t m]
13 FW Tank S	49.50	-22.60	5.95	0.00	13.00
13 FW Tank P	99.10	-20.50	5.95	0.00	25.00
Totalt	148.60	-21.20	5.95	0.00	38.00

Fuel Oil

Tank name	Weight[ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]	FSM [t m]
Tk 4 S	53.20	47.10	6.04	0.00	275.40
Tk 10 P	95.00	-5.80	0.65	0.00	261.30
Tk 11 P	95.00	-22.72	0.66	0.00	261.30
Tk 11 S	95.00	-22.89	0.66	0.00	261.30
Settl. Tank P	28.50	-29.94	4.25	0.00	20.90
Service Tank	52.25	-29.94	4.25	0.00	20.90
Totalt	418.95	-11.45	2.03	0.00	1101.10

Diesel Oil

Tank name	Weight[ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]	FSM [t m]
DO Tank C	74.80	-50.52	3.17	0.00	375.80
Service Tank S	10.56	-26.80	4.17	0.00	0.00
Totalt	85.36	-47.59	3.29	0.00	375.8

Lubrication Oil

Tank name	Weight[ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]	FSM [t m]
Storage Tank	9.00	-46.72	3.71	0.00	2.70

Stores

Type	Weight[ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]
Stores Extra	250.00	-50.00	9.50	0.00
Crew and baggage	5.00	-39.50	22.00	0.00
Stores	80.00	-12.00	9.50	0.00
Provision	5.00	-49.50	24.00	0.00
Totalt	340.00	-40.90	9.90	0.00

Miscellaneous

Tank name	Weight[ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]	FSM [t m]
Sluge	5.00	-33.68	0.25	0.00	6.00
Waste	5.00	-46.72	3.10	0.00	2.00
Condens. Water	5.00	-38.66	0.50	0.00	4.00
Coolant Fluid	5.00	-44.66	0.50	0.00	4.00
Totalt	20.00	-40.93	1.09	0.00	16.00

2.2. Cargo

In order to calculate the actual weight and centre of gravity of the cargo, the available information on deck cargo units was collected in a detailed excel file. The summarised data is given in below table.

Cargo

Deck	Weight [ton]	LCG [m fr L/2]	VCG [m fr BL]	TCG [m fr CL]
Top Deck	563.17	20.44	23.65	-1.16
Upper Deck	1383.17	-4.15	16.80	-0.32
Main Deck	1913.42	16.52	10.00	0.06
Lower Hold	618.36	16.89	3.50	1.17
Totalt	4478.12	10.68	12.92	-0.06

3. Intact Stability

Below, the results of the stability calculations are given.

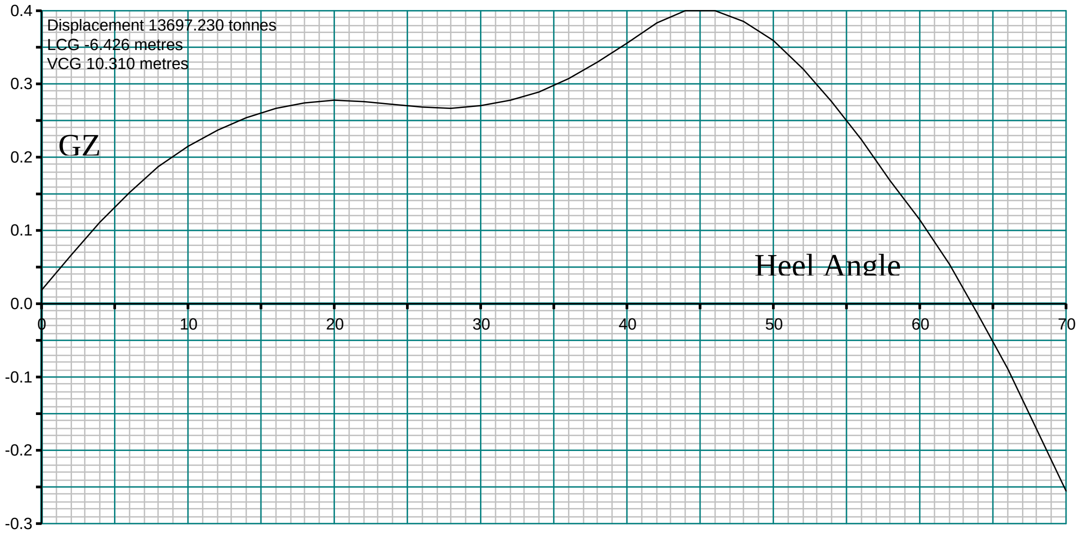
3.1. Summary of loading condition Departure Helsinki

Item	Weight	LCG	LMom	VCG	VMom	TCG	FSM
Water ballast	1311.200	-3.849	-5047.01	4.217	5528.69	0.000	2620.800
Cargo	4478.118	10.678	47818.97	12.919	57854.69	-0.059	0.000
Fresh water	148.600	-21.200	-3150.25	5.950	884.17	0.000	38.000
Lub oil	9.000	-46.720	-420.48	3.710	33.39	0.000	2.700
Fuel oil	418.950	-11.447	-4795.89	2.033	851.67	0.000	1101.100
Diesel oil	85.360	-47.586	-4061.90	3.294	281.15	0.000	375.800
Constant	90.000	-15.611	-1405.00	11.000	990.00	0.000	0.000
Stores	250.000	-50.000	-12500.00	9.500	2375.00	0.000	0.000
Other tanks	20.000	-40.930	-818.60	1.087	21.75	0.000	16.000
Deadweight	**6811.228**	**2.293**	**15619.85**	**10.104**	**68820.51**	**-0.039**	**4154.400**
Lightship	**6886.000**	**-15.050**	**-103634.30**	**9.910**	**68240.26**	**0.000**	**0.000**
Displacement	**13697.230**	**-6.426**	**-88014.45**	**10.006**	**137060.80**	**-0.019**	**4154.400**

Draught	Aft	7.036 metres
	Mid	6.849 metres
	Fwd	6.661 metres
Trim Between Marks		0.375 metres by the stern

GM Solid	1.658 metres
GM Fluid	1.355 metres
Effective VCG	10.310 metres
Moulded Displacement	13656.330 tonnes
Waterline at LCF referred to hull definition datum	6.883 metres
LCF referred to hull definition datum	-12.530 metres
Heel Angle	0.82 degrees to port

GZ curve for loading condition at Departure Helsinki



Heel Angle degrees	Righting GZ metres	Lever KN metres	Waterline metres	Trim metres	VCB metres	GZ Curve Area metres.rad
0.0	0.019	0.000	6.849	0.375	3.936	0.000
10.0	0.214	1.986	6.746	0.339	4.048	0.022
20.0	0.277	3.785	6.462	0.179	4.353	0.067
30.0	0.270	5.408	5.983	0.002	4.826	0.114
40.0	0.356	6.968	5.287	-0.132	5.528	0.167
50.0	0.359	8.244	4.392	-0.363	6.337	0.235
60.0	0.114	9.033	3.395	-1.039	7.083	0.277
70.0	-0.256	9.426	2.355	-1.928	7.798	--

3.2 Calculation with ship owner's computation routine

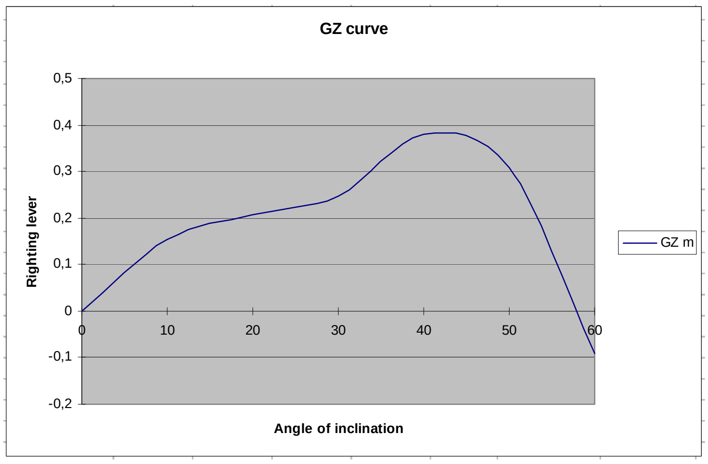
The below calculations were carried out for comparison using the shipowner's Excel calculation sheet obtained from the sister ship MS FINNFOREST.
Data was adjusted for MS FINNBIRCH.

