[MSI Report 2023-002]

Marine Safety Investigation Report

– Fatal Accident aboard Research Vessel Isabu –

Date of Accident: 5 July 2022

Date of Publication: 18 April 2023

Korea Maritime Safety Tribunal
Marine Safety Investigation Team

Note

This marine safety investigation report aims to identify the cause of the marine accident and prevent similar marine accidents or incidents in the future under Article 18.3 of the Act on the Investigation of and Inquiry into Marine Accidents. It is therefore advised that this report not be used for assigning blame or determining liability.

This report quotes the names of the relevant acts and agencies that were in place at the time of writing.

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1 Executive Summary

1. Executive Summary

1.1 R/V Isabu departed from Port Louis in Mauritius with a total of 52 persons on board and set sail for the Indian Ocean on 23 June 2022.

1.2 At 14:18 on 5 July 2022 (LT; UTC+4, the same hereinafter local time), Isabu conducted a research and survey operation at sea in the vicinity of 04°00'S 067°00'E.

1.3 From 13:00 to 13:50 on the same day, the first engineer (1/E) convened an afternoon toolbox meeting (TBM) in the engine control room (ECR). After that, the crew of the engine department, including the chief electrician, went back to their positions and carried out their afternoon tasks.

1.4 At 14:00, the chief electrician took out tools from the engine room workshop and went to the fitness room on the second deck where Watertight Door No. 5 is installed. While staying there from 14:15 to 15:05, she checked the power switchboard of the watertight door. Also, she inspected and cleaned the inside of the actuation system by opening a panel at the bottom.

1.5 From 15:05 to 15:13, the chief electrician smoked and took a brief break in the smoking area on the poop deck and returned to the fitness room.

1.6 At 15:30, the chief engineer (C/E) of Isabu, who was looking towards the bow area on her way to the engine room, found the chief electrician trapped by Watertight Door No. 5 in a standing position at the entrance of the fitness room.

1.7 The C/E informed the ECR of the accident and reported it to the master. The vessel's crew, including the master, immediately rushed to the fitness room and tried to rescue the trapped chief electrician. When the door was opened, she slumped to the floor.

1.8 While checking the condition of the fallen chief electrician, the crew called the Maritime Emergency Medical Service (EMS) Center to report her condition and repeatedly asked for urgent medical assistance. Meanwhile, they confirmed she had stopped breathing and had no pulse.

1.9 At 16:00 on the same day, Isabu left for Mauritius and arrived at Port Louis in Mauritius at 21:00 on 9 July 2022. After that, the local police agency and doctors concluded that the chief electrician was dead.

section

2

Findings of Fact

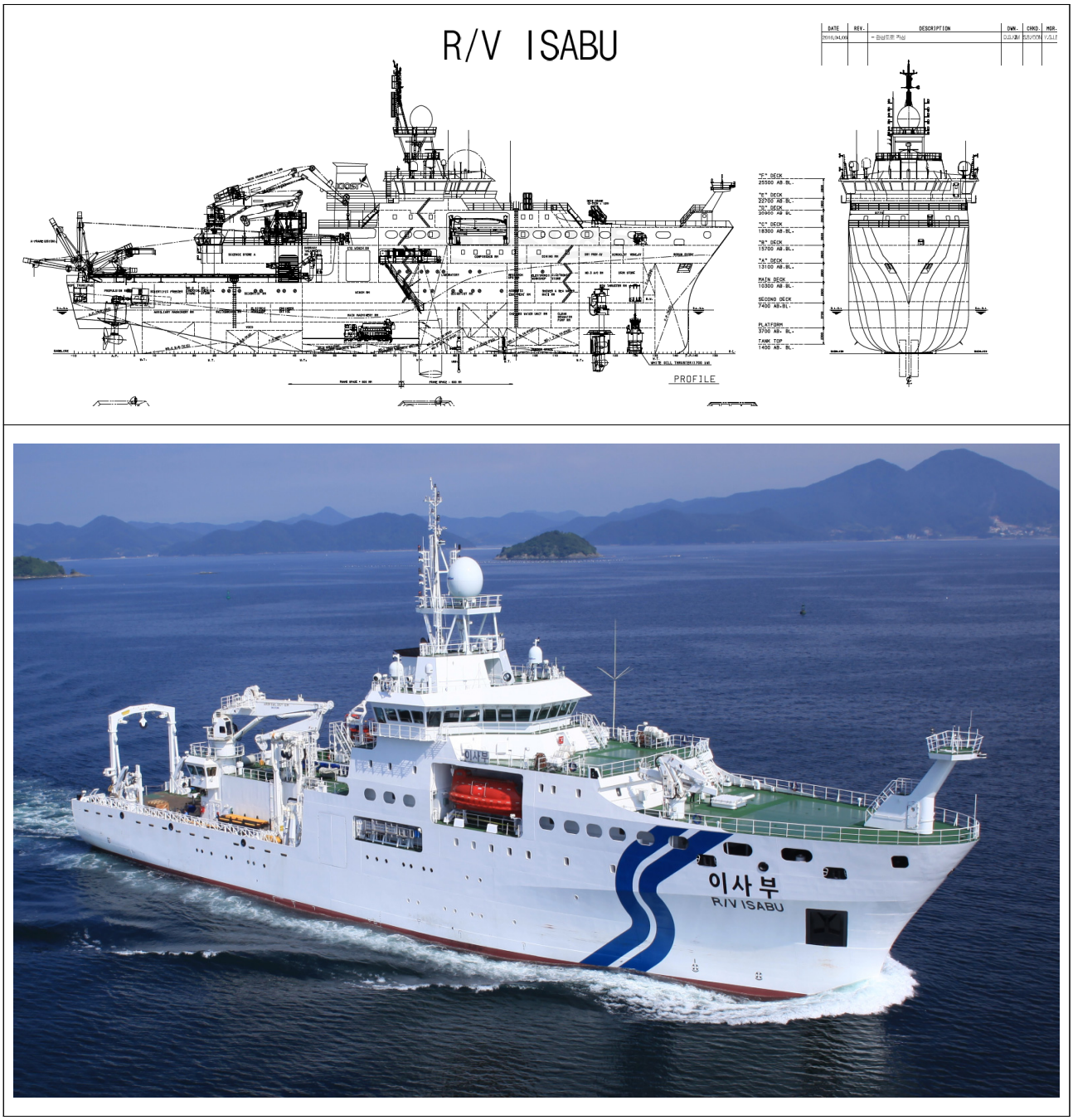
2. Findings of Fact

2.1 Ship particulars

2.1.1 Principal particulars of Isabu

Ship Name	Isabu
Flag State	Republic of Korea
Port of Registry	Busan
IMO No.	9751042
Ship Type	Other (research ship)
Owner	Korea Institute of Ocean Science and Technology (KIOST)
Safety Management Company	KIOST
Builder	STX Offshore & Shipbuilding Co., Ltd.
Date of Keel Laid / Date of Launch	15 Oct. 2014 / 15 May 2015
Classification Society	Korean Register of Shipping (KR)
Gross Tonnage (t)	5,894
Length / LOA (m)	89.33 / 99.80
Beam (m)	18.00
Depth (m)	10.30
Main Engine	Electric motor (2)
Max. Output	2,400kW × 2
Propeller	Screw-type (2)
Rudder	Azimuth thruster

2.1.2 Isabu, launched by STX Offshore & Shipbuilding Co., Ltd. on 15 May 2015, is a research vessel with a gross tonnage of 5,894 tons, a length of 89.33 meters, a beam of 18.00 meters, and a depth of 10.30 meters.



<Figure 1> General arrangement and photo of Isabu

2.2 Shipowner and operation

2.2.1 The owner of this research vessel is the president of the Korea Institute of Ocean Science and Technology (KIOST) who manages all matters related to her operation, such as navigation plan, crew management, and safety management.

2.2.2 Isabu is a vessel designed and equipped to carry out research at sea. An annual operation plan is established at the beginning of each year under which the vessel is being operated. Isabu was engaged in research and survey in the Indian Ocean at the time of the accident.

2.3 Ship surveys

2.3.1 Isabu completed a renewal survey by Korean Register of Shipping (KR) on 9 March 2021, and she was holding certificates under the international conventions, including the Cargo Ship Safety Construction Certificate, valid till 8 March 2026.

2.4 Crew composition

2.4.1 Isabu accommodates up to 60 persons on board: 25 crewmembers; and 35 special personnel, meaning non-crew passengers, such as senior researchers and chief observers. At the time of the accident, a total of 52 persons, including 25 crewmembers and 27 special personnel, were on board.

2.4.2 The ship's master came aboard in February 2020. The C/E had joined Isabu as a 1/E in September 2019 and was promoted to a C/E in January 2021. As such, he was serving aboard Isabu as a C/E on the day of the accident.

2.4.3 The chief electrician, the accident victim, originally boarded Isabu as a third engineer (3/E) in February 2020. And in January 2021, her position was changed to a chief electrician.[1)]

2.5 Deck arrangement

2.5.1 Isabu, with a mid-ship bridge arrangement, has total nine decks from the bridge to the tank top at the bottom. The main deck consists of research labs and workshops

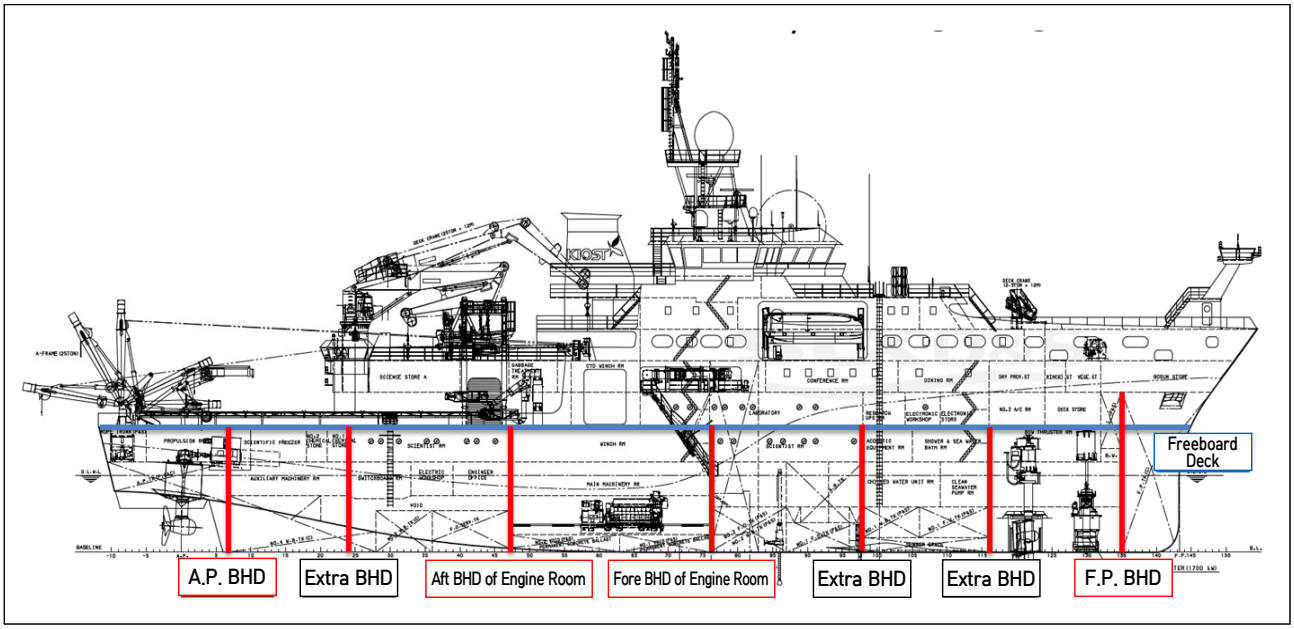
1) The chief electrician had previously served aboard a coastal ferry (GT. 15,000-tonne level) as a chief engineer.

with A-frame cranes astern for launching research equipment. Above the main deck are decks A to F, where the meeting room, mess room, crew cabins, and steering room are located.

