THE COMMONWEALTH OF THE BAHAMAS

ANTHEM OF THE SEAS

IMO Number: 9656101
Official Number: 7000686

Report of the marine safety investigation into a heavy weather incident on 7th & 8th February 2016

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1 GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AWT	Applied Weather Technology, Inc.
BMA	Bahamas Maritime Authority
BVS	The Bon Voyage System
℃	Degrees Celcius
CCTV	Closed-Circuit Television
IEEC	International Energy Efficiency Certificate
LSA	Life Saving Appliances
mb	Millibar (1 mb = 1 hectopascal)
ms^{-1}	Metre per second
M.V.	Motor vessel
NOAA	The National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
OPC	Ocean Prediction Center
P/S	Port side
RCCL	Royal Caribbean Cruises Limited
S/B	Starboard side
USCG	United States Coast Guard
UTC	Universal Time Coordinated
VDR	Voyage data recorder

All times noted in the report are given in the style of the standard 24-hour clock without additional annotation and as local time in the Eastern Standard Zone.

2 SUMMARY

The following investigation has been classified as a marine casualty. The investigation aims to focus on the specific extreme weather events experienced from 06th February 2016 which resulted in restricted manoeuvrability of the vessel whilst off the eastern seaboard of the United States of America.

The Anthem of the Seas sailed from Bayonne, New Jersey on 6th February 2016 bound for Port Canaveral with 4,529 passengers and 1,616 crew members aboard.

The weather at Bayonne on departure was recorded as South-westerly winds at 5 knots, partly cloudy and 5°C.

The weather forecast was expected to deteriorate, with winds increasing up to 37-51 knots. During the early afternoon of 7th February, the weather deteriorated beyond the forecast conditions.

Heavy weather precautions were taken to improve stability and reduce injury and exposure to passengers and crew alike. Loose objects were secured and regular announcements were made to inform everyone on board of the fact that the vessel may roll heavily and unexpectedly and passengers should remain in their cabins until informed otherwise.

On 7th February at 1806 hours, the vessel recorded the largest true wind magnitude (corrected to 10 meters above sea level) at 146 knots. The Master estimated sea state to be in the region of 15 meters[1].

The severe weather conditions and water slamming against the Azipod unit led to complete failure of all four clutches on the port side Azipod and complete failure of one clutch and damage to the remaining three clutches on the starboard Azipod rendering the vessel with significant, albeit temporarily, restricted manoeuvrability.

Due to the significant weather and restricted manoeuvrability experienced the vessel was at times unable to maintain a heading which would place the seas and wind in a more favourable relative position to minimise vessel exposure to the prevailing weather. By the early hours of the 8th February, the Captain was able to turn the vessel to place the seas astern and thus reduce the vessel heel which was induced as a result of the wind on the beam.

The vessel safely returned to Bayonne under its own power but required technical assistance to repair affected Azipod propulsion units.

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[1] The vessel has no equipment to measure this and it is based on Master's own judgement.

3 DETAILS OF THE INVOLVED VESSEL(s) AND OTHER MATTERS

3.1 Details of the vessel

The Anthem of the Seas is a passenger vessel built in 2015 by Meyer Werft in Papenburg, Germany.

The vessel had the following principal particulars:

Call sign	C6BI7
IMO number	9656101
MMSI number	311 000 274
Built	2015
Length overall	321.10 metres
Breadth	41.40 metres
Depth	14.15 metres
Azipod	2 x X02300 ABB Oy, Marine Ports (Port & Starboard Azipods - 20,500kW/unit – 133.5rpm
Manoeuvring Thruster	4 x Electric Power Unit (Forward)
Propulsion power	41,000 kilo Watt
Gross registered tonnage	168,666 tonnes
Net registered tonnage	152,023 tonnes
Type	Passenger vessel
Class Notation	DNV GL

The vessel has two ABB Azipods for propulsion and steering.

At the time of the incident, the vessel was owned by Anthem of The Seas Inc. and managed by Royal Caribbean Cruise Lines.

