MA2011-2

MARINE ACCIDENT INVESTIGATION REPORT

February 25, 2011

Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

Norihiro Goto
Chairman,
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

MARINE ACCIDENT INVESTIGATION REPORT

Vessel type and Name:	Ro-Ro Passenger Ferry ARIAKE
Vessel number:	134594
Gross tonnage:	7,910 tons
Accident type:	Listing
Date and time:	Around 05:06, November 13, 2009 (local time, UTC+ 9 hours)
Location:	Off the southeast of Kiho Town, Mie Prefecture (the Kumano Nada), Approximately 115.5° true bearing, 14.0 nautical miles from North Lighthouse, East Breakwater, Udono Port (Approximately 33° 38.1′ N, 136° 16.5′ E)

February 3, 2011

Adopted by the Japan Transport Safety Board

Chairman Norihiro Goto

Member Tetsuo Yokoyama

Member Tetsuya Yamamoto

Member Toshiyuki Ishikawa

Member Mina Nemoto

CONTENTS

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

On November 13, 2009, while the ro-ro passenger ferry Ariake, boarded with a master and 20 crew members, was proceeding in the southwest direction in the Kumano Nada, carrying seven passengers,, 150 containers and others on board, the hull of the ferry listed heavily to starboard at around 05:06, and afterward, she grounded and laid sideways off the coast of Mihama Town, Mie Prefecture.

Two passengers and one crew member were injured.

1.2 Outline of the Accident Investigation

1.2.1 Setup of the Investigation

The Japan Transport Safety Board appointed an investigator-in-charge and four other marine accident investigators to investigate the accident on November 13, 2009.

1.2.2 Collection of Evidence

November 14, 15, 19, and 27, December 15 and 24, 2009, and February 25, 2010: On-site investigation and interviews

November 26, December 1, 18, and 24, 2009, January 15, February 12, 17 and 24, March 10, July 2 and 5, and October 21, 2010: Interviews

January 20, March 15, and May 4, 2010: On-site investigation

February 3 and 4, April 16, May 21, June 22, July 28, August 3, September 9, and October 7, 2010: Collection of written replies to the questionnaire

1.2.3 Tests and Research by Other Institutes

The Board entrusted the National Maritime Research Institute with tests and research on the listing and collapse of cargoes sustained by the ro-ro passenger ferry Ariake in this accident.

1.2.4 Factual Information in Public

On December 15, 2009 and March 24, 2010, the Board made public the wake of the ro-ro passenger ferry Ariake and other information which became available as a result of fact-finding.

1.2.5 Comments from Parties Relevant to the Cause

Comments on the draft report were invited from parties relevant to the cause of the accident.

2 FACTUAL INFORMATION

2.1 Events Leading to the Accident

2.1.1 Events Leading to the Accident According to the Statements

Events leading to the accident were as follows, according to the statements of the master, crew and passengers on board the ro-ro passenger ferry Ariake (hereinafter referred to as "the Vessel"), an operation manager of A-Line Ferry Co., Ltd. (hereinafter referred to as "Company A") , a cargo superintendent of Nippon Express Co., Ltd. (hereinafter referred to as "Company B") and other persons.

(1) Events up to the time of departure

The Vessel, which was a roll on roll off and passenger ferry engaged in a regular service among Tokyo Section of Keihin Port, Shibushi Port at Shibushi City in Kagoshima Prefecture, Naze Port at Amami City in Kagoshima Prefecture, and Naha Port in Okinawa Prefecture, departed from Shibushi Port at around 07:00, November 11, 2009, and berthed at Ariake Pier, Tokyo Section of Keihin Port at around 10:10 on the following day, November 12, 2009.

Learning from the prognostic wave chart of the Japan Meteorological Agency that a water area with a wave height of about five meters was expected off the Kumano Nada in the vicinity of the standard course specified in the safety management manual (operation standards) of company A, the master of the Vessel decided to proceed an area close to the Kii Peninsula in the Kumano Nada where a wave height of four meters was expected. Also, while the Vessel was supposed to proceed in following sea conditions in the Kumano Nada, the master estimated from his previous navigating experience that the Vessel would not sustain a rolling motion of seven degrees or more specified in the operation standards as an approximate intensity of ship motions requiring suspension of the standard navigation.

Although the master thought from the weather and sea states information that the hull would not sustain large pitching[*1], he decided to take preventive measures for the chassis[*2] to be loaded at the fore and aft of No.1 car deck (hereinafter referred to as "C Deck") where relatively large motions were expected.

Company A had entrusted Company B for many years cargo handling operation at Ariake Pier, and the master, the chief officer and the second officer of the Vessel as well as the cargo superintendent and the stevedore had a meeting for the cargo handling operation as usual.

At that time, the master ordered them to secure the chassis to be loaded in the front row and the last row on C Deck with six lashing chains by adding two lashing chains (hereinafter referred to as "6-Point Lashing Chain), and to secure the other cargoes with four lashing chains (hereinafter referred to as "4-Point Lashing Chain) as usual.

In the presence of the chief officer who was also an on-board work supervisor, six longshoreman of Company B and 31 longshoreman of a subcontractor of Company B (hereinafter referred to as "Company C"), in addition to the cargo superintendent and the stevedore, loaded, as scheduled, 150 containers, 44 chassis, six heavy machines, six trucks and 26 passenger cars, and lashed them as instructed by the master.

At around 15:00, the master examined the weather and sea states information again with

---

*1 "pitching" refers to the rotation (back and forth) of a vessel about its horizontal and transverse axis through the center of gravity.

*2 "chassis" refers to a vehicle towed by a tractor while carrying mostly cargoes on it.

the operation manager who had been in Tokyo, and confirmed that he would proceed the Kumano Nada, and that weather and sea conditions would not become so bad as to require suspension of departure as prescribed in the operation standard.

(2) Events since departure until reaching the vicinity of the mouth of Tokyo Bay

The Vessel, boarded with the master and 20 crew members, carrying seven passengers and cargoes mentioned as above on board, departed from Ariake Pier for Shibushi Port at around 17:15, while the right and left heeling tanks[*3] were loaded with almost equal quantity of ballast water[*4] with hardly any list to either of them.

Upon the completion of the departure works, the chief officer inspected the lashing conditions of the cargoes on board as usual with the boatswain and an able bodied seamen, and after confirming that the lashing chains had not been loosened, he went on the bridge and reported to the master that there was nothing abnormal.

(3) Events since reaching the mouth of Tokyo Bay until 20:00

At around 19:20 when reaching off the south exit of Uraga Channel, the master handed vessel maneuvering over to the chief officer who was on duty. The master remained in the bridge for a while, and after checking the surrounding situation and confirming that a northeasterly wind had started blowing at a speed of about 13 to 15 meter per second (m/s), and waves with a wave height of about 2.0 to 2.5 meters had occurred, he left the steering room and returned to his own cabin adjacent to the steering room, when the Vessel passed off the cape of Tsurugi Saki, Kanagawa Prefecture.

As usual, while off the cape of Tsurugi Saki, the chief officer deployed the fin stabilizers[*5] out of the hull and put it into operation.

At around 19:30, the able bodied seaman A on the bridge watch-keeping duty executed an inspection round of the Vessel as prescribed in the safety management manual (work standard), and confirmed that the lashing chains had not been loosened.

(4) Events between 20:00 and 24:00

At around 20:00, the third officer and the able bodied seaman B took over the bridge watch-keeping from the chief officer and the able bodied seaman A.

At around 20:45, when the Vessel reached off the coast of Kazehaya Saki, Izu Oshima, the master went to the steering room, and confirmed that a northeasterly wind was blowing at a speed of about 15 m/s, and there were no ship motions. After that, he ordered the third officer on duty to alter the course to 255° (true bearing, the same will apply hereinafter) off the coast of Mikomoto-shima in the vicinity of the southern tip of the Izu Peninsula, and to 237° off the coast of Daio Saki, Shima City, Mie Prefecture, and to proceed to off the coast of Shiono Misaki, Wakayama Prefecture. Then he returned to his cabin.

The able bodied seaman B executed an inspection round of the Vessel while on the bridge watch-keeping duty, and confirmed that the lashing chains had not been loosened.

(5) Events between 00:00 and 04:00 on November 13

At around 00:00, the second officer and the able bodied seaman C took over the bridge

---

[*3] "heeling tank" refers to water tanks installed on the both sides on the midship of a vessel, which helps transferring, sea water in order to correct its tilt position which has been caused by cargo loading.

[*4] "ballast water" refers to sea water or fresh water which is loaded on board to help maintain the stability of a vessel.

[*5] "fin stabilizers" refers to instrument which are mounted near the bottom of a vessel and emerge laterally into the sea with fin-shaped wings. It is used to reduce a rolling motion of a vessel with the lifting force of the wings to be generated while underway.

watch-keeping from the third officer and the able bodied seaman B.

At around 03:00, the Vessel altered the course to 237° off the coast of Daio Saki, when she received a wind with a speed of 15 m/s and a wave with a wave height of about 3.5 meters from behind on the port quarter. The Vessel kept navigating at a speed of about 21 kn on autopilot without sustaining any abnormal rolling of the hull.

Afterwards:, the able bodied seaman C executed an inspection round of the Vessel, and confirmed that the chains lashing the cargoes on board had not been loosened.

At around 03:50, the chief officer and the able bodied seaman A went on the bridge.

(6) Events since 04:00 until the Vessel heeled heavily

At around 04:00, the chief officer and the able bodied seaman A took over the bridge watch-keeping from the second officer and the able bodied seaman C with a message that they had found nothing abnormal inboard.

While judging by visual estimation that the Vessel was proceeding in following seas from the port quarter with almost the same speed as the Vessel's, and that an east-northeasterly to easterly wind was blowing at a speed of about 16 to 17 m/s, the chief officer felt that weather and sea conditions were not so bad, contrary to the estimation.

At around 04:30, as the ship position given by the GPS system was deviated from the west of the planned course line, the chief officer altered the course to 235°, and he continued the bridge watch-keeping without feeling anything abnormal about the navigation a instrument or any rolling of the hull. At around 05:00, he filled in the ship's position in the chart.

Besides, the master and two crew members who got up between around 04:30 and 05:00 in order to go to a toilet and other matters did not feel any rolling of the hull.

(7) Situation at the time of the occurrence of the accident

At around 05:00 to 05:10, the Vessel suddenly listed 20° to 30° to starboard.

The chief officer and the able bodied seaman A were flung away almost to the sidewall on the starboard side in the steering room, and while trying to return close to the steering stand placed in the center of the steering room, they could hardly do so as the Vessel had already listed heavily and the floor had become wet and slippery with water coming from somewhere.

When the master was about to sit down on the bed in his cabin, the Vessel listed heavily to starboard as if lifted up, and when the listing seemed to have stopped, he felt the list becoming larger again. At that moment, he went out into the passage to go to the steering room, but he could hardly reach the entrance to the steering room because of the list and the wet and slippery passage.

When the Vessel listed, passengers sleeping in starboard passenger cabins slipped down to the sidewall with windows, and saw the sea surface about one meter below the windows. Also, some crew members dropped from the bed while sleeping, and other crew who were in their cabins on the port side saw the starboard sea surface close to them when they went out into the passage.

The list of the Vessel which was gentle until that time became severe, and the angle of list became about 45° to starboard.

At around 05:14, the chief officer and the able bodied seaman A at last came close to the steering stand.

While the chief officer could not afford to check the steering condition, heading, and alarms shown on the warning display on the steering stand, he stopped the warning sound by turning off the system selector switch[*6] of the steering equipment, turned on the system selector switch after shifting the mode selector switch from automatic steering to manual steering, and turned the steering wheel, when he found that the steering equipment operated normally.

In the meantime, the master at last reached the entrance to the steering room, and confirmed with the chief officer who was operating the steering wheel that the steering equipment was operating normally. He also found that the able bodied seaman A was transferring ballast water from the heeling tanks on the starboard side to the heeling tanks on the port side by operating the bilge pump, and that various warning sounds were ringing.

The chief officer reported to the master that the list to starboard had exceeded 40°.

Meanwhile, some of the passengers and crew members heard strange sounds like a creak, a clickety-clack like something hard was hitting the hull, and a burbling sound from the bottom of the Vessel.

As the master decided to correct the list to starboard as much as possible by making use of ballast water, blowing winds and outward heel[*7] while turning, he ordered the able bodied seaman A to transfer ballast water until the heeling tanks on the port side became full, and the chief officer to steer to starboard in order to prepare for receiving winds and waves from starboard.

(See Figure 1: Navigation Route 1, Figure 2 : Navigation Route 2, Figure 3 : Navigation Route 3, Figure 4 : Wave Observation and Analysis (as of 2100 hrs, November 12, 2009), Figure 5 : Heading and Course over the Ground (COG), Figure 6 : General Arrangement Plan)

The accident occurred at around 05:06, November 13, 2009, and the location was approximately 115.5°, 14.0 nautical miles (M) from the Udono Port East Breakwater North Lighthouse, Kiho Town, Mie Prefecture.

(8) Events since the occurrence of the accident until preparing for rescue

Crew members gathered in the steering room one after another.

While taking the con, the master ordered the chief officer to continue the steering of the Vessel, the second officer to contact the Japan Coast Guard and Company A, the third officer to engage in radar surveillance, the chief engineer and the first engineer to operate the main engines, the boatswain and the able bodied seaman A to transfer ballast water, and the purser and the other crew to take care of the passengers.

As the crew members checked the alarms in operation and reset them one by one the orders of the master, the fire alarm and engine-related alarms indicated the normal condition, while the water leakage alarm system sensed abnormality again. The master also found that the fin stabilizer alarm system did not sense abnormality and was in normal condition.

Finding that the angle of list had become about 30° to 35° to starboard at around 05:20, the master explained the situation to the Japan Coast Guard with the phone at around 05:22, and requested rescue by helicopter, while transmitting a distress alert with the international VHF radio telephone equipment. After that, he requested Company A for establishing an emergency task force according to the safety management manual (accident handling standard).

[*6] "system selector switch": There are two system types of steering equipment for diverting signals sent from the steering stand to an oil hydraulic pump for the steering gear. A system selector switch refers to an electric switch that selects or turns off either of them.

[*7] "outward heel" refers to an inclination of a vessel to the opposite side of the pivoting point by virtue of centrifugal force while turning.

While instructing the purser to check the safety of the passengers, the master broadcast the situation to the passengers and the crew with the public address system, and that he had already requested the Japan Coast Guard for rescue, and he instructed them to wear a life -jacket.

At around 05:30, when the purser went with three clerks to the passenger subdivision on the promenade deck (hereinafter referred to as "B Deck"), he found that all of the passengers gathered composedly in the passage wearing a life-jacket. He provided them PET bottles of water, asking each of them whether or not they were injured.

Meanwhile, the shift of ballast water was stopped as the heeling tanks on the port side had become almost full.

At around 05:35, the master found that although put the helm to starboard, the Vessel could not make a right turn as intended, and as the Vessel was proceeding in the southeast direction (offshore), he decided to make a left turn while getting prepared for the list becoming larger because of outward heel. Then, he not only reduced the speed with the intention of easing the impact of the outward heel, but also gave order to port 10°.

When the Vessel completed the left turn and became prepared to proceed in the northwest direction, the master learned through the Japan Coast Guard that a container ship of foreign registry which had received the distress alert was offering to cooperate with rescue operations, and that the container ship was situated to the aft of the Vessel. However, the master could not afford to check the position of the container ship.

Meanwhile, the Vessel was receiving winds and waves from starboard, and the angle of list became about 25°.

At around 05:40, the master ordered the purser and crew members to guide the passengers into the passage on the port side of the bridge deck (hereinafter referred to as "A Deck").

By using ropes and fire hoses, the purser and the crew guided the passengers from the passenger subdivision, by passing through the restaurant, galley and stairs, into the passage on the aft side of the chief engineer's cabin on A Deck and stood by the passengers for a rescue operation by helicopter.

When it was around past 06:00, the list to starboard started to be larger gradually.

(See Figure 7: Evacuation Route of the Passengers)

(9) Rescue and evacuation

When a helicopter of the Japan Coast Guard came in site, the master stopped the engines on both sides as the distance to the shore became about 2.0 M. After that, when the distance to the shore became as close as 0.7 M due to the effects of the winds and waves, the master moved the Vessel to off the coast by putting the starboard engine to dead slow astern, with the intention of avoiding grounding and easing the impact of the waves on the stern.

At around 07:15, the helicopter of the Japan Coast Guard arrived in high over the Vessel. At the direction of the mobile rescue technicians of the JCG (hereinafter referred to as "Mobile Rescue Technicians" : a party of two, rescue operations were commenced at around 07:30 by hoisting passengers from the external passage on the port side of A Deck (near the location where inflatable liferafts were stowed).

In the meantime, one of the crew observed that the fin of the fin stabilizer on the port side, exposing on the water surface, was in operation.

Preparing for the worst, the master decided to stand-by ready an inflatable liferaft with a capacity of 25 passengers on the port side (leeward) (hereinafter referred to as "Inflatable

Liferaft"), and ordered the boatswain to drop the Inflatable Liferaft and a vertical escape Chuter (hereinafter referred to as "Chuter").

Finding that although the Inflatable Liferaft had rolled down the outside plating on the port side, the view of the Inflatable Life Raft which should have inflated on the sea surface was obstructed by the heavy listing to starboard, and that although the Chuter itself had been detached from the shed, the Chuter could not be used as it stayed on the outside plating without dropping to the sea surface, the master gave up evacuating from the port side.

At around 08:10, all of the seven passengers were rescued by the helicopter.

After being advised by the Mobile Rescue Technicians that there would be only one rescue flight by the helicopter left while the helicopter was still engaged in rescuing crew members, the master recruited, from among the crew, who would volunteer to remain in the Vessel for maintaining the ship and should evacuate from the Vessel by making use of life-saving appliances. From among who volunteered, the master nominated a total six crew members consisting of the chief officer, the second officer, the third officer, the chief engineer, the first engineer and the able bodied seaman A (hereinafter referred to as "the maintenance and security crew").

At around 09:07, as the list to starboard increased, the master decided on the evacuation of the ship maintenance and security crew from the Vessel, and gave ordered to drop an Inflatable Liferaft, a Chuter and Jacob's ladder on the starboard side, and to bring the engines to an emergency stop.

After dropping the starboard Inflatable Life Raft, the ship maintenance and security crew moved to B Deck and tried to drop the Chuter. However, due to the list to starboard, they were unable to disengage the stopper of the seaward door of the magazine storing the Chuter which had jutted over the sea, and therefore gave up evacuating with the Chuter, and decided to move onto the Inflatable Liferaft with the Jacob's ladder.

Going down the Jacob's ladder step by step with a life-jacket on, the master and the six maintenance and security crew jumped into the sea according to the instructions of the Mobile Rescue Technicians which were given when wave conditions became appropriate.

When the master, the ship maintenance and security crew and the Helicopter Rescue Divers got on board the two different Inflatable Liferafts while being covered with the oil which had spilled out of the hull in large quantities by that time, these Inflatable Liferafts overlapped each other because of the waves. Moreover, one of the ship maintenance and security crew failed to get on board either of the Inflatable Liferafts and was carried away by the waves, who was later rescued by a patrol craft and rescue vessel of the Japan Coast Guard which came for their rescue. The master and all of the six maintenance and security crew were transported on board a patrol craft to Owase Port, Owase City, Mie Prefecture.

The Vessel subsequently grounded and laid sideways in the vicinity of the coast of Mihama Town, Mie Prefecture.

(See Photo 1: The Vessel Aground and Lying Sideways (Bridge), Photo 2: The Vessel Aground and Lying Sideways (A Deck at Midship), Photo 3: The Vessel Aground and Lying Sideways (Stern))

2.1.2 Events Leading to the Accident According to the Information Records of the Automatic Identification System

According to the information records of the Automatic Identification System[*8] on board the Vessel (hereinafter referred to as "AIS Records") which were received by the National Maritime Research Institute (hereinafter referred to as "NMRI"), the navigational developments were as follows.

Time (h : m : s)	Speed (kn)	Latitude (° - ′ - ″)	Longitude (° - ′ - ″)	Course over the Ground (COG) (°)	Heading (°)
02:57:11	21.7	34-03-25.4	137-01-17.9	237.9	236
03:43:58	21.2	33-54-06.6	136-44-32.4	239	236
04:00:05	20.2	33-51-07.8	136-38-48.0	237	237
04:31:47	20.3	33-45-09.0	136-27-48.6	235	235
04:59:59	20	33-39-17.4	136-18-36.6	233	235
05:04:59	21.2	33-38-18.6	136-16-55.8	236	235
05:06:09	21.1	33-38-06.6	136-16-31.8	239	229
05:07:04	13.9	33-37-52.8	136-16-22.8	183	138
05:10:13	8.6	33-37-52.2	136-16-44.4	034	042
05:12:57	8.7	33-37-58.2	136-17-05.4	146	150
05:22:07	12.6	33-36-22.2	136-17-39.6	168	157
05:32:50	10.1	33-34-43.8	136-18-55.8	138	121
05:37:20	12.6	33-35-03.6	136-19-12.0	340	350
05:52:58	14.6	33-38-34.2	136-17-46.8	328	325
06:05:52	12.9	33-38-51.0	136-17-30.6	333	335
06:40:32	13	33-45-44.4	136-13-06.0	319	315
07:15:01	12.5	33-50-57.0	136-07-00.0	313	314
07:42:02	1.2	33-51-25.8	136-05-46.8	261	359
09:04:01	1.4	33-49-58.8	136-04-36.6	200	302
09:07:01	2.1	33-49-53.4	136-04-37.8	148	288
10:09:37	0.2	33-49-46.2	136-03-45.6	354	511[*9]

[*8] "Automatic Identification System (AIS)" refers to a device used by vessels to transmit and exchange call sign, type, name, position, course, speed, destination, navigational status and other safety-related information with other vessels and land-based navigational aid facilities, etc.

[*9] "511" shows that the heading is unavailable.

10:21:02	0.5	33-49-45.6	136-03-45.0	226	511

2.2 Injuries to Persons

According to the statements of the crew and the person in charge at Company A, and to the medical certificates of the injured, conditions of the injuries were as follows.

While going down the Jacob's ladder, one of the crew was swept away by the waves and was injured. The hospital in Owase City to which he was transported diagnosed his injury as greater tuberosity fracture of the right humerus, and he was given hospital treatment for 19 days.

Passenger A was injured on the sole of the foot when the list occurred, and received treatment at a hospital in Mihama Town.

Passenger B hit the head against the wall of the cabin when the list occurred, and received treatment at an orthopedic clinic in Kumano City, Mie Prefecture.

2.3 Damage to Vessel

(1) According to the Japan Coast Guard, the location where the Vessel grounded was in the vicinity of the coast of Mihama Town (approximately 33° 49′ N, 136° 03′ E).

(2) According to the record of the accident by Company A (hereinafter referred to as "Record by Company A"), and to the written reply to the questionnaire by the person in charge at Company A, damage to the Vessel was as follows.

November 15 — A crack in No.1 oil tank and oil leak from the funnel hatch were found, for which temporary repairs were made. Floorboards of B Deck and C Deck of the aft side of the funnel fell off.

November 16 — Large quantity of oil spilled.

The salvage company which was entrusted by Company A with disposition of the Vessel and the cargoes on board started collecting the cargoes which had dropped inside the Vessel and to the bottom of the sea, and started removing the Vessel from January 5, 2010. Afterwards, the hull of the Vessel became separated gradually and its crumbling advanced due to the effect of waves and other factors, and then during the stormy weather in early March of that year, the Vessel collapsed into the sea leaving only the funnel and its adjacent part on the sea.

2.4 Crew Information

(1) Gender, age and certificate of competence

[1] The master: Male, 49 years old

First grade maritime officer (navigation)

Date of Issue	March 28, 1991
Date of Revalidation	September 20, 2007
Date of expiry	September 19, 2012

[2] The chief officer: Male, 55 years old

Third grade maritime officer (navigation)

Date of Issue	November 18, 1992
Date of Revalidation	February 26, 2007
Date of expiry	November 17, 2012

[3] The operation manager: Male, 59 years old

(2) Sea-going experience

[1] The master

In about 1994, the master joined Company A (the name of which changed to the current name in June, 2005), and after boarding vessels as a deck officer, he left Company A in about 2002. He entered Company A again in May, 2008, and boarded the Vessel as a third officer and as a second officer for two months each. After that, he boarded another ro-ro passenger ferry as a chief officer since December, 2008, and boarded the Vessel as a chief officer since the beginning of May, 2009. Then, he received a captain training course on board the Vessel as a first officer since June 17 until October 14, 2009. Since October 15, 2009, he had been engaged in the operation of the Vessel as the master.

[2] The chief officer

He joined Company A in April, 1973. After boarding vessels as an able bodied seaman, he held the posts of a third officer and a second officer successively. While holding the post of a chief officer since October, 2002, he boarded the Vessel since September 28, 2009.

[3] The operation manager

After boarding ocean-going vessels, he joined Company A in December, 1990. He boarding vessels of Company A as a deck officer, and after holding the post of a master for about 12 years, boarded the Vessel as the master which was his final post as a seaman at Company A. He had been working as an operation manager since December, 2007.

2.5 Vessel Information

2.5.1 Particulars of Vessel

Vessel number: 134594

Port of registry: Naze City, Kagoshima Prefecture (The city became Amami City after the consolidation on March 20, 2006)

Owner: Company A

Gross tonnage: 7,910 tons

L × B × D: 166.86 m × 22.80 m × 15.27 m

Length between perpendiculars*10: 150.00 m

Hull material: Steel

Engine: Two diesel engines

Output: 8,826 kW / 17,652 kW in total (maximum continuous)

Propulsion: Two 5-blade fixed pitch propellers

Rudder: Single rudder with a maximum rudder angle of 35°

Date of launch: May, 1995

Use: Roll on Roll off and Passenger Ferry

Complement: 448 in total with 426 passengers and 22 crew members

Navigation area: Greater Coasting area (limited to water area A2*11 (including rivers and lakes))

Maximum loading capacity: 434 containers (ten-feet equivalent unit), 55 chassis, 180 passenger cars

*10 "length between perpendiculars" which is often called LPP refers to the length of a vessel along the design waterline from the forward surface of the stem, or main bow perpendicular member in the case of a vessel with a rudder (to the after surface of the sternpost in the case of a vessel with a rudder post).

*11 "water area A2" refers to the water area (excluding lakes, rivers and water area A1), where communication between ships and shore stations is possible by means of a MF radiotelephone apparatus and radio transmission of distress call to shore stations is possible by means of a MF digital selective calling installation, which is specified by public notifications (water area within about 150 M of a MF shore station)

2.5.2 Loading Conditions

According to the stowage plan and the statements of the master and the chief officer, loading conditions were as follows.

(1) Cargoes

[1] At the time of the occurrence of the accident, five passenger cars were loaded on B Deck, while 39 chassis, six vehicles (four trucks, two passenger cars) and one heavy machine were loaded on C Deck. Moreover, 150 containers (39 units of 20-ft containers*12, 56 units of 10-ft container*13, 35 units of 12-ft container*14 and 20 units of flat rack container*15), five chassis, three vehicles (two trucks, one passenger car) and five heavy machines were loaded on No.2 car deck (hereinafter referred to as "D Deck"), while 18 passenger cars were loaded on No.3 car deck (hereinafter referred to as "E Deck").

[2] The loading weight of the cargoes was 3.22 tons on A Deck, 16.63 tons on B Deck, 1,001.31 tons on C Deck, 1,343.80 tons on D Deck and 25.00 tons on E Deck. In addition to these, the weight of the tanks of the deck department was 13.90 tons, bringing the total loading weight of the cargoes on board to 2,403.86 tons.

[3] All the chassis were stacked toward fore and aft directions, and after the steel landing gears mounted at the front of the bodies were grounded, joints (kingpins) part with tractor were placed on sub landing gear..

[4] To be brief, the containers, which were placed in three blocks on the port bow, starboard bow and starboard quarter, were stacked on top of each other (double-stacked) athwartship, very close to each other.

[5] The trucks were stacked toward fore and aft direction around the center line.

(2) Ballast water

The quantity of sea water loaded in each ballast tank and heeling tank was as follows:

No.1 ballast tank	about 200 tons (47% load)
No.4 ballast tank	about 160 tons (full load)
No.5 ballast tank	about 280 tons (full load)
No.1 heeling tanks (in total on each port and starboard tank)	about 240 tons (50% load)
No.2 heeling tanks (in total on each port and starboard tank)	about 240 tons (50% load)

(3) Draft

At the time of departure, the fore draft and aft draft were about 5.2 meters and 7.2 meters, respectively.

