Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Ministry of Transport,
Building and Urban Development

Investigation Report 510/08

Very serious marine casualty

Fatal accident on board the CMV CHICAGO EXPRESS during Typhoon "HAGUPIT" on 24 September 2008 off the coast of Hong Kong

1 November 2009

www.bsu-bund.de

The investigation was conducted in conformity with the law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law – SUG) of 16 June 2002.

According to this the sole objective of the investigation is to prevent future accidents and malfunctions. The investigation does not serve to ascertain fault, liability or claims.

The present report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to art. 19 para. 4 SUG.

The German text shall prevail in the interpretation of the Investigation Report.

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1 Summary of the Marine Casualty

At about 0245 h[1] in the morning on 24 September 2008, a very serious marine casualty occurred on board the 8749 TEU[2] container vessel CHICAGO EXPRESS sailing under German flag, in which a Philippine crew member was fatally injured, the German Master of the vessel suffered serious injuries, and four more German seamen suffered minor injuries.

At about 1730 h on the previous day, the vessel put to sea from Hong Kong and sailed for Ningbo[3] following instructions to shipping from the local port authority because of the approaching Typhoon "HAGUPIT". At about 1945 h, immediately after reaching the open sea, the CHICAGO EXPRESS encountered heavy winds and swell from a south-easterly direction; this exposed the vessel to rolling motions of up to approximately 32 degrees.[4] The ship's command therefore decided to deviate from the intended general north-easterly course towards Ningbo and weather the storm, which at the time of the accident had reached a wind force of 10 with gusts of up to 12 Bft, by steering variable courses against the direction of the wind and swell. This led to the roll angle being reduced to values of about 20 degrees.

At about 0245 h, the vessel, which at the time was under the control of the Master and steered by the Helmsman manually, was suddenly hit by a particularly violent wave coming from starboard just as she rolled to starboard. Following that, the CHICAGO EXPRESS keeled over severely several times, at which the inclinometer registered an (uncorrected) maximum roll angle of 44 degrees for an estimated period of 10 seconds. Due to the enormous accelerative forces on the bridge, the Master, the Helmsman (OS[5]) and the Lookout (AB[6]) also present lost their footing and were thrown across the bridge. The Officer on Watch, who was the only person on the bridge able to hold on to the chart table, hurried to the helm and stabilised the vessel's course. The uninjured Helmsman was able to regain his footing relatively quickly and after a short period of orientation, he and the Officer on Watch found both the Master and the AB lying unconscious on the floor with bleeding wounds. While the Master regained partial consciousness shortly after, in spite of immediately initiated first aid measures carried out with the assistance of other summoned crew members and guided by medical consultations via radio (Medico Cuxhaven), they were unable to save the unconscious AB. At 0417 h, resuscitative measures were discontinued.

At the same time as the rescue operations on board, the ship's command established contact with MRCC[7] Bremen and MRCC Hong Kong and organised the evacuation of the severely injured Master. At about 0753 h, after the weather had calmed, a rescue helicopter from Hong Kong alerted by MRCC Hong Kong reached the vessel, took the Master on board and transported him to a hospital in Hong Kong. The CHICAGO EXPRESS subsequently also returned to Hong Kong to hand over the body of the AB

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[1] Unless stated otherwise, all times shown in this report are local = UTC + 8.

[2] Container stowage capacity (**T**wenty-foot **E**quivalent **U**nit standard container according to the vessel operator).

[3] Chinese port approximately 600 nm north-east of Hong Kong.

[4] Source here and below: reading taken from the bridge-inclinometer by the Officer of the Watch (corrected values are probably about 15 to 20% less, see comments below at sub-para. 5.5.2.6.)

[5] OS = **o**rdinary **s**eaman, function on board according to muster-roll.

[6] AB = **a**ble **b**odied seaman, function on board according to muster-roll.

[7] MRCC = **M**aritime **R**escue **C**oordination **C**entre.

and facilitate the official investigation of the accident by the coastal state. The CHICAGO EXPRESS left the port of Hong Kong for the final time on 26 September 2008 at 1400 h.

During the ensuing weeks, the Master, who was in acute danger of losing his life for an extended period because of the severity of his internal injuries, initially received medical care in Hong Kong and was flown back to Germany after his fitness to travel was restored. Thanks to the excellent medical treatment his initial acutely life-threatening condition was stabilised after several weeks.

2 Scene of the accident

Type of event:	Very serious marine casualty
Date/Time:	24 September 2008, approximately 0245 h
Location:	25 nm south of Hong Kong
Latitude/Longitude:	φ 21°46.2'N λ 114°12.9'E

Excerpt from Nautical Chart 2702 (great circle chart of the Indian Ocean), BSH[8]

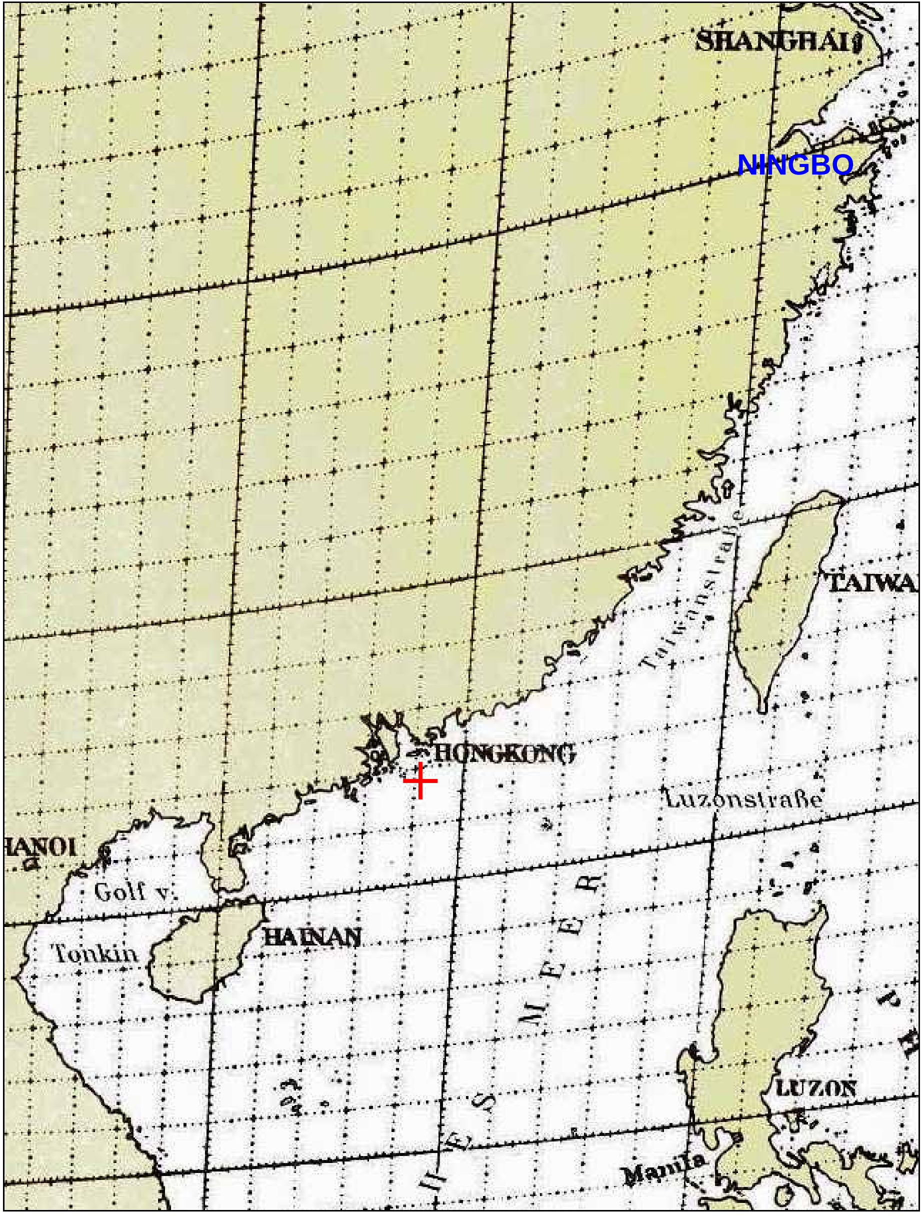

Figure 1: Scene of the accident

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[8] BSH = Federal Maritime and Hydrographic Agency

3 Vessel Particulars

3.1 Photo

Figure 2: Photo[9]

3.2 Particulars

Name of the vessel:	CHICAGO EXPRESS
Type of vessel:	Container vessel
Nationality/flag:	Germany
Port of registry:	Hamburg
IMO number:	9295268
Call sign:	DCUJ2
Vessel operator:	Hapag-Lloyd AG
Year built (keel laying/completion)	2005/2006
Shipyard/yard number:	Hyundai Heavy Ind. Co., Ltd., Ulsan / H 1597
Classification society:	Germanischer Lloyd
Length overall:	336.19 m
Breadth overall:	42.80 m
Gross tonnage:	93,811
Deadweight:	103,691 tdw
Draught (max.):	14.61 m
Engine rating:	68,640 kW
Main engine (type/manufacturer):	Diesel 12 K 98 ME Hyundai MAN
Speed (max.):	25.2 kts
Hull material:	Steel
Number of crew:	35 (including 8 cadets)
Number of passengers:	1

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[9] Source: Hapag-Lloyd AG.

4 Course of the accident

4.1 Events on board before the accident

Statements made by crew members, records in the Deck Log Book and the Manoeuvre Log Book as well as information from Hong Kong[10] indicate that the course of the accident was as follows.
The CHICAGO EXPRESS moored at the port of Hong Kong at 0320 in the morning on 23 September. Container handling took place during the course of the day. Due to Typhoon "HAGUPIT", which was moving from the east towards the Chinese mainland and threatened Hong Kong, the local authorities initiated a typhoon alarm during the course of the day. This led, inter alia, to vessels being requested to leave the port. At 1400, the pilot service distributed information to the effect that it would cease activities at 1700, meaning that the departure manoeuvre would need to begin by that time. Due to these external constraints, loading of the CHICAGO EXPRESS was prematurely terminated. According to the vessel operator, 167 empty 20-foot containers that were waiting to be loaded remained ashore.

At 1659, the pilot boarded the vessel and the departure manoeuvre began with the support of a stern tug. At 1727, all lines were hauled in and at 1735 the tug was released. The pilot left the vessel at 1813. The CHICAGO EXPRESS then sailed slowly from the coast of Hong Kong on a south-easterly and later on an easterly course at speeds of 8 to 10, later only 4 to 6 kts over ground. In addition to the weather conditions, the heavy traffic reportedly demanded the full concentration of the bridge crew. From about 1945, the vessel was reportedly exposed to strong gusts and started to roll severely with heel angles of up to 32 degrees. At about 2018, corresponding to the voyage planning the course was changed to a north-easterly direction. However, due to the effect of side and aft winds as well as swell, this reportedly led to particularly severe roll angles. Therefore, just a few minutes later, the original, south-easterly course direction began to be re-established against the wind and swell. During the following hours, the rolling motions of the CHICAGO EXPRESS were thus reportedly limited to acceptable levels of about 20 degrees. Repeated attempts were made to sail the vessel directly into the wind and swell, the direction of which was seeing constant, moderate changes, with minor, but sometimes also large – in each case considerably more than 10° – course alterations. The speed of the vessel was reportedly also being adjusted constantly with the aim of influencing the seagoing behaviour. A precise estimation of the direction of the swell was reportedly very difficult to make because of the darkness. Turning on the full deck lighting reportedly only led to a very limited improvement in sea visibility. The courses on which the CHICAGO EXPRESS was navigated in the following hours after leaving the north-easterly course, i.e. between about 2030, and the time of the accident, were in a sector of 175° to 70° with speeds over ground of less than 1 kt up to very isolated instances of 8 kts and mean speeds of about 3 to 5 kts.

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[10] Note: Predominantly, the particulars concerning the course and speed could be verified by referring to the AIS records of Vessel Traffic Service Hong Kong (see **sub-para. 5.2** below).

In addition to the effort to limit the vessel's motion to a tolerable level, the primary goal of the ship's command was reportedly to keep sufficiently clear of the westerly, i.e. "at the back" of the CHICAGO EXPRESS, islands of the archipelagos DANGAN LIEDAO and JIAPENG LIEDAO.

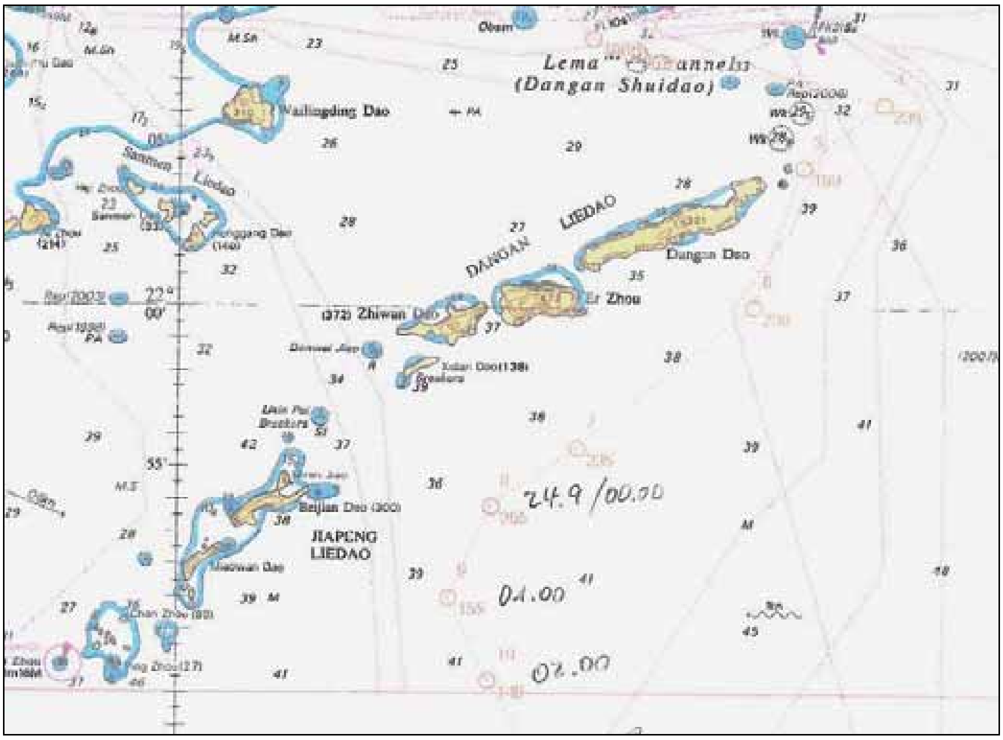

Figure 3: Excerpt of the electronic nautical chart[11]

The sea watch of the Second Officer on Watch began at 0000. The Master in command of the vessel and two Philippine seamen, whose role it was to rotate between the task of Helmsman and Lookout at hourly intervals, were also on the bridge. Accordingly, the OS took over the task of Helmsman at 0200 and the later fatally injured AB that of Lookout.

At that particular time, the CHICAGO EXPRESS was approximately 5 nm south-east of the Jiapeng Liedao archipelago off mainland China at φ 21°48.5' N and λ 114°10.0' E, i.e. in the 6.5 hours since casting off she was only some 22 nm away from Hong Kong. Wind was 130° and continued to reach hurricane force gusts (12 Bft).

4.2 Course of the accident

At the time of the accident, at about 0245, the Master was reportedly situated at the right of the two radar screens integrated in the bridge console and the Second Officer on Watch was at the chart table. The AB who was acting as Lookout was reportedly situated at the GMDSS[12] station (see **Fig. 4** and **5**).

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[11] The excerpt of the nautical chart was prepared subsequently for clarification in the office of the vessel operator.

[12] GMDSS = **G**lobal **M**aritime **D**istress and **S**afety **S**ystem.

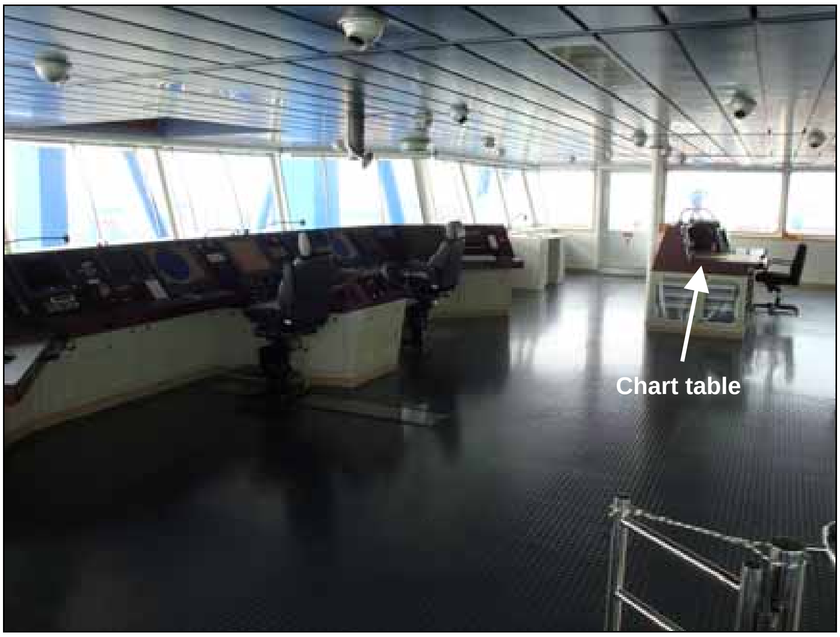

Figure 4: Bridge (1)[13]

Figure 5: Bridge (2)[14]

The reportedly prevailing, subjective impression on the bridge was that the storm was slowly beginning to subside and the rolling motion of the vessel was decreasing slightly. Suddenly, just as the vessel rolled towards starboard, a completely unexpected and particularly violent wave reportedly hit the CHICAGO EXPRESS from starboard. A very severe roll to port and then back to starboard with a heel angle of 44° and a period of 10 seconds was reportedly the outcome. The Master,

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[13] Note: The AB was found close to the companionway handrail, which can be seen in the foreground of the photo, which points to starboard (see also Fig. 5).

[14] Note: The companionway handrail can be seen on the left edge of the photo, which points to port.

the Helmsman and the Lookout lost their footing. The Second Officer on Watch managed to hold on to the chart table. Although the Helmsman fell over, he regained his composure well and was on his feet again very quickly. In contrast, the Master and the Lookout fell to the ground and were unable to find any support. Since it was dark on the bridge and a high noise level prevailed because of the storm, the Officer on Watch and the Helmsman were reportedly initially unaware that the Master and the Lookout had both fallen badly. They reportedly initially noticed only that both individuals were no longer situated at their previously occupied positions. After a reportedly brief moment, they found the Master on the starboard side at the rear of the bridge behind the chart table and the Lookout near the bridge companionway.

4.3 Course of events after the accident

While the OS reportedly immediately checked the condition of the two injured persons, the Second Officer on Watch reportedly took temporary control of the helm in order to stabilise the vessel. At the same time, he reportedly used his VHF transceiver to establish contact with the Chief Engineer in the Board Management Centre (BMC)[15]. The Chief Officer was reportedly informed by telephone. The two individuals mentioned above and other crew members gradually reached the bridge and carried out first-aid as well as attempts at resuscitation. The Chief Officer assumed command of the vessel and handed over the watchkeeping duties on the bridge to the Second Engineer, who is also in possession of a nautical certificate of proficiency, at about 0305 so that he, the Second Nautical Officer and other crew members were able to carry out the resuscitative measures for the AB and treat the Master.

