MA2024-02

MARINE ACCIDENT INVESTIGATION REPORT

February 29, 2024

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.

TAKEDA Nobuo
Chairperson
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.

《Reference》

The terms used to describe the results of the analysis in "3. ANALYSIS" of this report are as follows.

i) In case of being able to determine, the term "certain" or "certainly" is used.
ii) In case of being unable to determine but being almost certain, the term "highly probable" or "most likely" is used.
iii) In case of higher possibility, the term "probable" or "more likely" is used.
iv) In a case that there is a possibility, the term "likely" or "possible" is used.

MARINE ACCIDENT INVESTIGATION REPORT

Vessel type and name: Container Ship ONE APUS
Vessel No. 143426 (IMO No. 9806079)
Gross tonnage: 146,694 tons

Accident/Incident type : Damage to container hatchcover,etc.
Date and time : November 30, 2020, around 23:22(ship time)(First heavy rolling) - December 1, 2020, around 00:59 (ship time)(Second heavy rolling)

Location: Off the northwest coast of the Hawaiian Islands, U.S.A.
Approximately 1,585 nautical miles (M) true 295° to 1,565 M
From Lehua Island Lighthouse, Niihau, Hawaiian Islands
(approximately 33°14.7′N, 172°31.8′E - 33°04.9′N, 172°51.5′E)

February 7, 2024
Adopted by the Japan Transport Safety Board
Chairperson TAKEDA Nobuo
Member ITO Hiroyasu
Member UENO Michio
Member SOUDA Hisako
Member OKAMOTO Makiko

SYNOPSIS

＜Summary of the Accident/Incident＞

The container Ship ONE APUS, with the master and 23 other crew members aboard, was proceeding east-south-east off the northwest coast of Niihau Island, Hawaiian Islands, U.S.A., when, between 23:22 on November 30, 2020 and 00:59 on December 1, 2020 (ship time), a rollover caused the cargo to collapse, causing 1,841 containers to fall overboard. The vessel then changed its destination and made an emergency entry into Hanshin Port.

The ONE APUS suffered a hole in the container hatch cover, etc., and 983 of the remaining containers were damaged, but there were no casualties.

＜Probable Causes＞

It is probable that the cause of the Accident was that, at night when the vessel was proceeding east-southeast off the west-northwest coast of Niihau Island in the Hawaiian Islands, when the ship was experiencing swells of approximately 5 to 6 m from the northwest and north-northwest directions on the port side and stern, and the master attempted to reduce the rolling. As the ship was sailing on a course of approximately 140°, the direction of the swell was close to the danger zone where the ship received waves from 30° to 60° to port stern, resulting in a roll angle of over 20° and the first cargo collapse.

After that, the master felt the rolling become even more intense, changed the course to approximately 120° and continued sailing, causing the direction of the swell to shift from the stern of the ship to 30° to 60° to port.

It is thought that this caused the cargo to enter the danger zone, resulting in a roll angle of 25 ° or more, and the second collapse of the cargo occurred.

It is probable that the cargo on the ship collapsed, causing the loaded containers to collapse and damage to container hatch cover and other equipment on deck leading to this accident.

The master set the course at approximately 140° and the direction of the swell was close to the danger zone. probably due to the fact that he could not properly assess the sea conditions at night.

The vessel is considered to have proceeded under conditions that were prone to parametric rolling from about 21:40 on November 30, when the rolling began, to about 00:59 on December 1, when the ship changed course significantly.

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

The container Ship ONE APUS, with the master and 23 other crew members aboard, was proceeding east-south-east off the northwest coast of Niihau Island, Hawaiian Islands, U.S.A., when, between 23:22 on November 30, 2020 and 00:59 on December 1, 2020 (ship time), a rollover caused the cargo to collapse, causing 1,841 containers to fall overboard. The vessel then changed its destination and made an emergency entry into Hanshin Port.

The ONE APUS suffered a hole in the container hatch cover, etc., and 983 of the remaining containers were damaged, but there were no casualties.

1.2 Outline of the Accident Investigation

1.2.1 Setup of the Investigation

On December 7, 2020, the Japan Transport Safety Board (JTSB) appointed a Regional Accident Investigator in charge of the investigation of this accident.

The investigator-in-charge was replaced by the Marine Accident Investigator.

1.2.2 Collection of Evidence

December 10, 2020: On-site investigation

December 24, 2020, February 9, 2021 On-site-investigation and interview

December 16, 23, 2020; January 7, 28, February 9, August 13, September 1, December 8, 24, 2021; January 31, February 15, April 11, May 6, June 14, 22, 2022; May 9, July 7, 28, 2023 collection of questionnaire

November 12, 25, 2021; March 4, October 27, 2022; January 13, 26, February 6, February 17, March 16, 2023: interview

1.2.3 Comments of Parties Relevant to the Cause

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

1.2.4 Tests and Research by Other Institutes

In the investigation of this accident, the JTSB entrusted the National Maritime Research Institute to analyze the ship's motion.

2 FACTUAL INFORMATION

2.1 Events Leading to the Accident

2.1.1 Navigation Track According to the Voyage Data Recorder

ONE APUS (hereinafter referred to as “the Vessel”) According to the records of the Voyage Data Recorder[*1] (hereinafter referred to as "VDR") of the vessel from 23:00 on November 30, 2020 to 01:30 on December 1, 2020 (ship time, hereinafter the same except as otherwise noted). Table 1 shows the vessel's operations during the period from around 23:00 on November 30, 2020 to around 01:30 on December 1, 2020 (ship time, hereinafter the same unless otherwise noted).

The ship time is 12 hours ahead of the Universal Time (UTC). The vessel’s position is the location of the GPS antenna mounted above the bridge, the heading and bow bearing are true heading, and the speed is in knots (kn) (speed over the ground[*2], the same applies hereinafter).

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*1 “Voyage Data Recorder (VDR)” is an instrument that is able to record the position, course, speed, radar information and other data about navigation as well as communication by VHF radio telephone and voices in the bridge.

*2 “Speed over the ground” refers to the speed of a vessel as measured against one point on the earth’s surface. The speed of a vessel as measured against the water in which the vessel is traveling is called “speed over water”.

Table 1 AIS Record (excerpt)

Time (HH:MM:SS)	Position		Course Over the Ground (°)	Heading (°)	Speed Over the Ground (knots(KN))
	Latitude (N) (° —′ —″)	Longitude (E) (° —′ —″)			
23:00:00	33-18-04.4	172-27-22.5	130.7	129	14.2
23:05:00	33-17-19.0	172-28-25.6	133.2	129	13.9
23:10:00	33-16-35.1	172-29-27.8	125.9	127	13.6
23:12:00	33-16-17.8	172-29-52.4	131.2	128	13.5
23:14:00	33-16-00.2	172-30-16.9	136.1	129	13.1
23:15:00	33-15-51.6	172-30-28.7	120.6	130	13.1
23:16:00	33-15-42.9	172-30-40.5	143.7	130	13.3
23:18:00	33-15-25.7	172-31-04.7	140.4	129	13.3
23:20:00	33-15-06.6	172-31-26.5	143.9	142	13.5
23:21:00	33-14-56.2	172-31-36.7	138.9	139	13.9
23:22:00	33-14-45.3	172-31-46.0	136.9	141	13.3
23:23:00	33-14-34.9	172-31-56.5	148.9	136	13.9
23:24:00	33-14-25.3	172-32-07.5	126.5	127	13.3
23:25:00	33-14-17.6	172-32-20.0	123.3	118	13.0
23:27:00	33-14-04.1	172-32-46.7	121.0	121	13.2
23:29:00	33-13-50.4	172-33-14.1	117.2	120	13.1
23:30:00	33-13-43.4	172-33-27.5	124.4	120	13.7
23:31:00	33-13-36.5	172-33-41.2	119.9	119	14.1
23:35:00	33-13-10.1	172-34-36.0	121.8	122	13.4
23:40:00	33-12-35.5	172-35-45.0	121.8	119	13.4
23:50:00	33-11-27.1	172-38-02.5	118.0	118	13.6
00:00:00	33-10-25.3	172-40-07.6	124.3	115	11.3
00:10:00	33-09-30.9	172-42-04.5	122.5	121	11.8
00:20:00	33-08-33.3	172-44-01.1	120.1	118	11.4
00:30:00	33-07-38.8	172-45-57.5	120.6	115	11.6
00:40:20	33-06-40.6	172-47-56.1	120.5	118	11.5
00:45:00	33-06-14.8	172-48-51.0	123.3	120	11.3
00:50:00	33-05-44.9	172-49-49.0	119.2	118	11.3
00:55:00	33-05-15.7	172-50-46.7	119.7	120	11.3
00:56:00	33-05-09.8	172-50-58.3	123.9	121	11.3
00:57:00	33-05-03.9	172-51-09.7	116.9	119	11.7

00:58:00	33-04-57.7	172-51-21.6	126.7	116	12.4
00:58:30	33-04-55.3	172-51-27.7	136.0	116	12.1
00:59:00	33-04-52.6	172-51-33.7	146.7	114	13.5
00:59:30	33-04-50.1	172-51-39.9	098.4	115	11.5
00:00:00	33-04-47.2	172-51-45.6	128.1	118	11.4
01:01:00	33-04-41.5	172-51-56.9	122.4	129	10.9
01:02:00	33-04-34.0	172-52-06.7	127.3	142	11.5
01:03:00	33-04-24.6	172-52-14.7	141.1	155	11.7
01:04:00	33-04-14.2	172-52-19.8	159.1	167	11.4
01:05:00	33-04-02.8	172-52-22.5	172.8	179	11.6
01:10:00	33-03-00.0	172-52-21.7	179.7	183	13.4
01:20:00	33-00-39.8	172-52-22.1	180.7	185	14.6

2.1.2 Record of the Voyage Data Recorder

(1) Record of voice communication on the vessel's bridge

According to the VDR records of the vessel, the main audio and other information recorded by the microphones installed in the bridge and on the bridge wing of the vessel during the period from around 22:46 on November 30th to 01:04 on December 1st is shown in Table 2.

In addition, the sound of the impact of the movement of installations and other objects in the bridge due to rolling*3 was recorded intermittently a total of three times, at around 23:14:47-15:25 (Table 2①), 23:21:48-22:20 (Table 2②), and 00:58:12-59:15 on December 1 (Table 2③), respectively.

*3 Rolling" refers to the rotational motion around the horizontal bowline axis passing through the center of gravity of the hull. (Rotational motion around each axis of the hull is otherwise referred to as "longitudinal sway (pitching)" for rotational motion around the horizontal axis through the center of gravity of the hull and "bow sway (yawing)" for rotational motion around the vertical axis.) (See 2.5.3 Table 7)

Table 2 VDR voice communication and other information (excerpts)

Time (HH:MM:SS)	Main conversation, etc.
22:46:45	Master of the vessel (hereinafter referred to as the "Master"): 129.
23:14:47	＜Gah (sound of a chair or something moving)＞①
23:15:01	<Giggle, clang, clang, clang (sound of a chair or something moving and bumping into each other)> ①
23:15:10	<Dawn (sound like a container or something collapsing)
23:15:12	Third Officer (hereinafter referred to as the "Officer C"): Oh.
23:15:16	Able seaman (hereinafter referred to as the "Able seaman A")：Hand steering moment sir.
23:15:20～25	<Gash, clang, clang (sound of something moving and bumping into something) > ①
23:16:16	Able seaman A：Hand steering sir. 130.
23:17:15	Master: 140, Able seaman A: 140.
23:19:25	Able seaman A: Steady 140 sir. Master: OK.
23:21:48	<Gee (sound of a chair or something moving)>②
23:21:55	Master: 120. Able seaman A: 120.
23:22:05～20	<Gee (sound of something moving)>②
23:23:05	Able seaman A: Heading for 120.
23:39:40	Able seaman (hereinafter referred to as the "Able seaman B")：One lower container. Right was high and seaside was very high.
23:39:55	Chief Officer ("Officer A")：You see.
23:40:00	Able seaman B：That is 42.
23:47:59	Officer C：How much speed sir.
23:48:03	Master：Speed 40,42.
00:35:26	Second Officer ("Officer B")：MORNING MIDAS＊. This is ONE APUS. How do you read me? Over.（＊Vessels navigating in the vicinity）
00:35:40	MORNING MIDAS：Yes. This is MORNING MIDAS. Officer B：Channel 13.
00:36:00	Officer B：We have safety navigation information. We have lost some containers at sea around 1 hour ago. Our coastal course 129 °. Please keep sharp look out.
00:36:20	MORNING MIDAS：OK. Understood. Can you give me approximate position?
00:36:36	Officer B：Approximate position latitude 33°13.8'N longitude 172°32.9'E.）
00:36:48	MORNING MIDAS：OK. Understood. Thank you very much for information.
00:36:52	Officer B：Thank you very much. Back to channel 16.
00:58:12	<Rattling rattling (sound of something hitting something)> 3)
00:58:15	Master：150. Able seaman B：150.
00:58:30～00:59:15	<Rattling rattling (sound of something moving and hitting) > 3) Crew: Oh, Ah.
00:59:17	Master：180. Able seaman B：180.
01:01:18	Officer B：Master, I will make sounds alarm. Master：Yes.
01:02:07	Officer B：Pan-Pan. Pan-Pan. Pan-Pan. This is motor vessel One Apus container vessel. Attention vessel all vessels in the vicinity. 13:02UTC. At approximate position latitude 33°04.5'N longitude 172°52.1'E. We have lost more containers at sea. Repeat. We have lost more containers at sea Please keep sharp look out.
01:04:46	Master：Go to cargo control room and adjust ballast.（ Instructions for Officer A.）

(2) Information on main engine operation

According to the records of the vessel's VDR, the operation of the vessel's main Engine telegraph control during the period from around 22:00 on November 30th to 01:40 on December 1st was as shown in Table 3.

The number of revolutions per minute of the main engine is rpm (the same below).

Table 3 Operation of the Engine telegraph

Time	Engine telegraph position
November 30,around 22:00 - 23:47	Navigation Full speed(50rpm)
November 30, around 23:47~ December 1, around 01:10	Full speed (40-49rpm)
Around 01:10 - 01:40	Navigation Full speed (50-55rpm)

2.1.3 Interview of the Crew Members, etc.

According to the interview of the master and officer A, and the collection of questionnaire of officer B and officer C, the following was true.

(1) Situation from the Yantian (November 17) to the day before the accident (November 29)

The vessel, aboard by the master (Indian nationality), officer A (Romanian nationality), and 22 others crew members(2 Romanian nationals, 2 Union of Myanmar nationals, 1 Socialist Republic of Vietnam national, and 17 Philippine nationals), entered the Yantian, People's Republic of China, on November 17 and began loading containers.

On the 18th, the master of the vessel received a Passage plan from Company W (（hereinafter referred to as the " Company W "), a provider of weather routing[*4] service (WRS), to the next destination, the Long Beach in the United States (after Departure the Yantian, the vessel will sail off the southern coast of the Japan). (The planned route from the off Nojimasaki, Minami-Boso City, Chiba Prefecture to the Long Beach via the Great circle route [*5] after departing from the Yantian, by e-mail.

After replying to Company W, the master received a revised Passage plan（hereinafter referred to as the "Passage Plan") from Company W on the 19th.

According to the information in the Passage Plan , at around 12:00 (Universal Time) on November 26, 'an area of high and low pressure sandwiched between high and low pressure areas to the south of the Aleutian Islands with wave heights of approximately 9 meters or more' (hereinafter referred to as the 'High Wave Area') is expected to occur on the planned route in the North Pacific. The vessel was scheduled to pass through the High Wave Area on the 30th.

Although the master of the vessel was concerned about the High-Wave area, he predicted that the waves would be around 5 meters by the time the vessel passed through the high-wave area and decided to adopt this Passage plan (see Figure 1).

[*4] "Weather routing" means forecasting the weather and sea conditions to be encountered during a voyage and setting the optimal route by evaluating items such as safety, fuel consumption, and minimum voyage time using evaluation criteria, taking into account the vessel's condition, performance, arrival time, and other factors.

[*5] The shortest distance between two points on the earth is a line that intersects the cross section including those two points and the earth's center with the earth's surface. This is called the great circle, and the traffic route along it is called the " Great circle route”.