(See Figure 8: Schematic Diagram of Cargo Stacking (C Deck), Figure 9: Schematic Diagram of Cargo Stacking (D Deck), Table 1: Weight and Balance Sheet at the Time of Departure)

2.5.3 Hull Structure and Equipment

(1) Hull structure

---

*12 "20-ft container" refers to a container which is 6.058 meters long, 2.591 meters high and 2.438 meters wide in outer dimensions.

*13 "10-ft container" refers to a container which is 2.991meters long, 2.591 meters high and 2.438 meters wide in outer dimensions.

*14 "12-ft container" refers to a container which is 3.658 meters long, 2.591 meters high and 2.438 meters wide in outer dimensions.

*15 "flat rack container" refers to a container which is open-construction type, structured with the floor as the base, the front and rear walls only (without side walls) and the posts at the four corners.

According to the specifications of the hull, the general arrangement and the midship sectional view, the hull structure of the Vessel was as follows.

Inside the Vessel, the steering room and an accommodation space for the crew were arranged on A Deck, while passenger cabins, a galley and a restaurant were on B Deck, car spaces were on C Deck, other car spaces as well as bow and stern ramp doors[*16] were on D Deck, and other car spaces were on E Deck.

C Deck and D Deck were a through deck structure, and in the cargo hold under E Deck were arranged the forepeak tank, No.1 to No.7 ballast tanks, No.1 and No.2 heeling tanks, No.1 to No.3 fuel oil tanks, No.1 and No.2 fresh water tanks and the fin stabilizer room.

The height from each deck to the lower end of the beam[*17] was 2.30 m on A Deck 2.35 m on B Deck, 4.45 meters on C Deck, 5.75 meters on D Deck and 2.05 meters on E Deck.

In each car space on D Deck and C Deck, there was ramps over the end of the stern and the port side at midship, which was leading to C Deck and B Deck, while there were no sidewalls at the end of the stern on C Deck, and a post was installed between there and B Deck. Moreover, 11 vent holes (about 0.6 meters high and about 0.6 meters or 1.2 meters wide) with slits were installed on the outside plating on both sides of C Deck at the height of about 0.9 meters from the deck board.

(See Figure 6: General Arrangement Plan)

(2) Navigation equipment

[1] Gyrocompass and steering stand

According to the statements of the master, the crew and the person in charge at the manufacturer of the navigation equipment, and to the handling instructions for PR-8000-E Hi- ADAPTIVE Autopilot, information on the autopilot was as follows.

The gyrocompass on board the Vessel had a Gimbal angle freedom[*18] of ± 45° against rolling[*19] and pitching. Accordingly, when the angle of list exceeds 45°, an error in the heading becomes so large that the gyrocompass will be of no use.

A repeater compass was fitted on the center of the upper surface of the steering stand. There were adjustment knobs to be used while on autopilot on the left side of the repeater compass, while there was a warning display section on its front, and steering mode selection unit on its right. And, there was a steering wheel on the front side of the steering stand, and a system selector switch on its right.

Concerning the procedures for setting proper adjustment values while on autopilot, the handling instructions described as follows: the rate adjustment[*20] should be set at the value specified by a service engineer of the manufacturer of the navigation instrument, and after setting the rudder adjustment[*21] value at "four" and the weather adjustment[*22] value at "0", the vessel should be sailed straight ahead for about 30 minutes, after which proper values

---

*16 "ramp door" refers to a sloping floor, path, etc., as in a ferry ship, that joins two surfaces at different levels, which serves as a door and as an outside plating.

*17 "beam" refers to a transverse structural member of a vessel's frame, used to brace frames (aggregate) on both sides against stress, and to support a deck.

*18 "Gimbal angle freedom" refers to a range within which a gyro axis can be maintained at a horizontal level against ship motions.

*19 "rolling" refers to the rotation (swaying from side to side) of a vessel about its horizontal and longitudinal axis through the center of gravity.

*20 "rate adjustment" refers to adjustment of the rudder position against an angular velocity of 1°/s.

*21 "rudder adjustment" refers to rudder angle adjustment against a deflection angle of 1°.

*22 "weather adjustment" refers to adjustment to restrain unnecessary steering in stormy weather.

should be set for them; the rudder adjustment value should be set at "four" normally, and the rudder limit[*23] value should be set at "15°", which would be appropriate enough under normal conditions.

In the case of the Vessel, the weather adjustment was set at "auto", while the rate adjustment value at "four", the rudder adjustment value at "four", the course deviation alarm[*24] value at "10°" and the rudder limit value at "15°".

[2] Fin stabilizer

According to the statements of the master, the crew and the person in charge at the manufacturer of the fin stabilizer, and to the final drawing of the gyro fin stabilizer and the result of the sea trial of the fin stabilizer, information on the fin stabilizer was as follows.

The fin stabilizers on board the Vessel were gyro fin stabilizers adopting a lift and angle control method, with 4.10 meters long and 1.83 meters wide retractable fins folding backward, which were mounted on both sides at midship.

(See Figure 6)

On the remote control board for the fin stabilizers placed in the steering room, those instruments were fitted like fins retraction and deployment switch, a vessel speed adjustment knob, a sensitivity adjustment knob and a visual-aural alarm system for the oil quantity, oil temperature and power source. At the time of the accident, both of vessel speed and sensitivity adjustment knobs pointed to "automatic".

When the fin stabilizers were in operation, the rotation axis was positioned a little close to the front end of each fin, and the maximum lift generated by the fin on each side was 58 tons at a speed of 20 kn and at an operating angle of 15 °.

While the Vessel was underway at a speed of 21 to 22 kn with a displacement of 8,335.25 tons and a metacentric height[*25] of 2.40 meters, the angle of heel was about 6° when maximum lift signals (58 tons) were given to the fins on both sides continuously, and the maximum roll angle of about 15° to 17° was created at the third to fourth cycle of the rolling when similar signals carrying a destabilizing phase were given to force the hull to roll. Also, the control system on board the Vessel was intended to reduce the extent of rolling from side to side around the heel, when the Vessel sustained steady heel.

Although fin stabilizers may malfunction in general, there was no record of malfunction occurring to the gyro fin stabilizers of the Vessel, and the record of repairs done to the gyro fin stabilizers of the Vessel showed only those malfunctions like small amount of oil leak from the hydraulic system.

[3] Water leakage alarm system

According to the car deck water leakage detector arrangement plan, water leakage detector device was placed near the ramp door on D Deck, and a visual-aural alarm system was installed in the steering room.

[4] Fire alarm system

According to the specifications of the hull, the fire detector system on board the Vessel

---

*23 "rudder limit" refers to restriction of the maximum rudder angle while on autopilot.

*24 "course deviation alarm" refers to an alarm warning that the heading has deviated from the specified course with an angle larger than the angle set in advance, while sailing on autopilot.

*25 "metacentric height" refers to the distance between the center of gravity of a vessel and its transverse metacentre (the point of intersection of the buoyancy line of action through the center of buoyancy with the center line of the hull through the new center of buoyancy when the vessel is heeled.

was as follows: heat detector devices[*26] were in car spaces, a smoke detector device[*27] was in the engine room, both of heat and smoke detector devices were in the accommodation space, and a visual-aural alarm device was installed in the steering room.

(3) Communications equipment

According to the statement of the master, the steering room was equipped with AIS, the international VHF radiotelephone appliance, the maritime telephone and the public address system.

(4) Life-saving appliances

According to the statements of the master, the list of equipment and the general arrangement plan, the Vessel was equipped with 11 inflatable liferafts on the port side of A Deck and ten of them on the starboard side, and with a rescue and support boat (with an engine for a capacity of six persons) on aft port side of A Deck. The Vessel was also equipped with Chuter (with a capacity of 250 persons) and a Jacob's rudder on both sides of the fore of B Deck. In addition to these, the Vessel was equipped with life buoys, life-jackets and EPIRB[*28] and other appliances as provided by the law.

Laws and regulations for Life-saving Appliance of Ships (Article 47 - 2) provides that a Chuter shall be the one which enables safe and prompt embarkation onto a liferaft or other survival craft on the water, when a vessel sustains list with an angle of 20° and trim with an angle of 10° to either side of the vessel.

(5) Heeling tanks

According to the statement of the master and the general arrangement plan, four heeling tanks were placed on fore and aft of the broadside on both sides of the midship. The capacity of the pump enabling transfer of ballast water in the heeling tanks was about eight tons per minute, and when transferring about 19 tons of ballast water from the left (right) heeling tank to the right (left) heeling tank, the angle of heel changed about 1° normally.

(6) Facilities of drainage from car spaces

According to the statement of the master and the system diagram of drain pipes on the decks, ten scuppers with a diameter of 100mm were installed on the port side of C DECK, and 13 of them on the starboard side, while 11 scuppers with a diameter of 150 mm were placed on both sides of D Deck, and a check valve[*29] was attached under the water line.

(7) Others

According to the statements of the master and the crew, there was no trouble or malfunction with the hull, the engines and the instruments at the time of departure and while underway.

2.5.4 Turning Ability

According to the result of the official sea trial, the turning characteristics were as follows.

(1) When the engines on both sides were in operation

Turning direction	Left	Right

[*26] "heat detector device" refers to a device which detects an extraordinary air temperature, an indicator of an incipient stage fire, and sounds the alarm automatically.

[*27] "smoke detector device" refers to a device which detects an extraordinary smoke density, an indicator of an incipient stage fire, and sounds the alarm automatically.

[*28] "EPIRB (Emergency Position Indicating Radio Beacon)" refers to radio equipment on board a vessel, which transmits distress signals, when the vessel is in distress, to help rescuers locate the position of the disaster.

[*29] "check valve" refers to a valve for preventing the backflow of a liquid.

Speed before turning (log speed)	24.05 kn	24.05 kn
Rudder angle	35°	35°
Maximum advance*30	628 m	644 m
Maximum transfer*31	701 m	703 m
Time required for turning 90°	1 min 16.4 sec	1 min 19.2 sec
Time required for turning 180°	2 min 24.1 sec	2 min 25.6 sec

(2) When one side engine (right) was in operation

Turning direction	Left	Right
Speed before turning (log speed)	8.41 kn	8.41kn
Rudder angle	35°	35°
Maximum advance	450 m	748 m
Maximum transfer	603 m	1,129 m
Time required for turning 180°	4 min 31.6 sec	7 min 55.0 sec

2.6 Information on Cargo Handling and Lashing

2.6.1 Car spaces

(1) Non-slip metal fittings

According to the drawing of "Procedures for non-slip work for D Deck and its ramp" made at the time of the shipbuilding, square bars 13 mm high, 13 mm wide and 50 cm long were welded on D Deck as non-slip metal fittings for cars. The square bars placed toward fore and aft were arranged about 55 cm apart from each other, while those placed athwartship were arranged about 60 cm apart from each other.

(2) Deck coating

According to the written reply of Company A and the statement of the person in charge at the manufacturer of painting materials, information on the deck coating was as follows.

At the time of the shipbuilding, a two-component type epoxy paint consisting of a main agent with particles and a hardening agent was coated on C Deck and E Deck, while a chlorinated rubber paint (with a coefficient of friction 0.822) was coated on Deck D.

As a result of the non-slip nature testing conducted in accordance with the testing method for friction coefficient measurement of non-slip painting materials, as prescribed in the official notice "Standards for Construction of Ro-Pax Ferry" based on the article 3 of Regulations for Construction of Vessels (hereinafter referred to as "Standards for Construction of Ro-Pax Ferry"), the friction coefficient of the epoxy paint as mentioned above was 1.54 when it was dry, 1.42 when it was wet with water and 1.06 when it was wet with oil, while the adhesive strength was 39.0 kg/cm^2.

According to the statements of the master and the chief officer, neither of them had an experience of coating the decks in the car spaces on board the Vessel.

2.6.2 Fixed Lashing Points

According to the arrangement plan of car lashing points, metal fittings such as cloverleaves, eye plates, crinkle bars were installed as fixed lashing points for cars on C Deck, D and E, while eye

---

*30 "maximum advance" refers to the maximum distance that the center of gravity of a vessel moves in the direction of her original line of advance over the path of the center of gravity (turning circle) initiated by shifting the helm, measured from the point where the helm was shifted.

*31 "maximum transfer" refers to the maximum distance that the center of gravity moves at right-angles to her original line of advance over the turning circle.

plates for miscellaneous use were on the frames[*32], and eye plates and eye rings for top-over lashing were on the beams. Setting state of lashing points for cars on each deck was as follows.

(1) C Deck

Along the lanes drawn on the deck, cloverleaves for large-sized vehicles (projecting type, maximum working load of 4.0 tons) were set about 3.5meters apart from each other toward fore and aft, and about 2.7 meters to 3.2 meters apart from each other athwartship.

In the port quarter section, cloverleaves for small-sized vehicles (projecting type, maximum working load of 0.4 tons) were installed about 4.9 meters apart from each other toward fore and aft, and about 2.1 meters apart from each other athwartship.

Eye plates (maximum working load of 2.5 tons) were set about three meters apart from each other on the deck about 0.45 meters inside of the outside plating, while eye plates for miscellaneous use (maximum working load of 2.0 tons) were set on the upper part of the frames (at intervals of four to six frames).

Crinkle bars for middle-sized cars (maximum working load of one ton) were set about three meters apart from each other near the fore and aft sidewalls, and near the ramp sidewalls.

172 eye plates for top-over lashing (maximum working load of 2.5 tons) and 115 eye rings also for top-over lashing were installed on the ceiling of the deck.

(2) D Deck

Cloverleaves for large-sized vehicles (projecting type) were set about three meters apart from each other on the center line of the bow section (frame No. 138 to 174) , and about three meters to eight meters apart from each other near the broadsides.

All over the car spaces, cloverleaves for large-sized cars (recessed type, maximum working load of 0.4 tons) were set about 3.5 meters apart from each other toward fore and aft, and about 2.9 meters to 3.6 meters apart from each other athwartship.

Crinkle bars and eye plates for middle-sized cars were set about three meters apart from each other on the deck about 0.45 meters inside of the outside plating.

Eye plates for miscellaneous use were set on the upper and lower parts of the frames (at intervals of four to six frames).

216 eye plates and 66 eye rings, both for top-over lashing, were set on the ceiling of the deck.

(3) E Deck

Cloverleaves for small-sized cars (projecting type) were set about 4.9 meters apart from each other toward fore and aft, and about two meters to 2.6 meters apart from each other athwartship.

Crinkle bars for small-sized cars were set about 4.5 meters to 5.25 meters apart from each other on the deck about 0.45 meters inside of the outside plating, and about 2.2 meters apart from each other near the fore sidewalls.

(See Figure 10: Fixed Lashing Points)

2.6.3 Lashing Devices

According to the statements of the master, the crew, the person in charge of engineering at Company A, and the person in charge at the manufacturer of lashing devices, and to the delivery specification of lashing materials (dated on November 1, 2002), information on the lashing devices was as follows.

[*32] "frame" refers to an aggregate to be placed inside of an outside plating.

(1) Lashing chain

The lashing chain which was made of steel was composed of a lashing chain about two meters long with a hook attached on one end (hereinafter referred to as "Sub-Chain"), and 'an about one meter long metal good' with a little large chain called a pair ring attached on one end of a clamp, and with a chain and a hook attached on the other end of the clamp (hereinafter referred to as "Clamping Part").

The lashing chain should be operated as follows: a hook on one end of a Sub-Chain should be hung on a corner fitting[*33] of a container, a lashing ring of a chassis or a member of a heavy machine; a hook of the Clamping Part should be hung on a cloverleaf; the other end of the Sub-Chain should be connected with the pair ring after passing it through; and the clamp should be operated for the lashing.

The maximum working load and the breaking load of the lashing chain was four tons and 16.0 tons, respectively.

Although the selling list by the manufacturer of lashing devices included Clamping Parts with metal fittings used only for cloverleaves and Sub-Chains with metal fittings used only for the corner fittings of containers, the number of the lashings devices purchased for the Vessel was small.

(See Figure 11: Lashing Devices (Part 1))

(2) Lashing belt

The lashing belt was a fabric belt, with a maximum length of about 2.5 meters and a hook on both ends. A clamp was attached near a hook on one end.

The maximum working load of the lashing belt was 2.5 tons or 1.5 tons, while the breaking load was 10.0 tons or 6.0 tons.

(See Figure 12: Lashing Devices (Part 2))

(3) Metal fitting for securing double-stacked containers

A metal fitting called a cone, symmetrical up and down, was put into the holes of corner fittings of both containers to prevent horizontal slippage.

(See Figure 12: Lashing Devices (Part 2))

(4) Sub landing gear

The sub landing gear was a square pyramid-shaped stand on which to place kingpin parts after a towing car was detached from the chassis.

(See Figure 13: Lashing Devices (Part 3))

(5) Others

Containers on a chassis were secured while a triangle-shaped steel projection called a twist lock fitted on the chassis's body was put into the holes of corner fittings at the bottom of the containers.

The tires of chassis and cars were secured with wooden wheel chokes to prevent them from moving back and forth.

(See Figure 13: Lashing Devices (Part 3))

2.6.4 Ordinary Lashing Conditions

According to the statements of the master, the crew, the cargo superintendent, the stevedore and the longshoremen, ordinary lashing conditions were as follows.

[*33] "corner fitting" refers to a metal fitting to be attached to four corners at the top and bottom of a container, which provide firm fixed-points at the time of lashing.

(1) Containers

As containers were carried on board through the bow and stern ramp doors with fork lifts, and were double-stacked successively from near the midship, cones were put into the corner fittings (two locations) only on the side of the forklifts.

Also, hooks of Sub-Chains were hung on the corner fittings at the bottom of the upper containers, at intervals of about three rows toward the port and the stern, along the broadside and the center line in each of the blocks on the port bow, starboard bow and starboard quarter, while hooks of Clamping Parts were hung on the lashing points on the decks.

As the lashing chain was only about 0.4 meters longer than the height of the container, it was almost in a vertical position while lashing the container.

When there was no appropriate lashing point to hook a Clamping Part on, it was sometimes hooked on a corner fitting at the bottom of an adjacent lower container.

(See Figure 14: Lashing Condition of Containers, Photo 4: Lashing Conditions of Containers)

(2) Chassis

Chassis were brought on board through the stern ramp door with tractors, stopped at specified positions on D Deck or C Deck. After the landing gears were grounded, kingpin parts were placed on the sub landing gear, the tires were secured with wheel chokes, and the chassis were lashed by hooking Sub-Chains on the lashing rings installed on the chassis' bodies, and by hooking Clamping Parts on the lashing points on the decks.

When a chassis was not equipped with any lashing rings, the tip of a Sub-Chain's hook was hung on a member at the back of the chassis's body.

(See Figure 15: Lashing Conditions of Chassis, Photo 5: Lashing Conditions of Chassis (6-Point Lashing Chain))

(3) Trucks and other large-sized vehicles

Trucks and other large-sized vehicles were secured with 4-Point Lashing Chains by hooking Sub-Chains on the front and rear wheels on both sides of the vehicles, while the tires were secured with wheel chokes. However, they were not top-over lashed.

(See Photo 6: Lashing Condition of Truck)

(4) Heavy machines

Heavy machines were secured with 4-Point Lashing Chains by hooking Sub-Chains on members at the front and rear of the bodies. When they were equipped with buckets, the buckets were put down on the deck and secured with lashing belts.

(5) Passenger cars

Passenger cars were secured with lashing belts stretched only in the front and rear direction diagonally, while the tires were secured with wheel chokes.

At the time of the accident, the cargoes on board the Vessel were in ordinary lashing conditions except for the chassis which were loaded in the front and last rows on C Deck.

2.6.5 Review of Lashing Method

According to the statements of the master, the crew, the longshoremen, and the person in charge at the manufacturer of lashing devices, information on reviewing the lashing method was as follows.

(1) In the case of transporting radioactive materials on board a vessel, Company A submitted to the Minister of Land, Infrastructure, Transport and Tourism an application for approval of a cargo loading method, accompanied by a lashing device statement which measured the tension applied

to the lashing devices in the case when a truck with a gross weight of 25,000 kgf was secured with 12 lashing chains while the vessel was at the rolling angle (25°), the rolling cycle (15 seconds), the pitching angle (5°) and the pitching cycle (5 seconds). However, for the transport of general cargoes, Company A had not reviewed the lashing method for containers and chassis, which was instead left to the decision of the master and the chief officer.

(2) The crew and the stevedoring workers had not been given instructions from Company A and from the manufacturer of lashing devices about the lashing method using lashing chains, and they were following the lashing method which they had practiced from before for the lashing of containers and chassis.

Concerning the RORO (Roll-on/Roll-off) ships[*34] and the ro-ro passenger ferries operated by Company A, there were cases in which tips of some hooks of lashing chains, which were not the designed load points, were hitting cloverleaves, members at the back of chassis' bodies and the corner fittings of containers, or some hooks were tightened in a twisted state.

The lashing method for containers and chassis adopted on these ships was almost the same as that adopted on the Vessel.

(See Photo 7: Lashing Chain Hooked on Cloverleaf, Photo 8: Lashing Chain Hooked on Member at the Back of Chassis's Body, Photo 9: Twisted Hook of Lashing Chain)

2.6.6 Shifting of Cargoes on Board When the Vessel Heeled

According to the statements of the master and the crew, cargoes on board the Vessel shifted as follows when the list of the Vessel occurred.

There was a case in the past in which containers slid and chassis shifted when the Vessel listed about 15° to 16° under the influence of side waves. Although lashing chains did not break at that time, hooks of some Sub-Chains became deformed.

It was customary for the RORO ships operated by Company A to spread discarded mooring ropes on the decks and place containers on them, for the purpose of preventing them from sliding. The Vessel had adopted similar measures before the accident. However, as the effect of doing so was not proven, the containers were placed directly on the decks at the time of the accident.

2.6.7 Condition of Cargoes on Board and Lashing Devices After the Accident

The situation inside the Vessel which rolled to starboard and the condition of the damage sustained by some chassis which were later recovered were as follows.

(1) When the front part of C Deck was seen from the ramp on C Deck and through the opening on the outside plating on the port side, the chassis loaded on the port side of the first row on the bow had rolled while the chassis (two) loaded on the port side of the second row had slid. The condition of the other chassis could not be visually recognized because the outside plating on the starboard side was missing and for other reasons.

(2) Most of the tires of the recovered chassis were damaged as though they had sustained sideways force, and their landing gears were bent. Also, a broken Sub-Chain was caught in some part of a chassis's body.

(3) The containers loaded in the port bow block had slid to starboard, while the containers loaded near the broadside on the port side had shifted about 3 meters. The direction the containers

[*34] "RORO (Roll-on/Roll-off) ship" refers to a vessel with a built-in ramp door like a ferry ship, which is designed to carry wheeled cargo such as chassis and trucks which are rolled-on and rolled-off the ship on their own wheels for the loading and unloading of the cargo .

shifted was almost diagonally backward.

(4) A few lashing chains remained on D Deck, hung on cloverleaves and on the eye plates on the frames, while hooks of some Sub-Chains were deformed and some other Sub-Chains were broken. In addition, a lashing chain with a metal fitting for a cloverleaf was on a container.

(5) One of the heavy machines loaded on the port side of D Deck had slid to starboard, and part of it was visible on the water while the lashing chain could not be found.

(6) The passenger cars loaded on E Deck could not be found, while lashing belts remained hooked on the cloverleaves for small-sized cars.

(7) The condition of other cargoes like trucks, heavy machines and passenger cars could not be visually recognized.

(8) The coating of the floor face in the car spaces on D Deck was peeled off. The condition of the floor face on C Deck seemed almost the same.

(See Figure 16: Shifting of Containers and Chassis, Photo 10: Deformed Hook of Sub-Chain)

2.7 Information on Rescue Operations and Actions Taken by Company A

2.7.1 Rescue Operations

According to the press releases of the Japan Coast Guard, the rescue operations are summarized as follows.

(1) Details of the rescue operations in sequence

[1] At around 05:25, the Vessel requested for rescue as the Vessel had listed about 45° to starboard while proceeding about 30 km off the coast of Shingu, Wakayama Prefecture.

[2] At around 05:44, the Japan Coast Guard provided information to vessels underway through NAVTEX (Navigation Telex: search and rescue information) broadcasting.

[3] At around 07:00, the Japan Coast Guard established the marine accident task force at the Fourth Regional Coast Guard Headquarters, and the local task force at Owase Coast Guard Office.

[4] At around 07:04, a helicopter of the Japan Coast Guard arrived at the accident site and commenced a rescue operation.

[5] At around 07:42, seven passengers were rescued.

[6] At around 08:32, seven crew members were rescued.

[7] At around 09:03, seven crew members were rescued.

[8] At around 09:47, the Japan Coast Guard requested the Ministry of Defense for a disaster relief operation.

[9] At around 10:21, a patrol craft vessel of the Japan Coast Guard rescued the master and the six maintenance and security crew who had evacuated from the Vessel.

(2) Personnel dispatched

[1] The Japan Coast Guard dispatched nine patrol vessels, six aircraft and six members of the Special Rescue Team as well as two Mobile Rescue Technicians at Kansai Airport Coast Guard Air Station and four members of the National Strike Team.

[2] The Ministry of Defense dispatched two aircraft.

[3] The salvage company dispatched three tug boats at the request of Company A.

[4] A vessel in the private sector offered to cooperate with rescue activities.

2.7.2 Reports From the Vessel and Actions Taken by Company A

According to the Record by Company A and the written reply from Company A, information on the reports from the Vessel and actions taken by Company A is summarized as follows.

Time	Reports from the Vessel and actions taken by Company A
05:28	Received a report from the Vessel that the Vessel had been hit by high waves off the coast of Oawase City (approximately 33° 40′ N, 136° 34′ E), and a request for establishing an emergency task force.
05:45	Contacted the safety general manager, who then reported to the operation manager and the president.
05:50	The emergency task force was established.
06:00	Reported the information on the accident to the Japan Coast Guard.
06:11	Reported the information on the accident to the Ministry of Land, Infrastructure, Transport and Tourism. Received a report from the Vessel that the distance to the shore was 30 M, and the speed was 12 kn.
06:30	Received a report from the Vessel that the distance to the shore was ten M.
06:45	Received a report from the Vessel that the distance to the shore was seven M, a helicopter was expected to arrive soon, and the passengers were guided to A Deck.
06:50	Received a report from the Vessel that it was hard to control.
07:00	Received a report from the Vessel that the angle of list was 36° to starboard.
07:01	Received a report from the Vessel that there was no passenger injured, no damage to the hull, no ingress water into the engine room, and the heeling tanks on the port side were full.
07:04	Received a report from the Vessel that the helicopter had arrived, a rescue operation by hoisting passengers was started, no one was injured, and the distance from the shore was 1.4 M.
07:20	Received a report from the Vessel that the engines had stopped at 33° 51.3′ N, 136° 06.4′ E.
07:30	Instructed Tokyo Branch Office to give assistance to passengers.
07:39	Received a report from the Vessel that the abandonment of the Vessel was under consideration.
07:50	Requested dispatch of three tug boats. Entrusted a local agency as a shipping agency.
07:54	Received a report from the Vessel that the passenger rescue operation was completed, and the Vessel had gained an offing about 0.7 M from the shore.
08:00	Received a report from the Vessel that a rescue operation by hoisting the crew had started, while a northeasterly wind was blowing at 10 m/s and the wave height was two meters.
08:06	Received a report from the Vessel that an oil leak was found on the starboard side, which was considered to have overflowed from the air vent pipe.
08:18	Requested the Maritime Disaster Prevention Center for oil control measures, and arranged with the salvage company for salvaging the Vessel.
08:27	Osaka Branch Office staff left for the site.

08:35	Received a report from the Vessel that seven crew members had been rescued.
09:00	Received information that although the arrangement for three tug boats was completed, it would take seven to eight hours to arrive at the site.
09:05	Received a report from the Vessel that a rescue operation of 14 crew members was completed, leaving the master and the six maintenance and security crew on board.
09:08	Received a report from the Vessel that the all hands would evacuate from the Vessel.
09:40	Sent documents related to the fuel oil to the Japan Coast Guard.
10:05	Received information from the Japan Coast Guard that the all hands had evacuated from the Vessel.
10:10	The local shipping agency met the seven passengers and seven crew members, and handled with the requests of the passengers.
10:30	The seven crew members newly rescued by the helicopter were accommodated. Received a report from the purser that one crew member was injured.
10:45	Received information from the Japan Coast Guard that the master and the six maintenance and security crew had been rescued and were on the way to Owase.
13:00	Transferred the passengers (7) and the crew (14) to lodging facilities.

2.8 Information on Weather and Sea Conditions

2.8.1 Weather Forecast

(1) Japan Meteorological Agency

The Japan Meteorological Agency had issued to the Kisei and East Kishu Districts in the southern region of Mie Prefecture[*35], as of 10:38, November 12, an advisory for gale that an average wind speed was expected to reach 15 m/s or more on the sea, and a high sea warning that a significant wave height was expected to reach 3.0 meters or more.

