Investigation report

C 1/2002 M

M/S FJORD PEARL, Shifting of Cargo and Danger Situation, January 2, 2002

This investigation report was written to improve safety and prevent new accidents. The report does not address the possible responsibility or liability caused by the accident. The investigation report should not be used for purposes other than the improvement of safety.

SUMMARY

M/S FJORD PEARL loaded a total of 8446 m^3 of timber at Pietarsaari on December 27-31, 2001. The timber was sawn length packages and covered by plastic-coated paper hoods. South of the Aland Islands, the wind increased to 17-18 m/s in the evening and at night on January 1, 2002. At midnight, the wind force was already 20 m/s with gusts up to 27 m/s. The vessel was travelling at heading 143° and was rolling and pitching violently. The Master detected a wind list of about 5° and the rolling was 5-10° to both sides. At 01:47 a.m. local time the heading had to be changed to 208°. During the turn, the vessel first listed about 15° to port and immediately after 30° to starboard at which point the shifting of the deck cargo about 1-1.5 m to starboard was noticed. The vessel remained listed about 22° to starboard. The speed was reduced to the slowest possible steering speed and the bow was turned into the wind. In a few hours the list increased to 26° due to leaks. By using all of pump capacity the list was stabilised to this reading. Upon assessing the situation, it was noted that ice was forming and that water was leaking into the fuel and ballast tanks and to the holds. The Master decided to seek to an emergency harbour to ensure the safety of the crew and of the vessel and he sent a radio message to Turku Radio concerning the emergency situation.

Escorted by the maritime rescue organisation the vessel arrived at Airisto where the rescue company lightened the deck cargo. The vessel was then transferred to Turku port for repairs and reloading. Since no deficiencies compromising safety were detected in the securing of the deck cargo or in other activities, the Accident Investigation Board decided to investigate the incident.

The investigation produced evidence of dangerous development of the friction coefficients in winter conditions. The Master of the vessel should be informed of the detected safety risks when the vessel is loading.

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INTRODUCTION

MRCC Turku reported the accident at 13:20 on January 2, 2002 to the Accident Investigation Board, who decided to conduct an investigation into it. Pertti Siivonen, Major retired, was appointed as Chairman of the investigation team, and Kalervo Mattila, Head of Occupational Safety and Kai Mäcklin, District Inspector, were called as members. The team invited Olavi Huuska, Lic.Tech., as an expert.

In the investigation, special attention has been paid to studying the friction coefficients of the deck cargo under the prevailing circumstances. The effect of winter conditions on the friction coefficients has been studied in tests, the forces affecting the deck cargo and the critical friction coefficient/listing angle combinations have been estimated and the cargo-securing manual compared to the data collected from the accident vessel. Finally, recommendations for preventing similar accidents in the future have been issued.

The representative of the Accident Investigation Board interviewed the officers of the vessel and photographed her when she was in Turku. Two members of the team visited the vessel in May when she called at Pietarsaari and asked further questions. Additional material was later requested from the vessel. Data relating to the subject has been collected from various sources.

The presented data is based on written statements by the officers, on memos by the persons who interviewed the officers, on photographs and on the technical documentation received from the vessel. An expert of the Accident Investigation Board performed stability calculations, cargo shift calculations and strength calculations of the securings.

In the estimation of the investigation team, the data on the accident and on the vessel was sufficient for conducting an investigation into the accident. The new waterline is estimated from the photographs and from the calculations performed on board the vessel after the accident. New hydrostatic calculations have not been made nor has hydrostatic data of the vessel been available.

The investigator authorised by the flag state of the vessel, Malta, gave a separate report of the incident to the flag state.

The draft report was sent for statement and comments to Finnish Maritime Authorities, Maritime Authorities of the flag state, to the vessel, to stevedores (Finnsteve Turku and Botnia Shipping Pietarsaari), to the Finnish Institute of Occupational Health (Helsinki) and to the Central Marine Research & Design Institute (CNIIMF) in St Petersburg. According to the received statements and comments some modifications have been made in the report and written statements in original language are included in the report as enclosures.

The statement received from St. Petersburg includes a proposal for further international investigation concerning the safety problem found in the report.

Figure 1. M/S FJORD PEARL on her way to Turku

Figure 2. M/S FJORD PEARL on her way to Turku

Figure 3. M/S FJORD PEARL on her way toward Utö

1 GENERAL DESCRIPTION AND INVESTIGATION OF THE ACCIDENT

1.1 Vessel

The design of the vessel had included carrying timber cargo on deck. The vessel had been built according to international rules and regulations and according to the rules and regulations by the former Soviet Union on this type of a vessel. The flotation of the ship is guaranteed with one compartment flooded.

1.1.1 General data

Name of the Vessel	M/S FJORD PEARL, former PIONER ONEGI
Built	1975, Vyborg
Home Port	Valletta, Malta
IMO Number	7524354
Radio Code	9HXG4
Type	Bulk cargo, e.g. for carrying timber
Crew	16 persons
Owner	Fjord Pearl Shipping Company Ltd
Classification	Originally Morskoi Registr KM ✪ УЛ [1] A2, timber cargo vessel
	Presently Registro Italiano Navale
Maximum Length	130.32 m
Length pp	119.03 m
Width	17.33 m
Timber Draught	7.33 m
Height, Main Deck	8.49 m
Displacement max	10720 t
DWT, max	6780 t
Engine Power	4478 kW
Speed	15.6 kn

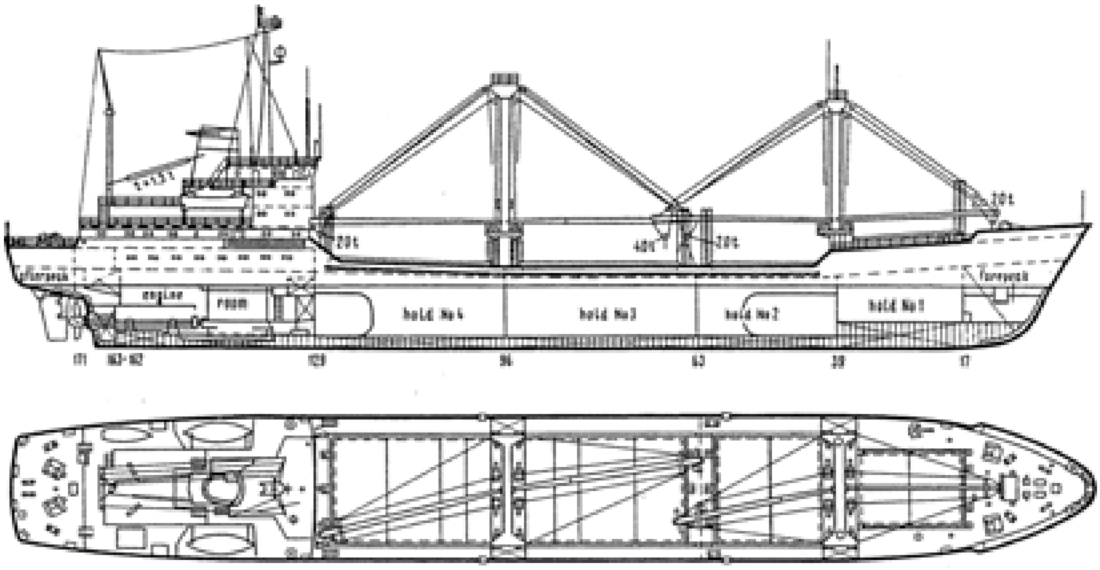

Figure 4. M/S FJORD PEARL

Table 1. Vessels hold data

Hold	Area m^2	Volume m^3	Dimensions		Max weight per square t/m^2
			Length m	Width m	
Hold 1	236.80	1370	14.8	16.0	10.0
Hold 2	206.64	1750	16.4	12.6	12.0
Hold 3	283.50	2530	22.5	12.6	12.0
Hold 4	283.50	2600	22.5	12.6	12.0
Total, all holds	1010.44	8250			
Hatch covers					
№1	104.16		12.4	8.4	1.75
№2	156.24		12.4	12.6	2.2
№1	233.31		18.5	12.6	2.2
№1	235.62		18.7	12.6	2.2
Total, hatch covers	729.33				

1.1.2 Crew

The vessel had a crew of 16 persons. The nationality of the crew was Russian.

1.1.3 Bridge and its equipment

The bridge of the vessel carried the necessary navigation equipment.

Figure 5. General picture of the bridge of the ship

1.1.4 Cargo handling equipment

The vessel has winch-operated booms. There is a sufficient selection of securing equipment for securing various loads.

