FINAL REPORT
ON THE CAPSIZING ON 28 SEPTEMBER 1994
IN THE BALTIC SEA
OF THE RO-RO PASSENGER VESSEL
MV ESTONIA

December 1997 ESTONIA

The Government of the Republic of Estonia

Final report on the MV ESTONIA disaster of

28 September 1994

Pursuant to an agreement concluded between Estonia, Finland and Sweden a "Joint Accident Investigation Commission" for the investigation of the capsizing of the passenger vessel MV ESTONIA on 28 September 1994 was set up on 29 September 1994, in accordance with a decision taken by the Prime ministers of the three countries.

The Commission consists of three members from each state and is chaired by one of the members from Estonia, the Flag State of MV ESTONIA. Each state has appointed experts to assist the Commission.

In April 1995 the Commission published a part-report that covered its first technical findings and conclusions. The Commission has now concluded its task and hereby presents the final report on the accident. On the whole the conclusions in the part-report are still valid. As well as technical matters, this final report covers all other factors and circumstances found to have contributed to the inception and development of the accident. Should there be any discrepancies between translations and this English text, the English text is to be considered the authoritative version. The final report is unanimous on all points.

for Estonia	for Finland	for Sweden
Uno Laur	Kari Lehtola	Ann-Louise Eksborg
Uno Laur	Heimo Iivonen	Hans Rosengren
Chairman	Tuomo Karppinen	Olle Noord
Heino Jaakula		
Jaan Metsaveer		

Identical letters to:

The Council of State of the Republic of Finland

The Government of the Kingdom of Sweden

PREFACE

The Joint Accident Investigation Commission has concluded its investigation of the foundering of the MV ESTONIA, a disaster that has taken the greatest toll of human life in the Baltic Sea in times of peace.

The Commission has thoroughly considered all available information directly related to the accident and the rescue operation. The information includes documents and statements regarding the ship and its operation, witness statements, analysis of the prevailing weather and sea conditions, results from diving investigations and analysis of the recovered bow visor. In addition, to reach a full understanding of the sequence of events, the Commission has initiated theoretical and experimental studies to analyse in more detail the vessel's wave-induced motion and loads, structural strength, manoeuvring characteristics and stability when flooded. The Commission has furthermore found it necessary to investigate the design procedures and operating history of the vessel as well as to collect information on other bow visor failure incidents and to consider legal and administrative issues.

This final report covers all factors and circumstances considered to have contributed to the development and outcome of the accident. In the report the Commission presents the facts found, the analysis and evaluation, conclusions drawn on the basis of the work and the recommendations made to help prevent the occurrence of similar accidents in the future. The fundamental purpose of investigating the accident was to determine its circumstances and causes, with the aim of improving the safety of life at sea and avoiding further accidents. It is not the Commission's task to apportion liability nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame.

Many people and organisations have helped significantly with support, advice and assistance to the Commission. Their contributions are gratefully acknowledged.

During the investigation, circumstances brought about changes in the membership of the Commission and its experts. It is with great regret that we remember Bö rje Stenströ m and Simo Aarnio, who did not live to see the final report. Their expertise and contribution to the report were of the greatest value.

Lastly, the Commission wishes to express to the relatives and friends of those who perished in the accident, its deepest sympathy

THE JOINT ACCIDENT INVESTIGATION COMMISSION

Appointment

The joint Estonian/Finnish/Swedish Accident Investigation Commission was set up on 29 September 1994, in accordance with a decision taken on 28 September 1994 at Turku, Finland, by the prime ministers of the three countries.

Chairmen

Andi Meister, Minister of Transport and Communications of the Republic of Estonia (until 1996-07-30)

After his resignation from the minister's post on 17 April 1995 Andi Meister's powers as a member of the Commission were extended by order the Estonian Government 12 May 1995.

Uno Laur, Master Mariner, Chairman, Consulting of Merchant Marine Ltd, Nominee of the President of the Republic of Estonia (from 1996-09-24)

Estonian members

Uno Laur (until 1996-09-23)

Enn Neidre, Master Mariner, Head, Navigational Department, Estonian Shipping Company (unti11996-04-16)

Priit Männik, Master of Laws, Deputy Director-General, Estonian Police (from 1996-04-16 until 1997-IO-27)

Heino Jaakula, Naval Architect, Head of Department, Estonian National Maritime

Board (from 1996-07-30)

Jaan Metsaveer, D. Sc., Professor, Tallinn Technical University (from 1997-10-28)

Finnish members

Kari Lehtola, Master of Laws, Director, Accident Investigation Board

Heimo Iivonen, Rear-admiral, Director, Finnish Life-Boat Society

Tuomo Karppinen, D.Tech., Senior Research Scientist, Technical Research Centre of Finland, Manufacturing Technology

Swedish members

Olof Forssberg, Master of Laws, Director-General, Board of Accident Investigation (until l997-OS-27)

Ann-Louise Eksborg, Master of Laws, Director-General, Board of Accident Investigation (from 1997-06-16)

Hans Rosengren, Master Mariner, Chief Nautical Investigator, Board of Accident Investigation

Börje Stenström, Naval Architect, Chief Maritime Technical Investigator, Board of Accident Investigation t 25.2.1997

Olle Noord, Master Mariner, United Tankers AB (from 1997-06-16)

Estonian experts

August Ingerma, Ph.D. (Structural Integrity)

Heino Jaakula (until l996-07-29)

Jaan Metsaveer (until l997-10-27)

Priit M nnik (until 1996-04-15)

Enn Neidre (from 1996-04-17)

Estonian observer

Kalle Pedak, Master Mariner, Director-General, Estonian National Maritime Board

Estonian administrators

Tiit Kaurla, M.Sc. (Tech.), Ministry of Transport and Communications

Aet Varik, B.A., Ministry of Transport and Communications

Finnish experts

Simo Aarnio, Master Mariner (Navigation) 22.1.1996

Kari Larjo, Master Mariner (Navigation) (from 1996-02-27)

Harri Rahikka, Detective Chief Superintendent (Liaison, Finnish Police)

Klaus Rahka, D.Tech. (Structural Integrity)

Seppo Rajamäki, M.Sc. (Maritime Radio)

Finnish observer

Jukka Häkämies, Head, Division of Maritime Inspections, Finnish Maritime Administration

Finnish administrator

Pirjo Valkamajoutsen,

M.Sc., Accident Investigation Board

Swedish experts

Mikael Huss, Ph.D. (Naval Architecture)

Olle Noord (until 1997-06-15)

Bengt Schager, M.Sc. (Organizational Human Behaviour) (until 1997-09-08)

Swedish observer

Sten Anderson, Master Mariner, Swedish Maritime Administration

Svedish administrator

Gunnel Göransson, Board of Accident Investigation

Status

The Joint Commission was set up to find the cause of the accident, to examine the reasons why the loss of lives attained such magnitude and to present proposals for measures that would help to prevent the future occurrence of a similar accident.

At the first meeting of the Commission, on 29 September 1994, it was deemed essential that the Commission act as a single unit in drawing conclusions and issuing official reports, but in carrying out the investigation the parties of the three countries were to have an independent status, without any duty to report back to, or to act on the instructions of, the states that proposed their appointment.

Work schedule

At the first meeting, the areas of the investigation were divided between the Estonian, Finnish and Swedish parties of the Commission.

The Commission has had 20 internal meetings, lasting a total of 51 days. In addition to the meetings of the entire Commission, meetings have been held by experts and other working groups.

Tracing the wreck of the ESTONIA

The locating of the wreck of the ESTONIA began on the day after the accident, 29 September 1994. The wreck was found on 30 September 1994.

Underwater operations by ROV

The wreck was filmed with a submarine ROV camera on 2 October 1994 and again for further details on 9-10 October 1994 and 19 June 1996.

Tracing and recovering of the bow visor

The bow visor of the ESTONIA was found on 18 October 1994. It was raised to the surface on 18 November 1994 and taken ashore in Hanko, Finland.

Diving operations

Diving investigations of the wreck, including a survey of the bow area and the navigation bridge, were carried out on 2-5 December 1994.

SUMMARY

This is the final report by the Joint Accident Investigation Commission on the background and sequence of events leading to the foundering of the ro-ro passenger ferry ESTONIA shortly before 0200 hrs (If not otherwise stated all times in the report are given in Estonian time = UTC + 2 hrs.) on 28 September 1994, and on the subsequent rescue operation. The vessel was on a scheduled voyage from Tallinn to Stockholm with 989 people on board.

The report consists of four parts. The first part gives factual information on the accident, the rescue operation, and on the ESTONIA and her operation. It includes a summary of testimonies by the survivors. The second part presents background information, or associated facts related to the accident such as a short development history of the passenger ferry traffic in the Baltic and a review of bow door failures. The third part presents the results of the analysis and evaluation by the Commission of the accident and the rescue operation. This part incorporates short accounts of the separate investigations carried out on behalf of the Commission. The detailed research reports and copies of the most important documents are collected in a separate Supplement. The fourth part presents the conclusions based on the work carried out by and for the Commission.

PART 1 FACTUAL INFORMATION

Chapter 1 gives facts on the most important events during the accident voyage, on the accident and very briefly on the rescue operation. Chapter 2

describes the operating history of the vessel under the Finnish and Estonian flags with emphasis on the organisation of the operations and on the experience of the partners in the Tallinn - Stockholm traffic. **Chapter 2** includes also general statistics on wave conditions in which the vessel had been sailing during her life.

Chapter 3 is a general technical description of the ESTONIA focusing on the bow visor and ramp installations with detailed data on the design and construction of their locking systems, including the monitoring and control. The history of the vessel and in particular of the bow visor and the ramp installations with regard to maintenance, modifications, damage and repairs is reviewed. Emergency and life-saving equipment and arrangements on board are outlined. in 3.4. The vessel was built to comply with several international conventions which are listed, and the compliance was documented by certificates. The collision bulkhead compliance is dealt with in some detail. Certificates valid at the time of the accident are reviewed and the changes in wording of the most important certificate, the Passenger Ship Safety Certificate, which has to be renewed every year, are explained in detail.

Chapter 4 describes the arrangement of operations on board and working routines, and gives summaries of qualifications of each deck officer and engineer on duty on the accident voyage. The safety organisation is outlined comprehensively

Chapter 5 is the second chapter directly dealing with the accident. The environmental conditions: wind, sea state, visibility and current during the accident voyage are defined on the basis of information obtained from meteorological institutes. The chapter concludes with an estimate of the ESTONIA' s speed during the voyage. The speed profile has been constructed from the DGPS recording of the passenger ferry SILJA EUROPA' s speed and is compared with observations of the

actual speed.

Chapter 6 is a summary of all statements made by the survivors and covers their experience from the time just prior to the accident until their rescue. The chapter is divided into two parts. The first part reports on statements made by the individual surviving crew members who were on duty during the accident, the second part summarises statements from both passengers and crew members off duty Chapter 6 summarises as closely as possible the statements made by survivors, hut specific details are not necessarily regarded as facts and may differ from the Commission's statements in other chapters.

Chapter 7 begins with a general description of the rescue operation. This description first deals with international agreements on the safety of life at sea and then with the maritime search and rescue organisations of Estonia, Finland and Sweden as well as the co-operation between these countries.

The section on the ESTONIA s distress message and distress traffic describes the radio systems in use at the time of the accident and the coast radio stations which were keeping watch on distress and safety channels. The ESTONIA' s entire distress traffic from 0122 hrs to 0130 hrs on 28 September 1994 has been transcribed on the basis of the tape recordings made.

The section on the search and rescue operations begins with a chronological list of the most important rescue actions during the first hours. After this, the operations undertaken by the vessels, helicopters and aircraft are described. The section concludes with data on victims and survivors.

Part 1 ends with **Chapter 8** which presents a detailed review of damage to the wreck, the ramp and the visor with their attachments, as observed visually during inspections with a submarine Remotely Operated Vehicle (ROV), the diving operation and after the visor had been recovered and taken ashore. The damage is illustrated with several photographs. The extent of the diving operation is described and the divers' observations on the bridge and elsewhere in the wreck concerning e.g. victims are summarised. The state of the ESTONIA's life-saving equipment and emergency beacons (EPIRBs) when found after the accident is specified in 8.10 and 8.1 l, respectively.

PART 2 ASSOCIATED FACTS

Chapter 9 includes a general review of international co-operation and conventions within the framework of the International Maritime Organisation (IMO) and shortly describes the organisation of the Estonian, Finnish and Swedish Maritime Administrations. The role of the classification societies and their relationship with the ship owners, shipyards and the national administrations is described. The problems recognised in safety of ro-ro vessels before the ESTONIA disaster are pointed out with particular emphasis on the HERALD OF FREE ENTERPRISE accident in 1987.

Chapter 10 is a brief commercial and technical history of the ro-ro ferry traffic in the Baltic. The chapter includes a list of passenger ferries put in traffic between south-west Finland and the Stockholm region in Sweden by the Silja Line and the Viking Line between 1959 and 1993, with the type of original bow enclosure defined.

Some of the incidents involving failure or part-failure of bow visor attachments of Finnish and Swedish ro-ro passenger ferries in the Baltic and the North Sea are summarised in Chapter 1 l. The type and extent of damage is indicated in each case as well as the action taken after the accident. The incident of DIANA II in January 1993 in the southern Baltic has been investigated in more depth since she had a similar visor and attachment system design to the ESTONIAs.

PART 3 ANALYSIS AND EVALUATION

Chapter 12 opens the analysis part of the report. It presents an overview of the separate investigations carried out for the Commission. These include analysis of wave loads on the visor based on model tests and numerical simulations, calculations of wave-induced motions and analysis of hydrostatic and hydrodynamic characteristics during flooding and sinking of the vessel. The chapter also summarises the various strength and metallurgic investigations carried out on parts recovered from the visor and ramp installations and calculations of the strength of the visor attachments.

Chapter 13 is a main chapter in the report presenting the Commission's views on the course of events starting from the preparations for the accident passage and ending with the sinking of the ESTONIA. The chapter is based on an analysis of witness statements (Chapter 6) and all technical observations and data of which the main part is summarised in Chapters 3, 5, 8,12 and 15.

The possible deficiencies existing in the visor and ramp closure before the accident voyage and their effect on the operation of the vessel are analysed in 13.2.3. Separation of the visor and development of the list and sinking are handled shortly in 13.2.5 and 13.2.6, respectively while a more thorough treatment is given in 13.5 and 13.6.

Actions on the bridge in the light of information available to the bridge are analysed in 3.3, including an analysis of the effect of the ESTONIA's speed on passenger comfort and the accident. The time span considered is from the first signs of something being wrong at about the time of changing watch at 0100 hrs until the end of the distress traffic at 0130 hrs.

There were indicator lamps on the bridge showing locked or unlocked visor and ramp, respectively Their indications and other advance alarms when the visor was becoming detached are analysed in 13.4.

Chapter 14 describes the ownership and operating arrangements of the ESTONIA and analyses whether these may have been a contributing factor in the accident.

Chapter 15 analyses the structural design of the visor and ramp attachments. The basis and procedures for design, manufacturing and approval are discussed. The estimated combined strength of the attachment system is compared to the estimated wave-induced loads and a probable load level and sequence of failure is presented.

Chapter 16 is an analysis of the evacuation of the ship from the first early signs of the accident until the ship was abandoned by all who could. The basis for this chapter is witnesses' statements and findings by divers after the accident. The chapter deals with the alarms, activities and efforts by parts of the crew, activities by passengers, various obstacles to the evacuation and the role of rational and irrational human behaviour displayed.

Chapter 17 is an analysis of the rescue operation on the basis of information and data summarised in Chapter 7. Chapter 17 considers first the distress traffic between the vessels and the coast stations. The action initiated by the distress calls on board the vessels in the vicinity of the ESTONIA and at the land-based rescue centres, in particular MRCC Turku, are evaluated in 17.3. The concluding part of the chapter deals with the action of vessels and helicopters during the rescue operation.

Chapter 18 begins with a consideration how the practice common amongst the Finnish and Swedish Maritime Administrations of accepting in passenger ferries a forward-located bow ramp as an upper extension of the collision bulkhead, contrary to the SOLAS regulations, may have developed. This chapter also evaluates the bow ramp arrangement of the ESTONIA in comparison with some other contemporary passenger ferries, and draws conclusions on the effect on the accident of non-compliance with the regulations.

The ESTONIA accident prompted an extensive investigation within the International Maritime Organisation (IMO) on all aspects of ro-ro passenger ships' safety. The work has led to improvement of existing safety regulations and development of detailed new ones of which a significant part has already come into force. The new safety regulations for passenger ferries developed by IMO after the accident are reviewed in **Chapter 19**.

PART 4 CONCLUSIONS

Part 4 presents findings, conclusions and recommendations, in **Chapters 20, 21 and 22**, respectively.

PART 1 FACTUAL INFORMATION

CHAPTER I THE ACCIDENT

The Estonian-flagged ro-ro passenger ferry ESTONIA (Figure l.l) departed from Tallinn, the capital of Estonia, on 27 September 1994 at 1915 hrs for a scheduled voyage to Stockholm, the capital of Sweden (Figure 1.2). She carried 989 people, 803 of whom were passengers.

The ship left harbour with all four main engines running. When she was clear of the harbour area full service speed was set. The engine setting was maintained up to the accident. The wind was southerly, 8-10 m/s. Visibility was good, with rain showers.

At 2000 hrs the watch on the bridge was taken by the second[1] officer B and the third officer.

The voyage proceeded normally. Sea conditions along the Estonian coast were moderate, but became more rough when the ship left the sheltered waters. The ship had a slight starboard list due to a combination of athwartships weight disposition, cargo disposition and wind pressure on the port side.

As the voyage continued the wind velocity increased gradually and the wind veered to south-west. Visibility was generally more than 10 nautical miles. At midnight the wind was south-westerly 15-20 m/s with a significant wave height of 3-4 m. The rolling and pitching of the vessel increased gradually, and some passengers became seasick.

At about 0025 hrs the ESTONIA reached a waypoint at position 59° 20' N, 22° 00' E and from there headed true course 287° . The speed was about 14 knots and the vessel encountered the seas on her port bow. Due to increasing rolling, the fin stabilisers were extended.

During his scheduled round on the car deck the seaman of the watch heard shortly before 0100 hrs a metallic bang from the bow area as the vessel hit a heavy wave.

The seaman of the watch informed the second officer B about what he had heard and was ordered to try to find out what had caused the bang. The seaman did so by waiting at the ramp, listening and checking the indicator lamps for the visor and ramp locking devices. He reported that everything seemed to be normal.

At 0100 hrs the watch on the bridge was taken over by the second officer A and the fourth officer. After being relieved the second officer B and third officer left the bridge.

Further observations of unusual noise, starting at about 0105 hrs, were made during the following 10 minutes by many passengers and some crew members who were off duty in their cabins.

When the seaman of the watch returned from his round, soon after the change of watches, he caught up the master and entered the bridge just behind him. Shortly afterwards he was sent down to the car deck to find out the cause of the sounds reported by telephone to the bridge. He did not, however, manage to reach the car deck.

At about 0115 hrs the visor separated from the bow and tilted over the stem. The ramp was pulled fully open, allowing large amounts of water to enter the car deck. Very rapidly the ship took on a heavy starboard list. She was turned to port and slowed down.

Passengers started to rush up the staircases and panic developed at many places. Many passengers were trapped in their cabins and had no chance of getting out in time. Lifejackets were distributed to those passengers who managed to reach the boat deck. They jumped or were washed into the sea. Some managed to climb into liferafts which had been released from the vessel. No lifeboats could be launched due to the heavy list.

At about 0120 hrs a weak female voice called "Häire, häire, laeval on häire" the Estonian words for "Alarm, alarm, there is alarm on the ship", over the public address system. Just a moment later an internal alarm for the crew was transmitted over the public address system. Soon after this the general lifeboat alarm was given.

A first Mayday call from the ESTONIA was received at 0122 hrs. A second Mayday call was transmitted shortly afterwards and by 0124 hrs 14 ship- and shore-based radio stations, including the Maritime Rescue Co-ordination Centre (MRCC) in Turku, had received the Mayday calls.

At about this time all four main engines had stopped. The main generators stopped somewhat later and the emergency generator started automatically, supplying power to essential equipment and to limited lights in public areas and on deck. The ship was now drifting, lying across the seas.

The list to starboard increased and water had started to enter the accommodation decks. Flooding of the accommodation continued with considerable speed and the starboard side of the ship was submerged at about 0130 hrs. During the final stage of flooding the list was more than 90 degrees. The ship sank rapidly, stern first, and disappeared from the radar screens of ships in the area at about 0150 hrs.

Rescue efforts were initiated by MRCC Turku. About one hour after the ESTONIA had sunk, four passenger ferries in the vicinity arrived on the scene of the accident. Rescue helicopters were summoned and the first one arrived at 0305 hrs.

During the night and early morning, helicopters and assisting ships rescued 138 people, of whom one later died in hospital. During the day and on the two following days 92 bodies were recovered. Most of the missing persons accompanied the vessel to the seabed.

The wreck was found in international waters within Finland's Search and Rescue Region, resting on the seabed at a water depth of about 80 m with a heading of 95° and a starboard list of about 120° . The visor was missing and the ramp partly open.

The position of the wreck is 59° 22,9' N, 21° 41,0' E. The visor, which has been recovered, was located at 59° 23,0' N, 21° 39,2' E, about one nautical mile west of the wreck.

CHAPTER 2 OWNERSHIP AND OPERATING HISTORY

2.1 Operating history under Finnish flag

The vessel was delivered to Rederiaktiebolaget Sally on 29 June 1980 under the name VIKING SALLY and placed in daily operation between Turku and Mariehamn in Finland, and Stockholm.

Rederiaktiebolaget Sally based in Mariehamn, was at that time one of the major Finnish shipping companies with engagement in tankers and passenger vessels. The company was one of three which together formed the marketing consortium "Viking Line" for ferry operations between Finland and Sweden (see 10.2).

In 1986, ownership of the vessel was taken over by the Finnish/Swedish group Effjohn, owners of the competing Silja Line. The vessel continued, however, to operate in the Viking fleet under the original name. The technical operation was subcontracted with the remaining part of the Sally company.

In April 1990 the Effjohn group took over full operation of the vessel and transferred her to the Silja Line under the name SILJA STAR for continued operation between Turku and Stockholm.

In January 1991 the vessel was transferred to the Wasa Line, another subsidiary of the Effjohn group, and was placed in the Wasa Line operation in the Gulf of Bothnia between Vaasa in Finland and Umeå and Sundsvall in Sweden. The ship was then renamed WASA KING. She was operated on this route until she was sold to the Estline Marine Company Limited, which is registered in Cyprus.

The ship was under Finnish supervision and flew the Finnish flag from delivery until 14 January 1993.

2.2 Under Estonian flag

The vessel was delivered on 15 January 1993 to the Estline Marine Company Limited. She was registered in Cyprus to satisfy the requirements of the European Bank of Reconstruction and Development for financing the vessel on a mortgage basis. Permission had been obtained for parallel registration in Estonia and the vessel was entered in the Estonian Ship Register on 28 January 1993.

After delivery drydocking in Turku she entered service for passenger and cargo traffic between Tallinn and Stockholm under the new name, ESTONIA. The first voyage took place on 1 February 1993 and the traffic continued thereafter with departures every second day from Tallinn and Stockholm respectively Figure 2.1 shows a summary of the vessel's operating history.

The Estline Marine Company Limited was owned equally by the Estonian Shipping Company Limited (ESCO) and Nordthulin Luxembourg S.A., the latter a company fully owned by the Swedish shipping company Nordström & Thulin AB.

The vessel was bareboat chartered to the Estonian company E-line Limited, also owned equally by ESCO and Nordthulin Luxembourg S.A.

E-line had signed a Ship Management Agreement with ESCO because ESCO had more extensive resources and experience than E-line for managing operations.

ESCO in turn signed a Technical Management Agreement with Nordström & Thulin AB, the reason being that the latter company had more experience of this type of ferry and easier access to spare parts and service. For the same reason Nordström & Thulin was contracted to handle insurance matters regarding the ESTONIA.

The commercial side of the operations, including catering, was handled by the Swedish company Estline AB under an agency agreement with E-line. Estline AB was owned equally by ESCO and Nordström & Thulin. Estline AB had a subsidiary company in Estonia to provide the commercial and catering services in Tallinn. Table 2.1 summarises the ownership of the companies involved in the ESTONIA's operation. Figure 2.2 shows the organisation of the Estline Marine Company Limited.

Nordström & Thulin AB is a Stockholm-based public company established in 1850, with experience of extensive world-wide operation of large modern tankers and bulk carriers, and passenger ferry operations between the Swedish mainland and the island of Gotland in the Baltic Sea. Shipbroking is another important company activity.

The day-to-day technical management functions regarding the ESTONIA were handled by one full-time superintendent and one purchasing manager, both based in Stockholm.

ESCO is a Tallinn-based, state-owned stock company. Its history dates back to 1879, when the first shipping company "Linda", was established in

Estonia. ESCO operates world-wide a variety of cargo vessels of up to 50,000 dwt. ESCO also operates passenger ferries in the Baltic Sea and the Gulf of Finland. In the autumn of 1994 the company owned and operated 55 vessels.

Operation of the ESTONIA was under the supervision of the Navigational Department of ESCO. The crew was provided by the Personnel Department of ESCO. Two full crews were employed, manning the ship in two-week shifts each. The qualifications and training of the crew are described in Chapter 4.

The master taking over a shift was required to visit the ESCO Navigational, Technical and Personnel departments for briefing. The master being relieved likewise had to report personally to the navigational department of ESCO on the situation on board.

A captains' meeting was held at the ESCO office once a week attended by all masters in Tallinn on that day, including those on vacation. Regular meetings were also held on board the ESTONIA, attended by the masters, chief officers and chief engineers of both shifts and by representatives from ESCO and from Nordström & Thulin AB.

2.3 Operating history with regard to wave conditions

The main part of the Tallinn-Stockholm route was in open sea, while the open-sea part was considerably shorter on the two previous routes. Table 2.2 summarises the route information for all the three routes.

No wave statistics exist specifically for the vessel's three operating areas. Some indication of the differences between sea conditions on the three routes may be obtained by comparing the significant wave heights which are exceeded at a probability of 10 % in the different sea areas (Figure 2.3). The wave heights were estimated by the Finnish Institute of Marine Research (MTL). The Institute also predicted wave statistics for the three routes on the basis of their experience, wind statistics, fetch and wave measurements at Bogskär in the northern Baltic Sea (for position, see Figure 13.1) and at Sandbäck in the southern Gulf of Bothnia.

Table 2.3 presents wave statistics for each route on the area where the worst wave conditions are encountered. The table also shows statistics measured at Bogskär for significant wave heights exceeding 2, 3 and 4 m.

Figure 2.3 indicates that the probability of encountering high seas on the Vaasa-Umeå route is significantly lower than on the Vaasa-Sundsvall route which was run only occasionally and mainly in the summertime. In addition, a review of the weather data from the Gulf of Bothnia for the period when the vessel was operating there indicates that strong winds generating high waves had not existed at any time during this period.

An upper estimate of the time the ESTONIA had spent in rough sea is obtained by combining the time spent in the open sea (Table 2.2) with the probabilities of significant wave height exceeding 3 or 4 m. The times in rough sea are given in Table 2.4 for the operation in the Turku-Stockholm and in the Tallinn- Stockholm traffic. The estimates for the latter traffic assume that the vessel had spent equally long times in the wave climates represented by the Bogskär and by the south-of-Utö wave statistics.

The vessel may have encountered these high seas from any direction. In the Å land Sea area, heavy seas can only be generated in south-south-easterly or north-westerly directions, thus creating beam seas for vessels sailing on the Stockholm-Mariehamn-Turku route. In the Northern Baltic most of the high sea states are generated in the south to west sector. This means in general port bow or beam seas for a passage from Tallinn to Stockholm and following or beam seas in the opposite direction. The probability of encountering high waves diminishes towards the ends of the open sea part.

CHAPTER 3 THE VESSEL

3.1 Background

3.1.1 Contract, specification, building and delivery

The vessel was built by the shipyard Jos. L. Meyer at Papenburg in Germany in accordance with a building contract signed on 11 September 1979 between the yard and Rederiaktiebolaget Sally (Supplement). The contract referred to a building specification number 5675/79, dated 5 September 1979. The contract followed a standard format originally developed by the Swedish Shipowners' Association.

The vessel was ordered and built for the rapidly expanding ferry traffic between Finland and Sweden. She was built during a period of rapid growth in the size of ferries and in their operating speed and was, when delivered, for a time the second largest ferry operating in the Baltic Sea. Only the gas-turbine-powered FINNJET, specially built for operation between Helsinki and Travemünde, was bigger.

The vessel was to be built within an unusually short delivery time and substantial parts of the hull and the superstructure were subcontracted with other yards. The bow visor and its attachments were however built by the Meyer yard.

The vessel had newbuilding number S.590, delivered after newbuilding S.592, named DIANA II, which had been ordered by Rederiaktiebolaget Slite, the Swedish partner in the Viking Line consortium.

The two vessels had large similarities, primarily in the main hull below the main deck and in machinery These similarities were a condition for meeting the desired short delivery time, 30 June 1980, for newbuilding S.590. The keel was laid on 18 October 1979. The two vessels were, however, not built to similar specifications. Newbuilding S.592 was built to a specification with Swedish origin whereas newbuilding S.590 was built to a specification developed from one used by the shipping company for other ongoing newbuildings at a Finnish yard. Newbuilding 5.590 was furthermore lengthened compared to newbuilding S.592 by extension of the parallel midship section by 18.4 metres. Related differences in the main hull were an increased length of the bulbous bow by 0.83 m and a related increase of the length of the forward ramp by 0.725 m.

Both vessels were built to the rules of Bureau Veritas with class notation "I 3/3 E + Passenger Ferry Deep Sea Ice lA (Aut)".

According to the building specification, the vessel was to be built to the rules and regulations of the Finnish Maritime Administration and additionally to the following international conventions and national regulations:

- Safety of Life at Sea Convention (SOLAS), 1974.
- Load Line Convention (ILLC) of 1966 with amendments of 1971 and 1975.
- Tonnage Measurement Convention of 1947.
- Marine Pollution Prevention Convention (MARPOL) of 1973.
- Collision Prevention Convention (COLREG) of 1972.
- Finnish regulations for Safety Ship Labour 77:33.
- US regulations regarding sanitation (as reasonably applicable).

- Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea, 1974/232.
- IMCO resolution A 325 (IX) 1975 concerning machinery and electric installations in passenger vessels and cargo ships.
- USCG requirements for passenger vessels, as reasonably applicable.
- Finnish Maritime Administration rules and recommendations for noise level criteria.

The 1974 issue of the SOLAS Convention was specified in lieu of the 1960 issue even though the 1974 issue had not yet entered into force. The contract specified that "Scandinavian standard for car/passenger ferries shall apply to all equipment, materials etc.".

The vessel was built and delivered according to schedule, but not all the passenger cabins were finished at the time of delivery. It was nevertheless considered important by the shipowner to be able to put the vessel in service before the summer season of 1980. The vessel was therefore delivered with a Passenger Ship Safety Certificate for a reduced number of passengers, originally 1100, and the number was increased as the interior work progressed whilst the vessel was in service.

The vessel was named VIKING SALLY and was delivered on 29 June 1980.

3.1.2 Newbuilding inspection

The ship was built to the rules of Bureau Veritas and to the special survey standard of the classification society This included, in addition to surveys at the yard, inspection of main materials and equipment at the respective works prior to delivery to the shipyard. Bureau Veritas was requested by the yard to survey the ship for conformity with the classification rule requirements applicable to the marks and notations mentioned below:

- I 3/3 E + Passenger Ferry Deep Sea Ice lA (Aut).
- Class notation "I" indicates that the vessel complies with all class construction requirements.
- Class notation "3/3" indicates that the vessel and its equipment met the full standard of the class rules with no restrictions.
- Class notation "E" indicates that the anchors and anchor chains were of approved standard.
- Construction mark "+" indicates that the vessel was constructed under Bureau Veritas survey from the beginning of the construction.

- Notation "Passenger Ferry" indicates that the vessel was a passenger ship with ro-ro car facilities.
- Navigation notation "Deep Sea" indicates that the vessel had no restriction regarding areas or conditions of operation.
- Notation "Ice IA" indicates that the vessel satisfied the "Finnish Swedish ice class rules 1971".
- Notation "(Aut)" indicates that the vessel was equipped with automated systems in the engine room areas for remote operation in open sea.

Bureau Veritas was authorised by the Finnish Maritime Administration to survey the vessel and its construction for compliance with the International Convention on Load Lines. The shipyard made a formal request to Bureau Veritas to perform this survey. The main responsibility remained, according to SOLAS and other conventions, with the Finnish Administration even when a classification society was authorised to perform certain functions.

The class survey took place from September 1979 until and including delivery in June 1980. Surveying of the installations for automated machinery went on also after delivery and was completed in December 1980.

The survey by the classification society did not encompass day-to-day detailed survey of the construction and the installation work in the ship. The classification society surveyor was to check conformity with the classification rule requirements and with approved drawings. He was also to ascertain that remarks regarding construction made on drawings were dealt with by the shipyard.

The Finnish Maritime Administration retained the responsibility for surveying the ship for compliance with international conventions and also with national safety rules and requirements on accommodation spaces. This surveying activity was done at intermittent visits to the yard.

The owners were represented at the yard throughout the construction period by shipowner's superintendents and the master and chief engineer assigned to serve on the vessel.

3.2 General description and data

This section contains a general description and data of the vessel. Details of the various areas are dealt with separately in 3.3-3.6. The general arrangement of the vessel is shown in Figure 3.1.

3.2.1 General arrangement

The VIKING SALLY was built as a development from previous ro-ro ferry designs. She was classified in shipping registers as a passenger/cargo ro-ro ferry. She was built with a continuous vehicle-carrying space on the main deck (A-deck). Below the main deck an economy accommodation area was arranged on deck number 1 (tween-deck) and an extensive sauna and pool area on deck 0 (tank-deck). The main passenger accommodation areas were on decks 4 (C-deck), 5 (D-deck) and 6 (E-deck). The crew accommodation was generally on decks 7 (F-deck) and 8 (G-deck) and the navigation bridge was on deck 9 (H-deck).

The ship was built with one bow loading ramp on the car deck, enclosed by a hinged bow visor that opened upwards, and two stern loading ramps. Passenger entrance doors were arranged on decks 4 and 5 and pilot and bunkering doors on the car deck.

The ship had the following main particulars according to building specification and certificates:

- Length, over all 155.40 m
- Length between perpendiculars 137.40 m
- Breadth, moulded 24.20 m
- Depth to bulkhead deck, moulded 7.65 m
- Maximum draft 5.60 m
- Deadweight at max. draft 3,006 dwt
- Light weight 9,733 t
- Gross tonnage 15,598
- Propulsion power 4 x 4,400 kW
- Electrical power 4 x 1,104 kW
- Bow thrusters 800 + 590 kW
- Maximutn number of passengers 2,000
- Maximum service speed 21 knots
- IMO number 7921033

3.2.2 The hull and deck arrangement

The hull was built to Bureau Veritas rules and to the Load Line and SOLAS Conventions regarding watertight subdivision. It was designed with a slender forebody extending into a bulbous bow and a "pram type" afterbody with two propellers and two rudders. Two bow thrusters were installed. The afterbody was modified during drydocking in 1985 by a "duck tail" extension giving increased buoyancy in the afterbody and a better hydrodynamic flow condition, preventing the stern from setting down at high speed. This was a problem in the original configuration unless forward located ballast tanks were filled.

The forebody had an extensive "flare", especially below the knuckle line at the car deck level. Such flares were increasingly applied at the time to provide full width of the car deck and accommodation area as far forward as possible. The hull form is shown in Figure 3.2.

An active roll-stabilising system with fins was installed in January 1994. Provisions for such installation had been made already at the newbuilding stage.

The hull below the bulkhead deck was subdivided by fifteen watertight transverse bulkheads, equipped with watertight doors as required.

The double-bottom spaces were arranged for fuel oils and other liquids and some were designated as empty tanks. Fuel oil tanks were also placed above the inner bottom.

Deck 0, the tank-deck, contained- from forward - the forepeak, the bow thruster room, an extensive sauna and swimming pool area and - in the aft half of the ship - the generator room, the engine room, the fuel purifier room and other machinery-related spaces. The deck next above, deck l, contained - in the forward half - economy class cabins for 358 passengers. The aft half of the deck contained the engine control room, workshop, main engine room and various utility spaces.

The car deck was one open space, with the exception of a centre casing, located slightly to starboard. Loading ramps were arranged one at the forward end and two at the aft end of the deck. The centre casing contained staircases from the spaces below the car deck, lift trunks and various utility spaces for machinery and catering functions. Five lifts were installed, extending from the passenger spaces below the car deck and from the car deck to deck number 7. Six sets of stairs led from the lower passenger spaces to a common passageway inside the casing. Four sets of stairs led from this passageway to deck 4 and six sets led upwards to higher decks. Stairs were also arranged at the aft open-air deck spaces from deck 4 upwards to deck 8. Emergency escape trunks from the engine room area were arranged inside the casing. Hanging car decks were arranged whereby the car deck space could be divided into two lower-height decks for cars. Access from the staircases to the hanging decks was via four doors on the starboard side and via two doors and gangways on the port side.

Smaller service spaces for power supply to the ramp and bow visor operation and the hoistable car decks were arranged on the car deck port and starboard, forward and aft. An office for the cargo officer during loading and discharging was arranged in the aft service space.

Deck 4 contained many passenger cabins and, aft, conference rooms, a cafeteria and passenger seats. The enclosed deck area terminated with two public exits to the open-air aft deck. Decks 5 and 6 had passenger cabins covering the forward third and the remaining parts were used for tax free shop, information desk, restaurants, bars and entertainment areas. Both decks had two double-door public exits to the open-air aft decks. The accommodation spaces on decks 4, 5 and 6 extended from side to side without any open-air passage or other open-air spaces except the aft decks.

Deck 7 contained the main part of the crew accommodation. This deck did not extend to the sides of the vessel, giving room for an open deck area on both sides. On the open deck there were the rescue stations and the embarkation area for lifeboats. The deck was accessible to passengers via two main staircases and staircases between the aft open-air decks. The passageways contained cradles for liferafts and bins for lifejackets for passengers and crew. Forward on deck 8 was accommodation for the senior officers and, aft, additional crew accommodation spaces. The intermediate space was taken up by ventilation equipment and other service functions. The lifeboat davits and additional liferaft bins were located at the sides of this deck. Deck 8 was accessible to passengers only via external stairs from deck 7.

The navigation bridge was on deck 9.

3.2.3 Propulsion system and control

The propulsion system consisted of four medium-speed diesel engines, connected in pairs to two propeller shafts via gearboxes. The engines were four-stroke turbo-charged engines with eight cylinders and a maximum continuous output of 4400 kW each. They were designed to operate on heavy fuel oil. Maximum continuous operating speed was 600 rpm.

Each propeller shaft carried one controllable-pitch propeller with a diameter of 4.0 m. The shafting had flangeless couplings and was arranged with the necessary sealing arrangements at bulkhead penetrations and oil-lubricated stern tube seals. Each shaft could be locked with a brake for operation with only one propeller. The port-side propeller rotated clockwise and the starboard-side one counter-clockwise.

The pitch control of the propellers was hydraulic, separate for each propeller. Each system had duplicate oil pumps and the necessary hydraulic components. The control was effected electrically by power selector levers on the main control console on the bridge, on the bridge wings and in the engine control room. The control signal from the power selector affected the engine speed as well as the propeller pitch via an electro-hydraulic combinator. Speed and pitch both increased at increasing power settings up to about 70 % power, when maximum continuous engine speed was reached. After that, higher power settings only increased the propeller pitch.

All the normal indicators, alarms and control devices were on the bridge and in the engine control room. The installation qualified for unmanned machinery space at sea in accordance with the classification requirements, but actual operation was at all times conducted with the engine control room manned by one engineer and one motorman.

The total fuel oil tank capacity was 940 m3 of heavy fuel oil and 291 m^3 of marine diesel oil. Bunkering for a complete round trip was always done in Stockholm.

3.2.4 Electrical system

The three-phase, 380 V 50 Hz electrical system was fed by four main electrical generator sets. They had an output of 1065 kVA each and were of the brush-less type, self-exciting and self-regulating, and capable of parallel operation.

The generators were driven by four-stroke trunk diesel engines, each supplying 1104 kW at 750 rpm. The engines had superchargers and inter-coolers, and could run on heavy fuel oil. They had all the necessary instrumentation and controls for automatic operation.

Transformers provided 220 V single- phase power for lighting and utility functions. The main electrical switchboard was in the engine control room.

An emergency generator set in compliance with the SOLAS requirements was installed in a separate room on deck 8 near the engine casing. The generator was powered by a diesel engine with an output of 312 kW at 1500 rpm. It supplied the emergency lighting system and also essential bridge equipment, including engine control, steering system, radars, gyrocompass, logs, echosounder, navigation lights, search lights, radio station, telephone system and public address system.

The emergency generator unit was designed to start automatically in case of loss of electrical power in the main network. The total starting and switch-in time was about 15 seconds. The unit could also be controlled manually from an emergency switchboard in the emergency generator room.

Accumulators for emergency power in case of loss of all other electrical supply were installed in compliance with the SOLAS requirements.

3.2.5 Ballast system

Two centrifugal ballast pumps were installed, each with a capacity of 300 m^3 /h. The pumps served ballast tanks which were the forepeak tank, the forward trim tank, two double-bottom tanks, one pair of heeling tanks and the aft peak tank, giving a total capacity of 1212 m^3 .

The heeling tanks were side tanks with a capacity of 183 m^3 each and intended for adjusting the list of the vessel as needed. The list that could be compensated for with one heeling tank full and the other empty was about eight degrees. The connecting valve between the heeling tanks was designed to close in case of failure of electrical power.

The separate heeling tank pump could be operated from the deck office at the aft ramp and from the engine control room.

3.2.6 Car deck arrangement

The vessel had a deck for loading trucks, cars and other wheeled cargo. The car deck was the vessel's freeboard deck and identified as deck number 2. It extended from side to side and from bow to stern, with a centre casing immediately starboard of the centre line. The available deck space was divided into four lanes on the port side and three on the starboard side.

Hanging car decks were arranged, stowed hoisted underneath deck number 4. When lowered to deck position number 3, the hoistable decks could be used for passenger cars. The starboard hoistable decks extended over the full deck width between the ship's side and the centre casing and the port decks from the ship's side for the width of the two outer lanes. These decks at each side were divided transversely into six sections, the foremost and atermost ones being sloping ramps to the elevated decks.

Lashing fittings were mounted along the lanes on the car deck.

Personal access to the car deck was via stairs and lifts in the centre casing. Four of the lifts had doors leading to the starboard side of the car deck and one had doors to the port side. A total of eleven doors, six starboard and five port, led from the car deck to the stairs inside the casing. The doors were sliding-type steel doors, meeting the SOLAS fire resistance requirements. The locks of the doors were remotely operated from the information desk on deck 5. The doors were locked at sea. They could, however, always be opened for passage from the car deck to the casing. Similar doors served the hoistable car decks.

The car deck space was ventilated by electrically driven fans, located on both sides at the forward and aft ends of the deck area and terminating at deck 4. The fans were together capable of providing 20 air changes per hour. The fans could be reversed and used for evacuation or for forced ventilation.

A smoke detection system covered the entire area. The system had its control and alarm panel at port side of the bridge.

A fire-fighting system was installed, based on water sprinklers mounted to cover all areas including the hanging car decks.

Twelve closable 4" scuppers were installed along each side of the deck. The scuppers were normally left open.

TV cameras for monitoring the car deck area were mounted as described in 3.3.5.

3.2.7 Bridge layout

The navigation bridge (Figure 3.3) was on the uppermost deck (deck 9), 9.2 m aft of the forward end of the superstructure. The bridge wings extended over the ship's sides by about 1.5 m and were fully enclosed.

The central part of the bridge extended forward of the wings by about 2 m. In the original design there was a console containing all major navigation and control equipment at the front bulkhead, just below the windows. The steering console was located on the centreline, just behind the front windows.

The bridge was rebuilt in January 1994 and some of the navigation equipment was renewed. The navigation console at the front bulkhead was partly removed, and a new conning station was constructed port of the centreline. The design of the conning station was of the Pilot-Copilot type, commonly used in Baltic ferries.

The new console contained two ARPA radars, DGPS (Differential Global Positioning System) receivers, the main auto-pilot, propulsion control levers, VHF telephones, mobile telephones and equipment for internal communications. From the two navigators' seats, and the captain's seat, normally placed to the port of the conning console, the panel with indicator lamps for visor and ramp was within sight.

The fin stabilisers and associated controls were also installed in 1994. The original "Roll-Nix" stabilisation system had been found inadequate. It was, however, not removed and had sometimes been used in strong following wind.

A separate chartroom was located on the starboard side, in the aft part of the bridge. The corresponding space on the port side was an open area containing the fire alarm centre and various cabinets for storage etc.

The main entrance to the bridge, from the accommodation, was on the centre line at the aft end of the bridge, where a door to the staircase connected the bridge with the officer and crew accommodation on decks 8 and 7. On the port side at the aft end of the bridge there was a door to the open deck.

Because of the retracted position of the navigation bridge, the bow of the vessel was not visible from the conning station, as Figure 3.4 indicates.

A monitor for the internal TV surveillance system was placed in the entrance to the chartroom and facing starboard. The monitor picture could not be viewed from the conning station.

3.2.8 Navigation equipment and systems

The navigation equipment was of a high standard, and met the requirements for the intended traffic.

The equipment had been upgraded and/or renewed on several occasions, and at the time of the accident the following equipment was installed on the bridge for navigation and vessel control:

- Radar, Atlas 9600 Arpa X-band
- Radar, Atlas 8600 Arpa S-band
- Radar, Raytheon 165012 SR Raycas
- Radar, Raytheon 1650 SR (slave to item 3)
- 2 Gyrocompasses, Sperry MK 36
- Magnetic compass, Plath
- Autopilot, Kockum Steermaster 2000
- Autopilot, Sperry Universal
- Speed Log, Raytheon Doppler Sonar (one axis)
- Echo sounder, Simrad DSN 450
- Radio direction finder, Debeg ADF 7410
- Antiroll system, Roll Nix (SSPA)
- Stabilisers, Brown Brothers folding fins
- Navigation computer, Navi Master NM-1000
- GPS receiver, Shipmate 5800 C
- DGPS receiver, Shipmate 5360
- DGPS receiver, Magnavox 200
- Speed/Fuel Consumption Optimisation Computer, ETA-Pilot

3.2.9 Communication equipment

The communication equipment was divided between the bridge and the radio room.

The vessel's radio room was on deck 8, aft of the captain's cabin. The radio room was mainly used for commercial communication, and contained the following equipment:

- Main Transmitter, Standard Radio ST 1680 A
- Main Receiver, Skanti AS SR-51
- Emergency Transmitter, Standard Radio ST 86 B. A1, A2, A3
- Emergency Receiver, RL Drake RR-11
- Autoalarm IMR A4 734/SRT B-2290 1000
- VHF Svensk Radio STR-40 - ME62

In addition to the equipment in the radio room, the following was installed on the bridge:

- MF/HF radio telephone
- VHF Svensk Radio STR-40-ME62
- VHF Sailor (1 master and 3 slaves)
- VHF Skanti
- Watch Receiver DC-300D
- NAVTEX receiver
- Lifeboat Radio IMR SOLAS III A
- Mobile Telephone NMT 450
- Weather Fax Receiver

Two Emergency Position-Indicating Radio Beacons (EPIRB) were mounted, one on each side of the top of the bridge. These EPIRBs are discussed in detail in 3.4.4 and 8.11.

3.2.10 Maintenance, modifications and damage

The vessel was maintained by the owners to class satisfaction in line with common practice and requirements. The surveys for maintenance of class were carried out by Bureau Veritas on a continuous five-year timetable for hull and machinery in combination with a schedule of annual surveys. On average, the surveying programme involved five to six on-board survey visits per year.

The vessel was also subject to the Port State Inspection programme in compliance with the Paris Memorandum of Understanding on Port State Control (see about Paris MOU in 9.1). Technical Port State inspections were carried out in February, April and December 1993 and March 1994. The first inspection was in connection with the start of traffic on the Tallinn-Stockholm route and did not give rise to any remarks. The next inspection was the consequence of an oil spill in the Stockholm Archipelago, the cause of which was a leaking stern tube seal (see below). At the third inspection three remarks of less significance were noted. The last inspection did not give rise to any remarks.

The annual drydockings were mostly at the Turku Repair Yard. Two were at the Valmet Helsinki Yard, one. after grounding damage in 1984 and one in 1985 for repair of ice damage and for modification of the stern area of the hull by incorporation of the "duck tail" extension. Two drydockings were made in Stockholm, one in 1985 for repair of a leaking propeller shaft seal and one in 1988 for repair of grounding damage. The damage was surveyed and repaired in dry dock following normal practice.

Besides the ice damage in 1985, two other occasions of ice damage were recorded, during the winters of 1982 and 1987.

The drydocking in conjunction with transfer to the Effjohn Group was done in 1990 at the Naantali branch of the Turku Repair Yard.

The vessel was laid-up at the Perno shipyard outside Turku for some months at the beginning of 1991 before she was put in service on the Vaasa trade. The interior was upgraded and the sound proofing in the cabin area was improved during this time.

The drydocking in connection with delivery to E-line in 1993 took place in Turku. On this occasion all signs and instructions were replaced by new ones in Estonian, Swedish and English. New surveys for certificates were carried out and the fire protection installations were upgraded to satisfy new, more stringent, SOLAS requirements.

The vessel was dry-docked twice in Turku - in March and April 1993 - to correct a leaking stern tube seal.

A public area on deck 5 was rebuilt during service in 1993 to accommodate a new bar and an area with airline-type seats.

The fin stabilisers were installed in dry dock at Naantali in January 1994.

One or two replacements of propeller blades in conjunction with drydockings have been reported. Minor on-board repairs of cracks in the ramp locking devices were reported a couple of times. Damage to a visor hinge pin was once repaired at the Finnboda yard in Stockholm. For further details regarding damage of the bow visor and the ramp, see 3.3.6.

No other damage to the vessel has been reported throughout her history Individuals concerned with maintenance of the ship during the various periods of her life have generally expressed satisfaction with the vessel as a sound and trouble-free one.

3.3 Bow visor and ramp installation

3.3.1 General

The bow visor and ramp installation of the ESTONIA was of a configuration common on ferries in traffic between Finland and Sweden at the time of her construction. The installation comprised an upward-opening bow visor and a loading ramp, hinged at car-deck level and closed when raised. In closed position, the upper end of the ramp extended into a box-like housing on the deck of the visor.

The complete bow ramp and the operating and locking devices for the visor as well as the aft ramps and the car platforms were designed and delivered by an independent company, von Tell AB, an established supplier of cargo handling equipment and systems. The design was based on a detailed specification by the shipyard. Von Tell AB used a subcontractor, Grimmereds Verkstads AB, for manufacturing complete sets of components for the ramps, the car platforms and the visor locking devices. The routine contacts between the yard and the supplier were via von Tell GmbH, a subsidiary of von Tell AB. Incorporation of the system into the ship and manufacture of the attachment structure were shipyard work. The equipment delivered by von Tell was identical to that built for the preceding newbuilding, DIANA II, except for the slightly increased length of the ramp and the changes of the car platforms dictated by the greater length of the vessel. According to available information the visor operating and locking system design for DIANA II was the first delivered by von Tell AB.

The Bureau Veritas rules valid at the time had no details regarding procedures for calculating sea loads on the bow visor installation. It was stated in general wording that doors should be firmly secured and that structural reinforcements should be made to attachment points of cleats, hinges and jacks. The general wording in the rules also specified that the scantlings of the visor structure should be equivalent to that of the hull itself.

The vertical and longitudinal sea loads to which the bow visor could be exposed were calculated separately by the yard and by the von Tell company The Bureau Veritas rules gave no detailed guidance for such calculations. The yard therefore used for this purpose nominal "pressure heights" given by Bureau Veritas in a note (Note Documentaire BM2, 5.4.1976), originally issued as general guidance for determining the loads on the bows of large ships.

The von Tell company used nominal pressure heads per unit of projected area specified in the rules of Lloyd's Register of Shipping, valid at the time. It has not been possible to verify in detail what exchange of information on this issue took place between the yard and the supplier prior to the detailed design of the von Tell equipment.

The general arrangement of the ramp and visor installation is shown in Figure 3.5.

3.3.2 Detailed technical description of the bow visor

The visor

The visor was the most forward part of the vessel's hull and was a steel structure similar to the normal bow structure of a vessel. The general shape and design are shown in Figure 3.6. The visor consisted mainly of the shell plating, being an extension of the ship's shell plating and contour, the deck part, the bottom part, the aft bulkhead and internal horizontal stringers, vertical partial bulkheads and transverse stiffeners. The internal structure was connected with a stiff tubular framework. Two beams on deck extended aft of the visor aft end and carried the hinge arrangements for the pivoting points of the visor. The lowest strake of shell plating was reinforced in order to satisfy the ice class requirements. The visor weighed about 56 t.

The visor including attachment devices was built of grade A mild carbon steel (yield strength minimum 235 N/mm^2 , ultimate tensile strength 400-490 N/mm^2).

The deck of the visor had a box-like housing between the two beams, enclosing the upper part of the ramp when the ramp was closed. The geometry was such that the ramp had to be fully closed in order not to interfere with the visor during its opening and closing.

The visor pivoted around the two hinges on the upper deck during its normal opening and closing. It was secured in the closed position by three hydraulically operated locking devices at its lower part. One of these was mounted on the forepeak deck and the other two on the hull front bulkhead with mating lugs on the visor. Additionally, two manual locking devices were located in the area of the hydraulic side locks. Three locating horns, one on the forepeak deck and two on the front bulkhead, engaged recesses in the visor in order to guide the visor to its proper position when being closed and to absorb lateral loads.

The visor was supported vertically in the closed position by the two deck hinges and rested further on three points on the forepeak deck. One of these was the solid stem post of the visor, resting on the ice-breaking stem on top of the bulbous bow, the other two were steel pads on the forepeak deck. The three locking devices kept the visor down in its closed position and the locating horns absorbed any side loads that might develop. Longitudinal loads were carried by the hinges, the locking devices and possibly by direct contact between the visor and the front bulkhead of the hull. The visor was supported in the open position by the two hinges and two parking devices consisting of hydraulically operated bolts engaging lugs on the hinge beams.

Rubber seals supported by steel flat bars were installed on the forepeak deck and the front bulkhead, together making a continuous seal against which the visor abutted when closed.

The bottom lock

The bottom locking arrangement is shown in Figure 3.7. The bottom lock was sometimes named the "Atlantic lock" as it was not in common use in early ferries but was later introduced to enable similar ferries to cross open oceans. The "Atlantic lock" had become established by the time the ESTONIA was built. The locking device consisted of a locking bolt, movable horizontally in a transverse direction, guided in a bolt housing. In extended position the tip of the bolt engaged a support bushing. The bolt housing was fixed to the forepeak deck by means of two steel lugs and the bushing was installed in a third similar lug. A mating lug, attached to the bottom structure of the visor, was located between the bolt housing and the support bushing when the visor was closed and the extended bolt then engaged the hole in the mating lug.

The bolt was moved in the bolt housing between the retracted position and the extended position by means of a hydraulic actuator, operated from the visor and ramp control panel as described in 3.3.5. A spring-loaded mechanical plunger, movable perpendicularly to the bolt, engaged grooves in the bolt in the open and closed positions respectively, thereby securing the bolt mechanically in its extreme positions regardless of hydraulic pressure. The bolt was also locked hydraulically at any time because the hydraulic fluid was trapped in the system, regardless of whether the system was under pressure or not.

Two magnetic position sensors were installed, actuated by a magnet attached to a bracket on the bolt. The sensors were actuated when the bolt was fully retracted or fully extended. The hydraulic control system as well as the arrangement and functioning of the sensors and the position indication and alarm system are covered separately in 3.3.5. The original mechanical switches were replaced by the magnetic sensors in the mid-1980s.

The mating lug in the bottom structure of the visor consisted of a single steel lug, welded to a transverse beam of the visor bottom structure and supported by a bracket as shown in Figure 3.8. The diameter of the bolt was 80 mm in the original von Tell drawing. The lug had a hole for the locking bolt with an original diameter of 85 mm.

The failure mode of the bottom lock installation and related findings are covered in Chapters 8 and 15.

The side locks

The side locks consisted of two lugs, attached to the aft bulkhead of the visor and extending, when the visor was closed, into two recesses in the front bulkhead of the hull, one at each side of the ramp opening. The visor lugs overlapped a horizontal stringer. In the closed position, hydraulically-operated bolts engaged holes in the lugs. The arrangement is shown in Figure 3.9. The hydraulic bolt installations were similar to that of the bottom lock, i.e. a bolt moving in a housing and, when extended, engaging a support bushing. The visor lug inserted between the bolt housing and the support bushing. The bolt was moved by a hydraulic actuator. A spring-loaded mechanical plunger was installed. The position of the bolt, fully retracted and fully extended, was sensed by magnetic position sensors.

Additional hydraulic cylinders were installed at each side to push forward on the visor lugs when the visor was to open. This installation was intended to assist in breaking the visor open in case it had become stuck in the closed position due to icing.

Two local vertical stiffeners on the forward side of the visor bulkhead plating were separated by a distance slightly larger than the thickness of the lug itself. These stiffeners were installed to satisfy a Bureau Veritas surveyor's requirement, as written on the bow visor assembly drawing, for "local reinforcements of the ship's structures in way of locking devices". The fillet weld of one of the stiffeners had some overlap with the fillet weld of the side-locking lug on the opposite side of the bulkhead plating. No other arrangements were made in the design to transmit forces from the lugs into the structure of the visor.

Manual visor locks

Two manual locks were installed, one at each side and mounted just below the hydraulic side locks. Each lock consisted of two lugs welded to the aft side of the visor and a hinged eye bolt with nut, mounted between two lugs in the front bulkhead as shown in Figure 3.10. In closed position the eye bolt was swung into position between the two lugs in the visor and the nut was tightened down. The locks had no remote position indicating devices.

The manual locks were described in the supplier's instruction manual as "reserve". No advice was given anywhere in instructions from the maker, the shipyard or operators as to the use of these manual locks. **The deck hinges**

The two beams on the deck of the visor extended about 3 metres aft of the visor. Each beam had a box structure, including heavy-gauge side plates, top and bottom plates and various internal and external brackets and stiffeners. The ends of the beam side plates carried the hinge arrangements (Figure 3.11). A heavy steel bushing was welded into a hole in each of the two side plates of each beam. The bushings had a bore, carrying a bronze bushing.

The deck part of the hinge consisted of two lugs welded to the deck, carrying between them a steel housing. This deck part was located, in the installed arrangement, between the two bushings of a visor beam. A steel shaft was installed through the entire assembly, secured by locking plates bolted to the outer ends of the hinge bushings. The bearings were lubricated through drillings in the shaft and grease nipples at its ends.

3.3.3 Design documentation for the bow visor and its locking devices

As mentioned in 3.3.1 the shipyard calculated the vertical and longitudinal total forces on the bow visor. The loads so arrived at were assumed to act in the centre of the projected areas. The total vertical force, 536 t, was in the calculations (see Supplement) distributed evenly between all five attachment points, including the hinge points. The total longitudinal force was calculated to 381 t. By a procedure analysed in more detail in Chapter 15, the calculations arrived at a design load of 100 t per attachment point.

These calculations were hand-written and were intended to determine design data for minimum effective cross-section of a lug. By assuming high-tensile strength steel, an allowable tensile stress of 164 N/mm^2 was used, indicating a required minimum cross-section of 6100 mm^2 in the loaded direction of the locking device. These calculations were not dated and they were not submitted to Bureau Veritas for examination.

The normal drawings were submitted to Bureau Veritas for examination and approval, including the following:

- 590/1103 rev 6, Bugklappe, Meyer Werft (Bow visor, Meyer Yard)
- 590/1106 rev G, Bugklappeverrieglung, Meyer Werft (Bow visor locking devices)
- 49111-373 Atlantilzsicherung, von Tell (Atlantic lock)
- 590/1101a, Vorshiff, spt 149-vorne bis A-Deck, Meyer Werft (Foreship from frame 149 to fore end and up to A deck)
- 49111-372, Automatische und manuelle Verschlussanordnungen, für Bugklappe, von Tel1 (Automatic and manual locking devices of bow visor)
- 49111-330, Bugklappe und Bugrampe Zusammenstellung, von TeI1 (Bow visor and bow ramp assembly)

The Bureau Veritas surveyor examining the drawings made by the shipyard and by von Tell made various additional notes in conjunction with the examination. On the von Tell assembly drawing for the ramp and the visor it was stated that the arrangement of the locking devices should be subject to approval by the national administration. This drawing was approved by Bureau Veritas in November 1979. The shipyard assembly drawing for the visor likewise had a remark that the arrangement of the locking devices should be subject to approval by the national administration. It further carried a note requiring "local reinforcements of the ship's structures in way of locking devices, cylinders and hinges to the surveyor's satisfaction", and a note requiring that the lifting lugs, the bottom lock visor lug and the side lock lugs should be made of grade St52-3 steel (high-tensile strength steel to cold toughness class 3). This shipyard drawing was not approved until 20 June 1980, as the drawing had only then been submitted to Bureau Veritas. The yard, however, learned informally about the note on the von Tell drawing through the Bureau Ueritas site surveyor in March 1980.

There was also correspondence about approval of the drawings in December 1979 when the von Tell company asked the Finnish Maritime Administration which drawings the Administration wanted to examine and approve. The Administration replied that it assumed that all drawings had been approved by Bureau Veritas and that it was satisfied with this unless any matter of interpretation of the rules should arise. No reference was made in this correspondence to the Bureau Veritas note about approval of the locking devices.

Further telex communication about approvals took place between Bureau Veritas and von Tell in March 1980 when von Tell was questioned about the loads applied in the design of the locking devices. The von Tell design office explained that it had, lacking detailed guidance in the Bureau Veritas' rules, used the Lloyd's Register of Shipping rules. These calculations had indicated a load on each locking device of about 80 t, and this value had been used in the design of the locking bolts. In the same telex, von Tell expressed their concern about the stresses, presumably in the lockingbolts, which were slightly above the stresses permitted by Lloyd's Register of Shipping. These calculations were not submitted to Bureau Veritas for examination.

The von Tell company made detailed and assembly drawings for the various part systems and components delivered by them. In the case of the bottom lock the assembly drawing indicated three mounting lugs to the ship structure, compatible with the overall design of the locking device. Similarly the side locking lugs were identified on the assembly drawing for the side locking devices. The parts were identified as "Werftlieferung" (shipyard supply) on the drawings. Main dimensions of these parts were indicated although no normal manufacturing information. The drawings did not make it clear whether the information given was for reference purposes only or was intended as guidance for manufacturing.

The shipyard steel drawing for the bow visor (590/1103) indicated the mounting of the mating lug for the bottom lock and also the lugs for the side locks. No welding instructions were given for these detailed parts on the shipyard drawing, nor in von Tell drawings 49111-372 and 49111-373. No arrangements for structural continuity behind the devices were shown.

A group of experts appointed by the shipyard to investigate the ESTONIA accident have commented on some of the conclusions in the Commission's Part- Report and inter alia stated the following:

" a.) Contrary to the practice of other newbuilding yards Meyer Werft designers do not state the required thickness of welding seams individually on the respective drawings, but make up a so-called "welding table" for each newbuilding. In this table the <u>minimum</u> thickness of welding seams for particular structural parts is stated. The table is approved by the class. - b.) In case the particular structural part to be welded does not fall under the categories listed up in the welding table, the welder follows the yard welding standard. - c.) The yard welding standard requires a welding seam thickness for structural parts accessible from both sides, e.g. bushings to be welded into the lugs of <u>the Atlantic lock, to correspond</u> to at least 50 % of the thickness of the part to be welded and 70 % as a maximum value. In other words, a structural part welded respectively is connected by welding seams corresponding to at least 100 % of its own cross-section".

No detailed assembly drawing existed for the side locks although an extract from the von Tell assembly drawing for the side lock and with the lug bottom length of 370 mm added is said to have been released to the workshop for manufacturing. The length indicated on the yard assembly drawing of the visor was about 550 mm. The lugs for the side locks were shown fitted by fillet welds to the flat surface of the aft bulkhead of the visor, being a plate of 8 mm in thickness.

Some other discrepancies have been noted between the steel drawing for the visor and the actual installation in the visor as recovered. These include the absence of some longitudinal and transverse stiffeners in the bottom structure of the visor. This matter is further covered in 8.12.

3.3.4 Detailed technical description of the bow loading ramp

The ramp was a steel design with four longitudinal beams and a number of transverse beams. A steel plate made up the upper surface of the ramp. Additional stiffeners were arranged between the main beams.

The ramp was longer than the available deck height and therefore protruded by about 1.2 m above the level of the upper deck (deck 4) when in the raised, i.e. closed, position. This extension was enclosed in the box-like housing on the visor deck. Flaps at the tip of the ramp were hinged along its front end and were controlled by means of steel cables to extend when the ramp was lowered. The cables were engaged on bellcranks at the ends of the flap axis. When the ramp was closed these flaps hung down to keep its total length as short as possible.

The ramp was hinged at its aft end to the hull structure by four hinges. Each hinge consisted of a steel lug welded to the hull and two lugs welded to the aft beam of the ramp. Bushings and hinge pins completed the hinge installation. The outer hinges were heavier than the two inner ones.

Raised bars were welded onto the sides of the ramp. Fixed railings were mounted on each side.

The ramp was manoeuvred by two hydraulic actuators, one at each side. Preventer wires served to avoid excessive opening. When in the raised, closed, position the ramp was pulled in by two locking hooks, engaging pins in the side beams of the ramp. These hooks were hydraulically operated via a lever mechanism arranged to move past its dead centre during the locking movement and to stay in this mechanically secured position.

Two additional wedge-shaped locking bolts were mounted along each side of the ramp. These were hydraulically operated, moving transversely in the ramp coaming. In the extended position they engaged box-like extensions on the ramp side bars. Mechanical friction plungers were installed in each locking bolt housing.

All the locking devices had position sensors for their retracted and extended positions as described separately in 3.3.5.

A rubber seal, supported by steel flat bars, was arranged in the ramp coaming and formed a weathertight seal against the surface of the ramp when the ramp was in the closed position.

3.3.5 Actuating, monitoring and control systems for the bow visor and the ramp

A control system served the ramp and visor installation. The system was supplied by the maker of the ramp and visor actuating systems. It was described in an instruction booklet issued by the supplier.

The control system consisted of a high-pressure hydraulic system with tank and three pumps plus the normal components of a hydraulic power system, providing hydraulic power to a control panel and to the visor and ramp operating and locking devices. The original hydraulic pumps which had been set to provide 180 bar pressure had been replaced in the mid-80s due to their inability to give adequate pressure. The new pumps had a maximum pressure rating of 400 bar and were set to deliver 225 bar to the system.

The two cylinders for opening the visor operated in parallel, the operating speed limited by restrictor valves. No other devices were incorporated for ensuring that operating speeds of the two cylinders remained equal.

The control panel was mounted on the car deck at the port side, just aft of the ramp. It contained manual controllevers for separately operating:

- the visor bottom lock
- the visor side locks
- the open visor parking plungers
- visor opening/closing
- the ramp pull-in hooks and locking bolts
- ramp opening/closing.

The opening/closing control for the ramp and the visor was effected by solenoid valves so connected that the visor could only be manoeuvred when the ramp was closed and the ramp could only be opened when the visor was open. The interlock system further ensured that the ramp and the visor, respectively, could only be manoeuvred when the related locking devices were open.

In normal operation the indicator lamps were monitored by the operator for proper function of each step during opening or closing, before the next step was activated.

The panel had red and green lights, powered via the sensors at the actuators for the visor and ramp locking devices. Position sensors were also installed to sense fully closed or fully open visor and fully closed ramp, respectively The panel had red and green lights separately for the bottom lock, the side locks, the parking devices, the ramp locking devices, and the positions of the visor and the ramp. The lamps for the locking devices were controlled separately by one position sensor for retracted position and one for extended.

The sensors for the visor side locks were wired in series as were those for the parking devices. Should any locking bolt be in an intermediate position no switch was activated and neither the red nor the green lamp was illuminated for that function.

Visor position was indicated by two sensors, one for "fully closed" and one for "parked". The "fully closed" sensor was mounted on the port manual locking device. Both positions were indicated with green lamps. A red "parked visor" lamp was on at all times when the parking bolts were retracted and was thus on at sea.

The panel section for ramp operation had red and green lamps for the locking devices, all wired in series. A red or a green lamp would come on only when all the locking devices had moved to the required position. If one device was in an intermediate position no lamp would come on. An independent position sensor mounted at the upper port side of the ramp coaming indicated fully closed ramp by showing green. There was no lamp for open ramp.

It has been stated that the lower locking bolt on the port side of the ramp sometimes failed to go to fully extended position. The standard procedure was then to retract the bolt and again command it to locked position, whereby it would normally go to fully extended position and the green indicator lamp would come on.

The position indicators for the visor side locks and for ramp locking were also wired to the bridge, with one set of red and green lamps for the visor side locks and one set for the ramp locking devices. The actual position of the visor itself or the ramp itself was not shown on the bridge indicator panel, nor was the position of the bottom locking device. The lamps on the bridge would only come on if all the devices wired in series for that function, i.e. both side locks for the visor and all six locking devices for the ramp, respectively were in the required position.

The indicator panel was mounted in the front console of the bridge, starboard of the seat of the officer of the watch.

Four TV cameras were installed for monitoring the car deck. One fixed camera monitored the area of the forward ramp and one the aft ramps. One turnable camera admidships at each side of the casing was for monitoring the rest of the car deck area. The cameras were operated independently from a control panel with monitor on the bridge. A second monitor and control panel were installed in the engine control room.

The indicator lamps on the bridge for the bow visor and ramp had been installed from the beginning. The monitoring cameras had been fitted later as a consequence of more stringent requirements following the HERALD OF FREE ENTERPRISE accident. The original indicator lamps on the bridge had been found adequate by the Finnish Maritime Administration for compliance with the new SOLAS Reg II-1/23-2 as applicable to existing ships.

3.3.6 Surveys, maintenance, damage and repairs

Survey of the bow visor and ramp for class was part of the continuous hull survey scheme. The bow door area was last inspected under this five-year rolling scheme in October 1993. No remarks related to the bow visor and the ramp have been recorded from any of these surveys.