(2) Grasping of weather information by the Vessel

According to the statement of the master, he regularly obtained weather maps and prognostic wave charts via weather facsimile transmissions and on the internet before departure. On the day of the accident, he obtained weather maps and prognostic wave charts.

2.8.2 Weather and Sea Conditions

(1) Weather observation data and other related information

[1] Estimated values for weather and sea conditions

According to the values estimated by the Japan Weather Association (hereinafter referred to as “Estimated Values by the Weather Association”), the weather and sea conditions in the vicinity of the accident site at around 05:10, November 13, 2009 were as follows:

Wind Direction: ENE, Wind Speed: 15.3 m/s, Wave Direction: E

Significant Wave Height: 4.59meters, Wave Period: 10 seconds, Wavelength: 156 meters

[2] Wave condition in the Enshu Nada through the Kumano Nada

[*35] “the Kii and East Kishu Districts in the southern region of Mie Prefecture” refers to the municipalities consisting of consist Daiki Town, Odao Town, Kihoku Town, Osase City, Kumano City, Mihama Town and Kiho Town in the prefecture.

(a) According to the coastal wave analysis chart (21:00, November 12, 2009), waves with a wave height of 4.2 meters and a wave period of nine seconds were surging from the east at Point H about 30 M off the east of Daio Saki (34° 20′ N, 137°30′ E) .
(See Figure 4)

(b) According to the record of the Nationwide Ocean Wave information network for Ports and Harbours by Ports and Harbours Bureau, Ministry of Land, Infrastructure, Transport, and Tourism (GPS wave meter off the coast of Owase, 33° 54.1′ N, 136° 15.6′ E), waves with a wave height of about four meters and a wave period of about eight seconds were surging.

(2) Meteorogical Observations

The weather data observed at Owase Special Regional Meteorological Station located at about 26 M northeast of the accident site were as follows:

05:00 Weather: Drizzle, Wind Direction: WSW, Wind Speed: 2.6 m/s, Visibility: 5.19 km

(3) Observation by crew

According to the statement of the second officer, the wind direction changed from the northeast to the east at around 02:00, November 13, and the wave height was about 3.5 meters.

According to the statement of the chief officer, when handing over the navigational watch at 04:00, he visually measured that the wind was east-northeasterly to easterly at a speed of about 16 to 17 m/s from the relative wind direction and the relative wind speed indicated by the anemometer. Also, it was too dark to see the waves as it was before dawn.

(4) Observation by vessels underway in the vicinity of the accident site

The weather data observed by six vessels underway in the vicinity of the accident site at the time of the accident were generally as follows:

Wind Direction: NE to E, Wind Speed: about 10.8 to 18.0 m/s

Wave Height: about 2.5 to 6 meters.

(5) Influence of sea current

According to the Kuroshio Strong Current Information (November 13, 2009), the Kuroshio was flowing to the east at a speed of 3.0 kn or more off the south of Shiono Misaki (approximately 33° N), while the speed later became 2.0 kn or less, and the direction of the flow changed to the northeast off the south of Suruga Bay.

(6) Time of sunrise

According to the nautical almanac (issued by the Japan Coast Guard), the time of sunrise was 06:25 and the period of time for civil twilight[*36] was one hour and 26 minutes on the day of the accident at Owase.

2.9 Information on Safety Management

2.9.1 Related Laws

(1) Marine Transportation Act and Coastal Shipping Business Act

The Marine Transportation Act and the Coastal Shipping Business Act obligate the marine shipping operators to stipulate in their safety management manuals matters regarding the policy of business operation for ensuring the safety of transportation, matters regarding the implementation of business and its management system, and matters regarding the implementation of business and its management method.

---

*36 "civil twilight" refers to the period of time between when 6-maginitude stars begin to be invisible or to be visible with the unaided eye and the time of sunrise or sunset.

(2) Standards for Construction of Ro-Pax Ferry

The Standards for Construction of Ro-Pax Ferry stipulates as follows.

4 Car space

(1) to (5) omitted

*(6) A c*ar space shall adopt either of the following methods to prevent cars from moving sideways excessively.

(i) a stringer with a height of 12 centimeters or more with a length of two thirds or more of the length of the car deck shall be installed between the rows of cars.

(ii) a non-slip painting material with a coefficient of friction (value against a car tire in a wet state) of 0.7 or more, and with sufficient pressure strength and durability shall be applied.

(7) A car space shall be equipped with devices for lashing cars on the deck which conforms to the following requirements (provided that this shall not apply to vessels which navigate in a port in a lake or a river). However, vessels (except those which navigate in a port in a lake or a river) which navigate in smooth water area and limited coasting area (referring to the Inland Sea and areas within coasting area in which the expected length of time for navigation is less than two hours) shall be equipped with devices for lashing cars on the deck which conforms to the requirement of (i).

(i) safety factor of 4 or more

(ii) roll angle and roll cycle of the hull 25° and the cycle of the vessel

(iii) pitch angle *and pitch cycle of the hull 5° and 5 seconds*

(8) to (11) omitted

2.9.2 Safety Management Manual

Company A prescribed as follows in the safety management manual (including operation standard, work standard and accident handling standard) which had been in practice since December 20, 2006.

(1) Duties and authority of operation managers (Safety Management Manual, Article 18)

Operation managers shall supervise the management of shipping operation and the other works entirely which are related to ensuring the safety of transportation, and shall ensure compliance with, and implementation of, the provisions in the safety management manual.

(2) Decision on whether or not to operate a vessel (Safety Management Manual, Article 25)

[1] The master of a vessel shall make an appropriate decision in a timely manner on whether or not to suspend the operation of the vessel, and shall take measures to suspend the operation when the weather and sea conditions are considered to have reached or expected to reach a certain level of requirement.

[2] Before departure, the master of a vessel shall check the information on weather and sea conditions to encounter while underway, and shall suspend the departure when the wind speed is expected to reach 25 m/s or more, and the wave height to reach 5.0 meters or more. (Operation Standard, Article 2, Section 2)

[3] If the standard operation should be continued, and when ship motions and other factors are expected to make it extremely hard for passengers to walk inside the vessel, leading to accidents involving shifting and overturning of the cargoes or vehicles on board the vessel, the master of the vessel shall suspend the standard operation, and reduce the speed, alter

the course in a timely manner, change the standard route and take other appropriate measures.

The situation as mentioned above is considered to occur when a vessel is in such sea conditions and ship motions with, approximately, a wind speed of 20 m/s or more (except winds blowing toward the bow and the stern), a wave height of 4.0 meters or more, and a roll angle of 7° or more. (Operation Standard, Article 3, Section 1 and 2)

[4] The master of a vessel shall check the information on the surrounding weather and sea conditions while underway, and when the wind speed is expected to reach 20 m/s or more or the wave height to reach 4.0 meters or more, the master shall suspend the operation to the port of destination, and shall take such measures as turnaround, harborage or a temporary call at another port. However, this shall not apply to such cases when continuation of the safe operation to the port of destination is judged possible by changing the standard route. (Operation Standard, Article 3, Section 3)

[5] The ordinary standard route from off the coast of Mikomoto-shima to off the coast of Shiono Misaki which is applicable to the Vessel is a direct route from off the coast of Mikomoto-shima to off the coast of Shiono Misaki. (Operation Standard, Article 7)

(3) Installation of lashing devices (Work Standard, Section 11)

[1] All the vehicles should be secured with wheel chokes.

[2] In principle, all the vehicles loaded on board (passenger cars, trucks, special vehicles and vehicles loaded with hazardous materials) should be secured with lashing devices.

[3] On the instructions of an on-board work supervisor (chief officer), vehicles loaded with lumber, trucks and vehicles with a high center of gravity like large-sized vehicles should be top-over lashed.

[4] When the angle of ship motions is expected to reach 7° or more while underway, the master of a vessel shall instruct the on-board work supervisor to reinforce wheel chokes, install lashing devices and implement top-over lashing for vehicles loaded with lumber, trucks, large-sized vehicles like special vehicles and vehicles loaded with hazardous materials.

(4) Shipboard patrol (Work Standard, Article 14)

A shipboard patrol by the deck department round of a vessel underway should be implemented as follows: after taking over the navigational watch, a deck officer and an able bodied seaman patrol each section inside the vessel for the sake of passengers, facilities, fire prevention and the security of the cargoes on board; report to the duty officer whether or not there is anything abnormal; and enter the result in the record book.

(5) Emergency operations center (Safety Management Manual, Article 47)

When the scale of an accident is so large or the impact of the accident on the public is so large that it is considered necessary for the entire company to handle the accident, the top management shall establish an emergency operations center as provided for in the accident handling standard, and direct the operation of the center.

(6) Safety education (Safety Management Manual, Article 51)

The safety general manager and operation managers shall regularly provide crew members a safety education in a plain and specific manner on the matters considered to be necessary for ensuring the safety of transportation, and make sure that they are thoroughly acquainted with the contents of the safety education.

(7) Training (Safety Management Manual, Article 52)

The safety general manager and operation managers shall make a plan for the training on accident handling, and conduct the training at least once a year. The training shall be conducted in a practical manner assuming that such an accident as requiring the entire company to handle has occurred.

(8) Internal audit (Safety Management Manual, Article 55)

Internal Auditors shall conduct an internal audit, at least once a year, of the condition of the vessels, the status of compliance with the provisions in the safety management manual and the overall safety management system, while vessels to be audited shall include those while at anchor and underway.

2.9.3 Safety Work Procedure Manual

According to the safety work procedure manuals of Company B and Company C, their safety work procedures were as follows.

(1) Company B

Company B established a safety work procedure manual in 1993 for stacking containers on board a vessel in service on the Okinawa route, by which Company B provided that a cone should be inserted when stacking containers on top of each other, and that it should be checked whether the lashings for containers, chassis, cars and special vehicles were completely fastened without any slackness, and whether the number of the lashing devices and their conditions were appropriate.

(2) Company C

Company C established a safety work procedure manual in March, 1983, including work procedures and points to be checked for roll-on and roll-off stevedoring works on board a domestic container ship. In that procedure manual, Company C provided that as procedures for lashing containers and chassis, lashing chains should be used and stretched securely, the tension of the lashing chains should be checked, the lashing chains should be hit to check whether there was no slackness, and the number of lashings should conform to the instructions of the stevedoring supervisor.

2.9.4 Muster List, Drill and Internal Audit

According to the statements of the master, the crew and the operation manager, and to the documents about the internal audit of Company A, information on the station bill, drill and internal audit was as follows.

(1) A muster list was prepared for the Vessel specifying the different stations to be taken in cases like passenger evacuation guidance, and the crew were thoroughly acquainted with it.

(2) On November 4, 2009, a fire drill was conducted on board the Vessel in Naha Port, which was intended for the crew on the assumption that a fire had broken out in the galley. During that drill, training for fire prevention and emergency escape was also implemented orally.

(3) Company A conducted an internal audit for the Vessel between April 29 and May 1, and between September 21 and September 22, 2009, in which the person in charge of the internal audit pointed out matters to be corrected to the Vessel. The internal auditors evaluated the lashing conditions of the cargoes on board as four out of five grades in the September internal audit, in which they expressed their views that installation of wheel chokes and lashing devices, top-over lashing of vehicles with a high center of gravity, and reinforcement of the lashing devices when the angle of ship motions was expected to reach 7° or more were properly implemented. The master of the Vessel submitted the internal audit correction report to Company A on October 23,

2009.

(4) Company A conducted comprehensive training for the emergency operations center on February 9, 2009 on the assumption that the Vessel had collided with a small-sized cargo ship.

2.10 Research on Listing and Collapse of Cargoes

The result of the research by NMRI is summarized as follows.

2.10.1 Verification of Estimated Values by Weather Association

According to the AIS Records and the Estimated Values by the Japan Weather Association, the Vessel was proceeding at a course over the ground of about 235°, at a speed of about 21 kn (about 10.8 m/s), and is considered to have been overtaken by the wave coming on the port quarter at about 35° at a velocity of about 15.6 m/s. According to the AIS Records, as a periodical fluctuation is observable in the speed of the Vessel, the Vessel is considered to have been strongly influenced by waves. The Estimated Values by the Weather Association are considered to be appropriate as the cycle of the fluctuation is found to have been about 23 seconds, and as the cycle of the vessel speed change was 23.1 seconds by calculation from the angle of encounter with the waves, the wave velocity and the wave period.

(See Figure 17: Vessel Speed Changes Immediately Before the Occurrence of the Accident)

2.10.2 Result of Stability Calculation

(1) Estimation at the time of departure

The displacement (W) was estimated to have been 11,530.35 tons while the metacentric height (G_0M) which took account of the free water effect*37 was estimated to have been 1.87 meters, according to the draft at the time of departure, the weight and balance sheet made by the master after the accident, the stability information for the master, the statement of the cargo loading gross weight, and the quantity of the fuel oil at the time of departure.

(See Table 1: Weight and Balance Sheet at the Time of Departure)

(2) Estimation at the time of the accident

It was estimated that fresh water from No.1 fresh water tanks (both sides) had consumed about 10 tons since the time of departure until the time of the occurrence of the accident. Also, according to the remaining quantity of the fuel oil prepared by Company A, the displacement and G_0M at the time of the accident were estimated to have been 11,486.95 tons and 1.8 meters, respectively.

(See Table 2: Weight and Balance Sheet at the Time of the Accident)

(3) Stability curve

[1] Stability curves while in smooth water at the time of departure and at the time of the accident

When the stability curves while in smooth water were calculated on the basis of the estimation of the status at the time of departure and at the time of the accident, much difference was not found in the stability curves while in smooth water between at the time of departure and at the time of the accident. Either of them had a larger righting arm*38 (GZ)

*37 "free water effect" refers to the effect on stability to be exercised by the liquid which has been moved by the motion of a vessel.

*38 "righting lever (GZ)" refers to the horizontal distance from the center of gravity (G) of a vessel, slightly listed from the equilibrium position, to a vertical line passing through the center of buoyancy. The product of the displacement and the righting arm of the vessel becomes a righting moment.

than in the full load departure condition estimated at the time of construction.

(See Figure 18: Stability Curves While in Smooth Water at the Time of Departure and the Accident)

[2] Stability curve while in waves at the time of the accident

According to [1] as above and the Estimated Values by the Weather Association, the stability curves while in waves were calculated in the following conditions: a regular wave with a ratio of 1.0 (a wave period of 9.8 s) between the wavelength and the length of a vessel's hull was chosen as a subject; the vessel was proceeding in real following seas in which the stability would be reduced largely, and in quartering seas with waves coming at an angle of 30° left oblique; the midship of the vessel was situated on a wave crest and on a down slope of the wave. Four variations of four meters, six meters, eight meters, and ten meters were chosen as the wave height (Hw).

(a) As a result, the following case was observed.

While in real following seas, reduction of the stability was observed extensively when the midship was situated either on a wave crest or on a down slope of the wave. According as the wave height was larger, reduction of the stability was larger than at the time of departure when the Vessel was in smooth water, and GZ was lower than the stability curve in the full load departure condition estimated at the time of construction.

However, it was estimated that GZ would not be much lower than the stability curve in the full load departure condition estimated at the time of construction if the wave height was at the level of the significant wave height observed at the time of the accident.

(b) While in quartering seas with waves coming at an angle of 30° left oblique, the sea levels on both sides of the vessel were asymmetric when the midship was situated either on a wave crest or on a down slope of the wave. Accordingly, the vessel was balanced by heeling to port when the midship was situated on a wave crest, while balanced by heeling to starboard when the midship was situated on a down slope of the wave.

The angle of heel to starboard when the vessel was balanced on a down slope of the wave was larger than the angle of heel to port when the vessel was balanced on a wave crest, and the larger the wave height was, the larger the angle of heel to either side.

(See Figure 19: Stability Curves in High Waves at the Time of the Accident)

2.10.3 Possibility of Collapse of Cargoes

Cargoes on board a vessel are subject to not only gravity acceleration, but also dynamic acceleration to be initiated by ship motions, which as a result may cause collapse of cargoes. There two types of cargo collapse, "sliding" and "overturning".

As the weight of the cargoes in the containers and on the chassis loaded on C Deck and D Deck accounted for about 98 % of the gross cargo weight, collapse of containers and chassis put on a static slope was examined for the purpose of seeking an approximate angle of list which would cause collapse of cargoes.

As it was necessary to estimate the position of the center of gravity for the examination of overturning, the position of the center of gravity "lateral position: center, height: one thirds from the underside" which was used by each classification society as an evaluation method for the lashing of cargoes (containers) was used to seek the angle of list where an overturning moment was generated. As a result of the examination, the containers which overturned first of all aboard the Vessel are considered to have been 20-ft containers double-stacked toward fore and aft, and this is considered to have occurred when the angle of list was 29°.

In order for containers not to start sliding when the angle of list is 29°, the maximum coefficient of friction 0.55 or more is required. According to previous examples when shifting of containers occurred (see 2.6.6), the minimum value of the maximum static friction coefficient between containers and a deck board is estimated to be approximately 0.27 to 3.36.

Also, The Mechanical Engineers' Handbook (written and published in 1977 by the Japan Society of Mechanical Engineers) recommends that the coefficient of friction between steel materials should be considered as approximately 0.35 to 0.40. Therefore, it will be appropriate to consider the maximum value of the maximum static coefficient of friction as 0.40.

Accordingly, "sliding" may be considered to occur prior to "overturning".

(1) Containers

The force which works to prevent containers from sliding are only the friction force to be created against the deck board with which they are in contact, and the tension of the lashing devices with which they are secured.

As the angle of heel which causes containers to start sliding when the maximum static friction coefficient is 0.4 is estimated to be 22°, most of the unlashed containers are considered to have slid when the angle of heel became 25°.

When most of the unlashed containers have started sliding, the load equivalent to the weight of several containers acts on the lashing chains. Therefore, the tension beyond the capacity of the lashing chains are considered to have occurred and have broken the lashing chains, which then forced the lashed containers to slide together with the unlashed containers.

There is a possibility that a hook of the lashing chains gets stretched or comes off before the lashing chain is broken if the hook is used inappropriately. Also, in order for containers not to start sliding when the angle of heel is 25°, the maximum static friction coefficient of 0.47 or more is required.

(2) Chassis

As most of the chassis were secured with 4-Point Lashing Chains, the balance of power between a chassis and a 4-Point Lashing Chain, tires, a landing gear and the suspension system of a sub landing gear was calculated.

As the friction coefficient between a dry asphalt road surface and a tire was said to be 0.6 to 0.8 generally, it was assumed that the maximum static friction coefficient between the tires and the deck board was 0.7, while the friction coefficient between the landing gear and the sub landing gear was 0.4 as they were made of steel.

When the angle of heel became about 22° to starboard, the ratio of the force toward the surface of the deck board to the force toward the normal line on the surface of the deck board was considered to exceed the maximum static friction coefficient, making the tires on the port side unable to sustain the force toward the surface of the deck board. Therefore, it was assumed that when the angle of heel was 22° or more, the tires on the port side would sustain only the force toward the normal line on the surface of the deck. Similar operations were repeated for calculating applicable angles of list for other suspension systems for which the ratio of the force toward the surface of the deck board to the force toward the normal line on the surface of the deck board exceeded the maximum static friction coefficient.

It was assumed that the lashing chain was broken when the tension exceeded the breaking load, and that the spring constant and the initial tension were zero.

Under these assumptions, when the angle of heel is 22° or more, the force of the tires, landing gear and sub landing gear toward the surface of the deck board exceeds the maximum static friction coefficient, and as a result, forcing the lashing chain to sustain most of the force toward the surface of the deck board.

Under these circumstances, when the angle of heel has reached 27°, there is a possibility that the lashing chain will be broken as its tension exceeds the breaking load. When a single lashing chain is broken, other lashing chains are forced to sustain the tension beyond their capacity, and are broken one after another, which then will cause chassis to slide.

However, there is also a possibility that a hook of the lashing chain gets stretched or comes off before the lashing chain is broken if the hook is used inappropriately.

Accordingly, there is a possibility that some of the chassis started sliding almost at the same time as the containers on D Deck started sliding, or in accordance with to an increase in the angle of heel resulting from the heeling moment caused by the sliding of the containers, and that other chassis started sliding one after another as the heel continued afterward.

2.10.4 Relation Between Angle of List and Listing Moment

(1) Relation with cargoes (collapse of cargoes)

The listing moment corresponding to the angle of heel can be obtained by multiplying GZ corresponding to the angle of list by the displacement at the time of accident.

(See Figure 19 and 20)

When collapse of cargoes is expected, the angle of list corresponding to the listing moment can be estimated by applying the product of the weight of the collapse of cargoes and the amount of the travel to the vertical axis (listing moment) in Figure 20.

(2) Listing moment on C Deck

Assuming that the cargoes on board the Vessel slid to starboard because of the list of the hull according to the statement of the cargo loading gross weight and the stacking conditions of the chassis, it is estimated that the listing moment on C Deck was 2,379.0 ton meters (tm) in total.

(3) Listing moment on D Deck

Assuming that the cargoes on board the Vessel slid to starboard because of the list of the hull according to the statement of the cargo loading gross weight and the stacking conditions of the containers, it is estimated that the listing moment on D Deck was 2,136.6 tm in total.

(4) Shift of the center of gravity inside the containers

Assuming that as most of the containers were stacked athwartship, cargoes inside the containers shifted to starboard from the center of the containers by one quarter of the length of the container because the vessel listed to starboard, it is estimated that the listing moment generated when the center of gravity shifted inside the containers was 1,588.9 tm.

(5) Listing moment generated on C Deck and D Deck

It is estimated that the listing moment generated on C Deck and D Deck was about 6,104.5 tm, which was the sum of (2), (3) and (4) as above.

(6) Listing moments on B Deck and E Deck

Assuming that the vehicles loaded on B Deck and E Deck slid to starboard because the Vessel listed to starboard, it is estimated that the listing moment on both decks was 326.3 tm.

(7) Influence of the fin stabilizers

According to the final drawing of the gyro fin stabilizers and the result of the sea trial of the fin stabilizers, the maximum listing moment generated by the fin stabilizers of the Vessel is 1,044 tm. The value of this listing moment is equivalent to the steady list of about 2.5° from the stability curve at the time of the accident when the Vessel was in smooth water.

2.10.5 Verification With AIS Records

When the dimensionless value from the heading, speed and length of the Vessel is sought, it is found that the Vessel was swung largely from side to side after 05:06, and afterward the rate-of-turn speed became larger on the port side (minus), which shows that the Vessel started turning to the left. Accordingly, it is estimated that the accident occurred after 05:06. (See Figure 21)

Also, as the vessel speed which became available from the AIS Records accelerated at around 05:06, the Vessel is considered to have been on a down slope of the wave, and as the acceleration was larger than before, it is estimated that the Vessel encountered a wave with a large wave slope.

It is estimated that the angle of encounter with the wave at that time (hereinafter referred to as "the First Wave") was about 40°. By examining the second wave while considering the encounter wave period, it is found that the hull of the Vessel was in the middle of the left-turning movement when the First Wave was over, and the Vessel did not accelerate even at positions considered to be on a down slope of the wave, although the angle of encounter and the encounter wave period changed every moment. This indicates that the relation between the hull of the Vessel and the waves changed largely from before, and therefore it is estimated that heavy heeling or a similar phenomenon occurred at that moment.

It is estimated that the angle of encounter with the second wave on a down slope at that time was about 55°. (See Figure 22, 23)

The static stability while in the First Wave and the second wave was calculated.

The static point of balance when the midship is situated on a down slope of the First Wave is about 10° in the case of a significant wave height (about 4.6 meters), while about 25° in the case of a wave height 1.5 times as high as a significant wave height (about 6.9 meters).

In the case of the second wave with which the angle of encounter is larger, reduction of the stability is more remarkable and the static point of balance is about 20° even in the case of a significant wave height.

Accordingly, assuming that some of the containers and chassis started collapsing after the Vessel was hit by the First Wave, there is a possibility that when being hit by the second wave, the Vessel heeled about 40° while accelerated by the outward heel generated during turning to the left. (See Figure 24, 25)

2.10.6 Development of List After Listing Heavily

In this accident, the period of time after the Vessel shifted the steering to manual can be divided roughly into the following three phases: the phase when the angle of list was 30° to 35° (hereinafter referred to as "Case 1"); the phase when ballast water in the heeling tanks on the starboard side was transferred to the heeling tanks on the port side in order to reduce the list (hereinafter referred to as "Case 2"); and the phase when the angle of list became 25°, while proceeding in the northwest direction receiving the wind from starboard (hereinafter referred to as "Case 3"). By doing so, the relation between the listing moment acting on the hull of the Vessel and the angle of list while the Vessel was in smooth water was examined for each case. Those like collapse of cargoes, wind moment, heeling tanks and flooding were adopted as factors of the listing moment acting on the hull.

(1) Estimation of wind moment

The wind moment was estimated by using Fujiwara's method ("A New Estimation Method of Wind Forces and Moments acting on Ships on the basis of Physical Component Models" by Toshifumi Fujiwara, Michio Ueno and Yoshihio Ikeda in Journal of the Japan Society of Naval Architects and Ocean Engineers Vol. 2, published in December, 2005)

Table 1: Estimated values of the wind moment

State	Case 1	Case 2	Case 3
Flow Angle	59°	59°	(−) 63°
Relative Wind Speed	17.5 m/s	17.5 m/s	17.2 m/s
Angle of List	30°	30°	25°
Heeling Moment	About 295 tm	About 295 tm	About (−) 400 tm

" (−)" in the column of Flow Angle indicates a state of receiving the wind from starboard, while " (−)" in the column of Heeling Moment indicates a heeling moment which reduces the list (The same will apply hereinafter).

(2) Heeling tank adjustment

Each of the heeling tanks on board the Vessel was loaded with sea water of 120 tons. By estimating the amount of sea water which had been shift from the heeling tanks on the starboard side to the heeling tanks on the port side when the angle of list was about 30°, taking the hull structure and the angle of list into consideration, the value of about (−) 1,755 tm was obtained as the heeling moment.

(3) Estimated amount of flooding

As it was hard to estimate the amount of flooding analytically, it was decided to estimate the amount on the basis of the circumstantial evidence.

In this accident, as it was the hardest to reproduce the state of Case 3, the amount of flooding was estimated on the basis of the state of Case 3.

As this examination was to seek the steady list while in smooth water, it was assumed that only D Deck had been flooded, and the free water effect was not to be considered.

The total sum of the wind moment, the listing moment after the heeling tank adjustment, and the listing moment generated by collapse of cargoes amounted to 4,275 tm. Therefore, assuming that the angle of list would ultimately become about 23°, it was estimated that the value of the listing moment generated by flooding had been about 1,085 tm, and the amount of flooding had been about 100 t.

Also, assuming that the amount of flooding was about 100 t, the listing moment would be about 1,095 tm, as flooded water would stagnate more on the side of the outside plating when the angle of list was about 30°.

(4) Case 1

When the listing moments obtained as above are added up, the angle of list after shifting the steering to manual will exceed the angle of 30° to 35° as in the statements.

Considering the course of the Vessel, it is hard to estimate that flooding occurred as a result of wave rushes and other factors after shifting to manual, as the Vessel listed to starboard (the down side of waves) while waves were coming on the port side after shifting to manual. Therefore, it is appropriate to consider that the flooding occurred before shifting to manual.

Accordingly, while the Vessel was in the state of Case 1, collapse of cargoes is considered to have been in progress.

Table 2: Listing moment after shifting the steering to manual and the angle of list

	Listing Moment
Collapse of Cargoes	About 4,870 tm
Flooding (100 t)	About 1,095 tm
Wind	About 295 tm
Total	About 6,260 tm
Angle of List	About 30°

(5) Case 2

The angle of list after the heeling tank adjustment can be obtained by increasing the heeling moment generated by collapse of cargoes to the maximum while reducing the listing moment after the heeling tanks adjustment obtained as above, when the Vessel was in the state of Table 2.

Table 3: Listing moment after the heeling tank adjustment and the angle of list

	Listing Moment
Collapse of Cargoes	About 6,430 tm
Flooding (100 tons)	About 1,095 tm
Wind	About 295 tm
Heeling Tank	About (—) 1,755 tm
Total	About 6,065 tm
Angle of List	About 29°

(6) Case 3

The angle of list after the heeling tank adjustment and turning to the left can be obtained by considering the influence of receiving winds from starboard after turning to the left, when the Vessel was in the state of Table 3.