1.2 Cargo and events during loading

1.2.1 Cargo of the vessel

The entire cargo of the vessel consisted of length sorted sawn timber packages, flush at both ends. The dimensions of the packages were according to the standards: width and height 1.00-1.15 m. The lengths of the packages varied between 3.60-6.00 m. Partially fully packages were used for packing the deck load.

The packages were covered with plastic hoods or with plastic-coated kraft paper. The hood protected the cargo on five sides; the bottom side was not covered. The top layer of the hood contained a non-slip surface. There were several different non-slip surfaces.

The total amount of cargo was 8446 m^3, of which 2690 m^3 were stowed on deck. 8190 m^3 of the cargo was pine and the rest was spruce. The actual shipping weight for pine was 0.55 t/m^3 and for spruce, 0.50 t/m^3.

The ports of destination were Oran and Skidka in Algeria. All the cargo bound for Oran, 1409 m^3, was up on deck. Of the cargo bound for Skidka, 1281 m^3 were on deck.

The cargo was stored in open air, since it had been shipped on deck option that allows this. The cargo was unloaded onto a storage field in December 2001. The weather conditions varied between frost and thaw and rain and snow.

The cargo and its placement are documented in the following documents: Manifest of Cargo, Loading Order and Stowage Plan.

Figure 6. Wintry timber packages waiting for transfer on board (photo by the Finnish Institute of Occupational Health)

Figure 7. In winter, the packages are snowy and icy (photos by the Finnish Institute of Occupational Health)

1.2.2 Loading instructions of the vessel

The IMO Maritime Safety Committee published Circular 745 (MSC / Circ.745) on July 13, 1996. According to this circular, a Cargo Securing Manual approved by the Navigation authorities of the flag state of the vessel has been required starting from 1998 from all vessels flagged in a state belonging to the IMO (International Maritime Organisation). The circular contains directions for drafting the cargo-securing manual.

The vessel had a comprehensive cargo-securing manual approved by the flag state. The cargo-securing manual is in Russian (наставление по креплению грузов), Cargo Securing Manual, 1950п/513-CSM/1-19, 1997, 105 pages). The Ministry of Traffic of the Russian Federation originally approved the cargo-securing manual. The navigation authority of the present flag state, Malta (Malta Maritime Authority) has also approved it. The section on handling sawn timber was translated into Finnish for purposes of the investigation. Knowing Russian one of the group members has also studied the original text.

The Cargo-Securing Manual is based on the Russian and IMO cargo shipping guidelines. With regard to timber, the manual is based on the 1992 IMO guidelines ”Code for Safe Practise for Ships Carrying Timber Cargoes”. The guidelines were first published in 1972 and have an official status of recommendation. The guidelines are based on practical experience and good seamanship practices.

1.2.3 Loading of the vessel at Pietarsaari

Weather during loading

The weather data is based on reports by the officers and on the data of the Finnish Meteorological Institute. When studying the weather information, the time difference of UTC being -2h Finnish time has been taken into consideration.

During the loading on December 27, 2001, the temperature at Pietarsaari was between -8 and -14°C, and on December 28 to December 30 about -20°C and on December 31, about -10°C. It snowed occasionally during the loading and the wind speed remained normally below 5 m/s; the wind speeds on December 27 and on December 31 climbed temporarily to 6-11 m/s. The direction of the wind varied.

Loading

The loading of the vessel was started at Pietarsaari on Thursday, December 27, 2001. The packages were transported alongside the ship by a forklift truck. A shore crane was used for the loading. The work continued from 7- 24 on the Thursday (1-2 groups) and from 7-16 on Friday, December 28 (2-3 groups). No loading took place on Saturday, December 29. One group was working on Sunday, December 30 from 10-17. The loading of the ship was completed on Monday, December 31, on which day two groups were working from 7-15:30.

Looped black polypropene ropes were used for the lifting. The timber packages were usually lifted in pairs with two lifting ropes. The ropes were left with the cargo. The slack rope remained coiled on top of the packages.

Holds 1, 2 and 3 were filled on December 28 and hold 4 on December 30. The deck was loaded on December 31.

The sawn timber packages were in part covered with snow and ice. The stevedore removed snow and ice by blasting air and by chiselling. The ice and the snow could not be fully removed. The load was packed as tightly as possible under the supervision of the ship officers. The second tier of deck cargo was placed across. Due to the varying lengths, gaps of half a metre remained here and there.

Figure 8. Placement of packages of sawn timber on deck (photo by the Finnish Institute of Occupational Health, not of the FJORD PEARL)

Dunnage was laid against the deck only under the furthermost stack of sawn timber stowed lengthwise between the railing and the edge of the hatch. In other places, the lift ropes remained between the tiers. At the hatch cover, the ropes were between the package and the hatch cover. Elsewhere in the seams between the tiers the ropes met in various ways, when the tight rope underneath the timber stack came into contact with the slack rope coiling on top of the packages in the previous tier. The diameter of the lifting ropes was about 3 cm. Under the weight the ropes were squeezed resulting in a thickness of 1-3 cm and width of 6-4 cm, depending on the weight on top of them.

Uprights

Before loading on the weather deck the crew of the vessel hoisted nine wooden uprights to each side of the vessel with the boom of the ship. The uprights belonged to the ship, were 5-6 m in length and 150-280 mm in diameter. The uprights were lowered through a hoop formed by a bent steel bar on the railing and the bottom end was positioned into a frame on the deck. A gap of 5 cm remained between the uprights and the outermost timber stacks for the cover. The uprights were not used for supporting the deck cargo but for keeping the stacks from toppling during the loading when the deck cargo was not yet secured.

Figure 9. Installation and placement of the uprights on M/S FJORD PEARL, May 2002

Securing the deck cargo

When the loading was finished the crew of the vessel covered the deck cargo with tarpaulins. The crew placed planks lengthwise over the tarpaulins and put into place the cargo securing wires and tightened them.

The lifting ropes of the cargo, two per package or pair of packages were left slack on top of the sawn timber packages. This resulted in the following combinations of two horizontal surfaces (the numbers refer to figure 10):

1. Two packages lengthwise stacked staggered on top of one another.
2. Packages stowed lengthwise on top of packages stowed across.
3. Packages stowed across on top of packages stowed lengthwise.
4. Packages lengthwise on top of a cargo hatch.
5. At the sides lengthwise packages stowed evenly on top of one another.
6. At the sides the lowermost lengthwise packages dunnage was placed.

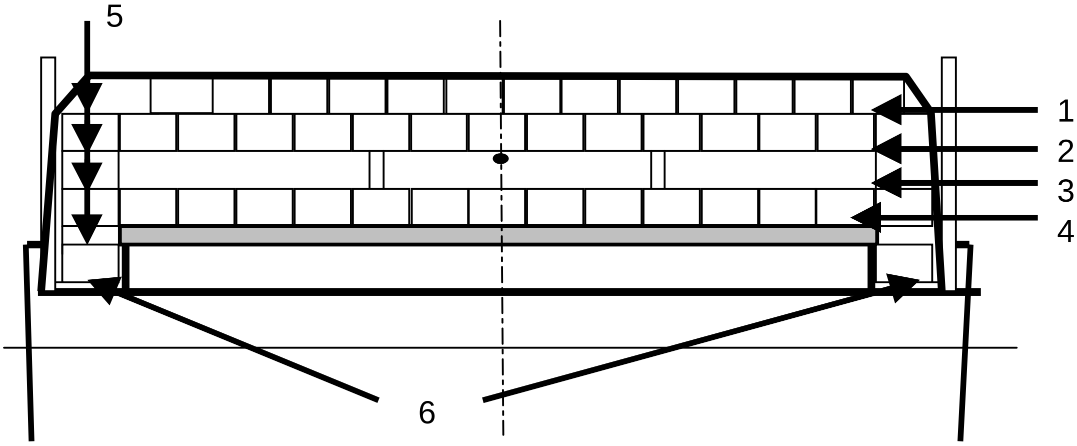

Figure 10. Cross-section of the secured deck cargo, bow end of hold 4 and the location of the various friction surfaces

The deck cargo consisted of sawn timber packages from various sawmills with different protective hoods. Figure 11 shows the supposed distribution of the various hoods, based on the stowage plan of the vessel. The placement is significant since the friction coefficient of the various hoods differ greatly.