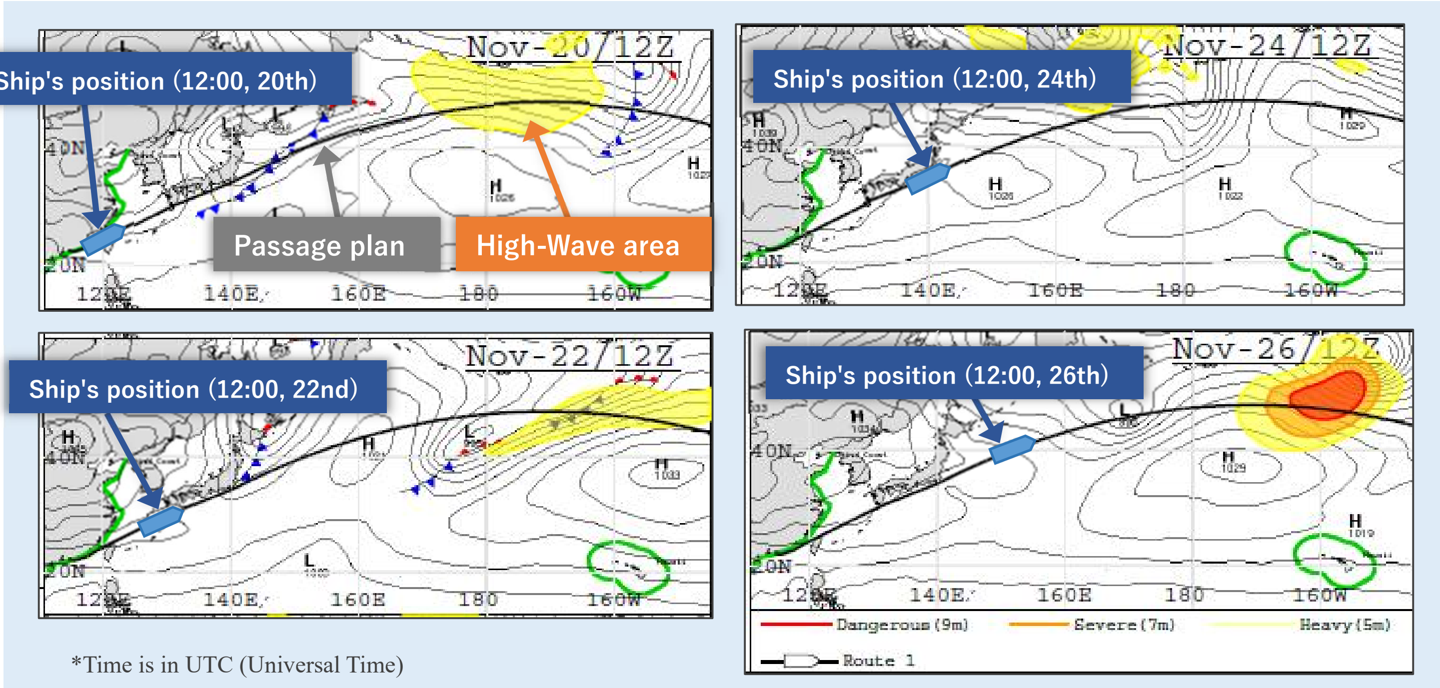

Figure 1　Passage Plan (received November 19)

The vessel, loaded with 7,016 containers (13,175 TEU*6), departed the Yantian for the Long Beach at around 17:54 (Chinese Standard Time) on November 19, 2012.

On November 25, while sailing off the south coast of the Japan, the master of the vessel, having ascertained weather information from weather charts, notified Company W of the danger of approaching the High-Wave area under the current Passage Plan, and requested that the Passage Plan be change 1 Plan") from Company W by e-mail at around 06:30 on November 26. (See Figure 2.)

*6　"TEU: Twenty feet Equivalent Unit" refers to the container quantity in units of one 20-feet container.

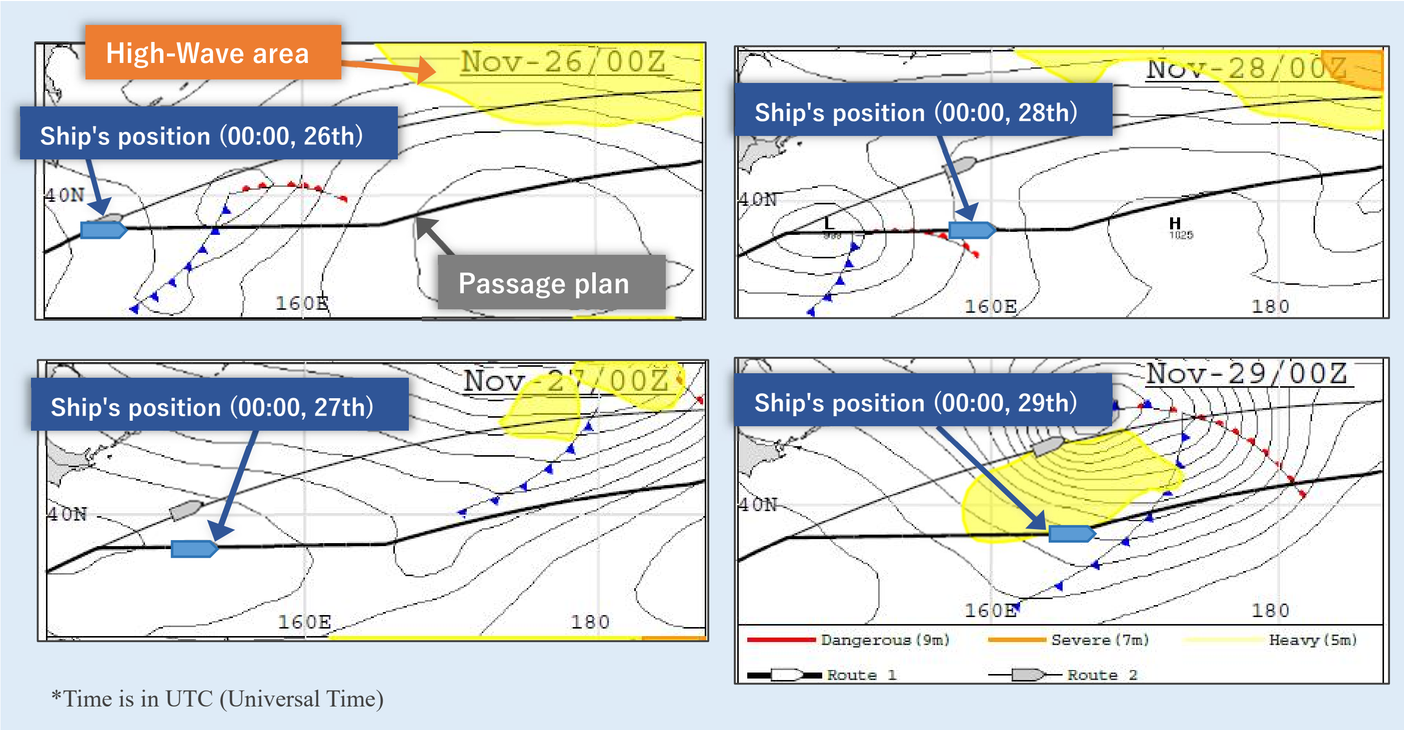

Figure 2　Change 1 plan (received November 26)

The vessel changed its course to approximately 090° in accordance with the Change 1 plan, and further changed its course to approximately 099° at approximately 13:00 on the 26th.

The master reported the change of course to approximately 099° to Company W and requested a change in the passage plan, and at around 18:50 on the 28th, the master received an e-mail from Company W stating that the vessel would maintain the course at approximately 099° to avoid the high-wave area in question and then proceed to the destination on the Great circle route (Change 2) (hereinafter referred to as the "Change 2 Plan"). (See Figure 3).

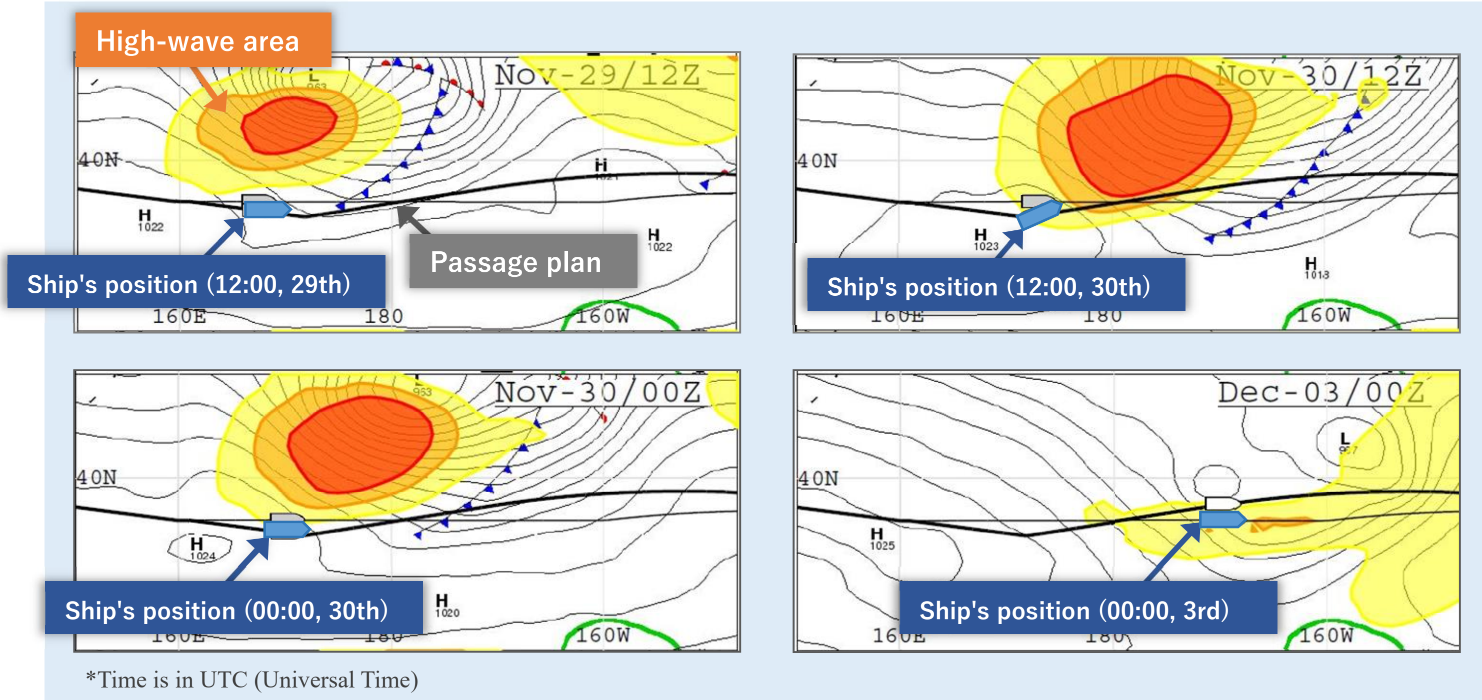

Figure 3 Change 2 plan (received November 28)

On the 29th, the master confirmed on wave charts, etc., that the High-Wave area in question was larger than initially expected, and was concerned that the vessel would be subjected to an approximately 5 to 6 meter swell from the northwest direction toward the stern, and again requested Company W to change the Passage plan.

(2) Navigational conditions on and after the day of the accident (November 30)

At around 12:13 on the 30th, the master received the revised Passage Plan (Change 3) (hereinafter referred to as the "Change 3 Plan") from Company W by email.

According to the Change 3 plan, the speed was increased to approximately 14.5 kn, the course was changed further south, and the plan was to head towards 32°20' north latitude and 174°00' east longitude, which is the southern point of the high wave area. In addition, since large swells are expected to come from the stern of the vessel up to the same point, a cautionary note is written to adjust the course and speed to reduce rolling according to the situation. (See Figure 4).

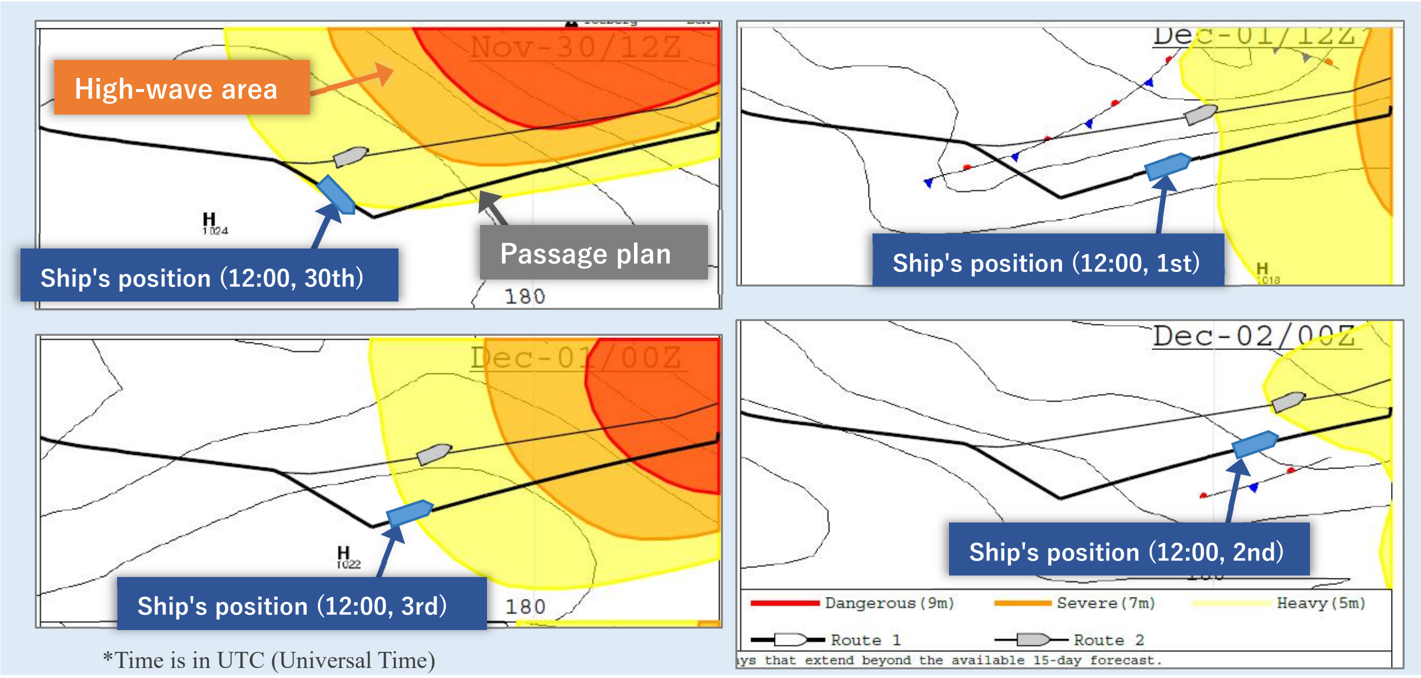

Figure 4　Change 3 plan (received November 30)

The master increased the speed to approximately 14.5 kn at around 12:20, and changed the vessel's course from approximately 099° to approximately 129° at around 15:30, in accordance with the change 3 plan. (See Figure 5)

Figure 5　Planned course of Change 3 plan displayed in ECDIS

At around 21:40, the vessel began to roll with the swell toward the stern to port stern. At around 21:50, Officer C set the ship on a course of approximately 140° in an attempt to reduce the roll.

At around 22:00, the master ascended the bridge to check the situation, took command of the vessel himself, assigned Officer C to assist with ship operation, and a Able Seaman A to the helm.

At around 22:47, the master changed the course to approximately 140°, which caused the ship's position to change and moved approximately 3M southwest of the planned course line in Change 3 Plan. At around 23:15, when the ship was checked to see how the ship was rolling, the angle of roll of the ship became more than 5° due to swells from the stern with a wave height of approximately 6m. After that, Master felt the rolling intensify to more than 10 °.

At around 23:17, the ship's rolling became hevy again, so the master decided to set the ship's course to 140° in order to determine which direction the ship's course should be to stabilize the rolling, and told able seaman A. He instructed the able Seaman to switch from automatic steering to hand steering and set a course of 140°.

At around 23:22, the master felt that the roll angle of the Vessel reached around 20 ° and the rolling became even more havy, and he instructed able Seaman A to change the course to 120 °.

At around 23:40, the master turned on the searchlight installed above the accommodation area to check the status of the loaded containers, and found that they were loaded in the upper part of Bay No. 42 in the center of the port side. It was observed that some of the containers had collapsed.

The master then reduced the speed to approximately 11.0 kn at around 23:48, and found that the ship's roll angle was 5°. Although the master could not see the swell coming from the stern because it was dark at night and could not accurately determine its direction, he judged that it would be safe to sail if the ship maintained its current course and speed. The vessel continued sailing on the same course and speed.

At around 00:58 on December 1st, while the ship was sailing on a course of approximately 120° and at a speed of approximately 11.7 kn, the ship suddenly began to roll significantly and its roll angle became approximately 25 to 27°. The master confirmed that at around 00:59, a container collapsed on her deck and part of the container fell into the sea.

Immediately after recognizing that the container had fallen, the master instructed able Seaman B to change course to 150°, and then to change course to 180°.

He instructed Officer A to adjust the ballast and made emergency radio communication (pan-pan) to the U.S Coast Guard, Honolulu Rescue Coordination Headquarters, Guam Rescue Coordination Headquarters, and Alaska Rescue Coordination Headquarters.

The ship needed to unload the collapsed container and repair the damage caused to the hull, and the ship's ship management company, NYK SHIPMANAGEMENT Pte. Ltd (hereinafter referred to as "Company A"), continued the voyage to the destination. At around 02:35 on December 2, the ship changed its destination and began sailing towards Hanshin-ko,Japan..

The vessel arrived at the berth in Kobe-ku, Hanshin-ko, on December 8.

The date and time of occurrence of the Accident was at around 23:22 on November 30, 2020 to around 00:59 on December 1, 2020, and the location was Approximately 1,585 to 1,565 nautical miles (M) true 295° to 1,565 M From Lehua Island Lighthouse, Niihau, Hawaiian Islands

(See Annex Figure 1-1 Estimated Navigation Route (overall view) and See Annex Figure 1-2 Estimated Navigation Route (Enlarged))

２．２　Injuries to Persons

There were no fatalities or injuries.

２．３　Damage to vessels and containers, etc.

