Investigation report

C 13/2001 M

MS TRADEN, incident caused by cargo shift in the Atlantic, October 19, 2001

SUMMARY

MS TRADEN, INCIDENT CAUSED BY CARGO SHIFT IN THE ATLANTIC, OCTOBER 19, 2001

Ro-ro cargo vessel ms TRADEN, en route from Valencia to Norrköping, occurred in emergency due to a severe cargo shift. The cargo shifted when the ship got into a storm for more than two days and into exceptionally troublesome confused seas.

The cargo shift took place in stormy Atlantic after passing Portugal, when containers on weather deck and Pendolino railway carriages on main deck came loose from their lashings. The containers came loose when fastenings on the deck broke and the railway carriages shifted because trestles below them had collapsed.

The crew managed to secure most of loosened cargo. The ship was in emergency due to an apparent risk of capsize, and a general alarm for “ship abandon” had been given. One life raft was lost during launching, and safe abandoning of the ship was not possible. The storm relented before an accident took place and the TRADEN was able to proceed with own power to haven.

Containers on the weather deck were fastened to D-rings, which were too weak. D-rings had become thinner but did not break, whereas welding junctures of D-ring fastenings were torn. After the emergency the D-rings have been replaced with new ones, and fastenings have been made clearly stronger than the broken ones.

Loosening of the Pendolino railway carriages was a consequence of the manner to fasten the trestles to the deck. There were degrees of freedom for motions / free unfastened motion directions without fastenings at all, and therefore the loose trestles’ legs were able to move and the trestles to collapse.

he shipper had determined principles and implementation of cargo securing but the master criticized about supporting the railway carriages on wooden beams. However, the critics was not taken into account in the final lashing.

The ship was relatively lightly loaded and this was compensated with ballast. The draught was, however, quite small in the current loading condition, and the ship was very stable, which increased loads acting on cargo. Bilge keels had been removed during previous docking because of ice damage, which also increased roll motion and loads on cargo.

The ship carried a Cargo Securing Manual according to the IMO Resolution A.714(17) and accepted by the Finnish Maritime Administration. However, as the manual was obscure, very extensive and partly inadequate, it was not in use. It lacked partly essential and guiding data of lashing of cargo.

Accident and success lie sometimes very near each other. Decisions, orders, and actions taken can be the same, but they can lead coincidentally to a different end result. Accident investigation can not explain this difference. In case of the TRADEN it can be only stated that master’s decisions and crew’s actions were correct. They saved the ship and the crew. It is possible, however, that the actions taken had not helped. An accident was nearby.

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INTRODUCTION

The Accident Investigation Board Finland was informed on October 25, 2001 that the ro-ro cargo vessel TRADEN had suffered a severe list caused by a cargo shift in rough seas in the Atlantic.

The Accident Investigation Board Finland decided on November 7, 2001, to appoint a board to investigate the occurred cargo shift. As investigators were appointed Tapani **Salmenhaara**, master mariner, and Kari **Larjo**, master mariner. Klaus **Rahka**, D.Sc. (Tech.) of VTT Industrial Systems and Seppo **Kalske**, D.Sc. (Tech.), initially of Deltamarin Ltd, from March 31, 2003 of Napa Ltd, were appointed as experts.

The master of the ship gave a maritime declaration of the incident at the Turku District Court on December 14, 2001. Investigator Kari Larjo was present in the session.

Investigator Tapani Salmenhaara examined the ship and its damage, and interviewed the crew after the ship arrived at Hietanen harbour in Kotka. The chief officer and the master were interviewed. Other members of the crew participating the incident voyage were not on board any more. The master was interviewed again during the investigation.

The final draft of the report was sent for statement to The Finnish Maritime Administration and to the ship owner. In addition, the final draft was sent for comments to the master of the ship and to the Department for Occupational Safety and Health of the Ministry of Social Affairs and Health.

1 EVENTS AND INVESTIGATIONS

1.1 Vessel

Figure 1. MS TRADEN.

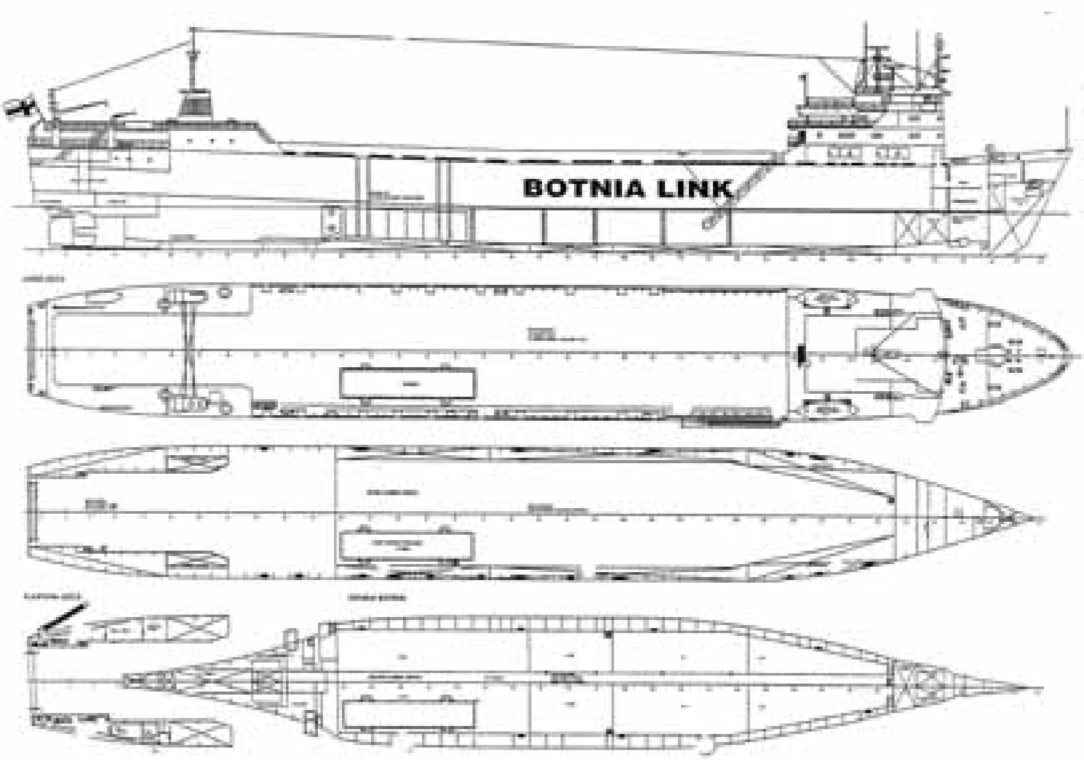

Figure 2. General arrangement of the TRADEN.

1.1.1 General data

Name:	TRADEN
Type:	Ro-ro cargo ship
Owner:	Rederi Ab Engship
Identification:	OJGA
Year of construction:	1977
Place of construction:	Rauma
Material of construction:	steel
Length, overall:	129.20 m
Length, between perpendiculars:	120.40 m
Breadth:	19.20 m
Draught:	6.30 m
Classification:	Lloyds Register +100 A1 LMC UMS 16 Finnish/Swedish Ice Class
Manning:	14
Gross:	8188
Net:	2457
Deadweight:	5850 tonnes
Main engines:	2 units MAK 6M551AK
Total power:	5960 kW

1.1.2 Crew

The manning certificate of the TRADEN was dated January 21, 2000 (valid until January 21, 2005) and stipulated the manning of the vessel at 12 persons.

The vessel had a crew of fourteen. The master (master mariner, born 1953) had about thirty years of maritime service. As a master he had worked since 1995. Prior to the incident he had worked on the TRADEN for about 5 months.

In addition to the master, chief officer, and 1st and 2nd officers were as deck officers on board. Chief engineer and first and second engineers were as engine officers on board. As crewmembers there were boatswain, two apprentice seamen, ordinary seaman, cook steward, catering assistant and electrician.

1.1.3 Wheelhouse and its equipment

The TRADEN's wheelhouse arrangement was versatile. The wheelhouse is sketched in Figure 3, and equipment are specified in Table 1. The wheelhouse is also shown in Figures 4 and 5.

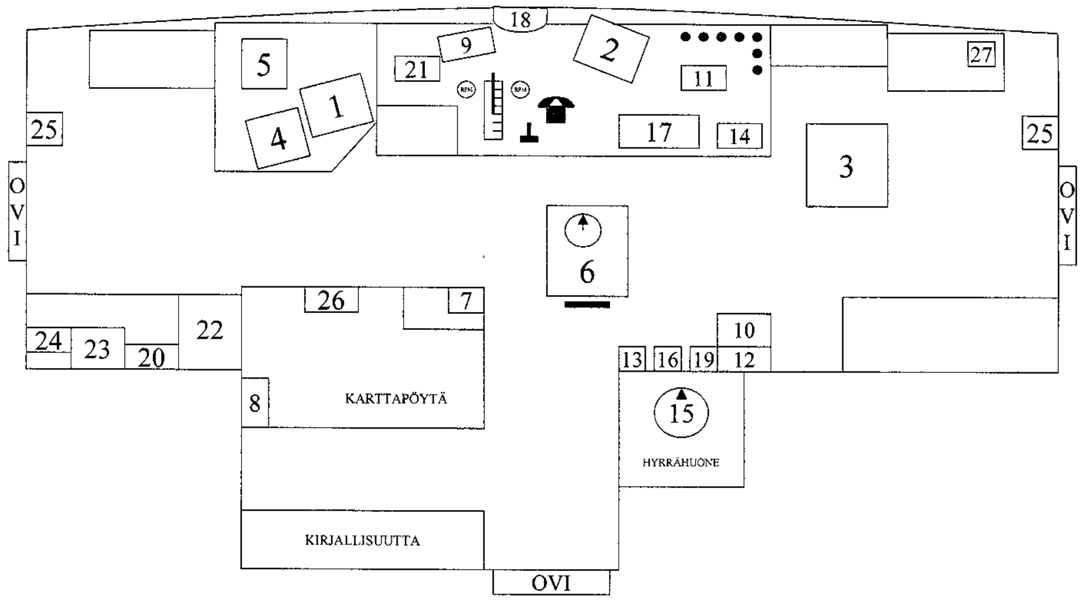

Figure 3. The TRADEN's wheelhouse arrangement as sketched by the shipping company. The figure is not in scale. (Rederi Ab Engship).

Table 1. Clarification of wheelhouse arrangement shown in Figure 3.

