MV ESTONIA Accident 28.9.1994
Summary

- MV ESTONIA was on scheduled voyage from Tallinn to Stockholm, carrying 803 passengers and a crew of 186 people.

- The ship capsized and sank within about 40 minutes shortly after midnight due to water ingress on the open car deck through the open bow ramp.

- The ramp had been forces open by the detached bow visor whose attachments had failed due to wave impact loads about 10 minutes before the water ingress started.

- The significant wave height was about 4 m at the time of the accident, it grew to about 5.5 m later during the night.

- 852 people lost their lives, most of the dead were Swedish (501) and Estonian (285) citizens.

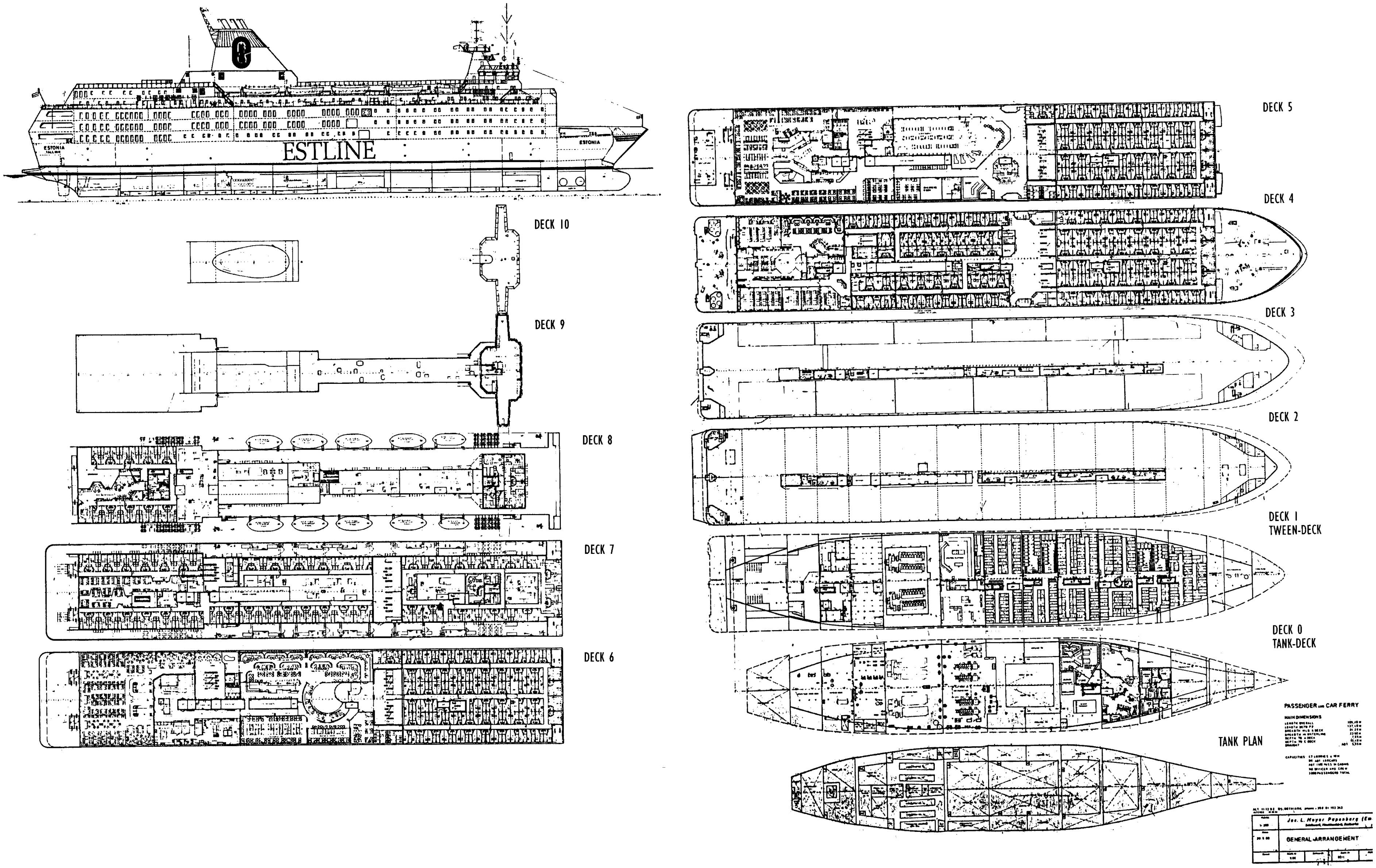
- Helicopters rescued 104 people, assisting vessels rescued 34.

- The joint Estonian/Finnish/Swedish Accident Investigation Commission was set up the day after the accident following a decision taken by the prime ministers of the three countries.

- A preliminary technical part report was released in April 1995, the final report was published in December 1997.

- The accident has resulted in significant changes in Codes, Rules and Regulations regarding passenger/roro vessels.

M/V ESTONIA – GENERAL ARRANGEMENT



MV ESTONIA Building/Operating History

- The vessel ”Viking Sally” was built by Jos. L. Meyer Shipyard October -79 – June -80 for Sally, one of the partners in Viking Line.

- Its design was based on DIANA II, ordered by Slite, (the other partner in Viking Line), but was lengthened with a 18.4 m midship section. This was a condition for meeting the extraordinary short delivery time.

- Hoistable decks, ramps and manoeuvring/control equipment for ramps and visor was delivered by a subcontractor, von Tell AB.

- The ship was built to the rules of Bureau Veritas and to the rules and regulations of the Finnish Maritime Administration and applicable IMO-Codes.

- The vessel was at the time the second largest roro/pax ferry ever built for the Baltic Sea.

- Estline Marine Co Ltd registered in Cyprus controlled 50%/50% by Estonian State/Nordström & Thulin AB
  Crew management – Estonian Shipping Co Ltd
  Technical management – Nordström & Thulin AB

	Finnish flag 1980–1992			*Estonian flag 1993–1994*
Name	**Viking Sally** →	**Silja Star** →	**Wasa King** →	**Estonia**
Date	June 1980–	April 1990–	Jan 1991–	Jan1993
Route	Stockholm–Mariehamn–Turku	Stockholm–Turku	Vaasa–Umeå and Sundsvall	Talinn–Stockholm
Owner	Rederiaktie-bolaget Sally	Effjohn Oy	Wasa Line	Estline Marine Co Ltd

What initiated the accident ?

- The accident was initiated by failure of the bow visor attachments under wave impact loads.

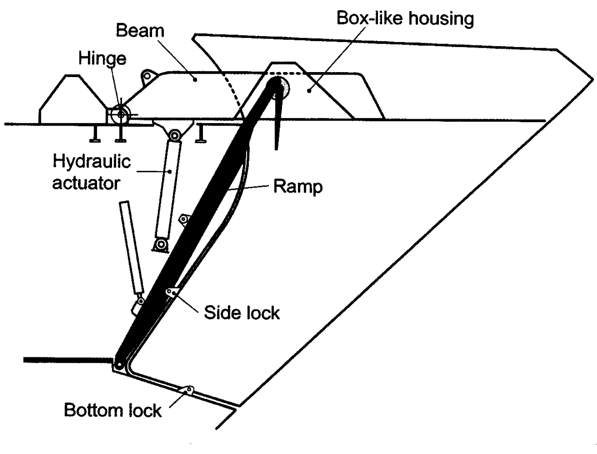
- The failure was primary due to local overload. The attachments were not designed to withstand even the rather moderate wave condition at the the time of the accident.

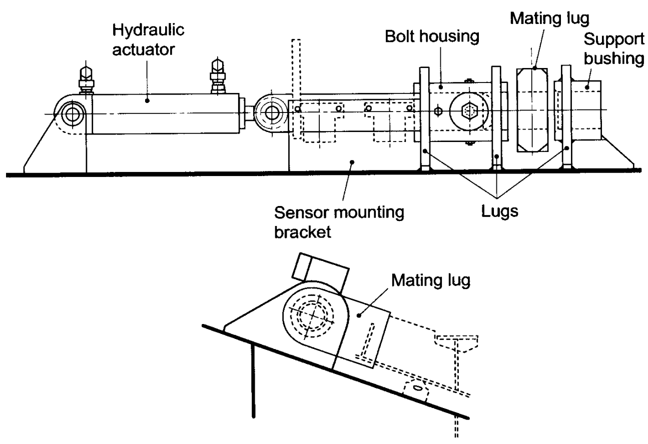
- Bureau Veritas had no detailed rules for design of visor locking devices and hinges. BV requested the locking devices to be approved by Finnish Administration.

- The Finnish administration did not make any hull surveys because the ship was classed under the rules of an approved classification society.

- The shipyard made rough estimates of wave loads according to other guidelines and rules available at the time (but which later have been significantly strengthened up). The assumptions made did not reflect realistic load distributions.

- The locking devices were not manufactured properly according to the design intent.