Due to the in part huge deformations and scuff marks on various parts of the interior panelling at floor level on the bridge (see **Fig. 6** and **7**), it later became apparent, that the Master and the AB must have been more or less catapulted across the entire width of the bridge after they fell. Both individuals suffered serious to very serious external and internal injuries.

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[15] The BMC is comparable with the former engine control room; however, it is situated on the main deck and is the information and control centre for overall technical operations on the vessel.

Figure 6: Impact damage to cabinet[16]

Figure 7: Deformed interior panelling at floor level[17]

Immediately after the accident, contact was established with MRCC Bremen and MRCC Hong Kong in order to coordinate the supporting measures pending initiation. In addition, treatment of the injured persons was coordinated with the emergency medical assistance service in Cuxhaven (Medico Cuxhaven) by telephone. Their evacuation by helicopter was initially impossible because of the continuing severe weather conditions. The vessel operator was also informed about the accident immediately.

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[16] Note: Cabinet on the port side of the bridge (in Fig. 5 partially concealed by the GMDSS station).

[17] Note: Such or similar deformations can be found in various places at floor level. The dents shown here are situated in a corner behind the area of the chart table (where the Master was found).

During the ensuing hours, the vessel reportedly continued to roll moderately with heel angles of 20 degrees, which confirmed the trend towards a slow but steady decline in the adverse effects subjectively identified before the accident. For example, moving the Master from the bridge to the shipboard hospital shortly after the accident was reportedly not a problem.

At 0417, the resuscitative measures for the AB were reportedly discontinued because of a lack of success and clear signs of death (no pulse, no respiration, vacant stare, loss of temperature).
In the meantime, efforts to treat the injured Master were continued. At 0753, the rescue helicopter alerted by Hong Kong MRCC reached the CHICAGO EXPRESS immediately after the resumption of air service at φ 21°02.9'N and λ 114°24.1'E. At 0835, the helicopter took the Master on board and at 0933 he was admitted into the Princess Margaret Hospital in Hong Kong.

At 1024, the course of the vessel, which while on a southerly heading had previously continued to weather offshoots of the typhoon, was reportedly changed to a northerly heading with Hong Kong as the destination. After an interim stop at the roads, the vessel moored there at 0300 on 25 September 2008. Representatives of various government agencies, the vessel operator and the port medical service immediately boarded the vessel. At 0600, the body of the AB was taken from the vessel. The CHICAGO EXPRESS left her berth in Hong Kong at 0630 and anchored at the South Eastern Lamma Anchorage at 0918. At 0930 on 26 September 2008, the vessel moored in the port once again before finally leaving Hong Kong at 1400.

4.4 Consequences of the accident

4.4.1 Personal injury

One seaman (AB) lost his life during the accident. He succumbed to severe head injuries on board a short time after the accident.
The Master of the vessel suffered severe multiple external and internal injuries. Inter alia, his spine, several ribs and the lung as well as the right leg (severe open fracture) were seriously injured. He was initially in acute danger of losing his life for an extended period. At the time of publication of this report, his recovery had made good progress. However, one year after the accident and despite participation in several rehabilitation programmes, it is not possible to tell whether or when he will regain full health because of the severity of the internal injuries he suffered. Beyond that, the violent rolling motion also caused four other crew members to suffer bruises and other minor injuries due to falling on the night of the accident.

4.4.2 Damage to the vessel

Despite the heavy forces to which the CHICAGO EXPRESS was exposed because of the typhoon in rough seas, there was no notable damage on or in the vessel.

4.4.3 Pollution of the environment

The environment was not significantly affected by the marine casualty involving the CHICAGO EXPRESS. No pollutants escaped. The loss of six empty containers[18] did not result in significant pollution of the sea.

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[18] Note: According to the vessel operator.

5 Investigation

5.1 Course, substantive particulars, sources

The vessel operator informed the Federal Bureau of Maritime Casualty Investigation (BSU) about the incident on board the vessel promptly after the accident and has subsequently been quick in providing information on the current state of affairs.
Immediately after the vessel returned to Hong Kong, the crew members of CHICAGO EXPRESS were interviewed by the local police department. Additionally, an internal local investigation of the accident was carried out immediately by the P & I[19] insurer. The vessel operator provided the BSU with copies of the records of the interview as well as the insurer's detailed investigation report. The vessel operator provided other documentation, such as printouts from the load computer and technical documents about the vessel during the course of investigation promptly upon request by the BSU, thereby supporting the investigations of the BSU.
A visual inspection took place on board the CHICAGO EXPRESS at the port of Hamburg on 31 October 2008, which involved several crew members being interviewed and reconstruction of the course of the accident.
The investigation team also maintained contact with the Marine Department (MARDEP) of the Hong Kong Special Administrative Region. Its Marine Accident Investigation Section (MAIS) did not perform its own investigation of the accident; however, MARDEP supported the investigations of the BSU by providing valuable information, such as AIS[20] records, which show the course of the voyage of the CHICAGO EXPRESS and information about the local typhoon warning system.

Substantive particulars of the investigation by the BSU requiring emphasis were shown in a detailed scientific appraisal by an expert of the seagoing behaviour of the CHICAGO EXPRESS at the time of the accident. It had become apparent after the initial information about the course of the accident that the generally very specific reaction of the vessel to the effects of the heavy seas was almost certainly the main cause of the accident.

An analysis of the records from the Voyage Data Recorder (VDR[21]) should represent an important resource for investigating the accident, in particular in terms of reconstructing the course of the voyage of the vessel. However, – as became apparent only after the accident – this was largely inoperable at the time of the accident and ultimately no usable data were available to the BSU from the system. As a factor which obstructs an investigation within the meaning of art. 15 para. 1

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[19] Note: P & I = **P**rotection & **I**ndemnity; designation commonly used in shipping for liability insurance cover.

[20] AIS = **A**utomatic **I**dentification **S**ystem; introduced to improve maritime safety. All ships equipped with this system transmit via VHF their current GPS-based data, such as position, course and speed as well as possibly other information, which can be made visible on a monitor. Moreover, an increasing number of sea markers and coastal radio stations are being equipped with AIS transmitters and/or receivers.

[21] VDR = **V**oyage **D**ata **R**ecorder, required system for gathering data to facilitate analysis of the causes an accident should one occur.

SUG in conjunction with art. 18 para. 2 FlUUG[22], the associated problems have been a particular object of the investigation by the BSU.

5.2 Reconstruction of the course of the voyage

Despite the lack of VDR data, the course of the voyage of the CHICAGO EXPRESS, from sailing from Hong Kong to the time of the accident, was very easy to trace because of the AIS records provided by the Marine Department in Hong Kong. The BSU received an Excel spreadsheet from Hong Kong, which shows the relative position of the vessel, its course[23] and the speed over ground[24] as well as the heading[25] in several thousand data records logged at 3-second intervals. A comparison of these data with the written records taken on board and corresponding witness statements did not reveal any significant discrepancies whatsoever.
It was thus possible, for example, to clearly trace the failed attempt by the ship's command to put the CHICAGO EXPRESS on a northerly general course towards Ningbo at about 2018 (see **Fig. 8** to **10**).

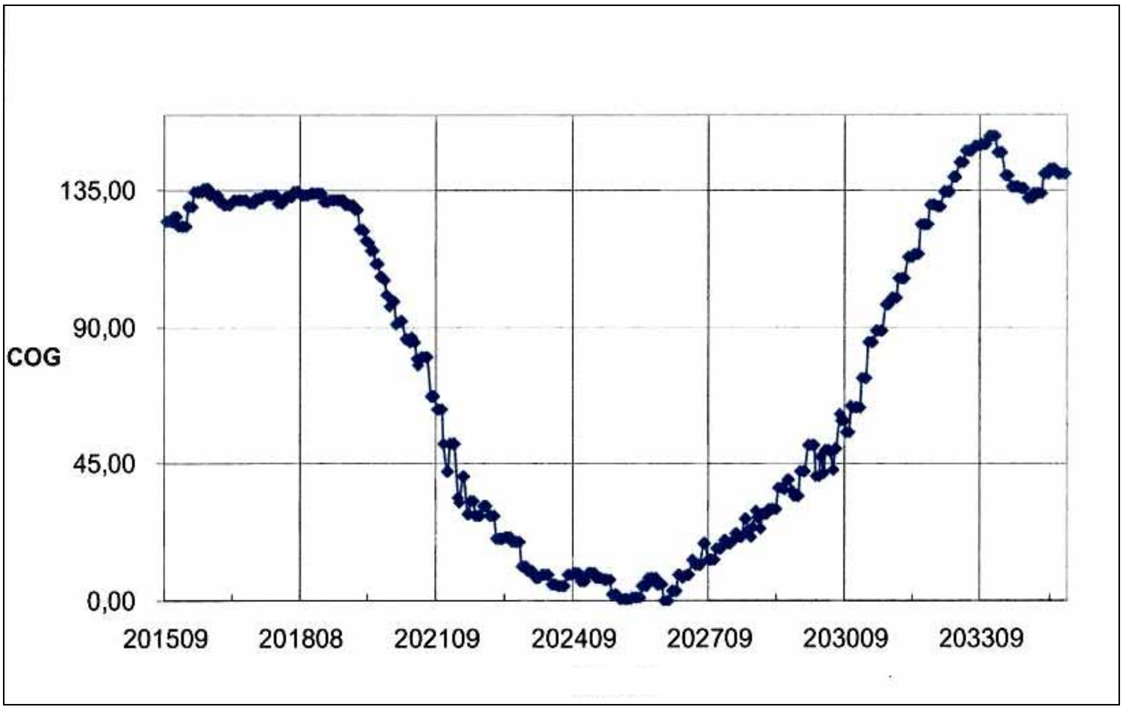

Figure 8: Course over ground between 2015 h and 2035 h

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[22] SUG = Seesicherheits-Untersuchungs-Gesetz (Maritime Safety Investigation Law),
FLUUG = Flugunfall-Untersuchungs-Gesetz (Aviation Accident Investigation Law).

[23] **C**ourse **o**ver **g**round = COG.

[24] **S**peed **o**ver **g**round = SOG.

[25] Heading = in an ideal case, approximately equivalent to the course through the water.

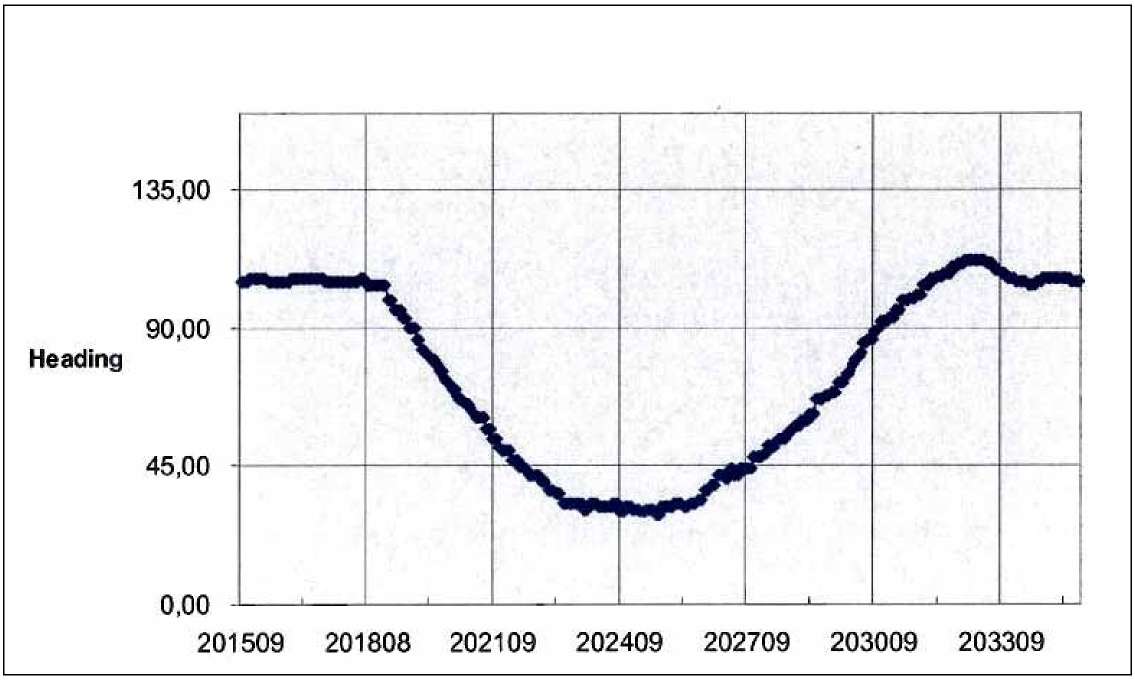

Figure 9: Heading between 2015 h and 2035 h

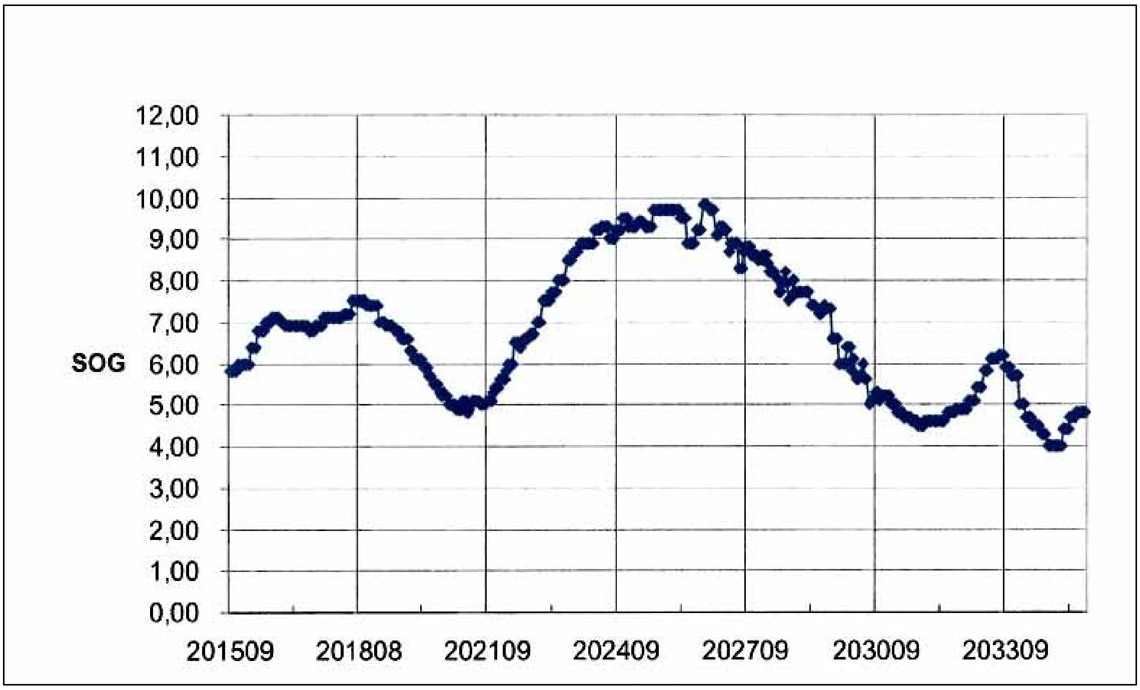

Figure 10: Speed over ground between 2015 h and 2035 h

The repeated attempts by the ship's command during the ensuing hours to reduce the severe effects on the CHICAGO EXPRESS of the wind and swell by adjusting the course and/or the speed are also shown very clearly by the AIS data. The final 45 minutes before the accident saw fluctuations in the course over ground of between 100° and 155° and in the heading of between about 100° and 130° (see **Fig. 11** and **12**).

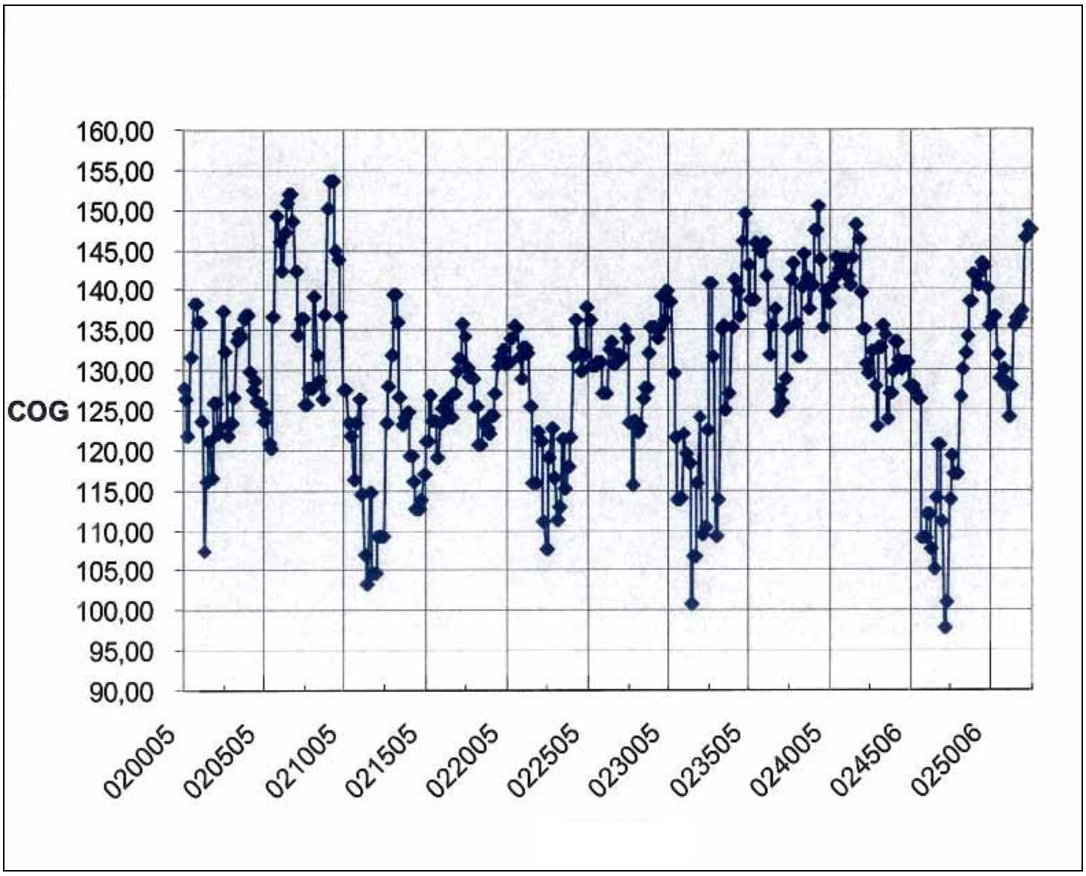

Figure 11: Course over ground between 0200 h and 0250 h

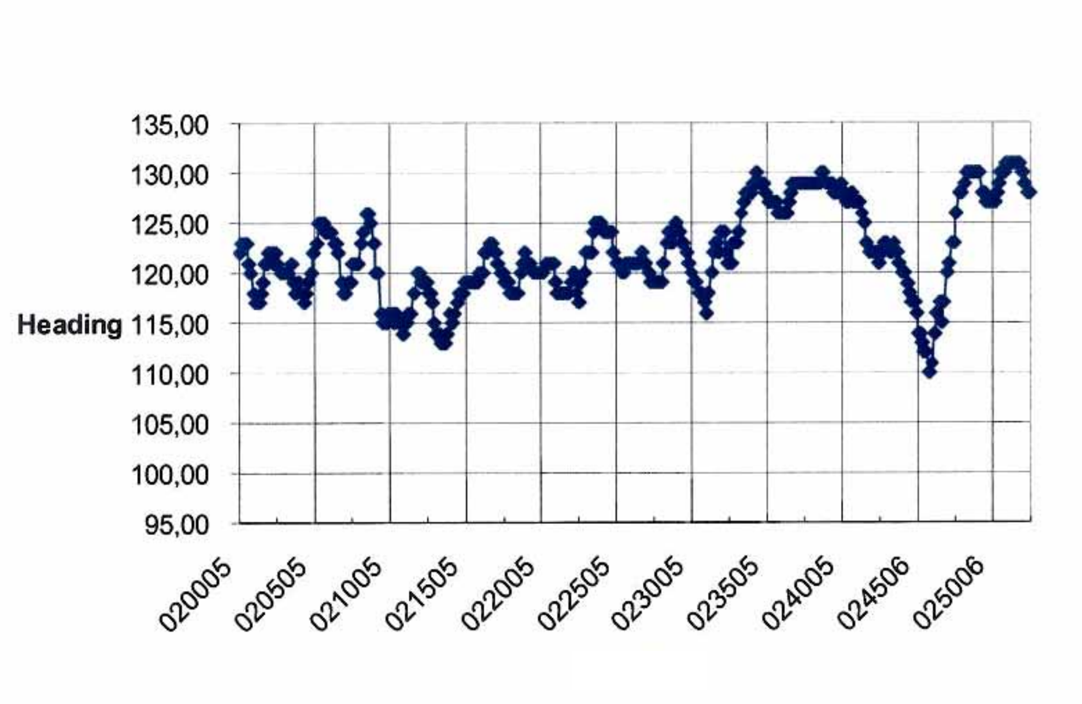

Figure 12: Heading between 0200 h and 0250 h

The speed over ground in the final hour before the accident was also changing constantly (see **Fig. 13**); however, these changes were moderate and in a range of between about 3 and 6.5 kts. These fluctuations are likely to have been caused only by the external factors and not changes in the speed ratings.