2.3.1 Damage to the vessel

According to the on-site investigation and Company A's collection of questionnaires, The vessel had a hole in the container hatch cover abrasions on the bow and center shells, bent handrails on the upper deck, fire hydrants from the fire extinguishing seawater pipes, etc., and compressed air and fresh water. The damage caused included damage to system pipes, damage to power receiving equipment from land, damage to the handrail of the lashing bridge (a bridge for attaching devices for Securing containers), and loss to the pilot ladder. (See photos 1 to 4)

Photo 1 Container hatch cover

Photo 2 Damage to the hull

Photo 3 Damage to equipment on deck

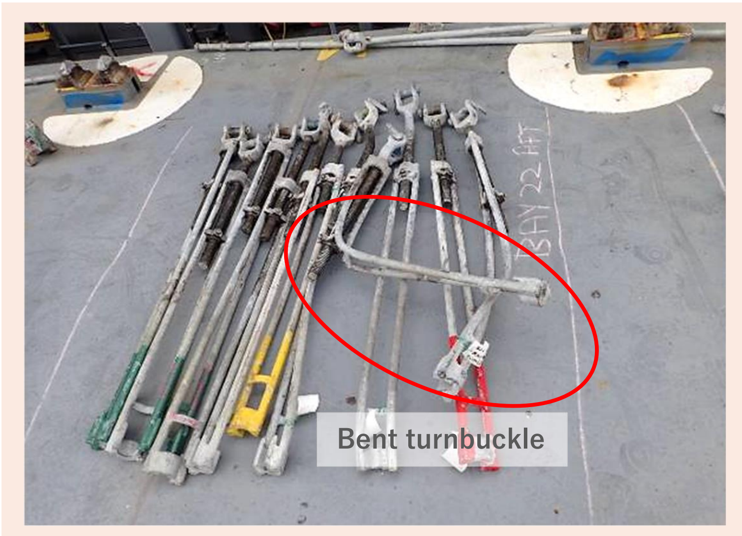

Photo 4 Damage to lashing equipment

2.3.2 Containers falling overboard and damage

According to the on-site-investigation and Company A's collection of questionnaires, the vessel was loaded with 7,016 containers (of which 3,593 were loaded on the upper deck), and the number of containers that fell overboard or collapsed on the deck at the time of this accident is shown in Table 4. (See Figure 6 and Photos 5-9.)

Table 4　Details of damage to containers, etc.

Loading quantity

state		Quantity
Total (including upper deck)		7,016 (3,593)
By Size	40ft (12.2m)	5,828
	20ft (6.1m)	857
	45ft1(13.7m)	331

Damage breakdown

Condition	Quantity
overboard	1,841
collapsed on deck	983

Figure 6　Approximation of damaged arrangement Upper deck loading containers and Securing Devices

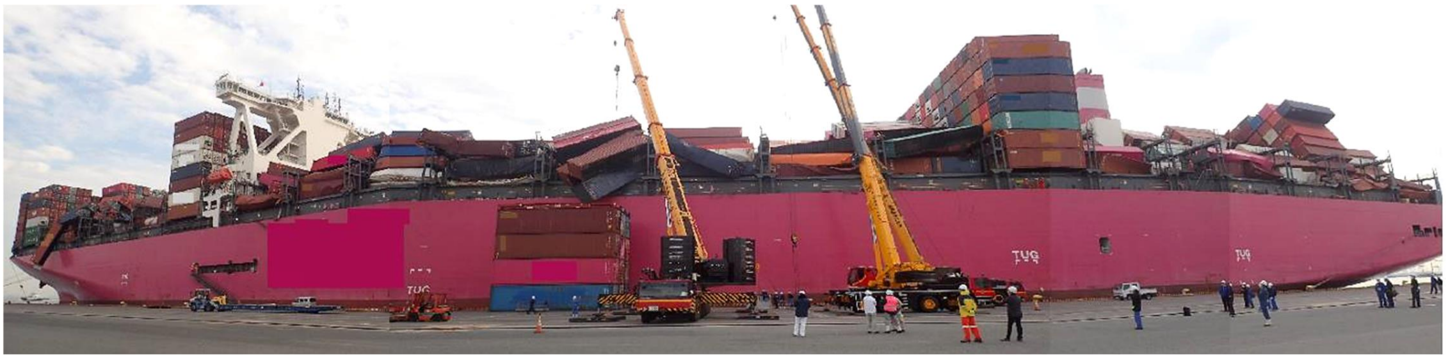

Photo 5 The collapsed container seen from the port side

Photo 6 Collapsed containers on upper deck

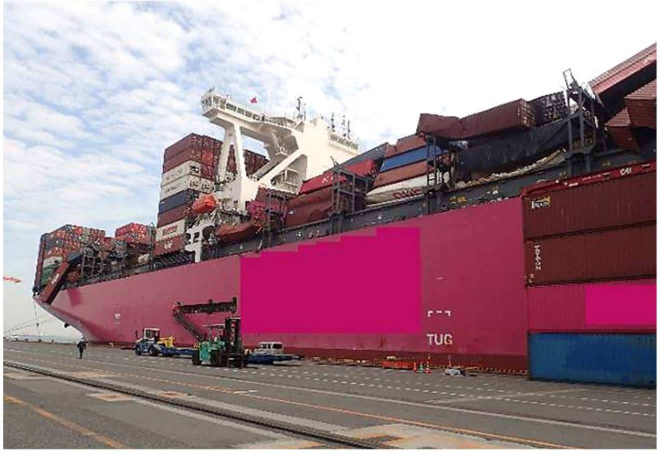

Photo 7 Collapsed containers on port bow

Photo 8 Containers on the verge of falling

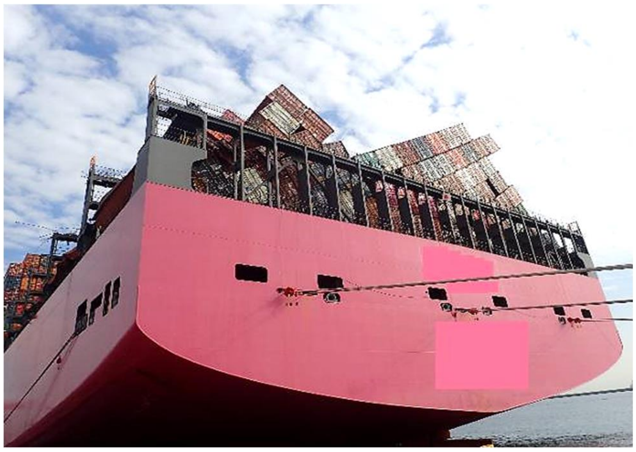

Photo 9 Collapsed containers at stern

According to the on-site investigation, the damaged container was pressed down by the adjacent container, causing pressure loss on the top and sides, and deformation of the container bottom member. (See Photos 10-11).

Photo 10 Container pressure loss situation

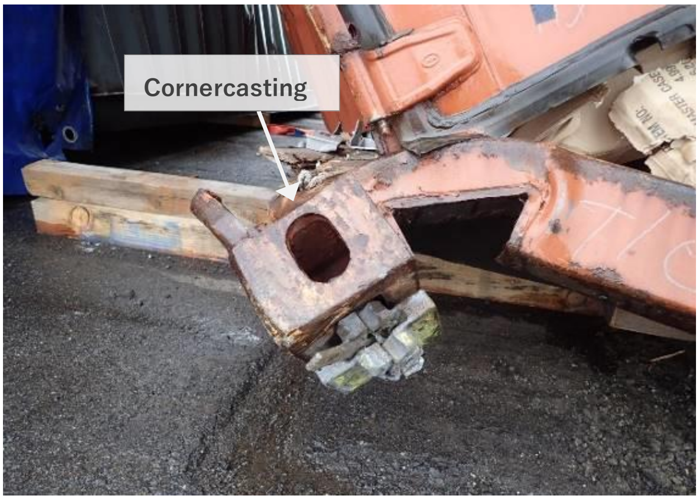

Photo 11 Deformation of the container bottom member

2.4 Crew Information

(1) Age and Certificate of Competence

1) Master: 49 years old Nationality: India

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

Date of issue: February 6, 2020

(Valid until January 19, 2022)

2) Officer A: 39 years old Nationality: Romania

Endorsement attesting the recognition of certificate under STCW regulation I/10: the First Officer (issued by Japan)

Date of issue: November 1, 2019

(Valid until December 12, 2022)

(2) Seagoing Experience

According to the interview and collection of questionnaires by the master and officer A, the follows:

1) The Master

The Master became a seaman in 1995, joined a ship operated by Company A as a Chief Officer in 2009, and began serving as master in June 2012.

He boarded the vessel as Master on November 5, 2020.

He had served on ships of the same type as the ship several times as a Master.

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

2) Officer A

The officer A became a seaman in 2005, and in 2007 he embarked on board a vessel operated by Company A as a third officer, and began serving as first officer in October 2011.

He embarked on board this vessel as Chief officer on September 27, 2020.

He had served as first officer on several occasions on vessels of the same type as the vessel.

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

2.5 Vessel Information

2.5.1 Particulars of Vessel

Vessel number:143426

Port of registry: Tokyo (Japan)

Management company: “Company A”

Charterer: “Ocean Network Express Pte. Ltd.”

Owner: Chidori Ship Holding LLC. (hereinafter referred to as “Company C”)
Classification Society: Nippon Kaiji Kyokai (hereinafter referred to as “Classification societyA”)
Gross tonnage: 146,694 tons
L×B×D: 364.15m×50.60m×23.04m
Hull material: Steel
Engine: Diesel engine
Output: 42,180 kW (maximum continuous output)
Propulsion: fixed pitch propeller
Date of launch: November 30, 2018
(See Photo 18)

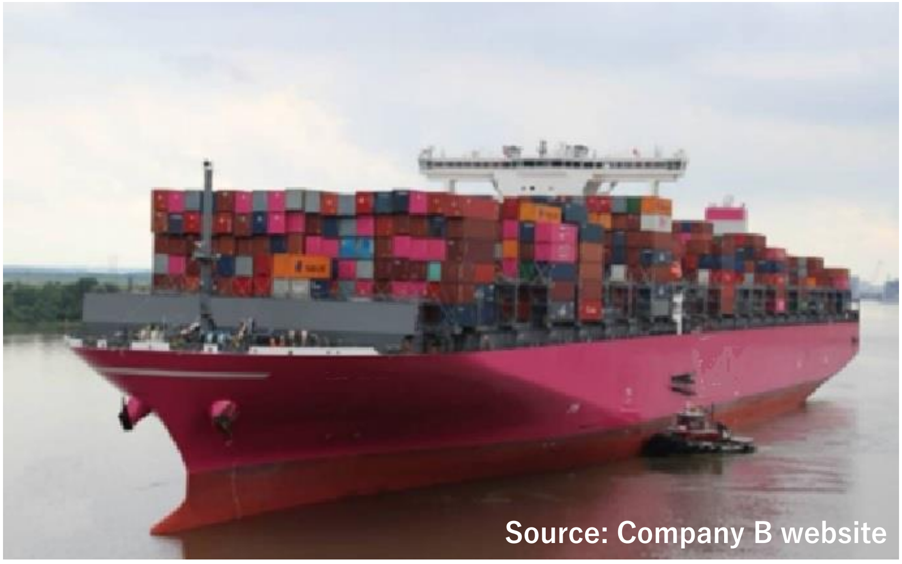

Photo 12 The Vessel

2.5.2 Propulsive performance

According to the propulsive particulars, the vessel's performance (speed) in full load (bow and stern drafts of approximately 15.75 m) and in ballast (bow draft of approximately 5.45 m and stern draft of approximately 10.97 m) was as follows.

Engine order（prm）	Speed（kn）	
	Loaded	Ballast
Full sea Speed（６３.１rpm）	２０.５	２１.５
Full ahead(４１rpm）	１２.９	１３.３
Half ahead（３５rpm）	１１.０	１１.４
Slow ahead（２８rpm）	８.８	９.１
Dead slow ahead（２２rpm）	６.８	７.１

2.5.3 Loading Condition and ship's motion

According to the interview of the master and of officer A, as well as Company A's collection of questionnaire, the following conditions were observed.

(1) Loading program, etc.

1) Loading program

The container stowage plan for the vessel was prepared by Company B's global storage planning office in Japan, and then a stowage program was used on the vessel to check whether there were any problems with the hull strength, etc., after adding various conditions such as fuel oil tanks, etc. to the plan (See Photo 13)

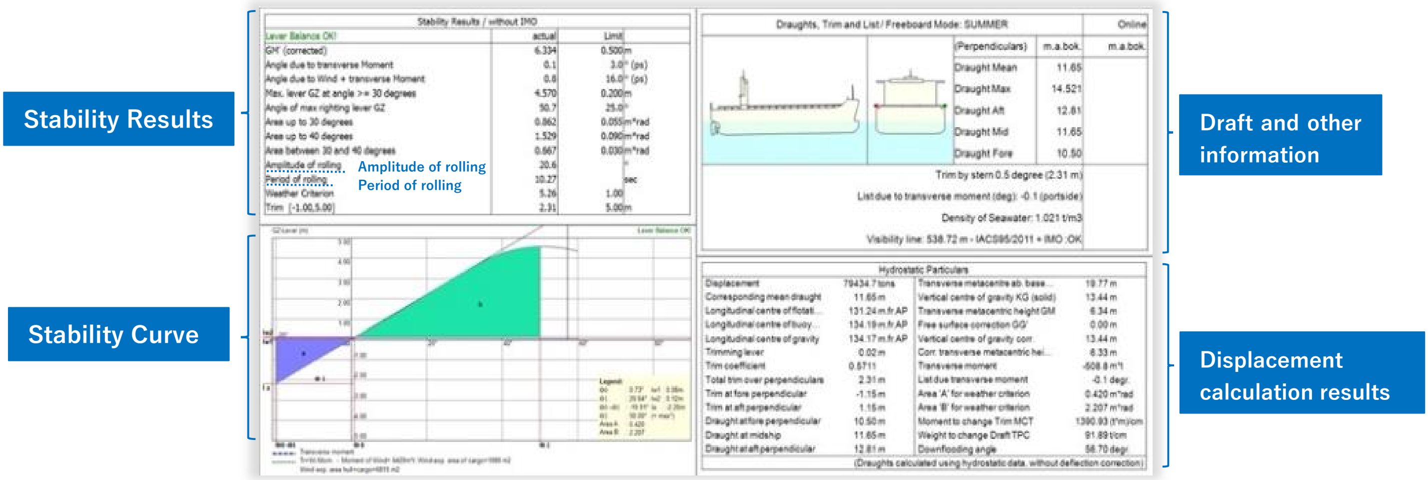

Photo 13　Example of a Loading program　(demo screen)

2)　Condition at departure from Yantian

The vessel was loading 7,016 containers (approx. 94,616 tons) and ballast water of approx. 17,984 tons, with a draft of approx. 14.64 m at the bow and approx. 14.46 m at the stern (average approx. 14.55 m) when it left the Yantian.

Of the 20 ballast water tanks on the vessel, 8 were full and 2 were being filled as needed for heel correction purposes.

Before the vessel's departure, a loading program was used to calculate the vessel's speed to be 18.5 kn and the standard number of container stacks to be 9 (8 for high-cube containers), with a GM (neutral equilibrium)[*7] of 1.605m.

According to these calculation results, Master and Officer A believed that there was no problem with the vessel's stability, including the state of container stowage, and that the vessel was in a safe condition to voyage.

(2) Securing evaluation of container stowage

1)　Lashing program

The lashing program was used to evaluate the securing strength of each container to be loaded on the vessel.

The lashing program could be linked with the Loading program, and the values calculated by the two programs could be displayed simultaneously. (See photo 14)

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*7　The intersection of the buoyancy action line passing through the center of buoyancy and the hull center line when the ship is rolled sideways is called the "transverse metacenter (M)," and the distance between the ship's center of gravity G and the transverse metacenter M is called "GM (neutral equilibrium).

(* The heavier the top of a ship is, the weaker the ship's stability in terms of recovery. A ship with a small GM is generally considered to be top heavy and to have weak resilience, and such a ship is called a heavy-headed ship. Such a ship is called a heavy-headed ship. A heavy-headed ship has a long period of motion and poor stability. In contrast, a light-headed ship is called a light-headed ship. (Light-headed vessels have strong resilience and generally sway violently in strong winds.)

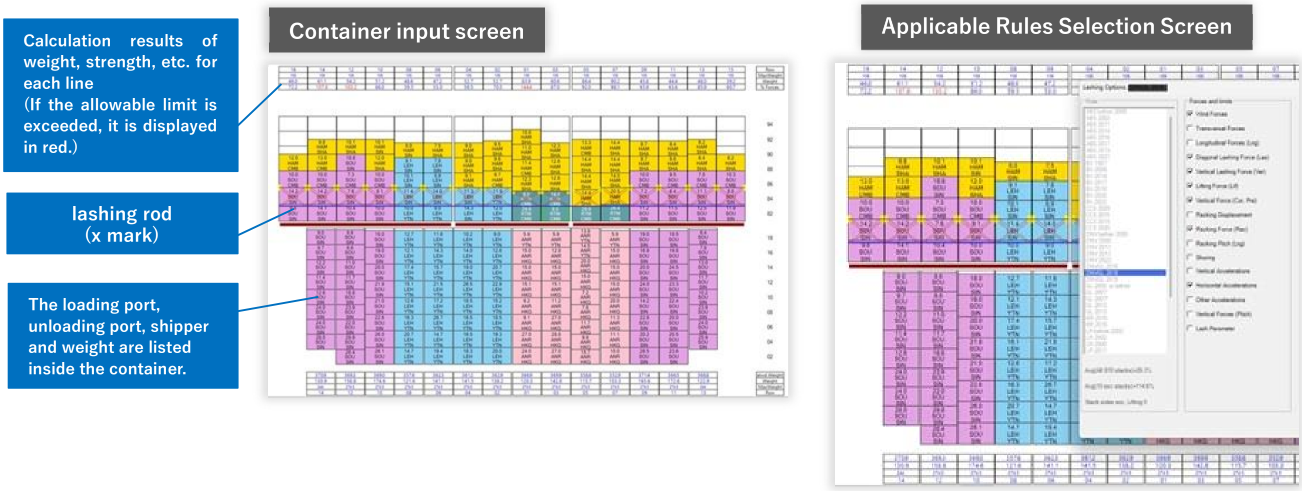


Photo 14 Example of lashing program (demo screen)

2) Regulations, etc. (Lashing program and Cargo securing manual)

The vessel's lashing program was programmed using procedures in accordance with Lloyd's Register (hereinafter referred to as "Classification Society B") Rules and Regulations for the Classification of Ships, July 2016.