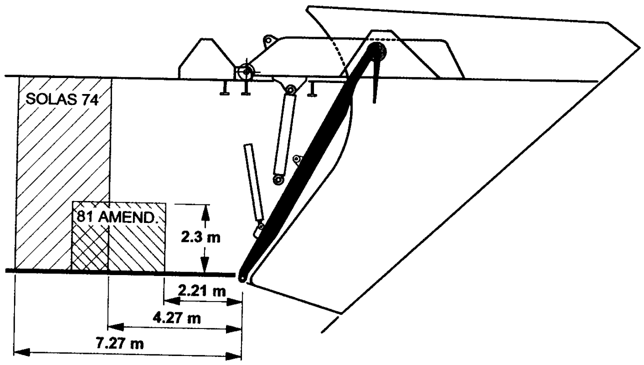




What made the vessel capsize and sink ?

- The forward ramp was integrated in the visor structure and was thus forced open when the visor attachments failed.

- There was no collision bulkhead extension in proper position according to SOLAS. The ramp was located to far forward to fulfil the requirements.



- The fully open car deck on these roro ferry designs make them extremely sensible to water ingress.

- The officers did not reduce speed or change course when the first indications of something being wrong at the bow or the forward part of the car deck was given.

- The bow visor could not be seen from the conning position, and the indicator lamps for locked visor did not detect the failure of the locking devices.

- The ship was turned towards the waves when the ship started to heel over.

- The rapidly developed list to starboard could not be compensated by the heeling tanks since the port tank already was full at departure.

- The buoyancy reserve in the superstructure diminished when windows and doors broke and progressive flooding started from aft/above.

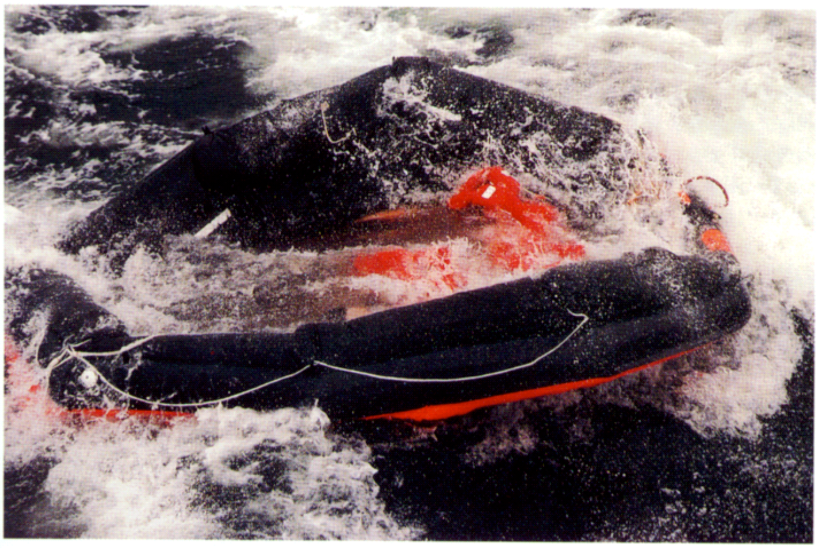
What made the outcome so serious ?

- The list developed rapidly, it became 15° within only a few minutes and over 40° within 15 minutes.

- The narrow passages in accommodation areas and the staircases quickly became crowded with injured and panic-stroken people. It was almost impossible to reach open decks when the list was more than 30°. Only about 300 people reached outer decks.

- The lifeboat alarm was not given until about five minutes after the list developed. No information was given to passengers over the public address system.

Figure 17.8 ESTONIA liferaft drifting upside-down.

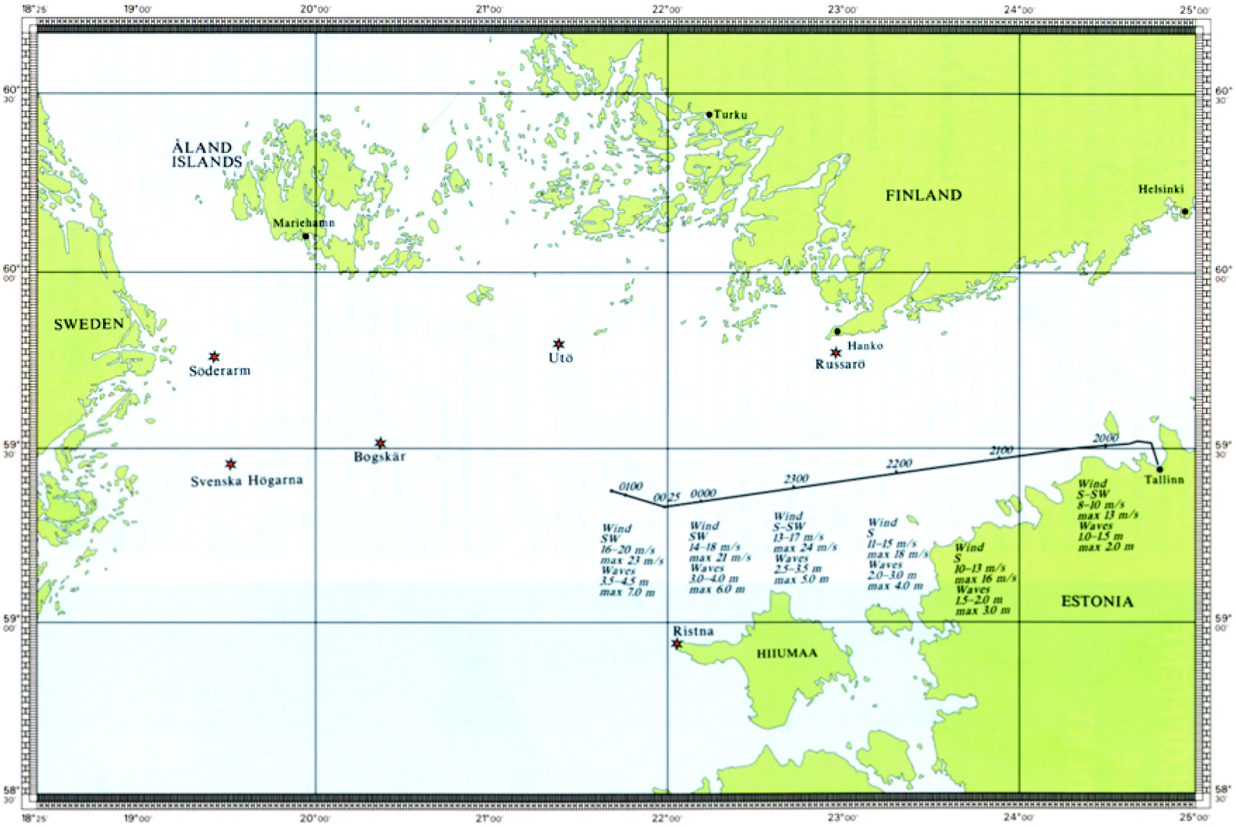


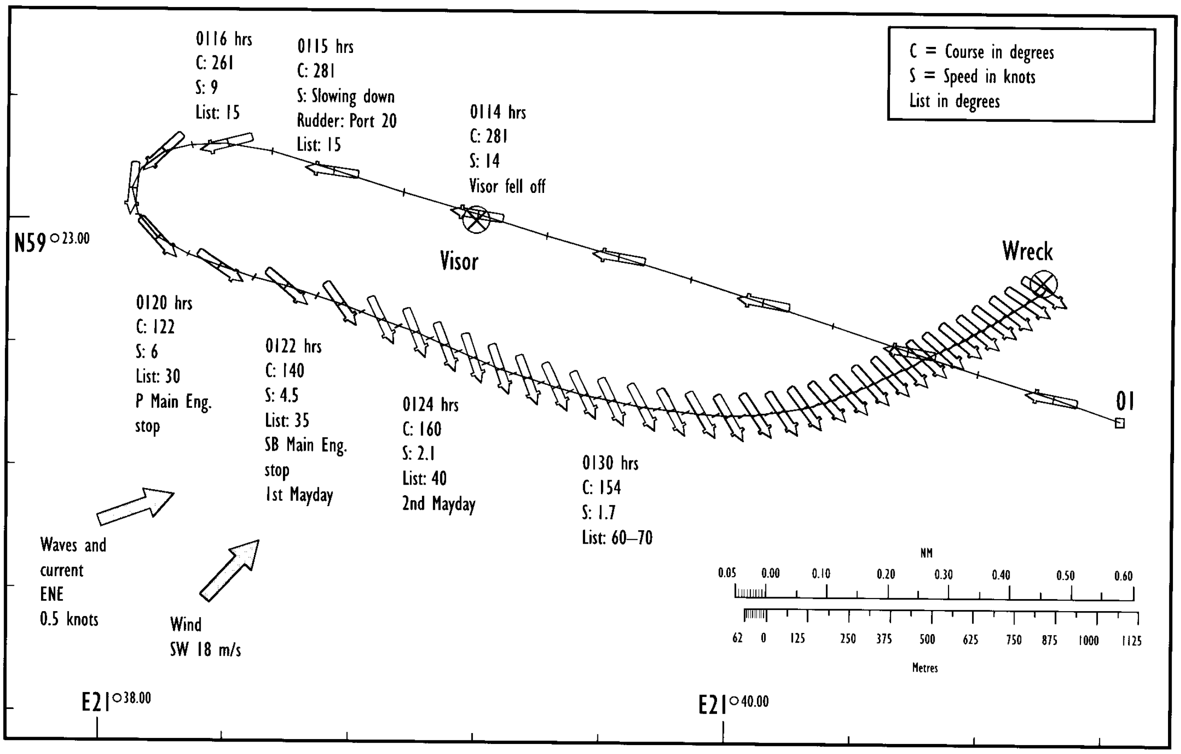
- None of the lifeboats could be launched properly. It was difficult to launch life rafts and most of the rafts was water trapped or overturned at sea.