No	Device	No	Device
1	RACAL-DECCA Bridgemaster X-band (3 cm) radar	**15**	MICROTECNICA, SIRIUS gyrocompass
2	FURUNO FR 1505DA, X-band (3 cm) radar	**16**	AUTRONICA "Dead Mans Alarm"
3	FURUNO FR 2030 S, S-band (10 cm) radar + Autoplotter ARP-2 + Videoplotter RP-2	**17**	Engine alarms
4	TRANSAS MARINE, Navi-Sailor 2400 electronic chart	**18**	Rudder angle indicator
5	Electronic chart computer HP Vectra VL.	**19**	Emergency telephone to engine control room
6	DECCA PILOT 550 Autopilot	**20**	SAILOR compact VHF RT 2048 + DSC SAILOR compact VHF DSC RM 2042 radio telephone
7	PHILIPS Global Positioning System + PHILIPS DGPS PBR 1000	**21**	SAILOR compact VHF RT 2048 radio telephone
8	ATLAS ECHOGRPH 460 echo sounder	**22**	SKANTI control unit 8000, TRP 8251S radio telephone
9	FURUNO AD-converter AD-10s	**23**	THRANE & THRANE TT – 300 INMARSAT-C sender/receiver
10	BJÖRK-engine order telegraph	**24**	SAILOR SP 3110, 3 units Portable emergency-VHF
11	AUTRONICA, Type BX- 11 Engine room fire alarm	**25**	2 x DEBEG 5900 EPIRB-buoys
12	GINGLE cargo hold fire alarm	**26**	NEWCOM AS, NC- 400D Navtex-receiver
13	MINETTE 100 Accommodation fire alarm	**27**	GSM-telephone
14	KOCKUM SONICS TI 50-1 Tyfon-sound emitter		

Figure 4. The TRADEN's wheelhouse.

Figure 5. Radio equipment of TRADEN's wheelhouse.

1.1.4 Vessel registration documents

The ship was surveyed for international traffic.

The ship's registration documents and their issuing dates:

• Certificate of Nationality	14.1.2000
• International Load Line Certificate	24.5.1994
• Minimum Safe Manning Document	21.1.2000
• Safety Management Certificate	19.6.2000

1.1.5 Cargo and its lashing

According to cargo documentation the ship carried Pendolino railway carriages, containers, palettes, and roll trailers in total of 1235 tonnes. The cargo was located in such a way that containers weighting 453 tonnes were located on the weather deck. On the main deck there were railway carriages, containers, palettes and roll-carriages in total of 782 tonnes. The lower hold was empty.

The ship carried 1700 tonnes ballast. At departure, the amounts of bunker and potable water were 130 tonnes and 50 tonnes, respectively. In addition, stores amounted to 113 tonnes. The ship's deadweight (DWT) at departure was 3232 tonnes, which was 52.9 % of the maximum capacity.

With current cargo and ballast arrangements, the ship's draft was 4.50 m forward and 5.50 m aft at departure.

Containers and Pendolino railway carriages loaded on the TRADEN were secured to ship's decks with 11 mm chains. On the weather deck the containers were secured with corresponding chains to D-rings of the deck.

The Pendolino railway carriages loaded on the ship were supported on specifically manufactured trestles of about 1 m in height located below the carriage wheels, Figure 6. The carriages were lashed from their wheels to the trestle's upper beam, which was further lashed from both ends by chains attached inclined to the ship's deck. The leg of the trestle and the upper beam were connected by a twistlock, Figures 7 and 8. The twistlock connects a steel plate holding the upper end of the leg together, and a plate combining the two parts of the beam. The junction is rather flexible for transverse bending forces. The lower part of the leg lay on a wooden base consisting of non-fixed 100 x 100 mm bars of about 0.5–0.6 m in length. They were set crossways in two layers between the leg's lower end and the ship's deck. The lower end of the leg was not secured to the deck either. The only lashings to the deck were thus the sloped chains of the upper beam of the trestle.

The loading of the ship took 6–7 hours in Vado Liguria in Italy. When the ship arrived at the harbour, the Pendolino carriages were lying on the trestles and secured to them, and thus ready to be loaded. According to the master the carriages were transported to the ship with a specific hydraulic trailer. The above-described bars were set below the trestles to remove the trailer from below the carriages. Ship's personnel secured the cargo because no stevedores were available during the weekend.

The chief officer had prepared a stowage plan for the ship, according to which two carriages were to be stowed at bow and four sideways aft of them. This would have prevented effectively their possible transverse movement. However, the railway carriages could not be loaded according to this plan, except the two bowmost ones, because the carriages with trestles were wider than previously informed. The shipper gave the instructions for stowage and securing.

According to the interview of the chief officer, the supporting of the carriages was criticized from the ship's side, and rubber mats were proposed instead of the bars but the shipper required the above-mentioned support. This arises also from the protest written by the master on October 24, 2001.

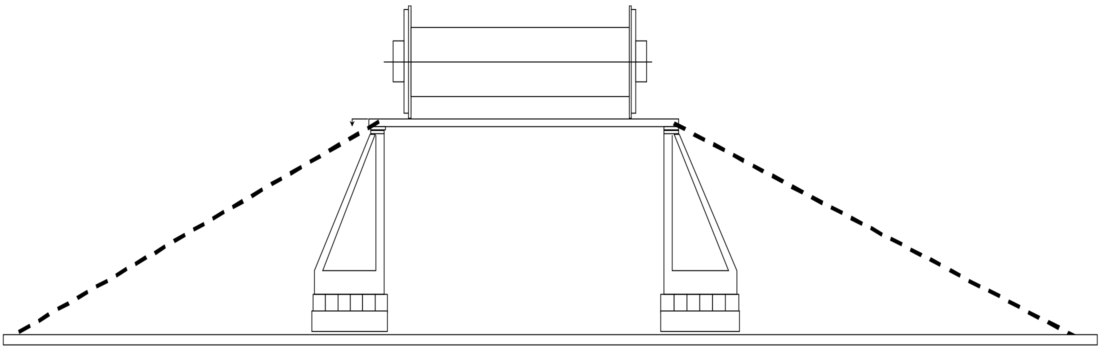

Figure 6. Supporting and binding the Pendolinos to the TRADEN's main deck.

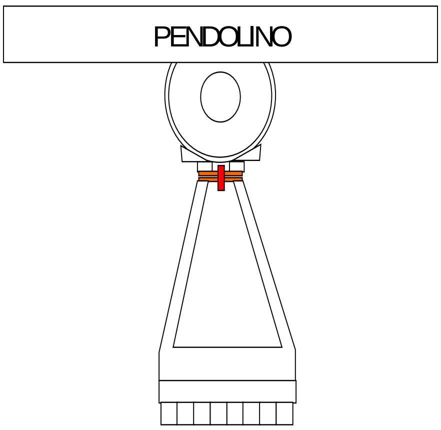

Figure 7. The junction combining the leg and the upper beam of the trestle.

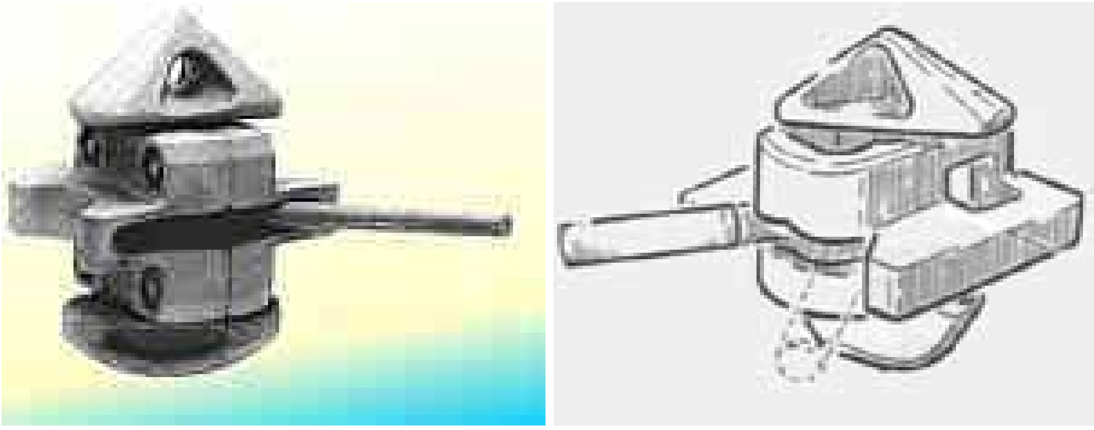

Figure 8. The twistlock.

1.1.6 Cargo Securing Manual

There were no specific authority requirements on cargo securing with the exception of existence of guidelines. The cargo securing manual of the TRADEN was approved by the Finnish Maritime Administration on August 5, 1996, and is based according to SOLAS on the IMO Resolution A.714(17) "Code of Safe Practice for Cargo Stowage and Securing" from the year 1991. At the time of the incident the SOLAS consolidated edition from the year 2001[1] was in force. This refers to the main principles of cargo securing in the above-mentioned resolution, which states that heavy cargo items, such as locomotives, have to be secured as shown in Figure 9[2]. This figure shows that each lashing point of a cargo unit has to be secured in at least three directions perpendicular to each other. The shipper has to inform the ship about cargo securing principles according to the chapter of cargo transporting.

The cargo securing manual of the TRADEN includes among others precise guidelines for lashing of containers. The IMO regulations in the form of Resolution A.714(17) are in Chapter 9 of the manual. It includes guidelines for lashing of heavy cargo items and calculations are required to evaluate the needed lashing forces and their directions. However, there are no data about lashing capacities of different lashing equipment.

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[1] Consolidated text of the International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1988: articles, annexes and certificates. Incorporating all amendments in effect from 1 January 2001. IMO London 2001, ISBN 92-801-5100-2. SOLAS, Carriage of cargoes, Chapter VI, Regulation 2:

1. The shipper shall provide the master or his representatives with appropriate information on the cargo sufficiently in advance of loading to enable the precautions with may be necessary for proper stowage and safe carriage of the cargo to be put into effect. Such information shall be confirmed in writing and appropriate shipping documents prior to loading the cargo on the ship.
2. The information shall include:

2.1 in the case of general cargo, and of cargo carried in cargo units, general description of the cargo, the gross mass of the cargo or of the cargo units, and any relevant special properties of the cargo. For the purpose of this regulation the cargo information required in sub-chapter 1.9 of the Code of Safe Practice for Cargo Stowage and Securing, adopted by the Organization by resolution A.714(17), as may be amended, shall be provided.

[2] Resolution A.714 (17), 6 November 1991. Code for Safe Practice for Cargo Stowage and Securing. Annex 5, Safe stowage and securing of heavy cargo items such as locomotives, transformers, etc. Paragraph 4.

The cargo securing manual is composed mainly of articles of various subjects copied from other literature describing transportation in general and the associated forces acting on cargo. Guidelines for calculating forces are also given. The end result is a non-uniform selection of forces, accelerations and friction coefficients acting on cargo to be secured during transportation, but actual recommendations about securing do not exist. The list of contents does not correspond to the real contents, and the language varies from one chapter to another, from Finnish to English and Swedish. There is no mention about structures like the trestles below the Pendolino railway carriages.

The owner’s guidelines concerned methods and practices in lashing. No written lashing or securing guidelines were available from the shipper.