2.5.2 Below the main deck are the second deck, where researchers' cabins, the fitness room, and the winch room are located; the platform, consisting of the engine room, the ECR, and the chilled water unit room; and the tank top, where the bow thruster room is located.

2.6 Arrangement of watertight bulkheads and watertight doors

2.6.1 Isabu is equipped with seven watertight bulkheads in total. Among those, the forepeak and after peak bulkheads, and both fore and aft bulkheads of the engine room are required under the rules and regulations of the Structural Standards of Steel Ships[2] and the classification society. The other three bulkheads were added during the design and shipbuilding process.

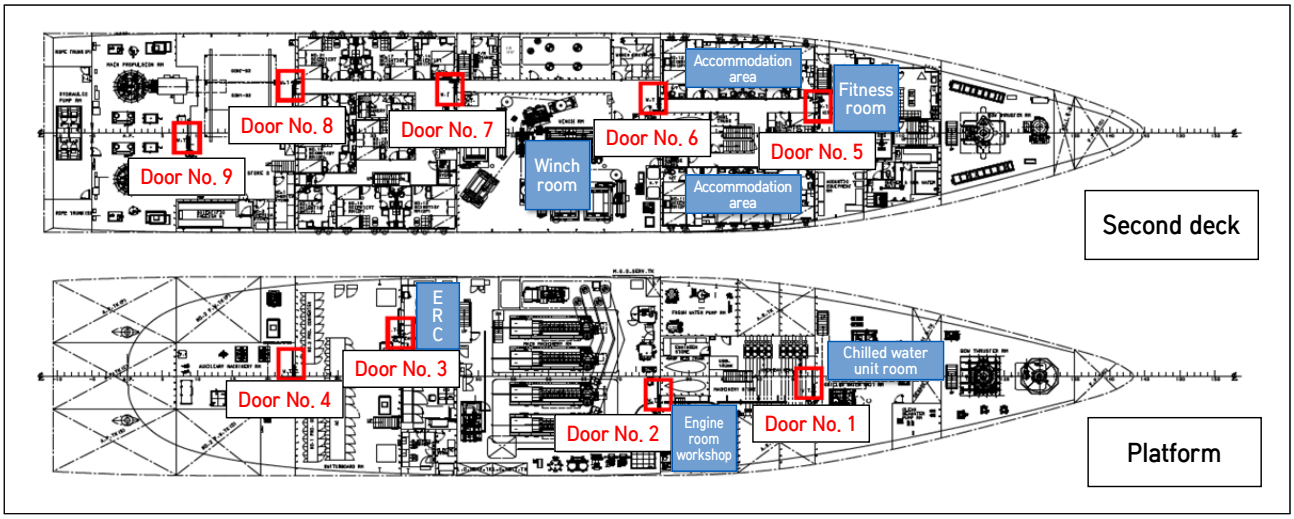


<Figure 2> Location of watertight bulkheads

2) Article 8, Section 1, Sub-section 1 (Arrangement of Watertight Bulkheads) of the Structural Standards of Steel Ships

2.6.2 As a research vessel, Isabu was required to comply with the Special Purpose Ship Code (SPS Code), and thus, damage stability requirements, which are similar to those of passenger ferries, were applied to the vessel[3]. At the request of the shipowner, Isabu was designed to set extra watertight doors within the required parameters. Therefore, elements, such as structural strength, reserve buoyancy, and watertight compartments, were adjusted in the design of Isabu, given the vessel's intact stability in the expected loaded condition as well as her damage stability should the main watertight compartment suffer damage.[4]

2.6.3 Isabu has a total of nine hydraulic sliding watertight doors: five on the second deck, where the fitness room and researchers' cabins are located; and four on the platform, where the engine facilities are located.



<Figure 3> Location and Nos. of watertight doors

2.7 Particulars and structures of watertight doors

2.7.1 The structure and material of the watertight doors and their parts of Isabu comply with the relevant rules and regulations, and specifications of the manufacturers, and they were approved by KR.[5] The size of each watertight door opening differs

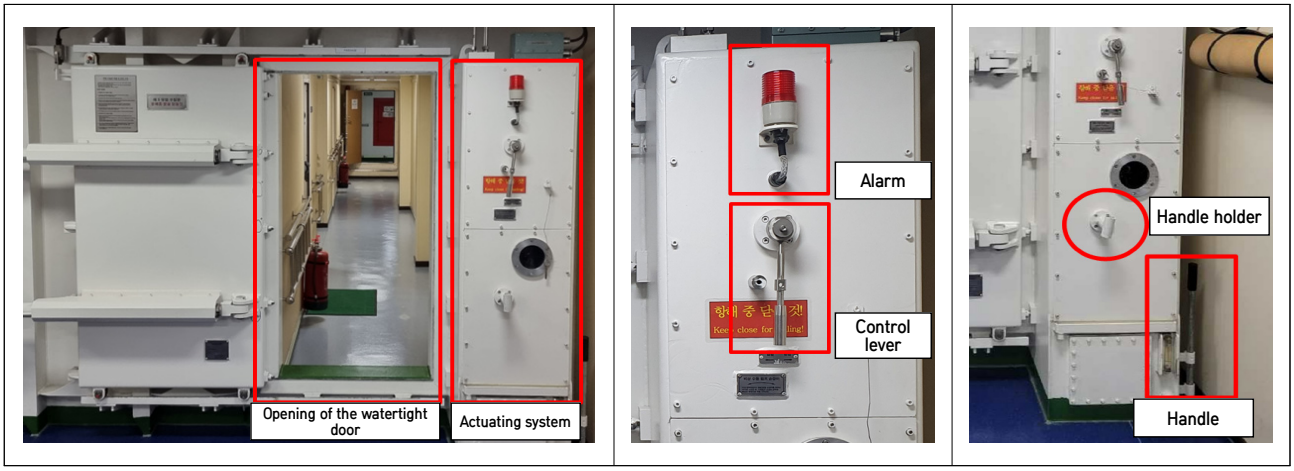
3) The requirements of the SPS Code are applied to the hull, engine, arrangement of watertight vertical zones, construction and safety devices for fire protection, and life-saving appliances.

4) KIOST, "Shipbuilding of Isabu," White Paper (2017), 155

5) KIOST, "Shipbuilding of Isabu," White Paper (2017), 210

according to location[6], and Watertight Door No. 5, where the accident occurred, is 165 centimeters high and 80 centimeters wide.

2.7.2 The vessel's watertight doors are operated by the hydraulic sliding system consisting of oil tanks, a hydraulic pump, an accumulator, control levers, hand pump handles, a pressure gauge, and an alarm. This system runs at a maximum pressure of 180kg/cm^2 with 440 volts, and the accumulator has a capacity of 32 liters. The alarm, connected to a 24-volt emergency power supply, gives off audible/visual signals.



<Figure 4> Opening and actuating system (left); control lever and alarm (middle); and hand pump handle (right)

2.7.3 The watertight door specifications say it takes 20 to 40 seconds to close the watertight door under normal conditions, and closing takes up to 90 seconds when the hand pump is used.

6) Watertight door openings of Isabu have three standard dimensions: (i) 80 cm x 165 cm (width x height); (ii) 100 cm x 175 cm; and (iii) 100 cm x 190 cm

section

3 Development of Accident

3. Development of Accident

When this accident occurred, the chief electrician was working alone, without other crewmates or witnesses. Moreover, no CCTV recorded the accident site, and no materials were available for witnessing or documenting how the accident progressed. Therefore, this investigation report relies on statements given by other crew members and film recorded by CCTVs in the other locations on board to track the victim's activities on the day of the accident. Then, it aims to identify the cause of this accident by restructuring and analyzing the event based on the situation when the victim was discovered.

3.1 Situation and whereabouts of the victim before the accident

3.1.1 Isabu departed from Port Louis in Mauritius with a total of 52 persons on board (25 crewmembers and 27 non-crewmembers, including researchers) and set sail for her destination on the Indian Ocean on 23 June 2022.

3.1.2 At 14:18 on 5 July 2022, the vessel was engaged in research and survey at sea in the vicinity of 04°00'S 067°00'E. Isabu is mounted with the controlled passive anti-rolling system[7] in order to complete research work on board under the Beaufort wind force scale of 6. At the time of the accident, the wind blew from the southeast at the scale of 6. Still, there was no significant rolling.