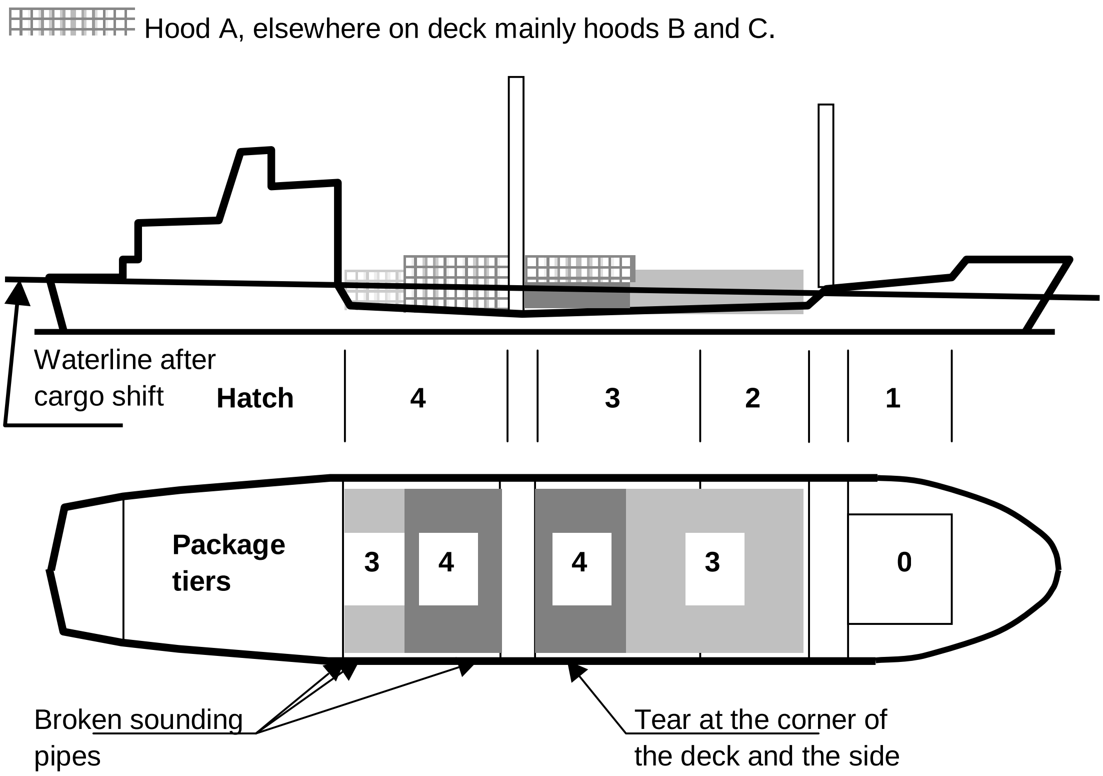

Figure 11. On-deck location of timber packages with the various hoods, the damaged sections are also marked

Placement of the deck cargo:

- Foremost part of hatch cover 4, about 70% of the length of the hatch cover was loaded with four tiers and the rest, the aft most section, about 30%, was loaded with three tiers.
- Aft most part of hatch cover 3, about 70% of the length of the hatch cover was loaded with four tiers and the rest, the foremost section, about 30%, was loaded with three tiers.
- Hatch cover 2 was loaded with three tiers.
- Hatch cover 1 was free of deck cargo.

The deck cargo was secured with securing wires from railing to railing at 1.4 m intervals. There were 44 securing wires. In addition to this, each hatch had two pairs of cross bindings reaching over the deck cargo from railing to railing. The wooden uprights were placed at 4.5 m intervals except at the bulkhead between the third and the fourth hatch cover.

The placement of the cargo and its securing had been performed in accordance with the cargo securing manual of the vessel.

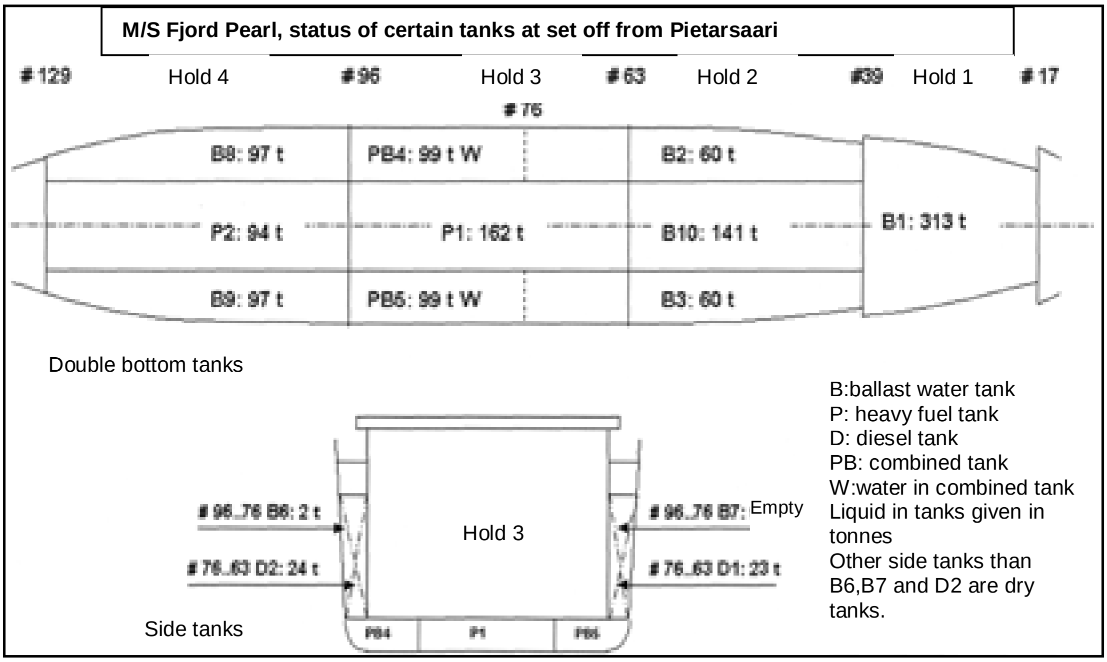

Figure 12. Status of tanks of M/S FJORD PEARL at departure from Pietarsaari

1.3 Accident events

1.3.1 Preparation for the voyage

The loading of the vessel was completed on December 31 at 17:00 hours. The tanks of the vessel were filled for the voyage, the amounts of the fluids were verified and the sounding pipes were sealed. The Master performed the stability calculations corresponding to the departure and checked that all the stability criteria were met:

- Initial metacentric height, effect of free liquid surfaces included = 0.34 m > 0.20 m
- Maximum value of righting arm = 0.47 m > 0.25 m
- Angle corresponding to maximum value of righting arm = 40° > 30 °
- Weather criterion = 2.305 > 1.0
- Range of positive stability = 72° > 55°
- Area of righting arm between 0-40° = 0.149 m rad > 0.080 m rad
- Maximum rolling angle 24°
- Rolling period 23 s
- Critical angle for securing the cargo 34°
- Dynamic stability angle of stacks of sawn timber packages = 16.5° (assumption by the investigators)

The stability calculations included 130 t of ice. Figure 12 presents the situation at departure from Pietarsaari on December 31 at 22:00 hours for certain tanks. When the ship reached open sea, the Master verified his concept of the stability of the vessel by inducing rolling with the rudder.

1.3.2 Weather conditions in the accident area

In addition to reports by the officers and the forecast and data commissioned from the Finnish Meteorological Institute, information about the weather is based on a report commissioned from the Finnish Institute for Marine Research on the weather and wave status in the accident area. The wave data is based on the information from the wave-measuring buoy for the North Baltic Sea. The buoy is located at 59º15' N and 21º E. The buoy is sufficiently close to the accident site for estimating the wave data.

Weather reports

The investigation did not study which weather service the ship had used but it can be assumed that the data was identical to the maritime weather forecasts of the Finnish Meteorological Institute. The forecast for the first stages of the voyage on December 31 at 18:50 was northerly winds at 3-6 m/s for the night and from the afternoon of January 1, 2002 increasing south to easterly winds at 12-16 m/s for the narrowest part of the Gulf of Bothnia and for the Archipelago Sea. Warnings for strong winds and icing were issued.

January 1, 2002 the forecast for the night was a wind shift from the south to north-east with an increase in force up to a storm, 21 m/s. The wind was expected to subside in the morning.

Prevailing weather

During the voyage the temperature varied between -4 and -15°C, the nights being colder than the daytime. The temperature in the accident area was about -4°C, according to the officers' reports, it was -10°C. The measuring of the weather stations are at a height of two metres from the ground. The temperature reported by the ship was measured on the bridge. The water temperature was + 1°C.