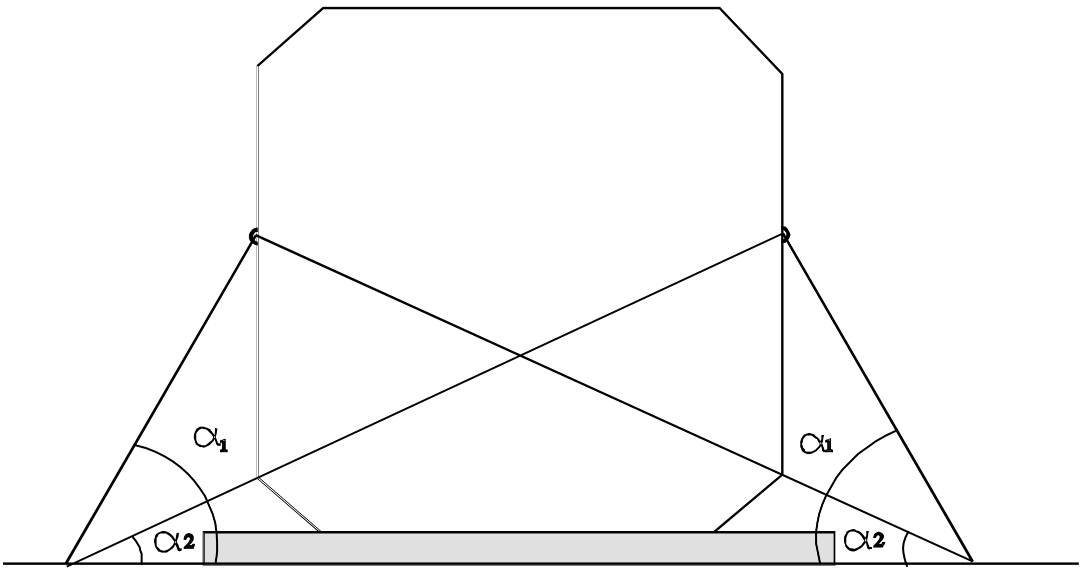

Figure 9. Principles of securing a heavy item according to the IMO Resolution. Securing in angle α_2 is for preventing cargo sliding in transverse direction. Securing in angle α_1 is for preventing cargo tipping. The intention is to have perpendicular securing directions at cargo lashing points.

1.1.7 Ship’s stability

The chief officer had calculated the ship’s metacentric height (GM_0) to be 1.12 m when free surfaces of tanks were taken into account. This value exceeds the required minimum value 0.15 m. Calculations were carried out by hand using hydrostatic tables.

Stability calculations carried out within the investigation with the NAPA software yielded the metacentric height value of 1.48 m when free surfaces are taken into account. This value is clearly larger than the one calculated onboard. The relatively small amount of cargo, and the ballast taken for this reason to bottom tanks increased GM_0 to a quite large value. The ship satisfied all required stability criteria. Stability is considered in more detail in the seakeeping study in Chapter 1.4 and Appendix 2.

Bilge keels had been partly damaged by ice and they had been consequently removed from the vessel during docking. The absence of bilge keels increased roll motion compared with the situation with retained bilge keels. Larger roll motion increased also lashing forces.

1.2 Incident

1.2.1 Voyage and its planning

The TRADEN was loaded at Haifa on October 8, 2001, at Vado Liguria in Italy on October 13, 2001, and at Valencia on October 15, 2001. The ports of destination were Norrköping in Sweden and Turku. The ship left Valencia on October 15, 2001, at 1310 with 14 crew members and a total load of 1235 tonnes of containers and Pendolino railway carriages. The voyage proceeded according to the route plan and the speed of advance was approximately 15 knots.

The ship was equipped with the Navi-Sailor 2400 navigation system program, which had been used in planning the voyage. In addition, the program had stored ship's data of movements and voyage during the current voyage.

Nothing special took place en route from Valencia to Gibraltar. When the ship proceeded from Gibraltar to Cabo de Sao Vicente of Portugal according to the route plan, the circumstances did not deviate from normal conditions. The ship passed Cabo de Sao Vicente on October 17 at 0425 ship time with a south-east wind force 2 to 3. During the day the wind turned to south-west and wind speed increased remarkably. The wave height increased also significantly towards the evening.

A more detailed description of the voyage is presented in Appendix 1. The description is based on the Navi-Sailor back-ups, ship's log book, and weather data of Meteo France.

1.2.2 Emergency in the Atlantic

According to the master's interview, the environmental conditions were tolerable up to the latitude of Aveiro. Beyond this location the sea was so rough that the ship had to change course.

In Wednesday evening on October 17, 2001, the master stayed also at the wheelhouse in addition to the crew on the watch. The weather deteriorated further and the ship started to roll at about 20 o'clock. The master steered according to waves and turned towards north-west, Figure 10. During the small hours of Thursday morning, the ship was able to maintain a moderate speed but the speed varied between five and ten knots during the morning because the sea conditions were so rough.

The sea remained rough during the entire Thursday, October 18, 2001, and the ship rolled heavily with an amplitude of about 20° to 25°. Swells were encountered from the left. The master turned to following seas at 0856, but the ship continued to roll heavily.

At 0928 the master turned back to the main direction 315°. After noon various directions were used according to the waves.

At 1620 it was announced from the deck to the wheelhouse that the second tier of containers (from the bow) on the weather deck was moving sideways. The ship was turned towards the sea. Four 20-ft containers on the weather deck had come out of their chain lashings. The entire crew tried to prevent cargo movements by adding lashings to all containers on the weather deck. Trailer trestles, among others, were added to the space (approximately 1 m) between containers and the bulwark. At 17 hours also the containers of the third tier became loose. The crew continued cargo securing throughout the night. The master steered towards south-west in head waves. The wind force in the evening was from 8 to 10. Cargo securing continued also throughout the following day. Lashings were added to the weather deck.

On Friday, October 19, 2001, the ship continued to roll 20° from one side to another, and it encountered heavy slams. The heading was initially towards west. The main heading was between 270° and 280°. At 0800, movements of all containers were eliminated with wire stoppers, which were fixed to strong ship structures. Chains were added to the containers on the main deck. Cargo on the main deck had stayed in lashings to the deck. At 1415 the 2nd officer announced the wheelhouse that the aftmost railway carriage on the main deck had loosened from the trestle and the lashings supporting it had broken. Some of the containers on the main deck were loose as well. The ship was held inclined to starboard to minimise movements of cargo. Noise from moving cargo was further heard from the hold. Lashings on weather deck were improved but for safety reasons it was not possible any more to enter the main deck to secure the cargo. The master announced ship's crew at 1500 about possible abandon of the ship. Soon after this, the following distress alerts were sent as ordered by the master:

- at 1510 VHF DSC Distress sent and acknowledged.
- at 1520 MF and HF Distress sent and acknowledged.
- at 1550 the INMARSAT Distress sent and acknowledged by telex
- both EPIRB buoys were activated on the deck above the wheelhouse. Several MRCC stations acknowledged the calls, which was observed from the Inmarsat messages.

The distress communication was carried out on frequencies MF/2182 and HF/14125.

The master gave a General Alarm for ”ship abandon” at 1745. Ship motions were furthermore violent as single wave heights were from 10 to 15 m. At 21 hours it was observed that all railway carriages were partly loose from their lashings and the trestles below them had collapsed.

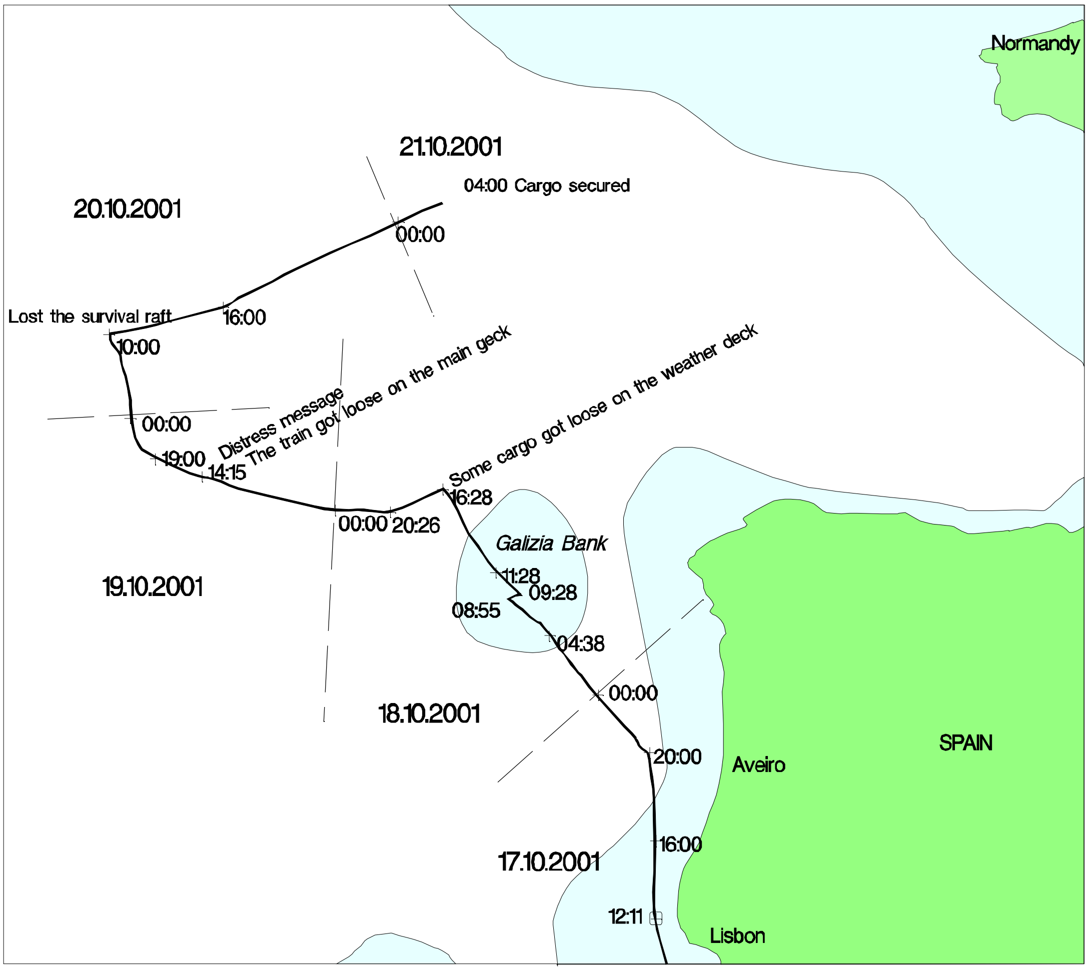

Figure 10. TRADEN's voyage in the storm during three days in the Atlantic (UTC+2).

On Saturday morning, October 20, the entire crew began to feel exhausted[3]. It was first attempted to keep the TRADEN at heading 15°–20°, and the crew wore survival suits and stayed at the wheelhouse. At about 10 o'clock the crew members wanted to try to rescue with a raft to DOLE AFRICE, which was near the bow. DUNCAN ISLAND was on the right–hand side. The bow thruster was turned on during the launch of the raft. Ship's movements according to the Navi-Sailor back-ups during this instant are shown in Figure 11. A couple of waves filled the raft, the painter line broke and the raft was lost. Part of the crew wanted to try still with another raft but the master denied it. He wanted to save it to the last moment.

After this the wind speed began to decrease, however. It was managed to decrease the list angle to value below 10° and to turn the ship to quartering seas toward north-east. During the following day, October 22, 2001, the cargo was secured and the ship managed to proceed to haven, Le Havre, with own power.

[3] Master's interview April 4, 2003.

