Report on the investigation of the heavy weather

damage to the passenger cruise ship

Pacific Star

South Pacific Ocean

10 July 2007

Marine Accident Investigation Branch
Carlton House
Carlton Place
Southampton
United Kingdom
SO15 2DZ

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Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

ARCHO	-	Auckland Regional Council Harbourmaster's Office
ASNT	-	American Society for Non-Destructive Testing
BINDT	-	British Institute of Non-Destructive Testing
CLIA	-	Cruise Lines International Association
cm	-	centimetre
CTO	-	Chief Technical Officer
Hp	-	horsepower
IACS	-	International Association of Classification Societies
IMO	-	International Maritime Organization
ISM	-	International Safety Management (Code)
kW	-	Kilowatt
MARPOL	-	International Convention for the Prevention of Pollution from Ships
MCA	-	Maritime and Coastguard Agency
MCR	-	Machinery Control Room
MGN	-	Marine Guidance Note
mm	-	millimetre
MNZ	-	Maritime New Zealand
MoU	-	Memorandum of Understanding
MS	-	Merchant Shipping
NDT	-	Non-destructive testing
OOW	-	Officer of the Watch
PCN	-	Personal Certification in Non-Destructive Testing
PR	-	Procedural Requirement
PSC	-	Passenger Ship Safety Certificate
QSCS	-	Quality System Certification Scheme

RINa	-	Registro Italiano Navale
SI	-	Statutory Instrument
SMS	-	Safety Management System
SOLAS	-	International Convention for the Safety of Life at Sea
TM	-	Thickness Measurement
UHF	-	Ultra High Frequency
UK	-	United Kingdom
UR	-	Unified Requirement
UTC	-	Universal Time Co-ordinated
VDR	-	Voyage Data Recorder
VER	-	Voyage Event Recorder
VHF	-	Very High Frequency

All times used in this report are local time (UTC+12)

SYNOPSIS

Pacific Star sailed from Auckland, New Zealand, in the late afternoon of 10 July 2007. Overnight the ship experienced easterly winds in excess of 90 knots, and a swell height of more than 5 metres. As a result, she suffered damage to internal fittings and to a number of windows in cabins and public spaces, as well as structural damage to the forecastle bulwark and the loss of a satellite communications dome. Significantly, the rough weather also exacerbated pre-existing corrosion damage causing the ship to take water through small holes in her side. Following an underwater survey at her next port of call, Port Vila, Vanuatu, she was instructed by the Maritime and Coastguard Agency (MCA) to proceed directly to a dry dock repair facility without passengers, arriving at Brisbane, Australia on 20 July.

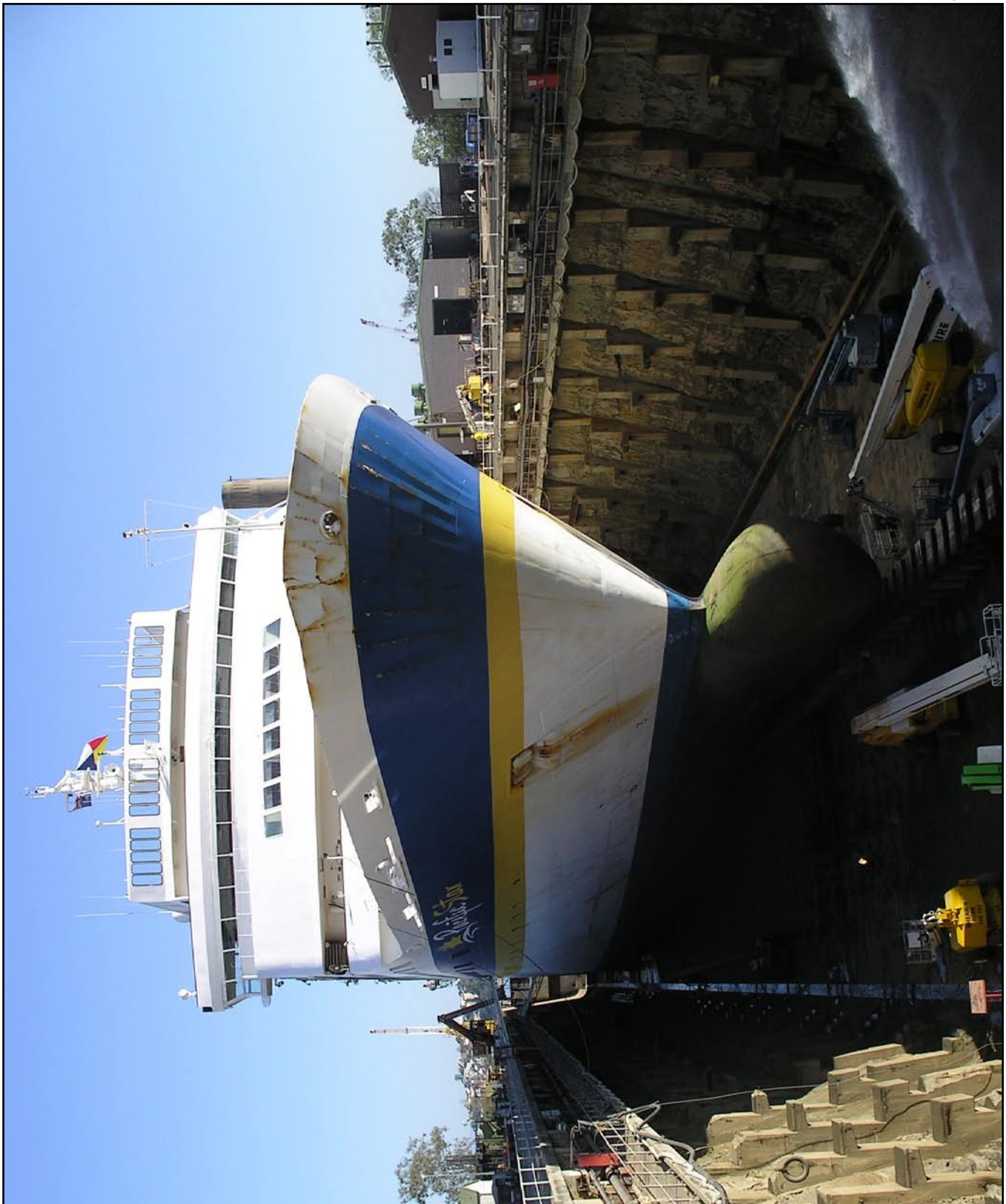
Before sailing from Auckland an announcement had been made advising passengers of expected rough weather. Weather forecasts had been closely monitored by the ship's staff, and precautions had been taken to secure the ship for expected storm force winds and large seas.