The accident area had had strong south winds, 17-18 m/s, for several hours, which created a significant wave height of 3.5 m. On January 1, 2002, in the early evening, the wind shifted to the east and developed considerable cross-waves for the night. The wind speed was still 18 m/s with gusts of up to 27 m/s. In the evening, the significant wave height had subsided to 2.4 m due to the shift in the direction of the wind, but again increased during the night to 3.2 m at the time of the accident. The cross-waves subsided during the night but the significant wave height could reach 4 m. The prevailing wave period was 8 s.

According to the ship's reports, the wind was ”force 9” meaning 21-24 m/s, direction 70°, wave height ”force 7”, which means a significant wave height of four metres on he scale and a maximum wave height of 5.5 m. This data is almost identical to the Finnish weather sources.

The form of the seabed had no great effect, since the wave period was less than 9 seconds and the wave structure was wide cross-waves. According to the depth data of the nautical chart, the turning of the vessel took place in a spot where waves coming in from the direction of the wind cross over a shallow first. The significant wavelength in deep water was 126 m, which corresponds to a wavelength of 104-114 m in shallow water. The significant wavelength was roughly equal to one shiplength.

After the accident the wind and wave conditions remained the same for six hours after which the wind shifted to the northeast and subsided gradually to 8 m/s in the next ten hours. In the evening of January 2, 2002, the wind shifted to the northwest. The temperature remained at -8°C all day.

The table below contains a summary of weather information of the latter part of the route and of the accident area. The automatic weather station of Bogskär was not functioning on the night of the accident. WS = wind speed WD = wind direction and T = temperature. The values are average readings; the wind speed in gusts has been greater.

The daylight hours were 6, from 9-15.

It can be concluded that the weather reports were quite accurate.

The automatic weather station of Bogskär was not functioning on the night of the accident. The bolded readings are at 14:00 hours. The wind speed in gusts was 27 m/s on the night of the accident. The wind speed is the average wind speed during 10 minutes at the moment of measuring. The greatest corresponding speed during the preceding hours is about 10-20% more.

Table 2. Observation from weather stations during the time of the accident

Date/Time	**Nyhamn**			**Bogskär**			**Utö**		
	WS	WD	T	WS	WD	T	WS	WD	T
1.1/05	0	0	-7.6				9	40	-9.9
1.1/11	14	210	-4.1	11	210	-4.1	11	190	-5.7
1.1/17	9	300	-2.1	**19**	**190**	**-3.7**	17	170	-2.5
1.1/20	9	360	-4.0				18	140	-3.3
1.1/23	10	350	-2.9				14	120	-4.0
1.1/24		90					15	100	-4.5
2.1/01		70					17	90	-4.8
2.1/02	15	70	-4.9				18	80	-5.8
2.1/03		60					18	80	-6.1
2.1/05	12	50	-7.9				17	60	-7.5
2.1/08	11	40	-8.5				15	50	-8.2
2.1/11	9	50	-8.6	13	40	-6.5	14	60	-8.8

1.3.3 The accident

According to the officers' reports, the wind increased to 17-18 m/s on January 1, 2002 shortly after 22:00 hours. The Master was called to the bridge. The vessel was travelling at heading 143°. The Master reduced the speed to manoeuvring speed, since the vessel was pitching heavily and rolling 5-10°. In the night the wind increased to 20 m/s. At that time the vessel was travelling a narrow passage and could not change course much. At 10 km northeast of Bogskär the vessel was approaching the eastern edge of the 18.2 m fairway. The wind speed was still increasing and the wind shifted to the east. This meant a side wind and waves. At 01:47 the Master decided to change course to starboard, to heading 208°. During the turn the vessel was in the side wind and waves for some time. In order to make her turn the speed of the vessel had to be increased from about 6 knots to 8 knots. During the turn the vessel rolled first 15° to port and then 30° to starboard, at which time the deck cargo shifted 1-1.5 m to starboard. Finally, the vessel remained listed 22° to starboard.

The turning of the vessel was executed in difficult conditions. According to the weather data, the wind speed in gusts was up to 27 m/s. According to the wave data, the prevailing wave period was 8-9 s. The corresponding wavelength was 120 m giving a phase velocity of 13 m/s for the wave. The significant wave height was 3-4 m. The speed of the vessel during the turn was 8 knots or 4.1 m/s. Figure 13 below presents the estimated turning of the vessel. The turning radius is not known but if it were assumed at 1200 m, the required time for the turn would have been 5 minutes. The moment of the cargo shift is not known.

The vessel had to travel parallel to the waves for some time, which amplified the rolling. During the turn the ship was positioned several times diagonally on the crest of the wave with regard to the wave front. In reality, the wave front was not as clear as in the picture, although the prevailing wave direction had already formed. There were moderate cross-waves. X marks the estimated time of the toss.

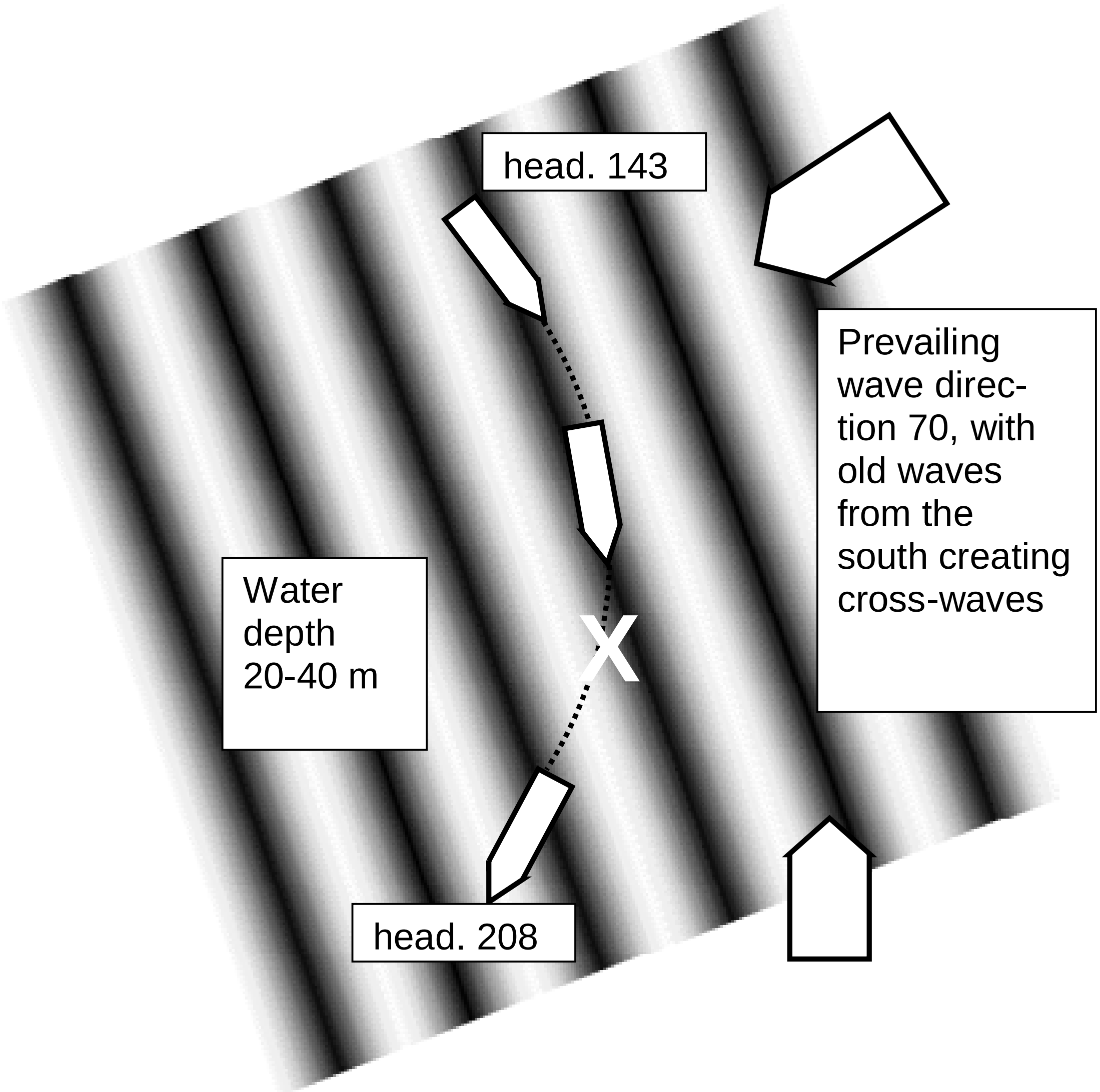

Figure 13. Turning of the vessel

1.3.4 Shifted deck cargo

Figure 14. Shifted deck cargo, close-up of figure 2

The drawing of the shifted deck cargo is based on the officers' reports, interviews, aerial photographs when the ship was on her way to emergency harbour in Turku and on photographs taken in Turku.