The vessel was also equipped with a Cargo Securing Manual (CSM) that contained procedures on how to properly load and secure cargo for the crew, including the master. (See Table 5)

Table 5　Comparison of Lashing programs and Cargo securing manuals for this ship

	Lashing program	CSM
Purpose	Container Lashing Strength Calculation	Securing procedure How to use Securing Devices, etc.
Classification society approval	2016 Rules (Cargo securing Arrangement)	2016 Rules (Cargo securing Arrangement)
Operation	After the container loading plan and data entry work is done ashore (at the loading plan office), check for any problems on board the vessel.	Vessel
Classification Society Approval	Only to check calculation accuracy (Approved by Classification Society A based on an accuracy check table comparing the results of calculations using the program with the results of calculations using software provided by Classification Society B)	Approved by Classification Society A (Approval by Classification Society B is optional)
Wind Speed Assumption	Wind speed 40 m/s　x　(coefficient varying by route and season)	
Maximum roll angle (Assuming 10,000 to 20,000 TEU container　vessels)	Varies between 13° and 22° with route, etc.	
Maximum roll angle planned based on the loading plan at the time of this accident	About16.1°	—

In response to the recent increase in the size of container vessels, Classification Society B has been revising the calculation procedures for cargo securing procedures since 2014, taking into account the ship's width, navigation waters, etc. The 2021 Rules make it a mandatory requirement for lashing programs to calculate securing strength, etc. using methods based on the said Rules.

3) Lashing strength evaluation (lashing program)

When the vessel was evaluated for lashing strength using the lashing program at the Yantian before departure, the assumed maximum roll angle (amplitude of roll) was set at approximately 16.1°.

On the lashing program, the maximum value of stress that occurs in the securing equipment of each container under the set amplitude of roll, etc. conditions is displayed as a percentage of the allowable strength, and if the stress exceeds 100%, the allowable strength is A warning is displayed where the line has been exceeded, but that warning was not displayed at Yantian.

(3) Ship motion at the time of the accident

1) Inclinometer

The vessel was equipped with an inclinometer at the front of the bridge. At the time of the accident, the maximum value of the roll was approximately 27°.

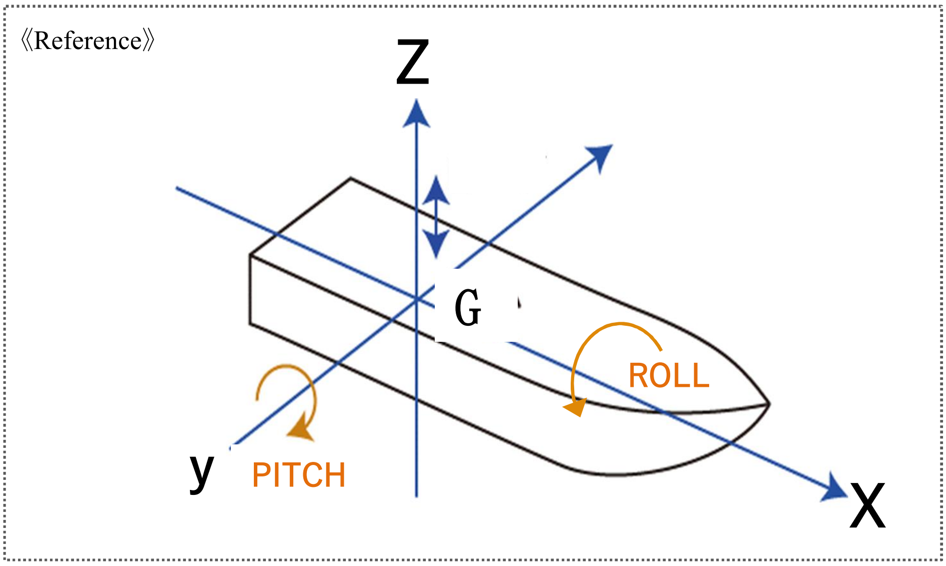
2) Attitude Sensor Measurements

An attitude sensor (Vibrating Silicon-gyro Attitude Sensor Measurements) is installed near the midship of the bridge of the vessel to measure hull motion. The measured values of roll angle, etc. at the time of the accident are shown in Table 6.

Table 6 Attitude Sensor Measurements

Time (HH：MM)	Roll angle (°)		Pich angle (°)		X axis Acceleration (m/s²)		Y axis Acceleration (m/s²)		Z axis Acceleration (m/s²)	
	Starboard	Port	Bow	Stern	+	−	+	−	+	−
21:39	12.46	14.25	1.53	1.10	0.21	0.16	2.45	2.32	9.56	10.19
21:59	12.73	17.57	1.47	1.27	0.20	0.16	2.88	2.50	9.36	10.18
22:19	5.30	5.87	1.11	1.17	0.19	0.14	1.00	1.01	9.76	10.14
22:39	2.93	4.93	1.22	1.23	0.18	0.17	0.86	0.63	9.72	10.24
22:59	9.62	10.65	1.31	1.17	0.18	0.15	1.82	1.71	9.64	10.18
23:19	16.83	18.95	1.43	1.20	0.19	0.27	3.28	2.94	9.18	10.29
23:39	20.00	17.62	1.54	1.28	0.26	0.18	3.06	3.42	9.31	10.29
23:59	7.23	7.55	1.34	1.35	0.23	0.18	1.33	1.41	9.69	10.25
00:19	8.70	8.71	1.43	1.87	0.26	0.20	1.53	1.58	9.66	10.38
00:39	6.92	7.15	1.66	1.74	0.25	0.21	1.23	1.25	9.61	10.38
00:59	21.60	25.35	1.69	1.75	0.78	1.39	4.89	4.43	8.45	10.29
01:19	7.34	6.05	1.51	1.85	0.35	0.29	1.32	1.73	9.49	10.43
01:39	7.57	5.76	1.72	1.77	0.28	0.25	1.20	1.63	9.59	10.34

*Measurement values such as roll angle of the attitude sensor are recorded as the maximum values for 20 minutes.



2.5.4 Vessel equipment, etc.

(1) Hull Structure

The vessel is a bow bridge type container ship with a structure that allows containers to be loaded In the hold and on the upper deck. The container loading compartment was divided into three sections by the accommodation spaces and the engine casing connected from the main engine. (See Figure 7)

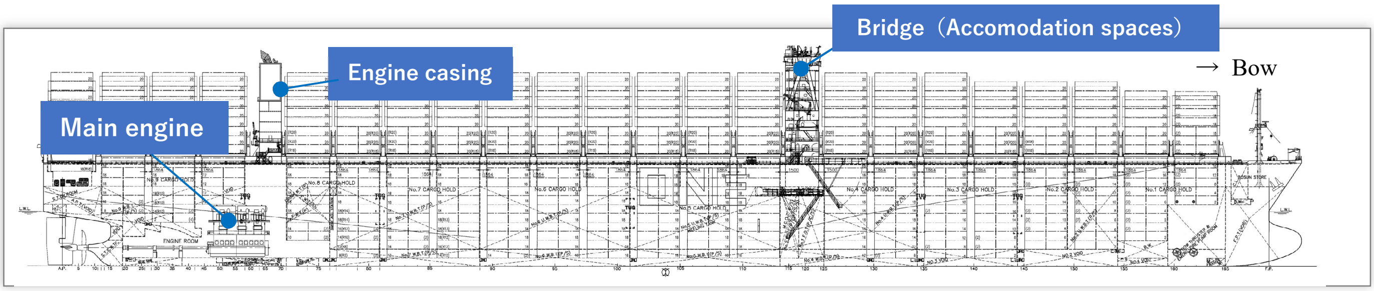


Figure 7 General arrangement plan

(2) Status of the vessel

According to the interview of the Master and Officer A, there was no malfunction or failure in the hull, engine, or machineries.

(3) Container Row

On the upper deck of the vessel, 22 rows of 40-feet containers could be loaded in the aft direction, and each row was assigned a bay number starting from the bow, beginning with 02 and adding every 4.The number of container stacks in each row.

(4) Container Stacking Rows (at Departure from Yantian)

The number of stacked containers in each row at the time of departure from the Yantian is shown in Figure 8.

(see Figure 8).

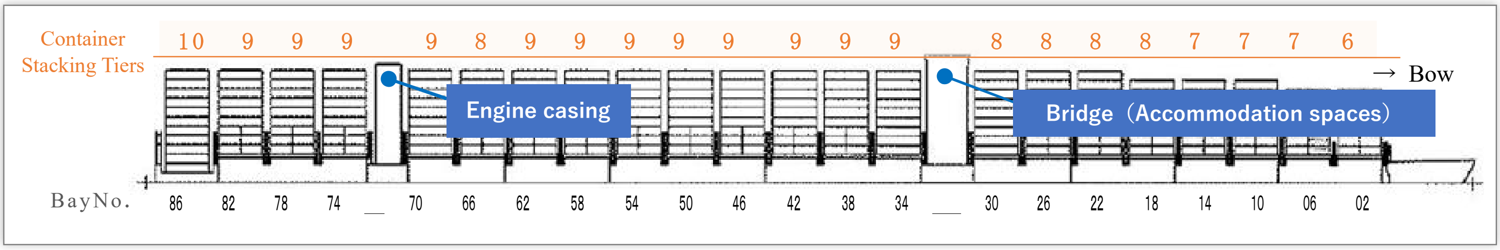


Figure 8 Stacking tiers of containers, etc.

(5) Container securing procedure

When a container was loaded on the upper deck of a vessel, it was secured by fitting twist locks installed in the deck sockets on the hatch cover into the corner castings on the bottom four corners of the container and locking them in place.

When another container was loaded on top of the same container, twist locks were installed in the four bottom corner holes of the upper container and fitted into the four ceiling corners of the lower container, and secured in the same manner.

(See Photo 15, Photo 16, Figure 9.)

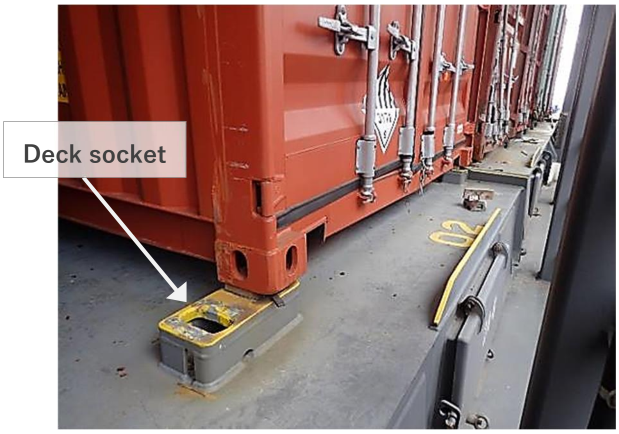


Photo15 Container on hatch cover

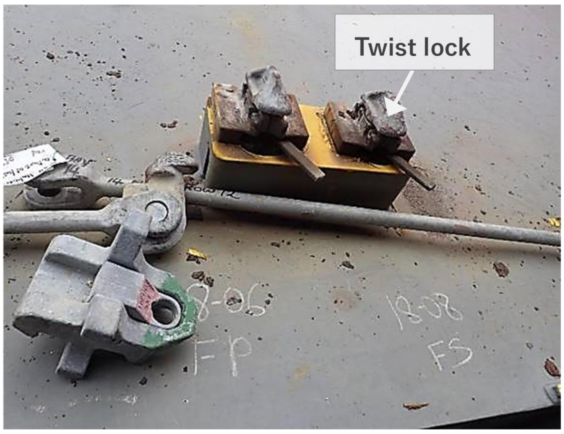
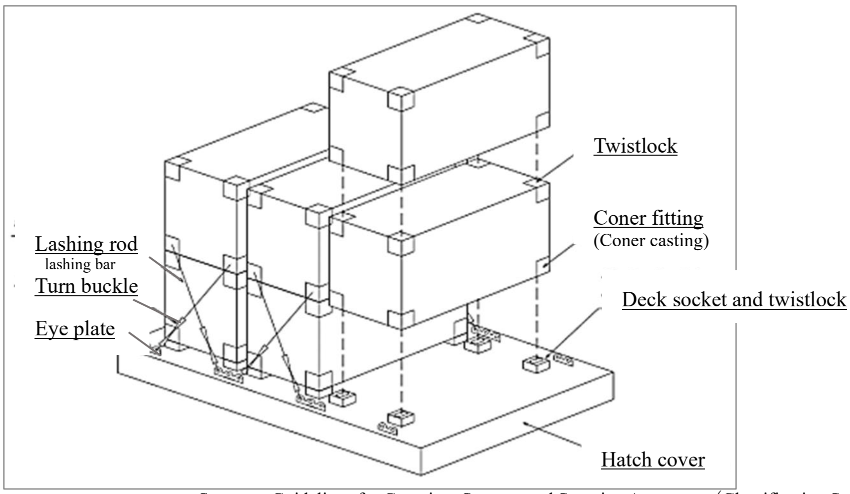


Photo 16 Twist lock



Source: Guidelines for Container Stowageand Securing Arrangem（Classification Society A)

Figure 9 Basic concept of Container securing

The third and fourth (partial) tiers of containers stacked on the deck of the vessel were secured by connecting two or three sets of lashing bars to turnbuckles attached to the eye plate of the lashing bridge, crossing them diagonally and attaching them to the top corners of each container, and tightening the turnbuckles. The turnbuckles were then tightened to secure the container. (See Photos 17-19)

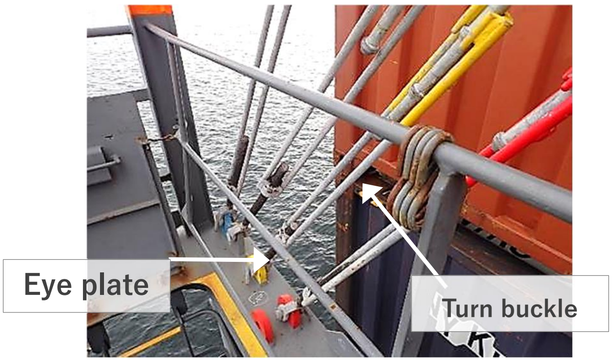


Photo 17: State of turnbuckle lashing

Photo 18: Lashing bar condition

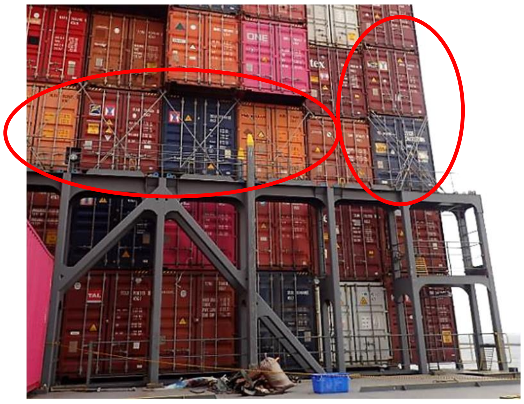


Photo 19: Secure binding from a lashing bridge

(6) Checking the lashing condition

According to the interview of the master and officer A and the logbook, the containers on the ship were secured in accordance with the lashing program and Company A's cargo securing manual, and even during the voyage, the containers were secured once every three days. At the same time, the deck crew inspected the lashing conditions of the containers loaded on the upper deck and retightened the turnbuckles as necessary.

(7) Allowable load of containers, etc.

1) Containers

According to the "Guidelines for Container Stowage and Securing Arrangements (Edition 3.1)" issued by the Classification society A, the allowable loads for each part of the container were as follows.

		Allowable loads (ISO)	
		ISO 1496-1:1990	ISO1496-1 (including amendments up to 2014)
Racking load acting on containers	Transverse direction	150	150
	Longitudinal direction	150	150
Compressive load acting on one corner post of containers		848	942
Lifting load acting on one corner post of containers		250	250
Lashing load acting on container corner fittings (corner casting)	Vertical direction	300	300
	Horizontal direction	150	150

Unit: KN

2) Securing device

According to the Cargo Securing Manual for this vessel, the allowable loads for the safe use of twist locks and lashing bars were as follows.

	Twist lock	lashing bar	
		Long	Short
SWL :Safe Working Load	２５０ (Tension) ２１０ (Shear)	３００ (Tension)	１８０ (Tension)
PL :Proof Load	３７５ (Tension) ３１５ (Shear)	４５０ (Tension)	２７０ (Tension)
BL :Breaking Load	５００ (Tension) ４２０ (Shear)	６００ (Tension)	３６０ (Tension)

Unit: KN

2.5.5 Notes on Securing containers

The document*8 (hereinafter referred to as "Technical Journal") published by Classification Society A contains the following information regarding container securing.