Once at sea, it became apparent that the wind speeds were far greater than had been forecast, and the master decided to adjust the passage plan so as to keep the wind and sea fine on the starboard bow.

For operational reasons, the forepeak tank was normally part filled with ballast. The coating in the tank had broken down over time and excessive corrosion in way of the internal water line area had resulted in leakage through the hull. The potential for increased corrosion in this area of the tank had not been identified during surveys even though it had been necessary to replace steel work in other areas of the tank. Further leakage had occurred through holes in the shell in way of ventilation ducts. These were designed, built and maintained in such a way that internal visual inspection of the ship's side in this area was impossible.

Recommendations have been made to the Cruise Lines International Association (CLIA) and the International Association of Classification Societies (IACS) concerning preparation for survey, including accessibility and provision of information to surveyors. A further recommendation has been made to Princess Cruises to review the scope and application of its defect reporting systems.

Figure 1



Pacific Star

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF PACIFIC STAR AND ACCIDENT

Vessel details		*Pacific Star* **(Figure 1)** *(ex Costa Tropicale,* ex *Tropicale)*
IMO Number	:	7915096
Registered owner	:	Pullmantur Cruises Atlantic Limited
Manager	:	Princess Cruises (part of Carnival Corporation)
Port of registry	:	London
Flag	:	UK
Type	:	Passenger ship
Built	:	1982 - Aalborg Vaerft A/S, Aalborg, Denmark
Classification society	:	Registro Italiano Navale (RINa)
Construction	:	Steel
Length overall	:	204.75m
Gross tonnage	:	35,190
Engine power and/or type	:	2 oil engines with clutches, geared to screw shafts driving 2 controllable pitch propellers. Total power 26,600hp (19,566kW)
Service speed	:	19.5 knots
Other relevant info	:	Twin screw, with single rudder between the screws. Bow and stern thrusters.

Accident details

Time and date	:	Overnight 10/11 July 2007
Location of incident	:	Off Auckland, New Zealand
Persons on board	:	1287 passengers, 543 crew
Injuries/fatalities	:	Minor injuries only
Damage	:	Damage to internal fittings, windows, forecastle, bulwark, satellite communications dome and pre-existing corrosion damage.

1.2 BACKGROUND

Pacific Star was built under the supervision of Lloyd's Register (LR) for Carnival Corporation by Aalborg Vaerft A/S, Denmark and has been operated by companies from The Carnival Corp Group throughout. She first entered service with Carnival Cruises as *Tropicale,* in January 1982, under the Liberian Flag. In May 2000 the vessel was transferred to the Panama register and later, in 2001, operational control of the ship was passed to Costa Cruises. At this time, the vessel also transferred onto the Italian register and her classification society was changed from LR to Registro Italiano Navale (RINa).

In 2005, operational control of the vessel was passed to Princess Cruises with the intention that she would be based in Australia and New Zealand and her cruises marketed by P&O Cruises Australia. At this time, the decision was taken to transfer *Pacific Star* onto the UK register.

Primarily because of the vessel's age, the initial application for the transfer to the UK register was given a conditional acceptance by the Maritime and Coastguard Agency subject to an inspection of the vessel. The initial inspection by MCA surveyors resulted in a recommendation that *Pacific Star* should not be entered onto the UK register until a further, more detailed inspection had taken place and a programme of remedial work on a number of critical defects agreed and completed.