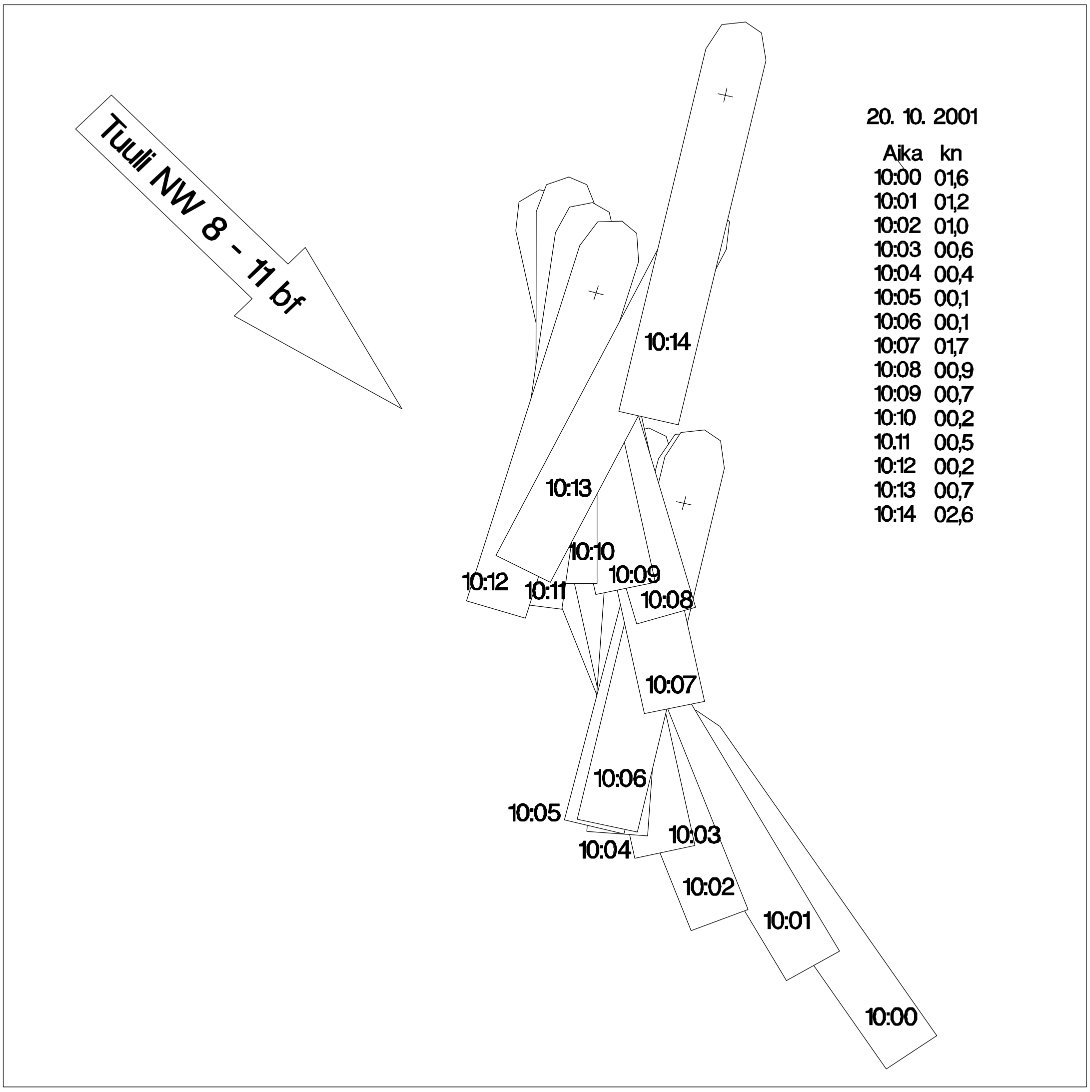

Figure 11. On October 20, 2001, between 1000 and 1014 a raft was launched and lost. The figure is compiled on basis of data recorded by the Navi-Sailor – program.

1.2.3 Weather conditions

The TRADEN received weather data using MF/HF-radio and in text form with INMARSAT C. Normal weather conditions with respect to ship's size and seaworthiness prevailed on the ship's sailing route during the initial phase of the voyage. According to the master, difficulties of the ship were caused by the strongly confused seaway, which made it impossible to find a heading where severe rolling and slamming could have been decreased.

Bad weather started to develop already on October 17 and circumstances deteriorated essentially during the evening. Meteo France issued the first wind warnings to the area on Wednesday October 17, at 0630 UTC:

WARNING NR 412, WEDNESDAY 17 October at 0630 UTC
GALICIA, north of WEST PORTUGAL continuing to 17/21 UTC
Southerly 8 or 9, veering southwest imminent. Severe gusts. Occasionally high sea.
From 18/06 UTC to 18/09 UTC at least southerly 8 or 9. Severe gusts.

It can be observed on basis of weather maps that an extensive and nearly stationary low pressure area existed in northern Atlantic. The deep centre was east of the British Isles. The deep low increased the seaway with the consequence that the high northern swell occurred also on TRADEN's route. According to the weather map on October 18, a partial centre of the low pressure area, which deepened, developed to the west of Portugal, Figure 12. This partial centre and the associated cold front moved towards east. Forward of the front the wind increased and turned to south. After the cold front the wind turned to west and north-west and changed also to gusty. The rapid turn of wind direction was due to the movement of the cold front towards the coast of Portugal. Due to the rapid change of wind direction, confused seaway with the prevailing swells occurred in the area. The weather maps and weather reports of Meteo France included warnings about the situation. The weather reports included also mentions about thunder squalls and gusts. After the cold front wind turned gradually towards north. Wave forecasts in the area varied between rough to very rough.

Daily surface analysis maps on the area are shown in Appendix 1. Figure 13 shows wind directions and forces on TRADEN's route.

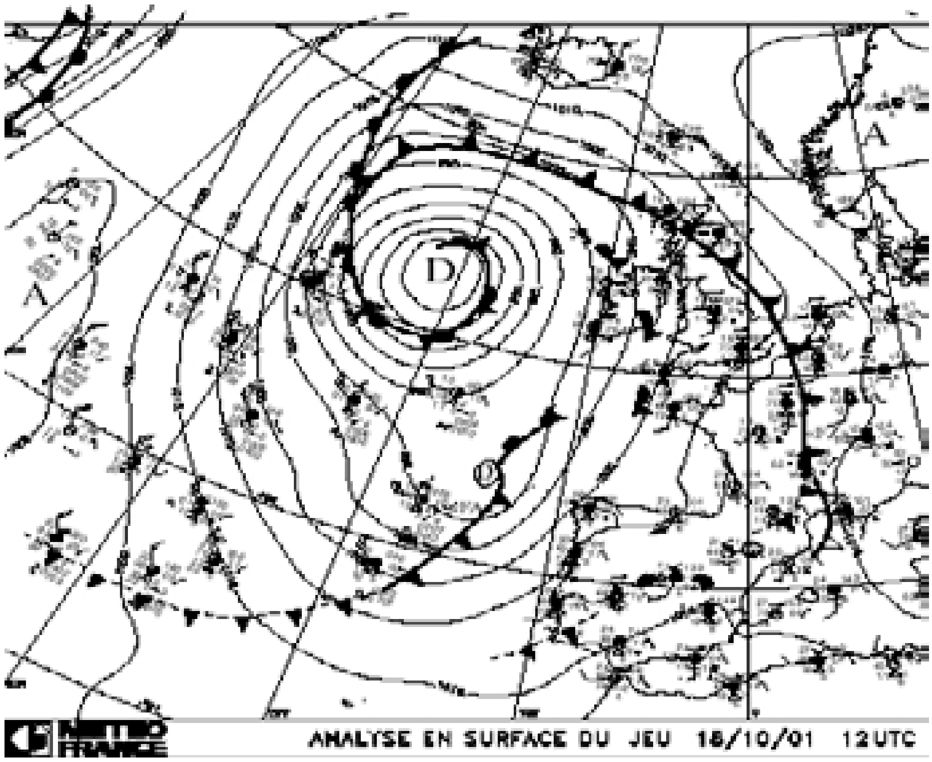

Figure 12. Surface analysis map for 1200 UTC on October 18, 2001 (METEOFRANCE).

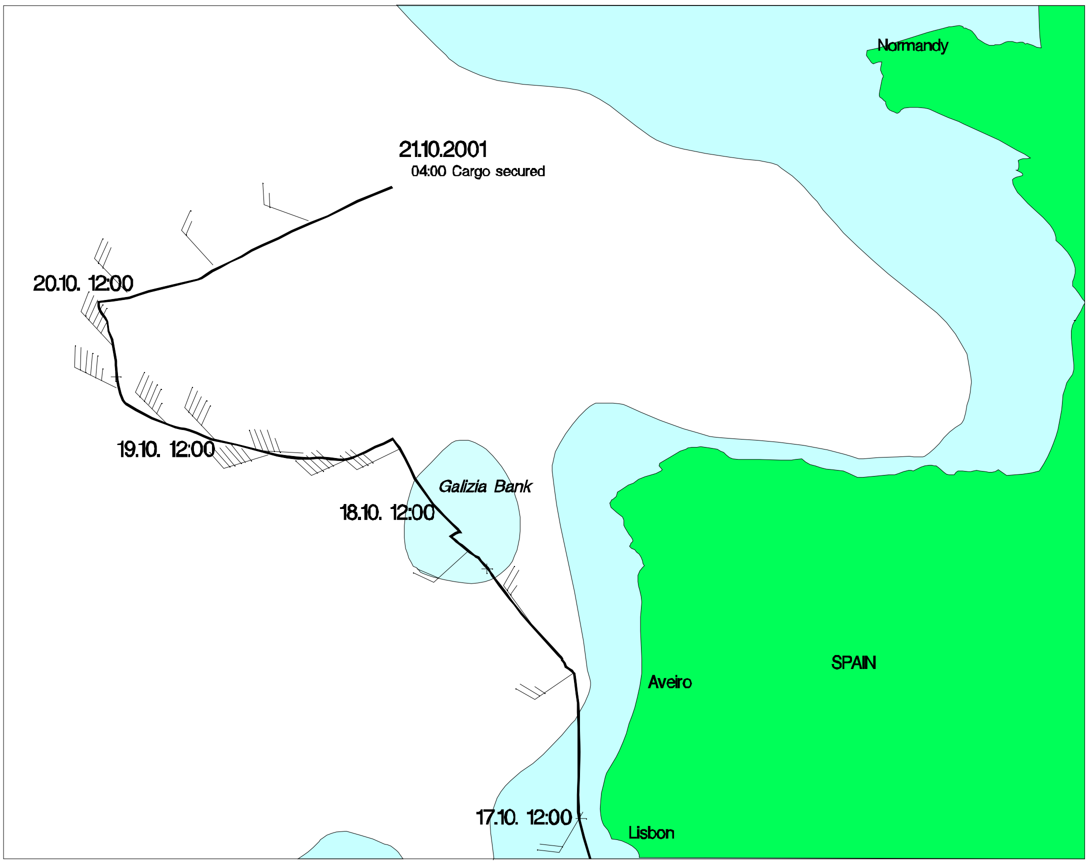

Figure 13. Summary of wind direction and speed according to TRADEN's log book on October 17 to 20, 2001.

1.2.4 Ship's damages

According to observations carried out in Kotka, major structural damages occurred to the cowbridge on the weather deck and structures on the main deck, Figure 14. Also the D-rings on the weather deck, which were used to secure containers with chains to the deck, were torn, Figure 15. The D-rings on the weather deck were in very poor condition and they were replaced with new ones. Received photos indicate also that the welding joints were quite thin. Fastenings of the renewed D-rings were made clearly thicker.