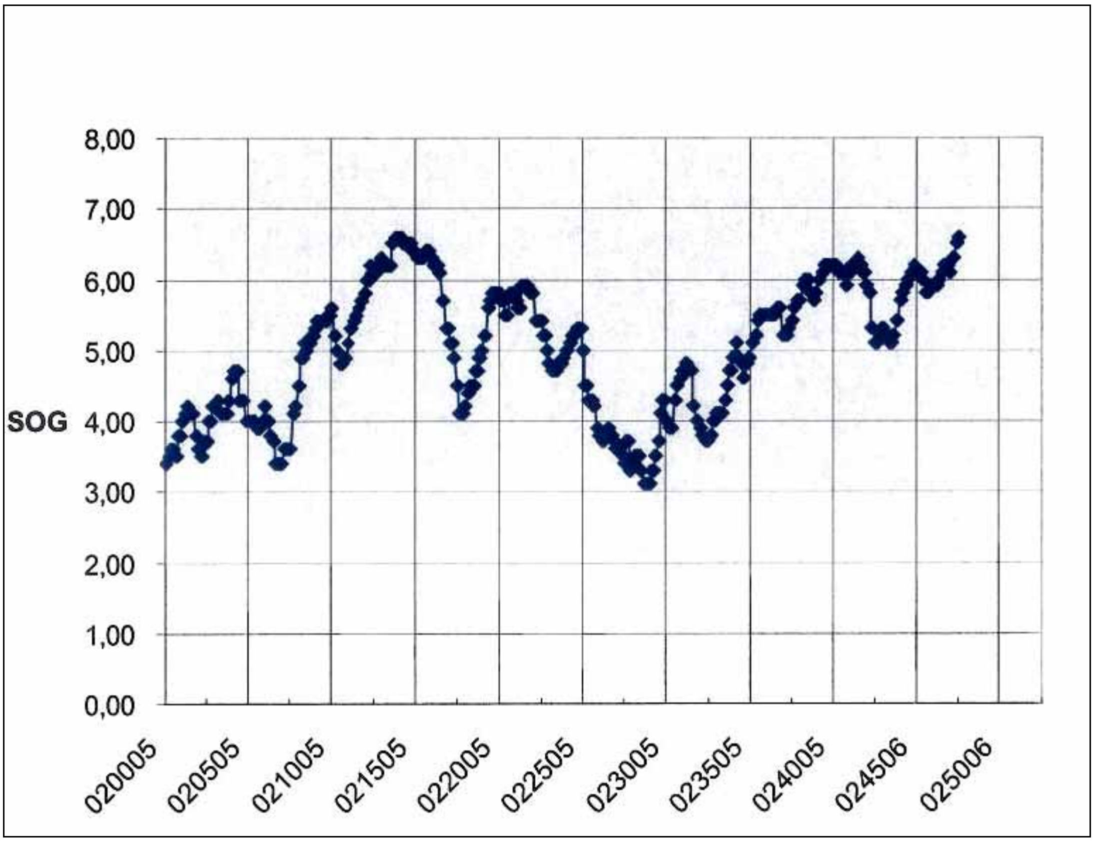

Figure 13: Speed over ground between 0200 h and 0250 h

At the time of the accident (approximately 0245), which, understandably, is not known precisely, the AIS records show all the large course leaps, which are further highlighted in the following table.

Time	Heading	COG	SOG
0240 h	129°	138	5
0241 h	127	144	6
0242 h	122°	140	5
0243 h	123°	123	6
0244 h	120°	130	6
0245 h	116°	128	6
0246 h	110°	109	6
0247 h	120°	111	6
0248 h	128°	117	5
0249 h	130°	142	6
0250 h	127°	135	6

Due to the external factors, the data itself does not indicate whether these course deviations of 20 degrees from the heading, which occurred over a period of seven minutes around the time the accident took place, were predominantly a consequence of, occurred alongside, or happened before the accident. According to witnesses, the ship's command did not initiate a change in course in the final minutes before the accident.

5.3 Weather and sea conditions

5.3.1 Observations on board

The progress of the weather conditions was constantly monitored on the CHICAGO EXPRESS. During the period relevant to the accident, the Officer on Watch on the bridge logged, inter alia, the following values in writing:

Time	Air pressure (hPa)	Wind force (Bft)	Wind direction	Swell
2100	990	10	090	8 to 9
2200	992	10 to 11	080	9
2300	991	11 to 12	090	9 to 10
2400	990	12	110	10
0100	991	12	110	10
0200	993	12	120	10
0400	996	10 to 11	130	8
0500	997	9	140	7 to 8
0600	999	8 to 9	160	6 to 7
0700	1000	7 to 8	150	7
0800	1002	6 to 7	150	6

5.3.2 Expertise by the DWD

The BSU requested an official expertise on the wind and sea conditions in the South China Sea between Hong Kong and the scene of the accident from the Maritime Division of Germany's National Meteorological Service (DWD) for the period 0800 on 23 September 2008 to 0800 on 24 September 2008. The expertise contains the following summary.

"In the sea area under consideration, the vessel came within immediate proximity of Typhoon "HAGUPIT". The mean wind force of the easterly wind stood at 11 Bft. The significant wave heights of the wind sea will have been close to 7.5 m, there was also a swell from the south-east with significant wave heights[26] *of about 3.0 m. These conditions can lead to the formation of cross seas or outsize waves; in that respect, DWD is not in possession of observations or calculations."*

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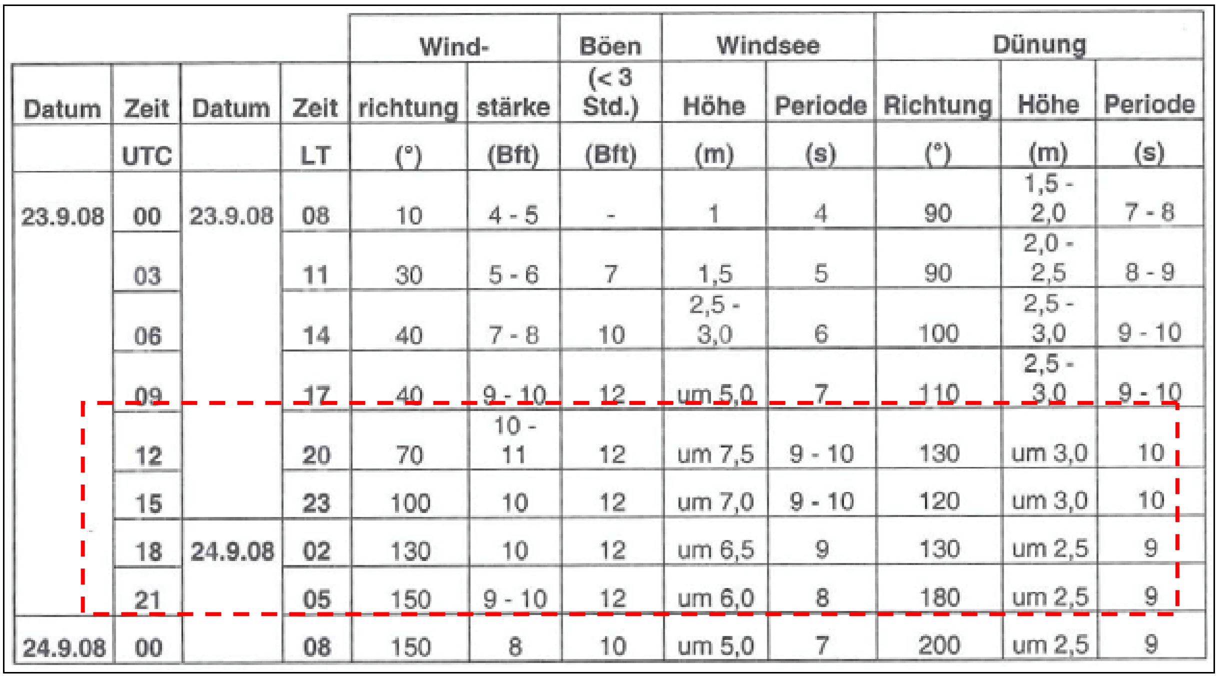
[26] Significant wave heights (Hs) represent the average height of the top third of the wave heights under observation for a given period. In this respect, it ultimately concerns the usual details of the mean conditions of the swell. It should be noted that single waves can exceed the significant wave height by 70 to 100%.

The following table, which contains information about the wind and swell, is also taken from the expertise compiled by the DWD.



				Wind-		Böen	Windsee		Dünung		
Datum	Zeit	Datum	Zeit	richtung	stärke	(< 3 Std.)	Höhe	Periode	Richtung	Höhe	Periode
	UTC		LT	(°)	(Bft)	(Bft)	(m)	(s)	(°)	(m)	(s)
23.9.08	00	23.9.08	08	10	4 - 5	-	1	4	90	1,5 - 2,0	7 - 8
	03		11	30	5 - 6	7	1,5	5	90	2,0 - 2,5	8 - 9
	06		14	40	7 - 8	10	2,5 - 3,0	6	100	2,5 - 3,0	9 - 10
	09		17	40	9 - 10	12	um 5,0	7	110	2,5 - 3,0	9 - 10
	12		20	70	10 - 11	12	um 7,5	9 - 10	130	um 3,0	10
	15		23	100	10	12	um 7,0	9 - 10	120	um 3,0	10
	18	24.9.08	02	130	10	12	um 6,5	9	130	um 2,5	9
	21		05	150	9 - 10	12	um 6,0	8	180	um 2,5	9
24.9.08	00		08	150	8	10	um 5,0	7	200	um 2,5	9

Figure 14: Wind and sea conditions at the scene of the accident[27]

Legend: Datum = Date; Zeit = Time; Wind = Wind; richtung = direction; stärke = force; Böen = Gusts; Std. = Hours; Windsee = Wind sea; Höhe = Height; Periode = Periods; Dünung = Swell

The DWD added the following remarks to the table.

- *"The values pertaining to wind force (Bft) are based on a 10-min. mean average of the wind speed measured at a height of 10 m."*
- *"There are only very limited observations of wave height from other shipping in the South China Sea; therefore, the assessment is essentially based on model results."*
- *"The values pertaining to wave height basically relate to the significant wave heights."*[28]

5.3.3 Comparison of the values

A comparison shows that the observations made on board are very consistent with the values calculated by the DWD using modelling techniques. This indicates both great care on the part of the Officer on Watch when collecting the data and also the reliability of the computational model.

---

[27] Note: The period of particular relevance on the night of the accident (2000 h to 0500 h) has been outlined by the author of the report.

[28] See fn 26 above.

5.4 Investigation of the immediate course of the accident

Since it was dark on the bridge at the time of the accident and the two uninjured witnesses of the course of the accident were, during the extreme rolling of the vessel which led to the accident, primarily concerned with not losing their own footing or, as regards the OS (Helmsman), regaining it as quickly as possible, the drawing depicting the paths each fall took in **Fig. 15** is based on assumption. However, the respective start and finish positions are regarded as definite. The intermediate impact positions are confirmed at least to the extent that there are more or less distinct dents or scuff marks on the bridge panelling or panelling on the bridge furniture, which were caused on impact by the AB or the Master.

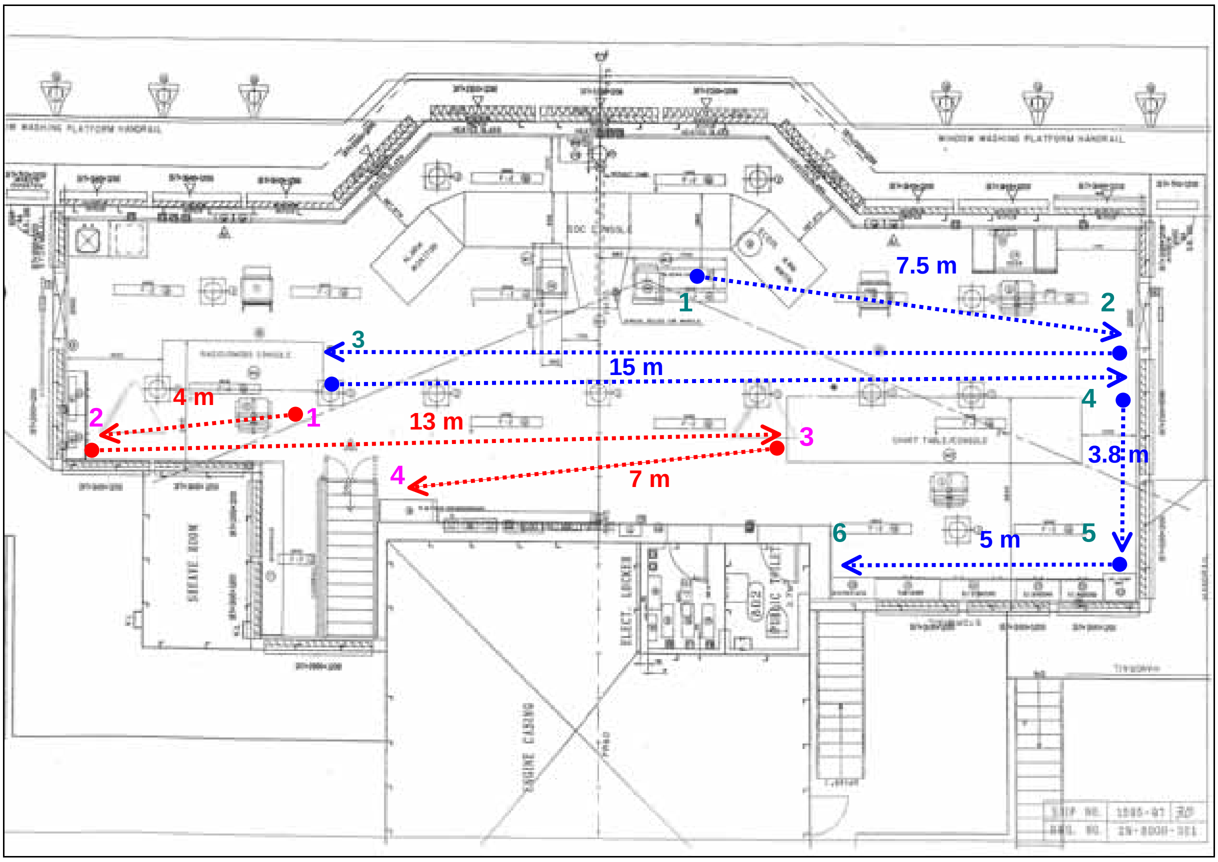


Figure 15: Path of the fall of the AB and the Master

The distance between the impact positions, the serious injuries of the casualties and the in part significant deformations on the console and bridge panelling illustrate just how severely the accident victims were affected by the acceleration and forces during their fall.

A visual inspection of the ergonomic conditions on the bridge, more specifically in the area of the workplaces there

- vessel command console with, inter alia, helm and radar equipment (amidships)
- GMDSS console (port side)
- chart table (starboard side)

showed that the structural layout of handholds is inadequate.

As regards the starting position of the Master (in front of the radar screen on the starboard side of the vessel command console), it transpires that there was no handhold where he was situated (see **Fig. 16**). Despite there being handrails across the entire width of the vessel command console at various points, rather than being continuous, these are interrupted by large areas without any handhold whatsoever. **Figure 17** shows the console is only partially equipped with handrails – in the example on the port side.

Figure 16: Radar position on the starboard side

Figure 17: Bridge console inadequately equipped with handrails

The preceding information applies to a similar extent for the GMDSS console, i.e. the starting position of the AB. This is indeed equipped with a relatively wide handrail, but the side of the console is not included (see **Fig. 18**).

Figure 18: Handrail on the GMDSS console

The front side of the chart table (position of the Officer on Watch, **Fig. 19**) is also not fitted with a handrail; however, a handrail is present at the usual operating positions of the GMDSS console and the table. The Officer on Watch was successful in holding on to the latter.

Figure 19: Handrail of the chart table

The inadequate fitting out of the bridge with handholds is finally shown by the examples in **Figures 20** and **21** below. Large sections at the side and aft of the bridge, the forward edges of the chart table and the GMDSS console as well as the front sides of the vessel command console have no handrail.