- Assisting vessels did generally not find it possible to rescue people from the sea.

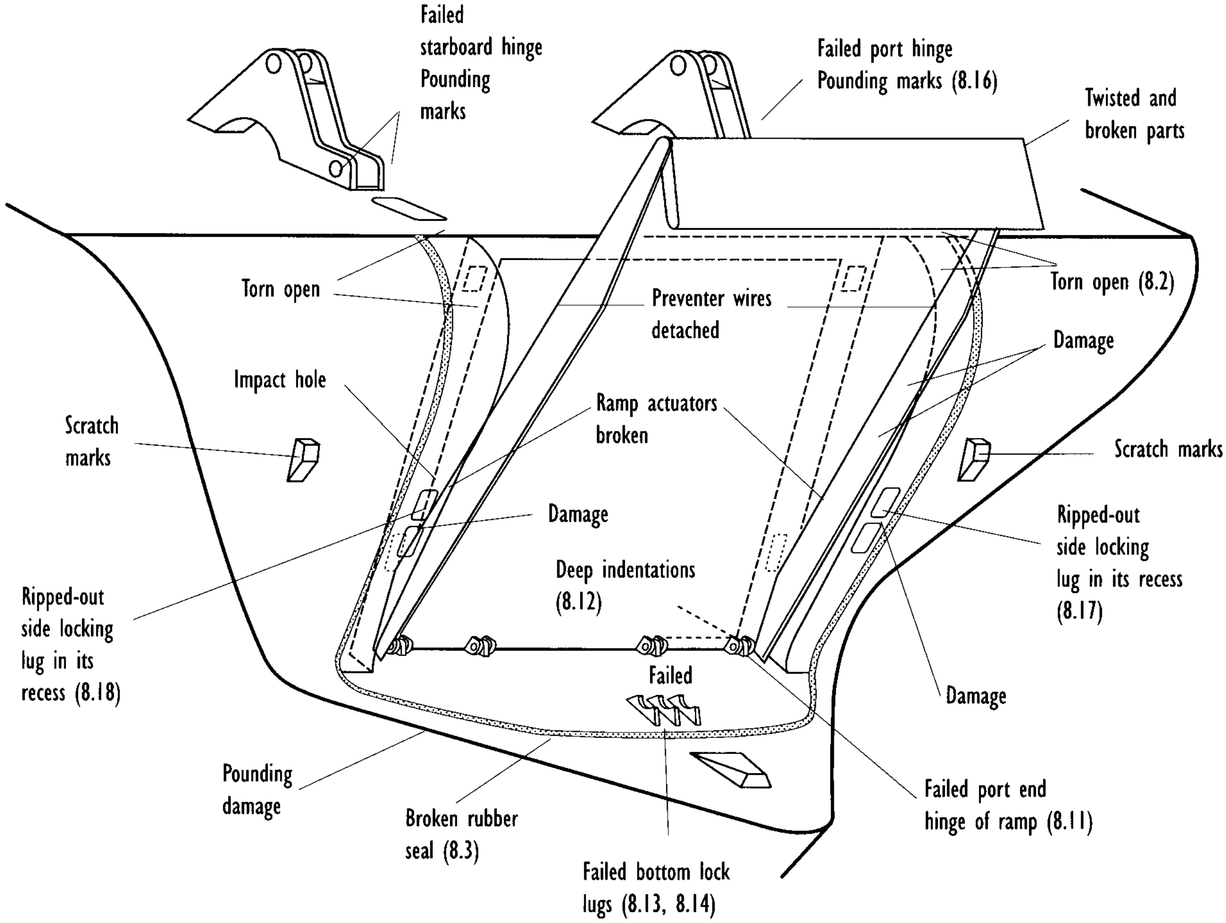
- The first helicopter arrived about 90 minutes after evacuation had become impossible. The capacity of helicopters was limited as most of them could not land or lower survivors onto the surrounding ships. Only one helicopter managed to rescue more than 15 people in total.

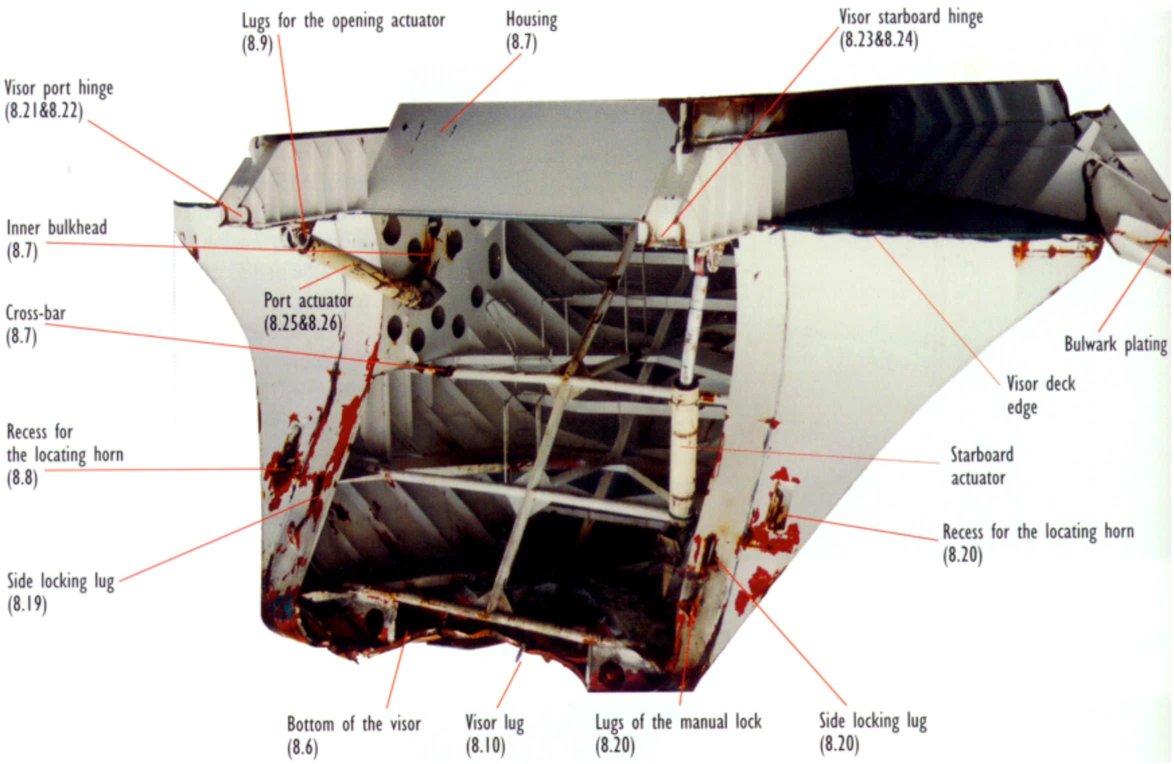
Sequence of events





Summary of damage to the bow area



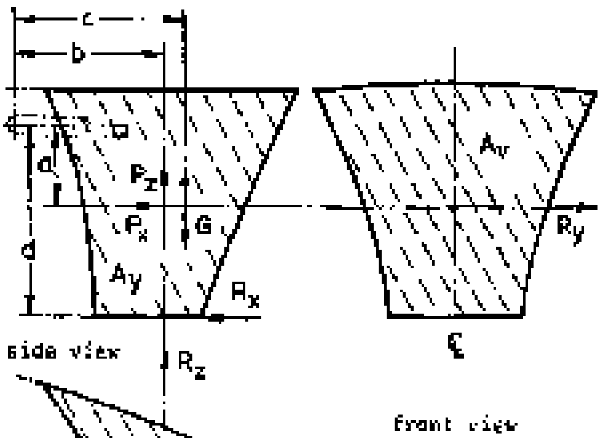


Analysis of visor design and strength

- Bureau Veritas had no rules for design of visor attachments, they made a note on the drawing that the locking devices should be examined and approved by the national authority. However the Finnish Maritime Administration did not examine the installation as the ship was built according to the rules of an approved classification society.

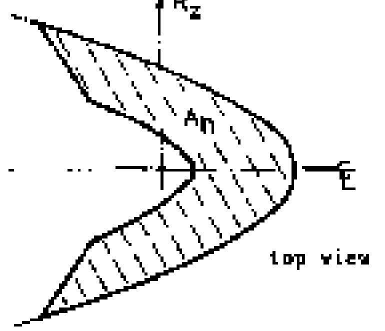
- The shipyard made hand calculations of required cross sectional area of all attachment points (3 locks, 2 hinge points) assuming HT-Steel (St52-3) as requested by Bureau Veritas.