Figure 14. The damaged cowbridge on TRADEN's weather deck.

Figure 15. D-rings in poor condition on TRADEN's weather deck.

Damages on the main deck were mainly repaired when the ship arrived in Kotka. Reparation work was carried out predominantly near the elevator and in the area of pillars at the centre of the main deck.

1.2.5 Cargo damages

Containers got loose on the weather deck and main deck, and Pendolino railway carriages stowed on the main deck. Cargo damages are not investigated in other respects than from the weight shifting point of view. The examination focused on forces acting on cargo and lashing. Figure 16 shows damaged containers on the weather deck, and Figure 17 shows one railway carriage and a collapsed trestle.

Figure 16. Damaged containers on the weather deck.

Figure 17. Railway carriage on the main deck and collapsed trestles.

1.3 Distress call and rescue operations

TRADEN started to roll in high swells at about 20 hours on Wednesday evening October 17. The heading had to be turned towards north-west, Figure 10.

On Thursday afternoon the ship rolled very violently, with an amplitude between 20° and 25°. The second tier of containers on the weather deck got partly loose from its lashings and speed was reduced. Speed was increased at 1637, which indicated that cargo had been secured.

On Friday morning, October 19, the crew added further cargo lashings. The ship encountered bottom slams and the list was 20° at maximum. The situation had not shown any signs of improvement for a long time and the master concluded that the danger increased. He informed at 1100 the FINISTERRE radio about TRADEN's situation and agreed with the radio station about mutual watch keeping on frequency 2182 kHz.

At 1415 the aftmost railway carriage got loose and list increased. At 1500 the master informed the crew about possible abandon of the ship. At 1510 the master sent a VHF DSC distress call. DOLE AFRICA acknowledged it at a distance of 13 nautical miles and announced she will come to assist. The crew was dressed in survival suits and was gathered in the wheelhouse. At 1520 the master sent distress calls with MF and HF DSC -radios and half an hour later with Inmarsat.

At 1745 the master gave the General Alarm for ship abandon. At 2100 the 2nd officer announced that all railway carriages were loose on the main deck. The trestles had collapsed.

On Saturday, October 20, at 0200, it was tried to keep the ship at a list of 15°–20°. The speed was only 4–5 knots. At 0600 it was stated that the situation in the hold was unchanged. Between 1000 and 1014 a raft was launched but it was lost. DUNCAN ISLAND and DOLE AFRICA observed near by. Wind started to settle after this.

On Sunday, October 21, at 0400, the cargo did not move any more and at 1600 the cargo was secured on all decks.

In the TRADEN's case relevant alarms were given when the distress was realized.

Successful rescue operations included cargo securing, steering, and use of ballast pumps.

1.4 Special studies in accident investigation

Special studies were carried out in the accident investigation to find out the reasons of cargo loosening. This work is divided into two parts: accelerations acting on cargo when the ship moves in waves and estimation of strength of lashings when loaded by motions of ship and cargo. The relatively small amount of cargo, and as a consequence, the quite large metacentric height gave specific interest to the estimation of accelerations.

Study of strength of lashings covers the forming of lashing forces as a function of lashing directions. In addition, properties of securing gear were studied.

1.4.1 Seaway effects on cargo

The estimation of forces acting on securing gear is possible only when the accelerations acting on cargo are known. These are expressed in three mutually perpendicular directions: ship's lateral direction, vertical, and longitudinal direction. Lateral acceleration is caused especially by ship's roll motion, and vertical acceleration in particular by pitch motion. Longitudinal acceleration is in general smaller in magnitude than the other two. Appendix 2 describes the method of calculation of accelerations.

Ship's accelerations acting on the foremost and aftmost Pendolino railway carriages and at the centre of gravity of one container on the weather deck were calculated in the sea conditions corresponding to the ones prevailing during the cargo shift.

Environmental conditions at the instant of the cargo shift can be estimated on basis on the weather report issued by Meteo France, notices in ship's log book, and partly also on published wave data bases on the area.

According to the report of Meteo France, wind was west gale force 8, significant wave height was estimated at most 6.4 m, and wave period 15 s. The report includes also observations from other ships in the area, which indicate maximum significant wave height 6 m and swell height 7 m during the day of the incident.

According to the TRADEN's log book, very high waves from various directions were encountered during that day and wave height was observed to increase further. Height of highest waves was recognized to be 10 to 15 m, and according to the maritime declaration given by the master, largest wave height exceeded 12 m. These estimates appear realistic when compared with other wave data.

During the day of the incident the ship was steered according to the seaway with the objective to avoid large roll angles. However, in prevailing confused seaway roll motion was violent, 20° to 25° from one side to another. The ship was steered now and then towards bow waves and the roll amplitude was approximately 25°.

Speed of advance during the time of the cargo shift varied between 5.5 knots and 9.4 knots, and was typically higher than 7 knots.

Seakeeping calculations were carried out using 7.5 m as the significant wave height, which corresponds to the prevailing sea state according to the scale of the World Meteorological Institute (WMO). Exceeding probability of significant wave height 7.5 m in September – November is slightly more than 2%, which corresponds to about 8 days per year. All wave periods observed for the current wave height according to the data base were used and the maxima of calculated acceleration values were selected. Ship's speed of advance was 7 knots in the calculations.

13 wave headings were used in the calculations involving all relevant heading angles, but the accelerations were examined only in head waves with heading angle 180°, and in bow waves with heading angle 150° (30° from the bow).

In irregular waves the study was carried out in short-crested waves, where other headings in addition to the dominant heading are also taken into account.

Ship motions and accelerations

In seakeeping calculations the ship motions and accelerations were calculated in wave conditions corresponding to the instant of the cargo shift. Maximum values encountered during the storm were calculated for both motions and accelerations. Duration of the storm is according to log book about 60 hours, which is the period the ship had to steer according to waves. The maximum values were calculated by allowing an exceeding probability of 20 %, i.e. once during five voyages of equal duration provided that wave conditions remain unchanged. Accelerations obtained in this way were compared with the IMO accelerations. In addition, accelerations on the aftmost railway carriage were compared with accelerations from rules of classification societies to estimate the magnitude of acceleration values on the TRADEN in a better way. Roll motion from seakeeping calculations was compared with the estimate in the log book. Whipping vibration caused by bottom slamming is not taken into account in the present calculations but encounter probability of bottom slamming is estimated on the basis of calculations.

Calculations show that maximum roll amplitude in head waves in 24° and in bow waves 28°. These values lie quite close to the maximum value in the log book, 25°. Maximum acceleration values and the IMO accelerations are shown in Table 2. Acceleration of gravity *g* is approximately 9.81 m/s^2, which implies that the maximum value in the table exceeds this value slightly, whereas other values are smaller than *g.* An acceleration of magnitude *g* acting on cargo implies a force equal to the weight of the cargo.

Table 2. The IMO accelerations and computed maximum acceleration amplitudes in irregular short-crested waves with significant wave height Hs = 7.5 m.

Point of calculation	Acceleration amplitude (m/s^2)								
	Transverse			Vertical			Longitudinal		
Angle of encounter	180°	150°	IMO	180°	150°	IMO	180°	150°	IMO
Aftmost railway carriage	4.58	5.28	3.45	3.09	3.68	2.72	1.58	1.32	1.28
Bowmost railway carriage	5.00	5.53	4.00	10.3	9.43	5.99	1.45	1.27	1.28
Container of weather deck	5.69	6.49	3.88	4.35	4.51	3.10	3.02	2.63	1.86

Transverse and vertical accelerations and the IMO accelerations are also shown in Figures 18 and 19.

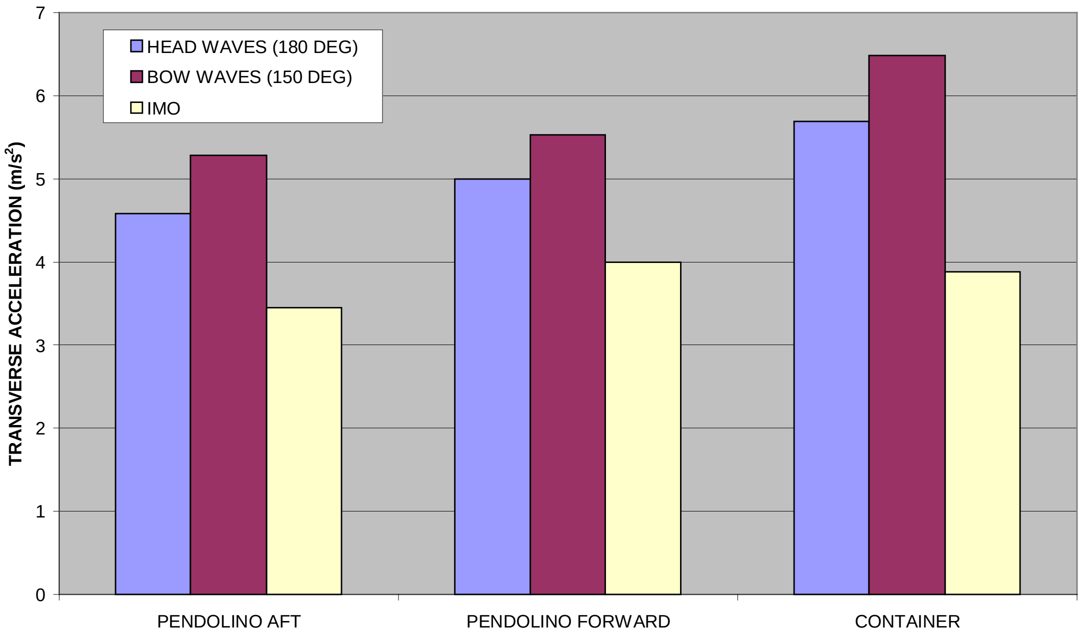

Figure 18. Maximum transverse accelerations and the IMO accelerations.

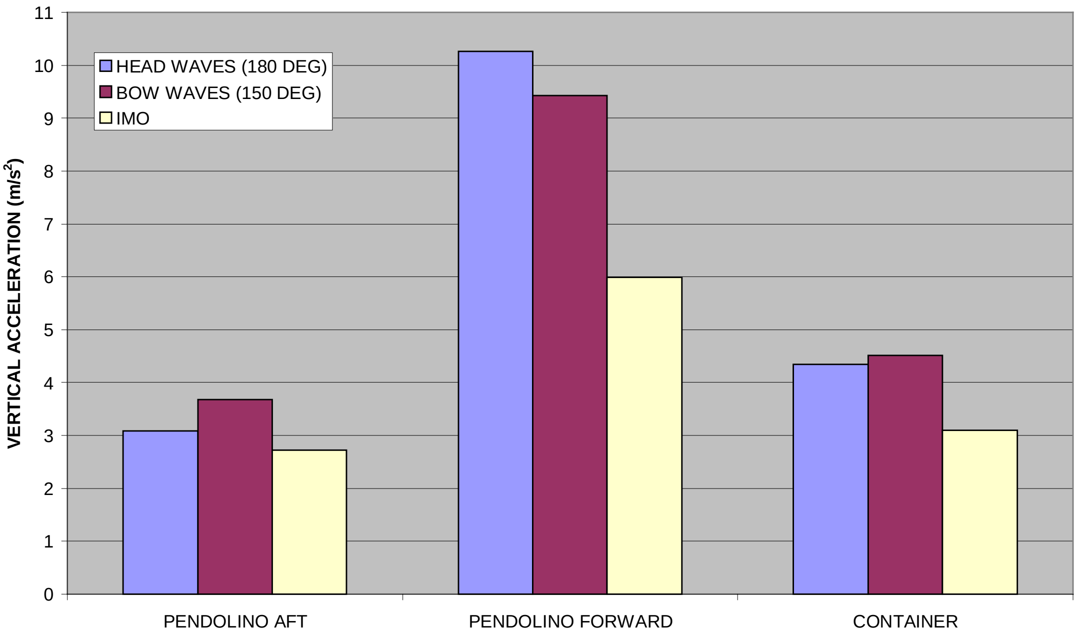

Figure 19. Maximum vertical accelerations and the IMO accelerations.