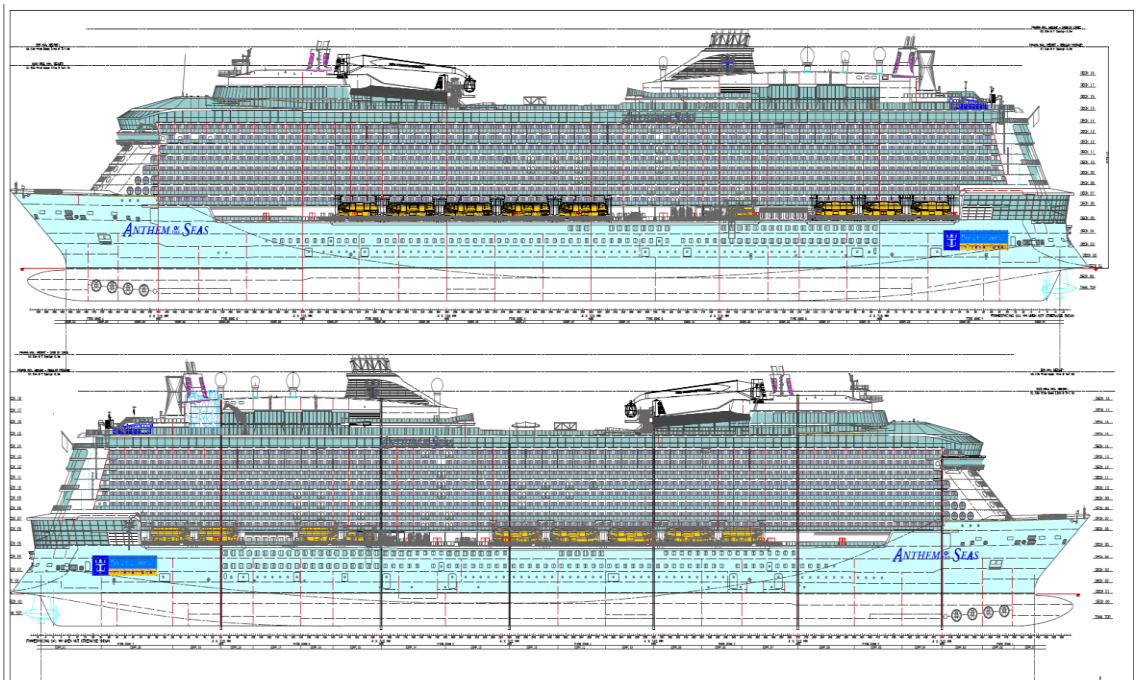

Figure 1: Anthem of the Seas general arrangement plan

3.2 Vessel Certification

The vessel was first registered with the Bahamas Maritime Authority (BMA) on 6th May 2015 and was classed with DNV GL Classification Society. At the time of the incident, the vessel complied with all statutory and international requirements and certification.

The vessel was subjected to a Bahamas Maritime Authority Initial Inspection at the Port of Bremerhaven on 10th April 2015. No deficiencies or observations were identified.

The vessel had a Port State Control Inspection at Fort de France, Martinique, on 15th November 2015 with one deficiency identified regarding the International Energy Efficiency Certificate (IEEC) which was not present at the time of inspection. The deficieny was not relevant to this marine casualty.

3.3 Propulsion System (Azipod)

The vessel was installed with the ABB Azipod propulsion system with two pods located at the stern under the transom on the port and starboard side respectively.

Azipod propulsion is a steerable propulsion system where the electric drive motor is in a submerged pod outside the ship's hull. The propulsion module with speed controlled fixed pitch propeller can be rotated 360 degrees around its vertical axis. The system offers high efficiency and manoeuvrability.

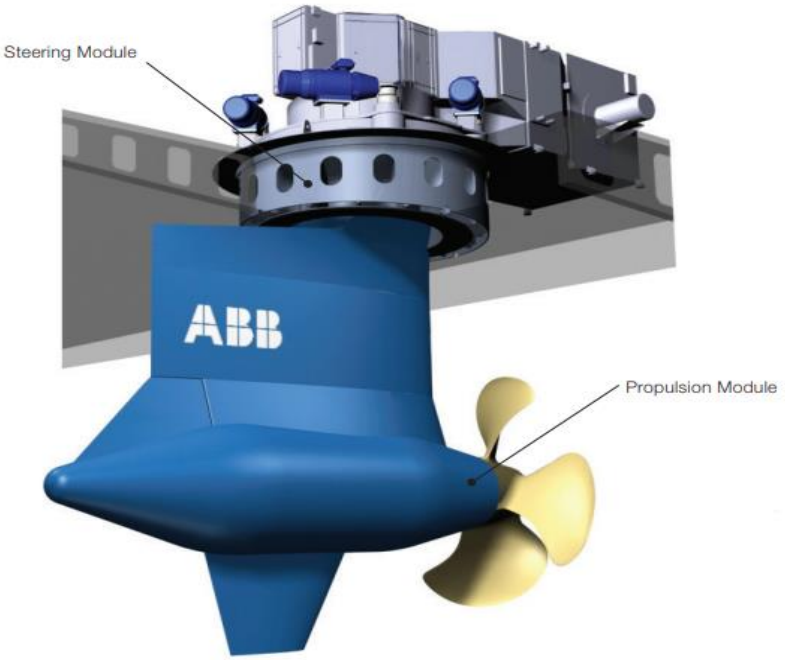

Figure 2: Basic arrangement of the Azipod (Source: ABB website)

The steering module contains mechanical components that enable the steering function of the Azipod. Such components include electric steering motors, slewing transmission, slewing bearing and slewing sealing. The steering mechanics are connected to the ship with a mounting block.

Each Azipod steering module consists of four steering motors, each motor transmits power to the main gear rim through an overload clutch and planetary gear[2]. An overload clutch is in the shaft between the reduction gear and steering motor. The overload clutch protects the steering mechanics from external accidental loads. It protects the planetary gear and main gear in case of heavy overload.

[2] The planetary gearbox is a gear system consisting of more than one gear, revolving about a central gear.

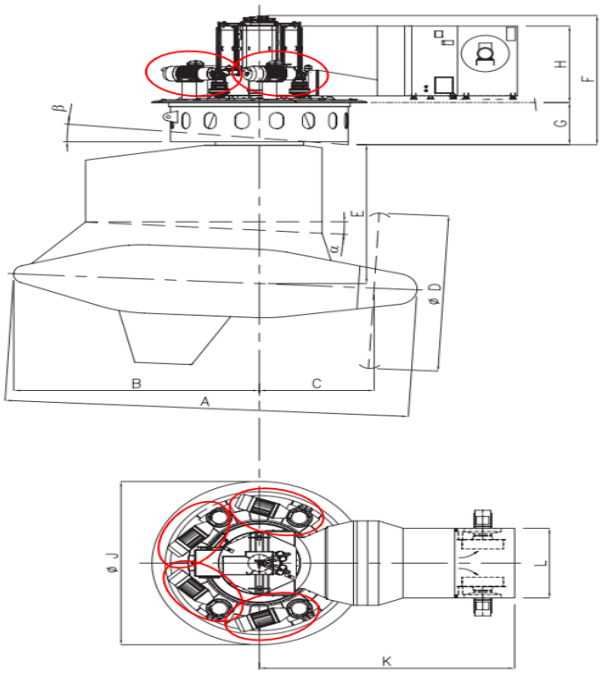

Figure 3: Motors arrangement on Azipod highlighted in red circles

Each electric motor has one overload clutch and one motor velocity encoder. The motor velocity encoder measures and controls the speed of the motor.