- The calculation was made similar to what was proposed by other class. societies but the load distribution seems to have been misinterpreted.



$$R_{zl} = P_z - g \cdot G$$

$$R_{xf} = \frac{g \cdot G \cdot c + P_{xc} \cdot a - P_z \cdot b}{d}$$



Standard method found in the rules of Lloyds Register, Germanisher Lloyd, DNV and IACS-82.

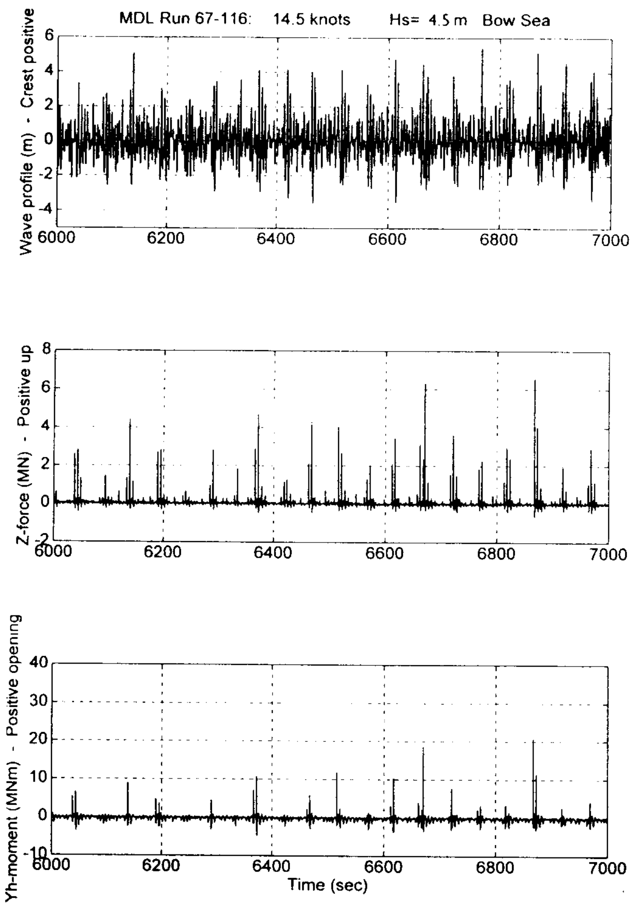
- A design wave pressure on projected areas of 54 kPa was used in shipyard calculations. (LR-78 would have given 30/60 kPa, GL: 157 kPa.) A resultant design load of of 1 MN per attachment was calculated giving a required cross sectional area of 6100 mm^2.

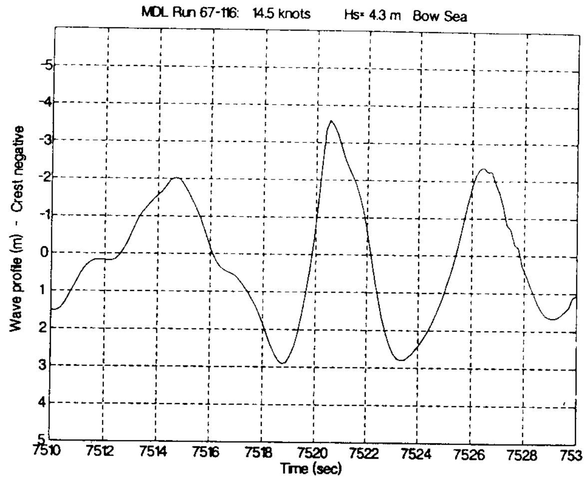
- The actual installation found was made of mild steel and the cross sectional area of the bottom lock was significantly less than required.

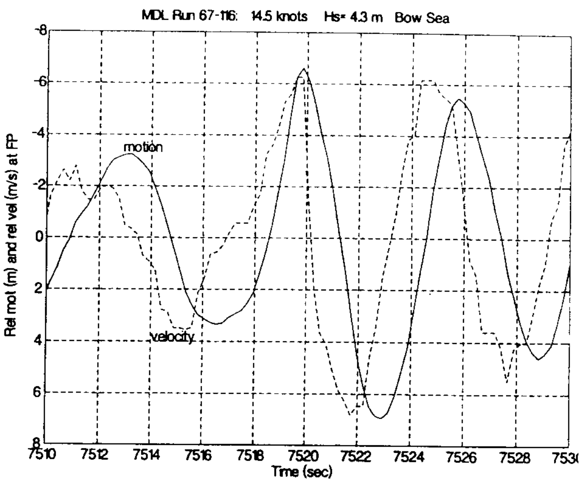
- Analysis of the ultimate strength in the installation as found gives approx. 1.5 MN for the bottom lock, 1.2/1.6 MN for side locks and 5-7 MN per hinge point (dependent on the load direction).

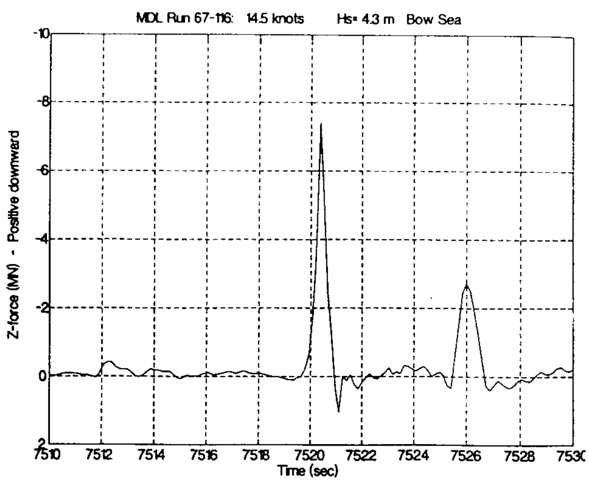
Analysis of wave loads at the time of the accident - Model test results

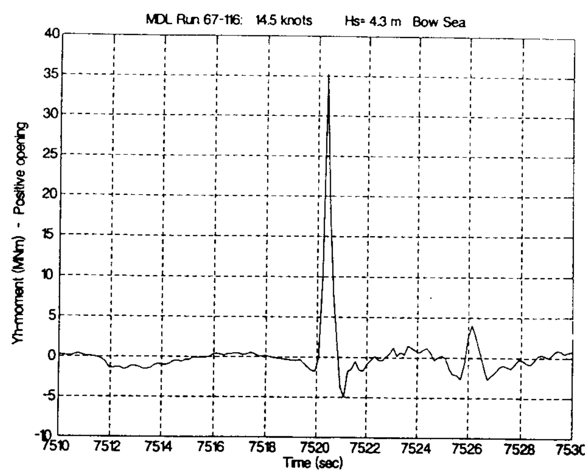
Figure 12.3 Example of time series from model tests.



