MA2016-8

MARINE ACCIDENT INVESTIGATION REPORT

August 25, 2016

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.

Kazuhiro Nakahashi
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: Cargo Ship MING GUANG
IMO number: 8513456
Gross tonnage: 1,915 tons

Accident type: Foundering
Date and time: Around 06:05, December 26, 2014
Location: Northwest off Ajigasawa Port, Ajigasawa Town, Aomori Prefecture
Around 318° true bearing, 8.3 nautical miles from the lighthouse on the northern breakwater of Ajigasawa Port
(approximately 40°53.3'N, 140°05.4'E)

August 4, 2016
Adopted by the Japan Transport Safety Board
Chairman Kazuhiro Nakahashi
Member Kuniaki Shoji
Member Satoshi Kosuda
Member Toshiyuki Ishikawa
Member Mina Nemoto

SYNOPSIS

< Summary of the Accident >

When the cargo ship MING GUANG manned with a master and 9 crewmembers was sailing south-southwest to Kwangyang, Republic of Korea, the vessel's interior could have been flooded from taking on seawater and she foundered to the northwest of Ajigasawa Port, Ajigasawa Town, Aomori Prefecture, around 06:05 on December 26, 2014.

All ten of the crewmembers were rescued but three died.

< Probable Causes >

It is probable that the accident occurred because, while MING GUANG was sailing at night against waves from her starboard bow west of Tsugaru Strait, the Vessel foundered due to the fact that water from striking waves flooded the CO_2 room, ballast tanks, and other compartments on the starboard side through holes in the hatch covers, ventilation fans, and air vent pipes of the upper deck and gaps in the manhole covers and access openings, etc." (hereinafter referred to as the "holes, etc., on the upper deck"), thereby causing a starboard list and putting the Vessel into a situation in which her upper deck's starboard edge became submerged, and that this resulted in the Vessel's turning on her side when a greater amount of water flooded into the hull's interior through hatch covers, access openings, etc., and the Vessel lost stability and turned over due to the effect of the wind and waves, which in turn allowed additional water to flood in.

It is probable that the flooding of the CO_2 room, ballast tanks, and other compartments on the

MING GUANG's starboard side from striking waves through holes, etc., on the upper deck occurred because the weathertightness of hatch covers, access openings, and other facilities of the upper deck was not maintained.

It is probable that the weathertightness of the hatch covers, access openings, and other facilities of the upper deck was not maintained because MING GUANG's crewmembers did not periodically check holes, etc., on the upper deck to maintain her weathertightness.

< Recommendations >

○ Safety Recommendations

It is probable that this accident occurred because MING GUANG was flooded through holes, etc., on the upper deck while she sailed through waves coming from her starboard bow.

It is probable that MING GUANG's flooding through holes, etc., on the upper deck occurred because the vessel's weathertightness was not being maintained, as crewmembers did not periodically check holes, etc., on the upper deck to maintain her weathertightness.

It is probable that HK SAFE BLESSING SHIPPING Ltd. did not appropriately engage in safety management of MING GUANG, such as by properly manning the Vessel and providing education for her crewmembers, and that MING GUANG sailed in a condition that exceeded her load line that was set based on the International Convention on Load Lines of 1966.

It is somewhat likely that if the Chief Officer had put on an immersion suit before abandoning the Vessel and if the Second Officer and the surviving Able Seaman had been able to prevent the inflow of seawater into the immersion suits they were wearing, the Chief Officer and the Second Officer would have survived and the surviving Able Seaman would not have suffered hypothermia.

In view of the result of this accident investigation, the Japan Transport Safety Board recommends that HK SAFE BLESSING SHIPPING, as the management company, and the Kingdom of Cambodia, as the flag state of the MING GUANG, should take the following measures to prevent recurrence of similar accidents and reducing damage.

HK SAFE BLESSING SHIPPING should engage in thoroughgoing vessel safety management that includes manning the vessels it manages with crewmembers who possess legally valid certificates of competence and appropriately providing education to crewmembers, and should instruct crewmembers to engage in the following practices:

(1) Crewmembers shall maintain weathertightness by periodically checking the integrity and closed condition of weathertight closing devices, etc., on the upper deck.

(2) Masters shall maintain sufficient freeboard in compliance with the International Convention on Load Lines of 1966.

(3) Crewmembers shall understand that seawater can enter immersion suits that are being worn, and shall wear immersion suits appropriately by periodically inspecting their storage conditions and practice putting them on.

Authorities of the Kingdom of Cambodia should direct management companies and recognized organizations to ensure that vessels in its registry are manned with personnel who possess the legally valid certificates of competence that are specified in Minimum Safe Manning Certificates and that safety management such as above items (1) to (3) are thoroughly practiced aboard them.

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

When the cargo ship MING GUANG manned with a master and 9 crewmembers was sailing south-southwest to Kwangyang, Republic of Korea, the vessel's interior could have been flooded from taking on seawater and she foundered to the northwest of Ajigasawa Port, Ajigasawa Town, Aomori Prefecture, around 06:05 on December 26, 2014.

All ten of the crewmembers were rescued but three died.

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 one other marine accident investigator to investigate this accident on December 26, 2014.

1.2.2 Collection of Evidence

December 26, 28 to 31, 2014 and March 17, 2015; Interviews

December 27, 2014, December 21 and 22, 2015: On-site investigations and interviews

January 13 and 15, February 23, March 4, 8, 20 and 25, May 28, June 16, July 3, August 1, October 8, November 12, and December 2, 2015: Collection of questionnaire

1.2.3 Tests and Research by Other Institutes

With respect to this accident, the JTSB entrusted to the National Maritime Research Institute (NMRI) the investigations into the stability and circumstances of foundering of the MING GUANG.

1.2.4 Cooperation with the Investigation

Drawings of the MING GUANG were provided by the accident investigatory organization of the People's Republic of China (China Maritime Safety Administration).

1.2.5 Comments from Parties Relevant to the Cause

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

1.2.6 Comments from Flag State

Comments on the draft report were invited from the flag state and the substantially interested state of the MING GUANG.

2 FACTUAL INFORMATION

2.1 Events Leading to the Accident

2.1.1 The navigational track of the MING GUANG according to the Automatic Identification System

According to the "records of the Automatic Identification System (AIS)[*1] data (hereinafter referred to as "the AIS record") of the MING GUANG (hereinafter referred to as "the Vessel") received by a data company in Japan," the Vessel's navigation track from 16:46:43 on December 24 to 05:48:14 on December 26, 2014 was as shown in Table 2.1 below.

It should be noted that no AIS record from the Vessel was received from 05:09:12 to 21:36:34 of December 25.

Table 2.1: AIS Record of the Vessel (Excerpt)

Date	Time (hr:min:sec)	Ship's position*		Course Over The Ground* (°)	Heading* (°)	Speed Over The Ground (knots [kn])
		Latitude (N) (° -′)	Longitude (E) (° -′)			
December 24	16:46:43	041-44.96898	140-39.17298	186.8	196	6.8
	17:08:44	041-42.52698	140-37.12800	211.1	213	9.0
	23:19:31	041-12.98400	140-02.15100	257.6	266	5.4
December 25	00:05:40	041-11.10102	139-56.97798	243.7	264	6.9
	01:00:40	041-09.06198	139-50.92200	230.8	260	5.0
	02:00:41	041-06.79302	139-44.12802	258.0	265	3.9
	03:01:21	041-04.76802	139-37.04400	258.8	259	5.6
	04:03:21	041-02.47398	139-29.36700	261.6	258	6.1
	05:09:11	041-01.02600	139-20.92698	269.5	269	6.3
	~	No AIS record was received.				
	21:36:35	040-36.63000	139-12.35700	121.4	118	7.2
	22:31:19	040-36.91602	139-20.28702	090.8	090	6.7
	23:15:24	040-38.06100	139-26.72298	085.5	083	6.4
	23:40:35	040-38.57802	139-30.42300	079.9	087	6.9
December 26	00:01:35	040-38.81802	139-33.45000	078.6	088	6.7
	01:00:05	040-40.33800	139-42.16098	066.0	078	7.6
	01:30:15	040-41.47800	139-46.57398	085.3	076	7.0
	02:00:16	040-43.08300	139-50.34198	049.7	052	6.4
	02:30:05	040-45.13998	139-52.90602	028.4	023	5.3
	03:00:15	040-47.38302	139-54.80000	035.4	048	6.0

[*1] AIS (Automatic Identification System) is a device that can automatically transmit and receive information such as vessel identification codes, ship types names, positions, and courses, and exchange information with other vessels or land based navigation aid.

	03:10:02	040-47.95602	139-55.85598	061.7	066	5.9
	03:30:05	040-48.76800	139-58.14798	080.2	085	6.1
	04:00:24	040-50.23200	139-59.67798	047.9	020	4.9
	04:25:06	040-51.82098	140-00.57702	023.3	035	4.3
	04:55:05	040-52.91298	140-03.24702	040.6	042	4.7
	05:17:02	040-54.10800	140-04.38102	060.9	069	4.4
	05:45:02	040-53.62002	140-05.19102	132.6	214	1.3
	05:48:14	040-53.55102	140-05.27202	131.2	232	0.9

*: The vessel position indicates the position of the GPS antenna installed above the bridge, and the courses over the ground and headings indicated in true bearings (hereinafter the same).

2.1.2 Events Leading to the Accident according to the Statements of Crewmembers and Others

According to the statements of the Master, Chief Engineer, Third Engineer, able seaman (hereinafter referred to as "Able Seaman A"), Oiler, Wiper, and Chief Steward and the reply to the questionnaire by Japan Coast Guard (JCG), the events leading to the accident were as follows:

(1) Development of Events from the Vessel's Leaving Port to her Foundering

At around 16:00 on December 24, 2014, the Vessel manned with the Master of the Vessel and 9 crewmembers (one with nationality of the People's Republic of Bangladesh, one with nationality of the Republic of the Union of Myanmar, and seven with nationality of the People's Republic of China) left Hakodate Port in Hakodate City, Hokkaido, heading to Kwangyang Port, Republic of Korea.

From around 05:00 to 09:00 on December 25, the Vessel, with her hull listing to starboard, proceeded west-southwest while receiving strong winds and waves from the direction of the starboard bow.

Due to the hull's listing, the other able seaman (hereinafter referred to as "Able Seaman B") went to check for flooding of the ballast tank. He was unable to confirm the existence of flooding and was returning to the crew's quarters from the starboard entrance on the upper deck when his left leg was caught in a weathertight door that had shut due to the hull's pitching and rolling. His calf was injured as a result.

At around 12:00 the Vessel proceeded with a starboard list of approximately 4° to 5° as the hull pitched and rolled. At around 15:30 the starboard list had increased to approximately 7° to 10°. With this situation and Able Seaman B's injury, the decision was made to return to port, and the Vessel started on a course toward the north coast of Honshu.

At around 16:00 the Oiler discovered approximately 40 cm of water in the CO_2 room[*2] of the starboard bow while making his rounds.

Four people—the Master, Second Officer, Third Engineer, and Able Seaman A—heard the Oiler's report of flooding in the CO_2 room and, responding to a request from the Oiler, brought a portable drainage pump and hose to the CO_2 room's hatch. The Master then returned to the crew's quarters alone.

[*2] "CO_2 room" generally refers to a compartment equipped with carbon dioxide gas fire extinguishers that use carbon dioxide gas as the extinguishing agent for extinguishing fires in an engine room, cargo hold, or other such compartment. The same definition applies to the Vessel.

After beginning to drain the CO_2 room, the Third Engineer, Able Seaman A, and the Oiler returned to their quarters, agreeing that the three of them would take turns checking the drainage situation as appropriate.

Around 22:30 Able Seaman A checked the drainage situation of the CO_2 room from the upper deck and found that the flooding was approaching the CO_2 room's ceiling. However, he could not see where the water was coming from.

At around 23:15 the Vessel's owner's agent (hereinafter referred to as "Agent A") reported to JCG that the Vessel was flooding while underway, was listing to starboard, and had one injured crewmember on board. At around 23:40 Agent A contacted JCG to request rescue of the injured Able Seaman B and provide notification that it had instructed the Vessel to head to Noshiro Port in Noshiro City, Akita Prefecture. And at around 00:05 on December 26, Agent A informed JCG that the Vessel was unable to reach Noshiro Port and would instead head to Shichiri-Nagahama Port in Ajigasawa Town, Aomori Prefecture.

All of the crewmembers put on immersion suits[*3] and life jackets and gathered on the port-side wing of the bridge to prepare to leave the Vessel.

Able Seaman A confirmed visually that the starboard side of the upper deck was constantly submerged due to the Vessel's list.

At around 03:00 JCG received notification from the Vessel via her international VHF radio telephone equipment that her starboard list was approximately 18°. At around the same time, JCG recommended to the Vessel through Agent A that she should proceed to the calm Tsugaru Strait, as the seas around Shichiri-Nagahama Port were very rough.

At around 03:10 Agent A notified JCG that the Vessel was heading to the Tsugaru Strait.

Two JCG patrol boats arrived separately in the area of the Vessel at around 03:43 and 04:25, respectively, and began escorting her.

The Oiler and Able Seaman A attempted to lower a lifeboat from the port side but were unsuccessful due to the hull's list to the starboard side.

At around 04:55 JCG noted visually that the Vessel had a starboard list of approximately 30°. Given this, JCG instructed the Vessel to close her fuel removal valves to prevent leakage of oil in preparation for foundering and to drop her anchors on both sides. However, the Vessel responded that she could not drop anchors because her bow was submerged.

The Oiler went to the engine room and closed all of the fuel removal valves except for that on the generator. He then emerged on the quarterdeck from the engine room's aft access opening and, thinking that it would be easier to evacuate from the port side of the upper deck, shouted to the crewmembers waiting on the bridge's port-side wing to come down. All of the crewmembers then moved to the port side of the upper deck.

The Third Engineer, Able Seaman A, and Oiler lowered one of the port life rafts. However, the rope that was tied to the Vessel to keep the life raft from drifting away broke, and the life raft separated from the Vessel.

[*3] "Immersion suit" refers to protective clothing worn by rescue boat workers to protect the body from wind and wave exposure during cold weather and prevent hypothermia when falling into the sea. The suit covers the entire body except the face, has sufficient warmth retention, and can be worn easily. Additionally, it allows the wearer to dive into the water from a height of 4.5 meters without interfering with evacuation work and maintains a safe floating posture in the water.

The Master then saw that seawater was flowing in from the engine room access opening on the quarterdeck.

The Vessel's main engine stopped at around 05:17 and the hull's starboard list reached approximately 30° to 40° at around 05:45.

The Chief Engineer saw that the Chief Officer was wearing a life jacket but was not wearing an immersion suit.

The Vessel lost onboard electric power at around 05:59. After all of the crewmembers escaped by jumping into the sea in order from port side of the upper deck, the Vessel rolled onto her starboard side at around 06:02 and then foundered near 40°53.3'N, 140°05.4'E at around 06:05.

(2) Development of Events from Foundering to Rescue of the Crewmembers

After escaping from the Vessel, the Master, Oiler, and Chief Steward climbed into the Vessel's life raft, which had been drifting nearby, and were rescued by JCG by around 07:34.

After escaping, 6 crewmembers—namely, the Chief Engineer, Second Officer, Third Engineer, Able Seaman A, Able Seaman B, and Wiper—were found by JCG drifting in the sea. They had been by holding hands and employing other means to keep from drifting apart. They were rescued by around 08:55. However, the Second Officer was in a state of cardiopulmonary arrest and Able Seaman B was unconscious.

The Chief Officer was found drifting in the sea in a life jacket and rescued by JCG at around 10:25. However, he was in a state of cardiopulmonary arrest.

The date and time of occurrence of the accident was at around 06:05 on December 26, 2014, and the location was around 318º, 8.3 nautical miles (M) from the lighthouse on the northern breakwater of Ajigasawa Port.

(Refer to Annex Figure 1 Estimated Navigation Routes)

2.2 Injuries to Persons

According to the postmortem certificates of the Chief Officer, Second Officer, and Able Seaman B; the medical certificate of Able Seaman A; and the reply to the questionnaire by JCG, the injuries to persons were as follows:

The Chief Officer, Second Officer, and Able Seaman B were certified dead by drowning at the hospital to which they were transported.

Able Seaman A was diagnosed as having hypothermia at the hospital to which he was transported and was hospitalized for 3 days there.

It should be noted that there was a large amount of seawater in the immersion suits of the Second Officer, Third Engineer, and Able Seaman A when they were rescued by JCG.

2.3 Damage to Vessel

According to information provided by JCG, the Vessel foundered.

2.4 Crew Information

2.4.1 Crew Information

(1) Gender, Age, and Certificate of Competence

(i) The Master: Male, 41 years old

Nationality: the People's Republic of Bangladesh (hereinafter referred to as "Bangladesh")

Endorsement attesting the recognition of certificate under STCW regulation I/10: Master (issued by the Kingdom of Cambodia)

Date of Issue: December 11, 2014

(Valid until March 23, 2018)

According to the statement of the Master and the reply to the questionnaire by Bangladeshi authorities, the Master has not received a certificate of competence. In addition, Bangladeshi authorities had not issued the certificate of competence of Bangladesh that was specified in the endorsement attesting the recognition of certificate under STCW regulation I/10.

(ii) The Chief Engineer: Male, 28 years old

Nationality: Bangladesh

Endorsement attesting the recognition of certificate under STCW regulation I/10: Chief engineer (issued by the Kingdom of Cambodia)

Date of Issue: December 11, 2014

(Valid until July 9, 2018)

According to the statement of the Chief Engineer and the reply to the questionnaire by Bangladeshi authorities, the Chief Engineer has not received a certificate of competence. In addition, Bangladeshi authorities had not issued the certificate of competence of Bangladesh that was specified in the endorsement attesting the recognition of certificate under STCW regulation I/10.

(iii) The Chief Officer: Male, 44 years old

Nationality: the Republic of the Union of Myanmar

Endorsement attesting the recognition of certificate under STCW regulation I/10: Chief Officer (issued by the Kingdom of Cambodia)

Date of Issue: October 6, 2014

(Valid until May 13, 2018)

The Chief Officer possessed a chief officer certificate that was issued by Belize.

(iv) The Second Officer: Male, 38 years old

Nationality: the People's Republic of China

Endorsement attesting the recognition of certificate under STCW regulation I/10: Second officer (issued by the Kingdom of Cambodia)

Date of Issue: December 26, 2014

(Valid until December 31, 2016)

Whether or not the Second Officer possessed a certificate of competence was unknown.

(v) Able Seaman B: Male, 49 years old

Nationality: the People's Republic of China

(2) Sea-going Experience

According to the statements of the Master, Chief Engineer, Able Seaman A, and Oiler, their experience was as follows:

(i) The Master

The Master had worked onshore in Bangladesh until October 2014. Subsequently, through a referral from a broker, he was instructed to board the Vessel at Dalian Port, People's Republic of China. He boarded the Vessel to serve as the Master on October 28, 2014.

Although the Master signed the space for the master's signature on documents for port clearance, this was his first experience with the work of a crewmember, and he engaged in hull maintenance work together with Able Seaman B, rather than taking navigational watch.

He was in good health at the time of the accident.

(ii) The Chief Engineer

The Chief Engineer had about 6 years of experience working on cargo ships. He first boarded the Vessel as Chief Engineer on October 28, 2014.

He was in good health at the time of the accident.

(iii) The Chief Officer

The Chief Officer's sea-going experience was unknown.

He appeared to be in good health at the time of the accident.

(iv) The Second Officer

The Second Officer's sea-going experience is unknown; however, he handled operations as the de facto master by, for example, commanding ship handling when entering and leaving port.

He appeared to be in good health at the time of the accident.

(v) Able Seaman B

Able Seaman B's sea-going experience was unknown.

At the time of the accident, he had a calf injury that was caused when his left foot was caught in a weathertight door. He had lost blood and looked pale.

2.4.2 Vessel Manning Information

According to the Vessel's Minimum Safe Manning Certificate, the Kingdom of Cambodia, which is the flag state of the Vessel, issued the Minimum Safe Manning Certificate for the Vessel on July 3, 2014, based on the SOLAS Convention.*4 This certificate stated that the owner must always man the Vessel with a master, a chief officer, a chief engineer, a deck officer, an engineer officer, and a hand with engine-room watch rating (one person in each position) as well as two hands with navigational watch rating and one with deck rating, all of whom must possess certificates meeting requirements of the STCW Convention.*5

2.5 Vessel Information

2.5.1 Particulars of Vessel

IMO number:	8513546
Port of registry:	Phnom Penh (Kingdom of Cambodia)
Owner:	HK SAFE BLESSING SHIPPING Ltd. (People's Republic of China; hereinafter referred to as "Company A")
Management company:	Company A
Recognized organization:*6	Union Bureau of Shipping (People's Republic of China;

*4 "SOLAS Convention" refers to the International Convention for the Safety of Life at Sea of 1974.

*5 "STCW Convention" refers to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers of 1978.