Maintenance of the operating and control system was, after the one-year guarantee period during the Finnish flag period, carried out by the Turku service base of the MacGregor group. The piston rod end bearing and pin for the port visor opening actuator were renewed in May 1990 due to play New rubber seals for the visor and ramp had been supplied almost yearly No other discrepancies had been recorded or other work carried out.

The visor locking devices and their operation were inspected every year by the MacGregor service base in Turku. The locking devices operated properly every time. According to information obtained from the service base it is very unlikely that any repair work would have been done on the visor locking devices without their knowledge during the period they maintained the operating and control system.

Just before transfer to Estonian flag at the end of 1992 attention had been given to the strength of the ramp and visor locking devices and a quotation for reinforcing them had been requested by Wasa Line. However, nothing was made to the locking devices.

After transfer to Estonian flag no more service work was carried out by the Mac-Gregor service base in Turku as the regular maintenance was carried out by the ship's crew and, according to the new owners, no need for external service had developed. New rubber seals had, however been ordered. It was known that the play in the ramp hinges was approaching the point where corrective action would be needed.

The locking bolt position sensors of the visors locks were originally of mechanical type. These were replaced whilst the ship was still on the Turku-Stockholm route by sensors of magnetic type, being less sensitive to moisture.

Minor routine welding repairs had been carried out on the mating boxes for the ramp locking bolts whilst the ship was in service in the Gulf of Bothnia. Local welding of a crack in a stiffener underneath the mounting platform for the port side visor actuator has been noted.

One of the visor hinge pins had, according to verbal information, a tendency to move out of position, breaking away the locking plate. This was repaired once at the Finnboda yard by pushing the hinge pin back in place and drilling for new locking bolts.

No other repair was, according to available information and extensive search, carried out during the lifetime of the vessel on or in the areas of the various operating and locking devices for the ramp and the visor.

As mentioned in 3.2.10, damage due to ice was recorded in 1982, 1985 and 1987. Damage to the bow visor occurred at those times. The first-mentioned was minor and was not claimed from the hull insurance company The last one was the most extensive and included replacement of the strake of plating next above the one originally reinforced, i.e. the second-lowest strake on the visor and at the corresponding level. somewhat aft of the visor. The thickness of the plating was increased from the original 14 mm to 20 mm (the thickness of the lowest strake was 28 mm). The extent of this repair is illustrated in Figure 3.12. No damage was recorded and no work was done to the bottom or the stem post of the visor, or to the locking devices.

3.4 Emergency and life-saving arrangements and equipment

3.4.1. General

The requirements for emergency and life-saving equipment are governed in detail by the SOLAS convention. The vessel was specified to be built to SOLAS 1974 but the first certificate was issued under SOLAS 1960. The Finnish Maritime Administration surveyed the vessel for compliance with the requirements whilst she flew the Finnish flag, and Bureau Veritas surveyed on behalf of the Estonian Administration during the following period. The surveys were annual and the one conducted on change of flag was extensive.

3.4.2 Lifeboats and rafts

The vessel was equipped with ten motordriven lifeboats of open type and of fibreglass construction. The five boats on the port side were approved for in total 368 people and the five on the starboard side for in total 324 people. One of the boats on the starboard side was a man-over-board (MOB) rescue boat. Two boats were equipped with searchlights. The boats were suspended under davits on deck 8. Embarkation was from deck 7.

The vessel carried 63 inflatable rafts, approved for a total of 1575 people. They were packed in containers stowed on decks 7 and 8 and were equipped with hydrostatic release mechanisms. Twelve rafts were equipped to be launched by davits, four of which were installed on deck 7. The remaining rafts were intended to be dropped into the sea. With one exception, the rafts were manufactured in 1980 and delivered to the VIKING SALLY during construction. They were serviced once a year in rotation. The service was carried out by a Swedish company authorised by the manufacturer and approved by the Swedish Maritime Administration.

Lifeboats and rafts provided on board satisfied the SOLAS 1974 requirements as to number and standard.

The lifeboats and rafts were surveyed every year in conjunction with the issuance of the Passenger Ship Safety Certificate. The last survey was in June 1994.

The vessel also carried six rigid floats on the uppermost deck. They were able to support 20 persons each. They were installed to comply with the SOLAS 1960 requirements for "buoyant apparatuses". All launching instructions had been renewed during the change of flag to reflect the new languages to be covered.

3.4.3 Lifebuoys and lifejackets

The vessel was equipped with 18 lifebuoys, nine of them with self-activating lights. One lifebuoy on each side of the ship was equipped with a lifeline and with self-activating light and smoke signals.

There were 2298 lifejackets for adults and 200 lifejackets for children on board. All the jackets were equipped with whistles. There were no lights on the lifejackets. This was not required on vessels trading on short international voyages (3.6.1).

On the open passage on deck 7, rescue stations and bins containing lifejackets were located on both sides of the ship. There were also lifejackets on the bridge and in the engine control room for the watch personnel. Donning instructions were placed where the lifejackets were stowed and in all passenger cabins. Crew members were assigned to assist passengers in putting on the lifejackets.

3.4.4 Emergency beacons

The ESTONIA carried two emergency beacons (EPIRBs) of type Kannad 406F.

The last check of the radio beacons was reported to have been made about one week prior to the accident by the radio operator. The check confirmed that the EPIRBs were in full working order.

3.4.5 Emergency alarm systems

The ship had an alarm system incorporating 197 alarm bells and 11 alarm sirens. Each alarm unit was equipped with a fuse, whereby a fault in a single alarm would not disable the rest of the system.

The alarm system was functionally checked once a week. The audibility of the system against the background noise in the accommodation areas had been judged to be adequate although no documented measurements had been made.

Alarms were installed in the passageways and public spaces as well as in non- passenger areas.

The alarm system operated on the 220 V system and was connected to the main and emergency generator systems. The alarm system was not powered by the emergency accumulators.

Alarm buttons were installed on every deck, including the sections and work rooms of the crew. By pressing an alarm button an audible signal was triggered on the navigation bridge and an indicator showed which section the alarm was coming from. In case of no reaction within 30 seconds, the alarm in the entire vessel was automatically activated. The receipt of one signal on the bridge did not prevent the receipt of additional signals from other alarm buttons.

The vessel had a fire and smoke detection system with a total of 1212 sensors. The sensors on the car deck and in the engine and boiler rooms were smoke-sensitive whereas the other sensors were heat-sensitive, set to give alarm at a temperature of 65° C.

The public address system was operated from the navigation bridge and also from the information desk. The microphone on the bridge had priority over the one at the information desk.

A separate personal paging system for crew members was installed.

3.4.6 Escape routes and instructions

The escape routes led to 18 rescue stations located on deck 7. The routes were marked with signs on the walls and fluorescent tape along the corridors.

Instructions for handling life-saving equipment were posted at the rescue stations. The detailed instructions for the crew were given in the Training Manual and Safety Manual, described in 4.3.

3.4.7 Passenger information

Each passenger cabin was supplied with an instruction pamphlet in Estonian, Swedish and English on safety measures, describing how to act in the event of an emergency There was also an evacuation scheme posted in each cabin, indicating the escape routes and the particular rescue station for the passengers accommodated in that cabin. The exits and emergency exits were marked by arrows in passageways, on staircase landings and in recreation areas as well as by signboards on exit doors.

In any distress situation, besides alarms given only to the crew, the passengers should according to the Safety Manual be given general information and instructions through the public address system.

3.5 Cargo handling system

3.5.1 Cargo lashing equipment

The vessel was equipped with standard lashing belts for securing heavy vehicles and containers. Chocks were available on board for additional securing of heavy vehicles and for securing passenger cars on the hoistable car decks and on sloping deck surfaces.

The lashing equipment was inspected every three months and was renewed as necessary The equipment was stored in the service areas at the forward and aft ends of the car deck.

3.5.2 Operating practice and instructions

The chief officer had the responsibility for cargo handling and planning loading operations. Both second officers were engaged in the actual loading and unloading on the car deck and all lashing of cargo was performed under their supervision.

Besides the second officers, the boat-swain was directly engaged in lasbing operations together with the deck hands.

No standard cargo loading plan was followed on board - but there was a general scheme - and a sketch of the cargo allocation was made before loading started. The overall guidance for lashing the cargo, given in IMO Resolution A 581 (14) "Guidelines for Securing Arrangements for the Transport of Road Vehicles on Ro-Ro Ships" and in IMO Resolution A 714

(17), was applied. The vessel also carried a cargo securing manual, issued by Estline AB.

Light passenger cars on the car deck were to be parked in low gear with the handbrakes on. The same precautions were applied to the light cars on the hoistable platforms where, additionally chocks were used. During the voyage the cargo was checked by the seaman of the watch on his watch round. The car deck could also be checked on the bridge and in the engine control room by means of the cameras covering the cargo area.

3.6 Certificates and inspections

3.6.1 Compliance with international conventions

The ship was built to comply with the conventions mentioned in 3.1.1.

The 1974 version of the SOLAS convention entered into force internationally on 25 May 1980 and in Finland on 21 February 1981. The 1960 version of SOLAS was in force at the time of the vessel's building. The 1973 MARPOL Convention and the related protocol of 1978 did not come into force internationally until October 1983 as far as the oil pollution annex is concerned. The building specification of 1979 included these conventions in expectation of their entering into force.

Compliance with relevant requirements of the conventions was verified in the stipulated certificates. The first Passenger Ship Safety Certificate (Supplement) to verify compliance with Chapters II-l, II-2, III and IV of SOLAS was issued by the Finnish Maritime Administration on 27 June 1980. It contained a restriction of the permitted number oI passengers to 1100 as the accommodation spaces were not fully completed. At the same time a restriction was ordered that the vessel was not allowed to sail more than 20 nautical miles from the nearest land. The first certificate was shortly thereafter replaced by a new one, dated 16 July 1980, permitting 2000 passengers. The certificates were valid for "short international voyages", defined in the SOLAS convention as a voyage of no more than 600 nautical miles and during which the ship is no more than 200 nautical miles from a port or place where passengers and crew can be placed in safety. In some later certificates, the traffic area was defined as "short international voyages between Finland and Sweden". Translated into Swedish and Finnish, the wording corresponds in English to "coastal traffic between Finland and

Sweden". This wording, however, does not refer to the SOLAS Convention but to the Finnish national law. In coastal traffic, where the ship was sailing all the time, the requirements as to officers' qualifications were lower than on vessels on short international voyages.

The permissible number of passengers was also dealt with in a separate resolution by the Finnish Administration on 26 May 1980. This resolution stated that the permitted number of passengers should be 2000, taking into account the requirements of Chapter III of SOLAS.

For reasons of comfort the Estline operators had lowered the number of passengers. The limit was set at 1456 bookable passengers, compatible with the available number of beds and sleeping seats installed. In the summer season an additional 100 deck passengers were allowed. This number did not include the crew or any non-paying persons on board.

The Passenger Ship Safety Certilicate was renewed every year in compliance with the rules. The certificates were issued in the format stipulated by the 1974 SOLAS Convention from 1981 onwards. An exemption certificate was issued for the radiotelegraph equipment in the certificate issued in October 1992. This exemption certificate restricted the operation of the vessel to voyages within the Baltic Sea in accordance with the provisions o I Regulation 5 of Chapter IV of the 1974 SOLAS Convention. This exemption was not extended when the ship's flag was changed to Estonian as the vessel had from that time again a radio officer.

From the beginning the vessel had an International Load Line Certificate, the first one based on a survey for freeboard carried out by Bureau Veritas, dated 23 April 1980. The certificate was issued in accordance with the 1966 version of the ILL Convention and was valid for five years, subject to periodic inspections. The certificates issued in 1985 and 1990 by the Finnish Maritime Administration were based on surveys carried out by Bureau Veritas.

3.6.2 Certificates valid at the time of the accident

International certificates cease to be valid when a ship changes flag. New certificates were therefore issued when the ship became Estonian in January 1993. Two new classification certificates (hull, machinery) were issued by Bureau Veritas in January 1993. The Estonian Maritime Administration had authorised Bureau Veritas in August 1992 to perform the surveys on its behalf and to issue certificates under the 1966 Load Line Convention, the

1974 SOLAS Convention, the 1973 MARPOL Convention and the 1969 Tonnage Convention. The status of the certificates at the time of the accident was as follows.

Passenger Ship Safety Certificate. As a new trim and stability manual was under development, the vessel carried an interim Passenger Ship Safety Certificate, issued on 26 June 1994.

Load Line Certificate. For the same reason the Load Line Certificate was interim, issued on 9 September 1994. International Oi1 Pollution Prevention Certificate. A conditional IOPP certificate was issued by Bureau Veritas on 14 January 1993. The validity was conditional on the issuance of a Passenger Ship Safety Certificate.

International Tonnage Certificate. Bureau Veritas issued, on behalf of the Estonian Government, a tonnage certificate under the Tonnage Convention of 1969. The certificate valid at the time of the accident was dated 29 August 1994.

At the request of the owners Bureau Veritas had also issued a Cyprus tonnage certificate, dated 8 June 1993, according to the Cyprus Merchant Shipping Regulations requirements. Bureau Veritas also issued, under the same authority, a Certificate of Survey pursuant to the Republic of Cyprus Merchant Shipping Law of 1963.

The valid certificates at the time of the accident are shown in the Supplement.

3.6.3 Collision bulkhead compliance

The SOLAS Convention requires passenger ships to have a collision bulkhead, and an upper extension of the collision bulkhead in ships with long forward superstructure, located at a distance from the forward perpendicular of minimum 5 per cent of the length of the ship between perpendiculars and maximum 5 per cent of the length of the ship plus 3 m. This requirement was formulated at an early stage and remained basically unchanged during the further development of the SOLAS Convention. However, in the 1981 Amendments to SOLAS 1974, which entered into force on 1 September 1984, the rule was extended to include cargo ships and modified to allow taking into account a bulbous bow. This was done by adding wording permitting the datum line from which the position of the collision bulkhead is determined to be moved forward from the forward perpendicular by half the length of the bulbous bow by 1.5 per cent of the length of the ship or by 3 m, whichever was the shortest. The 1981 Amendments considered also for the first time especially the use of the ramp as an upper extension of the collision bulkhead. It was stated that the part of the ramp which is more than 2.3 m above the bulkhead may extend forward of the limit specified above.

The position of the bow ramp of ESTONIA did not satisfy the SOLAS requirements for an upper extension of the collision bulkhead. No exemption was issued. Such an exemption could be given on condition that the vessel in the course of its voyages did not proceed more than 20 nautical miles from the nearest land.

The building specification stated that a "partial collision door" was "for the intended service not required by the Finnish Board of Navigation". An upper extension of the collision bulkhead, complying with the SOLAS 1974 rules, should have been located minimum 4.27 m and maximum 7.27 m aft of the position of the lower end of the ramp (Figure 3.13). Complying with the 1981 Amendments to SOLAS 1974 the upper extension of the collision bulkhead could have been about 2 m further forward.

The surveys under the SOLAS convention were, during the period under Finnish flag, carried out by the Finnish Board of Navigation. Bureau Veritas had no authorisation to survey the vessel for compliance with the SOL.AS Convention. When Bureau Veritas surveyed the vessel for change of flag this was done in accordance with the requirements to the extent of a periodic survey, which did not include examination of construction drawings. The location of the extension of the collision bulkhead was thus not considered during this survey. The background and likely circumstances related to the location of the ramp are covered in Chapter 18.

3.6.4 Statutory inspections

The inspections of the vessel regarding compliance with international conventions and national regulations were, during the period under Finnish flag, carried out by the Finnish Maritime Administration except for compliance with the International Load Line Convention and the MARPOL Convention. The authority to perform surveys under these conventions was given to Bureau Veritas.

Bureau Veritas carried out the first load line survey at the time of delivery of the vessel. The compliance with the load line convention requirements was verified at the stipulated annual surveys and the five-year periodic surveys. The load line certificate was renewed when the ship changed flag in January 1993. The last annual inspection for verification of the load line certificate was carried out on 9 September 1994.

The Finnish administration

Between 1980 and 1992, the Finnish authorities carried out annual seaworthiness surveys, machinery surveys and certain other surveys required by Finnish maritime legislation. On the basis of these surveys, the Finnish Maritime Administration annually issued the vessel a SO- LAS Passenger Ship Safety Certificate demonstrating that the vessel met the requirements of the SOLAS Convention.

However, the records of the seaworthiness surveys carried out by the Finnish authorities regularly include a note that the surveyors have not carried out surveys of the hull or boiler, since these were done by the classification society.

In Finland, a Commercial Vessel Decree was originally issued in 1920 and reformed in 1924. According to section 45 of both decrees, a vessel is exempt from a hull survey if it has a valid classification certificate issued by a classification society approved by the Finnish Maritime Administration. On 18 January 1921, when the decree entered into force, the Administration approved certain classification societies, among them Bureau Ueritas, so that certificates issued by them exempted the vessel from the Administration's hull survey.

Before issuing the SOLAS Passenger Ship Safety Certificate, the Finnish Maritime Administration verified that the classification certificate was valid and that the classification society had carried out the hull survey Bureau Veritas also carried out machinery surveys on the vessel. However, the focus of the classification society surveys had been on issues related to the soundness of the machinery while the Finnish Maritime Administration surveys concentrated on equipment, for example fire safety equipment.

In 1983, a new decree was issued on ship surveys, which superseded the 1920 Commercial Vessel Decree. The new decree lacks provisions comparable to section 45 in the 1920 Decree. The practice of accepting classification society inspections as part of the basis for issuing a Passenger Ship Safety Certificate has, however, been retained under the new decree.

The Estonian administration

By an agreement signed on 18 August, 1992, the Estonian administration authorised Bureau Veritas to perform the statutory inspections on Estonian vessels being classed with that society This explicitly included inspections to verify compliance with the SOLAS, MARPOL and Load Line Conventions. Bureau Veritas accordingly performed inspections and issued new certificates as listed in 3.6.2 above.

Based on an agreement between Bureau Ueritas and the technical managers it was also arranged for certain items not covered by the conventions to be taken care of. Lifts for instance were inspected by the relevant Swedish authority.

The Estonian administration issued the Certificate for safe minimum manning of the vessel. The Estonian authorities also made their own inspection of crew accommodation arrangements and sanitary installations.

3.6.5 Classification society inspections

Bureau Veritas inspected the vessel for compliance with class requirements in accordance with their rules and standards. The main inspection period was five years and the items to be inspected were divided so that about one fifth of the total inspection work was carried out each year on a rolling schedule. The bow area was inspected under this programme in 1983,1988 and 1993. No discrepancies were recorded during any of these inspections.

3.7 Operational characteristics of the vessel

3.7.1 General observations

The vessel was equipped with two controllable-pitch propellers, two rudders and two bow thrusters. It was designed for berthing and unberthing without external assistance. Senior officers who have served on board the vessel have generally expressed satisfaction with the handling characteristics of the vessel. The fact that the navigation bridge was located aft of the front bulkhead of the superstructure in such a way that the bow of the ship was not visible from the bridge has not been reported as a disadvantage.

3.7.2 Speed resources

The ship had a contractual speed of 21 knots at 90 per cent of maximum continuous rating. The practical maximum operating speed of the ship in later years was considered to be 19 knots. This was adequate for the service in which the ship was engaged. To meet the timetable, the average speed in open sea was required to be about 17.0 knots on eastbound voyages and about 16.5 knots on west-bound voyages.

3.7.3 Stability documentation

The ESTONIA was built to satisfy the two-compartment-damage stability requirements specified for passenger ships in the 1974 SOLAS Convention. In the shipyard's trim and stability book, seven loading conditions were given in the damage stability conditions were checked and found adequate. These included residual metacentric height, heel angle and freeboard to the margin line.

A new trim and stability manual was developed, based on inclination tests carried out in Turku on 11 January 1991. The new manual was approved by the Finnish Maritime Administration. It was subsequently approved by Bureau Veritas in conjunction with the change of flag.

The Commission has noted that at the inclination test, the ship's centre of gravity, was positioned to starboard to such an extent that the port-side heeling tank was filled with about 115 t more water than the starboard tank in upright condition. The load cases in the trim and stability manual, however, include the heeling tanks as being either both empty or both full.

Damage stability was checked by Bureau Veritas for compliance with the requirements in the 1992 Amendments to SOLAS and it was concluded that the vessel also complied with the new requirements for existing vessels, i.e. the damage stability index met to 95 % that required for new passenger ships. These additional damage cases were intended to be incorporated in the trim and stability manual and were approved separately on 16 September 1994.

In normal sailing condition the vessel had a transverse metacentric height of about 1.2 m in combination with a slight trim by the stern and a draft of about 5.5 m.

3.7.4 Seakeeping characteristics

The vessel had extensive flare in the bow area. This gave rise to wave impacts during running in heavy seas. The flare slamming was noticed on board as heavy bangs and shaking of the entire ship. Senior officers who have been interrogated on the issue of the vessel's seakeeping behaviour have generally expressed satisfaction with the vessel, with the remark that one had to reduce speed or change course in heavy head seas for the comfort of passengers.

CHAPTER 4 OPERATIONS ON BOARD

4.1 General

The work schedule for the crew of the ESTONIA was in general two weeks' service on board, followed by two weeks ashore. Consequently two full crews were employed alternately and all positions on board were held by two persons.

In the deck department there were, besides the master, five deck officers, one radio officer and eight ratings. Organisationally the ship's doctor was also a member of the deck crew. The engine department consisted of eight engineers and eight ratings. In the catering department there were eight positions with officer's status and 113 other staff.

4.2 The crew

4.2.1 The manning of the ship

Prior to departure on 27 September 1994 a crew list of 186 people was presented to the Tallinn harbour master. Of these 149 comprised the actual crew, which was into the l3th day of its current 14-day duty period. In addition the list contained 6 trainees,18 entertainers, 9 advisors and 4 crew members of the alternate crew One of them was the master of the alternate crew, aboard for examination for his pilot exemption certificate.

All members of the actual crew were employed by the Estonian Shipping Company (ESCO). When senior officers were to be employed, Nordström & Thulin was consulted in compliance with the contract on technical management.

Nine advisors (one master mariner with pilot exemption certificate for the two fairways used in the Stockholm archipelago, one advisor with knowledge of the ship's computer systems and seven with long experience of catering in Baltic ferry traffic) were all employed by the Swedish manning company Rederi AB Hornet. Before employment, catering personnel were recommended by Estline and the pilot and the computer specialist by Nordström & Thulin.

All the deck officers and most of the crew were Estonian citizens. The working language on board was Estonian, and that language was understood by all crew members.

All crew members held certificates required for their positions on board.

4.2.2 Qualifications of the deck officers and the deck crew

The deck officers on board Estonian vessels - as well as on Swedish and Finnish - are called chief officer, second officer, third officer and fourth officer. The ESTONIA had two second officers, here designated second officer A and second officer B.

The master

The master was born in 1954. He graduated at the Maritime School of Tallinn in 1973 and started his career at sea in 1974. He served as fourth and third officer until 1977. He studied at the Admiral Makarov Highest Engineering Maritime Academy in Leningrad from 1977 to 1982. He subsequently served as second and then chief officer until 1986, when he got his master mariner's licence, and his first command as master on general cargo ships in transocean traffic.

In 1992 he became master of the passenger ship GEORG OTS on the route between Tallinn and Helsinki. When the ESTONIA was bought, he was appointed first captain. He was from the start involved in the transfer of the

' The Maritime School of Tallinn together with the Tallinn Fisheries Maritime School merged to form the Estonian Centre of Maritime Education which was

established on 1 January 1992 and is the highest maritime academy in Estonia.

Leningrad changed name to St. Petersburg in November 1991

ship and development of the organisation on board. After Estonia's re-independence and the creation of the new Estonian Maritime Administration, he received in 1994 the first master mariner's certificate issued in Estonia.

He held radiotelephone operator's general certificate, Automatic Radar Plotting Aid (ARPA) certificate and a pilot exemption certificate for the fairway via Sandhamn through the Stockholm Archipelago. He had just before the accident passed his examination for the fairway via Söderarm.

In addition to his formal licence, he had taken relevant courses in, among other areas "Passage planning in narrow waters".

Apart from his native Estonian, he was able to communicate in Swedish, English, Finnish and Russian.

The chief officer

The chief officer was born in 1964. He graduated at the Admiral Makarov Highest Engineering Maritime Academy in Leningrad in 1988. He held a chief officer's unlimited licence. He had served as third officer on general cargo ships 1988- 1990 and was third and then second officer on the GEORG OTS 1990-1992. In January 1993 he was appointed second officer on the ESTONIA, and in August 1994 was promoted to chief officer.

He also held radiotelephone operator's general certificate and ARPA certificate. He had taken additional courses in, among other subjects, "Passage planning" and "Bridge Resource Management".

The second officer A Second officer A was born in 1963. He graduated at the Maritime School of Tallinn in 1988. He held an officer-of- the-watch licence, issued in Leningrad in 1988. He served as third officer on ro-ro vessels between 1988-1992. In 1992 he became second officer on the GEORG OTS. From 1993 he was appointed second officer on the ESTONIA.

He held radiotelephone operator's general certificate and ARPA certificate. He had also taken additional courses in "Passage planning" and other subjects. The second officer B Second officer B was born in 1964. He held a chief officer's unlimited licence, issued in Tallinn in 1994. He graduated at the Admiral Makarov Highest Engineering Maritime Academy in Leningrad in

1991. In 1992 he was second officer on the GEORG OTS and from 1993 held the same position on the ESTONIA.

He held radiotelephone operator's general certificate and ARPA certificate. He had also taken additional courses in "Passage planning" and other subjects.

The third officer

The third officer was born in 1966. He graduated at the Maritime School of Tallinn in 1988 and at the Kotka Maritime College, Finland, in 1992. He held an officer-of-the-watch licence, issued in Helsinki in 1992. He was appointed fourth officer on the ESTONIA in 1993 and in 1994 promoted to third officer.

He held a radiotelephone operator's general certificate, issued in Helsinki in 1992. He also held an ARPA certificate, and had taken additional courses in among other things "Passage planning". The fourth officer The fourth officer was born in 1973. He graduated at the Estonian Centre of Maritime Education in Tallinn in 1992. He held an officer-of-the-watch licence, issued in Tallinn in 1994. In 1993 he was appointed quartermaster on the ESTONIA, and in 1994 he was promoted to fourth officer.

The radio officer

The radio officer was born in 1941. He graduated as ship's radio operator and radio navigator at Tallinn Technical School No.1. in 1962 and at the Tallinn Fisheries Maritime School in 1986. He held a first-class radio operator certificate, issued in Leningrad in 1974. He had served as radio officer in cargo ships 1962- 1993. In March 1993 he was appointed radio officer on the ESTONIA.

The deck ratings

The boatswains and all the able seamen had attended the general ship safety course on the training vessels ARZA- MASS or KORALL.

The AB seaman of the watch during the critical hours of the accident was born in 1970. He was employed by ESCO in January 1993. Before serving on the ESTONIA, he had worked on board the ro-ro ferry TRANSESTONIA and on the GEORG OTS.

4.2.3 Qualifications of the engineers and the engine crew

The engine officers on board Estonian vessels - as well as on Swedish and Finnish - are called chief engineer, first engineer, second engineer and third engineer.

The chief engineer

The chief engineer was born in 1950. He graduated at the Maritime School of Tallinn in 1972 and at the Admiral Makarov Highest Engineering Academy in Leningrad in 1989. He held a chief engineer's unlimited licence, issued in Tallinn in 1994. From 1972 until 1990 he worked as third, second and chief engineer in different vessels. He served as chief engineer on the ro-ro ferry TRANS- ESTONIA and on the motor vessel SAINT PATRICK II 1990-1993. From February 1993 he was chief engineer on the ESTONIA.

The first engineer

The first engineer was born in 1952. He graduated at the Admiral Makarov Highest Engineering Academy in Leningrad in 1976. He held a first engineer's certificate, issued in Leningrad in 1976. He also held a certificate from the Advanced Training Course in Leningrad in 1990.

He worked as fourth, third and second engineer in various vessels 1976-1992. In January 1993 he was appointed second engineer on the ESTONIA and in June 1993 promoted to first engineer.

The second engineer

The second engineer was born in 1947. He graduated at the Maritime School of Tallinn in 1968 and at the Admiral Makarov Highest Engineering Academy in Leningrad in 1981. He held a second engineer's certificate, issued in Leningrad in 1972.

He served as third and second engineer on various vessels 1968-1981, and between 1982 and 1992 he was third engineer on a ro-ro vessel. In January 1993 he was appointed second engineer on the ESTONIA.

The third engineer

The third engineer was born in 1964. He graduated at the Admiral Makarov Highest Engineering Academy in Leningrad in 1990. He held a third engineer's certificate, issued in Leningrad in 1990.

He served as fourth and third engineer on different vessels 1990-1993. In July 1993 he was appointed fourth engineer on the ESTONIA and in September 1994 he was promoted to third engineer

The fourth engineer

The fourth engineer was born in 1966. He graduated at the Maritime School of Tallinn in 1986. He held a third engineer's certificate issued in Leningrad in 1986.

He served as motorman and fourth engineer in cargo ships 1989-1993. In 1994 he was appointed motorman on the ESTONIA and from September he was promoted to fourth engineer.

The electrical engineer

The electrical engineer was born in 1951. He graduated at the Admiral Makarov Highest Engineering Academy in Leningrad in 1974. He held a first-class electrical engineer's licence, issued in 1984.

Since 1977 he had worked on board different types of ship as electrical engineer. In January 1993 he was appointed electrical engineer on the ESTONIA.

The refrigeration engineer

The refrigeration engineer was born in 1959. He graduated at the Tallinn Fisheries Maritime School in 1978. He held a refrigeration engineer's certificate, issued in Tallinn in 1992.

He worked as refrigeration engineer in a fishing company 1978-1992. In January 1993 he was appointed refrigeration engineer on the ESTONIA.

The systems engineer

The systems engineer was born in 1969. He graduated at the Maritime School of Tallinn in 1991. He held a third engineer's certificate issued in Leningrad 1991. He held positions as fourth engineer 1991-1992. In January 1993 he was appointed systems engineer on the ESTONIA.

The engine ratings

There were eight ratings in the engine department: four senior motormen, two electricians, one welder and one turner. All had passed the general ship safety course on the training vessels ARZAMASS or KORALL.

4.2.4 The catering crew

The highest-ranking officer of the catering crew was the chief purser (sometimes called hotel purser). He was born in 1965. He had been employed by the ESCO since 1985. He had passed the general ship safety course.

The professional qualifications of the catering crew have no relevance for the accident. The only aspect for the investigation is their role in the ship's safety organisation.

4.3 Working routines and organisation

4.3.1 Deck department

The master was responsible for all activities on board the vessel. He reported to the ESCO on all matters regarding navigation, day-to-day operation, personnel and related issues. In technical matters, he reported to Nordström & Thulin.

The master in command on the accident night was the Number 1 master of the ESTONIA, and it was he who, together with his superiors at the office, laid down rules and routines for work on board. According to standing orders laid down by him the various responsibilities and duties, in addition to normal watch duties, were divided between the deck officers as described below

The chief officer had the responsibility for cargo operations and the planning of these. He was also responsible for the daily work of the deck crew.

The second officer A was responsible for the navigation equipment, and also assisted the chief officer with cargo operations. He led the port lifeboat group and was responsible for associated life-saving equipment.

The second officer B was responsible for stability calculations prior to departure, and assisted the chief officer with the cargo operations. He also led the starboard lifeboat group and was responsible for associated life-saving equipment.

The third officer was in charge of nautical charts and literature, and was also responsible for the calibration of all clocks on board.

The fourth officer was responsible for keeping the log of the working hours of the deck crew, and for keeping lists of certificates of competence and passports for the deck crew. He was also responsible for cargo declarations to the harbour authorities, and for the documentation of cargo operations.

The radio officer was responsible for the radio, including the emergency beacons (EPIRBs), and communication equipment, and in co-operation with the second officer A for the maintenance of the electronic navigation equipment. He was also responsible for making and updating crew lists. The ESTONIA was certified for pre-GMDSS operation (7.3.1), and consequently the radio officer had to keep watch on 500 kHz and 2182 kHz. The watch hours at sea were from 1900 hrs to 0100 hrs.

When the vessel was at sea, there were always two officers and one AB seaman on duty.

On westbound voyages, the second officer B was on duty between 2000 hrs and 0100 hrs assisted by the third officer, and the second officer A was on duty between 0100 hrs and 0600 hrs, assisted by the fourth officer. For the periods between departure and 2000 hrs and between 0600 hrs and arrival, the bridge watch was taken by the master and the chief officer.

During the sea voyage, the AB seamen changed watches at 2200, 0200 and 0600 hrs. Their duties at sea were to be additional lookouts and to make watch rounds on a defined route throughout the vessel (Supplement). These rounds were made once every hour, starting at 2030 hrs, and lasted for about 25 minutes.

Watch rounds were also made by the security guards. They had no other duties than to ascertain the safety and security of the vessel and the passengers, and they patrolled continuously

4.3.2 Engine department

The chief engineer was responsible for the organisation and all work in the engine department, for the purchase and storage of spare parts and consumables, and for the technical maintenance of the entire vessel. He reported to the technical superintendent of Nordström & Thulin, and certain parts of these reports were copied to ESCO.

The first engineer was responsible for the maintenance and running of the main engines and the propulsion system.

The second engineer was in charge of the separators, the steering gear and all other hydraulic and pneumatic systems, including the systems for manoeuvring and locking the visor, the ramps and the hull doors.

The third engineer was in charge of the compressors, the bunkering of the vessel, and of the electrical generator sets, including the emergency generator.

The fourth engineer was in charge of boilers, deck machinery and lifeboat engines.

The systems engineer was in charge of the fresh water distribution systems, the sewage system and the galley equipment.

The refrigeration engineer was in charge of the air conditioning plant and the refrigerating plant for storerooms.

The electrical engineer was in charge of all electrical systems and installations. The work schedule in the engine department was a traditional three-watch system. On each watch there were one engineer and one motorman.

The 1200-1600 hrs and 2400-0400 hrs watches were held by the third engineer, the 0400-0800 hrs and 1600-2000 hrs by the second engineer and the 0800- 1200 hrs and 2000-2400 hrs by the fourth engineer.

4.3.3 Catering department

The total number of persons employed in the catering department was 121.

Many of them spoke two or more languages. In addition to Estonian, English was compulsory for all persons in positions involving work contact with passengers.

The catering department was managed by the chief purser, who was responsible for the organisation and conduct of the work. He was also responsible for the commercial result of the department. Regarding personnel, maintenance and other operational matters, he reported to ESCO, via the master. His economic reporting was to Estline in Stockholm.

The catering department consisted of five sub-departments with their own managers. The sub-departments were the hotel department including the information desk, the galley; the restaurant department including the conference department, the tax-free shops and the automatic data processing (ADP) administration. The security guards were administrated by the hotel department, but they reported direct to the master.

The chef, the restaurant manager, the shop manager, the ADP administrator and the conference purser were employed on behalf of Nordström & Thulin in accordance with the agreement on ship management between the parties involved. They were formally employed as advisors and were consequently not part of the crew. However, they acted in all aspects as responsible work leaders for their departments. Since they were not crew members, they were not included in the safety organisation of the vessel.

The catering department working hours were adapted to the opening hours of the various restaurants, bars and shops. The information desk was manned 24 hours a day and, during the busy periods 0900-1100 hrs and 1700-2200 hrs, by two pursers.

4.4 Safety organisation

4.4.1 The development of the safety organisation

When the operation of the ESTONIA was taken over by ESCO in 1992, a new safety organisation was established. The new organisation was based partly on the previous owner's organisation plan, and partly on the experience of Nordström & Thulin from their previous vessel on the same route.

All documents, plans and manuals included in the safety system were in both Estonian and English, and the safety organisation was implemented at all crew levels prior to commencement of traffic. The safety organisation was tested during the port state control in February 1993 (see 3.2.10). The safety organisation and the training and implementation thereof were described in the emergency plan, the safety manual and the training manual.

4.4.2 Alarm signals

Various types of alarm were used on board the ESTONIA. The lifeboat alarm and fire alarm were general alarms, addressed to passengers and crew. Besides these there was a coded alarm "Mr Skylight" addressed only to the crew and intended to alert relevant parts of the safety organisation.

The alarms were described in the emergency plan and in the safety manual, available at various locations in the crew accommodation such as mess rooms, day rooms and all major workplaces.

Lifeboat alarm

The lifeboat alarm - seven short sound signals, followed by one long one - was given repetitively with the alarm bells and/or the vessel's horn. When the alarm was given, the command group, the port and starboard boat groups, the engine control group and the eleven evacuation groups were alerted.

Fire alarm

The fire alarm - continuous repetitive short sound signals - was also given with the alarm bells and/or the vessel's horn. When the alarm was given, the command group, the two fire groups, the engine control group, the control group, the port and starboard boat groups and the first aid group were activated.

"Mr Skylight"

Without alarming the passengers, the crew could be alerted over the public address system with the coded message "Mr Skylight". This message could also be used with a suffix. Depending on which suffix was used, selected parts of the safety organisation were activated. The boat groups were activated by all Skylight messages.

4.4.3 Alarm groups

The safety organisation was led by a command group mustering on the bridge. The command group consisted of the master, the chief engineer, the chief officer, the chief purser and the third officer.

The master was the overall commander of the operations. The chief engineer was the fire chief, commanding the two fire groups and the engine control group. The chief officer was responsible for stability calculations and was also the deputy fire chief. He commanded the port and starboard lifeboat groups, the first aid group and the helicopter groups. The chief purser was responsible for evacuation, the evacuation groups reporting to him through forward and aft zone leaders. The third officer's main responsibility was to record times of events and to take notes.

According to the emergency plan and the safety manual, the chief officer - not the radio officer - was responsible for external radio traffic. The reason for this is believed to be that the safety organisation for the ESTONIA was partly copied from organisation plans made for vessels not carrying a radio officer. The Commission has not been able to elucidate whether this order was applied in practice

Various checklists were included in the equipment of the command group. Among these were checklists for collision, grounding, leakage and evacuation.

Fire groups no.1 and no. 2 were led by the second engineer and the third engineer respectively They were alerted by the coded alarm signal "Mr Skylight" and by the general fire alarm given by the alarm bells. A number given after "Mr Skylight" indicated the fire station where the group should meet. The call "Mr Skylight" followed by the Estonian words for "damage control" indicated that the damage control group should bring equipment for damage control and without further instructions start their work. Fire group 1 was trained and equipped mainly for fighting fires in the accommodation, and fire group 2 was focused on fires on the car deck and in the engine room. Fire group 2 was also trained in the use of chemical protection equipment.

The engine control group was led by the first engineer, and the only other member was the motorman on duty The group was alerted by the "Mr Skylight" alarms, and by lifeboat and fire alarms. The muster station for the engine control group was the engine control room, and the prime task was to relieve the engineer on duty and take over responsibility for the running of the engine plant.

The lifeboat groups were alerted by the call "Mr Skylight" and by the general alarms. The muster stations were for the port lifeboat group number 2 lifeboat and for the starboard lifeboat group number 1 lifeboat. The main responsibility for the lifeboat groups was to ready lifeboats and liferafts for launching, and to prepare the ladders for use. Organising passengers on boat deck and distributing lifejackets were also duties included in the directions for these groups. Each group was under the command of a second officer and consisted of four other members. Four of these, two in each group, belonged to the deck crew and the other two were from the catering crew. The members of the lifeboat groups were all assigned positions in the lifeboat or liferaft crews.

The first aid group was led by the ship's doctor, and consisted of 11 members. The group was alerted by the call "Mr Skylight 727", and the meeting place was the ship's hospital. The meeting place could be somewhere else, and in this case a suffix was added to the alarm call, indicating the meeting place. The main duties of the first aid group were to take care of injured and/or deceased persons, give first aid and prepare them for transport ashore or to other vessels. In an emergency situation which included "abandon ship", the first aid group was also responsible for moving the injured to lifeboats.

The helicopter group was not intended to work in "abandon ship" or other situations when the entire safety organisation was mobilised. The group was therefore made up of persons with suitable skills from other groups in the emergency organisation such as the lifeboat groups and the fire groups. The tenmember helicopter group was led by the second officer and its duties were to prepare the vessel for helicopter landing.

For restricted evacuation and for closing off specific areas, there was a control group. The seven-member group was led by the security assistant. This group was alerted by a "Mr Skylight" alarm, and assembled at the cashier's office on deck 5. The duties of the group included restricted evacuations, searching of restricted areas, blocking off of areas where other groups were working, and assisting the first aid group. The control group was disbanded by the lifeboat alarm, the members then taking other duties in the evacuating groups.

Total evacuation of the vessel was the responsibility of 11 evacuation groups, led by the forward and aft zone leaders. The forward zone leader was in charge of groups l, 2 and 3 and responsible for evacuation through the forward staircase. The aft zone leader was in charge of the other eight groups, and responsible for evacuation through the aft staircase. The evacuation groups were mustered by the lifeboat alarm or by "Mr Skylight". Each group had a specified area to evacuate, from the muster station within, or in the vicinity of, that area. The evacuation groups were as far as possible composed of persons normally working in the area they were to evacuate, to ensure local knowledge thereof.

Each lifeboat had seven crew members with defined duties during launching and on board. All liferaft stations had one station leader, and there was one raft leader for each liferaft. Every crew member was assigned his/ her own unique alarm number upon commencing service on board. This alarm number indicated his/her duties and position in the safety organisation.

4.4.4 Training and drills

The various groups in the safety organisation drilled according to the vessel's exercise schedule. The drills were led by the group leader, who also made a report of the content of the drill and of any group members absence. This report was submitted to the responsible officer in the command group.

The fire groups, the engine control group and the boat groups were scheduled for training every two weeks, and the first aid group and the evacuation groups were to exercise once every month.

Lifeboats on the port side were launched into the water every three months, and those on the starboard side once a year. Under normal operation the vessel always had her starboard side alongside the dock. The starboard lifeboats were, however, lowered every three months.

Of the current crew, 142 had undergone a one-week IMO-approved safety training course on a training vessel, and were certified as proficient with survival craft.

When the ESTONIA commenced her traffic between Tallinn and Stockholm, an operative control was carried out on board by the Swedish Maritime Administration. The control included implementation of the entire safety organisation and a check on the skills of the crew in conducting their duties according to the plan.

In January 1994 the ESTONIA also participated in a major fire exercise. The purpose of this exercise was to train co-operation between helicopter-landed, shore-based, fire-fighters and the vessel's safety organisation.

CAPTER 5 THE CIRCUMSTANCES OF THE VOYAGE

5.1 Timetable and route

The ESTONIA operated on the route between Tallinn and Stockholm. She left Tallinn every second night at 1900 hrs and arrived in Stockholm the next morning at 0900 hrs local time. She left Stockholm the same day at 1730 hrs local time and was back in Tallinn the next morning at 0900 hrs. As the vessel was in port a great part of the day a late arrival did not affect the next departure. In Tallinn the ship had her starboard side to the berth and the cargo was handled via the forward ramp. In Stockholm the ship docked in Frihamnen, and there also she had her starboard side to the berth. All ro-ro cargo handling in Stockholm took place via the aft ramps.

Normal passage through the Stockholm Archipelago was via Sandhamn, but when the weather conditions were considered unfavourable, the passage was via Söderarm.

The total distance between Tallinn and Stockholm via Sandhamn is 225 nautical miles and via Söderarm 228 nautical miles. To keep the schedule, the required average speed in unrestricted waters between Tallinn and Stockholm was 16.5 knots via Sandhamn and 17.0 knots via Söderarm. The normal time for entering the Stockholm Archipelago by the Sandhamn passage was 0515 hrs at the Revengegrundet lighthouse, and by the Söderarm passage 0425 hrs at the Söderarm lighthouse.

The voyages were very regular and, according to the log book at Stockholm Pilot station, the passing times at the Söderarm lighthouse did not vary more than about 15 minutes.

5.2 Status of the vessel on departure

On departure from Tallinn on 27 September the ESTONIA was seaworthy and properly manned. There were no outstanding items either from the authorities or from the classification society's surveys. The maintenance standard of the vessel was good as witnessed by various instances.

During the last day in Tallinn the vessel was used in a training programme for Estonian Maritime Administration surveyors in the conducting of a Port State Control in compliance with the Paris Memorandum of Understanding on Port State Control (see about Paris MOU in 9.1). The trainees made a thorough Port State Control inspection of the ESTONIA and were supervised and instructed by two senior inspectors from the Swedish Maritime Administration. The exercise was documented in protocol, set up in a form according to the Paris MOU. A copy of this protocol is included in the Supplement.

The Swedish inspectors leading the exercise have been interrogated by the Commission and have stated that the vessel was in good condition and very well maintained. They found no deficiencies that would have caused detention or other serious remark, if the inspection had been a regular Port State Control. However, some deficiencies were noted, such as that the rubber seals for the bow visor were worn, had tear marks in some places, and were in need of replacement, and watertight hatch covers on the car deck were open and in a condition indicating that at least one was not normally closed. It was also stated during the interrogation that the Swedish inspectors had experienced "lack of respect for issues related to load line matters" in their contact with officers met during the exercise.

5.3 The departure condition

The vessel had on departure from Tallinn a loading condition that was normal for the route. The car deck contained mainly cargo vehicles. The bunker and stores condition was based on the normal routine of supply during the stop in Stockholm. The trucks and trailers were identified on the cargo manifest for the voyage, giving information about vehicle identity length, weight and content in general.

Due to uneven weight distribution on departure the vessel's port side heeling tank was filled.

Instructions had been given by the chief officer to secure the heavy cargo carefully due to the forecast heavy weather.

Table 5.1. gives the departure condition of the ESTONIA. Dead-weight on departure has been estimated to a total of about 2300 t as detailed in Table 5.1. Quantities of oils and water have been estimated by Nordström & Thulin, based on the normal consumption rates and replenishment routines. The weight of the heavy vehicles is taken from the cargo manifest. One truck included in the custom list but not in the cargo manifest has been added to the weight given in the cargo manifest. The number of passenger cars, vans and buses is taken from the custom list. Their weight is an estimate. The hydrostatic particulars are based on calculations by the NAPA program assuming a water density of 1.01 t/m3. The transverse metacentric height of 1.17 m includes the correction due to free liquid surfaces.

According to the valid stability booklet the minimum required metacentric height was 0.63 m.

5.4 Meteorological conditions

5.4.1 Weather

Forecast Prior to departure from Tallinn the vessel had received the route-adapted weather forecast from the Swedish Meteorological and Hydrological Institute (SMHI) in accordance with the subscription arrangement. The forecast, issued on 27 September at 1311 hrs, was transmitted by fax and acknowledged by the ESTONIA in the afternoon. It contained the information shown in Table 5.2.

In Tallinn the Harbour Authorities forwarded the weather forecasts given by the Estonian Meteorological and Hydrological Institute (EMHI) to ships in port. The forecast distributed during the morning of 27 September predicted south- westerly wind of 12-17 m/s with a wave height of 2-3 m for the Northern Baltic area. At 1230 hrs a new warning message was issued, forecasting the wind to increase to 17-20 m/s, veering to west in the morning of 28 September.

Prior to departure the vessel also had the use of weather forecasts from the Estonian and Finnish regular broadcasting stations and coastal radio stations on VHF or MF and via the NAVTEX system.

The NAVTEX message - transmitted by Stockholm Radio on the morning of 27 September - forecast the wind to be SW 10-13 m/s, increasing first to 17-22 m/s and during the night to 20-25 m/s and veering to west.

After departure, marine weather forecast for the Northern Baltic and the Gulf of Finland could have been received on VHF The forecasts transmitted during the night of 27 September by Tallinn Radio, Helsinki Radio and Mariehamn Radio all included warnings of winds of 20 to 25 m/s from a westerly direction.

Prevailing weather

The weather situation on 27 and 28 September 1994 has been analysed by the SMHI, FMI and EMHI. The reports the analyses are given in full in the Supplement.

According to the reports there was a severe depression covering Northern Scandinavia and the Norwegian Sea. One of the low-pressure centres intensified on 27 September and moved rapidly eastward via southern Norway and eastern Sweden to southern Finland. The depression deepened and was located over Oslo on 27 September at 1400 hrs with pressure 987 hPa. On 28 September at 0200 hrs it was over the south-eastern part of the Gulf of Bothnia with 982 hPa, and at 1400 hrs over eastern Finland with 985 hPa.

A warm front, associated with this low, together with an area of rain, moved quickly eastward during the evening of the 27th over the northern Baltic Sea. South and south-west of the low, the wind shifted from south-westerly to westerly, and then became very gusty.

The wind direction, the mean and the maximum wind speeds in m/s at the most relevant observation sites are shown in Table 5.3. The indicated maximum values are the highest mean value for any 10-minute period during the preceding three hours except for Ristna, where the maximum values are measured in gusts. Maximum wind speed in gusts was also recorded at Bogskär and was 24.6 m/s at 2246 hrs on 27 September and 27.7 m/s at 0625 hrs on 28 September.

5.4.2 Waves

Wave conditions for the night of the accident have afterwards been calculated by the Finnish, Swedish and German institutes of marine research, MTL, SMHI and DW respectively using their own numerical models of wave growth. The most important input data to the wave calculation models were the estimates of area sea wind speed and direction for a certain time period before and after the accident. The basic wind data were provided by the national meteorological institutes. Wave calculation models predict significant wave height, wave period and mean wave direction at different points of the sea area under consideration. Significant wave height is defined in the numerical models by the area under the wave spectrum, but is very close to the statistical measure of the mean value of the highest one-third of the waves. Table 5.4 shows the significant wave height Hs, spectrum peak or modal wave period T, and the mean direction of the waves predicted by the Finnish, Swedish and German institutes of marine research before, during and after the accident.

MTL experience is that the root-mean- square error in predicted significant wave height is about 0.5 m, in wave period about 1 s, and in wave direction about l0a.

Due to the wind shift six hours before the accident, waves were at the time of the accident still duration-limited. If the wind direction had remained constant, the waves would have been fetch-limited, significant wave height could have been about 5 m and the modal period about 10 s. This gives the absolute upper limit for the significant wave height.

Numerical predictions by MTL show that significant wave height may increase significantly in shallow water due to focusing of refracted waves. The minimum water depth in the accident area as verified by the Finnish Maritime Administration was over 40 m, which means that there was no shallow-water effect on the route of the ESTONIA.

Numerous studies of wave statistics in a seaway show that during a short interval when the significant wave height may be assumed constant, the distribution of measured wave crest-to-trough heights and heights of individual wave crests and troughs follow closely the Rayleigh distribution. Table 5.5 shows probabilities of an individual wave height exceeding different levels determined by the Rayleigh distribution. Wave height is given in a non-dimensional form divided by the significant wave height

Thus, if the significant wave height is 4 m, one wave in 100 will be higher than about 6 m. Often as a rule of thumb the maximum wave height is estimated as twice the significant height.

The calculated significant wave height of about 4 m agrees well with visual observations made on board vessels which took part in the rescue operations. Masters of these vessels have estimated that before the accident waves were not higher than 5-6 m while after the accident individual waves were up to 7-8 m high and in general the wave height was 4-6 m. The estimates of wave height by the Swedish helicopter pilots who arrived at the accident site between 0350 hrs and 0645 hrs vary more than estimates by the mariners. A majority of the pilots have given estimates between 5-6 m or 6-8 m, one pilot gave 6-9 m and another 6-10 m. One pilot reports even a single very high wave of 12 m height measured by radar.

5.4.3 Light conditions and visibility

During the night of the accident the moon was about half in the last quarter. Moonrise was at about 2150 hrs and sunrise at about 0625 hrs.

Pictures from weather radar's (Figure 5.1) show that broken cloud fronts were passing over the Northern Baltic and the accident area at about the time of the accident.

The night was cloudy with an occasional clearing of the sky just before midnight. After midnight the cloud coverage gradually increased again and in the early morning the sky was cloudy

For most of the night visibility was more than ten nautical miles, but was occasionally reduced by rain showers.

5.4.4 Hydrological conditions

Currents were not measured during the night of the accident in the northern Baltic. However, the surface current speed and direction were later estimated by both MTL and SMHI.

According to MTL the velocity of the surface current was between 0.2 and 0.6 knots in an easterly direction at the time of the accident. The velocity of the current was estimated by SMHI to be 0.5 knots in a direction between east and north east. A surface water temperature of between l2° C and l3° C was measured in the accident area before midnight on 27 September. After midnight the temperature dropped to lO° C-ll° C.

The air temperature during the night was l2° C-8° C.

5.5 Speed

There are no recordings of the speed of the ESTONIA during her voyage from the harbour in Tallinn to the time of the accident. The Commission has made an estimation of how the speed was affected by the waves, inter alias by comparing her speed with the speed of the SILJA EUROPA, another passenger ferry steering a nearly parallel course about eight nautical miles north of the track of the ESTONIA. Other available observations have also been used in the estimations. The speed of the SILJA EUROPA is taken from the DGPS recording which 30 times/ minute registers the position, the time, the speed over ground, the course over ground and the heading. The data reveal how the speed was affected by the wind and waves.

The ESTONIA departed from Tallinn 15 minutes late from her normal schedule. The manoeuvre from the port to the Tallinn leading lights is estimated to have taken about 10 minutes. It must be assumed that full service speed, i.e. about 19 knots, was maintained from the Tallinn breakwater to Osmussaar lighthouse, which she passed very close at 2200 hrs. Her estimated speed was still close to 19 knots and she was now a few minutes ahead of normal schedule. Between 2215 and 2245 hrs (approximate) the ESTONIA was plotted by a meeting vessel, the AMBER and according to AMBER's plot, the speed was then about 18.5 knots. The speed of the SILJA EUROPA was at this point 18.8 knots and further decreased to 17.6 knots between Russarö lighthouse and the Apollo buoy.

After passing Osmussaar lighthouse the ESTONIA lost her land shelter and the sea conditions deteriorated. Based on experience it is believed that the sea conditions were slightly worse in the area where the SILJA EUROPA was sailing.

At about 2255 hrs the Apollo buoy was abeam and the ESTONIAs speed is estimated to have been close to 17 knots. The ESTONIA passed the Glotov buoy at about 2355 hrs and, by comparing with the SILJA EUROPA, it can be assumed that her speed was now about 15 knots. This estimate is also confirmed by the trainee second officer, who has stated that the speed was between 14 and 15 knots, as well as by the third engineer who has stated that the speed was 15 knots when he started his watch in the engine control room at midnight.

During the first thirty minutes after midnight the average speed of the SILJA EUROPA dropped by about one knot.

When the ESTONIA reached the waypoint at 59o20$ N, 22o00$ E between 0025 and 0030 hrs, her true course was changed from 262o to 287o and the stabilisers were extended. Her average speed was between 14 and 15 knots. Table 5.6 gives the speed of the SILJA EUROPA and illustrates how the sea state affected her speed. At 0042 hrs the SILJA EUROPA changed course from 259o to 276o. The change of course and possibly also deteriorating sea conditions resulted in increased motion of the vessel and at 0059 hrs the officer of the watch reduced the speed to 13 knots. The position of the SILJA EUROPA at about 0100 hrs was bearing approximately 350o and distance 10 nautical miles from the ESTONIA. In the table the Max, Min and Aver columns give the highest, the lowest and the average speeds, respectively, during one minute.

CHAPTER 6 SUMMARY OF TESTIMONIES BY SURVIVORS

6.1 Introduction

Chapter 6 is based upon 258 testimonies from 134 survivors interrogated between 28 September, 1994 and 2 February 1997. (One Swedish survivor was not interrogated because of post-traumatic distress and two Latvians left for their home country before being interrogated. All three were passengers.)

The major part of the interrogations were conducted by the Estonian, Finnish and Swedish police and mainly in those three languages. Interrogations by Commission members have, whenever applicable, been interpreted into either Swedish or English.

Police interrogations in languages other than Swedish have been translated into Swedish and this summary is based on the Swedish text.

Some details deviate from what witnesses actually stated. The Commission has edited some detailed statements in order not to confuse the reader in cases where witnesses have made obvious mistakes, e.g. regarding deck numbers or other locations on the vessel. Statements concerning timing, estimations of list as well as all quotations are, however, at all times written as stated.

The summaries follow the witnesses' statements as closely as possible. Some of the details may therefore not necessarily correspond with facts or other findings and may consequently differ from conclusions made by the Commission in other chapters.

6.2 Summary of testimonies by surviving crew members on duty

Two officers and one able-bodied (AB) seaman were, at the time of the accident, on watch on the bridge, and one engineer and one motorman in the engine room. The system engineer was called in for duty during the night. The master of the ship's alternate crew was also on board on this particular voyage. He was to do an examination for a Pilot Exemption

Certificate. He performed no duties during this voyage. There was also a trainee second officer on board.

At 0100 hrs there was a normal watch change for the bridge officers. Normally the relieving officers arrived on the bridge 5-10 minutes before the change and the relieved officers left the bridge about 5 minutes after the change.

The trainee second officer, the AB seaman of the watch, the third engineer, the motorman on watch and the system engineer survived. All of them have been interrogated several times by the Commission and the police. The other surviving crew members and passengers have been interrogated by the Estonian, Finnish and Swedish police and some also by Commission members.

6.2.1 Summary of testimonies by the trainee second officer

The trainee second officer was interrogated five times: 1. 29 September 1994 in Turku by the Finnish police. 2. 29 September 1994 in Tallinn by the Estonian police. 3. 7 October 1994 in Tallinn by the Estonian State Security Police. 4. 17 October 1994 in Tallinn by Commission members. 5. 28 August 1996 in Tallinn by the Estonian police.

The basis for the present summary is the earliest testimony Where subsequent interrogations reveal more information or contradict the earliest testimony the later testimonies are referred to in square brackets. The trainee second officer was on board to be trained for deck officer's duty aboard the MARE BALTICUM, a recently acquired passenger ferry He had passenger cabin number 4103 on deck 4.

He was on the car deck and followed the loading between 1520 hrs and 1830 hrs. Between 1520 hrs and 1845 hrs [4]. All the lorries were lashed down with straps and chocks were used for the cars. Heavy trucks were loaded centre-line aft and smaller trucks and cars at the forward end. Although this witness left shortly before the loading was completed he understood that they were carrying a full load on the car deck. When in Tallinn the ship was without list, but in the open sea, the strong wind caused a starboard list of 2-4 degrees.

The trainee second officer went to the bridge at about 2020 hrs. The master together with the master of the alternate crew came up to the bridge after 2100 hrs. Both stayed on the bridge for 20-30 minutes.

A large wave hit the ship's port bow at about 2300 hrs. The master arrived on the bridge about 30 minutes later and stayed for 15 minutes. He asked the third officer whether all four engines were running and got an affirmative answer. The trainee second officer then heard the master's order to activate the stabilisers after passing the waypoint. The master left the bridge about 15 minutes before the ESTONIA reached the waypoint. Her speed at this time was 14-15 knots. The waves and the wind came from different directions, the wind being more southerly than the waves. The wind was south- west and veering west [4].

After the ESTONIA changed course, the second officer B on the watch told the trainee second officer that the speed was somewhat reduced because of the stabilisers. At about 0000 hrs the sea was heavy

After the waypoint the AB seaman on watch arrived after completion of his round. He reported that everything was normal but that people were seasick. The trainee second officer left the bridge for his cabin about 0030 hrs or 5 to 10 minutes later. He also said that he left at 0030 hrs when the AB seaman started his next round and that the speed was about 14.5-15 knots [4, 5]. He was in his cabin for a couple of minutes and then went to the Pub Admiral. He thought that he saw the AB seaman on watch in the doorway to the bar. In a later testimony [3] he stated that he saw the AB seaman in the staff doorway He also stated [4] that the time was 0030-0040 hrs. He went back to his cabin at about 0050 hrs.

He went to bed but was not yet asleep when, after 5-10 minutes, he heard a strange unfamiliar sound which could have been a blow or something like a vibration [4]. He could not say where the sound came from but after this, the ship heeled over to starboard. He got the feeling that something was amiss [2]. He started to dress to get out on deck quickly Before he had put on his shoes, the list increased and the table slid towards the door.

He left his cabin and found the corridor empty. Up on deck 5 there were some 20-30 people running to and fro. While moving between decks 6 and 7 on the main staircase he heard a noise as from a blow and thought this was the noise of trucks moving [4]. The list increased and people were hanging onto the handrail which came loose. People fell to the floor and there was panic. In the staircase several injured people, drunks and halfdressed people were trying to ascend. This was difficult, however, due to the panic. It was also difficult to climb between decks 6 and 7 because the handrail was loose. The witness managed to climb up to deck 7 together with the boatswain [5] and now the list was so great that it was impossible to walk on the carpets, it was difficult even to crawl. They helped each other out to the open deck and he estimated the list at this time to about 45 degrees [5].

On the open deck 7 there were 70- 100 people; in another testimony he put the number at 150 to 200 [4]. Together with other crew members he started to distribute lifejackets and after a while other crew members started trying to release lifeboats. Others threw lifejackets to people who were unable to climb the stairs.

He left the ship, jumped into the water and looked at his watch which showed 0130 hrs. In other testimonies [3, 4] he has stated that he looked at his watch, ran aft and slid into the water. When he looked at his watch the stern was already under water up to the stabiliser fin [4]. He left the ship when the list was approximately 90 degrees, the stern was into the water and the ship's siren sounded [5]. He came under a liferaft with his lifejacket down around his waist. Because his feet and one hand were tangled in ropes, which he believed belonged to the raft's sea anchor, he was not able to get onto the first raft, which drifted away Another liferaft drifted towards him upside-down and with the help of a young man he managed to climb on board. On top of this raft there was also a naked elderly man and beneath the raft a Swedish man. They were all rescued by a helicopter at about 0700 hrs.

6.2.2 Summary of testimonies by the able-bodied seaman (AB seaman) on watch

The AB seaman on watch was the only survivor of those on duty on the bridge during the critical hours. His duties were to make 25-30-minute rounds in the ship. The round commenced 30 minutes past every hour. During the rounds he was to check the general order and fire safety in the accommodation and on the car deck. Between rounds he was on duty on the bridge as a lookout and handyman. The AB seaman has been interrogated eight times:

1. 29 September 1994 in Turku by the Finnish police.

2. 29 September 1994 in Turku by Commission members.

3. 3 October 1994 in Tallinn by the Estonian police.

4. 17 October 1994 in Tallinn by Commission members.

5. 17 November 1994 in Tallinn by the Estonian police.

6. 3 December 1994 in Tallinn by the Estonian State Security Police.

7. 31 March 1995 in Gothenburg by Commission members.

8. 27 January 1996 in Tallinn by the Estonian police.

This summary is based on the earliest testimony When subsequent interrogations reveal more information or contradicts the earliest testimony; the later testimonies are referred to in square brackets.

At 2230 hrs the AB seaman started his regular watch round. The round started from the bridge and he continued to deck 7 where the crew's cabins were. From deck 7 he went to deck 8 to check the rest-rooms and from there down to the car deck where he arrived at about 2235 hrs. On the car deck he checked the lashings which he found were in order, the cargo was not moving. It was stormy weather and he noticed some water coming in through the ventilation channels. This small inflow of water on the car deck was normal during heavy weather and he had seen it earlier. He stayed for about 15 minutes and continued through deck 1 to deck 0 and then back up to the place where his round commenced. Shortly after his arrival on the bridge [5], the master together with the master of the alternate crew arrived and talked in a normal manner with the officers. They left after 5-10 minutes.

On the round starting at 0030 hrs, the weather was worse than earlier. In the last testimony [8] the AB seaman said that he was not sure about leaving the bridge at exactly 0030 hrs. In the same testimony he stated that after leaving the bridge he went into cabin 750 and talked to a friend. He stayed less than a minute, saw some friends on deck 7 and stopped to talk to them. Then he went into the laundry room where he collected a jacket, passed two checkpoints and went on into his cabin, where he left the jacket. After that, he went up to deck 8 where he saw some friends in the day room. Without being quite sure about it he thought that he walked further down looking for a girl who worked in the Baltic Bar, but he did not see her. He also stopped at the Pub Admiral to look for another girl.

While he was on the car deck the ship was moving so heavily in all directions that it was difficult to walk and he had to support himself against the bulkheads. When he was approximately one metre from the ramp, a heavy wave hit the bow He gave the time as 0045 hrs [3]. In another statement [4] he said 0035 hrs at the latest. Later [5] he stated that he was on the car deck between 0035-0040 hrs. He also said [6] it was about 0040 hrs. In the last testimony [8] he stated that the time was 0050-0055 hrs.

He nearly fell due to the effect of the wave. When the wave struck the bow a particularly "hard sound" was heard from the bow, a sound that stood out from the others. The sound was accompanied by a heavy vertical ship movement that made him fall [2]. The bow was rising when the blow was heard [4] and continuous heavy waves raised it further.

The blow sounded like two heavy metal pieces clashing together with great force. This lasted for about half a second. He notified the second officer B on watch via portable radio and was ordered to stay and try to determine the source of the sound.

He stayed for a while on the car deck but everything was in order and the visor and the ramp were obviously closed as the signal lamps were green. In another testimony [4] he said that he stayed for 5 minutes, that he checked the lamps and that the ramp was closed. In yet another testimony [7] he stated that he opened a locker to see the lamps, which were green, and that he asked for permission to leave the car deck.

On his round upwards he passed the Baltic Bar [5]. He caught up with the master and entered the bridge just behind him at about 0058 hrs. The watch changed at this time. The master noted that the ship was rolling heavily and that they were behind schedule in spite of having all engines running. He also said that the master said they were one hour behind schedule [4, 7]. In other testimonies [3 and 4] the AB seaman said that he came to the bridge at 0100 hrs, that he could see the top of the jack pole indicating that the visor was there, that the master arrived after him and that the second officer A and the fourth officer were on watch. In still later testimonies the AB seaman stated that prior to his arrival on the bridge the watch had already changed [6] and the relieved officers had left [7]. In his last testimony [8] he said that after leaving the car deck he went to deck 1 and then to his checkpoint in the sauna on deck 0. After that he worked upwards at his normal speed, looked into the Night Club and the Pub Admiral, and continued to the information desk where he looked at a clock which showed about 0100 hrs. Subsequently he went up to the bridge and arrived just behind the master.

When the AB seaman came up to the bridge, the second officer had received a telephone call from below, saying that strange blows had been heard from below. In a later testimony [2] he stated that the second officer A said that he had had a telephone call about noise from the "bow door". The AB seaman also stated [8] that the 2nd officer A had a telephone call from the engine room about heavy blows. The second officer A ordered the AB seaman to go down to the car deck to check the "bow doors" and also to take a look at the general situation. In another testimony [4] the AB seaman said that there were strange blows from below and that he got an order to check the ramp together with the boatswain, and that this happened less than 10 minutes past one o'clock. He also stated [5) that he and the boatswain were ordered to go down together to check some blows. Later [6] he said that they got orders to go down and check the ramp. In a still later testimony [7] he said that he was ordered to check the ramp and visor together with the boatswain and to see that they were properly secured, and he also stated that the orders were given in a routine manner. He tried unsuccessfully to contact the boatswain via portable VHF radio. He told the second officer A that he could not reach the boatswain. The second officer said he would telephone the boatswain in his cabin. It was an unusual step to wake the boatswain, but he was the crew member responsible for both visor and ramp [7]. The AB seaman stayed less than 2 minutes on the bridge before being ordered down again [7].

When he was on his way down, people were already asking for help because the ship's list was so heavy that some could no longer manage to walk. In the last testimony [8] he stated that he helped two passengers on deck 7 who had fallen over. He also stated [2] that he noticed a slight list on his way to the car deck. In another testimony [7] he said that he ran down straight from the bridge to the information desk. He also stated [8] that on his way down he passed the Baltic Bar and looked through the door for a friend. He couldn't see his friend but observed that the musicians had stopped playing.

The situation calmed down somewhat when the ship heeled over to starboard. He ran to the information desk on deck 5 to ask them to unlock the car deck doors because he had been ordered to go there. He did not yet think that the ship would go down. In the last testimony [8] he said that when he arrived at the information desk the girl there was exchanging money for a passenger. The AB seaman had to wait for a couple of minutes. While he was waiting, the ship heeled over so much that all objects fell. He continued down to deck 4 where the staircase was full of people and he realised that the situation had become serious. The list was now around 25-30 degrees.

He ran to deck 7 and tried to reach the outer deck but fell. Lying on the deck he reported to the officer on watch over his portable radio that people were screaming in panic, saying that "deck 1 is under water". In another interrogation he stated that the people said "there is water on deck 1" [2] and in a further interrogation he stated that one passenger, either from cabin 1069 or 1096, had told him that there was water on deck 1 [6]. This was new information to the bridge [5]. The bridge was surprised by this information [6].The officer ordered him to go down and check the situation even though the AB seaman thought that the situation was hopeless.

He managed to support his feet against the bulkhead and to give some lifejackets to passengers. Out on deck he realised that he had lost his portable radio [5]. When the ship heeled over "altogether", he managed to save himself by getting to a liferaft on the ship's side. At this moment the funnel and three quarters of the ship were already under water. In a later testimony [7] he said that he was in the liferaft at 0124 hrs and that the ship had a 90-degree list when he left. In the last testimony [8] he said that he looked at his watch several times after midnight because he was instructed to do so while on duty At 0125 hrs the ship's bottom was upwards and he was floating on a raft.

When the AB seaman slid into the water he lost contact with one of his friends. He fell into the sea from the raft but someone pulled him back again. He also managed to pull two girls into the raft. When the ship sank it turned upside down and went down stern first. He noticed that the bow visor was missing.

6.2.3 Summary of testimonies by the third engineer

The third engineer was interrogated seven times:

l. 29 September 1994 in Turku by the Finnish police.

2. 29 September 1994 in Turku by the Estonian State Security Police.

3. 29 September 1994 in Turku by Commission members.

4. 3 October 1994 in Tallinn by the Estonian police.

5.17 October 1994 in Tallinn by Commission members.

6. 31 March 1995 in Gothenburg by Commission members.

7. 28 February 1996 in Tallinn by the Estonian police.

This summary is based on the earliest testimony When subsequent interrogations reveal more information or contradict the earliest testimony, the later testimonies are referred to in square brackets. During the loading of the ESTONIA the third engineer heard on his portable VHF radio the order from the chief officer that the cars must be carefully lashed because hard weather was expected.

The third engineer was on duty from 0000 hrs. His work station was the engine control room. Wind velocity was 20-25 m/s (according to the ship's anemometer) and the ship's speed 15 knots. The run seemed normal despite the heavy weather. At 0030 hrs [3, 5] the stabilisers were activated. When he started his watch he looked at the instrument panel and observed that the ship had a starboard list of approximately one degree. The fourth engineer, who had the watch before the third engineer's, told him that he had tried to compensate for the list, which was due to the distribution of the cargo, by filling the port heeling tank. However, the tank was already full and the list could not be fully compensated.