ms FINNBIRCH

Port	H-fors
Date	31-10-2006

CARGO		VCG	Tonnes	Ballast	Volume	capacity	VCG		FS mom
Top deck	Trailers	23,65	563	UFP	0	280	9,92	0,0	0
	Mafi	23,15	0	LFP	0	234	4,84	0,0	0
	Containe	22,85	0	2	0	107	3,32	0,0	0
Upper deck	Trailers	16,80	1355	3	415	405	4,37	1813,6	340
	Mafi	16,30	28	5P	0	192	3,35	0,0	0
	Containe	16,00	0	5S	0	190	3,35	0,0	0
Ramp		13,80	0	8P	75	73	0,73	54,8	0
Main deck	Trailers	9,90	1215	8S	75	73	0,73	54,8	0
	Mafi	9,40	225	9P+S	279	273	0,7	195,3	1057
	Containe	9,10	0	16	212	418	6,97	1478	487
	Storo	10,40	473	17C	99	96	7,46	738,5	0
Lower hold	Trailers	3,50	140	18P+S	156	153	7,55	1177,8	0
	Mafi	3,00	479	Volume	1311	cbm		5512	1884
	Containe	2,55	0	Weight	1311	tonnes	Ballast density		1
	Storo	3,90	0						
				Dock water densit	1				
	Cargo		**4478**						

HFO		Capac	VCG	FS	Max FS	**Calc**	**TS**	**VCG**	
						Cargo	4478	12,85	57525
4	53	246	6,04	264	264	Ballast	1311	4,20	5512
10	95	204	0,63	501	501	HFO	419	2,03	850
11	190	225	0,66	501	501	MDO	86	3,30	284
15	0	221	6,85	0	285	Lub oil	9	1,50	14
19	29	51	4,25	20	20	FW	148	5,95	881
20	52	51	4,25	20	20	Stores	250	9,50	2375
Total	419			1306		Light ship	6886	9,91	68240
MDO						Constant	110	10,00	1100
12	75	159	3,17	376	376	**Displ**	13697	9,99	136780
21	11	17	4,17		0		Seawat	Dock water	
Total	86					**Draft**	**674**	**691**	
Lub oil	9		1,50			KM	11,64		
FW						KG	9,99		
13P	99	99	5,95	25	25	GM solid	1,65		
13S	49	50	5,95	13	13	FS corr	0,26		
						GM liquic	**1,39**		
						Min GM	**1,079**		



4. Cargo displacement

According to available information, the ship had a permanent heeling of 30-35 degrees after the reported large rolling movements.
By changing the centre of gravity of the cargo transversely in the calculation model, the cargo displacement for obtaining such a static heeling angle was determined.
If the total cargo is displaced 1.055 m to the side, the obtained heeling angle is 35 degrees.
At 0.9 m transverse displacement, heeling becomes 30 degrees.

4.1. Summary of loading condition with cargo displacement

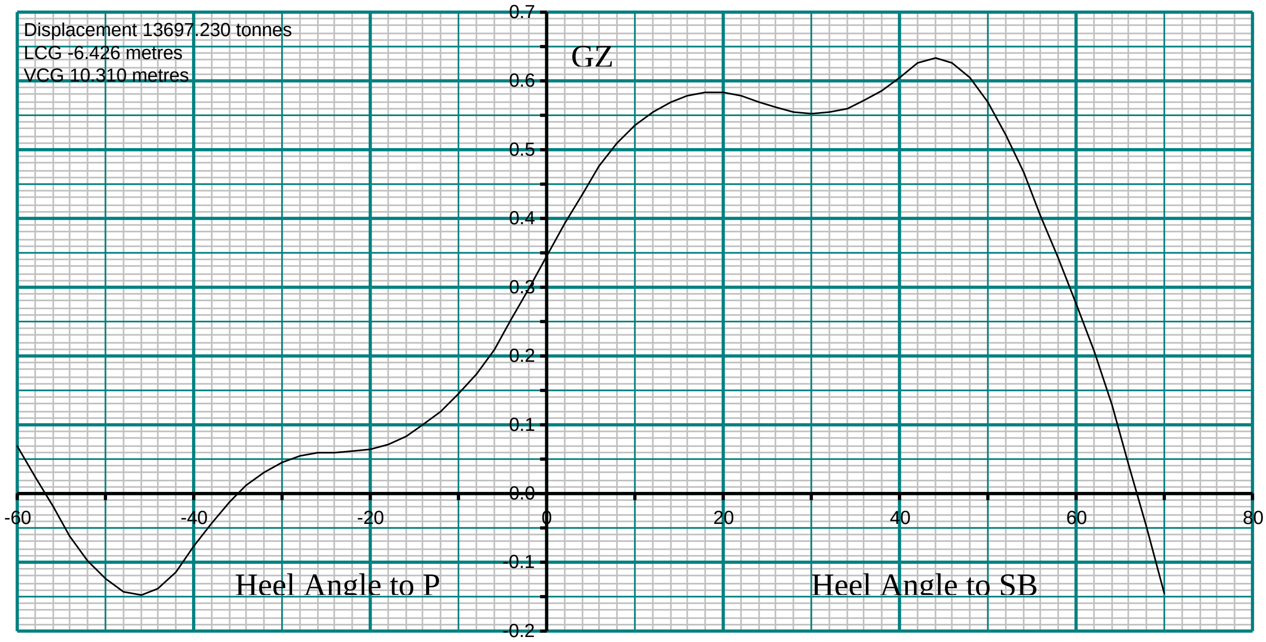
This loading condition was created in order to obtain a permanent heeling of 35 degrees.

Item	Weight	LCG	LMom	VCG	VMom	TCG	FSM
Water ballast	1311.200	-3.849	-5047.01	4.217	5528.69	0.000	2620.800
Cargo caps	4478.118	10.678	47818.97	12.919	57854.69	-1.055	0.000
Fresh water	148.600	-21.200	-3150.25	5.950	884.17	0.000	38.000
Lub oil	9.000	-46.720	-420.48	3.710	33.39	0.000	2.700
Fuel oil	418.950	-11.447	-4795.89	2.033	851.67	0.000	1101.100
Diesel oil	85.360	-47.586	-4061.90	3.294	281.15	0.000	375.800
Constant	90.000	-15.611	-1405.00	11.000	990.00	0.000	0.000
Stores	250.000	-50.000	-12500.00	9.500	2375.00	0.000	0.000
Other tanks	20.000	-40.930	-818.60	1.087	21.75	0.000	16.000
Deadweight	**6811.228**	**2.293**	**15619.85**	**10.104**	**68820.51**	**-0.694**	**4154.400**
Lightship	**6886.000**	**-15.050**	**-103634.30**	**9.910**	**68240.26**	**0.000**	**0.000**
Displacement	**13697.230**	**-6.426**	**-88014.45**	**10.006**	**137060.80**	**-0.345**	**4154.400**

Draught*	Aft*	7.036 metres
	Mid*	6.849 metres
	Fwd*	6.661 metres
Trim Between Marks		0.375 metres by the stern

GM Solid	1.006 metres
GM Fluid	0.702 metres
Effective VCG	10.310 metres
Moulded Displacement	13656.330 tonnes
Waterline at LCF referred to hull definition datum	6.883 metres
LCF referred to hull definition datum	-12.530 metres
Heel Angle	35.00 degrees to port

Note: All data refer to the original coordinate system shown in Section 1.
*) Calculated draughts refer to the keel (base line).



<u>GZ-curve with cargo displacement.</u>
Equilibrium (GZ=0) is obtained at –35 degrees (permanent heeling to port). In this position the lever GZ is increasing with increasing heeling angle (to starboard).

Stability would be lost and the ship would capsize at heeling angles –57 degrees (to port) and +67 degrees (to starboard).

Heel Angle degrees	Righting GZ metres	Lever KN metres	Waterline metres	Trim metres	VCB metres	GZ Curve Area metres.rad
-60.0	0.068	-9.033	3.395	-1.039	7.083	0.000
-50.0	-0.125	-8.244	4.392	-0.363	6.337	0.000
-40.0	-0.076	-6.968	5.287	-0.132	5.528	0.000
-30.0	0.045	-5.408	5.983	0.002	4.826	0.002
-20.0	0.065	-3.785	6.462	0.179	4.353	0.012
-10.0	0.144	-1.986	6.746	0.339	4.048	0.029
0.0	0.345	0.000	6.849	0.375	3.936	0.070
10.0	0.535	1.986	6.746	0.339	4.048	0.149
20.0	0.583	3.785	6.462	0.179	4.353	0.248
30.0	0.552	5.408	5.983	0.002	4.826	0.347
40.0	0.605	6.968	5.287	-0.132	5.528	0.447
50.0	0.568	8.244	4.392	-0.363	6.337	0.554
60.0	0.277	9.033	3.395	-1.039	7.083	0.629
70.0	-0.144	9.426	2.355	-1.928	7.798	--

4.2 Heeling moments

Below, the magnitude of the heeling moments obtained from various unsymmetrical loads are given for comparison. The heeling moments were calculated for the ship in upright position.

1. **Transverse displacement of the total deck cargo of 4478 ton by 1,06 m.**
   (Equivalent heeling is 35 degrees).
   M_1=Equivalent heeling moment in upright position.

   M_1 = 4478 x 1,06 = 4747 ton m

2. **Transverse displacement (hypothetical) of the total deck cargo of 4478 ton by 1,6 m.**
   (Equivalent heeling is 45 degrees).