*6 "Recognized organization" refers to an organization that has been granted authority by the government of the relevant flag state to conduct inspections based on international treaties, such as the SOLAS Convention and the

	hereinafter referred to as “UBS”)
Gross tonnage:	1,915 tons
L×B×D:	86.40 m x 12.80 m x 6.70 m
Load line: [*7]	Summer load line: 1,514 mm downward from the upper edge of the deck line
Hull material:	Steel
Engine:	Diesel engine x 1
Output:	1,103 kW
Propulsion:	Fixed pitch propeller x 1
Date of completion:	May 1986

(See Photo 2.5-1)

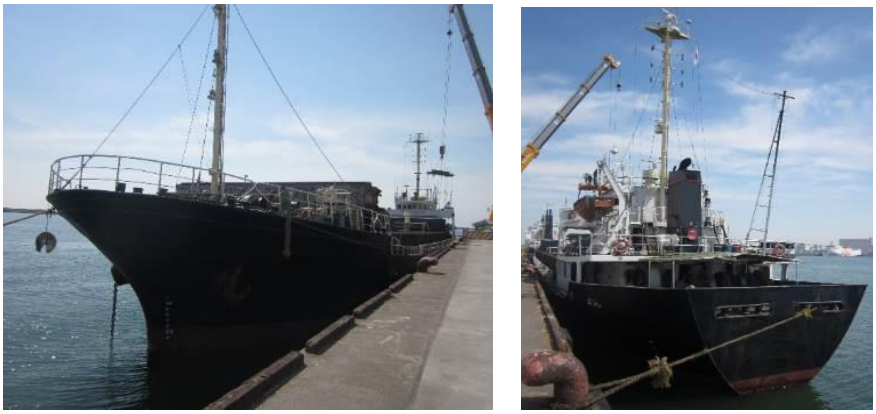

Photo 2.5-1 Vessel (Provided by the Tomakomai Maritime Office, Muroran Transport Branch Office, Hokkaido District Transport Bureau)

2.5.2 Load Conditions

According to statements of the person in charge of the Vessel’s ship’s agent at Hakodate Port (hereinafter referred to as “Agent B”) and the loading business as well as the cargo record and International Load Line Certificate, the load conditions, draft, etc., at the time of the Vessel’s departure from Hakodate Port were as follows:

International Convention for the Prevention of Pollution from Ships (MARPOL Convention), as well as domestic regulations of the flag state and to issue certifications.

*7 “Load line” refers to a marking of the minimum “freeboard” (height from the waterline to the top surface of the upper deck) when a vessel is fully loaded that is regulated and calculated based on the International Convention on Load Lines of 1966 (LL Convention). It is the threshold at which sufficient freeboard can be maintained for safe navigation with sufficient reserve buoyancy while a vessel is under way. Because the circumstances of the sea’s surface change in different sea areas, or even in the same sea area, in terms of wind and waves, the water’s specific gravity, and other conditions from season to season, the degree of safety for vessel navigation also changes. Thus, there are various load lines, including winter load line and summer fresh water load line. In the sea area in which the Vessel was operating, the summer load line is applied throughout the year.

Loaded cargo	Weight (tons)
Shredded scrap[8] (Cargo Hold No. 1)*	900.0 (half load)
Shredded scrap (Cargo Hold No. 2)*	2,100.0 (full load)
Fuel oil A	19.0
Fuel oil C	13.0
Lubricating oil	2.6
Fresh water	63.0

Summer load line	At time of departure from Hakodate Port	
	Draft (Bow/stern)	List
5.20 m	5.20 m/5.30 m	None

*After loading was completed, the surfaces of the shredded scrap in the cargo holds were made level with heavy equipment. (See Photo 2.5-2)

Photo 2.5-2 Leveling of Shredded Scrap in a Cargo Hold
(Photos provided for conceptual purposes.)

2.5.3 Hull Structure

(1) Hull Structure

According to the general arrangement plan, the Vessel was a twin decker-type bulk carrier with a docking bridge that engaged in international navigation. She had a No. 1 cargo hold and No. 2 cargo hold arranged from the bow. She had her forecastle in the bow and her bridge in the stern. A CO_2 room was in the starboard bow. (See Figure 2.5)

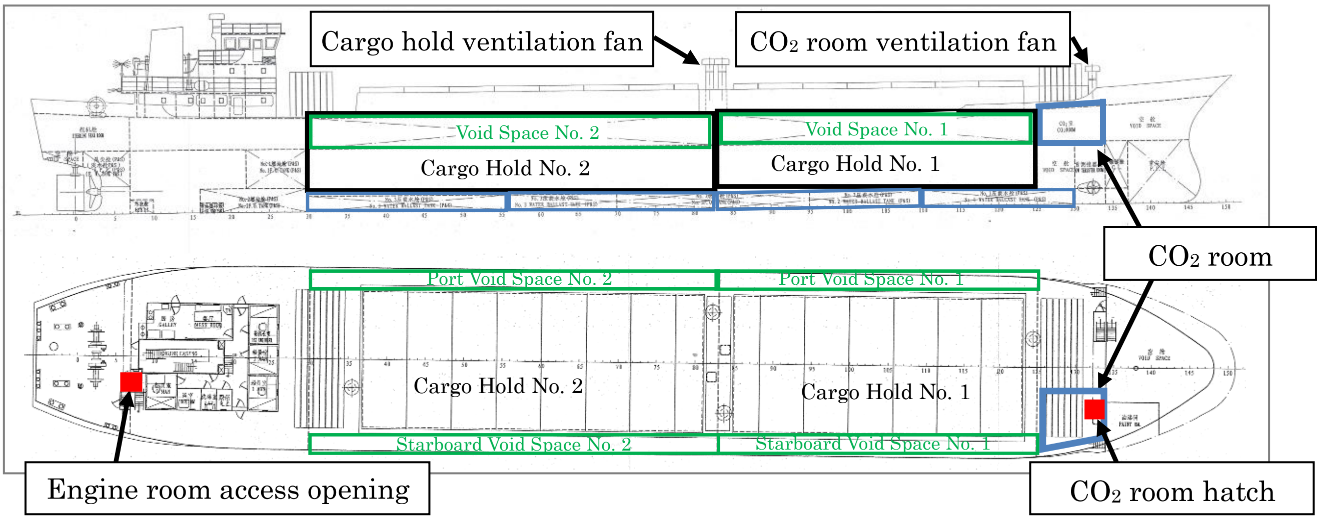

Figure 2.5 General Arrangement Plan

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*8 "Shredded scrap" refers to scrap that has been shredded with a shredder. It comes in various shapes and weights.

(2) Hull Modification Work

According to general arrangement plans prepared at the time of the Vessel's construction and in July 2005 as well as the reply to the questionnaire by the Maritime Bureau, MLIT, the following hull modification work was carried out:

(i) The hull was constructed at a shipyard in Japan as a Japan-registered coastwise vessel with a gross tonnage of 494 tons and an L×B×D of 60.00 m x 12.80 m x 6.70 m (hereinafter referred to as the "Pre-Modification Vessel").

(ii) The Pre-Modification Vessel was a double-decker-type rock, sand, and gravel carrier with a docking bridge. She had a crane in the bow and one cargo hold in the center.

(iii) The Pre-Modification Vessel was sold to Company A in February of 2005. Beginning in February of 2005, she underwent modification work that included extension of her hull. However, due to a lack of cooperation from Company A, the modification work period, shipyard that did the work, and detailed work content were unknown.

(3) Other Information

According to the statements of the Third Engineer and the Oiler, there was no malfunction or failure with the engine or machineries.

2.5.4 Port State Control

According to the reply to the questionnaire by MLIT (Muroran Transport Branch Office of the Hokkaido District Transport Bureau and Hokuriku-Shin'etsu District Transport Bureau), instances of Port State Control of the Vessel by Port State Control Officers were as follows:

(1) May 29, 2012 (at Tomakomai Port)

An order for conformity to technical standards was issued for serious deficiencies that included holes and cracks in the ventilation fans for the cargo holds and non-functioning closing devices on the ventilation fans and disc floats[*9] in the pipe heads[*10] of the ballast tank air vent pipes.[*11]

(2) April 10, 2014 (at Niigata Port)

It was found that the disc floats in the pipe heads of the ballast tank air vent pipes were not functioning, and that a manhole cover for the fore peak tank[*12] (FPT) in the boatswain's store[*13] was left open.

(3) May 12, 2014 (at Tomakomai Port)

It was found that an emergency escape hatch of the engine room and a fire door of a staircase were fixed with rope to keep them in an open position; that the grip handles of the weathertight doors on the upper deck were not maintained, thus preventing many of the doors from closing completely; and that crewmembers could not put on immersion suits properly.

(4) October 10, 2014 (at Wakamatsu Area, Kanmon Port)

It was found that lifeboats were not being properly maintained.

(5) October 29, 2014 (at Dalian Port)

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*9 A "disc float" is a part installed inside a pipe head to prevent seawater from pouring in when the pipe head is submerged.

*10 A "pipe head" is an automatic closing device that is installed on an air vent pipe to keep waves, etc., from entering the pipe.

*11 An "air vent pipe" is a pipe installed to prevent pressure increase or negative pressure in a tank.

*12 A "fore peak tank" is a tank located below the upper deck at the bow. It is used to hold fresh water to use in the vessel and trim the vessel .

*13 A "boatswain's store" is a room for storing rigging, tools, etc. It is ordinarily located in the bow.

It was confirmed that the items identified at Kanmon Port on October 10, 2014, had been rectified.

2.5.5 Condition of the Hull's Weathertightness

According to the statement of the Master, Chief Engineer, Able Seaman A and Oiler, the Vessel's weathertightness was as follows:

(1) At the time of the accident, the hatch cover for the Vessel's CO_2 room had holes from corrosion and was not completely closed.

(2) The Vessel's crewmembers did not check the Vessel's weathertightness prior to departing from Hakodate Port, and thus they did not know the condition of said weathertightness—specifically, that "there were holes in the hatch covers, ventilation fans, and air vent pipes of the upper deck and gaps in the manhole covers and access openings, etc." (hereinafter referred to as the "holes, etc., on the upper deck", except for Chapter 6)—at the time of the accident.

2.5.6 Regulations concerning Load Line, etc.

Article 12 of the LL Convention and Regulation 12, Regulation 14, and Regulation 16 of Chapter II of Annex I of the LL Convention stipulate as follows:

Article 12: Submersion

(1) Except as provided in paragraphs (2) and (3) of this Article, the appropriate load lines on the sides of the ship corresponding to the season of the year and the zone or area in which the ship may be shall not be submerged at any time when the ship puts to sea, during the voyage or on arrival.

(2) and (3) Omitted

Annex I, Chapter II

Regulation 12: Doors

(1) All access openings in bulkheads at ends of enclosed superstructures shall be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. (The rest is omitted.)

(2) to (4) Omitted

Regulation 14: Cargo and other Hatchways

(1) The construction and the means for securing the weathertightness of cargo and other hatchways (omission) shall be at least equivalent to the requirements of Regulation 16 (omission).

(2) Omitted)

Regulation 14-1 (Omitted)

Regulation 16: Hatchways closed by Weathertight Covers of Steel or other Equivalent Material

(1) All hatchways (omission) shall be fitted with hatch covers of steel or other equivalent materials. (Omission) such covers shall be weathertight and fitted with gaskets and clamping devices. (Omission) The arrangements shall ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness shall be

required at the initial survey, and may be required at renewal and annual surveys or at more frequent intervals.

(2) to (7) Omitted

2.6 Weather and Sea Conditions

2.6.1 Marine Forecasts and Marine Warnings

(1) According to the Japan Meteorological Agency (JMA), local marine forecasts for the sea off Hiyama and Tsugaru[*14] and sea off Akita[*15] announced at 07:00 on December 25 were as follows:

Local marine forecast	Off Hiyama-Tsugaru	Off Akita
Warning	Marine warning (continuing): Near gale (from 05:30, Dec. 25)	Marine warning (continuing): Near gale (from 17:35, Dec. 24)
Wind	NW 20 kn (approx. 10.8 m/s) Later 30 kn (approx. 16.1 m/s)	NW 25 kn (approx. 13.5 m/s) Later 30 kn (approx. 16.1 m/s)
Weather	Snowy with occasional cloud	Cloudy with occasional snow, local lightning
Visibility	3 M	1 M
Waves	2.5 m later 3 m	4 m

(2) According to JMA, local marine warnings for the sea off Akita and sea off Hiyama and Tsugaru announced at 05:35 on December 26 were as follows:

Local marine warning	Off Hiyama-Tsugaru	Off Akita
Marine warning: Near gale	Northwest wind is strong, maximum wind speed is 30 kn (16.1 m/s)	Northwest wind is strong, maximum wind speed is 30 kn (16.1 m/s)

2.6.2 Meteorological Observations

(1) According to JMA's coastal wave analysis chart, estimated wind and wave values near the sea area through which the Vessel was passing at the time of the accident were as follows:

[*14] "Sea off Hiyama and Tsugaru" refers to the portion of a sea area defined as existing north of a line draw at 110° from Shiriyazaki (Aomori Prefecture), north of a line drawn at 315° from the border between Aomori and Akita Prefectures, south of a line drawn at 270° from the tip of Mottamisaki (Hokkaido) and a line drawn at 90° from Shiretokomisaki (Hokkaido), and extending out 300 M from the coastline south of the Kuril Islands that is situated to the west of a line drawn between the tip of Shirakamimisaki (Hokkaido) and the tip of Kodomarimisaki (Aomori Prefecture).

[*15] "Sea off Akita" refers to the portion of a sea area defined as existing west of a line drawn at 315° from the border between Aomori and Akita Prefectures and east of a line drawn at 315° from the border between Fukui and Ishikawa Prefectures extending out 300 M from the coastline that is south of a line that passes through 42°N, 138°E and 39°N, 134°E, and east of a line drawn parallel to the line drawn at 315° from the border between Aomori and Akita Prefectures and through the center point of a line existing at the shortest distance between Tobishima and Awashima.

Time and date	Wind direction	Wind speed	Wave direction	Frequency	Significant wave height[*16]
09:00, Dec. 25	WNW	20 kn (approx. 10.8 m/s)	WNW	7 sec.	2.5 m
21:00, Dec. 25	WNW	20 kn (approx. 10.8 m/s)	WNW	7 sec.	3.0 m

(2) According to NOWPHAS,[*17] waves at the time of the accident were as follows:

Time and date	Wave direction	Significant wave height	Maximum wave height	Observation point*
05:00, Dec. 25	W	2.3 m	4.8 m	Off west coast of Aomori (area 37.0 M ESE of Vessel)
21:40	WNW	3.8 m	7.1 m	Off coast of Aomori Pref. (area 35.0 M SE of Vessel)
00:40, Dec. 26	WNW	3.3 m	5.1 m	Off west coast of Aomori (area 14.0 M ENE of Vessel)
03:40	WNW	3.9 m	6.2 m	Off west coast of Aomori (area 3.6 M SW of Vessel)
05:20	WNW	3.6 m	6.7 m	Off west coast of Aomori (area 9.5 M SW of Vessel)
06:00	WNW	3.7 m	5.7 m	Off west coast of Aomori (area 11.2 M SW of position where Vessel foundered)

* The observation points are those that were nearest to the Vessel's position on the time and date of observation.

(3) According to the reply to the questionnaire by JCG, the weather and sea conditions observed by the patrol boats that escorted the Vessel off Ajigasawa Port on December 26 were as follows:

Time and date	Weather	Wind direction	Wind speed	Wave height	Seawater temperature
04:00, Dec. 26	Snow	NW	Approx. 20 m/s	Approx. 4.0 m	Approx. 13°C

(4) Current

According to JMA's daily current analysis chart, the current near the location of the accident on December 26 was 0.0 to 0.1 kn (current direction is unknown).

(5) Temperature

The temperature at Ajigasawa Regional Meteorological Observation Station, which is located 7 M southeast of the location of the accident, at around 06:00 on December 26 was about -2.8°C.

(6) Time of Sunrise and Sunset

[*16] "Significant wave height" is obtained when observing continuous waves at a particularly point by selecting one-third of the number of all observed waves in order from the highest and then finding the mean height of those waves.

[*17] "NOWPHAS" (Nationwide Ocean Wave information network for Ports and HArbourS) is a wave information network for Japan's coastlines that was built and is operated through a collaborative effort by the Ports and Harbours Bureau, MLIT; Regional Development Bureaus, MLIT; Hokkaido Bureau, MLIT: Okinawa General Office, Cabinet Office; National Institute for Land, Infrastructure and Management (NILIM); and Port and Airport Research Institute (PARI).

According to JCG's astronomical table, sunset in Ajigasawa Town on December 25 was at 16:17 and sunrise on December 26 was at 07:02.

2.6.3 Observations by Crewmembers

According to the statement of Able Seaman A, from 1:00 to 15:30 of December 25, the weather was light snow, the wind direction was from the northwest, the wind speed was 5 to 6, visibility was poor, and wave height was about 3 meters.

2.7 Flooding Information

According to the statements of the Master, Chief Engineer, Third Engineer, Able Seaman A, Oiler, and Wiper, the Vessel's weathertightness was as follows:

(1) The Vessel received waves of a height of about 3 meters from the direction of the starboard bow from 01:00 to 15:30 of December 25. Waves crashed into the upper deck.

(2) Able Seaman B investigated flooding of the ballast tank before around 11:30 on December 25 but could not confirm the existence of flooding.

(3) At around 16:00, the oiler discovered flooding of the CO_2 room in the starboard bow.

(4) At around 05:00 on December 26, the Third Engineer and Oiler confirmed that there was no flooding in the engine room.

(5) Prior to escaping from the Vessel, the Master saw seawater flowing in from the engine room access opening of the after upper deck as the starboard list increased.

2.8 Safety Management

2.8.1 Document of Compliance and Safety Management Certificate

According to Company A's Document of Compliance and the Vessel's Safety Management Certificate, Company A was issued the Document of Compliance based on the International Safety Management Code for the Safe Operation of Ships and for Pollution Prevention*18 (ISM Code) on December 1, 2013, and the Vessel was issued the Safety Management Certificate based on the ISM Code from UBS, which is the recognized organization, on December 30, 2013.

2.8.2 Safety Management Manual

According to Company A's Safety Management Manual, qualification, manning, and training of the Master and crewmembers are based on the STCW Convention and are established as follows (provisional translation of excerpt):

(1) Master

The Company should ensure that the master employed is qualified in accordance with requirement of STCW Convention and other concerned agreements. The master should have proper ability of command and be fully conversant with SMS.

(2) Seafarers

The Company should ensure that each ship is manned with qualified, certificated and

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*18 "The International Safety Management Code for the Safe Operation of Ships and for Pollution Prevention" (ISM Code) was adopted by the International Maritime Organization (IMO) on November 4, 1993, for the purposes of ensuring the safe navigation of vessels and protecting the environment. It was incorporated into the Annex of the 1974 SOLAS Convention and entered into effect on July 1, 1998, following a revision of the SOLAS Convention in 1994. It applies to all passenger vessels as well as all vessels with a gross tonnage of 500 tons or more that engage in international navigation.

healthy seafarers in accordance with requirements of STCW 78/95.

(3) Crew Training

The Company shall establish a "Training Procedure for Personnel Ashore and Onboard" to continuously indicate necessary requirements of SMS and ensure that training shall be provided to all personnel ashore and onboard.

2.8.3 Education and Training on the Vessel

According to the statements of the Master, Chief Engineer, Third Engineer, Able Seaman A, Oiler, and Wiper, the Vessel's education and training were as follows:

(1) Abandon ship drills, fire drills, and other drills based on the SOLAS Convention were held once monthly.

(2) The Master did not know of the existence of the Safety Management Manual.

(3) The Chief Engineer, Third Engineer, Able Seaman A, Oiler, and Wiper (5 crewmembers) knew of the existence of the Safety Management Manual but did not know its content.

2.9 Information on the Immersion Suits

(1) Information on the Immersion Suits on the Vessel

According to the replies to the questionnaire by the surviving crewmembers and JCG, the circumstances of immersion suit wearing, the conditions of suit storage, and the suit models at the time of the accident were unknown.

(2) Information on the Immersion Suits' Performance

According to the three manufacturers of the immersion suits, the suits had the following performance capabilities:

(i) Although there were some minor differences among the manufacturers' immersion suits in terms of their fabrics and specifications, the suits met the following performance requirements that are based on the International Life-Saving Appliance Code*[19] (LSA Code). (See Figure 2.9)

a) The amount of water that enters the suit after a jump from a height of 4.5 m into the water is no more than 500 g (jump test).

b) When a subject wearing an immersion suit containing an amount of water equivalent to the amount entering the immersion suit during the jump test is made to float in gently circulating water of from 0 to 2°C for 6 hours, the subject's rectal temperature does not fall more than 2°C (temperature retention test).

(ii) No standards or tests envision use in a sea area with waves, and thus it is possible that a large amount of seawater could enter a suit if the suit is not worn or stored appropriately.