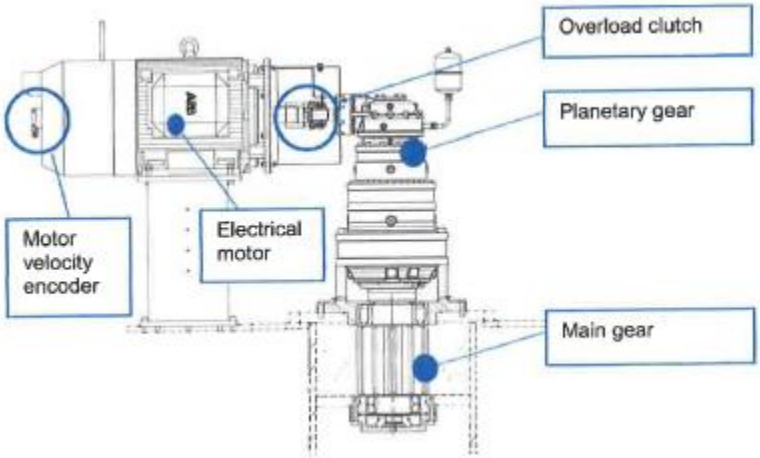

Figure 4: Steering motor unit parts (source: AN Propulsion Study report by ABB, DNV-GL, Elomatic, MeyerWerft, RCCL, VTT)

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4 NARRATIVE OF EVENTS

On 6th February 2016 at 0351 hours, the vessel arrived at Bayonne New Jersey from Labadee, Haiti. The vessel was all fast alongside at 0615 hours completing a 12-day Eastern Caribbean cruise.

At 1106 hours a change of command took place. The incoming Master had been a Captain with the company since 2008 and had been a Captain on the Anthem of the Seas on multiple occasions since the vessel's maiden voyage in April 2015.

At 1107 hours the passengers started to board the vessel for the upcoming cruise.

At 1330 hours the vessel's steering gear was tested. The pilot boarded the vessel at 1341 hours and the Master and Pilot information exchange was completed at 1429 hours.

At 1430 hours a passenger muster drill was conducted in accordance with SOLAS Ch III Regulation 19.2.2 and 19.2.3. Emergency alarms were tested at the drill. A total of 429 passengers failed to report for the drill and a second drill was scheduled later that same day. However, at the time of the investigation, no logs/records were found to confirm if the second drill was conducted.

At 1457 hours watertight doors were closed for departure, bridge engine control was tested at 1459 hours and the bridge was put on the red condition[3] at 1502 hours.

At 1513 hours the gangway was removed and shell doors were verified closed, all mooring lines were let go at 1522 hours and the vessel departed the berth at 1526 hours.

The bridge team pre-departure briefing included weather prospects for the upcoming voyage (figure 5).

[3] Additional manning level and controlled access

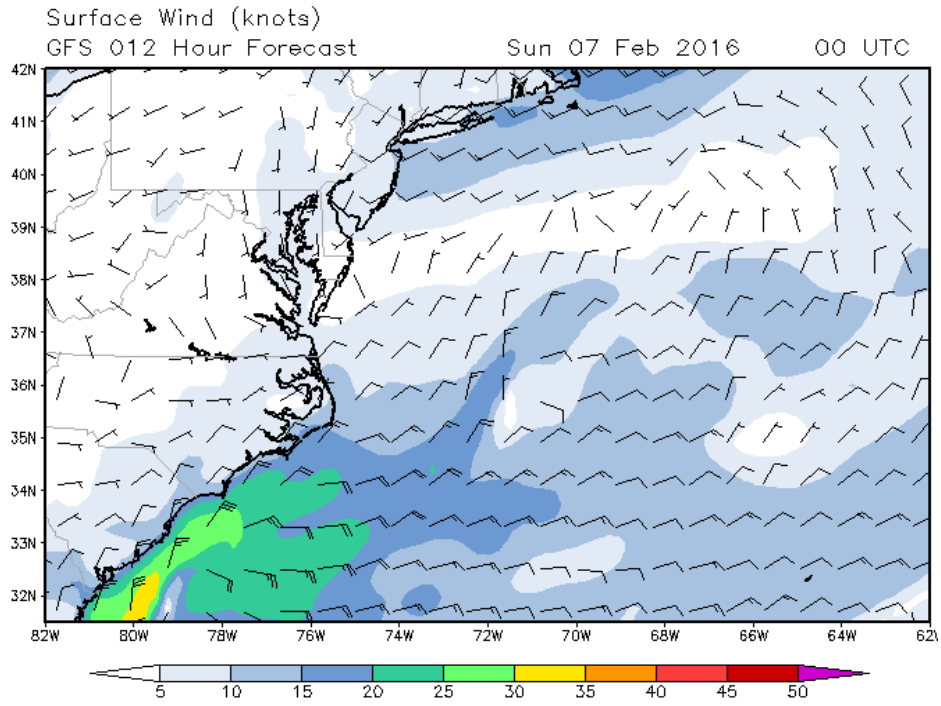

Figure 5: Weather forecast for 7th February voyage

At 1727 hours, the vessel deviated from the 10-knot speed restriction in the Whale Seasonal Management Area reaching a maximum speed of 22 knots. The deviation was deemed necessary to avoid a developing weather system on the planned route.