Figure 20: No handrails at the aft end and starboard side of the bridge

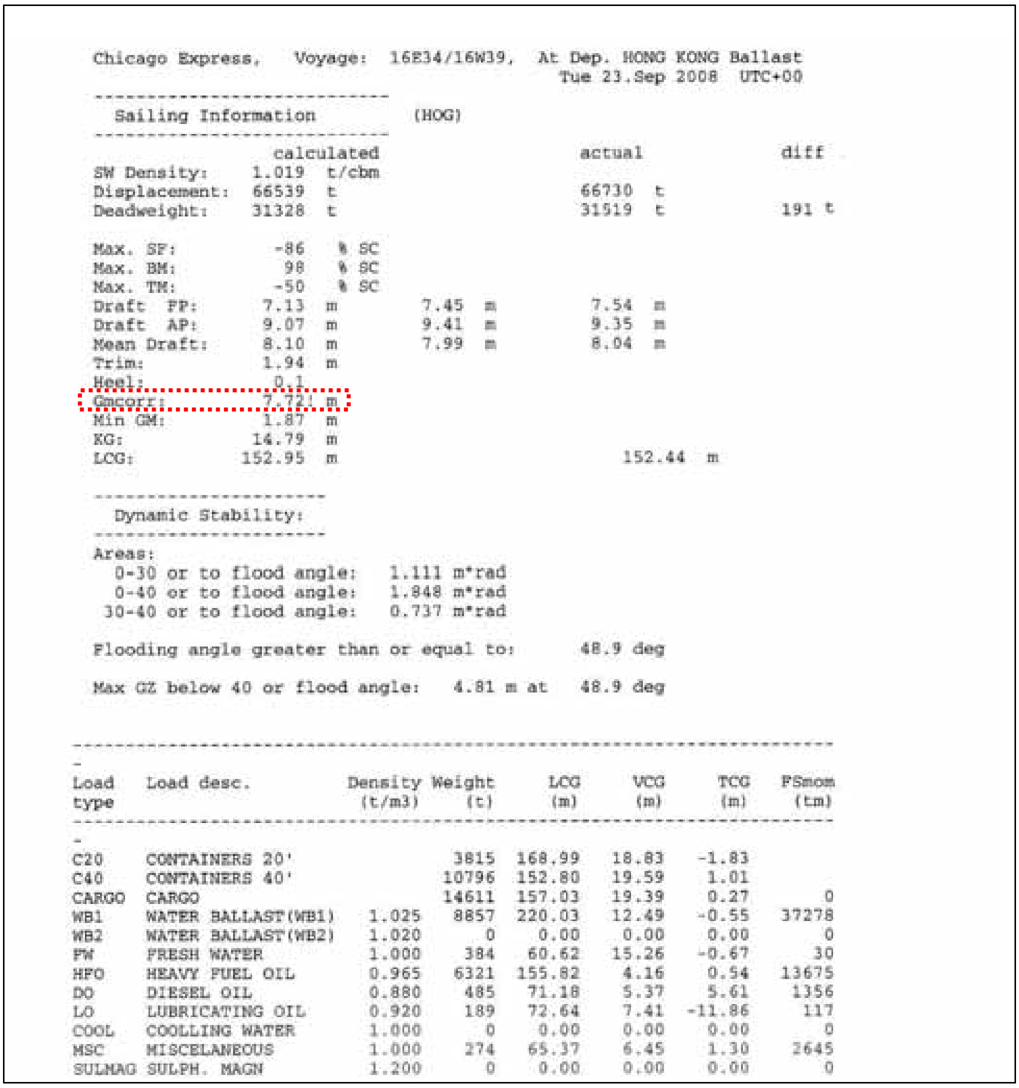
Figure 21: No handrails at the port side of the bridge

During the shipboard inspection by the BSU, the flooring on the bridge was also examined. This was slip resistant and as such did not facilitate the fall of the casualties.

5.5 Investigation of the seagoing behaviour

5.5.1 Preliminary notes

Due to the external circumstances of the accident and the witness statements, it was presumed shortly after the investigation begun that the seagoing behaviour of the CHICAGO EXPRESS significantly influenced the course of events on the night of the accident. The documents provided by the vessel operator concerning the load case of the vessel (see excerpts in **Fig. 22** and **23**)[29], from which it was derived that the CHICAGO EXPRESS begun her journey with a GM[30] of 7.72 m, reinforced this suspicion.



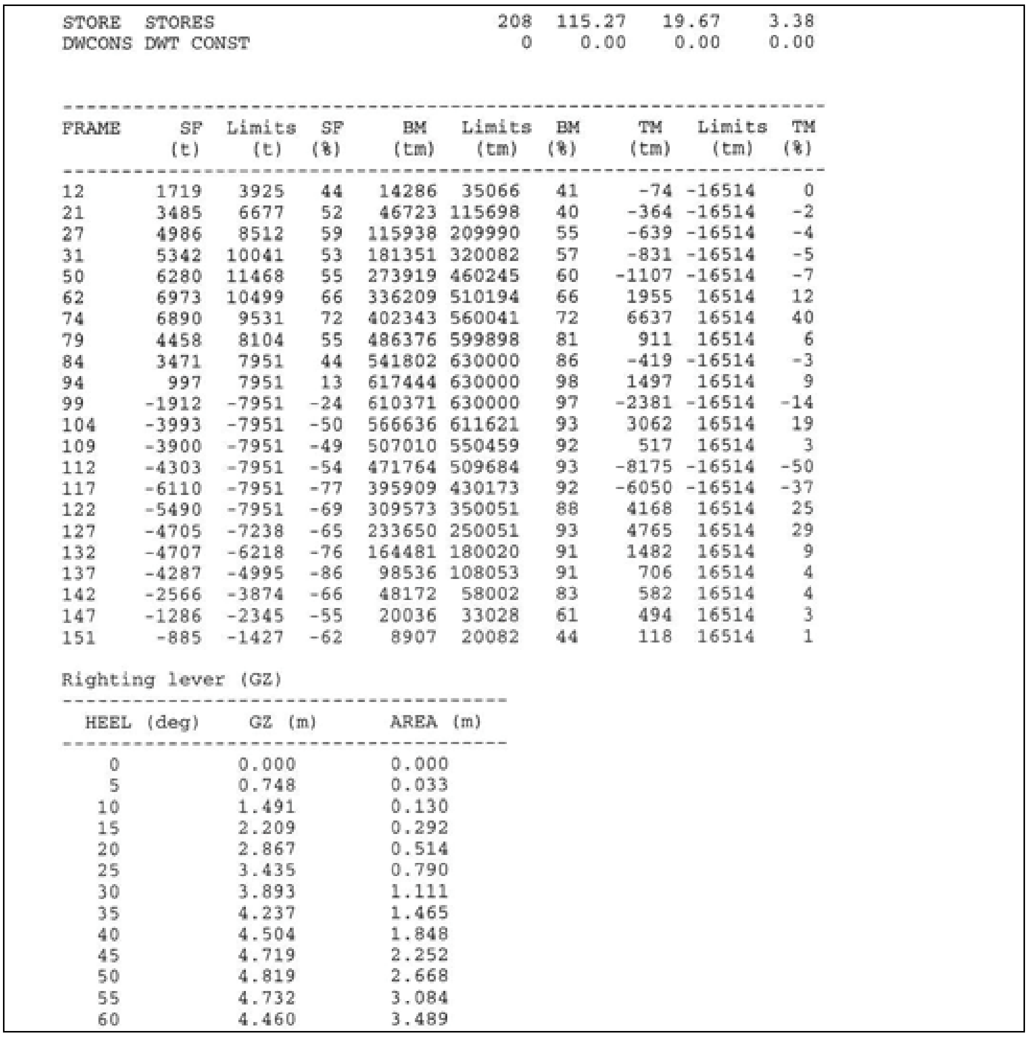
```
  Chicago Express,   Voyage:  16E34/16W39,  At Dep. HONG KONG Ballast
                                                Tue 23.Sep 2008  UTC+00
  ----------------------------
    Sailing Information            (HOG)
  ----------------------------
                calculated                        actual              diff
  SW Density:    1.019  t/cbm
  Displacement:  66539  t                         66730  t
  Deadweight:    31328  t                         31519  t            191 t

  Max. SF:         -86   % SC
  Max. BM:          98   % SC
  Max. TM:         -50   % SC
  Draft  FP:      7.13  m        7.45  m          7.54  m
  Draft  AP:      9.07  m        9.41  m          9.35  m
  Mean Draft:     8.10  m        7.99  m          8.04  m
  Trim:           1.94  m
  Heel:            0.1
  Gmcorr:         7.72! m
  Min GM:         1.87  m
  KG:            14.79  m
  LCG:          152.95  m                            152.44  m

  ----------------------
    Dynamic Stability:
  ----------------------
  Areas:
    0-30 or to flood angle:   1.111 m*rad
    0-40 or to flood angle:   1.848 m*rad
   30-40 or to flood angle:   0.737 m*rad

  Flooding angle greater than or equal to:      48.9 deg

  Max GZ below 40 or flood angle:   4.81 m at   48.9 deg


-----------------------------------------------------------------------
-
Load   Load desc.            Density Weight     LCG      VCG      TCG   FSmom
type                          (t/m3)    (t)     (m)      (m)      (m)    (tm)
-----------------------------------------------------------------------
-
C20    CONTAINERS 20'                  3815  168.99    18.83    -1.83
C40    CONTAINERS 40'                 10796  152.80    19.59     1.01
CARGO  CARGO                          14611  157.03    19.39     0.27       0
WB1    WATER BALLAST(WB1)     1.025    8857  220.03    12.49    -0.55   37278
WB2    WATER BALLAST(WB2)     1.020       0    0.00     0.00     0.00       0
FW     FRESH WATER            1.000     384   60.62    15.26    -0.67      30
HFO    HEAVY FUEL OIL         0.965    6321  155.82     4.16     0.54   13675
DO     DIESEL OIL             0.880     485   71.18     5.37     5.61    1356
LO     LUBRICATING OIL        0.920     189   72.64     7.41   -11.86     117
COOL   COOLLING WATER         1.000       0    0.00     0.00     0.00       0
MSC    MISCELANEOUS           1.000     274   65.37     6.45     1.30    2645
SULMAG SULPH. MAGN            1.200       0    0.00     0.00     0.00       0
```

Figure 22: Excerpt from the load computer printout (1)

---

[29] Source: Printout from the shipboard load computer, marked by the author of the report.

[30] GM = Metacentric height, measurement of initial stability for very low angle of inclination. The higher the GM, the higher the initial stability. Very high GM values (as is the case here) lead to so-called hard seagoing behaviour.



```
STORE  STORES                          208   115.27    19.67    3.38
DWCONS DWT CONST                         0     0.00     0.00    0.00


--------------------------------------------------------------------
FRAME       SF Limits   SF       BM Limits   BM       TM Limits   TM
           (t)    (t)  (%)     (tm)   (tm)  (%)     (tm)   (tm)  (%)
--------------------------------------------------------------------
12        1719   3925   44    14286  35066   41      -74 -16514    0
21        3485   6677   52    46723 115698   40     -364 -16514   -2
27        4986   8512   59   115938 209990   55     -639 -16514   -4
31        5342  10041   53   181351 320082   57     -831 -16514   -5
50        6280  11468   55   273919 460245   60    -1107 -16514   -7
62        6973  10499   66   336209 510194   66     1955  16514   12
74        6890   9531   72   402343 560041   72     6637  16514   40
79        4458   8104   55   486376 599898   81      911  16514    6
84        3471   7951   44   541802 630000   86     -419 -16514   -3
94         997   7951   13   617444 630000   98     1497  16514    9
99       -1912  -7951  -24   610371 630000   97    -2381 -16514  -14
104      -3993  -7951  -50   566636 611621   93     3062  16514   19
109      -3900  -7951  -49   507010 550459   92      517  16514    3
112      -4303  -7951  -54   471764 509684   93    -8175 -16514  -50
117      -6110  -7951  -77   395909 430173   92    -6050 -16514  -37
122      -5490  -7951  -69   309573 350051   88     4168  16514   25
127      -4705  -7238  -65   233650 250051   93     4765  16514   29
132      -4707  -6218  -76   164481 180020   91     1482  16514    9
137      -4287  -4995  -86    98536 108053   91      706  16514    4
142      -2566  -3874  -66    48172  58002   83      582  16514    4
147      -1286  -2345  -55    20036  33028   61      494  16514    3
151       -885  -1427  -62     8907  20082   44      118  16514    1

Righting lever (GZ)
----------------------------------------
  HEEL (deg)     GZ (m)       AREA (m)
----------------------------------------
    0          0.000         0.000
    5          0.748         0.033
   10          1.491         0.130
   15          2.209         0.292
   20          2.867         0.514
   25          3.435         0.790
   30          3.893         1.111
   35          4.237         1.465
   40          4.504         1.848
   45          4.719         2.252
   50          4.819         2.668
   55          4.732         3.084
   60          4.460         3.489
```

Figure 23: Excerpt from the load computer printout (2)

The BSU therefore decided to arrange for the seagoing and stability behaviour of the CHICAGO EXPRESS on the night of the accident to be checked thoroughly by means of an external expertise. The final version of the expertise by expert Prof. Dr.-Ing. S. Krüger, Director of the Institute of Ship Design and Ship Safety of the Hamburg-Harburg Technical University, supported by his colleague Dipl.-Ing. C. Steinbach was submitted to the BSU on 22 June 2009.

5.5.2 Expertise on the seagoing behaviour

The following remarks provide a summary of the substantive particulars and results of the aforementioned expertise in edited and partially abridged form.

5.5.2.1 Input information, computational model

With the support of the vessel operator, the expert was provided with the following input information for the expertise:

- General arrangement plan, dock plan, shell development and stability manual of the CMV Chicago Express

- Weather expertise from Germany's National Meteorological Service on the environmental conditions at the time of the accident
- Various witness statements
- Load case printout from the shipboard computer showing the loading conditions during the accident
- Photographic evidence of the damage on the bridge of the vessel taken in Hong Kong
- Vessel photos, in particular, of the underwater hull (fore and aft section)

The submitted technical documentation was used to generate the computational model for the calculations (see Fig. **24** and **25**).

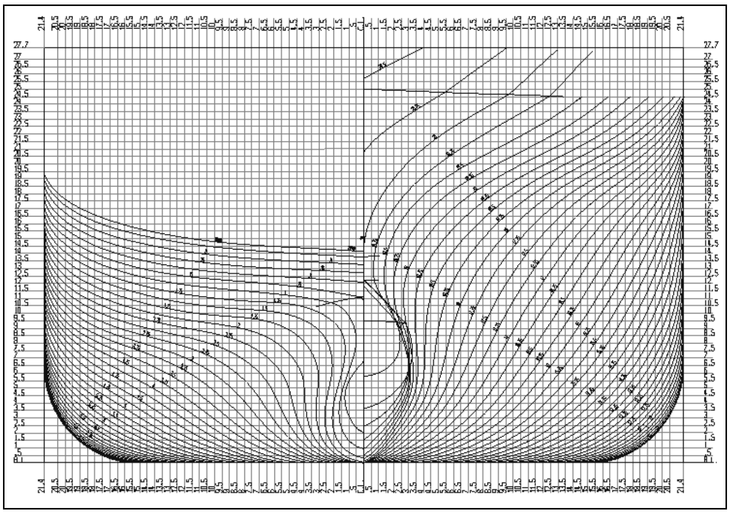


Figure 24: Reconstructed framing plan of the CMV CHICAGO EXPRESS

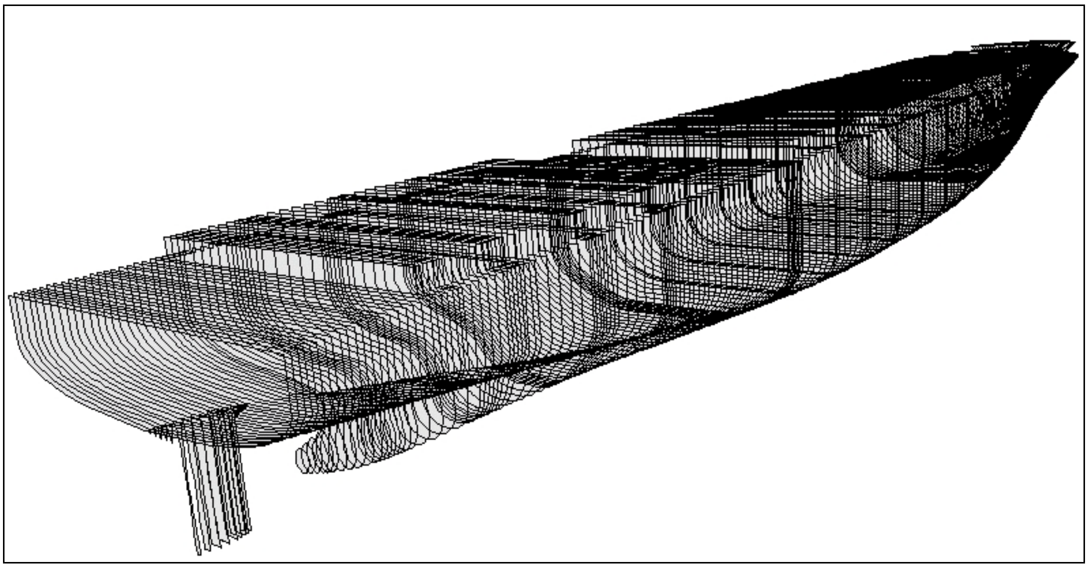
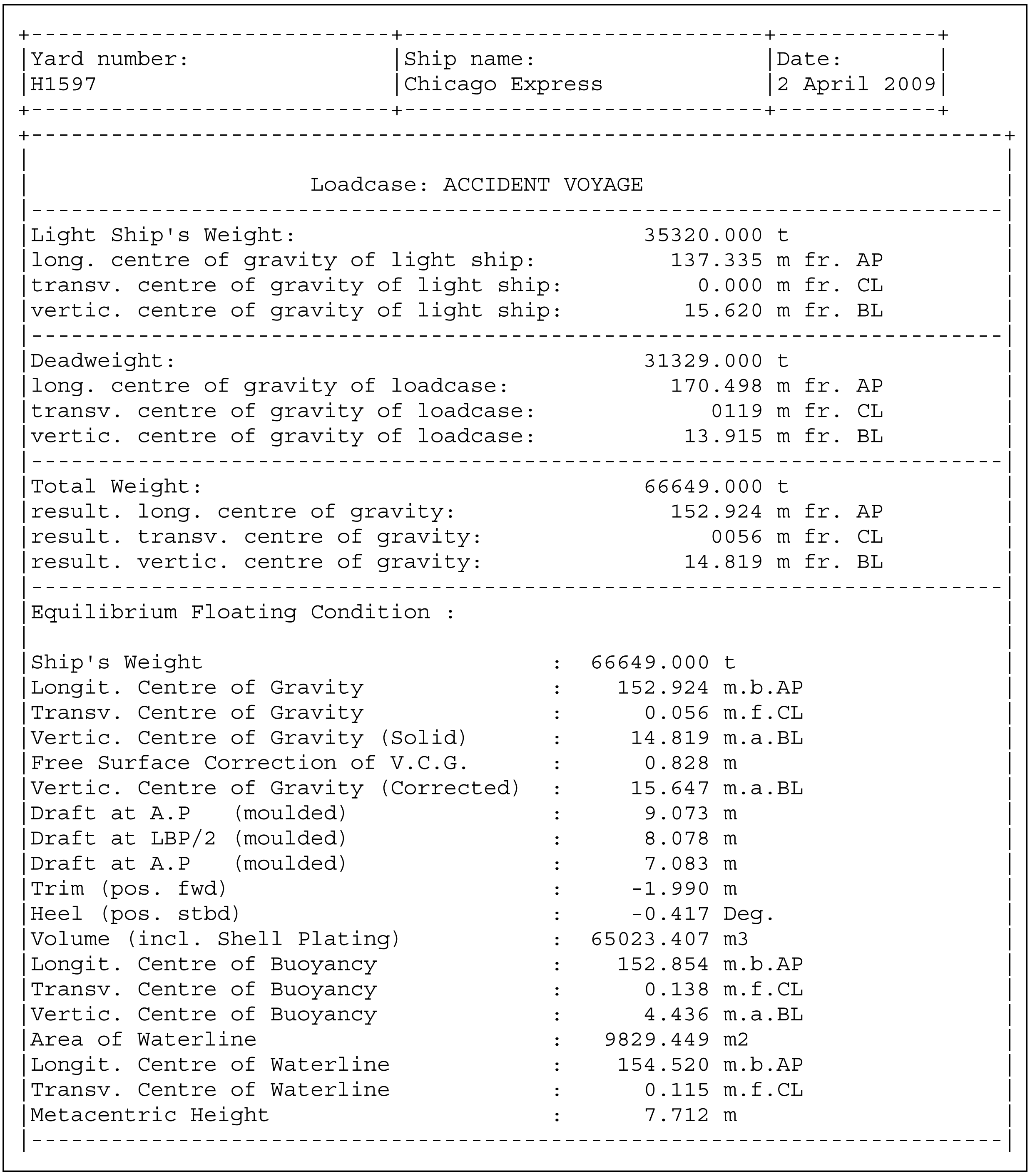