Following an extensive period of repairs, the MCA issued *Pacific Star* with a Passenger Ship Safety Certificate (PSC), and she was entered onto the UK register on 25 December 2005.

Carnival Corporation sold the vessel to Pullmantur Cruises Atlantic on 30 May 2007, however the ship continued to be managed and operated by Princess Cruises through a bareboat charter. This arrangement meant that the vessel was dual registered. While the vessel was registered by her new owners under the Maltese Flag, she also continued to be registered in the UK under her bareboat agreement, and for operational purposes she remained under the stewardship of the MCA.

During the southern hemisphere winter period, *Pacific Star* was based in either Brisbane or Auckland. Her cruise schedule involved 8 to 12 day cruises from these ports to the north for "winter sunshine".

1.3 NARRATIVE

Passengers began boarding *Pacific Star* at about 1200 on 10 July 2007, as the vessel lay alongside Princes Wharf, Auckland. At 1600 the previous afternoon, while the vessel was approaching the New Zealand coast on her previous cruise, the master conducted a navigational briefing which covered the vessel's arrival in Auckland and her next cruise. The meeting was attended by all the ship's deck officers and the discussions included an assessment of the likely weather conditions that would be experienced over the next few days. Recognising that severe weather was going to be the dominant feature of the first days of the next cruise, the master ordered that, prior to the vessel's departure from Auckland, all deadlights were to be closed on decks 3 and 4, and storm shutters placed over the windows of the forward 13 cabins on the starboard side of deck 5. He also instructed that additional precautions were to be taken, including briefing the passengers and ensuring that notices were placed on doors opening onto the upper deck, advising of strong winds. The staff captain also sent a general e-mail to all departments on the ship advising of the expected rough weather and reminding staff to make sure that equipment was effectively secured.

Pacific Star's subsequent approach was uneventful and she arrived alongside Princes Wharf at 0700 on 10 July.

Among the passengers to join the vessel in the early afternoon was the designated pilot for the departure from Auckland. He was scheduled to remain on board *Pacific Star* for the duration of the cruise for a vacation. From 1500, the pilot was on the bridge, discussing the options for sailing with Port Control, the master and other deck officers. At 1550, the pilot and master held a formal briefing for the deck officers to explain the sailing plan. Wind speed, and the effect this would have on the ship's turning ability, was a significant part of this briefing. The master and pilot agreed that full speed would be required for the two large turns in the channel to ensure enough turning moment to complete the manoeuvres safely. Contingency plans were discussed should the wind strength prove excessive, but it was noted that the wind was still below the maximum strength for operations at the berth. Three tugs had been ordered to assist with sailing, with the intention of having one 50 tonne bollard pull tug made fast at either end with the third, smaller, 24 tonne bollard pull tug standing by at the end of the jetty, and downwind of the ship, to assist if necessary.

At 1610, the master made an announcement to the passengers, welcoming them on board and telling them of the weather forecast. During this broadcast, he pointed out that it would be an uncomfortable night but that the weather would ease later the following day. He also reminded the passengers to be careful when moving about the ship, and to use the handrails, especially when using the stairs.

At 1614, with the wind gusting to 44 knots from the east, the master delayed sailing to allow the gusts to abate. By 1625 the wind speed had reduced, and the master gave the order to let go. Once *Pacific Star* had been successfully turned in the channel, and with the tugs still made fast, the pilot sought to confirm with the master that they were both still content to proceed out of the port. They agreed, and the necessary orders were given to release the tugs and increase speed to commence the passage to the sea.

The departure from Auckland proceeded without incident. Full power was used to effect the two large turns in the channel, and the ship followed the planned track to the pilot station. Once the vessel had passed the pilot boarding station, he handed over the con of the vessel to the master and left the bridge to join his family.

Full away on passage was rung at 1736 as the ship entered Hauraki Gulf **(Figure 2)**. The wind direction and speed were noted shortly afterwards as ESE and 82 knots respectively, significantly stronger than the last weather forecast received before sailing had predicted. By 1750, the master had concluded that it would be unsafe to follow his original plan which took the vessel through the Jellicoe Channel, thereby increasingly exposing the ship to the unexpectedly strong wind and sea on the starboard beam.

Figure 2

Hauraki Gulf

He therefore decided on an alternative route which took the vessel through the Cradock Channel. The adjustment to the passage plan was expected to place the wind and sea on the starboard bow, reducing ship movement, and with the ballast already distributed to starboard to counter the wind heeling moment, keep the ship upright to facilitate safe movement of passengers and crew. Speed was also reduced to further ease the vessel's movement but was kept sufficiently high to maintain steerage. A further advantage to the amended route was that *Pacific Star* would pass in the expected lee of Great Barrier Island. Once clear of the Cradock Channel, the master's intention was to continue at reduced speed with the wind and sea on the starboard bow, progressively altering course to starboard as the wind veered. Once the storm had abated, his intention was to alter course to port and put the wind and sea on the ship's starboard quarter and resume passage to the north.