Container stacks arc generally subject to various types of deformation, namely, racking, floating of the comer castings, compression and shearing. It is necessary to determine the container securing method, the weight of the containers to be stowed and the container stacking sequence so as not to exceed the allowable loads that occur during these types of deformation. In cases where lashing rods*9 are connected, attention must also be paid to the allowable load of the lashing rods because tensile loads are generated in the lashing rods when racking deformation occurs in a container stack. (See Figure 10)

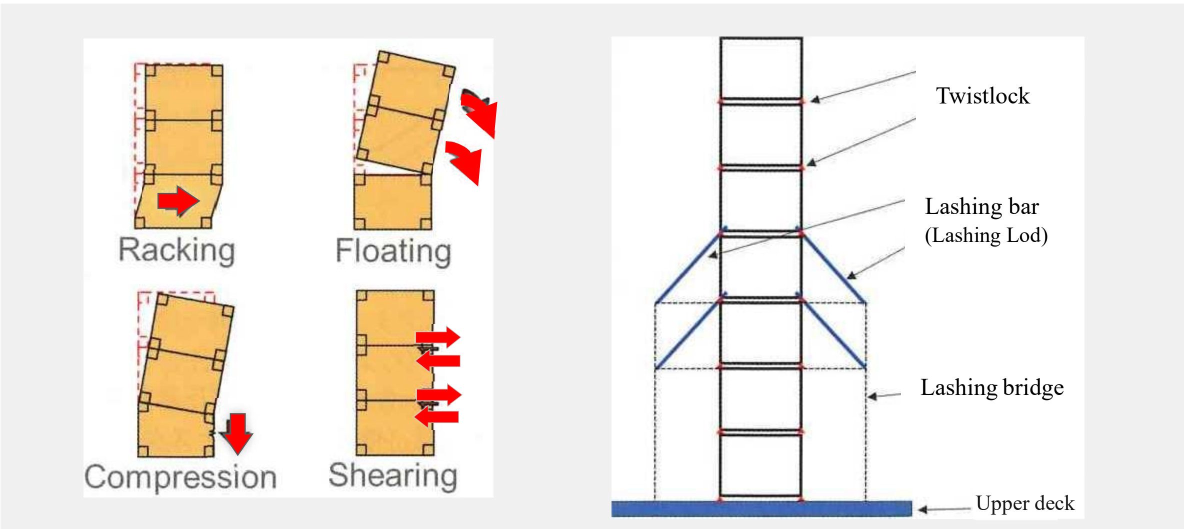


Figure 10 Container collapses, etc.

2.6 Information on Safety Management, etc.

(1) Information on Company A's Safety Management manual

The Safety Management manual by Company A contained the following statement regarding Heavy Weather Guidelines & Precautions. (Excerpt from Company A's Safety Management manual)

2.1. Weather Monitoring

1. and 2 Omitted

3. *Use of "Weather Routing Service (WRS)" should be considered. When using WRS, read the I nstruction carefully and report necessary items to the service provider in a timely manner. Gather*

*8 Source: Classification Society A Technical Journal No.7,2023(I)

*9 The lashing rod is the same as the lashing bar.

weather information as much as possible from all available sources.

4. Omitted

5. Company should be notified if vessel experiencing heavy weather.

2.2. Navigation

1. and 2 Omitted

3. Adjust the Course and Speed of the vessel so as to reduce the impact of wind and waves as much as possible.

4~7 Omitted

8. Be guided by the following attachments to assist in planning for avoiding heavy weather damages:-

i) Chart/Reference Figure - "Guidelines To Master For Avoiding Heavy Weather Damage" (hereinafter referred to as "reference chart")

ii) Maritime Safety Committee Circular 1228 - "Revised Guidance to the Master for Avoiding Dangerous Situations in Following and Quartering Seas"

2.3. Stability

1 . The C/O, in accordance with the Master's instructions, must make the necessary adjustments to ballast, giving consideration to the following, in order to put the ship in an optimum condition with respect to Stability and Stress.

2. When ballasting, tanks should be filled up completely, as far as possible, to reduce free surface effects.

3. Achieve optimum GoM, to prevent vessel from being unduly stiff or too tender.

4. Ensure vessel has adequate Hull strength.

2.4. Deck / Accommodation / Cargo

1~6 Omitted.

7. Check Cargo Lashings & take additional lashings if deemed necessary.

(2) Information regarding the determination of the vessel's Passage plan and the management of Company A's operated vessels, etc.

According to the interview of the master, officer A, and the person in charge of Company A, the following was true

1) Master

The master used the Passage plan transmitted by Company W as a reference to the actual Passage plan, taking into consideration the ship's condition of navigation.

The master was aware that the Passage plans sent from Company W were also sent by CC (copy) to the person in charge of Company B, and when the master replied to Company W, he also sent the plan by CC to the person in charge of Company A, so that both companies were also aware of the vessel's movements.

2) Company A

Company A had a system in place that enabled it to check the communication between the master and Company W regarding the Passage plan, but did not interfere with the plan unless it had concerns about the plan, as the Passage plan was determined at the master's discretion.

3) Company W

Company W had a contract with Company B for weather routing services for the vessel.

Company W prepared and provided to the vessel a Passage plan that set an optimum route based on the vessel's length and other essentials, draft and GM at the time of departure, and updated the plan during the voyage in response to changes in weather conditions.

The Passage plans sent to the vessel by Company W contained information on winds (wind direction and speed) and waves (wave direction, height, and period) expected at 00:00 and 12:00 (UTC) on the planned course, and the three revised plans contained information as shown in Table 7.

Date Time [UTC]	Position [lat/lon]	Wind		Wave			
		Dir	Speed [kts]	Dir	Height(Sig) [m]	Period [sec]	Max [m]
Nov-30/1200	33-11.8N/172-39.9E	NNW	12	NNW	5.7	15	-
Dec-01/0000	32-44.9N/175-16.2E	SSW	2	NNW	5.2	13	-
Dec-01/1200	33-39.0N/178-13.8E	SW	26	NW	4.4	12	-
Dec-02/0000	34-35.5N/178-18.9W	NW	18	NW	4.6	11	-
Dec-02/1200	35-24.0N/174-56.2W	WSW	21	WNW	4.5	11	-
Dec-03/0000	36-08.9N/171-18.6W	W	24	WNW	4.7	9	-
Dec-03/1200	36-45.7N/167-46.4W	WNW	24	WNW	4.1	9	-
Dec-04/0000	37-16.9N/164-03.7W	WNW	20	WNW	3.7	9	-
Dec-04/1200	37-41.9N/160-10.0W	WNW	28	WNW	4.0	9	-
Dec-05/0000	37-58.0N/156-33.5W	WNW	26	WNW	4.5	9	-
Dec-05/1200	38-07.7N/152-49.1W	SW	23	W	4.3	10	-

※Time is in UTC

Table7　Information on forecasted waves, etc. (Change 3 plan)

(3)　Information on the Reference Chart

The reference chart was prepared to raise the master's awareness of the possibility that the longitudinal and transverse inclination of the vessel may stabilize or increase depending on the direction in which the vessel is subjected to waves and wind. ～The following diagram shows how the vessel moves when subjected to waves (wave height: 4 to 7 meters) and wind (wind force: 7 to 9 mph) at each of the six angles and the guidelines for responding to them.　(See Annex Figure 2 Reference chart)

＜Reference Diagrams in this case＞

Number	Waves Receiving Range	Type of motion and action
1	30° to port and starboard from bow	VERY HEAVY PITCHING In wave > 5 meters or wind force “8 (20 m/s)” Pitching > 3 degrees (Bow pitching 8 mtrs) 1. Alter Course (More than 20 deg) 2. Reduce M/E RPM more than 10 rpm (Speed realest by 10%)
Midline between 1-2	bow 30° (port and starboard)	HAZARDOUS! Green Sea; In wave ht. > 4 mtrs or wind Force > 7 (17 m/s). 1. Alter Course (More than 10 deg)
2	30° to 60° port and starboard from the bow	Pitching
3	60° to 90° port and starboard from the bow	Expect vessel to be Stable with up to Wave 5～7 meters wind Force 8 or 9 (20～24 m/s)
4	60° to 90° from normal stern	Rolling
5	30° to 60° port and starboard from the stern	VERY HEAVY ROLLING (Parametric rolling) If Rolling > 20 degrees 1. Alter Course
6	30° to port and starboard from the stern	Expect vessel to be Stable with up to wave 6 meters or wind Force 9 (24 m/s)

a) Above sample is for a container vessel (approx 4000TEUS) and length overall 289 mtrs.

b) Actual Conditions may vary basis actual displacement / Stability / Container Tiers. Above diagram is only a guideline for raising awareness of possible hazards.

c) Weather tolerance (Limits) and RPM reductions etc will be different for vessels based upon their respective engine, ships particulars and Master’s requirements

d) Index of Pitching can be approximately calculated using foremast movement.

e) The Wave impact force on the vessel’s hull is SQUARE of the vessel’s relative speed.

f) Parametric rolling in extreme head or near head seas can occur when unfavorable tuning is combined with low roll damping (reduced speed) and large stability variations (governed by wavelength, wave height, general hull form, bow flare and stern shapes). Parametric rolling is an unstable phenomenon, quickly generating large roll angles coupled with significant pitching. Rolling occurs in phase with pitch and on containerships introduces high loads into the containers and their securing systems. Please see attached MSC Circular 1228.

２.７　Weather and Sea Conditions

2.7.1 Logbook

According to vessel A's logbook, from 23:00 on November 30, 2020 to 02:00 on December 1, 2020, the weather was cloudy, visibility was good, there was a swell with a wave height of about 5.0 to 6.0 m, and the wind direction and speed were as follows.

Time (HH:MM)	Wind Direction	Wind forth	Wind Spped(m/s)
November 30, 23:00 - December 1, 02:00	NW	4	5.5～7.9

2.7.2 Japan Meteorological Agency Ocea Wave Chart

According to JMA's ocean wave chart as of 12:00 UTC on November 30, 2020, waves were flowing from the northwest to the southeast with a significant wave height[*10] of approximately 6 meters near the accident location

The JMA's ocean wave chart notes the following. Note that the actual individual waves include waves higher than the significant wave height.

(See Annex Figure 3, Ocean Wave Chart).

[*10] "Significant wave height" refers to the average wave height of up to 1/3 of the waves observed at a certain point over a certain period of time, starting from the highest. It is said to be close to the wave height observed by visual observation.

2.7.3 Wave analysis

After the accident occurred, the wave analysis values along the vessel's navigation route, estimated by Company W based on surrounding observation data, were as follows.

Day Time	Wind		Waves				Swell			
	Direction (°)	Speed (m/s)	Direction (°)	height (m)	length (m)	Period (s)	Direction (°)	height (m)	length (m)	Period (s)
November 30 12:00	319	21.44	315	1.92	77.18	7.03	330	5.50	354.66	15.08
15:00	319	20.16	315	1.66	63.80	6.40	330	5.97	354.66	15.08
18:00	333	18.05	330	1.53	63.80	6.40	330	5.77	354.66	15.08
21:00	279	13.54	285	0.84	36.00	4.80	330	5.77	354.66	15.08
December 1 00:00	327	13.53	330	0.84	36.00	4.80	330	5.53	354.66	15.08
03:00	346	13.25	345	0.81	36.00	4.80	330	5.28	293.10	13.71
06:00	351	9.37	345	0.44	20.33	3.61	330	4.99	293.10	13.71
09:00	344	6.66	345	0.26	13.88	2.98	330	4.71	293.10	13.71

２.８ Estimation of Ship Motion

Based on the vessel's navigation conditions at the time of the accident, including the ship's course and the estimated waves along its navigation route, National Maritime Research Institute : NMRI, was commissioned to perform a Short-term Prediction[*11] forecasting calculation of the ship motion. Table 8 shows the estimated values of the Rolling Amplitude and Pitching amplitude between 23:59 on November 30th and 00:59 on December 1st.

[*11] Jun-ichi Fukuda: Statistical Prediction of ship Response, Text of Symposium on Seaworthiness, The Society of Naval Architects of Japan, 1969. (This method predicts normal ship motion without assuming parametric rolling as described below.)

○ Outline of estimated calculations

・Based on the sea conditions at the time of the accident, and assuming a standard wave spectral shape, a short-term prediction forecasting calculation of the ship motion was used to estimate the motion of the vessel at the time of the accident.

○ Calculation conditions (Values at 00:00 (ship time) on December 1)

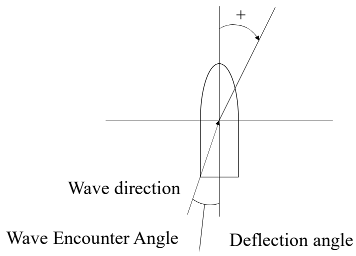
・Ship speed: 11.44kn ・Wave period: 4.80sec ・Wave height: 0.84m

・Swell period: 15.08sec ・Swell Height: 5.53m

・Wave Encounter Angle: 32.30

Wave direction - (heading (average value for 1 hour) + 180°

330° - (117.7° + 180°) = 32.3°



Roll Amplitude

	Calculation conditions	estimated value (°)
①	average	8.43
②	1/3 maximum average	13.47
③	1/10 maximum average	17.12
④	1/100 maximum expected value (Maximum roll of 1 wave per 100 waves encountered)	21.69
⑤	1/188 maximum expected value (Maximum roll of 1 wave for every 188 waves ncountered)	22.97

Pitch Amplitude

	Calculation conditions	estimated value (°)
①	average	0.77
②	1/3 maximum average	1.23
③	1/10 maximum average	1.57
④	1/100 maximum expected value (Maximum pitch of 1 wave per 100 waves encountered)	1.99
⑤	1/188 maximum expected value (Maximum pitch of 1 wave for every 188 waves encountered)	2.10

*1/3 maximum average: Average of the amplitudes of 1/3 of the total number of pieces in order from the one with the largest amplitude (= significant value)

*1/10 maximum average: Average of the amplitudes of 1/10 of the total number of pieces in descending order from the one with the largest amplitude (=about 1.27 times the significant value)

*1/100 maximum expected value: Expected value of the amplitude of 1/100 of the total number of pieces in order from the one with the largest amplitude (statistically, about 1.61 times the significant value)

*1/188 maximum expected value: Expected value of the amplitude of 1/188 of the total number of waves in order from the one with the largest amplitude (188 waves－the number of waves encountered in one hour)

Table 8 Estimated ship motion (roll and pitch)

2.9 Parametric Roll Motion

2.9.1 Parametric Roll

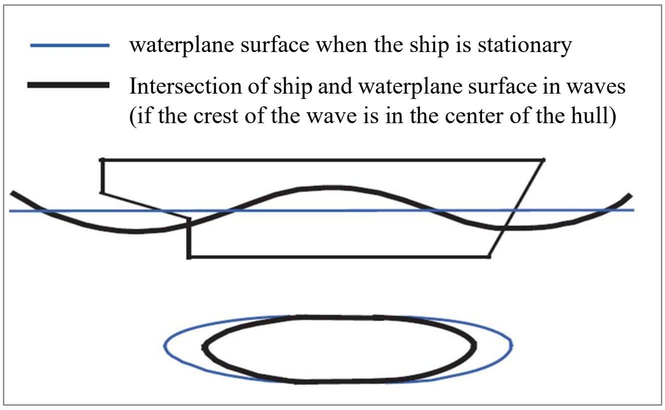
Parametric roll is a resonance phenomenon in which the roll of a ship is rapidly amplified when the roll period of the ship and the encounter period of waves are in a certain relationship. The "Guidelines on Preventive Measures against Parametric Roll " issued by Classification Society A (see 2.9.4 for details) states that in recent years, there have been a series of cargo collapse accidents on large container ships and car carriers that appear to have been caused by parametric rolls, including one accident in which more than 2,000 In addition, the " Beware of parametric rolling in followin " issued by the Maritime Research Institute Netherlands：MARIN (see 2.9.3 for details) states that containerships are susceptible to parametric rolling in following wave conditions. It states that a combination of roll period, speed, course, and wave conditions can cause a sudden increase in roll to a level that threatens the safety of the ship, crew, and cargo.

2.9.2 Occurrence of Parametric Rollover in Container ships

The literature[*12] contains the following descriptions of the occurrence of parametric rollover in container ships. (excerpts below)

Container ships operate at higher speeds than tankers and bulk carriers, so their bows and sterns are skinnier. Therefore, the surface where the hull sinks into the water is more variable than that of tankers and bulk carriers. This also makes the ship's resilience unstable.

When the restoring force becomes unstable, parametric rolling occurs when the natural period of rolling coincides with about twice the period of the encounter wave.



Change in waterplane area surface in waves

2.9.3 TopTier Report

In January 2022, The TopTier Project, a project established by the Maritime Research Institute Netherlands to "investigate and evaluate accidents involving container losses on container vessels" (The TopTier Project), issued a parametric rolling (hereinafter referred to as the "TopTier Report"). The TopTier Project issued beware of parametric rolling in January 2022 (the "TopTier Report").
(See Appendix Figure 4 TopTier Report)

2.9.4 Parametric Rolling Measures (Classification Society A)

In February 2020, Classification society A decided to add a ship's Classification characters that have taken effective parametric rolling countermeasures, compiled related requirements, and added a "Parametric Rolling Countermeasure" to ships that have taken effective parametric rolling countermeasures. ``Guidelines on Roll Countermeasures" (hereinafter referred to as ``Guidelines for Classification Society A").

The guidelines of Classification Society A include precautions to avoid parametric rolling and methods to avoid parametric rolling as an appendix. (Excerpt below)

[*12] " The literature : NMRIW, a tool for evaluating seaworthiness and wave loads - Enabling 6-DOF calculations closer to actual phenomena - Evaluation program for hull motion and wave loads" (National Maritime Research Institute (NMRI Newsletter Science of Ships and the Sea 2011-SPRING), April 2011)

(1) Key Points for Avoiding Parametric Rolling

Parametric rolling is a dangerous phenomenon in which a ship suddenly makes a heavy roll while navigating in a head sea, following sea or oblique sea. When a ship encounters a resonant condition that induces parametric rolling, extraordinarily large roll angles can occur in a very short time, and it is almost impossible to take any action. In addition, since the common and ingrained operation of the crew for heaving to in rough seas may possibly trigger parametric rolling, the usual and ordinary precautions, practices and measures against heavy weather conditions cannot always apply to parametric rolling.