In the control room there was a monitor connected to video cameras on the car deck and in the engine room. The cameras scanned automatically every five seconds but it was possible to stop the scan manually and to keep a desired picture.

He saw on the monitor that the AB seaman on the watch was on the car deck at about 0100 hrs or five minutes later [4]. In another testimony [7] he stated the time to be 0055-0059 hrs, that he saw the AB seaman at the ramp and that there was no water at this time.

At 0115 hrs he perceived two heavy waves, one after another, and they could really be felt. Later he stated that the time was Ol 10 hrs [2], 0114 hrs [6] and also that he looked at his watch which said 0113 hrs [7]. He had never before experienced such powerful blows against a ship. The ship was sailing practically straight into the waves and consequently their full force was directed towards the bow. He immediately looked in the monitor. At 0115 hrs he saw in the monitor [2] that water was coming in from the bow or - as stated in another testimony [4] - that a huge amount of water was pressing in from the sides of the ramp. At the same moment he heard the AB seaman on the watch report "water on the car deck". In other testimonies [3, 5] he said that the AB seaman's words were "Bridge from watchkeeping seaman: there is water on the car deck". The inflow of water was enormous. In fact, the monitor picture became unclear because the camera was sprayed with water. He locked the camera on the ramp and, according to him, the same picture was displayed on the bridge monitor [5].

The effect of the inflow of water was immediate, the ship developing a 2-3 degree list to starboard. She also started to roll, 3 degrees to starboard and 1.5 degrees to port [6]. Then she heeled even more to starboard and subsequently the starboard list became permanent. Loose objects started to move. At this time the system engineer and the motorman entered the control room.

Within a couple of minutes the list increased to 10-15 degrees while the ship continued with all four main engines and two auxiliary engines still running. At this time the fourth officer called and asked if the list could be adjusted by increasing the amount of water in the port heeling tank. In a later testimony [2] he said that this question was asked at about 0120 hrs. In another testimony [5] he stated that the time was 0121 hrs and that he heard the alarm - Mr Slkylight to number one and two-at the same time. He tried to pump in sea water, hoping that the list might have created some space in the tank but the pump only sucked air. From this time on, the starboard list

increased rapidly [2].

Approximately one minute after the alarm Mr Skylight to number one and two, the boat alarm went out over the public address system and the alarm bells started to ring [6].

Within a couple of minutes the ship had developed a 20-25-degree list to starboard and the port main engines tripped because of an automatic shut-down, i.e. the lubrication system was no longer working. When this happened the list was 30-35 degrees and he tried to restart the engines but without success [2]. The ship's speed was then 5-6 knots. Some minutes later, engine no 4 tripped for the same reason and after a while also no 3. The time was then 0120-0125 hrs [5]. He reported to the fourth officer via portable radio that the main engines had tripped [4]. They were running at 560 rpm before the accident nd around 500 rpm before they stopped [5]. In another testimony [6] he stated that the engines were running at approximately 400 rpm. With the help of railings, he crawled to the control panel and tried to restart the engines [6].

He sent the motorman up when the engines had tripped because the motorman was in a state of near panic. In a later testimony [3] he said that he sent the motorman to the bridge to report. The system engineer left the control room at

the same time.

At about 0130 hrs the list was approximately 40-45 degrees. At this moment the auxiliary engines also stopped and the emergency generator on deck 8 started automatically In a later testimony [6] he stated that the list was around 70 degrees when the auxiliary engines stopped. The fourth officer also contacted him at this point and asked if it was possible to pump out fresh water into the sea from the tanks on the starboard side. This was no longer possible due to lack of electric power.

The third engineer felt there was nothing he could do in the control room any more and told the bridge that he was going up on deck to check the function of the emergency diesel generator [2, 7]. When he left the control room there was no water there and all watertight doors were closed. In a later testimony [5] he said that he left at about 0130 hrs and that the list was at this time 70-75 degrees. He also said that he left about 0125 hrs, not earlier because he then looked at his watch for the last time [7].

The third engineer took the engine staff's own staircase to deck 8, to the emergency diesel generator. On his way up he heard noises indicating that the cargo was moving. He checked the emergency generator, which was still running. The ship was at this time lying on her side, i.e. the list was 90 degrees. Because of this, the emergency generator shut down almost immediately He had no more duties and moved aft along the hull where there was a crowd of people. When the emergency diesel generator stopped, the hard plastic flooring on deck was falling over him [6]. (This flooring consisted of 30x30-centimetre 14-millimetre-thick, structured polypropylene tiles that snapped together.)

He saw that some passengers had opened liferaft containers but that they did not know what to do with the rafts. He went to help, but at the same moment a wave washed him into the sea.

He was not wearing a lifejacket but he found two, which he put on. He found a damaged lifeboat, floating upside down, with four people sitting on it. He managed to climb on. After a while another person also got up on this lifeboat but this person later died.

At a distance of about 80 metres he saw the ship go down. She was lying on her starboard side as she sank, stern first. During the last few moments the bow pointed upwards at 45 degrees.

He observed that the bow visor was missing and assumed that the heavy waves had torn it away.

The third engineer assumed that he was one of the first to be rescued. He and the others from a lifeboat were picked up by a helicopter at about 0350 hrs [2].

6.2.4 Summary of testimonies by the system engineer

The system engineer was interrogated five times.

1. 28 September 1994 in Turku by the Finnish police.

2. 29 September 1994 in Turku by members of the Commission.

3. 29 September 1994 in Turku by the Estonian police.

4. 10 October 1994 in Tallinn by the Estonian State Security Police.

5. 13 January 1996 in Tallinn by the Estonian police.

This summary is based on the earliest testimony When subsequent interrogations reveal more information or contradict the earliest testimony the later testimonies are referred to in square brackets.

The system engineer was asleep in his cabin and was called on duty at about 0030 hrs by the third engineer due to vacuum problems and subsequent difficulties in emptying one of the toilets. In a later testimony he said he was called at0045 hrs [5]. He arrived in the engine room on deck 0 at about 0045 hrs to solve the problem. He felt a couple of hard shakes when a wave hit the bow. The shakes were stronger than usual for this kind of weather. He concluded that the weather was foul.

It took about 20 to 25 minutes to find the cause of the vacuum problem and make the necessary repairs [3]. He stayed in the engine room for about 25 minutes [4]. Later in the same testimony he specified that he did not leave the engine room until he realised that the ship was going to sink.

On finding the cause of the problem, which was air entering the vacuum system, he felt that something was amiss because the ship heeled over to star-board. In a later testimony [3] he stated that he felt two or three heavy blows and that the electrical panels started to shake in their fastenings. After these blows, the ship started to heel and some cans slid about. After the next blow the cans, which had stopped, started to roll to the other side. In a later testimony [5] he said that he heard a heavy blow, heavier than from a wave. Less than a minute later a new blow came and the ship started to heel.

Because of the list he went to the engine control room where the third engineer and the motorman were. The move took about two minutes. The surveillance monitor showed a great deal of water entering the car deck from both sides of the ramp, possibly more from starboard than from port. He was not able to tell whether water was also coming in from the top of the ramp because the camera did not cover this area. Shortly after his arrival in the control room, the watertight doors were closed.

In later testimony [5] he said he went to the control room one or two minutes after the list. The third engineer ordered him to check the car deck with the surveillance camera. The cars were in place and he could not see any water on the deck but water was pressed in at the ramp. He was sure that the third engineer also saw this, presumably before himself.

In the latest testimony [5] the system engineer made a drawing to illustrate what he saw in the surveillance monitor (Figure 6.1).

The three wondered if the bow visor had opened because this amount of water could not possibly enter only because of some damaged seals. The water was entering continuously and not only in connection with waves. The ship developed a 30-40-degree list and the engines tripped, first two and then the third and finally the last remaining engine. The system engineer did not know if all four auxiliary engines were working or only two of them.

While still in the control room, the system engineer heard the bridge ask if it was possible to right the ship. He thought that the third engineer had by that time informed the bridge about water entering the car deck. The pumps were running to drain the water. The bridge also asked if it was possible to reduce the list by pumping water between the heeling tanks. While the system engineer was following the events on the monitor he was unable to hear the third engineer's reply.

He wanted to call the chief engineer but before he could reach the telephone everything fell over. He managed to crawl to the central table but this broke loose from its welds [S].

After the engines had stopped he heard the alarm Mr Skylight to number one and two over the public address system and soon after that the watertight doors were closed and the boat alarm sounded. He asked the third engineer what was going on and why the water was coming in, which he was able to see on the monitor, but got no reply [4]. Later in this testimony he clarified that he did not observe any water entering the car deck, only that the third engineer told him about it.

When the list was about 45-50 degrees, he and the motorman left the control room. At that point the electric power was still on. In a later testimony [2] he said that they left when the list was about 60 degrees and that he, on the monitor, saw the cars shifting approximately one metre to starboard when the ship was at about 45 degrees of list. When he had reached deck 6, the auxiliary engines stopped and after two or three seconds the emergency generator started and the power came on again. The system engineer, together with the motorman, gained the outer deck 8 amidships, quite near the emergency generator which worked until the list was about 90 degrees. Their climb, he stated, took one minute or two [5].

Out on deck 8 he saw crew members preparing liferafts in case the ship should turn over. By this time the list was already too heavy to permit the release of lifeboats. People had released inflatable rafts on the ship's port side and were able to slide into the sea when the list increased.

When the ship was practically on its side, a typhoon signal was given. This meant that everybody had to save them-selves. In a later testimony [2] the witness stated that there was a message over the public address system, advising passengers in the water to stay clear of the sinking vessel. He also stated [3] that he saw the second and third officers leave the bridge at that time and start helping to release rafts. At that moment the system engineer was together with other people, mostly crew members. They waited for a relatively safe moment and slid into the water in a raft, holding on to

ropes.

When the ESTONIA sank, stern first, he could see that the bow visor was missing. He was about 20 metres from the ship in a raft together with 9 to 10 others. He has estimated that the time from his first observation of water entering the car deck to the sinking was 15-20 minutes.

In the raft he, together with the AB seaman and the motorman, helped others aboard and finally they were 16 people. The last person got into the raft about two hours after the sinking; in a later testimony [4] he said 1.5 hours.

At 0815 hrs the system engineer together with the others was rescued by two helicopters.

6.2.5 Summary of testimonies by the motorman

The motorman was interrogated three times:

l. 29 September 1994 in Turku by the Estonian State Security Police.

2. 29 September 1994 in Turku by Commission members.

3. 31 March 1995 in Gothenburg by Commission members.

This summary is based on the earliest testimony When subsequent interrogations reveal more information or contradict the earliest testimony the later testimonies are referred to in square brackets.

This was the motorman's first voyage as a crew member on the ESTONIA [2]. He was on duty that night from 0000 hrs together with his supervisor, the third engineer. When on duty he made a round in the engine room and checked that everything was working normally After the round he went to the control room and the third engineer made his round. During the third engineer's round the motorman received an order from the bridge to activate the stabilisers.

At about 0046 hrs the motorman saw on the monitor that there was a small trickle oI water pouring in on the star-board side of the ramp. He thought it was rain which had penetrated the seal. On this occasion he was alone in the control room and when the third engineer re-turned the motorman went to an adjacent workshop. In a later testimony [3] the motorman, questioned about seeing water entering at 0046 hrs, stated that he had since given it much thought but that he was no longer sure of having seen it. After further questioning on this topic, he stated that he was no longer certain of having said so at all in the first testimony

While he was working in the work-shop, the ship suddenly developed a list which he found strange. He went to the control room and the 3rd engineer told him that the situation was serious be-cause a wave had broken the ramp. On the monitor he saw that there were big waves on the car deck and that the water surface was level with the cars. Right after this, several lamps started to flash "boat alarm", meaning an order to the lifeboat groups to man the lifeboat stations.

At this time the system engineer arrived and the watertight doors had been closed. The water pumps were turned on and from the bridge they received orders to try to do something with the pumps. At this time the list increased and because loose objects started to move it was no longer possible to stand upright. At a certain point the main engines tripped. The motorman also heard noises of movement on the car deck. It was now obvious to everyone that the ship was going down.

Then the motorman and the system engineer left the control room through the emergency exit. The list at this time was about 50 degrees [2]. When they were on their way up, the auxiliary engines stopped and the emergency generator started automatically The list was about 90 degrees when they reached deck 8 and at that time the emergency generator stopped. The motorman put on a lifejacket and slid into the water where he saw the ship sinking stern first. He could see that the bow visor was missing.

6.3 Summary of testimonies by surviving passengers and off-duty crew members

6.3.1 Testimonies concerning cargo lashings

Two able-bodied seamen have testified about the lashing of cars, lorries and trailers prior to the journey Both were involved in this work. Trailers and large vehicles were secured with four lashings and trailer chocks. Passenger cars were not lashed but parked with handbrakes on and in gear.

While loading, the two seamen were ordered to do the lashings with care because winds up to 25 m/s were expected. Both were certain that vehicles were secured in accordance with their instructions and with the equipment to hand.

Both stated that the bow visor was properly closed before sailing.

6.3.2 Reports from deck I

On deck 1 there was one cabin department with 124 cabins and beds for 358 passengers. The cabin area extended forward from amidships. In the centre line of the cabin department there was a central corridor with six upward-going staircases. Several transverse corridors on both sides joined at this central corridor. The six staircases joined in the casing, ending up as three on deck 4. The middle one of these joined the main staircase, the forward one continued to deck 7 (Figure 6.3).

From this deck there were 22 survivors. Three of them were crew members from the engine room and 19 were passengers from the cabin area. Figure 6.2 shows the engine area and the cabin department with all known locations of survivors.

Many passengers were unable to sleep prior to the accident due to the ship's heavy motion and the noise and vibrations from waves hitting the bow.

Several passengers were seasick. Some had been sleeping and woke shortly before the accident due to the motion and the noise.

One witness, in a starboard forward cabin, heard some hard thumping and something banging. She thought it was strange and spoke to her friends about it. She had a horrid feeling and left her cabin. Her friends said they would follow. She went up to deck 7 and sat in a chair for a few minutes when she suddenly heard a heavy blow and the ship started to heel over.

In another cabin, further aft on the starboard side, were two persons. They reported heavy ship motion. Every time the ship pitched, one of them reported, he heard blows against the hull, as if someone were hitting it with a large stone. This witness was worried and discussed the sounds with the other, feeling that something was amiss. He got out of bed and started to dress. The other witness, in the same cabin, did not hear these blows but was also worried. After a while she heard a faint, new bubbling sound from above, like water being poured slowly She stated that this happened a little after one o'clock: a wrist-watch had beeped the hour and she had also looked at her own watch. She stayed in bed half asleep for about five minutes when there suddenly was a loud, scraping, howling, creaking and screeching sound from overhead, quite close, as if something large and heavy was sliding. A witness from a nearby cabin has also reported the same kind of noise. After this the ship heeled. They were convinced that something was amiss.

Several witnesses have reported being awakened by loud noise or bangs. Three passengers fell out of their beds because of the ship's motion. Shortly afterwards, they heard a tremendous thud, so "hard" that one of them, who was now standing, was thrown against the bulk-head. It was like a collision. The ship immediately started to roll "incredibly". Another witness has stated that, around 0100 hrs, he heard a familiar hydraulic sound, the kind "that is made when the bow visor opens and closes". He lit a cigarette and shortly afterwards, still smoking, he heard a clear metallic blow or crash. After another one or two minutes he heard the same sound again. He dressed and left his cabin. When just outside his cabin door, he estimated the time to 0115-0120 hrs, the ship raised its bow and heeled to starboard immediately after.

Another witness opened his cabin door. The corridor outside was empty but there was a thin trickle of water on the floor. At this time the ship had only a very slight list. He ran out in his under-wear. The ship remained starboard heeled. In the central corridor there was water on the floor.

At about the same time most cabin doors were opened and half-dressed passengers emerged into the corridors. Many were in panic, shouting and screaming. In the central corridor they ran back and forth searching for staircases and colliding with each other. On one staircase, a woman stood in her night-dress, screaming hysterically In a cabin doorway an elderly woman was hanging on, trying to pull herself out.

One witness, in a forward central cabin, left after hearing an alarm in Estonian. At this time he saw water coming into his cabin.

When passing deck 2 up the stair-case, several witnesses reported cold water running down the bulkhead and onto the floor. One witness saw water spraying from chinks in the closed doors leading to the car deck. He estimated one decimetre of water on the floor.

It was increasingly hard to move because of the list. Some paralysed and exhausted passengers were standing on the staircase. They were passed by others.

6.3.3 Reports from deck 4

On deck 4 there were two cabin departments, one forward and one amidships, containing 98 and 81 cabins respectively. In the midship department there were beds for 200 passengers and in the forward for 204 passengers. The cabin departments were separated by the entrance hall with the main staircases. Aft there was a conference area which, at the time of the accident, was closed. Close to the conference area was the Night Club, which was open.

The forward cabin department there were three parallel longitudinal corridors, one central, and one on each side. Between the corridors there were cabins. From the central corridor one staircase led to deck 7. The three corridors ended forward at a transverse corridor and amid-ships at the entrance hall. The central corridor ran between the two main staircases. At the forward ends of the port and starboard corridors two staircases led to the boat deck, deck 7.

In the midship cabin department there were also three parallel longitudinal corridors, with one transverse corridor connecting the central corridor with the starboard corridor and another connecting the central with the port. The longitudinal corridors ended forward at the entrance hall and aft at the aft staircase and the conference department.

From deck 4, 32 people survived. Most remembered their cabin numbers. Probably seventeen escaped from the forward cabin area and six from the midship cabin area, two from the Night Club, one from the lavatory close to the conference area and two from the cinema in the conference area. Four survivors from this deck cannot remember their cabin numbers. Figure 6.3 shows the plan of deck 4 and the locations of survivors.

Reports from the forward cabin department

In the forward cabin department a few witnesses have reported that they were seasick. One was woken, he says, at about 0000 hrs by a noise which made him worried. It was a dull sound, but powerful and as if something was sliding from one side to another, hitting hard against the ship's hull. The noise reverberated through the entire ship. Because of this noise the witness decided to leave his cabin. Another witness has said that he heard strange blows while undressing in his cabin, a sound like metal against metal vibrating through the entire ship. It seemed to him that the blows were coming from the bow.

One witness, in a starboard cabin, was lying awake in his bed wondering about the blows from the waves and the ship's speed which he thought too high for this kind of weather. The ship was pitching. He noted that the sound from the engines suddenly changed, as if the ship was slowing. After a while he heard an enormous crash and the entire ship shook. He looked out through the window and was not sure whether the ship was moving or not. After the blow there was the familiar roar of the waves hitting the bow again. Suddenly there were two metallic, clanging sounds each coming a moment after a wave hit the bow. When the next wave struck he heard the same sound again three times and after that a rustling sound beneath his cabin from the car deck. He remained in his bed for another moment. Then he told his roommate that something was wrong and that they had to get out of their cabin. At this time the ship had a slight list.

Another witness, also lying seasick in bed, was listening to the sounds. He fell asleep now and then but woke up because of blows. Suddenly he was woken by a blow and because the ship rolled heavily three to five times. After a further, powerful, blow he heard two or three loud scraping sounds a few seconds apart.

The ship heeled over and things fell from the table to the floor. Immediately after another heel all loose objects slid towards the cabin door. After the last heel, the vessel remained listed to starboard and he left his cabin rapidly He took with him his alarm clock which had stopped at 0102 hrs.

One witness felt that the ship was behaving strangely as if ploughing heavily right through the waves. At the same time he heard loud metallic thumps and noted that the engines stopped. The time was around 0105 hrs to 0110 hrs. Another witness was awakened by a huge bang, sounding as if the ship collided. He fell from his bed to the floor. A further witness was woken by an enormous crash. All loose objects slid to the floor and two men, who were sleeping in the upper beds, fell to the floor.

One witness could not sleep because of vibrations and the sounds of the ship hitting the waves. At around 0100 hrs he heard two bangs one shortly after the other. He got up, dressed and opened his cabin door. There was no one in the corridor but some cabin doors were open and he saw people inside. He went aft while the ship started to heel moderately Later the list increased. Many cabin doors were open by this time. In the corridor there were many people, some of them naked, others wearing only underwear. There was panic and people were running both aft and forward screaming. Some of them were standing still, apparently in shock. According to one witness, at approximately Ol 15 hrs there was an alarm call, "Häire, häire, laeval on häire!", meaning "Alarm, alarm there is alarm on the ship!" in Estonian. (The Estonian language has similarities with the Finnish but is not understood by Swedes.) It was a woman's voice and she sounded afraid or injured. The voice was very weak. Some of the passengers in this cabin department ran aft to the entrance area and some forward to the forward starboard and port staircases.

The corridors were full of people fighting to reach the port staircase. A witness threw himself forward and got his hands on the handrail. For older people, it was impossible to move upwards. On the starboard forward staircase much sea water came from above, and the people climbing became soaking wet.

Reports from the midship cabin department

One of the witnesses, a dancer on her first working day was trying to find her cabin after the show which finished at 0030 hrs. She got lost and came outside the car deck where she heard a crash. She finally found her cabin, got to sleep but was awakened by another crash. Other witnesses were wakened by belongings and loose objects sliding about in their cabins.

One witness could not sleep because of the heavy sea. He heard a rolling sound from the car deck below and got a feeling that something was wrong. Belongings started to fall to the floor. Directly afterwards, there was a loud metallic bang and the vessel heeled over. Another witness went forward along the starboard corridor followed by his parents and his girlfriend. When he came to the entrance area there were many people there. He estimated the list at this time to be about 10-15 degrees. The lights were still on.

One witness, from a cabin very close to the entrance hall, was going aft but fell into a cabin where there were already two people. She pulled herself out into the corridor again, leaving the two behind. Most cabin doors were open but only a few persons were in the corridor. The witness walked along the bulkhead and jumped over cabin doorways.

Reports from the Night Club

In the Night Club there were six people, three passengers and three crew members. At about 0115 hrs one witness noticed that objects started to move to starboard. He rushed out and up the aft staircase. He reported no crowding.

In the lavatory outside the Night Club and close to the aft staircase there was another passenger. While leaving, in the hall, he saw a crack in the ceiling and water pouring down. He went up the staircase quite early, before there were any crowds, to the open deck 7.

Reports from the entrance foyer

The foyer was a rather large open space. The list rendered movement there very difficult. The staircases were situated on the ship's centre line and became difficult to reach.

One witness from deck 1 was ahead of the others and did not see other people until he reached the entrance foyer on deck 4. On deck 5 he passed a man lying on the floor, injured or maybe drunk this witness thought, because the ship's list was not too heavy at this moment. He also met two male crew members and told them that he had seen water below. They rushed downstairs.

Another witness arrived on deck 4 somewhat later and saw many people in panic. He held on to the handrail and managed to cross the open area near the bureau d' change where the floor was soaking wet. Two girls fell from the staircase and struck the bulkhead. One of them probably died immediately Another witness saw two young women wearing only panties just standing still, holding on firmly to the handrail. This witness lost his grip and slid approximately 10 metres into a glazed wall which broke. He was not injured, and managed to regain the staircase. On deck 5 he saw a person lose his grip and fall into the wall, which cracked. Several people slid screaming across the foyer carpet into the wall, most of them receiving injuries.

People entered the entrance area in great numbers from both forward and aft corridors. Some were standing along the walls and on the stairs. One witness has reported that a crew member was there, trying to help passengers many of whom were just standing still with no chance of climbing upwards. Some found free handrails and started to climb by pulling and dragging themselves upwards. Gradually more and more people came. Many were lying down badly injured and bleeding, some probably dead. They had slid into the walls or fallen from the staircases. There was full panic and chaos. Some people were trying to stand up, some just holding on. The witness who was leading his parents and girlfriend had difficulties reaching the staircases. Once there, he turned to look for the other three who were still on the other side. They could not cross the foyer because of the bodies and the crowd. They shouted and urged him to continue to climb the staircase alone.

6.3.4 Reports from deck 5

On deck 5 there was a forward cabin department, almost identical with that on deck 4, with 102 cabins and 212 beds. Amidships was the manned information desk and a forward hall with the main staircases. Two arcades, starboard and port, with a tax-free shop and several other shops, connected the forward and aft halls. In the aft hall there were the aft staircases. On the starboard side, aft of the shops, there was a lounge with easy chairs. Further aft on this side was the Pub Admiral where entertainment was going on. At the stern on the starboard side there was the Cafe Neptunus from where doors led out to the aft open deck where outdoor staircases led to the upper decks.

From deck 5, 31 people survived. Four of those were in the cabin area, five were on different locations in the arcade and hall close to the shops and the information desk. Fifteen were in the Pub Admiral, three in the Cafe Neptunus and four in the lounges. Figure 6.4 shows the plan of deck 5 and the locations of survivors. Photos in Figures 6.5 and 6.6 show Cafe Neptunus and the aft staircase on deck 5, respectively

Reports from the cabin department

One witness was moving around in the forward port staircase. He noticed that the matting was soaking wet between decks 5 and 6 and also that some water was pouring down the staircase. The matting became, however, less wet further up. He stood at about 0100 hrs looking out through the windows towards the forecastle deck. He could hardly see it because of the darkness but the bow looked normal. After this he went to his cabin and approximately five minutes later the heel came.

One witness, from a forward port cabin, reported that high waves were beating against the ship and huge cascades of water rising into the air. He could not sleep due to the sound of the waves and the ship's motion. Later there were a couple of heavy bangs and he decided to get up and have a look outside. The heel came just when he was at his cabin door.

Another witness stood on the outside deck a while before going to bed, looking at the enormous cascades of water and fascinated by the sight. After a couple of hours' rest in his cabin he became seasick and stayed in bed, but listened carefully to the sounds. He had a feeling that the ship was lifting 10 to 20 metres and banging down into the water again, accompanied by heavy sounds and vibrations. Suddenly he heard an additional slight metallic sound above the normal noise of the waves and the fittings. He heard this sound for a couple of minutes, then he heard a metallic blow. After perhaps another minute, there was a faint metallic blow and after a further 40-50 seconds a very heavy metallic bang. He became worried because the noise sounded as if the hull plating was being pressed in. He realised that something was amiss. He left his bed. Soon afterwards the ship developed a starboard list. Approximately one minute after the first list and two minutes after the last bang, the engines stopped. The list was now around 20 degrees to starboard. He left his cabin in a hurry only half-dressed. He put the time from the first metallic sounds to the heel at between 5 and 10 minutes.

A witness in a cabin near the main stairway was woken by objects falling to the cabin floor due to the list. He estimated the time as 0120 hrs. He was uncertain of the timing even though he usually looked at his watch when waking abroad.

Some witnesses from various locations have stated that the engines stopped, or that the. sound and vibrations from the engines changed, after the first heel. Others, also from various locations, have said that the engines were running as before.

One witness managed to leave his cabin after the heel, by moving all loose objects into the lavatory, thereby getting the cabin door free so that he was able to open it. He stated that the sounds from the engine were normal.

In another forward cabin a man and his wife were awakened by a sound as of large sheets of metal beating together. Soon after this, the ship developed a list. The couple, in their night clothes, rushed out into the corridor. They noticed others leaving their cabins, some running back and forth and others falling and crawling. The list increased by jerks and somewhere along their way out, the wife lost sight of her husband.

Reports from the lounges

In the lounges 10 to 15 people were sleeping and resting. All were awakened by a scraping sound and by the ship's list. Some seemed to be apathetic and bewildered but others shouted to the rest that they must get out quickly Only a few responded.

Four passengers ran out directly to the starboard arcade and saw many people in the area around the shops and the information desk. Near the information desk and the main staircases there were two female crew members who did not seem to know what was happening or what to do. People were trying to reach the forward main staircases to go up, but the list made it difficult to move in the arcade as did the crowd further forward. There was much screaming among those fleeing. In the crowd in the open forward hall many passengers failed to reach any of the four staircases going up. Several passengers were lying down and others falling or sliding along the floor and hitting the bulkhead. Several appeared to be injured.

Reports from the Cafe Neptunus

There were six or seven people in the Cafe Neptunus (Figure 6.5). Most were resting or sleeping. One witness was sitting, resting his head against the bulkhead and he felt and heard a heavy metal blow to the hull, apparently from the bow. Soon afterwards, the ship heeled over. Another witness said that 5 to 7 minutes later, furniture and cutlery racks, glasses and china fell to the floor and slid with a loud noise to starboard, waking those present. Two passengers slid into the bulkhead. Some passengers were sitting perfectly still, seemingly petrified and horrified.

The alarm Mr Skylight to number one and two was heard from the public address system just after the heel and while one of the witnesses was moving towards the aft doors out to the open aft deck.

A few witnesses lay down on the floor and started to drag themselves up to the doors using the tables which were fixed to the floor. One witness, who was together with his mother, took off his shoes and socks and dragged himself from one table to another, helping his mother by pulling her across the floor table by table. They had to move upwards towards the centre line of the ship and then another 10 metres aft to reach a door. He pulled his mother four or five tables. She had to rest for a while. When the list had increased and he was standing on the pillar of a fixed table trying to pull her further aft, she was exhausted. Clinging to a pillar, two tables from the port doors, she begged him to leave her and continue by himself. She told him that she didn't have any more strength. He shouted at her in vain to continue. At this time, water was coming in from the outside to where they had been sitting earlier, and pictures on the wall appeared to be hanging at a 45- degree angle. This witness managed to drag himself out to the open aft deck and by use of both stairs and rails, he hauled himself further up and eventually to the port side of the hull.

Reports from the open areas

In the open space aft and in the arcades near the information desk and shops quite a few passengers were moving around or sitting in chairs. One witness said that the ship was moving heavily in the storm, making balance difficult. Intuitively he felt a slight list. Suddenly the ship shook and a few moments later heeled over. This heel was very sudden and increased. Passengers and loose objects started to move and tumble around. The witness reported how passengers were thrown violently against the starboard bulkhead and injured. He fell too, but without hurting himself much. The heel caused immediate panic among the crowd and people were running in all directions.

Another witness said that the ship heeled over and remained with a list of about 15 degrees. Ten seconds later a new heel came, which was immediately followed by another. After the three heels the ship had a list of about 45 degrees.

People escaping from deck 1 were coming up the main staircase to deck 5 and the foyer at the information desk. A few witnesses had heard a ringing sound from below on their way up. They had passed several others who were too exhausted to continue climbing. In the main foyer a female crew member slid violently across the floor, screaming loudly When she hit the wall she became silent. Shortly afterwards, another woman slid the same way One witness did not dare to look any more but gripped the handrails and pulled himself upwards. It was increasingly difficult to climb the staircase and people had to cling to the handrails. More people were coming all the time and many crowded near the main staircase next to the information area, making it difficult to pass and also hard to hold on to the handrails.

When passing deck 5, witnesses saw a row of gambling machines falling down on people, but no one was able to do anything to help because if they released their grip they would be lost as well. Reports from the Pub Admiral Witnesses put the numbers of people in the Pub Admiral at between 30 and 60. Some were sitting at the bar, some in sofas and others at tables. An entertainer on a small stage was leading a karaoke competition and conducting sing-alongs. Witnesses reported that during the show, the ESTONIA's motion increased and that some glasses hanging over the bar counter fell to the floor, as well as some from the tables. The staff started to clear away glasses and bottles from the bar. It was hard for those who were standing and walking to keep their balance.

The entertainer was scheduled to end his show at 0100 hrs but said approximately five minutes before the hour that he would continue for another fifteen or twenty minutes because they were having such fun. Soon after his announcement there was a heavy noise; one witness estimated the time to be around Ol 15 hrs. It felt as if the ship had hit a big wave. Another witness said that he heard a heavy metallic blow above the noise and the music in the pub, the sound seeming to come from forward.

The metallic blow was not like that of a sledgehammer, but gave a huge, distinct metallic noise, like a shot, reverberating through the hull. It was followed by a slight list.

A few people in the pub commented on the sound, with remarks such as "now we've hit an iceberg", but most passengers paid no attention. Because of the bang, one witness wanted to leave the bar, but others in his company told him to stay and wait.

Half a minute or a minute after the first blow, there was another, similar blow and the ship started rolling instead of pitching as before. After a short time she moved in different directions and then heeled to starboard. Some witnesses reported that the ship rolled over to starboard three to four times, then back again but not entirely, i.e. rolled further to starboard every time. After the fourth heel she remained in a distinct list.

One witness stated that after the uncontrolled movements in all directions, the ESTONIA started to roll more and more in all directions and finally only sideways, followed by a moderate heel. Some glasses fell to the floor and a karaoke monitor on wheels started moving. Ten seconds after the first heel there was another one and this time all loose objects started moving. The ship stabilised in a 30-degree list, as stated by several witnesses, and was still rolling somewhat. According to one witness, she kept this angle for about S to 6 minutes.

The bar counter ran along the bulkhead to port near the pub entrance facing starboard. When the ESTONIA heeled over the second or third time, all glasses and bottles fell on top of the female bartender, and the refrigerators behind the bar counter came loose. The bartender, who tried to brace herself against the bar, screamed loudly and was knocked down and injured by the falling objects. The guests sitting at the bar had to hold on and some stools slid away from them. There was immediate panic in the pub: several guests screamed while others seemed to be paralysed, staring and horrified.

At the third or fourth heel, almost everyone fell to the floor and slid violently; together with loose objects, into the starboard bulkhead where a large pile of passengers and objects was building up. Most passengers were trying to reach the exit and when some of them were on their way up, the bar counter came loose. A few jumped up on sofas, thereby managing to avoid being hit. People struggled for the door and several female passengers hung onto each other's legs to form a human chain. A few took a running start upwards and some managed to get a grip on the door-post. Outside the pub, more passengers formed a human chain to help and pull each other up to the handrail of the staircase in the aft hall.

Many; both inside and outside the pub, appeared paralysed, just holding on to whatever they could. Escaping passengers had to pull loose the hands of those who were paralysed with fear and shout directly in their ears not to block the way but to run up to deck 7 and save themselves.

6.3.5 Reports from deck 6

On deck 6 there was a forward cabin department with 103 cabins and 212 beds, almost identical with the other forward cabin departments. Amidships there was a hall with the main staircase. Further aft was the Baltic Bar with the casino on the port side and a stage amidships. On the starboard side amidships was also the Restaurant Seaside which was closed at the time of the accident. Further aft was the aft hall with staircases and, at the stern, the Restaurant Poseidon, also closed. At the stern there was a small afterdeck with two outside staircases starboard and port connecting the afterdecks on decks 4 to 7.

During the evening the band, which was playing in the Baltic Bar, finished their show early at 0030 hrs due to the heavy sea. They were scheduled to play until 0200 hrs. A dance team had difficulties performing their show and dancers had fallen several times, as had music stands and other equipment.

From deck 6, sixteen people survived. At the time of the accident eleven survivors were in their cabins, one in the Baltic Bar, three in the casino and one out on the aft deck. Figure 6.7 shows the plan of deck 6 and the locations of the survivors.

Reports from the cabin department

In the cabin department most witnesses had gone to bed. One witness who went to her cabin just before 0100 hrs reported that 7 to 8 minutes later the ship heeled over. Another was awakened by the heavy movement. One sleeping witness was thrown out of bed due to the list.

One witness, in an aft starboard cabin, was awakened by the regular blows from the waves but noticed a vague trembling which deviated from the usual. A trembling and markedly thudding noise was repeated four times at short intervals, then a longer interval and then repeated again. The witness got out of bed and shortly afterwards the ship heeled over. Other witnesses in more forward cabins reported sounds resembling huge crashes and bangs just prior to the heeling.

The passengers ran out of their cabins and into the corridors. One witness had to drag furniture and luggage into the lavatory to be able to open the blocked cabin door. Running along the corridor, this witness heard an alarm siren. People were screaming in cabins and corridors. Out in the open hall near the main staircases there were numerous flying objects and broken glass. This witness saw people lying on the starboard side of the stairway, some seemingly apathetic and others with injuries that may have included broken legs.

A few passengers who were heading for the port side forward staircase were seen sliding in the corridor across the ship, severely injuring themselves when they violently hit the starboard bulkhead.

Reports from the Baltic Bar

One witness from the Baltic Bar said that after 0030 hrs the ship's motion increased. Some time after 0100 hrs the ship raised her bow violently and dived deeply After the second or third dive she behaved differently The expected rising of the bow did not occur and the ship's movements felt more rigid. A few minutes later, she heeled over to starboard and glasses and other objects fell from the tables. This witness left his place for the staircases and while moving upwards he heard glasses crashing from the bar and several passengers screaming. On his way this Swedish witness also heard some message, in a foreign language, over the public address system.

Reports from the casino

In the casino there were about four passengers and a croupier playing cards. One witness heard three or four heavy metallic blows one after the other. The sounds appeared to come from beneath. Moments later the ship heeled. Playing cards and gambling chips flew across the table. Seconds later, the ship trembled once more, the list increased, and the gambling table fell over and slid against a bulkhead. The players and the croupier moved out together, heading for deck 7.

The three witnesses from the casino reported that approximately five minutes after the heel they heard alarm signals: first the word "Häire" two or three times and immediately after that a man's voice announcing "Mr Skylight number one and number two".

In the main staircase there were many people and it was quite difficult to force one's way upwards. Many were moving upwards and some were also heading down. One witness from deck l, passing deck 6 saw two crew members lying on each side of a corridor shouting in their walkie-talkies. As he passed them he said "lifeboats?" to them but got no answer.

Reports from the outer deck

One passenger was alone on the starboard side of the aft outer deck. To starboard he could see the lights from two other distant ships, one abaft and one abeam of the ESTONIA. He looked at his watch at 0105 hrs. According to his estimation, twenty minutes after, the ship suddenly listed without any forewarning. He saw through the windows into the restaurant that chairs and tables were shifting and down the staircase from deck 7 a barrel and a folding chair came tumbling. It was impossible to walk straight to the other side. With the help of the railing he dragged himself round the aft deck and up to the port side. There he put his head out and looked forward alongside the ship. The ship was now slowing down and turning to port, and he could see a part of the stabiliser fin over the water surface.

When the ship jerked over again he sat down on the deck and slid from the port side railing to the nearest stairs and climbed up to deck 7. During the climb he heard two different alarm messages over the public address system but was unable to understand them. Once up, he turned around and could see through the staircase opening on deck 7 that the place where he earlier stood on deck 6 now was level with the water. From the staircase he had to jump in order to get a grip on the aft shield plate extension of the port bulkhead superstructure. He missed and slid down violently, but managed to get a grip somewhere round the staircase. He pulled himself up again and jumped for a new grip. Eventually he was able to raise himself and climb to the port side of the superstructure on deck 7.

6.3.6 Reports from deck 7

On deck 7 there were three cabin departments or the crew, one forward with 25 cabins, one amidships with 25 cabins and one aft with 29 cabins. The aft department also contained messrooms for officers and crew, and a pantry Between the forward and the midship cabin departments was the hall with the main staircases and between the midship and aft cabin departments the aft staircase. In the forward cabin department, one door led out to open deck forward of the four aftmost cabins on the starboard side and from the aft staircase a transverse corridor led out to the starboard open deck.

From deck 7, 26 people were rescued, most of them crew members and entertainers but also two passengers. Twenty-two were in cabins, one out on starboard deck, one in the hall near the main staircase. One was in the main staircase between deck 6 and 7 and one in the forward port staircase. Figure 6.8 shows the plan of deck 7 and the locations of survivors.

Several crew members said that they had had a storm like this the preceding winter. A cook, who also recollected the previous storm, said that the heavy sea this time was exceptional and that he could not sleep.

One witness, a passenger, went together with his friend up to deck 7 at about 2300 hrs to find a place to sleep. He had slept in this place on several previous trips. They were in the forwardmost port staircase where two windows overlooked the bow area and a door on the port side led out to the open deck. They were lying on the landing in sleeping bags. At about 0000 hrs the witness felt a very heavy blow against the bow and got up to look through one of the forward windows.

The ship behaved as if she was jumping on the waves. The sea was violent. Farthest out on the bow a searchlight was on, shining within a 10-metre radius in the direction of the bow The ship was pitching heavily and the water was almost up to bow level, sometimes submerging the searchlight. Much water was coming onto the deck and through the forecastle deck rail.

About two minutes after having seen how a large part of the forecastle deck was bouncing up and sinking, this witness looked at his watch which read 0028 hrs. A transverse opening at the head was seen, whence much water was gushing up. The cascades of water seemed to be heavier on the starboard side. At this moment the searchlight went out and the engines stopped. The witness and his friend started to dress and decided to leave. After the cascade from the transverse opening in the forecastle deck, the bow seemed to sink under the water. When they came to the open deck at the forward port side there were about 20 people supporting themselves against the bulkhead. The witness started to prepare a lifeboat for launching.

In a later hearing, this witness stated that he was no longer certain whether his watch was correct on the night of the accident. He had changed batteries the day before the journey and suspected that it might not have been set correctly on the night in question. He is also uncertain whether he actually saw the bow rise and sink or whether he concluded this from the transverse opening and the cascades of water which he had never seen before on any of his six previous journeys. His conclusion was based on the fact that the transverse opening grew larger and that the water cascading in through the opening increased.

Three to five minutes prior to the heel, a motorman, off duty and in his cabin, heard sounds like someone banging the hull with a huge hammer. The sounds seemed to come from the car deck and his first thought was that the cars were loose.

The second engineer was awakened in his cabin and stated that he heard beating, which he at first thought was coming from the lifeboats on deck 7. He also thought that the bow visor had come loose. He calmed down when the beating ceased and did not phone the bridge to report it.

The female witness who had left her friends in the cabin on deck 1 was sitting on a chair on deck 7 and reported that she heard a distinct bang when the ship heeled over and things tumbled. People slid downwards to starboard and could not get up again. Most witnesses were awakened by the heel or by falling objects in their cabins. One woke up because his alarm clock fell. He gave the time as around Ol 10 hrs and stated that the list was then about 5-10 degrees. Another could not sleep due to the movements and was alarmed when objects fell to the floor.

A few witnesses stated that the ship's engines stopped and one witness said that the vibrations in the hull were ordinary, as if from the main engines running. One of the entertainers felt that something was amiss and went out on deck on the starboard side. After a couple of minutes the ship suddenly heeled over and a woman came from inside and fell against the rail. She could not get back because of the list. He had to jump, and managed to grip on the loosely hanging door and pull himself and the woman inside.

Some witnesses ran out into the corridor where there were many crew members. There was panic, several people were holding on to the handrails, some were screaming and seemed hysterical. The storekeeper, together with his cabin mate, wanted to leave their cabin but waited for further orders because they realised the situation was abnormal. After waiting in vain for orders or alarm signals, they decided, when the list was 30 degrees, to leave the cabin through the window.

Two witnesses have reported that the ship had a steady 5-degree list for a few minutes and then suddenly developed a list of about 25 to 30 degrees. The time for this second heel, as stated by two crew members, was around 0120 hrs.

The second engineer opened his cabin door and saw the lst engineer outside. According to the second engineer and a mechanic, the first engineer said: "Seems as if the bow visor has been thrown open; it would be a good thing if we got her beached". (The first engineer could overlook the forecastle area from his cabin.) The second engineer returned to his cabin for his torch and a radio. He then had to leave the cabin through the window. Several other crew members in port cabins were also escaping through windows.

In another cabin, two crew members could not escape through the window. Instead they jumped on the door, which now was in the position of the floor. The door broke and they tumbled down into the corridor.

On their way out, several crew members heard "Häire" twice and soon after Mr Skylight to number one and two over the loudspeakers. The second engineer heard on his walkie-talkie someone from the information desk trying to contact the bridge. He tried to help by using his own radio to call the bridge, but received no reply Another crew member, a watchman, stated that besides the other alarm signals there was also an order to passengers and crew to get out and an order to release the lifeboats. (It is not clear whether this order was given over the public address system or in some other way) Another witness, a shop assistant, has stated that sometime during the chain of events a male voice announced that the ship was sinking.

6.3.7 Reports from deck 8

Forward on deck 8 there were cabins for the master, the chief engineer, the owner, the radio officer; and the radio room. As these cabins were situated just below the bridge, a very short corridor connected them to the bridge staircase. Aft there were 18 cabins, 9 on each side, all for officers and crew In between the rows of cabins there were messrooms.

From deck 8 four crew members survived. Two of them were in cabins, one in the messroom and one was in an undecided port cabin. Figure 6.9 shows the plan of deck 8 and the known locations of survivors.

A shop assistant could not sleep because she was afraid and seasick. When the ship heeled over she screamed as loud as she could. Screaming was also heard from other cabins. Another witness, a cabin attendant, was awakened by the beds shaking and by the screaming, another at Ol 10-Ol 15 hrs by a cupboard falling. There were many panic-stricken crew members in the corridor. This witness had to walk along the bulkhead due to the list. One witness went into the messroom where two female shop assistants and a couple of men were looking out of the windows. All seemed to be panic-stricken. This witness returned to her cabin, together with a friend, and dressed. They left the cabin when the ship heeled over again, causing this witness to fall along the corridor and her friend to fall back into the cabin.

Four witnesses eventually managed to climb out on deck and down to deck 7. During the events they heard the alarm message "Häire, häire, laeval on häire" and Mr Skylight to number one and two. One of them interpreted the last alarm to mean that something had happened on decks one and two. One said that she could not hear any sound from the engines due to all the screaming.

6.3.8 Reports from uncertain locations

Three testimonies are by witnesses who were in their cabins at the time of the accident but the locations of these cabins have not been reported.

They report that there was a terrible thudding in addition to the more natural blows they heard at the beginning. Some time after 0100 hrs the first bump came, a strange bang, as though they were running aground, or a bang as from sheet metal or metal rubbing against metal.

6.3.9 Reports from the staircases

At the beginning, the first passengers did not experience any special difficulties climbing the various staircases. They reported only a slight list and there was no crowding. The list suddenly increased in jerks, however, and more and more people reached the staircases on different. decks. Several witnesses reported the list to be about 30-35 degrees and only slowly increasing, and that the ship's rolling more or less ceased. People coming from cabin and public areas tried to climb up to deck 7 to reach the lifeboat deck.

The forward staircases

The forward port and starboard staircases were in the forward corners of the superstructure. Both led from deck 4 to deck 7 and on each deck there were doors to the respective cabin areas, as well as out to the open deck on deck 7. Halfway between each deck there were landings.

Reports from the forward port staircase

On the forward port staircase only a few passengers were climbing. Due to the list some were unable to reach this staircase because in each cabin department they had to pass a transverse corridor. One couple lost their balance, slid down a corridor towards the starboard bulkhead and hurt themselves. On this staircase there was no crowding but the list made it increasingly difficult to climb. An elderly couple lay on the landing between decks 6 and 7. Both were bleeding and they were passed by other passengers.

The staircase through the forward cabin departments

The six staircases from deck 1 joined to make three on deck 3. One of these three ran inside the forward cabin departments up to deck 7. This staircase was connected to the central corridors on each deck and was located somewhat to the starboard of the corridor.

Reports from the staircase through the forward cabin departments

Several people from deck 1 came up the staircase through the forward cabin department to deck 4. Some climbed further up to decks 5 and 6, others ran along the corridors forward and some aft towards the foyer. The passengers who were heading aft to the foyer on deck 4 met. a person pointing forward in the corridor and saying in Swedish "Get back, death-trap, run forward". This person calmly spoke to those who were coming up the staircase. One witness, who together with 10 to 15 others was running forward, looked back and could see through the glazed doors into the foyer, with its yellow glazed tile flooring, how people were sliding on their backs to starboard.

The main staircase

The main staircase, going up from the entrance foyer, consisted of eight flights, four on the starboard side and four on the port, separated on each deck by the central corridors leading into the forward cabin areas.

On the deck levels, the two upward flights on either side of the corridor were adjacent between the downward flights. On the landing levels, this was reversed.

The main staircases began on deck 4, from where one narrow flight led down to the car decks and the cabin department on deck l. From deck 4 they ascended to deck 7. From there and up to decks 8 and 9 there were separate staircases for crew only

On deck 4 the staircases led directly into the entrance foyer, while on other decks they were separated by bulkheads from the public areas and halls. On these decks the bulkheads had an open front towards the halls. On deck 7 the staircase was entirely separated from other areas by bulkheads with fire doors, one forward and two aft, leading to the crew's cabin areas. To port and starboard there were glazed double doors with a central pillar, leading out to the open deck.

The railings of the main staircase were made of five parallel aluminium tubes with a thicker tube as a handrail on top. The railings followed the profile of the staircase, being fixed to the floor and to every fourth step by vertical flat steel at approximately one-metre intervals. All eight flights had railings on both sides.

Reparts from the main staircase

On deck 4 many people were trying to reach the staircase. Many stood along the walls and part-way up the stairs. People were having growing difficulties climbing because of the increasing list. Some stood still, just holding on while others reached the handrails and tried to pull themselves upwards. Several were half-dressed and many were drunk. One witness saw her husband lose his grip and fall down the staircase where another, quite heavy, female passenger slid down on top of him. Several witnesses escaped by dragging themselves up along the handrails. On most of the landings there were people lying and sitting. Witnesses saw others in need of help but they could scarcely help others because they could hardly help themselves.

One witness said that he felt trapped, with many people behind him and many in front, some of them not moving at all. Another witness on his way up saw many people in a state of panic. Some were only sitting in corners, incapable of doing anything. On deck 4 this witness saw some crew members trying to guide passengers. Another witness said that during his climb he passed many people who were screaming and crying and that several were in panic. The climbing was difficult in parts of the staircases where carpets had come loose and slid away Many people hung onto handrails, which also broke, causing several to slide down and many to panic.

Most of those trying to make it up to deck 7 were moving upwards, but quite a few were standing still. One witness said that he had to wait between decks 4 and 5 for about five minutes due to the crowd. A woman's voice shouted "out, out". While waiting, he heard the "Häire, häire, laeval on häire" call from the public address system. The ship's list increased in jerks and there were many people and total chaos on deck 6. A vending machine slid down the foyer. Later on, a witness saw an officer wearing a white shirt and shoulder straps with stripes of rank and a triangle. He had a walkietalkie. On the landing between decks 6 and 7, many people were lying and standing. Those who were climbing could also see many people in various corridors lying all over the place.

Quite a few on the crowded staircase lacked the strength to continue. By the time some reached deck 7, the ship had a list of about 35-40 degrees. The lights were still on. On the deck there were plenty of lifejackets and at the open doors a crew member was trying to lead people out. People formed a human chain, helping each other out to the port side of the deck. One witness said that the chain was mostly made up of crew members. Crew members also told passengers outside to move on and not to block the open doors. A few witnesses saw a crew member with a walkie-talkie and a "scooter uniform" out on deck while other witnesses reported having seen no organised action by the crew.

One witness who came up early to the main hall on deck 7 saw one or two crew members with walkie-talkies. While outside distributing lifejackets, he heard the bell ringing. Another witness who arrived quite early reported that there were four or five people whom he thought were crew members. They were keeping passengers back. This Russian-speaking witness did not understand their language and was therefore not able to tell whether they were giving instructions to the passengers. Another witness reported that on the port side of the main staircase, one crew member had braced himself somehow and was helping people from the staircases to the open port doors by pulling them upwards.

Up in the hall on deck 7 people had to hang on to handrails and drag themselves up to the doors. One witness saw people sliding down the hall on the carpeted deck. She saw one woman hit the door on the other side violently; losing consciousness. This witness managed to hold on to the handrail despite the many people forcing their way forwards. In some places the handrail had come loose, making it difficult to climb up to deck 7. People were coming out through the glass doors one by one and the witness had to wait her turn. It was impossible to get out without holding on to the door or something else.

One passenger from deck 1 who arrived early on deck 7 said that it looked as if the open doors were standing straight up. On coming out he saw 5-6 persons on the outside deck. Another witness violently forced his way up and through the doors, pressing someone else out at the same time. To be able to get out, one witness said some had to pull and others had to push from behind. This witness also said that people who reached the deck 7 level seemed to be acting more constructively than others. Another witness saw, on arriving on deck 7, that the opposite side of the ship was already level with the water line.

A male witness threw himself at the door, trying to grasp the central pillar but failed and slid down. Somebody threw lifejackets to him but he managed to force himself up once again to grasp the pillar. This time he managed to hang on and push out five more people. By now there were many people out on deck. Another witness said that he grasped a handrail and reached deck 7. This witness also said that the crew appeared bewildered and did not seem to know what to do.

A few witnesses reported hearing alarm signals such as a bell ringing and public address system messages such as Mr Skylight to number one and two and "Häire, häire, laeval on häire". Some were not able to distinguish what messages they heard and others stated that they could not possibly hear alarms due to the screaming. One witness said that he heard rushing water from below the staircase and that there was water in the staircase.

The aft staircase

The aft staircase was situated to port of the ship's centre line. It consisted of three parallel flights with landings between every deck (Figure 6.6). It went from deck 4 up to deck 7 where, to port, glass double doors led to the open deck.

The railings of this staircase were similar to those of the main staircase.

This staircase connected the public areas such as the conference department on deck 4, the lounges, the Pub Admiral and the Cafe Neptunus on deck 5, and the Restaurant Poseidon and the casino on deck 6. On deck 4, access from the midship cabin department was through all three longitudinal corridors, which had doors leading to this staircase.

Reports from the aft staircase

On the aft staircase there were also many people, mostly from the Pub Admiral, the lounges, the casino and the Cafe Neptunus, i.e. from decks 5 and 6.

One early witness had no difficulties climbing to deck 7. He looked inside corridors when passing and stated that they were completely empty of people.

People climbed by shuffling their hands up along the handrail. If one hand was released it resulted in a fall. Several people were falling down, hitting the lower landing. Only the strongest were able to struggle further up.

One witness reported seeing a crew member trying to arrange a human chain to help passengers up from lower parts of the ship. People were shouting to each other to run up to deck 7 and get out.

The aft outdoor stairs

Aft of the ship's superstructure there were rather small open-air decks with two staircases, one on each side. They went from deck 4 to deck 8 and could be reached only from the inside public areas through doors on decks 4, 5 and 6 and through the crew areas on decks 7 and 8.

Reports from the aft outdoor stairs

Two survivors, who were able to reach the afterdeck after quite some time, reported heavy wind and waves. While struggling to reach the aft port side door, one of these witnesses reported that the lights went off first momentarily and then for good when he reached the outer deck. Once out on deck he threw himself at some fixed tables. From these tables he managed to get hold of the iron handrails on the port side staircase. He was not able to climb the stairs due to the heavy list but tried to climb along the handrail. Waves lifted him and moved him upwards metre by metre. In this manner he eventually reached deck 6 where he came under water and had to swim for an open area in between the decks. Eventually he reached the surface but without a lifejacket on. At some time during his climb he saw a man passively standing on the inside of the closed half-glazed doors, presumably unable to open them because they were already partly under water.

The other witness from this staircase looked for lifejackets out on deck but could not find any This witness managed to climb from the port side of the afterdeck on deck 5 straight up onto the hull when the list was about 90 degrees.

6.3.10 Reports from the open deck, deck 7

The first passengers out did not experience any crowding on staircases and outside. One of the first passengers out on deck 7 reported that he saw one or two crew members coming into the hall on deck 7 at the same time. The list at this time was estimated by this witness to be around 30 degrees. Helped by another passenger, he managed to open the doors out. While doing this he noticed that more people were coming up the staircases after him. This witness came out as the first or second person and immediately opened a nearby lifejacket container. He saw more people coming out and he distributed lifejackets both forward and aft. He could not keep up with all the people coming so he shouted to others, and got help.

Another witness moved up through the staircases without noticing any crowding but he found it difficult to get out due to the increasing list. This witness helped an officer out through the doors and the officer, once out on deck, started throwing lifejackets down into the hall and staircase. Out on deck, the lights were on and the moon was shining. Under the bridge was a small crowd and they were quite calm. There were 8-10 people outside when one witness noticed the time by her watch as 0105 hrs. People started to put on lifejackets and passed lifejackets from hand to hand. More people were coming out all the time. Several people threw lifejackets down into the ship to others still climbing in the staircase and the open hall.

Another passenger said that when he came out there were about 20 people as well as "groups of drunken youngsters". Some passengers said there was panic while others said there was no panic. On deck, several people heard the "Häire" announcement from the loudspeakers. One witness saw around ten persons lying on the deck near the bulkhead. They seemed apathetic and he threw lifejackets to them. He did not see them react or put on the lifejackets. Most passengers out on deck were in their underwear with lifejackets on. There was heavy spray and much water was coming down the main hall. Out on deck there was much activity most people trying to do something. The ship was rolling and jerking.

More and more people emerged to deck 7 and a large crowd grew just outside the open doors. People helped each other out and some had to tell others to move away from the doors to make way for those still inside on the staircase. One female witness saw three men from the crew, and her impression was that they were behaving like any passenger, although they were helping others out. She also tried to get help from another crew member to release the lifeboats, but she found him even more passive than most of the passengers.

Several witnesses reported that they tried to open the liferaft containers. One unfastened the rubber strap around the container and pulled the handle to open the lid but this broke into pieces. He found the containers impossible to open. At one point a human chain was formed where people tried to pull each other out. One crew member in a white shirt and tie was seen in the chain. At another point some people were lying down on the deck pulling others out.

Several witnesses reported that there were many panicking people on deck and that, "everyone was only looking out for him- or herself'. There was screaming, crying and full panic, and people were treading on each other. Some passengers were injured, lying down and shouting for lifejackets. One woman was on all fours screaming and begging for a lifejacket. Someone threw one in her direction but it was uncertain whether she managed to put it on.

Several seemingly apathetic passengers were sitting on deck with their feet up and their backs against the bulkhead. Two men near the lifeboats were desperately pulling and tearing at ropes while others were coming out from the staircase. One of these fell on the threshold but managed to get hold of the railing. A number of crew members pulled and dragged more people out. On deck, people dispersed, some moving forward and others moving amidships and aft.

One witness trying to reach the port door, slid across the hall and through an open door out to starboard. He saw a couple of elderly people lying outside, seemingly dead. He opened a locker to a lifejacket container and started giving out lifejackets to the few people nearby. Soon he had to hold firmly onto the railing so as not to slide into the water, the surface now being quite near him. He was right under lifeboat number 5 when he saw lifeboat number 7 washed loos by a wave. At the same moment two lifejacket containers also came loose and tumbled into the sea. He and a female bartender were standing together, holding on to the railing, and were washed over by waves several times, sometimes being completely under water. Suddenly lifeboat number 5 came loose and in the next wave the bartender disappeared. The following wave washed the witness into the sea.

On the open deck to port there was much activity Several people were distributing lifejackets from containers, others were throwing them into the staircase or passing them on to other passengers on the deck. Two passengers tried to release a lifeboat and others started to climb onto the liferaft containers. Two men tried to loosen these containers and others tried to open them by hand. One container broke loose and fell into the sea. While this was happening, the lights went out several times. Every time the light went out it was accompanied by screams. The passengers who were working to release the lifeboats found a panel with buttons of various colours. They tried to press all the buttons but nothing happened. They could not find any instructions. There was also a manual winch but three passengers together were not able to move it. They went on trying to open liferaft containers. They managed to open one and the raft inflated.

Around the same time there were about 100 people on the open decks. Some were passing lifejackets from hand to hand and people were trying to put the jackets on as best they could.

Out on deck a member of the crew talked calmly to the others and together with other crew members tried unsuccessfully to release a lifeboat. He said that the lashings were too rusty and that it was impossible to release this lifeboat. Another witness reported seeing a man standing, composed and assured, trying to calm those who were frightened. He arranged a human chain to distribute lifejackets from an open container. He saw to that everyone got a lifejacket and also instructed and helped passengers to put them on. One woman lent her knife to a passenger who was trying to open liferaft containers, but he failed.

Several crew members have reported that other crew members worked to release liferafts which, however, once inflated, were blown from the deck and into the water. Other crew members secured liferafts with ropes to the railings. One passenger managed to release a couple of liferaft containers which fell into the water and the rafts started to inflate.

On the deck there were, according to several witnesses, a couple of able-bodied seamen, the security guard, a manager from the Stockholm terminal, a few storekeepers and the boatswain. The boatswain was seen doing a heroic job helping many passengers and releasing rafts. A storekeeper was reported to have taken charge of some rescue operations. Crew members distributed lifejackets or released liferafts both amidships and aft.

The master of the alternate crew was also seen forward on the deck, just under the bridge, distributing lifejackets and giving orders to other crew members and passengers. The trainee second officer and the AB seaman of the watch were also there at an early stage and, according to other crew member witnesses, did a great job in helping others. Other crew members have reported that the crew played no particular role in the evacuation. Several passengers have reported the same.

When the ship was listing about 30 degrees, the "Häire, häire, laeval on häire" announcement was heard out on deck. At this time the engines were still running and the floodlights and ordinary lights were on. Some witnesses said that they could not hear any sound from the engines due to the screaming.

From inside the staircase, people were heard screaming, crying and shouting for more lifejackets. Many lifejackets were blown into the sea by the strong wind, but there were also plenty lying on the deck. One witness said that most people were calm and queuing for jackets but most stated that there was panic and chaos. Some people reassured each other that this ship could not sink, and this calmed a few passengers somewhat. Later about 250 people were out on deck with lifejackets on, most of them not dressed, some only in underwear and some naked. One witness reported that many people came out during the first five to ten minutes. After that it was impossible because of the increasing list.

One of the last who tried to come out, a woman, was seen lying in the staircase hanging on to the threshold. She could not pull herself out and, after a while, she lost her grip and slid back.

Somewhat later the master of the alternate crew was seen near the door to the alt. staircase coming from the fore and shouting orders and helping people. He ordered the safety guard to help two women release a liferaft. The security guard did not see, however, if the master got a lifejacket.

A few people started to climb up to deck 8 and formed a human chain to help more people up. Some ten people were on this deck trying to find lifejackets. After some difficulties, some of them managed to open one container and started distributing jackets. Some witnesses found the containers impossible to open due to the list. More people reached deck 8 and several fought for jackets, some trying to tear lifejackets from others even though there were plenty of jackets lying on deck. One witness reported that others told the fighters to calm down.

As the list increased, the hard plastic deck covering started breaking apart. Later this flooring broke free, preventing people from moving; and in some places it slid and rolled away This covering also lay against the open aft doors, and later it fell into the sea on top of people in the water. More and more people grabbed the railings and hauled themselves up, afraid of being trapped below them when the ship's list increased. Some passengers helped lift others to get a grip on the railings, while others tried to jump up, but the railings were beyond the reach of many. According to one witness the ship had a list of 35 to 40 degrees for about ten minutes. Other witnesses reported that the ship suddenly heeled to 45 degrees, at about which point the engines stopped. Other witnesses stated that there were two distinct heels one to about 20 degrees and one to 45.

After lying at a 45-degree angle, according to some for about 5 minutes while the lights blinked a few times, the ship started to heel over again to 80 degrees and began to sink by the stern. At this time there were some very loud crashes from the inside and a loud hissing noise as air was expelled.

To starboard, one witness saw how people were clinging to the railing and were washed away when this became submerged. He also reported that he could see water rushing into the ship.

More and more people climbed up and out onto the ship's port side. Of the approximately 250 people, about 100 were sitting on the hull and holding on to the railing. Others who were not able to reach the railing stood on the bulkhead. Some jumped into the sea and many were forced off the ship by huge waves. Some witnesses held on, in spite of the seas, waiting for the right moment and a wave big enough to wash them safely over the ship's superstructure. They were afraid of being trapped or injured by railings, wires, lifeboats or davits. Some crew members and passengers together released a ladder which got stuck at the fender. One passenger, seen entering a lifeboat that was in its davits, lay down inside making no effort to launch it. Another passenger was seen losing his grip and sliding in right through the staircase hall and into the water on the starboard side.

A few people slid away on the ship's hull. Some were washed into the water but others were halted at the fender or got a grip on the ladder.

Several passengers reported that, as the Estonia's list reached 80 degrees, two crew members emerged from a shaft near the funnel shouting that there was water on the car deck. (They were presumably the system engineer and the motorman escaping from the engine room.) As the ship heeled, the lights went out, but soon the emergency light came on for four to five minutes then it was completely dark. A few witnesses also reported hearing a message on the public address system as the list reached 90 degrees. Two Estonian-speaking witnesses heard the message "the ship is going down" in Estonian. Another stated that he heard crew members urging passengers in Estonian to leave the sinking ship. When the funnel reached the water, witnesses could hear the bridge windows breaking. They also heard a long-drawn-out typhoon signal. They saw the firing of a distress rocket. At this angle, diesel oil started to flow over the ship, rendering surfaces rather slippery.

Out on the hull many people were now sitting, crawling, walking and standing. One passenger sat on a window holding onto a grating. Another trod on a window which broke injuring the person's leg. The moonlight and the white hull of the ship gave enough light to see what was happening. One witness has reported that the ship's hull was billowing and this made him afraid that the ship would break apart.

Several witnesses hung onto the rail but could not haul themselves up to climb onto the hull. One of them standing on the bulkhead was stuck just under a rack of liferaft containers. He ran aft on the bulkhead where he saw numbers of people crowding around a liferaft. Several climbed into it and under the tarpaulin canopy Others were just hanging on to it, yet others throwing themselves onto its canopy People were arguing about what to do and several thought it was too dangerous to launch the raft just at that moment. When the ship's angle seemed favourable they started to pull the raft, which slid into the wind alongside the hull. Soon after they were washed into the water together with the raft.

Some people worked in vain to open other liferaft containers but had to give up and run. About 15 people, forward on the hull, jumped into another liferaft which, after some sliding, got stuck against the rail. One witness shouted to the others to get out and help launch it and after a while everyone was out. They tried briefly but were unable to launch the raft. All of those who had been in the raft jumped into the water.

One man was seen climbing on the liferaft container racks, systematically opening containers one after another. One witness said it was the trainee second officer. The rafts inflated and many blew away Others were caught by passengers and dragged over the hull towards the fender. Most of the liferafts were on the aft part of the hull. One raft, forward, slid down on the hull towards the keel and got stuck on the fender. About 20 people were in the raft, some under the canopy and some above, and after a short while, when the ship's funnel reached the water, this raft slid back over the rail and into the water now covering parts of the superstructure.

There was another liferaft on the hull with several people in it, some trying to pull it into the sea. The raft started to slide and, hitting the water, it turned over and most of the people fell off.

Several people were reported to have been standing on the almost horizontal bulkhead with their backs against the deck, watching the funnel sink into the water. When the funnel reached the water surface, they were all engulfed in pungent smoke spreading over the deck. One passenger on the bulkhead reported that heavy waves pressed him against the deck and that he had nowhere to escape. He decided to let go when the next wave came because he was afraid of getting caught by the rail. When the next big wave came he threw himself forward into the water where he had seen the funnel disappear.

Far aft on the hull another inflatable liferaft lay upside-down. On the bottom were about ten people, around it was a crowd and many others were running to it. Most jumped into the raft at the same

time causing some chaos. One passenger rushed along the hull towards the raft and threw himself violently past the rest and into it. Shortly thereafter this raft with people on and outside, began to slide along the hull and into the water.

On the hull a man, wearing underpants only; was seen rushing aft. He pulled a lifejacket over his head and threw himself directly into the water. Another witness was washed into the sea after having seen people fighting for a liferaft. One man was together with his wife who was very afraid of the water. He jumped and waved and shouted to her to follow, but she did not do so.

Some 50 people moved towards the highest level of the hull near the bilgekeel where a stabiliser fin stood straight up, rocking back and forth. The list was now gradually increasing, but not faster than people were able to crawl or walk towards the bottom. At about this moment one passenger asked some crew members if this was the time to abandon ship and jump into the sea. They answered that it was not yet necessary.

When the list was about 135 degrees several lifeboats broke loose and were thrown violently against the ship and got damaged. Damaged lifeboats floated upside down and one splintered lifeboat floated back and forth in the waves, striking the ship hard. Some people slipped into the water among cranes, wires and lifeboats and one witness re-

ported that it was terrible to see.

Most remaining people were now on the bottom of the ship and many slid into the water. According to one witness it was as if the water was coming up to fetch the people, a couple at a time, and drag them down. Around the ESTONIA there were many inflated liferafts. Aft there

were more than ten, some of them upside down, others with the canopy up and with lights. All around the ship the water was full of floating empty lifejackets.

About ten people were left on the bottom of the hull when the ship turned nearly upside down. Most of them were washed into the sea and one of the last sitting near the bilge-keel, saw the stern sinking quite rapidly and liferafts floating around the stern. The ship had heeled

against the wind. A wave from stern swept this witness into the water. By

0130 hrs the stern was under water and the bow was rising, according to the trainee second officer who looked at his watch as he slid off the ship.

6.3.11 Reports from witnesses in the water

As the ESTONIA sank, many liferafts floated up to the surface. Numerous lifejackets floated around the vessel and also many liferafts. Several lifeboats floated upside down and witnesses also reported seeing dead people floating face down. Around and between liferafts were also people with lifejackets on, floating and swimming. Many screams and calls for help, including children's voices, were heard all around the rafts.

A few witnesses have reported seeing the ESTONIA sink. She went down, upside down, stern first, with the fore up in the air, clearly visible at a 45-degree angle. Part of the bridge was visible, the bulbous bow being the highest point. The ship maintained this position for several minutes and then gradually turned and sank into a sea of bubbles. Several people clinging to the ship followed her down. Two witnesses in liferafts saw people still climbing and clinging to the ship's bottom or hanging onto the rail. One witness saw several people climbing on the rail which broke and they all fell into the water. Another witness stated that he could see the ship sinking but with no people visible. There was much screaming at the moment she sank, but then a sudden silence. One witness reported that the ship was illuminated as she sank, and presumed it was the moonlight.

6.3.12 Reports from witnesses in various floating devices

From the witness testimonies it has been possible to identify many of those who were rescued from the same liferafts or lifeboats. Some witness reports include names of those they spent time with in the rafts while others do not. It has been possible, however, to trace many of the witnesses and identify the various floating devices by similarities in the reports. This cannot, however, be done with certainty in all cases.

Note also that all information in this summary, as well as in the other parts of this chapter, is derived exclusively from witnesses' testimonies. The number of people on board various floating devices and details about the rescue may therefore not necessarily correspond with the reports from helicopter and vessel crews involved in the rescue operations.