This amended passage plan was put into operation, and the ship continued to make slow progress towards the Cradock Channel. The wind speed was continually monitored, with gusts observed of 80 knots reaching a maximum of 92 knots, and the sustained wind speed in excess of 70 knots. These hurricane force winds were observed while the vessel was in the lee provided by Great Barrier Island. Although ship movement reduced due to the reduced height of the seas, the expected reduction in wind speed was not evident. In the extreme conditions it was necessary to offset her heading by 30°- 40° to ensure *Pacific Star* maintained her planned track. At 1945, the master made a second broadcast to the passengers warning of worse weather to come in anticipation of encountering heavier seas once the lee of Great Barrier Island was lost.

Once clear of Great Barrier Island, the seas began to increase, and a number of small unrelated incidents took place. Damage to ship's fittings was reported to the bridge, such as bar refrigerators toppling, mirrors falling off bulkheads and, more significantly, windows breaking. Information concerning the damage was passed to the technical department, and manpower was tasked to effect temporary repairs and remove any debris. The ship's movement was also having an effect on the main engines, in that pounding of the hull, and propeller race as it came clear of the water, caused the turbo-blower vibration alarm to activate which, in turn, limited the available engine power. The pounding also activated fire detector heads in a number of cabins and other spaces. The additional work required to deal with the alarms and telephone calls was distracting the OOW from his main task of navigating the ship. The master therefore instructed the chief security officer to send a member of his team to the bridge to assist with the additional workload.

It was at this time that the master felt that the bow was not rising as high as it had been, and he was concerned that water might be getting into the forepeak tank. He instructed the engineers to manually sound the forepeak tank, and for security staff to check for water ingress in the forepeak stores. The store areas were dry, but the forepeak tank was full. The tank had been half full on sailing, so the master gave instructions for it to be pumped out to its half full state and to be maintained at that level. There was no indication at this stage of where the water was coming from. However, the master had had previous experience on another ship, when the ball float non-return valve for the forecastle air pipe had failed to operate, allowing sea water to enter the space. He concluded that the water ingress was probably caused by the same problem, but in the prevailing weather conditions it was impossible to verify this.

Reports of damage and of water ingress through the shell doors, and doors to the upper deck, continued to be received on the bridge, and were passed to the technical department for action. The off-going bridge watch officers also conducted rounds of the ship, and reported back to the master on the bridge the status of damage and repairs.

By 0430 on 11 July, the master assessed that he would not be able to make the first port on the ship's itinerary. To start making arrangements to cancel the visit, which would include cancelling tours arranged for the passengers, the master attempted to use the satellite communications equipment to inform the cruise operator's Australian office. No signal was being received from the satellite, and the master instructed that the senior communications officer be called to re-establish the satellite link and allow a telephone call to be made. The solution to the communications problem was not immediately apparent, and at 0606 the master contacted the coast radio station by VHF radio and asked for a message to be passed to his agents in Auckland for onward transmission to the Australian office. This message was to give the shore staff an early indication that the vessel would not make the first port, and that the ship had suffered minor damage, including damage to a satellite dome and the forecastle bulwark now visible from the bridge as daylight approached **(Figures 3 and 4)**. The master also asked the radio station operator for a weather update since no new information had been received on board for approximately 12 hours. Specifically, he asked for the latest positions of the two low pressure areas which formed a complex depression over North Island. The reported position of one of the depressions agreed with the master's own assessment that its centre lay immediately over *Pacific Star*. The centre of the second depression was to the north west, and on the ship's intended track.