   M_2 = 4478 x 1,6 = 7165 ton m

3. **Transverse displacement of cargo within the cargo units**
   Assume that 1000 ton move transversely by 0,5 m

   M_3 = 1000 x 0,5 = 500 ton m

4. **50 ton of water accumulate in deck corner at the ship side on upper deck**
   (This condition could appear only at certain large heeling angles)

   M_4 = 50 x B/2 = 50 x 10,8 = 540 ton m

5. **Wind pressure** about 500 N/m^2

   Calculation was made using data from stability booklet for sister ship FINNFOREST.

   Ship's lateral projected wind area about 2342 m^2
   Centre of wind area above keel 15,9 m

   Heeling moment calculated with a lever reaching from a point at ½ draught to the centre of the lateral area (wind area),
   i.e. about 15,9 – 3,3 = 12,6 m

   M_5 = 2342 x 0,5 x 12,6 = 14755 kNm about 1505 ton m.

5. Ship in following waves

The (static) stability of a ship is influenced by the waves.
In following waves, i.e. waves approaching from behind, (but also in head waves approaching from forward) the stability is sometimes reduced compared with smooth water conditions.
Reduction of stability appears for wave lengths (calculated along the centre line of the ship) of between a good half and twice the ship's length when the wave crest is approaching the half ship's length (L/2).
With the position of the wave crests close to the quarter lengths of the ship (L/4), the stability is usually increased.

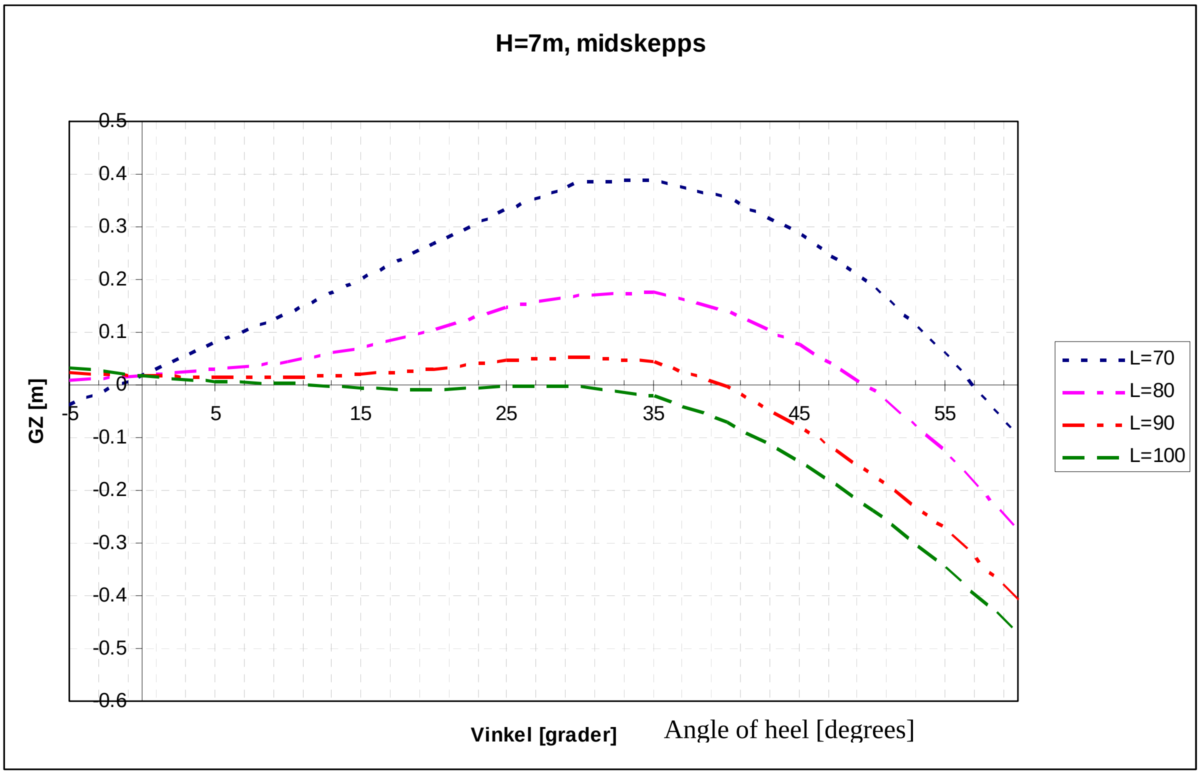
In order to investigate those effects on FINNBIRCH, a number of combinations were studied.
In the stability calculations, the ship was positioned in a water surface forming a static trochoidal wave, i.e. a wave with geometry similar to a sea wave.
The loading condition for departure from Helsinki was used, see above.
The wave crest was positioned at the half length (L/2) of the ship. Alternatively was one wave crest positioned at the forward quarter length (L/4) , about 35 m forward of the half length, whereas the positions of other wave crests vary with the wave length.

The maximum wave height was 7-8 m in the sea condition at the time of the accident.
A wave height of 7 m was used in the calculations, marked H=7 in below figures.
Also a wave height of 4 m was studied for comparison.
The studied wave lengths (distance between wave crests in direction of ship's centreline) are 70, 80, 90 and 100 m.

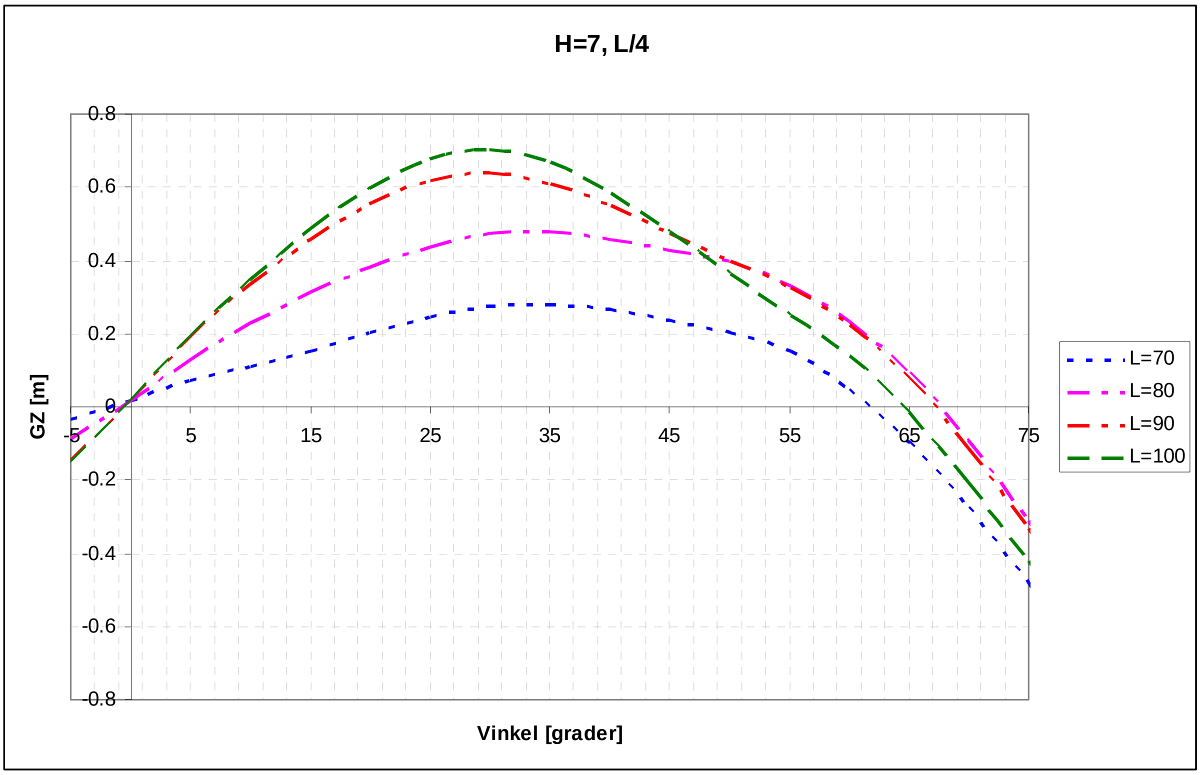
From the calculation results, it can be concluded that a major reduction of stability appears in 7 m waves with wave lengths of 80 m and above, when the wave crest is positioned at the half length of the ship (amidships, L/2).
The first figure below shows the calculation results for the wave crest amidships. The GZ curve values could become close to zero for waves above 90 m length, meaning that the ship would loose its static stability.
In waves of a length of 70 m or shorter, the effect on stability is very small.
It could also be observed that the hollow, found in the GZ-curve for smooth water, disappears.

The second figure below shows calculation results with one wave crest at the forward quarter length (L/4). The GZ-value is reduced in short waves but is increasing considerably in long waves.