Reports from liferafts

Liferaft "A"

One male passenger, wearing a lifejacket, was swept from the hull into the sea. After being deep under water, he reached the surface and got hold of one more lifejacket. He found and clung firmly to some ropes from a lifebuoy. While hanging on, he heard someone close to him calling out for help in English. He got hold of the collar of a man in the water and saw that the man had no lifejacket. Suddenly a wave broke over them and the man was swept away This witness later swam to a liferaft and managed to get in. The raft was full of water and the canopy was not raised. There were no other people in the raft. He managed to raise the canopy and the lights in the raft came on. After a while he found a suit made of aluminium foil. He tried to dress but the suit was too thin and tore, becoming useless. For several hours, water entered constantly because he was not able to close the canopy opening. During the early hours of the morning he was rescued by a Finnish helicopter.

Liferaft "B"

Two male passengers were rescued from another liferaft. One of them crawled along the ship's hull towards a raft which slid into the water. The witness held on to a rope and slid together with the raft into the water. He ended up quite close to another raft and managed to hang on to it. A young woman from inside held his hand, trying to pull him into the raft, but neither of them had the strength and after a while he lost his grip. He sank very deep and on regaining the surface he was quite dazed. He was floating very close to the ship's bow when he saw another raft drifting towards him. He managed to climb into this empty raft.

The other person rescued from the same raft was in the water for about an hour, swimming and floating on hard plastic deck covering from the sun deck. Several occupied rafts passed him but no one on board was able to throw a rope in his direction. He was wearing four lifejackets and now and then collided with rafts. He swam towards a drifting raft, calling for help. He saw a man who at first could not locate him in the dark. The man in the raft has reported that he heard calls for help and after a while he managed to get the swimmer on board.

They sat on top of the canopy at first but were able to crawl into the raft after a while. They also managed to raise the canopy and close the openings. There was a light in the raft. They helped each other to bail out the water with a plastic bailer and after a while they found a plastic bag containing another bailer and a hand torch. They were, however, unable to open this bag because their hands were frozen. One of them tried in vain to open it with his mouth but had to give up after losing some teeth. At about 0700 hrs these two men were rescued by a helicopter.

Liferaft "C"

One female passenger fell, hitting her head on something, and sank deep in the water. She thought she was going to die so she inhaled water. She eventually rose to the surface where she could see the ESTONIA and people clinging on. She collected several lifejackets from around her and floated on them towards a raft. She had difficulties getting on it and ayoung man from inside reached out to her. It took some time because she had tied herself to ropes, but the young man, an Estonian, held on and eventually pulled her up. In this raft there were six people some of whom were wearing overalls with "Estline" printed on them. Together they managed to release the canopy and got lights in the raft. From the water they heard screaming but were not able to see anyone.

After some time they fired distress rockets. Later they found a bag of plastic clothing, which they distributed to those who were nearly naked. From this raft six people were rescued by a Swedish helicopter.

Liferaft "D"

One passenger was thrown into the sea aft where the water smelled heavily of diesel oil. He swam to a raft that was upside down and a man helped him up. When on board he slid towards the centre of the raft where there was a large pool of water. He was exhausted and had to catch his breath. On the raft there were six persons. The raft turned over in the heavy seas and all on board fell into the water. This witness lost contact with the raft but hung on to a rope for several minutes, totally exhausted. He managed to get onto the raft again where there were still six people, one of them dead with severe head wounds. From this raft, five people were rescued at about 0700 hrs by a Finnish helicopter.

Liferaft "E"

In another raft there were two female crew members, (a mess attendant and a cabin attendant) together with a male passenger, all Estonians. The cabin attendant was inside the raft when it slid into the water. While in the water she managed to get hold of the man and pulled him on board. He had been swept off the ship by a wave. The mess attendant was also swept into the sea by a wave and surfaced close to this raft. The two inside helped her aboard and they were all rescued by a helicopter at about 0820 hrs.

Liferaft "F"

One passenger was swept overboard by a huge wave and after a short time in the water he managed to climb onto a liferaft which was upside down. He was alone and slid into the sea again because he realised that he could not survive in the open air. For protection against the cold wind he managed to get under the raft and inside the canopy The raft was turned over by the heavy seas and he was suddenly inside the right way up. This raft was completely filled with water and he was constantly being washed over. He could not lie down or sit, only stand up. The raft suddenly turned over and he ended up beneath it again. The raft turned over in this manner several times during the night. One helicopter made two unsuccessful attempts to rescue him during the early morning hours but had to give up. He was rescued by a Finnish Coast. Guard vessel at about 0600 hrs.

Liferaft "G"

In another liferaft there were one male passenger and two dancers, one female and one male, all Estonians. The female dancer was rescued from the water by the other dancer and she was taken off by a Swedish helicopter at about 0330 hrs. Later the two men were rescued by a Finnish helicopter and brought to the SILJA SYMPHONY.

Liferaft "H"

One Estonian passenger slid along the ship's hull into the water and managed to get onto an empty liferaft. The canopy could not be raised and the waves washed over this passenger several times. He was rescued by a helicopter at about 0400 hrs.

Liferaft "1"

In one raft there were many people. Among these,14 were identified through their witness testimonies. The identified passengers were one male Norwegian, two male Estonians, one male Latvian and six Swedes (five male and one female). The crew members were a male Estonian shop assistant, a Russian turner, a cook and a motorman. The motorman had a broken arm and head injuries.

One of the Swedish passengers jumped from the ESTONIA into the water and swam to get hold of a nearby raft. After being pulled up by others he was totally exhausted. At this time the canopy was not yet raised. The turner, who had slid into the water, got stuck between two rafts and boarded one of them containing only three other persons. After a while others hauled themselves into the raft. Some of the people near the openings pulled in several swimmers.

Five people rushed to a raft lying upside down aft on the hull of the ESTONIA. About 50 people were jumping into and clinging onto it. As the raft slid over the rail and into the water most people fell off. The female witness, a Swedish passenger, slid down together with the raft, holding on to the ropes. She went under and was caught by a rope around the foot. She struggled under water but eventually cut the rope with a knife and reached the surface, where she hung on to an overturned raft. Close to her a Swedish man was also hanging on, one of those who had slid with the raft. They floated together for about 30 minutes until the man managed to get hold of a drifting raft. This raft was full of people who helped them aboard.

Cascades of water entered the raft at every wave and it was already full of water. A few bailed and they managed to close the opening after about 45 minutes. They could hear people in the water calling for help but were unable to see from where because of the darkness and the big waves. Many of them could do nothing to help because they were too exhausted. A few struggled with a crew member over a hand torch. The crew member held desperately on to the torch. They eventually managed to loosen his grip and started signalling with it. The people in the raft tried to lie very close together to keep warm but they were moved around by the water inside and the heavy sea. Several people, crew members and passengers, were quite active and they also fired several distress rockets. One young Norwegian passenger made an especially heroic contribution.

After several hours (after daybreak), they were able to see the ISABELLA. The raft was drifting towards the ship which manoeuvred to intercept. On board the ISABELLA the crew had released a liferaft and three crew members in survival suits urged the drifters from the ESTONIA to move from their raft to the ISABELLA s which had a rope on top and could be hoisted on board. The ESTONIA's raft struck the ISABELLA s hull repeatedly but after a while one survivor after another started to haul themselves over to the ISABELLA s raft, which by this time was filling with water. ISABELLA crew members made several attempts to hoist the raft and the crew members in survival suits eventually jumped into the water so as to lessen the weight. After about ten attempts they managed to lift the raft, but the bottom split and all but one of those on board fell into the sea. One witness managed to hold on to the raft in spite of being stiff with cold and exhaustion. Several came under the raft and some disappeared in the water.

After some time the ISABELLA opened a port in the hull and released a slide. The people in the water and a couple of crew members with survival suits were helped up onto the slide by other crew members. Sixteen people from this raft were rescued this way and one by helicopter.

Liferaft 'J"

In one liferaft there was only one passenger, a Swede, and he was rescued by helicopter.

Liferaft "K"

In another raft two people were rescued, the repairman, and a male Swedish passenger. Both witnesses were washed from the hull by a wave. The Swedish passenger managed to climb onto a liferaft which was floating upside down. On board were two girls in their twenties. The Estonian repairman swam for about ten minutes before being hauled on board the raft by the others. All four of them lay close together to keep warm and also massaged and hugged each other. Waves sprayed over them constantly, and washed them into the water four or five times. Each time they helped each other back on board, someone always managing to hold on to some part of the raft. The men wanted to turn the raft the right way up but the girls were very nervous and afraid of going into the water voluntarily to make this possible. When a wave once again washed over

the raft, the two girls slid away and disappeared. The last thing the witnesses heard was one of them groaning. Waves threw the two men into the sea at least twice more. After the last time, the Swedish passenger got caught in a rope, but the repairman managed to get onboard again. He tried to pull up the Swede but they were now both too weak. The repairman held the Swede in the water by the hands until a helicopter arrived and rescued them at about 0700 hrs.

Liferaft "L"

A musician wearing a lifejacket slid into the water and managed to get hold of a liferaft floating upside down with a man on the bottom. He did not manage to enter this but got onto another raft floating by the right way up. Once on board this, he helped another man, an Estonian passenger, by taking his hands and pulling him up. There were numerous calls for help nearby but he was unable to locate them in the dark. After a while it was silent. They were thus two in this liferaft. and the canopy was released. They helped each other and fired distress rockets which were eventually seen by the SILJA SYMPHONY. Soon afterwards, a helicopter rescued them and landed them on board the vessel.

Liferaft "M"

One passenger crawled into a raft on the ESTONIA's hull. Other people threw themselves on top of the canopy of this raft. The raft slid and got stuck on the fender. Another passenger standing on top of the raft saw about 20 people running along the hull towards him. Several threw themselves on top of the canopy It seemed dangerous to launch the raft from this height and they were arguing about whether the ship would stay afloat or sink. When the angle was favourable they dragged the raft towards the bridge where several rafts were floating in the water. As the raft slid, this witness was sitting and facing the direction of travel. When the raft hit the water, the witness was struck in the face by a floating object and fell overboard bleeding severely He saw two rafts with the canopies released blowing towards him and managed to catch one of them. This raft was violently thrown by the waves several times against the hull of the ESTONIA.

The passenger who was under the canopy had to get out because the raft was full of water. He lost his trousers and shoes while fighting his way out and was completely naked. He managed to get over to another raft with several people inside and some on top of the canopy He had the feeling that people were being exchanged by the waves, i.e. chat some were washed into the sea and others were coming on board. He heard calls for help and screaming outside and tried for a long time to pull a man into the raft, holding on to him asking for help from the others inside the raft. One man could not help because he was bleeding severely and could not bend his face forward, and another was powerless to help because of an injured back. After about ten minutes he let the man go because he was afraid of losing all his remaining strength in attempting to pull him up or even holding him. Because of the water in the raft and because the waves were constantly flattening the canopy, he stood up to hold the canopy in place.

A third witness managed to grasp a rope to this liferaft. He reported that there were numerous people in the water and around the raft, many in panic. People were climbing onto his back and he got several bruises and scratches. The raft was thrown against the hull several times by the heavy sea. He got squeezed between the raft and the hull several times but by bracing his feet against the hull he managed to get on to the raft. During the struggle he injured his back against the hull.

Another witness reported that the raft slid down "at full speed" and that he jumped off. He fell into the water, hitting his head and his back. He swam towards this raft but found nothing to hang on to. A woman on it took his hand and held it. Several people in the water clung to his back and around his face. He also got a hand in his mouth. He got help from the woman to get onto the raft and when interviewed he stated that he could not have made it without her help.

This raft collided with another and the witness with the face injury managed to get hold of it. Several people climbed on his back to the other raft and when he lost his grip there were only five remaining, four male passengers and one woman, all Swedish.

The witness with the face injury has reported that one man was very active. He tried for over an hour to pull aboard a younger Estonian man but did not have the strength and the man eventually disappeared after calling for help in Estonian for quite a while. This witness also reported that there was a great deal of water in the raft and one male passenger stood, naked holding the canopy for most of the time. This witness could not move, let alone help because every movement increased the bleeding. (Later at the hospital, this man was found to have five facial fractures.)

The witness who held up the canopy has reported that an injured man in the raft was bleeding heavily from the face and holding the head of a woman above the water. The woman was wearing a brassiere and panties only. Occasionally waves flattened the canopy, causing this

witness to fall. Every time, he forced it up again. While standing, he tried to close the openings to prevent any more water from coming in. He found the ropes to control the openings but did not find any place to fasten them and he therefore held them tight. He was standing for about four hours and became very tired.

The others tried to fire distress rockets but one of them ignited inside the raft filling it with smoke. No one was able to throw the rocket out and this witness had to stick his head outside for air. The woman, he reported, was becoming more and more listless and limp. She occasionally slid down into the water in the raft and was pulled up by the others, who tried to massage her and shake her to arouse her. One hour prior to their rescue, she died.

After several hours the sea movement changed. Water entered the raft and pushed down the canopy again. The occupants found nothing to bail with and have said that by now it was only a matter of minutes before they would have to give up. They were not able to struggle any more in a raft filled with water and with the canopy down.

They were saved by a Finnish helicopter at dawn, the rescue taking three or lour minutes. The witness who was standing up expected to be smoothly, lifted by the helicopter as the last person. Instead, both he and his rescuer were violently jerked out of the raft by the wire, plunged deep into the water and then violently jerked up again to the helicopter

Liferaft "N"

One female Swedish passenger ran aft along the hull towards a raft. Several other people joined her when they were suddenly swept into the sea by a huge wave. Another female witness, a croupier, was also swept away, striking the bulkhead and then ending up deep under water. She reported being quite resigned to drowning, feeling the situation to be hopeless. She eventually surfaced close to a raft. Another female passenger jumped into a raft on the hull. This raft slid into the water and turned over. All those on board fell into the water and she swam for a while shouting for help. A male passenger jumped into a raft on the hull with two men and one woman in it. The raft slid into the water with a couple of people hanging on its outside.

The Swedish woman who had just surfaced swam to a raft and was helped on board by a man inside. Once on board she helped the croupier up, and the two women then pulled up four more persons. The women started to bail with their shoes. They urged others to help but most of the others seemed shocked or apathetic. The raft was taking in much water so one of the two women cut a rope hanging out from the raft (the rope to the sea anchor). After this the inflow decreased considerably They shouted and urged each other to fight and to master the situation, and they were quite active. For about twenty minutes they struggled to drag on board a female Estonian shop assistant who had been swimming for a while, calling for help. In her report this shop assistant stated that she was helped by a Swedish female who tried for quite some time to pull her on board. After a while they also managed to get help from others and pulled her onboard. In addition to these three women this raft contained a male and a female Russian, an Estonian waitress, another Estonian shop assistant and an Estonian, a Swedish and a German passenger. The latter was pulled on board after about half an hour in the water.

One witness has reported that they had difficulties with the canopy and that there were no lights on board. Now and then this water-filled raft buckled and stretched out again and all the people were thrown together. Several were seasick and vomiting, only a few were active, signalling with torches and trying to bail out the water. One witness wound a rope around his arm to secure himself from being thrown out. The two most active women tried to fire distress rockets when they saw other ships but they were having difficulties in working out how to operate them. With some help, they managed to release one, which apparently was seen on board one of the ferries.

The raft floated near the ferry which lowered a raft with a rope. On board the ferry the crew called over a megaphone to the people in the ESTONIA raft to move over to theirs, where there were some men in orange coloured clothing helping them. This raft was then lifted by a handdriven winch aboard the MARIELLA and nine people were rescued.

Liferaft "O"

One Swedish passenger jumped into the sea and came up close to a raft floating upside down. He got a grip and managed to hold on for a while. Suddenly a wave turned the raft right-side-up and the next wave washed this person into it. There was much water inside and he was alone. After about fifteen minutes he heard calls for help but was unable to see anyone in the darkness. Some time later a wave overturned the raft again and then immediately another one righted it. After this he realised that there was another man in the raft, an Estonian crew member. The lamp in the raft was alight and he found a survival blanket which he wrapped around himself. The two men were transferred to a raft lowered by a ferry and were hauled aboard at about 0500 hrs.

Liferaft "P"

One witness lost his lifejacket while running along the hull towards the water. In the water he bounced against the ship several times but suddenly a raft appeared "as from nowhere" quite close to him and he managed to grab hold. Another witness jumped from the funnel at the same time as the typhoon signal was heard and gained an empty raft. All around him there were calls for help and after some time he managed to pull inside a Lithuanian man. They helped others into the raft and after some time they were about 15 people. These included several crew members, a motorman, a store keeper, one able-bodied seaman and his wife, the welder, one cabin attendant, the hotel purser and one Estonian and four Swedish passengers.

One of the witnesses has reported seeing at least 20 rafts in the vicinity and hearing numerous calls for help, but without being able to locate the people.

One of the passengers found a thermal protective suit and tried to put it on. The suit was too thin and tore in several places.

There were no lights in the raft and because it was somewhat crowded, two people moved over to another raft. Those that remained drifted towards the MARI-ELLA, which launched a raft. The people climbed over to this raft and the MARI-ELLA crew hauled them on board.

Liferaft "Q"

One witness was washed overboard from the ESTONIA without a lifejacket. He sank deep under water several times but eventually managed to grip a rope from a raft. A man inside the raft bent over, took a firm grip on his collar and tried to pull him aboard. He lacked the strength, however, and the witness begged him to let go because he was near being strangled by the grip and could not breathe. The raft was too high and he could not find anything to climb on. He managed to get onto another, damaged, raft and from this he crawled into the first raft. In this raft there were about 15 people, many of them Estonian crew members, and they were very active. Many were signalling, waving and shouting to ships nearby All in this raft were rescued by a Finnish helicopter which put them on board the MARIELLA. A few witnesses from this raft have reported that they were totally exhausted and that they had only faint memories of being rescued.

Liferaft "R"

Witnesses from another raft have reported that they tried to pull it into the water from the hull. Suddenly the raft slid away with several people on board. Some witnesses had to let go their grip and they fell deep into the water. Others managed to stay aboard and there was much water in the raft. Another witness saw a man start to swim towards the raft, tried to pull him into the raft but the man was heavy and disappeared. Another male witness was swimming towards the same raft and ended up underneath it. He managed to get loose and called for help. He was heard by someone inside who managed to get a grip on his arm. Around him were many people swimming and calling for help and the man inside reassured him that he would not let go. After a while he was pulled into the raft, by then completely exhausted. In this raft there were about 15 people, many of them seasick and vomiting both inside and outside the raft. They were having difficulties closing the canopy and there was .much water inside. One witness reported that he used his boots to bail with. About 15 persons, 11 male and 4 female, were rescued from this raft, according to witness reports, and they were transported by helicopter to the SILJA EUROPA.

Liferaft "S" A crew member, the system engineer, was releasing liferafts on the hull. He made them fast with ropes and when the angle was right he cut the ropes so the rafts could slide into the water. He slid together with a raft into the sea and, once inside, started to pull people on board from another crowded raft nearby One passenger helped pull rafts into the sea. He fell into the water and when the raft turned over he managed to get hold of a lifejacket. and climb in. Once aboard he helped several other people onto the raft.

A Swedish woman and a man holding hands jumped overboard and sank deep under the water. They lost their hold, and the man got a rope around his foot, which dragged him further down. He started to inhale water because he thought he was going to die. Eventually he freed himself by kicking off his shoe and he reached the surface. The woman got her lifejacket around her legs but surfaced quite near an upside-down raft. Together they managed to climb on board. Another witness climbed into this raft and started to help others by pulling them inside.

One Estonian passenger in the water saw a raft after a while, but was unable to reach it. After another 20 minutes in the sea he was dragged on board this raft by other people. It was full of water and people were lying together with their arms around one another to keep warm. The water made them slide around in the raft and it was difficult to stay on board without holding on to a rope or something else. One witness remembered that several people disappeared during the night. Several others were washed overboard several times but manage to get a grip on something and pull themselves aboard again. At times there was panic in the raft and several people died. One witness said that there were six or seven dead in the raft by morning. One witness, the AB seaman of the watch, found another raft and moved over to this, where he was alone. Altogether 16 people were rescued at about 0830 hrs by Finnish helicopters. During the lift to the helicopter one person fell into the sea and was later found dead.

Liferaft "T"

One Swedish passenger was thrown into the water and washed into an empty lifeboat. He saw a hand on the gunwale and tried unsuccessfully to pull the other person up. While he was struggling a wave turned the lifeboat upside down and he landed underneath. He kept hold of a keel rail on the outside of the boat but lost his grip when another wave came and he ended up near a raft, where he managed to get hold of a rope. He could not see where he was but later found he was under a liferaft which was floating upside down. The canopy was released and he managed to sit and stand inside this. On top of the upside-down raft there were three other men and he managed to contact them by pounding on the bottom of the raft above him. One of the men on top of the raft, the trainee 2nd officer, had been clinging on for a while unable to get onto it because his feet were caught in ropes. His lifejacket had slid down and was hanging around his waist. A boy helped him up. Lying on top of this upside-down raft there was also a naked elderly man.

The passenger under the raft shouted to the others on top not to forget him. After several hours he heard a helicopter and he pounded on the bottom again with the help of a distress rocket, afraid he would be forgotten. When the helicopter rescue man had hoisted the men off the top of the raft, he and the Swede below it were able to localise each other by pounding on the raft. The rescue man made a slit in the bottom with his knife and the passenger dragged himself out through this. He was rescued together with the others by a Swedish helicopter at about 0630 or 0700 hrs.

Liferaft "U"

One passenger fell from the bilge keel and reached the surface near several rafts. He was helped onto one and started helping others by pulling them in. After some time there were 11 people in the raft, most of them passengers. One woman was helped inside by a very strong Norwegian who later abandoned this raft for another one because he said it was leaking. A female witness who had been hanging outside was helped by a passenger and a big wave and managed to slide into the raft. Once aboard, she was completely exhausted and lay down seasick, dozing occasionally Inside there were lights, and the canopy was raised.

One female Swedish passenger has reported that in this raft one person took the lead. Several were without lifejackets, some quite passive, one rather drunk and wearing only underpants. He got upset and started to fight with, the "leader", who tried to calm him down and to protect himself. The man fought violent ly and was not easily calmed. After about an hour, this man died in the arms of another passenger.

Somewhat later another man started to fight with the "leader", and there was some tumult but this man calmed down alter a while. He was hanging on to a rope in the middle of the raft. He had suddenly became violent, shouting in English about knives, evidently wanting to cut his way out through the canopy.

Two men died during the night, one with a heart disease and the drunk man already mentioned. One witness reported that the "leader" was very active and did a fantastic and heroic job. After about two hours, witnesses heard someone outside the raft and managed to pull aboard a German passenger who had been swimming all the time. This person smelled strongly of diesel oil.

The witnesses in this raft tried to fire several distress rockets, one of which ignited inside the raft and filled it with smoke. People helped each other but some, wearing underwear only became quite apathetic. Some people held others' heads above the water. From this raft twelve people were rescued at about 0700 hrs by a helicopter which put them on board the SILJA SYMPHONY.

Liferaft "V"

One woman jumped together with her husband into the water. The husband lost his lifejacket and her own slid down to her waist. She heard her husband tell her about the lifejacket and then he disappeared. Several other people inside this raft had slid from the hull down into the water. Some pulled themselves over from other rafts and others were pulled from the water by yet others. They were not able to close the openings and water sprayed in. There was about 20 cm of water on the bottom and almost all of the people were seasick and vomiting. Despite the terrible smell they were forced to lie very close with their arms around each other to keep warm.

During the night a hole developed in the bottom of the raft. The occupants mended it with reflector tape from their lifejackets. They used all the reflector tape on board and they also bailed with their shoes. All became increasingly fatigued and the bailing was, after some time, very slow. All were rescued by a Finnish helicopter at about 0900 hrs.

Reports from lifeboats

Lifeboat "A"

One crew member, a waiter, was thrown overboard from the starboard side. He swam towards a lifeboat and managed to get hold of it but lacked the strength to get into it. He clung to a rope for several hours and eventually worked up the strength to get on board. He heard many calls for help around him and at one time he remembered a young woman grasping the lifeboat but the next moment she was gone. In the boat he found two distress rockets which he fired. After four hours alone in this lifeboat he was rescued by a helicopter.

Lifeboat "B"

An Estonian head waiter got hold of the keel rail of an upside-down lifeboat. He rested for a moment and managed to climb up onto the bottom. On top of it there were already three men, one of them the third engineer. One man with severe head injuries later died.

Somewhat later the head waiter managed to help another man and a woman up onto the lifeboat. One of them had been floating on a wooden cupboard for about 30 minutes. In the darkness he heard and noticed someone in the water holding on to the lifeboat, but was unable to help and this person disappeared. The occupants of this lifeboat were all rescued by a helicopter at about 0400 hrs.

Lifeboat "C"

One Swedish passenger jumped into the water and was thrown around violently While under water he gave up and inhaled water but eventually reached the surface. He saw a piece of wreckage and managed to get hold of it. A woman was holding on to the same wreckage and together they moved towards an upsidedown lifeboat. The man's lifejacket was round his waist. The woman climbed up onto the keel of the lifeboat and helped others up. This witness was helped on to the keel, and held firmly on to the propeller, praying and calling to God. He reported that he had no contact with others around him, although he was aware of people in the water and behind him. He did not dare to loosen his grip. After a few hours, the woman who had helped him up disappeared.

Another witness jumped into the water and was very deep under. Surfacing, he swam for about 25 metres and became exhausted. Dead people were floating face down in the water around him. One lifeboat came near him upside-down. On this was a man holding on to the propeller, constantly praying and shouting to God in panic. The witness reported being annoyed by this screaming while he himself was helping others up on the boat. He managed to help a man up on the lifeboat and saw two others get onto it by themselves. A Swedish woman was hanging on to the lifeboat. He spoke to her and tried unsuccessfully to help her up. She was very frightened. He has reported her clinging onto the lifeboat for what seemed like an eternity until a couple of big waves washed over the lifeboat and the woman disappeared.

This lifeboat drifted towards a ferry which illuminated it with a searchlight. Sometime thereafter a Swedish helicopter rescued the witnesses.

Report from one witness swimming

The second engineer was swept from the hull by a huge wave. In the water he managed to find two lifejackets and put them on. He also had a torch with which he. could signal. After swimming for more than three hours he was rescued by the ISABELLA at 0445 hrs.

6.3.13 Summary of witness reports concerning lifejackets

Many passengers reported difficulties with the lifejackets, all of which had "VIKING SALLY" printed on them. Several stated that the lifejackets appeared old-fashioned. One passenger said that they were tied together in threes and were difficult to separate. Others found the straps too short to be fastened at the crutch. Most witnesses did not understand how to put the lifejackets on, they did not seem to fit. Some reported that straps were missing or too short. Many witnesses put on two jackets and one witness who could not tie the vest at the crutch because the straps were too short tied the strap around his belt.

Many witnesses lost their lifejackets when they jumped or were washed into the water and several reported that the jackets slid down around their waists.

CHAPTER 7 THE RESCUE OPERATION

7.1 Summary of the operation

The ESTONIA sank in international waters in Finland's Search and Rescue Region (SRR), in its Archipelago Sea maritime SRR under the responsibility of the Maritime Rescue Co-ordination Centre (MRCC) in Turku. Consequently Finland was responsible for the overall co-ordination of the Search and Rescue (SAR) operation.

On the night of the accident there were four large passenger ferries on the Finland-Sweden route, the MARIELLA and the SILJA EUROPA sailing westwards and the ISABELLA and the SILJA SYMPHONY eastwards. Another passenger ferry, the FINNJET, was sailing from Finland to Germany

The first distress call was received from the ESTONIA at about 0122 hrs and was answered by the MARIELLA, which was north-east of and closest to the ESTONIA. When the distress call was heard on the SILJA SYMPHONY, a tape recorder was turned on to record the radio traffic.

A second distress call from the ESTONIA was received at 0124 hrs by 14 radio stations. One of these was MRCC Turku, which assumed control of the SAR operation.

At 0129 hrs the ESTONIA s position became known, and after receiving the distress message vessels in the vicinity turned towards the scene of the accident. The MARIELLA was by that time about nine nautical miles away from the ESTONIA. The SILJA EUROPA, which had direct radio contact with the ESTONIA during the distress traffic, assumed control of the distress radio traffic and at 0205 hrs MRCC Turku designated her master as the On-Scene Commander (OSC).

After receiving the distress call MRCC Turku alerted rescue units and those responsible for the management of the rescue services. The first units to be alerted were the coast guard patrol vessel TURSAS at 0126 hrs and stand-by maritime rescue helicopter OH-HVG in Turku at 0135 hrs. The helicopter took off at 0230 hrs. MRCC Turku formally designated the situation as a major accident at 0230 hrs and the appropriate alarms were initiated.

At 0142 hrs the MARIELLA informed Helsinki Radio about the accident. Instead of transmitting a Mayday Relay Helsinki Radio transmitted a Pan-Pan message at 0150 hrs.

Maritime Rescue Subcentre (MRSC) Mariehamn informed MRCC Stockholm of the accident at 0152 hrs, whereupon the alerting of Swedish maritime rescue helicopters was initiated. The first of these, stand-by$ helicopter Q 97, took off at 0250 hrs.

MRCC Helsinki notified MRCC Tallinn of the accident at 0255 hrs.

The MARIELLA was the first vessel to reach the scene of the accident, at 0212 hrs. At this time many persons, liferafts, lifeboats and lifejackets could be seen in the water. People were heard screaming in the sea. At 0230 hrs the SILJA EUROPA arrived and by 0320 hrs all five passenger ferries had reached the scene of the accident.

OH-HVG arrived as the first helicopter at the scene of the accident at 0305 hrs, and Q 97 arrived at 0350 hrs.

About 0450 hrs there were four helicopters and eight vessels on the scene, and the number of rescue units continued to increase. The TURSAS arrived at 0500 hrs. By 1200 hrs 19 vessels and 19 helicopters had arrived to participate. In addition three aircraft assisted in the search and in the control of the radio traffic.

The helicopters used rescue men and winches to pick people up from the sea and liferafts. Two helicopters transferred survivors to the nearest passenger ferries, while the others flew them to land-based assembly points.

The vessels did not launch their own man-over-board (MOB) boats or lifeboats due to heavy weather. Instead, liferafts were lowered to the sea and were then raised with survivors transferred from the ESTONIA s liferafts. The ISABELLA lowered its rescue slide, and 16 survivors were rescued by being pulled up it.

The last survivor was rescued at about 0900 hrs. After this, the helicopters and vessels searched for and brought up bodies from the sea and from rafts.

The helicopters operated in the area from the early morning for about 15 hours. Most of the vessels searched the whole day and were released from their duties in the evening. The last vessel to be released was the SILJA EUROPA which left the area about 2030 hrs, relieved by the TURSAS, whose master was appointed Co-ordinator Surface Search (CSS) until 3 October.

The vessels rescued 34 survivors and the helicopters rescued 104 survivors. One rescued person later died in hospital. Ninety-four bodies were recovered from the sea. Missing persons totalled 757.

7.2 The rescue organisation

7.1.1 General

The basis of the international rules covering the search for and rescue of human beings at sea is the 1979 International Convention on Maritime Search and Rescue (the SAR Convention). This entered into force in 1985 and Sweden and Finland have ratified it. Some of the Convention's provisions deal with the organisation of maritime rescue services and international co-operation in this respect. These include the decision to establish Search and Rescue Regions (SRR) in agreement with neighbouring countries, each with at least one Maritime Rescue Co-ordination Centre (MRCC), and if necessary subordinate centres known as Maritime Rescue Subcentres (MRSC).

The Convention also contains provisions governing the duties and operational procedures of these rescue centres. According to the provisions an MRCC is "a unit responsible for promoting efficient organisation of search and rescue (SAR) services and for co-ordinating the conduct of SAR operations within an SRR". If the position of the ship is known the responsibility for initiating SAR operation will be that of the MRCC or MRSC in which area the ship is located.

As well as in the SAR Convention, the tasks of an MRCC are laid down in the IMO Search and Rescue Manual and in national provisions. Some of their main tasks are summarised below:

- An MRCC prepares detailed plans for conduct of SAR operations in its own area. Each MRCC and MRSC maintains up-to-date information relevant to SAR operations in its area.
- An MRCC should be in a constant state of operational readiness.
- When an MRCC receives a distress signal, it must establish the facts of the situation, so as to determine the state of emergency and decide on the extent of the operation required.
- The MRCC initiates and co-ordinates the operation through the available rescue units in accordance with a plan of action.
- The MRCC notifies the owner of the vessel and the appropriate authorities of the operations being launched. Other MRCC s and MRSC s and rescue units which may be concerned must also be notified and kept informed of developments.
- When the emergency no longer exists, or further search seems useless, the MRCC terminates the operation and notifies the authorities and individuals who had previously been informed.
- The sphere of authority of the MRCC in each country is established by national provisions.

The IMO Search and Rescue Manual (IMOSAR) is a supplement to the SAR Convention. It provides guidelines for a common maritime SAR policy; encouraging all coastal states to develop their organisations on similar lines and enabling adjacent states to co-operate and provide mutual assistance.

The IMO Merchant Ship Search and Rescue Manual (MERSAR) is a second manual based on the SAR Convention. This contains guidelines for masters of ships that may be called upon to act in connection with SAR operations.

The International Convention for the Safety of Life at Sea (SOLAS) is the most important convention dealing with maritime safety It contains provisions concerning the responsibility of the master of a ship when he becomes aware of an emergency at sea involving a risk to human life. It also enjoins each Contracting Government to ensure that any necessary arrangements are made for watching and for the rescue of persons in distress at sea around its coast.

The Radio Regulations (RR) appurtenant to the International Telecommunication Convention contain provisions governing communications in a distress situation.

7.2.2 Finland

General

At the time of the accident the rescue services in Finland consisted of three parts, the General Rescue Service, the Aeronautical SAR Service, and the Maritime SAR Service.

The Ministry of the Interior was responsible for the general management and co-ordination of the rescue services.

The General Rescue Service covered operations related to fires and general rescue operations carried out by the local rescue services, such as the fire brigades, the police, the medical centres and ambulance units as well as the auxiliary volunteer organisations, e.g. the National Commission for Volunteer SAR Services. The Finnish Lifeboat Society co-ordinated voluntary SAR services at sea.

The Aeronautical SAR Service covered rescue operations concerning aircraft or carried out with aircraft. It also supported the General Rescue Service and the Maritime SAR Service. The responsible authority for the Aeronautical SAR services was the Civil Aviation Administration, under the Ministry of Transportation and Communications.

The Aeronautical Rescue Co-ordination Centre (ARCC) for Southern Finland was in Tampere.

Maritime SAR service

The maritime SAR operations in Finland were governed by the Maritime Search and Rescue Act and Decree. The Act and Decree defined the authorities which had to participate in maritime SAR services and their following functions:

- The Frontier Guard carried out maritime SAR operations and attended to the planning, management and supervision of maritime SAR services as well as to the co-ordination of the operation.
- The Defence Forces watched over marine areas in order to detect and locate emergencies. It also participated in SAR operations.
- The National Maritime Administration attended to distress and safety communications and to the co-ordination of these, and participated in SAR services operations.
- The police, the National Board of Customs, the Road Administration and the local rescue authorities participated in SAR operations.
- The health care authorities attended to the medical aspects of rescue operations.
- The aviation authorities participated in maritime rescue operations through the aeronautical SAR organisation.
- Helsinki Radio was a national coast radio station, owned by Telecom Finland, from which the National Maritime Administration purchased distress and safety radio communication services.

MRCC and MRSC

Finland's SRR encompassed Finnish territorial waters as well as international waters as agreed with neighbouring countries. The region was divided into three maritime rescue regions, each with its own MRCC, situated in Helsinki, Turku and Vaasa. The accident took place in the Archipelago Sea Maritime SRR, under MRCC Turku.

Each MRCC was operated by the Frontier Guard. MRCC Helsinki was manned by staff of the headquarters of its Gulf of Finland Coast Guard Section, MRCC Turku by those of the headquarters of its Archipelago Sea Coast Guard Section and MRCC Vaasa by those of the headquarters of its Gulf of Bothnia Coast Guard Section. Each MRCC was headed by a commander of the coast guard section or an officer designated by him and assisted when necessary by a maritime rescue expert group. This group consisted of the authorities mentioned in the Maritime SAR Decree, representatives of volunteer SAR services, and other experts as needed.

Under MRCC Turku there were MRSC Mariehamn and MRSC Turku. MRSC operations were directed by the commander of the respective coast guard sub-district, assisted when necessary by an expert group. MRSC Turku located at Pärnäinen in the island of Nauvo, was a combined maritime traffic and coast guard centre also known as Turku Radio.

The MRCCs were manned around the clock to a readiness to receive distress messages 24 hours a day and initiate rescue operations. During office hours, two to three persons worked in an MRCC, a duty officer (DO), a radio operator and the chief officer of the centre. Outside office hours the practice varied, with one or two persons, depending on the resources of the coast guard section. However, the radio operators worked in regular shifts. A stand-by duty officer (SDO) and a coast guard emergency duty officer (EDO) were on stand-by at home, ready to arrive for advanced operational management at one hour's notice.

Outside office hours an MRSC was manned by only one person. However, MRSC Turku, as a maritime traffic centre and rescue subcentre, was manned by two.

Planning for major accidents

In each SRR there was a plan outlining operations in the event of a major accident. For the Archipelago Sea Maritime SRR the major accident rescue plan was adopted on 18 June 1991. The main elements of the plan were risk assessments, the basis for SAR operations, the SAR plan, communications and public information. Separate annexes included diagrams and illustrations of the chain of command for SAR, alarm arrangements, assembly points and radio communications.

The applicability of the plan had been tested in several SAR exercises involving simulated accidents to passenger ferries.

The tasks of the rescue leaders of MRCC Turku according to the plan were (Supplement):

the duty officer

- to know the readiness situation of the rescue units,
- to keep a radio log of communications traffic and mark the information on the situation map,
- to order the most rapidly operational maritime rescue units to the scene of an accident, (to conduct rescue operations and obtain a detailed assessment of the situation,
- to alert the SDO and the EDO,
- to start general alerting according to the alarm diagram,

- to order the latest weather reports and forecasts, and to order drift calculations if needed.

the stand-by duty officer

- to alert further resources if needed,
- to alert the commander and other necessary personnel,
- to inform the headquarters of the frontier guard, the adjacent coast guard section, the Ministry of Environment and the shipping company affected,
- to draft a press release and publish it.

the emergency duty officer

- to lead the operation as an assistant or deputy to the commander,
- to organise the work of the maritime rescue expert group,
- to inform neighbouring states.

Further tasks were addressed to the MRCC generally, not assigned to individuals.

Other rescue resources

When operating at sea, coast guard vessels, patrol boats and helicopters were at the highest readiness to participate in SAR missions. Maritime SAR helicopters at base during office hours were on almost immediate take-off alert. At other times, on-duty helicopters were at the highest readiness (one hour).

7.2.3 Sweden

The basis for Sweden's maritime SAR services - in addition to the international conventions mentioned under 7.2.1- was the 1986 Swedish Rescue Act which was drafted to correspond with these conventions. The maritime SAR service was one part of the national SAR services.

The National Maritime Administration was responsible for Sweden's maritime SAR service.

Maritime SAR operations in Sweden s SRR in the northern Baltic were conducted and co-ordinated by MRCC Stockholm located at Telia Mobitel AB's coast radio station in Stockholm. Under contract to the Maritime

Administration, Telia Mobitel AB provided distress and safety watch-keeping as well as maritime SAR co-ordination services. In the event of a maritime SAR effort the coast radio station personnel could be used to support MRCC normal manning in accordance with an agreed personnel plan. The MRCC was always manned by a maritime SAR duty officer and a deputy duty officer. Another deputy was on thirty minutes stand-by.

The maritime rescue units used consisted of state-owned vessels, helicopters and aircraft, and vessels belonging to the Swedish Sea Rescue Institution. Both the Navy and the Air Force had helicopters suitable for maritime SAR missions (Boeing Kawasaki 107 and Super Puma, respectively).

The Aeronautical Co-ordination Centre (ARCC) was at Arlanda Airport outside Stockholm. ARCC Arlanda commanded all military helicopters in SAR operations and was responsible for alerting civilian air units.

To co-ordinate rescue operations, primarily on land, and to provide alarm services, a publicly-owned special company had been formed, SOS Alarm. This company had 20 SOS centres, together covering the whole of Swedish territory Each regional centre had agreements with the regional medical services on the basis of which they could alert hospitals and prepare them when a major accident had happened.

7.2.4 Estonia

In Estonia the National Maritime Administration was responsible for the SAR operations at sea in accordance with the Estonian Merchant Shipping Code. To perform this function, the Maritime Administration established the Coast Guard Department, which besides maritime SAR matters also dealt with the localisation and combating of marine pollution

Although Estonia had not ratified the SAR Convention before the accident, the coast guard service acted in accordance with the Convention as closely as possible.

The MRCC was situated in Tallinn and was manned round the clock. If the situation called for it, the co-ordinators called in other experts.

MRCC Tallinn carried out maritime SAR operations in co-operation with the National Border Guard Administration, the Estonian State Sea Inspection Agency, the Estonian Lifesaving Association, the Estonian National Rescue Board and ARCC Tallinn.

7.2.5 Co-operation

Finland and Sweden

An agreement between Finland and Sweden on maritime and aeronautical SAR and a protocol thereto entered into force on 20 March 1994. This agreement replaced one of 1982.

The agreement states that the border between the maritime and aeronautical rescue services of the respective countries is also the border of the flight information regions (FIR). It also covers notification, mutual assistance, joint rescue exercises, regular tests of the communications between the states, mutual visits of rescue service experts and exchange of information and experience on rescue services.

Co-operation since 1982 has included maritime SAR exercises in 1990 and 1992 concerning simulated accidents to passenger ferries.

Practical SAR co-operation has primarily been between MRCC Turku and MRCC Stockholm. MRSC Marienhamn has been in frequent contact with MRCC Stockholm, primarily in connection with maritime SAR in the Å land Sea and the southern part of the Gulf of Bothnia.

Finland and Estonia

Finland and Estonia entered into an interim agreement on maritime SAR on 15 June 1992, under which the border between the rescue areas is the same as the border between the respective flight information regions (FIR). The arrangements regarding operational and notification obligations in the event of a maritime emergency are the same as in the agreement between Finland and Sweden.

In addition to this agreement, the Finnish Frontier Guard and the Estonian Border Guard concluded on 24 May 1994 a protocol on co-operation in saving human lives at sea and on the related air operations.

Estonia appointed the National Maritime Administration as responsible maritime SAR authority and the Coast Guard operations centre as MRCC Tallinn with effect from 1 January 1993.

The bodies responsible for practical operations are the headquarters of the Gulf of Finland Coast Guard Section and the headquarters of the Estonian Border Guard.

The arrangements for meetings between representatives of the respective parties are the same as in the agreement between Finland and Sweden.

After the interim agreement entered into force, a joint maritime rescue exercise concerning a simulated accident to a passenger ferry off Helsinki was organised jointly by Finland, Estonia and the Russian Federation on 21 October 1992.

Between 1992 and 1994 Finnish and Estonian maritime rescue authorities and volunteers have met considerably more often than required by the agreement, to develop co-operation in maritime SAR matters.

Sweden and Estonia

At the time of the accident there were no maritime SAR co-operation agreements between Sweden and Estonia. However, since 1991 Sweden has trained personnel from Estonia in SAR management and co-ordination. Courses and seminars have been conducted in Sweden and Estonia.

7.3 The maritime radio distress and safety systems and the distress traffic

7.3.1 The maritime radio systems

The SOLAS convention requires that all passenger vessels on international voyages and all cargo vessels of at least 300 tons gross are equipped with a maritime radio station for distress and safety There are two maritime radio systems in use, an old one here termed the pre-Global Maritime Distress and Safety System (pre- GMDSS), and a new one, the GMDSS. All vessels and coast radio stations must change to the GMDSS during a transition period ending on 1 February 1999. During this period, vessels may be equipped with either system.

In the old system the radio station on board a vessel may be either a radiotelegraph station or a radiotelephone station. The international distress and safety frequencies are: 500 kHz for radiotelegraphy and 2182 kHz and

VHF channel 16 for radiotelephony In a radiotelegraph station all these frequencies are required and a vessel must carry a radio officer holding a radiotelegraph operator's certificate. For radiotelephone stations the telephone frequencies are required and the station is operated by deck officers holding a radiotelephone operator's general certificate (GOC).

In the GMDSS every ship while at sea shall be capable of transmitting ship-to- shore distress alerts by at least two separate and independent means. Therefore the equipment of the radio station on board a vessel is governed by the sea area of sailing. Four sea areas exist: Al (VHF communication), A2 (MF communication), A3 (satellite communication) and A4 (HF communication). All ships must also be capable of receiving shore-to- ship distress alerts, and of transmitting and receiving ship-to-ship distress alerts and SAR co-ordinating communications. Except when satellite communications are used, the communication is initiated with a digital selective call (DSC), which is received fully automatically by other stations. The international distress and safety frequencies for DSC are: VHF channel 70, MF 2187.5 kHz, and five frequencies in the HF band. After contact by DSC the stations shift to the distress and safety frequencies for radiotelephony: on VHF to channel 16 and on MF to 2182 kHz. The radio station on board a vessel is operated by deck officers holding a general operator's certificate or a restricted operator's certificate (ROC). A reserve source of electrical power must be provided on every ship to supply the radio installation, for conducting distress and safety radio communication in the event of failure of the ship's main and emergency power sources.

In both systems, the radio equipment on board a vessel also includes an emergency position indicating radio beacon (EPIRB). The EPIRB is a small radio buoy of "float-free" structure. If the vessel sinks, the buoy is released, rises to the surface and begins to transmit a distress alert. Three (or two) portable VHF radiotelephones are also required. They can accompany the lifeboats or liferafts when the vessel is abandoned.

With the pre-GMDSS a vessel in distress alerts primarily other vessels in the vicinity With the GMDSS the intention is for the distress alert always to be routed to shore, primarily to rescue co-ordination centres. At the same time, other vessels in the vicinity will be alerted. Both systems can be used to transmit, on behalf of others, a distress message - Mayday Relay (pre-GMDSS) or Distress Alert Relay (GMDSS) - e.g. when the vessel in distress cannot itself transmit a message or when further assistance is required.

Distress traffic must always be initiated by using the procedures specified by the Radio Regulations. With the old system for radiotelegraphy on 500 kHz, a radiotelegraph alarm signal must be transmitted, and for radiotelephony on 2182 kHz, a radiotelephone alarm signal must be transmitted. The purpose of the alarm signals is to arise attention and to turn on the muted loudspeakers of the radiotelegraph and radiotelephone auto alarm receivers keeping automatic watch on 500 kHz and 2182 kHz, respectively. After the alarm signal, a distress call is transmitted, followed by the distress message. 0n VHF channel 16,0nly a distress call and a distress message are transmitted

In the GMDSS the distress traffic is initiated on 2187.5 kHz and VHF channel 70 by transmitting a distress alert using DSC. After DSC acknowledgement, primarily by a coast station, the distress traffic is shifted to the radiotelephone distress and safety frequency on the band where the acknowledgement was received.

The ESTONIA was equipped in compliance with the old system with a radio-telegraph station and a radiotelephone system. The radio installation and the competence of those serving it satisfied the SOIAS requirements. For details of the equipment, see 3.2.9. Regarding the formal competence of the crew, see 4.2.2. In addition various crew members had some 30-35 portable VHF maritime radiotelephones (including channel 16) not indicated in the vessel's radio licence. The radio officer of the ESTONIA had special watchkeeping hours,1900-0100 hrs, during which he kept watch on the radiotelegraph distress and safety frequency 500 kHz. At other times, frequency was monitored by a radiotelegraph auto alarm. The frequencies 2182 kHz and VHF 16 were monitored on the bridge

7.3.2 Distress and safety watch

Vessels

Every vessel at sea must keep continuous radio watch for distress and safety Vessels with radiotelegraph stations keep watch 500 kHz,2182 kHz and VHF channel 16. The frequency 500 kHz is watched by a radio officer or by the radiotelegraph auto alarm, while 2182 kHz is watched with a loudspeaker, filtered loudspeaker or muted on the bridge. This latter method where the equipment functions as a radiotelephone auto alarm is the most common. VHF channel 16 is watched on the bridge. Vessels with radiotelephone stations keep continuous watch on 2182 kHz and VHF channel 16 as above. Vessels with GMDSS radio stations keep automatic watch by DSC on the bridge on VHF channel 70 and, if the radio installation is for other sea areas than Al, also on 2187.5 kHz. During the transition period ending in

February 1999 GMDSS vessels must also keep watch on 2182 kHz and VHF channel 16.

Coast stations

Several rescue co-ordination centres and other coast stations keep continuous watch on 2182 kHz and VHF channel 16. Some rescue co-ordination centres and a many other coast stations keep watch on 500 kHz. At the beginning of 1993, Finnish Maritime Administration established sea area A2 covering the Gulf of Finland, the Northern Baltic and the Gulf of Bothnia. Continuous distress and safety watch is kept on 2187.5 kHz by DSC by the Finnish rescue co-ordination centres and by Helsinki Radio.

At night the radio traffic in the Baltic area on distress frequencies 500 kHz, 2182 kHz and 2187.5 kHz can usually be received throughout the entire Baltic, unless the frequencies are badly disturbed. The ranges over which messages may be transmitted on the VHF channels depend greatly on the structure and height of the antenna and are normally under 100 km.

On VHF channel 16, Helsinki Radio and MRCC Turku were using the same base stations in Utö, Järsö and Hanko, near the site of the accident. MRSC Turku was also using the Utö base station. 16 was also being watched by MRSC Mariehamn, MRSC Hanko, coast guard stations in Kökar, Storklubb and Hiittinen and central pilot stations in Nauvo and Hanko, near the site of the accident.

7.3.3 The recorded distress traffic

The facts regarding the distress traffic from the ESTONIA, which was transmitted on VHF channel 16, are based on recordings and log entries regarding the traffic. The distress traffic was initiated by the second officer A. Two minutes later the third officer took over as operator. The initiation of the distress traffic recorded only by MRSC Turku. Except for the initiation, the distress traffic was recorded by the SILJA SYMPHONY among others. This recording has the quality.

MRCC Turku had a system that should continuously record all radio traffic on VHF channel 16. However, the equipment did not function properly Thus, the beginning of the recording primarily contains only its own traffic.

The distress traffic was conducted mainly in either Swedish or Finnish; English were used very little.

The distress traffic started with a call[1] which reads as follows: "Mayday Mayday Estonia please". Shortly afterwards a second call "Mayday Mayday SiIja Europa" was transmitted.

The Mayday calls were received by 14 ship and shore-based radio stations.

It is evident from the table that there are considerable differences between the times for recording the two Mayday calls. At least five radio stations, including MRCC Turku, logged the *2nd Mayday call* as received at 0124 hrs. Counting backwards in tape recordings from this moment, the most probable time of the *1st Mayday call* was just before 0122 hrs. However, this time is uncertain, the margin of error being plus/minus two minutes.

7.3.4 EPIRB beacons

No signals from the ESTONIA`s EPIRBs were received.

7.4 Initiation of rescue actions

7.4.1 General

On responding at 0123 hrs to the *1st Mayday call*, the SILJA EUROPA became the control station for the distress radio traffic. The other ships and shore-based stations in the area that had received the Mayday calls understood and accepted the resulting situation. When the full importance of the distress messages was understood on board the vessels they began to contact the SILJA EUROPA to verify information received, report their positions and inform her about measures being undertaken.

Helsinki Radio did not receive the ESTONIA's distress message nor the subsequent radio communications. The MARIELLA informed Helsinki Radio by NMT telephone of the distress at 0142 hrs after failing to get contact on channel 16 and on 2182 kHz. On request by the SILJA EUROPA, MRCC Helsinki also alerted Helsinki Radio.

The channel 16 distress traffic transmitted by the ESTONIA did not reach the coast radio stations in Sweden or Estonia because of the distance.

Helsinki Radio transmitted at 0150 hrs a Pan-Pan (urgent message) of the accident instead of a Mayday Relay (distress message), which MRCC Turku had requested several times by telephone, VHF and via MRCC Helsinki. The Pan-Pan message was transmitted to all stations on 2182 kHz and channel 16. These transmissions were not received by the coast radio stations in Sweden or Estonia.

7.4.2 Action

In accordance with the organisation and division of responsibility of the Finnish SAR services, the overall responsibility for the SAR action in the case of the ESTONIA was held by the commander of the Archipelago Sea Coast Guard Section or by the coast guard officer designated by him. The headquarters of the Coast Guard Section in Turku served as the MRCC, where at night a duty officer was prepared to initiate and carry out all relevant coast guard management functions. He was supported by two stand-by duty officers at home on one-hour stand-by.

Two minutes after receiving the 2nd Mayday call MRCC Turku began, at 0126 hrs, to alert the various groups involved according to the diagram in the Major Accident Rescue Plan. Only Finnish and Swedish standby helicopters and the first five vessels to arrive are mentioned in the table. Events after 0500 hrs are commented on very briefly.

7.5 The rescue operation

7.5.I The sea traffic in the area

The mouth of the Gulf of Finland is the busiest maritime area in the northern Baltic Sea. Here the traffic proceeds towards the southern Baltic or west towards Sweden. Cargo vessel traffic in the Archipelago Sea uses primarily the Utö route. In the western part of the northern Baltic, a traffic route goes between Bogskär lighthouse island and Svenska Björn caisson lighthouse to the Gulf of Bothnia. Vessels entering the Gulf of Finland from the southern Baltic take the southern route, north of Hiiumaa and around the Glotov buoy. Vessels proceeding in the opposite direction take a more northerly route, as determined by the traffic separation scheme.

Off Hanko and Hiiumaa, the route selected by passenger ferry traffic between Finland and Sweden in crossing the northern Baltic is determined by weather conditions. The southern, Sandhamn, route is preferred, the northern, Söderarm, route being used in weather conditions unfavourable for the Sandhamn route.

Passenger ferry traffic between Tallinn and Stockholm follows the northern coast of Estonia in the Gulf of Finland. The route alternatives mentioned above are used when crossing the northern Baltic.

That night the sea traffic in the northern Baltic and in the mouth of the Gulf of Finland was lighter than normal. Because of the forecast heavy wind, fishing vessels and coasters had remained in harbour and Russian river vessels had withdrawn to protected anchorages.

All scheduled passenger ferries were at sea. At midnight the four westbound ferries, the ESTONIA included, were in their usual area at the mouth of the Gulf of Finland. Two passenger ferries were on an eastbound course north of Bogskär lighthouse. Two cargo ferries were on a westerly course south of Hanko, two cargo vessels were passing Utö lighthouse on their way south and two cargo vessels were between Hiiumaa and Bogskär.

Because of the heavy weather, the coast guard vessel from the Archipelago Sea Coast Guard Section, the TURSAS, had anchored at Örö. Twelve government vessels, three of them Swedish, had been engaged in an oil spill control exercise in the Archipelago Sea near Nauvo but were in the Pärnäinen harbour by the time of the accident. Two mine ferries belonging to the Finnish Defence Forces were near Örö, and a Navy minelayer was at Hanko.

Two coast guard vessels from the Gulf of Finland Coast Guard Section were at sea south-west of Helsinki.

7.5.2 General considerations, vessels

The masters' decisions to turn towards the scene of the accident to rescue those in distress also affected the safety of their own vessels, crews, passengers and cargoes. All the masters who received messages about the accident were faced with the same choice. Most decided to proceed to help those in distress, a few vessels received permission to continue their voyage following their request to do so, and one master decided independently not to provide assistance, since he deemed that this would seriously endanger the safety of his vessel and crew.

The first vessels to approach the scene of the accident had to decide independently how best they could help rescue people. The heavy weather prevented, or rendered inadvisable, the lowering of lifeboats or rescue boats. This decision was discussed between the masters. Each vessel prepared to rescue survivors in accordance with her own possibilities. Most lowered rope ladders down the side to the sea. While sailing to the scene of the accident the vessels were made ready to take survivors aboard.

Liferafts were lowered to the sea on wires and then raised again to bring up survivors from the ESTONIA's liferafts. The ISABELLA lowered its rescue slide, and 16 persons were pulled up along it.

In the beginning the search consisted of an attempt to find people and liferafts near the scene of the accident. As dawn broke, the participants grasped the extent of the entire rescue operation.

At 1000 hrs - when no more survivors were found - the vessels proceeded with a systematic search of the area, in formation in the direction of the calculated drift. The vessels reported any victims observed and the helicopters winched them up from the sea. The calculated area, which was patrolled from the air, was searched systematically several times.

Most of the vessels searched the whole day and were released from their duties in the evening. The FINNJET was allowed to leave at 0755 hrs to avoid additional damage caused by the heavy rolling. The ISABELLA, MARIELLA, and SILJA SYMPHONY were released at 1320 hrs. However, as more vessels arrived, the rescue capacity increased.

All merchant vessels, except the SILJA EUROPA, were released at 1832 hrs when darkness fell.

The last vessel to be released was the SILJA EUROPA which left the area at about 2030 hrs, at which time a helicopter picked up the assisting OSC and the air operation co-ordinator and their assistants. Left on the accident scene searching for bodies were government vessels. The SILJA EUROPA was relieved by the TURSAS coastal patrol vessel.

A total of 34 persons were rescued from the ESTONIA's rafts directly to other vessels; the TURSAS rescued one, the MARIELLA 15, the ISABELLA 17 and the SILJA EUROPA one.

7.5.3 Action taken by the vessels

MARIELLA

The passenger ferry MARIELLA was closest to the ESTONIA at the time of the distress signal. She had departed from Helsinki, bound for Stockholm, at 1800 hrs.

The officer of the watch was talking on the telephone with the master about reducing speed when the first Mayday call was received. On learning of the call the master went quickly to the bridge. The vessel was nine nautical miles north-east of the ESTONIA at 0132 hrs when she turned towards the site of the accident. When she was four nautical miles away the radar image of the ESTONIA disappeared at about 0150-0155 hrs.

The MARIELLA was the first vessel to reach the assumed scene of the accident, at 0212 hrs. The master ordered an emergency stop at 0220 hrs so that no people or rafts would run foul of the propellers. When the vessel arrived on the scene many people could be seen in the sea around the vessel, wearing lifejackets, screaming. In addition, lifeboats and rafts were floating on the surface. The vessel threw some 150 lifejackets into the water and launched four liferafts. The bunker door was opened to provide access for the rescue of persons from the sea, but it had to be closed quickly as waves washed on board.

When no people could be seen around the vessel, the master steered carefully with the starboard side to the wind, from one liferaft to the next. Most of the rafts, however, were empty.

Four open liferafts were winched down into the sea from the MARIELLA so that people on board the ESTONIA`s rafts could transfer to these. One of the rafts was secured to the MARIELLA`s bow and another to her stern. The area between was used to catch the ESTONIAs rafts. The rafts had to be winched manually from the sea, although two large electric drills were used at the bow to help in this work. In this way 13 persons were brought up from the ESTONIA`s rafts.

Those persons on board rafts found after 0500 hrs were so exhausted that they could no longer move from one raft. to another unaided. At this stage two crew members of the MARIELLA volunteered to be lowered down to her liferafts. Dressed in rescue suits and secured by rope they managed to pull two persons to their own raft, whence they were winched up to deck 8.

All in all, the MARIELLA rescued 15 persons from the ESTONIA`s liferafts.

The MARIELLA continued her own rescue work until dawn, by which time the constantly worsening weather prevented her from keeping one side to the wind. She began to roll so heavily as to endanger the safety of her passengers and cargo.

The vessel turned to the wind and proceeded slowly, searching for liferafts. A report of any rafts sighted was made to the helicopters, which lifted people from the rafts and brought them to the vessels and to land-based assembly points. In this way 11 more persons were rescued, and brought by the OH-HVG helicopter to the MARIELLA at 0657 hrs. These survivors were treated by the vessel's own personnel together with three physicians and 30 nurses among the passengers. One of the survivors was transferred by helicopter to Hanko for hospital treatment for a broken leg.

At 1320 hrs the MARIELLA received permission to continue to Stockholm. The vessel arrived in Stockholm at 2355 hrs with the 25 survivors.

SILJA EUROPA

The passenger ferry SILJA EUROPA had departed from Helsinki at 1800 hrs, bound for Stockholm. According to the ship's log and the radio log the *lst Mayday call* was received at 0120 hrs. The officer of the watch has stated that transmission was poor and he could not identify the name of the ship.

On receiving the Mayday call, the vessel was 10.5 nautical miles north-west of the ESTONIA. Ten minutes after being informed of the ESTONIA`s position the master, according to the DGPS recording, started to turn to heading 134° towards the accident site. At this time ESTONIA's radar image could still be discerned. The recording shows that the distance to the ESTONIA was about 12.5 nautical miles when the turn was completed. At 0205 hrs MRCC Turku appointed the master On-Scene Commander (OSC). The SILJA EUROPA arrived at the scene at 0230 hrs.

The master summoned the command group to the bridge in accordance with the vessel's emergency plan. The group consisted of the master, the chief engineer, the chief officer, the hotel manager and the hotel purser to record the events.

By the time the vessel had turned, the radar image had disappeared. For the rest of the way to the scene, the vessel proceeded cautiously, using searchlights to scour the sea. While approaching the area, the vessel was readied for rescue operations and for taking survivors on board.

When the other passenger ferries were approaching the scene, the master, acting as OSC, allocated operational areas and followed on his radar how the vessels were proceeding to the stations allotted to them in the SAR formation. The OSC concentrated on managing the overall situation, and placed his vessel somewhat away from the others.

Two large liferafts were prepared and one of them was winched down to the sea. This, however, soon drifted away hit by a wave that opened the locking mechanism thereby releasing it. In addition, rope ladders were lowered along the side of the vessel to the sea.

At 0448 hrs, a man who had been alone in a partially waterlogged liferaft managed to climb up a rope ladder. The vessel was steered so that the raft drifted along its side. On seeing the rope ladder reaching down to the water, the man jumped into the sea, swam to the ladder, grasped it and climbed unaided up to the sixth deck.

Several liferafts found and examined were all empty There were many lifejackets floating in the sea, many still packed. The focus of the rescue operations moved eastwards, since the wind and the waves carried those in the water in this direction.

The OSC managed the operations of the vessels and the helicopters, passed on reports from the vessels to the helicopters and maintained contact with MRCC Turku, providing status reports and relaying instructions from MRCC to the vessels and the helicopters. An air operation co-ordinator was flown out to assist the OSC. He was put on board the SILJA EUROPA at 0650 hrs with two 5 W portable aviation radios to control the air operations. At 0945 hrs the SILJA EUROPA received the assistance of a co-ordinator surface search (CSS), his assistant and an air traffic control officer, equipped with a portable 25 W aviation radio. At 1300 hrs two more air traffic control officers boarded the vessel.

To direct the search properly; MRCC Turku telefaxed the OSC at around 0800 hrs information on the currents in the area, drift calculations and the weather forecast. On the basis of this information, the search formation was directed at 1000 hrs to proceed on a course of l00o. It turned around at 1151 hrs when the calculated limit of drift had been reached. In addition, the drift was followed on patrol flights by three maritime surveillance aircraft. The operational areas for the helicopters were determined on the basis of the results of the patrol flights. Empty liferafts were observed to drift in the strong winds considerably beyond the calculated line.

The OSC continued to manage the search until 1832 hrs, at which time all the vessels were informed in Finnish, Swedish and English that the search would be de-escalated. All were thanked for their assistance. The SILJA EUROPA rescued one survivor. One helicopter brought five survivors and another a wounded Swedish rescue man on the vessel, which arrived in Stockholm on 29 September at 0313 hrs. SILJA SYMPHONY.

The passenger ferry SILJA SYMPHONY was on her way from Stockholm to Helsinki. At 0123 hrs she had the Suomen Leijona caisson lighthouse 6.9 nautical miles away on a bearing of 207o. The distance to the ESTONIA was about 25 nautical miles. The SILJA SYMPHONY was proceeding on a course of 97° at 21 knots.

After receiving the distress call the lookout watch on the bridge started a tape recorder, at about 0123 hrs.

At 0150 hrs the SILJA SYMPHONY changed course to 122o towards the scene of the accident, continuing to maintain full speed. The tailwind and quartering seas, coming from starboard, did not slow the speed.

The vessel reached the scene of the accident at about 0240 hrs and positioned herself upwind from the MARIELLA at a distance of about one nautical mile. She received from the OSC instructions regarding the search and the area of the search.

Liferafts hanging from the wire of a crane were lowered into the sea off the starboard side of the vessel in case one of the ESTONIA`s rafts could be brought nearby; the survivors could transfer to the SILJA SYMPHONY's rafts, which could then be winched up.

At 0312 hrs the forward port slide was manned.

Four survivors, hoisted up from liferafts by a helicopter, were brought to the vessel at 0410 hrs and taken for treatment.

At 0620 hrs five survivors and at 0757 hrs eleven survivors and one body were brought on board by the same helicopter.

The SILJA SYMPHONY continued, proceeding cautiously and searching for liferafts carrying survivors. At 1320 hrs she received permission to continue to Helsinki, where she arrived at 1848 hrs with 20 survivors and one body.

ISABELLA

The passenger ferry ISABELLA was sailing from Stockholm to Helsinki. At 2400 hrs she passed the Svenska Björn caisson lighthouse at 4.4 nautical miles on a bearing of 187°.

Unlike the above mentioned vessels the ISABELLA did not pick up the distress call from the ESTONIA. At about 0150 hrs the crew on watch saw the SILJA EUROPA change course to cross her line of course. At the same time the SILJA SYMPHONY, which was proceeding to the north of the ISABELIA, announced on VHF that she was changing her course towards the ESTONIA and would therefore have to pass ahead of the ISABELLA. On being informed that the ESTONIA was in distress, the officer of the watch of the ISABELLA turned his vessel towards the reported scene of the accident, 17 nautical miles away.

According to the ISABELLA`s master, the vessel arrived at the scene of the accident at about 0252 hrs. At this time the propellers were stopped and the vessel was allowed to drift together with the MARIELLA nearby. The ISABELLA was instructed to begin the search south of the MARIELLA. While drifting the starboard side was to the wind.

At 0314 hrs the vessel winched one of her own liferafts down to the sea. The bunker door was opened, but had to be closed due to heavy seas. Ten minutes later a second raft was lowered with two voluntary rescue men from the ship. On reaching the sea they rescued a swimmer with a lifejacket. He was transferred to their raft, which was then winched up at 0445 hrs.

The next ESTONIA raft came near the ISABELLA at 0530 hrs. The master steered the vessel so that three voluntary rescue men who had been lowered in one of the ISABELLA`s rafts were able to get hold of it. About 20 people on board the raft were transferred to the ISABELLA's raft. When the crew of the ISABELLA tried to winch up this raft, it was too heavy because of the number of people in it and water poured into it. The raft tore in the process and filled with water, upon which at least two of the survivors and the three rescue men fell into the sea. A helicopter called to the scene lifted up one survivor who was hanging on to a lifebuoy, and the three rescue men. All lour were brought to Hanko. At least one of the persons who had fallen into the sea disappeared. The sixteen survivors still on the damaged raft were pulled one by one up the slide and into the vessel.

A helicopter winched one survivor in deep hypothermia from the ISABELLA at 0905 hrs and flew him to a hospital in Turku.

The vessel continued her search in the vicinity of the accident site until 1320 hrs, when the OSC gave her permission to continue her voyage to Helsinki, where she arrived at 1900 hrs.

The ISABELLA rescued 17 persons of whom 16 were taken to Helsinki.

FINNJET

The gas turbine passenger ferry FINNJET departed from Helsinki for Travemünde in Germany at 1900 hrs. Her average speed was about 16 knots, and she was using her diesel engines. On receiving the Mayday call at 0124 hrs, the FINNJET was about 23 nautical miles east of the ESTONIA.

The FINNJET turned towards the scene of the accident at 0133 hrs on a heading of 276o. At first she proceeded with her diesel engines running at a speed of 15 knots, but at 0215 hrs the gas turbines were started in order to improve manoeuvrability.

According to the master's report the vessel arrived at the scene of the accident at 0320 hrs.

To keep the rolling to a tolerable level, the FINNJET proceeded at 5-7 knots during the search. When changing course, the vessel rolled so heavily that the crew feared that the cargo would start to shift. Several passenger cars shifted and were damaged, and one almost fell from the vessel's hoistable car deck.

During the search the vessel reported to the OSC three rafts containing survivors.

At the beginning of the rescue operation the officers on the bridge worked actively to get helicopters alarmed quickly and involved in the rescue. Because of the continuously worsening weather and to prevent further damage, the vessel requested permission from the OSC to continue her voyage to Travemünde. The OSC gave this permission at 0755 hrs, and it was confirmed by MRCC Turku ten minutes later.

No survivors were rescued from the sea or brought to the vessel from helicopters.

FINNMERCHANT

The cargo ferry FINNMERCHANT sailing from the Gulf of Finland to Lübeck in Germany received parts of the distress traffic. The crew called up the SILJA EUROPA at about 0145 hrs and received instructions to proceed to the scene of the accident. The vessel's speed to the scene was about 15 knots and she ar- rived at 0325 hrs.

On approaching, her master report- ed to the OSC that, because of the rough seas, the vessel would not be able to lift survivors from the water.

All liferafts observed were reported to the OSC. The first liferafts were observed already on her arrival. When the OSC asked whether any persons could be seen in the liferafts, the master tried to steer the FINNMERCHANT as close as possible to the rafts so that they could be well lit with searchlights. However, there was not enough time to examine all the liferafts in this way, since manoeuvring was difficult. When the coast guard patrol vessel TURSAS reached the scene, the two vessels worked together, the FINNMERCHANT lighting up the rafts and the more manoeuvrable TURSAS checking for survivors. The vessel continued the search throughout the entire day and was released at 1832 hrs, at which time she continued her voyage to Lübeck.

No survivors were rescued from the sea or brought to the vessel from helicopters.

FINNHANSA

The passenger/ro-ro cargo vessel FINNHANSA, which had departed at 2000 hrs from Helsinki bound for Lübeck was south of Hanko at about 0130 hrs. Some 30 minutes later she slowed from 18 knots to 15 due to the heavy head wind and waves.

The distress radio traffic was not heard until at about 0245 hrs, when she was closing to 25 nautical miles of the scene of the accident. When her master had been called to the bridge, the course was altered towards the scene and speed increased. Because of the head wind and the high waves however, speed soon had to be reduced again to 10-12 knots. At about 0430 hrs the vessel arrived at the scene of the accident. On approaching the scene, she was requested by the OSC to search for people in the water and rafts, locate them precisely and report these to OSC so that they could be picked up by helicopters. Several rafts were seen; most were empty but a few were observed to hold survivors. There were also some capsized liferafts as well as water-filled or capsized lifeboats. No survivors were rescued from the sea or brought to the vessel from helicopters.

At 1832 hrs she received permission to continue her voyage to Lübeck.