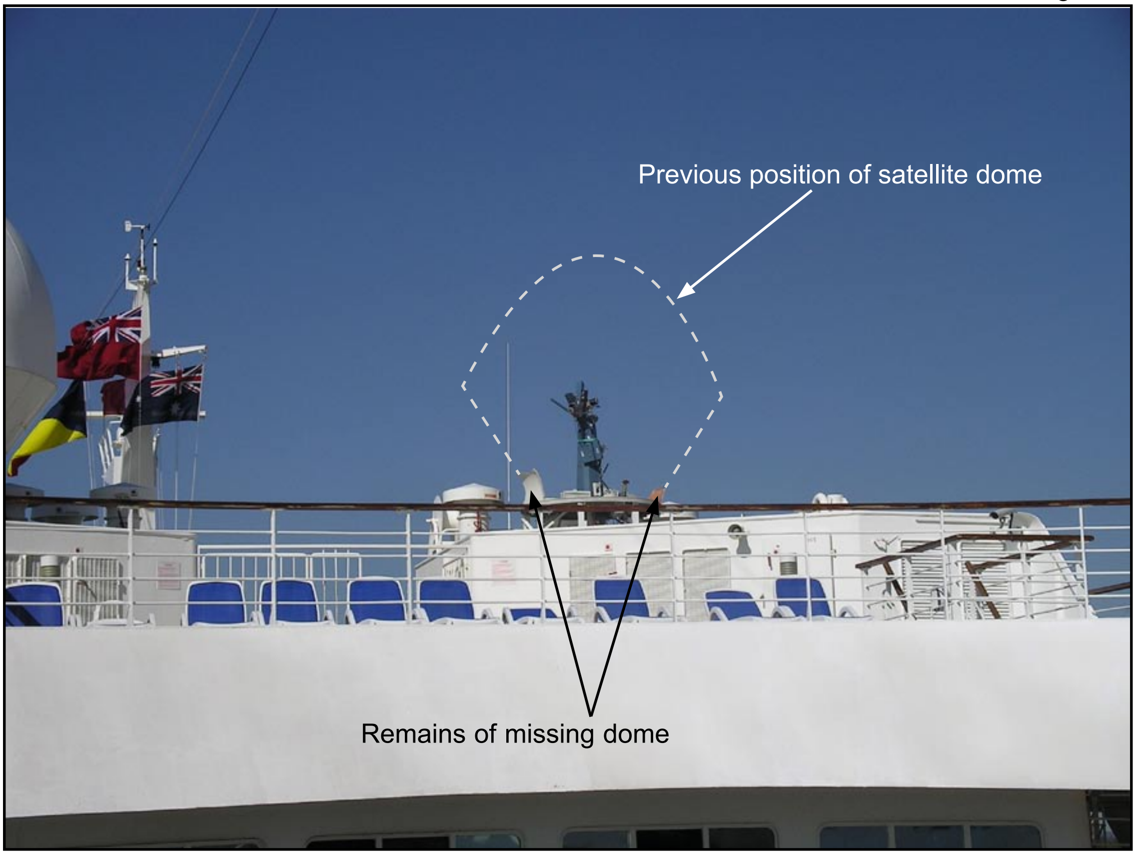
With the wind speed now reducing and the seas easing, the master decided to adjust the ship's ballast disposition to produce a port list to counteract the effect of the expected wind shift when *Pacific Star* altered course to the north west in order to regain her original intended track. At 0629, *Pacific Star* altered course to port onto a northerly heading and increased her speed. This placed the wind and sea on the ship's starboard quarter.

By 0800, *Pacific Star* was moving more easily in the prevailing sea conditions, and it became possible for the ship's staff to begin to assess the extent of the damage that had been caused by the storm. Once an initial assessment had been completed, and with satellite communications now restored, the master made a telephone call to the technical and operations departments at the company's head office in California to report the situation, and to discuss options for the ship's programme. It was decided that the ship should head directly for Port Vila, the second port on the vessel's cruise itinerary, at best speed. There, a classification society surveyor and divers would attend the vessel to determine what temporary repairs could be made. During the telephone conversation the master was also instructed to extract the Voyage Data Recorder (VDR) hard drive before arrival in Port Vila, and to send it to the company's head office for review.

The master made a further broadcast to passengers to allay any concerns about the previous night's weather and, having been awake and on the bridge all night, went to bed. He left instructions for either the staff captain or the senior first officer to be on the bridge with the junior watchkeeping officers while the weather was still poor.

In the engine room, the on watch engineer had had to pump out the starboard shaft tunnel bilge, as it had filled with water. Water was observed to be coming from within a locked store room to which he did not have the key. Since the ingress of water was not large, the engineer decided to leave further investigation of the leakage until the storekeeper began work in the morning. Once the store room was opened up, the ingress of water was found to be coming from a ventilation duct which passed through the store. The water was found to be salty. On being informed of the leak, the chief technical officer (CTO) could not find an obvious source of salt water from the ship's plans, and

Figure 3



Satellite dome position

Figure 4

Damage to forecastle bulwark

therefore concluded that the most likely cause was a leak in the hull. He instructed the ventilation engineer to remove the fan from the ducting. The ducting was of rectangular construction, and used two adjacent transverse frames and the ship's side plating to form three sides, with the duct completed by fitting a plate over the two frames. With the fan removed, it was clear that the ducting to the level of the fan was full of water. With no obvious sign of water ingress visible, the ducting was pumped dry using a portable salvage pump. Water could be seen seeping into the ship, apparently from under a large rust flake at the ship's side **(Figure 5)**. Assessing that disturbing the rust flake might cause the plate to fail, the CTO looked at alternative methods of maintaining the watertight integrity of the hull. In discussion with the staff captain and staff engineer, and aware that the classification society surveyor would be attending at the next port, it was decided to keep the ducting dry with the salvage pump, and to fabricate a blanking piece to fit where the fan had been sited. The blanking piece was loosely attached to the trunking, and a man was stationed in the area to monitor the situation. In the event that the ship's side plate failed, he was to inform the engineer on watch in the Machinery Control Room (MCR) by UHF radio, withdraw the salvage pump, swing the blank plate into position and secure it with more bolts. In this way, water would be kept within the ventilation duct.