According to the statement of the officers of the ship, the vessel listed first 15° to port, then 30° to starboard, then righted to 22° and within a few hours stabilised at 26-27°.

All uprights at the starboard railing snapped but the wires kept the cargo on board.

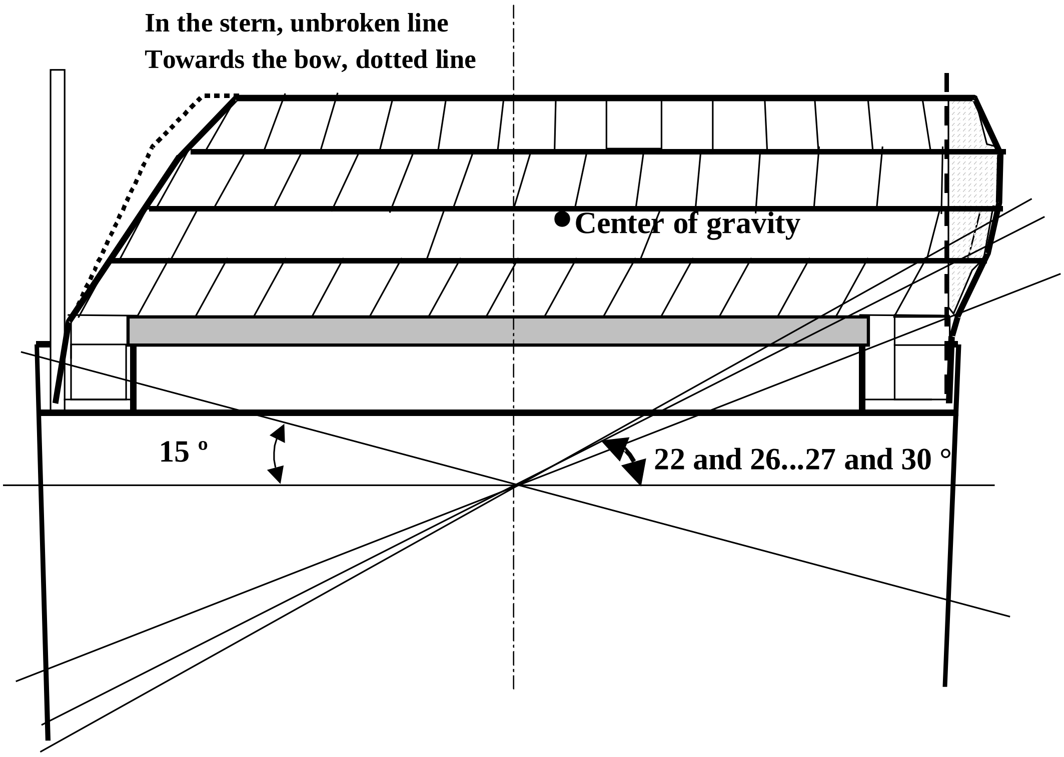

Figure 15. Shifted deck cargo in the area of four package tiers, shaded area gives extra righting volume compared to stability calculations

Figure 16. The vessel in the port of Turku, cargo partially unloaded

1.3.5 Immediate action on board after the accident

At 01:55 the Master of the vessel reduced speed and the vessel was turned into the wind (and into the waves). Port ballast tank nr 6 was filled to offset the list. Due to the effect of the wind and the waves more ice started to form onto the structures of the vessel and onto the deck cargo. At 02:28, port ballast tank 6 was full. At 04:15 the bilge water alarm of hold 3 gave an alarm and the bilge pump was activated. Due to the damage the list grew to 26-27°. The attempt to pump starboard ballast tank 9 empty proved futile since the air and sounding pipes of this tank had sustained damage and were under water. At 09:55, the entire pumping capacity, 2 x 100 t/h was taken into use and the list stopped increasing.

At 08:40 the Master estimated that the crew and the vessel were at risk. The Master notified Turku Radio of the vessel being in distress because of the list. He requested a pilot at Utö at 14:30 and reported the intention to seek emergency harbour in Turku in order to right the deck cargo. The vessel was 5 km northwest of Bogskär.

The Master did not radio a distress signal but, according to the IAMSAR[1] agreement, he issued forewarning of a danger situation to Turku Radio.

1.3.6 Rescue activity

Turku Radio received a notification from the FJORD PEARL on January 2 at 09:15 on VHF channel 25, in which the vessel announced her position at 59°33' N and 20°19' E. The vessel had listed considerably whereby the FJORD PEARL needed to drive in to Turku for reloading of the deck cargo. During the ensuing conversation the Master estimated that the vessel would arrive at the Utö piloting point in approximately five hours and reported the depth at 7.4 m. Turku Radio advised the vessel to get into contact with Archipelago VTS (AVTS) on channel 71 for requesting a pilot.

After the above radio traffic Turku Radio reported the situation of the FJORD PEARL by telephone to AVTS and to the Head of the Archipelago Navigation District. After the second telephone call Turku Radio contacted the vessel on channel 24 and inquired about the magnitude of the list, the nature of the cargo and the possible need for assistance. The FJORD PEARL replied that the list was 30° to starboard and that the cargo was timber. The vessel replied to the question about assistance: "We do not need help, we are driving towards Utö".

After the above dispatches at about 09:40 Turku Radio reported the situation of the FJORD PEARL by telephone to Turku Maritime Rescue Coordination Centre. After this report, Turku Radio inquired about the number of crew on board the FJORD PEARL and her ports of departure and destination.

[1] International Aeronautical and Maritime Search and Rescue Agreement

The MRCC dispatched a Dornier-type aircraft to monitor the vessel in distress at 9.43. The plane arrived above the vessel at 10.13. Open sea patrol vessel UISKO was ordered to the FJORD PEARL at 10.14. The MRCC contacted the ship at 11.00 and received a report that the list had stopped increasing. The vessel was notified that the two helicopters that had been alerted would arrive at an estimated time of 12.30 and that patrol vessel UISKO would reach Utö in one hour.

At 12.08 a Super Puma helicopter reached the vessel. At 12.21 the helicopter was given the instructions to follow the vessel to Utö at full alert for evacuation. The other helicopter remained on standby at Utö. At 12.15 the ship was contacted again. It became clear at this time that the draught of the vessel, 11.5 m, was too much for Turku. The vessel was cleared for proceeding towards Turku and for anchoring off Turku.

At 12.19 The MRCC Turku requested VTS to guide the vessel in from Utö. The AVTS had made routine provision for this in any case, since it was dealing only with a case of a vessel in difficulty that had not sent any kind of a distress signal and, furthermore, had requested a pilot according to standard procedure. In light of the information received, Turku MRCC decided to treat the situation as an emergency and thereby considered it appropriate to stand by for ensuring the safety of human lives. At 12.54 M/S HESPERIA, travelling nearby was requested to remain in the area until the accident vessel reached Utö.

At 13:16 the Master of patrol vessel UISKO reported that in his opinion the accident vessel would not be able to enter the archipelago safely without tug assistance. The Master of the FJORD PEARL accepted the offer for tug assistance after consulting the owner of the vessel. Tug ISO-PUKKI reported at 15:33 that she was leaving Turku to meet the incoming ship. She met the FJORD PEARL at 18:42. The UISKO continued to escort the vessels. However, tug assistance was not needed until the vessel was anchored off the opened fairway at the location for lightening the cargo at Airisto.

At 13:49 M/S HESPERIA was cleared for free passage. At 14:32 two pilots boarded the FJORD PEARL while the UISKO was escorting her. Due to the list of the vessel she was difficult to pilot resulting in an extremely demanding task. Due to the aperture angle of the radar beam the radar screen provided information only from the rear and the front in the heading the vessel was travelling. Only erroneous data and clutter was received from the sides. The situation was very difficult in the narrow stretches. Because of the list of the vessel it was in practice impossible to even stand alone without support. After nine hours of piloting the vessel finally reached Airisto. At 22:30 tug ISO-PUKKI started to tow the FJORD PEARL towards the anchor place, which was reached at 23:00. The anchors could not be lowered due to the freezing of the anchor winch and the 26° list of the vessel so the tug remained to hold the vessel in position. According to the interpretation of the MRCC Turku, the alert phase had passed at 23:46.