TURSAS

The coast guard patrol vessel TURSAS, alerted at 0130 hrs, was ordered to proceed to the scene of the accident, where she arrived at 0500 hrs. At 0615 hrs a survivor was found on the second raft examined and brought aboard the vessel. The survivor had an injured hip and slight hypothermia. When the body temperature of the rescued person began to increase, he started to complain of pain in the hip. A helicopter was summoned to the vessel, but was unable to winch the patient aboard. At 0800 hrs a body was found in a water-filled raft, but could not be recovered to the vessel despite several attempts. (On co-operation with the FINNMERCHANT, see above.)

Towards the end of the search the TURSAS together with the minelayer UUSIMAA and the coast guard patrol vessels KIISLA and VALPAS were left in the area. The master of the TURSAS was appointed CSS at 1850 hrs. By this time the vessel had inspected 25 liferafts. A new attempt to winch up the injured person to a helicopter failed and at 1950 hrs the TURSAS got permission to take the rescued man to Hanko for medical care.

The vessel returned to sea and the master acted as CSS in the area also on 29 and 30 September, participating in the search for victims. Several bodies as well as debris were found. After this the TURSAS changed crew and continued its mission until 3 October. The TURSAS rescued one person.

MINI STAR

The cargo ship MINI STAR, proceeding from Kiel in Germany to Kotka in Finland, was 35 nautical miles SSW of the FSTONIA and arrived at the scene of the accident at about 0430 hrs. She was assigned the task of searching the area at her master's own discretion. The vessel was also instructed to go near liferafts that had been observed in order to check whether there were any people on board. At 0510 hrs motion was observed on board a liferaft. When it had been se- cured to the vessel with a line, two persons were seen on board. It proved impossible to bring them on board the vessel because of the heavy rollingup to 45 degrees. Then a pilot ladder hanging down from the side was brought near the raft so that they could try to climb up. A man on board the raft failed several times to climb up. He did not understand the instructions shouted to him to wait calmly for a helicopter. When he made a new attempt, a wave washed him into the sea, where he disappeared. A helicopter arrived at 0520 hrs and brought up the second survivor from the raft.

The vessel continued its search until 1830 hrs, when she was given permission to continue her voyage to Kotka.

Final remarks

Two hours after the ESTONIA sank, 6 vessels had reached the scene of the accident. By 1600 hrs, 29 vessels had arrived to carry out a surface search.

7.5.4 General considerations, helicopters

Readiness

Three helicopters in Finland and four in Sweden had been on stand-by These were the first to be summoned. In addition, Denmark had two helicopters on stand-by under an agreement to assist in Swedish SAR operations when necessary.

Both in Finland and in Sweden the crews of the helicopters were on stand-by at their homes. The requirement in Sweden is that the helicopter has to take off within the stipulated readiness period. The requirement in Finland is that the crew is obliged to arrive at the base within the readiness period. In practice, Finnish helicopters are also able to take off within this period.

Planning of action

At 0325 hrs the deputy commander of the rescue operation determined as the principle for the use of the helicopters that they would retrieve people from the sea and from the rafts and take them to the nearest passenger ferries. This was intended to optimise use of the helicopters and minimize transfer flights.

The Finnish helicopters OH-HVG and OH-HVD landed on the passenger ferries, but the other helicopters took the rescued survivors to land-based locations. Landing on heaving and rolling ferries was considered too dangerous. The pilot of OH-HVG stated that landing on the ferries was the most difficult part of the whole rescue operation. The medical executive team at MRCC Turku immediately started to raise medical readiness and decided at 0245 hrs to send a team headed by a physician to the coastal island fortress of Utö, the closest island to the scene of the accident. However, no helicopters were available for transport, so a team headed by a physician was sent from Mariehamn to Utö at 0620 hrs.

When it became clear that not all the rescued survivors could be carried to the vessels, MRCC Turku gave instructions to bring them to Utö as necessary The reasons were that the flight time would be shorter and the risk of hypothermia less. Utö thus became the most important assembly point for survivors, of whom the helicopters brought 24 to the fortress for transfer to hospital care. The fortress personnel, guided by nurses, attended to the survivors' treatment. The medical team arrived at Utö at about 0650 hrs.

The use of Utö as an assembly point became more difficult by 0630 hrs when the supply of helicopter fuel ran out. Helicopters were advised to fly to

Nauvo, Turku or Hanko for refuelling. MRCC Turku ordered hospitals to prepare to receive patients, and ground transport was organised from the refuelling sites to the hospitals. Helicopters arriving in Turku for refuelling landed first at the Turku University Central Hospital landing site to leave the survivors before proceeding to the base for refuelling.

OSC continuously advised the helicopters regarding the refuelling sites. Their crews could assume that the ground transport of survivors from the refuelling sites had been arranged.

Action

Up to 0600 hrs four rescue helicopters operated in the area and four more arrived at dawn, somewhat before 0600 hrs.

At the break of day the operational possibilities for the helicopters improved, and liferafts were found more quickly and easily than in the dark using search- lights.

The last survivors were found at about 0900 hrs. At about 1000 hrs the helicopters were instructed to lift also bodies observed and reported by the vessels.

On the same day by 1330 hrs, all liferafts had been examined. After this, seven Finnish and three Swedish helicopters remained at the scene. The others were released from duty to return to their bases.

On the day of the accident, 26 helicopters participated in the rescue operation and search for bodies. Of these eight came from Finland,14 from Sweden, one from Estonia, two from Denmark and one from the Russian Federation. In addition five helicopters served as logistical support, e.g. by transporting first-aid personnel.

The helicopters continued their search and retrieval until dark, when the search was broken off and they returned to their bases. The helicopters operated in the area for about 15 hours, from 0305 hrs to 1800 hrs. The search for and retrieval of bodies and objects in the water continued until 2 October, after which searches continued in connection with the regular patrol flights of aircraft and helicopters. The helicopters rescued 104 persons and found 92 bodies within the first days. The correct number of bodies, 92, differs slightly from the total obtained by summing the numbers of bodies given by the pilots. Section 7.5.5 describes the results of the helicopter operations up to the evening of 28 September in the order in which the helicopters first arrived at the scene of the accident. The search for the deceased on the following days is dealt with only briefly.

Maintenance

At 0300 hrs MRCC Turku sent a tank truck to Nauvo to establish a refuelling site for helicopters. Later during the morning a tank truck was also sent to Hanko to replenish the supply there.

Utö had a permanent refuelling facility for maritime rescue helicopters. The oil spill exercise that had been conducted during the previous evening had depleted this, however, and a new supply did not arrive until the following day Meanwhile, the refuelling took place in Hanko and Nauvo.

At 1000 hrs the Hanko fuel supply was exhausted and later during the morning a tank truck was sent there.

Meals for the helicopter crews had also been arranged at the refuelling sites.

7.5.5 Action by SAR helicopters

OH-HVG (Super Puma)

The stand-by helicopter OH-HVG, taking off at 0230 hrs from Turku and arriving at the scene of the accident at 0305 hrs, began its search in the darkness, using its searchlights to locate people in the water.

During its first rescue flight OH-HVG inspected four liferafts and rescued four persons, who were taken to the SILJA SYMPHONY. The crew of OH-HVG noted that the darkness made it difficult to see people floating in lifejackets even if searchlights were used. The use of only one rescue man proved to be slow and dangerous, and at 0445 hrs OH-HVG flew to Turku to pick up a second rescue man. On the same trip, it flew the air operations co-ordinator to the scene. During the second flight, from 0515 hrs to 0915 hrs, several rafts were inspected. Forty survivors were rescued, and one body was retrieved. Of the survivors 11 were Ilown to the MARIELLA, 16 to the SILJA SYMPHONY and 13 to Nauvo. In Nauvo they were met by a physician and ambulances. The survivors were taken to a health centre and from there the ten worst cases were taken to hospital.

During its third flight, from 0930 hrs to 1230 hrs, OH-HVG inspected 25 rafts, but only dead people were found.

After a change of crew, and maintenance of the helicopter, OH-HVG transported representatives of the media to the scene of the accident and to Utö, and then back to Turku.

During the fourth search mission, from 1600 hrs to 1915 hrs, bodies were retrieved from liferafts and from the sea. After this flight, OH-HVG flew back to Hanko. On its return flight from Hanko to Turku, from 1950 hrs to 2100 hrs, OH-HVG flew by way of the scene of the accident in order to carry out a search.

During the following two days OH-HVG was engaged in search operations and picking up bodies. In several statistics published after the accident, the number of survivors rescued by OH-HVG has been given as 37. This number has also been reported by the crew. In reality the helicopter rescued 44 people. This has been verified from the vessels' and the Nauvo assembly point log books.

Q 97 (Super Puma)

The Swedish stand-by helicopter Q 97 took off from Visby at 0250 hrs, arriving at the scene of the accident at 0350 hrs. The OSC requested the helicopter to pick up as many people as possible from the sea.

On its first flight Q 97 rescued six survivors from the keels of two upside-down lifeboats. As instructed by the OSC, Q 97 flew them to Utö, where it landed at 0500 hrs. During the stop the crew called ARCC Arlanda, informing about the situation at the scene and asking for as many helicopters as possible.

After refuelling, Q 97 returned at 0540 hrs to the scene and rescued nine survivors, five from a liferaft and four from the water. They were in very poor condition. The pilot decided to take them directly to Hanko on the mainland. Q 97 landed at a sports field in Hanko at 0735 hrs, and local residents quickly summoned ambulances to the field. The crew was advised to fly to the Hanko coast guard station landing field, where they could refuel.

Q 97 took off from Hanko for the accident scene at 0810 hrs and returned to Hanko at 1050 hrs. After refuelling Q 97 returned to its base and finished the mission at 1615 hrs.

Y 65 (Boeing Kawasaki)

The Swedish stand-by helicopter Y 65 took off from Berga at 0320 hrs. Because the MBS system was shut down that night due to a malfunction, the alerting of the crew was delayed ten minutes. When the pilot heard from Berga that the ESTONIA had presumably sunk, he decided to fly directly to the scene of the accident without, according to routines, picking up medical personnel from Huddinge Hospital.

On arriving at the scene of the accident at 0400 hrs, Y 65 observed a large number of liferafts to the east of the SILJA EUROPA and began to inspect them. The first two were empty At this stage a red emergency flare was fired in front of the helicopter. People on board a raft were flashing lights and waving. Because of the heavy sea, it was difficult to lower a rescue man to the raft, but the helicopter succeeded in rescuing one person from the raft.

When the helicopter started to lift the two remaining survivors, one of the strands of the wire broke, and then the winch engine malfunctioned. Since there were no mountings on the helicopter for an emergency winch, winching the survivors up to the helicopter was impossible and they had to be left in the raft. The rescue man had to be carried at the end of a 30-40 metre wire to the deck of the SILJA EUROPA. Y 65 alerted Berga for a new winch and took the survivor to hospital in Stockholm, from where one nurse was taken on board to assist in the rescue work. After this, Y 65 proceeded to Berga to change the winch and wire.

After taking on board two rescue men along with a reporter and a cameraman from a Swedish TV company, Y 65 took off again for the scene of the accident at 0812 hrs. During its second flight it inspected a large number of liferafts and hundreds of empty lifejackets. No more survivors were found. Several bodies were observed and Y 65 informed other helicopters. Three bodies were retrieved and flown to Hanko, where Y65 arrived at 1137 hrs. After refuelling, Y 65 returned to Berga, arriving at 1550 hrs.

Q 99 (Super Puma)

When Q 99, the stand-by helicopter at Ronneby received the alarm, it was already on another rescue mission just south of (tm)land, where it rescued two survivors from a fishing vessel. This mission finished at 0238 hrs. Ordered immediately to proceed to the scene of the accident, Q 99 landed at 0325 hrs at Visby for refuelling and maintenance of equipment and took off from Visby at 0355 hrs, reaching the scene of the acci- dent at 0440 hrs.

During its first flight Q 99 launched two of its rafts so that they could drift into the area. Three survivors were winched up from a raft. Two more survivors were hoisted into the helicopter from another raft. Q 99 then had to break off as the rescue man was exhausted.

Q 99 proceeded to Utö where it landed at 0547 hrs. After refuelling from the last reserves of fuel on Utö, Q 99 returned at 0651 hrs to the scene of the accident and discovered a raft with four people. While winching up the first survivor a huge wave of about 12 m high almost overturned the raft. After winching all four persons up, the crew returned to Hanko due to the bad condition of the rescued people. Q 99 carried out one more search flight between 0831-1125 hrs but could not find any more survivors or bodies. After refuelling at Hanko, Q 99 departed for base, arriving at 1610 hrs.

OH-HYD (Agusta Bell 4I2)

OH-HVD was on stand-by at its base in Helsinki. At 0218 hrs MRCC Turku asked MRCC Helsinki to call out OH-HVD. The crew were alerted at 0225 hrs in their homes. They arrived at 0255 hrs at the base and reported to MRCC Helsinki, which responded that MRCC Turku was in charge of the rescue operation and that they would be given their assignment as soon as MRCC Turku and MRCC Helsinki had clarified the situation. At 0320 hrs MRCC Helsinki reported that the ESTO- NIA had sunk and ordered OH-HVD to take off. The helicopter arrived at the scene of the accident at 0532 hrs.

When OH-HVD reported to the OSC on arriving at the scene of the accident it was assigned the task of retrieving survivors from the rafts and from the sea, where 20-30 liferafts, 2-3 lifeboats and many lifejackets could be seen in the water.

OH-HVD began to inspect the life- rafts. Four survivors found on board the third raft were flown to the SILJA EUROPA. After this OH-HVD continued to inspect rafts, and soon a badly injured person was found on one of them. He was also taken to the SILJA EUROPA. The other persons on the raft were dead.

OH-HVD continued inspecting rafts for twenty minutes. The FINNMER- CHANT had observed survivors on a raft near by and OH-HVD was summoned. Two survivors in good condition were found on the raft, and they were flown to Hanko, where the helicopter refuelled. OH-HVD returned to the scene of the accident at 0800 hrs and found five bodies in lifejackets in the water.

During the day OH-HVD continued search operations - only broken off for refuelling until 1945 hrs. The following day it continued its (lights until dusk and recovered nine bodies from the sea.

Q 9I (Super Puma)

Q 91 took off from Ronneby at 0345 hrs and reached the scene of the accident at 0550 hrs.

At the beginning of the operation Q 91 launched two liferafts into the sea. It began to search an area 7-8 km to the west of the search areas of the other units. Several rafts with survivors were found at the beginning of the search. The helicopter winched up five survivors from one raft. From the next raft, one survivor was winched up. The attempt to winch up a second person failed. He was in a state of panic and almost drowned the rescue man. The winching had to be halted. Q 91 took the survivors to Utö, and on hearing that there was no more fuel avail- able there, proceeded to Mariehamn.

During the flight the helicopter's equipment gave two chip warnings (a warning of metal chips in the transmission system). Q 91 landed safely in Mariehamn but had to leave the operation because of the failure.

Y b4 (Boeing Kawasaki)

Y 64 took off from Berga at 0445 hrs, picked up a physician and a nurse from Huddinge Hospital and arrived at the scene of the accident at 0552 hrs.

The crew noticed that many rafts were searched more than once because there were no markings showing that a raft already had been examined. Therefore the crew proposed by radio that the rescue men should cut up the canopies of searched rafts.

Y 64 began to rescue three people, one in a raft, one lying in the water tied to the raft and one lifeless entangled in the raft's sea anchor. The helicopter winched down its rescue man to the person in the water. Although the winch wire failed, the rescue man managed to raise him. The next to be lifted up was the man in the raft. He was not wearing a lifejacket. He fell into the water just before gaining the helicopter. The rescue man jumped after him and succeeded in grasping him. The winch now failed totally and another helicopter, Y 74, was called upon to rescue them. However, before Y 74 arrived, the person died.

Y 64 brought the survivor to Utö. The medical personnel on board were left to assist the Finnish nursing staff. As requested by the staff, Y 64 transported 20 survivors from Utö to Turku University Central Hospital. After this Y 64 got permission from the OSC to return to Berga to repair the broken winch, and landed there at 1530 hrs.

Y 74 (Boeing Kawasaki)

Y 74 took off from Berga at 0546 hrs. Carrying a physician and a nurse from Huddinge Hospital, Y 74 reached the scene of the accident at 0642 hrs. Dawn had already broken. At the beginning of the operation, Y 74 found a raft containing a body with the head under water. At the same time the helicopter received a radio message that Y 64 had had to leave its rescue man in the sea. Y 74 went to assist Y 64.

Y 74 had difficulties in locating Y 64 since the OSC lacked exact information on the position of each helicopter. The Y 64 rescue man was holding onto a body, which was winched up to Y 74 with the assistance of Y 74's own rescue man. When the body had been recovered, the Y 74's rescue man fell about one metre, receiving a heavy blow from the harness to the lower part of his body Nonetheless, he requested that he be lowered to bring up one more body. This body, however, had become badly tangled with the ropes on the raft and could not be winched up.

At this stage the pilot decided to interrupt the recovery of the body since there might still be survivors in the sea and on rafts. Finally a spare harness was lowered to the Y 64's rescue man and used to winch him up to the helicopter. The injury to the Y 74 rescue man proved so serious that he was unable to do more. The work was continued by Y 64's rescue man.

At 0715 hrs Y 74 found a raft with three survivors, who were winched up into the helicopter. At one point the rescue man had to be brought up because his flippers had been torn off by the waves.

At 0740 hrs Y 69 reported that it, too, had had to leave its rescue man in the water because of a malfunction of the winch. In addition, this rescue man was suffering from concussion, since he had hit his head on a lifeboat that was upside-down in the water.

Y 74 went to Y 69's assistance. A hook and harness were dropped to the rescue man, and he was able to use them to get up to the helicopter.

Three survivors were hanging on to the keel of an upside-down lifeboat. Y 64's rescue man was lowered, and all three survivors were winched up. In connection with the rescue of the last of the three, a strong wave threw the rescue man against the lifeboat, injuring him. Since Y 74 now had three injured rescue men, it had to interrupt its rescue operations. In addition, fuel was running low. The six survivors, the injured rescue men and the body were taken to Huddinge Hospital, where the helicopter arrived at 0930 hrs. Y 74 returned to Berga at 0940 hrs to change crew.

Y 74 took off again from Berga at 1025 hrs with a new mechanic and two new rescue men. A fresh physician and nurse were taken on board from Huddinge Hospital. On reaching the scene of the accident, the helicopter recovered four of the five bodies on a liferaft. The fifth, which was not wearing a lifejacket, was washed overboard and disappeared in the waves.

Y 74 was then assigned a search area along the southern edge of the scene of the accident, but did not observe any- thing related to the accident. Y 74 proceeded to Hanko for refuelling. While in Hanko the helicopter was informed by ARCC Arlanda that it did not need to continue the search. The helicopter returned to Berga, landing at Utö on the way to leave the bodies. It landed at Berga at 1657 hrs.

Y 69 (Boeing Kawasaki)

Y 69 took off from Ronneby at 0430 hrs. On reaching the scene of the accident at 0645 hrs, Y 69 reported to the OSC and was ordered to wait. At the same time, it observed a raft which, however, proved to be empty Immediately after this an upside-down lifeboat came into view with three persons hanging on to its keel. When the rescue man was lowered into the water, a strong wave washed him against the boat, injuring him in the head. When the helicopter tried to winch him up, the winch malfunctioned. Y 69 had to ask Y 74 for assistance. Y 74 was able to bring up the rescue man and the three survivors.

Since the OSC could not assign the winchless helicopter additional tasks, Y 69 left for Mariehamn.

For the remaining period Y 69 served as a reconnaissance and transport helicopter from Turku. It ended its mission in the afternoon and landed at Berga at 1530 hrs.

On the following day Y 69 carried out search operations at the scene of the accident with a crew transferred from Y 72. Six bodies were recovered.

Y 68 (Boeing Kawasaki)

The stand-by helicopter Y 68 took off from Säve at 0345 hrs, arriving at Berga for refuelling at 0515 hrs and reaching the scene of the accident at 0645 hrs.

Immediately on arrival Y 68 found an upside-down liferaft carrying six survivors and five bodies. The six were winched up. The winching was very difficult, since the raft bobbed up and down in the waves, and the wire was in danger of being jerked. The survivors were suffering badly from hypothermia, and since no rafts or persons swimming in the sea could be seen near by the pilot decided to fly the survivors as quickly as possible to receive medical care.

Y 68 was aware that Q 91 (see above), which left the area at the same time, was experiencing technical difficulties and was en route to Mariehamn. To ensure that Q 91 made it safely, Y 68 decided to proceed to Mariehamn also. On the way Y 68 asked to be met by six ambulances to take care of the survivors.

After refuelling, Y 68 returned to the scene of the accident to perform a second search flight. During this flight it only found one body which was floating in a lifejacket. At the end of the flight, the body was flown to Nauvo.

After refuelling at Nauvo, Y 68 took off on a third rescue flight. It retrieved two bodies from the sea and took them to Turku. After refuelling, Y 68 returned to Berga where it landed at 1640 hrs.

On the following day Y 68 flew with a new crew from Berga to Turku. It was assigned, together with a Finnish helicopter, to fly media representatives to the scene of the accident between 1200 hrs and 1900 hrs. During the flights Y 68 was requested to patrol the sea, but no survivors or bodies were found.

O 95 (Super Puma)

95 took off from Söderhamn at 0410 hrs for Berga where it landed at 0510 hrs for briefing and refuelling. At 0600 hrs O 95 took off and on arriving at the scene of the accident at 0645 hrs, O 95 immediately observed many liferafts and lifejackets in the water. By 0720 hrs the helicopter had brought up six survivors from two different rafts. After this O 95 flew to Utö drop off the survivors. From Utö, it proceeded to Turku for refuelling.

On its second rescue flight, from 0925 hrs to 1210 hrs, O 95 was assigned a search area along the eastern area of the scene of the accident. The helicopter inspected several liferafts, but no more survivors were found. Three bodies were winched up to the helicopter and taken to Hanko.

On its third flight no more bodies were found. O 95 returned for its base in Söderhamn at 1530 hrs by way of Hanko and Berga.

OH-HVF (Super Puma)

OH-HVF was at its base in Turku, but it had been stripped down for its regular maintenance. When the chief of the Turku patrol flight arrived at MRCC Turku at 0345 hrs, he had the helicopter prepared for operations. At 0540 hrs the inspector certified that the helicopter was airworthy for the duration of the rescue operations.

OH-HVF took off at 0615 hrs and arrived at the scene of the accident at 0645 hrs. Unable to make radio contact with the air operations co-ordinator, it called OH-HVG, which was in the area, and was instructed to winch up survivors from the liferafts. OH-HVF inspected several rafts, but all were empty The best approach proved to be to lower a rescue man to the sea down-wind, from where he could swim to the rafts. A body was on one raft. When an attempt was made to place the body in the hoist, a large wave capsized the raft and she disappeared.

At this stage OH-HVF departed for Nauvo to refuel. It arrived at Nauvo at 0935 hrs. It took off again for the scene at 1025 hrs, arriving there at 1045 hrs.

OH-HVG notified OH-HVF of a raft carrying several bodies. OH-HVF found an overturned raft with 12 bodies. Nearby two rafts had become entangled in each others' ropes, and two bodies were attached to the ropes. OH-HVF brought up eight bodies from the over-turned raft. The winch wire was then found to be frayed. OH-HVF notified the OSC of this and flew to Utö, where it landed at 1200 hrs. No more fuel was available at Utö. In addition, the wire was so badly frayed that it had to be replaced. OH- HVF took off from Utö at 1245 hrs, carrying a new air operations co-ordinator and the air traffic control officer to the SILJA EUROPA. On the way one more liferaft was checked by the rescue man, and several more visually From the SILJA EUROPA, OH-HVF returned back to the base and landed in Turku at 1355 hrs.

A second crew took off from Turku to the scene of the accident at 1535 hrs, taking with them two police investigators to Utö. OH-HVF searched for survivors and bodies at the scene of the accident for 1.5 hours, but no more were found. The helicopter landed at Hanko at 1855 hrs. Later that evening, OH-HVF transported six persons who had participated in the rescue operations from the SILJA EUROPA to Turku.

On the next day OH-HVF carried out one further search flight, during which it brought up seven bodies. It served also in transport duties.

X 92 (Mi-8)

Together with the other Finnish Air Force Mi-8 helicopters X 92 was called out at 0315 hrs. It took off from Utti at 0438 hrs, refuelled at Turku, and arrived at the scene of the accident at 0650 hrs.

On arrival X 92 was assigned a search sector by the air operations co-ordinator, and asked to search the liferafts for survivors. The rescue man inspected several rafts, but all were empty. After this the crew was advised that the inspected rafts were to be marked with a buoy or by ripping open the canopy During the first flight, no survivors were found, but a large number of bodies were observed.

At the end of its first flight X 92 picked up one survivor on a stretcher from the MARIELLA and took him to Hanko. The assignment to pick up another survivor from the ISABELLA had to be transferred to X 42, since it would have taken some time to get him up on deck, and X 92 was running low on fuel.

After landing in Hanko, X 92 returned to the scene of the accident and picked up eight bodies, which were taken to Utö. Following refuelling at Nauvo, a third search flight was carried out but no more survivors or bodies were found.

On the following day X 92 flew one flight to the scene of the accident to transport journalists.

On 30 September X 92 performed three search flights and picked up five bodies from the sea. Three of them lacked lifejackets. The helicopter returned to Utti at 1943 hrs.

X 42 (Mi-8)

X 42 took off from Utti at 0445 hrs, landed in Turku to refuel and took on board seven men from the special task group (EKA) of the Turku city fire department to serve as rescue men. They could not board the SILJA EUROPA because the vessel was rolling so badly that it would have been dangerous to land on the helicopter deck. They therefore stayed with the helicopter all day as first-aid personnel.

Some 50 rafts could be seen in the water. Flying low, X 42 examined them visually. A rescue man was lowered to check those with intact canopy. He searched ten rafts, but no survivors were found.

While X 42 was inspecting the rafts, OH-HVG reported that it had to interrupt a rescue from one raft, since it was low on fuel. X 42 winched three survivors from this raft. It then flew to the ISABELLA to pick up a survivor in a stretcher who, together with the other survivors, was flown to Turku.

During its second flight X 42 took on board three EKA men to serve as rescue men and to operate the winch. On a search in the area indicated by the OSC, X 42 brought up two bodies from lifeboats.

After taking three bodies from Hanko to Utö, X 42 returned to the scene of the accident and brought up four more from the sea. The bodies were taken to Utö, and X 42 returned to Turku at 1803 hrs.

On the following day X 42 carried out several search flights and picked up seven bodies from the sea. It returned to base at 2144 hrs.

X 62 (Mi-8)

X 62 took off from Utti, landed in Turku and arrived at the scene of the accident at 0720 hrs. It reported in to the SILJA EUROPA by radio. Since X 62 carried no rescue man, it was assigned only search operations. At 0735 hrs X 62 was ordered to transport physicians from Turku to Utö. On the way to Turku, it was also requested to transport firemen from Turku to Utö, and the CSS from Nauvo to the SILJA EUROPA.

X 62 took off from Turku at 0841 hrs with five physicians, six firemen/rescue men and an air traffic control officer. The CSS was picked up in Nauvo. The physicians and the firemen were dropped off in Utö. The flight continued to the SILJA EUROPA where, however, it proved impossible to land, as the stern deck of the vessel was rising and falling about 10 metres at a time. Those who were supposed to have been landed on the vessel had to be winched down to the deck. Before the last person could be lowered, a dangerous situation arose when wind turbulence caused by the shape of the vessel almost caused X 62 to strike the helicopter deck. The last person could not be winched down until the vessel had been turned.

After this X 62 began to search the sea for survivors, and possible oil spill from the ESTONIA. It soon found a small slick. Some 20 to 30 bodies in lifejackets were floating flat in front of the bow of the SILJA EUROPA, but no survivors could be seen.

X 62 returned to Turku to refuel and back to the scene of the accident at 1244 hrs. Two firemen/rescue men from the Helsinki Fire Department were taken on board at Utö. At the scene of the accident, X 62 began to inspect rafts, and one overturned lifeboat. One body was brought up from a raft.

During the rescue work, one of the two rescue men was injured when the hook of the winch tore through his clothes and gouged his thigh. The work was broken off, and the injured rescue man had to be flown to Hanko for medical treatment. X 62 arrived at Hanko at 1528 hrs. X 62 performed one more search flight, from 1600 hrs to 1900 hrs, but no more survivors or bodies were found. On the following day X 62 carried out one sortie, but again no more survivors or bodies were found.

U 280 (Sea King) and U 277 (Sea King)

After refuelling in Visby U 280 and U 277 flew together and arrived at the scene of the accident at 0815 hrs.

The OSC assigned them a search area and they operated together. No survivors were found during the rescue flight, and at this stage no action was taken to raise bodies from the water. They flew to Hanko and from there at 1215 hrs, to Denmark.

OH-HYH (Agusta Bell 4I2)

An Agusta Bell 206 helicopter (OH-HRH) was on stand-by in Rovaniemi. In view of the mission, the crew decided to use the larger Agusta Bell 412 helicopter OH- HVH. A back-up crew was also taken on board the helicopter.

OH-HVH Look off from Rovaniemi at 0510 hrs and arrived at the scene of the accident at 1015 hrs. The air operations co-ordinator first assigned it the inspection of liferafts, in addition to searching for possible survivors in the sea. OH- HVH was also informed about how to mark rafts that had been inspected. No rescue man was lowered during this flight, the rafts being inspected visually while the helicopter hovered over them. OH- HVH returned Lo Hanko at 1245 hrs.

At 1330 hrs, OH-HVH took off on a new mission, to look for oil spill which would indicate the location of the wreck. A streak of oil about 0.5 nautical miles long was found at the site. OH-HVH was soon requested to fly over to a Russian cargo vessel, where it was believed a person had fallen overboard. However, it soon became apparent that three bodies from the ESTONIA were in the water near the vessel. Since there were two other helicopters at the site, OH-HVH received permission to move further away. After recovering one body and inspecting two more liferafts, OH-HVH left to take the body to Utö. After this, it flew to Turku to change crews, landing there at 1600 hrs.

The second crew took off on its first flight at 1630 hrs. The air operations co-ordinator requested it to carry out search flights. Informed that a vessel had spotted three bodies in the sea, OH-HVH departed for the scene, where two bodies were brought up to the helicopter and taken to Utö. After this, OH-HVH took off for Nauvo for refuelling, landing there at 1920 hrs and taking off again at 1950 hrs. During the evening, OH-HVH further transported a first-aid team, and transferred one person injured in the accident from Hanko to a hospital in Turku. This last assignment lasted until 0055 hrs on the following morning.

The next two days were spent on searches and transport duties. On 30 September OH-HVH recovered one more body from the sea.

Y 61 (Boeing Kawasaki)

Y 61 took off from Berga at 1030 hrs and picked up two nurses from Huddinge Hospital. Arriving at the scene of the accident at 1140 hrs, Y 61 was assigned a search area north-east of the assumed location of the wreck. Nothing was found but empty lifejackets. Subsequently, Y 61 was ordered to search lifeboats and rafts. The canopies of the rafts were cut after search, and other crews were informed about the measures taken. No survivors or bodies were found.

Y 61 flew to Hanko in order to refuel and check the winch, which had been giving off a burning smell. After landing Y 61 was ordered to return to Berga. On the way it transported seven bodies to Turku. Y 61 landed at Berga at 1900 hrs.

Y 75 (Boeing Kawasaki)

Y 75 was assigned to transport a physician and a psychologist from Karolinska Sjukhuset, Stockholm, to the SILJA SYMPHONY. It departed from Berga at 1300 hrs. There were also two journalists on board during the flight. On the way, it was notified by a Russian merchant vessel that three bodies were in the sea near the vessel. Arriving at 1410 hrs, Y 75 observed the bodies. Two were completely submerged but one had its head above the surface. The latter was picked up. After this the physician and psychologist were taken to the SILJA SYMPHONY, to which they were lowered at 1500 hrs.

Y 75 returned to the Russian vessel and picked up one more body The third had been picked up by Y 68 while Y 75 was en route to the SILJA SYMPHONY. Y 75 took the bodies to Utö and returned to Berga at 1705 hrs.

X 82 (Mi-8)

During the morning the personnel at the Utti helicopter base manned more helicopters for the rescue operation. X 82 took off at 1226 hrs. Three firemen/rescue men from the Helsinki Fire Department were taken on board at Utö. X 82 arrived ac the scene of the accident at 1525 hrs and was requested to examine the liferafts that had drifted furthest away. No survivors or bodies were found during this flight.

O 98 (Super Puma)

98 took off from Söderhamn at 1155 hrs. On its way to the scene of the accident O 98 picked up one pilot and two rescue men from Uppsala. After refuelling in Hanko, O 98 took off for the scene of the accident at 1505 hrs, and returned to Hanko at 1840 hrs. No survivors or bodies were found during this flight.

Staying overnight at Turku, O 98 flew to Hanko on the following day and carried out one more search flight, between 0925 hrs and 1315 hrs, without finding survivors or bodies. O 98 departed for Söderhamn at 1400 hrs.

Y 72 (Boeing Kawasaki)

Y 72 carried out one search flight, taking off from Berga at 1500 hrs and returning there at 1940 hrs. The crew and two journalists were on board during the flight. Only empty liferafts and lifejackets were found in the search sector indicated by the OSC.

On the following day; the crew transferred to Y 69. Y 72 was manned by a new crew, and took off from Berga at 0919 hrs with a medical team from Huddinge Hospital. Y 72 flew to Turku, where the crew and team were briefed on the situation. Y 72 took off for the scene of the accident at 1307 hrs.

Y 72 began to search its assigned sector at 1350 hrs. After picking up three bodies, the crew observed that bodies and flotsam were drifting in quite a narrow area. Two more bodies were picked up from the sea. At 1640 hrs the helicopter departed for Utö to leave the bodies. The crew arranged with the coast guard vessel TURSAS, which was conducting the operations, that Y 69 would take over Y 72's search sector. Y 72 departed at 1950 hrs.

Y 76 (Boeing Kawasaki)

Y 76 flew from its base in Säve, via Berga from where it took off at 1600 hrs for the scene of the accident. Two journalists were on board. Y 76 was assigned a search area south of the main accident area. It returned to Berga at 2025 hrs. During the flight, no survivors or bodies were found.

ES-XAC (Mi-2) and ES-XAB (Mi-2)

On the day of the accident, ES-XAC, a Mi-2 helicopter belonging to the Estonian AeroCo company, conducted a search flight along the northern coast of Estonia. The flights were continued during the following days with another helicopter, ES-XAB, belonging to the same company.

RA 22511 (Mi-8)

A Russian civilian Mi-8 helicopter, RA 22511, arrived in the accident area in the late afternoon of the day of the accident. Later in the evening it landed at Turku.

RA 22511 was equipped for maritime SAR but the crew did not have proper rescue clothing. On the following afternoon, RA 22511 was assigned a search mission, after which it returned to the base.

7.5.6 Action taken by fixed-wing aircraft

OH-PRB (Piper Navajo)

The crew of the Finnish Border Guard Navajo OH-PRB at Turku was alerted at 0445 hrs. The aircraft took off at 0547 hrs and arrived at the scene of the accident at 0613 hrs. It flew above the helicopters, searched for liferafts and informed helicopters and vessels of the location of these. Since radio communications did not function properly OH-PRB served as a relay station between the vessels, MRCC and the helicopters. It returned to Turku at 1025 hrs. After changing crews it took off for the scene of the accident at 1115 hrs with the same tasks as before. It returned to Turku at 1535 hrs. A third flight was carried out between 1620 hrs and 2045 hrs.

On the following morning OH-PRB took off at 0610 hrs. On arrival the crew requested a situation report so that the helicopters could be briefed on the basis of this information. The aircraft carried out three search flights during the day.

OH-PRB's search flights were continued until 4 October.

SE-KVG (Casa)

On the night of the accident, the Swedish Coast Guard Casa 212 aircraft SE-KVG was in Turku, where, during the preceding night, it had participated in a joint Finnish-Swedish oil spill exercise in the vicinity When informed of the accident, the Swedish Coast Guard's operations centre alerted its units in Finland.

On being alerted the crew of SE-KVG departed immediately for Turku from their hotel in Parainen.

SE-KVG was ready to depart at 0615 hrs. It was assigned tasks as a search aircraft and as a radio relay station. On the day of the accident it flew two search flights in the area of the accident, from 0630 hrs to 0930 hrs, and from 1125 hrs to 1445 hrs. Following instructions from the OSC, it searched for liferafts and lifeboats as well as survivors in lifejackets, reporting to the OSC.

Another Swedish Coast Guard Casa 212 aircraft, SE-IVF was flown from its base in Sturup to Gotland in case it was needed. However, the aircraft was not assigned any task.

ES-PLW (L-4I0) and OH-AYH (AA-5)

On the day of the accident and for several days thereafter, ES-PLW an L-410 aircraft belonging to the Estonian Government, conducted search flights along the Estonian coast. Beginning on 29 September OH-AYH, an AA-5 aircraft leased by AeroCo, also took part in these flights.

7.5.7 Transport of rescued persons to safety

The first helicopter to reach the scene of the accident was instructed to transfer the survivors it had rescued to the nearest passenger ferries, and at 0222 hrs MRCC Turku ordered the vessels to ready their helicopter pads. However, only two helicopters, the Super Puma OH-HVG and the Agusta Bell 412 OH-HVD, were capable of landing on the pads.

The Utö coastal fortress island, the closest island to the scene of the accident, became the most important assembly point for the rescued survivors. The helicopters brought a total of 24 survivors to the fortress for transfer to hospital care.

A summary of the distribution of the survivors in various hospitals is shown in Table 7.8.

7.6 The human outcome

7.6.1 Data about victims and survivors

Based on the latest passenger and crew lists on 4 January 1996 it is believed that there were 989 people from 17 countries on board. Tables 7.9-7.13 give statistical information on the passengers, crew, survivors, identified bodies and missing persons.

Only 26 (5 %) of the women on board, as opposed to 111 (22 %) of the males were rescued. The majority of the rescued were aged between 15 and 44 years. Only 3% of the males, but none of the females, over 65 years old were rescued.

7.6.2 Autopsy observations

The Estonian police requested executive assistance from the Finnish police to examine the causes of death of the victims as well as to identify them. After the Swedish authorities had accepted this procedure, the identification process was officially started.

Autopsies were performed on all victims found within the first days of the accident. All autopsies, except one, which was performed in Stockholm, were performed at the Department of Forensic Medicine, University of Helsinki, which had the best resources in Finland for this.

In all the cases of drowning, hypothermia was regarded as a factor contributing to death. Of the victims, 25 were naked or almost naked, 18 had very insufficient clothing and 40 insufficient clothing for the weather conditions at the time of accident. Only 10 victims had extra clothing.

Fractures and/or injuries to inner organs were found in 28 cases and all victims had suffered minor or more extensive superficial excoriation's, bruises etc.

Alcohol and/or medicaments did not play any significant role. Only three persons had more than 0.5 promille alcohol in blood. Classical narcotics were not found.

CHAPTER 8 OBSERVATIONS AFTER THE ACCIDENT

8.1 Locating the wreck

The locating of the wreck of the ESTONIA started on 29 September 1994, the day after the accident. The work was performed by the hydrographic survey vessel SUUNTA operated by the Finnish Maritime Administration. A side-scan sonar and a multibeam echo sounding system were used in the search.

The work was hampered by heavy weather. The wreck was spotted on 30 September, the location was confirmed and the position was marked with a buoy.

The wreck is located at 59° 22,9' N 21° 41,0' E. It is lying on the sea bed with a list of about 120° to starboard and with the bow towards the east. The vessel is resting in a stratum of soft clay at a water depth of 85 m at the bow and 74 m at the stern. The thickness of the clay stratum varies from 5 m, approximately amidships, to about 15 m at the stern and 25 m at the bow. Below the soft clay the sea bottom consists of stiff boulder clay The vessel is probably in contact with the boulder clay amidships. The highest point of the wreck is at the stern, at a depth of 58 m.

The side-scan sonograms also indicate that there was debris from the wreck in an area 100 to 350 m west of the wreck.

8.2 ROV inspections

At its first meeting on 29 September 1994 the Commission decided that the wreck should be examined with a submarine Remotely Operated Vehicle (ROV) to ascertain her general condition and whether the bow visor had become detached. This work was performed by the Archipelago Sea Coast Guard Section of the Finnish Frontier Guard. The oil pollution control vessel HALLI of the Ministry for the Environment of Finland served as the operational vessel.

Videotapes were made on 2 October after some delay due to heavy weather.

The Commission decided at its meeting in Turku on 3-4 October that additional detailed ROV videotapes should be made for a more detailed view of the damage in the visor and ramp area. These tapes were made from the Finnish Coast Guard vessel TURSAS on 9-10 October.

8.3 Recovery of the visor

The Commission decided at its meeting in Turku on 3-4 October that a search was to be made for the bow visor. This was done by the TURSAS, equipped with a side-scan sonar and a low-frequency echosounder. The Estonian Coast Guard vessel EVA-200, equipped with a side-scan sonar, took part in the search.

The visor was found at 59° 23,0' N 21° 39,2' E about one nautical mile west of the wreck, on 18 October. That it was the visor was confirmed by ROV video-recordings.

The Commission decided that the bow visor should be recovered and brought ashore for a detailed survey The recovery was carried out on 12-19 November. The Swedish Navy mine-sweeper FURUSUND and the Finnish Maritime Administration multipurpose icebreaker NORDICA participated in the work.

The bow visor was recovered on 18 November. It was taken ashore in Hanko, Finland.

8.4 Diving investigation

The Swedish Government ordered a diving survey of the wreck to establish the condition of the interior of the vessel and the feasibility of lifting the entire wreck or recovering individual victims. A commercial deep-sea diving contractor was commissioned by the Swedish Maritime Administration for this purpose. The diving contractor was also commissioned to perform - for the Commission - a survey of the navigation bridge and the vessel's bow area. The diving survey was supplemented by ROV inspection of certain areas. The survey was carried out on 2- 5 December 1994.

The divers' observations and the ROV surveys were recorded on videotapes and in written reports. Certain parts from the visor attachment devices were recovered from the wreck for investigation. The detailed findings in the various areas are described in the following sections. The following parts were removed and brought to the surface:

- One deck hinge bushing housing, most probably the inner starboard one.
- All three attachments lug for the bottom-locking device.
- The locking bolt for the bottom lock.
- One failed hinge lug from the port side inner ramp hinge.
- Two steel spacer rings from the failed ramp hinge.
- One EPIRB stowage case.
- One GPS receiver.
- One portable lifeboat radio set.
- One ship's bell.

8.5 Damage to the wreck

Damage to the visor and ramp attachment devices is covered briefly here for completeness of the description and is covered in further detail in 8.6.

8.5.1 General condition of the wreck

No external damage other than that in the visor and forward ramp area was observed on the wreck. Window panels were, however, pushed out in several places on the accommodation decks and doors in the aft bulkhead on decks 5 and 7 were missing. A door in the front bulkhead on deck 5 was open.

8.5.2 External hull damage

Diving and ROV inspections of the bow area of the wreck revealed certain damage to the installations in the bow area which are summarised in Figure 8.1.

The deck hinge fittings on deck were undamaged except for pounding marks on their forward faces. The visor parking support was undamaged.

The deck was torn open from the visor operating actuator openings and forward. The openings continued for some length down the front bulkhead. The deck damage was extensive with uneven fracture surfaces whereas the opening in the front bulkhead on the port side had rather clean-cut contours (Figure 8.2).

The side locking lugs remained in their recesses, engaged on the locking bolts.

The bottom lock bolt housing was torn away as well as the support bushing.

The mounting bracket for the locking bolt position sensors appeared to be undamaged. The sensors were not on the mounting bracket but the magnet was still attached to the bracket on the locking bolt.

Various damage to the front bulkhead was found and in particular to its lower part.

There was various damage to the rubber seals and their supporting flat bars on the front bulkhead and, extensively, on the forepeak deck (Figure 8.3).

Pounding damage was recorded to the shell plating edges around the forepeak deck and to the ice-breaking stem on the bulbous bow. Various scratch marks were noted on the bulbous bow.

8.5.3 Visor damage

Figure 8.4 shows a summary of visor damage.

The visor shell plating had an extensive indentation on its front side, slightly starboard of the centre line (Figure 8.5). This indentation was a continuation of a sharp indentation and heavy scratch marks along the stem from its bottom. The heavy indentation continued with scratch marks along part of the starboard side of the visor. The damage contained extensive colour marks from the blue bottom paint of the vessel.

The solid stem post was folded inwards and was cracked in several places. The stem post had separated from the shell plating by cracking of the welds.

The bottom of the visor was heavily pounded and distorted (Figure 8.6). It was compressed upwards, varying up to about 0.5 m compared to the original shape.

The inner vertical bulkheads of the visor had indentations and score marks on the port side (Figure 8.7).

The uppermost cross-bar in the visor had heavy impact marks (Figure 8.7). Other cross-bars had lighter marks.

The aft bulkhead of the visor had various damage. In particular the recess for the port side locating horn had been torn completely open in the area below the recess (Figure 8.8). Various impact marks from heavy contact between the visor and the hull were noted with some visor displacement to starboard and upwards.

Both side locking lugs had been torn out of the visor bulkhead, leaving rectangular holes in the plating.

The hinge bushings at the ends of the hinge beams had separated from the beam side plates.

The bottom plates of the hinge beams had pounding and impact marks around the attachment lugs for the visor opening actuators. The lugs for the opening cylinders had score marks on their starboard sides (Figure 8.9).

The bottom lock mating lug was stretched and pushed to starboard and the attachment structure cracked at the port side (Figure 8.10).

The housing on the visor deck had impact damage to the port part of its aft inner wall, including bent and dented bulb bars (Figure 8.7).

The aft edges of the hinge beams and the deck plating of the visor had heavy pounding marks.

The aftmost part of the bulwark plating of the visor on the starboard side and above deck 4 was folded outwards.

The visor lifting actuators had been pulled out of the hull structure, remaining connected to the visor hinge arms.

8.5.4 Ramp damage

The bow loading ramp was found slightly open, with a gap of about one metre at the top. The condition of the ramp was inspected primarily from its lower side due to the limited access to the upper side.

The two port side hinges at the bottom of the ramp were torn apart (Figure 8.11). Both hydraulic actuators for the ramp had failed in their piston rod end eyes, i.e. at the ramp attachment points. The actuators were in partly extended position as when the ramp is partly open. The wires preventing the ramp from falling down to the forepeak deck had detached from the lugs on both sides of the ramp.

Various deep indentations were found on the beams on the lower side of the ramp, in particular towards the bottom end (Figure 8.12).

The ramp port side beam was damaged in several places, mostly towards the top end.

The lugs for the pull-in locking hooks were twisted. The hooks themselves could not be inspected closely.

The boxes on the ramp side bars, mating the bolts of the ramp side cleats, were twisted to open position, except for the lower port side one. The side lock bolts were fully extended except for the lower port side one which was only partly extended.

8.6 Damage to the visor and ramp attachment devices

8.6.1 The visor bottom lock

All three attachment lugs for the bottom lock installation had failed (Figures 8.13 and 8.14). The locking bolt (Figure 8.15) remained attached to the actuating cylinder piston rod, which was bent (Figure 8.13). The remains of the attachment lugs and the locking bolt were removed from the wreck during the diving operation for close investigation.

It was noted that the weld beads between the lugs and the bolt housing and the support bushing respectively had failed partly in the bead itself and partly in the fusion zones. The steel plate of the lugs had failed in their thinnest sections, generally in a forward-upward direction. The two lugs for the bolt housing were twisted towards the port side.

When the locking bolt was removed from the actuator piston rod, the actuator was in fully extended, i.e. locked, position. The piston rod was bent upwards, away from the forepeak deck. The hydraulic hoses were connected. The bolt was checked for wear and deformation. The bolt was straight. The general diameter of the bolt was about 78 mm. Only a slight variation in diameter was measured at the contact area between the bolt and the visor lug. No other damage to the bolt was noted.

The mating lug in the visor was attached to the structure but was bent about ten degrees to starboard and the adjacent structure was deformed and cracked (Figure 8.10). The hole in the lug for the locking bolt had an original diameter of 85 mm while after the accident the hole was oval with dimensions at mid-thickness about 83 x 95 mm. The visor lug was removed from the visor after it had been brought ashore.

The recovered parts have been investigated with regard to properties of the material and characteristics of the fracture surfaces and deformations.

8.6.2 The visor side locks

The visor side locking lugs remained in their recesses in the front bulkhead of the ship, located on their locking bolts. The port side lug had rotated as far as it could in the recess in a direction indicating an initial upward movement of the attachment. The bottom face of the starboard lug was pointing out from the recess (Figure 8.18) indicating only a slight rotation in the same direction as the port lug. The divers estimated the play between the bolts and the holes in the lugs to be about ten millimetres. A hole due to an impact by the lugs of the starboard manual lock was noted in the front bulkhead just above the starboard side lock.

The lugs had separated from the visor by shearing of the visor plating around the attachment welds, leaving rectangular holes in the visor bulkhead plating (Figures 8.19 and 8.20). The tear pattern and deformation of the bulkhead generally indicated that the lugs had been torn off in a downwards and aft direction.

The length of the bottom face of the lugs was estimated from the length of the holes remaining in the visor to about 380 mm. The thickness of the lugs was confirmed to be 60 mm. The plating of the visor aft bulkhead was confirmed to be 8 mm.

8.6.3 The visor hinge arrangement

The visor deck hinge fittings were found during the ROV and diver surveys to be intact except for pounding marks on the side plates, essentially at their upper parts, above the centre of the hinges (Figure 8.16). The hinge shafts had almost fully fallen out from the housings and the shaft starboard ends were resting on the deck railing. The starboard side bushing of the port hinge was still attached to the shaft as Figure 8.20 shows.

All four hinge bushing housings had separated from the side plates of the hinge arms. The failure had generally taken place at the fillet welds and the rim of the lug, surrounding the aftward facing part of the housing. The welds had failed generally in the fusion zones between either the weld beads and the housing or the bead and the side plates. Figures 8.21, 8.22, 8.23 and 8.24 show port and starboard failed hinge beam lugs.

One bushing housing, most probably the inner starboard one, was recovered by the divers and has been investigated in detail. The hinge beam side plates were likewise removed from the visor and have been investigated in detail.

8.6.4 The visor actuating arrangement

The failure of the visor actuating mechanism was caused by failure of the bottom mounting platform of the port side actuator and full extension of the starboard side actuator, whereupon the mounting platform was pulled out of the hull.

The port side actuator was found closed but showed signs of having been extended by about 0.4 m, indicated by scratch marks on the piston rod (Figure 8.25), which remained straight. The bottom mounting platform consisted of a reinforced section of deck 3, surrounded by vertical longitudinal and transverse structural members. Two bulb bars were arranged below the platform as part of deck 3 structure. One of these bulb bars showed repair of a previous crack, close to its end attachment to the vertical bulkhead. The platform was pulled out of the hull by shearing of the plating and failure of welds around the entire platform, sized about 600 x 450 mm (Figure 8.26). The bulb bars separated from the adjacent bulkheads because of weld failure. The old repair weld had not failed. The shear surfaces show indications of old cracks along a considerable part of their length.

The starboard side actuator initially failed because of failure of the hydraulic seals around the piston rod, allowing the rod to become fully extended. The piston rod was bent in the forward direction by about 30 degrees. The bottom platform of the mounting was eventually pulled out of the hull due to shearing of the platform and failure of the welds. A tongue of the forward bulkhead at the mounting platform was pulled out of the hull together with the platform.

The lugs for connecting the actuators to the visor deck beams showed indentations and scoring on the forward and starboard side faces (Figure 8.9). The sealing arrangement around the deck openings for the actuators, consisting of rubber seals supported by steel flat bars, was compressed over most of the surface and some paint marks showed that the hinge arms had been in limited contact with the deck plating.

8.6.5 The ramp attachment and locking devices

The two port side hinges at the bottom of the ramp had failed because of tension fracture of the ramp-mounted lugs.

The mounting of the pins for the upper locking hooks was heavily twisted. The locking hooks could not be inspected in detail but were confirmed to be in locked position. The hydraulic actuators were in extended (locked) position.

Three of the four side locking bolts were in their extended position and the mating boxes on the ramp side beams had been ripped open. The port side lower locking bolt was only partly extended and its mating box was undamaged.

8.6.6 The visor and ramp indicating devices

The magnetic-type position sensors for the bottom lock were not in position on their mounting bracket according to pictures taken during the ROV and diving investigations. The electric cabling that had been part of the sensor installation and the ends of the cables were visible in the area. The mounting bracket for the sensors appeared to be intact or possibly bent slightly aft. No other signs of any mechanical action could be seen on the

bracket. The 12-millimetre-diameterbolt holes for the originally installed mechanical switches were empty. It is not fully clear how the magnetic sensors had been installed on the bracket.

The magnet which was part of the bottom lock position indicator was after the accident visible on its mounting bracket in the locking bolt. According to information obtained from the electrical engineer who installed the magnetic sensors and the magnet in the mid-1980s they were of the Siemens 3SE6-type.

The indicating sensors for the side locking lugs could not be inspected but the damage picture indicates that the locking devices were in fully closed position.

8.7 Condition of the interior

The interior of the vessel had suffered considerable damage caused by her turning over and by the rapid inflow of water during the sinking. Only part of the interior was, however, inspected during the diver investigation.

All loose equipment had slid down to the starboard side of the respective areas and collected there together with various debris. Ceiling panels and parts of the interior had likewise broken loose and collected along the starboard side. In the forward half of the accommodation decks the interior bulkheads and ceiling had been less damaged and many cabin doors remained closed.

The car deck was not surveyed due to the hazards related to divers working in the area. It is therefore not known whether the lashings had been able to restrain trucks.

8.8 Observations on the navigation bridge

The bridge, which was on deck 9, was entered by the divers mainly to collect instruments and other material for the accident investigation and to determine the status of instruments and controls. The inspection of the bridge was difficult due to poor visibility, the considerable vertical depth inside the bridge in the turned-over condition and the absence of items the divers could climb on. During this inspection the divers saw three bodies. One was near the door to the open deck and one in the chart room. The third body was seen on the starboard side bridge wing by a diver who tumbled down to the wing and accidentally came across the body

A large amount of equipment had fallen down to the starboard side bridge wing, which was crushed against the seabed. The bridge wing could not be inspected due to mud and accumulation of debris, and for reasons of safety.

On the port bridge wing manoeuvre console the control lever for the port engine was found in full astern position and the lever for the starboard engine in 10 to 20 % forward position. The corresponding pitch indicators both indicated 100 % forward pitch. On the main manoeuvre console the port engine control lever was in about 50 % astern position and the starboard lever in 95 % astern position, both pitch indicators indicating between 50 and 55 % forward pitch. According to information from KAMEWA AB, the supplier, the pitch indicators should all irrespective of the actual pitch return to zero in case of electric power failure.

The navigation computer containing a data logging function with possible detailed information about the last part of the voyage could not be found. A GPS receiver was recovered, but no information could be retrieved from it. No other information could be retrieved from the navigation and operations equipment.

The radio station clock in the chart room showed 2335 UTC. Another bulkheadmounted clock in the aft part of the bridge showed 0212 hrs.

The EPIRB beacon cages were traced on top of the bridge and one was recovered. They were both open and empty.

8.9 Victims

A total of 852 persons lost their lives in the accident. Of them one died in hospita1 and 92 were found in the water and in liferafts during the rescue operation and the following days. No victims were found on the seabed surrounding the wreck or on the external areas of the wreck during the diving survey. Two bodies have subsequently been found in the area of the Gull of Finland, one in the open sea and one on the shorelines of Estonia. Still missing are 757 persons.

The survey of the interior was only partial and essentially limited to public areas and cabins along the port side of the wreck. About 130 victims, including those on the bridge, were observed in different areas. Many victims in various localities had lifejackets on. The parts of the ship inspected by the divers and the locations where victims were seen are shown in Figure 8.27.

On deck 8 the port aft cabins, the port aft passage and the aft part of the officers' mess were examined. No victims were seen, but most of the interior, including cabins and partitions had collapsed making visibility poor.

On deck 7 the cabins on the port side in the midship section were inspected through the windows. Visibility was limited due to floating debris but twelve victims were seen in four cabins. The main staircase, parts of the starboard corridor in the midship section and the aft staircase were inspected from inside. The starboard side of the main staircase was blocked by debris, making inspection impossible, but ropes were found hanging down, fastened on the outer deck 7. One victim was found in the main staircase. One starboard cabin was inspected and found empty. In the aft staircase, a lifeboat ladder was hanging down from deck 7 to deck 6.

On deck 6, the forwardmost port stairwell was inspected and contained many bodies. The entire starboard side of this staircase was full of debris. Six victims were found in the port side corridor in the forward section and in the transverse corridor. In seven cabins, inspected in this area, no victims were found. Two victims were found in the dance saloon near the stage and another nine in the Baltic Bar. Piles of debris made inspection of the starboard side impossible. In the main staircase no victims could be seen but much debris had piled up on the starboard side. The aft staircase and the adjacent lounge were inspected. In the lounge three victims were found and another five close to the staircase. Four cabins were inspected from the outside and revealed no victims.

On deck 5, the forwardmost port staircase was inspected through the windows and contained many victims also at this level. The corresponding staircase on the starboard side was also inspected and found empty. The adjacent cabins and corridors were also empty All outside cabins in the port forward section were inspected through the windows. None of these appeared to contain any victims although visibility was poor due to floating debris. In the corridor outside these cabins, however, eight victims were seen. The divers also entered the shopping area amidships. Much merchandise had piled up or was floating and three victims were seen in the limited area that could be inspected. The staircase and adjacent hall aft were also inspected. Two victims were found but the collapse of the deck head linings made further inspection impossible. The cafeteria was inspected from the windows aft and from inside on the port side and two victims were seen.

On deck 4, divers inspected localities through all windows on the port side. Visibility was sometimes poor but three victims could be seen inside cabins and one in the night club. Two forward cabins in this area, one outside and one inside, contained two and three victims, respectively, and in the corridor were another three. In the main staircase the divers counted 35 victims but they stated that the actual number of victims in the area was much higher.

On deck 1 the divers entered ten cabins in the foremost part of the cabin department. No victims were found and the cabins seemed to have been unoccupied. Further aft two victims were seen in a corridor and in six inspected cabins in this area a total of four victims were seen in three of the cabins.

8.10 Life-saving equipment

After the accident, lifeboats, liferafts and lifejackets from the ESTONIA drifted towards the Estonian coast in an east- south-easterly direction and were recovered by vessels and by people on shore.

One lifeboat was observed on the wreck, still attached to its davits. The other nine lifeboats were detached and have been recovered from the sea. However, only two small pieces were found from one of them. The man-over-board boat (MOB) was found drifting outside Hanko on the Finnish coast.

Of the liferafts, 52 of the 63 have been found. Two of them were not inflated. One raft was found by a Russian helicopter, 21 were found on the Estonian coast and the rest were recovered by vessels in the area.

Ten rafts that belonged to vessels participating in the search and rescue operation were found as well as three launched by Swedish rescue helicopters. Also a Russian-manufactured raft, used for training on board the ESTONIA, was recovered.

It has not in general been possible to determine which rafts were used by survivors or victims of the accident.

Technical experts from the Finnish police have examined all recovered lifesaving equipment and found some damage. In particular with reference to the liferafts, it should be recalled that part of the observed damage was most likely caused when the equipment was recovered by vessels or washed ashore.

8.11 The EPIRB beacons

The EPIRB beacons along with some liferafts and lifejackets were found on 2 October 1994 by two Estonian fishing vessels in the vicinity of Dirhami on the north coast of Estonia. The beacons were switched off when found. On 28 December 1994 the condition of the above EPIRBs was tested by the Finnish experts. The radio beacons proved to he in full working order when switched on.

On 24 January 1995 both EPIRBs were activated on board the Estonian icebreaker TARMO, when they worked without interval Ior four hours. According to the Russian COSPAS Mission control centre, whose area of responsibility includes the Estonian waters, the radio beacons were transmitting the signal in the normal way throughout the test period.

8.12 Other observations

The propellers were observed to be in almost zero pitch position and the rudders in hard starboard position. The only watertight dour on deck 1 which the divers were able to inspect was closed.

The eye bolts of the manual visor locks were in open position according to the ROV survey. The lugs of the manual lock on the starboard side of the visor were heavily twisted due to a blow to the front bulkhead of the vessel.

Certain discrepancies were noted between the structure of the visor as recovered and manufacturing drawings. These included:

Absence of two longitudinal flat bars and related transverse brackets on the visor bottom plating. No signs of such flat bars having been installed could be seen.

The lowest bow band to the stem plating was welded only from above (area affected by ice damage repair).

One bracket at the aft bulkhead on the port side and between stringers 2 and 3 had been replaced, with defects in the new welding.

One bracket located where the aft bulkhead meets the shell and deck platings on the port side was missing, and cutting marks indicated it had been removed.

Lower edge of bottom lock mating lug differed from drawing shape by flame cutting of its forward corner.

The deck part of the installed hinge arrangement differeded considerably from the manufacturing drawing.

It was learned after the accident that a student working temporarily in an onboard maintenance team observed, but failed to report, in August 1994, some cracks in the fillet welds between the hinge beam side plates and the hinge bushings. The cracks were located in the lower section of the weld beads between the hinge beam side plates and the hinge bushings on the side facing the deck part of the hinge installation. One crack, about 100 mm long, and one shorter crack were observed in the starboard hinge lugs. One crack, about 60 mm long, was observed in one lug at the port side hinge. The cracks were in an area not visible when the visor was closed.

The Finnish police have taken several paint samples from inside the visor. TLC (thin layer chromatography), LC (liquid chromatography) and spot tests analysis of these revealed no vestiges of explosives.

PART 2 ASSOCIATED FACTS

CHAPTER 9 INTERNATIONAL CONVENTIONS, LEGISLATION, REGULATIONS AND CO-OPERATION

9.1 International co-operation and conventions

Shipping is an international activity and co-operation to enhance safety and uniformity has long been in progress. Extensive international co-operation evolved, however, only after the United Nations' decision to create an Inter-Governmental Maritime Consultative Organisation (IMCO). The first working meeting of the Organisation was held in 1959.

The authority of the Organisation was expanded in 1982 and its name was changed to the International Maritime Organisation (IMO). IMO has its permanent administrative office in London and consisted in September 1994 of 149 Member States.

Heading the IMO is its Assembly, which meets once every second year. A Council normally meets twice each year. The Council acts as the IMO's governing body and consists of 32 elected Member States. The IMO is a technical organisation and most of its work is carried out in a number of committees and sub-committees. The structure of the Organisation is subject to changes as new demands arise.

The Organisation's two most important technical bodies are the Maritime Safety Committee (MSC) and the Marine Environment Protection Committee (MEPC).

The MSC, which is responsible for all safety matters except marine pollution, has the following sub-committees with specific areas of expertise:

- Ship Design and Equipment
- Stability and Load Lines and Fishing Vessels' Safety
- Fire Protection
- Safety of Navigation
- Bulk Liquid and Gases
- Dangerous Goods, Solid Cargoes and Containers
- Standards of Training and Watch-keeping
- Flag State Implementation
- Radio Communications and Search and Rescue

The work of the MSC is generally identified by, its goal of fostering and enhancing several international conventions related to maritime safety The result is reflected, inter alia, in the International Convention for the Safety of Life at Sea (SOLAS), the International Convention on Load Lines (ILLC), the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), the Convention on the International Regulations for Preventing Collisions at Sea (COLREG) and the International Convention on Tonnage Measurement of Ships.

Conventions enter into force when they have been ratified either by a specified number of Contracting Governments, or Contracting Governments with a combined merchant tonnage constituting not less than a specified percentage of the gross tonnage of the world's merchant fleet.

Most of the conventions are continuously under development as the work within the IMO progresses and is updated by Amendments, and as new issues need attention whenever deemed appropriate by Contracting Governments. Amendments to technical requirements and regulations enter into force automatically after a certain period and are binding on states which have ratified the Convention itself. A number of minimum performance standards, guidelines, interpretations and other recommendations are issued as Assembly Resolutions. These are recommended for implementation but are not binding on Member States unless explicitly referred to in the texts of the Conventions.

The 1960 SOLAS convention, the first to be adopted under the auspices of the IMCO, entered into force in 1965. It replaced earlier conventions of 1914, 1929, and 1948. The present version was adopted in 1974 and entered into force in 1980. The Convention has been, and continues to be, modified and amended and two Protocols (1978 and 1988) have been adopted to respond to increased safety needs and to allow for technical development. Amendments made in 1988, known as SOLAS 90 increased the requirements as to damage stability of new passenger ships and in 1992 similar requirements were extended to existing passenger ships.

IMO Conventions do not generally have retroactive effect and the requirements applicable to a ship are therefore those which were in force at the time the ship was built. However, in recent years certain requirements have been made applicable retroactively for existing ships.

Problems related to the effective implementation and application of IMO's instruments by certain member states have been recognised by the Organisation and a special sub-committee on Flag State Implementation has been established to develop ways of ensuring compliance with the Conventions and other relevant instruments.

In response to the ESTONIA accident and upon the initiative of the Secretary- General of the IMO, a Panel of Experts was set up in December 1994, under the supervision of a Steering Committee, open to all Member Governments and international organisations concerned. The Panel's task was to review all safety aspects of ro-ro ships and advise the MSC of any action required (Chapter 19).

Telecommunication at sea is regulated by rules and regulations issued by another UN organisation, the International Telecommunication Union (ITU). This body co-ordinates the global telecommunication networks and services and is responsible for regulating the standards of all kinds of telecommunication. A committee within ITU deals with all matters related to radio communication, including allocation of frequencies and the technical properties of transmissions for maritime radio. It lays down performance standards for maritime radio equipment and also issues certificates for the personnel of ship stations and ship land stations. ITU publishes the International Radio Regulations and many maritime radio catalogues, e.g. the List of Coast Stations, the List of Ship Stations, the List of Radio Determination and Special Service Stations.

Another UN organisation, the International Labour Organisation (ILO), deals with certain matters relating to shipping, such as crew accommodation, working conditions and health.

The Commission of the European Communities has also taken action to increase safety at sea, primarily by urging its Member States to be more active in IMO's work towards higher safety standards, requirements for increased port state control and other efforts made to reduce accidents related to human error.

The Organisation for Economic Co-operation and Development (OECD) has expressed concern about safety at sea and has also stressed that ships must comply with international requirements. The use of substandard ships in transport is regarded as unacceptable from the point of view of economic equality since it leads to distortion of competition.

Regional co-operation between the states surrounding the Baltic Sea led to the Helsinki Convention for the Protection of the Marine Environment of the Baltic Sea Area, HELCOM 1974, which entered into force in 1982. The Convention is, however, insofar it addresses shipping, binding only upon ships flying the flags of the Baltic Sea states. IMO has issued a recommendation that the Convention should also be respected by ships of other nationalities.

An agreement, the Paris Memorandum of Understanding (MOU) on Port State Control, which was concluded in 1980 by the Maritime Authorities of 14 European states, took effect in 1982. This agreement provides for port state control with a view to ensuring that, without discrimination as to flag, foreign merchant ships visiting the ports of a Member State comply with the standards laid down in the relevant instruments. The MOU requires, among other things, that a Member State achieves an annual total of inspections corresponding to 25 per cent of the estimated number of individual foreign merchant ships entering its ports during a 12-month period. Such inspection is primarily a visit on board to check the relevant certificates and documents and, in case of doubt, to carry out a more detailed inspection.

Similar agreements have subsequently been adopted in other regions as well. IMO's Assembly resolution A787(19) recommends inter alia that Member States also include operational checks on the competence of the crew during port state control inspections.

9.2 National maritime administration and legislation

The United Nations Conference on the Law of the Sea (UNCLOS) stipulates that the flag state has the main responsibility for enacting legislation to ensure the safety of its ships. States that have ratified a Convention are required to introduce the Convention's requirements into their own national legislation or to make equivalent arrangements. Some nations have added requirements over and above those of the Conventions. The general philosophy is, however, that the minimum requirements should be stringent enough for world-wide acceptance. A state's national regulations apply only to ships flying the flag of that state.

Conventions normally permit the administration of a state to delegate certain functions, required by the Convention, to authorised organisations, usually classification societies. Nevertheless, the responsibility for ensuring the ships' compliance with Convention requirements remains entirely with the state administration on whose behalf the organisations act.

The Estonian administration

The Estonian National Maritime Board has four departments: General Department, Maritime Safety Department, Coast Guard Department (until 17 April 1995) and Lighthouse and Hydrography Department.

The Maritime Safety Department consists of the Fleet Section and two sections with service functions, Ship Control Service and Pilot Service.

The Ship Control Service, which was established in April 1994, consists of eight sections, Navigation and Communications Section, Technical Section and six Harbour Master Sections (five sections on the coast, and one on inland waterways). The Pilot Service is responsible for pilotage in the Estonian inland sea.

The main tasks of the Coast Guard Department are the search for and rescue of humans at sea, the localisation and combating of pollution at sea, surveillance of the purposeful exploitation of Estonian waters and surveillance of ships' safety.

The Fleet Section is responsible for the maintenance of the fleet of the Estonian National Maritime Administration.

The Maritime Board has authorised six classification societies, all members of IACS (on IACS see 9.3), to perform statutory surveys under the SOLAS, MARPOL, Load Line, Tonnage and COLREG Conventions and to issue the related certificates.

The Finnish administration

The Finnish Maritime Administration consists of the Head Office and four Maritime Districts. The Maritime Administration is an independent body reporting to the Ministry of Transport and Communications. The Head Office is divided into five departments, one of which is the Maritime Safety Department.

The Maritime Safety Department supervises that ships are properly constructed, equipped, manned and operated. The department takes care of international co-operation related to ship safety and marine pollution.

The department is divided into the Ship Inspection Section and Ship Technical Section. The Inspection Section handles seafarers' competence, manning, life-saving, navigation and radio matters. The Technical Section handles construction, stability, load line, fire safety tonnage measurement, dangerous cargoes and pollution prevention matters. The department is manned by 35 persons.

There are 25 inspectors, organised in four districts, for surveys of Finnish flag vessels and for port state control of foreign ships.

Finland has authorised four classification societies, belonging to IACS, to carry out surveys for compliance with the SOIAS, MARPOL and Load Line conventions.

The Swedish administration

The Swedish Maritime Administration, with headquarters in Norrköping, is organised into six departments, one of which is the Maritime Safety Inspectorate.

The Maritime Safety Inspectorate is headed by the Director of Maritime Safety, appointed by the Government. The Inspectorate has approximately 140 employees, of whom just under hall work in the head office. The rest are divided between the regional Inspectorate Areas and the Rotterdam office.