The following day, once the rough weather had abated, the CTO made arrangements for the forepeak air pipe valve to be examined. Finding that the valve operated correctly, and noting that other tanks nearby were empty, he concluded that the only possible source of water ingress to the forepeak tank was through the ship's side plating. Aware that he may not be able to determine the source of the water ingress, the CTO nevertheless had the tank access plate removed. A visual inspection of the space, using a torch from outside the tank, revealed the source of the water ingress to be a stream of water coming through the ship's starboard hull plating, which increased and decreased in flow rate as the ship pitched in the seaway **(Figure 6)**.

On arrival at Port Vila, on Friday 13 July 2007, an underwater survey of the known areas of damage was carried out by divers. The source of water ingress to the forepeak was found to be three small holes in close proximity, and the shell plate in the vicinity of the holes was so badly corroded that it was possible for the diver to push a finger through the ship's side. Ultrasound measurements were taken in way of the leaking ventilation trunking. This measured the thickness of the side plating as 3mm, and further scraping of the corrosion on the ship's side around the area of leakage increased the rate of flow of water through the ship's side both above and below the original site. Additional damage to the hull was also found by the divers in way of No 2 deep ballast tank where a crack was discovered in a previous repair, but it was established that it had not penetrated the hull.

Once the extent of the damage to the hull had been established, the attending RINa surveyor consulted with members of the MCA survey department. It was decided that the vessel should not be allowed to sail from Port Vila until appropriate temporary repairs had been effected. Further, it was agreed that the vessel's passenger ship's safety certificate would be withdrawn but *Pacific Star* would be permitted to conduct a single voyage to a dry dock repair facility once temporary repairs had been completed.

Arrangements were then made to fly the passengers back to Auckland, and for the ship to sail to Brisbane for dry docking, where she arrived on 20 July.

Figure 5

Damage to ventilation duct

Figure 6

Damage to the forepeak tank

1.4 REPAIRS

1.4.1 Temporary repairs Port Vila (13-16 July 2007)

The following repairs were undertaken:

Forepeak tank - Doubler plate welded over the holes in the starboard side **(Figure 7)**.

No 2 deep ballast tank – Magnetic plate positioned over the crack, and the plate sealed around with epoxy cement **(Figure 8)**.

Ventilation duct at frame 31 Starboard – A cement box was fitted to the inside of the ducting. There were concerns that the ship's side would not be able to support the weight of the cement box due to the size required. A reinforcing structure was therefore constructed of 6mm bar passed through holes drilled in the frames, and welded into position to bind the cement structure and prevent it from cracking. A layer of steel mesh was placed over this framework to provide reinforcement for the cement **(Figure 9)**. Shuttering was placed inside the duct to reduce the thickness of the cement box. The blanking plate was refitted, with a drain spill and valve arrangement, so that any water ingress to the ducting could be monitored **(Figure 10)**.

1.4.2 Repairs Brisbane

Repairs to *Pacific Star* were effected in dry dock in Brisbane between 20 and 27 July **(Figure 11)**. Details of the repairs are listed at **Annex 1**.

On completion of the repairs, the ship was reissued with her passenger ship safety certificate, and she sailed from Brisbane on 27 July 2007.

1.4.3 Further damage and repairs August 2007

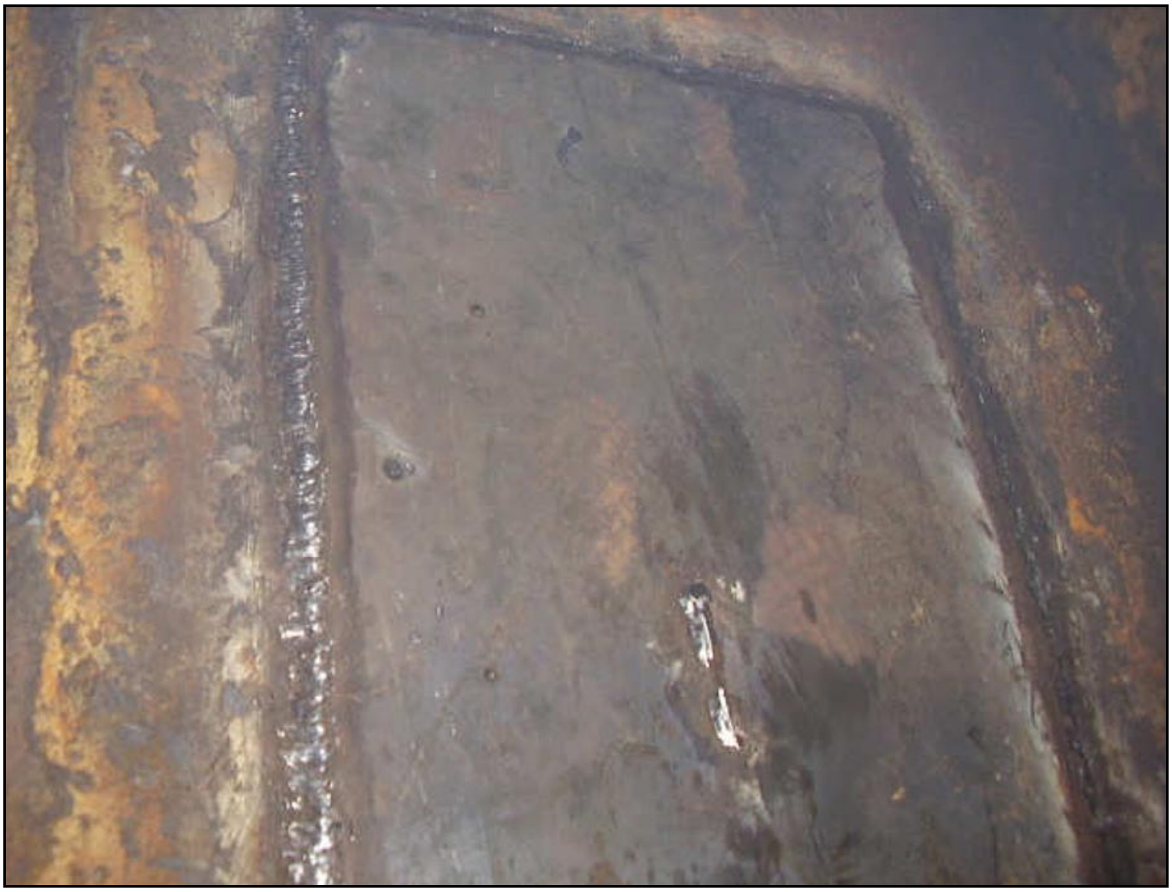
After leaving Brisbane, the ship again encountered heavy weather. At about 1600 on 6 August 2007, water was noted coming from a port side ventilation duct at frame 50 - 51. An inspection port was cut into the duct above the waterline, and on initial inspection revealed that, once more, sea water was seeping from under the surface corrosion layer of the shell plate below the waterline. This was reported to the MCA, RINa, and Maritime New Zealand (MNZ).