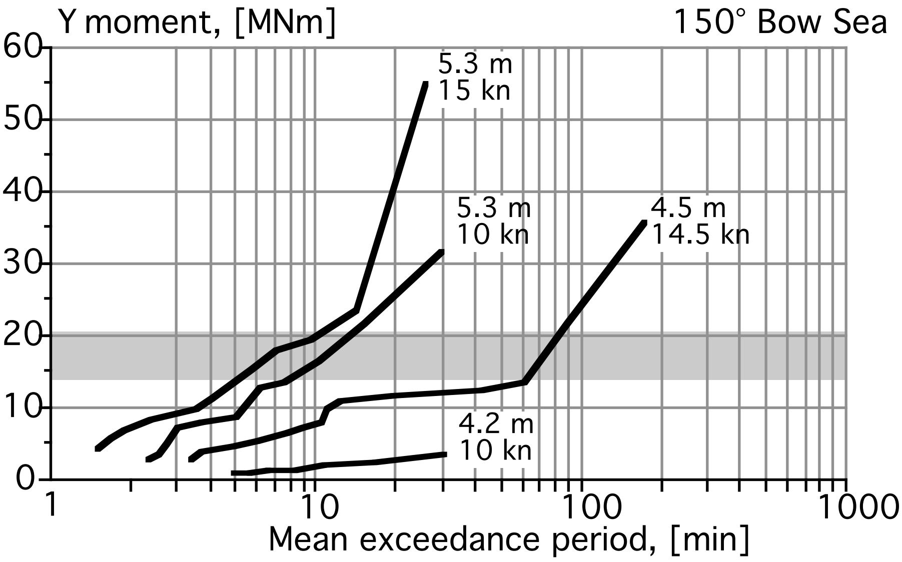


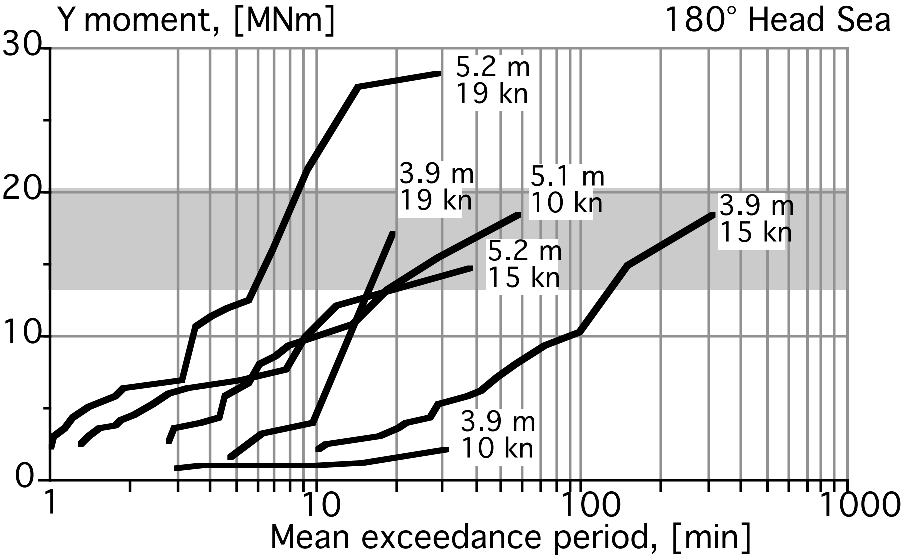


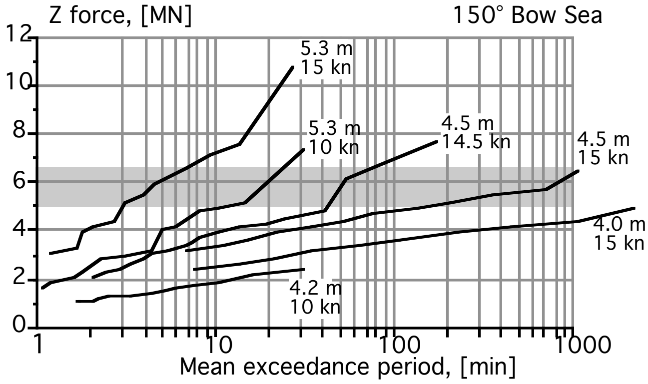


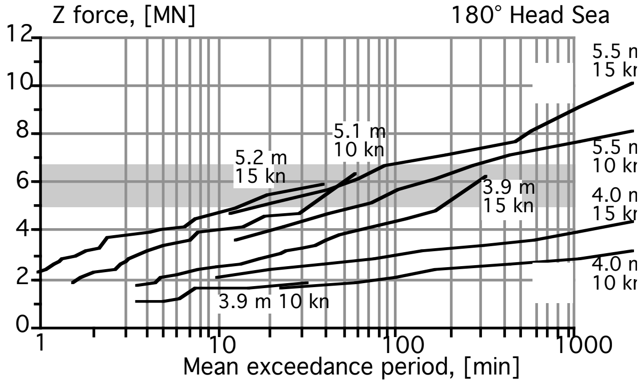


Analysis of wave loads at the time of the accident - Probability distributions