The Inspection Department at head office was at the time of the ESTONIA accident divided to four sections: the Ship Technical Section, the Ship Operational Section, the Investigating Section and the Planning Section. An international secretariat within the department handles international matters related to safety and marine pollution prevention, including co-ordination of Sweden's participation in the work of IMO. The organisation has subsequently been expanded with a pollution prevention section and a quality section.

Inspection and related works have largely been delegated to the regional Inspectorate Areas.

The Administration has authorised five classification societies, members of IACS, to perform surveys and inspections required by the SOLAS, Load Line and MARPOL Conventions. The right to issue the relevant certificates has in some cases been delegated to the classification society and in other cases been retained by the Administration.

The master of the ship is required by law to report incidents on a standard form to the Marine Accident Investigation Section.

9.3 Classification societies

The first classification society was formed in the mid-l8th century to give underwriters independent information about the condition of ships intended to be insured. Several other classification societies were formed at the beginning of the l9th century.

The main purpose of a classification society is to perform neutral surveys and inspections. A classification society is engaged for a given ship by the shipowner from the design stage of the newbuilding, through the construction phase and subsequently throughout the life of the ship. A classification, carried out by a recognised society is normally a requirement of insurance companies. A classification society's requirements, valid at the time of building a vessel, generally apply to the vessel throughout her life. Retroactive application of new requirements has not been practised although some movement in that direction has recently taken place.

Classification societies are generally organised as non-profit organisations and charge shipyards and shipowners for their services at cost. A classification society performs independent research into ship design and safety for the development of appropriate rules.

Classification societies are also involved, depending on their resources, competence and world-wide coverage, in performing, on behalf of administrations, the statutory surveys required by the various international conventions. The arrangements are agreed between the national administration in question and the society and define the level of delegation and issuance of certificates.

The eleven major classification societies have a co-operative organisation, the International Association of Classification Societies (IACS), which co-ordinates the policy of the societies, co-ordinates exchange of experience and technical knowledge and issues unified recommendations for the standard to be applied in essential technical matters. Bureau Veritas is one of the members of IACS. Several other, national, classification societies exist which are not members of IACS and which do not qualify for such membership.

Classification societies have from time to time and in particular at the beginning of the 1990s been criticised regarding the quality and integrity of their work. The IACS has therefore developed a quality assurance concept which all the member societies must comply with. Individual classification societies have also instituted extensive internal training and development. of work procedures in order to increase the effectiveness of their work.

9.4 The relationships between owner, shipyard, administration and class

Ships have traditionally been built in close co-operation between the owner, the shipyard, the flag administration and the classification society Before a building contract is signed, an outline specification is developed by the owner or the yard or both parties together. After a contract has been agreed a detailed building specification is developed by the two parties in co-operation. This specification is sufficiently detailed to specify all essential features of the newbuilding, but is still flexible enough to allow the yard to find practical design solutions.

The yard produces drawings for the newbuilding. Major drawings are examined by the classification society for compliance with its building requirements and - where applicable and based on authorisation - with international conventions. The owner has the right to examine all drawings in which he might have an interest. Revisions to the drawings are often made during this work which eventually results in drawings approved by the owner and the classification society.

Drawings specifying the safety and accommodation standard will also normally have to be approved by the flag state administration.

The shipyard builds the ship according to the approved drawings. Due to the complexity of a large ship and the fact that often only one ship is to be built to the drawings, drawings for every detail are not in practice produced.

Some details are therefore often left open to the workmanship of the yard and the inspection by the classification society and the owner.

Attendance by the classification society during the building normally also includes inspection of important sub-contractors' products at their works. Inspection at the yard includes general visual inspection of all essential work for compliance with approved drawings and detailed inspection or non-destructive testing of items that may call for such attention. The surveyor at the yard is the representative of the classification society The surveyor's task is to ascertain that the ship is built according to the rules but normally, however, he is not in a position to make detailed examination of every small section of the ship. The responsibility for adequate workmanship and compliance with the approved plans and drawings still remains with the shipyard.

The owner may have his own inspectors and will often have more inspection capacity on a particular newbuilding than the classification society has. The owner's inspectors will often perform detailed inspection of the workmanship and will also cover areas where the classification society has no specific requirements. The owner's inspection team often includes the captain and the chief engineer who are selected to become the master and the chief engineer of the ship when delivered.

When the ship is completed, sea trials take place in accordance with a programme agreed between the yard, the owner and the classification society After successful trials and any required supplementary work, the ship is delivered to the owner. The yard will be closely related with the ship during a subsequent guarantee period, normally one year.

The classification society will follow up the ship in accordance with its requirements and practice. The work is often divided into annual portions on a rolling time schedule of maximum five years. The annual surveys are made in conjunction with annual dockings of ships for which this frequency is required, or in conjunction with afloat underwater surveys of ships for which this procedure has been approved.

The co-operation between the classification society and the owner is a commercial one, designed to assist the owner to obtain a ship of good class and to demonstrate during the life of the ship that the standard required by the rules is maintained.

9.5 The impact of the HERALD OF FREE ENTERPRISE accident on the development of safety regulations

In 1987, the ro-ro passenger ferry HERALD OF FREE ENTERPRISE capsized and foundered just outside Zeebrugge Harbour, Belgium, with heavy loss of life. The vessel had left the harbour with the bow doors open. When the ship increased speed, the bow wave exceeded the freeboard and water started to enter the lower vehicle deck through the open bow doors. In less than two minutes, at least 500 t of water had accumulated on the vehicle deck and the vessel capsized.

Though ro-ro vessels had been lost prior to the HERALD OF FREE ENTERPRISE disaster, this accident drew renewed attention to the need for improving the safety of ro-ro vessels. Problems of the inadequate stability of such vessels when damaged had long been recognized, but the need for practical and efficient transport seems to have taken priority over safety considerations.

The HERALD OF FREE ENTERPRISE accident triggered an intense world-wide discussion on all aspects of ro-ro safety Improved damage stability standards for existing vessels were being proposed with the aim of introducing these internationally via the IMO network of convention requirements.

In the discussion, the large, open vehicle space near the waterline was generally considered the main problem with regard to damage stability in the design of ro-ro ferries. If the external watertight integrity of the vehicle space is breached, unfavourable circumstances may initiate an ingress of water to the vehicle deck. Water is free to flow over the unsubdivided deck and large free surfaces are quickly formed, leading to the loss of stability and to list. In a heeled condition, the free surface is reduced and some stability is regained, but usually a small list is enough to immerse the car deck. Progressive flooding is likely to start and the list quickly develops to a capsize.

The risk of collision was considered the most serious threat to the watertight integrity of the vehicle space though statistically ro-ro ships had been involved in few collisions. Numerous other possible ways of losing watertight integrity were listed including weather damage due to wave forces. The research was directed to generating data to support the development of new damage stability standards for ro-ro passenger ferries, but other subjects were also studied. As far as the Commission is aware, very little attention was paid to the wave impact forces on the bow doors and the strength of the locking devices.

One of the main items emerging from the discussions following the HERALD OF FREE ENTERPRISE accident was the very modest formal requirements for the damage stability of passenger ships in the final stage of flooding. A damaged ro-ro passenger vessel with a minimum freeboard and transverse residual metacentric height would be unlikely to survive in anything but calm conditions. This had already been demonstrated in the early seventies by damage stability model experiments, and was later confirmed in several extensive series of similar tests after the HERALD OF FREE ENTERPRISE accident. The new tests also indicated that even the residual stability criteria in SOLAS 90 would give sufficient protection against capsizing for a typical damaged ro-ro passenger vessel only in waves with a significant height of less than about 1.5 m. The chances of survival improved, in general, significantly with increasing residual freeboard and metacentric height.

Since a characteristic ro-ro passenger vessel sinking involves rapid heeling, the evacuation of large numbers of passengers from a high-sided jumbo ferry perhaps in rough weather or at night, was considered a major problem. It was pointed out that "ro-ro ferries have no transition between survivable accidents and complete disaster". The minimum requirement should be that a ferry during the flooding stage should stay sufficiently upright For sufficient time to give the passengers and crew a fair chance to evacuate.

Many devices including different sponsons and movable, partial bulkheads on the vehicle deck were developed and tested in model experiments to improve the damage survivability of existing ro-ro passenger vessels, but none of these devices obtained general acceptance.

CHAPTER 10 HISTORY OF RO-RO FERRY TRAFFIC IN THE BALTIC SEA

10.1 Introduction

From about 1960 the ro-ro ferry traffic between south-west Finland and the Stockholm region in Sweden developed extraordinarily fast regarding number of ships built for the trade, their increase in size, capacity and comfort and the number of passengers and vehicles carried. The development was spurred by the competition between the two major shipping company groups engaged in the trade, Viking Line and Silja Line, both under mixed Finnish and Swedish ownership. In several respects it probably progressed faster than international regulations and the classification societies could accommodate. The rate of development during the 1970s and 1980s has generally been considered to lack equivalence in any comparable trade.

Understanding of this development has been considered important for appreciation of the overall circumstances of the ESTONIA accident. A separate study of the history of this ferry traffic was therefore commissioned from a consultant company; ADC Support AB. The study is included in the Supplement.

10.2 Development of the traffic

Scheduled steamer traffic has long existed between Helsinki and Stockholm. Passenger and cargo services were generally separate. A small number of cars could be carried on the steamers, being lifted on board in the traditional manner.

On 1 June 1959 the shipping company SF Line, Mariehamn, Å land, introduced a ro-ro passenger service between Å land and the Swedish mainland, north of Stockholm. At about the same time the project was joined by another Mariehamn-based shipping company; Rederi AB Sally

Only four days after the first ro-ro line opened, a competing service on the same route was started by the Swedish Rederi AB Slite.

One of the vessels used for these first ro-ro-lines was a converted railway ferry and the other one was a coaster, rebuilt to allow ro-ro handling of cargo and the carriage of passengers. Passenger comfort was not considered important since the voyages lasted only a few hours. The traffic was greatly dependent on tourism and during the first few years it was suspended during the winter.

The three shipping companies involved in the first ro-ro traffic between Å land and the Swedish mainland later formed the joint marketing company Viking Line, one of the leading companies in the development of the traffic between south-west Finland and the Stockholm region.

The concept proved successful, and purpose-built ro-ro ferries were ordered. The first one, SKANDIA, was delivered in May 1961 to the competitor Silja Rederi AB, a company jointly owned by Bore Line AB, Finska Å ngfartygs AB and Rederi AB Svea.

SKANDIA could carry 1000 passengers and was built with a full-size car deck, served by bow and stern ramps. The ship was put in service between Helsinki and Stockholm. In May the following year a sister ship, the NORDIA was delivered.

New ships were added every year to meet the increasing demand for transport between the different ports in southwest Finland and the Stockholm region. The standard of the vessels improved. Size and engine power increased, and from 1965/1966 the traffic could be maintained regularly also in winter.

The ro-ro service quickly became an indispensable transport element, primarily for the Finnish export industry, which could now provide deliveries to Sweden and onwards to western Europe in a safe, convenient and reliable manner.

Various factors contributed to make the ferry traffic viable. The lower demand for trucking transport during the general summer vacation period was compensated for by tourist travel during that season. Taking the car on a trip to one's neighbouring country became a convenient, economical and practical arrangement. The large number of Finnsh people working in Sweden and the many family relationships between people living on both sides of the Baltic added to the need for passenger transport. Differences between prices in the two countries of daily commodities made "shopping trips" economical, as did the opportunities to buy tax-free goods on board.

In the 1970s the demand for conference facilities increased rapidly amongst Swedish companies. The ferry companies responded, and with a combination of lower prices than shore-based facilities and the adventure of a sea voyage, the ferries soon became a popular alternative. Existing ferries were rebuilt and extensive conference areas were incorporated in the design for newbuildings.

The ferries built from the mid-1980s had conference facilities and restaurants, bars, shopping arcades and entertainment areas with few equivalents ashore in the two countries.

The basis for the ro-ro ferry traffic between the two countries thus steadily increased as the table below shows.

The competition demanded a steady increase of comfort and ship size. The ferries were very attractive on the second-hand market and the financial risk involved in ordering more newbuildings with more attractive features was low. Nearly fifty, ferries were built for the trade between 1960 and 1990 and the general period in service was only about seven years. Considerable development took place rapidly as experience accumulated and opportunities to introduce improved concepts were frequent.

10.3 Cargo deck arrangement

The cargo deck arrangement has remained generally unchanged since the building of SKANDIA. Improvements have been introduced regarding access and safety arrangements. Hoistable car decks, covering part of the cargo deck, were generally included so to increase the capacity during runs when passenger cars dominated.

Stern ramps and stern openings have increased in size but the design has remained the same, i.e. in lowered position the ramp gives vehicles access to and when raised seals the car deck.

Access to the car deck via a forward ramp became desirable to eliminate the need for turning long vehicles on the car deck and thus to reduce the time required for cargo handling. The concept was known from railway ferries and some cargo vessels. The outer enclosure of a bow opening - the bow door - can be arranged either as a pair of clam doors, hinged at the sides and opened sideways, or as a visor, hinged at the upper deck and opened upwards. Figures 10.1 and 10.2 show various bow door and ramp arrangements.

The visor concept became quite common from the 1960s. Clam doors were initially considered more complicated and before 1985 were incorporated only in a small number of ferries. Most larger ferries built since then, however, have clam doors.

The length of the ramp was determined by the distance to the landing on the jetty and the position of the hinges. The position of the hinge point was in turn determined by the desire to have the ramp serve as an upper collision bulk- head. The SOLAS requirement on ramp position with regard to the rules for an upper extension of the collision bulk-head was, however, often disregarded. The history of compliance with this requirement is covered in Chapter 18.

The available deck height was often too low to allow the ramp to be raised to a closed position. The solutions developed were then either to let the ramp protrude above weather deck level and be enclosed in a housing, or to divide the ramp into two sections with a hinge arrangement in between. The visor housing arrangement was less complicated and was generally selected. It had, however, the disadvantage that the visor and the ramp were then mechanically interconnected, a major disadvantage that was only fully realised as a consequence of the ESTONIA accident.

Clam doors, serving as the outer enclosure, have the advantage that sea loads are absorbed into the ship's structure. Although damage to clam doors has been recorded it has therefore very seldom been of a critical nature.

Visors on the other hand may under unfavourable sea conditions be exposed to sea loads in the opening direction. This has resulted in several cases in the visor moving to more or less open position (see Chapter 11). Where the visor accommodates the top of the ramp, the risk is imminent that the ramp will be forced open, if the visor attachments fail totally and the visor falls off. In such a case, if the vessel has no watertight doors aft of the ramp, water will be free to enter the car deck as was the case in the ESTONIA accident.

Table 10.2 gives an overview of the ferries placed into service on the route by Silja Line and Viking Line between 1959 and 1993 with the type of original bow enclosure and ramp stowage solution selected in each case. Side doors and stern ramps are not mentioned.

10.4 The Tallinn-Stockholm ro-ro ferry operations

Ferry operation between Tallinn and Stockholm was initiated in 1989 while Estonia was still an incorporated region within the Soviet Union. The endeavour to re-establish regular vessel traffic between Estonia and Sweden resulted in signing a General Agreement between the Estonian Transport Committee and Nordström& Thulin AB on 28 August 1989.

The Agreement provided the basis for starting joint ferry operations, including the principles for the necessary investment in related infrastructure. It was stipulated that the Estonian side would undertake the reconstruction of the terminal in Tallinn and Nordström & Thulin would undertake to provide a terminal in Stockholm. The agreement provided that the Estline Marine Company Limited would be granted the concession for operating the ferry line for the first ten years. For the joint undertaking on the Estonian side, Estline Eesti was established in November 1989 by the transport enterprises which were under Estonian jurisdiction. In October 1992, under the conditions of regained independence, the Government of

Estonia reformed the enterprise into the company E-Line Limited and appointed the Estonian Ship ping Company (ESCO) to represent the state in operating the Tallinn-Stockholm services. The decision was made with reference to the General Agreement mentioned above.

Regular ferry service on the route started on 17 June 1990 and was carried out by N& T EstLine AB, a fully-owned subsidiary of Nordström & Thulin AB, in co-operation with a consortium of smaller tourist-related Estonian-government-owned companies. The traffic was carried in the NORD ESTONIA, a ro-ro passenger ferry with capacity for 1060 passengers, owned by Nordström & Thulin and registered in Sweden. The vessel was operated and manned by N& T EstLine AB. The NORD ESTONIA departed every second day from Tallinn and Stockholm respectively. The ferry line was considered to be of the greatest importance to Estonia. Its establishment was opening the country westwards and giving opportunities to establish commercial as well as other relations with other countries, an essential factor in creating new prospects for the country. Traffic was maintained by the NORD ESTONIA for about two and a half years, until she was replaced by the ESTONIA on 1 February 1993.

On 20 September 1994 the passenger ferry DIANA II (see 3.1.1.) was bare-boat-chartered by ESCO. The purpose was to expand the ferry service between Tallinn and Stockholm with one daily departure in each direction. This did not come about, however, due to the ESTONIA accident.

The DIANA II, after considerable upgrading including permanent closure of the bow visor and forward ramp, was put into service in November 1994 under the name of MARE BALTICUM. In August 1996 she was replaced by the REGINA BALTICA.

CHAPTER 11 BOW DOOR FAILURES AND INCIDENTS

11.1 General

A number of incidents involving failure or part-failure of bow visor attachment devices have occurred in the Baltic Sea and the North Sea during the history of the ro-ro ferries. The ships involved have all been under the survey of one of four major classification societies. The following list of some of these incidents includes two involving vessels equipped with clam doors. It is especially noted that many of the incidents occurred during the first year of the vessel's operation.

With two exceptions, the list contains only Swedish and Finnish vessels and is not complete. It may be concluded that similar incidents have occurred in other areas of the world. It is, however, worth noting that the extensive flare in the bow profile of the vessels has in several instances been blamed as a contributing factor. Ferries built for Baltic Sea operators had at the time a more pronounced bow flare profile than ferries built for other services.

After the ESTONIA accident administrations and classification societies performed extensive surveys of the condition of locking devices and hinges on all ro-ro ferries within their territory. The results showed a rather high frequency of defects of varying degrees of severity needing corrective work. One of the classification societies reported that some kind of defect, e.g. cracks or deformation of locking devices, was found in about 30 per cent of the ferries inspected. Most of the defects were, however, relatively small.

VISBY, a passenger ferry built in 1972-whilst proceeding from Nynäshamn to Visby in December 1973 - hit a couple of heavy. waves which caused the visor to open. The ship was turned and returned safely to Nynäshamn. It was concluded that the locking devices were too weak, and heavier devices were installed. The matter was dealt with in correspondence between the Swedish Maritime Administration and the classification society involved and information was received that the society had substantially increased the strength requirements. The effect of extensive flare in the bow contour was also discussed.

STENA SAILER, a cargo ferry built in 1973, experienced heavy weather and head sea in January 1974. Speed was reduced but the visor locking devices failed. The ramp remained intact and the ship turned and headed for shelter. It was noted in the investigation that a similar incident had happened earlier and that a sister vessel under another flag had also had a similar incident.

An administration report concluded inter alia that "nearly all locking devices of bow doors on existing vessels are too weak" and recommended that the administration should first investigate how such should be designed and built, and thereafter inspect existing vessels (see 15.13).

SVEA STAR, a passenger ferry built in 1968, experienced heavy weather in May 1974. A heavy wave lifted the visor. Water collected in the visor but the ramp remained closed. The ship turned and regained port.

WELIAMO, a passenger ferry built in 1975, encountered a south-westerly storm on a scheduled voyage from Helsinki to Stockholm on a December night in 1975. About 10 nautical miles south of the Bengtskär lighthouse the officer of the watch noted that the bow visor lifted. He woke up the master. The visor was illuminated with an Aldis lamp and about five minutes later the visor lifted again. Speed was immediately reduced from about eight knots to three knots. The master and the chief engineer inspected the visor and due to the damage and the storm the master decided to turn back to Helsinki.

Next morning in Helsinki it was observed that the locking cleats were torn away and the arms of the visor were partly broken. Side plating on both sides of the visor was dented, as was a light bulkhead inside the visor. There was a small hole on the tanktop, caused by pounding of the visor. The local structure at the locking devices was reinforced, the arms were repaired and reinforced, side plating was renewed and the bow visor hull was repaired on both sides. The bulkhead was reinforced with stiffeners. Two sister vessels were similarly reinforced.

FINLANDIA, a passenger ferry built in 1981 on a scheduled voyage from Helsinki to Stockholm in the autumn of 1981 encountered heavy south-westerly seas south of Hanko. Next morning in Stockholm, the visor did not open and severe damage was found including dented structure on the port side and two broken locking bars on the centre line. The visor had lifted a few centimetres and moved to starboard. Thus, additional locating horns were fitted on both sides and the structure on the back was reinforced. Locking devices were also reinforced. A sister vessel was similarly reinforced.
SAGA STAR, a cargo and passenger ferry built in 1981, was about to depart from port in May 1982. When the visor was being lowered the port side hinge failed, resulting in failure also of the starboard side hinge, and the visor fell down. The ship was allowed to sail a couple of voyages without visor until repairs had been performed.

VIKING SAGA, a passenger ferry built in 1980, was extensively damaged on the fore part and on the lower port side of the bow visor south of Hanko in October 1984, on a scheduled voyage from Helsinki to Stockholm. The incident took place when the vessel was running at 16 knots in heavy bow seas with a wind speed of about 14 m/s. Next morning in Stockholm it was observed that a large part of the port visor shell construction together with a horizontal platform had been dented. A locating horn on the port side was bent towards the centre line and side lockings were damaged. Several stiffeners, beams, large areas of shell plating and part of the platform were renewed. The visor construction was not reinforced, since the incident was considered typical heavy weather damage.

STENA JUTLANDICA, a passenger ferry built in 1983, experienced in October 1984 failure of the visor hinges during normal opening. The main reason for failure of the hinges was cracks in the welds. The hinges were reinforced, also on a sister vessel.

ILYICH, a passenger ferry built in 1973, encountered heavy seas with a wind speed of about 18 m/s on a scheduled voyage from Leningrad to Stockholm in December 1984. At a speed of about 17 knots, one of the visor deck hinges failed fully the other partly and all visor locking devices broke. The visor hung on the hinge and moved up, down and sideways every time the seas lifted the visor. The incident was quickly observed from the bridge, speed was significantly reduced and the vessel run to more sheltered waters. The vessel was also involved in an incident in September 1986 at a speed of about seven knots. In this case, three visor locking bolts broke and other damage occurred. The structure of the bow visor and hinges was reinforced, locking devices were replaced by significantly stronger ones and side locating horns were fitted in 1989.

MARIELLA, a passenger ferry built in 1985, experienced heavy seas on a scheduled voyage from Helsinki to Stockholm in November 1985. The starboard hinge brackets sheared. Both starboard and port hinge beams were almost fully cut. Locking devices and the hydraulic actuators failed and the visor was forced open. Indications of brittle fracture were subsequently noted in shorn-off locking bars. The incident occurred at about 13 knots. Speed was significantly reduced when the incident was visually observed from the bridge, whilst the vessel continued her voyage in more sheltered waters.

The visor was temporarily repaired immediately after the incident. Permanent repairs, including heavy reinforcements of the locking devices and appropriate structures, were carried out later. Reinforcements were made for instance at the lower locks of the visor and below the upper locking devices. Additional locating horns were fitted on each side and the structure on the backs of these was reinforced with stiffeners. A sister vessel was similary reinforced.

TOR HOLLANDIA, a passenger ferry built in 1973, in heavy weather during the winter of 1986/87, experienced failure of the visor bottom attachments and one deck hinge. The condition was observed visually from the bridge and rapid evasive action prevented an accident. Extensive reinforcements were made in conjunction with the repair. FINNHANSA, a passenger ferry built in 1966, lost her clam doors in January 1977 in heavy weather close to the Helsinki lighthouse. The doors were not properly secured. When it was noted that the clam doors were about 0.5 m open, the vessel was stopped in order to get the doors closed. Heavy seas had, however, already torn off the doors. The vessel returned to Helsinki.

SILJA EUROPA, a passenger ferry built in 1993, damaged her port clam door during the same night or morning as the ESTONIA sank. The damage was noted after arrival in Stockholm on 29 September 1994, when efforts were made to open the bow doors. The starboard bow door opened as normal, while the port side door could be opened only about 0.4 m. Among the damage were dented plates in the hinge arm and in a support frame. The exact time of the damage is not known. The shipowner claims that the damage occurred during the ESTONIA rescue operation. Table 11.1 shows a summary of known bow visor incidents which occurred before the ESTONIA accident and involved passenger ferries built from 1975 to 1986 for the Finland-Sweden traffic. The list includes all passenger ferries built between 1975-1986 originally for the traffic even if they had not been involved in such incidents. The table indicates whether the bow visor has been reinforced since the incident. The information for sister vessels is given in the same box. After 1986, all passenger ferries built for the Finland to Sweden traffic have had clam doors (Table 10.2).

11.3 The DIANA II incident

In January 1993 there was a period of heavy weather in the southern Baltic Sea. During this period the Polish ro-ro ferry JAN HEWELIUSZ capsized in the early morning of 14 January DIANA II, a Swedish-flagged near-sister vessel to ESTONIA, operated under charter on the route between Trelleborg in southern Sweden and Rostock in Germany She normally made two double day trips at full speed and one double night trip with reduced speed each day According to available information, on the night of the foundering of JAN HEWELIUSZ no abnormalities were noticed as the DIANA II made the trip from Rostock to Trelleborg at low speed. She made the scheduled day and night trips on 14 and 15 January in bad but improving weather conditions. During the morning of 16 January whilst the vessel was enroute to Trelleborg, the chief officer to be relieved and the one starting his tour of duty made a joint inspection round throughout the vessel, whereupon they noticed damage to the visor locking arrangements.

Since the visor design of DIANA II was the same as that of ESTONIA, the Commission has further investigated this damage and the repair work (Supplement).

Bureau Veritas was called upon when the vessel arrived in Trelleborg. The survey report in the Supplement shows that the starboard locking device lug was lost, the bottom lock was bent and its welds cracked and the port side locking device lug was bent and its weld cracked. Figure 11.1 shows the damage at the site of the starboard visor lug. The damage was repaired by normal procedures, to what was estimated to be equivalent to the original standard.

The survey report, when read at the Bureau Veritas regional office in Gothenburg, was not considered to indicate a serious incident. No initiative was therefore taken to investigate the matter further, nor was any general action taken.

The repaired side locking lug mounting site was surveyed after the ESTONIA accident. The survey showed repair by multiple welding of the cracked lug weld sites, and local backing plates had been added. Some old cracks were also detected.

The visor mating lug to the bottom lock of DIANA II was also recovered with the bottom locking bolt. The locking bolt had extensive wear on its upper forward sector in a location mating with the eye of the lug that had also worn. The visor mating lug also showed marks from over-loading in tension, as its eye had been extended by stretching at the aft tip of the lug. Strengthening plates had been added to the mating lug both to strengthen its tip and to add vertical rigidity to its attachment to the visor structure. It is not known when these reinforcements were installed. The bolt of the bottom lock was made of high-strength steel grade approximately 700 MPa ultimate strength, and the visor mating lug was of mild steel.

The Commission has not been able to verify whether the local office of the Swedish Maritime Administration was informed of the DIANA II incident. From the vessel it is claimed that was given to the Administration by way of a telephone call one of the first days after the incident, and that the inspector answering the call was satisfied with the way the repairs had been carried out. The Administration on the other hand claims that no information on the incident was received until after the ESTONIA accident. An inspector from the Administration visited the DIANA II about one month after the visor incident. He was called to survey a gangway and claims that at the time of the visit, he had no information on any damage to or repair of the bow visor or its attachments.

PART 3 ANALYSIS AND EVALUTION

CHAPTER 12 OVERVIEW OF SEPARATE INVESTIGATIONS

12.1 Determination of sea loads on the visor by model tests

12.1.1 Test program

Extensive model tests ordered by the Commission have been performed at the maritime research centre, SSPA laboratories. The main purpose of the test programme was to determine the wave impact loads on the visor at the speed, on the heading and under the wave conditions in which the ESTONIA was likely to have been operating at the time of the visor failure. In addition, the influence of variations in some of these parameters was tested. The model test results have further been compared to computer simulations of wave loads as summarised in 12.2. SSPA's complete test report is appended in the Supplement.

A 1:35 scale model of the ESTONIA was built and equipped with propulsion units and controllable rudders. The bow visor was made separate from the hull and attached with a six-component balance to measure integrated forces andmoments on the visor in all six degrees of freedom. The static weight of the visor was excluded from the measurements and the moments were transferred to the centre position of the visor hinge axis.

Sea load tests were carried out both in the towing tank (TT), for head sea conditions, and in the Maritime Dynamics Laboratory (MDL) for oblidue sea conditions. The model was in both cases selfpropelled. Long-crested irregular waves were generated according to the JON- SWAP wave spectrum.

The model tests emphasised the determination of extreme values and the statistical distribution of loads. Two of the conditions were therefore tested in a large number of repeated runs with slightly modified wave amplitudes and phase lags.

The test programme in irregular seas consisted of the conditions given in Table 12.1.

A peak period of 8.0 s for the wave spectrum was used for all conditions except for the last one which used a period of 8.3 s. This last condition was at the time assumed to be the most probable condition in which the bow visor of the ESTONIA failed.

12.1.2 Summary of results

Due to the non-linear and random nature of the bow impact loads, the absolute quantitative measured loads must be judged with care. Small changes in the relative motion between the ship bow and the waves, as well as in the wave profile, resulted in large differences in load values. The maximum loads were not generally measured in the highest individual waves but rather in the worst combinations of waves and ship motions.

The most critical wave-induced load component, the opening moment around the deck hinges, the Y moment, measured in the different tests is plotted in Figures 12.1-12.2 on the basis of mean exceedance period. The vertical force, the Z force, is shown in a similar way in Figures 12.7-12.8. Mean exceedance period means here the average time between individual load peaks equal to or higher than the corresponding value. The graphs were produced by taking the total full-scale time of each test series and dividing it by the number of load peaks exceeding a certain level as given by the Weibull plot in SSPA Report 7524.

The wave-induced forces and moments shown do not include the static weight of the visor itself. This will decrease the vertical force by about 0.6 MN and the opening moment by about 2.9 MNm. (1 MN equals the force of 102 metric tons).

12.1.3 Long test series in oblique bow seas

The long series of tests at MDL in port bow sea with a nominal significant wave height, H5, of 4.3 m and a ship speed of 14.5 knots were, at the time the tests were performed, believed to represent the prevailing condition when the attachments of the visor of the ESTONIA failed. In this series, during three fullscale hours of measurements, the individual maximum components of wave loads on the bow visor were recorded as given in Table 12.2.

All the maximum values except for Y force and Z moment were measured at the same incident (Y force was measured to 2.2 MN and Z moment to 3.8 MNm simultaneously). When these highest loads were measured, wave crest amplitude was 3.7 m, relative motion between bow and wave was 6.3 m and relative velocity 6.2 m/s.

The longitudinal and vertical force peaks always appeared in phase and with approximately the same magnitude. Only a few of these load peaks, however, resulted in a positive opening moment about the hinge axis that would have been large enough to exceed the closing moment from the static weight of the visor, and only two opening moments were above 20 MNm. Most of the load cycles caused closing moments with peak levels up to about 5 MNm. Figure 12.3 shows an example of a time series of measured wave profile, vertical force on the visor and opening moment about the hinge axis. The figure covers about 17 minutes of full-scale time.

12.1.4 Wave load components - influence of wave height, heading and speed

The influence of significant wave height, heading and speed on the wave-induced loads on the visor is summarised in Figures 12.4-1Z.6 and 12.9. In the comparison, the most probable maximum values over 30 min. of exposure are used. For most of the test series this means that the given value corresponds to the single highest measured, and hence the uncertainty in these levels is large. In the figures, the test results are connected with straight lines to show the same condition. However, the sea loads are a function of Hs raised to a higher power, and the straight lines should not be used for inter- or extrapolation.

It is apparent that the wave height influence is much larger in bow sea than in head sea. The results indicate that there is a `threshold' sea condition in bow sea below which the wave-induced loads on the visor are very low. When this condition is exceeded, the risk of high forces and moments rapidly increases even though the general condition with regard to motions and accelerations on board is not changed significantly In the conditions tested, the threshold is apparently found at about 4 m significant wave height.

The wave forces show an approximately linear relation to the speed in bow sea for both wave heights studied. A decrease of speed from 15 kn to 10 kn thus reduces the forces by about one third. In head sea, at higher wave heights, the speed influence seems to diminish.

12.2 Numerical stimulation of vertical wave loads on the bow visor

12.2.1 Introduction

Vertical wave loads on the ESTONIA bow visor have also been simulated using a non-linear numercail method to estimate the loads during the accident voyage and to investigate the effects of the most important load parametres. The numerical predicions supplement the SSPA model experiments since it has been possible to stimulate much longer time sequences than could be tested in a model basin.

Due to the very complicated flow phenomena around a body entering water, no exact numercial methods exist for analysing the flow, and the simulation method used is based on an engineering approach with which the vertical component of the wave load could be calculated. It has thus not been possible to simulate the other load components or compute the pressure distribution on the visor surface.

The numercial method is discussed in more detail in the complete report in the Supplement. To evaluate the accuracy of the method, the simulated vertical wave loads have been compared with the experimental results.

The stimulations have been carried out for long-crested, irregular wave time histories generated according to the JONSWAP wave spectrum formula. In each case, the simulated time sequence was 36 hours long, consisting of six 6-hour simulations. The full simulation programme is shown in Table 12.3.

12.2.2 Simulation method

The simulation method is based on the non-linear strip theory, which is a practical method for simulating ship motions and hull loads in waves. In the method applied, the time histories of irregular, long-crested waves and ship motions are generated by employing the linear superposition principle. The bow visor was considered as a small body entering water. Thus, in determining the vertical force on the visor it has been assumed that the dynamic wave pressure and the wave motion, velocity and acceleration are constant within the volume occupied by the visor. The assumption is valid when the wave length is significantly longer than the dimensions of the bow visor.

The numerical model includes the hydrostatic and hydrodynamic forces incorporated in the strip method and the non-linear hydrodynamic forces according to the momentum consideration. The nonlinearities of the hydrodynamic forces arising from the variation of the submerged portion of the visor are taken into account by considering at each time step the instantaneous waterplane. The following force components are incorporated in the numerical model:

Weight of visor, assumed to be 0.6 MN (60 t). ù

Inertia force based on rigid-body vertical acceleration of ship at centre of visor.

Hydrodynamic force due to added mass and damping of visor assumed to be proportional to vertical relative acceleration and velocity respectively Heave added mass and damping coefficients were computed before-hand at different waterlines with a three-dimensional sink-source method and curve-fitted. At each time step, values corresponding to instantaneous draught were used.

Hydrostatic buoyancy force due to instantaneous submerged volume of visor.

Froude-Krylov force defined as the integral of the linear hydrodynamic pressure in the undisturbed, incident, wave over submerged surface of visor.

Non-linear, vertical impact force in which the important term is rate of change of the heave-added mass times vertical relative velocity squared.

Force due to the stationary flow around the submerged visor was computed beforehand by the SHIPFLOW program in calm water at different fore draughts. At each time step, curve-fitted values were used.

The effect of the stationary bow wave was considered as a constant offset increasing the submergence of the visor. Thus, the height of the bow wave estimated by the SHIPFLOW program for different forward speeds was added to the vertical relative motion on the centre line of the visor.

12.2.3 Results

The main results of the simulations are graphs presenting probabilities at which the vertical component of the wave force on the visor exceeds different levels. If exceedance probabilities referring to the number of wave encounters are plotted on a logarithmic scale, and the vertical force on a linear scale, straight lines seem to fit the data quite well. There is no theoretical basis for the linear relationship between the logarithm of the exceedance probability and the vertical visor load. The Weibull distribution has often been applied in fitting long-term wave height and wave load data, but in this case it is unknown how well it would represent the extreme end of the distribution. For this reason, long simulations have been carried out to avoid extrapolation of the data.

The wave load on the bow visor is highly non-linear with regard to wave amplitude. Low waves do not even reach the visor. While the simulated waves have approximately equal wave crest and trough amplitude distributions, a simulated visor load record shows high peaks only when the bow is submerging to the incident wave. When the bow emerges from the water, the force on the visor is close to its weight. The highest simulated load values have an exceedance probability of about 1/ 30 000, corresponding to the approximately 30 000 waves encountered during the 36-hour total simulation time. Thus the exceedance probabilities may be changed to mean exceedance periods by using the number of waves encountered during the period in question. In head seas at 10 kn speed the vessel encountered about 780 waves per hour and at 15 kn speed 970 waves per hour. In bow seas at 15 kn, the number of wave encounters was 860 per hour.

Table 12.3 summarises the simulation programme and the results in terms of visor loads with mean exceedance times of 30 min. and 10 hours respectively There is a chance of about 1/20 that during 30 min. of exposure the extreme load was larger than the value corresponding to 10 hours mean exceedance period. The results are given in the same way as for the model tests with the static weight of the visor excluded.

Table 12.3 and Figure 12.9 show the large effect of wave height on the vertical visor loads. When the significant wave height increases in head seas from 4 to 5.5 m, the load increases by 160 % for 10 kn and 120 % for 15 kn. In bow seas, an increase in wave height from 4.0 to 4.5 m causes an increase of about 35 % in the visor load.

The effect of forward speed on the vertical component of the visor load is approximately linear in the lower sea state. Thus, at 15 kn speed the visor load is about 50 % higher than at 10 kn speed in head seas with H = 4.0 m. In the higher sea state, the visor load increases more gradually with speed than in the lower sea state. The visor loads increase when the heading changes from head to bow seas by 15 to 20 % in waves of 4 m significant height.

The effect of stationary bow wave height on the visor load is much smaller than the effect of significant wave height. However, the bow wave is taken into account in a rough way in the numerical method and may in reality have a larger effect on the loads.

12.2.4 Comparison with experimental results

Qualitatively the simulated results agree well with the experimental data. The experimental time histories of the vertical load on the visor have high upward peaks similar to those of the simulated records and in the downward direction the loads are negligible. The model tests confirm the very strong effect of wave height on the loads and the approximately linear relationship between visor loads and forward speed. Also in the experiments the visor loads were larger in bow seas than in head seas.

Quantitatively the simulations are compared to the model experiments in Figures 12.7 and 12.8 showing vertical visor load plotted against mean exceedance period, and in Figure 12.9 showing the influence from wave height and speed for 30 minutes mean exceedance period.

In all cases, the simulated loads were smaller than the measured loads. In general, the correlation was better in the higher sea state than in the lower. The correlation was very good in the lower sea state at 10 kn speed in head seas. In 4.5 m bow sea ac 15 kn speed, the simulated results agreed quite well with the experimental data up to a mean exceedance period of about 40 minutes, after which the test results increased at a much higher rate than the simulated visor loads.

In addition to the general approximate nature of the numerical simulation method and the several simplifying assumptions involved, there may also be other reasons for the growing divergence of the numerical and the experimental results for mean exceedance periods longer than about 30 minutes. Statistics may have contributed to the divergence at the extreme end of the experimental load values since naturally the model tests were not very long.

A second possible reason for the divergence is a difference in the characteristics of the waves. The simulated wave crests and troughs followed the symmetrical Rayleigh distribution while the higher waves of the experimental wave record were unsymmetrical with higher crests than troughs. Some of the wave crest amplitudes in the tests were rather extreme compared to the significant wave height.

Both the model experiments and the simulations indicate, however, that it is not the highest wave crests which exert the largest loads on the visor. It is not clear what kind of individual wave characteristic are mandatory for high loads, but it seems that the wave crest must be relatively high and steep. Often the trough preceding a high visor load has been quite flat. Though the highest wave crests did not cause the highest loads, the experimental results indicate that there may be some correlation between the highest wave crest in the wave record and the highest vertical load on the visor. It may be anticipated that if the wave crest heights are extreme, those wave characteristics which are significant for high loads on the visor may also be extreme. Waves measured in the open sea in deep water in general follow the Rayleigh distribution quite well. During heavy storms, however, wave crests start to become steeper and troughs become flatter so that their distributions deviate from that in milder conditions. Also, short wave records may include one or a few very high individual waves.

12.3 Estimate of maximum wave loads on the visor for the conditions at the accident

After the ESTONIA had changed course at the waypoint she sailed for about half an hour at about 14 knots in bow seas before the failure of the visor attachments. The significant wave height has been estimated by different meteorological institutes to 4.0-4.1 m at 0100 hrs at the accident site. Based on the results from model tests and numerical simulations, the Commission has evaluated a probable range of maximum wave loads on the visor during this last period.

The long model test series in bow seas with a significant wave height of 4.5 m is used as the prime basis for the evaluation. Weibull probability distributions have been fitted to the different load components measured at the test. As shown by the long numerical simulations, this type of distribution seems t be valid even down to very low levels of probability From the basic distributions, extreme value distributions for 30 minutes of exposure time have been calculated, and from these the most probable maximum loads and the range of maximum loads for a 90 % confidence interval. The analysed model test is summarised in Table 12.4. Since the number of recorded load peaks per 30 minutes was low, the range of evaluated probable maximum values becomes wide. Especially the X and Y moments, which have a significantly lower shape parameter, k, than the forces, show a large spread in the distribution of maximum values. The Z moment distribution was not analysed in detail.

Finally, the loads for the accident condition were roughly estimated by reducing the model test loads with respect to the differences in significant wave height, 4.5 m and 4.0-4.1 m respectively The forces were reduced by 30 % and the moments by 50 o/a. The level of reduction in forces is taken from the numerical simulations, see Table 12.3 and Figure 12.9, while the reduccion in moments is based on an analysis of the correlation between forces and moments, Figure 12.10.

The Commission's estimate of maximum wave loads on the bow visor for the accident conditions is summarised in Table 12.5. Since the waves in the model tests had rather high crests compared to their troughs, this estimate may be on the high side. On the other hand, the uncertainty in sea state is, according to the meteorological institutes, about 0.5 m in significant wave height. Were this uncertainty also accounted for, the maximum values in the given range would increase significantly

12.4 Predictions of waveinduced motion

12.4.1 Computation method

To analyse the general situation on board the ESTONIA with regard to wave-induced motions, numerical predictions have been made by applying the linear strip theory and the linear superposition principle. The strip theory underlies a very well known numerical method which has been validated in many comparisons with model and full-scale experimental results. In the present case also the theoretical results show good correlation with experiments.

Main attention has been paid to passenger comfort as dictated by vertical accelerations, to green water on deck and to bottom slamming. The full report on wave-induced motions is included in the Supplement.

The numerical predictions were made for long-crested irregular seas defined by JONSWAP and ISSC wave spectra. The wave periods corresponding to the spectrum peaks, the modal periods, were 7.0, 7.8, 8.5 and 9.5 s. In the case of 7.8 s, which is close to the wave period at the time of the accident, wave-induced motions were also computed in short-crested seas. The significant wave height used was always 4 m, i.e. the estimate of the conditions prevailing at the time of the accident.

The effect of ship speed on the wave-induced motions was examined assuming speeds of 7,12,15 and 17 knots. The headings to waves were 180o i.e. head seas, and 150o and 120o representing bow oblique seas. The ESTONIA encountered the waves slightly on her port bow.

12.4.2 Results

The numerical results show in general that modal wave period and heading to waves have a greater effect on waveinduced motions than does forward speed

within the wave periods and headings considered here. Significant motion amplitudes increase with increasing wave period and when the heading to waves changes from direct head seas towards beam seas. The motions were larger in short-crested seas than in long-crested with the exception of the heading 120o. The results indicate that the waves during the accident night were relatively short compared to the length of the ship and she was more or less running through the waves, in particular before midnight.

Just before the accident the significant amplitude of vertical acceleration at the bow visor was 2-2.5 m/s^2 and the largest amplitudes may have been about 0.4g. This acceleration level is roughly half of the level at which cargo vessels change heading or slow down to decrease the accelerations, and about two thirds of the corresponding level for ro-ro cargo vessels.

In the fore part of the passenger compartment shortly before the accident, the vertical accelerations significantly exceeded the severe discomfort boundary of the Motion Sickness Standard ISO 2631/3. The corresponding ISO boundary value is 1.0 m/s^2 in terms of a significant amplitude corresponding to a motion sickness incidence (vomiting) of 10 %. About 20 % of the passengers in the ESTONIA`s fore cabins may have been seasick. Amidships the vertical accelerations were significantly below the ISO boundary value and aft they were approximately at that value. Before midnight, when the wave height was smaller, the vertical accelerations were at least 25 % less than just before the accident.

A reduction in speed from 15 knots to 7 knots would have decreased the significant vertical acceleration from about 1.5 m/s^2 to 1.3 m/s^2 in the fore part of the passenger compartment, or at the station of the bridge. By changing the heading to waves, the acceleration level would have started significantly decreasing in stern-quartering waves. Considerably higher vertical accelerations than these predicted for the ESTONIA have been measured on board passenger vessels in severe storms in many sea areas including the Baltic.

The water level at the bow rose above the level of the car deck at nearly every wave encounter due to the combined vertical motion of bow and wave surface. On average, one wave in a hundred, i.e. one every five minutes, reached the level of the upper edge of the ramp opening. From here, there was still 2.5 m freeboard to the stemhead. On these occasions, spray and water reached the foredeck. Survivors have stated generally that there was quite a lot of spray and water flying in the air with occasional submergence of the bow. However, serious amounts of green water on the foredeck were rare as were real bottom slams. Flare impacts probably occurred much more frequently than bottom slams.

12.5 Determination of hydrodynamic characteristics in heeled condition using model tests

It has been discovered both from the sonar investigations of fragments on the seabed and from manoeuvring simulations that the ESTONIA made a port turn at an early stage of the accident. To determine whether the port turn could possibly have been initiated spontaneously by the ship's changed hydrodynamic characteristics when she started to heel in forward speed, a series of model tests was carried out at SSPA Maritime Dynamics Laboratory in conjunction with the wave load tests. A full report of the test results is given in the Supplement.

The self-propelled model of the ESTONIA was run in calm water and in bow seas respectively at a forward speed of 14.5 knots. During running, different weights were placed on the ship side, causing static heel angles from 9° to 27° . With the autopilot working there were no problems to maintain a straight course using only moderate rudder angles. With the rudders locked, the ship had a tendency to turn in the same direction as the heel angle i.e. a starboard list would cause a starboard turn. There were no significant differences in behaviour when the weights were placed at different longitudinal positions.

From the model tests it can be concluded that the possible port turn at an early stage of the capsize was not initiated by the changed hydrodynamic characteristics of the ship in heeled condition. However, the tests were carried out without any wind. From manoeuvring simulations, it has been shown that with locked rudders and decreasing speed a bow wind would cause the ship to turn towards the wind, but not fully through the wind over to the other side.

12.6 Simulation of flooding and sinking of the vessel

Theoretical studies were ordered by the Commission to clarify and simulate the rapid flooding, capsize and sinking of the ESTONIA. These studies include analysis of hydrostatic floating conditions and stability wave-induced motions in heeled condition and water inflow rate on the car deck in the initial phase of the capsize. The full reports are included in the Supplement. Below is given only a brief summary of the major results.

12.6.1 Floating conditions and stability during flooding

New stability calculations were carried out for the Commission, based on the latest valid inclination test. The calculations confirm that for the loading condition of the accident voyage the ESTONIA satisfied the two-compartment damage stability requirements specified in the SOLAS 1974 Convention. The damage stability requirements concern only the watertight part of the vessel below the bulkhead deck, i.e. below the car deck in this case.

The initial stability of a ro-ro ferry with a large open car deck is extremely sensitive to water ingress to the car deck. Small amounts of water will impair upright stability and cause extensive heel in equilibrium condition.

The ESTONIA`s static stability with various amounts of water on the car deck has also been analysed. Shows static stability curves for increasing amounts of water on the car deck, from 0 to 4,000 t. These curves apply when ship side is intact. The analysis shows that 400 t of water on the car deck will give a static list angle of just over l0° and 1,000 t just over 20° . The additional heel from a sharp turn at 15 knots would be about 3° .

Even though the list developed rapidly; the water on the car deck would not alone be sufficient to make the ship capsize and lose its survivability As long as the hull was intact and watertight below and above the car deck, the residual stability with water on the car deck would not have been significantly changed at large heel angles. The capsize could only have been completed through water entering other areas of the vessel.

According to the hydrostatic calculations, a continuously increasing amount of water on the car deck would make the aft windows of deck 4 the first possible flooding point to other areas. Soon thereafter the windows and the aft entrance doors of deck 5 would also be submerged. A little less than 2,000 t of water on the car deck would be sufficient to bring the first flooding points down to the mean water surface. In this condition the list would be about 35° . The lowest corner of the ramp opening would here be still a little above the mean water surface.

As soon as water was free to enter the accommodation decks all residual stability would be impaired and the ship in practice lost. Without an intact superstructure above deck 4, the largest possible equilibrium heel angle before a complete capsize would be 40° . This condition would be exceeded with about 2,000 t of water on the car deck.

Stability calculations show that the ESTONIA would have had a small positive initial stability if the two sauna compartments and the next compartment aft on deck 0 had been flooded. The stability would have been worst at the initial phases of flooding and would have improved when more water flowed to these three compartments.

The influence of cargo shifting was also investigated in separate studies. Due to the distribution of vehicles on deck, the maximum transverse shifting of cargo centre of gravity could have been of the order of just a few metres. Two metres of cargo shift would have the effect that the progressive flooding of deck 4 started with about 10 % less water on the car deck.

12.6.2 Water inflow simulations

The water inflow through the ramp opening after the visor had failed and was lost was simulated with two different numerical methods. One is similar to the numerical wave impact load simulation, i.e. an approach where the relative motions between bow and waves are described in the time domain. The other approach uses the frequency distribution of relative motions.

The common input to the simulations is:

- A description of relative motion in a random sea condition,
- a description of the relative velocity of water particles in the ship's longitudinal direction as a function of vertical position, wave profile and the ship's heading and speed,
- a description of the changing floating condition during water ingress.

Results obtained from the simulations are very sensitive to small changes in the initial parameters, and the inherent uncertainty in the random nature of waves and ship motions during short periods of time is very large. Therefore, the results cannot be used to independently prove a certain time sequence of water inflow. The value of the simulations is primarily to verify whether the assumed capsizing scenario is possible with regard to the water inflow rate.

During the first phase of the accident, the ESTONIA is assumed to have been sailing at a speed of about 14 knots into bow-incoming waves with a significant wave height of about 4 m. The average water inflow at the instant when the ramp was torn fully open has been calculated to be in the range of 300-600 t/min depending on what assumption is made regarding forward freeboard in running condition. This means that within just one or a few minutes a heel angle of about 20° could possibly have developed.

The successive phases of the capsize are dealt with in more detail further on in this report, where the time sequence and the full capsize scenario are analysed based on witnesses' statements and an interpretation of the results obtained from these simulations. Here the general influence of changing conditions is briefly summarised.

The speed of the vessel greatly influences the inflow rate. If the speed is reduced from 15 to 10 knots, the inflow rate in head and bow seas decreases by about 50 %. This effect is due partly to reduced inflow velocity and partly to reduced bow wave height.

The amount of water on the car deck also affects the inflow rate. When the ship heels over, the freeboard to the ramp opening decreases and the inflow accelerates. To some extent this effect is contradicted by changed motion characteristics in heeled condition. The separate studies produced some differences regarding the motion characteristics and the results diverged with respect to heel angles; however, the inflow rate is generally 2-3 times larger than the initial upright condition when 1,800 t has entered the car deck and the heel is around 35° .

Wave direction also affects water inflow. The highest rate of inflow is found in bow sea due to large relative motion amplitudes. In beam sea the inflow rate is very low as long as the speed and heel angle are not excessive.

The simulations indicate that the time from the first inflow through the ramp opening until progressive flooding of accommodation deck 4 started was about of 5-15 min. However the time estimates depend greatly on what action is assumed to have been taken during the first critical minutes.

12.7 Investigation of visor attachment

12.7.1 General

Different investigations of the failed visor attachments and closely related items were performed. They include detailed studies of recovered parts from the actual installation, strength analysis and laboratory tests. Components retrieved from the near-sister ship DIANA II were investigated for comparison. This section contains a brief summary of the reports included in the Supplement. A conclusive analysis of the visor attachments' strength is given in Chapter 15.

Materials of recovered parts were identified by analysing their constituent chemical elements and with mechanical, hardness, tensile and impact testing as appropriate to establish strength and basic standard cold brittleness. The deformed visor lug of the bottom lock was measured for estimating the type of overload and the load level to which it would have been subjected comparing it with deformation-load interdependencies obtained through full-size model testing. The stiffness of the whole visor was measured to assess its effects on the wave load distribution to the various attachment points.

Analytical and finite element calculations were used for estimating the strength of the different attachments taking account of their actual geometry and material. The welds as well as any deficiencies found were assessed where pertinent.

The combined strength of the visor attachment system was estimated with balanced reaction load calculations using variation of external loads. In the calculations, either parameters describing load sharing and/or attachment site stiffness were used, or attachment loads were assigned by using parametric variation of the wave load centre of action in relation to the positions of the attachments. The paint layers on the surface of the bottom lock were investigated in some detail to estimate approximately the age of the attachment.

12.7.2 Material identifications and microscopical observations

Optical and electron microscopy were used to find signs of cracking and to identify the character of various fractures. Particularly the visor actuator mounting platforms had fatigue cracks of marked significance for ultimate strength. On the port side about half of the perimeter cross-section through deck 3 had developed fatigue cracks before the accident. Some repair welding had been undertaken.

12.7.3 Investigations of the attachments

Bottom lock attachment and visor lug

Specimens of the actual bottom lock attachment lugs recovered from the wreck were tested with regard to material properties. The material was regular mild steel with a yield strength of about 240 MPa and an ultimate tensile strength of about 410 MPa. The lug fractures showed patterns typical of good-quality ductile plate that failed due to local overload. Some branched cracks that were small compared to the size of the lugs were detected close to the primary fracture surfaces of the welds between the plates and the locking bolt housing. These cracks may have developed under normal operation due to the cyclic nature of operating loads or e.g. during the sequence leading to failure of the bottom lock. The separate effect of these small cracks has been impossible to quantify but their combined effect on the load-carrying capacity of the lock was apparently small due to the ductility of the plate material.

The fracture surfaces of all three bottom lock attachment lugs were examined by optical stereo microscope and by scanning electron microscope. It was concluded that all the fracture surfaces had a ductile character and that the failure types were the result of overload. It was also noted that the fillet welds attaching the housing and the lock bushing showed signs of poor fusion and lack of penetration.

Hardness was measured on welds and base plate of the lug assembly on the forepeak deck to estimate the strength of the weld. The hardness of the bushinglug weld material was HV 10 = 270-275, which translates to an ultimate tensile strength of 865 MPa (DIN 50150) for the weld material. The hardness of the lug plates was HVl O =128-150, which correlates well with the ultimate strength of 417 MPa measured. The weld material and the adjacent heat-affected zone were thus significantly stronger than the material of the plates that had been joined together.

The failure strength of each attachment lug was calculated based on the material properties found in the testing and the actual cross-section of each fracture surface.

The welds contribute significantly to the strength of the lug assembly A large variation in the path of the weld fracture made measurements of the weld size contributing to strength very tedious. The most unambiguous value for the strength of the bottom lock was obtained by analysing the deformations of the mating lug. A transfer calculation developed as part of the investigation served to estimate the contribution from the welds. The calculation indicates that the effective size of the weld joint could have been around 3 mm. This was also observed, although the actual weld joint was quite irregular.

The mating visor lug was bent and elongated. Hardness testing showed the plate material to be most probably mild steel and similar to the material of the hinge plate. The aft or eye end of the mating lug had been elongated and bent to starboard. By analysing the shape of the hole and lug rim it was concluded that the original dimensions of the lug aft end had conformed to drawing. In its retrieved condition the aft end eye ligament had the designed dimension of 47.5 mm suggesting no damage by wear to this side of the eye.

Comparison with tests with several mock-ups of full or subsize scale showed that the lug had been stretched, most probably prior to the bending. The tests indicate that permanent yielding in the authentic lug started at a tensile load of about 0.5 MN. The measured net stretching of around 6 mm may have occurred under a load of about 1.5 MN. In addition wear of up to 2 mm was observed on the stem (forward) side of the eye suggesting leaning of the visor against the locking bolt. The dimensional analysis indicated that the initial length of the lug stem was 3 mm less than the drawing dimension.

Load capacity of the forepeak deck lug assembly was estimated by calculations based on two different methods. One used the deformation energy principle employing the assumption of a perfectly stiff locking bolt. The other was a simplistic strength estimate based on the assumption of the weld carrying its ultimate strength in shear of the simply sheared part of the failure path cross- section and the projection of the weld cross-section actually subjected to mixed shear and tension. Both methods included parameters that needed quantification by test results.

It was impossible to determine whether usage-related damage e.g. fatigue cracks had reduced the strength of the bottom lock. No fatigue cracks were found in the forepeak deck lugs, but cracks could have existed in the welds prior to failure. Recognising this it was estimated that if half or more of the weld joint related load-carrying capacity had been lost, the strength of the bottom lock would have been about 0.8 MN at its lowest as demonstrated by testing at the Technical University of Hamburg (see 15.3). In this case, logically the 1.5 MN load that had sometimes acted to stretch the visor lug must have actually occurred earlier. This load must then have initiated the damage to the welds, and the original strength of the bottom lock would have been more than about 1.5 MN. It has also been calculated that the strength of the bottom lock could theoretically not have exceeded 1.8 MN, the estimated load needed to break the visor lug by shearing the lug tip, as indicated by testing at the Technical University of Hamburg.

Bottom lock details from the DIANA II with a similar visor locking installation as in the ESTONIA were also investigated. They included the visor lug and the bolt. The bolt material was identified to be of a higher strength grade than the lug plate. The visor lug material was identified as mild steel. The aft or eye end had stretched apparently by overloading up to several millimetres in similitude with the visor lug of the ESTONIA. The lug eye and the bolt had several millimetres more wear on their stem sides due to leaning of the visor onto the locking bolt and the rubbing that had occurred.

Paint layer analysis

Samples of paint coatings were analysed from the forepeak deck starboard lug and from the visor lug for the bottom lock. The paint system consisted of several paint layers, from 4 to 7 in the samples from the forepeak deck lug and 8 layers in the sample from the visor lug. Many of the layers were discontinuous. The chemical compositions of the paint layers indicate that both lugs had similar light brown "varnish" and grey primer. The yellowish primer closest to the steel in the visor lug was not detected in the paint samples from the forepeak deck lug. White and red paint stains found between the topmost layers and on the surface of the forepeak deck lug had similar chemical composition as the red and white paint layers in the sample from the visor lug. It thus seems evident that the whole bottom lock was old and dated at least to the early history of the ship. The detailed reports of the paint systems investigations are included in the Supplement.

Side locks

The side locking lugs with part of the visor plating remain on the wreck, still attached to the locking bolts. Thus the only parts possible to investigate from the actual installation were from the visor structure at the original position of the side locking lugs.

The bulkhead plating in the areas where the lugs for the side locks had been mounted were investigated. It was concluded that the lugs had separated by shearing of the horizontal stringer plate, the vertical stiffener at the related weld and through the visor aft plating. Some delamination of the aft plating material was observed. The shear surface in the aft or bulkhead plating had marks of heavy rubbing.

The attachment arrangement for the side locking lugs was investigated in detail and their strength was evaluated with both full scale mock-up tests and computer modelling and calculations. A loading direction commensurate with visor release by rotation either about the hinge axis or the stem post without twisting or yawing was primarily considered. Thus only tension at 38° to the visor aft plating was considered in the tests, but other directions were assessed by calculation.

Four full-scale mock-up tests were made with various degrees of rigidity in the plate membrane and stiffener plates onto which the lock lug had been welded. In the relevant test cases the failures were very similar to the authentic failures, i.e. tearing of the aft plating. Membrane and stiffener stiffness had a significant effect on the strength of the lug attachment model. The test which was deemed to be most representative gave a failure load of the lug attachment of about 1.8 MN. Tensile tests of authentic plates were made. A welding defect was noted on the authentic port side installation of the horizontal stringer. This defect was estimated to reduce the strength to 1.2 MN, account also taken of the differences between the test mock-up materials and the authentic plates. Similarly the strength of the starboard locking site was estimated to be 1.6 MN. The failures took place by shear of the stringer plate first and then in the plating around the fillet weld of the lug, leaving similar fractures to that noted in the actual failure.

Calculations made parallel to the testing confirmed the test results. A numerical estimation by the finite element method, using the actual material stress strain curve data and partial visor structure, gave an ultimate collapse load level of 1.6 MN. The failure load of the lug attachment would have been lower if the acting force had been parallel to the bulkhead plating, e.g. if the visor had been lifted vertically instead of rotated around its end points.

Hinges

Fracture surfaces of the hinge beams were partially investigated in the same way as the bottom locking lugs. The studied failures were of ductile character and signs of fatigue were not seen. A fracture was observed in one sample, penetrating through the weld. The gap inside the weld was filled with magnetite, indicating slow corrosion in an atmosphere with low oxygen content. This was taken as indication that the crack had existed for a long time before the accident, allowing some moisture to penetrate. In subsequent studies it was also confirmed that the welds at the hinge bushings had extensive cracking in the roots and that these cracks had to some extent progressed under fatigue conditions. It was concluded that the failure of the rims of the hinge beam side plates started with ductile failure of the lower part of the periphery as a result of overload, followed by failure of the upper part due to bending as evidenced by lateral contraction of the tensile or inner side and lateral expansion of the outer or compression side. Microscopic features displayed ductile character.

The parts of the hinge lug plate rim fractures that were flat fractures called for evaluation of their character also with respect to material toughness or cold brittleness. For this reason impact toughness specimens from the hinge beam side plate were tested. The values indicate high toughness and thus no tendency to reduced strength by brittleness.

The ultimate failure strength of the plate material was found by standard tensile testing to be 450-460 MPa, i.e. mild steel.

Two tensile tests were also carried out on the weld joints using a slice of the bearing support bushing-hinge plate rim. Test specimens were prepared from segments of one recovered hinge bushing with parts of the outer rim of the visor hinge beam side plate attached to it. These gave a failure load of 0.12 MN for the tested length (14 mm) of actual fillet welds. The failure occurred dominantly in shear with an ultimate shear stress of about 700 MPa. Thus, the weld material had a very high strength.

The strength of a complete hinge was calculated on the basis of the test results for the strong tensile aftward direction of 21° down from horizontal and aft, and the weak shearing direction of 21° forward from down. The strong direction is assumed to coincide with the line bisecting the angle of the hinge beam in its aft part and the weak direction is normal to this.

The strength for one hinge was estimated to be 4.6 MN for the weld joint shear fracture of bushing to lug weld and an additional 2.3 MN for the lug rim at yielding load if this addition applied in case of close clearance between the lug and the bushing.

A previously observed crack in the downward segment of the hinge bushing weld joints that was reported to the Commission was taken into account in the strength estimates. Root cracking detected in the forward segments was not accounted for separately and may have lowered the actual strength from the values given.

Actuator attachments

The attachments of opening actuators had secondary influence on the release of the visor. Material identification and fractography was undertaken for completeness of the investigation. It was found that the mounting platform at the bottom of the port actuator on deck 3 had cracking significant for the strength of the platform. Deck 3 plate had finally fractured by the cold brittleness mechanism cleavage. One lug of four on the hinge beams-providing for the upper attachment of the actuators was identified by hardness testing to be mild steel.

Attachment system

The combined strength of the visor attachment system was estimated by calculations covering strength estimates for the individual attachment components and studies of the load distribution within the system.

A system of five attachments is statically indeterminate and reaction forces will depend on the stiffness both globally and locally at the attachments. Also misalignment and play between bolts and lugs at the locks may influence the load distribution. It was thus considered to be of little value to make a complete numerical analysis of the whole visor. Instead the failure load levels for different assumed load or stiffness distributions were assessed. The results of the analyses are therefore indicative rather than conclusive.

The global stiffness of the visor was measured in its upside-down, stored position as supported at the hinge beams. By adding a weight at one hinge beam and lifting at the other, a vertical displacement compliance of approximately 25 mm /1 MN lifting load was obtained. The visor was thus moderately flexible across its centre line in relation to the expected loads of several MN. Each side of the visor is a box structure and is estimated to be fairly stiff compared to the visor's side-to-side distortion flexibility The lower part of the structure holding the bottom locking lug is also flexible compared to the sides.

Three different calculation schemes using principles of statics including assumed load sharing by the locking sites were formulated for estimating the load levels and directions at the attachments from an applied bow load level and direction. One of the methods varied load sharing systematically between the attachments, another varied the relative stiffness of the attachment points and the third varied the location of the wave load centre of action. Load component ratios obtained from SSPA's model tests were used in estimating the total load needed to break the visor attachments. The results indicate that the port side lock appears to have broken in bow sea at a lower level than the load required to break the next attachment. It could not be determined which of the remaining attachments, the bottom lock or the port hinge, would break second as the uncertainty in finding the strength level of the hinge was quite large. Estimated failure load levels in bow sea were significantly lower than those in head sea.

Observed damage to the visor indicates that the hinge may have broken second, allowing subsequent rising of the visor with damage caused to the port locating horn recess as well as a marked downward bending of the mating bottom lock lug on the visor.

CHAPTER 13 DEVELOPMENT OF THE ACCIDENT

13.1 Meteorological conditions

The weather at the accident site at about 0100 hrs was rough but not extreme. The wind was south-westerly mean velocity 18-20 m/s. Statistically winds of such force occur five to ten times annually during the autumn and the winter in the northern Baltic Sea. The significant wave height was about 4 m. Generating a wave pattern with a significant wave height of this magnitude requires wind of 15-20 m/s from S-SW for at least ten hours.

Numerous studies of wave statistics show that, if the significant wave height is 4 m, one wave in a hundred will be higher than 6 m. A maximum wave height is estimated as twice the significant height.

The weather forecast for the midnight hours predicted a significant wave height of only 2.5 to 3.5 m whereas the actual height was about one metre more. Even if the predictions had been correct, this would most likely not have changed the way the passage was conducted.

The weather forecast was not regarded as severe on board the two passenger ferries leaving Helsinki for Stockholm the same day. They both selected the coastal route in shallow waters instead of the deep-sea route followed in heavy weather.

The direction of the waves is difficult to determine as indicated by the different meteorological institutes. The Commission is of the opinion that before reaching the waypoint the ESTONIA encountered waves close to head sea. Thus after the turn of about 25 degrees to starboard she had the waves coming at about 30 degrees on the port bow.

ESTONIA had been operating indicate that significant wave heights above four metres on the bow should have occurred for a total of less than about twenty hours during the full operating history of the vessel. Most of this time refers to the 20 months on the Tallinn-Stockholm route.

A review of the weather reports for the entire time while the vessel operated on the Tallinn-Stockholm route shows that wind and wave conditions similar to those during the accident voyage only occurred once or twice.

Thus it can be concluded that the vessel had generally been protected from heavy sea conditions during her lifetime.

A probable development of the directions and forces of the wind, and of wave heights hour-by-hour along the route.

13.2 Course of events

13.2.1 Introduction

The general course of events described in this section has been plotted from observations on the wreck, analysis of statements by witnesses, analysis of the damage and evaluation of the strength of the visor and ramp attachments. Calculations and model tests of the vessel's behaviour in waves have also been used.

The Commission has analysed 258 statements from 134 survivors. The Commission is aware that none of the survivors is a witness proper, in the sense of an observer. All the witnesses are victims of the accident, involved in it and a part of the chain of events. Their observations and recollections are thus influenced by prolonged anxiety, exhaustion and stress. All statements are furthermore restricted to individual experience on board and outside the vessel only and no witnesses have had any possibility of gaining an overall view.

When analysing the chain of events the Commission has usually put somewhat more emphasis on earlier statements than on later ones. The reason for this is that earlier statements were made at a time when witnesses' recollections were presumably less influenced by information from other witnesses and the media.

The Commission has also given more weight to witnesses' recollections of objective and perceived events than to statements concerning time or time spans. This is because most objective events were experienced by many in different locations whereas statements concerning points of time vary radically and are judged to have been more subjectively influenced. Also statements concerning degree of list are judged to be considerably subjective. Somewhat more credibility is, however, given to such estimations by crew members and to their judgements of sounds, because of their experience.

A few crew members when interrogated, however, were more inclined directly to give exact and precise information about actions and points of time rather than to reveal any uncertainty In such cases they often stated that they had acted in accordance with their instructions.

One of the key witnesses, the AB seaman of the watch, was interrogated several times and some details are not consistent throughout his statements. His latest statement seems, however, to be more reliable concerning specific parts and supplementary details because he then revealed new information that was partly to his discredit, and also commented upon his earlier statements.

13.2.2 Preparations for the voyage

The route-specific weather and wave height forecast was received from the Swedish Meteorological and Hydrological Institute (SMHI) in accordance with the existing subscription arrangement as well as other weather forecasts. The master was informed prior to departure that a low pressure with increasing winds would be encountered during the night.

No route plan has been available to the Commission, as planning was done on board only It is deemed likely, however, that the plan was to proceed along the normal route with full service speed as long as the vessel was in sheltered waters in the Gulf of Finland, and thereby gain some time margin for crossing the Baltic Sea.

Loading began at 1620 hrs via the forward ramp and was completed shortly before departure. The loading was supervised by second officer A. According to witnesses large trucks were loaded al- most bumper to bumper on the aft and mid parts of the car deck. Smaller trucks and cars were loaded on the forward part.

Heavy vehicles seem to have been loaded on the car deck without sufficient account of the athwartships weight disposition, resulting in the ship leaving port with the port side heeling tank almost full and the starboard one empty Due to this cargo disposition and the wind pressure on the port side the ESTONIA, gaining the open sea, had a star- board list of about one degree according to the third engineer.

In compliance with the loading practice for ro-ro ferries on short routes, when strongwinds are expected the major part of the weight should be located on the windward side in order to maximise possibilities to compensate for wind-induced heel. Hence, the ESTONIA should have been loaded differently.

The deck crew had been instructed to secure the heavy cargo with extra care due to the weather expected. Surviving crew members have testified that the trucks were properly secured with lashings, generally four per vehicle. It is claimed to be common practice that securing of vehicles is not finished when the vessel leaves port but is completed during an early stage of the voyage. All indications are that the cargo was se- cured to normal standard.

In this context the Commission has noted that the number of cargo damage claims was low while the vessel was operating on the Tallinn-to-Stockholm route and that no damage has been related to inadequate lashing of trucks, containers or other cargo.