Table 4: Listing moment after the heeling tank adjustment and the left turn, and the angle of list

	Listing Moment
Collapse of Cargoes	About 6,430 tm
Flooding (100 tons)	About 1,085 tm
Wind	About (—) 400 tm

Heeling Tank	About (−) 1,755 tm
Total	About 5,360 tm
Angle of List	About 23°

2.11 Environmental Impact by Spillage of Oil and Other Materials, and Their Removal

2.11.1 Leaked Oil

According to the written reply of Company A, the fuel oil which was loaded on board the Vessel at the time of the accident consisted of about 431 kilo liters of heavy oil C and about 53 kilo liters of heavy oil A, while the amount of the fuel oil mixed with sea water which was later recovered by the salvage company was about 630 kilo liters.

According to the publicly released documents of the Japan Coat Guard, none of the oil which spilled from the Vessel was found washed ashore, when the coastline in the vicinity of the Vessel aground was searched on November 14. However, at 16:30 on the following day, November 15, drifting oil was found with a width of about 150 meters and a length of about 3,000 meters toward the east from the Vessel, while its eastern end had dispersed and disappeared.

According to the search conducted on November 20 by a disaster prevention helicopter of Mie Prefecture, belt-shaped drifting oil (very light gray-colored) was confirmed with a width of about 200 meters to 250 meters and a length of about 5,900 meters toward the southeast from the Vessel.

2.11 2 Oil-Based Refuse (Resin Pellets[*39] and Other Materials)

According to the written reply of Company A, about 3 tons of oil-based refuse was collected from the coast along Mihama Town and Kiho Town and other places while about 2 tons of oil-based refuse was collected from the coast and other places in Wakayama Prefecture.

2.11 3 Research on Environmental Impact

For the period between December 4, 2009 and January 29, 2010, Mie Prefecture conducted researches including visual observations by diving (39 points), water examination (2 points), bed material examination (3 points) and biological research (3 kinds at 4 points: spiny lobsters, turban shells and seaweeds), with a view to grasping the current condition of the fishing grounds surrounding the Vessel aground as well as the impact on fisheries, and to obtaining basic data for comparing them with those after the removal of the hull of the Vessel. The result of the researches was published as Fiscal Year 2009 Commissioned Report on the Kumano Nada Area Emergency Fishing Ground Research.

The report states as follows.

(1) Result of visual observations by diving

[1] At about 100 meters north of the Vessel, a lot of collapsed rock reefs about 2 to 5 square meters were observed within the area of about 300 square meters.

[2] In the area from about 250 meters north of the Vessel to about 150 meters south of the Vessel, metal pieces, blankets, clothes, calculators and food bags were found, while it was confirmed that similar items were scattered in large numbers in the vicinity of the Vessel.

*39 "resin pellets" refers to plastic intermediate materials in the shape of a globe, a disk or a round slice with a diameter of 2 to 6 mm. As some types of plastic have an affinity for certain kinds of materials, resin pellets with toxic substances may enter the body of a living thing in some cases, and there is a possibility for them to be absorbed into the fat content of the body.

(2) Result of water and bed material examinations

Concerning items related to oil pollution, no oil content was detected as a result of the indoor analysis of the sea water and marine soil gathered around the Vessel.

(3) Biological research

Concerning items related to oil pollution, no oil content was detected as a result of the indoor analysis of the spiny lobsters, turban shells gathered around the Vessel, and the large seaweeds growing thickly around the submerged breakwater to the south of the researched sea area.

The Fishery-Related Organizations Liaison Conference on the Ferry Accident, which was organized by relevant parties including local fishermen's cooperatives, declared on January 22, 2010 that the marine products in the sea areas surrounding the location where the Vessel was aground were safe, as they concluded that because no oil content had been detected from the fish and shellfish caught in the fishing grounds in the vicinity of the Vessel aground, they were not contaminated by oil pollution.

2.11.4 Removal of Hull and Recovery of Cargoes

According to the written reply of Company A, the removal of the hull of the Vessel and the recovery of the cargoes were completed on December 27, 2010.

2.12 References on Ship Maneuvering in Following Seas

(1) Concerning hazards while navigating in following sea conditions, "REVISED GUIIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN ADVERSE WEATHER AND SEA CONDITIONS" (MSC.1/Circ.1228 dated January 11, 2007) published by International Maritime Organization (IMO) (hereinafter referred to as "Navigation Guidance in Adverse Weather Conditions") describes as follows in summary.

When a ship is riding on a wave crest, the intact stability can be decreased substantially according to changes of the submerged hull form. This stability reduction may become critical for wave lengths within the range of 0.6 L upto 2.3 where L is the ship's length between perpendiculars in meters. Within this range the amount of stability reduction is nearly proportional to the wave height. This situation is particularly dangerous in following and quartering seas, because the duration of riding on the wave crest, which corresponds to the time interval of reduced stability becomes longer.

In case of navigation in following and quartering seas, the rolling period of a ship becomes longer because of the stability reduction, and large rolling motions may be excited when the rolling period of the ship coincides with the wave period. This is called synchronous rolling motions.

Also, when the wavelength is larger than 0.8 or L.P.P. and the significant wave height is larger than 0.04 L.P.P., the master should pay attention not to enter in the dangerous zone as indicated in Figure 26 (hereinafter referred to as "Dangerous Zone in Following Seas with High Waves"). When the ship is situated in this dangerous zone, the ship speed should be reduced or the ship course should be changed, because dangerous phenomena like synchronous rolling motions may be induced. (See Figure 26)

While a ship is on the sea, the wave period can be measured with a stop watch by making use of a foam patch generated by a breaking wave, and the wavelength can be determined either by comparison with the ship length or by radar.

It should be noted that the Navigation Guidance in Adverse Weather Conditions is restricted to hazards in adverse weather conditions that may endanger a ship to large listing with a risk of capsizing. It should further be noted that the Guidance has been designed to indicate guidance of a general nature that will accommodate for all types of merchant ships, and that certain particulars in this Guidance may not be applicable to certain ships. Therefore, masters are requested to use this Guidance with fair observation of the particular features of the ship and her behaviour in adverse weather conditions.

According to the statements of the master and the operation manager, although both of them were acquainted with the hazards in following sea conditions which would cause the broaching-to phenomenon[*40] while navigating in a high wave on the quarter, they had no knowledge about the contents of the Navigation Guidance in Adverse Weather Conditions. As they had not experienced large ship motions on board the Vessel even while proceeding in following seas, they deemed that the Vessel was resistant to following sea conditions.

Moreover, according to the statement of the chief officer, although it was too dark to see the waves as it was before dawn at the time of the accident, he felt that the Vessel was proceeding in following seas with waves coming as fast as the Vessel from the direction of 7 o'clock. He had no knowledge about the contents of the Navigation Guidance in Adverse Weather Conditions, as in the same manner as the master.

(2) Literature

"Introduction to Ship Maneuvering (8th Edition)" (written by Keinosuke Honda, published by Seizando-Shoten Publishing Co., Ltd. in June 2008) describes that *"while proceeding in large following seas, a ship may continue an accelerated motion back and forth with periodical fluctuation, and the speed of the ship may sometimes be accelerated to the wave velocity, although these movements do not involve any particular hazards to the maneuvering of the ship."*

2.13 Examples of Accidents Involving Listing of Ferries

According to the records of determinations by Japan Marine Accident Inquiry Agency (reorganized as Japan Maritime Accident Tribunal on October 1, 2008), there was one accident case in which a ferry listed heavily while navigating in following sea conditions, and as a result, collapse of cargoes was caused. The outline of the accident was as follows.

A passenger ship (with a gross tonnage: 13,539 tons and length between perpendiculars: 175.0m), with 125 passengers and 217 cars on board, was altering the course to the entrance to Oarai Port, Ibaraki Prefecture on October 24, 2006, when the ship was hit by waves higher than 6 meters on the starboard quarter at an angle of 30°, and rode on the wave crest amidships. The stability of the ship was reduced, and at the same time the ship was hit by a wind with wind force ten almost from the starboard beam, and suddenly she listed heavily to port at an angle of 40°, at 13:10 on that day. Due to the heavy listing, four passengers and one crew member were injured while 103 cars were damaged.

[*40] "broaching-to phenomenon" refers to a phenomenon that may occur when a ship can be accelerated on a down slope of a wave, and falls into a state of surf-riding, while navigating in quartering and following sea conditions. In this situation, the effect of the steering may be decreased extremely by the external force of the wave that is far larger than the steering power, and the ship may be forced into uncontrollable and critically unstable condition, when the ship may turn sideways to the wave with the action of quartering and following seas, and may be endangered to capsizing as a result of unexpected large listing in the direction of the wave.

3 ANALYSIS

3.1 Situation of the Accident Occurrence

3.1.1 Course of the Events Leading to the Occurrence of the Accident

According to 2.1, 2.10.3 and 2.10.5, it is probable that the course of the events leading to the occurrence of the accident was as follows.

(1) When departing from Tokyo Section of Keihin Port for Shibushi Port, the master confirmed from the information on weather and sea conditions that they would not become so bad as to require suspension of departure. Also, learning that a water area with a wave height of about five meters was expected off the Kumano Nada, he decided to navigate an area close to the Kii Peninsula in the Kumano Nada where a wave height of four meters was expected, and estimated from his previous experience that the Vessel would not sustain a rolling motion of 7° or more, while the Vessel was supposed to navigate in following sea conditions in the Kumano Nada.

(2) While the Vessel was berthed at Ariake Pier, the master had a meeting for the stevedoring work with the chief officer, the second officer, the cargo superintendent and the stevedore, and instructed them to secure with 6-Point Lashing Chains, the seven chassis in the front row and the three chassis in the last row which were to be loaded on C Deck, and to secure the other cargoes as usual.

(3) Upon the completion of the departure works, the chief officer inspected the lashing conditions of the cargoes on board as usual with the boatswain and the able bodied seamen, and confirmed that the lashing chains had not been loosened.

(4) The Vessel operated the fin stabilizer when coming close off the cape of Tsurugi Saki.

(5) The Vessel altered the course to 255° off the coast of Mikomoto-shima, and to 237° off the coast of Daio Saki.

(6) The able bodied seaman A, B and C who were on the bridge watch-keeping duty executed inspections respectively round of the Vessel while on duty, and confirmed that the lashing chains had not been loosened.

(7) At around 04:30, the Vessel altered the course to 235°, and proceeded on autopilot at a speed of about 20.5 kn.

(8) At around 05:06, when the heading turned to 229° and the speed became about 21.1 kt, the Vessel heeled 25° to starboard and turned sharply to the left, when the water leakage alarm system was activated.

(9) At that time, cargoes on board the Vessel started collapse of cargoes, and soon afterward the Vessel listed about 40°.

3.1.2 Time, Date and Location of the Occurrence of the Accident

According to 2.1 and 3.1.1, it is highly probable that the accident occurred at around 05:06, November 13, 2009, and the location was approximately 115.5°, 14.0 M from East Breakwater North Lighthouse, the Udono Port.

3.1.3 Course of the Events Since the Accident Occurrence Until Rescue Operations

According to 2.1, 2.7 and 2.10.6, it is probable that the course of the events since the accident occurrence until the rescue operations was as follows.

(1) At around 05:14, the chief officer shifted the steering from autopilot to hand steering.
(2) While taking the con, the master ordered the chief officer to continue the steering, the second officer to contact the Japan Coast Guard, the third officer to engage in radar surveillance, the chief engineer and the first engineer to operate the main engines, the boatswain and the able bodied seaman A to shift ballast water, and the purser and the other crew to take care of the passengers.
(3) At around 05:20, the master found that the angle of list had become about 30° to 35° to starboard.
(4) At around 05:25, the master reported the situation to the Japan Coast Guard, and requested rescue by helicopter.
(5) At around 05:28, the master contacted Company A and requested an emergency task force to be established.
(6) At around 05:30, the purser went to the passenger subdivision, and confirmed that all of the seven passengers gathered composedly in the passage wearing a life-jacket.
(7) In the meantime, the heeling tanks on the port side had become almost full.
(8) At around 05:35, the Vessel started turning to the left.
(9) After that, the Vessel proceeded in the northwest direction, and while receiving winds and waves from starboard, the angle of list became about 25° to starboard.
(10) At around 06:45, the seven passengers were guided by way of the passage into the passage on the port side of A Deck, and waited there.
(11) At around 07:15, the helicopter of the Japan Coast Guard arrived, and on the instructions of the Mobile Rescue Technicians (a party of two) arriving afterward, rescue operations were commenced by hoisting passengers from the external passage on the port side of A Deck.
(12) At around 08:10, all of the seven passengers were rescued by the helicopter.
(13) At around 08:06, oil leakage from the Vessel was confirmed.
(14) In the meantime, the master nominated six crew members as ship maintenance and security crew.
(15) At around 08:32, seven crew members were rescued by the helicopter.
(16) At around 09:03, seven crew members were rescued by the helicopter.
(17) At around 09:07, as the list of the Vessel increased, the master decided on the evacuation of the maintenance and security crew from the Vessel.
(18) After that, the master and the six maintenance and security crew dropped an Inflatable Life Raft on the starboard side and evacuated from the Vessel. At around 10:21, they were rescued by patrol craft.

3.1.4 Situation of the Injured

According to 2.2, two passengers were slightly injured when the Vessel listed, and one of the maintenance and security crew sustained greater tuberosity fracture of the right humerus while evacuating from the Vessel.

3.1 5 Situation of the Damage

According to 2.3, the Vessel grounded and rolled sideways in the vicinity of the coast of Mihama Town. After that, crumbling of the Vessel advanced gradually due to the effect of waves and other factors, and in early March of 2010, the greater part of the Vessel collapsed into the sea.

3.1.6 Preventive Measures Against Cargo Shifting in Car Spaces

According to 2.6 and 2.9.1 to 2.9.3, it is probable that preventive measures taken against cargo shifting in the car spaces were as follows.

(1) Lashing points such as cloverleaves were installed in the car spaces, while non-slip metal fittings were installed on D Deck.

(2) At the time of constructing the Vessel, a painting material compatible with the standard prescribed in Standards for Construction of Car Ferries was coated on the deck boards in the car spaces. However, because a similar painting material (with a friction coefficient of 0.7 or more) had not been coated on the deck boards by the time of the occurrence of the accident, the friction coefficient between the deck boards and the steel containers was about 0.4.

(3) The Vessel was equipped with lashing chains with a breaking load of 16.0 tons, metal fittings for securing double-stacked containers, and sub landing gear.

(4) At the time of the accident, the containers were placed directly on the decks.

(5) There was a case in the past in which lashed containers and chassis shifted when the Vessel heeled about 15° to 16 °, although lashing chains did not break.

(6) Company A had not reviewed the lashing method for containers and chassis, which was instead left to the discretion of the master and the chief officer.

(7) Although the safety management manual (operation standard) of Company A, and the safety work procedure manuals of Company B and Company C mentioned about the installation of lashing chains and the tension of them when installed, neither of the companies had a manual providing for effective lashing methods to prevent excessive cargo shifting.

(8) The crew and the longshoremen secured the containers and chassis in the lashing method which they had practiced from before, and they did not top-over lash trucks and other large-sized vehicles.

3.2 Causal Factors of the Accident

3.2.1 Situation of the Crew

(1) According to 2.4, both the master and the chief officer possessed a legal and valid seamen's certificate of competence.

(2) According to 2.4, it is probable that the master had the experience of boarding ro-ro passenger ferries operated by Company A for 12 years as a deck officer and for about one month as a master, while the chief officer for about 17 years as a officer, and the operation manager for five years as a deck officer, 12 years as a master and two years as an operation manager.

3.2.2 Situation of the Vessel

(1) According to 2.1.1, 2.5.3 (2) and 2.5.3 (7), it is probable that there was no failure or malfunction with the hull, engines and autopilot of the Vessel.

(2) According to 2.1.1 (6) to (9), 2.5.3 and 2.10.4 (7), it is probable that there was no failure or malfunction with the fin stabilizers at the time of the accident. Accordingly, it is probable that the list of the Vessel was not caused by the forced oscillation or by the malfunction of the fin stabilizers.

3.2.3 Weather and Sea Conditions

According to 2.8 and 2.10.1, weather and sea conditions were as follows.

(1) The Japan Meteorological Agency had issued an advisory for gale and a high sea warning to the

Kisei and East Kishu Districts in the southern region of Mie Prefecture, as of 10:38, November 12.

(2) It is probable that in the vicinity of the accident site, a wind was blowing from the east-northeast at a speed of about 15 m/s and a wave was surging with a significant wave height of about 4.6 meters, a wave period of about 10 seconds and a wavelength of about 156 meters.

3.2.4 Stacking Conditions of Cargo and Stability at the Time of Departure

According to 2.1.1 (2), 2.5.2 and 2.10.2, it is probable that stacking conditions of the cargoes and the stability at the time of departure were as follows.

(1) The loading weight of the cargoes was 3.22 tons on A Deck, 16.63 t on B Deck, 1,001.31 tons on C Deck, 1,343.80 tons on D Deck and 25.00 tons on E Deck. In addition to these, the weight of the spare tanks on the decks was 13.90 tons, bringing the total loading weight of the cargoes on board to 2,403.86 tons.

(2) Most of the chassis were loaded on C Deck, where all of them were stacked toward fore and aft direction

(3) The containers were loaded on D Deck, where, to be brief, they were double-stacked athwartship in three blocks on the port bow, starboard bow and starboard quarter sections.

(4) The trucks were loaded on C Deck and D Deck, where they were stacked toward the fore and aft direction around the center line.

(5) The heavy machines were loaded on C Deck and D Deck.

(6) The Vessel departed with hardly any list.

(7) The Vessel had a larger righting arm at the time of departure than in the full load departure condition estimated at the time of construction.

3.2.5 Lashing Conditions of Cargoes

According to 2.1.1 (1), 2.6.3 (1), 2.6.4, 2.6.5 and 2.6.7, lashing conditions of the cargoes were as follows.

(1) Containers

[1] It is probable that the upper and lower containers double-stacked were prevented from horizontal slippage with cones, while a Sub-Chains were hooked on the corner fittings at the bottom of the upper container.

[2] It is probable that the containers were secured with lashing chains at intervals of about three rows toward fore and aft directions, on the broadside and on the side of the center line in each of the blocks.

[3] It is probable that the method of securing containers with lashing chains was not effective enough to prevent excessive cargo shifting, because the lashing chains were almost in a vertical position while lashing the containers as the lashing chain was only about 0.4 meters longer than the height of the container.

[4] It is somewhat likely that some of the hooks lashing chains' hooks were not used appropriately as their tips were hitting cloverleaves and the corner fittings of containers.

[5] It is somewhat likely that a Clamping Part was hooked on a corner fitting at the bottom of an adjacent lower container, when there was no appropriate lashing point like a cloverleaf.

[6] It is somewhat likely that Clamping Parts equipped with metal fittings used only for cloverleaves and Sub-Chains equipped with metal fittings used only for the corner fittings of containers were not used.

(2) Lashing conditions of chassis and vehicles

[1] It is probable that their tires were secured with wheel chokes while Sub-Chains were hooked on the lashing rings.

[2] It is probable that the seven chassis in the front row and the three chassis in the last row on C Deck were secured with 6-Point Lashing Chains, while the other chassis were secured with 4-Point Lashing Chains.

[3] It is probable that for the chassis without any lashing rings, the tips of Sub-Chains' hooks were hung on the members at the back of their bodies.

(3) It is probable that the trucks and other large-sized vehicles were not top-over lashed, although they were secured with 4-Point Lashing Chains while their tires were secured with wheel chokes and Sub-Chains were hooked on their wheels.

(4) It is probable that the heavy machines were secured with 4-Point Lashing Chains while Sub-Chains were hooked on the members at the front and rear of their bodies, and that when they were equipped with buckets, the buckets were put down on the deck and secured with lashing belts.

(5) It is probable that the passenger cars were secured with lashing belts hung only in the front and rear direction diagonally, while their tires were secured with wheel chokes.

3.2.6 Decision on Whether or Not to Operate the Vessel

According to 2.1.1, 2.5.3 (2), 2.8.2, 2.12, 3.1.1 and 3.2.3, a decision on whether or not to operate the Vessel was made as follows.

(1) It is probable that when departing from Tokyo Section of Keihin Port for Shibushi Port, the master thought that weather and sea conditions would not become so bad as to require suspension of departure as prescribed in the safety management manual.

(2) It is probable that the master estimated from his previous experience that the Vessel would not sustain a rolling motion of 7° or more, while the Vessel was supposed to navigate in following seas with a wave height of about four meters in the Kumano Nada.

(3) It is probable that while navigating at a speed of about 20.5 kn after altering the course to 237° off the coast of Daio Saki and to 235° at around 04:30, the Vessel was proceeding in following seas with waves coming on the port quarter at about 35° with a wave period of about eight to nine seconds and a wave height of four meters.

(4) Although the Vessel is considered to have been influenced by waves as a periodical fluctuation was observed in the speed over the ground, it is probable that the fluctuation in the speed over the ground did not involve any particular hazards to the maneuvering of the Vessel.

(5) It is somewhat likely that as the Vessel was proceeding with the fin stabilizers and the autopilot in operation, no abnormal ship motions occurred to the Vessel or the deviation of the course (heading) from the specified course was not larger than 10°.

(6) It is probable that the because of the situation as mentioned in (5) above, the chief officer did not report to the master or take measures such as reducing the speed or altering the course in a timely manner. Besides, it is probable that the master and the two crew members who got up between around 04:30 and 05:00 felt nothing like a rolling motion to the hull before the occurrence of the accident.

(7) It is probable that at the time of the accident, it was too dark for the chief officer to see the waves as it was predawn

(8) It is probable that the master deemed the Vessel was resistant to following sea conditions, as he had not experienced any large ship motions on board the Vessel even while proceeding in following seas.

3.2.7 Hazards While Navigating in Following Sea Conditions

According to 2.12, 3.1.1, 3.2.3 and 3.2.6, hazards to the Vessel while navigating in following sea conditions were as follows.

The Navigation Guidance in Adverse Weather Conditions describes that as the Guidance has been designed to indicate guidance of a general nature, masters are requested to use this Guidance with fair observation of the particular features of the ship and her behaviour in adverse weather conditions. It also describes that when a wavelength is larger than 0.8 L.P.P and a significant wave height is larger than 0.04 L.P.P, the master of the ship should pay attention not to enter in the Dangerous Zone in Following Seas with High Waves.

Under the sea conditions with a wavelength as large as 0.8 or more of the length between perpendiculars and a significant wave height as large as 0.03 of the length between perpendiculars, the Vessel heeled heavily while navigating in following sea conditions.

Accordingly, it is probable that the Vessel was navigating in the Dangerous Zone in Following Seas with High Waves, according to the findings that the Vessel was proceeding in following seas with waves coming on the port quarter at about 35° under the sea conditions at the time of the occurrence of the accident.

It is probable that the master deemed the Vessel was resistant to following sea conditions, as he had no knowledge about the Dangerous Zone in Following Seas with High Waves as described in the Navigation Guidance in Adverse Weather Conditions, and as he had not experienced any large ship motions on board the Vessel even while proceeding in following sea conditions.

It is probable that it was difficult for the chief officer to judge that he was in a position to reduce the speed or change the course, as he had no knowledge about the Dangerous Zone in Following Seas with High Waves as described in the Navigation Guidance in Adverse Weather Conditions, as it was too dark for him to see the waves as it was predawn at the time of the accident, and as no abnormal ship motions occurred to the Vessel or the deviation of the course (heading) from the specified course was not larger than 10°.

3.2.8 Left Turn at the Time of the Occurrence of the Accident

(1) Situation of the left turn

According to 2.1.2 and 2.5.4, the situation of the left turn was as follows.

[1] The time required for turning 90° to the left from a heading of 229° (55 seconds) was shorter than the time required for turning 90° to the left when the engines on both sides were in operation at the turning trial.

[2] The angle between the heading and the course over the ground (drift angle) was larger than the drift angle of about 20° considered to be generated when a general merchant ship takes the maximum rudder angle (Reference “Introduction to Ship Maneuvering”), and the angle became 45° at 05:07:04.

[3] It is probable that the left turn at the time of the occurrence of the accident was made more sharply than when the rudder and the engines were in operation, as the tactical diameter of the left turn was about 130 meters smaller than the tactical diameter when the engines on both sides were in operation at the turning trial, and about 30 meters smaller than the

tactical diameter of the left turn when an engine on single side (right) was in operation.

(2) Factors causing the left turn

According to 2.5.3 and (1) as above, it is considered probable that the left turn at the time of the occurrence of the accident was caused not by shifting the steering while on autopilot, but by the occurrence of the turning moment to the hull of the Vessel while proceeding in following seas with waves coming on the port quarter.

3.2.9 List of the Vessel and Collapse of cargoes at the Time of the Occurrence of the Accident

(1) List of the Vessel

According to 2.10.5 and 3.1.1, the Vessel was proceeding in following seas with waves coming on the port quarter with a wavelength as long as the hull of the Vessel, a wave period of about 10 seconds and a significant wave height of about 4.6 meters, and the static point of balance when the midship was on a down slope of a wave was about 25° when the wave was 1.5 times as high as a significant wave height (about 6.9 meters). Accordingly, it is probable that the Vessel was hit by the First Wave on the port quarter at about 40° with a wave height of about 6.9 meters, and listed about 25° to starboard when the midship was situated on a down slope of the First Wave.

(2) Collapse of cargoes

According to 2.1.1 (7), 2.5.3 (1), 2.6.6, 2.6.7, 2.10.3 to 2.10.6 and 3.1.1, it is probable that the situation of cargo shifting was as follows.

[1] According to the situation when containers shifted before the occurrence of the accident, and to the findings that the containers were placed directly on D Deck whose non-slip coating was peeled off, the maximum static coefficient of friction between the containers and the deck board was about 0.4, similar to that between steel materials. According to the findings that the angle of heel which causes containers to start sliding is estimated to be 22°, most of the unlashed containers had slid when the angle of heel became 25°.

[2] When most of the unlashed containers slid, the load equivalent to the weight of several containers acted on the lashing chains, and the tension beyond the capacity of the lashing chains was occurred and broke the lashing chains, which then forced the lashed containers to slide together with the unlashed containers.

[3] Assuming that the maximum static coefficient of friction between the deck board and the tires was 0.7 from the coefficient of friction coefficient between a dry asphalt road surface and a tire, and that the coefficient of friction between the deck board and the landing gears as well as the sub landing gear was 0.4, similar to that between steel materials, the force of the tires of chassis, landing gears and sub landing gear toward the surface of the deck board exceeded the maximum static coefficient of friction when the angle of heel became 22° or more, and most of the force toward the surface of the deck board was sustained by the lashing chains.

[4] Under the circumstances as in [3], when the angle of heel reached 27°, the lashing chains for chassis were broken as their tension exceeded the breaking load.

[5] When a single lashing chain was broken, other lashing chains were forced to sustain the tension beyond their capacity, and were broken one after another, which then caused the chassis to slide.

[6] Because of the heel of the Vessel, cargoes inside the containers shifted to starboard.

[7] While collapse of cargoes was in progress as described in [1] to [6] above after being hit by the

First Wave, the Vessel was hit by the second wave on the port quarter at about 55°, and when the midship was situated on a down slope of the wave, the Vessel listed about 40° or more to starboard while accelerated by the outward heel generated during turning to the left.

[8] When the Vessel fell into the state as described in [7] above, waves rushed in from the stern end of the car spaces on C Deck or from the vent holes on the starboard outside plating.

Also, because hooks of inappropriately used lashing chains would get stretched or come off before the lashing chains were broken, cargo shifting occurred at an angle smaller than the angle of list mentioned as above.

3.2.10 Ship Motions After the Accident

According to 2.1.1 (8) and 2.1.2, ship motions after the accident were as follows.

(1) After turning to the left sharply by being hit by the First Wave as well as the second wave while on autopilot, the Vessel turned to the right, and the bow was directed to the southeast. However, it was unable to clarify the season for the right turn.

(2) Although steered to starboard afterward, the Vessel was unable to turn to the right. The following points may be considered as reasons for the inability to turn to the right: the rudder pressure contributing to the turn was reduced by the list of the Vessel about 30° to 35° to starboard; ship resistance to the right turn increased; and the output of the engines on the starboard and port sides differed from each other. However, it was unable to clarify the exact reason for that.

3.2.11 Development of List After the Accident

According to 2.1.1 (8) and (9), 2.5.3 and 2.10.6, it is somewhat likely that the list of the Vessel developed as follows after the accident.

(1) When shifting the steering to manual, the angle of list of the Vessel was about 30° under the influence of the wind from the port side, the flooding with an amount of about 100 tons, and the progress of collapse of cargoes.

(2) When the heeling tanks on the port side became almost full, the angle of list became about 29° under the influence of the wind from the port side, the flooding with an amount of about 100 tons, and collapse of cargoes.

(3) When starting to proceed in the northwest direction after the left turn, the angle of list became about 23° under the influence of the wind from starboard.