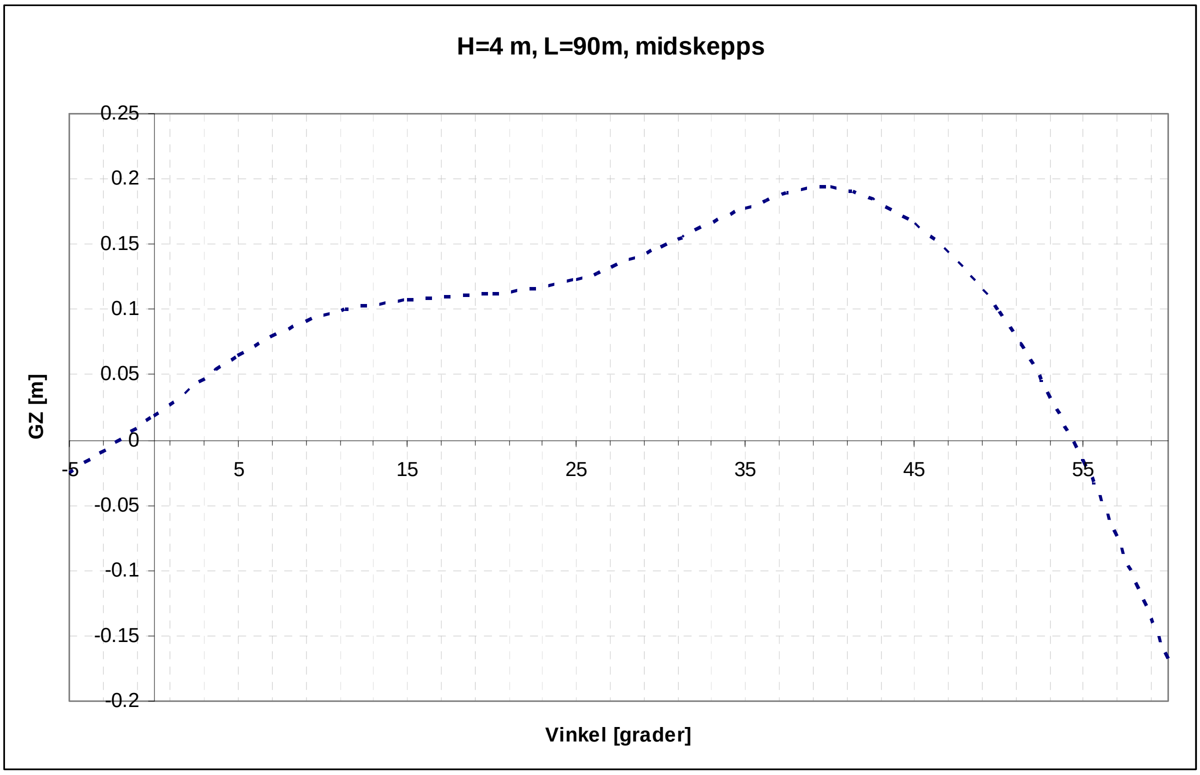
The wave height plays an important role, but also in 90 m waves with height of 4 m, the stability is considerably reduced, see the third figure.



GZ curves for wave crest amidships, L/2. Wave height 7 m. Wave lengths 70, 80, 90, 100 m



GZ curves for one wave crest at forward quarter length, L/4. Wave height 7 m. Wave lengths 70, 80, 90, 100 m



GZ curve for wave crest amidships, L/2. Wave height 4 m. Wave lengths 90 m.

APPENDIX 3
Translation Jan. 09/TM

Calculations according to MSC.1/Circ. 1228
"Revised guidance to the master for avoiding dangerous situations in adverse weather and sea conditions".

Ship Particulars FINNBIRCH

Loa 156 m
Lbp 137 m
Bmld 21,6 m at main deck
Bmax 22,7 m at sponsons
Tmax 7,3 m

Note: The calculations in the examples below are made with quartering waves heading from port, whereas the waves in the FINNBIRCH accident were heading in similar angles but from starboard.

Wave data

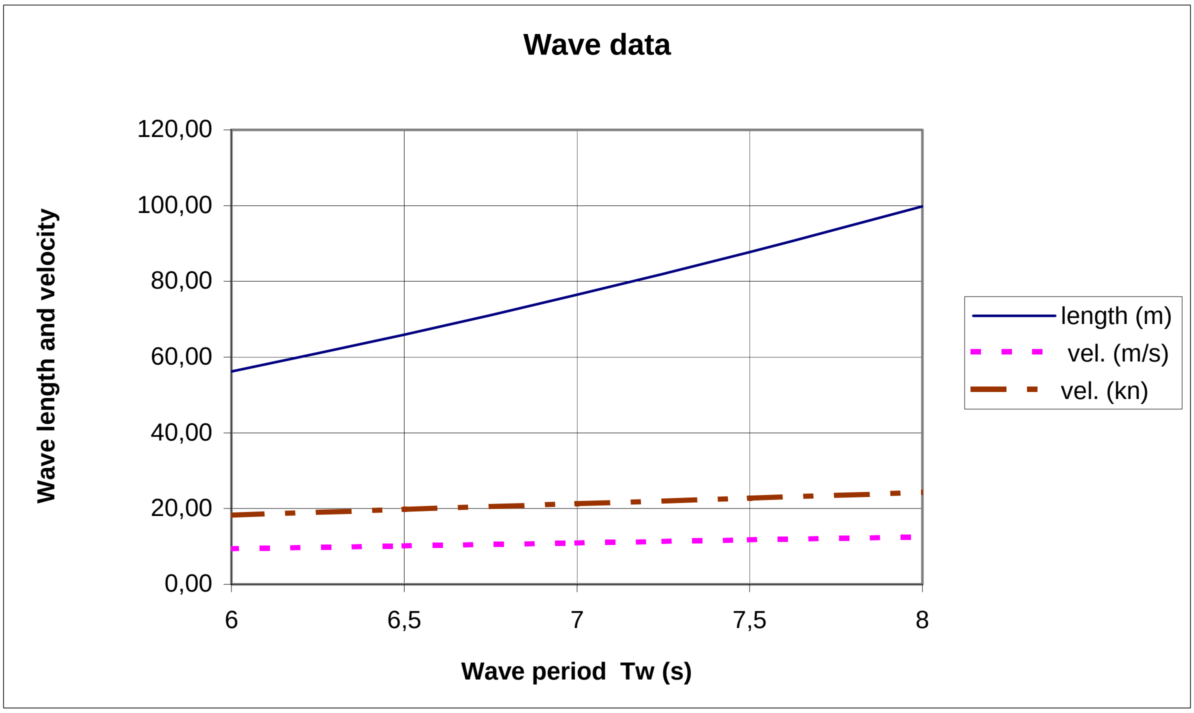


Figure 1. The diagram shows the wave period on x-axis
Wave length in m (between wave crests) and wave velocity in m/s and in knot is shown on y-axis.

Period of encounter between ship and following waves versus ship’s speed and angle alpha

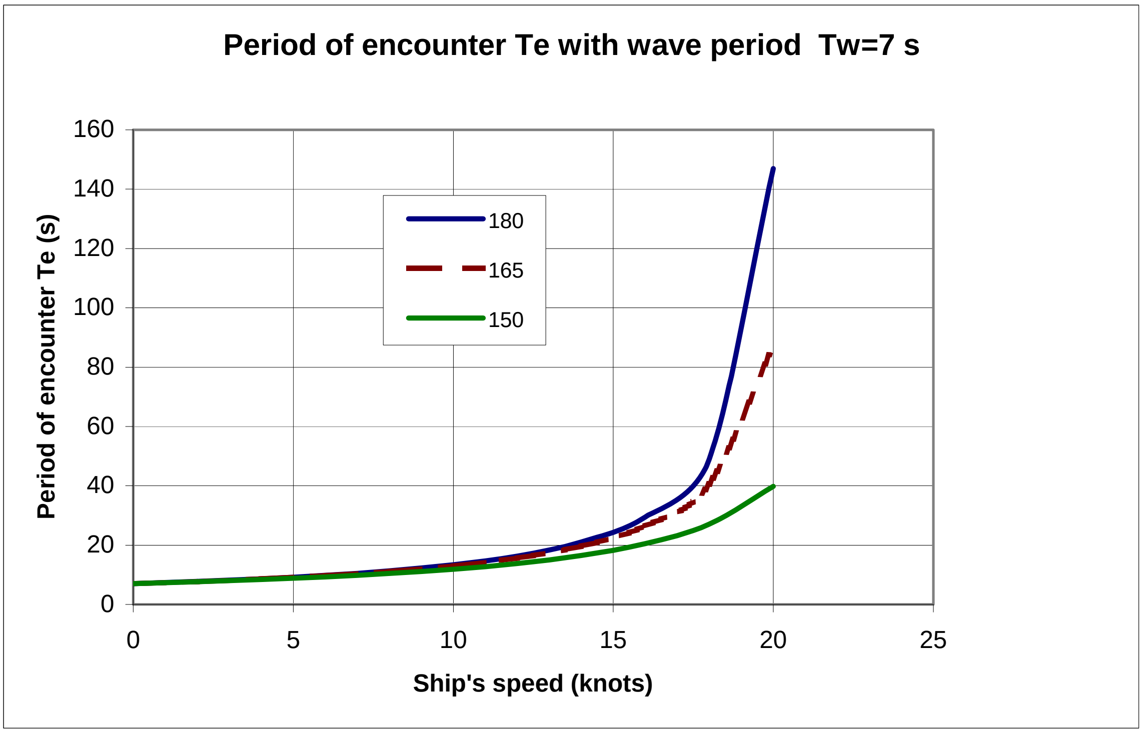


Figure 2: Period of encounter Te between ship and following waves at different angles alpha between ship’s direction and wave direction off bow.