13.2.3 Condition of visor and ramp closure

The Commission has noted from observations on the wreck that one of the locking bolts for the forward ramp was most probably not in its properly extended position at the time of the accident, and the related indicator lamp on the bridge was then not lit. The deficiency did not prevent closing of the visor.

It is possible that the locking bolt had been in its proper position and had backed out prior to the accident due to movement between the ramp and the ramp coaming in combination with hydraulic leakage, e.g. past the operating piston seals. Such movement of locking bolts at sea has been noted in other ro-ro ferries.

Even if this defect had existed at the time of departure it has not been possible to find out whether any action was called for. This potential deficiency would have had no effect on the development of the accident, as the ramp would have been forced open by the visor even if all the locking bolts had been in their proper positions.

Some rags can be seen on pictures filmed from a remotely operated vehicle (ROV) in the area of the half-extended locking bolt on the lower port side of the ramp. This may indicate that a sealing problem in the ramp, mentioned by the second engineer in his testimony, had been temporarily cured by packing rags into the gap. However, the Commission considers it likely that the mattresses and rags were washed into the area from nearby storage spaces during the final flooding of the car deck. They were observed at a point which was the highest on the car deck and still over the water surface when the stern reached the sea bed. Other floating objects and debris were also observed in the bow area, all probably trapped by the partly closed ramp when the bow started sinking.

If rags had been tucked along the sides of the ramp it is most likely that they would have been washed away when the ramp was forced open. The rags were partly in a position between the failed hinge lugs and the lug in the hull, where they could not have penetrated when the hinge was intact. The plastic covers of the mattresses appear intact, which indicates that they had not been subjected to heavy rubbing. It would hardly have been possible to close five ramp locks with rags packed in the positions observed.

Truck drivers have stated that sometimes there were problems in opening the ramp locks, and tools had to be used. Such problems have also been encountered on other vessels.

The magnet of the visor bottom lock position indicator was on the bracket in the locking bolt but the sensors could not be found during the ROV and diving investigations. The empty ends of the sensor cables were near the mounting bracket of the sensors. The mounting bracket appeared to be undamaged like remains of the broken port lug and the deck plating near the bottom lock. This indicates that the sensors were not in their place during the accident voyage. However, since the distance from the magnet to the nearest sensor was a few centimetres, a small chance remains that the pounding visor detached the sensors. According to crew members and the technical superintendent the bottom lock position indicator had been in working order. The most likely absence of the sensors would not have had any effect on the accident since there was no indicator lamp on the bridge showing the position of this locking bolt.

According to statements by members of the alternate crew, a strict routine was followed in the closing and securing of the ramp and visor, and technical assistance was called upon if any malfunction developed. No problems were evident at the time of the last crew change, nor had any reports about deficiencies in the ramp or visor locking system been made to the technical superintendent of the vessel.

The Commission's conclusion, which is supported by the failure pattern, is that the visor had been properly closed and secured at departure and that there were no deficiencies in the ramp affecting the development of the accident.

13.2.4 The voyage up to the accident

The ESTONIA departed from Tallinn at 1915 hrs. The crew was into the l3th day of its current 14-day duty period.

The speed was around 19 knots at the beginning of the voyage and when passing Osmussaar lighthouse at about 2200 hrs the ESTONIA was approximately on her normal schedule in spite of Tallinn 15 minutes late. Weather conditions deteriorated during the night. Because of this the resistance of the vessel increased and the speed gradually decreased. After the course change at the waypoint at about 0025 hrs, the ESTONIA encountered waves on the port bow and conditions became more unfavourable, with increased rolling and pitching and more severe wave impacts on the bow. The stabilising fins had been extended just after the waypoint. Shortly before the accident the speed had dropped to about 14 knots.

It may be of interest to compare the ESTONIA's speed with those of the MARIELLA and the SILJA EUROPA, two other passenger ferries en route to Stockholm on the same heading and encountering the same sea state as the ESTONIA. On the MARIELLA, speed was reduced at about 2300 hrs to 12 knots by order of the master. The SILJA EUROPA was running at approximately the same speed as the ESTONIA, i.e. 14.5 knots at about 0055 hrs. Just afterwards the SILJA EUROPA's officer of the watch reduced the speed due to the weather.

13.2.5 Separation of the visor

The first indication that something was wrong in the bow area was noted and reported to the bridge about five minutes before one o'clock by the AB seaman of the watch when he, at the forward ramp on his routine watch round, noted a sharp metallic bang from the bow area. This coincided with a heavy upward acceleration that nearly made him fall. He reported this bang to the bridge. Remaining about five minutes near the ramp he then continued on his round to decks 1 and 0 and finally to the bridge. He heard no more unusual sounds, nor made any unusual observations.

Shortly after one o'clock a few wave impacts on the visor caused the visor attachments to fail completely The visor started cutting openings in the weather deck plating and associated structures. Soon the back wall of the visor housing came into contact with the ramp, hitting its upper edge and thus breaking its locks. The ramp fell forwards and remained resting inside the visor. In a few minutes the visor started falling forwards.

The ramp then followed the visor in a forward, tumbling motion. The starboard side actuator was extended to its full length and was torn out of the hull during the final stage of the sequence. The visor subsequently tilted over the stem, left the ramp fully open allowing large amounts of water to enter the car deck, and as it fell collided with the bulbous bow of the vessel.

This sequence of events is supported by witnesses from several areas on board who heard a repeated metallic noise from the bow area during a period of about ten minutes, starting shortly after one o'clock. The detailed timing is, however, uncertain. The witnesses have given several good descriptions of these sounds and it is beyond doubt that the sounds were caused by the visor moving and pounding on the forepeak deck. Some of the metallic blows were associated with hull vibrations. The sounds from the bow area ended in a few loud, metallic crashes, caused by the final separation of the visor and its colliding with the bulbous bow of the vessel. This occurred at about 0115 hrs. The collision is documented by clear impact marks on the visor. The observations by the witnesses are described in detail in Chapter 6.

13.2.6 Development of the list and sinking of the vessel

On deck 1 the first passengers left their cabins already when they began hearing metallic blows from the bow area. A few have reported seeing small amounts of water in corridors on deck 1 and feeling that the vessel already at this stage had a slight list.

While the ramp was partly open in- side the visor, water entered the car deck along the sides of the ramp, as observed first by the third engineer at 0110- 0115 hrs on the TV monitor showing the forward part of the car deck.

The water noted by the first passengers fleeing from their cabins on deck 1 could at this stage have poured down to the accommodation on deck 1. Later, during the evacuation, several passengers observed on deck 2 that water entered the staircases through the slots around the fire doors to the car deck.

After the ramp had been forced open by the visor, waves may have caused the ramp to move between fully open and partly closed position but generally a significant opening was available for waves to enter the car deck as further described in 13.5 below. The large amounts of water flooding onto the car deck caused the vessel to heel over and after a few rolling movements a significant list developed to starboard. This happened within the first minutes after the visor had separated from the ship. According to witnesses the ship steadied temporarily at a list angle of about 15 degrees.

Just before the moment when the list developed many crew members and passengers noticed a change in the vessel's motion. This coincides with the time when the visor separated from the vessel and may have been the effect of the first larger volume of water to enter the car deck.

At about the time when the list developed, the engines were throttled back close to idling speed and the vessel was turned to port into the wind as dealt with further in section 13.3. She passed through the wind's eye and continued to port with decreasing speed. Information from some survivors indicates a reduction of engine speed just before the accident but the timing is uncertain. It is, however, the opinion of the Commission that full service speed setting was maintained right up to the time when the list developed.

During the port turn water continued to enter the car deck and the list increased to 20-30 degrees where the vessel for some minutes stabilised as the water inflow decreased. By about 0120 hrs all four main engines had stopped, at intervals of a few minutes, starting with the port side engines, due to lack of lubricating oil pressure. The main generators stopped about five minutes later.

After the main engines stopped, the ESTONIA drifted with a list of about 40 degrees and the starboard side towards the waves. Water continued to enter the car deck through the bow but at a significantly lower rate. Waves were pounding against the windows on deck 4. Window panels and aft doors broke, allowing flooding of the accommodation to start. As the flooding progressed, the list and the trim by the stern increased and the vessel started to sink. At a list of about 80 degrees the bridge was partly flooded. This happened shortly after 0130 hrs as indicated by a clock in the chartroom whose hands had stopped at 2335 hrs UTC. The emergency generator stopped at about the same time but the accumulators supplied power for limited lighting. The sinking continued, stern first, and the vessel disappeared from the surface of the sea at about 0150 hrs.

3.2.7 The evacuation

Shortly before the start of the accident, most passengers were in their cabins. The major part of the crew were off duty; some in bed and others together in the messrooms or in cabins on decks 7 and 8.

Passengers were moving about in the foyer areas, passageways, corridors and staircases. A few remaining passengers and some crew members were in the Night Club, and in the Pub Admiral there were 30 to 60 people. Some passengers were resting or sleeping in the lounges and in the café. A limited number were resting in other public areas, passage- ways and staircases.

Some passengers had left their cabins at an early stage due to the motion of the ship and the noise. As the list developed, passengers had difficulties in getting out from their cabins due to the furniture and luggage which had slid against the doors. The list made it increasingly difficult to move inside the vessel and to reach open decks. First people tried to help each other, for instance by forming human chains, but soon it became impossible due to the increasing list.

At about 0120 hrs, i.e. five minutes after the list developed, a weak female voice was heard over the public address system calling in Estonian "Häire, häire, laeval on häire" (Estonian for: "Alarm, alarm, there is alarm on the ship"). Shortly thereafter the second officer A called the alarm *Mr Skylight to number one and two*. About two minutes later the general international life boat alarm was initiated.

Many of those who succeeded in reaching open decks had difficulties in putting on lifejackets properly People hung on to the railings and climbed onto the side of the vessel when she was lying nearly on her side. Waves washed some people into the sea and others started jumping into the sea at about half past one o'clock. Most had difficulties in gaining the rafts, tens of which were floating around the vessel. Few people were able to board a raft on the side of the vessel.

The time available for evacuation to open deck was between 10 and 20 minutes. During this period at least 237 people escaped from the vessel. The evacuation is further analysed in Chapter 16.

13.3 Action on the bridge

When the ESTONIA was at sea the bridgewatch always consisted of two officers and one AB seaman. The duties of the AB seaman were to make inspection rounds in the vessel and to serve as an additional look-out.

When the officers on the bridge received the AB seaman's report of the metallic bang shortly before one o'clock, second officer B ordered him to stay in the area and investigate the origin of the sound. After about five minutes he re- ported back that he had found nothing abnormal and the sound was not repeat- ed. The AB seaman was ordered to continue his watch round.

There was a watch change on the bridge at one o'clock when the second officer A and the fourth officer relieved second officer B and the third officer. Normally the ongoing watch arrived at the bridge not later than five minutes prior to the start of its watch, and there are no reasons to believe that the routines were deviated from during this night.

It is considered confirmed that the reported sound from the car deck was known to the officers commencing their watch at one o'clock. The Commission concludes that the information received was not considered alarming since the relieved watch left the bridge as normal. When the AB seaman of the watch returned to the bridge from his round about five minutes after one o'clock, he saw the master arrive just ahead of him. The master made general comments on the speed and their probable late arrival in Stockholm. Nothing has been reported to indicate that his visit was other than routine and thus not caused by any concern about the prevailing situation.

Shortly after his arrival at the bridge, the AB seaman was ordered to call the boatswain and accompany him to the car deck to check the bow area and the general situation. Second officer A who gave the order had received a telephone call, most likely from a crew member, reporting loud noises, believed to be originating from the forward part of the car deck. The boatswain was responsible for operating the ramp and the visor, and the fact that he was called out on his free watch indicates that the situation was considered serious by the officers of the watch. There are no indications that any other action was taken at this stage. By this time the bridge had received two reports of sounds. The Commission considers these reports so alarming, that the officers should at least have reduced speed at this stage. The AB seaman has testified that the master was on the bridge when he was sent to the car deck. It is therefore considered most likely that the master was informed of the situation and agreed to the action taken, and that he remained on the bridge during the development of the accident.

The AB seaman never managed to reach the car deck. He waited at the information desk on deck 5 to have the car deck doors unlocked, and at about this time or possibly some minutes earlier, the visor was lost and the ramp pulled open. While he was waiting at the information desk the vessel heeled over and remained with a list of about 15 degrees to starboard. The AB seaman immediately proceeded downwards but was kept back by a stream of passengers escaping from the lower decks, some of them screaming that there was water on deck 1. He turned around and ran towards the boat deck. The whereabouts of the boat- swain during this period is not known. It is not known what additional information the officers on the bridge received after the AB seaman left the bridge, but it is obvious to the Commission that at least the sound from the visor's collision with the bulbous bow must have been noticed. It is evident to the Commission that, because of the list and the sound from the collision the officers on the bridge initiated a reduction of speed and a turn to port. Some minutes later they also closed all watertight doors.

Three to five minutes after the list had developed, the bridge was informed by the AB seaman of the watch, who now was on the boat deck, that passengers were escaping in great numbers from the lower decks screaming that there was water on deck 1. He was again ordered to go down and find out more about the situation. At about the same time the third engineer was ordered by telephone to compensate for the list by pumping ballast. He tried to pump sea-water to the almost full heeling tank but the pump sucked air. The starboard list was at this time about 30 degrees and the officers on the bridge were obviously still seeking more information to understand what was going on. They evidently thought that the adverse conditions could be rectified. In view of what is known about the rapid course of events and the consequent short time for evacuation, the Commission finds it most unfortunate that the lifeboat alarm was not given until about five minutes after the list developed and when the list was around 35 degrees. Nor was any information given to the passengers over the public address system.

The. first Mayday call was received from the ESTONIA at about 0122 hrs, i.e. at about the same time as the lifeboat alarm was given and just after the main engines had stopped. It was a very brief message, containing no other information than the word "Mayday" and the name ESTONIA. The operator has been identified by voice as second officer A on duty In later radio traffic the operator has been identified as the third officer. A voice heard in the background has been identified as the chief officer's. He and the third officer had come to the bridge obviously alarmed.

The time for the distress traffic, from the first call to the last, was eight minutes. Nothing is mentioned to indicate that the officers had any appreciation of what had caused the vessel to develop a list and take in water. The information given was': "Yes, we have a problem here now, a bad list to starboard. I believe that it was twenty thirty degrees" followed later on by "We have black out" and, at the end of the distress traffic, "Really bad, it looks really bad here now". It was about seven minutes before the ESTONIA gave her position. Due to the very fast development of the accident the late start of the distress traffic did not, however, have much effect on the final outcome of the rescue operation. The distress traffic is reproduced in full in 7.3.3. Figure 13.5 illustrates the development of the list during the distress traffic as experienced on the bridge.

Of the five officers known to have been on the bridge, second officer A and the third officer were seen leaving the bridge in the final stage of the accident. It is believed that the master, the chief officer and the fourth officer remained on the bridge throughout the accident. This assumption is also supported by the fact that three bodies were seen inside the bridge during the diving investigation.

The two officers that left the bridge were later seen distributing lifejackets and trying to launch lifeboats and rafts. Also the boatswain, who just before the start of the accident was called out to help investigate the sounds on the car deck, was seen on deck 7 taking part in this.

It is noteworthy that so little exchange of information seems to have taken place between the bridge and the engine control room during the development of the accident. The third engineer did not in form the bridge about the inflow of water he observed (see 6.2.3). Nor did the officers of the watch call him for an assessment of the situation. If the observation on the monitor had been discussed and evaluated immediately, there could still have been a possibility to influence the development of the accident. Nothing indicates that the officers realised that the bow was fully open, although it must have been obvious that the situation was very serious, and that the survival of the vessel was threatened.

Simulations carried out by the Commission show that a quick reduction of speed and change of heading would have significantly reduced the rate of water ingress. The safest condition for the vessel with the bow open would have been lying beam on to the waves at zero speed. It has also been established that turning the vessel to starboard would not have endangered her stability The wind pressure would have increased the list by only a few degrees. Thus turning the vessel, with the bow fully open, towards the wind and the high waves was not the best action. On the other hand it must be kept in mind that from the officers' point of view turning the vessel to starboard away from the wind would have exposed the port side to the full force of wind and waves and would have further increased the list and the roll. In this light the decision to turn the vessel to port and into the wind is understandable.

The question of whether a lower speed would possibly have prevented the accident has been reviewed by the Commission. Extensive model tests and number- cal simulations have been carried out as summarised in 12.1 and 12.2. The result confirms that a lower speed would have reduced the general loads on the visor and hence the probability of failure. How- ever even at a speed of 10 knots, the loads would still have been close to the strength limits of the visor attachments. The Commission has also considered whether the officers of the watch had reasons for reducing the speed prior to the start of the accident.

As is the case for many ships, there were no strict procedures or company policy for heavy weather routines on the ESTONIA. The Commission has noted that passengers' comfort, which can easily be observed by the crew, normally seems to be the prime reason for speed reduction for this type of large ferry In the Commission's experience most masters consider that speed must be reduced for comfort reasons long before it reaches the vessel's strength and safety limits.

Although some survivors have described the voyage as being rough before the accident, the officers did not apparently find comfort-related reasons for reducing speed.

For comparison, numerical analyses and model tests show that in the fore- most part of the ESTONIA vertical accelerations after midnight exceeded by 50 percent the severe discomfort boundary of International Organisation for Standardisation motion sickness standard. In the restaurant and entertainment areas amidships and in the aft part of the vessel the vertical accelerations were on the other hand significantly below and close to the severe-discomfort boundary respectively Considerably higher accelerations than predicted for the ESTONIA have been measured on board passenger vessels in rough weather in many sea areas including the Baltic. Calculations also show that the general condition on board with regard to vertical accelerations and sea-sickness would not have improved much even if speed had been reduced considerably (see 12.4.2).

Thus it is concluded that the voyage was uncomfortable for many passengers but not exceptional. The vessel was run above or close to the boundaries for comfort criteria. Referring to the above, the officers obviously believed that there was still a good margin to the limits of the bow strength.

The accident points out the need for crews on large ro-ro ferries to have operating instructions and training in manoeuvring vessels in heavy weather. It is a serious shortcoming for the whole ship ping industry that there is in general no information on the limits of operability with regard to the ship's strength available on the bridge of large vessels with powerful engines, specially as the size of the vessels makes their motion less perceptible. In the case of the ESTONIA accident, the operating limit with regard to the strength of the visor attachments was significantly lower than the crew had reason to believe.

13.4 Advance indications and alarms from the bow area

As described in 3.3.5 indicator lamps on the navigation bridge showed locked or unlocked visor and ramp, respectively The indicator lamps for the ramp were controlled from the locking devices in such a way that all devices had to be in the position ordered for the lamps to go on, green for locked ramp and red for unlocked. Since one of the locking bolts was most likely not fully extended already at departure, there was no indication on the bridge that the ramp was locked.

The indicator lamps for the locking of the visor were, as far as the Commission has been able to verify connected in the original way controlled via the position sensors for the side locking devices only The lamps thus did not directly indicate the position of the visor. The side locks were in locked position during the last voyage and the visor position lamp was thus green. The green light remained also after the separation of the visor as the side locking devices remained in locked position. Hence no light indication was given on the bridge when the visor started to become detached.

The first audible indication may have coincided with a partial failure at one of the visor attachment devices. Loud metallic sounds could hardly be generated before that point in time.

Four TV cameras surveyed the car deck with monitors on the bridge and in the engine control room. The monitors sampled the four cameras manually or automatically One camera showed the area inside of the forward ramp. The bridge monitor was mounted at the en- trance to the chartroom, facing starboard. It could not be kept under observation from the conning station. The inflow of water along the sides of the ramp was first noted on the monitor in the engine control room. It has not been possible to establish whether the officers on the bridge made the same observation.

In many other reported incidents of equivalent severity as far as the failure of the various attachment devices is concerned, the opening of the visor was observed visually from the bridge and the officers of the watch were able to take appropriate action. On the ESTONIA, however, the visor was not visible from the conning position.

The circumstances and arrangements did thus not give the officers on the bridge any direct information or warning about events in the visor area as the accident developed.

13.5 Failure sequence of bow visor and ramp

This section describes what the Commission considers to be the most likely sequence of events leading to the loss of the visor and opening of the ramp. The loads to which the visor was exposed in the seaway were simulated theoretically and examined in model tests in conditions similar to those deemed to have prevailed at the time of the accident. Experimental and theoretical results are presented in 12.1-12.3 and summarised in 15.2. The maximum opening moment to which the visor was exposed after the ship had turned at the last waypoint is estimated to have been between 4 and 20 MNm and the maximum resultant force between 4 and 9 MN. Such high loads and opening moments occurred randomly The resultant load and the opening moment may have exceeded the lower limit of the range a number of times within half an hour under the prevailing conditions. Levels above the upper limit of the range have a low probability of occurring but cannot be excluded. The vast majority of wave impacts created no opening moment at all.

As described in 15.10 it is concluded that the strength of the visor attachments was insufficient to withstand a resultant wave load of 7-9 MN, corresponding to opening moments in the range of 13-20 MNm. There is a theoretical probability higher than 1 in 20 that a single wave load would exceed the largest estimated combined strength of the attachments within 30 minutes in the conditions after the last waypoint. The port side lock may have failed at a lower load level than the maximum given above.

All the attachments of the visor, the locking devices, the deck hinges and the lifting cylinder mountings failed under local overload tension. The attachments may have failed in one or, possibly, a few steps. The partial initial failure may have coincided with a single metallic bang, observed by the AB seaman.

The main failure is believed to have happened in a subsequent wave impact, shortly after the metallic bang. In this main failure the remaining locking devices failed completely allowing the visor to open partly. Once the visor had lifted off its locating horns, the port side hinge failed under the overload generated by the high twisting and yawing moments and the vertical force. The starboard side hinge failed as a result of twisting when the visor was rotating clock- wise. Hydrodynamic loads pressed the visor against the front bulkhead along which it slid upwards. The hydraulic lifting cylinders may have failed at the same moment or may have remained connected for some further time. The port side actuator, which at some stage was pulled out of the hull by failure of the already weakened bottom mounting plat- form, had extended by about 0.4 m at least. The starboard side actuator failed hydraulically but remained connected and was ripped out of the hull, fully extended, as the last physical connection between the visor and the hull.

After the locking devices and hinges had failed and the actuators had lost their restraining effect, the visor had a natural tendency to tumble forward due to its forward-located centre of gravity relative to the new centre of rotation, i. e. the stem post area. The visor's position was at this stage governed by the actuators and the actuator attachment lugs on the hinge beams, protruding into openings in the forecastle deck. The visor was thereby constrained in the longitudinal direction.

Subsequent wave impacts caused the visor to move backwards and forwards in combination with some vertical movements, resulting in various impact dam- age to the bulkhead and the hinge beams. Impact marks indicate violent transverse movements, and upward movements of about 1.4 m. The damage is described in detail in Chapter 8. As estimated from impact marks on the aft edges of the visor hinge beams, the number of heavy aft- ward blows was at least two and probably less than five. The vertical wave force exceeded the weight of the visor on average once a minute under the prevailing conditions. The dynamics of this aft- forward movement of the visor generated sufficient impact forces to enable the hinge beam lugs to cut through the transverse deck beam, which was the heaviest structural element preventing the visor from moving forward.

It was when the deck beam, and thereafter about 360 mm of the deck plating, had been cut through that the visor housing came in contact with the top of the ramp, primarily on the port side as the sea loads had caused the visor to twist somewhat to starboard. Probably in one single movement, the visor pulled the ramp forward so that its locking devices and hydraulic actuators failed. The ramp was then free to fall forward towards the uppermost cross-bar of the visor. Subsequently the visor actuator lugs cut the rest of the deck and the front bulkhead plating until the visor was free to tumble forwards and overboard.

The exact timing of this development cannot be determined as it was affected by the irregular occurrence of wave loads sufficiently high to move the visor. Several visor movements were needed to cut through the deck and beam. Only during the final phase, when the ramp had been forced partly open could water, collected in the visor, flow onto the car deck through the openings along the sides of the ramp. The time from the initial water ingress on the car deck until the visor separated from the vessel and the starboard list started to develop is thus likely to have been short, of the order of five minutes.

Great force was needed only twice during this final part of the failure sequence, when the deck beam was cut through and when the ramp was forced open.

The many uncertainties involved make detailed calculations of this development meaningless. However, calculations under simplified assumptions verify that the course of events described is fully possible. The time for the full failure sequence which is illustrated in Figure 13.6 may have been 10-20 minutes.

13.6 Flooding of the accommodation and sinking of the vessel

Although damage stability requirements concern only the watertight part of a vessel below the bulkhead deck, a large stability reserve remains in the super- structure as long as it remains intact. The stability manual for the ESTONIA included the hull up to deck 4 as contributing to the stability range.

Because of the list, waves reached up to the accommodation decks, breaking doors and windows. The interior started to flood and the stability reserve disappeared. Critical openings were (see 12.6.1) large aft-located windows on decks 4 and 5, the cafeteria doors on deck 5, a weathertight door to the forecastle deck, and the ramp opening. Ventilation ducts to the car deck were installed at deck 4level. According to testimony from a member of the alternate crew the ducts were normally closed. The ducts may however, have opened during flooding.

The first potential openings to be submerged were the aft windows on deck 4. In calm water this would have happened when about 2,000 tons of water, or about 70 cm evenly distributed had entered the car deck and caused a heel angle of about 40 degrees. Waves with considerable impact energy would have pounded against these windows earlier. It is unlikely that the windows, although of heavy construction, withstood such impact forces. The first windows broke probably a little after the main engines had stopped and when the vessel was drifting with her starboard side to the waves. Quickly submerged were also the aft windows and the aft door on deck 5. This happened at a list of about 50 degrees, which is supported by an observation from a witness in the Cafeteria on deck 5.

When some of the large windows on decks 4 and 5 broke, these decks became subject to progressive flooding and no buoyancy or stability contribution was available from this part of the superstructure. List and trim to stern increased and the flow rate through the openings accelerated. As soon as the accommodation spaces started flooding, the flooding could not stop before the vessel sank, or the condition could no longer remain stable as there were connections between different decks via staircases and other openings. The watertight compartments be- low the car deck were thus flooded from above.

The speed of flooding, however, depended on the size of the openings to the sea and on the escape of air from inside the. hull regarding Which there are several witness observations. Calculations indicate - as an example - that 18,000 tons of water on board, distributed between the car deck and decks 4 and 5, would have given a heel angle of about 75 degrees. This amount of water had entered the vessel in about 15 minutes, indicating an average flow rate of 20 tons per second. This is feasible through openings which have a total area of 5-10 m2. Progressive flooding was under way to several decks and compartments at the same time as the upper decks gradually sank under the mean water level.

If the windows and doors had remained unbroken the vessel may have remained in a stable heel condition for some time. It is, however, less likely that any reasonable strength of the large windows would have been adequate to with- stand the wave impact forces.

It can be concluded that, although the vessel fulfilled the SOLAS damage stability requirements valid for its building period, she had no possibilities to withstand progressive flooding through the superstructure openings once the heel angle approached 40o. When windows on the accommodation decks were broken by wave forces, subsequent sinking was inevitable.

CHAPTER 14 OWNERSHIP AND OPERATING ARRANGEMENTS

The initial ferry, operation between Tallinn and Stockholm started on 17 June 1990 and was carried out by N&T EstLine AB, a fully-owned subsidiary of Nordström & Thulin AB, in co-operation with a consortium of smaller tourist-related companies owned by the Estonian government. The initial positive development in traffic volume was drastically reversed in 1991 due to the political unrest in Estonia, resulting in large economic losses for N&T EstLine AB, which firm in practice carried the total financial burden of the traffic. Attempts to lower operating costs by employing senior officers from Sweden and the rest of the crew from Estonia failed due to objections from the Swedish trade unions. The traffic was, however, maintained and in 1992 a positive development of passengers and cargo volumes started, indicating a future need for a bigger ferry Due to the accumulated losses, however, it was not deemed feasible for Nordström & Thulin AB alone to finance a further large investment in N&T EstLine AB. To ensure continued traffic it was therefore agreed with the Estonian government that the N&T EstLine operation should be discontinued and the traffic should be taken over by a new joint venture company.

For this reason the Estline Marine Company Limited was established in Cyprus. The company was owned equally by the Estonian Shipping Company Limited (ESCO) and Nordthulin Luxembourg S.A., (for further details, see Chapter 2). The ESTONIA was acquired by the Estline Marine Company These complex ownership arrangements were necessary to allow the vessel to be financed on a mortgage basis and seem to have had no other function.

The Estonian partner in the joint venture, ESCO, assumed the responsibility for operating the vessel. Technical management and the responsibility for insurance matters were subcontracted to Nordström & Thulin AB in a standard ship management contract. Commercial operations, including catering, were handled by the Swedish company Estline AB. This company was owned equally by ESCO and Nordström & Thulin AB and had a subsidiary company in Estonia to provide the corresponding services in Tallinn.

Complex arrangements between the true owner and the actual performers of the various operational functions are common in the shipping industry and have become increasingly so as competitiveness has demanded a high level of performance at the lowest possible cost.

The Commission has not found any evidence that the ownership and operating arrangement for the ESTONIA could in any way have influenced the development of the accident, or that any matters of importance for the safety of the vessel had been neglected because of these arrangements.

It appears that Nordström & Thulin AB kept a closer eye on the operation of the vessel than called for by the technical management agreement. This seems to have benefited the operation as Nordström & Thulin AB had previous experience of the traffic. The areas of responsibility, however, seem to have been clear and respected by all parties and as far as the Commission has been able to verify co-operation between the parties has been at an acceptable level.

ESCO was responsible for the overall operation of the vessel including the manning, the qualifications of the crew and increasing crew members' proficiency However, Nordström & Thulin AB had the right - under the technical management agreement - to refuse the appointment of masters and chief engineers, in order to ensure that good communication could be maintained in English. A number of candidates were reject- ed by Nordström & Thulin AB as being under-qualified in this respect.

ESCO was also responsible for providing qualified catering personnel. The exception was that Estline AB, via the Swedish shipping company Rederi AB Hornet, provided advisors for the top positions in the catering organisation.

The ESCO land organisation was rigid and of traditional, strict hierarchical

structure.. This condition possibly supported a mentality whereby individuals carefully performed their explicit duties but were not encouraged to show initiative. The operating arrangements relied totally on the ship's master, who had to determine the operational limits for the vessel, operational practice for nautical instruments, the use of automation and the remote control system and the implementation and updating of the on-board safety system. The Commission has not found any documented procedures or instructions about these elements. How- ever, the Commission has noted that the radio officer, according to the Safety Manual, was not responsible for radio traffic in emergency situations.

The operative controls carried out in connection with port state controls, as well as a major fire exercise carried out under the supervision of the Swedish Maritime Administration, elicited good remarks, with active and ambitious par- ticipation by crew members.

The Nordström & Thulin AB organisation responsible for technical management consisted only of one full time technical superintendent, reporting directly to the chief superintendent, who in turn reported to the fleet manager. The technical superintendent met the master and the chief engineer regularly during the vessel's calls in Stockholm and discussed maintenance and any other technical items that may have come up. He sailed frequently with the ship. One purchaser was also involved. This arrangement seems to have been fully satisfactory for the function intended.

The pilot regulations for the Stockholm archipelago require that to operate a passenger vessel of the size of the ES- TONIA in the Stockholm fairways under the pilot exemption rules, the master and one more officer of equal qualification must have pilot exemption certificates for the fairway and the vessel. Up to the time of the accident, only the masters of the ESTONIA had acquired such exemption certificates and only for the fairway via Sandhamn (4.2.2). To avoid the in- convenience and the costs incurred in taking a pilot on board every voyage, it was arranged with Rederi AB Hornet that they should provide two alternating Swedish officers with the required qualifications. The officers appointed were former employees of Nordström & Thulin AB and had been sailing in senior positions on the previous ferry on the same route. The Commission has noted that these Swedish pilot officers were not part of the crew and had no other formal function on board than participating in the navigation in the Stockholm archipelago.

One of these officers was occasionally consulted by the masters of the ESTONIA regarding improvements to the safety organisation and related documentation. The two may also have served partly as Nordström & Thulin's observers of the operations on board.

The fact that the vessel was manned and operated by an Estonian company and flew the Estonian flag initially spurred an intense debate in Sweden regarding "flag-of-convenience" arrangements and substandard operations. The Commission has found no basis for this debate.

It is the opinion of the Commission that the operating arrangements in general worked satisfactorily and that traditions and experience from the established ro-ro ferry traffic in the northern Baltic area were incorporated in the operations by way of the influence of Nordström & Thulin AB and through the personnel provided by Rederi AB Hornet.

CHAPTER 15 STRENGTH EVALUATION OF THE VISOR AND THE RAMP ATTACHMENTS

15.1 Design basis and requirements for the bow visor

15.1.1 Bureau Veritas' requirements for the visor attachments

The bow visor structure was built to scantling requirements specified in the Bureau Veritas Rules of 1977. Compliance with these has not been verified in detail in this investigation.

The locking devices should, according to the Bureau Veritas rules valid at the time, cause the bow door to be "firmly secured". Structural reinforcements were specified in general wording to be required at attachment points for cleats, hinges and jacks.

Thus the Bureau Veritas rules did not specify minimum pressure heads to be applied to the horizontal and vertical areas of the visor. The yard has stated that it therefore used a Bureau Veritas "Note Documentaire", number BM2 dated 5.4.1976 for determining the design loads. This note was intended as guidance in the design of the bow of large tankers and bulk carriers. It has not been possible to fully explore how this guidance note was interpreted and used in arriving at the applied loads. The loads so derived were, however, of the same magnitude as those required by some other classification societies at the time.

The design loads to be applied to the attachments of a bow visor of a ro-ro vessel have been continuously developed incorporating new data, and were in general not well established when the ESTONIA was built. The pressure head and the calculation procedure to be applied be- came more clearly defined and detailed rules were given, for instance, in the 1982 Unified Requirements of IACS and later recommendations. The requirements of IACS 1982 specified equivalent design loads per locking device of about twice as high as those used in the design of the ESTONIA. However, Germanischer Lloyd already in 1978 had a specific formula for the design load of a bow visor which would have given about three times the load used for the ESTONIA.

15.1.2 Shipyard design procedures

From the external design pressure on the visor shell plating determined by the procedure indicated above, the total external load components were calculated by the yard to 536 t (5.3 MN) in upward vertical direction and 381 t (3.7 MN) in aft horizontal direction. These were assumed to act at the centres of the projected areas. The reaction force at the position of the bottom lock was determined by calculations of the momentum about the longitudinal middle point between hinges and side locks at the level of hinges, and found to be 152.5 t (1.5 MN). This horizontal force and the total vertical load reduced by the static weight were divided by 5 and a design force of 100 t (1.0 MN) was obtained as a result- ant for each attachment point, hinges included.

Although there is an obvious lack of logic in the procedure used, it was to some extent supported by rules of other classification societies at that time, e.g. Lloyd's Register of Shipping. However, in these design rules, the calculated reaction forces were only to be distributed evenly to the cleats and not to the hinges. It is the opinion of the Commission that the calculations by the shipyard resulted in considerably lower design loads per attachment point than would have been the case if a more realistic design load distribution had been applied.

The design load was used by the yard for calculating a minimum load-carrying cross-section of 6100 mm² for an attachment device. This was obtained by applying a normal stress level of 164 N/ mm² calculated from a permissible normal stress of 123 N/mm² for mild steel divided by a material factor of 0.75 due to the intended use of high-tensile strength steel, St52-2. The calculations did not take into account. the reduced strength in the shear mode to which many of the attachment elements would be subject- ed. A copy of the calculations by the ship- yard is included in the Supplement. The hand calculations by the shipyard were not submitted to Bureau Veritas for approval. In the actual installation, the calculated effective design cross-section was not incorporated in the bottom lock, nor was high-tensile strength steel used in any of the attachment lugs investigated by the Commission.

The von Tell assembly drawings did, in accordance with the purchase order, identify the operational loads the hull would have to absorb via hinges and operating devices due to the weight and geometry of the visor and the ramp. Loads to be absorbed at the attachment devices due to wave-induced forces were not indicated on these drawings. Bureau Veritas communicated in March 1980 with the von Tell company regarding the design loads used by von Tell in determining the strength to be built into the locking devices. The von Tell company explained in a brief telex that they had used the rules of Lloyds Register of Shipping in the absence of Bureau Veritas rules and had calculated a load of about 80 t for each device. A1- though no details are known, the out- come of this correspondence seems to have been satisfactory to Bureau Veritas. Two notes made by the Bureau Veritas surveyor, one on the assembly drawing of the visor and one on the von Tell general arrangement drawing for the visor and ramp installation, stated that "Arrangement of locking devices subject to the approval of the National Authorities" and "local reinforcement of the ship's structures in way of locking devices, cylinders and hinges to Surveyor's satisfaction." On the assembly drawing was also a remark that "jack lifting eye on arms, atlantic lock eye, side lock eyes requested in steel grade St52-3" i.e. a high-tensile-strength steel. These drawings were approved by Bureau Veritas with these comments in November 1979 as regards the von Tell drawing and in June 1980 as regards the shipyard drawing.

The shipyard drawing for the visor was submitted to Bureau Veritas for approval only shortly before the vessel was delivered. The note on the von Tell drawing was, however, brought to the attention of the yard by the Bureau Veritas site inspector in March 1980 as recorded in his daily work statement. It is also worthy of note that the von Tell company communicated with the Finnish Maritime Administration in December 1979 about approval of the von Tell design in general but did not then make any reference to the note on the von Tell drawing a month earlier regarding the Bureau Veritas requirement for specific approval of the locking devices by the national administration.

The Finnish Maritime Administration was, under a national decree, exempt from carrying out a hull survey if the vessel had a valid class certificate issued by an authorised classification society Bureau Veritas did not, on the other hand, make a detailed survey of the visor attachments, as requirements for these were not included in their rules at the time. This situation and the confusing timing of the correspondence about approval of the locking devices, seem to have led to the calculations and the de- sign of the attachment points for the locking devices not being examined for approval either by Bureau Veritas or by the Finnish Maritime Administration.

15.2 Sea loads on the visor

A visor is subjected to hydrodynamic and hydrostatic loads when the vessel is pro- ceeding in a heavy seaway Due to the geometry of the visor, the wave load amplitude increases in a non-linear way with respect to the relative vertical motion between the bow and the wave surface. A small increase in the displacement and velocity of the relative motion will cause a significantly higher increase in the wave loads.

In straight head or oblique bow sea, the resultant force on the visor of the ESTONIA would be directed approximately 45 degrees from the waterline due to the shape of the visor, causing upward- and aft-directed load components of equal levels. In bow sea there would in addition be a transverse load component, but mostly smaller. The centre of action of the larger forces on the visor would be positioned high up and forward, causing opening moments, and in a bow sea also twisting and yawing moments about the longitudinal and vertical axes, respectively The forces from lighter sea impacts would generally cause closing moments on the visor.

Due to uncertainty in the estimate of the sea state, the randomness of relative motions and the non-linearity of the forces created on the ESTONIA's visor, there is considerable uncertainty in the estimates of the maximum loads. On the basis of numerical simulations and model tests (see 12.1-12.3) the Commission has concluded that the most probable maximum resultant force on the visor, developing in a significant wave height of about 4 m and after the vessel had changed course at the waypoint, was between 4 and 9 MN. Divided into force components, this equals simultaneous upward and aft forces of 3 to 6 MN and a starboard transverse force of 0.5 to 2.5 MN. The resultant maximum moments about the hinge points were 4 to 20 MNm opening moment, 0.5 to 7.5 MNm twisting moment and 0.5 to 2.5 MNm yawing moment. Load and opening moment levels in the lower part of the range could well have been exceeded a number of times. Levels above the upper limit of the range are judged to have had a low probability of being exceeding, but cannot be excluded.

The Commission has noted that the estimated maximum sea loads at the time of the accident in terms of vertical and longitudinal forces on the visor were of magnitudes about equal to those used by the shipyard as design loads. Later during the accident night the wave height increased and the forces would have in- creased significantly if the ship had continued at the same speed and heading towards the waves.

The distribution of reaction forces and their directions in the visor attachments are affected by the positions of the attachment points in relation to the position of the centre of wave load action on the visor, the play in the locking devices, the overall stiffness of the visor and the local stiffness at the attachment points. In the following sections the strength of the various attachments is discussed separately based on calculations and tests as described in the Supplement. An estimate of the combined overall capacity is given in 15.10.

15.3 Evaluation of the bottom locking device

The bottom locking device failed in its attachments to the forepeak deck (Figure 8.13). The failure took place by fracture in the three plate lugs carrying the bolt housing and the mating support bushing and in the weld around the housing and the bushing (Figure 8.14). The fracture of the parts indicates tensile failure load directed forwards. The starboard and centre mounting lugs had essentially failed in the longitudinal plane of the vessel whereas the port lug had restrained the forward movement of the locking bolt and housing and become twisted. The locking bolt had slipped out of the mating lug on the visor at an angle of about 30 degrees.

The failed lugs were recovered from the wreck and have been subjected to metallurgical and strength examination of the fractured surfaces and of the base material (Supplement). All indications are that the lugs failed in a local overload condition with one or a few cycles. The general appearance of the failed lugs is shown in Figure 15.1. The failure in the weld joint was partly in the weld beads and partly in the surrounding material. The thickness of the weld beads was around 3 mm. Indications of pre-accident root cracking or lack of fusion can be seen in the fractured areas of the weld beads.

The load-carrying capability of the bottom lock assembly (Figure 15.2) to failure has been estimated using calculations detailed in the Supplement. Only two lugs, symmetrically located one on each side of the visor lug, effectively contributed in carrying load applied in the longitudinal direction via the visor lug. This failure pattern is also supported by the result of tests carried out in Ham- burg and referred to below. The load was carried by the rims of the lugs and by the welds between the lugs and the housing and support bushing for the locking bolt. The fracture area of each lug was about 1100 mm² of mild steel, contributing a load-carrying capability of about 0.3

MN to the failure load of the welded assembly This value is based on a failure mode wherein the lugs would only have been loaded to the yield level when the welds failed due to their lower ductility. The welds had a load-carrying capability of 0.3 to 0.5 MN at each lug, the actual contribution depending upon the quality of the welding and any existence of root cracks.

The total failure strength of the assembly will have been the strength to failure of the welds plus loading of the two lugs to their yield stress, or altogether 0.6 to 0.8 MN per lug. Two contributing lugs would then have given the complete bottom lock assembly a holding capacity of about 1.5 MN including a small contribution from the starboard bracket. The Commission considers this to be a realistic maximum value.

The Commission is aware of a series of tests carried out in 1996 at the Technical University of Hamburg on behalf of the yard with full scale mock-ups of the bottom lock assembly made of high- tensile strenght steel. In these tests, char- characterised by different extent of welding between the attachment lugs and the locking bolt housing, failures occurred between 1.0 and 2.0 MN. A test that incorporated intermittent welds resulted in failure at 1.42 MN.

The mating lug on the visor had a tensile load-carrying capacity to failure of about 1.8 MN, taking into account the material (mild steel) and that the lug tip was loaded more critically in the shear mode than in the tensile mode assumed in design. The visor lug was therefore just a little stronger than the forepeak deck assembly Results of analysing the deformation of the recovered lug using modelling and experiments indicate that the lug may at some time, have been exposed to a tensile load of up to 1.5 MN (Supplement).

The Commission has learnt that the bottom locking device assembly was manufactured by the yard as a shop sub- assembly that was subsequently welded to the forepeak deck. No detailed drawing with welding data was issued specifically for this subassembly as welding data was generally contained in yard standard tables. The Commission has not found information on any modifications or repairs of the bottom lock. The paint test (see 12.7 and the Supplement) and statements by people involved in maintaining the lock indicate that it is original or dates back to a very early period of the vessel.

To satisfy the outcome of the yard design calculations, the lugs should have had a larger minimum cross-section. It appears that dimensions of the attachment lugs as indicated schematically on a von Tell assembly drawing for the bottom locking device were used in the manufacture of the attachment lugs rather than a design based on the yard calculations. It is noted that the design calculations also assumed high-tensile strength steel, where- as the actual attachment lugs were made from regular mild steel. With regular mild steel the load-carrying effective cross-section of the bottom lock attachments should, according to the shipyard's design calculations, have been about 8300 mm2 whereas the built-in equivalent cross-section, including the small welds and the load effectively being carried by two lugs, was only about 4600 mm2.

It is concluded that the load-carrying capacity of the installed bottom locking device was not adequate to satisfy the design load and calculated minimum cross-section requirement.

15.4 Evaluation of the side locking devices

The side locks failed at the attachment of the lugs to the aft bulkhead plating of the visor. No drawing showing details of the installation and welding of these to the visor plating has been identified. An extract from the von Tell assembly drawing for the side locking arrangement was apparently released for manufacture of the side locking lugs. This sketch shows the lugs to have a bottom length of 370 mm, compared to about 550 mm as indicated on the general assembly drawing for the visor.

The lugs were ripped out of the visor plating together with part of the plating

itself, leaving rectangular holes, about 390 by 85 mm, with fracture surfaces mainly in shear through the aft plating (Figures 8.19 and 8.20). The lugs remain on the locking bolts in the wreck. The bottom surfaces of the lugs are shown in Figures 8.17 and 8.18. The thickness of the aft plating of the visor was 8 mm. Two vertical stiffeners were installed behind each lug at the surveyor's request for local reinforcement of the structure bearing the locking devices (Figure 15.3). One of these stiffeners was so located that there was an overlap of the fillet weld of the lug and one of the stiffener weld to the bulkhead plating. The other vertical stiffener had no overlap. The strength contribution from these stiffeners has been estimated to be small. A horizontal stringer on the visor aft bulkhead, located close to the upper corner of the lug, had failed in the plating and partly in the weld between the stringer and the bulkhead surface. No other strength continuity was incorporated behind the lugs.

The force required to pull and break the lug away from the visor in a direction tangential to the rotation about the hinge points and in the lug plane has been estimated with mock-up testing and calculations to be at most about 1.2 MN on the port side and 1.6 MN on the star- board (Supplement). These values take into account a weld defect at the stringer behind the port lug and the uneven distribution of the fillet weld between the stiffeners and the bulkhead plating. The load-carrying capacity would be lower for a load applied at a smaller angle to the bulkhead plating and higher for a load more normal to the plating.

It is especially noted that the side locks had deficient loading capacity be- cause their geometry induced primary shear in the aft plating of the visor. Thus, although the minimum cross-section of the lugs was almost equal to that required by the design calculation, the strength was, very approximately only half of what a similar tension-loaded cross-section could provide. However, the cross- sections of the horizontal stringer and the very modest vertical stiffener weld added some holding strength.

The ultimate load-carrying capacity of the side locking lug welds has been calculated to be less than the value above for a weld bead of 8 mm, but the thickness and strength of the weld material is uncertain. The actual failure did not, however, occur in the welds.

It is concluded that the absence of sufficiently detailed manufacturing and installation drawings for the lugs and their supporting structure resulted in an insufficient load-carrying capacity in comparison with the calculated design load requirement.

15.5 Evaluation of the hinges on deck

The hinges at the aft end of the visor deck beams were subjected to loads of about 1.2 to 1.5 MN during normal opening and closing of the visor, acting in directions between downward and aft de- pending on the position of the visor. The lower rims of the hinge plates had generally failed under tension and the upper ones under bending leaving stretched tongues with strongly contracted tensile, ductile shear fractures of the failed lower rims and flat fractures of the upper rims with clear signs of bending overload (Figures 8.21-8.24). The welds to the bushing failed in the forward part leaving the rim attached to the separated part. The lugs and one recovered hinge bushing have undergone metallurgical and strength investigations as described in 12.7 and in more detail in the Supplement. The investigation of the recovered hinge bushing has revealed extensive cracking in the weld beads, primarily in the downward-facing area. This cracking was initiated by cracks in the root of the weld and progressed through the weld, generally in one of the fusion zones. At a couple of places the cracking proceeded to the outer surface of the welds, as reported after the accident by a student doing paint work on board. The loads generated during normal operation are judged to have been sufficiently high to cause fatigue cracking to progress in the welds, initiated by the original root cracks.

The lug rims ultimately failed in tension of the lower lip and bending of the upper one without previous fatigue cracking, as clearly noticeable on the recovered specimens. The fracture surfaces of the lugs indicate that the final failure took place within one or a few load cycles.

The cracks observed had only marginally influenced the strength of the hinges against wave-induced loads primarily because of the load directions generated.

The load-carrying section of the hinges consisted of the rims of the lugs of the visor hinge beams and the fillet welds around the hinge bushings. The rims of the lugs had a cross-section of 60 by 25 mm in each plate. The lugs of one hinge assembly (two plates) would then, ac- cording to simplified assumptions and calculations, have had a load-carrying capability in aft-directed tension of maximum 2.7 MN, using an ultimate tensile strength of 450 N/mm2, verified during actual testing. With the minimum cross-sections of the rims at yield in a welded assembly their contribution to ultimate strength in aft-directed tension would be 1.5 MN. In the same loading mode the weld would contribute about 5.8 MN making the total resistance to a single load at most about 7.0 MN for aft-directed tension.

The ultimate strength of a hinge against lifting load has been estimated to about 4.6 MN assuming a clearance larger than about 1 mm between the steel bushing and the lug plate.

The surfaces of the holes in the lugs where the bushings had been inserted had, along much of their peripheries, a very rough contour as from manual flame cutting. This applied to all four lugs, but more so in the starboard hinge. The burn marks were in the lug plates only with no corresponding marks on the recovered bushing. In addition, the forward con- tours of the holes in the lugs in the starboard side hinge were located about 10 mm further forward relative to the

outer contours of the hinge beam than those. on the port side. It has not been possible to find the reason for the rough surface, whether it was an adjustment of the hinges during assembly or remains from a later repair. No documentation from any repair in this area has, however, been recorded.

It is most likely that the forces to cause the hinges to fail were generated when the visor, moving upwards around its hinges and having lost support from the locating horns, was exposed to twisting and yawing moments. Given the relatively high stiffness of the deck hinges compared with that of the attachment of the locking devices it is also possible that initial failure of the port hinge was caused by high reaction forces before all locking devices failed.

The Commission notes that the hinge strengths were in general commensurate with design intent. However, the cracks generated during normal service indicate insufficient strength of the hinge lug rims and bearing bushing welds. Also the ri- gidity of the lug rims to vertically-directed loading is considered poor because of the modest bearing bushing weld and the flame-cut bushing hole with its rather loose tolerance.

15.6 Manual locking devices

The manual locks at each side consisted of two plate lugs welded to the aft bulk- head of the visor and an eye bolt in a cavity in the hull, so arranged that it could be rotated to position between the lugs and tightened. The total load-carrying capacity of the manual locks has been estimated to be at most 0.7 MN each. Had they been applied they may to some extent have contributed to the overall load-carrying capability of the visor locks. The fact that there were no instructions for their use has been taken as an indica tion, however, that they were not regarded as part of the operational locking system.

15.7 Evaluation of the visor actuators and their attachments

The visor had two heavy-duty actuators for controlling the opening and closing of the visor. These were connected to the visor hinge beams at a distance of 1.3 m from the hinges and were mounted on reinforced horizontal platforms in the front structure of the hull. The actuators were connected hydraulically to a sole- noid-type control valve, which was closed at all times except when the visor was being moved. Various restrictor valves were installed in the system to limit the speed of opening and closing. The pumps in the hydraulic power supply system had been replaced once with new ones capable of delivering a higher hydraulic pressure as the original ones had marginal capacity.

When sea loads started to open the visor, an upward load was also applied to the actuators, which resisted the opening movement. The leverage from the centre of attack of the sea loads compared to that of the actuators enabled a high pulling force to be transmitted to the actuators. The port side actuator was at this moment pulled out of the hull (Figure 8.26) while only partly extended whilst the locked-in hydraulic fluid acted to transmit the force to the lower attachment of the unit. The vertical force to shear the actuator support out of the hull has been estimated to be from 4 MN down to possibly as low as 2 MN, taking into account the unsymmetrical attachment point of the load and extensive cracking in the platform edges and welds as well as the steel grade used for deck 3. Tests revealed signs of cold brittleness in this steel even at room temperature. The actuator mounting platform has under- gone a detailed investigation (Supplement). The normal operating loads from the actuators appear to have been high enough to initiate fatigue cracking of the platform plating and the welds, in particular where some crack-promoting discontinuities may have existed. The port platform exhibited cracks around a large part of its periphery generated by vertical loads from normal visor opening and closing.

The seals in the starboard actuator failed, preventing the hydraulic fluid from transmitting the load. The piston rod of this actuator was therefore extended and the actuator remained connected in the hull during the initial phase of the visor movement. The load initially taken is uncertain but must have been below the ultimate strength of the platform, estimated to be below 8 MN.

15.8 The ramp locking devices

The ramp was secured in the closed position by six locking devices, i.e. two pull-in hooks at the upper end and two locking cleats along each side of the ramp.

After the accident, the upper pull-in hooks were in closed position as verified by ROV video pictures of the actuator and lever mechanism. It has, however, not been possible to determine in which mode the hooks themselves failed. An upper limit of the load-carrying capability of a hook may have been the load at which the metal in the contacting area between the hook and the mating pin started to yield. This load was approximately 0.2 MN. It is assumed that the pin slipped off the hook when yielding started in the hook material, as the bend-over angle of the hook tip was small.

The side securing bolts, in locked position, extended into box-like structures welded to the side bars of the ramp. These boxes were ripped open following failures in their welds. The force required to rip any one of these boxes open has been estimated to be 0.2-0.3 MN. The lower port box, however, was not dam- aged and it is concluded that the locking bolt was not engaged when the ramp was forced open by the visor. A question remains about the condition of this locking device just before the accident. This did not, however, have any effect on the overall development of the accident. The locking devices failed sequentially as a result of load applied to the port side first. A force applied to the top of the ramp from contact with the visor had larger leverage than the locking devices had, reducing the force actually required to break the devices. The contact force required to deform the stiffeners in the deck housing of the visor has been estimated at 0.3-0.4 MN, sufficient to break open the ramp locking devices.

15.9 Other damage to the visor

Other damage to the visor that is related to the accident includes extensive pounding of its bottom and indentations on its front. The bottom plating was forced upwards and had cracks in many places, primarily in welds. The stem post had separated from the side plating and been folded inwards together with the bottom plating. Damage marks indicate that this happened when the visor started to tumble forward and was rotating downwards on the ice-breaking prong of the bulbous bow This damage caused by the ice prong continues upwards along the stem, culminating in large mid-height indentation. Further indentations, scratch marks and paint marks on the starboard side of the visor indicate its continued movement when it slid off the bulbous bow and sank underneath the vessel.

Analysis of paint marks in the main indentation shows that these came from paint of the same type as that used below the waterline of the vessel, including the bulbous bow.

It is concluded that the bottom plating of the visor became deformed when the visor was dropping back after having been lifted by waves, initially pounding on the forepeak deck and, secondly and extensively, on the stem head.

Some indications of old cracks have been found in welds, primarily in those between the stem post and the side plating and between the side plating and the bottom plating. Some of these joints may have been exposed to cyclic loading from opening and closing and from waves and ice. Fatigue cracking may have developed, generally starting in stress concentration points in the roots of the welds. It has, however, been difficult to determine the characteristics of the cracked surfaces due to subsequent extensive corrosion.

The stem post, folded inwards under the visor, had four transverse cracks on its front side. It is assumed that these developed during the deformation of the stem by beating on the ice prong al- though indications in the crack surfaces suggest that cracks may have existed before the accident.

Small paint marks from paint similar to that used on the hull were found in one of the cracks. It could, however, not be established whether these marks were flakes coming from the surrounding paint or had actually entered an existing crack during painting.

It is concluded that some cracks may have developed in some welds during the vessel's lifetime. In view of her age these cracks are considered to be normal and did not contribute to the cause or the development of the accident. Progressive cracking in some weld seams might have affected only the development of the secondary damage, once the damage had been initiated.

Two longitudinal flat bars, though shown on the visor steel drawing as running one on each side of the recess for the locating horn on the bottom plate of the visor, seem not to have been installed. The bottom of the visor therefore had no other structural continuity in its load- carrying members than its almost beam to which the visor locking lug was attached. The bottom is therefore considered to have been weaker than intended, in particular when taking vertical loads. This is also likely to have affected the amount of deformation occurring during the accident influencing the ability of the visor bottom structure to resist vertical forces that may have developed during the failure.

The interior of the visor shows sever- al dirty "waterlines" indicating that water had been standing inside the visor for some time. Some oil, presumably hydraulic oil leaking from the hydraulics of the bottom lock, had floated on top and had settled on the vertical surfaces giving the "waterlines". The sealing on the fore- peak deck had clearly not always been in a condition to keep the lower part of the visor watertight. The Commission has learned from individuals involved in other ferry operations that this is quite common in many ferries as the seals on the fore peak deck are so easily damaged by the rubbing action occurring during opening and closing of the visor.

The Commission has concluded that the general maintenance standard of the visor was satisfactory The steel work was little corroded and no reduction of plate thickness, nor pitting, has been noted on the various parts collected for detailed investigation.

15.10 Failure modes and combined strength of the attachment devices.

The failure pattern of all the attachments indicates an overload caused by forward- upward motion of the visor. The Commission has considered different possibilities that could have caused the attachments to fail, but has come to the conclusion that it was an external wave impact on the visor that created the necessary failure loads.

The visor of the ESTONIA was not fully watertight, and probably some water penetrated into it in the rough head and bow sea the vessel encountered. Hydrostatic pressure from trapped water inside the visor would create a resultant force directed about, 45 degrees forward and down. The pressure and the result- ant force would be amplified by the vertical accelerations of the bow. However, the possible amount of trapped water could not have created tension reaction forces in the attachments sufficiently high to make any of them fail. As an example, 3 m of water inside the visor would create a hydrostatic resultant force of only about 0.5 MN.

Green water on deck could be critical due to the unfavourable lever arm to the aft-positioned visor hinges. About one metre of water on the deck would double the weight of the visor, but several times this height would be needed to break the attachments. The model tests and the numerical simulations show that the probability of any significant amount of green water on deck was negligible for sea conditions at the time of the accident.

In general, the lower level of wave- induced forces on the visor occurring every few minutes in the prevailing sea condition would cause closing moments about the deck hinges. The reaction forces so created were taken up by the stem post and steel pads on the forepeak deck. The model test results indicate that the maximum closing moment including the visor's weight was about 8.0 MNm. If the stem post alone had supported the visor, the stresses from this moment would have been about 120 N/mm^2 in compression, possibly with some added bending stresses. If the visor locking devices had taken up the closing moment, the reaction forces would have been directed forward, causing compression in the lugs. The closing mode is not considered critical for the attachment system.

When the resultant wave-induced forces exceeded 2.0-2.5 MN, the line of action would pass above the hinge axis and create an opening moment. With an average period of about 10 minutes in the accident condition, the opening moments were high enough, about 3 MNm, to exceed the static weight of the visor. Less frequent, higher wave loads caused much larger opening moments. Opening moments would create tension in the visor lugs of the locking devices and forward- down compression in the visor hinge lugs. In oblique bow sea the reaction forces would be unevenly distributed between the side lugs, increasing the tension on the side that encountered the waves. This effect is clearly visible in the visor damage which shows strong movement from port to starboard.

The attachment system was statically undetermined and the distribution of reaction forces was therefore affected by the stiffness of the structure as well as by the play in the locks. By studying different levels and combinations of wave load components and different possible distribution of reaction forces, an estimate of the total load-carrying capacity before failure of any of the attachments has been obtained. The estimated strength of the individual attachments is described earlier in this chapter. Assuming that all locks worked efficiently and using realistic correlations of wave load forces and moments obtained from model tests in port bow seas, it is estimated that the combined strength of the attachment system would be exceeded by an external resultant wave load of 7-9 MN, corresponding to opening moments 13-20 MNm.

Most likely the port side lock failed first, possibly at a lower load level than the maximum estimated above. The subsequent failure could have occurred either by shearing of the port hinge lugs, or by tension in the bottom lock. The estimated necessary level of wave load for either of these possible second failure modes is about the same. Hence, the complete failure sequence could have required only one or two wave impacts. If only the port lock failed in a first large wave impact and the other attachments remained intact, then the visor was probably kept in place - appearing undamaged - for a significant period. The hypothesis of a side lock failing first is supported by the similar damage pattern incurred by the visor attachments of DI- ANA II in 1993.

Figure 15.4 illustrates an example of a possible reaction force distribution over the attachments when the port side lock fails. The load on the hinges, though large, is acting in an uncritical direction while the bottom lock and the starboard side lock are loaded only to about half of the critical level. A possible reaction force distribution after the port side lock has failed is shown in Figure 15.5.

The final stage of the attachment failures leading to the loss of the visor took place in the remaining hinge lugs and in the lifting actuator sealings and mounting platforms when the visor was free to move. Significant forces in the actuators are judged to have developed only after the locks had failed. The maximum necessary resultant wave load to fail the actuators simultaneously would be about 6 MN, but they most likely failed in sequence under dynamic conditions at a significantly lower level.

The extreme value distribution of wave-induced loads given in 12.3 for the accident condition indicates a theoretical probability of more than 5 % that a single wave load would exceed the largest estimated combined strength of the attachments during 30 minutes at a speed of about 14 knots in oblique bow seas with a significant wave height of 4.0-4.1 m. The probability of wave loads exceeding the attachment's strength increases rap- idly with increasing wave heights.

The Commission concludes that the largest forces generated by sea loads under the prevailing conditions were higher than the combined strength of the attachments and hence caused the failure of these and the subsequent loss of the visor.

It is notable that the ultimate strength of the visor attachment system was ex- ceeded already for a load level about equal to the design load used, and that this load level developed in a sea condition that was far from the worst the ship could have been expected to encounter. There was consequently no margin of safety incorporated in the visor attachment system.

15.11 Design considerations

After having studied the design, manufacturing and procedures for approval, the Commission finds that none of the parties involved considered the visor attachments as critical components for safety of the ship. There is however no Figure I5.4 Example of reaction force distribution resulting in port side lock failure. indication that the routines in this respect deviated in general from routines followed by other parties for other new-buildings in the Baltic area at the time. Information has been found, however, that in some other parts of the world in the 1970s visors and their attachments were more thoroughly designed and considered critical for the vessel's safety

The ESTONIA was designed and built after a decade of very rapid development in shipbuilding and naval architecture. Ship sizes increased, shipyard technology was modernised and new computerbased direct methods for calculation of structural strength and wave-induced loads were introduced in the design process. As a consequence, experience lagged behind technological development. Ships are in general highly optimised with regard to structural strength, and experience from damage, incidents and accidents has always been an important basis for the development of codes and procedures.

Ro-ro passenger ferries for the Baltic traffic developed very fast during the 1970s as described in Chapter 10. The ESTONIA was at the time of newbuilding among the largest bow visor ferries designed, and experience from designs was obviously limited. Today with the outcome known, it is easy to find several items to criticise the design of the visor. However, if anyone had made a rational analysis of concept, the same items could have found open to criticism even at the time the ship was designed. Here are listed a few such design considerations that the commission regards as important.

All attachment points for a bow door should be regarded as highly loaded design items and subjected to detailed and strength analysis.

Where operating experience is limited and design rules and recommendations give little support, it is of utmost importance to make a failure consequence analysis. Even a very simple analysis would in this case have highlighted critical interconnection between visor ramp and the possible consequence of water on the car deck after failure of the visor attachments.

The conclusion would then have been either to separate the two barriers or to incorporate a very large safety margin in the design of the attachments. The design load calculation and the assumption of equal distribution of forces on the attachment lugs for which there was also support from some classification societies' design rules at that time, had no basis in physics. The reaction forces obtained were not in balance with the external load, and no specific directions of forces were determined. Since the design pressure head was equally distributed over the shell of the visor, oblique loading was not even considered. The Commission is of the opinion that even very simplified design calculations of vital items should include analysis of different possible load directions and failure modes. In a statically undetermined system of supporting points, either detailed analysis including flexibility should be performed or sufficient strength should be assessed for any combination of reduced system that could be evaluated by simple equilibrium of forces.

Locking devices of the common de- sign such as those installed on the ESTO- NIA are subject to wear and corrosion on the locking bolts and mating lugs, leading to play in the arrangement. Some initial play is also built in, to safeguard functioning during opening and closing of the devices. The play was about 10 mm in the ESTONIA's locking devices and extensive play of about 35 mm is known from other ships. Play between the connecting parts has the consequence that the contact load distribution between the locking devices is undeterminable and in an extreme condition one single device may be subjected to the entire external load. Play in a connection subjected to dynamic loads will always lead to accelerated wear and may induce fatigue. The Commission is therefore of the opinion that locking devices should be of such design that play is eliminated during closing and bow doors should, in the closed position, be physically tightened against mating surfaces.

The local design of the ESTONIA s visor attachments shows weakness particularly because the lowered strength in the shearing mode had been ignored. The hinges were weak due to weld shear and bending of lug rims induced by vertically directed reaction. The side lock induced shear in the visor aft plating in all load modes, and the bottom lock design capacity would have been limited by shear of the visor lug tip even if the forepeak assembly had been welded to better standards.

15.12 Comparison of design requirements and actual installation.

The design requirements for the visor attachment devices at the time the vessel was built generally indicated a design load level of about 1 MN per device based on an even distribution of the bow load on all the attachment points. This applied to the way the loads were deter- mined by the yard, and also followed from the rules of some other classification societies at that time.

The ultimate failure load, corresponding to the 1 MN design load, would in the simplified analysis made by the yard have been about 3 MN per device taken as the ratio between ultimate strength and permitted stress. However, in a mixed de- sign where various design elements are included and different failure modes will develop sequentially, this relationship is not directly applicable.

The failure load of the bottom and side locking devices as installed has been determined to be about 1.5 MN per de- vice, account taken of the uncertainty in load direction and failure modes.

It seems obvious to the Commission that the ultimate load-carrying capability of the attachment system and its individual devices would have been considerably higher if the reduced strength in the shear mode had been considered and the manufacture would have been according to the design intent.

The design loads used were, however, low and it is noteworthy that even an installation fully meeting the design assumptions applicable at the time of construction would not in all cases have withstood the hydrodynamic forces generated during the night of the accident, considering the increasing wave heights. As an illustration, the model test results show that the maximum opening moment generated by wave loads would be more than three times higher than estimated for the accident condition in bow seas with a significant wave height of 5.3 m and a speed of 10 knots.

15.13 Class and administration implementation requirements

A number of serious incidents are referred to in Chapter 11. The cases mentioned are those for which the Commission has found information without extensive research. The ships involved were in most cases operating in Scandinavian waters. It is fair to assume that a number of incidents have taken place also in other trading areas.

In the individual ship involved in an incident, the relevant structures were in most cases reinforced during the necessary repair. In several cases reinforcements were also made on sister ships. However, in some cases the classification society involved was satisfied with a re- pair restoring the strength of the device to the original standard. This was the case e.g. after the DIANA II incident in January 1993. The vessel was at that time 13 years old and the damage seems to have been regarded as isolated and no further alarms were raised or action taken.

The Commission has noted that in several cases the affected Administration communicated with the classification society involved and was satisfied with the information that the strength requirements had been increased. This would apply, however, to new ships only Retroactive upgrading of existing ships through rules and regulations with retroactive effect has generally been considered unacceptable within the shipping industry and this attitude has been accepted with- in IMO as well as amongst classification societies.

The Commission finds this attitude unacceptable in cases of incidents with serious safety implications. The Commission is of the opinion that all amendments to requirements, founded on actual risks having become known, should lead to requirements with retroactive effect, both in IMO regulations and in the rules of the classification societies. The Commission has also noted that a move in that direction has taken place since the ESTONIA accident

CHAPTER 16 ANALYSIS OF THE EVACUATION

16.1 The start of the evacuation

Many passengers, especially in cabins on deck 1 and in forward cabins on other decks, heard, during about 10 minutes, metallic sounds which they gradually found abnormal and alarming. These sounds frightened some of them. A few witnesses left their cabins, certain that something was amiss. Some left to investigate and others for the open deck 7.

The majority of passengers and crew members, however, were not alarmed until the more powerful blows before the first heel. The noise and the subsequent list obviously made them immediately recognise the situation as life-threatening. Many then escaped hastily and with- out taking the time to put on proper clothing. The reaction pattern varied, however, and some passengers, although alarmed, did not seem to believe or grasp the seriousness of the situation, or could find no options for rational action.

Most passengers and crew members were thus alarmed by the accident itself and started to seek the open decks spontaneously and, in most cases, individually. Alarm signals seem not to have had any significance for the passengers or for most of the crew.

16.2 The mobilisation of the command group on the bridge

The officers on watch after 0100 hrs were the second officer A and the fourth officer. The master arrived at the bridge 5 to 10 minutes prior to the first heel and is believed to have stayed because of the ongoing inquiry about sounds from the visor and the ramp area. The complete command group did not gather on the bridge.

The chief purser was awakened by the list and went directly to the open deck. The chief officer's voice was identified from the distress radio traffic together with the voices of the second officer A and the third officer. These two officers climbed out from the bridge when the ESTONIA had a list of approximately 80o. The Commission has no information about the chief engineer or the purser's assistant.

Except for the chief purser, no member of the command group survived.

16.3 Alarms and activities by the bridge

The bridge sent out alarm signals approximately five minutes after the list and when the situation had already be- come aggravated. The alarm they first used, Mr Skylight to number one and two, was a fire alarm which was coded so as not to disturb the passengers, but was, as most "Mr Skylight" alarms, also a signal for mustering the command group and the lifeboat groups simultaneously.

This alarm, which was not so well suited to the situation, came on at a time when there were already people wearing lifejackets below the bridge wing and when the list was around 30o. One of the two fire groups, to which this alarm was directed, was instructed to muster on the car deck which at about that time contained approximately 1,500 t of water.

According to the safety manual the bridge could use a "Mr Skylight" alarm if they wanted to prepare and organise the crew for an evacuation before alarming all the passengers. To muster the lifeboat groups, the command group should, ac- cording to their safety manual, use the "Mr Skylight" alarm without any suffix. To muster the lifeboat groups and evacuation groups simultaneously they should have used "Mr Skylight Evac" followed by the digits for each evacuation group.

Approximately two minutes after the "Mr Skylight" alarm, the lifeboat alarm came on.

A possible explanation for the use of a "Mr Skylight" alarm before the lifeboat alarm is that the bridge had not yet understood the seriousness of the situation but wanted to prepare the crew for evacuation. The use of this alarm was, however, inappropriate and late and suggests that there was confusion on the bridge and that the bridge was without a clear understanding of the situation. Since the lifeboat alarm came later it is reason- able to assume that this alarm and the distress radio call came close after one another and not before the bridge had fully perceived the situation as both life- threatening and irreversible.