It can be observed from the results that the IMO accelerations were exceeded clearly in transverse and vertical directions and moderately in the longitudinal direction.

In addition to motions and accelerations, the seaway induced bottom and bow slamming to the ship when the ship's hull partly raised above water surface hit back to water. Probability of slamming can be estimated by calculating the vertical relative motion of the hull at a desired location. When the relative motion exceeds the local draft, i.e. the hull immerses from water, and in addition the relative velocity exceeds a certain threshold velocity, it can be stated that circumstances for a slam exist.

When the vessel had to steer according to waves in the storm for about 60 hours, the number of estimated bottom slams is very high: 9300 using results in head waves, and 7620 when estimated from results in bow waves. According to notices in the log book and maritime declaration, the slams were severe, and the hull had bent as a result of the impacts. This naturally increased forces acting on securing gear. Hull whipping vibrations and associated accelerations cannot be estimated with the method applied in this work, because ship's structures are not modeled.

Classification societies have published guidelines in their rules to calculate motion quantities and accelerations. These were applied in the investigation at the centre of gravity of the aftmost railway carriage. Bureau Veritas (BV), Det Norske Veritas (DNV) and Lloyd's Register of Shipping (LR) were selected as objects of investigation. The rules differ in many details but their treatment is limited outside this work. Accelerations for the aftmost railway carriage are shown in Figure 20. Transverse and longitudinal accelerations lie quite close to the mean of values of classification societies, but vertical acceleration is smaller than the corresponding mean value. Location of the examined railway carriage near midship reduces in particular vertical accelerations compared with the bowmost railway carriage.

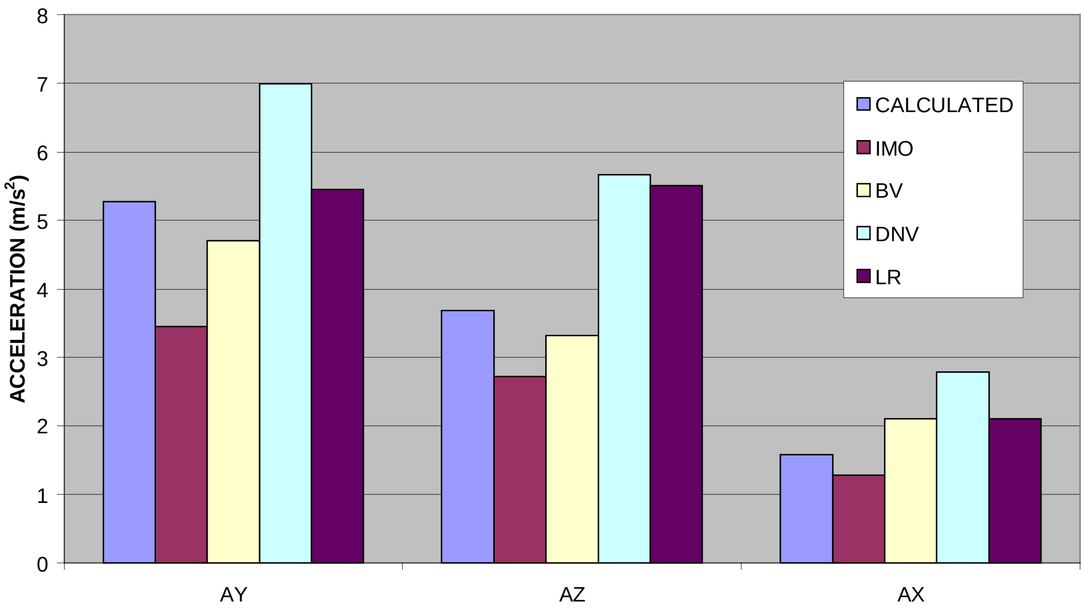

Figure 20. Comparison of accelerations in different directions for the aftmost railway carriage.

1.4.2 Strength of lashings

Loosening of TRADEN’s cargo in the seaway shows that strength and tightness of the applied lashings were not sufficient in relation to weather and sea area. For this reason, a study of features influencing strength and tightness of lashings was carried out as a part of the accident investigation. One part studies sufficiency of binding directions and, among others, flexibility of chains used for lashing the Pendolino railway carriages. Flexibility means how much the length of a chain changes as the loading acting of it varies, and this together with used binding directions determines how tight the binding can be. Changes of chain lengths as the loading varies and absence of binding in certain directions have obviously implied that there has been cargo loosening from the fastening surfaces. In these cases the friction force, which is meant to keep the cargo on place, has instantaneously disappeared and the cargo, trestles, and in particular the loose beams below the trestles have been able to move gradually.

Force components and binding directions

Mechanics-based examination of force components shows that a tractive binding interlinked perfectly from the ends has no force effect (holding power) in direction perpendicular to the binding until displacement is several per cent of the length of binding. Therefore, initial stiffness in direction perpendicular to the binding is lacking. When a small movement has taken place in direction perpendicular to the binding, the straight angle has changed slightly. Holding force starts to develop in the originally perpendicular direction but to such a small extent that it has no effect on functioning of the binding. For this reason, binding of a point is always marked with three binds in directions perpendicular to each other. Each end of the trestles below the Pendolino railway carriages was bound only in two oblique directions approximately 20 degrees from the deck plane, i.e. from the horizontal calm water plane when the ship is in harbour. The ends of the trestles were neither bound in ship’s longitudinal nor vertical directions in a clear way. When the ship rolled in seaway during the voyage, the above-mentioned 20 degrees affected in such a way that the binding held only with respect to transverse motions and in direction of horizon to some extent of tightness. As the ship rolled and the lower bind yielded as a result of the load acting on it varied, vertical holding force of the other bind disappeared totally in practice. Thus, the trestle end being in turn in upper position was free to heave. It could not keep up with ship’s motion because this bind was to be in horizontal direction with respect to earth and this end of the trestle was free to move in perpendicular direction to the binding, i.e. in vertical direction. Ship’s vertical motion and in particular rolling and whipping when inclined where then sufficient to unfasten the other trestle end from deck. In that case beams below the trestle end were able to move and the stack to fall apart, which resulted in gradual collapse of the trestle.

Tightness of binding

Flexibility of the used lashing chains was measured to determine the tightness of binding. The spring constant of a chain was obtained to be $\Delta F/\delta$ = 6 tonnes / % in chain direction. Thus, load variation of two tonnes would imply a movement of one centimetre in bind direction. This would imply a movement of the other bound end by about 1.5 centimetres in a direction perpendicular to the binding of the other end without any resulting force to keep the trestle leg attached to the deck. There is no holding force in perpendicular direction to a bind until a small displacement has taken place because of so-called dead angle effect. This means that in perpendicular direction to the chain (i.e., in vertical direction when the ship heels) a holding force equal to 100 kp would be achieved with a chain of 3 m in length not before the attachment point has moved 50 mm, in other words, when the trestle leg had already unfastened from the deck. Collapse of the Pendolino trestles and loosening of railway carriages is explained most naturally in this way.

2 ANALYSIS

2.1 Loading event

Stevedores loaded the ship and ship's personnel fastened the cargo. Ship's crew had also fastened containers loaded at Haifa and Valencia. Containers on the weather deck were stowed on planks and fastened with chains to the deck. It can be deduced from damages of the ship's weather deck that the deck fastenings were torn from the deck and caused the loosening of the cargo. Material thickness of fastenings was essentially smaller than the thickness of the new D-rings welded in Kotka, Figure 15.

When the ship arrived at Vado Liguria, the railway carriages were ready in harbour on the trestles. The loading itself took 6–7 hours. Guidance from the shipper were used in lashing the railway carriages, but the ship's officers were not satisfied with the given instructions. In accordance with loading the railway carriages, the chief officer suggested that rubber mats were placed under the transportation trestles to increase friction. The shipper required, however, beams to be placed below the trestles because this was the practice applied also previously in corresponding shipments. The cargo was transferred to the ship with a specific trailer and removal of the trailer from below the railway carriages and trestles required stands below the trestles. Each railway carriage was fastened to the ship with sixteen chains, and bars of approximately 10 cm in thickness were placed below the trestles in two layers. Timber and trestles seemed acceptable and according to the master the stevedoring company knew their stuff.

The master interpreted, however, the railway carriages as specific cargo and had expected an external surveyor, a "supercargo", who had had sufficient knowledge of language. A young representative of the shipper, who had not sufficient experience regarding loading, surveyed the loading. In addition, there were many supervisors in the loading situation.

Although the ship had the responsibility about cargo transportation and seaworthiness, it was nearly impossible to affect the loading itself, the support and lashing of cargo.

Problems in interplay of ship and shipper came out clearly in a loading situation. The master criticized the harbour personnel's language problems and expertise in load planning. In addition, railway carriage dimensions given for the ship did not hold with the real dimensions of carriages fastened on the trestles. As a result of this the entire loading had to be quickly redesigned because the railway carriages could not fit to the ship according to the plan of the ship.

2.2 Cargo securing manual

The TRADEN carried a cargo securing manual approved by authorities, but one could not find advice directly from it about fastening the cargo concerned. The cargo securing manual prepared already by the previous owner, consists mostly of items of various subjects copied from other literature. They describe transportation in general and the associated loads acting on cargo. Guidelines for calculating forces are also given. These guidelines include descriptions of cargo securing methods, but no information is given on holding forces achieved with different bindings. The end result is a non-uniform collection of forces, accelerations and friction coefficients, which act on cargo during transportation, but actual recommendations about bindings are lacking. List of contents does not correspond to real contents of the manual. There are no guidelines about holding capacity of different cargo securing gear, which implies that a centrally essential part is lacking from the manual, and it includes lots of nonessential items, which could be deleted to promote learning.

Language of presentation differs from one chapter to another from Finnish to English and Swedish. Chapter 4 of the manual is in English. It covers lashing of containers, trailers and other cargocarrying vehicles, break bulk and other unitized cargoes and cars by using examples. Chapter 5 according to the list of contents of the manual is numbered to begin with number 4. It thus begins with Chapter 4 of another reference, presenting in a principal level and in a text book style features about forces acting on units to be loaded, and road transport is also widely discussed.

The manual does not clearly discuss those cases where accelerations comparable to acceleration of gravity acts on cargo located at ship’s bow or stern. Forces caused by these accelerations have a snatching effect on cargo in storm conditions.