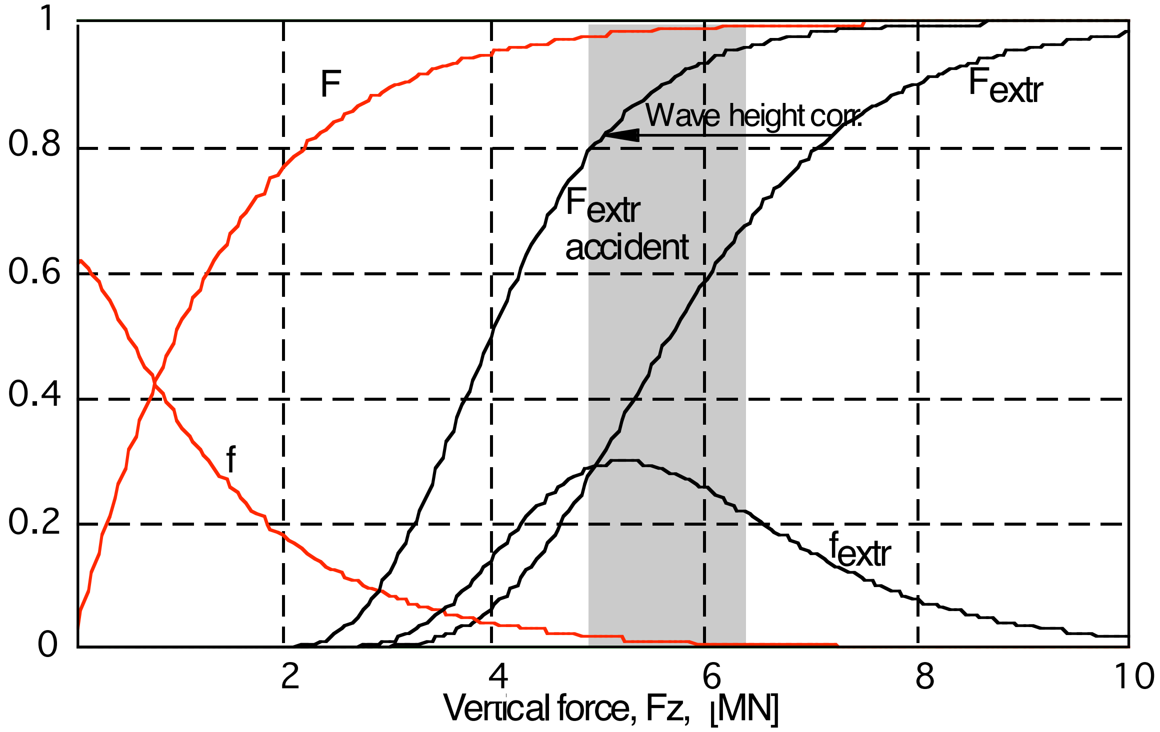


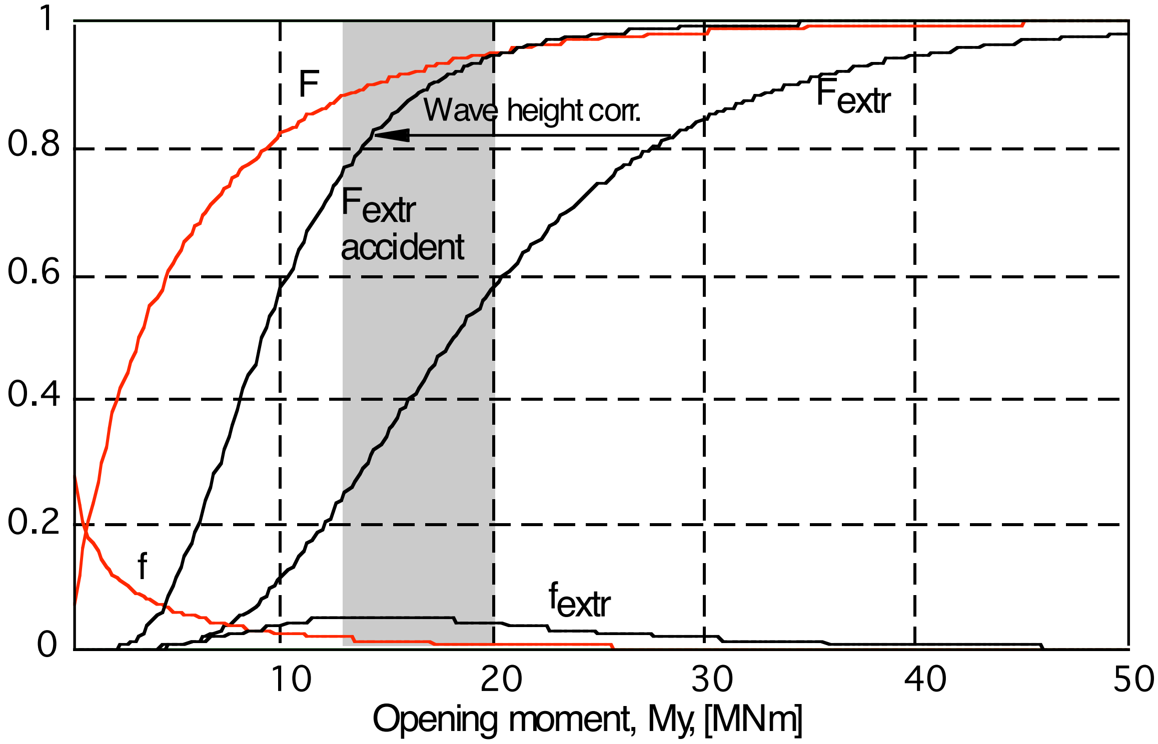




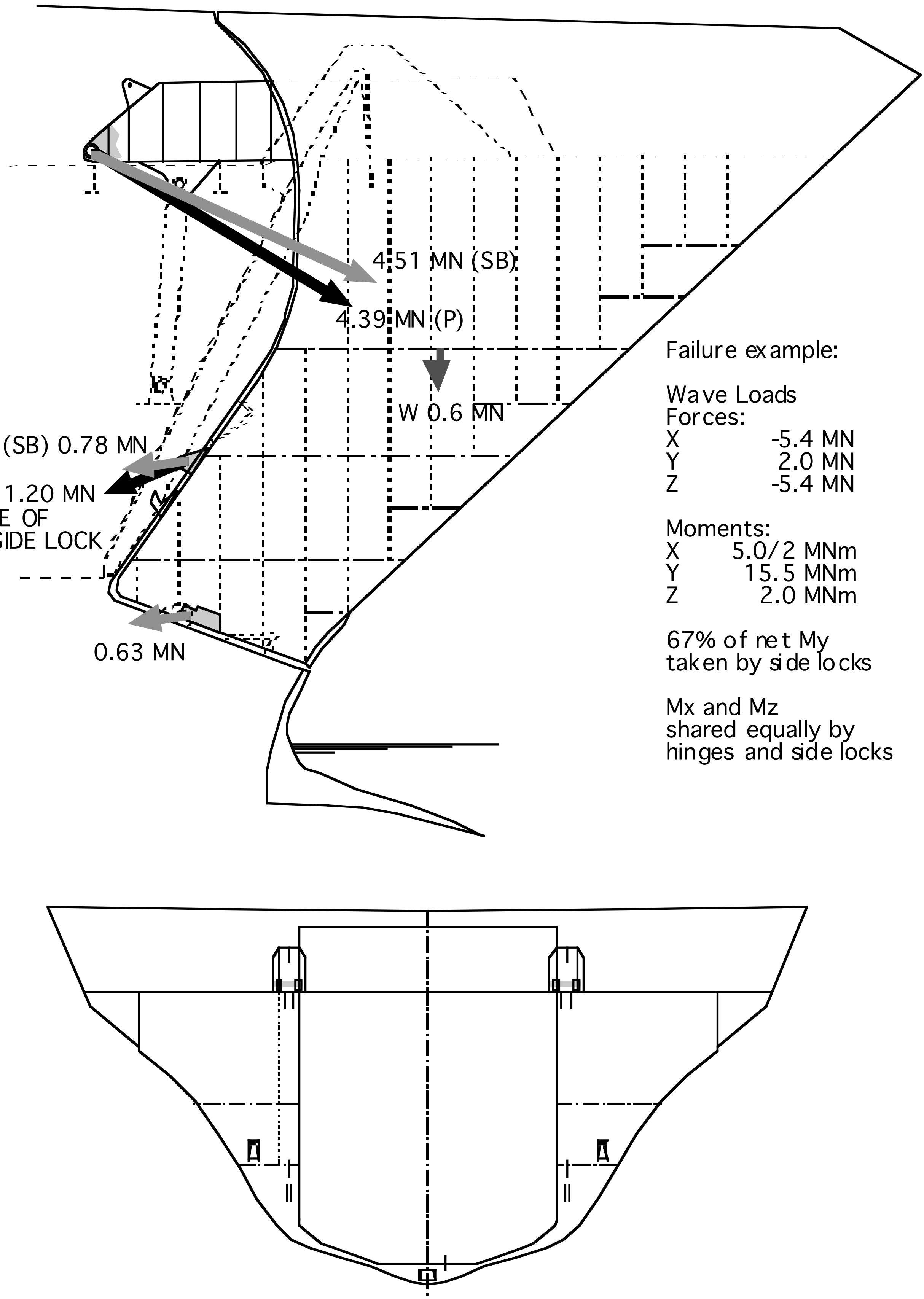
5-7 MN per hinge point (dependent on the load direction).