Some survivors have reported hearing the alarms, but others report not having heard any alarm at all. Other survivors only heard parts of these alarms over the noise in the ship and most passengers did not understand what the alarms meant. No additional information was sent from the bridge.

The rapid development of the accident made organised efforts by the rest of the crew impossible.

16.4 Activities by crew members

The "Häire, häire laeval on häire" (Alarm, alarm there is alarm on the ship) message which came on prior to the alarms was probably not authorised from the bridge but sent on the initiative of the crew member at the information desk. This message might have had some effect upon the evacuation but it was mostly under- stood by Estonians only. Evidently it was interrupted at the very moment it was to be repeated in English.

Some individual crew members, how- ever, took responsibility and initiative for alarming, and organised the evacuation locally by guiding passengers, helping, arranging human chains, distributing life- jackets and releasing liferafts. Divers' findings of ropes and a lifeboat rope ladder down the staircase aft at deck 6 are further evidence of efforts led by crew members to rescue those inside. A witness statement concerning individuals, probably crew members, keeping passengers back in a staircase may be referring to an attempt to organise the escape. It is understandable that crew members, before being ordered to evacuate or hearing any alarm signals, might try to neutralise spontaneous escape.

The chief task of the crew was to take responsibility for and organise the evacuation of the passengers. The Commission understands, however, that this be- came almost impossible as the situation later developed into imminent deadly peril to all, irrespective of category.

Taking responsibility implies risk-taking and risks during the accident were evenly distributed among both crew and passengers. The crew members' responsibilities were to see to passengers' well- being, to help and to use their knowledge and training actively in the rescue efforts. Passengers are justified in expecting that crew members should be aware of their responsibilities and at least be active. The reported passivity of some crew members, the delay in alarming and the lack of guidance from the bridge suggest that training and preparations were not sufficient.

A further indication of this was that members of the catering staff apparently did not play any specific role in the evacuation. Their duties were to form a first aid group, a guard group and 11 evacuation groups. When not involved in other duties, they were assigned to man the lifeboat and liferaft rescue stations. Individual members of the deck and engine crew, however, took responsibility for passengers and fellow crew members. Some of these crew members, including two who did not survive, made heroic contributions and were very active, apparently disregarding their own safety Passengers also helped and sup- ported each other, often sticking together in twos or in small groups. A few especially energetic and active passengers also helped to organise and to direct others.

16.5 Obstructions to the evacuation

Besides the increasing list, the architecture of the ESTONIA made the evacuation difficult. Most corridors and stair- cases in the cabin areas were 1.2 m wide. This was probably sufficient space for two normally-built people to pass each other but when people were crowding, standing still or lying and crawling on the floor, movement in such a limited space became difficult with reasonable consideration and without forcing one's way Such narrow longitudinal corridors were also apparently difficult to move in when the list exceeded 30o. At about 45o, effective movement along the corridors be- came almost impossible for any adult of normal build.

Deck 1 contained cabins for 358 passengers. All the transverse corridors ended in the only longitudinal, and al- most equally narrow central corridor where there were six staircases. The limited width of this corridor, combined with the crowding and the disorganised behaviour of many passengers, probably created an insurmountable obstacle when the evacuation started.

It is believed that the narrow width of the corridors in combination with the list contributed to the crowding and the irrational behaviour.

Although the width of the corridors and evacuation staircases complied with the SOLAS Convention the Commission considers that this limited width constituted a major evacuation obstacle for most of the passengers. The Commission concludes that the applicable regulation in SOIAS was not appropriate, as demonstrated in this accident.

Only a few witness reports are from people who escaped through the forward most port staircase. One of these stated that there was no crowding. The divers' investigation revealed, however, that a large number of people got stuck in this staircase on all decks and landings inspected. A possible interpretation is therefore that this staircase was more difficult to climb because of its transverse direction and that those few who did manage to reach the open deck did so when the list was still minor.

Other obstacles to evacuation were objects which came loose and the escape ways or struck people who were trying to escape. Heavy objects such as vending machines, gambling machines, flowerpots and some furniture in passageways and foyers should have been fixed to either deck or bulkheads. Some objects slid away others came loose when the list was still small and heavy fixed objects later broke loose from their fastenings when the list increased. Also sliding carpets and slippery flooring material prevented some from evacuating and created obstacles that slowed others down.

The Commission has noted that some decorative objects were not properly fastened and also that heavy fixed objects broke loose within an angle of heel at which people still had possibilities to evacuate. These objects injured some or otherwise prevented the movement of others. It is therefore evident that more people could have reached the open deck had they not been hampered by the loose or sliding objects.

The Commission considers that all objects along evacuation routes such as passageways, staircases and foyers should be fixed and properly fastened with no possibility to break loose within a range of list where people are still able to move and have the possibility to evacuate. Flooring material should also be fastened and, especially in open areas like foyers, slippery material should be avoided so as to facilitate movement on moving and sloping floors.

16.6 Passengers' and crew members' reactions

The large number of people and their various reaction patterns also created an obstacle to the evacuation. During the evacuation, people had, because of the increasing list, increasing difficulties to move. A number of people fell or slid, thereby creating obstacles for others. Others were standing but not moving, thereby preventing others from passing them. Many were seen just holding on without moving; yet others appeared paralysed and seemingly unable to understand what was happening. From the very start of the list many were reported to be passive and stiff, despite reasonable possibilities for escaping.

A few of those who survived behaved in an irrational way, but most did not. A number of people reacted incredulously to the very early signs. They slowly realised that the sounds they heard were abnormal, or rather, they failed to persuade themselves that the situation was still normal. When they became clear about the situation, they acted promptly and with a clear goal: to get out to deck 7. They were the first to evacuate.

A majority of those rescued, however, seem to have grasped the seriousness of the situation when the blows and the list came. They also promptly understood what to do and thus reacted clearly and appropriately Not without fear they yet managed to remain rational and to move effectively

Many elderly people were seen making no or only faint efforts to escape. A great number of people were panicking, i. e. behaving without control, and screaming. Some of these were moving but not in a rational or purposeful way Others were apathetic and some only held on to something without making further efforts to save themselves.

A number of people were shocked and seemingly unable to understand what was going on or what to do. Some of these seem to have been incapable of rational thought or behaviour because of their fear, and screamed or moaned helplessly; others appeared petrified and could not be forced to move. Some panicking, apathetic and shocked people were beyond reach and did not react when other passengers tried to guide them, not even when they used force or shouted at them. Other people tried to escape but lacked the strength to continue climbing, be- came exhausted and held onto handrails, blocking the way for others.

The Commission considers that information from the bridge over the public address system could have affected peoples' behaviour, especially if the system had been used to give orders to the passengers and the crew. Authoritative instructions could have saved many bewildered people, and should have been sent during the first few minutes in the development of the accident.

Spontaneous altruistic behaviour during the evacuation seems to have been more prevalent in the early stages where many people helped and took responsibility for each other or urged each other to move and climb. The building of human chains involved many both crew members and passengers, but these efforts ceased when it became difficult to hold on and when people became afraid. Collective and co-operative efforts then broke down into individual efforts. Some collective and spontaneous attempts were made later on when people felt more secure. Those who had reached the open deck helped each other again and also tried to help those still trapped on the staircases. There are also indications that constructive communication between the escaping people broke down when they started to flee individually.

Many of the survivors forced their way whereas others seem to have ceased struggling at some stage, as if giving them- selves up for lost. Some have stated that they also, at some time, felt a strong urge to give up although they still possessed some strength. This strong feeling came over them when they suddenly felt their situation was hopeless. Overwhelmed, they lost all mental and physical strength and became passive. They regained their strength and willpower after coming to think of their loved ones, especially of children. Then they immediately decided to continue their struggle with great force and try to live on, as if needing an outside reason for staying alive.

During the struggle people became injured or forced out of the way by others. Consideration for others and rules of behaviour ceased at moments when individuals perceived themselves to be in a death-trap. A situation arose where many took care of themselves only More primitive behaviour was revealed and some were apparently rescued at the expense of others

16.7 The limits for evacuation and the outcome

The Commission has estimated that the possibilities for escape to the ESTONIA's open decks ceased when the list was between 45 and 50 degrees. Around these angles there might perhaps still be some possibilities to get out for the few who were agile enough, who also had suitable footwear and who received help from others inside or out on deck. The time span for the evacuation to the open decks, from the time people started to the 45-to 50-degree list, was thus between 15 and 20 minutes. For the majority, who were not alarmed until the first heel, the time span was about 10 minutes. Bearing the narrow corridors and the great number of people in mind, this time span was extremely short.

During this time at least 237 reached the open decks. This includes people who were seen on deck 7 and 8 but are still missing, 138 rescued, one of whom died in hospital, and 70 of the 94 bodies found. Next day 24 bodies were found near the wreck and it is very likely that they had come up from inside the wreck. This figure of 237 tallies with witnesses' statements that between 200 and 300 people were seen out on deck.

16.8 The rescue equipment

Crew members were seen working methodically releasing liferafts and distributing lifejackets. Passengers out on deck, however, had difficulties to understand how to put on the lifejackets. Instructions were in most cases not looked for, not found, not read or not understood correctly This was sometimes due to passengers being overwhelmed by emotions and also to a stress-related narrowing of consciousness and perception. Passengers even struggled to release liferafts on their own although this task was intended for crew members only. In other cases, planless and highly stressed attempts were made by many passengers simultaneously, with nobody able to take the lead or have the time to work more methodically Some individual passengers who were quite competent, active and rational also failed in their attempts.

At least one container with lifejackets came loose and fell into the sea. Many survivors have stated that the lifejackets appeared old-fashioned while a common opinion among those rescued was that it was difficult to understand how to use them and how to put them on. Many lifejackets were tied together in threes and were difficult to separate. Lifejackets were also torn off when people hit the water. Survivors reported that the life- jackets appeared incomplete, with missing straps or straps that seemed too short. People had to help each other both to understand how to use the jackets and also to put them on.

The reports from witnesses are in line with reports from rescue units and personnel searching the water during the days after the accident. They found several drifting bundles of lifejackets tied together. Members of various rescue units also confirmed that they found very few people wearing lifejackets that had been put on correctly

It is therefore the Commission's opinion that the design of lifejackets should be simplified so that their proper use appears self-evident even for untrained people, and also that instructions on liferafts and liferaft containers should be very short, distinct, easy to find and to understand.

No one left the ship in an orderly fashion. Some were forced to jump, but most were swept into the sea by waves or slid into the sea inside or outside liferafts.

CHAPTER 17 THE RESCUE OPERATION

17.1 Introduction

The ESTONIA sank only about an hour after the first observations that presaged the accident and only about 30 minutes after the lst Mayday call.

About 680-750 people were trapped inside the vessel while at least 237 but probably 310 reached the outer decks. Lifejackets were distributed and liferafts were inflated and launched by the crew and by passengers. None of the ten life- boats could be launched, but nine broke free and floated up to the surface when the vessel sank.

The people who fell or jumped into the sea without lifejackets, and those who were badly injured, drowned or otherwise succumbed so quickly that no rescue organisation or unit could have reached them in time.

Some 160 people succeeded in climbing onto liferafts or lifeboats. Of them, about 2O succumbed to hypothermia or hypothermia-induced drowning. At least two persons were lost during the rescue operation.

The MARIELLA reached the accident scene 50 minutes after the lst Mayday call, i.e. 2O minutes after the vessel sank. Four passenger ferries and the first rescue helicopter were on the scene within one hour and 10 minutes of the sinking. During the next three hours six more vessels and six more helicopters arrived.

Thirty-four people were rescued by the vessels and 104 by the helicopters in the time period between 0330-0900 hrs. Considering the circumstances a high percentage of people on the liferafts could be rescued. Almost all of those missing were trapped inside the vessel or were not able to get on a liferaft.

In the plans and exercises considerable reliance had been placed on rescue vessels and lifeboats from passenger ferries and other vessels. The first rescue vessel, the TURSAS, arrived at the scene of the accident about three hours after the ESTONIA foundered. No lifeboats or MOB boats were lowered by the vessels on the scene.

17.2 The distress traffic

The ESTONIA addressed her distress calls to the passenger vessels in the vicinity Also the form of the distress calls did not comply with the formal requirements of the radio regulations. The Commission has learned with regret that in this area distress messages nowadays are very seldom transmitted in the correct form.

However, since the ESTONIA started the traffic by using the Mayday distress signal, the Commission considers that those receiving the message should have been in no doubt that the ESTONIA was requesting immediate assistance and that there was a distress situation on board.

Almost the entire distress traffic was conducted in Finnish. This language was understood by the MRCCs and coast stations in the area, and on board the nine vessels nearest to the ESTONIA.

The ESTONIA was asked for, but could not give, her position immediately due to the list and "black-out". It took about seven minutes from the 1st Mayday call until the position was reported. No subsequent distress traffic was received from the ESTONIA.

Several minutes passed before any station tried to re-establish radio contact. At 01.39 hrs, i.e.10 minutes after receiving the ESTONIA   s position, the SILJA EUROPA called the ESTONIA very briefly and without result. No other station tried to contact the ESTONIA.

MRCC Turku did not acknowledge receipt of the distress message from the ESTONIA, thus not confirming that the centre was conducting the rescue operation. Therefore it was not known by the SILJA EUROPA and the MARIELLA whether the distress calls had been received by the coast radio stations, and both vessels spent a considerable time trying to contact Helsinki radio for information on the distress messages received. It is the opinion of the Commission that MRCC Turku should have acknowledged the distress message even though the message was addressed to the ferries.

According to rescue instructions issued by the Finnish Ministry of the Interior, distress traffic should be handled by Helsinki Radio or Mariehamn Radio. This arrangement did not function as intended and, the Commission considers, contributed to information delays during the initial phase of the rescue operation.

In the event, Helsinki Radio did not hear the ESTONIAs distress calls. Nor did Helsinki Radio respond to calls from the MARIELLA or the SILJA EUROPA on VHF channel 16 and on MF distress frequency 2182 kHz. The MARIELLA succeeded in contacting Helsinki Radio by mobile telephone (NMT) at 0142 hrs and reported the distress calls from the ESTONIA. After unsuccessful attempts to contact Helsinki Radio the SILJA EU- ROPA notified MRCC Helsinki of the distress calls also at around 0142 hrs. Two minutes later Helsinki Radio contacted the SILJA EUROPA on VHF channel 16, and at 0145 hrs Helsinki Radio responded to the MRCC Turku call on channel 16 without problems.

The Commission finds no other explanation of the fact that Helsinki Radio did not hear the distress traffic than that the distress frequencies were not kept watch continually With only one officer on duty for many hours there must be, for natural reasons, periods when the watch keeping will be interrupted. This was also noted and accepted in the agreement between the National Maritime Ad- ministration and Telecom Finland regarding the conduct of distress radio traffic.

After contacting Helsinki Radio the SILJA EUROPA and the MARIELLA had good reasons to believe that Helsinki Radio would control the distress traffic. There was discussion on channel 16 between the vessels about transmitting a Mayday Relay but it was assumed that Helsinki Radio would do this.

The Commission's opinion is that a Mayday Relay should have been transmitted, primarily by the vessels, immediately after the ESTONIA had reported her position to the SILJA EUROPA and, when they did not do this, by MRCC Turku and Helsinki Radio. Both the pre- GDMSS and the GDMSS procedures, as well as VHF and MF distress frequencies, could and should have been used. Had this been done, the coast stations and other vessels could have received the distress information simultaneously and without delay.

Finnish rescue instructions for radio traffic separate the controller of the distress traffic from the actual rescue organisation. In the ESTONIA case this was a contributing factor to the omission to transmit a Mayday Relay The Commission considers this omission to be very serious.

At 0145 hrs the operator at Helsinki Radio intended to transmit a Pan-Pan message. This was discussed with the duty officer at MRCC Helsinki and agreed to by him.

When MRCC Turku was informed by MRCC Helsinki that Helsinki Radio was going to transmit a Pan-Pan message, MRCC Turku contacted Helsinki Radio on VHF channel 16 and requested that a Mayday Relay should be transmitted. The Helsinki Radio operator responded that he was just preparing such a message. Notwithstanding this, the Helsinki Radio operator went ahead and transmit- ted the Pan-Pan message on channel 16 and 2182 kHz, reporting the ESTONIAs list and her Mayday calls. This was done at 0150 hrs, five minutes after MRCC Turku had requested a Mayday Relay to be transmitted, and some 20 minutes after the distress traffic from the ESTO- NIA had come to an end.

The Commission considers it remark- able that the Helsinki Radio operator neglected a request from the conductor of the rescue operation and that MRCC Turku did not take any corrective measures.

It is the opinion of the Commission that the alarms during the initial phase of the accident were late. The prime reason for this is believed to be the manning of the MRCCs and the radio stations, with only one man on duty It was also too much for one person at MRCC Turku to initiate the alarms required in a major accident and at the same time follow the situation and take part in the distress traffic.

Consequences of the reduced manning at the MRCCs and the coast radio stations had been discussed in the organisation, and fears that the cost savings had resulted in insufficient resources for handling major accidents had been brought to the bodies responsible prior to the ESTONIA accident.

The manning had been decided in anticipation of conventional maritime accidents, when MRCCs were expected to be able to receive distress messages around the clock and to initiate rescue operations. The duty officer at MRCC Turku fulfilled these requirements, even though in the ESTONIA disaster the manning proved to be inadequate. The system was underdimensioned for a major maritime accident.

As noted in 8.11 the ESTONIA s emergency beacons (EPIRBs) were not switched on when put in their housings. The only reason that they were found switched off is that they were not properly activated.

17.3 Responses to the Mayday calls

17.3.1 Vessels

Almost all the vessels that participated in the rescue operation arrived after hearing the ESTONIAs distress call or receiving information from another vessel in the vicinity Only the vessels of the Finnish coast guard and navy were alerted by the coast stations.

The positions of the vessels around the ESTONIA on 28 September 1994 at 0130 hrs are shown on the map in Figure 7.1.

There were five passenger ferries in the Northern Baltic around the ESTO-NIA. Closest was the MARIELLA at a distance of about 9 NM and furthest was the SILJA SYMPHONY, 23 NM away Within a 35-nautical-mile radius from the ESTONIA there were three more vessels that received her Mayday calls.

On hearing the I. Mayday call, the MARIELLA tried twice to answer it but the ESTONIA did not reply The officer of the watch saw the ESTONIA s lights and her radar image. According to a shore- based radar the MARIELLA started to turn towards the ESTONIA at 0132 hrs. The MARIELLA reached the scene of the accident at about 0210 hrs.

The SILJA EUROPA's was the only radio station that had contact with the ESTONIA. The information given from the ESTONIA reported only a severe list, a "black-out", that the situation looked serious and that assistance was needed. The extent of the accident and the assistance required were not known at this stage.

Figure 17.1 shows tracks of some vessels during the accident. The tracks are based on radar observations.

About 10 minutes elapsed between receipt of the lst Mayday call and 2 minutes between receipt of the ESTONIA s position and the MARIELLA's change of course towards the accident site. Corresponding times for the SILJA EUROPA were 16 and 8 minutes. The Commission is of the opinion that a Mayday call from a large passenger ferry is in itself so alarming that the vessels should have changed course immediately The rough position of the ESTONIA must have been known.

The MRCC appointed the master of the SILJA EUROPA On-Scene Commander (OSC) at 0205 hrs.

The two other passenger ferries near the ESTONIA, the SILJA SYMPHONY and the ISABELLA, approached the ES- TONIA from the west at full speed. Three other vessels approached the scene of the accident from the east. They reported to the OSC and took part in the search and rescue. Three vessels further west of the ESTONIA continued their voyage south- west. Two of them reported to the OSC and were released from the obligation to render assistance. The master of the third vessel considered that his ship in the circumstances was unable to provide assistance and he entered in the radio log the reason for this. The Commission considers that it was a reasonable judgement to let these three vessels proceed.

The Commission considers that vessels in the vicinity despite some delays in reaction, acted correctly.

17.3.2 MRCCs and MRSCs

The accident took place within the rescue region of MRCC Turku. The rescue plan for major maritime accidents at that time included the alerting schedule shown in Figure 17.2.

At the time of the accident there was only one officer on duty in MRCC Turku. According to the rescue plan for major maritime accidents the duty officer was responsible to:

- order the most rapid operational maritime rescue units to the scene of the accident to conduct the rescue operation at the scene and obtain a detailed assessment of the situation,
- alert the stand-by duty officer and the emergency duty officer,
- start general alerting according to the alerting schedule.

The duty officer's first action was to call MRSC Turku to confirm the distress message and to alert the coast guard patrol vessel TURSAS which was at anchor in the archipelago. This was done at 0126 hrs, or two minutes after the beginning of the 2nd Mayday call. The duty officer listened to the distress traffic until its end at 0130 hrs. At 0133 hrs he alerted the stand-by officer. After receiving the ESTONIA s exact position at 0129 hrs, at 0135 hrs he alerted the stand-by maritime rescue helicopter, which in the circumstances was the most rapid operational rescue unit. Between 0135 hrs and 0145 hrs he responded to telephone calls from crew members of the alerted helicopter.

The stand-by duty officer arrived at 0140 hrs. On arrival he assumed responsibility for the operation of the centre. After assessing the situation, he spent five minutes contacting MRCC Helsinki and Helsinki radio in order to get a Mayday Relay transmitted.

The emergency duty officer was not alerted until 0146 hrs. He arrived at 0203 hrs.

The first contact from MRCC Turku with vessels at sea took place somewhat before 0200 hrs, when the stand-by duty officer asked whether the master of the SILJA EUROPA agreed to lead the rescue operation at the scene of the accident.

At 0152 hrs MRCC Stockholm was informed of the accident by MRSC Mariehamn which, in accordance with normal practice, contacted MRCC

Stockholm to check whether they knew about the accident. After first calling MRCC Helsinki, at 0157 hrs MRCC Stockholm called MRCC Turku and offered helicopter assistance.

At 0218 hrs MRCC Turku ordered MRCC Helsinki to alert the stand-by rescue helicopter in Helsinki. The crew was called at 0221 hrs. At 0252 hrs MRCC Turku alerted the Aeronautical Rescue Co-ordination Centre (ARCC) at Tampere to obtain military helicopters from the Transport Flight at Utti. At 0258 hrs the ARCC called the Air Force control centre and requested as many Air Force helicopters as possible. All these alerts of helicopters were late.

By 0200 hrs the seriousness of the accident had been realised and the MRCC Turku commander and deputy commander were alerted. It was not until 0230 hrs, or about ten minutes after the arrival of the deputy commander, that MRCC Turku determined formally that the situation was a major accident and began to sum- mon the members of the maritime rescue expert group to MRCC Turku. The members of the group, in turn, alerted their own organisations, informed them of the situation and passed on assignments, and received from them reports on their action and on the situation.

As the Commission states above, a Mayday call from a large passenger ferry must be considered a most alarming situation and immediately assessed as a major accident. Clearly the instructions and the manning were inappropriate for coping with an accident of this magnitude. For this reason the rescue plan for major maritime accidents was not fully complied with. Among other things the summoning of MRCC Turku personnel was delayed. Further, MRCC Turku did not announce on the radio that they were conducting the rescue operation.

Another shortcoming was that no mission co-ordinator, as recommended in the SAR Convention, was designated. This function was at first performed by the duty officer. The stand-by duty officer took over on his arrival and was relieved by the emergency duty officer on his arrival. He in turn was relieved by the deputy commander, and lastly by the commander. Continuity was maintained through briefings at each change. A system with so many changes is not considered efficient, since so much time and energy is required to ensure continuity.

With the deputy commander's arrival at 0220 hrs there were four rescue offic- ers working at MRCC Turku. Even this group proved to be far too small for a rescue operation of this magnitude and it was not until the members of the maritime rescue expert group arrived that capacity was sufficient.

The personnel at MRCC Turku was divided into four groups. The operational group of three officers and two warrant officers maintained an overview of the situation, considered and ordered action and assisted the commander. The communication group was responsible for radio and telephone communications. It consisted of three warrant officers trained in communications. The maritime rescue expert group consisted of experts from various fields of importance for rescue operations. Each member of the group had his own area of responsibility The public information group, finally, took care of information functions, and arranged briefings for the media and various official delegations. In spite of the work of this group these briefings also tied up a considerable amount of the commander's working capacity It is the opinion of the Commission that despite initial difficulties the work improved alter the first hour and functioned well. Decisions were made and accomplished quickly under the commander's overall control.

17.4 Readiness of the rescue units

The Gulf of Finland and the Northern Baltic form a significant focus for maritime rescue services since on the average 34,000 passengers cross this small sea area every day The Helsinki, Turku and Berga helicopter bases are on the fringes of this area (Figure 17.3). Any passenger vessel using the main ship routes can be reached from these bases in less than two hours. The location of the Turku base at the half-way point of the main route is considered appropriate, although the best accessibility and the shortest flight time would be from the Hanko peninsula.

Three Finnish helicopters were on stand-by at various bases. The crews were on one-hour alert, meaning that they should be assembled within that time. Three of the Swedish stand-by helicopters should be ready to depart within one hour, and one should be ready to depart within two hours. All stand-by helicopters fulfilled the requirements. The first helicopters took off earlier than their alert times required.

It is of utmost importance in an accident like this one that rescue helicopters reach the accident scene fast, as survival time in cold water is short. It is the view of the Commission that stand-by times can be shortened, with minimum costs, through:

- more efficient ways of alerting helicopter crews and other personnel required for take off, e.g. by using more modern technology,

- briefing the crews during transport to the helicopter bases and during the initial phase of the flight,
- speeding up transport times to the bases, especially for crew members living far from the bases.
- The contribution of maritime rescue vessels remained small. Some arrived late at the scene of the accident because of the delay in alerting them and their slow speed in the prevailing weather with strong head wind. Some smaller rescue vessels on stand-by a few hours' sailing time away from the scene of the accident were not alerted, which the Commission considers an acceptable decision in the circumstances.

17.5 Management

17.5.1 MRCC Turku

The organisation and chain of command of the maritime SAR services of Estonia, Finland and Sweden were established on the principles outlined by the IMO. The northern part of the Baltic Sea was divided into regions of responsibility of three MRCCs, Turku, Stockholm and Tallinn. The basic principle was for the MRCC responsible for the region to con- duct the operation, while the others provided support as requested. Exceptional arrangements could be made as necessary.

As stated above, MRCC Turku assumed the responsibility for the rescue operation on receiving the Mayday calls. MRCC Turku had recently been restructured, and its organisation and communications equipment had been modernised. The internal chain of command was clear and simple. The commander was ultimately responsible for rescue operations, and he had at his disposal the staff and the maritime rescue expert group. The work of the expert group had been practised, and procedures for alerting the members were in working order. Co-operation between the different national rescue services was governed by a 1985 Finnish Ministry of the Interior instruction on conducting and maintaining maritime rescue services. The instruction stated that "the Headquarters of the Frontier Guard conducts, co-ordinates and oversees the co-operation among maritime rescue services, assisted as necessary by the maritime rescue division of the National Consultative Board for Rescue Services".

Contrary to the instruction, the tasks were carried out by the Security and Safety Management Group, headed by the Minister of the Interior. This body provided no practical assistance in the operative conduct of the rescue action. In the event of a major accident like the ESTONIA accident all measures should have been taken to support MRCC Turku.

Already before the ESTONIA accident there had been criticism among the personnel of the Finnish Frontier Guard, pointing out that insufficient attention was given to the SAR service.

17.5.2 The On-Scene Commander

The master of the SILJA EUROPA was appointed OSC although this was not in line with the SAR Convention. The decision was a logical consequence of the fact that the SILJA EUROPA managed the distress traffic and thus served as control station for the traffic. The master of the SILJA EUROPA was also personally known to those at MRCC Turku, and was deemed capable of carrying out these demanding duties.

Although the master of the SILJA EUROPA carried out his duties and responsibilities as OSC in exemplary fashion without proper training or earlier experience, it is the opinion of the Commission that it is appropriate to provide selected masters of vessels in this traffic with the training needed to conduct such operations.

During the first hours the entire rescue operation was conducted by the OSC himself, assisted only by his own crew. On his instructions the vessels searched for and rescued survivors. When a vessel located a liferaft that was believed to contain survivors, this was reported to the OSC who either called on a helicopter to check this raft or broadcast a general message. The participating vessels sometimes also contacted the helicopters directly

The helicopters arriving on the scene of the accident reported to the OSC and were assigned a mission. With the in- creasing number of helicopters the OSC had difficulties in overseeing their operations.

At 0650 hrs additional resources were flown out to assist the OSC. An air operation co-ordinator was then landed on board the SILJA EUROPA. He took over control of the air operation in the area. A co-ordinator surface search, appointed by MRCC Turku, with an assistant and an air traffic controller left Nauvo by helicopter at 0700 hrs but did not reach the vessel until 0945 hrs, since the helicopter that they first used could not land on the vessel or winch them on board.

At the beginning of the operation, when there were many liferafts in a small area, the helicopters acted independent- ly When the air operation co-ordinator took over the control of the air operation, he gave the incoming helicopters their instructions and informed them of other helicopters in the area. He also gave them instructions and orders regarding the rescue operation management, e.g. regarding refuelling possibilities. Later on he assigned search areas, and in practice managed the air operation.

The safety of the helicopters engaged in the rescue operations depended mainly on radio communications on the over- loaded distress frequencies, since the air traffic radars were unable to follow the helicopters at low altitudes and there was no supervision and tracking system over the sea. The Commission's opinion is that the professional skill and experience of the helicopter crews contributed in a positive way to the outcome of the rescue operation.

In this kind of major air operation, it is essential that the OSC is assisted by personnel with experience of air traffic control. The air operation co-ordinator was not in place during the critical hours of darkness and the air traffic controller needed for supervising the air traffic and for ensuring flight. safety did not arrive until 0945 hrs.

When the co-ordinator surface search and the air operation co-ordinator and his assistant had arrived on board the SILJA EUROPA, the staff of the OSC is considered to have reached a standard sufficient for conducting an operation of this magnitude. However, this did not happen until about 45 minutes after the last survivors were found.

17.6 Action at the accident site

17.6. 1 Vessels

On-board preparations

While proceeding to the scene of the accident the assisting vessels made necessary preparations for the rescue operation and for taking care of survivors.

The helicopter pads were prepared for landings. Reception and treatment facilities for the survivors were readied and nursing staffs prepared. Voluntary medical experts among passengers were alerted to assist the permanent staffs. The preparations on board and the professionalism and willingness of people to help were afterwards highly appreciated by the survivors.

No lifeboats or rescue boats were launched from the vessels participating in the rescue operation. The possibilities of launching boats were discussed between some of the masters, but in the prevailing weather the operation was considered too risky Instead liferafts were prepared for use and in some ferries the possibilities of using evacuation slides were discussed and the slides prepared.

The masters realised that the rescue operations would be difficult and the possibilities of rescuing people from the water were limited when lifeboats and rescue boats could not be used.

Rescues from vessels

On the MARIELLA an inflated liferaft was placed each end of the vessel's flat side. The vessel was manoeuvred with that. side towards the wind and caught drifting rafts from the ESTONIA in between them. Another raft was lowered and used as a hoistable platform. People from the ESTONIA's liferafts moved over to the lowered raft and were winched up. The winches on the liferaft davits were manually operated, but during operations electric drilling machines were converted and used to improve the winching speed

Two volunteers from the MARIELLA were lowered to a liferaft from which they managed to rescue two exhausted persons in another liferaft.

The ISABELLA also lowered a liferaft with volunteer rescuers on board.

They succeeded in getting about 20 people from one of the ESTONIAs rafts over to their own raft. The weight of the people and the water in the liferaft caused its bottom to rip during hoisting. At least five people fell into the sea, among them the three rescuemen. Four of these people were lifted up by a helicopter. One or more persons were lost during this operation.

To save the 16 persons hanging onto the damaged liferaft, the evacuation slide was inflated and the raft lowered back to the sea. A rescueman was lowered down to the slide platform and assisted people in getting from the raft to the platform and up the slide. The evacuation slide proved to be a good means of rescuing people from the rafts and from the sea. From the platform people were pulled up the slide itself to safety

The decision to inflate the evacuation slide was quite extraordinary in the circumstances and testifies to good creative thinking.

Although the participating vessels contributed to the rescuing of many lives, it is established that their suitability for rescue operation in these severe weather conditions was limited. The safe launching of rescue boats or lifeboats was considered impossible, and rescuing people directly onto the vessels proved very difficult. The boat deck on the ferries, in most cases the only open deck, was situated more than 15 m above the water and lifting the survivors on board proved both risky and difficult. The experience of the rescue highlights the importance of having appliances permitting large ferries to recover people and liferafts from the surface. It also points out the need for liferafts to be strong enough to withstand lifting from the sea with full load.

17.6.2 Helicopters

The helicopter operation

When the first helicopter, OH-HVG, arrived at the scene of the accident at 0305 hrs, no one was yet able to give its crew an exact description of the situation. The crew assumed that people who had been able to leave the vessel were floating on liferafts or were in the sea. On the way to the scene of the accident the crew had decided that they would first try to rescue those who were in the water, and only then begin to rescue people from liferafts and lifeboats. On arrival the helicopter flew at a height of about 20 m, the crew searching for survivors in the light of the searchlights. The crew saw a number of lifejackets and liferafts but no people in the water. For this reason, some ten minutes after arrival, they began to examine the liferafts and rescue survivors from these. At this stage the helicopter had not yet received any rescue instructions from those responsible for conducting the operations (the OSC or MRCC Turku); so the crew had to make the decisions on its own.

When the two following helicopters Q 97 and Y 65 arrived on the scene at about 0400 hrs, they reported to the OSC and received instructions from him to concentrate on rescuing the survivors and for the time being leave those who were clearly dead.

Because of large wave-induced motions, landing on the vessels was very difficult. Few crews were trained for landing on vessels in heavy weather. Only the Finnish helicopters OH-HVG and OH- HVD made successful ship landings, setting down 36 people. The ability of helicopters to land on large passenger ferries in adverse weather conditions during rescue operations should be improved.

The Swedish helicopters took survivors primarily to Ut , but also to Hanko, Mariehamn or Huddinge Hospital in Sweden. The justification for these flights could be found in technical problems (e.g. a failed winch, an engine failure warning lamp). The pilot of the Q 97 had noted even on the first rescue flight that the survivors were in such bad condition that they had to be transported directly to the mainland for immediate hospitalisation. For this reason he flew directly to Hanko and landed on a sports field. No arrangements had been made in Hanko for receiving the patients, but local citizens helped in quickly transferring the survivors from the helicopter for treatment and care.

The medical specialists of the expert group at MRCC Turku, beginning work soon after 0300 hrs, decided that the survivors should be brought to the vessels or to Ut without delay to lessen the risk of hypothermia. The flight from the scene of the accident took five to ten minutes to the vessels,10 to 15 minutes to Ut , 20 to 25 minutes to Mariehamn, Nauvo and Hanko, and 25 to 30 minutes to Turku.

When MRCC Turku was informed that it was considered dangerous to land helicopters on the vessels it was decided to use primarily Ut , where medical personnel and facilities were available.

The diagram in Figure 17.4 shows the number of helicopters at the scene at different times, and the numbers of survivors rescued. The diagram is partly based on estimates. Since the times at which survivors were winched were not logged, the numbers rescued during an individual flight have been distributed evenly over the entire flight time. Helicopters are considered to have been in the area of the accident even when they were transporting survivors to a vessel or to Ut . Helicopters flying survivors further than this are deemed to have left the scene of the accident at the estimated time of departure.

Problems in action

At a time when survivors could still have been rescued, the winch wires on three Boeing Kawasaki helicopters malfunctioned, and the winch mechanism on one of these broke down. These helicopters had to interrupt the rescue operation for several hours, and one was transferred to transport duties. The survivors and rescue men who were left on the rafts or the sea when the winches malfunctioned were rescued by other helicopters, and one rescue man was transported, hanging onto the wire, to the deck of a vessel. These operations reduced the resources available for the rescue work. The unreliable operation of these winches had been identified prior to this accident and had also been reported to responsible parties as constituting a hazard to the rescue men. Unfortunately how- ever, no action had been taken. The fourth helicopter, a Super Puma, had an indicated engine problem and had to return to base.

The helicopters operational period was limited by fuel and the fatique of the rescue men. Using two rescue men made it possible to continue as long as fuel lasted. The rescue work was very exhausting both physically and mentally Already on the first helicopter on the scene the pilot noted that one rescue man was not enough. The man became quickly exhausted and thus the limiting factor of the operation.

Many of the rescue men were also injured, more or less seriously by hooks and by objects in the water such as life- boats.

It has subsequently been noted by many rescue men that in such conditions, with violent movements of the rafts causing the wires to jerk severely the NATO harness, in which the rescue man is in a sitting position, would have been more appropriate.

The rescue men had had varying training and experience, since the group included soldiers and border guard men on active duty, firemen and, in the helicopters of the Swedish Air Force, conscripts. There is no indication that the training of the rescue men was insufficient, but it is the opinion of the Commission that in rescue operations when more than a few persons are expected to be recovered from the water the participating helicopters should carry at least two rescue men.

At the beginning of the operation, the rafts that had been searched were not marked in any way. As a result, the same raft could have been searched several times. Later during the operations, instructions were given to mark searched rafts by ripping open the roof with a knife.

At about 0630 hrs the helicopter fuel supply, at Ut¢ ran out. After this, the helicopters flew the survivors and the deceased to Hanko or Nauvo, where refuelling took place. The fuel supply at Hanko, in turn, ran out at about 1000 hrs, and five helicopters had to wait for half an hour for a new supply

17.7 Other observations

17.7.1 Rescue equipment

Lifejackets

The ESTONIAs lifejackets were of an approved type common in passenger vessels. They were not equipped with lights since this was not required. There were donning instructions in cabins and at various locations on the boat deck, but many passengers had nevertheless difficulties, as described in 16.8, in putting them on properly

Many of those who were rescued from liferafts have stated that they had heard calls for help in the dark in the water nearby but because there were no lights they were unable to locate the persons calling for help.

Self-lighting lights on the lifejackets would have been vital during this rescue operation.

Lifeboats

The crew did not manage to launch any of the ten lifeboats. Nine broke loose when the vessel sank, and the tenth is still attached to its davits. The rapidly in- creasing list and the lack of time for organising the crew are considered to be the main reasons for this shortcoming. The lifeboats found drifting during the rescue operation had either capsized or were waterlogged

Three lifeboats were found near the place where the ESTONIA sank. A crew member had managed to climb into one of them and on each of the other two, which were floating upside down, six persons were hanging onto the bottom. One person from each was later washed away by the sea.

Once again traditional lifeboats proved to be useless in distress.

Liferafts

The liferafts were launched partly by crew members and passengers and partly by automatically release and inflation when the vessel sank. The rafts were found very difficult to use in the severe sea conditions partly for the following reasons:

- Many rafts capsized due to the wind pressure and drifted upside down, and many did not fully inflate.
- Some of the upside-down drifting rafts were later righted by the waves When this happened, however, those who were on the raft were again thrown into the sea and had great difficulties in climbingback.
- Capsized rafts with the canopy under water provided no shelter for those on board.
- The canopies of the rafts did not raise themselves automatically and the openings could not be closed properly
- Much water accumulated on the bottom of the rafts. In the worst case reported, there was 20 cm of water on the bottom of the raft. The bale scoops were so small that they were ineffective, and many survivors used their shoes to bale with.
- The knives on board the rafts proved to be useless.
- When the rafts were drifting the various lines for inflation and for keeping the raft in position for boarding constituted obstacles for people trying to board. The rope ladder went underneath the raft, swinging the feet of those who were trying to climb on, and thus affording practically no help
- The operating head was not properly tightened to the COZ pressure cylinder in many rafts found after the accident. This may be a reason why many rafts were not fully inflated.
- Entangled painter lines were also found around the operating heads.

As mentioned earlier the liferafts had no individual identification and were therefore not distinguishable. The helicopter crews and the mariners were un- able to keep track of which rafts had already been searched. Many are believed to have been searched many times, there- by delaying the search of others

Another problem was that the black colour of the liferafts' bottoms made the rafts difficult to detect when floating upside down.

Examination of the recovered liferafts shows that almost all the drift anchors and their ropes were missing. Likewise, many emergency packs were missing. The missing equipment may have been lost during the rescue operation or later.

Liferafts were under these circumstances useful rescue equipment but the serious deficiencies listed above diminish their value in heavy seas and when people have to climb into them from the water.

17.7.2 Journalists in helicopters

On the morning of the accident, from 0812 to 1137 hrs, a Swedish Boeing Kawasaki helicopter carried two TV re- porters. Between 1300 and 2025 hrs that afternoon, three Swedish Boeing Kawasaki helicopters each carried two reporters. A Finnish Super Puma helicopter flew journalists to Ut island from 1325 to 1530 hrs on the same day On the next day both Finnish and Swedish rescue helicopters flew journalists into the area.

The Swedish Defence Forces justified flying in journalists by noting the importance of public relations and by referring to the positive feed-back received. The helicopter crews were told that they had the right to refuse to carry journalists. The commander who gave permission further justified this decision by noting that he, before the 0812 hrs flight, had been told by the pilots that no more survivors had been found at the scene of the accident.

Representatives of the Finnish Frontier Guard noted that the journalists were flown in more than four hours after the last survivors had been found, and after a decision to reduce the numbers of helicopters in the area. The Finnish helicopter crew protested against their assignment, and flew the journalists around as quickly as possible to be able to return to search duties.

Carrying passengers on board helicopters engaged in rescue duties is not allowed without approval by the rescue leader, and is inappropriate in particular during such a large and difficult opera- tion. In critical situations the carrying of passengers reduces transport capacity Furthermore, it is questionable whether the privacy of the survivors should have been jeopardised immediately after their rescue by exposing them to cameras and journalists.

CHAPTER 18 COMPLIANCE WITH COLLISION BULKHEAD REQUIREMENTS

18.1 History of compliance with requirements

The SOLAS Convention has since its inception contained a requirement for an upper extension of the collision bulk- head in passenger ships with long for- ward superstructures. The rules of the classification societies did not at the time reflect the SOIAS requirements.

In the 1981 Amendments to SOLAS 1974 the requirements were extended to apply also to cargo vessels. Previously cargo ro-ro ferries had been developed with a ramp, located far enough forward to reach ashore. This location was generally further forward than that permitted by SOLAS for passenger vessels if the ramp was to form part of the upper extension of the collision bulkhead.

In Finland and Sweden the arrangement of the forward ramp in ro-ro passenger ferries seems to have been inherited from the cargo ferries. The Commission has not found any formal document showing approval, exemption or disapproval of any such design under the SOLAS requirements. The first reference that the SOLAS regulations for an upper extension of the collision bulkhead need not be fully applied is a letter of January 1979 concerning two passenger ferries for the Gotland traffic. An exchange of telexes in March 1981 between the ship owner and the Swedish Maritime Ad- ministration also exists, where the placing of the KRONPRINSESSAN VICTO- RIA's ramp too far forward (1800 mm too far forward under SOLAS 1974 and about 500 mm under 1981 draft Amendments) was accepted with a reference to "inter- national and Swedish practice". No such documentation has been found for the VIKING SALLY/ESTONIA or the DIANA II. A letter dated 20.4.1977 from the Finnish Maritime Administration to the shipyard, however, states that an excessively forward-placed ramp could not be accepted as an upper extension of the collision bulkhead in the TURELLA. Partial collision doors where thus built in e.g. the TURELLA and the ROSELLA.

Some of the first passenger ferries built at the beginning of the 1960s with bow visors had an "equivalent" upper extension of the collision bulkhead in the right place but only on the sides, leaving free access to the car deck aft of the bow ramp. The first passenger ferries were used in sheltered waters near land so that the SOLAS regulation on an exemption if the voyage remains within 20 nautical miles of the nearest land may have been in the background when the decisions were made.

It thus became common amongst the Finnish and Swedish Maritime Administrations to accept the forward-located bow ramp arrangement. Many ferries built for Baltic ferry operations from 1961 up to about 1985 had a forward-located bow ramp that did not meet the SOLAS requirement for passenger vessels regarding the location of the collision bulkhead upper extension.

A reason for reluctance to apply the regulations regarding position of the forward ramp fully may have been the IMO work throughout the 1970s on this subject, eventually leading up to the 1981 Amendments. The practical problems in fully applying the SOLAS requirements to ro-ro cargo ferries constituted one of the items considered during this work. The IMO work also resulted in an alter- native set of requirements regarding sub- division and stability of passenger ships, in which an upper extension of the collision bulkhead was only required under certain conditions. It may be that the Administrations were awaiting the out- come of this work before they started to change a long-established practice.

The 1981 Amendments permitted the upper extension of the collision bulkhead in vessels with a bulbous bow to be positioned further forward than the SO- LAS 1974 regulations did. The availability of the text already at the end of the 1970s may at that time have supported the practice of forward-located bow ramps. It has thus not been possible to find any formal steps taken in the affected countries regarding approval of the position of the forward ramp in any ship built during the period. There may have been a lenient attitude from the Administrations at the time as they had very limited staffs and relied heavily on the classification societies. These, in turn, did not in most cases have the authorisation to verify compliance with the SOLAS requirements.

Only when the 1981 Amendments to SOLAS 1974 came into force on 1 September 1984 specifying in further detail the requirements for the collision bulk- head in passenger ships as well as in cargo ships, did shipyards, administrations and classification societies start to follow the regulations in full.

18.2 Effects of non-compliance with requirements

Using the ramp in the ESTONIA as an extended collision bulkhead in compliance with SOLAS 1960 or 1974 would have required a more aft positioning and thus a considerably longer ramp. For housing the longer ramp on the car deck the ramp must have been divided into sections. An alternative would have been to add a second, movable barrier in the proper position and reaching up to deck 4. Both these solutions would have been more expensive and more complicated than the alternative chosen.

The 1981 Amendments to SOLAS 1974 accepted the ramp as a part of an extended collision bulkhead provided there was a second barrier of a minimum height of 2.3 m in the proper position. This solution was common in ro-ro passenger ferries built for the Finland-Sweden traffic at the same time and subsequent to the ESTONIA, among others the TURELLA and the ROSELLA (see Table 10.2). This solution was also considered in the building specification of the ES- TONIA. It was, however, rejected since it was "for the intended service not required by FB.N" (Finnish Board of Navigation). The Commission has not found any information on participation of representatives of the Finnish Maritime Ad- ministration in formulating this sentence.

It is the opinion of the Commission that an extended collision bulkhead, built in compliance with either SOLAS 1974 or the 1981 Amendments, would have increased the ESTONIA's chances of surviving the loss of the visor. The 2.3-m- high barriers built in the TURELLA and the ROSELLA in 1979 and 1980, respectively had however a rather low design load of about 2 m static water head and were not designed to withstand hydrodynamic impact loads which may arise if the ramp is fully open in heavy head or bow seas.

18.3 The role of the administration

The Finnish Maritime Administration was, according to a national decree, originally issued in 1920 (3.6.4), exempted from carrying out a hull survey as part of the basis for issuing the passenger ship safety certificate, if a vessel had a valid class certificate. The Administration did not therefore survey the hull construction during the building of the ESTO- NIA.

The Bureau Veritas regulations for the initial hull survey included compliance with all applicable requirements specified in the rules of the society and valid at the time. These rules did not include requirements for an upper extension of the collision bulkhead, and hence no reference to the position of such an extension.

According to the Finnish Administration, the problem concerning the deviation of the ramp location from the SOLAS requirement for an upper extension of the collision bulkhead was not known to its inspectors. Anyhow, ac- cording to the same information, the Administration would have accepted the deviation in line with previous practice, applied also by the Swedish Maritime Administration.

The Commission has noted that full responsibility for enforcing compliance with the Conventions nevertheless, ac- cording to SOLAS, remains with the Ad- ministration. The Commission has also noted that the unrestricted right of the Finnish Maritime Administration to rely on classification society hull surveys in this respect was withdrawn in the new decree on surveys of ships issued in 1983.

It seems obvious to the Commission that the interpretation of the SOLAS Convention's collision bulkhead regulations common at the time did not ensure satisfactory compliance with applicable rules and made it possible to design the ESTO- NIA in a way which may have contributed to her capsizal. The Commission finds it unacceptable that practice is developed that makes it possible to deviate from a Convention with no documentation or exemptions in the certificate.

CHAPTER 19 DEVELOPMENT OF REGULATIONS AFTER THE ACCIDENT

A Panel of Experts was set up within the International Maritime Organisation (IMO) shortly after the accident, with the task of investigating all aspects of safety related to ro-ro passenger vessels.

The Panel reported to the Maritime Safety Committee (MSC) meeting in May 1995 and work proceeded further in preparation for a SOLAS Conference to be held at IMO headquarters in the last week of November 1995.

The extensive proposals made to the Conference included controversial issues such as a requirement that all ro-ro passenger ships should be capable of maintaining positive stability in damaged condition with a quantity of water on the car deck corresponding to half a metre over the entire deck area.

Compliance with this requirement would involve extensive modifications to existing ferries and was found unacceptable to several IMO member states. The requirement was therefore not adopted.

The November 1995 Conference adopted a number of amendments to the SOL.AS 1974 Convention. They entered into force on 1 July 1997. The amendments were based on proposals put for- ward by the Panel.

The most important of the amendments are concerned with requirements for the bow doors and the stability of ro- ro passenger ships. The Conference agreed to significantly upgrade the dam- age stability requirement to be applied to all existing ro-ro passenger ships.

A new regulation II-1/8-1 will require existing ro-ro passenger ships to comply fully with SOLAS 90 in accordance with an agreed phase-in programme, which will depend on the ship's damage stability index (A/Amax value).

A new regulation II-1/8-2 was also adopted which contains special requirements for ro-ro passenger ships carrying 400 passengers or more. This is intended either to require that new ships to be built, and existing ships already built, to a one-compartment-flooded standard should be phased out; or to ensure that they can survive with two compartments flooded following damage.

Other amendments to Chapter II-1 deal with such issues as extending the collision bulkhead, keeping doors that do not comply with Convention provisions closed during navigation, the strength of ventilation trunks penetrating the bulkhead deck, and the positions of the ends of air pipes. The upper extension of a collision bulkhead must be so arranged as to preclude the possibility of a bow door causing damage to it in the case of damage to, or detachment of, the door.

Three new regulations added to Chapter II-1 deal with watertight integrity from the ro-ro deck (bulkhead deck) to spaces below, access to ro-ro decks when the ship is under way (when they are to be banned to passengers) and closure of bulkheads on the ro-ro deck.

Regulation II-1/23-2, which deals with the integrity of the hull and super-structure, damage prevention and control, has been completely replaced.

Indicators shall be provided on the navigation bridge for all shell doors, loading doors and other closing appliances for doors which, if left open, could lead to flooding of ro-ro cargo space.

Television surveillance and water leak- age detection systems shall be arranged to provide an indication to the navigation bridge and to the engine control station of any leakage through inner and outer bow doors, stern doors or any shell doors which could lead to flooding of ro-ro cargo spaces.

Amendments have also been made to Chapter II-2. A new regulation II-2/28-1 deals with escape routes on ro-ro passenger ships. It introduces requirements for handrails in corridors along escape routes. The routes must not be obstructed. For ships constructed on or after 1 July 1997 the lower part of bulkheads along escape routes must be strengthened so that the bulkheads can be walked upon safely when the ship is at a large angle of heel.

The amendments to Chapter III, which deals with life-saving appliances and arrangements, include a number of important additions. Requirements for liferafts are more stringent. Liferafts must be served by marine evacuation systems and must be automatically self-righting, or be of the canopied reversible type capable of operating safely whichever way up.

Ro-ro passenger ships will be required to carry at least one fast rescue boat. The ships must also be fitted with means for recovering survivors from the water and transferring them from rescue units to the ship.

Sufficient numbers of lifejackets will have to be provided near the assembly station. Each lifejacket shall be fitted with a light. Some of the above mentioned amendments to Chapter III will not be required on existing ships until 1 July 2000.

New regulation III/24-2 covers information to passengers. By regulation III/24-3, all ro-ro passenger ships shall be provided with a helicopter pick-up area, on ships constructed before 1 July 1997 to apply latest from the first periodical survey after that date. Passenger ships of 130 m of length and upwards, constructed by or after 1 July 1997, shall from 1 July 1999 be fitted with a helicopter landing area.

A number of amendments have been made to Chapter IV dealing with radio communications. A distress panel is to be fitted at the conning position. This is to enable a distress alert to be given by pressing a single button. All passenger ships are to be provided with means for two-way on-scene radio communications for SAR purposes using the aeronautical frequencies. At least one properly qualified person will have to be assigned to perform only radio communication du- ties during distress incidents.

Chapter V (safety of navigation) has also been amended. Obligations and procedures in the event of emergencies have been clarified, a working language is to be established on passenger ships and ships trading on fixed routes must carry a plan for co- operation with appropriate SAR services.

A new regulation 23 deals with operational limitations, such as restrictions in operating areas, weather restrictions, sea state conditions, limits on permissible loads, speed and other factors. The list of all such limitations shall be documented and kept on board readily available to the master.

Chapter VI (carriage of cargoes) has been amended to require cargo units to be loaded, stowed and secured in accordance with a Cargo Securing Manual. In addition to the amendments, the Conference adopted 13 resolutions. Many of them are designed to assist implementation of the amendments adopted by the Conference.

Five resolutions concerning the safety of ro-ro passenger ships were adopted by the IMO Assembly in November 1995, which was run prior to the SOLAS Conference

Resolution A.793(19) is concerned with the strength and the securing and locking arrangement of shell doors on ro- ro passenger ships. It notes that the Inter- national Association of Classification Societies (IACS) Unified Requirement for Bow Doors (as amended in 1995) will apply not only to new ro-ro passenger ships but retrospectively to existing ships as well.

In 1996 IACS reviewed its Unified Requirement for Side Shell Doors and Stern Doors with retrospective application to existing ro-ro passenger ships.

As seven countries were dissatisfied with the Conference rejection of the pro- posed new stability requirements dealing with water on car deck, two meetings of parties requiring more stringent regional regulations were held in Stockholm in January and February 1996. Nineteen countries participated.

The meetings agreed on specific requirements for the capability of the ferry to maintain stability with water on the car deck. The quantity of water on deck is dependent on residual freeboard after damage, on significant wave height and on variable angle of list at the damaged side of the ferry

The Stockholm meetings adopted a proposed Agreement. By 25 September 1996 seven states had become parties and the Agreement entered into force on 1 April 1997.

In accordance with this Agreement, specific stability requirements shall apply to all ro-ro passenger ships undertaking regular scheduled international voyages between designated ports in North West Europe and the Baltic Sea, irrespective of flag. No more favourable treatment should be given to ships entitled to fly the flag of states non-parties to the Agreement. Ro-ro passenger ships shall comply with the provisions of the Agreement not later than dates varying from 1 April 1997 to 1 October 2002 depending on the ship's damage stability index (A/ Amax).

In July 1995 the Conference of Par- ties to the International Convention on Standards of Training, Certification and Watchkeeping of Seafarers (STCW) 1978, adopted amendments to the STCW Annex. The ¢7th session of the MSC in December 1996 approved additional amendments to the STCW Convention and Code. These amendments require crisis management and human behaviour training for masters, officers, ratings and other personnel on ro-ro passenger vessels.

PART 4 CONCLUSIONS

CHAPTER 20 FINDINGS

Accident

The ro-ro passenger ferry ESTONIA sank in the northern Baltic Sea during the early hours of 28 September 1994. Of the 989 people on board, 137 survived. All 95 victims recovered from the sea have been identified and 757 people are still missing.

Weather

- The wind at about 0100 hrs at the site of the accident was south-westerly, 18-20 m/s, and the significant wave height was about 4 m.
- At the time of the accident the ESTONIA was encountering the waves on her port bow.
- The wave-induced motion made several passengers seasick but the situation on board was not exceptional.

Ship's condition

- The vessel was seaworthy and properly manned.
- The cargo was secured to normal standard and the visor was properly closed and secured on departure.
- The vessel had a starboard list of about one degree when she gained the open sea.

Failure

- The failure sequence may have started at about 0055 hrs when the AB seaman heard a metallic bang at the bow ramp.

- The locking devices and the hinges of the bow visor failed fully under one or two wave impact loads on the visor shortly after 0100 hrs.
- The visor worked its way forward and forced the ramp partly open due to mechanical interference between the visor and the ramp, inherent in the design. Water started entering the car deck at the sides of the partly open ramp.
- The ramp rested for a while within the visor before the visor at about 0115 hrs fell into the sea, pulling the ramp full open.

Capsize

- Large amounts of water entered the car deck and in a few minutes a starboard list of more than 15o developed.
- The main engines stopped at about 0120 hrs, one after the other, due to lubricating oil pressure loss caused by a list of about 30o.
- The vessel drifted with her starboard side towards the waves.
- At about 0125 hrs the list was more than 40o. By then, windows and a door had broken in the aft part on the starboard side, allowing progressive flooding of the accommodation. The main generators stopped.
- As the list increased the ESTONIA started to sink stern first. At about 0135 hrs the list was about 80o.
- The vessel disappeared from the surface at about 0150 hrs.

Action by the crew

- Two reports of unusual sounds from the bow area were given to the officers of the watch, the first about 20 minutes prior to the loss of the visor.

- Attempts were made to find the reason for the sounds.

- The master arrived at the bridge and was present when the second attempt was initiated shortly after 0100 hrs.
- The speed setting was maintained until the list developed. At about 0100 hrs the speed was about 14 knots, with all four main engines running at full service speed setting.
- The visor indicator lamps on the bridge did not show when the visor was detached, and the visor was not visible from the conning position. Nor did the lamps show when the ramp was forced open.

- The ingress of water at the sides of the partly open bow ramp was observed on a monitor in the engine control room, but no information was exchanged with the bridge.
- As the list developed the officers of the watch reduced the speed and initiated a turn to port. They also ordered the engineer to compensate for the list by pumping ballast, but the pump sucked air and, furthermore, the tank was almost full. The officers of the watch also closed the watertight doors.
- The first known Mayday call from the ESTONIA was transmitted at 0122 hrs, and at about the same time the lifeboat alarm was given. Shortly before that, a brief alarm in Estonian was given over the public address system. Just after this, the crew was alerted by a coded fire alarm. No general information was given to the passengers during the accident.
- Besides the master and the two officers of the watch, at least the chief officer and the third officer were on the bridge at the time of the distress traffic.

Technical matters

- There were no detailed design re-quirements for bow visors in the rules of Bureau Ueritas, the classification society concerned, at the time of the building of the ESTONIA.
- The Finnish Maritime Administration was, according to a national decree, exempt from doing hull surveys of vessels holding valid class certificates issued by authorised classification societies.
- The visor locking devices were not examined for approval by the Finnish Maritime Administration, nor by Bureau Veritas.
- The visor design load and the assumed load distribution on the attachments did not take realistic wave impact loads into account.
- The visor locking devices installed were not manufactured in accordance with the design intentions.
- No safety margin was incorporated in the total load-carrying capacity of the visor attachment system.
- The attachment system as installed was able to withstand a resultant wave force only slightly above the design load used.
- A long series of bow visor incidents on other ships had not led to general action to reinforce the attachments of bow doors on existing ro-ro passenger ferries, including the ESTONIA.
- Wave impact loads generated on the night of the accident exceeded the combined strength of the visor attachments.
- Wave impact loads on the visor increased very quickly with increasing significant wave height, while forward speed had a smaller effect on the loads.

- The SOLAS requirements for an upper extension of the collision bulkhead were not satisfied.
- The general maintenance standard of the visor was satisfactory Existing minor maintenance deficiencies were not significant factors in the accident.

Evacuation

- The time available for evacuation was very short, between 10 and 20 minutes.
- There was no organised evacuation.
- The evacuation was hampered by the rapid increase in the list, by narrow passages, by transverse staircases, by objects coming loose and by crowding. About 300 people reached the outer decks. Most victims remained trapped inside the vessel.
- The lifesaving equipment in many cases did not function as intended. Lifeboats could not be lowered.

Distress traffc

- Mayday calls were received by 14 radio stations including MRCC Turku. At the beginning the SILJA EUROPA took the role of control station for the distress traffic.
- The distress traffic was not conducted in accordance with the procedures required by the radio regulations.
- The ESTONIA's two EPIRBs were not activated and could therefore not transmit when released.
- MRCC Turku did not announce on the radio that they were conducting the operation.
- Helsinki Radio did not hear the ESTONIA's distress calls or the distress traffic.
- Helsinki Radio transmitted a Pan-Pan call (urgent message) at 0150 hrs instead of the distress message requested by MRCC Turku

Rescue operation

- Initially the accident was not treated as a major accident. It was formally designated as such at 0230.
- MRCC Turku started alerting rescue units at 0126 hrs. One standby helicopter was alerted at 0135 hrs, another at 0218 hrs, and the military helicopters at 0252 hrs.
- Assistance by Swedish helicopters was agreed at 0158 hrs.
- The master of the SILJA EUROPA was appointed On-Scene Commander (OSC) at 0205 hrs.

- The first rescue unit, the MARIELLA, arrived on the scene of the accident at 0212 hrs, 50 minutes after the first distress call.
- MRCC Tallinn was informed of the accident at 0255 hrs by MRCC Helsinki.
- The first helicopter arrived at 0305 hrs.
- Two Finnish helicopters landed survivors on the passenger ferries. Other helicopters carried rescued persons to land.
- An air co-ordinator arrived to assist the OSC at 0650 hrs and a surface search co-ordinator arrived at 0945 hrs.
- The participating vessels did not launch lifeboats or MOB boats due to the heavy weather. Their rescue equipment was not suitable for picking up people from the water or from rafts.
- Winch problems in three Swedish Navy helicopters seriously limited their rescue capacity
- Some helicopters carried journalists during the later rescue flights.
- Of the approximately 300 people who reached the open decks, some 160 succeeded in climbing onto liferafts, and a few climbed onto capsized lifeboats. Helicopters rescued 104 people, and vessels rescued 34.

CHAPTER 21 CONCLUSION

Failure

- The ESTONIA's bow visor locking devices failed due to wave-induced impact loads creating opening moments about the deck hinges.

- The ESTONIA had experienced sea conditions of equivalent severity to those on the night of the accident only once or twice before on a voyage from Tallinn to Stockholm. The probability of the vessel encountering heavy bow seas in her earlier service had been very small. Thus, the failure occurred in what were most likely the worst wave load conditions she ever encountered.

- The visor attachments were not designed according to realistic design assumptions, including the design load level, load distribution to the attachments and the failure mode. The attachments were constructed with less strength than the simplistic calculations required. It is believed that this discrepancy was due to lack of sufficiently detailed manufacturing and installation instructions for certain parts of the devices.

- The bowvisor locking devices should have been several times stronger to have a reasonable level of safety for the regular traffic between Tallinn and Stockholm. At the time of the ESTONIA's construction, despite scattered information, the industry's general experience of hydrodynamic loads on large ship structures was limited, and the design procedures for bow doors were not well-established.

- The classification society design requirements for bow doors became more clearly defined and the design load levels were in general increased after the ESTONIA had been built but, according to established practice, the new rules did not apply to existing vessels.

- Numerous bow visor incidents occurred prior to the accident on vessels built before and after the ESTONIA for the Finland-Sweden traffic. These included an incident on the DIANA II, a near-sister vessel to the ESTONIA, but the experience did not lead to systematic inspection and requirements for reinforcement of visor attachments on existing vessels.

- Information on bow visor incidents was not systematically collected, analysed and spread within the shipping industry Thus masters on board had, in general, very little knowledge of the potential danger of the bow visor closure concept.

Capsize

- The ESTONIA capsized due to large amounts of water entering the car deck,1oss of stability and subsequent flooding of the accommodation decks.

- The full-width open car deck contributed to the rapid increase in the list. The turn to port - exposing first the open bow and later the listed side to the waves - shortened the time until the first windows and doors broke, which led to progressive flooding and sinking. The design arrangement of bow ramp engaging with visor through the boxlike housing had crucial consequences for the development of the accident.

- Non-compliance with the SOLAS regulations regarding the upper extension of the collision bulkhead, accepted originally by the national administration, may have contributed to the vessel's capsizing.

Action by the crew

- The initial action by the officers on the bridge indicates that they did not realise that the bow was fully open when the list started to develop.

- The bridge officers did not reduce speed after receiving two reports of metallic sounds and ordering an investigation of the bow area. A rapid decrease in speed at this time would have significantly increased the chances of survival.

- The visor could not be seen from the conning position, which the Comission considers a significant contributing factor to the capsize. In all incidents known to the Commission where the visor has opened at sea due to locking device failure, the opening was observed visually from the bridge and the officers of the watch were able quickly to take appropriate action.

- There are indications that the crew did not use all means to seek or exchange information regarding the occurrence at a stage when it would still have been possible to influence the development of the accident. The bridge crew apparently did not look at the TV monitor which would have shown them that water was entering the car deck; nor did they ask those in the control room from where the ingress was observed, or get information from them.

- The position sensors for signallamps showing locked visor were connected to the side locking bolts in such a way that the lamp on the bridge showed locked visor even after the visor had tumbled into the sea. The indirect information on the status of the visor was thus misleading. The signallamp for locked ramp was most likely not on because one of the locking bolts was not fully extended. There was thus no lamp warning when the visor had forced the ramp partly open and it was resting inside the visor.

- It is most likely that the crew were unaware of visor incidents involving other vessels, in particular the DIANA II.

Evacuation

- The rapid increase in the list contributed to the large loss of life.

- The lifeboat alarm was not given until about five minutes after the list developed, nor was any information given to the passengers over the public address system. By the time the alarm was given, the list made escaping from inside the vessel very difficult. This together with problems in using lifesaving equipment contributed to the tragic outcome.

Rescue operation

- The alarming of helicopters was late.

- The helicopters had a key part in the rescue operation by rescuing most of the people who had succeeded in climbing onto liferafts or lifeboats.

- One rescue man per helicopter was not enough due to the very exhausting rescue work.

- It is deemed inappropriate for helicopters to carry journalists in critical situations and where they may encroach on the privacy of survivors.

- The main reasons for the delay in issuing alarms in general were that the distress traffic was conducted separately from MRCC Turku, and that there was only one person on duty at MRCC Turku, at MRCC Helsinki and at Helsinki Radio, respectively.

- In the Finnish MRCCs the instructions regarding distress traffic were inadequate.

- The lifesaving equipment of vessels participating in the rescue operation proved unsuitable for rescuing people from the water in the prevailing heavy weather conditions.

CHAPTER 22 RECOMMENDATIONS

Introduction

The Commission notes that work has started on development of regulations in line with the three recommendations given in the Part-Report. This work includes IACS' new stricter requirements on the strength of locking arrangements for shell doors. The requirements will apply retroactively to existing ships. New amendments to SOLAS require that damage to, or detachment of, a bow door may not cause damage to the upper extension of the collision bulkhead. IMO has also decided on full enforcement of the

SOLAS 90 damage stability regulations. Several countries in Northern Europe have agreed on more stringent regional regulations on damage stability for ro-ro passenger ferries in regular traffic. These regulations address the effects of water trapped on a car deck. The work by IMO after the ESTONIA accident is reviewed in Chapter 19 of the present report. It is the opinion of the Commission that application of the new regulations will significantly improve the safety of ro-ro passenger vessels. However, based on the ESTONIA experience, the Commission finds reason to present the following further recommendations.

Ship design and construction

The installed bow visor locking devices were not thoroughly designed and manufactured, and were not inspected for approval by any external authority The installation did not incorporate a sufficient safety margin with regard to the design load level used. Further, the consequence of mechanical interference between visor and ramp was not realised before this accident. For these reasons,

- formal safety assessments and strict quality assurance procedures must be applied in design, manufacturing, assembly and approval of components critical for the safety of passenger vessels. The design basis for elderly tonnage must be reviewed in the light of new knowledge and standards of safety. A clearer relationship and division of responsibility between the shipyard, ship owner, classification society and administration needs to be established in this context.

The visor lock indicator on the bridge was accepted by the national maritime administration according to the SOLAS amendments after the HERALD OF FREE ENTERPRISE accident. However, it did not show that the visor was detached. Therefore,

- alarm systems should be constructed so that the actual and complete status of entire functions is supervised, rather than only parts thereof. Alarms should be limited to critical functions and should always lead to defined operational actions.

Operation

Upgrading of design requirements and a series of visor incidents in the Baltic area had not led to strengthening of locking devices, nor to operative instructions. The extent of previous visor incidents was not generally known among operators at the time of the ESTONIA accident. Hence,

- procedures for collecting and analysing incident data must be improved and upgrading of existing vessels as regards the safety of human life must become regular. Ways of distributing this information efficiently and internationally must be established. The responsibility for following up the status of existing ships must be taken by the national authorities, supported by the classification societies.

- Operational guidelines and limits for manoeuvring in heavy weather should be issued to all passenger ferries. The safety limits should be based on ship-builders' original design levels and on the level of upgrading of the vessel with respect to increased design requirements after building. Documentation of operational limits must be included in ship certificates, and,

- the crews of ro-ro passenger ferries should have clear instructions on maximising their vessels' chances of survival in cases of water ingress to the car deck. Possible corrective action should be simulated and practised.

Evacuation

A significant factor in the ESTONIA accident was the very quick increase in the list to an angle exceeding 30° , leading to the loss of manoeuvrability to difficulties in getting out from inside the vessel and to the start of progressive flooding. Investigations have shown that relatively small changes in construction could have had a significant effect on the outcome of the evacuation. Therefore,

- all existing passenger vessels should be re-assessed with regard to evacuation and all reasonable measures taken to increase the time available and possibilities for evacuation.

Rescue

Serious shortcomings in the effectiveness of the on-board rescue equipment became apparent during the ESTONIA accident and the rescue operation. The equipment fulfilled the requirements and is of standard type common on comparable vessels.

- The Commission recommends urgent action to develop new lifesaving concepts and equipment, especially for passenger vessels where large numbers of untrained people are to be rescued.

- Systems should be developed for enhancing the ability of passenger ferries to rescue people from the sea in heavy weather.

- All-weather systems should be developed for enhancing co-operation between ferries and helicopters in sea rescue.

Distress traffic

No station conducted the distress traffic according to the procedures required by the radio regulations. In the normal work of deck officers and radio operators it is understandably difficult to maintain very firm routines for distress communications. However, good simulators for training in maritime radio systems and communications are available. Therefore,

- Certain key persons, such as deck officers on large passenger vessels and rescue centre radio operators, should regularly update their practical knowledge of distress and safety traffic using a maritime radio simulator.