(Conceptual image)

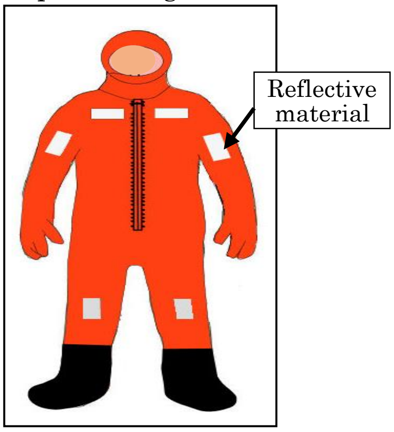

Figure 2.9 Immersion Suit

*19 The "International Life-Saving Appliance Code" (LSA Code) is a compulsory code that was adopted by the IMO in June 1996 for the purpose of providing international standards for life-saving appliances required by Chapter III (Life-saving Appliances and Arrangements) of the Annex of the 1974 SOLAS Convention. It entered into effect on July 1, 1998.

(3) Seawater Temperature and Survival Time

According to a literary source,[20] although there are differences among individuals, the survival time in water with a seawater temperature of approximately 13°C for a person wearing ordinary clothing is less than 6 hours.

2.10 Investigation of the Circumstances Leading up to Foundering

2.10.1 Summary of the Investigation

In order to investigate the circumstances that led up to the Vessel's foundering, the JTSB entrusted to NMRI the investigations into the Vessel's stability and circumstances of her foundering.

2.10.2 Estimation of the Vessel's Stability

(1) Estimation of the Height of the Center of Gravity

Because information on the height of the center of gravity (KG)[21] could not be obtained to estimate the Vessel's stability, it was decided to estimate the Vessel's KG based on the KG of two aggregate carriers that are similar to the Pre-Modification Vessel and to set the light-condition KG (hereinafter referred to as "KGLC") at 4.49 m and 4.82 m.

(2) Estimation of Stability at the Time of Departure

The weight on board at the time of departure from Hakodate was as shown in Table 2.10-1 and the weight on board of the ballast water at the time of departure was as shown in Table 2.10-2. The draft was about 5.2 m in the bow and about 5.3 m in the stern. The Vessel's displacement estimated from the draft was 4,407.9 tons. The Vessel was not listing.

Table 2.10-1 Weight on Board at Departure

Load	Weight (tons)	Specific gravity
Shredded scrap (Cargo Hold No. 1)	900.0	1.000 (Bulk specific gravity[22])
Shredded scrap (Cargo Hold No. 2)	2,100.0	
Fuel oil A (No. 2 F.O.T.)	19.0	0.880
Fuel oil C (No. 3 F.O.T.)	13.0	0.900
Lubricating oil (L.O.T.)	2.6	0.860
Fresh water (F.W.T., F.P.T.)	63.0	1.000
Ballast water	173.0	1.025
Total	3,270.6	

[20] "SOLAS Training Manual" (Editorial supervisor: Safety Management and Seafarers Labour Division, Maritime Bureau, MLIT; Publication No. 27 of the Association for Accident Prevention Among Seafarers)

[21] "Height of the center of gravity (KG)" refers to the height from the top surface of the bottom plating to the center of gravity of the hull.

[22] "Bulk specific gravity" is a value arrived at by dividing a mass loaded into a certain capacity by that capacity.

Table 2.10-2 Weight on Board of Ballast Water at Departure

Ballast tank	Weight (tons)
Ballast Tank No. 1 (port)	47
Ballast Tank No. 1 (starboard)	47
Ballast Tank No. 2 (port)	4
Ballast Tank No. 2 (starboard)	5
Ballast Tank No. 3 (port)	0
Ballast Tank No. 3 (starboard)	0
Ballast Tank No. 4 (port)	35
Ballast Tank No. 4 (starboard)	35
Total	173

The condition of stability at the time of departure, calculated by adjusting the loaded weight of fuel oil on the port and starboard sides so that the angle of list is 0° at the time of departure, is shown in Table 2.10-3, and the stability curve*23 for that condition is shown in Figure 2.10-1.

Table 2.10-3 Condition of Stability at Departure

KGLC (m)	4.49	4.82
Bow draft (m)	5.20	
Stern draft (m)	5.30	
Mean draft (m)	5.25	
Displacement (t)	4,407.90	
Height of center of gravity (m)	3.71	3.79
Metacentric height*24 (GoM) (m)	1.51	1.43
Angle of list (°)	0.00	

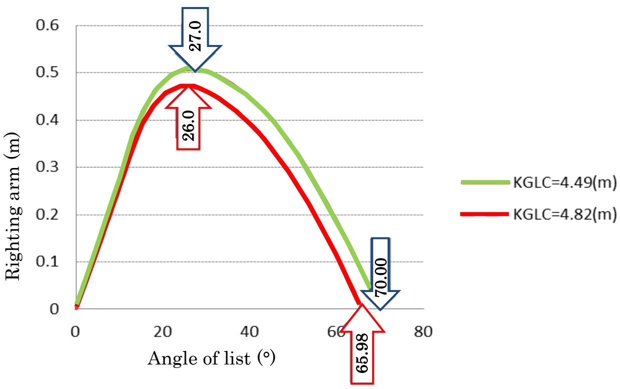

Figure 2.10-1 Stability Curve at Departure

2.10.3 Estimation of the Conditions Leading up to Foundering

In order to estimate the circumstances leading up to foundering, the Vessel's residual stability was calculated for flooding occurring in the CO_2 room as well as in compartments other than the CO_2 room in which the listing moment may have occurred.

(1) Flooding of the CO_2 Room

(Assumption: The CO_2 room is full of water [flooding of 65.9 tons].)

The stability curve is as shown in Figure 2.10-2. The angle of list is from 3.13° to 3.31°. It is thought that sufficient residual stability exists.

*23 "Stability curve" refers to a graph representation of the righting arm (a value obtained by dividing the couple that attempts to return the list to its original position by displacement) against the hull's angle of list.

*24 "Metacentric height" refers to the distance (GM) between the hull center of gravity G and the metacenter M, which is the intersection of the line of action of the buoyant force that passes through the center of buoyancy when the vessel is listing and the hull center line. In this report, it refers to metacentric height that takes free water effect into account (GoM).

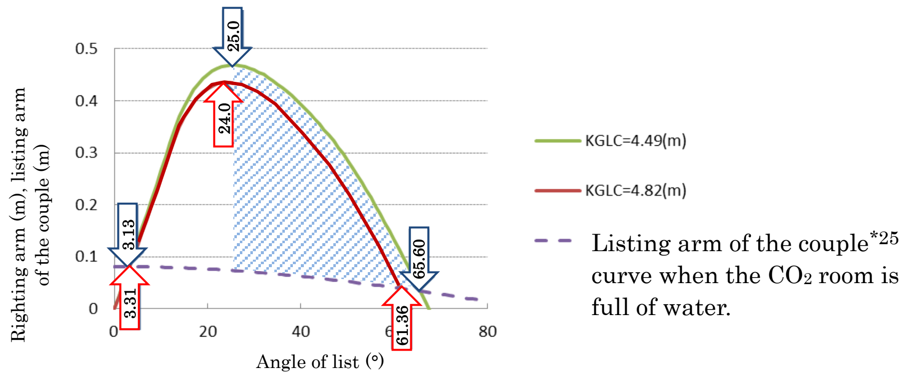

Figure 2.10-2 Stability Curve when the CO_2 Room is Full of Water

(2) Flooding of the CO_2 Room, Ballast Tanks, and Void Spaces

(Assumption: The CO_2 room as well as Ballast Tank Nos. 2 to 4 and Void Space Nos. 1 and 2 on the starboard side are full of water.)

The stability curve is as shown in Figure 2.10-3. The angle of list is from 13.11° to 14.36° and the angle of vanishing residual stability is from 42.54° to 54.75°. Because the residual stability at the angle of list at which the righting arm is largest is relatively small, it is thought that capsizing would occur with the action of a relatively small heeling moment.

*The amounts of seawater needed to fill the starboard Ballast Tank Nos. 2 to 4 are 55.3 tons, 58.4 tons, and 49.2 tons, respectively, and to fill the starboard Void Space Nos. 1 and 2 are 72.9 tons and 92.0 tons, respectively. Ballast Tank No. 1 was nearly full of water when the Vessel departed Hakodate Port.

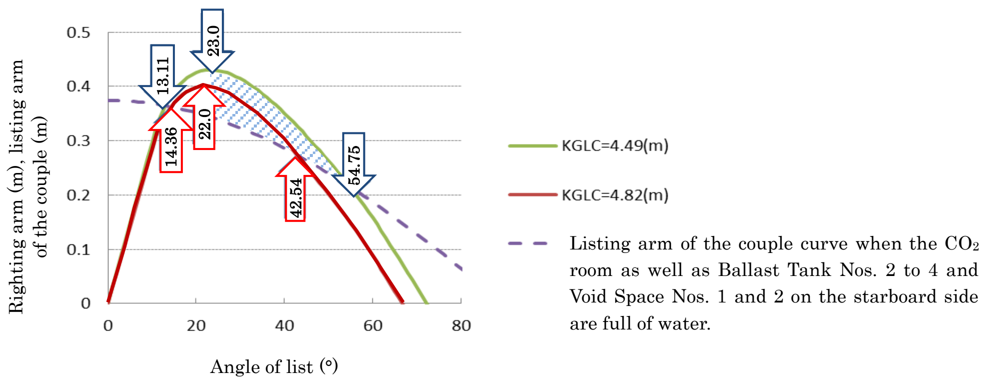

Figure 2.10-3 Stability Curve when the CO_2 Room as well as Ballast Tank Nos. 2 to 4 and Void Space Nos. 1 and 2 on the Starboard Side are Full of Water

(3) Flooding of the CO_2 Room and Cargo Hold

(Assumption: The CO_2 room is full of water and Cargo Hold No. 1 has 3.5% flooding [50.4 tons])

The stability curve is as shown in Figure 2.10-4. The angle of list is from around 5.82° to 6.53°; however, the free water effect is extremely large, and the GoM is from 0.69 to 0.78 m. As a result, residual stability suffers as overall stability worsens, and if flooding and

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*25 "Listing arm of the couple" is a value obtained by dividing the couple that is causing the hull to list (e.g., wind, waves, the movement of people or cargo in the vessel, etc.) by displacement.

listing increase and the list rate exceeds 17°, where the righting arm is largest, it is thought that wind and waves would cause capsizing in a relatively short period of time, a situation that is unlike the listing circumstances at the time of the accident.

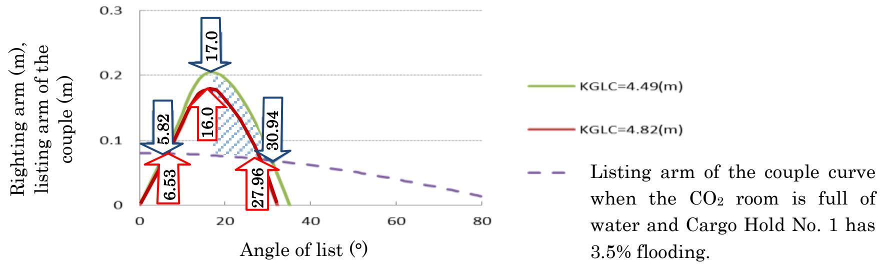


Figure 2.10-4 Stability Curve when the CO_2 Room is Full of Water and Cargo Hold No. 1 has 3.5% Flooding

(4) Flooding of the CO_2 Room, Ballast Tanks, and Void Spaces and Shifting of Cargo

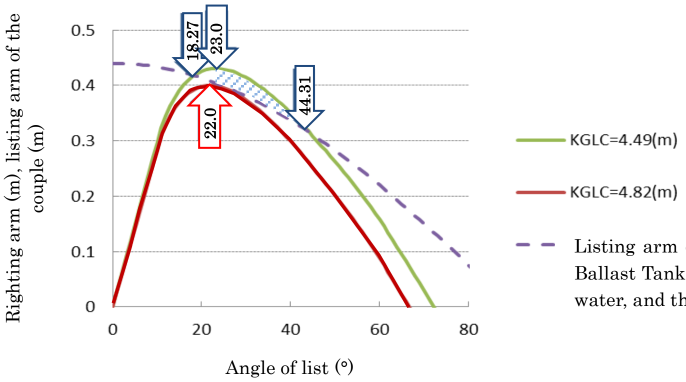
(Assumption: The CO_2 room, starboard Ballast Tank Nos. 2 to 4, and Void Space Nos. 1 and 2 are full of water, and there is a cargo shift in Cargo Hold No. 1 [5° cargo angle of inclination].)

The Vessel's attitude is as shown in Table 2.10-4 and the stability curve is as shown in Figure 2.10-5. When KGLC is 4.49 m, the angle of list is 18.27° and the angle of vanishing residual stability is 44.31°. Because residual stability is extremely small, it is thought that a situation occurs in which capsizing cannot be avoided. This roughly matches the 18° list of the Vessel at 03:00 on December 26.

It should be noted that when KGLC is 4.82 m, the listing moment is larger and thus it is thought that capsizing will occur without achievement of equilibrium between the listing moment and stability.

Table 2.10-4 Attitude of the Vessel when there is Full Flooding in the CO_2 Room, Starboard Ballast Tank Nos. 2 to 4, and Void Space Nos. 1 and 2, and there is a Cargo Shift in Cargo Hold No. 1

KGLC (m)	4.49	4.82
Bow draft (m)	5.87	
Stern draft (m)	5.46	
Mean draft (m)	5.67	
Displacement (t)	4,800.74	
Height of center of gravity (m)	3.69	3.77
Metacentric height (GoM) (m)	1.70	1.62
Angle of list (°)	18.27	-
Listing arm of the couple (m)	0.42	-



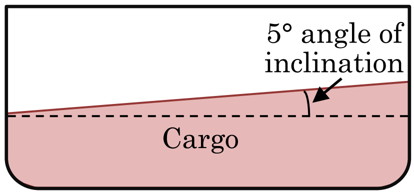


Figure 2.10-5 Stability Curve when the CO_2 Room, Starboard Ballast Tank Nos. 2 to 4, and Void Space Nos. 1 and 2 are Full of Water, and there is a Cargo Shift in Cargo Hold No. 1

2.10.4 Summary of the Circumstances Leading up to Foundering

It is thought that the Vessel's listing at the time of the accident can be explained by flooding and other developments in the CO_2 room, and compartments other than the CO_2 room where flooding was assumed, without flooding of the cargo holds, and that, when the angle of list exceeded 18°, a situation existed whereby capsizing was unavoidable with the action of even slight heeling moment.

3 ANALYSIS

3.1 Situation of the Accident

3.1.1 Analysis of Vessel Speed and Course over the Ground

According to 2.1, 2.6, and 2.7, it is somewhat likely that the Vessel's speed (speed over the ground; hereinafter the same) and course over the ground from around 05:09:12 to 21:36:34 on December 25, 2014, for which no AIS record was received from the Vessel, were as follows:

(1) Speed

(i) From about 05:09:12 to 15:30

Since the Vessel was receiving strong winds and waves from the direction of her starboard bow during this period, if it is estimated that the mean speed was the same as that from 01:00:40 to 05:09:11, when the wind direction and wave direction were roughly the same, then the Vessel's speed was approximately 5.4 kn.

(ii) From about 15:30 to 21:36:34

Since the Vessel was returning to the north coast of Honshu during this period, if it is estimated that the mean speed was the same as that from 21:36:35 to 01:30:15 on December 26, when it is probable that the wind direction and wave direction were roughly the same, then the Vessel's speed was approximately 6.9 kn.

(2) Course over the Ground

If the Vessel's position at around 15:30 is considered to be the intersection of circles drawn using runs estimated from the speeds mentioned in (1) above as radii on her positions at 05:09:11 and at 21:36:35, when AIS records were received, courses over the ground were as follows:

(i) From around 05:09:12 to 15:30: Approximately 241°

(ii) From around 15:30 to 21:36:34: Approximately 085°

3.1.2 Course of the Events

According to 2.1 and 3.1.1, the following events occurred.

(1) It is highly probable that the Vessel departed Hakodate Port for Kwangyang Port at around 16:00 on December 24, 2014.

(2) It is highly probable that the Vessel sailed on a heading of from 196° to 269° and at a speed of from 3.9 to 9.0 kn from 16:46:43 on December 24 to 05:09:11 on December 25.

(3) It is somewhat likely that the Vessel sailed at a course over the ground of approximately 241° and at a speed of approximately 5.4 kn from around 05:09:12 to 15:30.

(4) It is somewhat likely that the Vessel began returning to the north coast of Honshu around 15:30 and sailed at a course over the ground of approximately 085° and at a speed of approximately 6.9 kn from around 15:30 to 21:36:34.

(5) It is highly probable that the Vessel sailed on a heading from east-southeast to north-northeast and at a speed of from approximately 5.3 to 7.6 kn from around 21:36:35 to 03:00:15 on December 26, and that she sailed toward the Tsugaru Strait on a heading from east to north-northeast and at a speed of from approximately 4.3 to 6.1 kn from around 03:10:02 to 04:55:05 on December 26.

(6) It is probable that the Vessel's main engine stopped at around 05:17 and that the Vessel turned on her starboard side at around 06:02 and then foundered at around 06:05.

3.1.3 Situation of Hull List

According to 2.1.2 and 2.5.2, the events of the increasing hull list of the Vessel at the time of the accident are as shown in Table 3.1 and the water line situation (conceptual image) when the hull (in the state in which it was loaded when the Vessel departed Hakodate Port) listed is as shown in Figure 3.1. It is probable from the starboard list that the angle at which the starboard edge of the upper deck submerged was approximately 13°.

Table 3.1 Increases in the Hull List at Time of Accident

Time and date		Starboard angle of list
December 24	Around 16:00	No list
December 25	Around 05:00 to 09:00	Angle of list unknown
	Around 12:00	Approx. 4° - 5°
	Around 15:30	Approx. 7° - 10°
December 26	Around 03:00	Approx. 18°
	Around 04:55	Approx. 30°
	Around 05:45	Approx. 30° - 40°

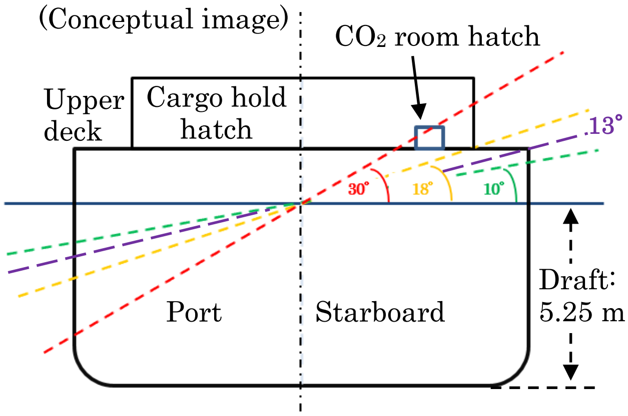


Figure 3.1 Water Line Situation at Time of List (State of Loading at Departure from Hakodate Port)

3.1.4 Date, Time and Location of the Accident Occurrence

According to 2.1.2, it is probable that the date and time of occurrence of the accident was at around 06:05 on December 26, 2014, and the location was around 318°, 8.3 M from the lighthouse on the northern breakwater of Ajigasawa Port.

3.1.5 Injuries to Persons

According to 2.1.2 and 2.2, the Chief Officer, Second Officer, and Able Seaman B died by drowning and Able Seaman A suffered hypothermia.

3.1.6 Damage to Vessel

According to 2.3, it is highly probable that the Vessel foundered.

3.2 Causal Factors of the Accident

3.2.1 Situation of Crew Members

According to 2.4.1, the situations of the crew members were as follows:

(1) Master

The Master did not possess a legally valid certificate of competence. This voyage was his first experience as master and he did not possess the necessary knowledge or experience required as master by the STCW Convention.

It is probable that he was in good health.

(2) Chief Engineer

The Chief Engineer did not possess a legally valid certificate of competence.

It is probable that he was in good health.

(3) Chief Officer

The Chief Officer possessed a legally valid certificate of competence.

It is somewhat likely that he was in good health.

(4) Second Officer

Whether or not the Second Officer possessed a certificate of competence could not be confirmed.

It is somewhat likely that he was in good health.

(5) Able Seaman B

It is somewhat likely that Able Seaman B's health was affected by an injury to his calf that occurred when his left leg was caught in a weathertight door.

3.2.2 Situation of the Vessel

According to 2.5.1 to 2.5.5, 2.7, and 3.1.3, the situation of the Vessel was as follows:

(1) It is probable that there was no malfunction or failure with the Vessel's engine or machineries.

(2) It is probable that the hatch cover of the CO_2 room developed a hole from corrosion or was not completely closed, which meant that the weathertightness of the CO_2 room was not being maintained.

(3) Given the circumstances of (2) above, the hull list at the time of the accident, and past incidents of Port State Control, it is probable that holes, etc., on the upper deck existed as a result of corrosion or other cause, and that the weathertightness of hatch covers, access openings, and other facilities on the upper deck was not being maintained at the time of the accident.