Figure 25: Computational model of the CMV CHICAGO EXPRESS

5.5.2.2 Calculation of the load condition

The load condition of the vessel was available to the expert in the form of a shipboard computer printout from the load computer. The values for ship's weight and payload were also imported into the calculation software. The condition of the vessel at the time of accident (according to the calculations of the expert) was derived from that as follows:



```
+---------------------------+---------------------------+------------+
|Yard number:               |Ship name:                 |Date:       |
|H1597                      |Chicago Express            |2 April 2009|
+---------------------------+---------------------------+------------+
+-------------------------------------------------------------------------+
|                                                                         |
|                     Loadcase: ACCIDENT VOYAGE                           |
|-------------------------------------------------------------------------|
|Light Ship's Weight:                          35320.000 t                |
|long. centre of gravity of light ship:          137.335 m fr. AP         |
|transv. centre of gravity of light ship:          0.000 m fr. CL         |
|vertic. centre of gravity of light ship:         15.620 m fr. BL         |
|-------------------------------------------------------------------------|
|Deadweight:                                   31329.000 t                |
|long. centre of gravity of loadcase:            170.498 m fr. AP         |
|transv. centre of gravity of loadcase:             0119 m fr. CL         |
|vertic. centre of gravity of loadcase:           13.915 m fr. BL         |
|-------------------------------------------------------------------------|
|Total Weight:                                 66649.000 t                |
|result. long. centre of gravity:                152.924 m fr. AP         |
|result. transv. centre of gravity:                 0056 m fr. CL         |
|result. vertic. centre of gravity:               14.819 m fr. BL         |
|-------------------------------------------------------------------------|
|Equilibrium Floating Condition :                                         |
|                                                                         |
|Ship's Weight                          :  66649.000 t                    |
|Longit. Centre of Gravity              :    152.924 m.b.AP               |
|Transv. Centre of Gravity              :      0.056 m.f.CL               |
|Vertic. Centre of Gravity (Solid)      :     14.819 m.a.BL               |
|Free Surface Correction of V.C.G.      :      0.828 m                    |
|Vertic. Centre of Gravity (Corrected)  :     15.647 m.a.BL               |
|Draft at A.P   (moulded)               :      9.073 m                    |
|Draft at LBP/2 (moulded)               :      8.078 m                    |
|Draft at A.P   (moulded)               :      7.083 m                    |
|Trim (pos. fwd)                        :     -1.990 m                    |
|Heel (pos. stbd)                       :     -0.417 Deg.                 |
|Volume (incl. Shell Plating)           :  65023.407 m3                   |
|Longit. Centre of Buoyancy             :    152.854 m.b.AP               |
|Transv. Centre of Buoyancy             :      0.138 m.f.CL               |
|Vertic. Centre of Buoyancy             :      4.436 m.a.BL               |
|Area of Waterline                      :   9829.449 m2                   |
|Longit. Centre of Waterline            :    154.520 m.b.AP               |
|Transv. Centre of Waterline            :      0.115 m.f.CL               |
|Metacentric Height                     :      7.712 m                    |
|-------------------------------------------------------------------------|
```

Figure 26: Load case (calculation by the expert)

5.5.2.3 Deviations from the shipboard load computer

By comparison with the values of the shipboard computer, the calculations of the expert revealed the following values for draught and GM:

	Expert	Shipboard computer
D aft	9.07 m	9.07 m
D mid-section	8.08 m	8.10 m
D fore	7.08 m	7.13 m
GM	7.71 m	7.72 m

The inconsistencies are virtually negligible and it could therefore be assumed that the shape of the vessel and the loading condition have been adequately recorded by the expert's model.

However, with otherwise almost identical values for KG and GM_{Corr}, when calculating the righting lever **non-negligible inconsistencies** emerged compared with the values specified by the load computer. Therefore, the righting lever was subjected to greater scrutiny. To that end, the values for the cross-curves calculated by the expert were compared with those of the final stability book of the shipyard. The latter was approved on 15 May 2006 by Germanischer Lloyd and on 5 September 2006 by the See-BG (Marine Insurance and Safety Association). The calculation showed that the shipyard calculated the cross-curves for a free trimming condition. The expert traced these calculations accordingly and, with an even initial trim and an initial draught of 8.00 m, which is approximately equal to the mean draught of the accident condition, obtained the following values for the righting lever (compared with the stability book):

Angle [deg]	5	10	20	30	40	50
KN (m) stability book	2.023	4.032	7.880	11.221	13.955	16.088
KN (m) expert	2.025	4.036	7.884	11.226	13.952	16.077

The comparison shows that the model of the shape of the vessel made by the expert's program leads to the same results when comparable calculation hypotheses are applied. In contrast, the following inconsistencies emerge between the expert's calculations and those of the shipboard computer when calculating the righting levers for the accident condition:

Angle [deg]	5	10	20	30	40	50
GZ (m) shipboard computer	0.748	1.491	2.867	3.893	4.504	4.819
GZ (m) expert	0.617	1.287	2.522	3.416	3.913	4.140

These inconsistencies are not negligible and occur for both small and large angles. Since the comparison of the calculations of the expert with the stability book is satisfactory, the difference must lie in the calculation hypothesis of the shipboard computer. When scrutinised more closely, it transpired that the shipboard computer data could be traced under the following conditions:

- untrimmed with fixed trim
- disregarded off-centre transverse centre of gravity
- disregarded stability reduction through the free surfaces

This could only be assumed by the expert, but provides a semi-plausible explanation for the inconsistencies. Only the bases of calculation of the expert were used for further computations because the underlying calculation hypotheses were physically correct and the results were also consistent with the stability book. Since it transpired that the accident would have also occurred with other stability values, the identified difference was not pursued. Nevertheless, the expert noted that due to the very different calculation hypotheses a problem could emerge in cases where the vessel verges on its stability limit in very heavy weather.

5.5.2.4 Righting lever of the vessel

The righting lever of the vessel calculated by the expert is shown in the usual manner for still water in **Figure 27** below. According to that, the stability in itself is more than sufficient, and saturation of non-weathertight sealable openings is not evident.

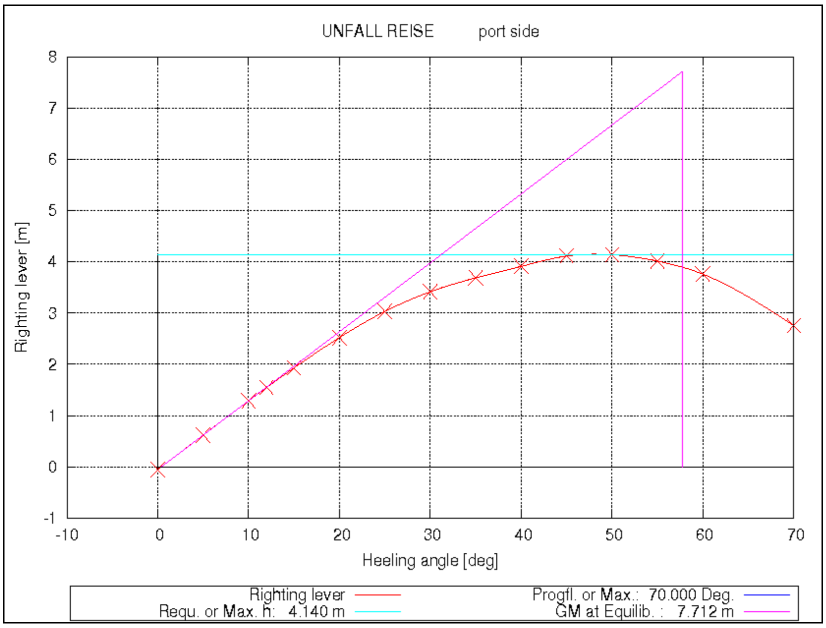


Figure 27: Righting lever curves for still water

5.5.2.5 Observations concerning parametric rolling

To examine the overall risk of parametrically excited rolling oscillations, by way of example the righting lever was also calculated using an equivalent-wave concept for the conditions "main frame at the wave trough" and "main frame at the wave crest". A sine wave of 156 m in length (about 10 s) and 7.5 m in height was chosen for the equivalent-wave. This corresponds more or less to the accident situation. The associated righting lever is shown in **Figure 28**. It can be seen in this figure that the curves practically coincide, which means that the differences between crest and trough are very small, especially in comparison with the stability in calm water itself. At first glance, this result appears to be unusual because it means it is unlikely that the parametric rolling is the primary cause of the accident; for parametric excitation presupposes sufficiently large fluctuations of the righting lever at sea. However, in this case this is clearly not evident, even though the type of vessel involved in the accident is known for this kind of roll excitation.

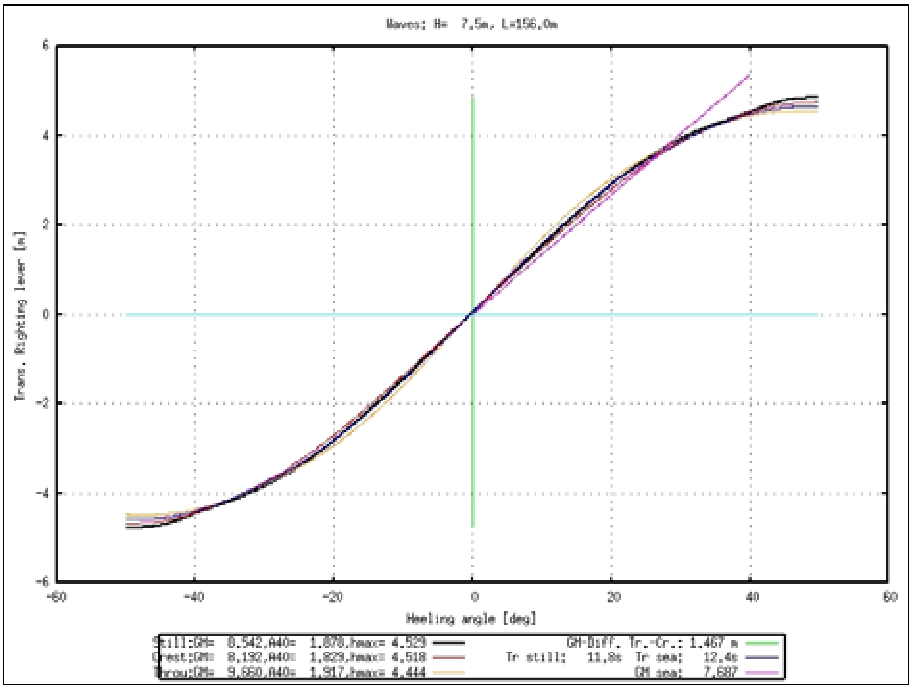


Figure 28: Righting lever curves in swell

In the opinion of the expert, the cause of the low righting arm fluctuations – and thus the only minor parametric excitation – emerges from the fact that the draught of the vessel was much shallower than in the design. The draught aft was only about 9 m; however, the centre of the transom did not contact water until about 14 m. The fluctuations of the waterline section in swell decline because of this partial immersion aft, thereby reducing the fluctuations of the righting lever induced by the swell.

These considerations suggest from the outset that parametrically excited changes in stability do not constitute the main cause of the accident, rather, the excitation moments induced by the swell in general.

5.5.2.6 Deliberations on the probable roll angle

Essential for clarification of the accident was the question of which vessel motions actually led to the accident. Based on the witness statements and largely corresponding AIS records from Hong Kong, the courses and speeds of the CHICAGO EXPRESS were known to be a reliable input variable (see above). Also, the prevailing direction of swell at the time of the accident is more or less confirmed by the observations on board and the corresponding values of the DWD expertise (shown above).

Correspondingly, the crew members reported that at about 0245, the vessel was hit by a large wave coming from the starboard side, after which she rolled heavily from side to side. The indicator on the inclinometer on the bridge remained at about 44 degrees on each side (see **Fig. 29**)[31].

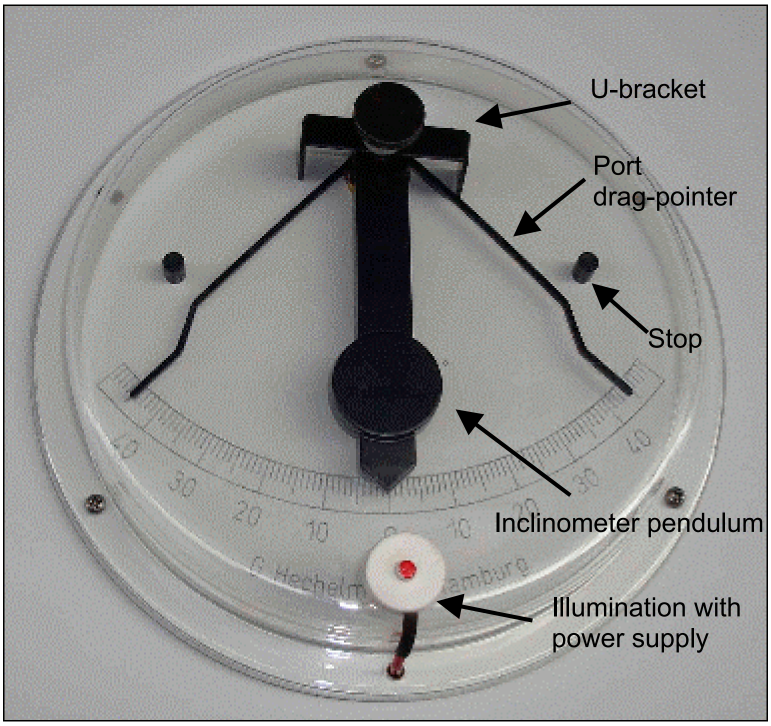


Figure 29: Photo of the inclinometer on the bridge of the CMV Chicago Express

It was thus concluded that the roll angle on board actually amounted to 44 degrees. However, at the beginning of the investigation the expert informed the BSU of his doubts that the roll angle could be accurately recorded by such a device in a situation of this nature. Following that, the BSU acquired an identical device and provided this to the expert. Closer examination of the structural properties of the inclinometer confirmed the above hypothesis and resulted in the following.

The design of the inclinometer is generally insufficient for drawing conclusions as to a dynamic roll angle. Under marginal vibration the inclinometer produced similar swings of 44 degrees to either side almost immediately. Therefore, an attempt was made to consider the problem in terms of acceleration. This showed that an inclinometer swing of 45 degrees can also be generated by a transverse acceleration of 1 g. Following that, additional vibration tests were performed on the inclinometer, which revealed the following:

---

[31] Note: Photo taken during the shipboard inspection by the BSU in Hamburg, whereby the crew gave their assurance that the position of the drag-pointer was not changed after the accident.

- With violent acceleration to starboard, the drag-pointer swings until it hits the stop and is then returned by the inclinometer pendulum (rebound). This means that significantly greater accelerative force than 1 g to starboard is likely to lead to a much lower reading than 45 degrees due to a significant rebound effect.
  This did not happen on the port side because the port drag-pointer could not come into contact with the anchor point.
  In **Figure 29** we see that on the port side the drag-pointer is pressed against the U-bracket, which facilitates resetting of the drag-pointer. This bracket is operated with a milled nut, the rotation of which requires a perceptible moment. Therefore, despite intense vibration it is not possible to move the drag-pointer by the pendulum against the locked bracket to the stop.

In the opinion of the expert, this leads to the following conclusions for further evaluation:

- A transverse acceleration to starboard must have taken effect, which amounted to about 1 g. This would probably not have been much greater, because the drag-pointer definitely did not reach the stop, otherwise it would have rebounded significantly.
- A transverse acceleration of at least 1 g must have taken effect to port; however, this may have been significantly greater. Unfortunately, it is not possible to determine exactly how great this was.

It was therefore agreed with the BSU that the presumed accelerative forces would be applied for the remainder of the investigation and a test would then be made to establish the resulting roll angle.

5.5.2.7 Results of the non-linear sea state calculations – roll angle

The expert examined the resulting roll angle at the load condition and environmental conditions at the time of the accident using the numerical calculations for different input variables. This initially involved calculations for various significant periods, notably, 9s, 9.5 s and 10s (corresponding to significant wave lengths in deep water of 127, 141 and 156 m).

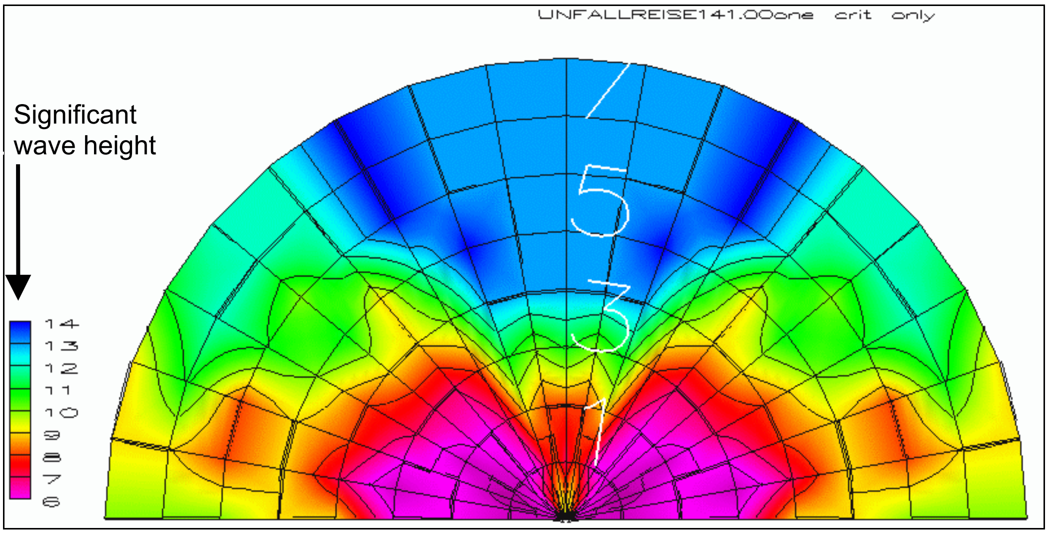


Figure 30: Calculated significant wave heights at a roll angle of 35 degrees[32]

Figure 30 shows the results of the calculations in the form of a polar coordinate diagram. This shows the respective significant wave height highlighted by colour for a natural swell for a period of 9.5 s, which at the different speeds and courses would lead to a roll angle of at least 35 degrees. The significant period of 9.5 s corresponds to a situation equal to that also calculated in the weather expertise from the DWD. The calculations permit some interesting conclusions about the accident. It clearly follows that for a situation which corresponds roughly to the prevailing conditions at the time of the accident an extremely large roll angle must have occurred. This is the case if the vessel is slower than a certain minimum speed while there is a sufficiently quartering head sea. In that respect, the calculations are clear. This also shows that in other situations, in which the vessel's speed is much higher, such a large roll angle cannot have occurred because the significant wave height required for this would be much higher. At the same time, the calculations also show that such large roll angles cannot be reached at lower speeds precisely at those times when it is possible to keep the vessel sailing sufficiently accurately against the sea.