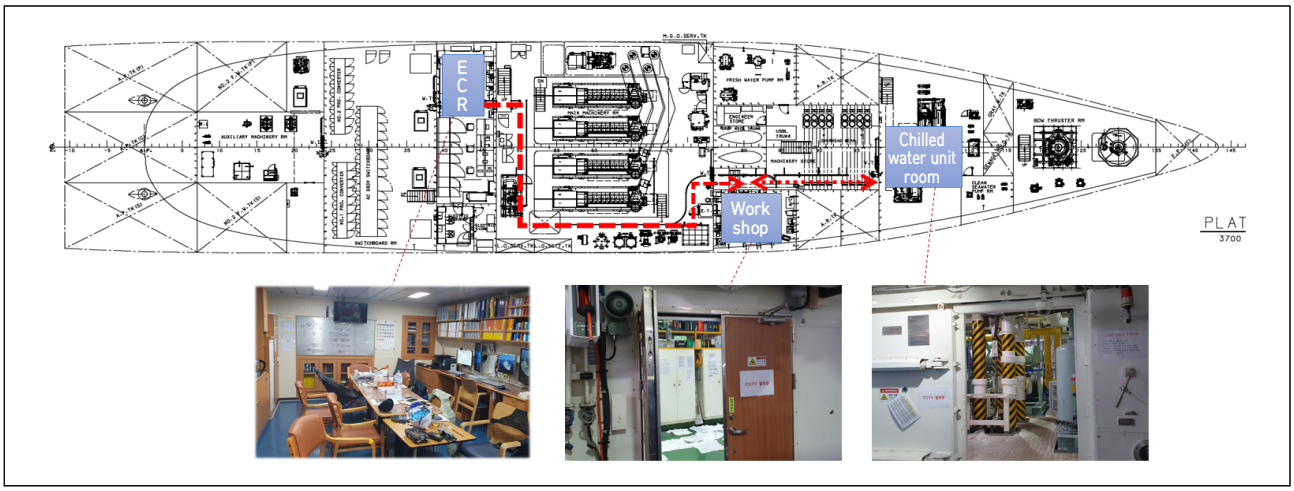
3.1.3 From 13:00 to 13:50 on the same day, the 1/E convened an afternoon TBM[8] in the ECR, and the chief electrician was also in attendance. During the TBM, the chief electrician spoke with the 1/E about a little leak in the converter. Apart from that, the two did not mention which work was to be carried out in the afternoon. After the TBM, the Engine Department members, including the chief electrician, went back to their positions.

7) KIOST, "Shipbuilding of Isabu," White Paper (2017), 127

8) The Engine Department holds TBMs at 8:00-9:00 in the morning and 13:00-14:00 in the afternoon.

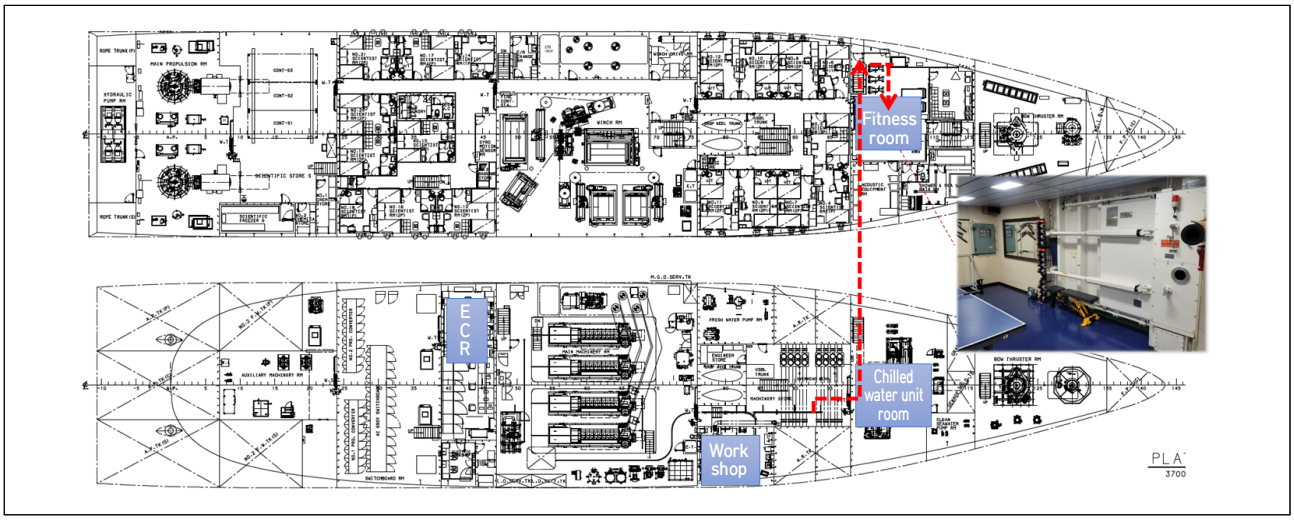
3.1.4 At 14:00, the chief electrician went to the workshop on the platform of the same level, took an electric screwdriver, some wrenches, cloths, and other items needed for the work and put them into a steel bucket.

3.1.5 From 14:10 to 14:15, she was standing in front of the chilled water unit room on the way to the workshop. Watertight Door No. 1 is the entrance of the room, which was always open.



<Figure 5> Route taken by the chief electrician (ECR → Workshop ↔ Chilled water unit room)

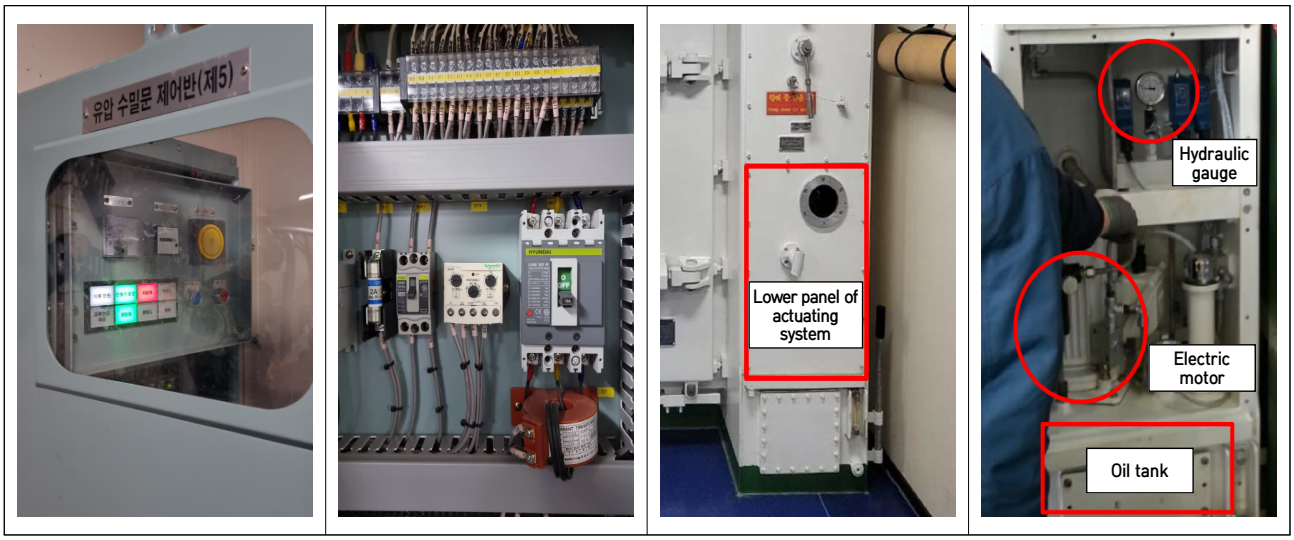
3.1.6 At 14:15, the chief electrician walked up the stairs inside the chilled water unit room and went to the fitness room. The fitness room has Watertight Door No. 5 with an actuating system attached on the right side.



<Figure 6> Route taken by the chief electrician (Chilled water unit room → Fitness room)

3.1.7 From 14:15 to 15:05, the chief electrician stayed at the fitness room.[9] She opened the cover of the power switchboard installed on the wall and checked its condition. The switchboard was closed with the power off. There are two power switches inside: one is a 440-volt power switch that operates the watertight door's hydraulic system; and the other one is a 24-volt emergency power switch for ringing an alarm and displaying a control console.

3.1.8 Then, she opened the lower panel of the actuating system where the watertight door's control lever was installed, checked the hydraulic gauges, electric motors, and other equipment, and cleaned the inside with cleaning cloths. While doing so, the watertight door remained closed.[10]

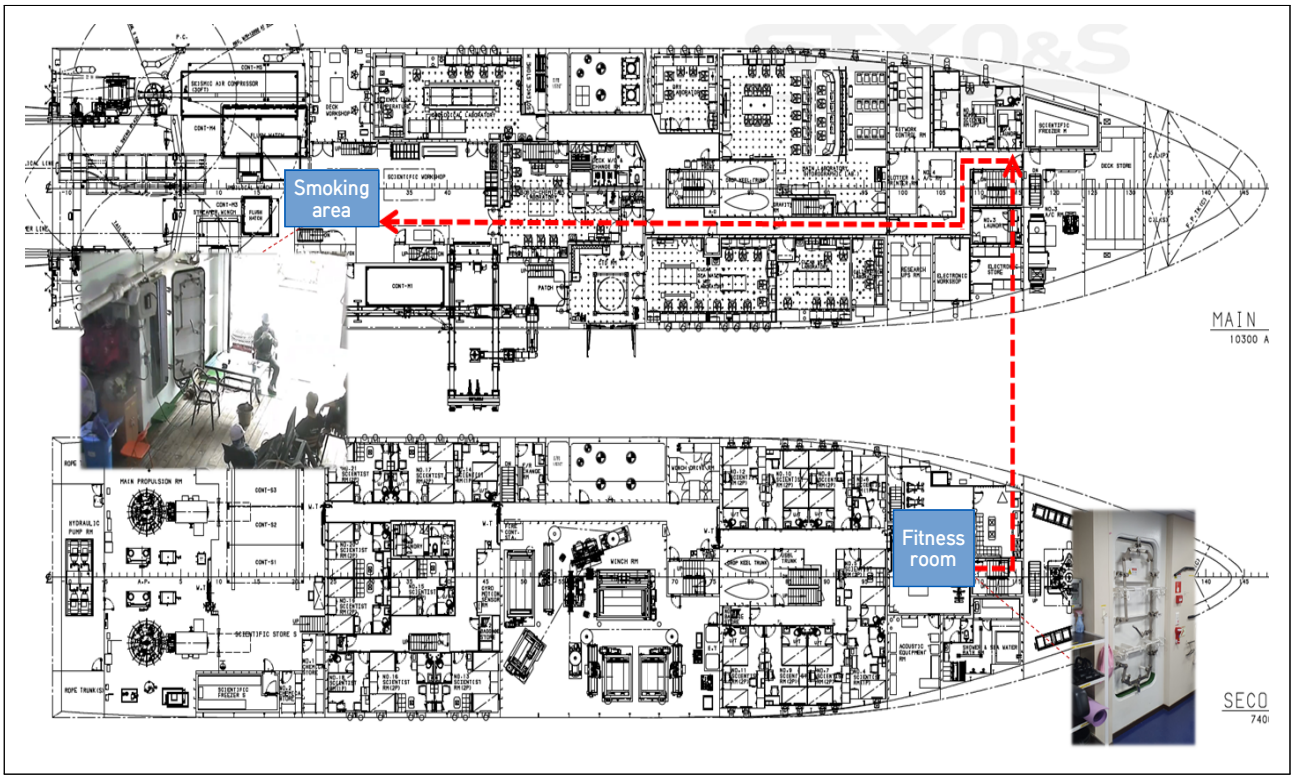


<Figure 7> Power switchboard, switchboard interior, lower panel of the actuating system, and inside the panel (from left)

3.1.9 At 15:05, the chief electrician stopped cleaning for a while, opened the front door of the fitness room, walked up one flight of stairs, and went to the smoking area in front of the deck workshop at the stern of the main deck. The smoking area was an open space with tables and chairs where she could see A-frame cranes at the stern of the main deck.