At 2221 hours the Master wrote night orders in the Deck Logbook and included a requirement for Deck Officers to monitor the weather situation, to bring potable water levels to 2500 cubic meters and prepare ballast and heeling to counter the effect of a low pressure building off Cape Fear.

The following day, on 7th February 2016 at 0700 hours, the Master came to the wheelhouse. At that time the weather as per the Deck Log records were as follows: wind direction 022 degrees at 37.9 knots, visibility unlimited, air temperature 11℃, sea temperature 23.5℃ and seas state (significant wave height) between 2.5~4 meters.

A course deviation was planned that increased the distance of the route by 15 nautical miles and reduced the expected wave height by 1 meter.

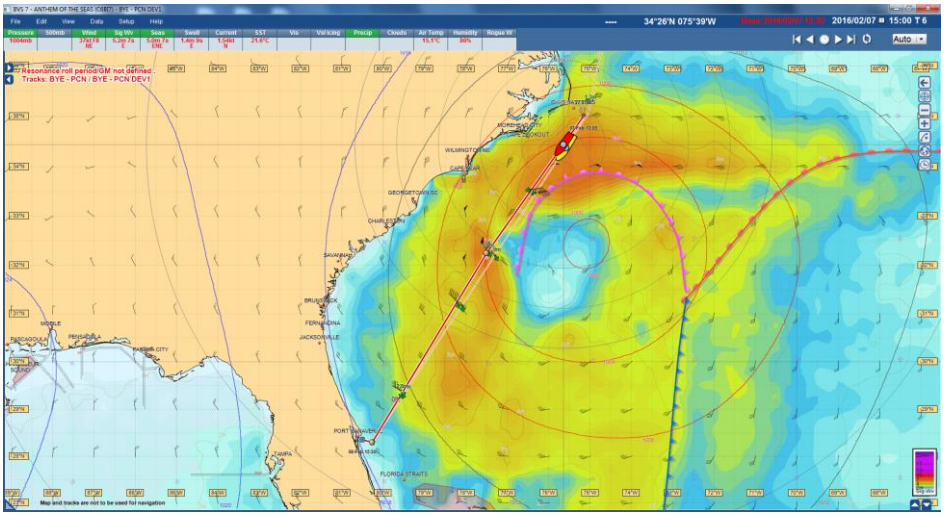

Figure 6: Weather map used to determine the course deviation

At 0722 hours the vessel's stabilizers were extended, shortly before the course deviation which commenced at 0723 hours.

At 1000 hours the Master made an announcement to all passengers and in all crew areas informing them of the impending heavy weather.

At 1300 hours the Captain reviewed the weather and expected winds as high as 40-45 knots and seas between 4 & 5 meters. The vessel was on autopilot and all systems were functioning normally.

At 1450 hours the Captain made a second heavy weather announcement to all passenger and crew areas.

At 1453 hours with deteriorating weather conditions the Captain took over the conn. The bridge was put on Red condition with additional manning. The Captain and Staff Captain were both on the bridge from this point onwards and the weather was under continuous review.

At 1530 hours draining of the pools was ordered and at 1542 hours the stabilizers were housed due to low vessel speed.

At 1553 hours ballast operation was commenced, to improve the vessel's stability.

At 1555 hours the vessel was put on Port Condition[4].

[4] All watertight doors were confirmed closed.

At 1556 hours the Staff Captain took over the conn as the Captain issued a third heavy weather announcement. During this time the Captain was at the ship's controls and announcements were made by the Cruise Director. Passengers were advised to return to their staterooms and avoid going on balconies.

At 1625 hours all shell doors were checked and found tight.

At 1627 hours the shore office of the company was updated.

At 1632 hours wind speed was noted to be in excess of 100 knots and at 1636 hours the ship’s sides were checked and damages were observed at several loose balcony partitions. Life-saving appliances were also checked and were found intact.

At 1637 hours the wind was recorded on the bridge at 145 knots and the vessel was heeled to 15 degrees and at 1639 hours the Captain resumed the conn.

At 1641 hours the vessel was operating with all four bow thrusters in operation in order to assist in maintaining a steady course. There were continuous failure alarms sounded on the steering system and difficulties were experienced keeping wind and swell from the vessel’s beam.

At 1649 hours attempts to turn the vessel both to port and to starboard failed and at 1653 hours the USCG at Norfolk were advised of the situation.

At 1732 hours some passengers were relocated from cabins to the music hall due to broken portholes in their cabins.

At 1736 hours a second attempt to turn to starboard failed and at 1744 hours mooring lines were noted adrift astern. Subsequently, at 1746 hours a second attempt to turn to port failed.

At 1755 hours the USCG at Norfolk were updated again and at 1803 hours the company’s shore office was updated again. The wind speed was recorded to be 135 knots at this point and the vessel had recorded a heel angle of 18 degrees.

At 1821 hours the fire detection system for decks 1 to 5, in the Main Fire Zone 1 failed and patrols were instigated.