(4) Because the Vessel received winds and waves from starboard while proceeding in the northwest direction, the amount of flooding increased and the angle of list became larger as waves rushed in from the stern end of the car spaces on C Deck or from the vent holes on the starboard outside plating.

3.2.12 Occurrence of the Accident

According to 2.1.1, 2.6, 2.9, 2.10.3, 3.1.1, 3.1.3, 3.1.6, 3.2.4 to 3.2.9, and 3.2.11, the situation of the occurrence of the accident was as follows.

(1) While proceeding in the southwest direction in the Kumano Nada, carrying seven passengers and cargoes such as containers and chassis on board, the Vessel listed about 25° to starboard and collapse of cargoes started after being hit by the First Wave on the port quarter at about 40°, and listed more heavily after being hit by the second wave subsequently. It is probable that although the angle of list was reduced after turning the heeling tanks on the port side almost

full as a means of restoring the stability, and getting prepared for receiving winds and waves from starboard, the angle of list started becoming larger again after a while, and after the passengers and the crew were rescued, the Vessel grounded and laid sideways in the vicinity of the coast of Mihama Town.

(2) It is probable that although the Vessel was equipped with fixed lashing points like cloverleaves in the car spaces, and with lashing devices like lashing chains, Company A had neither reviewed the lashing method for containers and chassis nor created a manual providing for effective lashing methods to prevent excessive cargo shifting. Besides, it is probable that Company A had not taken preventive measures against vehicles moving sideways excessively which were compatible with the standard prescribed in Standards for Construction of Car Ferries, according to the findings that although a non-slip painting material was coated on the deck boards in the car spaces at the time of constructing the Vessel, a similar painting material had not been coated on C Deck and D Deck by the time of the occurrence of the accident, and that the coating of both decks was peeled off. Accordingly, it is probable that concerning C Deck and D Deck, the maximum static friction coefficient between the deck boards and the containers, landing gears and sub landing gear respectively was about 0.4, similar to that between steel materials.

(3) It is probable that although most of the containers placed in three blocks were double-stacked athwartship and secured with lashing chains at intervals of about three rows on the broadside and on the side of the center line in each of the blocks, the lashing method adopted there was not effective enough to prevent excessive shifting of containers.

(4) It is probable that while most of the chassis were loaded on C Deck, the seven chassis in the front row and the three chassis in the last row were secured with 6-Point Lashing Chains and the other chassis were secured with 4-Point Lashing Chains.

(5) It is probable that at the time of departure, the Vessel was loaded with cargoes and other materials with a weight of about 2,400 tons, sustained hardly any list, and held a righting arm larger than in the full load departure condition estimated at the time of construction.

(6) It is probable that although navigating in the Dangerous Zone in Following Seas with High Waves at the time of the occurrence of the accident, the Vessel continued navigating on autopilot, according to the findings that no abnormal ship motions occurred to the Vessel because the fin stabilizers were in operation, and that the deviation of the course (heading) from the specified course was not larger than 10°.

(7) It is probable that while under the condition of (6) as above, the Vessel was hit by the First Wave on the port quarter at about 40° with a wavelength as long as the hull of the Vessel and a wave height of about 6.9 meters, and listed about 25° to starboard and turned sharply to the left when the midship was situated on a down slope of the First Wave.

(8) It is probable that when most of the unlashed containers slid at that time, the load equivalent to the weight of several containers acted on the lashing chains, and the tension beyond the capacity of the lashing chains was occurred and broke the lashing chains, which then forced the lashed containers to slide together with the unlashed containers.

(9) Cargoes inside the containers shifted to starboard because of the list of the Vessel.

(10) Concerning the chassis on the other hand, it is probable that when the angle of list became 22° or more, most of the force toward the surface of the deck board was sustained by the lashing chains, and when the angle of list reached 27°, the tension of the lashing chains exceeded the breaking load and the lashing chains were broken.

It is probable that when a single lashing chain was broken, other lashing chains were broken one after another, which then caused the chassis to slide.

(11) It is probable that cargoes started collapsing as they slid sideways as described in (7) to (10) above, and while collapse cargoes was still in progress, the Vessel was hit by the second wave on the port quarter at about 55°, and when the midship was situated on a down slope of the wave, the Vessel listed about 40° or more to starboard while accelerated by the outward list generated during turning to the left.

(12) It is somewhat likely that although the angle of list was reduced after turning the heeling tanks on the port side almost full as a means of restoring the stability, and getting prepared for receiving winds from starboard, the angle of list became larger because the amount of flooding increased when waves rushed in from the stern end of the car spaces on C Deck or from the vent holes on the starboard outside plating, while proceeding in the northwest direction toward the shore.

(13) It is somewhat likely that if Company A had taken preventive measures against vehicles and other cargoes moving sideways excessively as prescribed in Standards for Construction of Ro-Pax Ferry, the containers would not have slid even when the angle of list became about 25°.

Accordingly, it is desirable that Company A should mention in its safety management manual (operation standard) about hazards while navigating in following sea conditions as described in the Navigation Guidance in Adverse Weather Conditions, and acquaint its deck officers and other crew members who are engaged in vessel operation thoroughly with the hazards. It is also desirable that Company A should consider using Clamping Parts equipped with metal fittings used only for cloverleaves as well as Sub-Chains equipped with metal fittings used only for the corner fittings of containers, study effective lashing methods for cargoes on board a vessel, and consider coating deck boards with non-slip painting materials and installing cargo shifting prevention devices like stringers and detachable cones.

3.3 Prevention of Damage Expansion

According to 2.1.1, 2.5.3, 2.9.4, 3.1.3 and 3.1.4, it is probable that the following factors contributed to the prevention of damage expansion.

(1) Serious damage such as falling overboard did not occur, because persons other than those on the bridge watch-keeping duty were sleeping in their cabins or in similar conditions when the Vessel listed.

(2) Emergency actions were taken systematically, because the system under the con by the master had been established with the preparation of the muster list and the implementation of drills.

(3) The Vessel was not seized with a panic, because none of the passengers and the crew was seriously injured when the Vessel listed, both the passengers and the crew were given an explanation about the situation and the request for rescue, the instructions were transmitted easily as the number of the passengers was small, and the list of the Vessel was relatively stable before the rescue operation by helicopter was conducted.

(4) The master maneuvered the Vessel close to the shore while making the left turn without increasing the angle of list.

(5) All of the seven passengers and 14 crew members (except for the master and the maintenance and security crew) were rescued directly from the Vessel by helicopter

(6) When the master and the six maintenance and security crew jumped into the sea, the Mobile Rescue Technicians gave them instructions to do so when wave conditions became appropriate.

It is probable that if the angle of list had been 20° or less, the maintenance and security crew could have evacuated more safely from the Vessel by making use of the Chuter.

3.4 Environmental Impact by Spillage of Oil and Other Materials

According to 2.11, although fuel oil leaked and oil-based refuse spilled from the Vessel lying sideways, the leaked fuel oil drifted, and dispersed and disappeared off the coast while the spilled oil-based refuse washed ashore was collected. Moreover, it is probable that the marine products in the sea areas surrounding of the location where the Vessel was aground were declared safety because no oil content had been detected from the sea water, marine soil and seabed life gathered in the vicinity of the Vessel aground.

4 CONCLUSIONS

4.1 Summary of the Analysis

(1) Course of the events leading to the occurrence of the accident

It is probable that the Vessel, carrying seven passengers and cargoes such as containers and chassis on board, heeled about 25° to starboard and the containers started collapsing after being hit by the First Wave, and listed more heavily after being hit by the second wave subsequently while proceeding southwest in the Kumano Nada with easterly waves coming on the port quarter. Moreover, it is probable that although the angle of list was reduced after taking measures to restore the stability, the angle of list became larger again while proceeding in the northwest direction toward the shore, and after the passengers and the crew were rescued, the Vessel grounded and laid sideways in the vicinity off the coast of Mihama Town.

In this accident, two passengers and one crew members were injured.

(2) Occurrence of the angle of heel about 25° after being hit by the First Wave

It is probable that the Vessel heeled about 25° to starboard and turned hard to the left when the Vessel was hit by the First Wave on the port quarter at about 40° with a wave height of about 6.9 meters, and the midship was situated on a down slope of the First Wave, according to the findings that the Vessel was navigating in following seas with waves coming on the port quarter with a wavelength as long as the hull of the Vessel, a wave period of about 10 seconds and a significant wave height of about 4.6 meters, and that the static point of balance when the midship was on a down slope of a wave was about 25° when the wave was 1.5 times as high as a significant wave height (about 6.9 meters).

(3) Occurrence of collapse of cargoes and the list after being hit by the second wave

It is probable that the occurrence of collapse of cargoes and the list of the Vessel after being hit by the second wave were as follows.

[1] Although the Vessel was equipped with fixed lashing points and lashing devices, Company A had neither reviewed the lashing method for containers and chassis nor created a manual providing for effective lashing methods to prevent excessive cargo shifting. Moreover, concerning C Deck and D Deck, the maximum static coefficients of friction between the deck boards and the containers, landing gears and sub landing gear were about 0.4, similar to that between steel materials, according to the findings that no painting material compatible with the standard prescribed in Standards for Construction of Car Ferries was coated on the deck boards in the car spaces at the time of the accident, that the non-slip coating was peeled off, and to the situation when containers had shifted before the occurrence of the accident.

[2] Although most of the containers were double-stacked athwartship and secured with lashing chains at intervals of about three rows, the lashing method adopted there was not effective enough to prevent excessive cargo shifting as the lashing chains were only about 0.4 meters longer than the height of the container and the lashing chains were almost in a vertical position while lashing the containers.

[3] While most of the chassis were loaded on C Deck, the seven chassis in the fore row and the three chassis in the aft row were secured with 6-Point Lashing Chains, and the other chassis (34 in total) were secured with 4-Point Lashing Chains.

[4] When the angle of heel became about 25° to starboard, containers started sliding.

[5] When the angle of list reached 27°, the tension of the lashing chains exceeded the breaking load and the lashing chains were broken. When a single lashing chain was broken, other lashing chains were broken one after another, which then caused the chassis to slide.

[6] When the Vessel was hit by the second wave on the port quarter at about 55° with a wave height of about 4.6 meters and the midship was situated on a down slope of the wave, the Vessel listed about 40° to starboard due to collapse of cargoes as they slid sideways while accelerated by the outward heel generated during turning to port.

(4) Passenger rescue

All of the seven passengers and 14 crew members were rescued by the helicopter of the Japan Coast Guard which came over the Vessel, while the master and the six maintenance and security crew, who evacuated from the Vessel after dropping two Inflatable Liferafts to the sea, were rescued afterward by the patrol craft.

(5) Causal factors of the occurrence of the accident

It is probable that the Vessel heeled about 25° to starboard and the containers and other cargoes on board the Vessel started collapsing as they slid sideways after being hit by the First Wave on the port quarter at about 40° with a wave height of about 6.9 meters, because the Vessel was navigating in the Dangerous Zone in Following Seas with High Waves while proceeding in the southwest direction in the Kumano Nada.

It is probable that both the master and the chief officer deemed the Vessel was resistant to following sea conditions, as they had no knowledge about the Dangerous Zone in Following Seas with High Waves, and as the master had not experienced any large ship motions on board the Vessel even while proceeding in following seas.

It is probable that Company A had not taken any preventive measures against cars and other cargoes moving sideways excessively which were compatible with the standard prescribed in Standards for Construction of Ro-Pax Ferry, according to the findings that although a non-slip painting material was coated on the deck boards in the car spaces at the time of shipbuilding the Vessel, a similar painting material had not been coated on C Deck and D Deck by the time of the occurrence of the accident, and the coating of both decks was peeled off.

4.2 Probable Causes

It is probable that the accident occurred when the Vessel heeled about 25° to starboard and cargoes on board the Vessel started collapsing as they slid sideways after being hit by a wave on the port quarter at about 40° with a wave height of about 6.9 meters, because the Vessel was navigating in the Dangerous Zone in Following Seas with High Waves while proceeding in the southwest direction in the Kumano Nada during the night.

It is probable that the reason why the Vessel was navigating in the Dangerous Zone in Following Seas with High Waves was that both the master and the chief officer deemed the Vessel was resistant to following sea conditions, as they had no knowledge about the Dangerous Zone, and as the master had not experienced any large ship motions on board the Vessel even while proceeding in following seas.

It is probable that the reason why cargoes on board the Vessel started sliding was that Company A had not taken any preventive measures against excessive cargo shifting with the deck boards in the car spaces as prescribed in Standards for Construction of Car Ferries.

5 REMARKS

It is probable that the accident occurred when the Vessel heeled about 25° to starboard and cargoes on board the Vessel started collapsing while navigating in following sea conditions.

It is desirable that vessel operating companies should reconfirm that they are entrusted with ensuring the safety of human lives and transport, mention in their safety management manuals (operation standard) about hazards while navigating in following sea conditions as described in the Navigation Guidance in Adverse Weather Conditions, and provide a safety education to those who are engaged in vessel operation and acquaint them thoroughly with the hazards. Moreover, in order to prevent containers from being caused to slide by the listing of a vessel, it is desirable that vessel operating companies should study effective lashing methods for cargoes on board, and consider not only coating deck boards with non-slip painting materials but also installing prevention devices for collapse of cargoes like stringers and detachable cones.

6 ACTIONS TAKEN

6.1 Actions Taken by Company A After the Accident

In accordance with the provisions in the safety management manual (Article 50), Company A established an accident investigation committee on November 15, 2009, which started interviewing the crew of the Vessel to investigate the cause of the accident and the appropriateness of the accident handling.

As a result, the accident investigation committee reached the following conclusions.

(1) As it was difficult for the accident investigation committee of Company A to draw a conclusion from many unknown factors about the cause of the accident, it decided to watch the development of the investigation by the public organization.

(2) It concluded that the crew took care of the passengers appropriately.

Company A took the following measures to prevent recurrence of similar accidents, and reported the contents of the measures to the Ministry of Land, Infrastructure, Transport and Tourism.

(1) Concerning lashing of cargoes on board, the following instructions were given to each vessel as the company order.

[1] The tires of all the vehicles should be secured with wheel chokes.

[2] All the vehicles should be lashed.

[3] Irrespective of weather conditions, heavy loading vehicles as well as chassis and trucks with a high center of gravity should be securely top-over lashed without fail.

[4] When adverse weather conditions are expected, all the chassis and large-sized vehicles should be secured with reinforced lashings in addition to be top-over lashed.

[5] Containers and loose cargoes should also be secured with reinforced lashings without fail.

(2) Concerning stacking of cargoes on board, the following instructions were given to each vessel as the company order.

[1] When stacking cargoes, the balance between the port and the starboard, and the top and the bottom should be considered.

[2] Never fail to load cargoes on a lower deck in order to ensure the stability of the hull.

[3] A shipboard patrol should be implemented in compliance with the safety management manual (work standard).

(3) Concerning lashing of cargoes on board, instructions were given to each vessel that a method ensuring secure lashing should be implemented in accordance with the newly created lashing manual.

(4) The outline of the newly created lashing manual is as follows.

[1] Lashing devices should be installed at an angle of about 30° to 60° to the horizontal plane and to the vertical plane as well.

[2] When the friction force between a cargo and a deck board is insufficient, suitable materials like soft boards and dunnages should be used to increase the friction force.

[3] When adverse weather conditions are expected, lashings should be tightened and reinforced, or top-over lashing should be implemented.

[4] As a standard, large-sized trucks should be secured with 6-Point Lashing Chains or 6-point lashing belts in addition to a single top-over lashing.

[5] As a standard, chassis should be secured with 6-Point Lashing Chains. While in adverse weather conditions, lashings with lashing chains and top-over lashing should be reinforced according to the shape and the weight of the body.

[6] As a general guideline, heavy machines and special vehicles should be secured with four lashing chains when the weight is less than 20 tons, with six lashing chains when between 20 tons and 40 tons, and with about eight lashing chains when 40 tons or more.

[7] Containers loaded in a cargo hold should be secured with 4-Point Lashing Chains when they are stacked flat independently. When containers are double-stacked, a cone should be placed on two positions and the containers should be secured on the lashing points on the deck board with lashing chains at intervals of three rows in principle, or should be connected together. When containers are loaded together with vehicles (trucks and chassis) or while in adverse weather conditions, lashings with lashing chains should be reinforced.

[8] Standards for disposal of lashing chains and lashing belts have been established. Moreover, Company A assigned an auditor additionally from outside for internal audits provide for in the safety management manual.

6.2 Actions Taken by Ministry of Land, Infrastructure, Transport and Tourism

6.2.1 On-Site Inspection at Company A and Directions Given

On November 26, 2009, the Ministry of Land, Infrastructure, Transport and Tourism conducted an on-site inspection at Company A on the basis of the Maritime Transport Act, and on January 13, 2010, the Ministry directed Company A to implement a shipboard patrol in full accordance with the safety management manual, review the work standard in the manual, create a lashing manual for the cargoes to be handled, and make sure that lashing of cargoes on board a vessel underway was securely implemented. Moreover, the Ministry conducted on-site inspections for 24 sea routes by 18 operators with a focus on long distance ro-ro passenger ferry routes in order to check the lashing conditions of cargoes on board.

As a result, the Ministry directed relevant operators to implement a shipboard patrol in full accordance with their safety management manuals, review the work standards in their manuals, create a lashing manual for the cargoes to be handled, and make sure that lashing of cargoes on board a vessel underway was securely implemented.

6.2.2 Recommendations to Relevant Industries

On April 6, 2010, the Ministry of Land, Infrastructure, Transport and Tourism reminded the relevant industries of hazards while navigating in following sea conditions as described in the Navigation Guidance in Adverse Weather Conditions as well as matters to be noted while maneuvering a vessel.

6.2.3 Measures to Prevent Recurrence of Similar Accidents

The Ministry of Land, Infrastructure, Transport and Tourism established “Committee for Studying Measures to Prevent Accidents by Heavy Listing of Ro-Ro-Passenger Ferries” consisting of persons with relevant knowledge and experience as well as persons in the relevant industries, where measures such as preventing heavy listing of a vessel while navigating in adverse weather conditions, preventing cargo shifting from being caused by the list of a vessel, and improving the safety in the operation of ro-ro-passenger ferries and other vessels have been under study.

Figure 1: Navigation Route 1

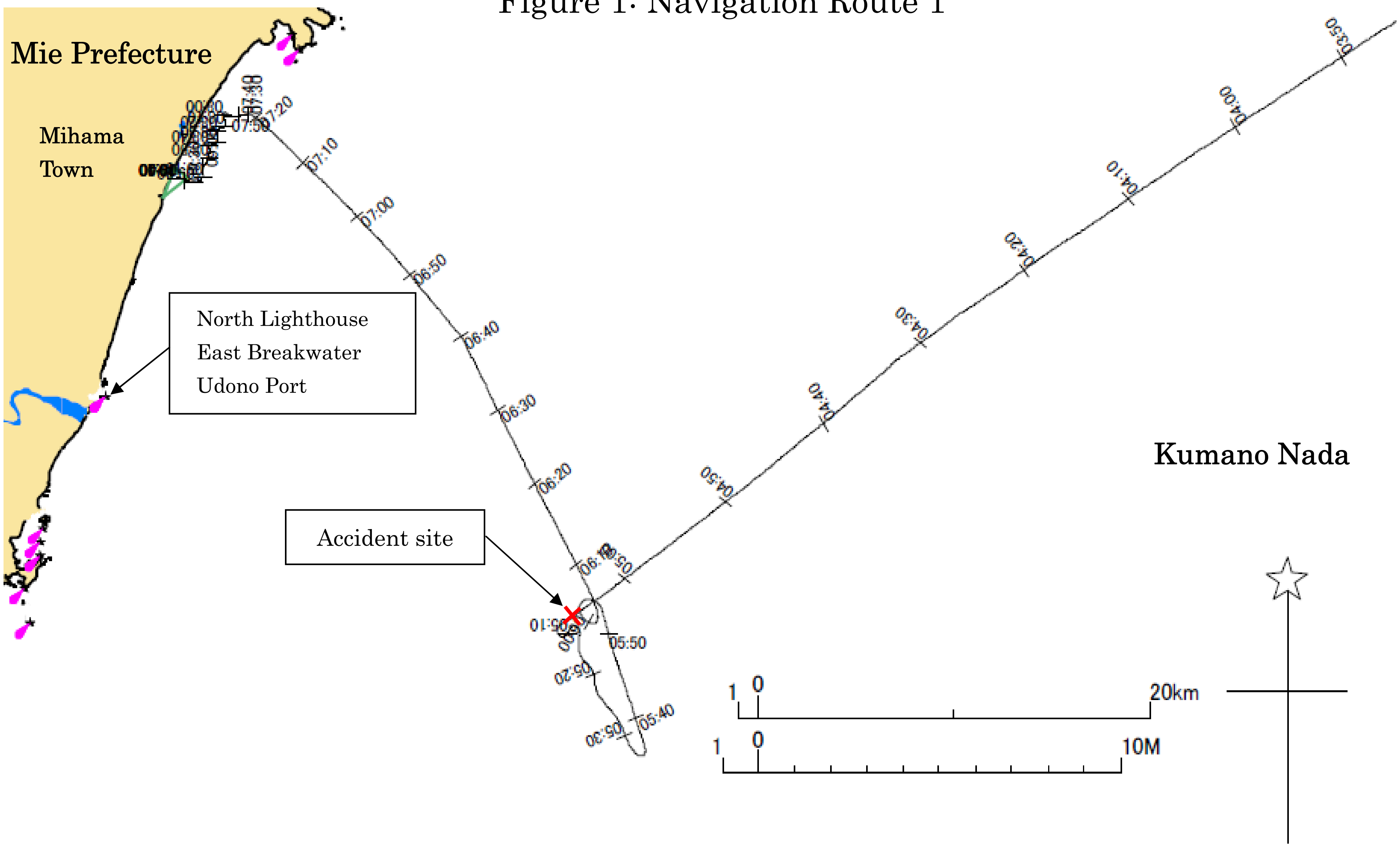


Figure 2: Navigation Route 2

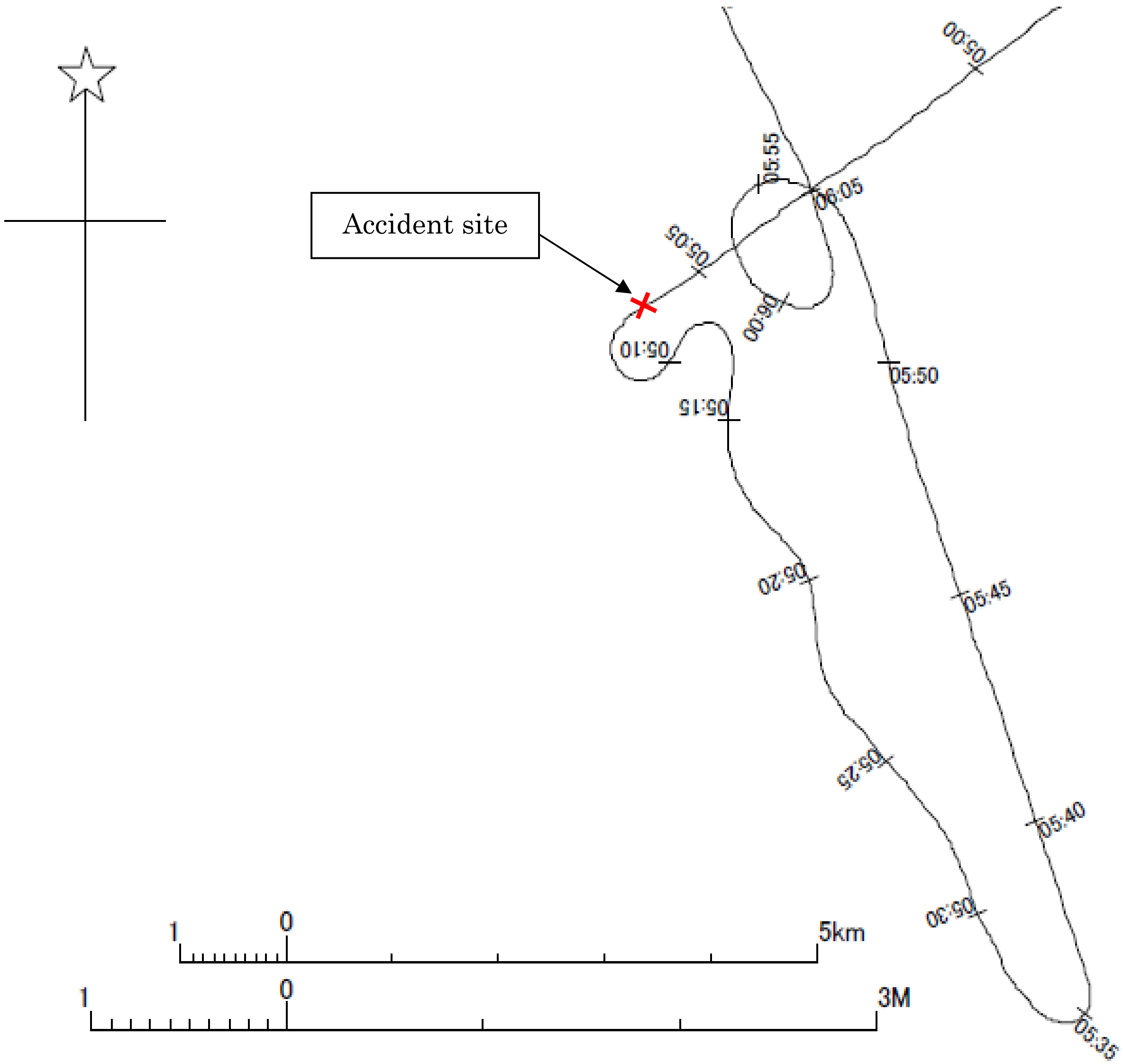


Figure 3: Navigation Route 3

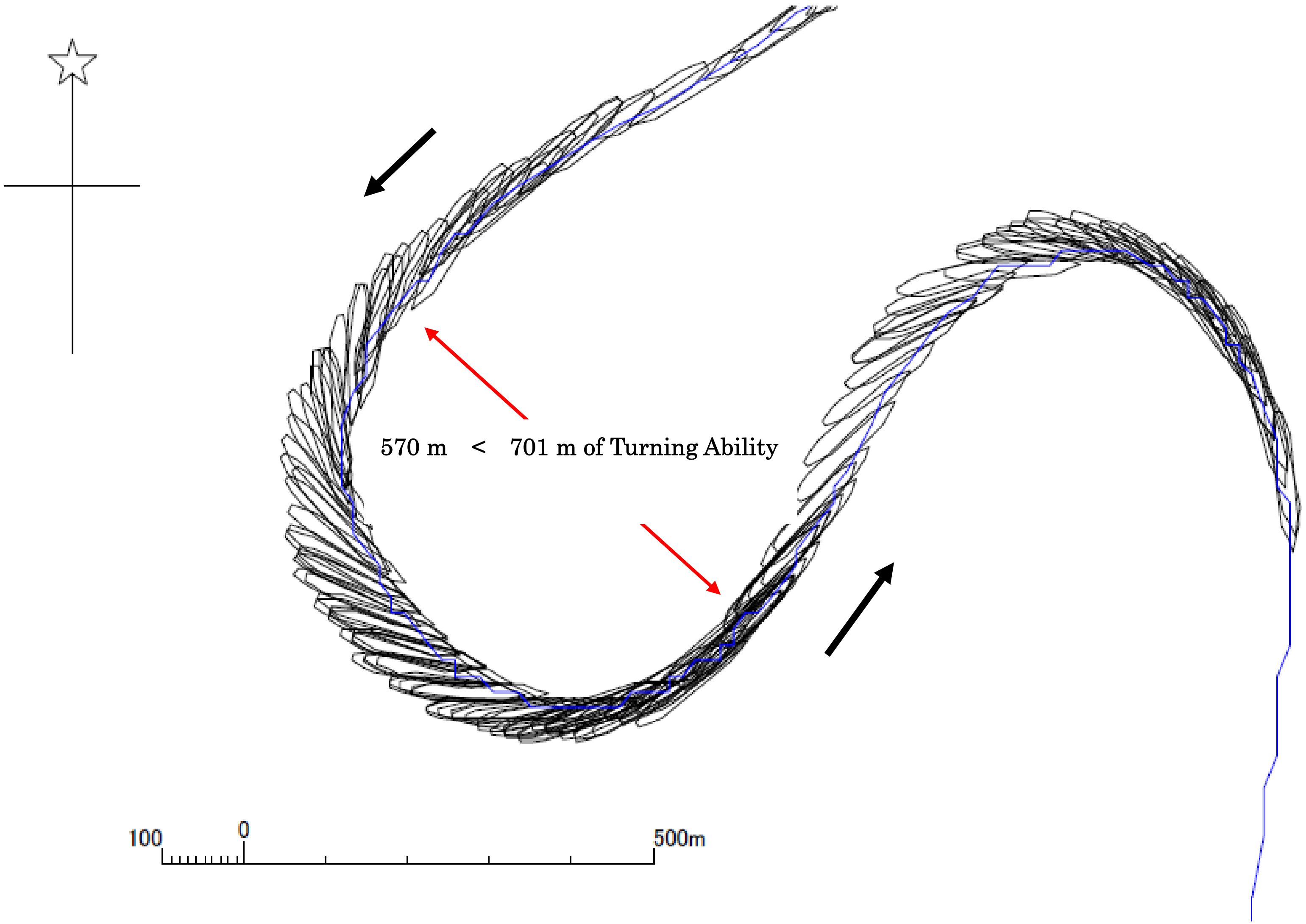


Figure 4: Wave Observation and Analysis
(as of 21, November 12, 2009)