9) It is based on the statement given by one of her crewmates who started exercising in the fitness room at 14:20 and stayed there for 30 to 40 minutes. While doing so, he stated that, the chief electrician had been there.

10) It is based on the statement given by a crewmember who was in the fitness room at that time.



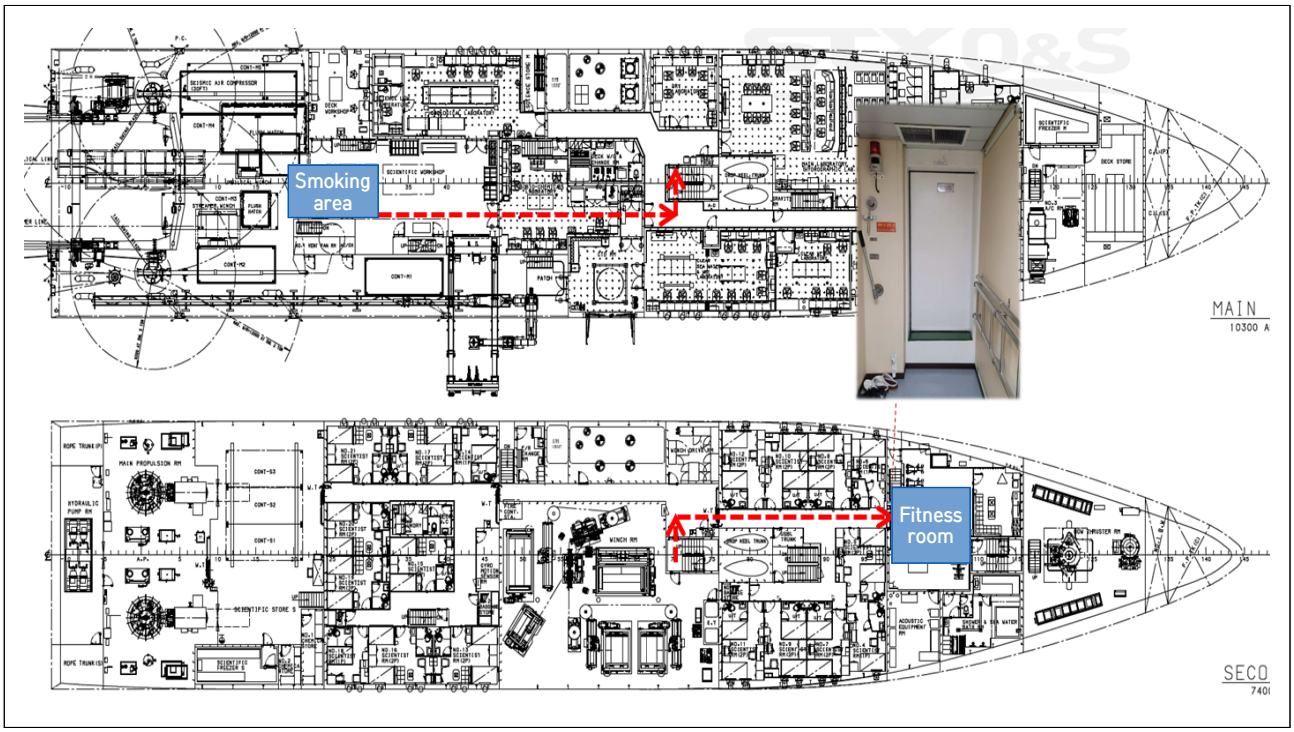
<Figure 8> Route taken by the chief electrician (Fitness room → Smoking area)

3.1.10 From 15:08 to 15:12[11], the chief electrician took a smoke break in the smoking area. She joined four or five crewmates there, smoking and chatting amongst themselves.

3.1.11 At 15:13, the chief electrician left the smoking area and returned to the accommodation area. On her way back, she did not take the same route as the one she took when she first went to the fitness room. Rather, she went down to the second deck along the stairs in the middle of the accommodation area on the main deck.

3.1.12 At 15:15 when coming down to the second deck, she walked along the corridor where the cabins for researchers and crew are located and arrived at Watertight Door No. 5. At that time, the door was kept closed.

11) It is the time shown in the film recorded by the shipboard CCTV in the smoking area, showing how long the chief electrician stayed.



<Figure 9> Route taken by the chief electrician (Smoking area → Fitness room)

3.2 Reconstructing the situation

3.2.1 The chief electrician tried to open Watertight Door No. 5. It is uncertain why she tried to open the door which is normally closed. Since she was maintaining the watertight door, she probably intended to check the door's condition, or to simply save time to go back to the fitness room from the smoking area. When the door was closed, a stopper was always put into the hole of its control lever in the corridor.

3.2.2 At 15:15, the chief electrician took out the inserted stopper from the lever and opened the watertight door by turning the lever to the right. Since power switchboards of all watertight doors were turned off[12] at that time, the door was powered by the accumulator's residual hydraulic pressure. While opening the door, the chief electrician was holding the control lever in the Open position.[13]

12) Driving power of 440 volts and emergency power of 24 volts

13) If she had released the control lever, the watertight door would have closed. That is because the solenoid valve and the limit switch which control the door's opening and closing do not work without power, returning the watertight door to the Close direction as designed in the basic circuit. The solenoid valve, the limit switch, and alarms of the actuating system are connected to the 24-volt emergency power of the vessel.

<Figure 10> Stopper in (left) and stopper out (right)

3.2.3 Watertight Door No. 5 is equipped with an alarm connected to the emergency power. When the door works, the alarm gives off an audible/visual signal. However, since all power switchboards were turned off, the watertight door was opened without sending any signal. The chief electrician checked that the door was being opened, which took less than 20 seconds.[14)]

3.2.4 When it was opened, she intended to pass through the door to go to the fitness room. At the same time, she tried to close the door and put the stopper into the control lever.

3.2.5 While standing in the middle of the watertight door frame, she pushed the corridor-side control lever with her left hand in the Close direction. The residual hydraulic pressure then caused the door to return to the Close direction. The chief electrician tried to put the stopper into the control lever while the door was closing.

3.2.6 It is not certain how she inserted the stopper into the lever at that time. However, the following can be assumed, given the operability of the lever. First, she would have tried what is believed to be the common way of doing it. As described in the paragraph 3.2.5, she is assumed to have operated the corridor-side lever with her left hand and inserted the stopper with her right hand by turning her body to the side. Second, she would have operated the lever near the fitness room with her right hand in the Close direction and put the corridor-side stopper with her left hand, which

14) The figure is based on the speed measured during the on-site investigation on 10 August 2022. When measured, it took about 17 seconds.

seems possible since both sides have control levers and they are interoperable. Last, she would have used her left hand to hold and insert the stopper as well as operate the lever. However, no matter what she did, it took time for her to put in the stopper.

3.2.7 At a moment when the chief electrician inserted the stopper into the lever, the watertight door pressed down on her powerfully from behind. The force of closing the door would have been weaker than the set pressure of 180kg/cm2 as it was a second force applied by the residual hydraulic pressure. Still, it was strong enough to trap a person in the door.

3.2.8 It takes about 25 seconds for a watertight door to reclose.[15] In fact, however, the time needed by the closing door to trap her was likely to have been much shorter than 25 seconds, given the space occupied by the chief electrician who was standing and the remaining width of the watertight door.

3.2.9 Getting caught in the door frame put the chief electrician at a loss, and she failed to react swiftly enough to escape. If she had removed the stopper again and pulled the control lever toward herself at that moment, she could have reopened the door and escaped the danger. However, it is assumed that she would have not been able to take such action to escape under such an urgent and awkward situation.[16]

3.2.10 In the end, the continuous pressure prevented the chief electrician from getting out, and she became trapped in the watertight door. The accident occurred between 15:15 and 15:30.[17]

15) The figure is based on the speed measured during the on-site investigation conducted on 10 August 2022 after the accident occurred. Given the fact that Watertight Door No. 5 is 80 cm wide, it amounts to a speed of 2.85 cm/sec. If the chief electrician had tried to pass through the door when the door was half opened, the door would have closed faster, pressing her forcefully.

16) The distance between two control levers of the watertight door is 91.6 cm. If someone stands in the middle of the watertight door, the levers are within the reach of the hands. If the stopper had not been inserted, she would have been able to operate the levers on either side immediately.

17) Investigators looked into the records of the opening and closing time of the watertight door and its operation condition filmed by the voyage data recorder (VDR) to ascertain the door's condition before and after the accident and the estimated time of occurrence. However, an error in the operational data prevented any conclusion from being reached. The error, caused by the disconnected common line of the central control console of the watertight door, was identified in the investigation process and corrected.

3.3 Discovering the accident

3.3.1 At 15:30 on the same day, the C/E[18] of Isabu came down from his cabin to the corridor on the second deck along the stairs at the center, and from there, he moved to the engine room entrance. He was the first person to come across the chief electrician trapped between the watertight door and its frame at the entrance of the fitness room while looking towards the bow area.

3.3.2 When the chief electrician was first discovered, she was facing the corridor of the accommodation area while standing pressed against the closing watertight door with each of her feet on a different floor: her right foot was in the fitness room; and the left one was in the corridor. Her body did not move.

<Figure 11> Positions of the first person on the scene and the watertight door (left); from the onlooker's view (middle); and reconstructing the victim's posture (right)

3.3.3 The C/E who had first discovered the situation immediately reported it to the ECR, and the second engineer (2/E) in the room went to the fitness room along with the No. 1 oiler and two oilers. Again, the C/E went to the captain's cabin and reported the accident to the master. The master then rushed to the scene with the C/O.

3.3.4 When the victim was first discovered, the power switchboard of individual watertight doors in the fitness room was turned off and its cover opened. The lower cover of the actuating system of the watertight door was also open and placed on the floor, and before the actuating system, there was a steel bucket with tools inside.

18) The C/E did not attend the afternoon TBM on that day. Instead, he had a separate meeting with the master and the chief officer (C/O).

3.4 Rescue operations

3.4.1 Having arrived at the fitness room, the 2/E switched the watertight door's control lever to the Open direction but to no avail because the other lever in the corridor was set by the stopper in the Close direction.

3.4.2 The 1/E, who came to the fitness room at that moment, went to the corridor on the opposite side of the room, shouting, "It's manual! Manual!" He removed the stopper from the control lever in the Close direction and switched it to the Open direction. The door then opened, and the chief electrician caught in the doorway slumped toward the fitness room.