At the same time, the calculations have demonstrated that the vessel was far removed from resonance conditions in the accident situation; therefore, roll resonance due to parametric rolling can definitely be ruled out as a possible cause of the accident.

The large roll angle calculated in the critical situations is clearly caused by the direct roll excitation of the sea, which emerges if the course is at a sufficient angle to the sea together with **simultaneous** low roll damping due to a low speed. The calculations have shown that other causes can be ruled out with a probability bordering on certainty.

---

[32] In this and the following diagrams the vessel is headed to the north, the waves are coming from the direction indicated by the radial axis. The rings indicate the vessel's speed in kts. (The theoretical "northerly heading" approach does not correspond with the actual course of the CHICAGO EXPRESS; however, this is irrelevant because in this case it is only a matter of illustrating the relationship between direction and swell.)

On the basis of these considerations, the cause of the accident can already be seen quite clearly with a probability bordering on certainty. The crew did everything in its power to steer the vessel against the sea. In the process, the vessel was rolling constantly. If the speed was slightly increased and/or if the vessel was sailed more accurately against the sea, the rolling motion decreased slightly. Eventually, the crew must have encountered a situation whereby the speed was reduced to below a critical limit while **simultaneously** the sea approached strongly from one side. If one or several waves were then slightly higher, a corresponding rolling motion was immediately induced. According to the expert, this enables the accident to be explained very plausibly. To support these results, other situations were calculated.

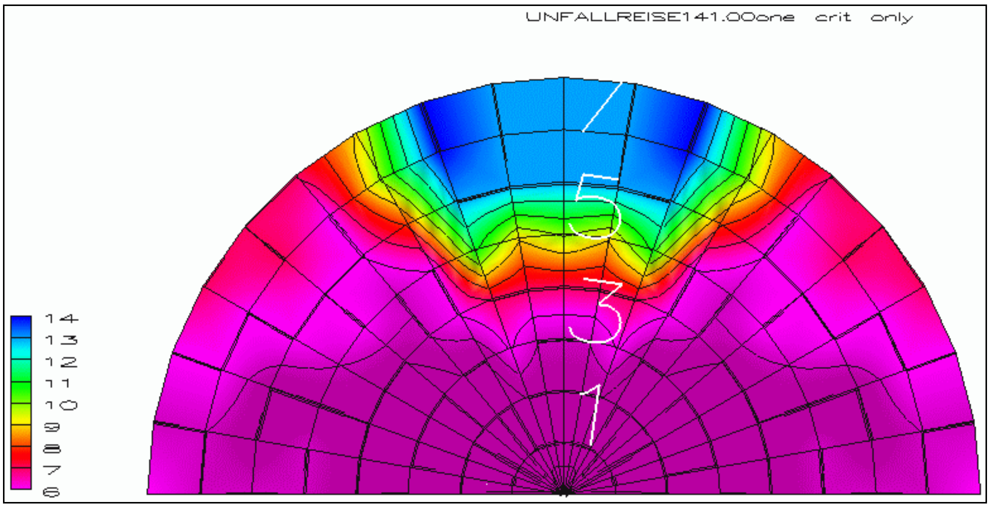


Figure 31: Calculated significant wave heights at a roll angle of 25 degrees

Figure 31 shows a diagram similar to **Figure 30**, but now for a roll angle of 25 degrees. It can be seen immediately that a roll angle of about 25 degrees occurs in virtually every situation below roughly 5 kts. At more than roughly 5 kts, the expected roll angle then decreases slightly if the vessel is steered relatively accurately against the sea. That corresponds very well with the statements of the crew that the vessel ran at speeds of 3-5 kts on various courses and was constantly subjected to rolling of at least 20 degrees, sometimes more violently, sometimes less violently.

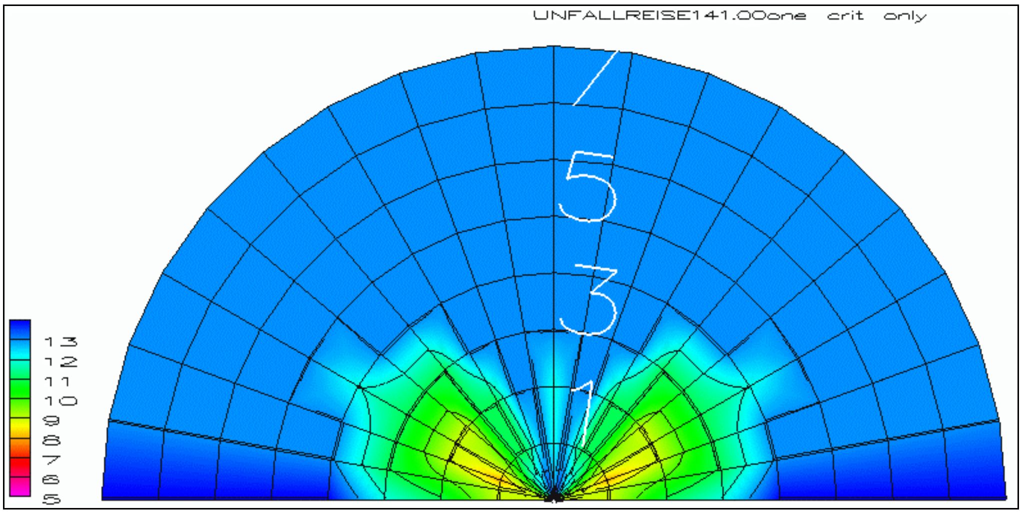


Figure 32: Calculated significant wave heights at a roll angle of 45 degrees

Figure 32 now shows the same situation for a roll angle of 45 degrees. We see very clearly that this roll angle can only occur in the specified situation, i.e., the speed is less than 3 kts and the course is at about a 60 degree angle to the waves.[33] Assuming that the significant wave height was actually less than or equal to the 8 m specified, then a large roll angle of 44 degrees would certainly have been reached in a situation where the speed was less than about 1 kt and the angle to the sea was about 60 degrees. If one assumes that such a roll angle was actually reached, it would have been possible in exactly this situation. If the roll angle is less than 44 degrees, which based on the above investigations is very likely, then the critical speed for reaching this roll angle would be higher.

The graphically presented calculations show that the aforementioned cause of the accident is correct with a probability bordering on certainty.

5.5.2.8 The effect stability had on the accident

It was initially thought that a major cause of the accident was that the vessel had to leave the port early with little cargo and was therefore sailing with extremely high stability. To that end, the BSU asked the expert whether it was generally possible to implement structural measures for modifying such vessels so that load conditions with excessive stability do not arise. To assess this question, the expert calculated how the roll angle and transverse acceleration would have changed in the determined accident situation had the stability been lower.

For enhanced comprehensibility, however, the physical effects which actually led to the accident should be re-emphasised. The expertise shows that the accident is the result of the swell transmitting energy into the vessel due to the direct swell moment. Since the vessel has very high stability, she absorbs a lot of energy; however, she is unable to disperse this rolling energy quickly enough because of the limited damping,

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[33] Here and below the description of the direction of swell has – pursuant to the navigational approach – been adjusted to conform to the reference system used on a compass dial for enhanced comprehensibility. In contrast, the expertise uses the physical reference system, in which a stern sea is defined with an incidence angle of 0 degrees and an exact head sea with an angle of 180 degrees.

meaning that extremely large roll angles occur when she is hit by about two or three big waves in succession. This is not a parametric excitation and there is also no resonance present. If in this situation one decreases the stability of the vessel, she is able to absorb less energy, which automatically means that she will roll less with the same damping. However, for container vessels – especially in this case – the opposite problem is present: a reduction in stability can only be effected by a large amount of highly stacked cargo on deck, which in turn causes the vessel's moment of inertia around the rolling axis to rise significantly and thus results in the vessel absorbing energy from the swell due to the increased moment of inertia. These effects are indeed opposite, but in the opinion of the expert a significant reduction in stability always prevails.

Therefore, provided that a critical resonance was not reached because of the change in stability or the vessel would not capsize because of insufficient stability, it is unlikely that the accident would have occurred at a certain level of reduced stability because of its physical fundamentals. However, now the crucial question when evaluating stability is to exactly what extent would the stability have to be reduced to achieve any appreciable effect and whether in practice that would have been at all possible.

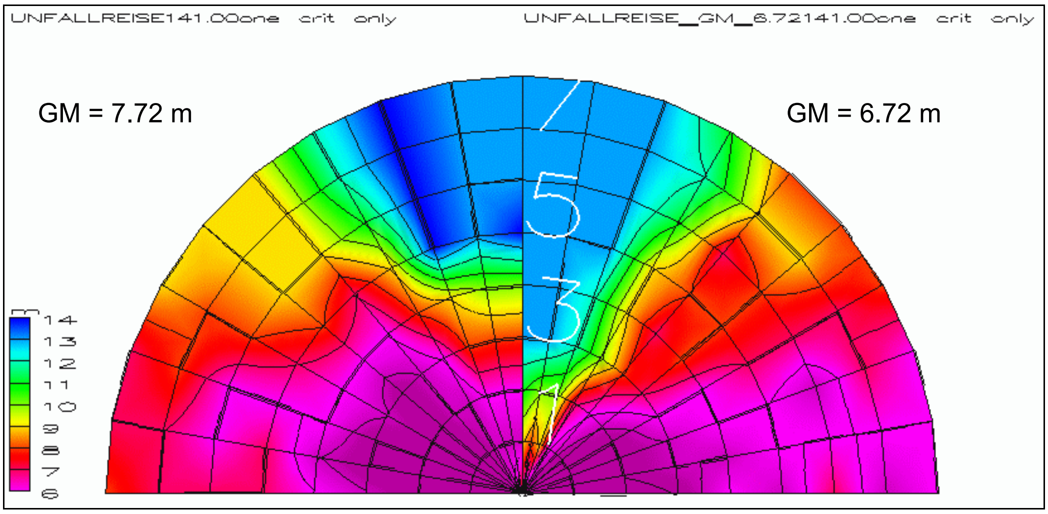

Figure 33: Calculated significant wave heights at a roll angle of 30 degrees

Figure 33 shows the significant wave heights that lead to a maximum roll angle of at least 30 degrees. The left side shows the stability situation of the accident condition and on the right side a GM value reduced by 1 m was applied for the calculation (6.72 m instead of previously 7.72 m). Under the circumstances that led to leaving the port, this GM reduction would have been practically impossible. However, we see that this would not have improved the situation. The risk shifts to a situation in which the sea would have to come from slightly more abeam. This is logical, because it results in the excitation moments increasing. Nevertheless, with parameters similar to those of the accident situation, the vessel would have also been exposed to an extremely large roll angle with these stability factors. Decreased stability thus improves the situation somewhat, but not fundamentally.

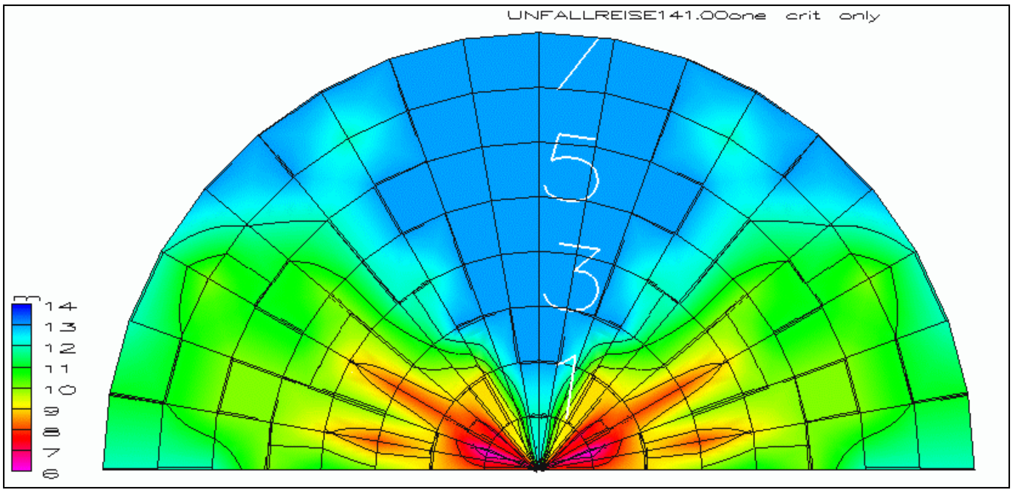

Figure 34: Calculated significant wave heights; roll angle = 30 degrees, GM = 4.2 m

To demonstrate the impact of stability changes, another calculation was carried out with a stability change about three times as great (see **Fig. 34**). The GM was reduced to 4.20 m, i.e. by about 3.50 m. We now see that the wave height necessary for reaching a maximum roll angle of 30 degrees increases considerably in similar situations. Accordingly, even in this situation a roll angle of 30 degrees would have occurred if the vessel was sailing at about 1 or 2 kts at an angle of about 60 degrees to the head sea. The fundamental threat therefore remains latent, which is also logical because it is not a matter of parametric excitation, but a forced oscillation with low damping.

In the opinion of the expert, the calculations only permit the following conclusions: Moderate changes in the stability of the vessel would not have prevented the accident. Almost the same accelerative forces emerge as those seen in the accident situation. It is expected that a marked reduction in stability would have improved the situation, but this would have been practically impossible. The vessel was forced to leave port in a condition that due to insufficient cargo was extreme far removed from that intended in the actual design.

5.5.2.9 Avoidability of the accident; conclusion of the expert

A central question requiring clarification within the framework of the expertise was whether the crew would have been able to recognise the danger and whether the accident would have thus been avoidable. It was also a matter of ascertaining whether the vessel's high level of stability caused the accident and if so whether, at reasonable expense, such a high level of stability ought generally to be avoided with this type of vessel.

In that respect, the expert determined the following:

"A reduction in stability that was practically feasible would not have prevented the accident. The calculations have clearly shown that with less stability similar accelerative forces would have also occurred. The problem with this accident is clearly low roll damping caused by low speed with the simultaneous effect of high rolling moments being transmitted to the vessel. This is solely dependent on the shape of the vessel and can only be reduced if the vessel has a generally smaller bow flare.
As regards the roll damping, it is noted that with an otherwise sound draft, this can only be achieved if the selected speed is adequate. In the given situation, the crew had no way of recognising this, and increasing the speed in heavy weather does not conform to the generally accepted principles of good seamanship, because doing so can cause other problems. Nonetheless, had the vessel's speed been set at about 7 kts, the rolling motion would have been damped noticeably. However, one would not have been able to establish this without specific calculations; furthermore, selecting a considerably higher speed may have led to bordering on a critical resonance (2:1). Therefore, we must generally accept the fact that large vessels can also roll violently in certain situations. This can be mitigated only if basic questions of the seaworthiness of vessels are taken into account in the design stage, because these questions are still not covered by legislation (and will not be in the foreseeable future).

From an operational perspective, it is the opinion of the expert that the accident would have been avoided only if the crew had opted to drift abeam, as doing so would have led to a significant portion of energy from the swell being converted into a drift motion rather than a rolling motion and typically large roll angles do not occur in such situations.
However, in the given situation drifting abeam was not an option since the vessel had to keep clear of land. Moreover, in such situations it is probable, especially with the type of container vessel in question, that the stern will turn against the sea and can then be exposed to extreme slamming pressures on the flat aft section.
In any event, it is clear that without a detailed prior calculation, a decision more rational than that taken by the crew, i.e. to keep the vessel against the sea at a slow speed, would not have been possible. If the vessel was equipped with commercially available wave and surface current monitoring software, to the knowledge of the expert it would have rated the accident situation (i.e. sailing slowly against the sea) as non-hazardous, in particular, because there are no critical resonances. Therefore, that would not have made the situation fundamentally different.

In terms of design, – apart from the issue of the shape of the vessel – an increase in the effective roll damping would have been especially useful as regards preventing the accident. Unfortunately, legislation is also outstanding in that respect. In the opinion of the expert, larger bilge keels, for example, would have been helpful because they would have increased the roll damping in the critical situation. Similarly, roll damping from free liquid surfaces would have helped, which can be achieved by implementing partially filled tanks. But the reality is that in practice the dynamic effect of free surfaces is not widely known and therefore one cannot expect the crew to take appropriate action in that respect. Moreover, such measures need to be supported by appropriate calculations because otherwise the opposite effect may occur.

<u>Therefore, the state of science and technology with regard to the accident can be summarised as follows:</u>

It is clearly possible to explain such accidents using currently available calculation technology. To some extent, this may be interpreted as progress. However, with the regulatory documentation and instruments generally used in the construction, approval and operation of vessels it is currently not possible to formulate recommendations for action or guidelines that would definitely help the crew to avoid such accidents. In this context, the expert makes reference to the still existing need for developing dynamic stability criteria for the intact stability of vessels, which are physically correct as regards mapping the swell-related stability effects."

5.6 Crew

5.6.1 Composition

The CHICAGO EXPRESS was properly manned. In total, there were 36 persons on board including eight cadets. The Master, the Chief Officer, one other Nautical Officer on Watch, four Engineers and a Ship's Mechanic were German nationals. The remaining crew members were Philippine nationals.

5.6.2 Qualifications and experience

The Master of the CHICAGO EXPRESS, who was 47 at the time of the accident, has many years of professional experience. Since 1998, he has been employed as Master on container vessels of various dimensions by the vessel operator of the CHICAGO EXPRESS. He had already been Master on ships of the size in question (8749 TEU) before this voyage.

The 28-year-old Nautical Officer on Watch, who was on duty on the bridge at the time of the accident, has been employed by the vessel operator since 2005 and during this period has gained experience on container vessels of various sizes.

Both the fatally injured 34-year-old AB and the 29-year-old OS have spent several years at sea and possessed experience in bridge and watchkeeping duty.

5.6.3 Workload

The investigation has produced no evidence to suggest that the fatally injured AB, the Master, or the other injured persons were suffering from fatigue or other types of physical overexertion.