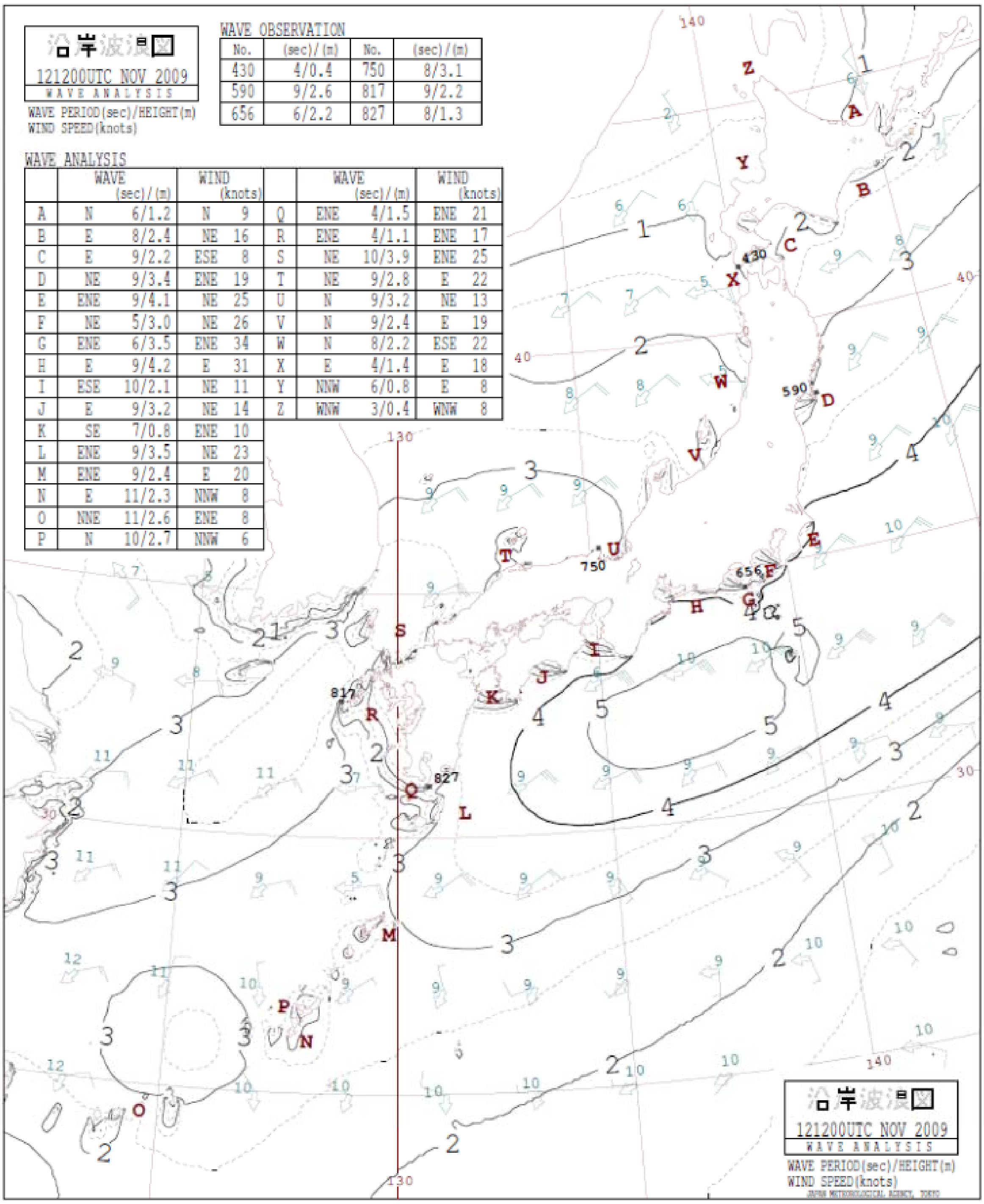


Figure 5: Heading and Course Over the Ground (COG)

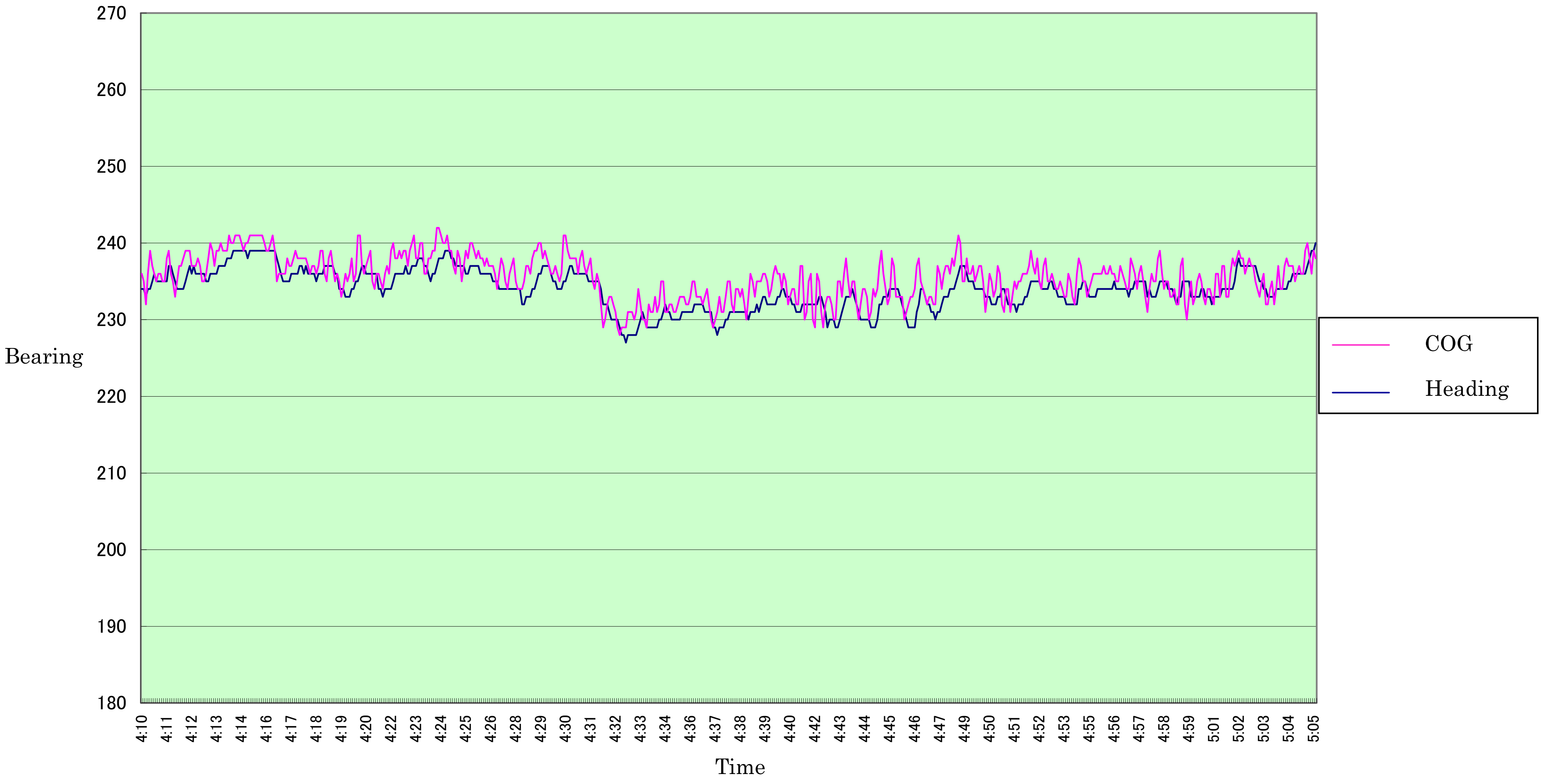


Figure 6: General Arrangement Plan

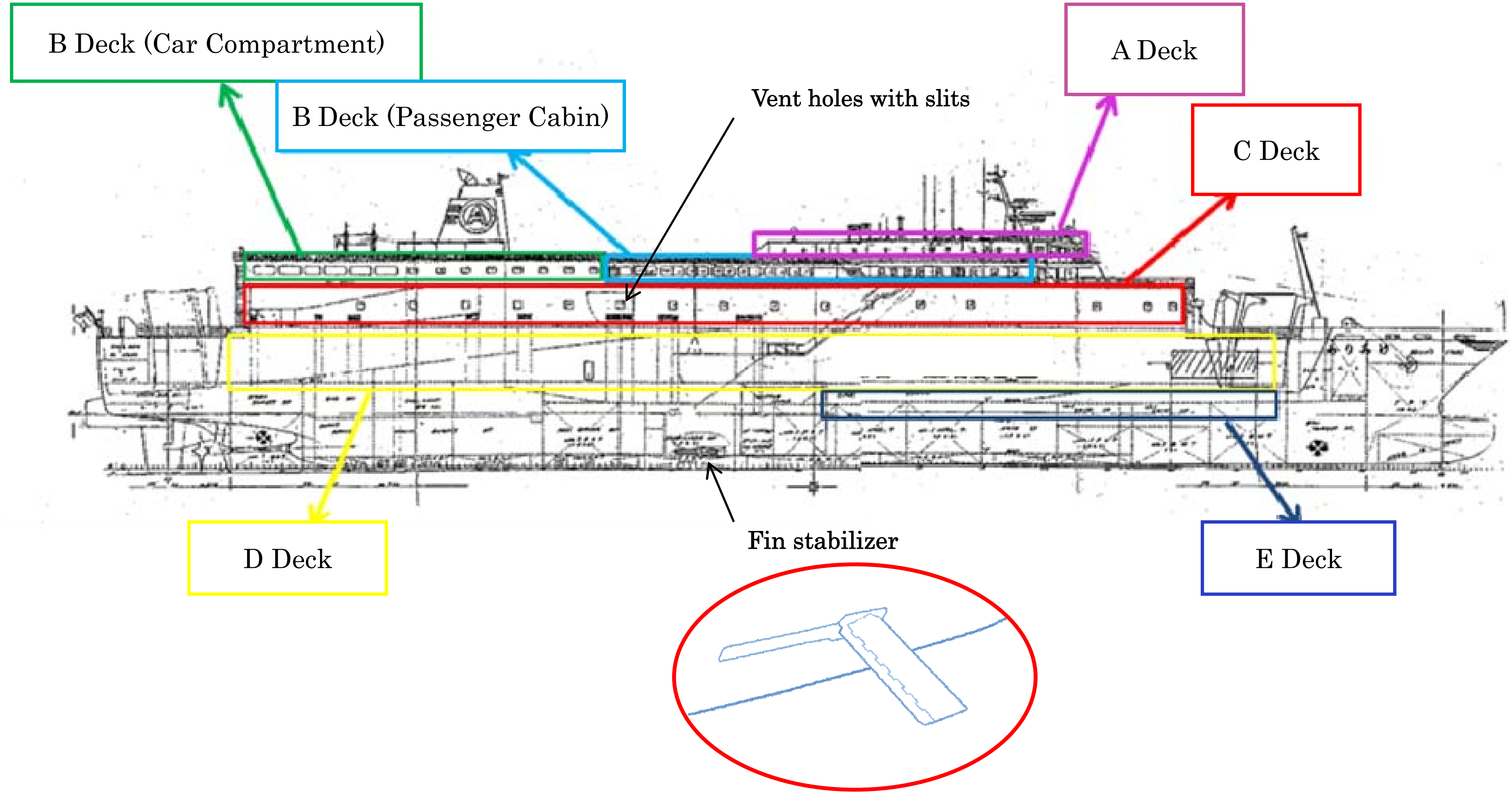


Figure 7: Evacuation Route of the Passenger

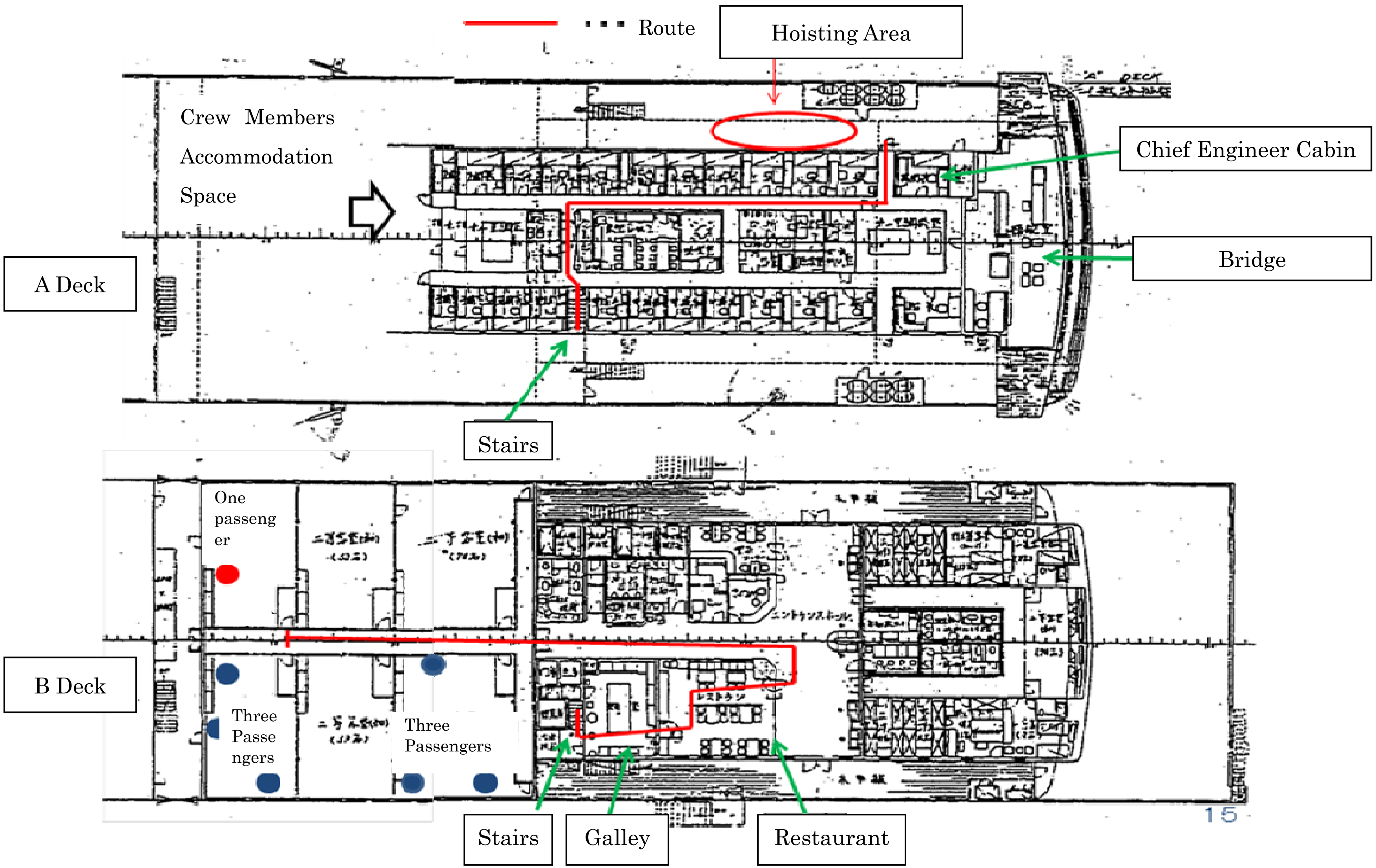


Figure 8: Schematic Diagram of Cargoes Stowage (Deck C)

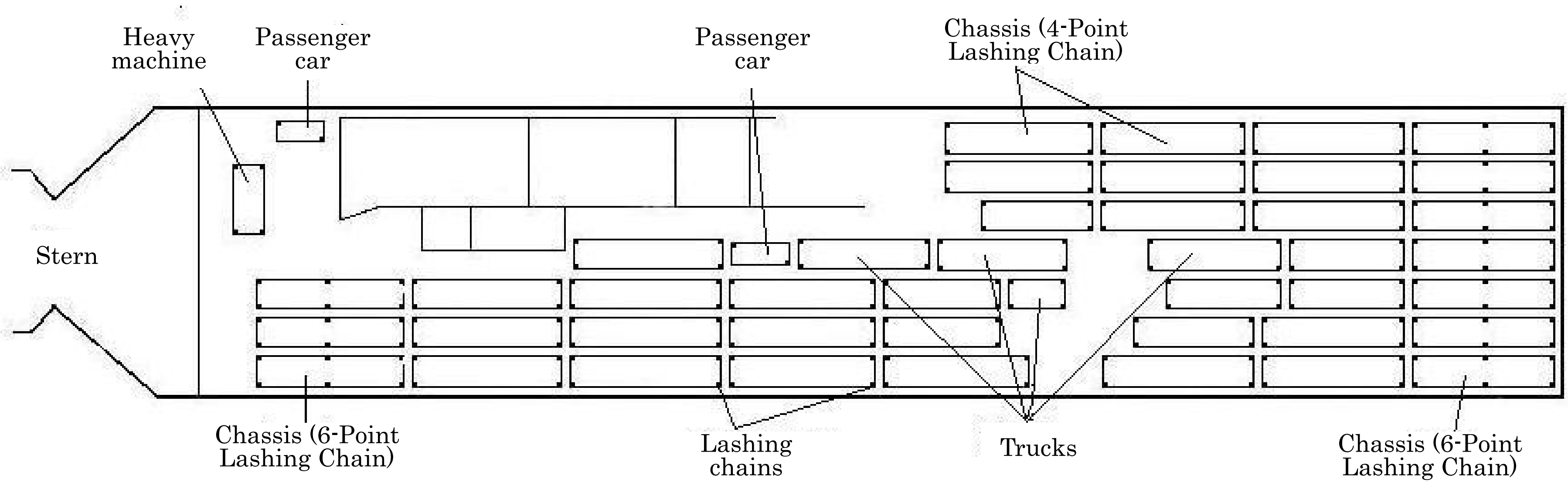


Figure 9: Schematic Diagram of Cargo Stacking (D Deck)

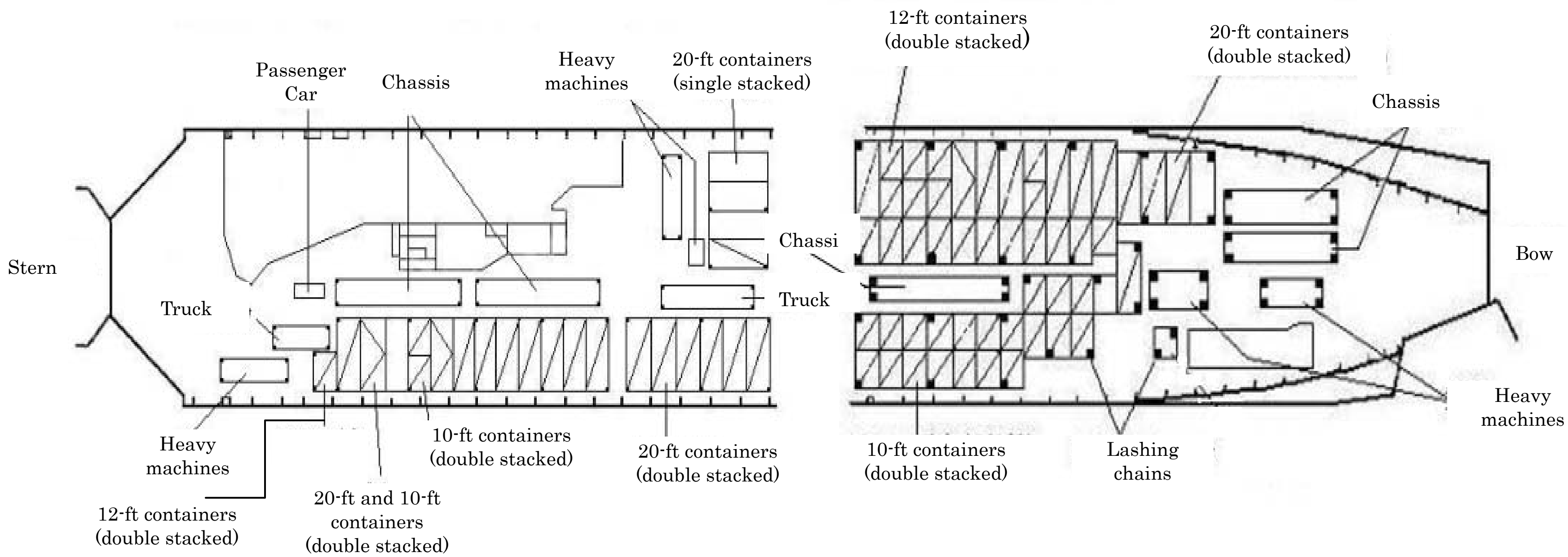
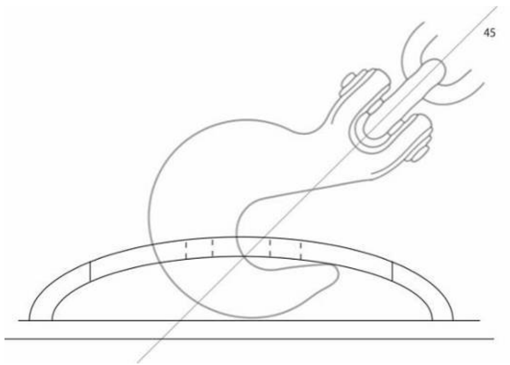
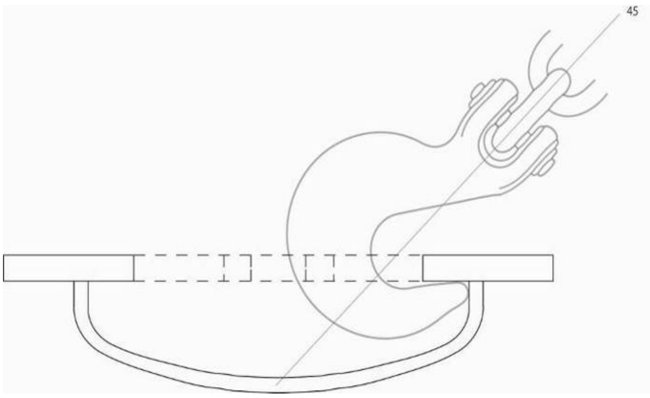


Figure 10: Fixed Lashing Points

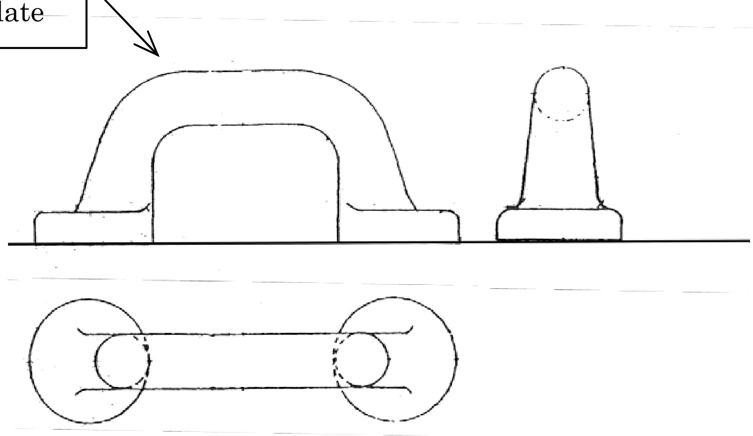


Point of contact (45°) between a hook and a cloverleaf (projecting type)



Point of contact (45°) between a hook and a cloverleaf (recessed type)

Eye plate



Crinkle bar

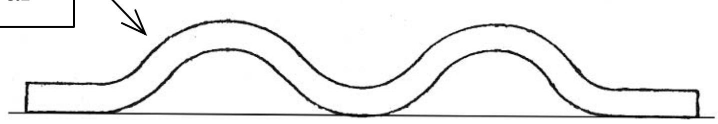


Figure 11: Lashing Devices (Part 1)

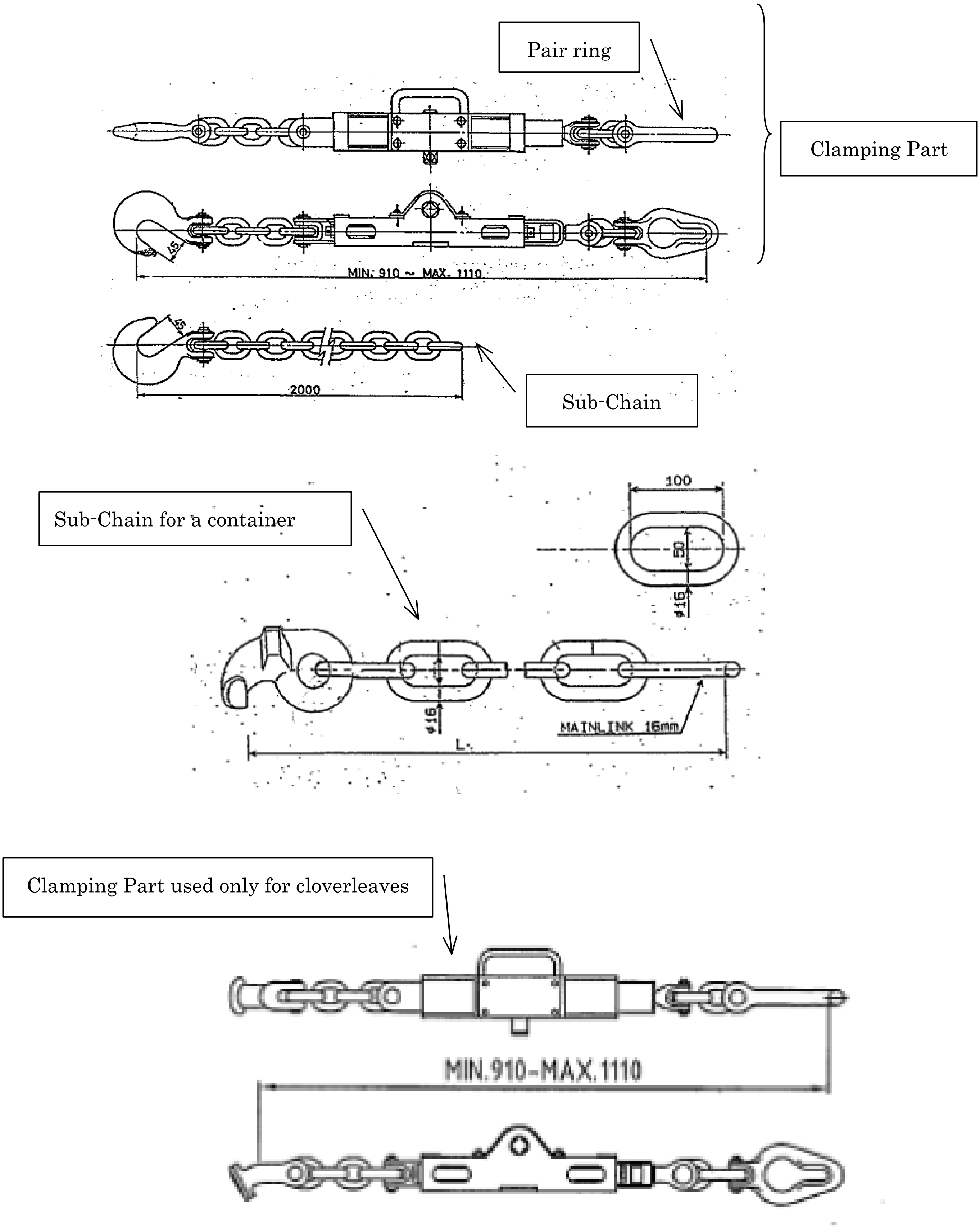
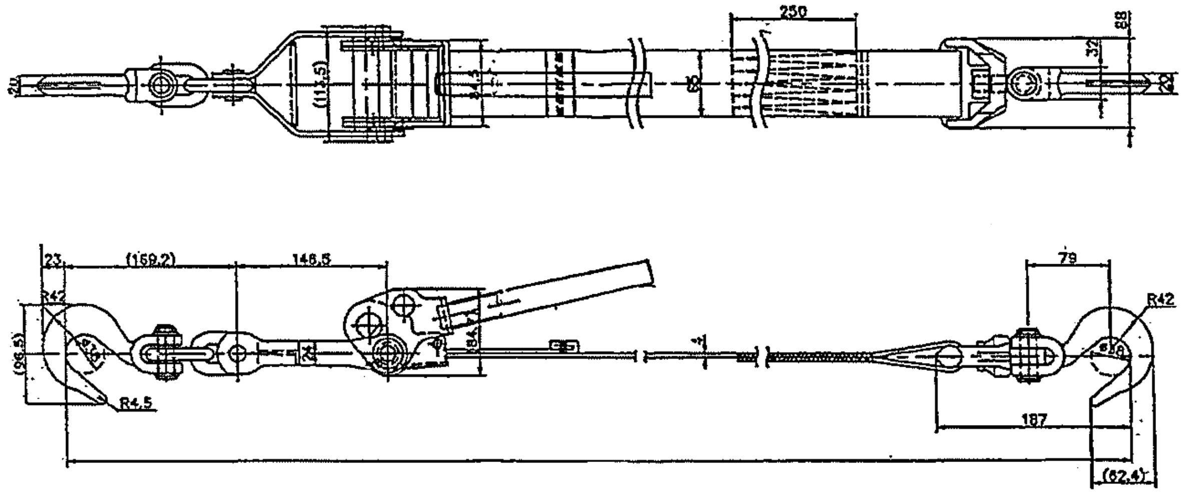