3.4.3 The crewmembers laid the fallen chief electrician on the floor and checked her condition. She stopped breathing and had no pulse. As ordered by the master, the second officer (2/O) reported her condition to the Maritime EMS Center at Pusan National University Hospital and asked about medical assistance. In response, he was told, "If she stops breathing and has no pulse, she is dead." Therefore, he confirmed that the chief electrician had no breathing and pulse by checking her vital signs multiple times with a blood pressure gauge.

3.4.4 At 15:43 on the same day, the master of Isabu reported the accident to the head of the vessel management section, who was an on-shore manager, by radio[19] and retrieved CTD (conductivity, temperature, and depth) devices being used at sea. Then, at 16:00, the vessel departed toward Mauritius. At 17:40 on the same day, the master informed the crew that the chief electrician had died.

3.5 Damage

3.5.1 The chief electrician of Isabu died from this accident. To take care of the victim, the vessel arrived at Port Louis in Mauritius at 21:00 on 9 July 2022, and the local police agency and doctors eventually pronounced the chief electrician had died from a shock due to multiple injuries.

19) The investigation report (HI-22-080) that the master of Isabu sent to the KIOST stated that "the accident is thought to have occurred at 13:50 (LT) when the chief electrician came out of the ECR and was checking a fuel leak in the hydraulic sliding watertight door. Since she was alone inspecting the door at that time, it is uncertain exactly when and how the accident took place."

section

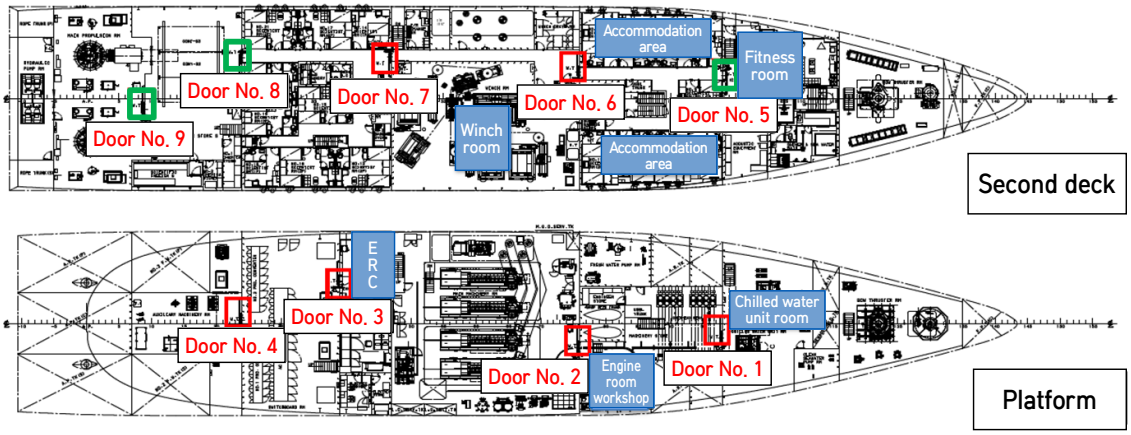
4 Analysis

4. Analysis

4.1 Operation and management of watertight doors

4.1.1 According to the vessel, Isabu, three of the vessel's nine watertight doors were normally kept closed while the other six remained open. The closed doors were Watertight Door Nos. 8 and 9 on the way to the machinery space on the second deck and Watertight Door No. 5 at the fitness room on the bow, where the accident occurred. The four doors on the platform and the two on the second deck were always open.

4.1.2 In addition, individual power switchboards connected to the watertight doors were all turned off, except those for Watertight Door Nos. 8 and 9. The following shows the ordinary condition of opening and closure and power supply of the Isabu watertight doors.



Door No.	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9
Open / Closed	Open	Open	Open	Open	Closed	Open	Open	Closed	Closed
Power	Off	Off	Off	Off	Off	Off	Off	On	On

<Figure 12> Ordinary condition of watertight doors

4.1.3 A watertight door shall always be kept closed under the regulation II-1/22.1 of the International Convention for the Safety of Life at Sea (SOLAS). SOLAS regulation II-1/22.3 also stipulates that even if it is opened to permit passage or work, the door must be immediately closed when the transit through the door or the work is finished.

4.1.4 A ship's watertight bulkhead is a critical structure which enables the ship to maintain hull safety when facing structural damage and flooding from a collision or grounding. Therefore, the watertight door that controls the opening of the watertight bulkhead should be strictly operated and managed under the relevant regulations. In case of Isabu, however, the opening and closure of the watertight doors were set randomly, and the importance of their operation and management seems to have been neglected.

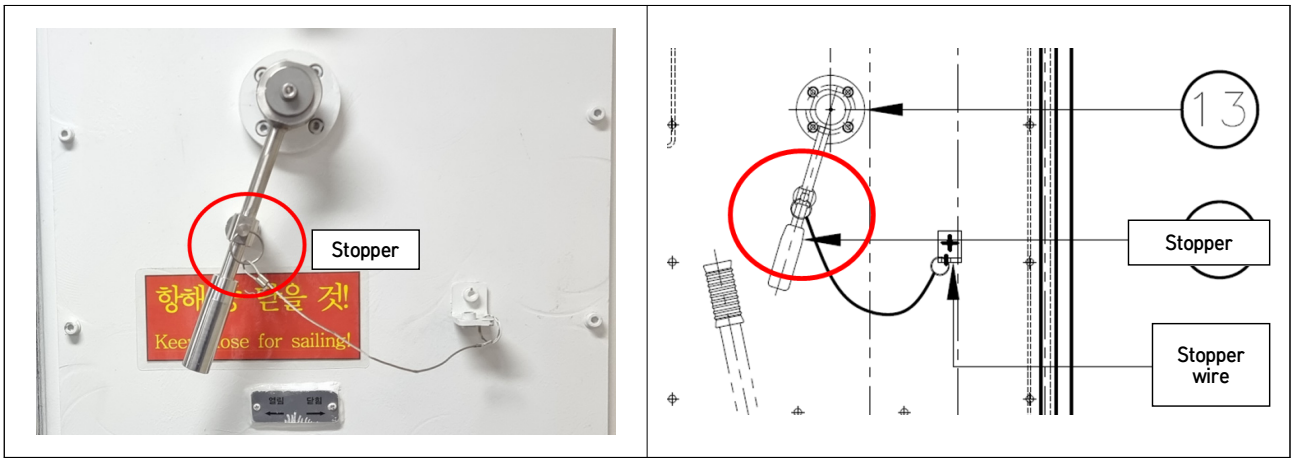
4.1.5 What is worse, the Code of Safety for Special Purpose Ships (SPS Code) was applied to Isabu from the stage of her design and construction[20], and watertight bulkheads and doors were thereby added within the range of satisfying her damage stability requirements. Considering that more rigorous safety design requirements were applied to the vessel, her safety should have been managed in a more sophisticated way. Her watertight doors were judged to have not been managed systematically.

4.2 Stoppers of watertight doors

4.2.1 This accident is assumed to have occurred when the chief electrician re-inserted a stopper, which was set in the Close direction of the door control lever in the corridor. Therefore, understanding the usage of this stopper is key for analyzing the cause of this accident.

4.2.2 First, the watertight doors of Isabu have a stopper which fixes control levers in the Open direction. The stopper was manufactured and attached to the watertight door after the door was installed on the vessel. It is located only at the actuating system.

20) The Code of Safety for Special Purpose Ships, 2008 (SPS Code) was applied to Isabu. However, she was not issued the Special Purpose Ship Safety Certificate.



<Figure 13> Stopper in the Open direction (left) and stopper in the diagram (right)

4.2.3 A stopper at the actuating system is installed to set a door control lever and prevent potential malfunction of the watertight door should the door need to remain open for a long time for inspection. When it is opened, its control lever is in neutral, and as long as the lever is not switched to the Close direction, the door remains opened.[21] If the lever is activated due to negligence or malfunction, thereby closing the watertight door, an accident is likely to occur. That is why a stopper was installed so that a watertight door can remain opened while work is being carried out.

4.2.4 However, if a watertight door is set open by a stopper, it cannot be remotely closed from the bridge in an emergency. Therefore, while the watertight door under maintenance is open and set with a stopper, communication must be maintained between the bridge, where the central control console of the watertight door is located, and the work site until the job is finished. At the same time the door must be managed in accordance with the company's safe working practices.

4.2.5 Meanwhile, the control lever of Watertight Door No. 5 in the corridor where the accident occurred also has a stopper to set the lever in the Close direction. This stopper was independently manufactured and set up by the vessel. It is installed only on Watertight Door No. 5.[22]

21) That is because oil pressure continuously supports power, and the watertight door is designed to maintain its condition even if the door's own weight is added.

22) The stopper of Watertight Door No. 5 in the corridor was installed around 2017 after Isabu had been delivered (in May 2016).

4.2.6 According to Isabu, Watertight Door No. 5 adjacent to the accommodation area was kept closed and its control lever in the corridor was fixed with the stopper due to noise from the fitness room. And, as researchers, who were not familiar with operating watertight doors, were mostly staying there, the door was kept closed, except special occasions such as classification surveys, to prevent accidents. Also, the power switchboards of the watertight doors were all turned off, meaning that Door No. 5 was normally closed, or practically sealed off.

<Figure 14> Closed control lever in the corridor (left) and opened lever (right)

4.2.7 A watertight door has a hand-operated mechanism that allows it to be opened and closed manually from any positions under SOLAS regulation II-1/13.7.1.4. There are control levers on both sides of the door, moving interconnectedly. Thus, if a control lever on one side is fixed with a stopper while the door is closed, the door cannot be opened from the opposite side, hampering normal operation of the control levers.

4.2.8 It has also been determined that the Isabu crew did not clearly understand the stopper of Watertight Door No. 5. They believed that it was a safety pin which must be inserted so that the control lever could not move.[23] The injured chief electrician probably also regarded it as a safety pin that should remain inserted, just as her crewmates did.

4.2.9 The watertight door's control lever is operated in a simple opening and closing movement of the door, as prescribed in SOLAS regulation II-1/13.7.4. However, the stopper apparently forced the chief electrician to put the stopper into the hole of the control lever in addition to her manipulating the lever, which would have delayed the whole process.

23) Discovered during interviews with the crew by the related agency after the accident.

4.2.10 Meanwhile, the victim is believed to have intended to pass through the door rather than check it[24]. Had there been no stopper, she would have simply opened the watertight door, and passed through, and closed it with its lever on the side of the fitness room. However, her misperception that she should insert the stopper as it was seems to have prevented her from passing through the door and increased the likelihood of an accident. In other words, together with her plan to pass through the watertight door, her belief that she had to insert the stopper is likely to have led to this accident.