Precautions and effective measures against parametric rolling, including early avoidance of danger zones and immediate course change on detecting any advance signs of parametric rolling, are important for preventing parametric rolling and the consequent accidents and damage. This section gives a brief explanation and basic knowledge on the following matters, which should be useful for such purposes.

① Determine the natural roll period of the ship

Parametric rolling is a phenomenon induced by synchronicity of a ship’s natural roll period and the temporal variation of stability in head seas or following seas. Therefore, it is essential to determine the natural roll period of the ship, although this is not necessarily a simple matter.

② Pay due attention to the direction and encounter period of swells

Parametric rolling occurs when a ship is navigating in head or following seas with swells whose encounter period is close to half of the natural roll period of the ship. Therefore, when the ship encounters large swells, it is necessary to pay due attention to the direction and the encounter period of those swells.

Swells from the bow or aft direction and within the range of approximately 60° on both sides of the centerline have a high possibility of causing parametric rolling, and the range of approximately 40° on either side requires special attention. The encounter period of swells is usually obtained by visual measurement, but information provided by available weather services can be useful for determining it.

Swell wavelengths which are equivalent to 0.6 times or longer a ship’s length are the worst case for parametric rolling.

③ Know the estimated roll angle of the ship (especially for large ships)

In heavy weather, roll angles exceeding 20° or even 30° are not unusual for small- and medium-sized ships. However, large containerships with a breadth exceeding 50m rarely experience roll angles of more than 10°. If a large roll motion of this size occurs suddenly, there is a high possibility that it is caused by parametric rolling.

④ Be familiar with the ship’s vulnerability to parametric rolling and the available operational guidance

SGISc (Second Generation Intact Stability Criteria[*13]) provides several methods for evaluating a ship’s vulnerability to parametric rolling. Among those methods, the Level 2-C2 criterion is practical in terms of accuracy and difficulty.

[*13] "Interim Guidelines on the Second-Generation Intact Stability Criteria" are a new set of resilience criteria that take into account dynamic hazards such as loss of resilience, which are under consideration by the IMO. The provisional guidelines were established by the IMO Maritime Safety Committee（MSC）in November 2020.

(2) Methods and Measures for Avoidance of Parametric Rolling

① Devices for prevention and reduction of parametric rolling

Parametric rolling can be prevented or reduced by installing devices such as fin stabilizers or anti-roll tanks.

② Operational guidance and WRS

By carrying out series calculations of the predicted parametric roll response (roll angles) for various navigation conditions and sea states, it is possible to prepare materials such as polar charts showing the degree of danger of parametric rolling. Together with these charts, if the captain is provided with operational guidance indicating the action to be taken upon encountering danger of a certain degree or larger, this is expected to contribute to appropriate action for avoiding parametric rolling.

WRS is appears that reliable services that combine forecasted meteorological/hydrographic data and ship operating characteristics related to parametric rolling can be expected in the near future.

③ Parametric rolling monitoring and alert systems

In order to predict the occurrence of parametric rolling and take appropriate action to avoid it, a proper understanding of the natural roll period of the vessel and the sea states encountered is necessary. For this reason, the development and introduction of devices that can measure these data accurately are desirable. Some of these devices are already in practical use. However, in addition to the further development and practical application of monitoring systems, development of systems that can accurately predict the occurrence of parametric rolling and issue alerts in combination with those monitoring devices is expected.

2.9.5 Awareness of parametric rolling (at the time of the accident)

According to the interview of the master, officer A, the person in charge of Company A, and the person in charge of Company W, the details were as follows.

1) Master

Although the master had considered removing the swell from the 'danger zone of receiving waves at 30° to 60° to port from the vessel's main stern' (hereinafter referred to as the 'danger zone'), which may cause parametric rolling on the reference chart in this case, he could not see the direction of the swell at night. Although we had considered removing the swell from the 'danger zone', we could not see the direction of the swell at night.

2) Company A

Company A had long been alerted masters about the danger of parametric rolling on the reference chart in question. However, since the calculation method for parametric rolling had not been clearly established, no special training for dealing with such shaking was conducted, nor was it assumed in the loading plan for the evaluation of securing strength.

3) Company W

Although WRS did not have the capability to predict the occurrence of parametric rolling shaking, it is currently developing a tool to visualize the danger of such rolling shaking through data analysis and other means.

2.9.6 Evaluation of parametric rolling of the ship

The IS code presents a method for evaluating the characteristics of ships with respect to parametric rolling. The company that designed the ship calculated the possibility of parametric roll occurrence using the same evaluation method, assuming a container ship of the same class as the ship, and the results were as follows.(This does not reflect the loading conditions and weather/sea conditions at the time of this accident.)

			Evaluation Criteria（IScode）		
Draft（m）	Trim	GM(m)	Level 1	Level 2 - C 1	Level 2 - C 2
１５．７５	0	１．００	A	A	B
		２．００	A	A	B
		３．００	A	B	B
１４．８０	0	１．００	A	A	B
		２．００	A	A	B
		３．００	A	A	B

A ：At risk of parametric rolling
B ：Resistant to parametric rolling

According to the guidelines of Classification Society A, a feature summary of each evaluation criterion was as follows.

Level 1	Level 1 has the advantage that vulnerabilities can be evaluated by a comparatively simple formula, but in many cases, Level 1 may impose significant restrictions on ship operation conditions, as this criterion is based on a large safety margin corresponding to its simplicity.
Level 2	Level 2 is technically more sophisticated and requires complex calculations, but operational restrictions are reduced because a smaller safety margin can be set, corresponding to its improved estimation accuracy. （C1）For parametric rolling, SGISc specifies two evaluation criteria as Level 2. The first, Cl, provides a more accurate estimate of the possibility of parametric rolling than the Level 1 criterion. above by introducing more realistic assumptions and conditions than those used in Level 1. （C2）C2 is obtained from the results of calculations for various wave conditions and ship speeds by a variety of statistical methods, which include estimation of the response value of

	parametric rolling in various sea states in the wave. SGISc is based on the premise that parametric roll angles of up to 25° are acceptable. However, this inconsistent with the fact that the lashing and securing arrangements for large-scale container carriers, etc. are generally assessed by using roll angles of less than 25°.

2.10 Containership Container Damage Accidents in Recent Years

The following table shows the cases of accidents involving container damage to container ships that have occurred since 2006 (hereinafter referred to as "similar accidents"). Table 9 shows the cases of similar accidents that have been investigated by overseas accident investigation organizations and for which accident investigation reports have been published.

Table 9 Cases of similar accidents

(investigated by Foreign investigating authority and for which investigation reports have been published)

	Year of Occurrence Place of Occurrence	Vessel name (Gross Tonnage)	Number of containers damaged, etc.		Rol angle	investigating authority (Country)	Main Causes
			Fell overboard	Damages			
①	2006 North Atlantic	CMA CGM Otello (91,410ton)	50	20	20°	BEAmer (France)	Combined factors (parametric rolling, container overweight and method of fastening, etc.)
②	2006 North Atlantic	P&O Nedlloyd Genoa (31,333ton)	27	32	30°	MAIB (United Kingdom)	Combined factors (parametric rolling, container overweight and method of fastening, etc.)
③	2007 Baltic Sea	Annabella (7,398ton)	–	7	30°	MAIB (United Kingdom)	Container loading procedure
④	2009 Off Australia	Pacific Adventurer (1,839ton)	31	–	30°	ATSB (Australia)	Container Fastening Method
⑤	2014 North Atlantic	SOVEREIGN MAERSK (91,560ton)	517	250	41°	DMAIB (Denmark)	Stormy weather forecast (including parametric rolling)
⑥	2017 North Atlantic	EVER SMART (75,246ton)	42	34	12°	MAIB (United Kingdom)	Combined factors (weight distribution of containers, method of fastening)
⑦	2018 North Pacific	CMA CGM G. Washington (140,872ton)	81	62	30°	ATSB (Australia)	Combined factors (parametric rolling, lack of container strength and method of fastening, etc.)
⑧	2018 Off Australia	Yang Ming Efficiency (42,741ton)	81	62	30°	ATSB (Australia)	Compound factors (weight distribution and fastening method of containers, maneuvering in rough weather, etc.)
⑨	2020 Off Australia	APL ENGLAND (65,792ton)	50	79	25°	ATSB (Australia)	Combined factors (container loading procedures, deterioration of fastening equipment, stormy weather including parametric rolling)
⑩	2021 North Pacific	MAERSK ESSEN (141,716ton)	689	258	30°	DMAIB (Denmark)	Combined factors (parametric rolling and weather routing services)
This accident	2020 North Pacific	ONE APUS (146,696ton)	1, 841	983	25°		

According to the investigation reports for each of the above cases, in many cases, there were multiple factors, including parametric rolling, as the cause of container damages, etc., and in 2018 and 2021, there were accidents involving container ship of a similar type to this vessel in the North Pacific Ocean, respectively. (Refer to ⑦ and ⑩ in Table 9)

3 ANALYSIS

3.1 Situation of the Accident Occurrence

3.1.1 Course of the Events

According to 2.1, the JTSB concludes that the course of the events leading to the Accident were as follows.

(1) At around 17:54 (Chinese Standard Time) on November 19, 2020, the vessel, with the master, officer A, and 22 others on board, departed from the Yantian for the Long Beach, carrying 7,016 containers (13,175 TEU).

(2) The vessel was proceeding on its scheduled course of approximately 129° when, at around 23:15 on the 30th, a swell with a wave height of about 6 m from the port stern caused a roll of more than 5°, followed by a roll of more than 10°, and at around 23:19 the vessel is most likely to have proceed on a heading of approximately 140°.

(3) The vessel was proceeding at around 23:22 on a heading of approximately 140° when the vessel's roll angle became more than 20° and the rolling became even more severe, and it is estimated that the vessel proceeded on a heading of 120°.

(4) The vessel was proceeding at around 00:58 on December 1 at a heading of approximately 120° and a speed of about 11.7kn when suddenly the roll increased to around 25-27° and the vessel is probably set on a heading of 180°.

(5) The vessel is considered to have collapsed and some of the containers loaded on the deck collapsed and fell into the sea due to the occurrence of the rolling motion described in (3) and (4) above.

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

According to 2.1 the JTSB concludes that it is highly probable that the situation was as follows.

The accident occurred between 23:22 on November 30, 2020 and 00:59 on December 1, 2020, at a distance of 295°1,585M to 1,565M off the Lehua Island lighthouse on the island of Niihau.

3.1.3 Status of Damage, etc.

According to 2.3 to 2.5.3(1), the JTSB concludes that it is certain the situation was as follows.

(1) Damage to containers

1) Of the 3,593 containers loaded on the upper deck, 1,841 containers fell into overboard, and of the remaining containers, 983 containers were damaged by collapsing on the deck.

2) The container that collapsed on the deck in 1) above is considered to have been subjected to a load in excess of the rated load of the securing device due to hull motion, judging from the pressure loss of the container , deformation of the container bottom member, and bent damage to the lashing bar.

3) Half of the container rows with eight or fewer tiers (total of nine rows) collapsed, while all rows with nine or more tiers (total of 13 rows) collapsed, more likely that the higher the number of stacked tiers, the greater the load on the containers due to ship motion.

(2) Damage to hull, etc.

The weight of the collapsed containers caused bent damage to the upper deck and lashing bridge handrails, bent damage to compressed air and fresh water pipes, etc., fractured holes in the hatch covers, and abrasion damage to the bow and center hull plates, respectively.

3.2 Causal Factors of the Accident

3.2.1 Crew Status

As described in 2.4, the Master and Officer A each held a lawful and valid Contracting State Party Recipient Approval Certificate, and were in good health, with no problems with their vision, hearing, or other faculties. The conditions of these crew members are not considered to have contributed to the occurrence of the Incident.

3.2.2 Condition of the Vessel

According to 2.5 4, the JTSB concludes that it is certain the situation was as follows.

(1) There was no malfunction or failure with the Vessel’s hull, engine, or machineries at the time of the Accident, and concludes that their condition did not play a role in the occurrence of the Accident.

(2) The containers loaded on the vessel were lashed in accordance with the lashing program and Company A's cargo lashing manual, and the state of turnbuckle lashing was checked and retightened by the deck crew once every three days during the voyage.

3.2.3 Weather and Sea Conditions

According to 2.7 above, the JTSB concludes that the weather at the time of the accident was more likely cloudy with a north-northwesterly wind blowing at a speed of about 5.5 to 7.9 m/s, a wave height of about 5.0 to 6.0 m, and good visibility.

3.2.4 Analysis of the master's maneuvering status

According to 2.1 above, the JTSB concludes that the master's maneuvering of the vessel after 21:40 on November 30, when the roll became severe, was as follows.

(1) The master went to the bridge at about 22:00 on November 30, when the vessel received a high swell from the northwest direction toward the stern to port stern and began to roll.

(2) The master decided to take command of the vessel himself, and at about 22:47, when the vessel's position was farther south than the planned course line, he returned the course from about 140° to about 129°, the planned course, to check the roll condition.

(3) At around 23:15, the master felt that the roll angle increased to more than 5 ° due to swells with a height of approximately 6 meters coming from the port stern, and then became more severe to more than 10 °, so for the purpose of determining which direction the ship should turn to, the master set the course to 140° at around 23:19.

(4) At around 23:22, the master felt that the roll angle was around 20° and becoming more intense and decided to change the course back to 120° at around 23:23.

(5) At around 23:48, the master slowed the speed to around 11.3 kn and continued to navigate. The roll angle was approximately 5°, and although the direction of the swell from the stern could not be accurately determined because it was too dark at night to see it, he determined that he could navigate safely if he maintained the same course and speed and continued to navigate at the same course and speed.

(6) At approximately 00:58 on December 1, while sailing on a course of approximately 120° and at a speed of approximately 11.7 kn, the master suddenly increased the roll angle to approximately 25°, and at approximately 00:59, following an instruction to set the course to 150°, changed the course to approximately 180°.(See Figure 12)

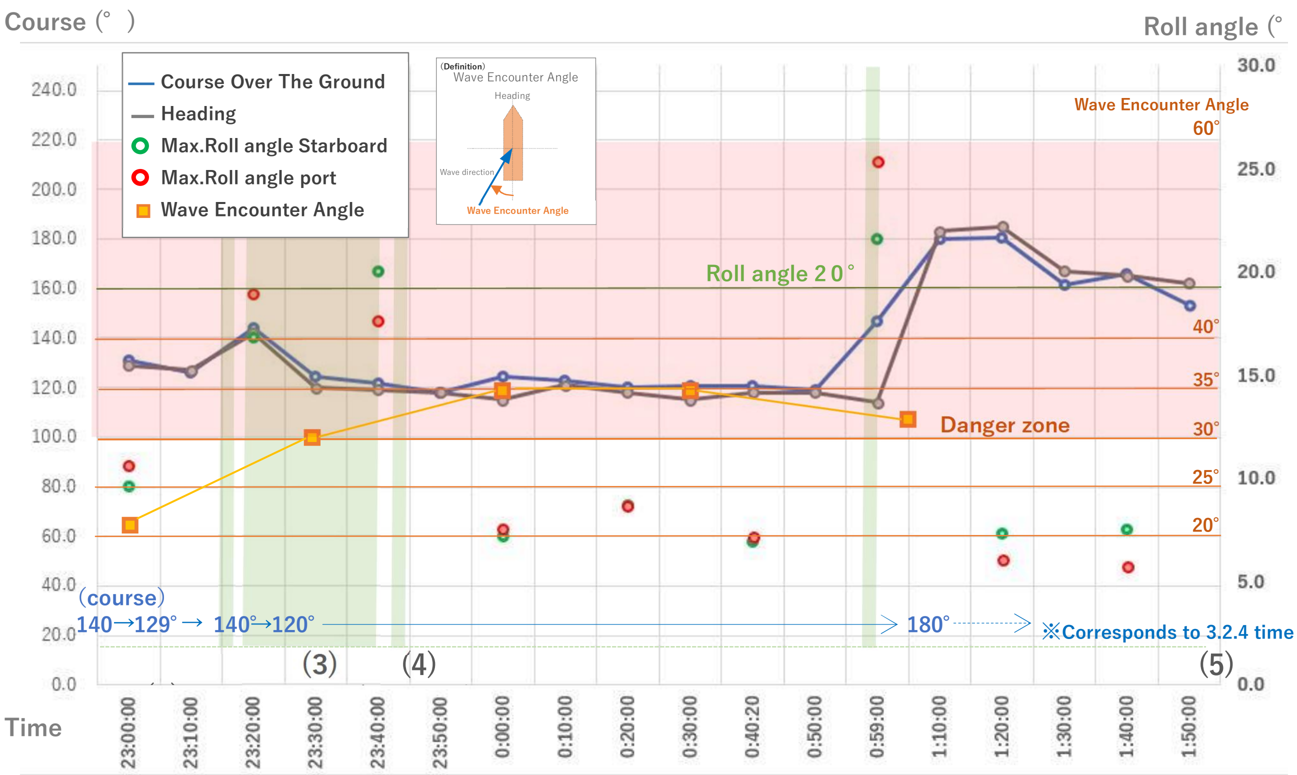


Figure 12 Course (COG and Heading) and roll angle with Wave Encounter Angle

3.2.5 Analysis of Passage Plan Determination, etc.

According to 2.1 ,2.6 and 2.9.5 above, the JTSB concludes that was as follows.

(1) The master received this Passage plan from Company W on November 19, and since the high-wave area in question occurred in the North Pacific Ocean at around 12:00 UTC on November 26 and the vessel would pass through the high-wave area four days later, the master was concerned about the High-Wave area but expected the waves to be around 5 meters by the time the vessel passed through it. The vessel's Passage plan is most likely to have been adopted.