At 1826 hours some water ingress was noted at deck 5 sliding doors.

At 1833 hours the Staff Captain took over the conn and the Captain made a further announcement to all areas and at 1840 hours, he resumed the conn.

At 1848 hours the vessel recorded gusts of wind of 140 knotes.

At 1855 hours sustained winds were 76 knots, as the vessel maintained 1 knot of headway.

At 1906 hours the USCG at Norfolk were updated again.

At 1908 hours the starboard Azipod failed.

At 1915 hours inspection of the aft mooring area revealed one line hanging overboard and no power available to any of the winches in order to attempt a recovery.

At 1920 hours the starboard Azipod resumed working. However, at 1928 hours it failed again.

At 1930 hours the port Azipod failed, leaving the vessel with no forward or astern propulsion capability and only limited steering provided by the operational bow thrusters. Heavy weather announcements were made and repeated in both Spanish and Portuguese.

At 1931 hours the wind and waves were abeam with wind speed recorded to be 60 knots.

At 1933 hours both Azipods resumed operation. However, at 1945 hours none of the Azipods were responding to orders. The Engineering team advised to avoid turning the ship at sharp angles.

At 2000 hours the USCG were updated again.

At 2035 hours the Staff Captain took over the conn to allow the Captain to make an announcement to all areas. Additionally, at 2057 hours the Captain made a further announcement to all areas. The shore office of the company was updated again at 2103 hours.

On 8th February 2016 at 0030 hours, the port side Azipod had a complete failure of all four clutches and was declared not operational thereafter. The starboard Azipod suffered a failure of one of its four clutches and remained operational.

Engine Logbook entry for the Azipod clutch failure reads:

"00:30 Discovered complete breakdown on all four clutches on P/S Azipod. Also confirmed Clutch #1 on S/B Azipod to be damaged. Remaining three clutches for S/B pod considered partly damaged."

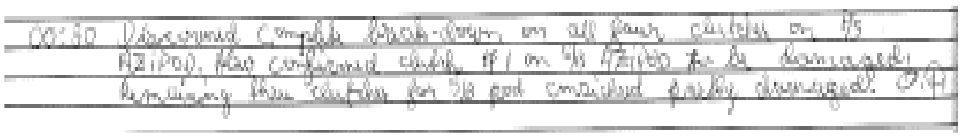

Figure 7: Engine Logbook entry describing the damage to the port side (P/S) and starboard side (S/B) Azipod

At 0141 hours the vessel was able to turn to port, putting the wind directly on the stern and thus reducing the vessel's heel which was induced by the wind on the beam.

A review of weather conditions was conducted and to avoid further heavy rolling, it was decided to return to Bayonne rather than proceed to Port Canaveral or Nassau.

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5 ANALYSIS AND DISCUSSION

The purpose of the analysis is to determine the contributory causes and circumstances of the incident as a basis for making recommendations to prevent similar events occurring in the future.

The source material used for weather analysis in this report was provided by the National Transportation Safety Board via the United States Coast Guard Technical Adviser and was obtained for the purpose of this investigation. While the technical deficiencies analysed in this report include the technical propulsion assessment conducted and provided by the propulsion manufactures (ABB), vessel manufacturer (Meyer Werft), Classification society (DNV-GL), Owners (RCCL) and technical research company (VTT).

5.1 Heavy weather and forecast

The vessel was equipped with three anemometers, two forward and one aft. The aft anemometer was considered unreliable by the vessel. With regard to the forward anemometers, one was located on the port side (forward mast) and one was located on the starboard side (forward mast). Both were about 58 meters above the waterline. The starboard side anemometer was of ultrasonic-type, which had a maximum measuring speed of 75 ms^{-1} (≈146 knots). The port side anemometer was of mechanical-type but its model number was not available at the time of the analysis, which means the maximum measuring speed is unknown (it is either 50 ms-1 or 75 ms-1 according to the technical documentation). The port side anemometer is the source of wind data recorded on the vessel's voyage data recorder (VDR). If the port side anemometer's data is invalid, then the starboard side anemometer becomes the source of wind data recorded on the VDR. It is not known what would invalidate this anemometer's data hence, it is assumed that all wind data recorded on the VDR originated from the port side anemometer.

The VDR wind data (port side anemometer) indicated the maximum true wind speed experienced by the vessel was 146 knots at 18:06:35 on 7th February. For safe navigation of the vessel and considering the comfort of the passengers and crew, 40-45 knots of wind speed was considered safe by the Master.

The barometric pressure dropped at an almost steady rate until 2000 hours. After 2000 hours, the rate of change dropped to -13 mbar/h and the pressure dropped to a minimum of 970 mbar. After 2100 hours the barometric pressure started rising again. Wind speeds also peaked at the same time. The wave height peaked between 0300 - 0400 hours to a height of 9-10 meters.