(4) Although the Vessel had a summer load line of 5.20 meters, since her draft was approximately 5.20 meters at the bow and approximately 5.30 meters at the stern when she departed Hakodate Port, and her mean draft was 5.25 meters, it is probable that she was sailing in a condition in excess of her LL Convention-based summer load line at the time of the accident.

3.2.3 Weather and Sea Conditions

According to 2.6, it is probable that, in the sea area in which the Vessel was sailing, from the time that the Vessel began listing until she foundered, the weather was snow with west-northwesterly and northwesterly winds of from 11.0 to 20.0 m/s, visibility was poor, waves with heights of from 2.3 to 3.9 m were coming from the west and west-northwest, and the seawater temperature was approximately 13°C. It is probable that the air temperature at around 06:00 on December 26 was approximately -2.8°C.

3.2.4 Analysis of the Hull's List

According to 2.1, 2.5.2, 2.6, 2.7, 2.10, 3.1.1 to 3.1.3, 3.2.2, and 3.2.3, it is probable that the causes of the hull's list are as provided in items (1) to (4) below. It is probable that, because the weathertightness of hatch covers, access openings, and other facilities on the upper deck of the Vessel was not being maintained at the time of the accident, waves striking the upper deck caused flooding through holes, etc., on the upper deck of not only the CO_2 room on the hull's starboard side but also the starboard ballast tanks or void spaces, or both, which generated listing moment and resulted in a starboard list.

(1) Waves striking the Vessel

(i) It is probable that from around 05:00 to 15:30 on December 25 the Vessel was sailing with her upper deck being struck by waves as the hull pitched and rolled.

(ii) It is probable that from 15:30 on December 25 to 06:05 on December 26 the Vessel was sailing while pitching and rolling because she was receiving waves of heights of from 3.0 to 3.9 m.

(2) Wind

(i) Given that from around 05:00 to 15:30 on December 25 the Vessel was sailing west-southwest and west, the wind was blowing from the west-northwest to northwest, and the Vessel as receiving winds from her starboard bow, it is probable that a wind-caused heeling moment to the starboard side had not occurred.

(ii) Given that from around 15:30 on December 25 to 05:17:02 on December 26 the Vessel was sailing from east-southeast to north-northeast, the wind was blowing from the west-northwest to northwest, and the Vessel was receiving winds from her stern and port bow, it is probable that the wind expedited the Vessel's starboard heeling.

(3) Flooding

(i) Flooding of the CO_2 Room

It is probable that because the CO_2 room's weathertightness was not being maintained, the CO_2 room flooded from striking waves. It is probable that the maximum list when the CO_2 filled with water was approximately 3.3°.

(ii) Flooding outside of the CO_2 Room

Based on the above item (i) and the following items a) and b), it is probable that, in addition to the CO_2 room, either the starboard ballast tanks or void spaces, or both, flooded, and that the maximum list this caused was approximately 14.4°.

a) It is probable that flooding of the CO_2 room and the starboard ballast tanks and starboard void spaces would cause a list of approximately 14.4°, enough to submerge the starboard edge of the upper deck.

b) In the case of flooded cargo holds, if stability suffered from the free water effect and the list exceeded 17°, it is probable that wind and waves would cause the Vessel to turn over on her side immediately, which is a situation that differs from the Vessel's situation at the time of the accident (turning over after approximately 3 hours with an 18° list). Thus it is probable that the cargo holds did not flood until immediately prior to the Vessel's turning over.

(4) Shifting Cargo

Given that when the Vessel departed Hakodate Port, her Cargo Hold No. 1 was not completely full, even though the surface of the cargo (shredded scrap) had been made level, there was room (space) for the cargo to shift to the starboard side due to the list and hull's pitching and rolling, and that, if it is assumed that the shredded scrap in Cargo Hold No. 1 shifted together with the flooding in the starboard compartments mentioned in item (3) (ii) above, this situation can explain the circumstances of the hull's list at the time of the accident (hull angle of list of 18° at around 03:00 on December 26), it is considered somewhat likely that the shredder in Cargo Hold No. 1 shifted to the starboard side as the starboard list increased and the hull pitched and rolled. However, as the shapes and weights of shredded scrap vary, it was not possible to determine the hull angle of list caused by the shifting of shredded scrap that was loaded onto the Vessel.

3.2.5 Analysis of the Vessel's Turning Over and Foundering

According to 2.1.2, 2.5.4, 2.5.5., 2.6, 2.7, 2.10, 3.1.1 to 3.1.3, and 3.2.2 to 3.2.4, it is probable that the following events occurred.

(1) After 15:30, when the Vessel began returning to the north coast of Honshu, her freeboard decreased as a result of the flooding and starboard list and the starboard side of her upper deck was repeatedly submerged by pitching and rolling caused by the waves. Consequently, seawater flooded the CO_2 room, ballast tanks, and other compartments of the starboard side from holes, etc., on the upper deck, causing the starboard list to increase.

(2) As the Vessel's starboard list increased, her upper deck's starboard side became submerged and the amount of water flooding into her hull's interior from hatch covers, access openings, and other facilities increased. At the same time she lost stability due to the effects of the wind and waves and began to turn over. The addition of even more water then resulted in her foundering.

3.2.6 Analysis of the Vessel's Safety Management

According to 2.4, 2.5, 2.7, 2.8, and 3.2.1 to 3.2.4, the Vessel's safety management was as follows:

(1) Given that neither the Master nor the Chief Engineer possessed a legally valid certificate of competence and that the Master did not possess the necessary knowledge or experience required as master by the STCW Convention, it is highly probable that Company A had not manned the Vessel with the master and chief engineer who met requirements of the STCW Convention that were specified on the Minimum Safe Manning Certificate issued by the Kingdom of Cambodia.

(2) It is probable that the Vessel's crewmembers did not periodically check holes, etc., on the upper deck to maintain her weathertightness.

(3) Given the surviving crewmembers did not know the content of the Safety Management Manual, it is probable that Company A did not properly provide them with education on the manual.

(4) Based on items (1) to (3) above, it is probable that Company A did not properly provide safety management for the Vessel based on the ISM Code or LL Convention in terms of, among other areas, properly manning the Vessel and providing education for her crewmembers.

(5) It is somewhat likely that if Company A had appropriately provided safety management for the vessel, such as by properly manning the Vessel and providing education for her crewmembers, the crewmembers would have understood the importance of maintaining weathertightness and would have been able to prevent flooding of the hull's interior and the starboard list by periodically checking holes, etc., on the upper deck to maintain her weathertightness.

(6) It is probable that the Vessel sailed in a condition that exceeded her load line that was set based on the LL Convention, and it is somewhat likely that if the Vessel had been in compliance with the LL Convention, the proper freeboard would have been maintained and the amount of flooding caused by waves striking the upper deck would have been reduced.

3.2.7 Analysis of the Accident Occurrence

According to 2.1, 2.10, 3.1.1 to 3.1.4, and 3.2.1 to 3.2.6, the analysis of the accident was as follows:

(1) As the Vessel sailed against waves from her starboard bow west of Tsugaru Strait, her CO_2 room, ballast tanks, and other compartments on the starboard side were flooded by water coming from holes, etc., on the upper deck when waves struck the upper deck. This occurred because the weathertightness of hatch covers, access openings, and other facilities on the upper deck was not maintained. Consequently, a listing moment was generated and the Vessel listed to starboard.

(2) After 15:30, when the Vessel began returning to the north coast of Honshu, her upper deck' starboard side was repeatedly submerged as a result of the flooding and starboard list as well as pitching and rolling caused by the waves. Consequently, seawater poured into the CO_2 room, ballast tanks, and other compartments of the starboard side from holes, etc., on the upper deck, causing the starboard list to increase.

(3) As the Vessel's starboard list increased, her upper deck's starboard side became submerged and the amount of water flooding into her hull's interior from hatch covers, access openings, and other facilities increased. At the same time she lost stability due to the effects of the wind and waves and began to turn over. The addition of even more water then resulted in her foundering.

(4) The Vessel's crewmembers did not periodically check holes, etc., on the upper deck to maintain her weathertightness.

3.3 Analysis of Measures to Alleviate Damage

According to 2.1.2, 2.2, 2.5.4, 2.9, and 3.2.3, the analysis of measures to alleviate damage was as follows:

(1) While it is probable that the crewmembers other than the Chief Officer abandoned the Vessel wearing life jackets and immersion suits, it is probable that the Chief Officer abandoned the Vessel wearing a life jacket but not wearing an immersion suit.

(2) When the Second Officer, Third Engineer, and Able Seaman A were rescued, their immersion suits contained large amounts of seawater. It is highly probable that the water entered their suits while they were drifting in the sea.

It is somewhat likely that contributing factors in the entry of large amounts of seawater into the immersion suits were failure to properly wear the suits and to properly store them. However, it was not possible to determine this situation, as information on these matters could not be obtained.

(3) Although the Chief Officer was wearing a life jacket and the Second Officer and Able Seaman B were wearing life jackets and immersion suits, all three died by drowning. Thus it is somewhat likely that, in an environment in which the air temperature was approximately -2.8°C and the seawater temperature was approximately 13°C, the fact that the Chief Officer was not wearing an immersion suit, that the Second Officer's suit contained a large amount of water, and that Able Seaman B had a calf injury were among contributing factors to this situation. However, it was not possible to determine the circumstances that led to their drowning.

(4) Although Able Seaman A wore both a life jacket and immersion suit, he suffered from hypothermia. Thus, it is somewhat likely that the fact that seawater at a temperature of

approximately 13°C entered his immersion suit was a contributing factor to this situation. However, it was not possible to determine why the Third Engineer did not suffer from hypothermia despite being in roughly the same situation as Able Seaman A.

(5) Each of the seven surviving crewmembers wore both a life jacket and immersion suit. It is probable their doing so allowed them to survive even under the weather and sea conditions described in item (3) above.

4 CONCLUSIONS

4.1 Probable Causes

It is probable that the accident occurred because, while the Vessel was sailing at night against waves from her starboard bow west of Tsugaru Strait, the Vessel foundered due to the fact that water from striking waves flooded the CO_2 room, ballast tanks, and other compartments on the starboard side through holes, etc., on the upper deck, thereby causing a starboard list and putting the Vessel into a situation in which her upper deck's starboard edge became submerged, and that this resulted in the Vessel's turning on her side when a greater amount of water flooded into the hull's interior through hatch covers, access openings, etc., and the Vessel lost stability and turned over due to the effect of the wind and waves, which in turn allowed additional water to flood in.

It is probable that the flooding of the CO_2 room, ballast tanks, and other compartments on the Vessel's starboard side from striking waves through holes, etc., on the upper deck occurred because the weathertightness of hatch covers, access openings, and other facilities of the upper deck was not maintained.

It is probable that the weathertightness of the hatch covers, access openings, and other facilities of the upper deck was not maintained because Vessel's crewmembers did not periodically check holes, etc., on the upper deck to maintain her weathertightness.

4.2 Other Identified Safety Issues

(1) Company A did not properly provide safety management for the Vessel in terms of properly manning the Vessel and providing education for her crewmembers. It is somewhat likely that, if Company A had appropriately provided safety management for the vessel, such as by properly manning the Vessel and providing education for her crewmembers, the crewmembers would have understood the importance of maintaining weathertightness and would have been able to prevent flooding of the hull's interior and the starboard list by periodically checking holes, etc., on the upper deck to maintain her weathertightness.

(2) It is probable that the Vessel sailed in a condition that exceeded her load line that was set based on the LL Convention, and it is somewhat likely that if the Vessel had been in compliance with the LL Convention, the proper freeboard would have been maintained and the amount of flooding caused by waves striking the upper deck would have been reduced.

(3) The Chief Officer and Second Officer died by drowning and Able Seaman A suffered hypothermia. It is somewhat likely that if the Chief Officer had put on an immersion suit before abandoning the Vessel and if the Second Officer and Able Seaman A had been able to prevent the inflow of seawater into the immersion suits they were wearing, the Chief Officer and the Second Officer would have survived and Able Seaman A would not have suffered hypothermia.

5 SAFETY ACTIONS

Implementation of the following measures is necessary to prevent occurrence of a similar accident and reducing damage.

(1) Crewmembers maintain weathertightness by periodically checking the integrity and closed condition of weathertight closing devices, etc., on the upper deck.

(2) Company A engages in thoroughgoing vessel safety management by, among other actions, manning the vessels it manages with crewmembers who possess legally valid certificates of competence and appropriately providing education to crewmembers.

(3) The Master maintains sufficient freeboard in compliance with the LL Convention.

(4) Crewmembers understand that seawater can enter immersion suits that are being worn, and wear immersion suits appropriately by periodically inspecting their storage conditions and practice putting them on.

(5) Authorities of the Kingdom of Cambodia direct management companies and recognized organizations to ensure that vessels in its registry are manned with personnel who possess the legally valid certificates of competence that are specified in Minimum Safe Manning Certificates and that safety management such as above items (1) to (4), etc., is properly practiced aboard them.

6 SAFETY RECOMMENDATIONS

It is probable that this accident occurred because MING GUANG was flooded through "holes in the hatch covers, ventilation fans, and air vent pipes of the upper deck and gaps in the manhole covers and access openings, etc." (hereinafter referred to as the "holes, etc., on the upper deck") while she sailed through waves coming from her starboard bow.

It is probable that MING GUANG's flooding through holes, etc., on the upper deck occurred because the vessel's weathertightness was not being maintained, as crewmembers did not periodically check holes, etc., on the upper deck to maintain her weathertightness.

It is probable that HK SAFE BLESSING SHIPPING Ltd. did not appropriately engage in safety management of MING GUANG, such as by properly manning the Vessel and providing education for her crewmembers, and that MING GUANG sailed in a condition that exceeded her load line that was set based on the International Convention on Load Lines of 1966.

It is somewhat likely that if the Chief Officer had put on an immersion suit before abandoning the Vessel and if the Second Officer and the surviving Able Seaman had been able to prevent the inflow of seawater into the immersion suits they were wearing, the Chief Officer and the Second Officer would have survived and the surviving Able Seaman would not have suffered hypothermia.

In view of the result of this accident investigation, the Japan Transport Safety Board recommends that HK SAFE BLESSING SHIPPING Ltd., as the management company, and the Kingdom of Cambodia, as the flag state of the MING GUANG, should take the following measures to prevent recurrence of similar accidents and reducing damage.

HK SAFE BLESSING SHIPPING Ltd. should engage in thoroughgoing vessel safety management that includes manning the vessels it manages with crewmembers who possess legally valid certificates of competence and appropriately providing education to crewmembers, and should instruct crewmembers to engage in the following practices:

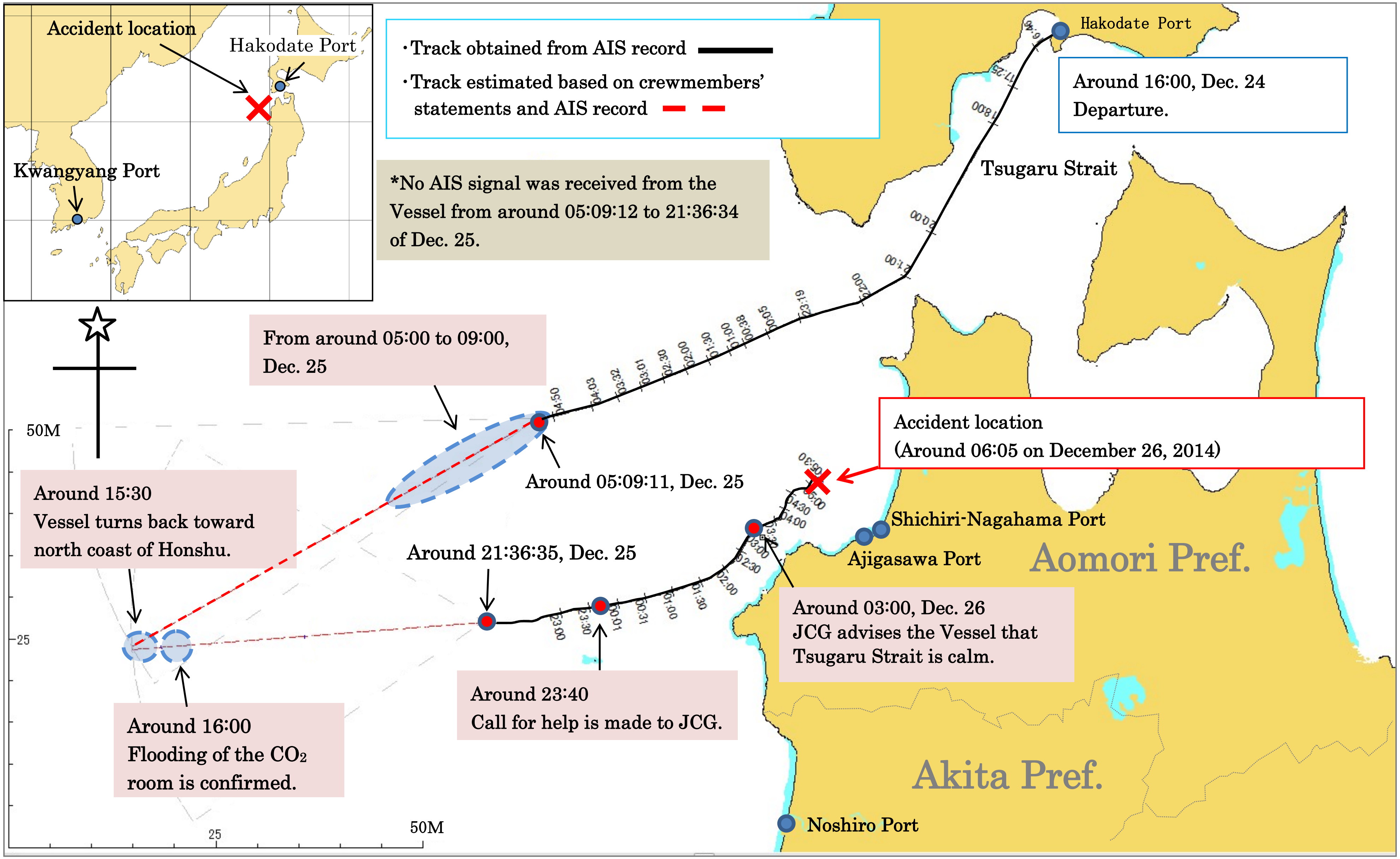
(1) Crewmembers shall maintain weathertightness by periodically checking the integrity and closed condition of weathertight closing devices, etc., on the upper deck.

(2) Masters shall maintain sufficient freeboard in compliance with the International Convention on Load Lines of 1966.

(3) Crewmembers shall understand that seawater can enter immersion suits that are being worn, and shall wear immersion suits appropriately by periodically inspecting their storage conditions and practice putting them on.

Authorities of the Kingdom of Cambodia should direct management companies and recognized organizations to ensure that vessels in its registry are manned with personnel who possess the legally valid certificates of competence that are specified in Minimum Safe Manning Certificates and that safety management such as above items (1) to (3) are thoroughly practiced aboard them.

Annex Figure 1 Estimated Navigation Routes



Analytical Investigation into the Foundering of “Cargo Ship A” Report

December 2015

National Maritime Research Institute
(NMRI)

Table of Contents

1. INTRODUCTION 1

2. ESTIMATION OF STABILITY 2

2.1 **Estimation of the Height of the Center of Gravity at the Time of Departure** 2

2.2 **Estimation of Stability at the Time of Departure** 3

3. ESTIMATION OF THE CONDITIONS LEADING UP TO FOUNDERING 6

3.1 Flooding of the CO_2 Room 7

3.1.1 20% Flooding in the CO_2 Room 7

3.1.2 Full Flooding of the CO_2 Room 8

3.2 Flooding of the CO_2 Room and Starboard Ballast Tanks (W.B.T.) 9

3.2.1 Full Flooding of Starboard W.B.T. Nos. 2 to 4 9

3.2.2 20% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4 10

3.2.3 76% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4 11

3.2.4 Full Flooding of CO_2 Room and Starboard W.B.T. Nos. 2 to 4 12

3.3 Flooding of CO_2 Room and Starboard Void Spaces 13

3.3.1 60% Flooding of Starboard Void Space Nos. 1 and 2 13

3.3.2 20% Flooding of CO_2 Room and Full Flooding of Starboard Void Space Nos. 1 and 2 14

3.3.3 76% Flooding of CO_2 Room and Full Flooding of Starboard Void Space Nos. 1 and 2 15

3.3.4 Full Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2 16

3.4 Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 to 4, and Void Space Nos. 1 and 2 17

3.5 Full Flooding of CO_2 Room, Starboard Void Space Nos. 1 and 2, and Starboard W.B.T. Nos. 2 to 4 with Cargo Inclination Angle of 5° 18

3.6 Full Flooding of CO_2 Room and 3.5% Flooding of Cargo Hold No. 1 20

4. Conclusion 21

Appendix 1 Compartments in which Flooding is Assumed to have Occurred 22

Appendix 2 Results of Preparatory Studies 23

	CO2 room	No. 2 W.B.T (S)	No. 3 W.B.T (S)	No. 4 W.B.T (S)	Void Space No. 1 (S)	Void Space No. 2 (S)	Cargo Hold No. 1	Chain locker	Cargo inclination angle	Angle of List
3.1.1	20%									0.62/0.66
3.1.2	100%									3.13/3.31
3.2.1		100%	100%	100%						3.78/3.96
3.2.2	20%	100%	100%	100%						4.28/4.48
3.2.3	76%	100%	100%	100%						5.71/5.97
3.2.4	100%	100%	100%	100%						6.31/6.61
3.3.1					60%	60%				4.57/4.83
3.3.2	20%				100%	100%				8.11/8.55
3.3,3	76%				100%	100%				9.68/10.2
3.3.4	100%				100%	100%				10.38/11.20
3.4	100%	100%	100%	100%	100%	100%				13.11/14.36
3.5	100%	100%	100%	100%	100%	100%			5°	18.27/-
3.6	100%						50.4t			5.82/6.53
A1	100%							100%		3.19/3.40
A2	100%				100%					6.47/6.83
A3	100%		50%							4.54/4.83
A4					30%	30%			4°	4.56/4.78
A5	20%				40%	40%			7°	7.22/7.49
A6	76%				50%	50%			10°	10.69/11.24
A7	76%				76%	76%			18°	18.24/-
A8	100%				100%	100%			10°	17.27/-
A9	100%	100%	100%		100%	100%			5°	17.84/-

1. INTRODUCTION

This report is a compilation of results obtained from the following studies that were conducted to assist the investigation of the foundering of Cargo Ship A (hereinafter referred to as "the Vessel"), which occurred to the northwest of Ajigasawa Port in Aomori Prefecture on December 26, 2014.