An angle alpha of 180 degrees corresponds a to wave direction straight from abaft.
Angles of 165 and 150 degrees correspond to quartering waves (from abaft the beam).

The period of encounter increases with increasing ship’s speed, which means that the waves pass the ship more slowly.
At speed 18 knots and wave direction straight from abaft, the period of encounter (i.e. time between two wave passages) is approx. 1 minute.

Dangerous phenomena

Reduction of intact stability when riding a wave crest amidships

Criteria		**Danger?**
Wave lengths 0,6 L to 2,3 L	Actual wave lengths 76-100 m i.e. 0,55L to 0,73L	Yes
Long duration of riding on wave crest	Yes	Yes
		Yes

Table 1: The criteria for dangerous loss of intact stability are satisfied

Dangerous zones - operational guidance

Surfing and broaching to

Criteria		**Danger?**
Alfa 136 to 225 degrees (angle of encounter)	Actual angle about 160-165 degrees (See note above)	Yes
Speed V (knots) > 1,8 √ (L) = 21,1	Actual max. 18	No
Compare figure 3	V/√ (L) = 1,5	**No**

Table 2: Table and below figure shows the criteria for surfing and broaching to. The criteria are not satisfied.

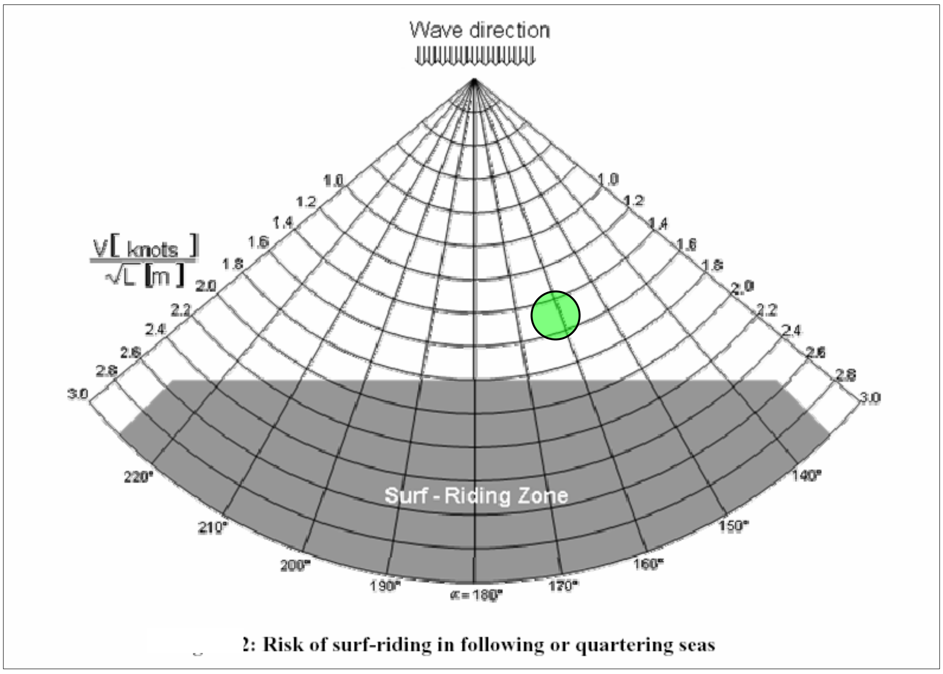


Figure 3: Criteria for surfing and broaching to. The criteria are not satisfied.

Successive high-wave attack

Criteria		Danger?
Average wave length > 0,8 L	Actual about 80/137=0,58 L	No
Average wave height > 0,04 L	Actual about 4/137=0,03 L	No
Figure 4	Actual V/Tw = 2,4	**No**

Table 3: Criteria for successive high-wave attack. The criteria are not satisfied.

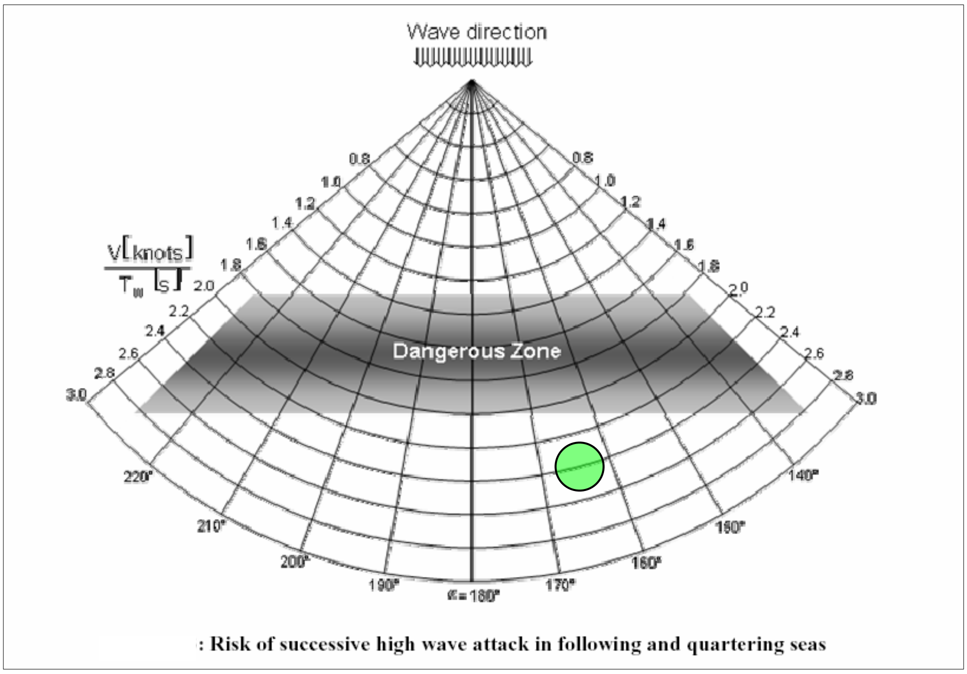


Figure 4: Criteria for successive high-wave attack. The criteria are not satisfied.

Synchronous rolling and parametric rolling

Criteria		Danger?
Te nearly equal to ship rolling period	At speed 17-18 knots actual Te about 25-50 s (see fig. 2). Actual natural period < 15 s.	No
Te nearly ½ of ship natural rolling period		No
		No

Table 4: Criteria for synchronous rolling and parametric rolling. The criteria are not satisfied.

Appendix 4

BALANCE EQUATIONS FOR SEMI-TRAILERS

To evaluate what accelerations and relative heeling angles the actual securing arrangement used for semi-trailers could withstand, the balance equations below have been used. These equations have also been used to calculate required strength of the lashings to withstand certain acceleration.

Due to the limited torsional strength of semi-trailers, separate balance equations have been set up for the rear and forward end of the trailer respectively. It has been assumed that the weight is relatively symmetrically distributed so that half of the weight acts on the rear lashings and half of the weight acts on the forward lashings.

Transverse sliding

The following balance of forces acting in transverse direction of the ship is used for transverse sliding calculations:

$$m \times a_t + A \times VT = n \times CS \times \cos\alpha \times \sin\beta + \mu \times m \times g + \mu \times n \times CS \times \sin\alpha$$

In this equation the parameters have the following meaning:

m	Half the trailer weight in ton
a_t	Transverse acceleration in m/s^2
A*	Half the exposed wind area in m^2, (The entire wind area is supposed to be about $3 \times 13{,}6 = 40{,}8$ m^2)
VT*	Wind pressure 1 kN/m^2
n	Number of lashings acting per side in the trailer's forward and rear end respectively.
CS	CS = MSL / 1,35, where MSL is the strength of the lashings and 1,35 is a safety factor. MSL is inserted in kN, which is 9,81 times the strength in ton.
α	The angle between the lashing and the ship's deck.
β	The angle between the lashing and the ship's longitudinal axle.
μ	Coefficient of friction between the trailer and the ship's deck.
g	Gravity acceleration that is 9,81 m/s^2

* Note; the effect of the wind pressure is taken into account on the Weather Deck only

Example – sliding

What transverse acceleration can one lashing on each side of the rear end of a trailer prevent from sliding sideways if the lashing angle relative to the ship's deck is 60 degrees and 30 degrees relative to the ship's longitudinal axle? The MSL of the lashings are 6 ton. The gross weight of the trailer is 36,5 ton and it is not exposed to wind.