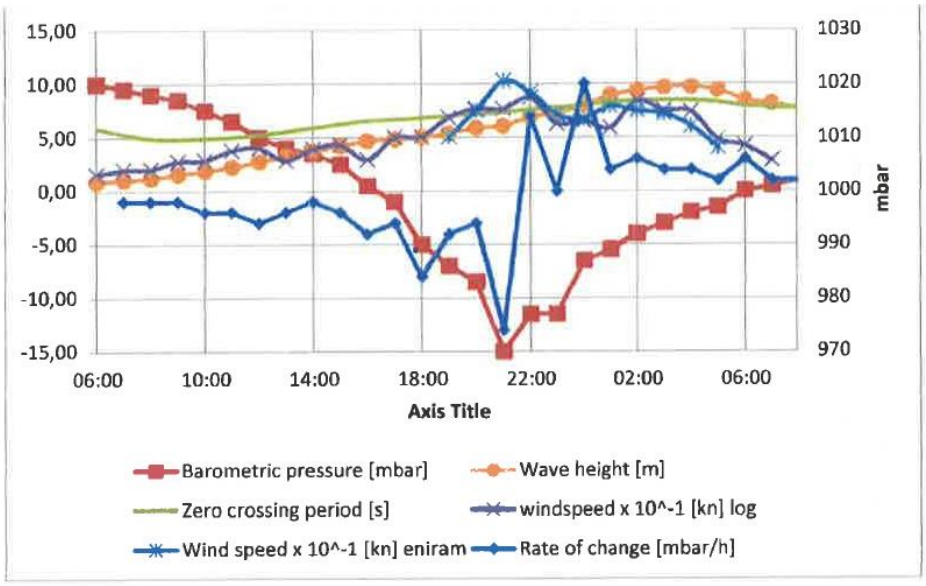

Figure 8: Weather Data (Source: AN Propulsion study by ABB, DNV-GL, Elomatic, Meyer Werft, RCCL, VTT)

National Weather Service (NWS) and Applied Weather Technology (AWT) forecasts for this storm in the days leading up to the incident did not accurately forecast the severity of the conditions. Further, these forecasts may not have anticipated an accurate maximum severity of sea state (significant wave height), based on the Master's assessment of encountering 15 meters wave heights. There was no onboard sensor to assist in quantitative measurement and assessment was made by Master considering his own judgment.

A review of the following NWS Ocean Prediction Center (OPC) forecast products valid through 1900 EST on 7th February was performed by NTSB:

- 24-hour surface forecast (graphical)
- 48-hour surface forecast (graphical)
- 24-hour wind/wave forecast (graphical)
- National Hurricane Center 48-hour High Wind and Seas Danger chart (graphical; not issued by OPC)
- High Seas Forecast
- NAVTEX text products
- Offshore Waters Forecasts

Overall, the NWS appropriately identified a developing and rapidly intensifying storm with hurricane force wind. Amongst these products during the times leading to the incident period, maximum sustained surface wind (10-minute average of the 10-meter wind) for the incident period was forecast to be 65 knots, and minimum sea-level pressure for the incident period was forecast to be 987 mbar (987 hPa). Further, the maximum significant wave height was forecasted to reach 7.31 meters (24 feet). However, the maximum wind speed recorded by the vessel was 146 knots, minimum sea-level pressure recorded was 970 mb and the maximum significant wave height experienced was 15 meters as per Master's assessment.

The Bon Voyage System (BVS) from Applied Weather Technology, Inc. (AWT) was available onboard the vessel during the voyage. BVS is a desktop application that can be installed on any computer (ship or shore). It provides the most recent weather and ocean data to the ship by broadband or email communications in a highly compressed format. This data is then used to generate colour-enhanced maps and graphics that allow the ship's Captain to easily view and interpret potential problem areas in advance.

In the days leading to the incident, AWT forecasts for the greater incident region did not identify sustained wind conditions that appeared to exceed 70 knots, significant wave heights that exceeded 12 meters, or a sea-level pressure that was below 988mb associated with the storm. These forecasts are generally consistent with the NWS forecast products. Nevertheless, these wind forecasts fall well below what was recorded by the vessel.

At the time of the investigation, no evidence was found indicating that the Anthem of the Seas made a ship's report of weather during the incident. Real-time reporting of weather information from vessels at sea provide meteorological authorities with critical data. Ship reports of weather help forecasters to tailor the forecasts and this data can be assimilated into global models to improve weather forecasts.

5.2 Cosmetic Damage

Several areas in the vessel sustained damage, these were predominantly where glass panels failed, minor water ingress via non-watertight doors and fixtures and fittings shifting.

Figure 9: CCTV screenshots show seas breaking on the lifeboat embarkation decks

Figure 10: Broken glass on deck

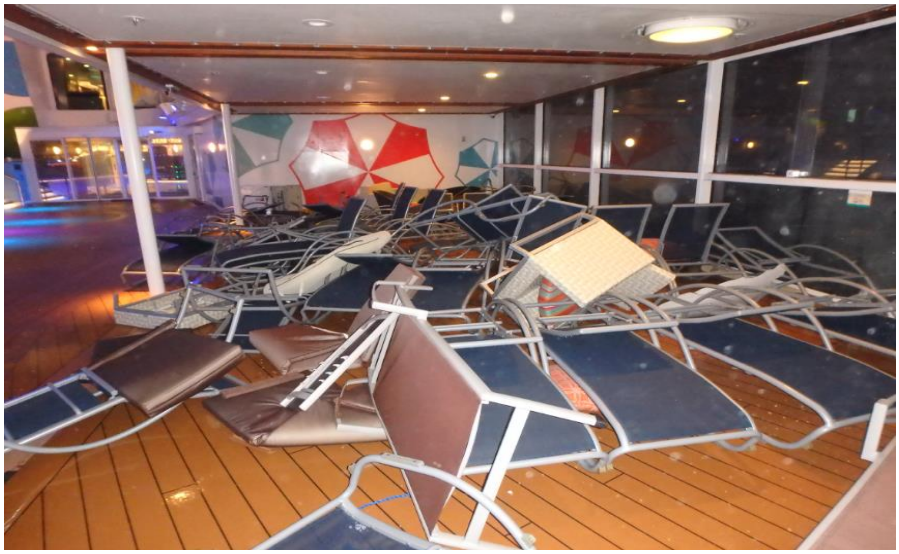

Figure 11: Damaged seats near the pool area

Figure 12: Broken glass window

Figure 13: Broken glass on the deck

Figure 14: Damaged ceiling on deck

Various lifeboats on both starboard and port boat decks were damaged. Mostly the reported damaged was due to the water ingress in the engine compartment, damage to plexiglass and battery charger failure. Also, multiple painter lines were pulled out from the overcapacity life rafts.