The nautical chart in figure 17 shows the passage of the vessel on the Aland Sea, the place of the accident, the place of notification and the passage of the vessel to Turku with times and wind/wave data.

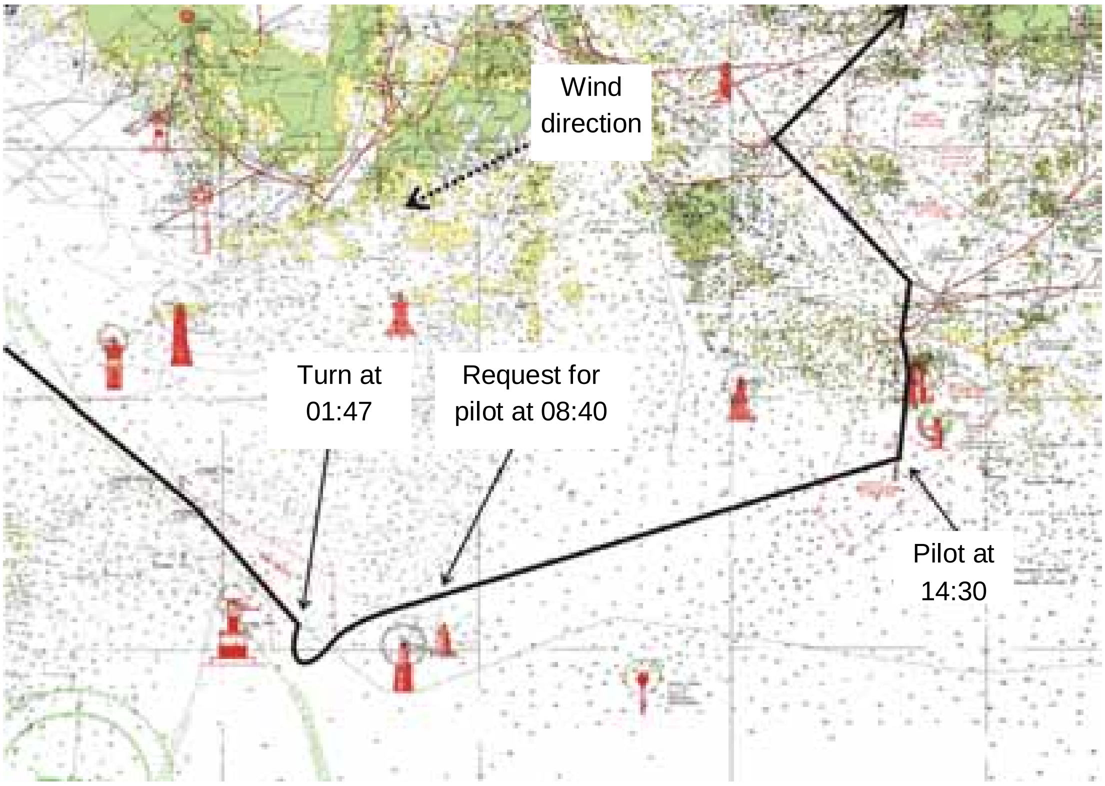

Figure 17. Supposed passage of the FJORD PEARL

1.3.7 Damage to the vessel

Figure 18. Damage to the railing

The shifting deck cargo caused damage to the starboard railing and caused a small tear at the corner seam of the deck and the side. In addition, air pipes and sounding pipes were damaged in this area. In consequence of the damages, water leaked into the dry tank on the starboard side in the area of hold 3, into fuel tank TT N 2 and into diesel tank N 2. In addition water leaked into hold 3 either from the broken pipes and/or the hatch seals. Ballast tank 9, which was full, could not be emptied to reduce the list.

All uprights on the starboard side splintered. The securing wires of the deck cargo held. The tarpaulins of the deck cargo were partially torn. There is no information of the damage inside the ship. Figure 11 shows the location of the damages.

1.3.8 Lightening of cargo and repair of damages

In order to reduce the list and the draught the Master agreed with the owner and the Finnish navigation authorities to unload some of the deck cargo into the sea provided that the sawn timber in the sea would then be picked up into a barge.

The lightening of deck cargo was begun at 14:15 on the following day, January 3, 2002. A floating crane did the work. By morning, 320 packages had been unloaded. The list of the vessel was now 16° and the draught 8.5 metres. The vessel was granted permission to sail into the Port of Turku. By 10:30 the anchor winch had been cleared of ice and the vessel could now drop her anchor. At 11:20 the tug left. The pilot arrived at 14:00, the anchor was lifted and the vessel started towards the port. At 16:30 the vessel docked at the West Harbour.

The unloading of deck cargo was continued with the dock crane at 17:30 in order to inspect the damages and to repair them.

In connection with the unloading the crew had to cut some of the securing wires of the cargo. All wires securing the deck cargo were intact.

The damages to the ship were inspected and repaired. The sawn timber unloaded into the sea was transported to Turku and most of it was loaded back on board. The deck cargo was secured once more and the stowage of the holds was inspected. After the initial preparations for the voyage the vessel continued her voyage to Algeria.

1.4 Shifting of the deck cargo

The following presents the factors affecting the shifting of the deck cargo.

1.4.1 Securing of the deck cargo of sawn timber

The securing of the sawn timber deck cargo is based on the friction between the cargo and the underlying surface. Supports can be used in addition. The effect of friction is increased with the securing wires by on top lashing. Tension forces of the wires increase the compression of the deck cargo against the surface and thus increase the friction force.

The properties of packaged sawn timber make it difficult to calculate the need for securing. In practice, the placement and securing of packaged sawn timber is done according to the simplified instructions of the cargo-securing manual.

Sawn timber packages are stowed in tiers. In order to increase the stability of the cargo, tiers can be stacked partly athwartship and partly lengthwise. In all cases, the packages must be stowed as compactly as possible. Despite of this, sawn timber packages form a partly loose stows that releases the lashings when compressed Therefore, the lashings must be tightened regularly. Packaged sawn timber is usually secured with securing wires across the load. The stow has different friction surfaces the largest uniform surface being that of the cargo hatch. Additional friction surfaces are inside the packages.

Enclosure 2 reviews the securing of sawn timber packages on to the deck.

1.4.2 Forces affecting the deck cargo of sawn timber

Enclosures 2-5 study the different forces created in the cargo and its securings in rough seas. The most important factors are the listing angle of the vessel, the friction coefficients of the surfaces and the securing forces.

The factors striving to shift the cargo are mainly caused by the waves and the winds. They are statistical variables. This case deals with a momentary incident, the development of which is relatively well known. Therefore, no statistical calculations based on the wave spectrum or on the relative amplitude operators of the vessel have been included.

In the name of safety of the vessel, the cargo-securing manual requires that the deck cargo become released if the ship lists more than 40°. The deck cargo must be soundly, but not too solidly secured.

Friction forces

The aim of the investigation was to determine the average friction coefficients for the surfaces between the tiers of sawn timber stacks on deck. In reality, all friction surfaces between packages consisted of several areas because of the following factors:

1. At the ropes the material pair upwards was rope/wood and downward rope/hood or rope/steel.
2. There was no contact next to the ropes or ice had formed in between the surfaces.
3. Because of the bending of the timber packages material pairs wood/hood or wood/steel were created in large areas while the contact pressure varied.
4. The measurements of the timber packages varied resulting in ridges, edges, grooves and dents in the contact surfaces of the packages.
5. Additional material pairs rope/rope and inside surface of hood/wood or outside surface of hood/wood were created. Since the structure of the hood consisted of layers internal friction surfaces were created inside the hoods.
6. Snowy, icy and frosty areas had been created already during the loading. In addition crushed ice was created during the voyage when the chunks of ice cracked. During the voyage water and humidity increased the icing.
7. Frost was created on the surfaces when the temperature rose (-20°C and -14°C $\Rightarrow$ -4°C).
8. The friction surfaces inside the packages had wood against wood.

Magnitude of the friction coefficient

According to the cargo securing manual the Master of the vessel should receive the information on the friction coefficients of the cargo from the shipper. According to the information obtained by the investigators these values were unobtainable. Therefore, the Master had to resort to the instructions in the cargo-securing manual.

The cargo-securing manual gives the static stability angle for a stack of sawn timber packages in case of three tiers stacked so that the middle stack is athwartship and the other ones lengthwise. The angle given is 17° which corresponds approximately to a friction coefficient μ = 0.306. Sawn timber stacked this way is supposed to remain stable unsecured until a list of 17°. The static stability angle was lowered according to the cargo-securing manual upon considering the motions of the vessel. The corrected angle is 16.5°, corresponding to a friction coefficient μ = 0.296. Investigation has not clarified how FJORD PEARL applied the manual.