(1) Estimation of Stability

(2) Estimation of the Conditions Leading up to Foundering

2. ESTIMATION OF STABILITY

To begin, we estimated the Vessel's stability at the time of her departure from Hakodate Port in order to provide a basis for our study. The particulars of the Vessel are provided in Table 1.

Table 1 Vessel Particulars

Length overall (m)	86.40
Length between perpendiculars (m)	79.80
Beam (m)	12.80
Depth (m)	6.70
Design draft (m)	5.20
Light weight (t)	1035.7
Gross tonnage (t)	1915

2.1 Estimation of the Height of the Center of Gravity at the Time of Departure

Originally a cargo ship with grab crane, the Vessel was modified by removing the crane and extending the hull. Consequently, no information on the Vessel's height of the center of gravity (KG), which is needed for this study, was available. Accordingly, we decided to estimate the Vessel's KG based on the assumption that "the Vessel's KG would not differ from the KG value of the pre-modification cargo ship with grab crane that is in a state in which the crane is removed. Specifically, in order to give the estimate breadth, from the light-condition KG values of four cargo ships with grab crane that are similar to the pre-modification Vessel, we used two, the largest and the smallest, and considered those values to be equivalent to the light-condition KG of the pre-modification Vessel. We then obtained KG' as the value when the crane is removed using Formula (1) and established it as the light-condition KG of the Vessel.

$$KG' = \{W_B * KG - W_{JC} * (KH + HC) - W_{BCKT} * HB\} / (W_B - W_{JC} - W_{BCKT}) \qquad (1)$$

Here,

W_B: Light weight of the pre-modification Vessel
W_{JC}: Gross weight of the jib crane (excluding bucket weight)
W_{BCKT}: Bucket weight
KH: Height from bottom plating to crane base
HC: Height of center of gravity from jib crane base
HB: Bucket's height of center of gravity from bottom plating

The KG values of the Vessel that were estimated in this way are provided in Table 2.

Table 2 Estimated KG Values

	KG (light condition) (m)	Light weight (W_B) (t)	Crane weight (W_{JC}) (t) (excluding bucket)	Bucket weight (W_{BCKT}) (t)	Crane gross weight (t) (W_{JC} + W_{BCKT})	Corrected light weight (t) (W_B- W_{JC}- W_{BCKT})	HC (m) (jib angle 5°)	KH (m)	Bucket height (HB) (m)	Estimated KG (m) (excluding jib crane)
Vessel before modification	Unknown	1164.50	74.94	9	83.94	1080.56	1.36	7.58	7.7	
①	4.80									4.49
②	5.11									4.82

From here, we conducted our study using the two KG values shown on the right side of Table 2 (4.49 m and 4.82 m) as the light-condition KG of the Vessel (hereinafter noted as "KGLC").

2.2 Estimation of Stability at the Time of Departure

According to the investigation conducted by the Japan Transport Safety Board (hereinafter referred to as the "JTSB Investigation"), at the time of the Vessel's departure from port, her draft was 5.2 m in the bow and 5.3 m in the stern. She did not have a list. The Vessel's weight on board at the time of her departure as found by the JTSB Investigation is as shown in Table 3.1. As the amount of ballast water that was onboard is unknown, we used the results of an inspection of cargo conducted two days prior to her departure to estimate that she had onboard the amounts provided in Table 3.2.

Table 3.1 Weight on Board

Loaded cargo	Weight on board (t)	Specific gravity
Shredded scrap (Cargo Hold No. 1)	900	1.00 (*Bulk specific gravity)
Shredded scrap (Cargo Hold No. 2)	2100	1.00 (*Bulk specific gravity)
Fuel oil A (No. 2 FOT)	19	0.88
Fuel oil C (No. 3 FOT)	13	0.90
Lubricating oil (LOT)	2.58 (3 kl)	0.86
Fresh water (FWT & FPT)	63	1.00
Ballast water (Table 3.2)	173	1.025
Total	3270.6	

Table 3.2 Weight on Board of Ballast Water

Ballast water tank	Weight on board (t)
NO1 W.B.T.(P)	47
NO1 W.B.T.(S)	47
NO2 W.B.T.(P)	4
NO2 W.B.T.(S)	5
NO3 W.B.T.(P)	-
NO3 W.B.T.(S)	-
NO4 W.B.T.(P)	35

NO4 W.B.T.(S)	35
Total	173

In accordance with instructions from JTSB, we established, as shown in Table 3.1, that fuel oil A was stored in the Fuel Oil Tank No. 2 (No 2 FOT) on port and starboard sides, fuel oil C was stored in Fuel Oil Tank 3 (No. 3 FOT) on the port and starboard sides, and lubricating oil was stored in the Lubricating Oil Tank (LOT) and six drums fixed to the starboard hand rail of the crew's quarters deck. We further established for the fresh water that the Fresh Water Tank (FWT) had been filled and that the remaining fresh water was stored in the Forepeak Tank (FPT). It should be noted that, according to the JTSB Investigation, the surfaces of the scrap in the cargo holds had been leveled out.

Adding the weights of everything mentioned above produces a total weight on board of 3,270.6 tons. The Vessel's displacement, which we estimated from her draft and her buttock lines, was 4,407.9 tons. According to the Vessel's particulars table, her light weight was 1,035.7 tons. Thus adding her light weight and weight on board produces a total of 4,306.3 tons, which means that 101.6 tons are an unknown weight constant.

We matched the Vessel's light-condition KG (KGLC), including the unknown weight constant amount, to the Vessel's estimated KG values that were obtained in Section 2.1. We then adjusted the listing moment to make the list 0° and made the fore-and-aft position of the center of gravity and the values of the fore-and-aft position of the center of buoyancy that was obtained from the draft the same. Additionally, we considered the free water effect of the fuel oil A tanks, fuel oil C tanks, ballast tanks, and fresh water tanks that were not in full load condition. For the moment of inertia of area, height of the center of gravity, and position of fore-and-aft as well as port-and-starboard center of gravity of each tank, we used values contained in the tank capacity plans. When a tank capacity plan was unavailable, we interpreted values from the general arrangement plan and other sources.

The Vessel's assumed condition when she left port is as shown in Table 4. The Vessel's height of center of gravity (KG) when she left port was either 3.71 m or 3.79 m, and the metacentric heights G_0M that take free water effect into account for those heights were 1.51 m and 1.43 m, respectively. The stability curves for those conditions are shown in Figure 1. G_0Z (righting arm) in the figure was corrected from GZ, which does not take free water effect into account, with Formula (2) using the free water effect GG_0.

$$G_0Z = GZ - GG_0 \sin\phi \qquad (2)$$

Here, ϕ is the angle of list.

Hereinafter, in all cases, the G_0Z (righting arm) value shall indicate a value that takes free water effect into account by being corrected in this manner. Additionally, the arrows in the figure indicate, from the left, the angle of list when the righting arm is at maximum and the angle of vanishing stability.

Table 4 Condition at Departure

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.20	
Aft draft (m)	5.30	
Mean draft (m)	5.25	
Displacement (t)	4407.90	
Height of center of gravity (m)	3.71	3.79
Metacentric height (m)	1.51	1.43
Angle of list (°)	0.00	

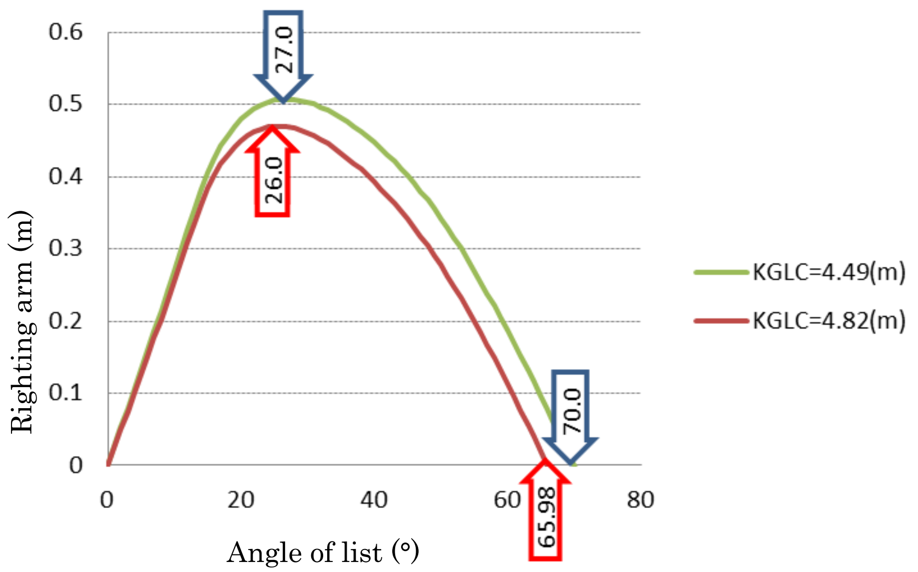


Figure 1 Stability (G_0Z) Curve in Condition at Departure

3. ESTIMATION OF THE CONDITIONS LEADING UP TO FOUNDERING

To estimate the conditions that led to the Vessel's foundering, we studied her situation and residual stability under various flooding conditions in starboard compartments of her hull, including the CO_2 room. Given that the JTSB Investigation identified the angle of list and flooding in the CO_2 room, we estimated situation and residual stability with focus on the Vessel's angle of list under various conditions in the CO_2 room and other starboard compartments of her hull. It should be noted that we did not take the amount of fuel or fresh water consumed during sailing into account when making our estimations. The angle of list appearing in the tables express the angle of inclination at the point of intersection between the stability curve and listing moment lever (hereinafter noted in the figures as "list lever"). Additionally, the arrows appearing in the figures indicate, from left, the angle of list at the point of intersection between the stability curve and listing moment lever, the angle of list where the righting arm is largest, and the angle of vanishing residual stability, which is the second point of intersection of the stability curve and listing moment lever.

3.1 Flooding of the CO_2 Room

Here, we estimated the Vessel's situation and residual stability with flooding in her CO_2 room, which is a situation that was revealed by the JTSB Investigation.

3.1.1 20% Flooding in the CO_2 Room

According to the JTSB Investigation, when flooding was first discovered in the CO_2 room, the water's surface had reached 40 cm above the floor. Flooding to 40 cm above the CO_2 room's floor is equivalent to 20% of the room's capacity. Here, we estimated the Vessel's situation and residual stability in a state in which flooding of 20% (13.2 t) existed in her CO_2 room. The Vessel's situation in this state is shown in Table 5 and the stability curves are shown in Figure 2. The angles of list are approximately 0.62° at KGLC = 4.49 (m) and approximately 0.66° at KGLC = 4.82 (m).

Table 5 Situational Data (CO_2 Room Flooding of 20%)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.25	
Aft draft (m)	5.28	
Mean draft (m)	5.27	
Displacement (t)	4420.65	
Height of center of gravity (m)	3.71	3.80
Metacentric height (m)	1.51	1.42
Angle of list (°)	0.62	0.66
Listing moment lever (m)	0.02	0.02

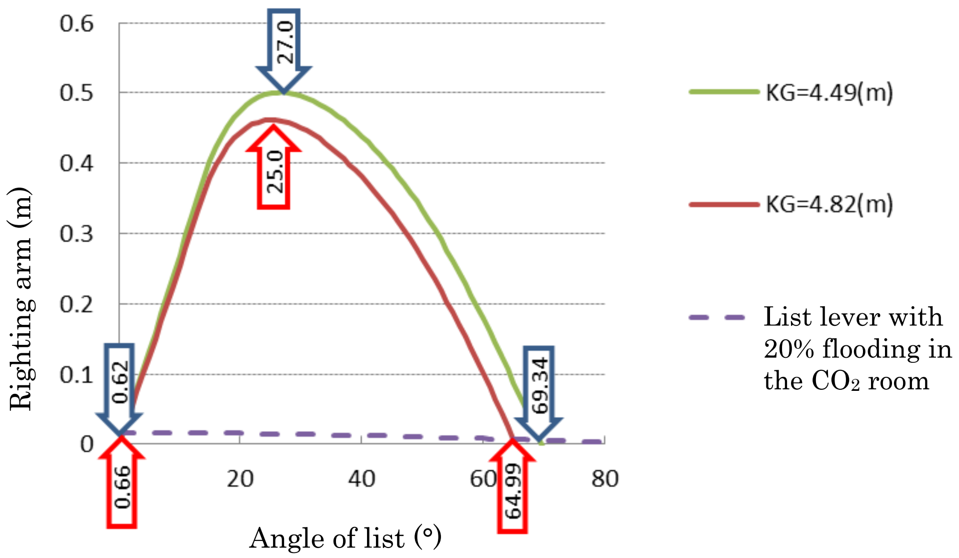


Figure 2 Stability Curves (CO_2 Room Flooding of 20%)

3.1.2 Full Flooding of the CO_2 Room

According to the JTSB Investigation, flooding eventually approached the CO_2 room's ceiling. Here, we estimated the Vessel's situation and residual stability in a state of full flooding (65.9 t) existed in her CO_2 room. The Vessel's situation in this state is shown in Table 6 and the stability curves are shown in Figure 3. The angles of list are approximately 3.1° at KGLC = 4.49 (m) and approximately 3.3° at KGLC = 4.82 (m).

Table 6 Situational Data when CO_2 Room is Fully Flooded

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.46	
Aft draft (m)	5.18	
Mean draft (m)	5.32	
Displacement (t)	4471.72	
Height of center of gravity (m)	3.74	3.82
Metacentric height (m)	1.48	1.40
Angle of list (°)	3.13	3.31
Listing moment lever (m)	0.08	0.08

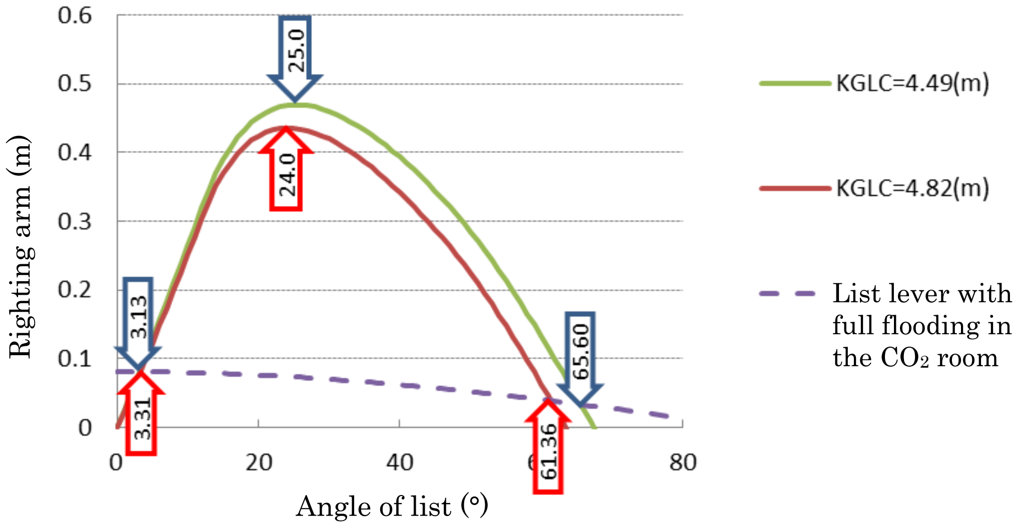


Figure 3 Stability Curves when CO_2 Room is Fully Flooded

3.2 Flooding of the CO_2 Room and Starboard Ballast Tanks (W.B.T.)

Here, we estimated the Vessel's situation and residual stability in the following four cases that assume flooding in the CO_2 room and starboard ballast tanks.

3.2.1 Full Flooding of Starboard W.B.T. Nos. 2 to 4

In the first case, we estimated stability when there is no flooding of the CO_2 room and full flooding of starboard W.B.T. Nos. 2 to 4 (tank weight: 60.3 t, 58.4 t, and 84.2 t, respectively.) The Vessel's situation in this state is shown in Table 7 and the stability curves are shown in Figure 4. The angles of list are approximately 3.8° at KGLC = 4.49 (m) and approximately 4.0° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (4 to 5°) identified in the JTSB Investigation.

Table 7 Situational Data (Full Flooding of Starboard W.B.T. Nos. 2 to 4)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.37	
Aft draft (m)	5.46	
Mean draft (m)	5.42	
Displacement (t)	4569.72	
Height of center of gravity (m)	3.60	3.68
Metacentric height (m)	1.76	1.68
Angle of list (°)	3.78	3.96
Listing moment lever (m)	0.12	0.12

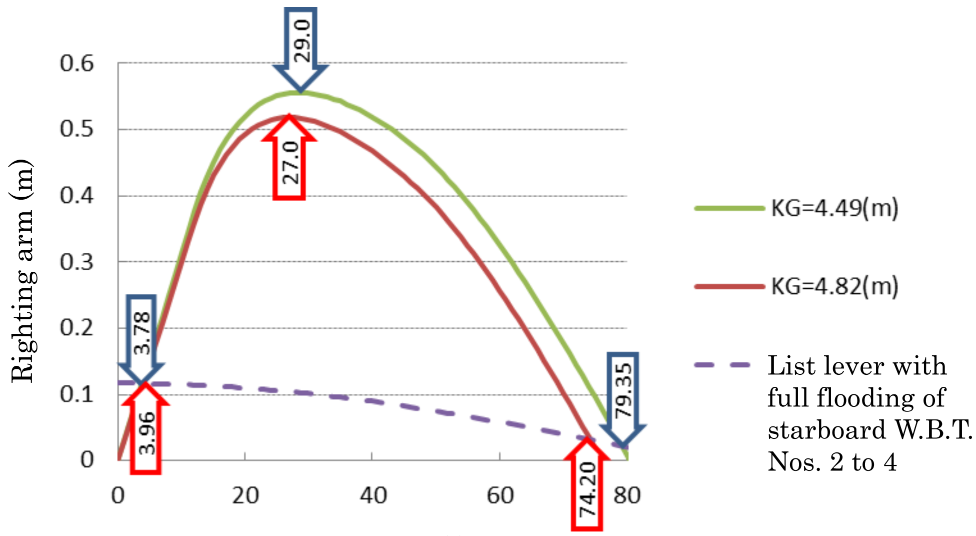


Figure 4 Stability Curves (Full Flooding of Starboard W.B.T. Nos. 2 to 4)

3.2.2 20% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4

Table 8 shows the Vessel's situation and Figure 5 shows the stability curves when the CO_2 room is 20% flooded and starboard W.B.T. Nos. 2 to 4 are fully flooded. The angles of list are approximately 4.3° at KGLC = 4.49 (m) and approximately 4.5° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (4 to 5°) identified in the JTSB Investigation.