Figure 15: Seawater breaking on the lifeboat embarkation decks

5.3 Propulsion System (Azipod) Damages

During the evening of 7th February the vessel experienced both overload and over speed of the Azipod clutches. Overload of the clutches indicates that the steering mechanics and gears (main and planetary) are impacted by the external loads. The over speed alarms caused the steering gear to stop, which led to a loss of propulsion numerous times.

The sudden torque losses caused over speed of each propeller and caused the ship's automation to reduce the power supply. With less power to the propeller, manoeuvrability was reduced and thus steering was affected because the Azipod unit provides power and steering. Steering could only be effective if the propeller was providing thrust. After the incident, the propeller thrust was back to the normal level. However, these power losses led to a situation where the ship was not able to fully steer under heavy weather conditions.

The Azipod Operating Guidelines - Operating Instruction states: '*In heavy weather conditions, it is essential to ensure the safety of the vessel and the people onboard. In these conditions, it may be necessary to use steering techniques, for example, manual steering and larger angles from the azimuth levers, which may cause increased levels of vibration and to allow the vessel to yaw more. Consider reducing speed to avoid the most difficult situations. Reducing speed also increases the redundancy of the power network, allowing it to better cope with power fluctuations from electrical responses.*' No evidence was found to determine if the vessel's speed was reduced intentionally to avoid damage to the vessel due to heavy weather conditions. However, it was found that the vessel's speed was reduced due to a loss of propulsion on various instances.

Between 2135 hours and midnight (7th February) the vessel attempted to turn, both with and against the waves, without success. Vessel records indicate that during this time period there were actual over speed on the port side 58 times and on the

starboard side 24 times. Throughout the heavy weather period, a total of 46 clutch overloads were recorded on the steering gear, 38 to port and 8 to starboard.

During over speed trips, power was reduced to zero and a loss of control of the propulsion unit was experienced, the recovery time was approximately 40 seconds.

Each Azipod unit consists of four clutches, one on each motor. Clutch release events occurred primarily due to water slamming against the Azipod unit, this eventually led to the complete failure of all four clutches on the port side. A complete failure of one clutch and damage to the remaining three clutches on the starboard side.

Based on Azipod's propeller location, aft lines and propeller design it is most likely that the Azipod ventilation[5] will occur when waves reach 6 meters in height. At the time of the incident, wave heights were significantly higher. This potentially led to multiple over speed trips and clutch overload issues, ultimately to the complete failure of the steering system on the port side Azipod.

The bow of the vessel was out of the water an estimated 50% of the time in the heavy weather. The use of bow thrusters was critical for maintaining the vessel's steady heading against winds and waves. The use of the thrusters loaded the vessel's network with power demands between one and eleven megawatts with rapid load variations.

5.4 Injuries reported on board during the Incident

As per the initial information provided by RCCL, a total of 23 passengers and one crew member were reported to be diagnosed with minor injuries after the incident. The majority of these injuries were limited to sprains, strains, bruises and contusions due to the vessel's movement.

5.5 Heavy Weather Operating and Reporting Policy

The SMS policy for 'Hurricanes, Typhoons, and Severe Weather Conditions' required Master to contact the applicable Nautical Support team if the ship is expected to encounter any of the following conditions:

> Hurricane or Typhoon potentially impacting the ship's official itinerary within the next 7 days
>
> Significant wave heights equal to or higher than 7 meters within the next 5 days
>
> Forecast sustained winds at the 10 meter level higher than 45 knots within the next 3 days
>
> Weather conditions that could potentially prevent the ship from entering a port of call, close the port for operations, or impact the safety of tendering operations within the next 3 days

[5] Propeller ventilation is caused by air from the surface or exhaust gases being drawn into the rotating propeller blades. This results in the propeller slipping more than usual due to the reduced water load on the blades and sudden in increase in RPM.

> Weather conditions that could cause delays arriving to a port in excess of 1 hour within the next three days
>
> Weather that could cause delays arriving or entering a turn-around port as soon as they are noticed
>
> Any weather conditions ahead that can potentially affect the ship safety or the itinerary and the Master considers prudent to notify the shoreside support team.

Further, the policy required the vessel to complete Severe Weather Reporting form on request of the Fleet Captain. The procedure states: '*The necessity of the report, as well as the starting point, end point, and frequency of the reports will be established by the Fleet Captain based on the proximity of the ship to the storm.'* The shore team was updated with the situation by the vessel. However, no evidence was found indicating that the Severe Weather Reporting form was requested from the vessel or was submitted by the vessel.

The policy also states: '*The decision to abort a port due to weather, is the responsibility of the Master. The Master will notify Marine Operations of his/her decision.'* The policy provides guidance to the vessel crew to look for weather patterns ahead and plan in advance for safe navigation, efficient contingency planning, and avoid weather-related last-minute cases whenever possible.