(2) While navigating south of the Japan Coast on the 25th, the master notified Company W of the danger of approaching the High-Wave area under the current Passage Plan , and requested that the plan be changed. It is probable that the ship Navigating with a course of approximately 090° according to the change 1 plan received from Company W.

(3) At around 13:00 on the 26th, the master further changed the course to approximately 099° and reported the change of course to Company W and requested a change in the passage plan.

(4) It is believed that the master received a change 2 plan from Company W at around 18:50 on the 28th to maintain the current course, avoid the High-Wave area in question, and then return to the destination on the Great circle route.

(5) On 29th, the Master again requested a change in the passage plan to Company W out of concern that the vessel would be subjected to a 5 to 6 meter swell from the northwest toward the stern, and on 30th, he received a revised Change 3 plan from Company W. In accordance with this plan, the vessel is considered to have set a course to the south in this High-Wave area, increased its speed and set its course at approximately 129 °.

(6) The master was considering removing the swell toward the port stern from the area of danger zone in order to adjust the ship's course and speed to reduce the impact of the wind and waves as much as possible, but could not see the direction of the swell at night.

(7) Company W's Change 3 plan includes information on waves expected on the plan's course, and

it is recognized that the wave direction expected at 00:00 on the December 1st was north-northwest (16 directions) and the wave height was 5.7m.

(8) At the time of the accident, the vessel was receiving swell from the north-northwest direction as shown in (7) above from the port stern, as indicated by numbers 1 to 6 in the reference chart in this case, as follows.

1) On November 30th, around 23:22, when the roll angle of 20° occurred, the course was 136 to 141°, which was within the range of the number 6, but close to the danger zone of the number 5. The reference chart in this case indicated that "Very heavy rolling (parametric rolling)" might occur as the condition of number 5.

2) On December 1st, around 00:59, when the roll angle of 25 to 27° occurred, the needle was 116 to 115°, which was within the danger zone of this case, numbered 5.

(9) The master is required by Company A's Safety management manual to adjust the ship's course and speed to reduce the impact of wind and waves as much as possible, and it is considered necessary to check the wave forecast and other information in the passage plan and make significant changes to the course so that the swell would not fall within the danger zone in this case.

3.2.6 Analysis of Company A's Contribution to the Passage Plan, etc.

According to 2.1.3 and 2.6 above, the JTSB concludes that was as more likely.

(1) The master was aware that the Passage plans sent from Company W were also sent by CC (copy) to the person in charge of Company B, and when the master replied to Company W, he also sent the plan by CC to the person in charge of Company A, so that both companies were also aware of the vessel's movements.

(2) Company A did not interfere with the passage plan unless it had concerns about the plan, as the passage plan was determined at the discretion of the master.

(3) Company A needs to establish a system to assist masters as necessary in determining passage plan when parametric rolling, etc. is expected due to heavy weather.

3.2.7 Analysis of Ship Motion

According to 2.3.2,2.5.3 and 2.8 above, the JTSB concludes that was as follows.

(1) The maximum measured roll by the vessel's attitude sensor was 20.0° (starboard side) at 23:39, then less than 10° from 23:59 to 00:39, and then 25.3° (port side) at 00:59.

(2) The vessel's roll became 20.0° at 23:39, exceeding the maximum amplitude (approximately 16.1°) assumed in the lashing program, damaging the Securing device of the container, etc., causing the container loaded on the deck to collapse, and furthermore, the side inclination became 25.3° at 00:59, The container collapsed and other damage to the container hatch covers and other structures on deck occurred.

3.2.8 Analysis of Parametric Rolling Occurrence

According to 2.1.3,2,5,3,2.8 and 2.9 above, the JTSB concludes that was as more likely .

(1) At the time of the accident, the ship was experiencing roll motion with a measured roll of 25.3° at 00:59, while the 1/188 maximum expected amplitude of the roll calculated by the short-term prediction method (normal ship motion estimation calculation) was 22.97° (see Table 8). Thus, the ship experienced large roll motion that was not calculated by the estimation calculation using the same method, and the situation is considered to have been different from normal hull motion.

(2) Comparing the results of the calculation of the possibility of parametric roll based on the IS Code for a container ship of the same class as the vessel by the company that designed the vessel with the conditions of the vessel at the time of the accident (draft (average) 14.55 m and GM 1.605 m), the results show that the vessel at the time of the accident was in Level 1 and Level 2 of the IS Code.

(3) "Conditions that are likely to cause parametric roll as described in the guidelines of Classification Society A" and " TopTier " and "2.8 Calculation of estimated ship motion". The

results of the calculation are shown in Table 10, which is based on the conditions of the accident (the calculated conditions in Table 8).

Table 10 Comparison of guidelines, etc. and the situation at the time of this accident

① Guidelines for Classification Society A (Conditions where parametric rolling is likely to occur)	Situation at the time of this accident	result
when a ship is navigating in head or following seas with swells whose encounter period is close to half of the natural roll period of the ship. (Estimation formula Tr=0.8B/√GM for the natural rolling period as described in the guideline)	There was a swell from the starboard stern. (Encounter period/natural rolling period = 0.64 times) (Encounter period (19.1 s)/ Natural rolling period (31.9 s)=0.59 times)	Generally applicable
breadth exceeding 50m rarely experience roll angles of more than 10°. If a large roll motion of this size occurs suddenly, there is a high possibility that it is caused by parametric rolling.	Occurred	apply
Swells from the bow or aft direction and within the range of approximately 60° on both sides of the centerline have a high possibility of causing parametric rolling, and the range of approximately 40° on either side requires special attention.	Swell direction approx. 35°	apply
Swell wavelengths which are equivalent to 0.6 times or longer a ship's length are the worst case for parametric rolling.	More than 0.6 times	Generally applicable
② TopTier report (In what cases should we be cautious etc.)	Situation at the time of this accident	result
Vessel rolling period is long because of low GM (rolling periods more than 20s for ships with length above 250m). (Estimation formula for the natural rolling period of lateral sway described in the report, Tr=0.86B/√GM)	Exceeds 20 seconds (Natural rolling period: 34.3 sec)	apply
Following sea conditions (or close to) are expected or experienced.	There was a swell from the starboard stern.	apply
The rolling period is twice the wave encounter period (±3 seconds).	1.79 times (2 times the encounter period - 3.9 seconds) (Rolling natural period / Encounter period = 1.79 times)	Not applicable
Wave lengths are longer than half of the ship length.	Within range (Wavelength 354.15m <L354.66m)	apply

As a result of the contrast, the situation at the time of this accident was such that many items were under the conditions, etc., that are considered to be prone to parametric rolling.

(4) From (1) to (3) above, it is considered that the vessel received a swell from the port aft side, and from around 21:40 on November 30th, when the roll began, to around 00:59 on December 1st, when the vessel changed course significantly, the conditions that were more likely to cause parametric rolling continued.

(5) When the weather became rough, the master should have taken appropriate evasive action against the occurrence of parametric rolling by, for example, properly assessing the sea conditions being encountered and drastically change course so that the direction of the swell would not fall within the danger zone.

(6) Company A needs to prepare operational guidance, etc. for the purpose of avoiding parametric rolling and have the crew members understand it. In the future, it is desirable for those involved in the operation of large container ship and other vessels prone to roll to develop a system that detects signs of roll based on data and other information and promptly take measures such as changing course and speed.

3.2.9 Analysis of the Accident's Occurrence

According to 3.1.1, and 3.2.3 to 3.2.8, the JTSB concludes that was as follows.

(1) At around 23:19 on November 30, the master was trying to reduce the roll and was considering removing the swell toward the port stern from the Danger zone, but he could not see the direction of the swell at night and set the course to approximately 140°, which caused the vessel to proceed on a course where the direction of the swell was close to the Danger zone. At around 23:22, the roll angle was more than 20°, exceeding the maximum amplitude (approximately 16.1°) assumed in the

lashing program, damaging the container's securing equipment, etc., and is considered to have caused the first collapse of the cargo.

(2) At 23:48, the roll angle of the vessel was about 5 °, so the master decided that the vessel could proceed safely if it maintained the same course and speed and continued to sail with the vessel in the Danger Zone. At about 00:58 on December 1, the roll angle increased to about 25° or more, and the second collapse of the cargo is considered to have caused the containers to collapse and other damage to the hatch covers and other structures on the deck.

(3) The vessel is considered to have proceeded under conditions that were prone to parametric rolls from about 21:40 on November 30, when the rolling began, to about 00:59 on December 1, when the ship changed course significantly. The reason why the master proceeded in such a manner is considered to be due to the fact that he was unable to properly assess the sea conditions at night, as described in (1) above.

4 PROBABLE CAUSES

It is probable that the cause of the Accident was that, at night when the vessel was proceeding east-southeast off the west-northwest coast of Niihau Island in the Hawaiian Islands, when the ship was experiencing swells of approximately 5 to 6 m from the northwest and north-northwest directions on the port side and stern, and the master attempted to reduce the rolling. As the ship was sailing on a course of approximately 140°, the direction of the swell was close to the danger zone where the ship received waves from 30° to 60° to port stern, resulting in a roll angle of over 20° and the first cargo collapse.

After that, the master felt the rolling become even more intense, changed the course to approximately 120° and continued sailing, causing the direction of the swell to shift from the stern of the ship to 30° to 60° to port.

It is thought that this caused the cargo to enter the danger zone, resulting in a roll angle of 25 ° or more, and the second collapse of the cargo occurred.

It is probable that the cargo on the ship collapsed, causing the loaded containers to collapse and damage to container hatch cover and other equipment on deck leading to this accident.

The master set the course at approximately 140° and the direction of the swell was close to the danger zone. probably due to the fact that he could not properly assess the sea conditions at night.

The vessel is considered to have proceeded under conditions that were prone to parametric rolling from about 21:40 on November 30, when the rolling began, to about 00:59 on December 1, when the ship changed course significantly.

5 SAFETY ACTIONS

It is probable that the cause of the Accident, the master proceeded on a course of approximately 140 ° during the night when the vessel was subjected to swell toward the stern, which caused the first collapse of the cargo, and then the master continued a course of approximately 120 °, which caused the second collapse of the cargo. The second collapse is considered to have occurred because the master continued to navigate at a heading of approximately 120 °, and the direction of the swell entered the danger zone.

The vessel is considered to have proceeded under conditions that were prone to parametric rolling.

Accordingly, must implement the following measures to prevent the occurrence of a similar accident.

(1) Company A shall instruct its crew members that if heavy weather is expected, they should check the wave forecasts provided in the weather routing service, consider the relationship between wave direction and course, and take appropriate avoidance measures against the occurrence of parametric rolling, such as drastically changing the course to avoid falling within the danger zone.

(2) If heavy weather is forecast on the planned course, the master shall contact company A and Company W at an early stage to discuss the adequacy of the passage plan including Cargo condition.

(3) Company A shall establish a system to assist the master, as necessary, in determining the course and

other passage plan when parametric rolling, etc., is expected due to heavy weather.

５．１　Safety Actions Taken Following the Accident

Company A established The Joint investigation Team (JIT) with Company B, Company C, and others, and took the following measures to improve the safe operation of its vessels.

(1) Crew members were given safety training on heavy weather, including parametric rolling, to prevent similar accidents from occurring.

(2) Lashing equipment was extensive tested for strength and some equipment was replaced.(lashings replacement program)

(3) Calculation settings in the loading program were changed to the following parameters.
- ・The assumed wind speed was fixed at 40 m/s.
- ・Assumed speed was fixed at 21 kn.
- ・The program was modified to be able to calculate hull strength, etc. when the maximum amplitude was set to 22°.

(4) The calculation settings of the lashing program were changed to the following conditions.
- ・Safe Working Load（SWL）of the container corner casting was changed from 300KN to 210KN. (Currently re-evaluating safety loads, etc.)

(5) The contract structure for weather routing services was changed to strengthen the dialogue between masters and the service provider, etc.

(6) A new reference chart (Polar Diagrams) was created for the vessel's class.

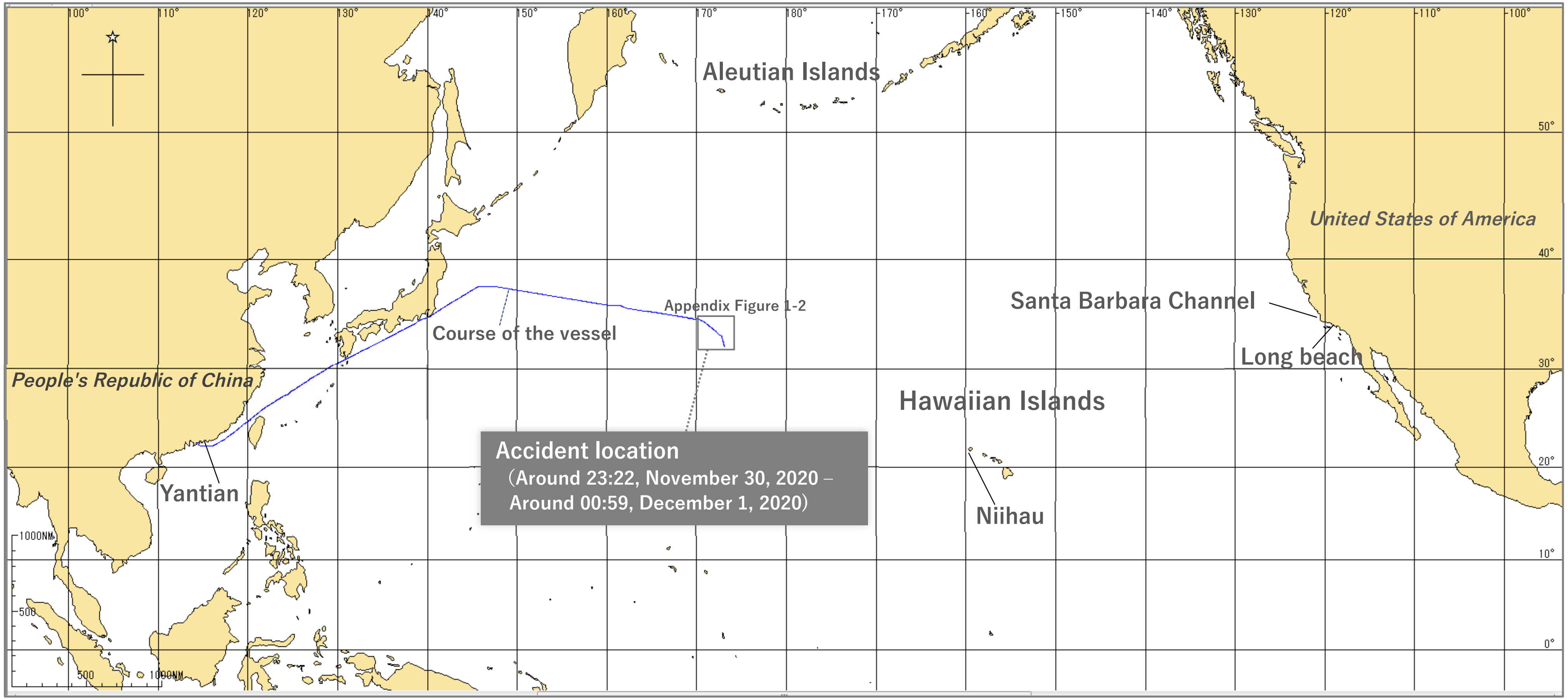
(7) During heavy weather, we continuously monitor the weather from land and strengthened our system to support the masters.

５．２　Safety Actions Required

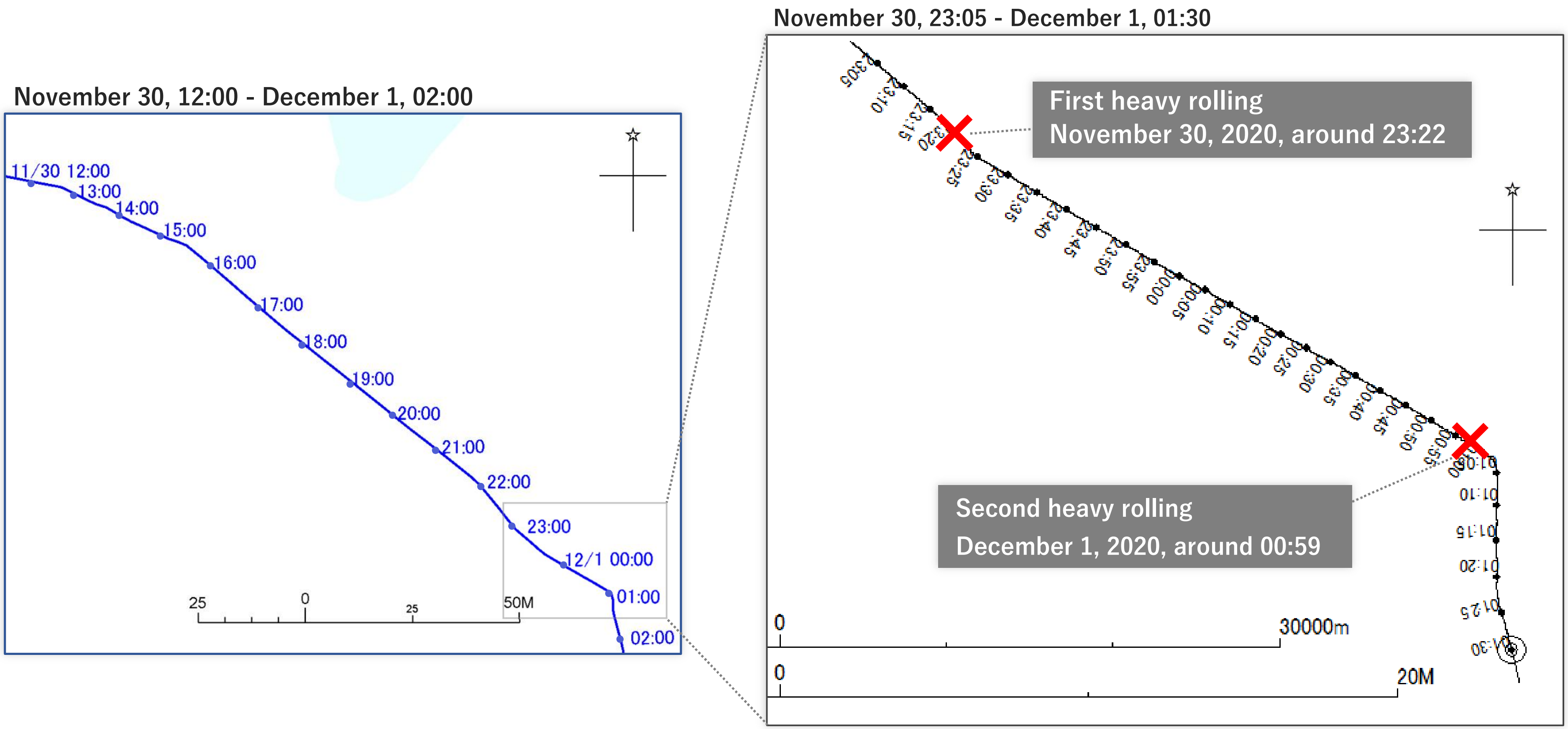
Company A should continue to establish a system to assist masters, as necessary, in determining passage plans when heavy weather is expected, such as parametric rolling, etc.