Figure 12: Lashing Devices (Part 2)

Lashing belt



Cone

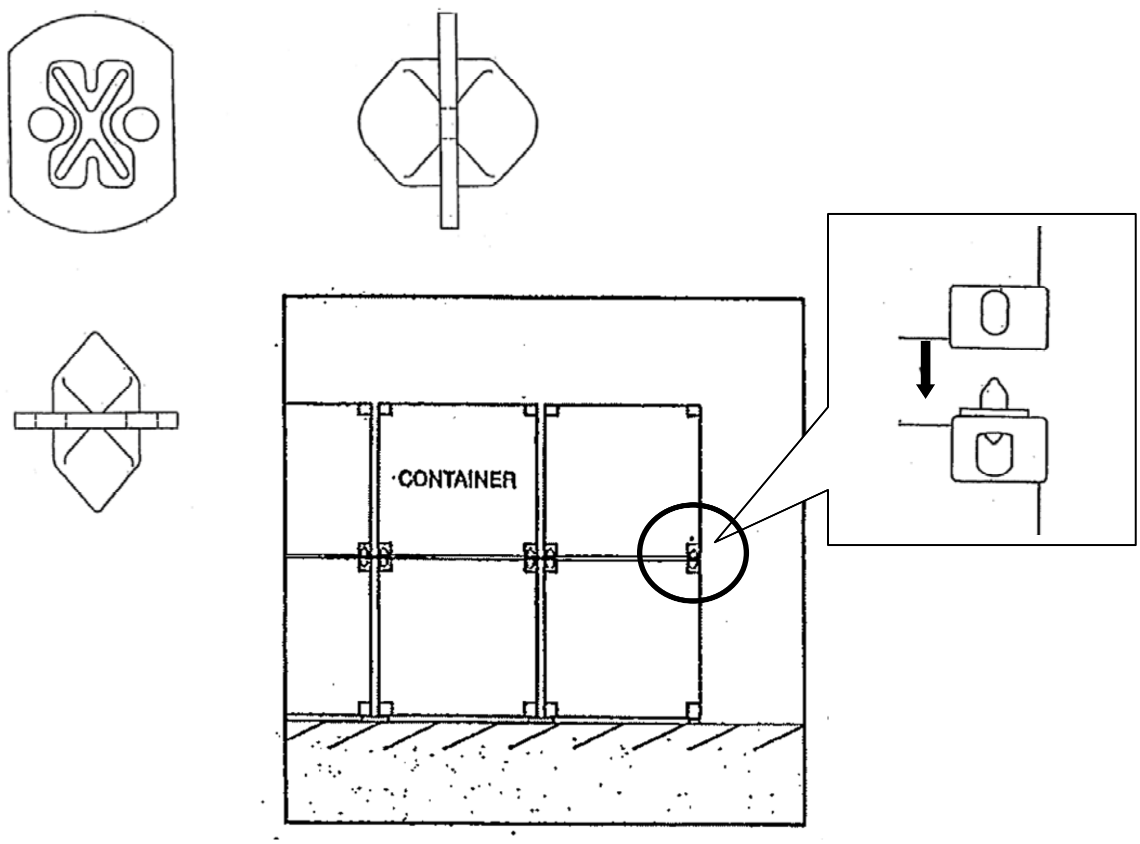
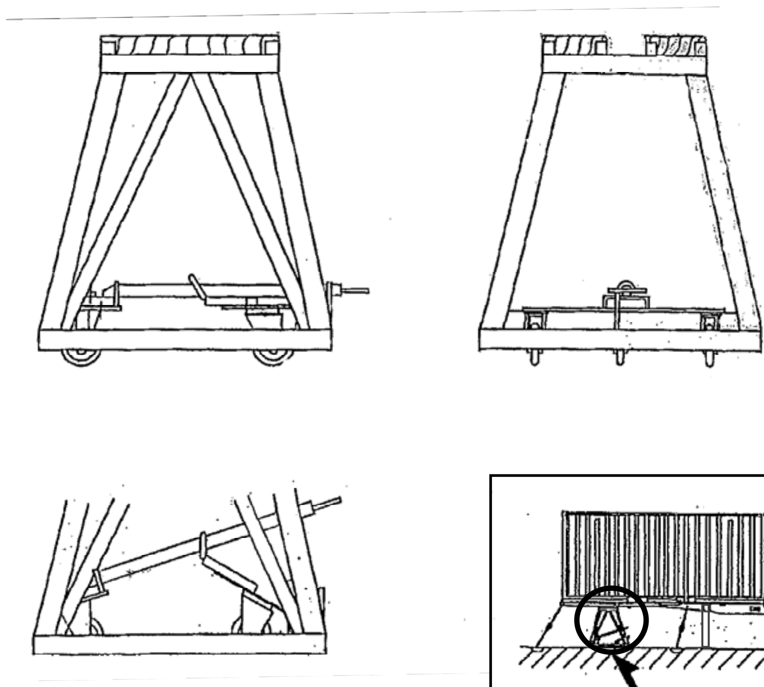
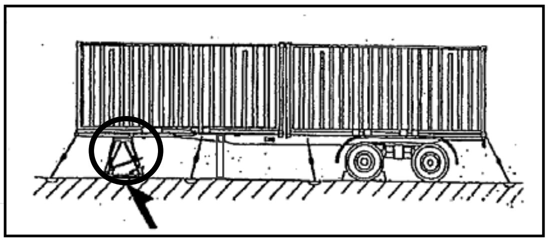


Figure 13: Lashing Devices (Part 3)

Sub landing gear





Wheel choke

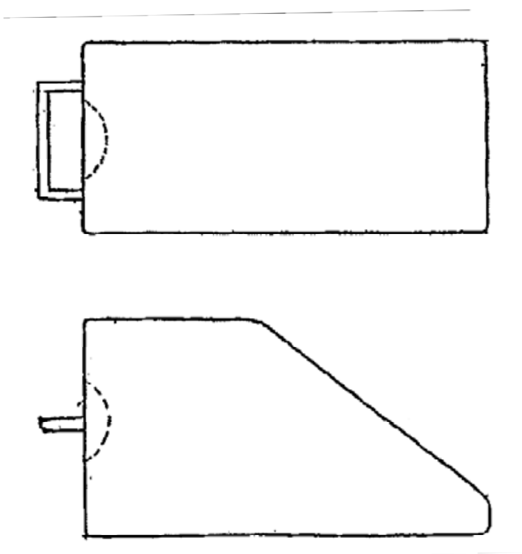
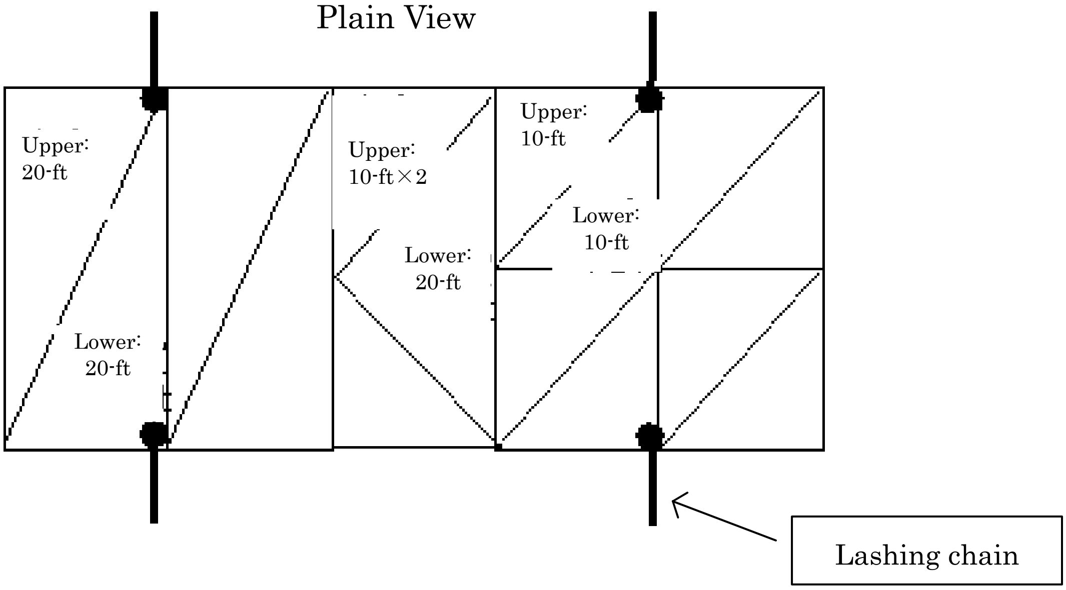


Figure 14: Lashing Condition of Containers

Plain View



Side View

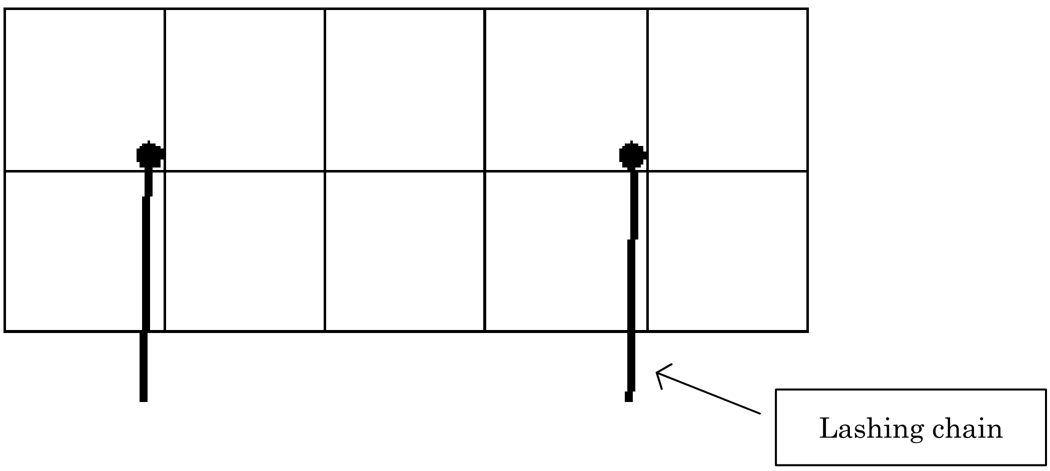


Figure 15: Lashing Conditions of Chassis

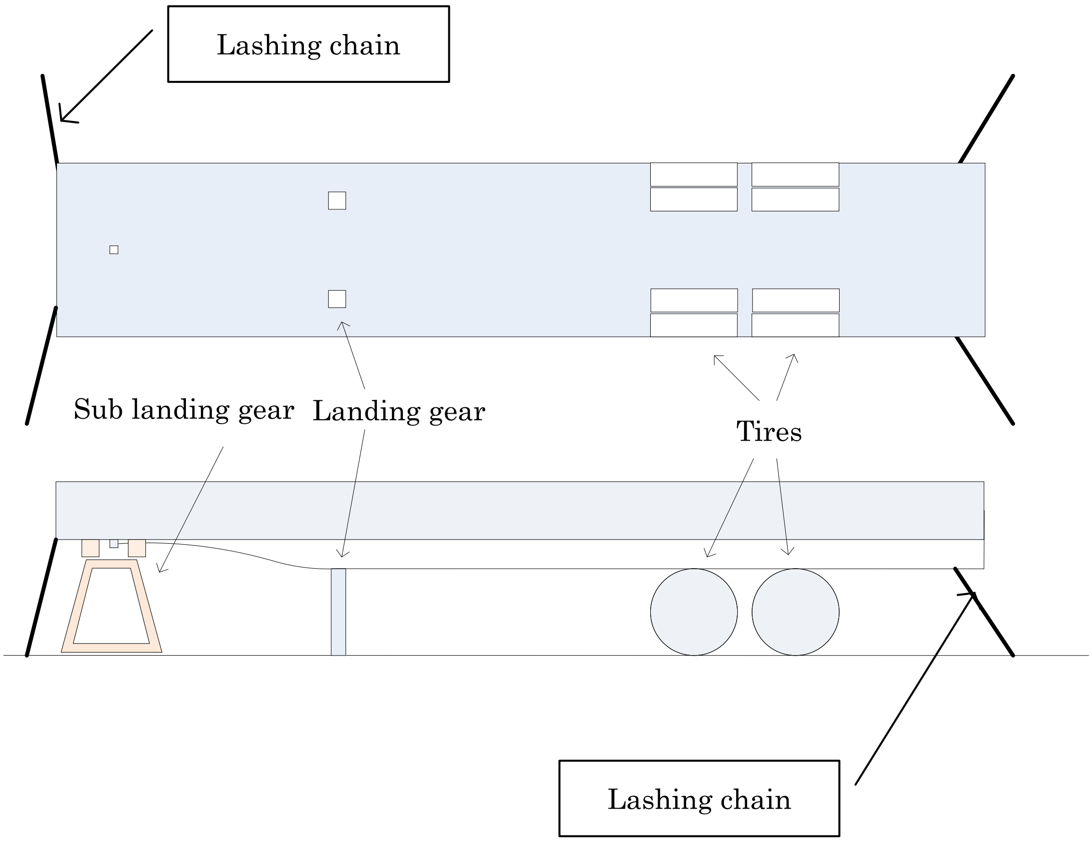


Figure 16: Shifting of Containers and Chassis

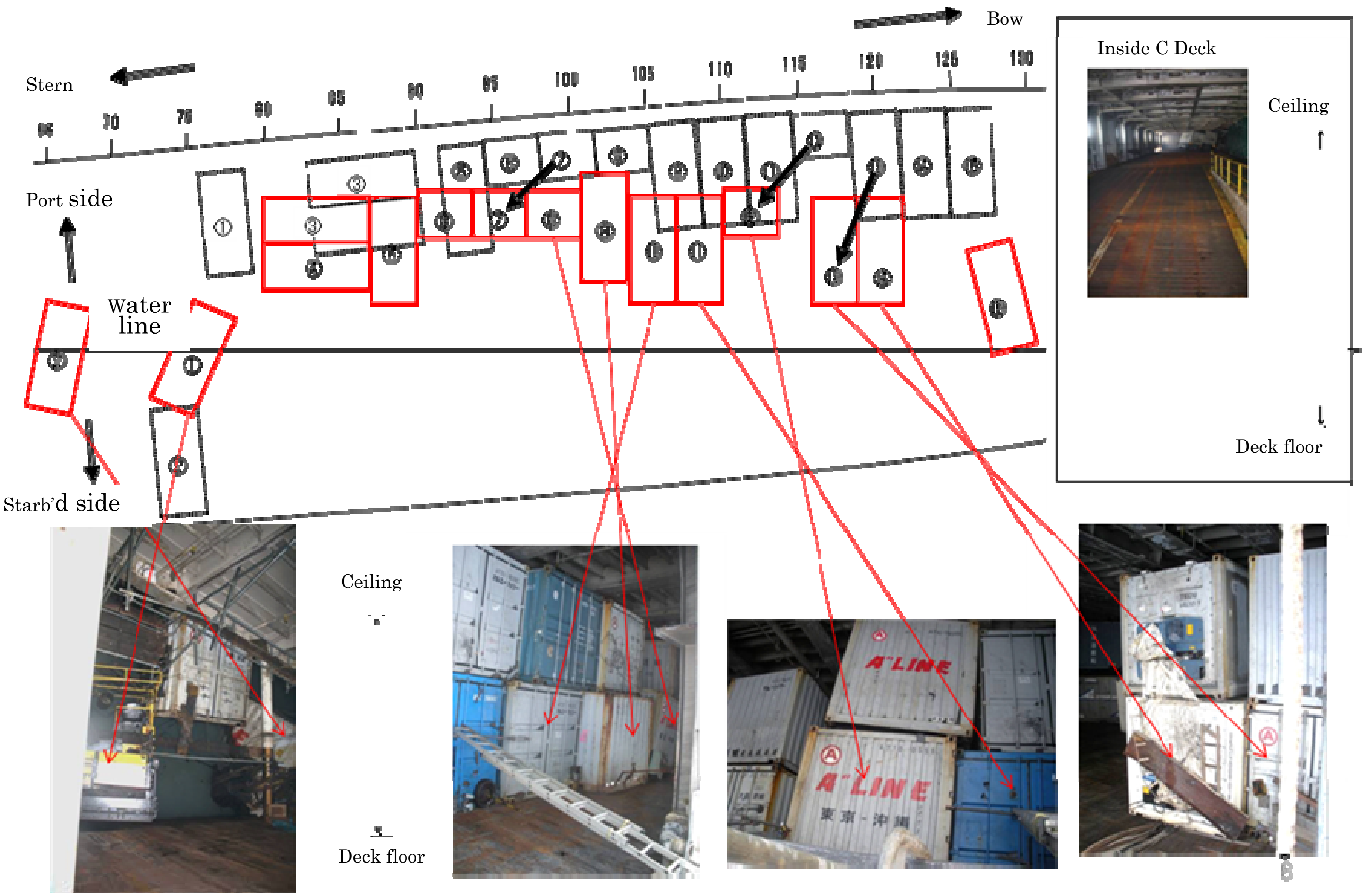


Figure 17: Vessel Speed Changes Immediately Before the Occurrence of the Accident

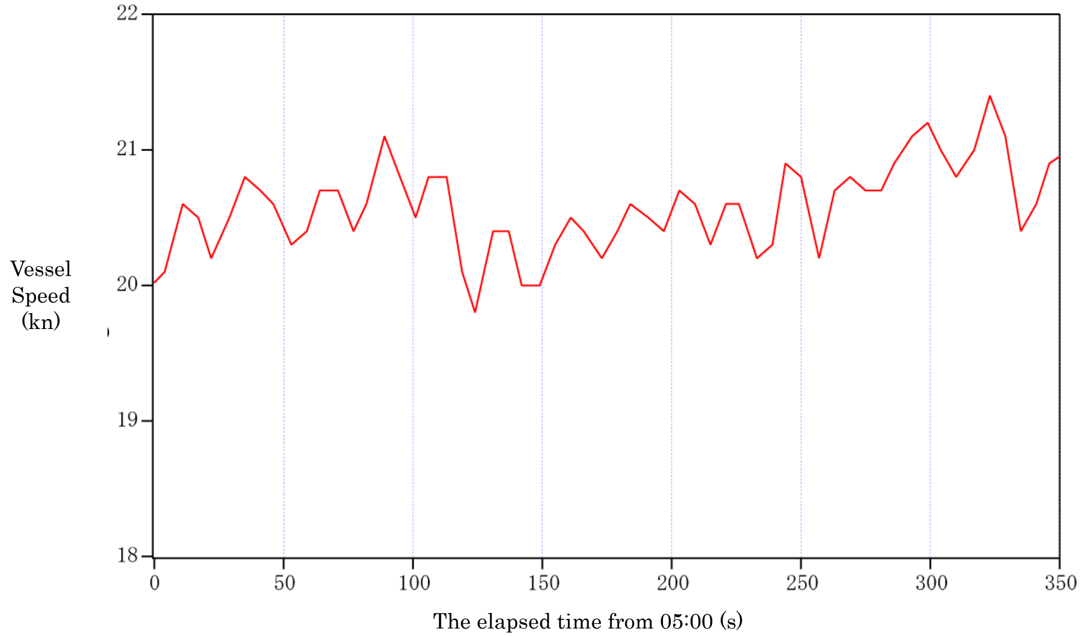


Figure 18: Stability Curves in Smooth Water at the Time of Departure and the Accident

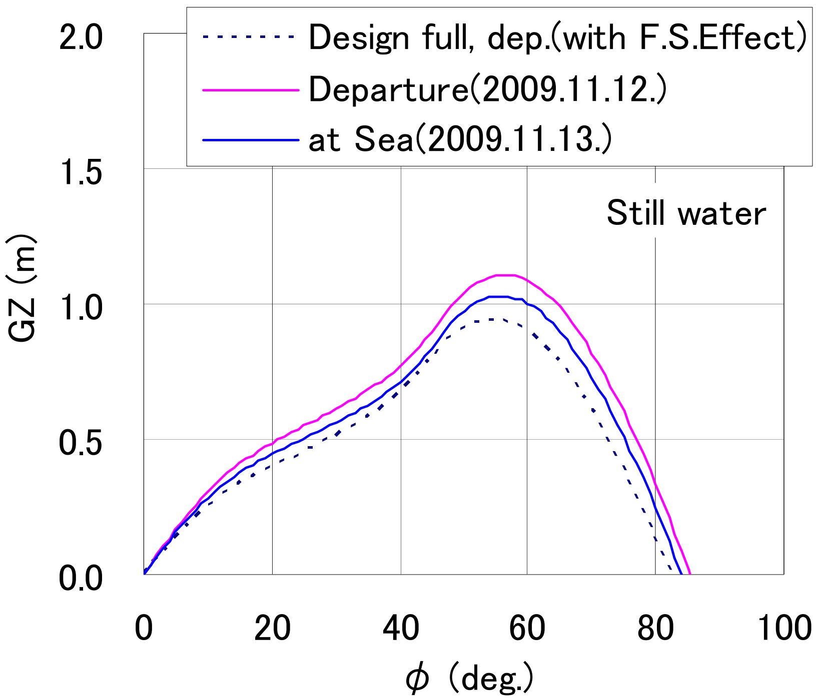


Figure 19: Stability Curves in High Waves at the Time of the Accident

(quartering seas with waves 30° left oblique, ratio of the hull length to the wavelength: 1.0, the midship: on a down slope of the wave)

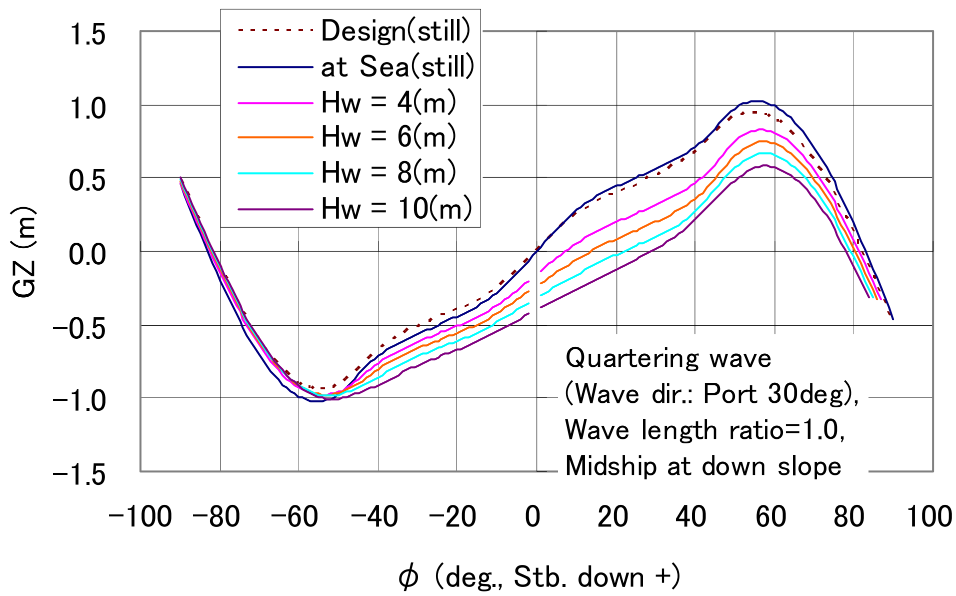


Figure 20: Relation Between Angle of List and Listing Moment

(quartering seas with waves 30° left oblique, ratio of the hull length to the wavelength: 1.0, the midship: on a down slope of the wave)

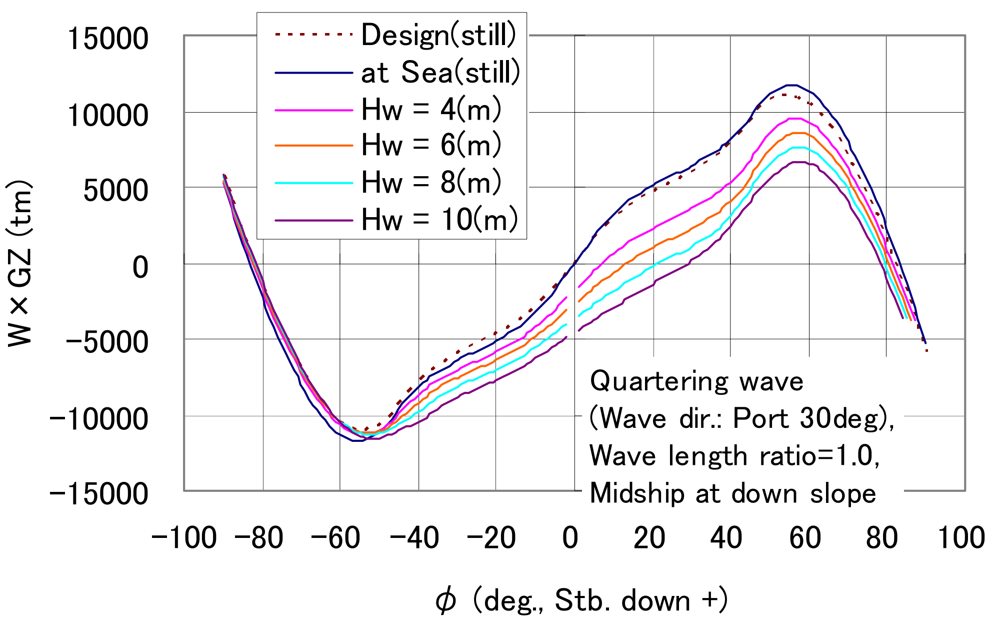


Figure 21: Dimensionless Rate-of-Turn Speed Obtained From AIS Records

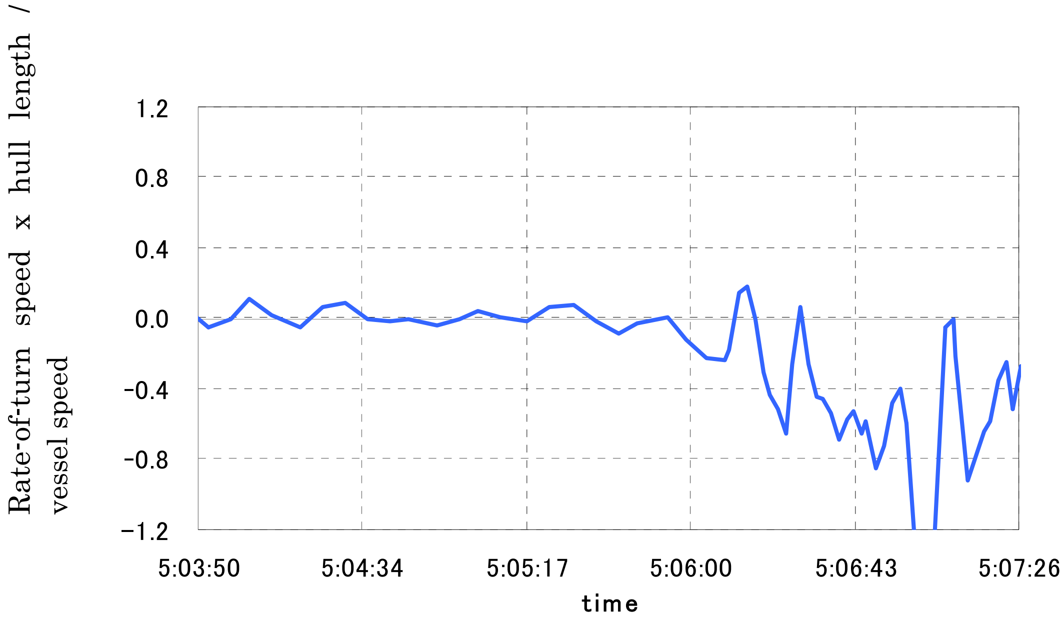


Figure 22: Vessel Speed Obtained From AIS Records

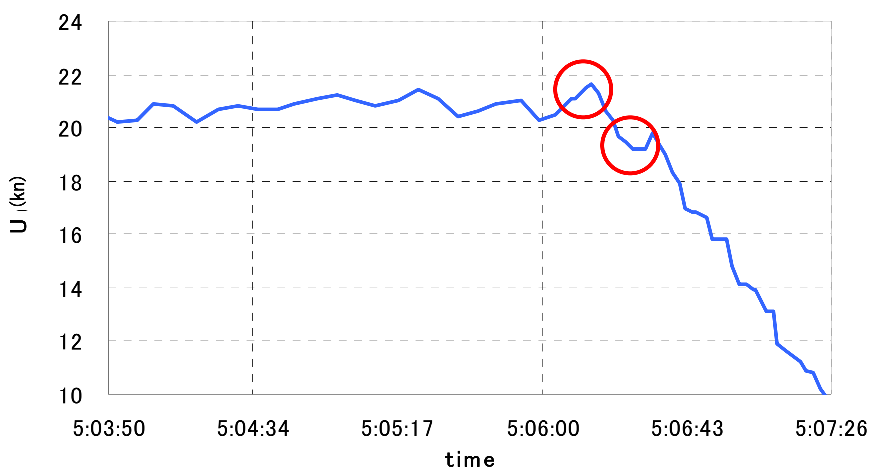
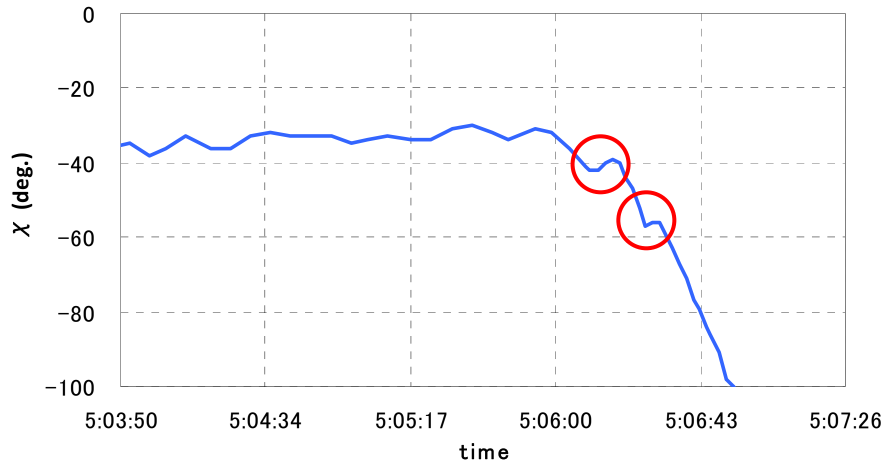


Figure 23: Angle of Encounter With Waves Obtained From AIS Records and Estimated Values by Weather Association



χ indicates an angle of encounter with a wave, while − (minus) indicates waves coming on the port side.