Accelerations are given several alternative ways of presentation, and it is very difficult for the reader to deduce what is the correct approach. Therefore, securing needs for those cases where cargo can be ”slinged” by the ship and where keeping of the cargo with ship motions requires even binding corresponding to weight of the cargo, is described very shortly and entirely insufficiently.

Lack of presentation of holding forces achievable with different bindings leaves the reader totally hesitant with respect to how many holding bindings and in which directions are needed for each cargo unit in different sea areas. Only a rough Swedish mention about the need to await for the worst ("Godset måste alltid förberedas på att det värsta kan inträffa") leaves the reader of the text, accepted as a manual, alone with the difficulty of transportation. In addition, this reminds about the loneliness of a seaman, and about the negligence of authorities, ship owner, as well as labour protection systems about the liability of the title manual. The manual does not give decision support in practical situations.

2.3 Ship stability

2.3.1 Stability in waves

The ship’s loading condition is presented in Chapter 1, and in the loading condition concerned the vessel fulfilled the required stability standards according to calculations carried out onboard as well as during the accident investigation. The calculation carried out onboard using hydrostatic tables yielded smaller initial stability (GM_0 = 1.12 m) than the computer-aided calculation (GM_0 = 1.48 m). This is a typical result, because one tends to approximate the results of calculation towards safer direction and to find the smallest possible value.

The ship was very stable in the current loading condition and the value of metacentric height (GM_0) can be regarded as large. Due to the relatively small amount of cargo it was necessary to use ballast in bottom tanks, and there were in practice no possibilities to affect the stability values.

The cargo shift caused a list to the ship and according to the log book the maximum list was 20° to the right. This reduced stability, together with the contemporary effects of roll and wind. If the cargo had been able to shift to a larger extent, the situation had become essentially worse from the stability point of view, and if securing of containers on the weather deck were not successful, the ship might have capsized.

It has been shown with the stability calculations approximately a 4 m transverse shift of the centre of gravity of cargo causes a list of 20°. A cargo shift equal to the ship's half-breadth, i.e. 9.2 m in transverse direction, is considered as the maximum possible one, when the ship attains a list of 35.5°. When considering ship's roll motion with an amplitude of 25°, and the effect of storm wind, the stability calculations show that the ship was not in danger of capsizing in case of 4 m cargo shift. However, a cargo shift equal to the ship's half breadth would have probably capsized the ship.

The results are presented in more detail in Appendix 2

2.3.2 External conditions from the point of stability and motions

The ship encountered a storm, which was not exceptional in the Atlantic area, and corresponding wave heights occur on average monthly during Autumn and Winter. From the point of view of ship motions and forces acting on cargo, the occurrence of confused sea made the situation much more difficult, inducing roll motion at all heading angles, and it was not possible to reduce roll significantly by a change of heading. According to the interview, the master had never before experienced such confused seas in the area.

Bilge keels had been removed from the ship in connection with docking as a result if ice damage, and roll motion was more violent than it had been if bilge keels were kept and repaired. This is still emphasized by the roll reducing capability of bilge keels at the entire speed range, in particular also at slow speeds, which had to be used in high seas. Loads acting on cargo had also been smaller if bilge keels had been retained.

435 tonnes of the ship's cargo were placed on the weather deck and 783 tonnes on the main deck. All six railway carriages were loaded on the main deck because they could not have been placed elsewhere. According to the original loading plan, two carriages were to be loaded at bow and four aft of them side by side, which would have effectively prevented their possible transverse movement. As the carriages were loaded with trestles, their total breadth was so large that the loading plan could not be applied as such with the exception of two railway carriages nearest to the bow. The other four carriages

were placed aft of these, three side by side and one aft of them near the ship's side. The last mentioned railway carriage loosened first from lashings, which could have possibly been prevented if the original loading plans could have been applied.

The amount of cargo was in total quite small and the deadweight of the ship was approximately 53% of the maximum capacity. This implied a quite large value for the metacentric height (GM_0), when the share of ballast is taken into account. Without ballast, a smaller draft of the ship would have been caused further more bottom slamming and possibly propeller and rudder immersion in storm and reduction of steering ability.

The metacentric height (GM_0) was rather high, 1.48 m, and the ship's natural roll period about 13 seconds, which increased accelerations acting on cargo, in particular the higher the cargo was located in the ship. However, it was not possible to reduce the metacentric height remarkably and increase rolling period by means of loading. The cargo was placed as sensibly as possible in case of current cargo. A part of containers could have been placed on the weather deck, but this would not have had a remarkable effect on the roll period and on the transverse accelerations acting on the railway carriages.

Essential additional forces on lashings were caused by slamming impacts and associated whipping accelerations, which resulted in observations of hull bending. Loosening of railway carriages was possibly caused by a consequence of this kind of event, and reduction of the amount of ballast would have increased the amount of slamming impacts furthermore.

2.4 Strength of lashings

The D-rings used to secure containers were rather worn. The welding joints had possibly also been eroded during the course of time. The D-rings had broken at locations of welding joints. It is clear that the D-rings were insufficient in strength for securing normal cargo in storm conditions. It is not possible to estimate their breaking strength, but the D-rings were renovated essentially stronger.

Support of the Pendolino railway carriages on trestles of about 1 m in height was meant to assist in transferring the carriages used in road transport on shore before leaving for the voyage. The Pendolinos were left on the trestles and were lashed only from the upper beam of the trestles to the deck. Legs of the trestles were secured only from their upper ends to the upper beams with twistlocks. Wooden beams under the trestles, and legs of the trestles were not secured separately at all. The trestle structure with beams seemed to be appropriate for road transport, but the chief officer of the ship had questioned the fact that rubber mats were not placed under the trestles to increase friction (and to compensate the flexibility of the chains). It is obvious that trestles' legs should have been secured separately to the deck and movements of the beams should have been prevented by "boundary obstacles". The number of lashing chains might have been insufficient, and the direction of binding too flat from the point of tightness of the lashing. Due to the light-type structure of the Pendolinos, there might not have been enough points with sufficient strength for lashing. It is possible that a sea transportation in severe storm conditions was not even predicted for the railway carriages, and, therefore, securing points for such conditions were not even designed.

The mechanism of collapsing of a trestle is shown in Figure 21. The red arrow marked in the figure shows the lacking binding direction where the cargo unit is nearly free to move, when simultaneously a small additional force stretches the other binding.

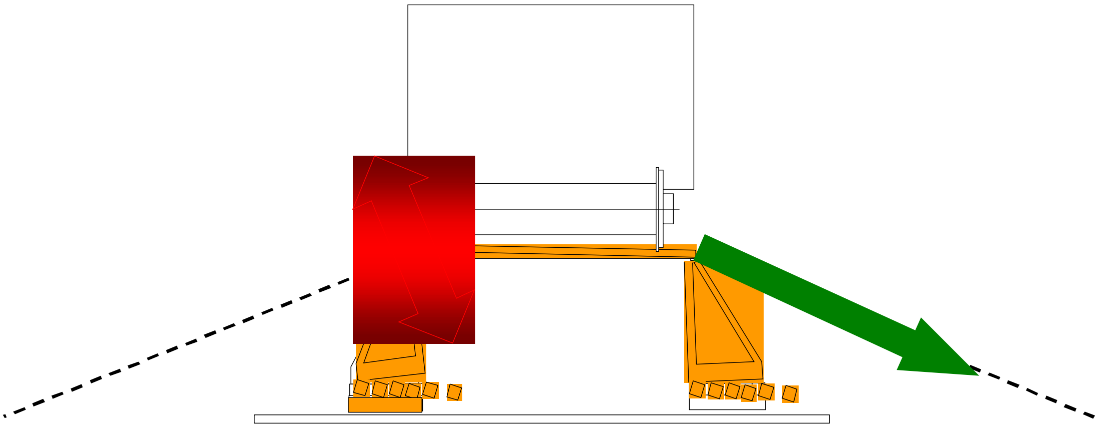

Figure 21. Collapsing mechanism of the trestle.

It is possible to examine the behaviour of the trestles in physical terms by using accelerations experienced by the ship. The total accelerations at the bow were according to the calculations of the order of magnitude of *g,* and at midship approximately 0.5 *g*. This implies that the force caused by a Pendolino carriage on lashing chains would be approximately the amount of its own weight added by a geometry coefficient according to the installation angle. Flexibility of a chain was measured to estimate if a trestle would detach from the deck. It is of the order of magnitude 6 tonnes / %. Thus, if a Pendolino is held stationary for example with 8 lashing chains, in rolling motion each chain will experience a force, which is sufficient to lengthen about 3 m chain with 30 millimetres. It is obvious that a trestle or the end experiencing lift will raise out of the deck, and nothing will prevent any more the parts of the beam stack. Translations will occur gradually until there is nothing left under the trestle's leg, and it can move freely and collapse.

The mechanism of loosening of the Pendolinos has probably been such that the stretching of a trestle has been associated with a gradual movement of a trestle's leg in the outward direction. The form of the trestle's leg has contributed to this together with the fact the trestle's lower end was not secured. The wooden beams under the trestles have obviously given loose, and their friction against the deck was not sufficient to prevent the cargo shift. If the beams have been wet, this has further advanced the escape of a trestle's leg sideways.

It might have been hoped that holding of the lashings of the Pendolino railway carriages has increased by making use of "friction surface" (dunnage). Wooden beams below cargo are traditional and typical to create a tight stowage and to prevent the otherwise easily moving cargo units from directly touching each other and the ship. The cargo securing manual of the TRADEN presents examples of this kind. The stack of beams used as friction pieces in two layers between the Pendolino trestles and the deck could retain its current form only if the stack was under compression.

As the ship moved, the cargo loaded the lashing chains, and as they were stretched a situation obviously arose, where beam stacks were not held together by anything any more. Together with raising of a trestle leg perhaps up in the air the chains stretched, and the loose beams between the trestle leg and deck could shift gradually away from their intended location. Thus, the assumed frictional action did not sustain, and due to the form of the trestle legs the structure became unstable already after small displacements.

In cargo securing terminology ”dunnage” means additional material such as beams to be used to secure cargo units. In this way the cargo material, being harder than beams, can be stowed as a mutually stationary entity. Dunnage is thus "stuffing" in this context. The beams used as a friction surface in supporting the Pendolinos are of this kind of material. Rubber mats proposed in addition/in place of them would have been more flexible and possibly permitted some more stretching of lashing chains before loosening of a trestle leg from the deck. However, remarkable addition of holding ability would not have been achieved, because the force required to hold the cargo with the current binding would have provided stretching of tens of centimetres to keep them attached to deck. This is a consequence of the applied way of binding with two chains of approximately equal length in sideways inclined direction. The additional binding perpendicular to the used direction was lacking, and, besides, parts of trestle legs were mutually loose pieces, which would have been bound to a unravelled packet.

2.5 Crew action

Weather was good until Gibraltar. Swell raised rapidly near Lisbon, and the ship began to roll. The master applied the route plan until 20 o’clock on Wednesday October 17, when the ship began to roll in high swell. The vessel was turned to heading 330° to reduce the roll motion. There were no reasons to reduce ship’s speed earlier for the purpose of approaching a storm. Weather forecast did not predict what was to come. Navtex had predicted decreasing wind

Roll was violent and rapid, because bilge keels were absent. The amount of cargo was small and GM_0 was large. The master had in mind the lashing of the railway carriages. Absence of bilge keels was observed in April 2001 in connection with docking. Ice had torn the bilge keels and the uneven parts of the bilge keels had been removed by the previous owner. The docking was the first one during the current owner, because the ship had been purchased not until January, 2000. The master noticed that in the Biscay the bilge keels would have been needed.