The ship arrived in Auckland at 0600 on 7 August and MNZ boarded the ship to carry out a scheduled 3 monthly Port State Control inspection. This inspection discovered a number of deficiencies, and *Pacific Star* was served with a condition, which required her not to depart Auckland until repairs had been effected to the satisfaction of the Flag State and classification society. The MCA directed that the ship was not to continue to carry passengers until effective repairs had been completed.

The ship therefore returned to Brisbane, and entered dry dock on 12 August 2007. At the instruction of the MCA, access panels were cut into all ventilation ducts to visually inspect the hidden areas of the internal shell plating. The following Table 1 lists the defects found and the repairs that were undertaken.

Table 1 - Repairs undertaken at second dry docking 12 – 18 August 2007		
No	**Position**	**Damage and repairs**
1	Ventilation duct Fr 50 – 51 port	Leak through ship's side detected at Auckland - shell plate cropped and renewed over 3 - 5 metres vertical extent.
2	Ventilation duct Fr 50 – 51 stbd	Area of heavy corrosion, cropped and renewed.
3	Ventilation duct Fr 31 – 32 port	Area of heavy pitting, cropped and renewed.
4	Ventilation duct Fr 40 – 41 stbd	Ultra-high pressure water washing of hull in way of previous repair resulted in further hole becoming evident. Insert plate cropped and renewed in way of hole.
5	Ventilation duct Fr 41 – 42 port	Duct opened and inspected. Some corrosion pitting evident on shell plate, no repairs undertaken.
6	Ventilation duct Fr 101 – 102 p&s	Duct opened and inspected. Some corrosion pitting evident on shell plate, no repairs undertaken.
7	Ventilation duct Fr 108 – 109 port	Large amount of scale at bottom of duct (Yard estimate 200 kg). Scale removed, and one small pinhole discovered. Area cropped and renewed.
8	Ventilation duct Fr 109 –110 stbd	Hole at bottom of trunk internal to ship. Hole sealed with doubler.
9	Ventilation duct Fr 118 – 119 port	Wastage to ship's side plate and to top of fuel oil tank 86. Doubler fitted to tank top in way of ventilation duct. Side shell and frames cropped and renewed.
10	Ventilation duct Fr 118 – 119 stbd	Duct descaled, no repair required.
11	Ventilation duct Fr 124 p&s	Opened for inspection, no repair necessary.
12	Ventilation duct Fr 145 – 146 port	Corrosion pitting – area cropped and renewed.
13	Ventilation duct Fr 145 – 146 stbd	Corrosion pitting – area cropped and renewed.