Analysis of wave loads at the time of the accident - Extreme distributions

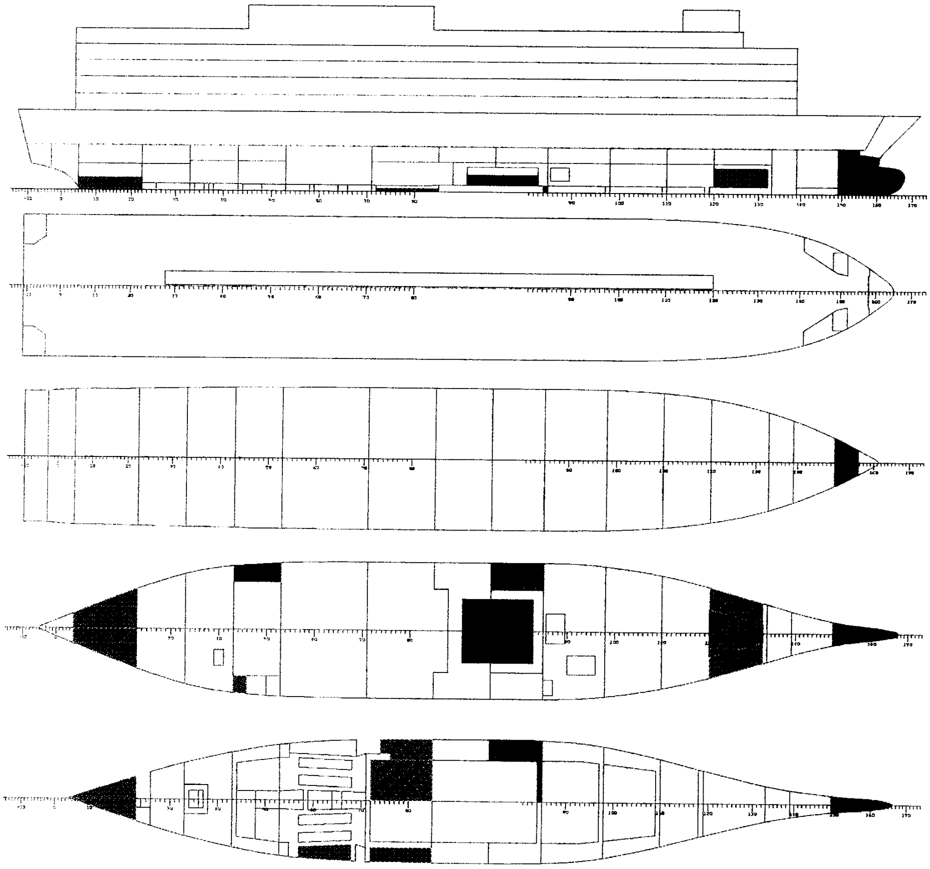


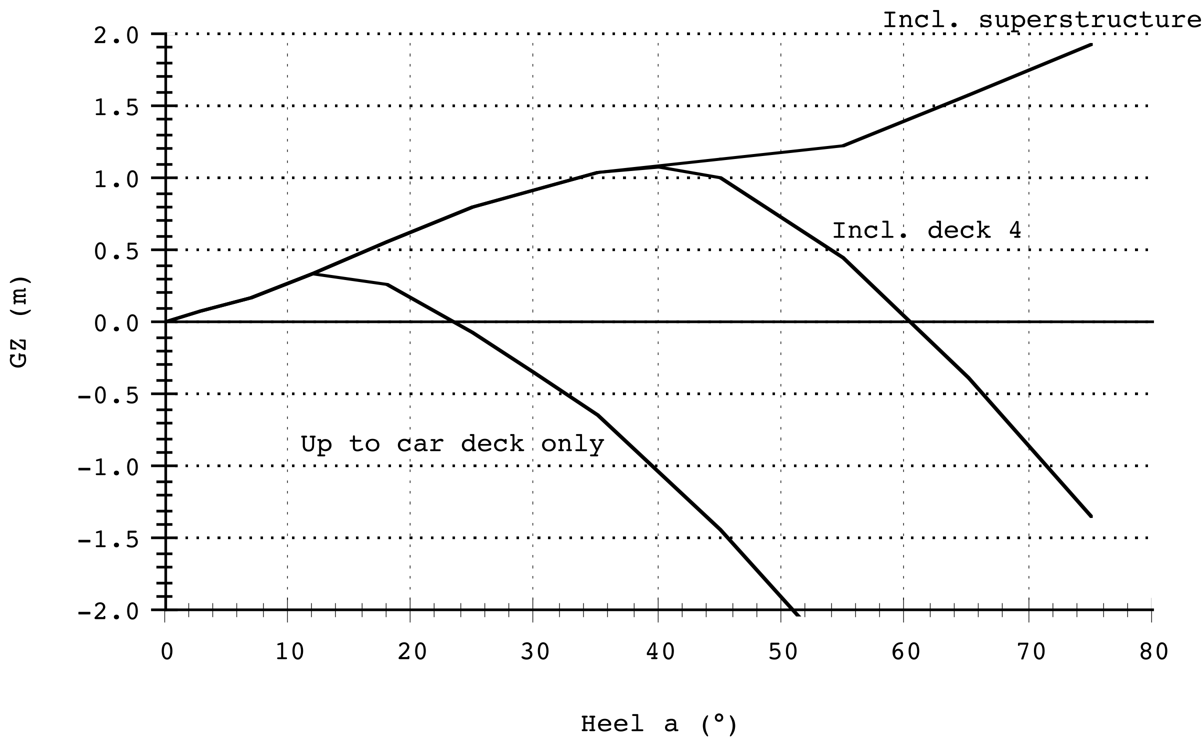


Example of load distribution for a possible failure condition

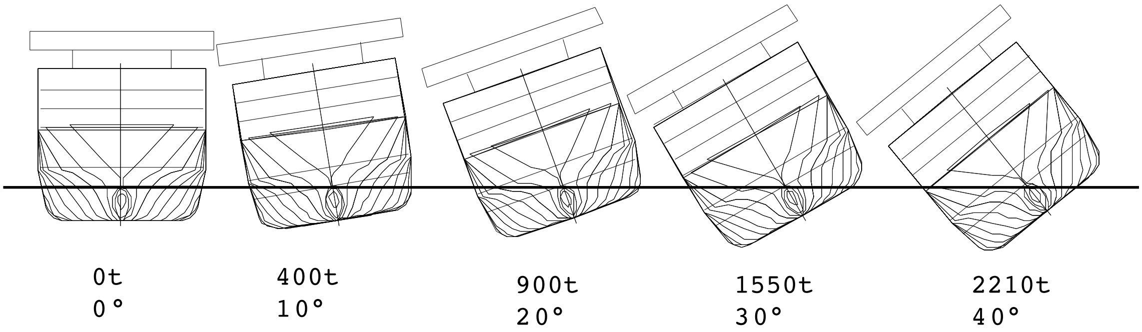


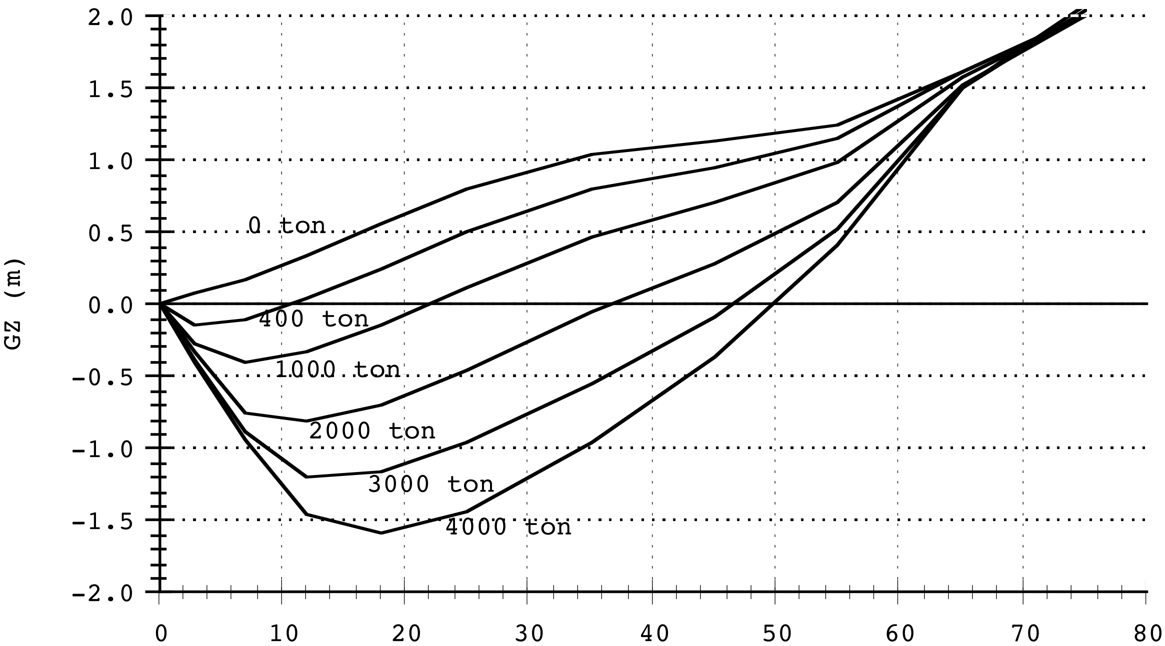
Analysis of the capsize – Intact stability

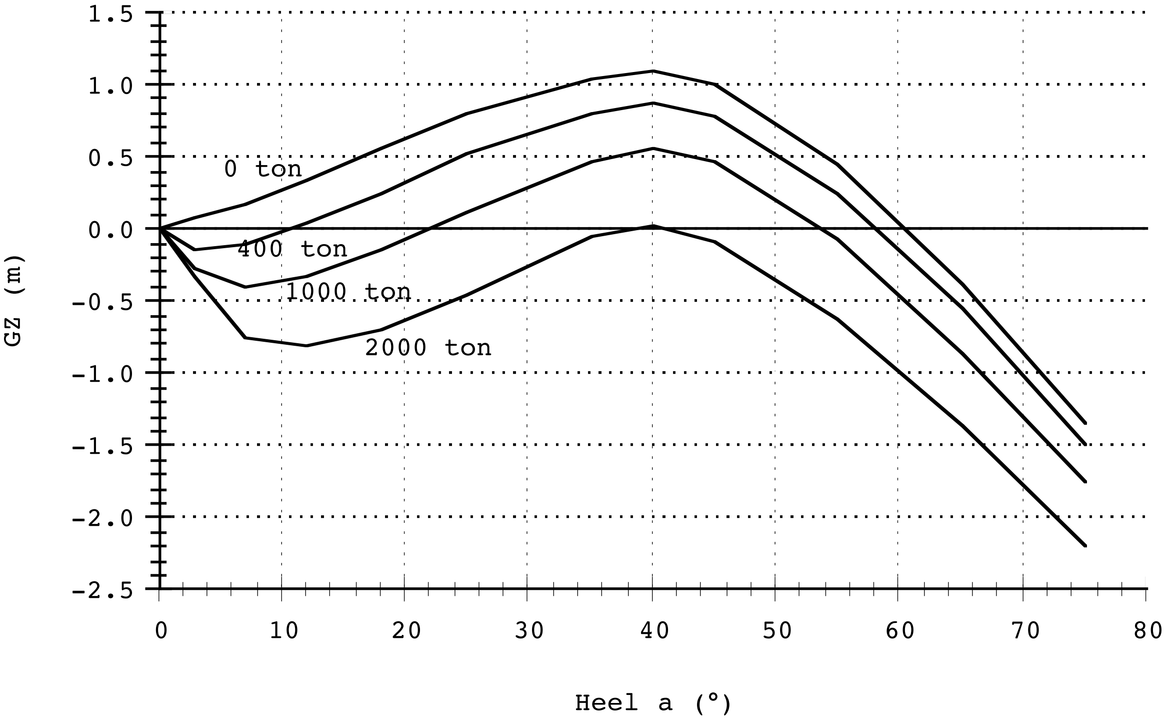




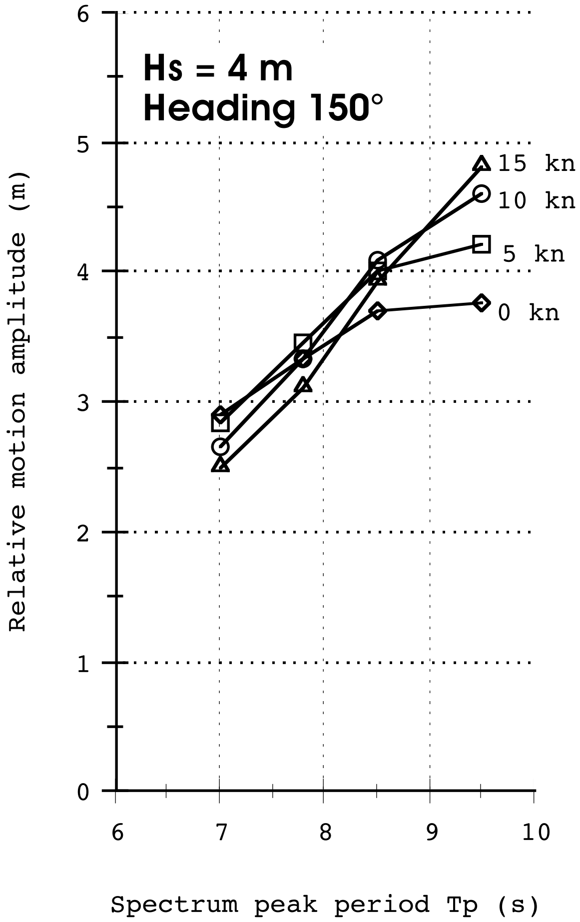
Analysis of the capsize – Stability during water ingress