However the policy does not clearly stipulate operating limitations for maximum allowable weather conditions (wind speed and sea state) for this class of vessel which if exceeded would prevent the vessel from sailing.

***

6 CONCLUSIONS

The BVS forecast available to the bridge team and reviewed by the Master prior to undertaking the voyage forecasted maximum wind speeds of 50 knots on the evening of 7th February 2016. The Master considered, after the incident, that wind speeds of between 40-45 knots was acceptable and within the safe operating envelope of the vessel. However, the maximum wind speed recorded by the vessel's ananometer was 146 knots and by far exceeded the expectations of the bridge team.

Due to adverse weather and wave height experienced by the vessel, all four clutches of the port side Azipod were damaged making the port side Azipod completely un-operational. The starboard Azipod had one clutch failure.

To reduce injury to passengers the Captain implemented mitigation procedures by restricting passengers' movement throughout the vessel. The passengers were advised to return to their cabin due to the combination of heavy weather and vessel movements. This was a proactive response and is almost certainly the reason behind the relatively low number of reported minor injuries.

The vessel managed to turn around to Bayonne using the starboard Azipod with three of four steering motor clutches functioning.

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7 RECOMMENDATIONS

Recommendation for the operator (RCCL):

Consider incorporating the suggestion and recommendation made in the Propulsion Studies related to this class of vessel carried out by ABB, DNV GL, Eliomatic, Meyer Werft, RCCL and VTT, to reduce the number of failures in case of ventilation and over speeding.

Actions and precautions to be conducted in a storm with existing steering system

Possibility for using different clutch type

Possible mechanical improvements to improve the recovery from clutch failure

Software improvements to minimize the risk of clutch damage

Consider amending the SMS policy to include the maximum allowable forecasted wave height, weather conditions and reporting requirements to ensure passenger safety on the respective class of vessels.

Consider providing training to all Deck Officers on board with the steering technique required to manoeuvring the vessel when experiencing heavy weather in accordance with the Azipod Operating Guidelines.

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8 ACTIONS TAKEN

Actions taken the Company

Company's updated operational guidelines (including operation in heavy seas or if propellers are venting) were distributed to the fleet.

A review of different clutch types was conducted by ABB. Used clutch type (KTR-SI Compact DK) was found to be the most suitable for the system.

A new split type coupling was introduced and installed on all pods allowing for easy onboard replacement in case of failure.

Next Generation Electrical Steering system was applied in the current deliveries. It implements learnings received from operating steering systems, brings new inverter product family to Azipod XO steering system and provides fast & accurate Drive-to-Drive communication to ensure smooth & undisturbed operation.

RCCL hired a full time, in house Meteorologist to oversee global weather forecasting and situation support, upgraded the metrological support team and changed the weather models used onboard ships.

Bespoke Podded shiphandling level 2 course was developed in collaboration with ABB, Simwave and RCCL. The course will be released to the fleet in 2020 and will be focused on emergency / high stress podded shiphandling, including machinery failures and simulated heavy weather.

A new Marine Meteorology training program for the Bridge Officers is in the final stages of development, including a traveling meteorologist to conduct onboard trainings with bridge officers and an online learning Marine Meteorology Course.

A new policy "Procedures for monitoring and reporting severe weather forecasts" has been put in place to alert shoreside and situation management well in advance should certain identified thresholds be met.

Appendix I: Deck Log Book records weather and sea conditions on 7th and 8th February 2016

Local Time	*Wind Direction*	*Wind Speed (knots)*	*Sea Condition Beaufort*	*Wave Height Meters*	*Ship's ground speed (Knots)*
07:00 (7 February)	*022.7*	*37.9*	*F5 Rough*	*2.5~4.0*	*21.66*
09:00	*041.4*	*28.57*	*F5 Rough*	*2.5~4.0*	*20.42*
11:00	*037.3*	*42.96*	*F6 Very rough*	*4~6*	*20.87*
12:00	*062*	*29.16*	*F6 Very rough*	*4~6*	*20.21*
13:00	*045.75*	*49.96*	*F6 Very rough*	*4~6*	*20.96*
14:00	*067.17*	*50.73*	*F6 Very rough*	*4~6*	*19.40*
15:00	*001.65*	*68.42*	*F6 Very rough*	*4~6*	*11.66*
16:00	*342.6*	*74.64*	*F6 Very rough*	*4~6*	*2.18*
17:00	*307.93*	*76.39*	*F8 Very high*	*9~14*	*5.99*
18:00	*325.72*	*120.13*	*F8 Very high*	*9~14*	*9.09*
19:00	*322.2*	*62.98*	*F7 High*	*6~9*	*2.96*
20:00	*323.47*	*65.31*	*F7 High*	*6~9*	*3.08*
21:00	*326.99*	*58.9*	*F7 High*	*6~9*	*1.81*
22:00	*314.07*	*86.89*	*F9 Phenomenal*	*Over 14 meters*	*3.45*
23:00	*310.02*	*75.03*	*F6 Very rough*	*4~6*	*4.46*
23:59	*309.64*	*73.87*	*F5 Rough*	*2.5~4*	*3.69*
01:00 (8 February)	*319.22*	*48.21*	*F7 High*	*6~9*	*5.10*
02:00	*319.99*	*41.99*	*F7 High*	*6~9*	*10.17*
04:00	*339.99*	*23.33*	*F7 High*	*6~9*	*11.64*