5.7 Voyage Data Recorder (VDR)

5.7.1 Carriage requirement

Pursuant to the requirements of SOLAS chapter V, regulation 20, the CHICAGO EXPRESS has been equipped with a **V**oyage **D**ata **R**ecorder since its entry into service. The shipboard VDR is distributed by German-based SAM Electronics GmbH, Hamburg. The type designation of the device is DEBEG 4300.

5.7.2 Technical and user-related difficulties

Immediately after the accident, while reporting it to the BSU the vessel operator gave, upon request, notification that the necessary measures had been taken on board to ensure execution of the incident backup required after an accident, which aims to prevent overwriting of the VDR's ring buffer.

On 2 October 2008, the vessel operator then informed the BSU that the internal hard drive of the VDR was removed for the purpose of sending it to Hamburg for analysis while the vessel was moored at the port of Hong Kong after the accident. In the process, it was reportedly established that the drive appears to have been inoperable at the time of the accident. The optional removable hard drive (CF card), which in addition to the internal hard drive is another storage device for backing up the data after an accident, was not connected to the system. Consequently, there were reportedly concerns that there would be no VDR data available for the time of the accident. Nevertheless, with the support of a data recovery laboratory and in coordination with SAM, the vessel operator was reportedly attempting to recover any records that may still exist.

However, despite extensive efforts by the vessel operator, the manufacturer and the BSU, which for its part engaged an external IT expert, it was ultimately not possible to reconstruct any VDR data whatsoever.

The investigation of the reason for the technical problems, which also included an inspection of the service records of the manufacturer and a meeting at its premises on 28 January 2009, at which the vessel operator's Superintendent Electric was also present, led to the following findings.

The VDR underwent its most recent annual inspection in Hamburg on 9 February 2008 and the manufacturer's service department confirmed the operability of the system. However, repeated error messages subsequently occurred, which reportedly concerned the internal hard drive. Since the error pattern in question matched a technote from the manufacturer, a service was reportedly organised for 25 August 2008 in Hamburg, during which a modification kit was to be installed. Due to technical problems, which SAM did not specify in more detail, it was reportedly neither possible to perform a software update nor install the modification kit on said date. To minimise the load on the IDE bus[34], which had been identified as problematic, the optional removable hard drive was reportedly not reconnected intentionally. The technician involved locally reportedly overlooked the fact that the internal hard drive was no longer recognised by the system and was defective. Reportedly, no alert had been provided for the error condition in question because of the defective software (the planned remedial update of which was unsuccessful).

Therefore, from that date the VDR reportedly only wrote incoming data (e.g., radar images, audio recording, courses and speeds, manoeuvre data) to the so-called Final Recording Medium (FRM = black box on the compass bridge), without the crew being able to detect that the system was not fully operable.

Due to contradictory statements, it was not possible to clarify in detail the specific measures that were taken after the accident to perform the backup. However, it was

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[34] IDE = **I**ntegrated **D**evice **E**lectronics = parallel interface on a PC, e.g., for connecting hard drives.

possible to reconstruct a summary of the procedures using the evaluated error logs (see **Fig. 35**) which were exported by the SAM service personnel during the repair of the VDR on 26 September 2008 in Hong Kong.

Nach dem Unfall wurde versucht die Daten des FRM's zu sichern:

```
I-24/09/2008 06:12:07 * Login: VDR Data Transfer with ID=2
I-24/09/2008 06:12:07 * ID=2: VDRtransfer.exe v3.2.4-2
```

Zwischen 6.37 und 7.36 wurden Daten gesichert, aus unbekannten Gründen wurde der Transfer aber abgebrochen:

```
I-24/09/2008 06:37:08 * ID=2: VDRtransfer.exe v3.2.4-2
I-24/09/2008 06:37:38 * ID=2: /mer/i9295268.cfg transferred
I-24/09/2008 06:37:54 * ID=2: Transfer in progress...
W-24/09/2008 07:36:29 * Engine with ID=2 lost Connection ...: implizit logout
I-24/09/2008 07:36:29 * Logout: VDR Data Transfer
```

Es ist zu vermuten dass eine große Menge Daten (Standard - Transfer dauert normalerweise etwa 1 Stunde) auf den Replay-PC transferiert wurden.
Danach wurde der VDR runtergefahren und am 26.09.08 wieder gestartet.

```
I-24/09/2008 08:26:42 * VDR is shutting down ...
I-26/09/2008 02:16:20 * CP304 Board Version:81.0, Logic Version 1 ...
```

Ein weiterer Versuch des Datentransfers durch den Service am 26.09. war sehr kurz. Gründe dafür können Bedienfehler sein.

```
I-26/09/2008 02:31:22 * Login: VDR Data Transfer with ID=3
I-26/09/2008 02:31:25 * ID=3: VDRtransfer.exe 3.5.10 Build 069
I-26/09/2008  02:31:25  *  ID=3:  Timeout  waiting  for  MER  configuration!  trying
FTP...
I-26/09/2008 02:31:32 * ID=3: No ISM data available!
I-26/09/2008 02:35:52 * ID=3: Log file(s) transfered
I-26/09/2008 02:35:53 * ID=3: Transfer done
I-26/09/2008 02:35:58 * Logout: VDR Data Transfer
```

Daraufhin wurde die neue Festplatte eingebaut und das System war wieder funktionstüchtig.

Figure 35: Excerpt from the error log with comments from the manufacturer[35]

After that, it was evidently the case that the limited functionality of the system described above gradually became apparent when attempting to execute the backup. A telephone call was made to the vessel operator's technical inspection department with the purpose of solving the problem, the cause of which (= hard drive failure) was unknown. Since a backup from the failed hard drive was not possible, an attempt was made to download the data via the system's replay station (see **Fig. 36** and **37**)[36] from the FRM to the hard drive of the replay computer. This download should have lasted a little longer than an hour but was aborted shortly before the end of this period. This was probably because after the preceding difficulties and the fact that the download process was perceived as being too slow, the personnel on board erroneously assumed that this data backup method had also failed.

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[35] Source: SAM record dated 21 October 2008 for the vessel operator.

[36] Note: The replay station is an optional PC installed on the bridge, which is connected to the VDR and makes it possible to load, view and save recorded data from the system's various storage media (internal hard drive, CF removable hard drive, FRM hard drive).

Figure 36: Replay station (integrated in the GMDSS console)

Figure 37: Replay station (close-up)

As indicated above, extensive efforts were made by the vessel operator, the manufacturer, and the BSU to save and restore any existing data or fragments thereof after the accident. The defective internal hard drive and the hard drive from the replay station were therefore subjected to in-depth testing by data recovery laboratories on behalf of the vessel operator and the BSU. However, the now identified problem with the internal hard drive had the inevitable consequence that no relevant data were written on this storage medium from the outset.

In contrast, testing the replay station's hard drive promised a greater chance of success. In a record dated 21 October 2008, which is in the possession of the BSU and refers, inter alia, to the aforementioned error log, SAM speculated that large amounts of data had most probably been written to the hard drive in question during the aborted download. Therefore, the vessel operator was advised that provisionally the data on the hard drive of the replay station should not be deleted or overwritten. SAM also agreed to assist the vessel operator in securing these data and the evaluation thereof.

On 27/28 October 2008, another service was conducted in the port of Southampton by an employee of SAM. An expert from the vessel operator accompanied the SAM technician to Southampton. During the joint visual examination of the replay computer's hard drive carried out locally, file directories, which were automatically created during the (prematurely aborted) download after the accident, were identified using Windows Explorer. However, these directories were – at least using the view options of Windows Explorer – reportedly empty. These, at least apparently empty directories were then reportedly deleted by the service technician in consultation with the vessel operator and new replay software was installed. It cannot be excluded that the final chance of restoring the directories in question from the night of the accident was inadvertently ruined only due to the above actions. It is possible that the directories only gave the (incorrect) impression that they were empty superficially due to the prematurely aborted download.

The BSU first received a copy of the above-mentioned service record during a shipboard inspection in Hamburg on 31 October 2008 and was not informed about the service carried out in the interim in Southampton until 28 January 2009 during a meeting at the premises of SAM. It was therefore not possible for the investigation team to have a separate test conducted on the replay station in relation to the speculation made in the service record dated 21 October 2008 before or during the service in Southampton. Despite thorough testing of the hard drive by a recognised specialist laboratory in Hamburg, it was subsequently not possible to find data or even fragments of data on the data carrier.

The difficulties in the backup stemmed most probably mainly from the limited operability of the system. Regardless of that, the interviews held by the BSU have also demonstrated that the functionality and practicability of the installed VDR type is problematic. In particular, activation of the incident backup via a user menu on the radar screen is questionable (see **Fig. 38** and **39**). The underlying principle of making it possible for the nautical officer to operate extensively from the vessel command console and in turn from the radar screen, the essential source of information, is basically understandable; however, that is outweighed by the risks and disadvantages that arise from the fact that a control element as essential as the emergency feature of a Voyage Data Recorder cannot be identified in a prominent place on the bridge and used. In that respect, it should also be borne in mind that circumstances are conceivable in which in a severe stress situation after an accident there is a possibility that crew members, who are not familiar with operating the radar equipment, must or should activate the incident backup system.

Figure 38: Extract – bridge console with port radar unit

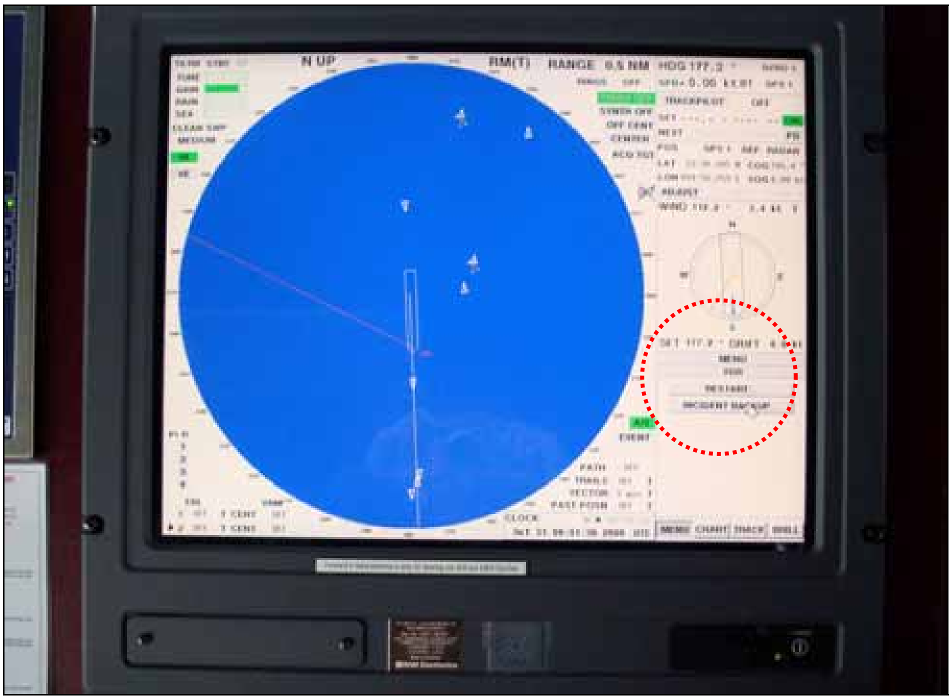

Figure 39: Button for incident backup on the port radar unit

This assessment by the BSU is also not changed by information from the manufacturer to the effect that it also offers an optional, separate operator unit, which is only rarely ordered by customers because they prefer to operate the VDR via the familiar RADARPILOT user interface.

Finally, although rather improbable, the possible failure of both radar screens after an accident opposes integrating the questionable operator interface in them. However, with the type used here, there is also the possibility of operating the incident backup directly on the VDR's so-called "Main Unit" (**Fig. 40** and **41**), but this is locked and is in turn located in an area below the bridge deck, which is also locked. Only the Master has access to the key.

Figure 40: Main Unit VDR (locked)

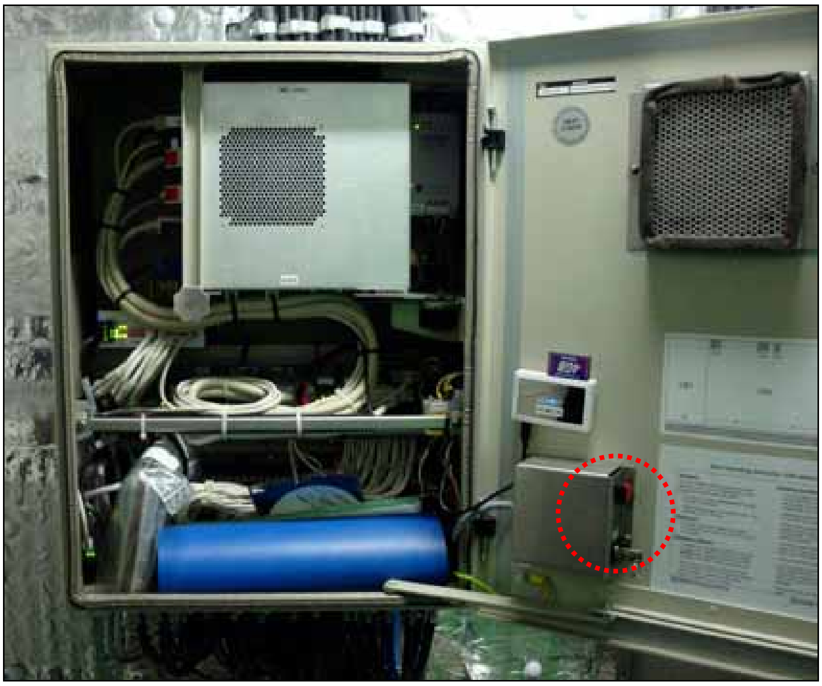

Figure 41: Switch for incident backup in the Main Unit

6 Analysis

6.1 Seagoing behaviour as the main cause of the accident

The expert's calculations of the seagoing behaviour of the CMV CHICAGO EXPRESS in the situation that prevailed at the time of the accident have proven beyond doubt that in the given parameters very large roll angles occur. This situation arises from a slow vessel speed of below a critical limit at a course of between about 60 and 30 degrees to the prevailing direction of swell. Depending on the roll angle applied, this critical speed is 3 to 5 kts, where a value of 3 kts would correspond to an actual roll angle of 45 degrees. The heel angle of 44 degrees displayed by the bridge inclinometer was most probably not reached, but is the result of the dynamics of roll motion. However, the calculations have confirmed that heel angles of more than 30 degrees occurred or could have occurred and would be reached below a critical speed of 5 kts. Said heel angles resulted in significant transverse acceleration of more than 1 g, which was the cause of the accident. Extremely large roll angles were identified for a range of vessel speeds below a critical level and when sufficiently abeam to the sea (60 to 30 degrees). Other courses and/or speeds also cause the vessel to roll considerably, albeit not so severely. The accident was ultimately caused by very strong excitation moments of swell coupled with very low roll damping due to the low speed. Critical resonances were definitely not evident; on the contrary, the vessel was moving significantly outside of such effects.

Further calculations have ultimately shown that a moderate change in stability would, in principle, not have improved the situation substantially. Under the prevailing circumstances, large roll angles would have still occurred even with a GM reduction by some 3.50 m; however, this would have resulted in markedly lower transverse acceleration. At any event, such a GM reduction was not possible due to the cargo volume available on departure from Hong Kong.

6.2 Shipbuilding deficits

The physical effects and phenomena from which the accident resulted that can be used to describe and explain the motions of a vessel in water occur, in principle, regardless of vessel type and size. However, due to the structural characteristics of large and very large container vessels these are particularly prone to absorbing high levels of swell moment because of their large bow flare. In that regard, it proves to be critical that there are no statutory, flag state, or – as far as one can see – class-related requirements for minimum roll damping. Rather, it is the case that, for example, the structural design of bilge keels[37] (see **Fig. 42** below), which serve as a proven structural means for influencing roll damping, has seen no significant changes in recent decades. This is astonishing when one considers that the length and breadth of some vessels has doubled in the intervening period.

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[37] Bilge keels = fixed flat steel sections welded on either side of a vessel for the purpose of damping the rolling motion along its longitudinal axis. The bilge keels are positioned at the bilge, i.e. the transition from the bottom of the vessel to the side walls. They generally run only in the parallel midship section on the widest part of the hull.

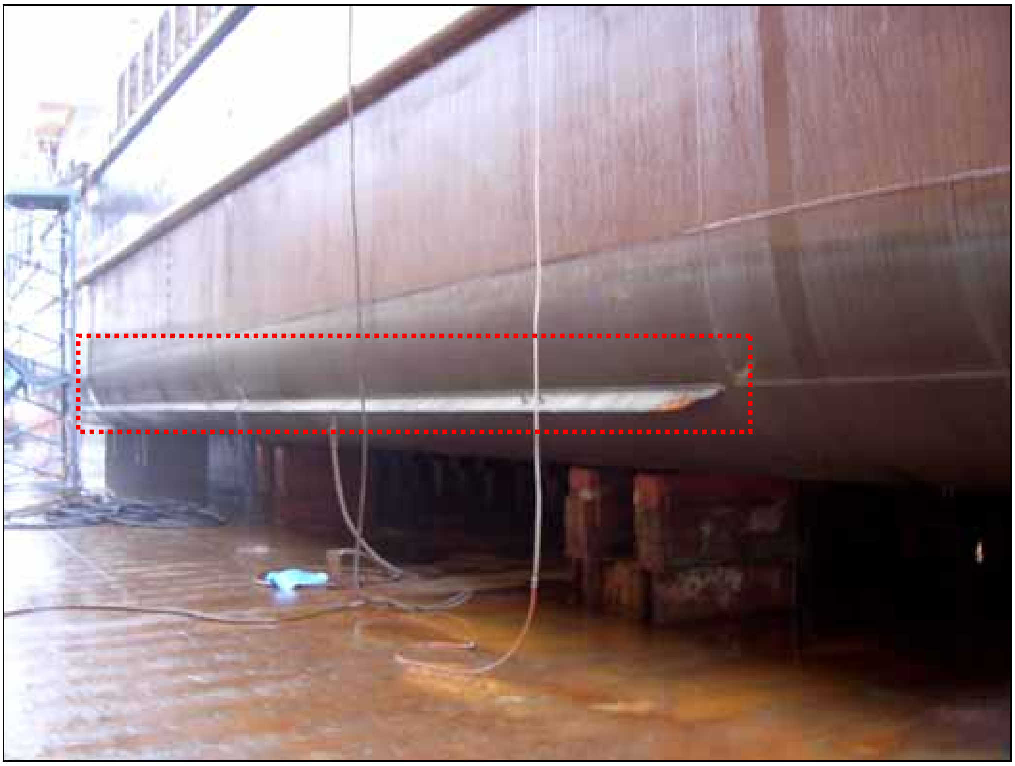

Figure 42: Example of a bilge keel[38]

The cause of the accident therefore clearly shows that accidents of the type investigated here can only be avoided in the future if more emphasis is placed on the swell-related effects when designing and approving such vessels.