4.2.11 It is hard to deny that this accident was caused by the chief electrician who had made the wrong decision while passing through the moving watertight door. However, the stopper randomly installed in Watertight Door No. 5 is also considered a potential risk factor as presented her with the extra task of inserting it into the hole of the control lever.

4.3 Inspection and maintenance of watertight doors

4.3.1 SOLAS regulation II-1/21 and Article 30 of the Standard for Ship Compartment prescribe that watertight doors shall be periodically operated and inspected, which includes a weekly drill on watertight door operation and a once-in-a-week inspection. The user manual given by the watertight door manufacturer also requires weekly inspections for operating the doors' levers and hand pumps to check whether they function normally.

4.3.2 However, such inspections and the related issues are not prescribed in the Operational Instructions for the Research Ship and Passengers[25] (hereinafter as "the Operational Instructions") of Isabu, owned by the KIOST, and the operational inspections were not carried out, either.

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24) If the chief electrician had intended to simply check the operational condition of the watertight door, she would have finished opening and closing the door on the corridor side without passing through the door, put the stopper in the lever to set the door as it was, and moved to the fitness room through the upper or lower floor. Given the context, such assumption seems reasonable.

25) Article 1 (Purpose) of the Operational Instructions of Isabu prescribes that "The Operational Instructions aim to set detail rules needed for operating marine research ships owned by the KIOST and personnel on board under the Regulation for Operation and Management of Research Ships and the Rules for Research Ship Crew." And, Article 2 (Scope of Application) stipulates that "The Operational Instructions are applied to operation of research ships and personnel on board, unless otherwise specified." Given these two articles, the Operational Instructions of Isabu are regarded as legally binding internal rules for operating research ships and personnel who serve aboard.

4.3.3 Also, it is hard to clearly identify who is in charge of maintaining watertight doors of Isabu according to the job descriptions. In the Operational Instructions, the chief electrician has six duties, including "maintaining onboard power and electric system facilities," except those of watertight doors. The following illustrates duties of the chief electrician as prescribed in the Operational Instructions.

⑨ As an officer of the Engine Department, the chief electrician is in charge of the following tasks while aiding the C/E:

1. maintaining onboard power and electric system facilities;
2. recording task performance and keeping the history of defects of the assigned facilities;
3. maintaining the main engine's electric power generation system;
4. maintaining electric parts of the azimuth thruster and bow thruster;
5. maintaining power switchboards, power distribution panels, power transformers, and emergency power; and
6. other jobs ordered specifically by the C/E

< Duties of the chief electrician in the Operational Instructions >

4.3.4 In addition, the KIOST mentioned that as Isabu was using an electric propulsion system, the main task of the chief electrician was to manage the vessel's propulsion, which, however, was defined as the duty of the 1/E in the Operational Instructions. In general, some of the tasks mentioned in the job descriptions are not clearly identical to the actual duties.[26)]

4.3.5 The Engine Department has a job description list that was written independently and separately from the vessel's Operational Instructions. The list showed that crewmembers were assigned to maintain different equipment and facilities by rank, and the chief electrician was in charge of the watertight doors.

26) The main propulsion machinery of Isabu consists of mechanical parts, including the main generator engine, shafting systems, and a propeller; and electric parts, including a propulsion motor, an alternator, a converter, AIS, and power management system (KIOST, "Shipbuilding of Isabu," White Paper (2017), 218). In fact, it can be said that the mechanical parts are managed by the 1/E while the electric parts by the chief electrician when managing Isabu's propulsion system. Still, such practices are not written in the Operational Instructions.

4.3.6 Apart from that, as ordered by the vessel's navigation team, the crew were inspecting the hull; equipment of decks and engine; fire extinguishing equipment and lifesaving appliances; and navigation and radio equipment twice a month, completing the "Safety Inspection Checklist," and sending it to the head of the team. Watertight doors, which are supposed to receive a regular operation inspection, were missing on the inspection list.

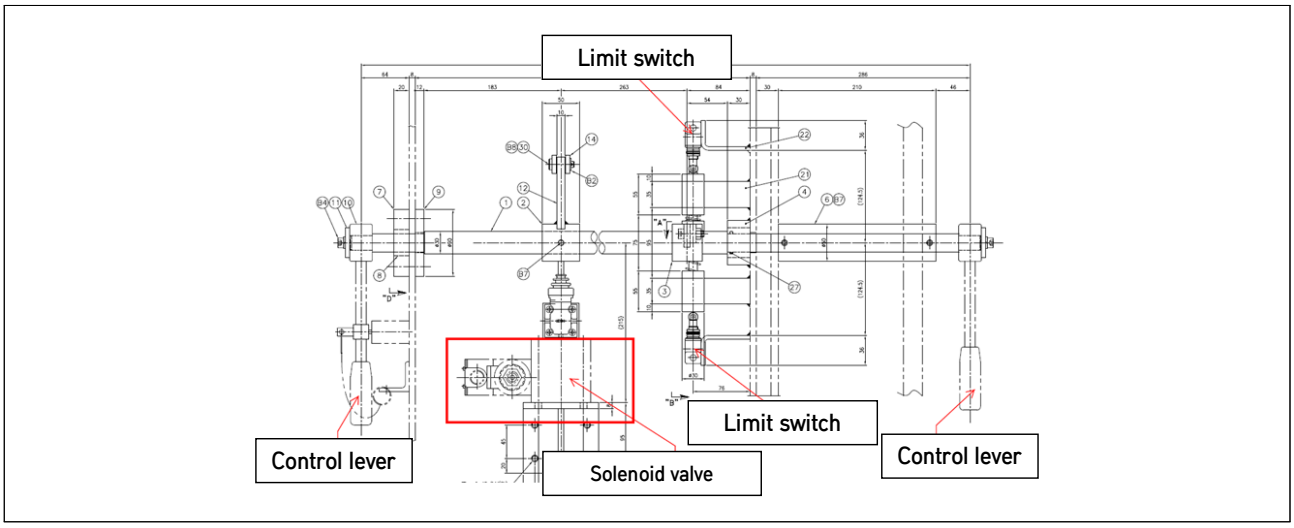
4.3.7 In this regard, crewmembers stated they inspect watertight doors visually when patrolling their designated areas. It is true that they can visually check the amount of oil and its leakage through the sight glass attached on the lower panel of the actuating system. However, since seven out of the nine watertight doors were normally turned off and a hydraulic pump was also idle, such visual inspection to check a proper hydraulic condition is considered less effective.

4.3.8 Given the discrepancies with the vessel's job descriptions for watertight doors and such an unclear inspection system, it seems hard to conclude that the watertight doors were inspected regularly and effectively.

4.3.9 Meanwhile, it was found out that Watertight Door No. 5 did not operate normally during the investigation. In principle, when a person moves a watertight door's control lever to the Open or Close direction, a limit switch sends out opening or closing signals to a solenoid valve. Then, the valve operates hydraulic lines to open or close the door. However, the on-site investigation identified that if a person had switched its control lever to the Open direction while the watertight door had been closing, the door would reopen. And, when the lever was in neutral, the door would reclose.

4.3.10 When asked, the manufacturer confirmed that there could be the case where a control lever failed to send opening or closing signals due to the defected solenoid valve or limit switch in the actuating system, requiring the lever to be repaired.[27)]

27) The manufacturer said that parts can be supplied and directly replaced on board.



<Figure 15> Solenoid valve and limit switch in the diagram

4.3.11 This accident occurred when the switched-off watertight door was being closed by the residual oil pressure, meaning that the defect of the power-driven parts are less likely to have caused this accident. However, such a defect may affect smooth operation of the door. Thus, it seems appropriate for the vessel to conduct regular operation inspections and, if necessary, to carry out maintenance or repair so that watertight doors are kept in normal condition.

4.4 Safety instructions for operating and working at watertight doors

4.4.1 Article 21 of the Operational Instructions of Isabu prescribed safe working standards. The standards require the vessel to assign two or more persons to the work; secure appropriate communication devices between the bridge and the assigned workers; and take safety measures prior to the assignment when working at a dangerous place, such as decks, the engine room, or stores. Also, the standards state that, if possible, two or more persons should work together to prevent any accidents during the operation.

4.4.2 The weekly inspection plan the chief electrician pre-submitted to the 1/E includes the "inspection of hydraulic sliding watertight doors." Also, given how the chief electrician opened the lower panel of the actuating system and operated the watertight door which required extra attention to its operation, it is considered

appropriate that, instead of one person, two or more persons should have been assigned to the work site to ensure safety precautions were taken while working together. However, such operation was not discussed during the TBM held that afternoon. Based on that, the chief electrician seems to have checked the watertight door voluntarily without reporting it separately on that day, and that is considered the reason she was unable to go over whether the safety measures had been taken prior to the work.

4.4.3 Meanwhile, the regulations[28] related to watertight doors set by the International Maritime Organization (IMO) state that the Operational Instructions of ships should cover "procedures for operating watertight doors to permit safe passage."[29] The procedures mentioned here are to permit safe transit of passengers. However, considering that Isabu's watertight doors were installed under the rules for passenger ships and that the vessel had many researchers on board in addition to the crew,[30] it seems necessary to consider applying the procedures to Isabu.

4.4.4 Isabu has the "user manual for hydraulic sliding watertight doors" provided by the watertight door manufacturer, and there are the "operation and safety procedures for watertight bulkheads and doors" attached at each watertight door. However, the manual and the procedures were only about how to operate watertight doors, not about precautions for safe transit. Also, neither the Regulation for Operation and Management of Research Ships of the KIOST, which applies to Isabu, nor the vessel's Operational Instructions include procedures for operating watertight doors.

4.4.5 Isabu has a total of nine watertight doors variously positioned, including on the second deck where the accommodation space for the crew and researchers is located. Still, there were no procedures set for safe passage through the watertight doors.

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28) MSC1/Circ.1564 "Revised Guidance for Watertight Doors on Passenger Ships Which may be Opened During Navigation"

29) MSC1/Circ.1564 – 9.1.3. the operational instructions should cover procedures for operating watertight doors to permit safe passage of passengers, in particular, that watertight doors should only be operated by qualified persons and not by passengers.

30) The Ship Survey Certificate of Isabu defined the maximum number of special personnel as 35 persons.

4.4.6 In addition, IMO's watertight door regulations recommend that watertight doors should be operated by qualified persons.[31] Since there is no one designated for operating the doors of Isabu, it seems necessary to consider revising the Operational Instructions to manage watertight doors better and safely.