The following parameter values are inserted in the above formula:

m	36,5 / 2 = 18,25 ton
a_t	To be solved by the equation
A*	0 - as the trailer is not exposed to wind pressure

VT*	0 - of the same reason as above.
n	1 pcs
CS	$6 \times 9{,}81 / 1{,}35 = 43{,}6$ kN
α	60 degrees
β	30 degrees
μ	0,3 for rubber on steel according to CSS
g	9,81 m/s^2

The following equation is used to solve a_t:

$$a_t = (n \times CS \times \cos \alpha \times \sin \beta + \mu \times m \times g + \mu \times n \times CS \times \sin \alpha) / m$$

With parameter values according to above the following equation is obtained:

$$a_t = (1 \times 43{,}6 \times \cos 60 \times \sin 30 + 0{,}3 \times 18{,}25 \times 9{,}81 + 0{,}3 \times 1 \times 43{,}6 \times \sin 60) / 18{,}25 = 4{,}2 \text{ m/s}^2$$

$$a_t = 4{,}2 \text{ m/s}^2$$

Transverse tipping

The following balance of moments around the tipping point for the forces acting in transverse direction in the ship is used for transverse tipping calculations:

$$m \times a_t \times H_{tp} + A \times VT \times H_{tpa} =$$
$$n \times CS \times h \times \cos \alpha \times \sin \beta + m \times g \times (B/2 - d) + n \times CS \times (B/2 + b) \times \sin \alpha$$

In this equation the parameters have the following meaning:

m	Half the trailer weight in ton
a_t	The transverse acceleration in m/s^2
H_{tp}	The vertical centre of gravity of the trailer in meter calculated according to the following formula for a trailer with a tare weight of 7 ton (half of the tare weight is 3,5 ton) and dimensions and filling degree according to the figure below: $H_{tp} = (3{,}5 \times 0{,}7 \times 1{,}15 + (m - 3{,}5) \times (0{,}8 \times 2{,}85 \times 0{,}5 + 1{,}15)) / m$
A*	Half of the exposed wind area in m^2, (The entire wind area is supposed to be about $3 \times 13{,}6 = 40{,}8$ m^2)
VT*	Wind pressure 1 kN/m^2
H_{tpa}	Vertical centre of gravity of the wind area in meter. H_{tpa} is assumed to be about 2,5 meter
n	Number of lashings acting per side in the trailer's forward and rear end respectively
CS	CS = MSL / 1,35, where MSL is the strength of the lashings and 1,35 is a safety factor. MSL is inserted in kN, which is 9,81 times the strength in ton.
h	The vertical distance from the ship's deck to the lashing points on the trailer in meter
α	The angle between the lashing and the ship's deck.
β	The angle between the lashing and the ship's longitudinal axle.
g	Gravity acceleration that is 9,81 m/s^2
B	Stability width between the tipping points in transverse direction in meter.

d	The horizontal distance from the trailer's centre line to the centre of gravity of the trailer in meter.
b	The horizontal distance from the trailer's centre line to the lashing points on the trailer in meter.

* Note the effect of the wind pressure is taken into account on the Weather Deck only

In the figure below dimensions of typical semi-trailers, which have been used in the calculations, are shown. The tare weight of the semi-trailer is assumed to be 7 ton and the vertical centre of gravity of the tare weight is assumed to be located on a height of 70% of the height up to the trailer platform, which has been set to 1,15 meter. Maximum gross weight about 37 ton. Friction between trailer deck and ship's deck as well as between trailer trestle and ship's deck has been assumed to be 0,3. The centre of gravity is assumed to be located 0,1 m from the centre line of the trailer. Due to the trailer suspensions the centre of gravity of the rear end of the trailer is assumed to move sideways and in the calculations a distance of 0,2 m has been used, see figure.

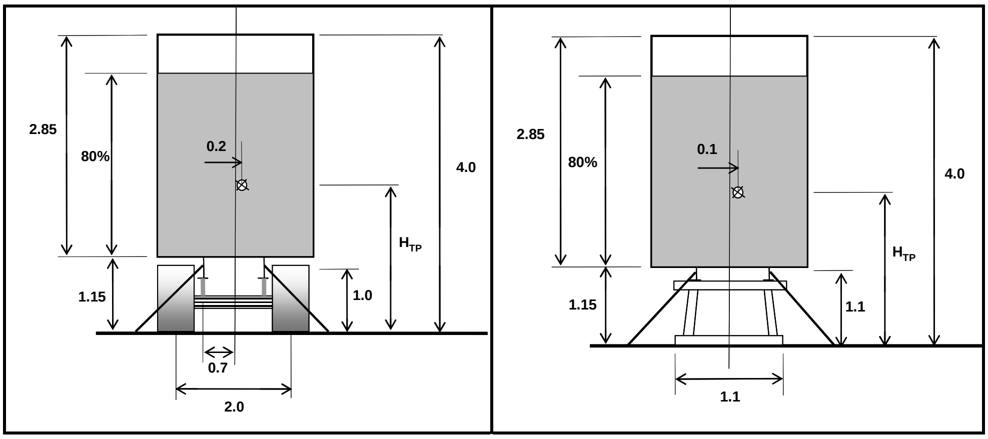


Fig. Typical parameter values for semi-trailers.

Example – tipping

What transverse acceleration can two lashings on each side of the forward end of a trailer prevent from tipping sideways if the lashing angle relative to the ship's deck is 30 degrees and 30 degrees relative to the ship's longitudinal axle? The MSL of the lashings are 10 ton. The gross weight of the trailer is 29,5 ton and it is exposed to wind.

The following parameter values are inserted in the above formula:

m	29,5 / 2 = 14,75 ton
a_t	To be solved by the equation
H_{tp}	H_{tp} = (3,5 × 0,7 × 1,15 + (m – 3,5) × (0,8 × 2,85 × 0,5 + 1,15)) / m = 1,94 meter
A*	20,4 m^2
VT*	1 kN/m^2
H_{tpa}	2,5 meter
n	2 pcs
CS	9,81 × 10 / 1,35 = 72,67 kN
h	1,1 meter
α	30 grader

β	30 grader
g	9,81 m/s^2
B	1,1 meter
d	0,1 meter
b	0,7 meter

The following equation has been used to solve a_t:

$a_t = (n \times CS \times h \times \cos \alpha \times \sin \beta + m \times g \times (B/2 - d) + n \times CS \times (B/2 + b) \times$
$\sin \alpha - A \times VP \times H_{tpa}) / (m \times H_{tp})$

With parameter values according to above the following equation is obtained:

$a_t = (2 \times 72{,}67 \times 1{,}1 \times \cos 30 \times \sin 30 + 14{,}75 \times 9{,}81 \times (1{,}1/2 - 0{,}1) + 2 \times 72{,}67 \times$
$(1{,}1/2 + 0{,}7) \times \sin 30 - 20{,}4 \times 1 \times 2{,}5) / (14{,}75 \times 1{,}94) = 6{,}1$ m/s^2

$a_t = 6{,}1$ m/s^2

Appendix 5

CALCULATION OF MAXIMUM HEELING MOMENT DUE TO A TOTAL CARGO SHIFT

Below calculations are found for the moment that is obtained from each unit if it is packed tightly to the port side against the ship's side, bulkhead or other unit. Assumptions done in the calculations are found in the right column in the table below. Among others it has been assumed that a sector of 25 degrees only of the Sto-Ro cargo on Main Deck has shifted and more over the upper layer of paper reels only of the three layers stowed in this sector.

For Weather Deck, as far as practicable the real cargo shifting, as it can bee seen from the photos taken from the helicopters, has been used in the calculations.