JTSB requests the cooperation of the Japanese Shipowners' Association and Japan Foreign Steamship Association in disseminating the contents of this report in order to prevent similar accidents from the results of the investigation of this accident.

Appendix Figure 1-1 Estimated Navigation Route (overall view)

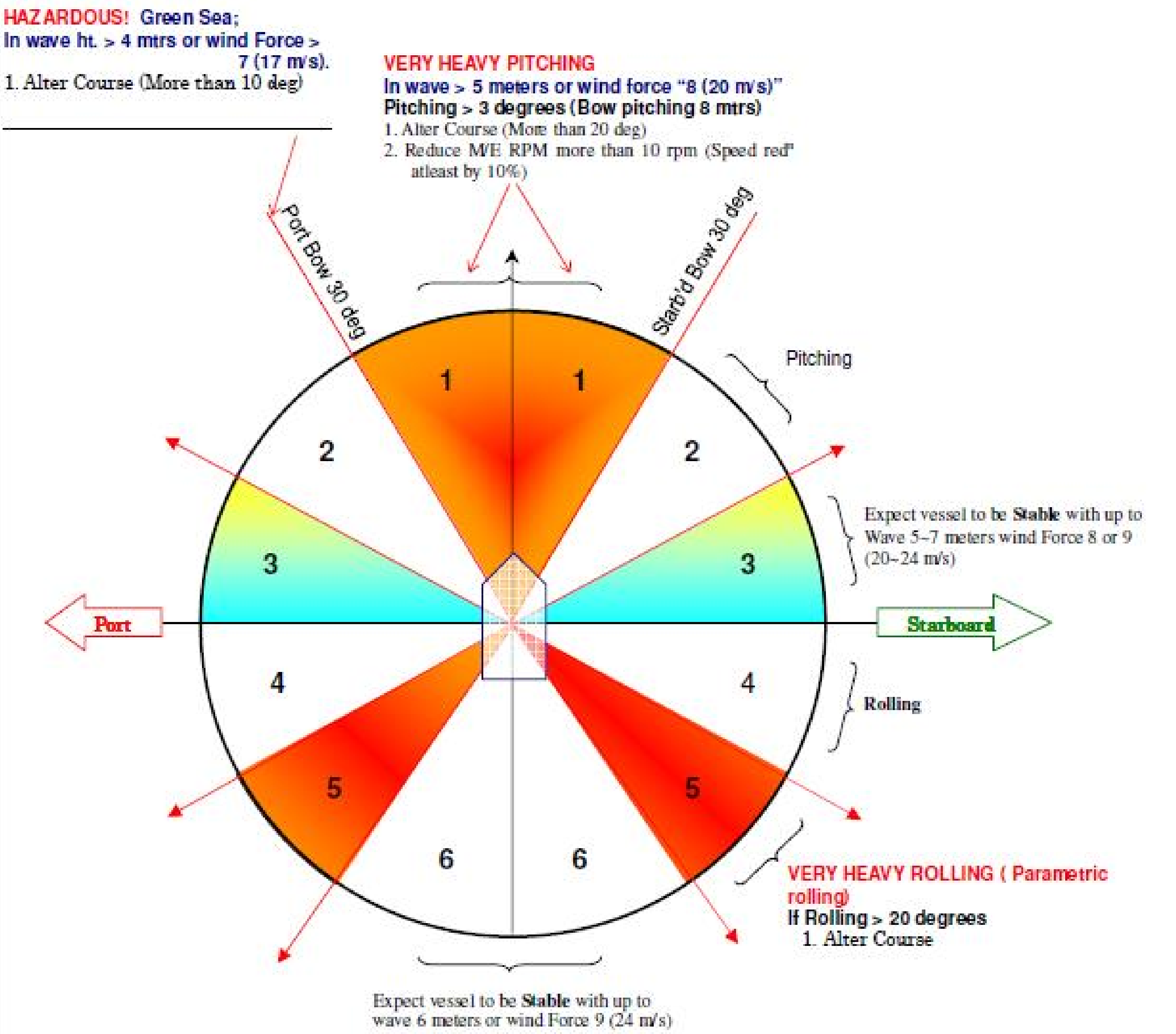


Appendix Figure 1-2　Estimated Navigation Route (Enlargd)



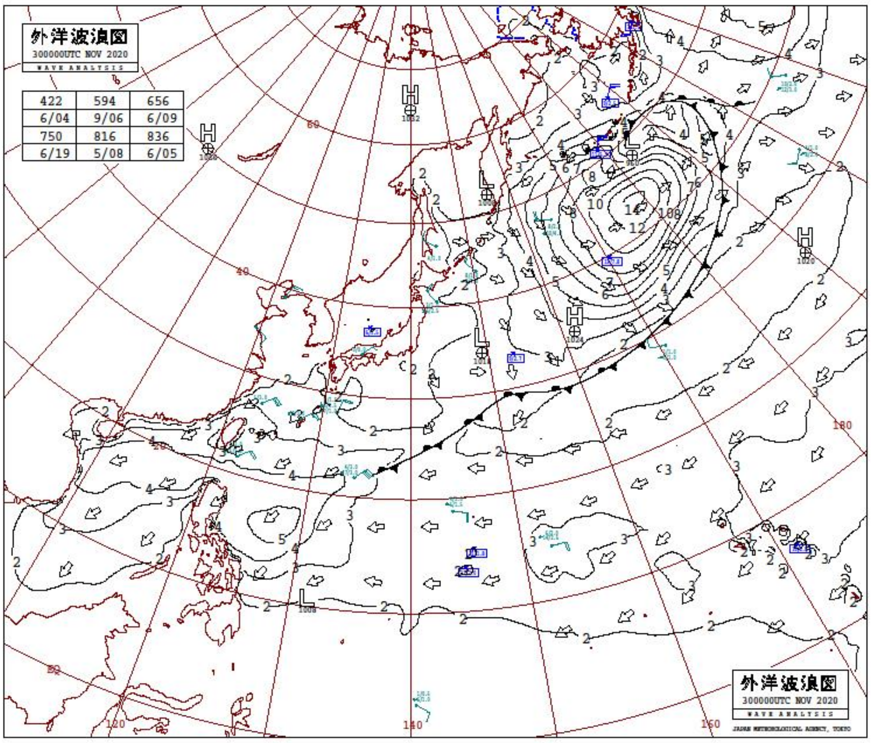
Appendix Figure 1-2 Reference chart

"GUIDELINES TO AVOID HEAVY WEATHER DAMAGES"

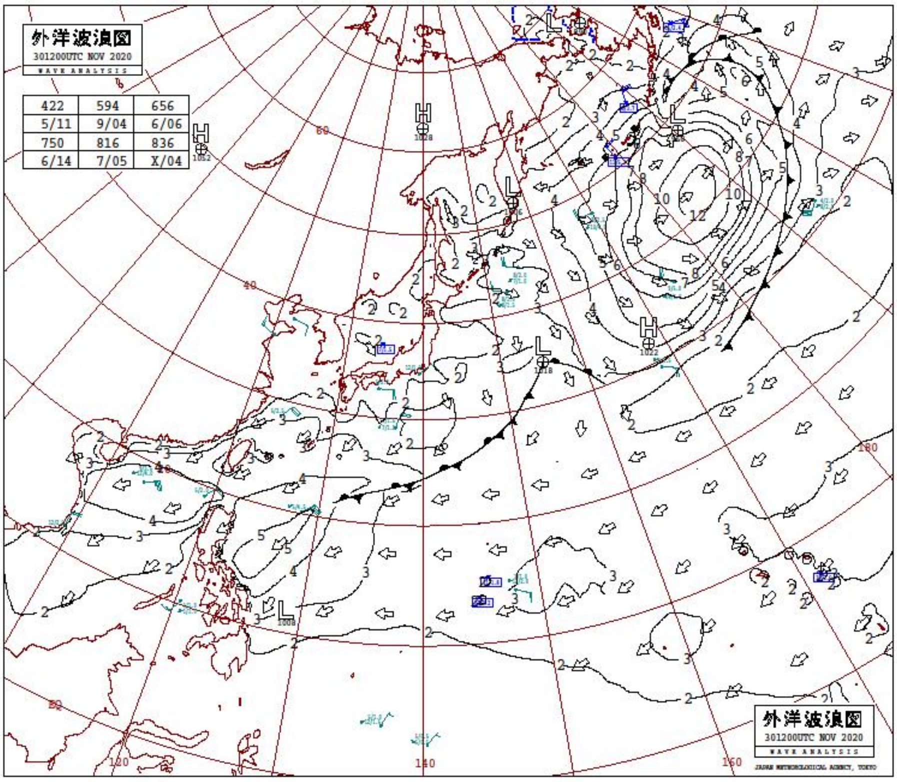


a) Above sample is for a container vessel (approx 4000TEUS) and length overall 289 mtrs.
b) Actual Conditions may vary basis actual displacement / Stability / Container Tiers. Above diagram is only a guideline for raising awareness of possible hazards.
c) Weather tolerance (Limits) and RPM reductions etc will be different for vessels based upon their respective engine, ships particulars and Master's requirements
d) Index of Pitching can be approximately calculated using foremast movement.
e) **The Wave impact force on the vessel's hull is SQUARE of the vessel's relative speed.**
f) **Parametric rolling** in extreme head or near head seas can occur when unfavorable tuning is combined with low roll damping (reduced speed) and large stability variations (governed by wavelength, wave height, general hull form, bow flare and stern shapes). Parametric rolling is an unstable phenomenon, quickly generating large roll angles coupled with significant pitching. Rolling occurs in phase with pitch and on containerships introduces high loads into the containers and their securing systems. Please see attached MSC Circular 1228.

Appendix Figure 3　 Ocean wave map



(12:00, November 30, 2020)



(00:00, December 1, 2020)

Appendix Figure 4 TopTier Report

Notice to Mariners

Beware of parametric rolling in following seas

A series of incidents with exceptional container losses occurred during the winter season 2020-2021. The TopTier project was put in place by industry to find ways to avoid similar incidents in the future, and initial results show that parametric rolling in following seas was especially hazardous. This notice describes how container vessel crew and operational staff can plan, recognize and act to prevent parametric rolling in following seas.

Hazard & rationale

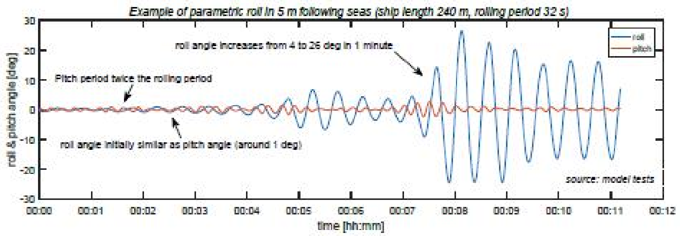
Container ships are also vulnerable to parametric rolling in following sea conditions. Unfavourable combinations of rolling period, vessel speed, heading, and wave conditions, can trigger sudden and extremely rapid increase of roll motions to hazardous levels, threatening the safety of vessel, crew and cargo. This can happen in relatively mild wave heights.

What is parametric rolling?

Parametric rolling can occur when:

- The rolling period is twice the wave encounter period
- Wave lengths are in the range of the vessel length

In these conditions the passing waves cause a variation in waterplane area that can trigger vessel instability in roll. This is most common in heavy head seas, but can occur also in following seas, when the rolling period is long. Even a few high waves after each other may trigger unexpected large roll motions, as shown by the measured time traces of roll and pitch motions in the figure below. In the example, the ship is 240m long with a natural roll period of 32s and is sailing in a 5m following sea.



When to be alert?

Ships at low GM are vulnerable to parametric rolling in following seas, especially when there are waves with a long length from the stern quarter. Long term routing and short term vessel handling should consider the risk of parametric rolling in following seas when:

- Vessel rolling period is long because of low GM (rolling periods in excess of 20s for ships with length above 250m). The rolling period should be measured after departure, as rules of thumb based on GM are not always accurate.
- Following sea conditions (or close to) are expected or experienced.
- The rolling period is twice the wave encounter period. The wave encounter period is equal to the pitching period and can be measured with a stopwatch.
- Wave lengths are longer than half of the ship length.

The combination of above conditions should be avoided already in route planning by calculating the wave encounter period and wave length using the vessel speed, the forecasted wind and swell wave periods and direction (see next page for details).

How to recognize the first signs or increasing risk?

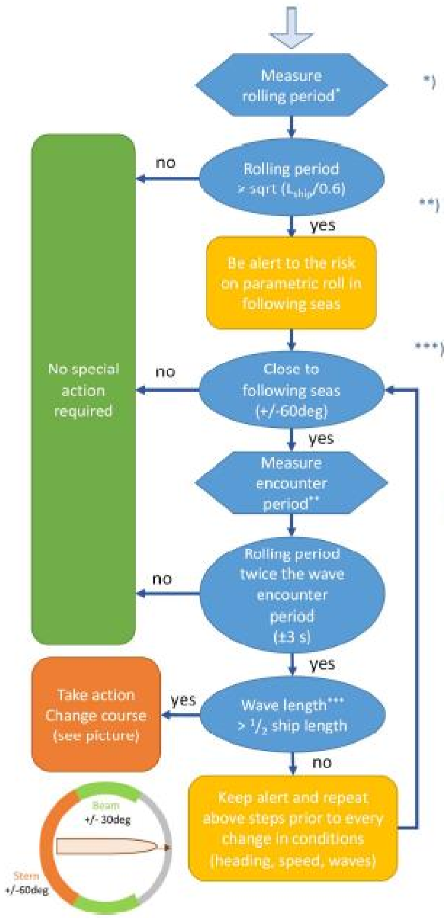
A vessel can go into parametric rolling very suddenly and unexpectedly. To prevent it, crew should therefore learn to recognize the conditions and danger signs at an early stage. Tell-tale behaviour is the synchronisation between the gentle roll and pitch motions as waves pass underneath, especially when the vessel starts rolling alternatingly from port onto starboard shoulder in perfect sync with successive pitching cycles. This indicates that wave encounter periods are close to half of the roll period and in this condition parametric rolling can happen at any time if waves are high enough.

What to do when it happens?

Break the synchronization between the roll period and the encounter period. The most direct way to do this is to change heading to beam or bow quartering seas. Avoid abrupt steering. The heading change can be combined with a speed increase but only if it does not increase the risk of other hazards. Changing course may seem counterintuitive but is the only way to reduce the risk of parametric rolling in following seas.

This notice to mariners in an initiative of the TopTier JIP. The Joint Industry Project TopTier is initiated to address the loss of containers with active participation of major stakeholders. More explicit guidance on the hazard of parametric rolling in following seas is work in progress. For more information https://www.marin.nl/en/jips/toptier

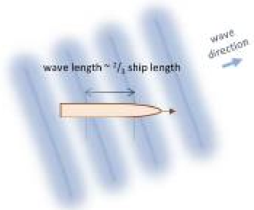
When to be alert on parametric rolling in following seas?



*) Measure roll period: Use a stopwatch to measure the time of 5 complete roll motion, divide measured time by 5.

**) Measure wave encounter period: Use a stopwatch to measure the time of 5 complete pitch motions, divide measured time by 5

***) Estimate the wavelength: The wave length can be estimated in comparison with the ship length.



Calculating the rolling period

An accurate assessment of the rolling period is preferred but may not yet be available during voyage preparation. In that case, you can use the formula below, adding an estimate for the encounter period and wave length.

$$T_{roll} = \frac{0.86B}{\sqrt{GM_{solid}}} \qquad T_e = \frac{3T_w^2}{3T_w + V\cos(\alpha)} \qquad L_w = \frac{1.56T_w^2}{\mathrm{abs}(\cos(\alpha))}$$

Where:

T_{roll}	=	Estimated rolling period of ship in [seconds]
B	=	Beam of ship in [meter]
GM_{solid}	=	Transverse stability (excluding free surface correction) in [meter]
L_w	=	Wave length in [meter]
L_{ship}	=	Ship length [meter]
T_w	=	Wave period in [seconds]
α	=	Ship fixed wave direction (α=0° means head seas) in [degrees]
T_e	=	Wave encounter period in [seconds]
V	=	Ship speed in [knots]
abs	=	Absolute value
sqrt	=	Square root