4.5 Drills for closing watertight doors and safety education

4.5.1 In accordance with Article 19 (Safety responsibility) of the Operational Instructions of Isabu, the overall responsibility for onboard safety falls onto the master. And, safe working and safety education, and safe working within the engine room and tasks related to fire extinguishing equipment are delegated to the C/O and the 1/E, respectively.

4.5.2 Article 22 (Safety education) of the Operational Instructions requires the master to conduct legally mandated safety education and emergency drills at least once in a month to ensure safe working practices are thoroughly implemented. Also, the master should hold safety education needed for onboard operation for non-crew passengers.

4.5.3 The vessel, Isabu, conducted monthly training sessions, pursuant to the Operational Instructions. In 2022, the year of the accident, the vessel had held drills on firefighting, ship abandonment, enclosed spaces, oil pollution prevention, and propulsion malfunction before the accident occurred. And it was documented that drills on collisions and groundings, related to operation of watertight doors, were also conducted twice.

4.5.4 Meanwhile, the "Table of Emergency Duties and Posts in case of Maritime Accidents" in Form No. 1, attached to the Isabu Operational Instructions, shows that the master should close the watertight doors from the bridge when a collision occurs. However, the master did not meet such requirements as per the Operational Instructions, including assuming a specific scenario, for instance, a collision or a flooding, and

31) MSC1/Circ.1564 - 9.1.3

closing the watertight doors from the bridge, during the drills onboard Isabu. Instead, the master set a random situation. And, given the fact that most power switchboards of the watertight doors were usually turned off, it is considered the vessel lacked systematic management and drills for watertight doors, and drills for the crew were insufficient.

4.5.5 When it comes to safety education for watertight doors, the KIOST stated that the vessel's hydraulic sliding watertight doors were opened for emergency steering drills so that the crew could learn how to operate the doors as well as precautions when they enter into the steering gear room.[32] However, instead of learning how to operate the watertight doors, the emergency steering drills are originally intended to train the crew to arrive at the steering gear room in time and directly operate the gear on site in an emergency caused by rudder malfunction. Also, some of training being conducted during the drills are limited to some of crewmembers assigned to the steering gear room, thus considered less effective for those who should have received safety education on the watertight doors.

4.5.6 According to the vessel, no training was conducted specifically on the watertight doors outside of telling the crew not to carelessly touch the equipment related to the doors. Considering that, although the crewmembers are usually aware that operating watertight doors poses the risk of an accident, they seem not to receive separate safety education for watertight doors, such as safe operation and precautions.

4.5.7 If a person passes through a watertight door, once the door is fully opened, he/she should hold the door's control levers on both sides in the Open direction and pass through the door. Also, the crewmembers should be aware that they could lose their lives if trapped by a watertight door, as the doors are set to close continuously under a strong force.[33]

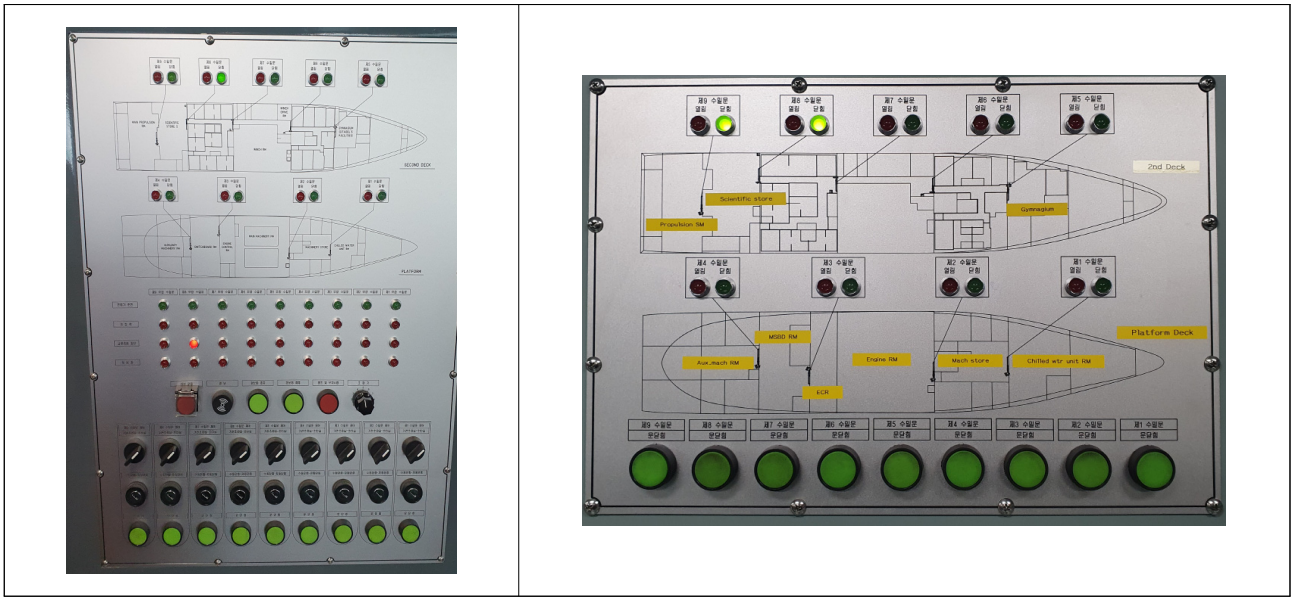
32) This is an answer on emergency drills and training given by the KIOST. In 2022, the emergency steering drills had been conducted in March and June before the accident occurred.

33) Gard, DNV-GL. 2017. https://www.gard.no/Content/22786693/Watertight

4.5.8 In this case, one crewmember who had not complied with such basic safety procedures made a misjudgment, leading to the accident. Given this fact, Isabu should teach the crew how to operate the vessel's watertight doors, their features, and precautions during the onboard safety education and make proactive efforts to prevent accidents.

4.6 Operation control of watertight doors

4.6.1 The watertight doors of Isabu are operated at three locations. They can be remotely controlled from both the bridge and the ECR while being locally controlled at each door.

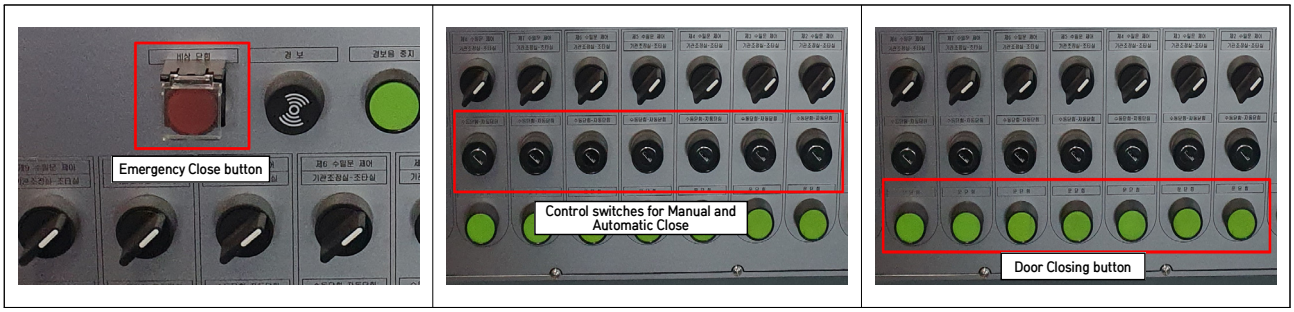


<Figure 16> Remote control console of the bridge (left) and ECR (right)

4.6.2 The remote operating system of the bridge and the ECR can only close the doors. The doors can be closed from the bridge in the following three ways: First, if a person pushes the red Emergency Close button with a cover attached on the console, all the watertight doors will close at once. Second, if a person sets the key switch[34] for each watertight door on an Automatic Close mode, the doors will close individually. Third, when a person pushes the green Door Closing button for an individual door, it will close. However, the ECR has only a green Door Closing button.

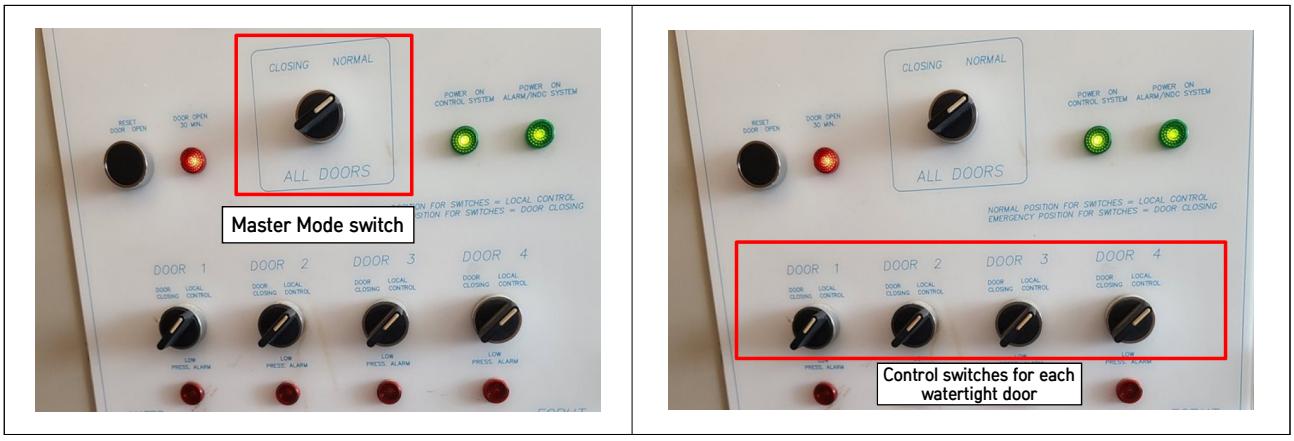
34) Users can choose between the two modes, Manual Close or Automatic Close. The key switch is usually placed on the Manual Close mode.

4.6.3 Under SOLAS regulation II-1/13.8.1, the central control console at the navigation bridge shall have a Master Mode switch with two modes of control, a Local Control mode and a Doors Closed mode. However, the control console of Isabu has slightly different terms and functions: its red button is labelled Emergency Close instead of Doors Closed, and the Manual Close mode of individual doors means a Local Control mode.



<Figure 17> Emergency Close button (left); Automatic Close switch (middle); and Door Closing button (right)

4.6.4 Another research vessel of the KIOST, "Onnuri," has the Master Mode switch with Control switches for each watertight door below it on the central control console at the bridge, showing that the console has different functions and arrangement from that of Isabu.