Max possible heeling moment							
Rolltrailer dim:	12,2 x 2,5 m						
Semitrailer dim:	13,6 x 2,55 m						
Swap Body dim:	13,6 x 2,55 m						
Unit	**Unit**	**Gr weight**	**Motion**	**Mom**	**Mom**		
number	**type**	**Ton**	**m**	**Ton x m**	**per sect**	**Cargo type**	**NOTE**
10210	R-T	16,3	0,4	7			Motion 0,4 m
PYO 390	TR	32	0,4	13		Wood	
ME 9184	TR	37,3	0,4	15		Steel	
102381	R-T	14	0,4	6	40		
102307	R-T	15	1	15			Motion 2 / 2 = 1 m
30101	R-T	26,1	1	26			
5006	R-T	32,1	1	32		Paper	
712293	R-T	12	1	12			
Tractor	Tractor	5	1	5			
WBS 649	TR	28,8	1,75	50	141	Wood	Motion 1 + 0,75 = 1,75 m
814067	R-T	31,1	1,25	39		Paper	Motion: 2,5 / 2 = 1,25
5097	R-T	37	1,25	46		Paper	
755060	R-T	34,6	1,25	43	128	Paper	
143055	R-T SB	28	0	0		Peat	Block stowed to Port side
815206	R-T	41,6	0	0		Paper	
814055	R-T	31,1	0	0		Paper	
65667	R-T	31,9	0	0		Paper	
WJT 590	TR	37,1	0,48	18	18	Steel pipes	Free space: 3,5 - 2,55 / 2 =
815168	R-T	42,7	0	0		Paper	Block stowed to Port side
815291	R-T	44,1	0	0		Paper	
815357	R-T	40,8	0	0		Paper	
712224	R-T	14,2	1,6	23	23	Paper	Line stowed: 13,2 m free space - 4 x 2,5 / 2 = 1,60 m
TOTAL TT				**349**			

Fig. Calculation of heeling moments at total cargo shifting on Tank Top.

STO-RO	Reels	38	9,5	361	361	Paper	1/3 of the cargo in a triangle 25 degrees fwd from the aft end
905128	R-T	36,2	0,1	4		Paper	Block stowed to SB: 17,6 m free space - 7 x 2,5 = 0,10 m
905094	R-T	30,5	0,1	3		Board	
855222	R-T	36,8	0,1	4		Paper	
905100	R-T	47,4	0,1	5		Paper	
795012	R-T	52,9	0,1	5		Paper	
815197	R-T	50	0,1	5		Paper	
755017	R-T	46,6	0,1	5	30	Paper	
905084	R-T	43,2	0,49	21		Board	Lane stowed: 18,4 m free space - 6 x 2,5 m / 7 = 0,49 m
814029	R-T	42,2	0,98	41		Board	
45026	R-T	43,55	1,47	64		Paper	
905013	R-T	43,9	1,96	86		Paper	
25015	R-T	20,15	2,45	49		Paper	
215243	R-T	36,15	2,94	106	368	Paper	
330338-7	R-T cont	27,3	0,9	25			Block stowed to SB: 18,4 m free space - 7 x 2,5 = 0,90 m
310125-7	R-T cont	28,4	0,9	26			
134799	R-T VX	29,5	0,9	27		IMDG cargo	
923976-0	R-T cont	27,1	0,9	24		IMDG cargo	
445210-0	R-T cont	32,2	0,9	29		Peat	
462081-0	R-T cont	11,8	0,9	11		Snow machines	
330349-5	R-T cont	28,8	0,9	26	167		
143052	R-T VX	27	0,49	13		Glass fibre	Lane stowed: 18,4 m free space - 6 x 2,5 m / 7 = 0,49 m
905043	R-T	31,4	0,98	31		Board	
755071	R-T	44,5	1,47	65		Board	
50424	R-T VX	32,7	1,96	64		Feldspar	
135944	R-T VX	29,5	2,45	72			
9048530	R-T	28	2,94	82	328	Board	
LD 6347	TR	36,5	0,44	16			Lane stowed: 18,4 m free space - 6 x 2,55 m / 7 = 0,44 m
STP 331	TR	33,9	0,88	30		Wood	
WKS 956	TR	33	1,32	44		Wood	
Tractors	Tractors	10,7	1,76	19		Tractor	
WBS 657	TR	27,6	2,2	61		Glass	
50425	R-T VX	32,6	2,64	86	255	Peat	
JY 6731	TR	35	0,7	25		Wood	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
WUY 448	TR	33	1,4	46		Wood	
WKS 998	TR	34	7	238		Wood	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
TJU 082	TR	33	1,4	46	355	Wood	
MS 743	TR	35	0,7	25		Wood	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
WBS 656	TR	29,1	1,4	41		Wood	
135920	R-T VX	24,4	0,45	11		Glass fibre	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
KV 5664	TR	30	0,7	21		Wood	
WBS 666	TR	28,5	1,4	40	137	Wood	
FTR 918	TR	13,3	1,84	24		Tools	Lane stowed: 15 m free space - 3 x 2,55 m / 4 = 1,84 m
ED 8396	TR	27	3,68	99		Wood	
ZJ 3125	TR	29,9	5,52	165	289	Generators	
TOTAL MD				**2290**			

Fig. Calculation of heeling moments at total cargo shifting on Main Deck.

WOC 280	TR	30,3	0,44	13		Wood	Lane stowed: 18,4 m free space - 6 x 2,55 m / 7 = 0,44 m
KS 9547	TR	37	0,88	33		Wood	
TMT 394	TR	34	1,32	45		Wood	
XWA 476	TR	36,4	1,76	64		Steel	
KS 8234	TR	37	2,2	81		Wood	
PZH 213	TR	32	2,64	84	321	Paper	
OJ 59 KS	TR	35	0,48	17		Wood	Lane stowed: 3,5 m free space - 2,55 / 2 = 0,48 m
UPN 796	TR	35	2,44	85		Wood	Free space to bulkhead: 18,4 - 3,5 - 0,5 - 4 x (2,55 + 0,44) = 2,44 m
LL 7051	TR	30,7	2,88	88		Wood	Free space between units: 0,44 m
OF 91 SR	TR	32	3,32	106		Wood	
MD 7436	TR	35	3,76	132	428	Wood	
WIZ 837	TR	14,4	0,48	7		General cargo	Lane stowed: 3,5 m free space - 2,55 / 2 = 0,48 m
LX 7597	TR	35,8	2,44	87		5 steel coils	Free space to bulkhead: 18,4 - 3,5 - 0,5 - 4 x (2,55 + 0,44) = 2,44 m
WME 962	TR	35,3	2,88	102		Steel bundles	Free space between units: 0,44 m
MB 6715	TR	34,4	3,32	114			
MJ 7058	TR	35	3,76	132	442	Wood	
OD 10 TZ	TR	34	0,48	16		Wood	Lane stowed: 3,5 m free space - 2,55 / 2 = 0,48 m
WKI 833	TR	34	2,44	83		Steel	Free space to bulkhead: 18,4 - 3,5 - 0,5 - 4 x (2,55 + 0,44) = 2,44 m
OJ 82 GY	TR	34	2,88	98		Wood	Free space between units: 0,44 m
GTZ 591	TR	32	3,32	106		Wood	
OJ 97 GY	TR	32	3,76	120	424	Wood	
OG 35 BL	TR	36	0,44	16		Wood	Lane stowed: 18,4 m free space - 6 x 2,55 m / 7 = 0,44 m
WHK 472	TR	36,2	0,88	32		Pipes	
PZU 605	TR	30	1,32	40		General cargo	
SWZ 877	TR	35,3	1,76	62		Paper + general	
WIZ 705	TR	33,5	2,2	74	223	Plywood	
LUK 6015	TR	17	0,7	12		Chain	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
MJ 6176	TR	34,5	1,4	48		Paper	
OG 49 ZN	TR	32	0,7	22		Wood	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
LT 8625	TR	33,5	1,4	47	130	Plywood	
WIM 940	TR	34	0,7	24		Wood	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
OJ 49 GY	TR	34	1,4	48		Wood	
WHS 175	TR	35	0,7	25		Wood	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
WMF 553	TR	32	1,4	45	141	Wood	
WHS 146	TR	34	0,7	24		Wood	Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
WUU 880	TR	33,2	1,4	46		Plywood	
UPH 956	TR	36,5	0,7	26			Lane stowed: 7,2 m free space - 2 x 2,55 m / 3 = 0,70 m
WLL 662	TR	30,7	1,4	43	139	Wood	
320355-4	R-T cont	28,2	0	0			According to witness - no shifting
WKS 923	TR	36,8	0	0		Steel coils	
TJT 868	TR	36,3	0	0		Steel	
WJV 780	TR	36,9	0	0		Steel	
LZ 9767	TR	32,8	0	0	0	Plywood	
TOTAL UD				**2247**			

Fig. Calculation of heeling moments at total cargo shifting on Upper Deck.