The night before Thursday was difficult, because in darkness one could not see the direction of waves. The master tried to turn the ship to a direction, where roll would have been peaceful. Best wave direction would have been about 20° from the bow, but a suitable direction could not be found because the seaway had changed to confused in character.

The second row of containers, i.e. tier, loosened at 1630 on October 18. The master dropped the speed to six knots. The seaway was from north-west and turned to west. The crew fastened containers as the ship heeled 20°–25° from one side to another. Dunnage was first placed between containers to prevent the about 2 m movement of containers in transverse direction. Thereafter a chain was fixed to the other end of container, and first thereafter the container could be secured in total. The master feared then about loosing containers and the possibility of work accident came into his mind. Danger of ship's capsizing did not yet exist. In the evening waves came from south-west.

In Friday morning at 0500 on October 19 the cargo on main deck was secured. At 1000 cargo securing was continued on the weather deck. The master announced to Finisterre Radio at 1100 that the situation might change into emergency. He was not worried any more only about containers and risks of crew accidents. The master had an idea that the situation might change to a danger of life. For example stopping of machinery could lead to capsizing of the ship in beam waves.

At 1415 the second officer announced that the aftmost railway carriage on main deck had loosened from its lashings. It was not possible to go to secure it. After one hour the master realised the severity of the situation. The railway carriages might hit a hole to the side of the ship. The ship was kept at a list of 20° to diminish the transverse movement of the railway carriages. The master deduced the danger of life and informed the crew about the emergency at 1500. He sent a VHF-DSC distress call at 1510, an MF-DSC distress call at 1520, and an Inmarsat distress call at 1550. According to the master it was necessary to send the distress calls. The master gave the General Alarm for abandoning the ship at 1745. The crew came to the wheelhouse dressed in survival suits. One engine officer stayed in the machinery room. As long as the engines were running there was hope left. The master acted correctly and firmly, but the idea of possibly leaving the ship was difficult. The entire crew began to feel exhausted.

The master contacted the Finisterre radio station. He enquired about possibilities of using rescue helicopters. He was answered that the TRADEN was outside the range of the helicopters. This was extremely disappointing information for the crew. When looking at the foaming sea, the well-known rescue attempts of the ESTONIA accident came into mind for many persons. Will the same take place now ?

The crew was on wheelhouse wearing survival suits. They wanted to try to rescue with a raft to the DOLE AFRICA, which had come to assist, and was located near the bow. The DUNCAN ISLAND was on the right hand side. During the launch of the raft a couple of waves filled the raft and the painter line broke, and the raft was lost. It became clear to all that if the ship capsizes: no helicopters – no raft – no rescue. Part of the crew wanted to try with another raft, but the master denied it. He wanted to save it to the last moment.

Later it was found out, that the DOLE AFRICA had a plan how to lift the TRADEN's crew from the raft. The aim was to throw a throwline over the raft. The master of the TRADEN thought later that it hardly could have succeeded. Finally, it was just a fortune the crew did not abandon the ship.

After loosing the raft the sea began to calm down. The crew was exhausted after staying awake for two days. List was reduced to four degrees, and with this list the ship was steered to Le Havre. Another world was waiting there, which was more interested in material losses than critically rescued persons.

2.6 Rescue possibilities

The TRADEN's incident shows that in ocean conditions the ship abandon was not possible in practice with the ship's own life saving appliances. Open life boats or rafts are not a feasible solution in rough seas.

3. CONCLUSIONS

Accident and success lie very near each other. Decisions, orders, and actions taken can be the same, but they can lead coincidentally to a different end result. Accident investigation can not explain this difference. In case of the TRADEN it can be only stated that master's decisions and crew's actions were correct. They saved the ship and the crew. It is possible, however, that the actions taken had not helped. An accident was nearby.

3.1 Summary of events leading to cargo shift

The cargo shifted as the ship encountered a storm and exceptionally difficult confused seas for more than two days. Ship's roll motion was violent and the hull experienced severe bottom slams, which resulted in hull bending. Difficult wave conditions prevented finding a heading, where rolling could have been remarkably diminished. The only way was to steer according to waves, and to try to avoid largest roll angles to arise.

The long-lasting and violent roll together with slamming impacts caused the ship's cargo varying accelerations, which resulted in increase of forces acting on lashings. The ship's small amount of cargo and remarkable amount of ballast resulted in quite a large metacentric height (GM_0), which increased accelerations acting on the cargo compared with a situation, where the ship had been fully loaded.

The forces induced by large accelerations broke the weak securing points on the weather deck and caused loosenings of containers. The insufficient binding of the Pendolino railway carriages on the main deck caused heaving of the trestles and movements of beams below the trestles, collapse of trestles, and further slackening of binding and loosening of railway carriages. Cargo shifted towards the right side of the ship and the ship was caused a 20 degree list at maximum. If the cargo shift had been larger, ship's capsizing would have been quite probable.

The shipper's lashing method was not according to the IMO Resolution, because the shipper has to prepare a loading plan according to principles of the Resolution. Cargo and its mounting are treated in SOLAS agreement as a single unit (cargo and cargo units).

It is difficult for the ship's crew to invoke to the IMO Resolutions, because the shipper is supposed to have a better knowledge about special cargo. Ship's personnel would have wanted to have rubber mats below the railway carriage trestles, but according to the resolution the mounting had to be wooden. In this respect the shipper was right. Ship's personnel should possess clear shipping company-specific cargo securing guidelines based on the IMO resolution. Using these guidelines the personnel can deduce which of the shipper's guidelines are acceptable.

3.2 Conclusion about background factors affecting on incident

Ship's personnel can not affect ship's amount of cargo, or prevailing external conditions. On the present voyage, the incident took place as a sum of many coincidences. However, it has to be noticed that the firm action of the crew in danger prevented a severe accident to take place, which would have threatened the crew and the ship.

Differences in ship's loading plan and real loading event became clear to the crew only in connection with the loading. In addition, there were problems in communication between the ship and the harbour. Besides language problems, there were conflicting views in cargo securing. Oral rules from the shipper's side were in conflict with the view of the master and the chief officer. Although the master is responsible for the ship, the cargo securing guidelines of the vessel were not followed in the present case, but the cargo was supported partly on basis of advice of the shipper. Ship's cargo securing manual did neither clearly define the securing method nor the amount of securing gear.

Ship's calculation show smaller stability than the ones carried out during the investigation. Differences can be explained by the fact that on board a ship the calculations are rounded towards safer direction and smallest possible value is searched. In addition, ship's stability calculations were carried out by hand using hydrostatic tables. The ship did not carry an actual stability calculation computer program.

Within the investigation it was observed that deck fastenings of the D-rings on the weather deck had weakened, which might explain the loosening of containers.

Several factors contributed to the origin of the incident. The ship's small amount of cargo required using ballast also in ship's bottom tanks, which further increased ship's stability. With the increase of added stability, also accelerations acting on cargo increased.

Weather on the voyage was not exceptional for the season, but the fast moving low pressure area raised high seas in the area. This together with the north swell caused confused seaway, which was difficult for ship motions and steering.

3.3 Cargo securing manual

The ship carried for cargo lashing a cargo securing manual approved by the Finnish Maritime Administration on August 5, 1996, from the time of the previous owner. Containers were secured according to the guidelines of the manual, but the D-rings, which acted as securing points were badly eroded and worn. Fastenings of the rings tore from the weather deck, and containers were able to move.

In Chapter 9 of the manual there are guidelines for securing heavy cargo items, such as locomotives, but there are no mentions about structures like the trestles below the carriages. It is difficult in a hectic loading situation to carry out calculations required by the guidelines to evaluate the needed lashing forces. Guidelines of the owner concerned methods in ship's loading. No written loading and securing guidelines were available from the shipper. The manual lacks information about holding ability achieved with individual lashings compared for example with forces acting on cargo in a seaway.

Planning of cargo securing

Specific calculations were not carried out for the ship about cargo securing, but the securing was based on experience and the shipper's guidelines. The cargo securing manual was not in use, and the securing plan as required by the IMO resolution was not made.

Securing of the Pendolino railway carriages

There were no actual guidelines concerning securing of the cargo like the Pendolino railway carriages. The Pendolinos were transported to the harbour as a road transportation using carriages with wheels. For them there existed evidently trestle equipment, below which it is possible to drive the carriage away and on which the railway carriages could be supported. Trestles consisted of an upper beam and loose legs, which were bound to the upper beam with twistlocks. The trestles had to be raised with wooden beams to make it possible to drive the carriage away, and when set to the ship, these beams were to form the surface increasing friction. The Pendolinos were secured with chains from the upper beam inclined to deck. There were also bindings between the upper beam and the bogie of the Pendolinos, but trestle legs were ”loose” and not bound, like the beams below the trestles.

3.4 Action of the master and crew

It was thanks to the crew that the containers on the weather deck were successfully secured before the railway carriages on main deck. The ship might have been capsized unless the containers were secured. The master's decisions were correct. He did not fear to publish the incident when sending a distress call. Although the decisions, orders and actions carried out are correct, they could have lead to another end result, because success and failure are very close each other. It was possible that the actions taken had not helped.

3.5 Rescue

In practice, it is very difficult to abandon a ship in storm conditions using the ship's own rescue equipment.

4 RECOMMENDATIONS

In the TRADEN's incident the welding joints of fixed securing points or D-rings were broken, and containers on the weather deck were able to move. The investigation recommends that

1. *ship owners confirm that in ship's safety management system also fixed securing gear are taken into a regular inspection process.*

The cargo securing manual of the TRADEN appeared to be an extensive selection of articles within the field of cargo securing. Therefore, it is very difficult to find essential facts from the manual and clear guidelines for securing the cargo. The investigation recommends that

2. *ship owners take care that ship's cargo securing manual is clearly guiding to cargo lashing. Predefined accelerations based on ship's size, stability, season and operation area are to be included in cargo securing guides.*

Results of stability calculations carried out on the TRADEN differed remarkably from the results of the computer-aided stability calculations during the accident investigation. The investigation recommends that

3. *ship owners start to use computer-aided stability calculations to achieve more precise results.*

The TRADEN encountered a storm, which was not exceptional in the Atlantic conditions. Due to the routes of the low pressure areas, troublesome confused seas developed in the area, and it was not possible to reduce ship's rolling by changing heading or speed of advance. Roll motion and loads acting on the cargo were larger because the bilge keels were removed compared with the case where the bilge keels were retained and repaired. The investigation recommend that

4. *ship owners repair ice damaged bilge keels instead of removing them.*

Clear guidelines for cargo securing have to be found easily from a cargo securing manual. TRADEN's cargo securing manual does not fulfill the requirements set for a manual. The investigation recommends that

5. *the maritime authority publishes criteria for issuing and approval of cargo securing manuals according to the IMO Circular MSC/Circ. 745.*

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Tapani Salmenhaara

Kari Larjo

Seppo Kalske

Klaus Rahka

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