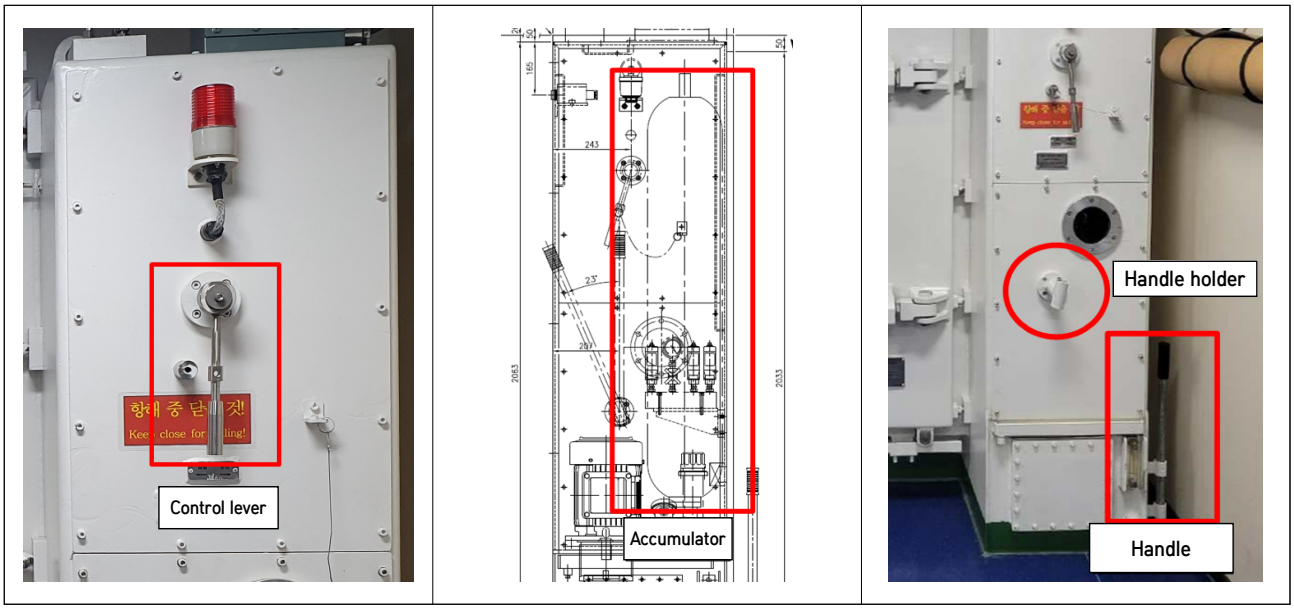
<Figure 18> Control console for watertight doors onboard Onnuri

4.6.5 It seems that the various functions of the control console on Isabu are likely to confuse the crew when they fail to understand their differences and functions. Therefore, it is considered important to provide sufficient training for the crew and

help them to practice operating the watertight doors so that they can clearly understand the functions of the console and use it without trouble in case of an emergency.

4.6.6 Also, as pursuant to SOLAS regulation II-1/13.6, the remote operating positions shall only be "at the navigation bridge and above the bulkhead deck." However, Isabu is designed to allow the watertight doors to be closed at the ECR, and this demands attention as it leaves a possibility that the vessel's watertight doors can be operated differently.[35)]

4.6.7 Meanwhile, the watertight doors onboard Isabu may be operated locally, at each door itself, in one of three ways: First, a person can use a control lever by running the hydraulic pumps; second, when the power is off, the door can be operated by the residual pressure of the accumulator; and third, if the oil pressure is not sufficient to operate the door, a person can use a handle for emergency operation to manually operate it.



<Figure 19> Control lever (left); accumulator in the diagram (middle); and hand pump handle (right)

35) The Operational Instructions of Isabu described closing the watertight doors as the master's duty, which should be done at the bridge.

4.6.8 On Isabu, the watertight doors can be on a Local Control mode if the key switch of the control console on the bridge is placed on a Manual Close mode. All switches of the nine watertight doors onboard Isabu are usually set on Local Control, which means a Manual Close mode. Even if they are on a Local Control mode, if anyone pushes the green Door Closing button at the bottom of the console on the bridge, the door would be closed just like they are on Remote Control. In that case, it is hard to say whether the Local Control mode is clearly defined and differentiated from the Remote Control mode, requiring the crew to pay extra attention when controlling and operating the watertight doors.

4.7 Opening and closing speed of watertight doors

4.7.1 SOLAS regulation II-1/13.7.1.7 and Article 18.8 of the Standard for Ship Compartment prescribe that the closure time of the watertight door shall never be less than 20 seconds or more than 40 seconds with the ship in the upright position. The classification survey Isabu received after having been equipped with watertight doors showed that all were opened and closed within the required time frame, and the accumulator was also operated three times, as stipulated in SOLAS regulation II-1/13.7.3.

2. OPERATING SPEED TEST (S=Second)

INSP' ITEM \ DOOR NO.	1	2	3	4	5	6	7	8	9	SPEC
DIRECTION V/V Open direction	21.77	22.87	26.02	23.47	21.5	27.89	23	20.49	21.54	20 ~ 40 Sec.
DIRECTION V/V Close direction	26.3	23.66	21.17	23.8	22.53	24.8	25.27	23.67	22.93	20 ~ 40 Sec.
ACCUMULATOR Closed→Open→Closed	ACCEP TED	ACCEP TED	ACCEP TED	ACCEP TED	ACCEP TED	ACCEP TED	ACCEP TED	ACCEP TED	ACCEP TED	
Local hand pump open	48.19	51.76	35.08	46.97	43..82	47.28	60.2	58.48	57.83	max. 90 Sec.

<Figure 20> Isabu's watertight door survey report (6 Nov. 2014)

4.7.2 However, the on-site investigation conducted after the accident showed that it took about 17 seconds when the vessel's watertight door was first operated by the residual oil pressure. Likewise, it was identified that the closing speed was much

faster than the required speed range when the watertight door was operated by the residual pressure, compared to the case when being closed by electric power.

4.7.3 It is necessary for the crew to fully understand the opening and closing speed of the onboard watertight doors and their operation features in their ordinary duties. Also, as seen in the on-site investigation, the crew should be aware that the doors' opening and closing speeds vary depending on individual conditions. And, regular operation tests are needed to help the crew to check the doors' operation speed so that they can adjust it before operating the doors when the doors close much faster than the required rate.[36)]

36) The opening and closing speed of the watertight door can be controlled by opening the upper cover of the actuating system and operating the flow control valve inside.

section

5 Conclusions

5. Conclusions

5.1 A fatal accident occurred on board Isabu where the chief electrician who was inspecting a watertight door died from being trapped by it. When it occurred, the watertight door was moving as she was trying to open and close it again on her way back to the work site after taking a short break.

5.2 While passing through the moving watertight door, the chief electrician tried to insert a stopper into a control lever at the same time, which however was delayed. It seems that she eventually ended up being trapped by the watertight door, and that high pressure prevented her from escaping the door in time.

5.3 It has been determined that this accident was caused by the chief electrician, who was operating the watertight door as she tried to pass through the moving door without implementing basic safety procedures.

5.4 In this regard, it seems that Isabu needs to achieve the following improvements: operating and managing the watertight doors; regularly inspecting and maintaining the watertight doors; and providing emergency drills and safety education on proper watertight door usage.

section

6 Recommendations

6. Recommendations

6.1 Setting procedures for systematic operation and management of watertight doors

6.1.1 The international conventions stipulate that a watertight door shall always be kept closed, and even if it is opened to permit passage or work, the door must be immediately closed once its use is over.

6.1.2 In case of Isabu, however, among a total of nine watertight doors, only two were in normal operation; six were left open with their power off; and Watertight Door No. 5, where the accident occurred, was kept closed with its power off.

6.1.3 A watertight door is important equipment that helps a ship to maintain buoyancy and safety of the hull by preventing water ingress when the ship faces flooding due to hull damage. Therefore, the door should always remain closed with the exception of watertight doors under maintenance.

6.1.4 However, as in the case of Isabu, if a majority of watertight doors are always kept open with their switchboards turned off and not ready for immediate operation, they could not be closed swiftly in the event of flooding, resulting in significant property damage and loss of life, which needs to be changed.

6.1.5 Therefore, the vessel should set up procedures for systematic operation and management of the watertight doors and reflect them in the Operational Instructions to keep the doors safe. In addition, the vessel needs to consider designating a person as the responsible officer for operating the watertight doors and working together on procedures for safe passage through the watertight doors[37].

6.1.6 Some issues remain to be addressed: For instance, a watertight door cannot be opened from one side due to the stopper randomly installed in its control lever. Therefore, the installed stopper should be removed so that the watertight door can remain in normal operation.

6.2 Developing systems for periodical inspection and maintenance of watertight doors

6.2.1 The watertight doors should be periodically operated and inspected under the regulations. As for Isabu, however, the watertight doors are not included on the list of inspection items in both the vessel's Operational Instructions and the "Safety Inspection Checklist," which is completed twice a month.

6.2.2 Also, the Operational Instructions do not specify a person responsible for maintaining the watertight doors. Instead, the doors are described as being managed by the chief electrician in the Engine Department's internal job description.

6.2.3 Therefore, the vessel needs to consider improving the procedures in the Operational Instructions to set out an effective prevention maintenance program by clarifying periodical maintenance plans and designating officers responsible for maintenance to ensure the watertight doors operate smoothly.

6.2.4 In addition, the vessel should come up with better procedures; for instance, if it is considered dangerous to open and close watertight doors during inspections, the vessel should deploy two or more persons to the position and maintain communications with the bridge for safe operation.

37) The procedures may include (i) when passing through a watertight door, using both hands to hold control levers on each side of the watertight door in the Open direction to keep the door fully open until passage is finished; (ii) when passing through the door with tools or objects, sharing roles between the person who operates the door (a supervisor) and another who carries the load; (iii) always keeping the areas around watertight doors clean to avoid fatal slips; and (iv) providing manuals and training on how to operate watertight doors (please refer to UK MCA, MGN 35, 17 Feb. 2022, http://bit.ly/3yU7QCa).

6.3 Strengthening drills for closing watertight doors and safety education

6.3.1 The Isabu Operational Instructions state the need to train the crew to ensure crewmembers play their roles duly for each situation based on their emergency duties and posts when a maritime accident occurs. However, such drills for closing the watertight doors under the scenario of a collision were not carried out.

6.3.2 Therefore, Isabu should put efforts to reinforce watertight door drills, such as training the crew to open and close watertight doors under a collision scenario. Also, when conducting safety education, the vessel should provide the crew with a handout, which includes how to safely operate the watertight doors and precautions, and initiate safety education to prevent accidents proactively.

6.3.3 Also, the officers of the watch (OOWs) of Isabu should be trained to fully understand the functions and features of the watertight door control console so that they can smoothly control the doors in an emergency.

Figures

Ministry of Oceans and Fisheries

Korea Maritime Safety Tribunal