Table 8 Situational Data (20% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.42	
Aft draft (m)	5.44	
Mean draft (m)	5.43	
Displacement (t)	4582.49	
Height of center of gravity (m)	3.60	3.68
Metacentric height (m)	1.76	1.38
Angle of list (°)	4.28	4.48
Listing moment lever (m)	0.13	0.13

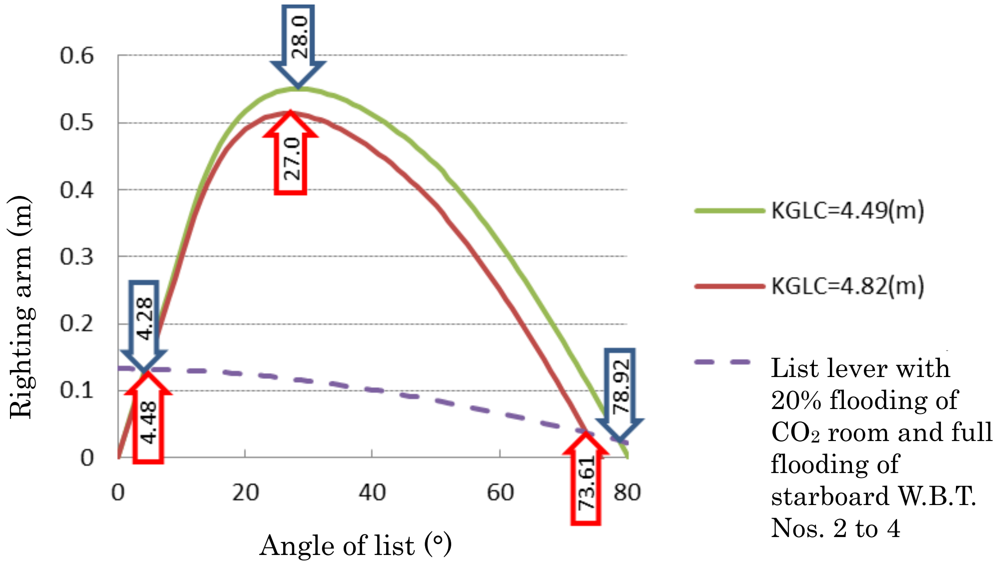


Figure 5 Stability Curves (20% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4)

3.2.3 76% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4

According to the JTSB Investigation, flooding up to 50 cm from the CO_2 room's ceiling was confirmed. Flooding at such state is equivalent to 76% of the CO_2 room's capacity. Table 9 shows the Vessel's situation and Figure 6 shows the stability curves when the CO_2 room is 76% flooded (50.1 t) and starboard W.B.T. Nos. 2 to 4 are fully flooded. The angles of list are approximately 5.7° at KGLC = 4.49 (m) and approximately 6.0° at KGLC = 4.82 (m).

Table 9 Situational Data (76% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.57	
Aft draft (m)	5.38	
Mean draft (m)	5.48	
Displacement (t)	4620.19	
Height of center of gravity (m)	3.62	3.70
Metacentric height (m)	1.74	1.66
Angle of list (°)	5.71	5.97
Listing moment lever (m)	0.17	0.17

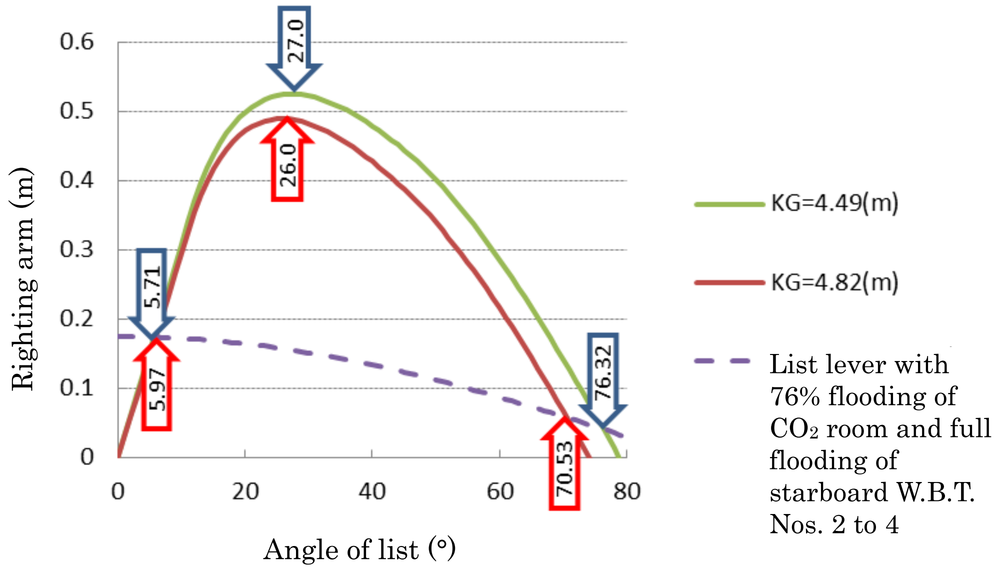


Figure 6 Stability Curves (76% Flooding of CO_2 Room and Full Flooding of Starboard W.B.T. Nos. 2 to 4)

3.2.4 Full Flooding of CO_2 Room and Starboard W.B.T. Nos. 2 to 4

Table 10 shows the Vessel's situation and Figure 7 shows the stability curves when the CO_2 room is fully flooded (65.9 t) and starboard W.B.T. Nos. 2 to 4 are fully flooded. The angles of list are approximately 6.3° at KGLC = 4.49 (m) and approximately 6.6° at KGLC = 4.82 (m).

Table 10 Situational Data (Full Flooding of CO_2 Room and Starboard W.B.T. Nos. 2 to 4)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.64	
Aft draft (m)	5.35	
Mean draft (m)	5.49	
Displacement (t)	4635.70	
Height of center of gravity (m)	3.63	3.71
Metacentric height (m)	1.73	1.65
Angle of list (°)	6.31	6.61
Listing moment lever (m)	0.19	0.19

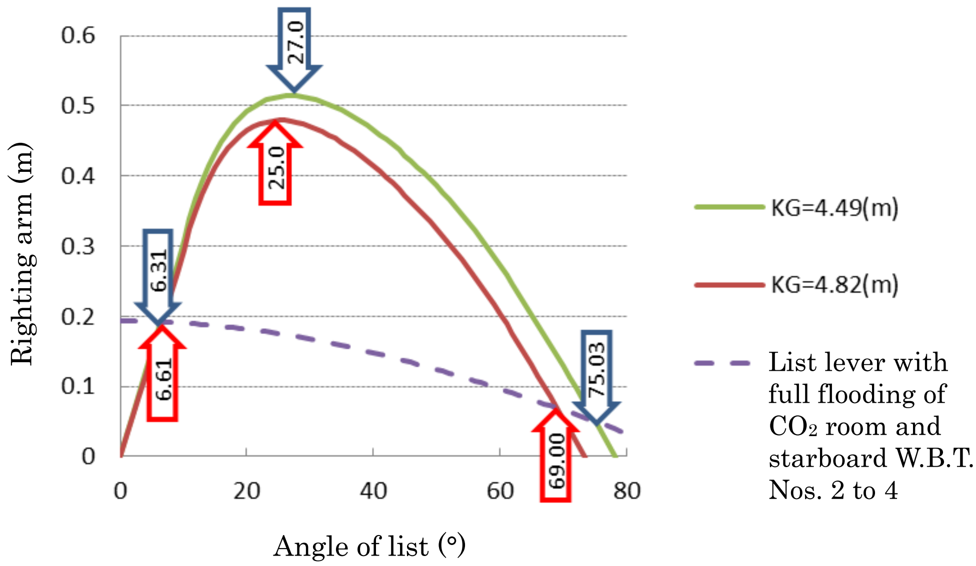


Figure 7 Stability Curves (Full Flooding of CO_2 Room and Starboard W.B.T. Nos. 2 to 4)

3.3 Flooding of CO_2 Room and Starboard Void Spaces

Here, we estimated the Vessel's situation and residual stability in the following four cases that assume flooding in the CO_2 room as well as in Void Space No. 1 on the upper starboard side of Cargo Hold No. 1, which was adjacent to the CO_2 room, and Void Space No. 2 on the upper starboard side of Cargo Hold No. 2, which was adjacent to starboard Void Space No. 1.

3.3.1 60% Flooding of Starboard Void Space Nos. 1 and 2

We estimated the Vessel's situation and residual stability based on the assumption that there was no flooding in the CO_2 room but 60% flooding in each of Void Space No. 1, which was adjacent to the CO_2 room, and Void Space No. 2, which was adjacent to Void Space No. 1. The amount of water when each of these void spaces is 60% flooded is 43.8 t in the case of Void Space No. 1 and 55.2 t in the case of Void Space No. 2. The Vessel's situation in this state is shown in Table 11 and the stability curves are shown in Figure 8. The angles of list are approximately 4.6° at KGLC = 4.49 (m) and approximately 4.8° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (4 to 5°) identified in the JTSB Investigation.

Table 11 Situational Data (60% Flooding of Starboard Void Space Nos. 1 and 2)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.34	
Aft draft (m)	5.37	
Mean draft (m)	5.35	
Displacement (t)	4504.85	
Height of center of gravity (m)	3.74	3.82
Metacentric height (m)	1.49	1.34
Angle of list (°)	4.57	4.83
Listing moment lever (m)	0.12	0.12

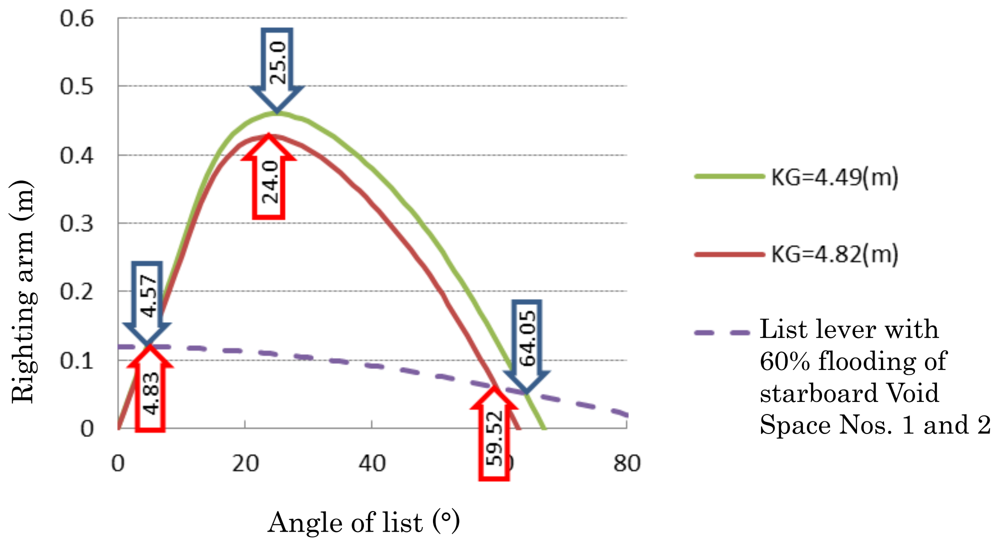


Figure 8 Stability Curves (60% Flooding of Starboard Void Space Nos. 1 and 2)

3.3.2 20% Flooding of CO_2 Room and Full Flooding of Void Space Nos. 1 and 2

We estimated the Vessel's situation and stability curves when the CO_2 room is 20% flooded (13.2 t) and starboard Void Space Nos. 1 and 2 are fully flooded. The amount of water when each of these void spaces is fully flooded is 72.9 t in the case of Void Space No. 1 and 92.0 t in the case of Void Space No. 2. The Vessel's situation in this state is shown in Table 12 and the stability curves are shown in Figure 9. The angles of list are approximately 8.1° at KGLC = 4.49 (m) and approximately 8.6° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (7 to 10°) identified in the JTSB Investigation.

Table 12 Situational Data (20% Flooding of CO_2 Room and Full Flooding of Starboard Void Space Nos. 1 and 2)

Light-condition height of center of gravity (m) (KGLC)	4.49	4.82
Fore draft (m)	5.48	
Aft draft (m)	5.39	
Mean draft (m)	5.43	
Displacement (t)	4582.24	
Height of center of gravity (m)	3.78	3.86
Metacentric height (m)	1.46	1.38
Angle of list (°)	8.11	8.55
Listing moment lever (m)	0.21	0.21

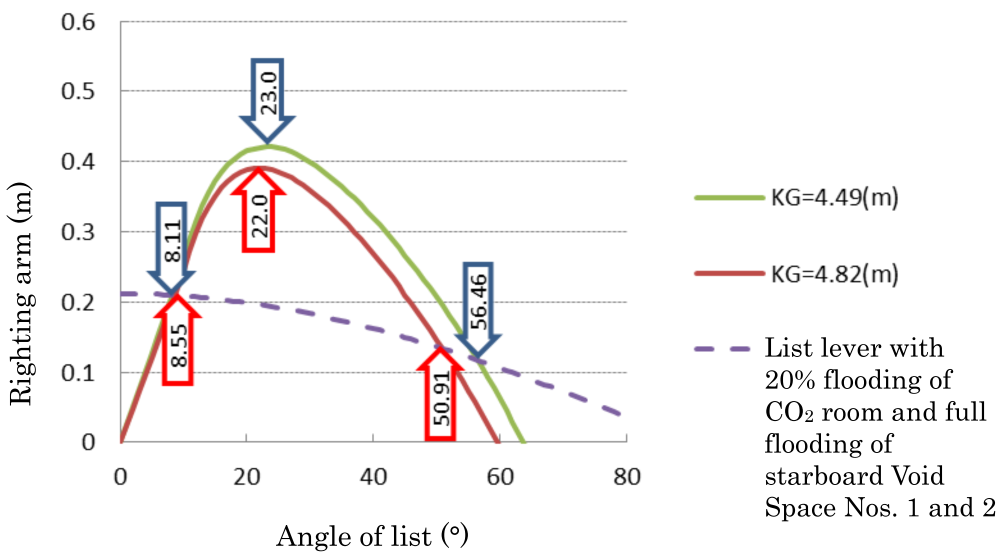


Figure 9 Stability Curves (20% Flooding of CO_2 Room and Full Flooding of Starboard Void Space Nos. 1 and 2)

3.3.3 76% Flooding of CO_2 Room and Full Flooding of Void Space Nos. 1 and 2

According to the JTSB Investigation, flooding approached 50 cm from the CO_2 room's ceiling. Flooding up to 50 cm from the CO_2 room's ceiling is equivalent to approximately 76% of the room's capacity. Accordingly, we estimated the Vessel's situation and stability curves when the CO_2 room is 76% flooded (50.1 t) and starboard Void Space Nos. 1 and 2 are fully flooded (72.9 t and 92.0 t). The Vessel's situation in this state is shown in Table 13 and the stability curves are shown in Figure 10. The angles of list in this state are approximately 9.7° at KGLC = 4.49 (m) and approximately 10.2° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (7 to 10°) identified in the JTSB Investigation.

Table 13 Situational Data (76% Flooding of CO_2 Room and Full Flooding of Starboard Void Space Nos. 1 and 2)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.63	
Aft draft (m)	5.32	
Mean draft (m)	5.48	
Displacement (t)	4620.06	
Height of center of gravity (m)	3.79	3.87
Metacentric height (m)	1.45	1.37
Angle of list (°)	9.68	10.20
Listing moment lever (m)	0.25	0.25

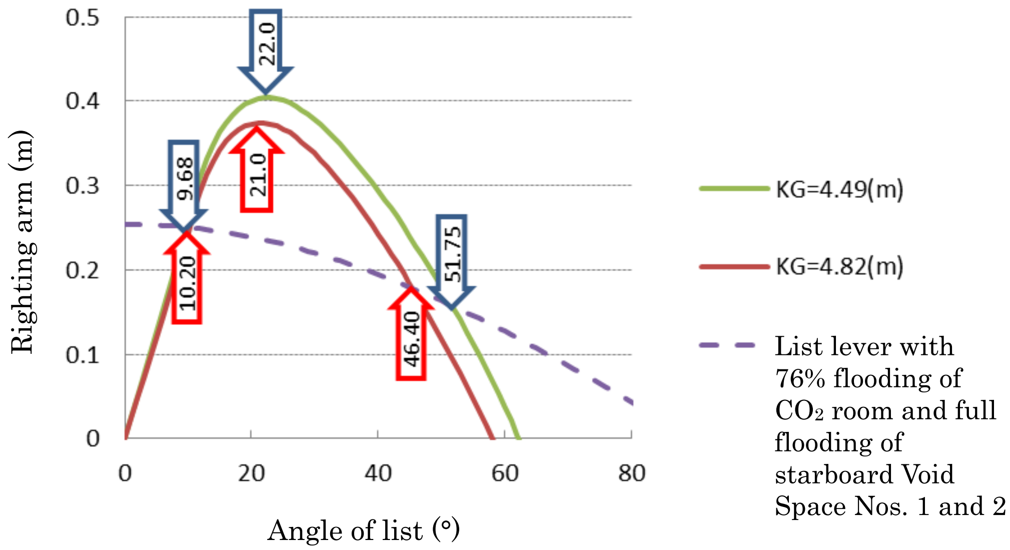


Figure 10 Stability Curves (76% Flooding of CO_2 Room and Full Flooding of Starboard Void Space Nos. 1 and 2)

3.3.4 Full Flooding of CO_2 Room and Void Space Nos. 1 and 2

We estimated the Vessel's situation and stability curves when the CO_2 room is fully flooded (65.9 t) and starboard Void Space Nos. 1 and 2 are also fully flooded (72.9 t and 92.0 t). The Vessel's situation in this state is shown in Table 14 and the stability curves are shown in Figure 11. The angles of list in this state are 10.4° at KGLC = 4.49 (m) and 11.2° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (7 to 10°) identified in the JTSB Investigation.

Table 14 Situational Data (Full Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2)

Light-condition height of center of gravity (m) (KGLC)	4.49	4.82
Fore draft (m)	5.70	
Aft draft (m)	5.29	
Mean draft (m)	5.50	
Displacement (t)	4635.58	
Height of center of gravity (m)	3.80	3.91
Metacentric height (m)	1.45	1.34
Angle of list (°)	10.38	11.20
Listing moment lever (m)	0.27	0.27

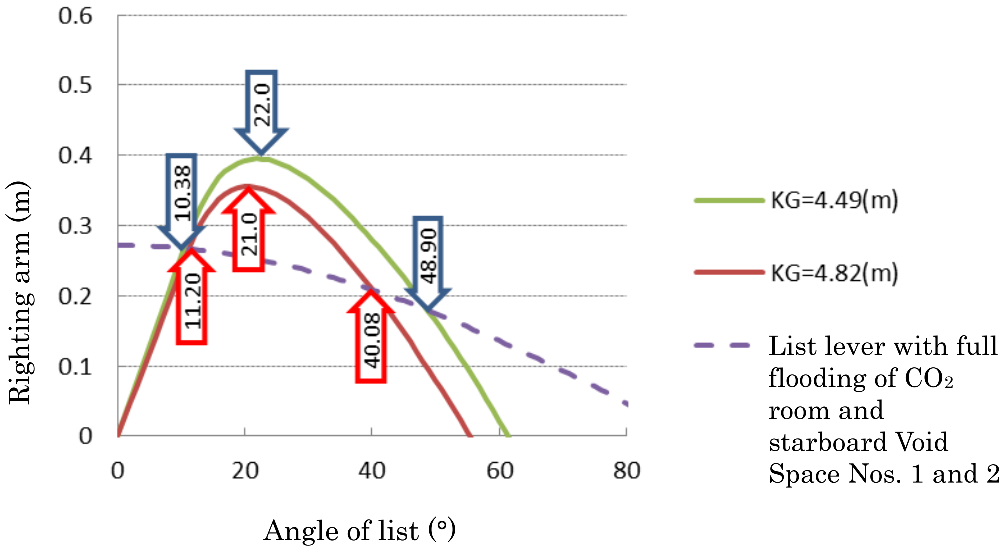


Figure 11 Stability Curves (Full Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2)

3.4. Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 to 4, and Void Space Nos. 1 and 2

We estimated the Vessel's situation and stability curves when the CO_2 room (65.9 t), starboard W.B.T. Nos. 2 to 4 (flooding amounts: 60.3 t, 58.4 t, and 84.2 t, respectively), and starboard Void Space Nos. 1 and 2 (72.9 t and 92.0 t) are fully flooded. The Vessel's situation in this state is shown in Table 15 and the stability curves are shown in Figure 12. The angles of list in this state are 13.1° at KGLC = 4.49 (m) and 14.4° at KGLC = 4.82 (m). The residual stability lever at the angle of list when the righting arm is at maximum is equivalent to 0.09 m at KGLC = 4.49 (m) and 0.05 m at KGLC = 4.82 (m). From this it can be inferred that capsizing would occur with the action of even slight heeling moment.