Information was collected from various sources for the evaluation of friction coefficients. The investigation team did not find data on friction coefficients for winter conditions, nor for cases with ropes between the surfaces. Therefore, a series of tests was commissioned from the Technical Research Centre of Finland (VTT). The values of the friction coefficients are shown in enclosure 4.

1.4.3 Stability of the vessel

Figure 19 presents the static stability curves. They have been calculated according to the instructions and fulfil the stability criteria. The figure also shows the static stability curve calculated on board the vessel after the accident. The investigation team has studied the stability issues as required by the various situations. Enclosure 3 takes a closer look at stability.

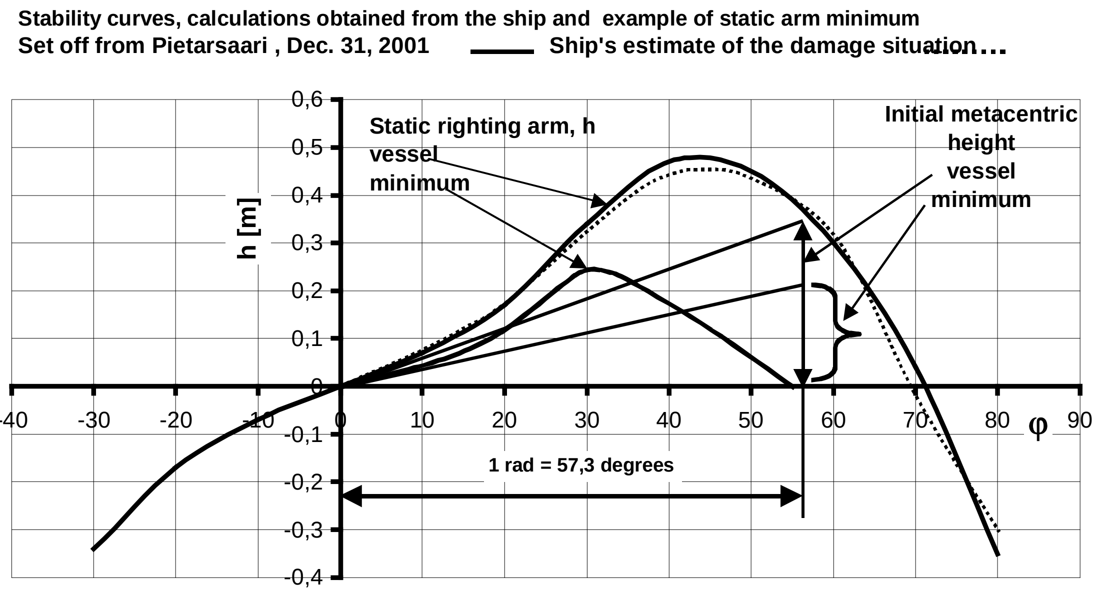

Figure 19. Stability curves calculated on board the vessel

The weather criterion or the ratio capsizing moment/maximum expected healing moment was 2.305, which is good. The calculations are based on the assumption that the centre of gravity lies on the centreline.

If the centre of gravity does not lie on the centerline the vessel has a permanent list. In addition to the list, the constant wind, the rolling and the gust all have an effect. The effect of the permanent healing moment is usually presented by correcting the static righting arm by an arm corresponding to the healing moment multiplied by the factor cos (healing angle). The situations corrected in this way and corresponding to lists of 22° and 26° are presented in figures 20 and 21. Since the vessel is rolling to both sides from the new equilibrium the curve provides an opportunity to study the stability of the listed ship.

These stability curves correspond to the situation in calm water. When the ship is in waves, her stability is sometimes better, sometimes worse. When the vessel is in head or following seas so that the midsection is on the crest of the wave, the situation is the worst. Normally a ship meets the waves in varying angels and the stability is not compromised for long.

Prior to the accident the FJORD PEARL was travelling in cross-waves where the main direction of the waves was from the port side. The vessel started to turn towards quartering seas. This resulted in an inferior position with regard to the waves from both directions. It is possible that the stability was momentarily reduced, which contributed to the toss of the vessel.

When a deck cargo of timber shifts, this creates extra righting volume or righting moment to the side. The stability calculations should not be based on this but it is a factor to be considered in the analysis of the accident. The permeability of the extra volume is 25% as that of the rest of the sawn timber on deck. It becomes wet gradually which reduces its righting effect. According to figure 16, the extra volume begins to have an effect at lists of more than 22° and there is still a small effect, about 75 tm at a list of 26°.

1.4.4 Toss of the vessel

The accident is studied with the help of the static stability curve. It is known from the officers' reports that the vessel had a list of about 5° to starboard because of the wind. The waves heeled the vessel to 15° to port and with the accumulated potential energy, back to starboard. Probably, a gust of wind blew at the same time.

In this situation, with no gust, the ship would list to about 20°, if the cargo would not move. The gust would result to a list of about 26°. It can be concluded, that the cargo started to move at a list of 16-25°, probably at 19-22°. The interviews during the investigation were unable to give any information on the exact time or angle of the start of the cargo shift.

Because of the static righting moment, a list of 22° remained after the rolling had subsided.

Possible accident scenarios are presented in enclosure 3.

1.4.5 Equilibria after the toss

List of 22°

The centre of gravity of the deck cargo moved about 0.8 m sideways based on a geometric study. The squeezing and packing of the packages and the ropes to the starboard side is estimated to have added a shift of about 5 cm to the centre of gravity. In addition, the extra moment caused by the wetting of the lowermost packages and the ice and water gathering on their surfaces and in the gaps (about $8m \cdot 50t$) is estimated to have caused a shift of about 0.2-0.3 m. The total shift was about 1.05-1.15 m. The listing moment caused by the shift, the weight of the deck cargo plus the additional weight being 1483 tonnes, is about $1.1 \cdot 1483 \cdot \cos 22°$ = 1512 tm.

According to the stability curve in figure 19, a static list of 22° would require 2070 tm. In addition to the shift of the deck cargo, e.g. the following factors increase the list:

- Packing of the cargo in the hold to the starboard side, approximately 35 cm $\Rightarrow$ $3166 \cdot 0.175 \cdot \cos 22°$ = about 510 tm.
- A slight weakening in the cross curves is caused by the slight increase in the draught.
- Wetting of the deck cargo and icing raise the centre of gravity of the vessel by 1-2 cm.

The listing moments total is 1512 + 510 = 2022 tm. The difference, 2070-2022 tm, can be attributed to the inaccuracies in the estimate and the initial data. Figure 20 presents the static stability curve for a list of 22°.

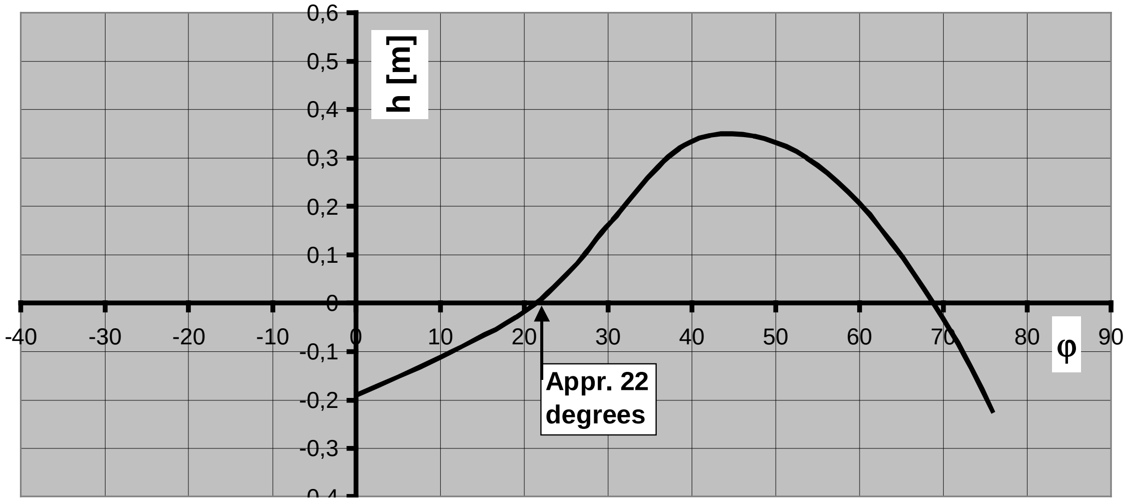

Figure 20. Static stability curve for a list of 22°

List of 26-27°

After a few hours the vessel stabilised into a new position with a list of 26-27°. The list had increased mainly because of leaks and could be stabilised with the pumps.