Figure 24: Heeling Moment and Angle of Heel in the First Wave

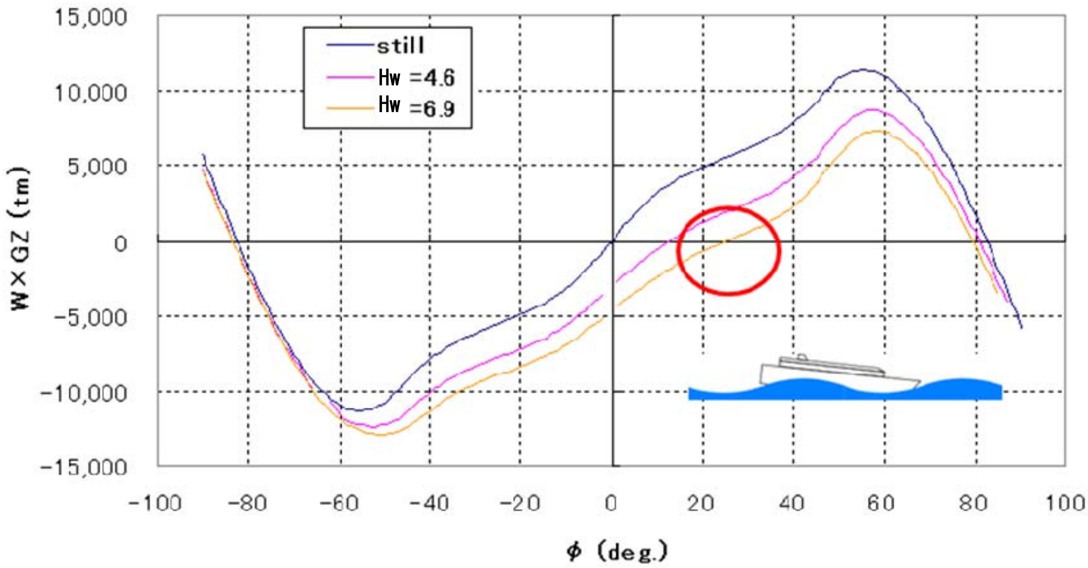


Figure 25: Heeling Moment and Angle of Heel in the Second Wave

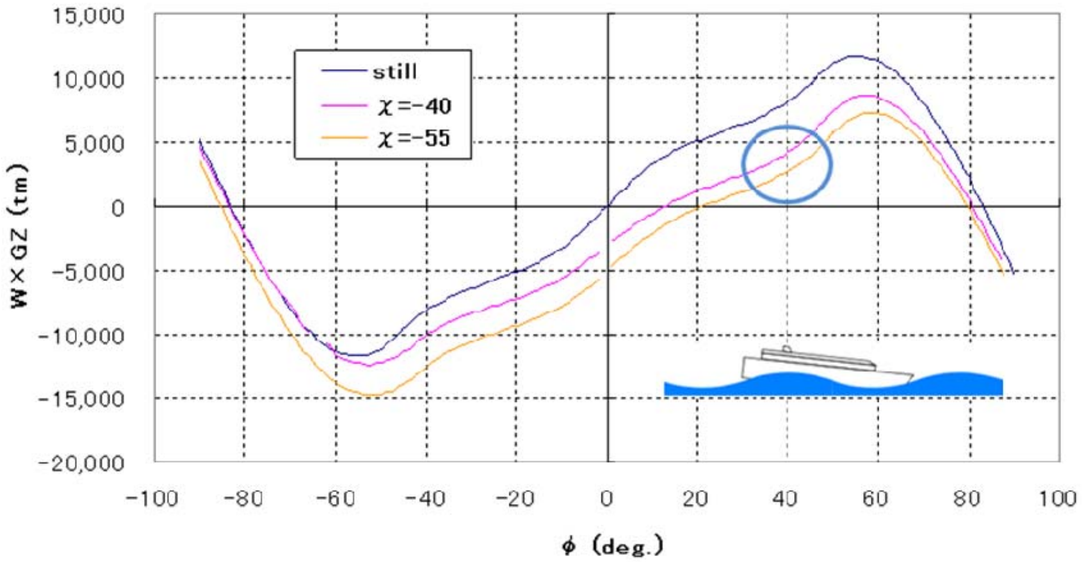


Figure 26: Dangerous Zone in Following Seas with High Waves

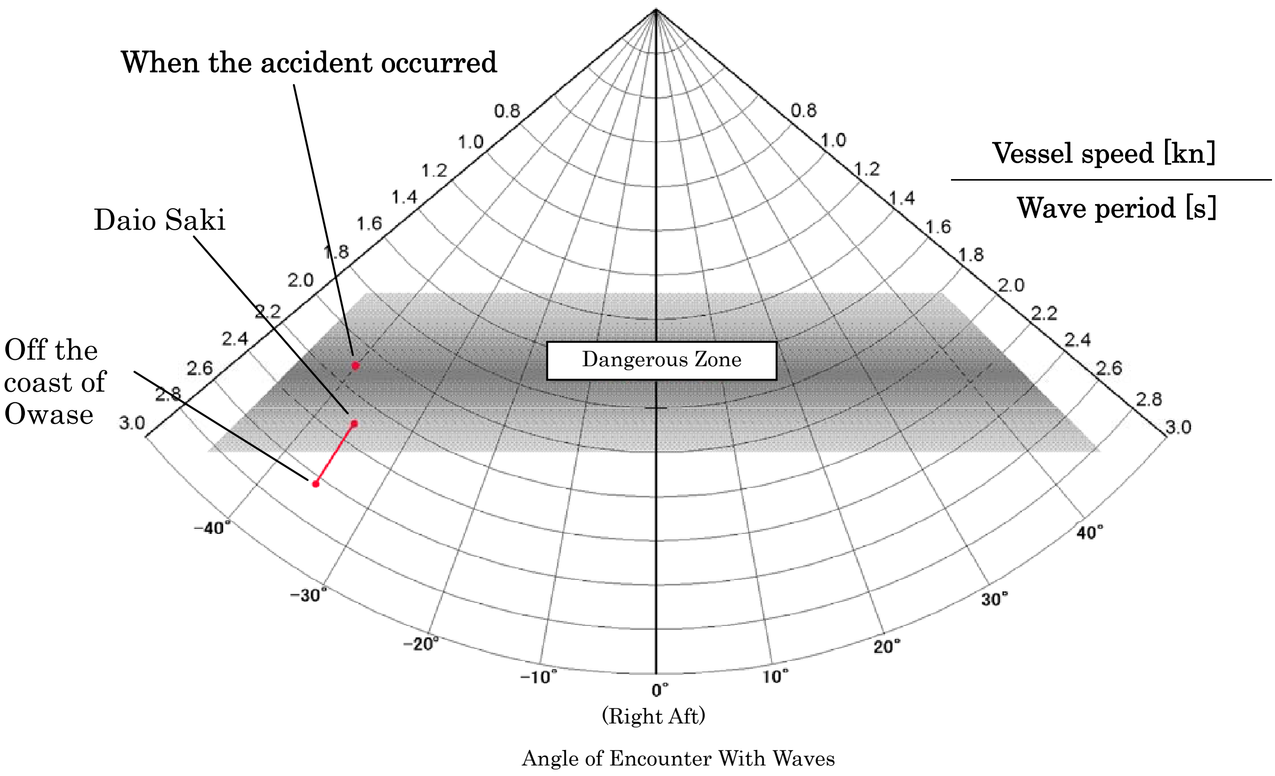


Table 1: Weight and Balance Sheet at the Time of Departure

CONDITION	DEPARTURE CONDITION							
ITEM	LOAD (%)	WEIGHT (KT)	Mid-G (M)	MOMENT (KT-M)	KG (M)	MOMENT (KT-M)	IXSF (M4)	ρ
DEADWEIGHT CONSTANT		37.52			5.17	193.98		0
PROVISION		5.00			23.74	118.70		0
CARGO;–								
Crews (A DECK)		2.52			25.13	63.33		
PASSENGER (B DECK)		0.84			22.35	18.77		
FAMILY CAR (B DECK)		8.29			22.02	182.44		
FAMILY CAR (C DECK)		3.60			17.55	63.18		
FAMILY CAR (E DECK)		25.00			8.48	212.00		
LARGE-SIZED CAR (C DECK)		30.85			18.59	573.50		
LARGE-SIZED CAR (D DECK)		161.27			14.10	2273.91		
CHASSIS (C DECK)		948.66			18.59	17635.63		
CHASSIS (C DK & SLOP W.)		59.10			14.10	833.31		
CONTAINERS (C DK & SLOP W.)		1086.23			12.53	13610.50		
Others(A deck)		0.70			25.13	17.59		
Others(B deck)		7.50			22.35	167.63		
Others(C deck)		18.20			13.95	253.89		
Others(D deck)		37.20			11.80	438.96		
Others(the tanks of the deck department)		13.90			12.70	176.53		
SUB TOTAL		2403.86			15.19	36521.16		
BALLAST;–								
F.P.T(B.W.). （C）					8.59	0.00		
NO.1 B.W.T. （C）	47	200.00			3.07	614.00	317.00	1.025
NO.2 B.W.T. （C）					3.15	0.00		
NO.3 B.W.T. （C）					1.01	0.00		
NO.4 B.W.T. （C）	100	156.21			0.97	151.52		
NO.5 B.W.T. （C）	100	282.89			0.92	260.26		
NO.6 B.W.T. （C）					0.85	0.00		
NO.7 B.W.T. （C）					4.70	0.00		
A.P.T(B.W.). （C）					7.86	0.00		
NO.1 HEEL..T.(P&S)	50	240.00			3.52	844.80	190.00	1.025
NO.2 HEEL..T.(P&S)	50	240.00			3.27	784.80	165.00	1.025
SUB TOTAL		1119.10			2.37	2655.38	672.00	
FUEL OIL;–								
NO.1 F.O.T.(C-OIL) (P)		107.70	1.13		3.26	351.10	66.70	0.95
NO.1 F.O.T.(C-OIL) (S)		103.28	1.13		3.21	331.53	65.90	0.95
NO.2 F.O.T.(C-OIL) (P)		107.02	27.18		3.07	358.52	10.50	0.95
NO.2 F.O.T.(C-OIL) (S)		125.22	27.50		3.19	428.25	85.80	0.95
NO.3 F.O.T.(A-OIL) (P)		27.40	37.64		0.29	9.59	88.90	0.87
NO.3 F.O.T.(A-OIL) (S)		25.07	37.84		0.26	7.77	76.70	0.87
L.O.及びothers.T		99.85			2.94	293.11	285.90	
SUB TOTAL		595.54	0.00		2.90	1779.87	680.40	
FRESH WATER;–								
NO.1 F.W.T. (P)		65.00	-34.38		2.90	188.50	49.00	1
NO.1 F.W.T. (S)		65.00	-34.38		2.90	188.50	49.00	1
NO.2 F.W.T. (P)		97.26	14.58		0.86	83.64		1
NO.2 F.W.T. (S)		97.26	14.58		0.86	83.64		1
SUB TOTAL		324.52	0.00		1.68	544.29	98.00	1
DEAD WEIGHT		4485.54	0.00	0.00	9.32	41813.38		
LIGHT WEIGHT		7044.81	11.14	78484.70	10.43	73477.37		
DISPLACEMENT		11530.35	6.81	78484.70	10.00	115290.75	1450.40	

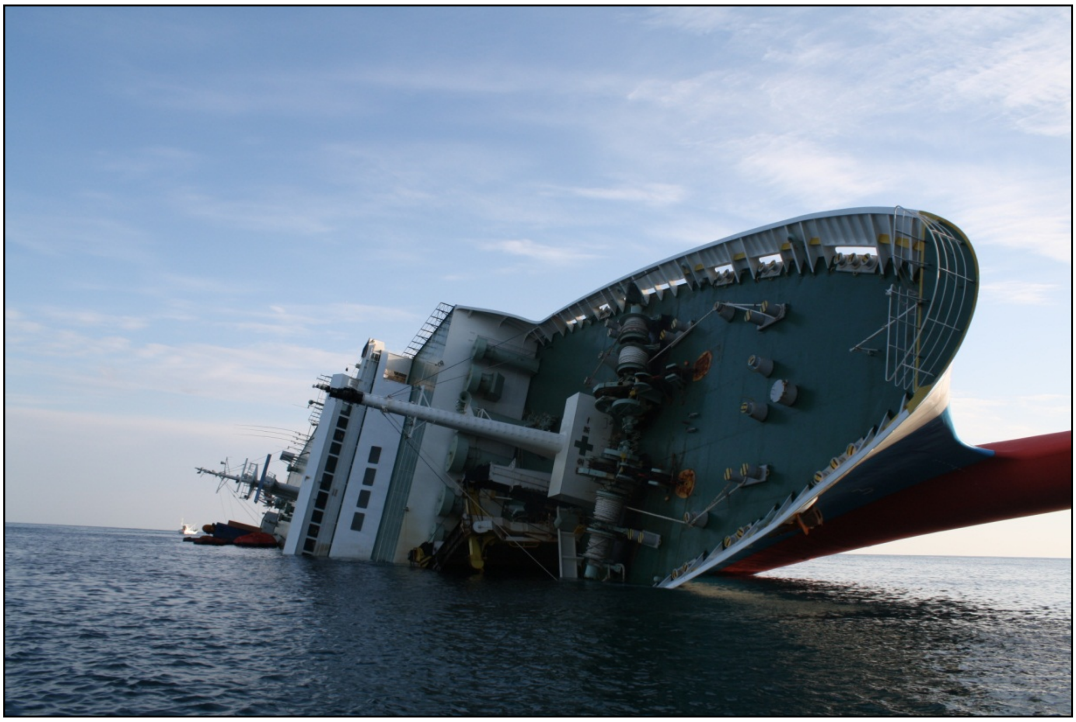
CORRESP.DRAFT (M)		6.31	MID.G	6.81	T.KM	12.00
DRAFT	FORE (M)	5.21	MID.B	5.96	K G	10.00
	AFT (M)	7.20	H.BG	0.85	G M	2.00
	MEAN (M)	6.20	MID.F	12.72	GGo	0.13
TRIM (M)		1.99	M.T.C.	236.57	GoM	1.87
PROP.IMMERS. (%)			T.P.C	27.13		

Table 2: Weight and Balance Sheet at the Time of the Accident

CONDITION	AT SEA CONDITION							
ITEM	LOAD (%)	WEIGHT (KT)	Mid-G (M)	MOMENT (KT-M)	KG (M)	MOMENT (KT-M)	IXSF (M4)	ρ
DEADWEIGHT CONSTANT		37.52			5.17	193.98		0
PROVISION		5.00			23.74	118.70		0
CARGO;-								
Crews (A DECK)		2.52			25.13	63.33		
PASSENGER (B DECK)		0.84			22.35	18.77		
FAMILY CAR (B DECK)		8.29			22.02	182.44		
FAMILY CAR (C DECK)		3.60			17.55	63.18		
FAMILY CAR (E DECK)		25.00			8.48	212.00		
LARGE-SIZED CAR (C DECK)		30.85			18.59	573.50		
LARGE-SIZED CAR (D DECK)		161.27			14.10	2273.91		
CHASSIS (C DECK)		948.66			18.59	17635.63		
CHASSIS (C DK & SLOP W.)		59.10			14.10	833.31		
CONTAINERS (C DK & SLOP W.)		1086.23			12.53	13610.50		
Others(A deck)		0.70			25.13	17.59		
Others(B deck)		7.50			22.35	167.63		
Others(C deck)		18.20			13.95	253.89		
Others(D deck)		37.20			11.80	438.96		
Others(the tanks of the deck department)		13.90			12.70	176.53		
SUB TOTAL		2403.86			15.19	36521.16		
BALLAST;-								
F.P.T(B.W.). (C)					8.59	0.00		
NO.1 B.W.T. (C)	47	200.00			3.07	614.00	317.00	1.025
NO.2 B.W.T. (C)					3.15	0.00		
NO.3 B.W.T. (C)					1.01	0.00		
NO.4 B.W.T. (C)	100	156.21			0.97	151.52		
NO.5 B.W.T. (C)	100	282.89			0.92	260.26		
NO.6 B.W.T. (C)					0.85	0.00		
NO.7 B.W.T. (C)					4.70	0.00		
A.P.T(B.W.). (C)					7.86	0.00		
NO.1 HEEL..T.(P&S)	50	240.00			3.52	844.80	190.00	1.025
NO.2 HEEL..T.(P&S)	50	240.00			3.27	784.80	165.00	1.025
SUB TOTAL		1119.10			2.37	2655.38	672.00	
FUEL OIL;-								
NO.1 F.O.T.(C-OIL) (P)		107.70	1.13		3.26	351.10	66.70	0.95
NO.1 F.O.T.(C-OIL) (S)		103.28	1.13		3.21	331.53	65.90	0.95
NO.2 F.O.T.(C-OIL) (P)		94.05	27.18		3.07	288.73	10.80	0.95
NO.2 F.O.T.(C-OIL) (S)		111.15	27.50		3.19	354.57	83.10	0.95
NO.3 F.O.T.(A-OIL) (P)		24.36	37.64		0.29	7.06	80.30	0.87
NO.3 F.O.T.(A-OIL) (S)		21.75	37.84		0.26	5.66	70.70	0.87
L.O.及びothers.T		99.85			2.94	293.11	285.90	
SUB TOTAL		562.14	0.00		2.90	1631.76	663.40	
FRESH WATER;-								
NO.1 F.W.T. (P)		60.00	-34.38		2.78	166.80	44.90	1
NO.1 F.W.T. (S)		60.00	-34.38		2.78	166.80	44.90	1
NO.2 F.W.T. (P)		97.26	14.58		0.80	77.81		1
NO.2 F.W.T. (S)		97.26	14.58		0.80	77.81		1
SUB TOTAL		314.52	0.00		1.56	489.22	89.80	1
DEAD WEIGHT		4442.14	0.00	0.00	9.37	41610.20		
LIGHT WEIGHT		7044.81	11.14	78484.70	10.43	73477.37		
DISPLACEMENT		11486.95	6.83	78484.70	10.02	115087.57	1425.20	

CORRESP.DRAFT (M)		6.30	MID.G	6.83	T.KM	11.94
DRAFT	FORE (M)	5.42	MID.B	5.95	K G	10.02
	AFT (M)	7.10	H.BG	0.88	G M	1.92
	MEAN (M)	6.26	MID.F	12.68	GGo	0.12
TRIM (M)		1.68	M.T.C.	236.10	GoM	1.80
PROP.IMMERS. (%)			T.P.C	27.08		

Photo 1: The Vessel Aground and Lying Sideways (Bridge)

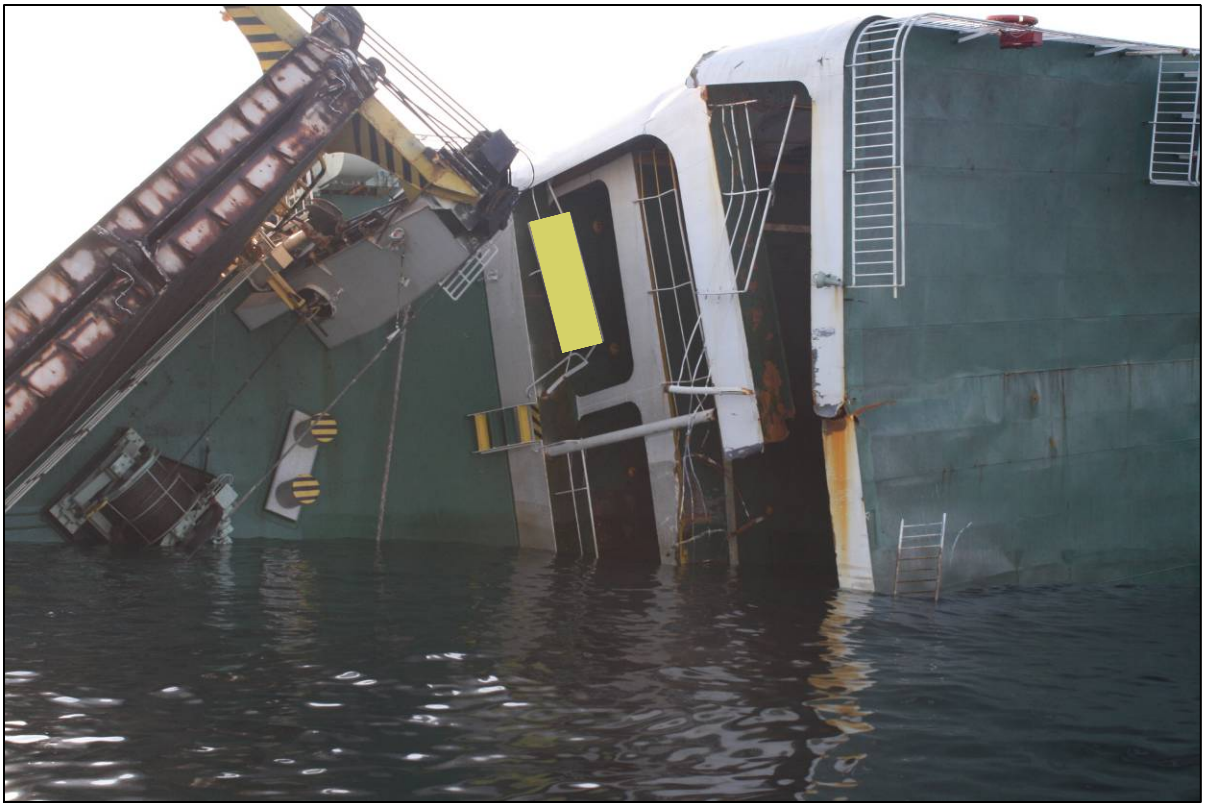


Photographed on November 15, 2009

Photo 2: The Vessel Aground and Lying Sideways (A Deck at Midship)

Photographed on November 15, 2009

Photo 3: The Vessel Aground and Lying Sideways (Stern)



Photographed on November 15, 2009

Photo 4: Lashing Condition of Containers

Photo 5: Lashing Condition of Chassis

(6- Point Lashing Chain)

Photo 6: Lashing Condition of Truck

Photo 7: Lashing Chains Hooked on Cloverleaf

Photo 8: Lashing Chain Hooked on Member
at the Back of Chassis's Body

Photo 9: Twisted Hook of Lashing Chain

Photo 10: Deformed Hook of Sub-Chain

Appendix: Course of the Events Leading to the Occurrence of the Accident

Departure

Weather and sea information

- The master estimated that the Vessel would navigate in following seas with waves with a wave height of 4m in the Kumano Nada.
- The master estimated from his previous experience that the Vessel would not sustain a rolling motion of 7° or more.

Ballast water

- The heeling tanks on board the Vessel were loaded with about 480 t of ballast water in total.

Conditions of car deck surface

- No non-slip painting material had been coated on Deck C and Deck D of the Vessel while the friction coefficient between the deck board and supporting gears, sub landing gear racks and containers was about 0.4.

Lashing conditions of containers

- Lashing chains were almost in a vertical position while lashing the containers, which was not an effective lashing method to prevent excessive shifting of containers.

Lashing work

- Company A didn't have a manual providing for effective lashing methods to prevent excessive cargo shifting.

Station bill and drill

- An emergency system had been established with the station bill and the implementation of drills.

The master confirmed that weather and sea conditions would not become so bad as to require suspension of departure.

Meeting for the stevedoring work

The master gave instructions to secure the chassis in the front and last rows on Deck C with 6-Point Lashing Chains, and the other cargos with 4-Point Lashing Chains as usual.

Arrival at Keihin Port Tokyo Section

Stevedoring

Cargoes including 150 containers, 44 chassis, 6 heavy machines and 32 cars were loaded on board the Vessel while the total weight of them was 2,403.86 t.

The Vessel departed with hardly any list.
The Vessel had a larger righting arm than in the full load departure condition estimated at the time of construction.

Departure

It was confirmed that the lashing chains had not been loosened.

The Vessel proceeded in following seas with waves coming from behind on the port side.

The master and the crew didn't feel any rolling motions to the hull.

While underway

- Lashing conditions of the cargoes on board the Vessel were checked during shipboard patrols inside the Vessel by able seamen on duty.
- The Vessel altered the course to 237° at Daio-zaki.
- A fin stabilizer and an automatic steering were in use while underway.

The Vessel was hit by the First Wave on the port quarter at about 40° with a wave height of about 6.9 m, and the midship was situated on a down slope of the First Wave.

The Vessel heeled about 25° to starboard and turned sharply to the left.

Collapse of cargoes occurred and lashing chains were broken.

Weather and sea conditions

Wind Direction: ENE

Wind Speed: about 15 m/s

Significant Wave Height: about 4.6 m

Wavelength: about 156 m

While collapse of cargoes was in progress, the Vessel was hit by the second wave on the port quarter at about 55° with a wave height of about 4.6 m, and the midship was situated on a down slope of the wave.

The angle of list exceeded about 40°.

By transferring ballast water to the port side, the Vessel was made to proceed while receiving winds and waves from starboard.

Although the angle of list became about 25°, while proceeding in the northwest after turning to the left, the amount of flooding increased and the list became larger as waves rushed in from the stern end of the car spaces on C Deck or from the vent holes on the starboard outside plating.

Internal audit provided for in the safety management manual

Company A conducted an internal audit for the overall safety management system at least once a year.

A rescue operation was conducted by Helicopter Rescue Divers and a helicopter of the Japan Coast Guard.

All of the passengers and the crew **were rescued** without getting panicked.

The Vessel grounded and rolled sideways.