Table 15 Situational Data (Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 to 4, and Starboard Void Space Nos. 1 and 2)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.87	
Aft draft (m)	5.46	
Mean draft (m)	5.67	
Displacement (t)	4800.74	
Height of center of gravity (m)	3.69	3.77
Metacentric height (m)	1.70	1.62
Angle of list (°)	13.11	14.36
Listing moment lever (m)	0.36	0.36

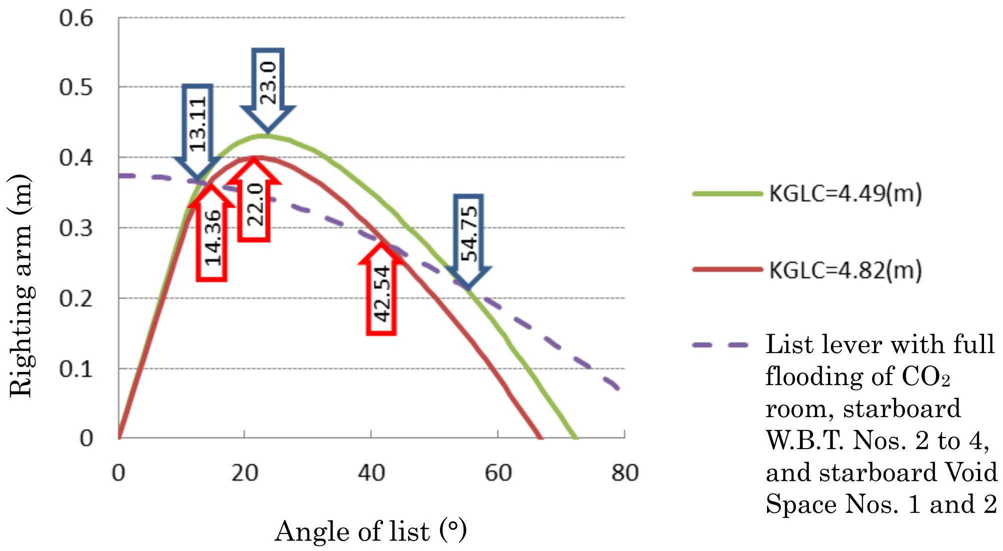


Figure 12 Stability Curves (Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 to 4, and Starboard Void Space Nos. 1 and 2)

3.5 Full Flooding of CO_2 Room, Starboard Void Space Nos. 1 and 2, and Starboard W.B.T. Nos. 2 to 4 with Cargo Inclination Angle of 5°

Given that the cargo (scrap) can behave in various ways, we conducted an analysis that assumes that the cargo is not compact and will move if the hull lists to a certain degree. We assumed movement in the half-full Cargo Hold No. 1 only, with no movement in Cargo Hold No. 2, which was in a full load condition. Based on this, we estimated the Vessel's situation and residual stability with the assumption that both tank flooding and cargo movement took place. Of course, we also took into account the fact that free water effect would be felt in the tanks assumed to be flooded if those tanks were not fully flooded.

To reproduce the approximately 18° angle of list revealed by the JTSB Investigation, we estimated the Vessel's situation and residual stability in a state in which, in addition to the circumstances described in 3.4 above, the cargo moved to produce a cargo inclination angle of 5°. A cargo inclination angle of 5° corresponds to a lateral shift of 0.35 m in the cargo's center of gravity. The Vessel's situation in this state is shown in Table 16 and the stability curves are shown in Figure 13. The angle of list in this state is 18.3° when KGLC = 4.49 (m). Moreover, residual stability is extremely small, corresponding to approximately 0.03 m at maximum stability lever. From this, it can be inferred that the Vessel would be in a state in which capsizing is unavoidable. In the case of KGLC = 4.82 (m), the angle of list at the point of intersection between the stability curve and listing moment lever cannot be obtained, meaning that the Vessel would be in a capsizing state.

Table 16 Situational Data (Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 to 4, and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 5° [Lateral Shift in Cargo's Center of Gravity of 0.35 m])

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.87	
Aft draft (m)	5.46	
Mean draft (m)	5.67	
Displacement (t)	4800.74	
Height of center of gravity (m)	3.69	3.77
Metacentric height (m)	1.70	1.62
Angle of list (°)	18.27	-
Listing moment lever (m)	0.42	-

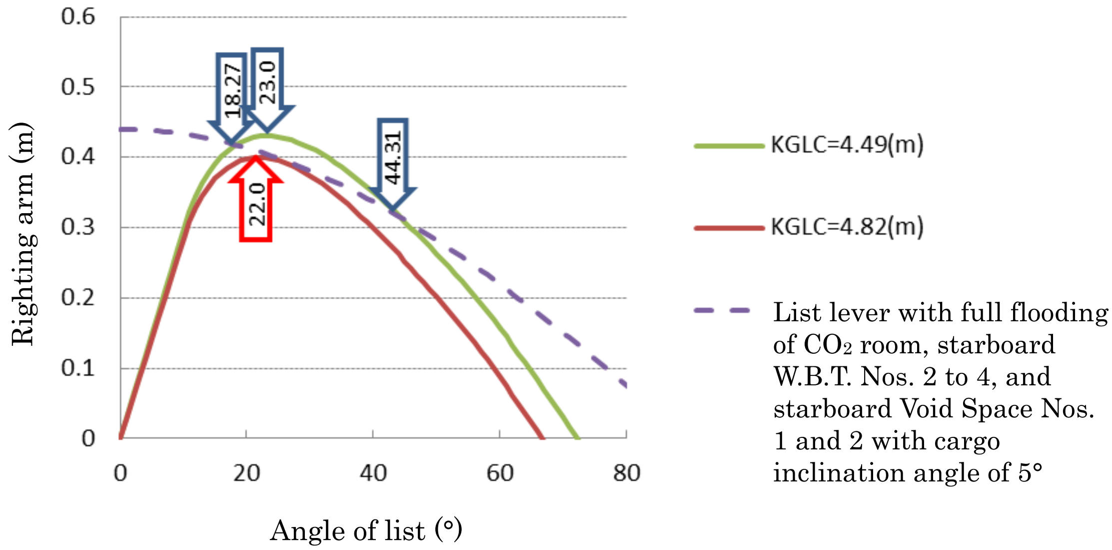


Figure 13 Stability Curves (Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 to 4, and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 5° [Lateral Shift in Cargo's Center of Gravity of 0.35 m])

3.6 Full Flooding of CO_2 Room and 3.5% Flooding of Cargo Hold No. 1

We estimated the Vessel's situation and residual stability in a state in which, in addition to full flooding in the CO_2 room, 3.5% flooding existed in Cargo Hold No. 1 (flooding amount: 50.4 t). In accordance with instructions from JTSB, we established the seawater's occupancy rate in Cargo Hold No. 1 at 83.2% (cargo's occupancy rate: 16.8%) in Cargo Hold No. 1 and the specific gravity of the flooded seawater at 1.025 x 0.832 = 0.853, and assumed thin and uniform distribution in the cargo hold. We assumed that there was no movement of the 900 t of cargo in Cargo Hold No. 1 and that the seawater had free water effect. The Vessel's situation in this state is shown in Table 17 and the stability curves are shown in Figure 14. The angles of list in this state are approximately 5.8° at KGLC = 4.49 (m) and approximately 6.5° at KGLC = 4.82 (m). The free water effect is extremely large and G_0M and residual stability are extremely small compared to the other estimated states discussed thus far. It is thought that if the angle of list increased to exceed 17° under such circumstances, the Vessel would capsize in a short period of time, which is a situation that is dissimilar to the circumstances of the angle of list in excess of 18° that were identified in the JTSB Investigation.

Table 17 Situational Data (Full Flooding of CO_2 Room and 3.5% Flooding of Cargo Hold No. 1)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.60	
Aft draft (m)	5.16	
Mean draft (m)	5.38	
Displacement (t)	4520.90	
Height of center of gravity (m)	3.71	3.78
Metacentric height (m)	0.78	0.69
Angle of list (°)	5.82	6.53
Listing moment lever (m)	0.08	0.08

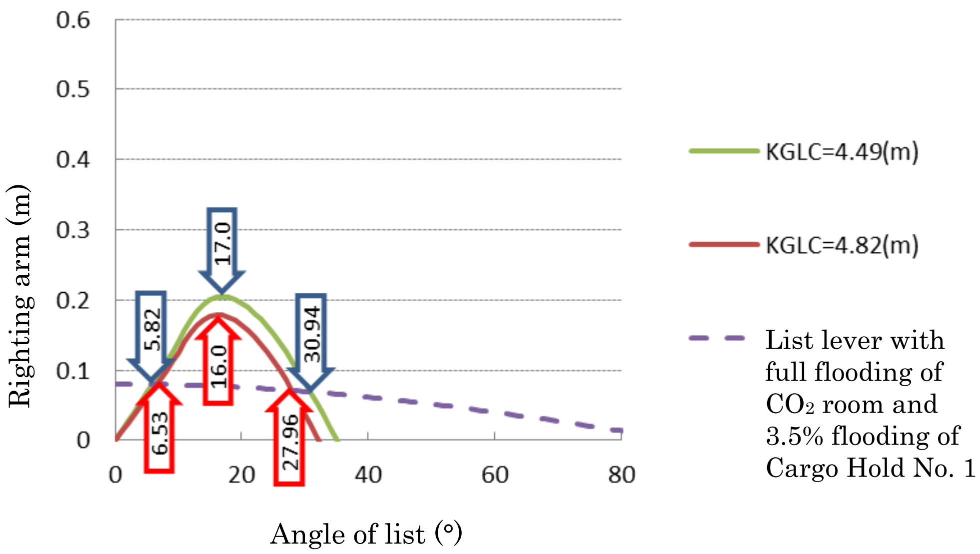


Figure 14 Stability Curves (Full Flooding of CO_2 Room and 3.5% Flooding of Cargo Hold No. 1)

4. CONCLUSION

We analyzed the Vessel's situation, angle of list, and residual stability in a number of states that would lead to foundering in order to contribute to the investigation into the Vessel's foundering. To begin, in order to estimate the Vessel's state at the time of her departure from port so as to provide a basis for our study, we estimated two light-condition heights of the center of gravity (KG) values from data on cargo ships with grab crane that resemble the pre-modification Vessel. We then estimated the Vessel's situation, angle of list, and residual stability in various states vis-à-vis the state when she departed from port that we determined based on the two KG values.

As a result, it is thought that, in all cases with the exception of flooding of the cargo holds, the circumstances of the assumed flooding and cargo movement satisfy the conditions of the angle of list, etc., that were identified in the JTSB Investigation. Specifically, the conditions of the 4 to 5° angle of list can be explained by items 3.2.1 to 3.2.2 and 3.3.1, those of the 7 to 10° angle of list can be explained by items 3.3.2 to 3.3.4, those of the angle of list exceeding approximately 10° can be explained by section 3.4, and those of the 18° angle of list can be explained by section 3.5.

Appendix 1 Compartments in which Flooding is Assumed to have Occurred

Figure A-0 presents the flooded compartments that were studied in this report.

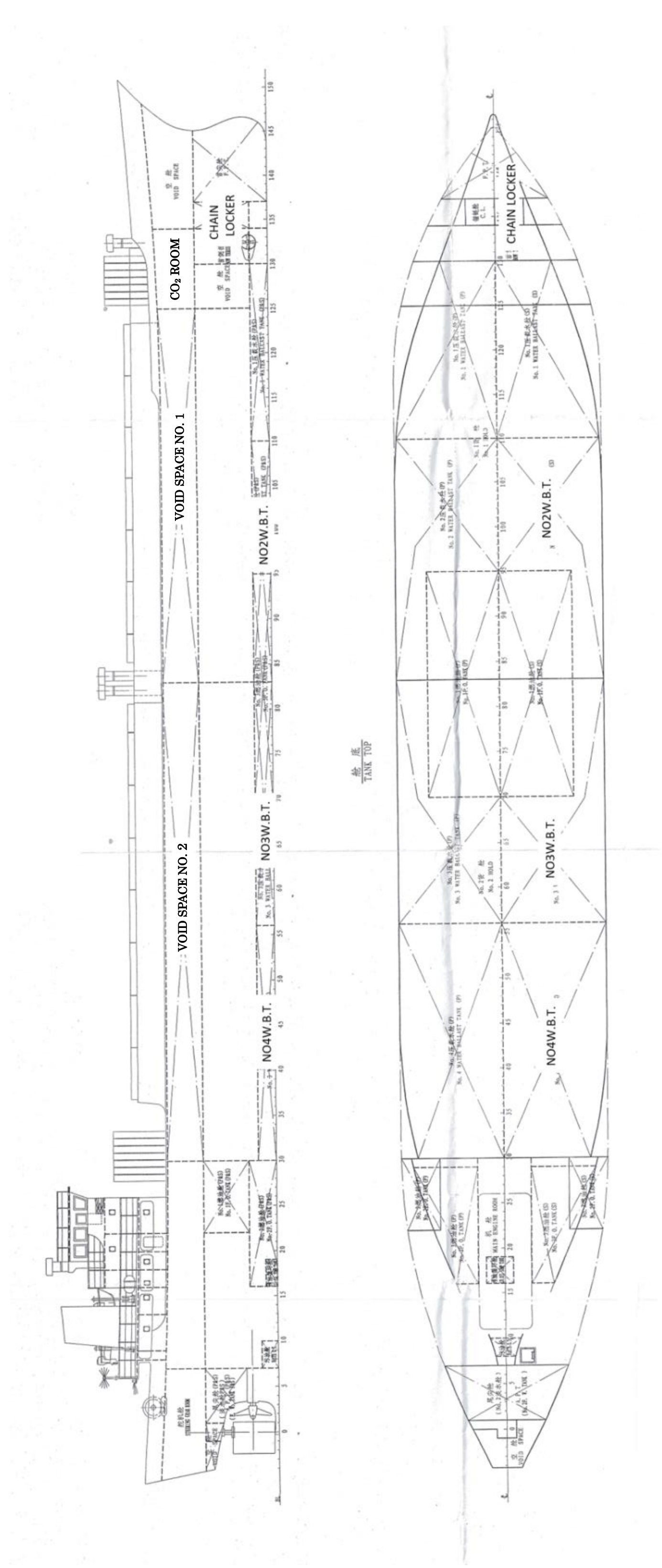


Figure A-0 Compartments in which Flooding is Assumed to have Occurred

Appendix 2 Results of Preparatory Studies

The following presents the results of evaluations on the Vessel's situation and residual stability under various flooding conditions that we conducted outside of the scope of the estimates provided in the report's main text.

A1 Full Flooding of CO_2 Room and Starboard Chain Locker

We estimated the Vessel's situation and stability curves when the CO_2 room and starboard chain locker are fully flooded. We obtained the amount of flooding of the chain locker (10.4 t) by subtracting the volume of the chain (established at 1.47 m^3 per 10 shackles in accordance with instructions from the Japan Transport Safety Board) from the capacity of the chain locker. However, we did not take the effect of free water into account for the chain locker. The Vessel's situation in this state is shown in Table A1 and the stability curves are shown in Figure A1. The angles of list in this state are approximately 3.2° at KGLC = 4.49 (m) and approximately 3.4° at KGLC = 4.82 (m).

Table A1 Situational Data (Full Flooding of CO_2 Room and Starboard Chain Locker)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.50	
Aft draft (m)	5.17	
Mean draft (m)	5.33	
Displacement (t)	4481.76	
Height of center of gravity (m)	3.73	3.82
Metacentric height (m)	1.49	1.40
Angle of list (°)	3.19	3.40
Listing moment lever (m)	0.08	0.08

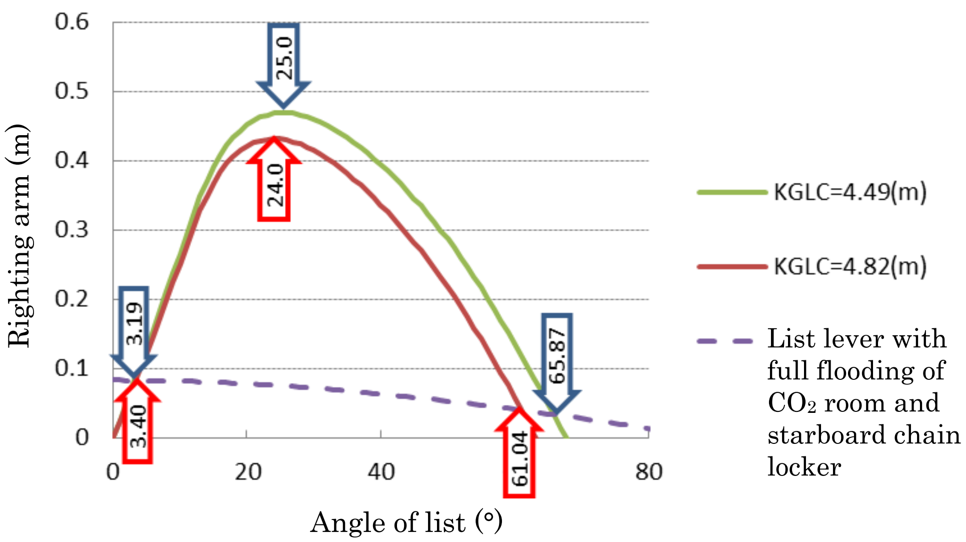


Figure A1 Stability Curves (Full Flooding of CO_2 Room and Starboard Chain Locker)

A2 Full Flooding of CO_2 Room and Void Space No. 1

We estimated the Vessel's situation and stability curves when the CO_2 room and starboard Void Space No. 1 (flooding amount: 72.9 t) are fully flooded. The Vessel's situation in this state is shown in Table A2 and the stability curves are shown in Figure A2. The angles of list in this state are approximately 6.5° at KGLC = 4.49 (m) and approximately 6.8° at KGLC = 4.82 (m).

Table A2 Situational Data (Full Flooding of CO_2 Room and Starboard Void Space No. 1)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.66	
Aft draft (m)	5.15	
Mean draft (m)	5.40	
Displacement (t)	4542.86	
Height of center of gravity (m)	3.77	3.85
Metacentric height (m)	1.46	1.38
Angle of list (°)	6.47	6.83
Listing moment lever (m)	0.17	0.17

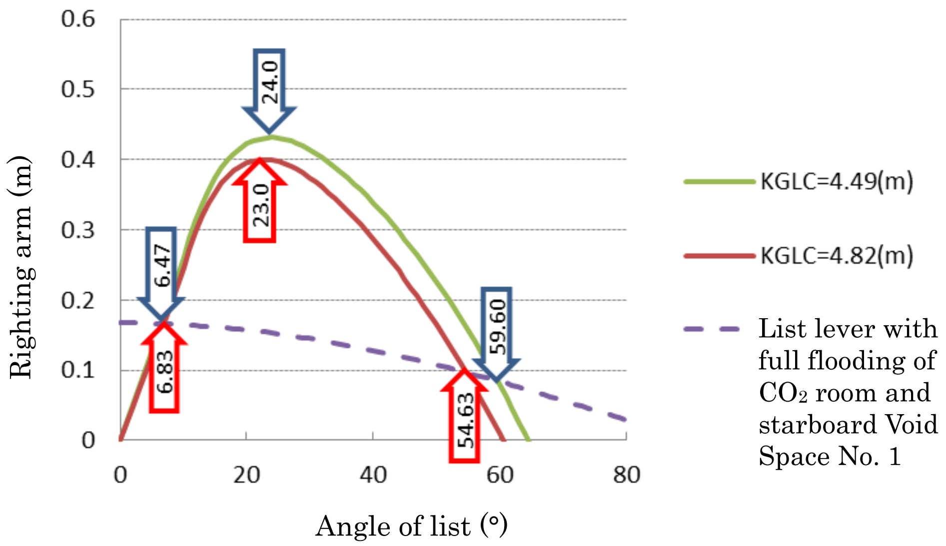


Figure A2 Stability Curves (Full Flooding of CO_2 Room and Starboard Void Space No. 1)

A3 Full Flooding of CO_2 Room and 86% Flooding of Starboard W.B.T. No. 3

We estimated the Vessel's situation and stability curves when the CO_2 room is fully flooded and the starboard W.B.T. No. 3 is 86% flooded (50 t). The Vessel's situation in this state is shown in Table A3 and the stability curves are shown in Figure A3. Of the W.B.T., only W.B.T. No. 3 was empty and free of the effect of free water, so to increase the angle of list, we hypothesized a situation in which flooding occurs to a degree that nearly fills the tank and produces a free water effect. The angles of list in this state are approximately 4.5° at KGLC = 4.49 (m) and approximately 4.8° at KGLC 4.82 (m).