A list of 26-27° requires an additional 930 tm of listing moment according to the curve in figure 20. Compared to the list of 22°, e.g. the following factors come into the picture:

- Water leakages into holds 2, 3 and 4, $6m \cdot 100t$ = 600 tm
- Water leakage into the dry tank on the starboard side, $8m \cdot 30t$ = 240 tm
- Water leakage into fuel tank TT N 2, $6m \cdot 30t$ = 180 tm
- Water leakage into diesel fuel tank N 2, $8m \cdot 25t$ = 200 tm
- Water was pumped into the port ballast tank making the compensatory moment $7.3m \cdot 55t$ = -400 tm
- The cargo packed slightly more to starboard, an estimated 10 cm on deck and 5 cm in the hold, the effect of which is about 70 tm + 80 tm = 150 tm
- The icing was not strong but slightly more ice formed on the side of the list, estimate 100 tm (weight increase appr. 20 t)
- The deck cargo got wet and froze some more, estimate $7m \cdot 10t$ = 70 tm
- Shifting of the deck cargo outside the railing created more righting volume, estimate 75 tm (additional displacement 10 t)
- The righting arm of the stability curve weakened slightly
- The vertical centre of gravity of the vessel rose by 2-3 cm as a result of these changes.

Total increase of the listing moments = (600 + 240 - 400 + 180 + 200 + 150 + 100 + 70 - 75)cos26° = 958 tm. The difference 958-930 can be explained as in the above. Figure 21 presents the stability curve corresponding to this situation.

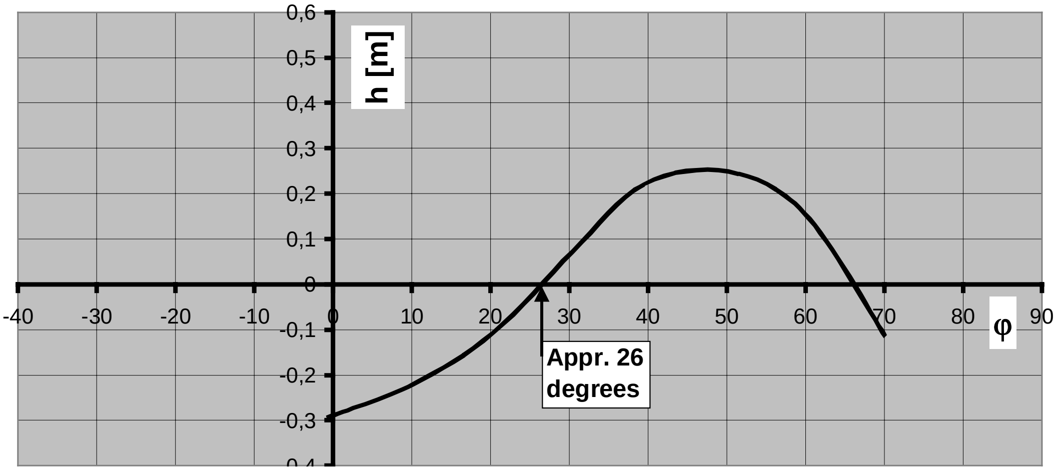

Figure 21. Static stability curve for a list of 26°

The displacement of the vessel grew by an estimated: 50 t (ice and wetting in the first stage) + 100 t (holds) + 30 t (dry tank) + 55 t (BB – side ballast tank) + 25 t (diesel fuel tank) + 20 t (additional icing) + 10 t (additional wetting and icing of cargo) - 10 t (extra volume from packages of sawn timber) = 280 t, which gives a displacement of 10640 tonnes. This is close to the result of the calculations performed on board the vessel, 10592 tonnes.

According to the calculations performed on board the vessel the draught diminished and the stability curve weakened slightly. The table below presents some data.

Displace-ment	**Stern draught**	**Average Draught**	**Bow draught**	**List**	**Centre of gravity**	
10360 t	7.52 m	7.29 m	7.04 m	0°	6.76 m	Departure
10592 t	7.50 m	7.21 m	6.91 m	25.7°	6.81 m	Accident

It can be concluded that the list of the vessel can be explained by these approximate studies. The vessel rolled to both sides of this equilibrium, apparently only a few degrees since the bow was turned against the wind.

1.4.6 Determination of the critical friction coefficient -listing angle combinations

The calculations for the critical friction coefficient -listing angle combinations are presented in enclosure 4.

The weight of the deck cargo was 1433 tonnes. Some of the cargo lies at the end of the hatches in the hollows some lay between the railing and the hatch coamings. The possibility for shifting concerning this cargo can be ignored. Thus about 1250 tonnes was resting against the securing wires.

The cargo-securing manual presents the following strength data for the securings. The diameter of the securing wire must be at least 16 mm (requirements of the IMO timber cargo guidelines in brackets).

Name	Num ber	SWL, kN	BL, kN (kg)
Securing wire 14 m	88	77.5	More than 133 (13600)
Securing wire 8 m	8	77.5	More than 133 (13600)
Chain 3 m	48	54	More than 133 (13600)
Rigging screw	59	34.3	More than 133 (13600)
Brackets on deck	44	50	More than 138.3 (14100)

In the above table BL is the breaking load; SWL is the safe workload in a lift. In this case, the term MSL = maximum securing load, should be used. The maximum securing load is determined by the weakest part of the securing.

The tensioning of the securing wires was done on top of the cargo. The tightening force was not measured. Therefore, the actual tightening force remained unclear. Due to the effect of the rope friction at corners of the cargo, the vertical tensioning force in the wires will be less than the tightening force. During the voyage forces in the wires will level out. This is why the securing wires were retightened twice a day according to the instructions of the cargo-securing manual. The wires were last tightened 6 hours before the accident. It is probable that the different securing wires have had different tension values.

Therefore, calculations for tightening forces of 40 kN, 60 kN and 80 kN and for the limit situation 0 kN were made. The results are presented in figure 24 in paragraph 2.4.2.

The number of securing wires is set at 44 plus 8 wires from a total of 12 diagonal ones.

1.4.7 Other securing methods for a deck cargo of sawn timber

The following securing options have been selected from the IMO guidelines.

- Uprights at the railing actually support the cargo.
- Hog lashing is used.
- The securing wires rounds the topmost tier. The strap effect of the wire is great.
- Every other tier is loaded athwartsip starting from the hatch cover. Only packages with flush ends are loaded across. The stack furthest to the side should lie lengthwise.
- A tilted base for packages located athwartships is constructed using longitudinally placed packages.
- A complex wiring system is used.
- Wedges are used for tightening.

Other securing devices than wires, such as chains, ropes, belts and various clamps (shackles and loops) are used.

Dunnage, boards or nets can be used in between the tiers of sawn timber packages. The IMO circular for drafting of a cargo-securing manual recommends the use of materials that increase friction when the friction coefficient is small.

1.5 Other accidents

M/S KODIMA

On Saturday, February 2, 2002 the crew of six persons of the M/S KODIMA was rescued off the coast of Cornwall. The vessel had got a list of 45° and was loaded with timber. She was flagged to Malta. The vessel risked sinking because of the great list. A helicopter of the British Royal Navy rescued the crew. The ship sank later in shallow water.

SUN BREEZE

In Australia, a Panama cargo vessel SUN BREEZE left Bunbury port on August 21, 1999, after having loaded sawn timber partly on deck. Half an hour after departure the ship listed in a turn, initially to port, then to starboard, 15° and 20° and finally 25°. Some of the top tier of the cargo slid into the sea. The position of the vessel was righted with ballast and she got back to port for reloading. The amount of deck cargo was reduced. The investigation report was completed on January 7, 2001. According to the results, there were deficiencies in the vessel data, the stability estimate for the vessel, the cargo data, the securing of the cargo and in the instructions. The report is available through the Internet at: www.atsb.au/marine/pdf/150.

1.6 Special studies during the investigation

The following special studies were made during the investigation:

- A series of tests was commissioned from the Technical Research Centre of Finland (VTT) for studying the friction coefficients of sawn timber packages in varying winter conditions.
- A report of wave conditions during the accident was commissioned from the Finnish Institute for Marine Research.
- The investigation team has estimated the factors affecting the shift of the cargo by calculations.
- The investigation team has estimated the strength of the support posts.
- The investigation team has studied the original cargo securing manual and Russian rules for cargo securing.