WIZ 881	TR	29,1	-7,9	-230		Steel pipes	Over board
WLG 217	TR	17	3,75	64		Beams	Lane stowed: 19,5 m free space - 2,55 - 0,6 - 5 x 2,55 m / 6 = 0,60 m
KY 6874	TR	7	4,35	30		Empty	
YY 3563	TR	25	4,95	124		Wood+motor	
MK 6660	TR	25	5,55	139		Wood	
WLJ 148	TR	22	6,15	135	262	General cargo	
145124-4	R-T cont	6	-7,9	-47	-47	IMDG cargo	Over board
LC 9333	TR	27,2	-1,9	-52		Wood	Over board
WII 676	TR	27,6	10,05	277		3 motors	Moving distance: 3 x 2,55 + 4 x 0,6 = 10,05 m
KU 7744	TR	21	13,2	277		Wood	Moving distance: 4 x 2,55 + 5 x 0,6 = 13,20 m
MY 7740	TR	11,8	0	0	503	General cargo	In position
OJ 88 BS	TR	26,3	-7,9	-208		Plywood	Over board
MS 7516	TR	17	0	0		IMDG cargo	
LB 6231	TR	17	0	0		General cargo	
KV 7762	TR	14	0	0	-208	Panel	
ME 9183	TR	25,7	0,5	13		Motor+axle	
VNF 476	TR	29	1	29		Wood	
WNH 649	TR	15	0	0		Panel	
PZU 600	TR	10	0	0	42	Pipes	
XZ 4133	TR	13,8	0	0		Plastic	
HT 9069	TR	12	0	0		Paper	
WLA 872	TR	12	0	0		Pallets	
JZ 6603	TR	13	0,5	7		Tyres	
WIZ 732	TR	29,5	1	30		Wood	
LV 7750	TR	27	1,5	41	77	Wood	
ME 9168	TR	12	0	0		Paper	
ML 7847	TR	12	0	0		Paper	
ET 6619	TR	12	0	0		Paper	
PSZ 634	TR	12	0	0		Pallets	
LX 7621	TR	15	0	0		Paper	
LL 7120	TR	12	0	0	0	Paper	
ACTUAL WD				**628**			**Real moment from actual shifting**

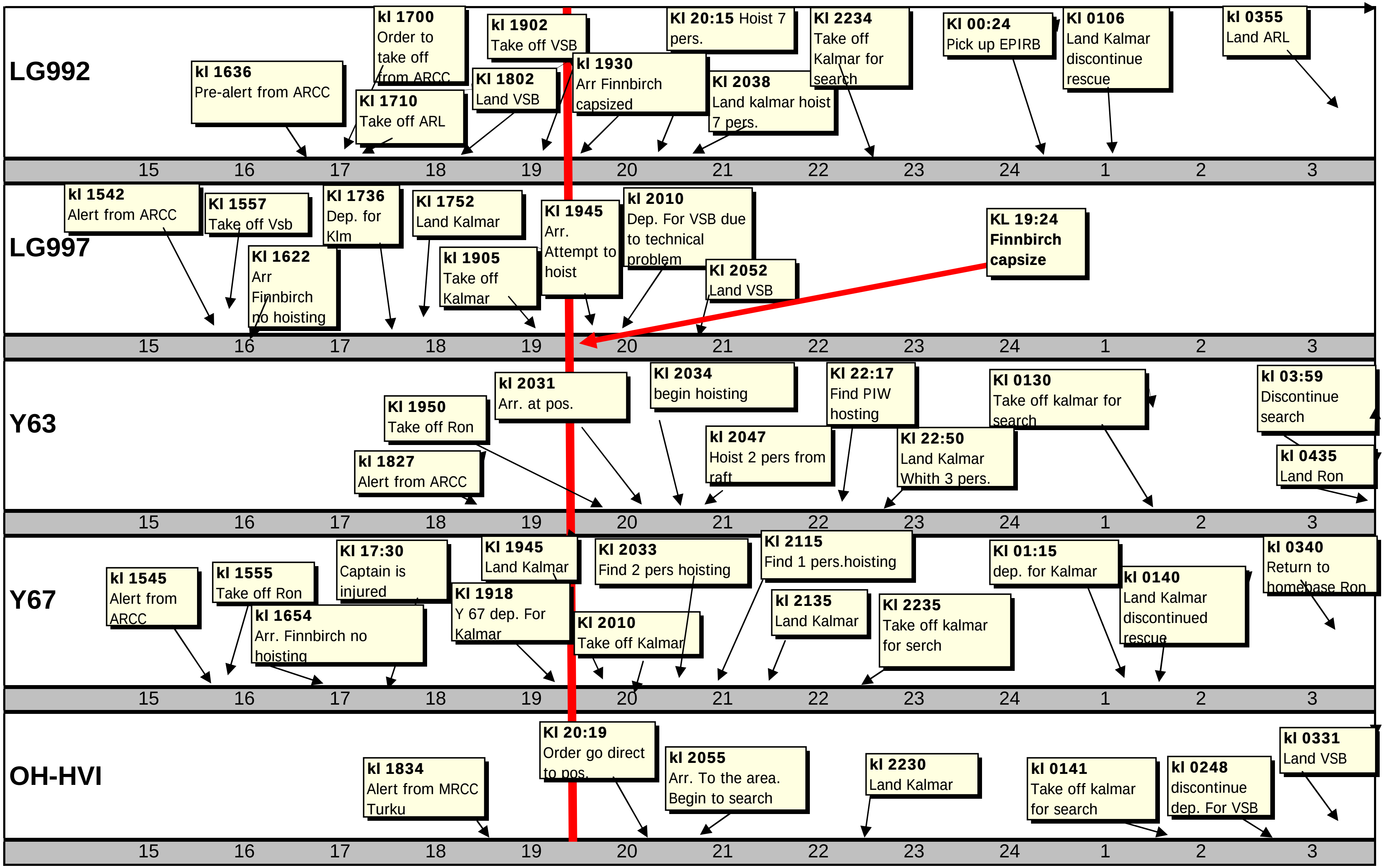
Fig. Calculation of heeling moments at total cargo shifting on Weather Deck.

With the above calculations a heeling moment according to below is obtained. It must be regarded as unrealistic that 100% of the units have been packed completely tight to port side. For example have witnesses told that the semi-trailers in the rear end of Upper Deck remained in their positions long after the initial cargo shifting. As a great deal of the semi-trailers on Weather Deck according to the photos from the rescue helicopters are still hanging in their lashings, it has been assumed that also some of the trailers on Upper Deck have remained in their lashings. Due to this it has been assumed that about 60% only of the cargo has shifted in the initial face on this deck.

For the units on Tank Top and Main Deck it has been assumed that a realistic cargo shifting is 90% of the maximum that can arise.

Deck	Total moment (tonm)	Assumed cargo shifting %	Likely moment (tonm)
Tank Top	**349**	**90**	**314**
Main Deck	**2290**	**90**	**2061**
Upper Deck	**2247**	**60**	**1348**
Weather Deck	**628**	**Real according to photos**	**628**
Total moment (tonm)	**5514**		**4352**

It is thus likely that a heeling moment of 4352 – 5514 tonmeter has aroused at an almost total cargo shifting.


LG992
kl 1636 Pre-alert from ARCC
kl 1700 Order to take off from ARCC
kl 1710 Take off ARL
kl 1802 Land VSB
kl 1902 Take off VSB
kl 1930 Arr Finnbirch capsized
Kl 20:15 Hoist 7 pers.
Kl 2038 Land kalmar hoist 7 pers.
Kl 2234 Take off Kalmar for search
Kl 00:24 Pick up EPIRB
Kl 0106 Land Kalmar discontinue rescue
kl 0355 Land ARL
15 16 17 18 19 20 21 22 23 24 1 2 3
LG997
kl 1542 Alert from ARCC
kl 1557 Take off Vsb
kl 1622 Arr Finnbirch no hoisting
kl 1736 Dep. for Klm
kl 1752 Land Kalmar
kl 1905 Take off Kalmar
Kl 1945 Arr. Attempt to hoist
kl 2010 Dep. For VSB due to technical problem
Kl 2052 Land VSB
KL 19:24 Finnbirch capsize
15 16 17 18 19 20 21 22 23 24 1 2 3
Y63
kl 1827 Alert from ARCC
Kl 1950 Take off Ron
kl 2031 Arr. at pos.
Kl 2034 begin hoisting
Kl 2047 Hoist 2 pers from raft
Kl 22:17 Find PIW hosting
Kl 22:50 Land Kalmar Whith 3 pers.
Kl 0130 Take off kalmar for search
kl 03:59 Discontinue search
kl 0435 Land Ron
15 16 17 18 19 20 21 22 23 24 1 2 3
Y67
kl 1545 Alert from ARCC
kl 1555 Take off Ron
kl 1654 Arr. Finnbirch no hoisting
Kl 17:30 Captain is injured
Kl 1945 Land Kalmar
Kl 1918 Y 67 dep. For Kalmar
Kl 2010 Take off Kalmar
Kl 2033 Find 2 pers hoisting
Kl 2115 Find 1 pers.hoisting
kl 2135 Land Kalmar
Kl 2235 Take off kalmar for serch
Kl 01:15 dep. for Kalmar
kl 0140 Land Kalmar discontinued rescue
kl 0340 Return to homebase Ron
15 16 17 18 19 20 21 22 23 24 1 2 3
OH-HVI
kl 1834 Alert from MRCC Turku
Kl 20:19 Order go direct to pos.
kl 2055 Arr. To the area. Begin to search
kl 2230 Land Kalmar
kl 0141 Take off kalmar for search
kl 0248 discontinue dep. For VSB
kl 0331 Land VSB
15 16 17 18 19 20 21 22 23 24 1 2 3