Table A3 Situational Data (Full Flooding of CO_2 Room and 86% Flooding of Starboard W.B.T. No. 3)

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.50	
Aft draft (m)	5.25	
Mean draft (m)	5.37	
Displacement (t)	4520.84	
Height of center of gravity (m)	3.70	3.79
Metacentric height (m)	1.48	1.39
Angle of list (°)	4.54	4.83
Listing moment lever (m)	0.12	0.12

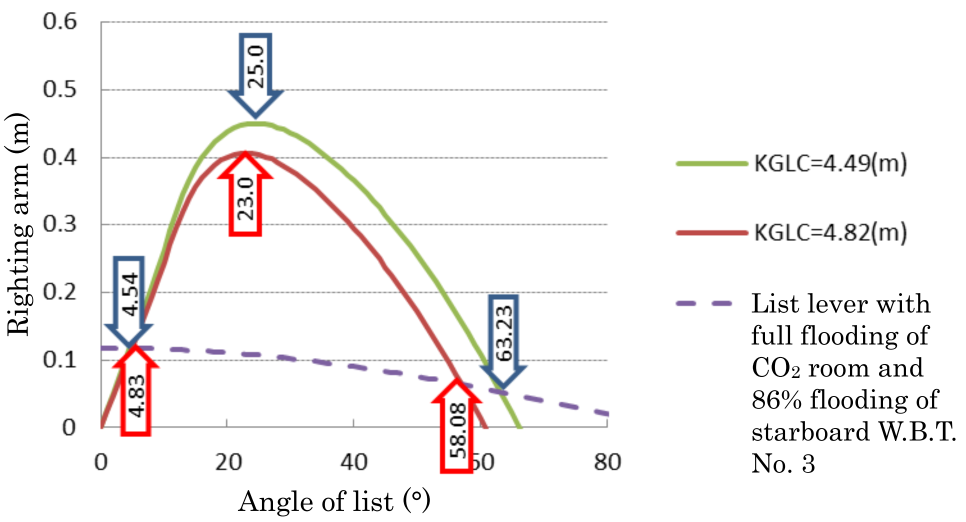


Figure A3 Stability Curves (Full Flooding of CO_2 Room and 86% Flooding of Starboard W.B.T. No. 3)

A4 30% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 4°

We estimated the Vessel's situation and stability curves when starboard Void Space Nos. 1 and 2 are 30% flooded (21.9 t and 27.6 t) and there is a cargo shift in Cargo Hold No. 1 (4° cargo angle of inclination). A cargo inclination angle of 4° corresponds to a lateral shift of 0.30 m in the cargo's center of gravity. The Vessel's situation in this state is shown in Table A4 and the stability curves are shown in Figure A4. The angles of list in this state are approximately 4.6° at KGLC = 4.49 (m) and approximately 4.8° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (4 to 5°) identified in the JTSB Investigation.

Table A4 Situational Data (30% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 4° [Lateral Shift in Cargo's Center of Gravity of 0.30 m])

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.27	
Aft draft (m)	5.33	
Mean draft (m)	5.30	
Displacement (t)	4456.36	
Height of center of gravity (m)	3.72	3.80
Metacentric height (m)	1.50	1.42
Angle of list (°)	4.56	4.78
Listing moment lever (m)	0.12	0.12

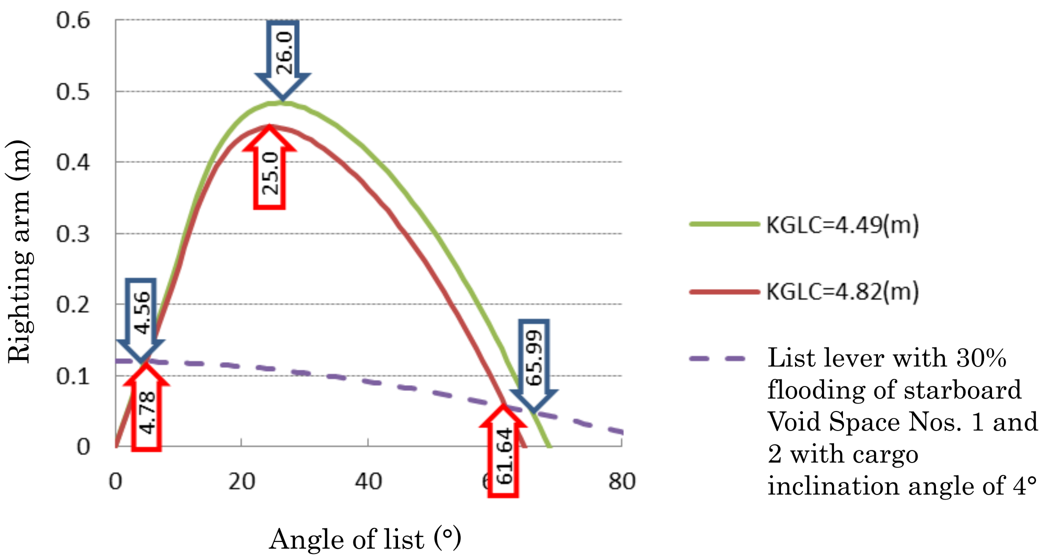


Figure A4 Stability Curves (30% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 4° [Lateral Shift in Cargo's Center of Gravity of 0.30 m])

A5 20% Flooding of CO_2 Room and 40% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 7°

We estimated the Vessel's situation and stability curves when the CO_2 room is 20% flooded (13.2 t) and starboard Void Space Nos. 1 and 2 are 40% flooded (29.2 t and 36.8 t) and there is a cargo shift in Cargo Hold No. 1 (7° cargo angle of inclination). A cargo inclination angle of 7° corresponds to a lateral shift of 0.47 m in the cargo's center of gravity. The Vessel's situation in this state is shown in Table A5 and the stability curves are shown in Figure A5. The angles of list in this state are approximately 7.2° at KGLC = 4.49 (m) and approximately 7.5° at KGLC = 4.82 (m), which roughly match with the Vessel's angle of list (7 to 10°) identified in the JTSB Investigation.

Table A5 Situational Data (20% Flooding of CO_2 Room and 40% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 7° [Lateral Shift in Cargo's Center of Gravity of 0.47 m])

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.35	
Aft draft (m)	5.32	
Mean draft (m)	5.33	
Displacement (t)	4485.28	
Height of center of gravity (m)	3.73	3.81
Metacentric height (m)	1.49	1.42
Angle of list (°)	7.22	7.49
Listing moment lever (m)	0.19	0.19

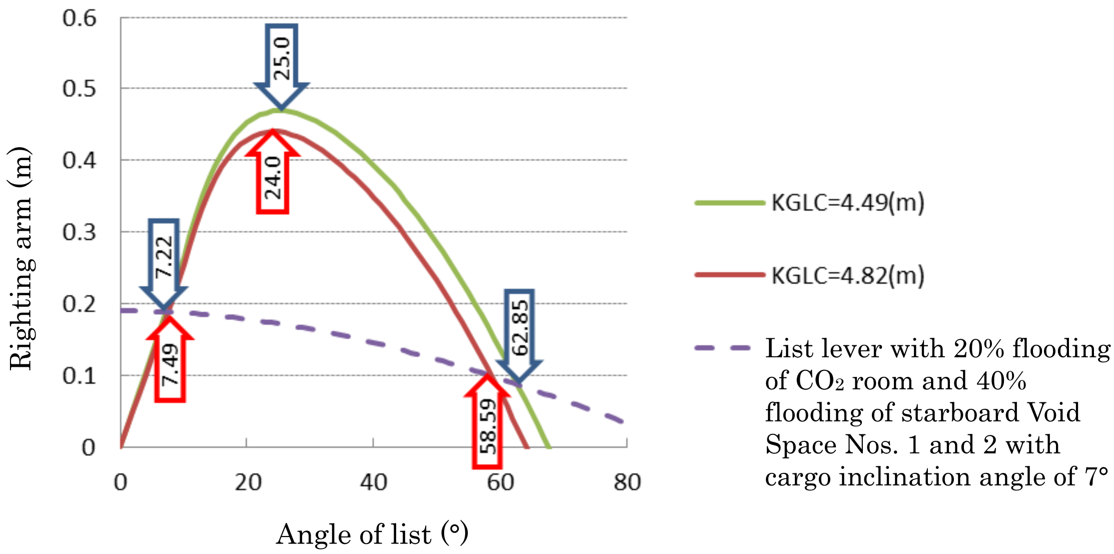


Figure A5 Stability Curves (20% Flooding of CO_2 Room and 40% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 7° [Lateral Shift in Cargo's Center of Gravity of 0.47 m])

A6 76% Flooding of CO_2 Room and 50% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 10°

We estimated the Vessel's situation and stability curves when the CO_2 room is 76% flooded (50.1 t) and starboard Void Space Nos. 1 and 2 are 50% flooded (36.5 t and 46.0 t) and there is a cargo shift in Cargo Hold No. 1 (10° cargo angle of inclination). A cargo inclination angle of 10° corresponds to a lateral shift of 0.64 m in the cargo's center of gravity. The Vessel's situation in this state is shown in Table A6 and the stability curves are shown in Figure A6. The angles of list in this state are approximately 10.7° at KGLC = 4.49 (m) and approximately 11.2° at KGLC = 4.82 (m).

Table A6 Situational Data (76% Flooding of CO_2 Room and 50% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 10° [Lateral Shift in Cargo's Center of Gravity of 0.64 m])

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.51	
Aft draft (m)	5.27	
Mean draft (m)	5.39	
Displacement (t)	4537.20	
Height of center of gravity (m)	3.75	3.83
Metacentric height (m)	1.48	1.40
Angle of list (°)	10.69	11.24
Listing moment lever (m)	0.28	0.28

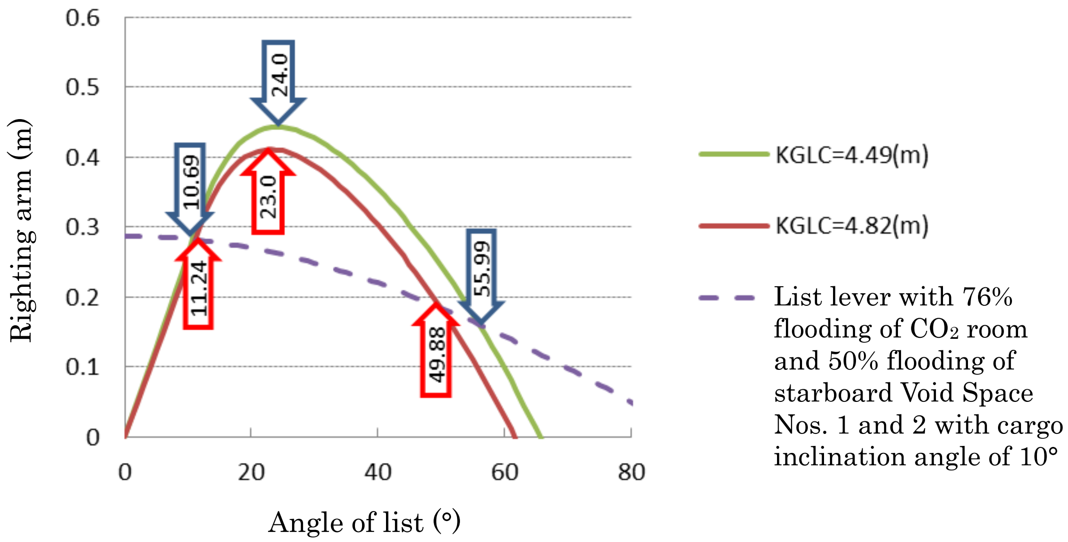


Figure A6 Stability Curves (76% Flooding of CO_2 Room and 50% Flooding of Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 10° [Lateral Shift in Cargo's Center of Gravity of 0.64 m])

A7 76% Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 18°

We estimated the Vessel's situation and stability curves when the CO_2 room is 76% flooded (50.1 t) and starboard Void Space Nos. 1 and 2 are 76% flooded (55.4 t and 69.9 t) and there is a cargo shift in Cargo Hold No. 1 (18° cargo angle of inclination). A cargo inclination angle of 18° corresponds to a lateral shift of 1.11 m in the cargo's center of gravity. The Vessel's situation in this state is shown in Table A7 and the stability curves are shown in Figure A7. The angle of list in this state is approximately 18.2° when KGLC = 4.49 (m). Moreover, residual stability falls greatly, and it can be inferred that the Vessel would capsize with just the addition of an external force equivalent to a heeling moment of around 0.02 m. When KGLC = 4.82 (m), the angle of list at the point of intersection between the stability curve and listing moment lever could not be obtained due to insufficient stability.

Table A7 Situational Data (76% Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 18° [Lateral Shift in Cargo's Center of Gravity of 1.11 m])

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.57	
Aft draft (m)	5.30	
Mean draft (m)	5.43	
Displacement (t)	4579.22	
Height of center of gravity (m)	3.77	3.85
Metacentric height (m)	1.46	1.38
Angle of list (°)	18.24	-
Listing moment lever (m)	0.41	0.41

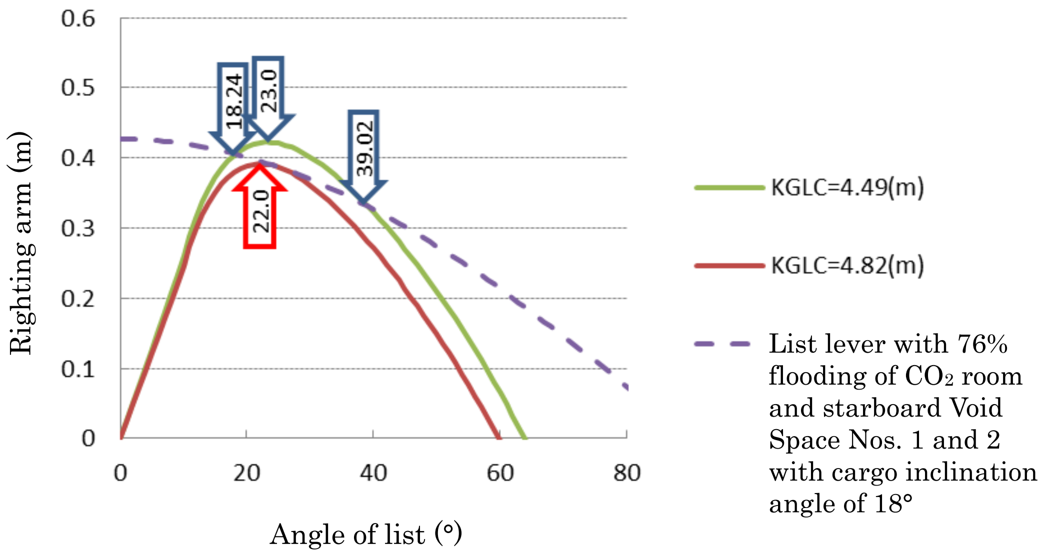


Figure A7 Stability Curves (76% Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 18° [Lateral Shift in Cargo's Center of Gravity of 1.11 m])

A8 Full Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 10°

We estimated the Vessel's situation and stability curves when the CO_2 room is fully flooded (65.9 t) and starboard Void Space Nos. 1 and 2 are fully flooded (72.9 t and 92.0 t) and there is a cargo shift in Cargo Hold No. 1 (10° cargo angle of inclination). A cargo inclination angle of 10° corresponds to a lateral shift of 0.64 m in the cargo's center of gravity. The Vessel's situation in this state is shown in Table A8 and the stability curves are shown in Figure A8. The angle of list in this state is approximately 17.3° when KGLC = 4.49 (m). Moreover, residual stability is extremely small, and it can be inferred that the Vessel would capsize with just the addition of an external force equivalent to a heeling moment of around 0.03 m. When KGLC = 4.82 (m), the angle of list at the point of intersection between the stability curve and listing moment lever could not be obtained due to insufficient stability.

Table A8 Situational Data (Full Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 10° [Lateral Shift in Cargo's Center of Gravity of 0.64 m])

Light-condition height of center of gravity (m) (KGLC)	**4.49**	**4.82**
Fore draft (m)	5.70	
Aft draft (m)	5.29	
Mean draft (m)	5.50	
Displacement (t)	4635.58	
Height of center of gravity (m)	3.80	3.91
Metacentric height (m)	1.45	1.34
Angle of list (°)	17.27	-
Listing moment lever (m)	0.38	-

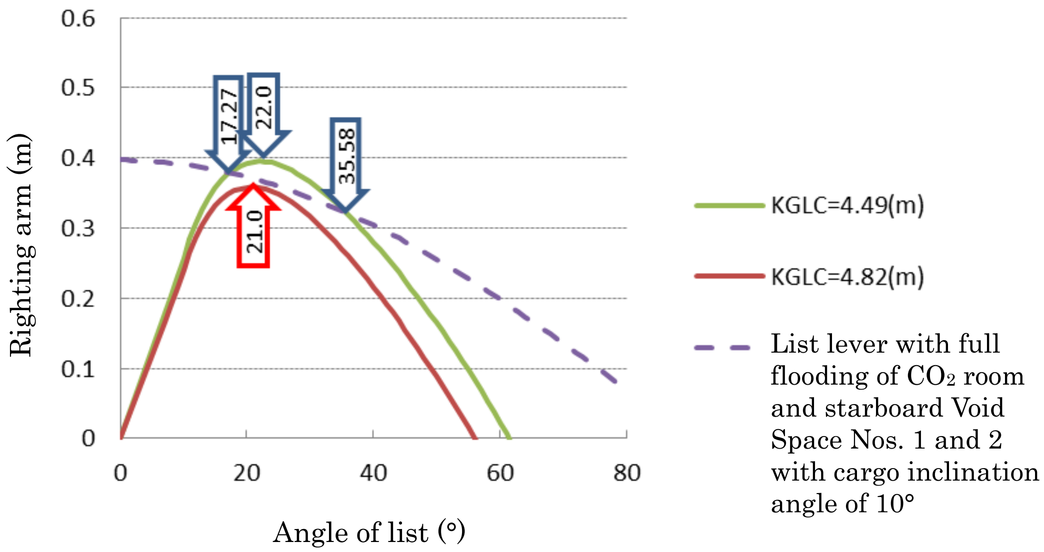


Figure A8 Stability Curves (Full Flooding of CO_2 Room and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 10° [Lateral Shift in Cargo's Center of Gravity of 0.64 m])

A9 Full Flooding of CO_2 Room, W.B.T. Nos. 2 and 3, and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 5°

We estimated the Vessel's situation and stability curves when the CO_2 room (65.9 t), starboard W.B.T. Nos. 2 and 3 (60.3 t and 58.4 t), and starboard Void Space Nos. 1 and 2 (72.9 t and 92.0 t) are fully flooded and there is a cargo shift in Cargo Hold No. 1 (5° cargo angle of inclination). A cargo inclination angle of 5° corresponds to a lateral shift of 0.35 m in the cargo's center of gravity. The Vessel's situation in this state is shown in Table A9 and the stability curves are shown in Figure A9. The angle of list in this state is approximately 17.8° when KGLC = 4.49 (m). Moreover, residual stability falls greatly, and it is thought that the Vessel would capsize with just the addition of an external force equivalent to a listing moment of around 0.02 m. When KGLC = 4.82 (m), the angle of list at the point of intersection between the stability curve and listing moment lever could not be obtained due to insufficient stability.

Table A9 Situational Data (Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 and 3, and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 5° [Lateral Shift in Cargo's Center of Gravity of 0.35 m])

Light-condition height of center of gravity (m) (KGLC)	4.49	4.82
Fore draft (m)	5.88	
Aft draft (m)	5.35	
Mean draft (m)	5.61	
Displacement (t)	4747.88	
Height of center of gravity (m)	3.73	3.81
Metacentric height (m)	1.58	1.50
Angle of list (°)	17.84	-
Listing moment lever (m)	0.39	-

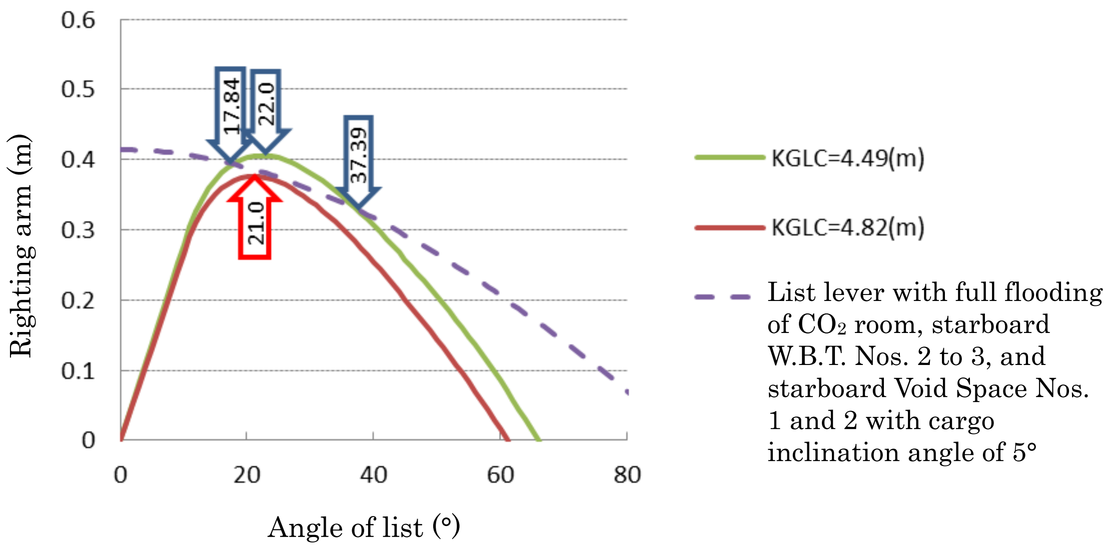


Figure A9 Stability Curves (Full Flooding of CO_2 Room, Starboard W.B.T. Nos. 2 and 3, and Starboard Void Space Nos. 1 and 2 with Cargo Inclination Angle of 5° [Lateral Shift in Cargo's Center of Gravity of 0.35 m])