6.3 Responsibilities of the vessel operator

The Federal Ministry of Transport, Building and Urban Affairs (BMVBS) explicitly refers, in relation to the necessity for increased attention to swell-related effects in ship design and approval, to the policy objective that the operator must be held accountable for the owner's responsibility for general safety issues. Notwithstanding the foregoing, in recent years efforts, especially initiated by Germany, have been made at the IMO[39] to raise awareness among the international community of the problems surrounding the dynamic stability of vessels and inasmuch develop internationally binding standards and subsequently put these into effect. However, prior to the adaptation of the safety provisions, scientific advancements are necessary. The aim must be to describe the various stability failure cases using scientifically sound criteria in a manner that is also clearly distinguishable for the crew. Only then will it be possible to develop the state of technology based on these findings in a manner that wave and surface current monitoring systems will become genuinely effective on this basis and thus safety-enhancing shipboard prediction instruments with certainty in the future.

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[38] Public domain picture from the Internet (Wikipedia); does not stem from the CHICAGO EXPRESS.

[39] IMO = International Maritime Organization; specialised agency of the United Nations for shipping matters based in London.

The BSU recognises that vessel operators, classification societies, and shipbuilders as well as the scientific community are of particular importance to the development and implementation of instruments for significantly improving ship safety as regards dynamic stability effects and therefore need to make a contribution in that respect. Nonetheless, there is the perception that alongside that, on the basis of the current state-of-the-art alone, the establishment or energetic promotion of a clear, internationally binding framework is needed, which facilitates greater recognition and practical utilisation of available scientific findings in relation to the vulnerability of vessels at sea.

6.4 Conduct of the crew

In view of the external circumstances, the crew had no way of avoiding the accident. Evaluation of the witness statements and technical records has shown beyond doubt that the ship's command tried everything possible to keep the vessel against the sea at slow speeds. In the process, the course was constantly adjusted and it was also essential to keep clear of the islands located "at the back" of the CHICAGO EXPRESS. Identifying and maintaining the optimum course against the sea was objectively impossible in the given circumstances (strong winds, high waves, possibility of cross seas, and added to that total darkness).

In theory, the accident could only have been avoided if the crew had sailed considerably faster or simply drifted the vessel abeam and both of these possibilities were impracticable. The option of drifting abeam was excluded by the risk of running aground. The crew could not have known that a relatively small increase in speed would have improved the overall situation because no corresponding calculations were present. Moreover, it should borne in mind that in this specific case the adverse effects of increasing the speed on other aspects of the vessel's safety have not been clarified.

Ultimately, increasing the roll damping by partially filling ballast tanks would, theoretically, have had a positive impact on the course of the accident. However, the crew was unable to implement this option for reasons of practicability since specific calculations are essential beforehand.

6.5 Technical resources

It follows from the discrepancy between theoretical knowledge on one hand and practical possibilities on the other that in addition to rethinking engineering aspects, i.e. shipbuilding, it is, more than ever, necessary to continue efforts to provide the ship's command with better information about the possibilities and limitations of actively influencing the seagoing behaviour of the particular vessel in borderline situations. In this context, by way of example the BSU refers to the investigation report concerning the MV JRS CANIS marine casualty on 12 January 2007 (Ref.: 45/07). With heel angles of approximately 20 degrees the vessel lost 10 containers whilst rolling in heavy seas. One important outcome of the ensuing investigation, which looked intensively at the issue of wave and surface current monitoring systems, is set forth in sub-para. 6.3 of the analysis to the investigation report:

"Finally, we can say that in practice (in particular onboard large container ships) there is a need to have access to a tool that can be used easily and clearly to avoid dangerous sea conditions.
This is a recognised need and is being worked on by numerous institutions. Research and development should be intensively expedited in order to be able to provide a reliable tool to vessel commands as soon as possible."

The safety recommendation[40] derived from the quoted finding: expediting research and development in the specified field, is strongly confirmed by the accident involving the CHICAGO EXPRESS.

6.6 Bridge ergonomics

The dimensions of the bridge on vessels the size of the CHICAGO EXPRESS can make it necessary to move significant distances within the bridge; for example, between the chart table and vessel command console, on which it is practically impossible for crew members to safely resist the impact of a severely rolling vessel. The same applies to a similar extent even when situated at the various operating positions on the bridge. The existing handholds do not guarantee safe footing in every situation and in every position. The BSU is aware that for reasons of practicability and/or design it will be virtually impossible to develop a system that will prevent swell-related falls on the bridge in every situation. Nevertheless, particularly for bridges which have or even exceed the dimensions of a handball field and on which the angle of inclination and effect of accelerative forces can reach extreme proportions when the vessel is rolling due to the height above the water level, account must be taken for the fact that the potential risk for people working there is very high.

6.7 Actions on board after the accident

The crisis management on board after the accident was marked by a very high level of professionalism. In his capacity as representative of the injured Master, the Chief Officer, who was 34 at the time of the accident, immediately assumed full responsibility for the command of the vessel. In the ensuing hours and during initially persistent critical external conditions, he, with the support of various crew members acting judiciously, successfully organised the initial treatment and evacuation of the Master, who was in danger of losing his life. However, the several hours on board trying to save the severely injured AB were spent in vain. Furthermore, the subsequent safe return of a vessel the size of the CHICAGO EXPRESS to the busy port of Hong Kong under the command of the Chief Officer deserves high recognition.

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[40] See sub-para. 7.2 of the investigation report specified.

6.8 Voyage Data Recorder

6.8.1 Taking stock

The major technical problems with the VDR installed on board the vessel not only complicated the investigation of this marine casualty, but also had an adverse effect on its duration that was not insignificant. As stated above in sub-para. 5.7.2, the latter was because there was initially some hope that recorded data could still be restored, at least by means of a workaround. However, ultimately the in part very negative experience of the BSU in recent years in terms of the absence or insufficient quality of recorded accident data and also in terms of user-issues is once again confirmed.[41]
Shortly after the introduction of VDR systems at the beginning of 2002, the occurrence of technical shortcomings, which in part only became evident in live operation on board and then only after an accident, was understandable for a transitional period. However, after more than five years of technological development and optimisation, we cannot understand how it is possible for a VDR system to fail in terms of both software and hardware to the extent seen here. Equally unacceptable is the fact that it was not possible to eliminate a fault or identify that a repair attempt had failed during an authorised service on board.

6.8.2 International progress

Exchanges of experience with foreign investigative authorities have repeatedly shown that the manifold problems connected with VDR technology are in no way limited to individual cases at national level. Accordingly, attempts have been made in the past to bring about internationally binding improvements in relation to the functionality and practicability of Voyage Data Recorders in specific areas, but also in terms of an extensive review of the overall performance requirements.
For example, in response to the collision between MV RITHI BHUM and MV EASTERN CHALLENGER on 14 November 2004 (ref.: 343/04) mentioned in footnote 41, on 15 July 2005, the BSU addressed a safety recommendation to the Federal Ministry of Transport, Building and Housing[42], the objective of which was for the Federal Republic of Germany to encourage the IMO to modify the VDR performance requirements concerning the quality of audio recordings. Following this recommendation, the Federal Republic of Germany initiated a corresponding amendment, which was included in the work programme of the **M**aritime **S**afety **C**ommittee (MSC) of the IMO on 25 June 2007 under file number MSC 83/25/4.
Moreover, in response to proposals from other member states of the IMO, MSC has commissioned the Subcommittee on Safety of **Nav**igation (NAV) to adapt the list of performance requirements for Voyage Data Recorders so that it meets both the advanced technical capabilities and the practical necessities.

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[41] In that respect, see investigation reports of the BSU concerning the following marine casualties: Collision between MV RITHI BHUM and MV EASTERN CHALLENGER on 14 November 2004 (Ref.: 343/04), Collision between MV LASS URANUS and MV XIN FU ZHOU on 12 July 2006 (Ref.: 305/06), Capsizing of Pilot Tender ELBE 3 while casting off from MV DELTA ST. PETERSBURG on 23 August 2006 (Ref.: 415/06), Collision between CMV HANJIN GOTHENBURG and MV CHANG TONG on 15 September 2007 (Ref.: 450/07).

[42] Now: Federal Ministry of Transport, Building and Urban Affairs.

In this context, as a consequence of the very extensive experience with the evaluation of Voyage Data Recorders and in addition to the proposals made by Germany, inter alia, the UK formulated far-reaching amendments, which together with proposals from, inter alia, Germany, Egypt and India, were on the agenda of Subcommittee NAV on 27 July 2009. Proposals include extending the retention period for data on the internal storage medium of the VDR from a current minimum of 12 hours to at least 720 hours (30 days!). Other very practical modifications relate to the need to equip Voyage Data Recorders more effectively in the future than hitherto with internal fault analysis tools, which emit an alarm immediately if deficiencies occur during the recording of data. One proposal by the UK, which would make, in particular, the investigation of accidents such as that seen with the CHICAGO EXPRESS easier, is to fit the VDR with an interface to an inclinometer (that determines values reliably) or, in the absence thereof, to make an inclinometer an integral part of the VDR system.

However, it is the opinion of the BSU that the standardisations in the paper from the UK do not go far enough as regards the data transfer to an external computer after an accident. In that respect, it is merely proposed that manufacturers are required to use any internationally recognised standard, such as Ethernet, USB, IEEE-1394[43], etc. It would be much more useful to provide one single standard for connecting the VDR to an external computer or, better still, to dispense altogether with the necessity for the error-prone computer connection and instead provide the VDR with a single, sealed, standardised removable storage media, which after an accident can be easily exchanged and removed from the vessel for investigative purposes.

6.8.3 Operating steps on board

It is once again confirmed that the operating philosophy of Voyage Data Recorders is often not readily understandable for crew members. Taking into account the particular physical and nervous strain to which the ship's command and entire crew is exposed just after an accident, it seems all the more urgent that the incident backup can be executed by the simple, single operation of a switch, which for its part can be located easily on the bridge.

The manufacturer, SAM, has indicated that as part of user training it recommends to its customers that the ship's command perform VDR tests at regular intervals. This would not only check the functioning of all components of the system, but also train the rarely used operating steps after an accident.

In that respect, it is noted by the BSU that periodic testing can bring about the indicated benefits. However, there are concerns inasmuch as, for example, the occurrence of faults is not necessarily immediately recognised simply by creating a backup. For that purpose, it would be absolutely necessary to have a replay system on board; however, this is not a mandatory part of a VDR. Moreover, the remaining undetected unsuccessful attempt at repair on the VDR of the CHICAGO EXPRESS before the accident (25 August 2008) is an example which demonstrates that evidently even highly trained service staff are not always readily familiar with the full functionality of the system on site. Finally, it must be remembered that VDR systems exist which for technical reasons permit only a limited number of backups in a given

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[43] Note: The IEEE-1394 industry standard was established in 1995 and is also known as, inter alia, Firewire (Apple) and Sony i.Link.

period, which can then only be deleted during a service or after the expiry of a time lock.
Therefore, the BSU is not in a position to make a universal recommendation as regards the performance of periodic testing of the VDR on board.

7 Actions taken

As a consequence of the accident, the vessel operator has organised for various additional handrails to be fitted on all vessels of the 8749 TEU class[44] and beyond that to enclose the position of the Helmsman with railing (see examples at **Figs 43** to **48**). Moreover, the accident has been discussed within the fleet and in this context possible additional safeguards on the bridge such as the clamping of lifelines or the securing of personnel with belt systems are being considered. However, such measures have not been passed on to the vessels as universally binding recommendations for reasons of practicability. Rather, it has been left to the discretion of the ship's command to carry out any steps that appear necessary and useful to minimise the risk of falls on the bridge due to heavy seas in consideration of the specific risk situation.

Figure 43: Handrail on the forward edge of the chart table

Figure 44: Handrail on the forward edge of the GMDSS console

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[44] Note: Larger vessels are currently not operated by the vessel operator.

Figure 45: Handrail on the port side and aft end of the bridge

Figure 46: Handrail on the aft end of the bridge

Figure 47: Handrail on the port side of the bridge

Figure 48: Safety railing for the Helmsman

8 Safety recommendations

The following safety recommendations do not attribute a presumption of blame or liability in respect of type, number or sequence.

8.1 Vessel operators, classification societies, shipyards

The Federal Bureau of Maritime Casualty Investigation recommends that, in cooperation with classification societies and shipyards, the operators of seagoing vessels increase efforts aimed at paying far more attention than hitherto to the dramatic consequences of swell-related stability effects, which are evident under certain circumstances, during the design and approval of future vessels. This must take into account the fact that very large units in particular often sail with very little cargo on board in a condition far removed from that intended in the actual design, and for that reason especially, depending on the weather, both crew and cargo can inevitably be exposed to the effect of very dangerous forces and acceleration when at sea.

8.2 BMVBS, IMO, classification societies

8.2.1 Revision of design specifications

The Federal Bureau of Maritime Casualty Investigation recommends that, in cooperation with the classification societies, the Federal Ministry of Transport, Building and Urban Development (BMVBS) take initiatives at the IMO aimed at developing and/or revising internationally binding rules, which from a shipbuilding perspective concern vessel safety. The trend in shipbuilding towards ever larger vessels shows that it is now more necessary than ever before to better address the issue of swell-related effects during the design and approval of such vessels. The hitherto existing requirements may indeed ensure that vessels the size of the CHICAGO EXPRESS and larger are able to resist any form of swell mechanically and hydrodynamically. However, as vividly demonstrated by the accident involving the CHICAGO EXPRESS, this does not apply fully with regard to the safety of and a bearable life for the crew living and working on board.

As regards the dimensioning of bilge keels, which hitherto are the most effective structural means of increasing roll damping, with respect to the above the introduction of mandatory building regulations should be examined.

8.2.2 Calculation hypotheses for intact stability

The Federal Bureau of Maritime Casualty Investigation recommends that, in cooperation with the classification societies, the Federal Ministry of Transport, Building and Urban Development (BMVBS) bring about at the IMO international standardisation of the fundamental calculation hypotheses and methods used for intact stability so that clear and comparative calculation results will be achieved in any given event. Due to the fact that in spite of mandatory guidelines on the requirements for the stability of a vessel, it is possible, depending on the program used with different calculation hypotheses, to calculate divergent lever arm curves, in borderline situations the current state can lead to the officially approved and monitored shipboard load computer returning safe results while there is a risk of capsizing when other calculation hypotheses are applied.

8.3 Classification societies and shipyards

The Federal Bureau of Maritime Casualty Investigation recommends that classification societies and shipyards pay greater attention and attach greater importance to the issue of handholds for the event of heavy swell during the planning, approval and construction of a vessel's bridge, especially with respect to those the size of the CHICAGO EXPRESS and larger.

8.4 Nautical colleges, vessel operators, ship's commands

8.4.1 Drifting abeam

The Federal Bureau of Maritime Casualty Investigation recommends that nautical colleges, vessel operators and ship's commands intensively address the issue of hazards on the bridge of large container vessels in heavy swell. Drifting abeam would have led to a significant portion of energy from the swell being converted into a drift motion rather than a rolling motion and typically a large roll angle does not occur in such situations. However, it should be remembered that the external circumstances (danger of running aground) and the eventual possibility that the stern will turn against the sea and can then be exposed to extreme slamming pressures on the flat aft section must be duly considered.

8.4.2 Speed

The Federal Bureau of Maritime Casualty Investigation draws the attention of nautical colleges, vessel operators and ship's commands to the fact that decreasing the speed below a critical value may result in a dangerous deterioration of the dynamic roll damping. Conversely, in that regard it is also necessary to be aware of the risks to the vessel and (deck) cargo associated with excessively high speed.

8.5 Scientific institutions and shipping related companies, Marine Insurance and Safety Association and BMVBS

The Federal Bureau of Maritime Casualty Investigation is using this opportunity to repeat its Safety Recommendation No. 7.2 concerning the marine casualty involving the MV JRS CANIS on 12 January 2007 (Ref.: 45/07):

*"The Federal Bureau of Maritime Casualty Investigation recommends to **maritime science institutions and shipping companies** to further expedite research and development of systems that enable the vessel's command to monitor and correctly assess sea-related vessel motions, in order for them to take necessary measures promptly to avoid vessel motions and manoeuvres that jeopardise safety.*

*The Federal Bureau of Maritime Casualty Investigation recommends to the **Marine Insurance and Safety Association** to continue to lend critical support to the development of these systems and if necessary to update guidelines for the use of these systems.*

*The Federal Bureau of Maritime Casualty Investigation recommends to the **Federal Ministry of Transport, Building and Urban Affairs** to support the research and development of these systems."*

8.6 Federal Maritime and Hydrographic Agency

The Federal Bureau of Maritime Casualty Investigation recommends that, in its capacity as licensing authority for Voyage Data Recorders, the Federal Maritime and Hydrographic Agency closely scrutinises the procedures for granting type approval. The fact that in the past officially tested and approved VDR systems have failed repeatedly in practice demonstrates that the suitability of a Voyage Data Recorder for daily use must be checked even more critically than before.

8.7 VDR manufacturers

The Federal Bureau of Maritime Casualty Investigation recommends that Voyage Data Recorder manufacturers comprehensively address the recurring technical problems of the assembled units. In addition to the evaluation of the manufacturer's own service records, the vulnerability analysis should at any event include accounting for principal problems externally, which could be achieved by, for example, sending questionnaires to investigative authorities and vessel operators and subsequently analysing these.

8.8 BMVBS

8.8.1 Revision of the performance requirements for VDRs

The Federal Bureau of Maritime Casualty Investigation recommends that in the context of international efforts to modify and further develop, the BMVBS continue to participate intensively in updating the performance requirements for VDRs. In the process, close attention should be paid to the rigorous simplification of operating the systems in general, and beyond that specifically also in terms of the possibilities for transferring data from the system without particular technical upheaval on board.

8.8.2 Integration of information from an inclinometer in the VDR database

The Federal Bureau of Maritime Casualty Investigation recommends, with respect to the revision of the performance requirements for Voyage Data Recorders, that the BMVBS support the UK's proposal to include the heel angle as data to be recorded.

8.9 Inclinometer manufacturers

The Federal Bureau of Maritime Casualty Investigation recommends that inclinometer manufacturers reconsider the constructive approach for these devices where necessary to ensure incorrect heel angles are not displayed as a result of dynamic effects.

9 Sources

- Written declarations/statements obtained with the kind support of the vessel operator:
  - Written statements by the ship's command
  - Witness interview records from the police in Hong Kong
  - Report on the internal investigation of the accident by the P & I insurer
  - Excerpt from the load computer (load case)
  - Technical documentation, stability book, drawings, photos of the vessel and structural modifications on the bridge after the accident
- Witness statements to the BSU
- E-mail correspondence with the Marine Department (MARDEP) of the Hong Kong Special Administrative Region, in particular, AIS data from VTS Hong Kong
- Official expertise from the Marine Division of Germany's National Meteorological Service (DWD) dated 28 October 2008
- Nautical charts and vessel particulars, Federal Maritime and Hydrographic Agency (BSH)
- Expertise concerning the very serious marine casualty on board the CMV CHICAGO EXPRESS off Hong Kong on 22 June 2009, Prof. Dr.-Ing. S. Krüger, Director of the Institute of Ship Design and Ship Safety, Dipl. Ing. C. Steinbach (research assistant), Hamburg-Harburg Technical University
- Statements on the draft investigation report