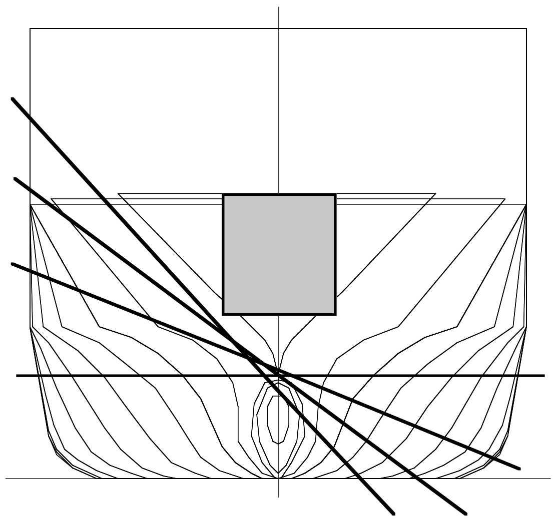


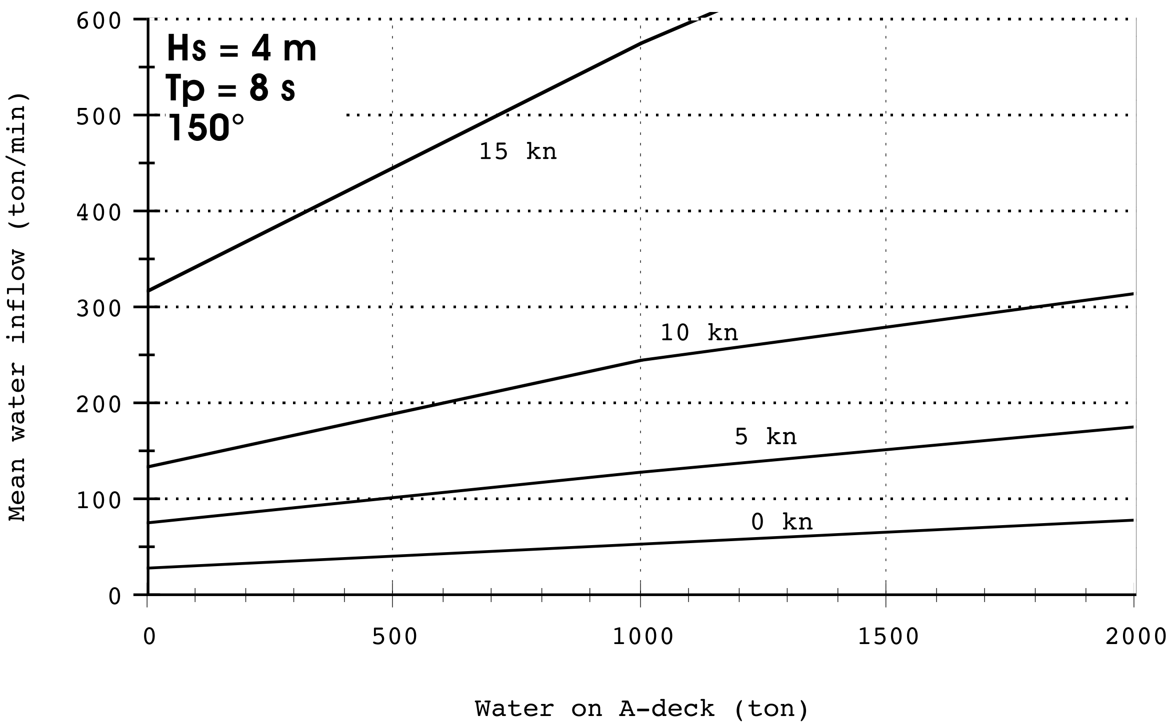




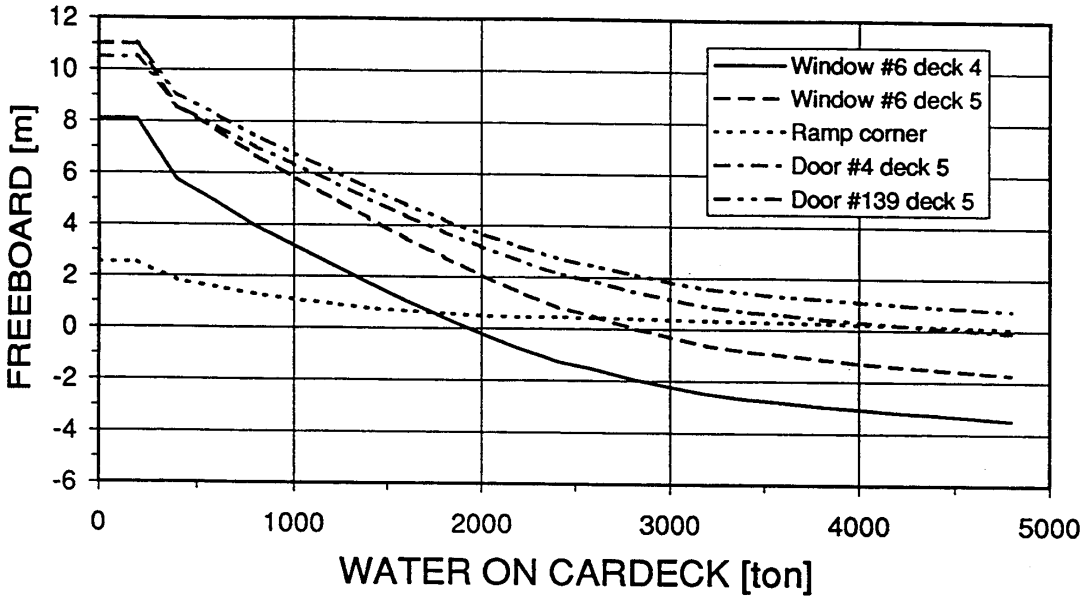
Analysis of the capsize – Inflow simulations







Analysis of the capsize – Progressive flooding



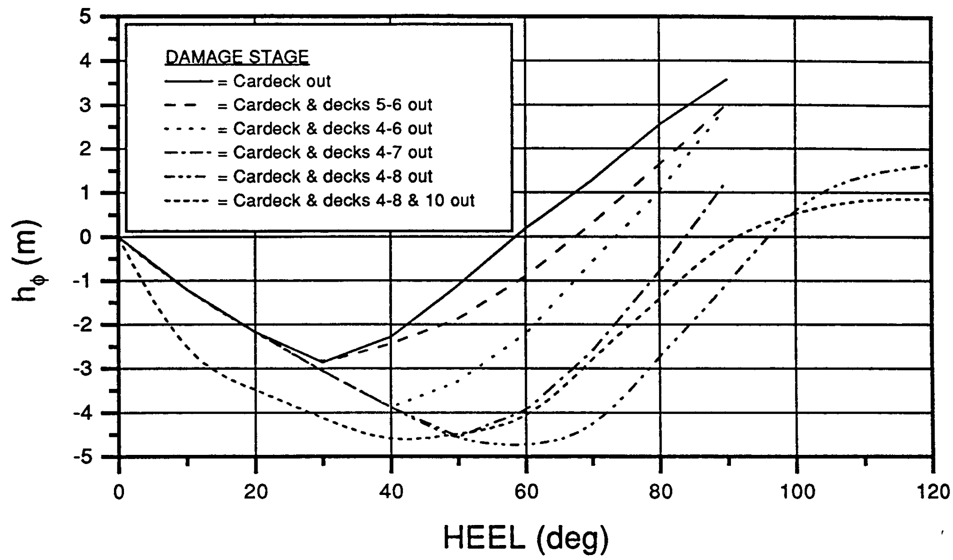


Figure 4.16 Static stability curves, effect of damage stage, 3200 ton water on cardeck.

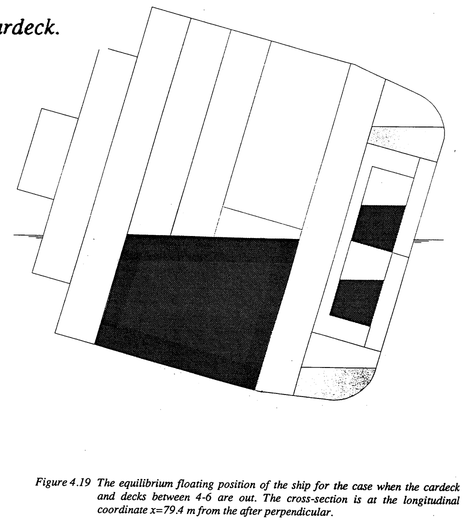


Figure 4.19 The equilibrium floating position of the ship for the case when the cardeck and decks between 4-6 are out. The cross-section is at the longitudinal coordinate x=79.4 m from the after perpendicular.

What could have been done to prevent the accident ?

Initiation

- Strict routines for identification (FSA), design and inspection of vital safety components.

- Upgrading of existing vessels according to new requirements based on research and experience. (The strength of the visor locking devices would have been 5 - 10 times higher if 1994 rules would have been applied).

- Learning by experience: DIANA II suffered severe damage to the visor attachments after heavy weather in January 1993. More than 14 roro/pax ferries have had incidents or even complete failure of visors before the ESTONIA. A Swedish Maritime Administration surveyor have reported that the visor attachments are far to weak on many ferries already at the time of newbuildning of the ESTONIA.

Capsizing

- Strict routines for compliance with SOLAS.

- Learning by experience: The HERALD OF FREE ENTERPRISE accident highlighted the risk with water on deck on roro/pax ferries.

- Training: The crew should have been trained for immediate actions in case of possible water ingress. Correct actions at the time of the first indications (reported sounds from the bow) would have saved the ship.

- Relevant alarm indicators on the bridge would have showed when the visor was detached.

Outcome in terms of lives lost

- Better conditions for evacuation to open decks and to the sea.

- Functioning life-saving equipment would have saved many lives. Equipment for taking people from the sea on board other vessels.