Figure 7

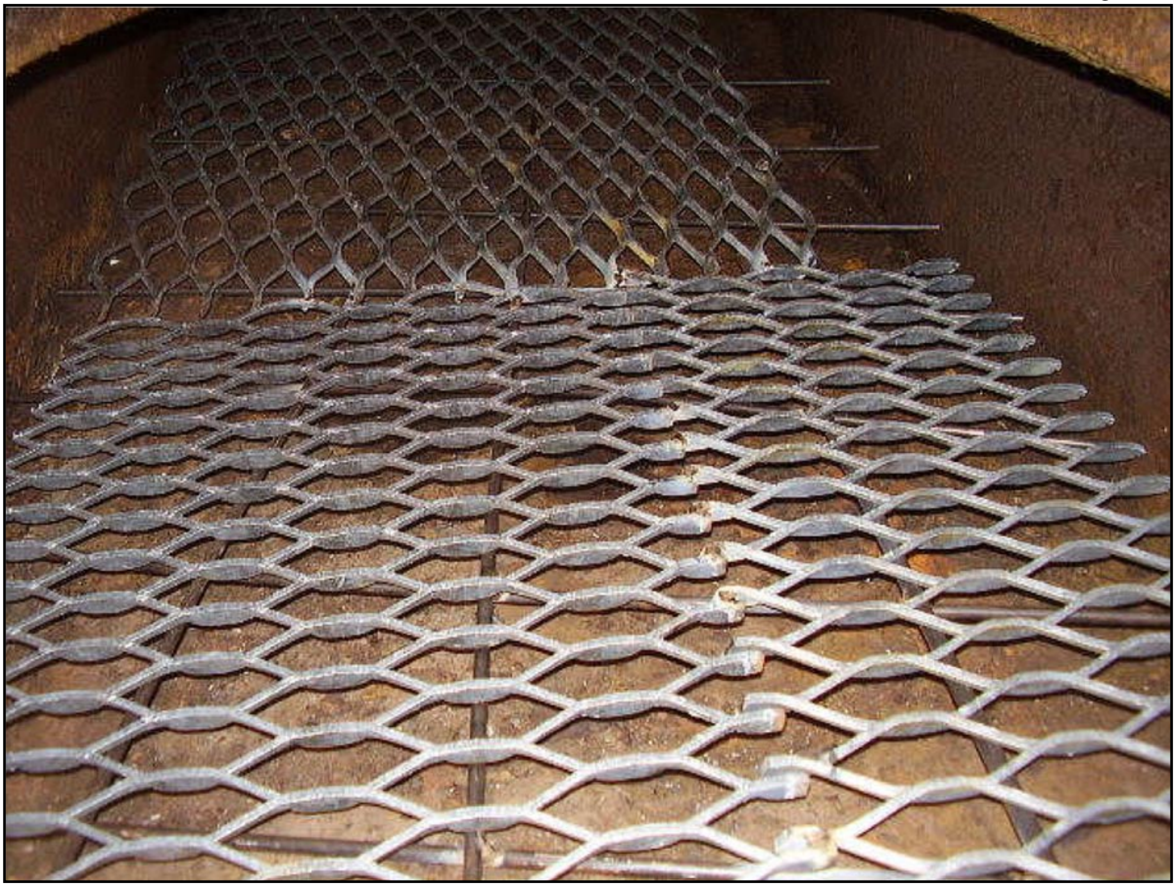


Temporary repair to the forepeak

Figure 8

Temporary repair to No.2 deep ballast tank

Figure 9



Reinforcement to cement box in ventilation duct

Figure 10

Closing of ventilation duct

Figure 11

Pacific Star in dry dock in Brisbane

All the shell plate repairs were inspected and associated welding vacuum box tested[1] by the RINa surveyors in attendance. To minimize the possibility of further corrosion, the steel which formed the internal surfaces of the ventilation ducts were coated from deck 3 to the bottom with surface tolerant epoxy sealer. The ship sailed once all the repairs to ship side plating had been completed, on 18 August 2007.

1.4.4 Previous inspections of ventilation ducts

When, in 2005, *Pacific Star* transferred from the Italian to the UK ship register, and Princess Cruises assumed management control over the vessel, a specialist steel surveyor was employed to inspect the hull. This occurred while the vessel was in dry dock and also subject to a routine 'special'[2] survey by the classification society, during which an extensive set of steel thickness measurements were taken using ultrasound equipment. As a consequence, a number of repairs were carried out including the renewal of the closing plate of 12 ventilation ducts and the partial renewal of 4 other ducts.

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[1] The vacuum box test is performed on extrusion welds and welds on thick films and supported materials. The seam is flooded with soapy solution and a vacuum box placed over the top. A vacuum is drawn on the box and the operator views the seam area through a viewing port. A stream of bubbles will indicate any discontinuities in the seam.

[2] Special Survey: enhanced inspection by classification society condition. Conducted during periods of dry dock every 5 years.

1.5 WEATHER REPORTS

Meteorological Service of New Zealand Ltd (MetSevice) prepares, publishes and archives daily meteorological Mean Sea Level analysis charts every 6 hours from 0000 UTC. The analysis area covers from the Equator to near the South Pole, and from about 100º East longitude in the South Indian Ocean to about 120º West longitude in the South Pacific Ocean. Analysis charts covering a sub-area approximately 20º South to 50º South latitude, and 140º East to 160º West longitude were provided for the MAIB.

MetService is responsible for issuing forecasts and warnings for the high seas between 150º East longitude and the east coast of Australia, and 120º West longitude and south of 25º South latitude; all sea areas up to 60 nautical miles from the New Zealand coast and for selected inshore and harbour areas. These forecasts and warnings are also archived and were made available to the MAIB.

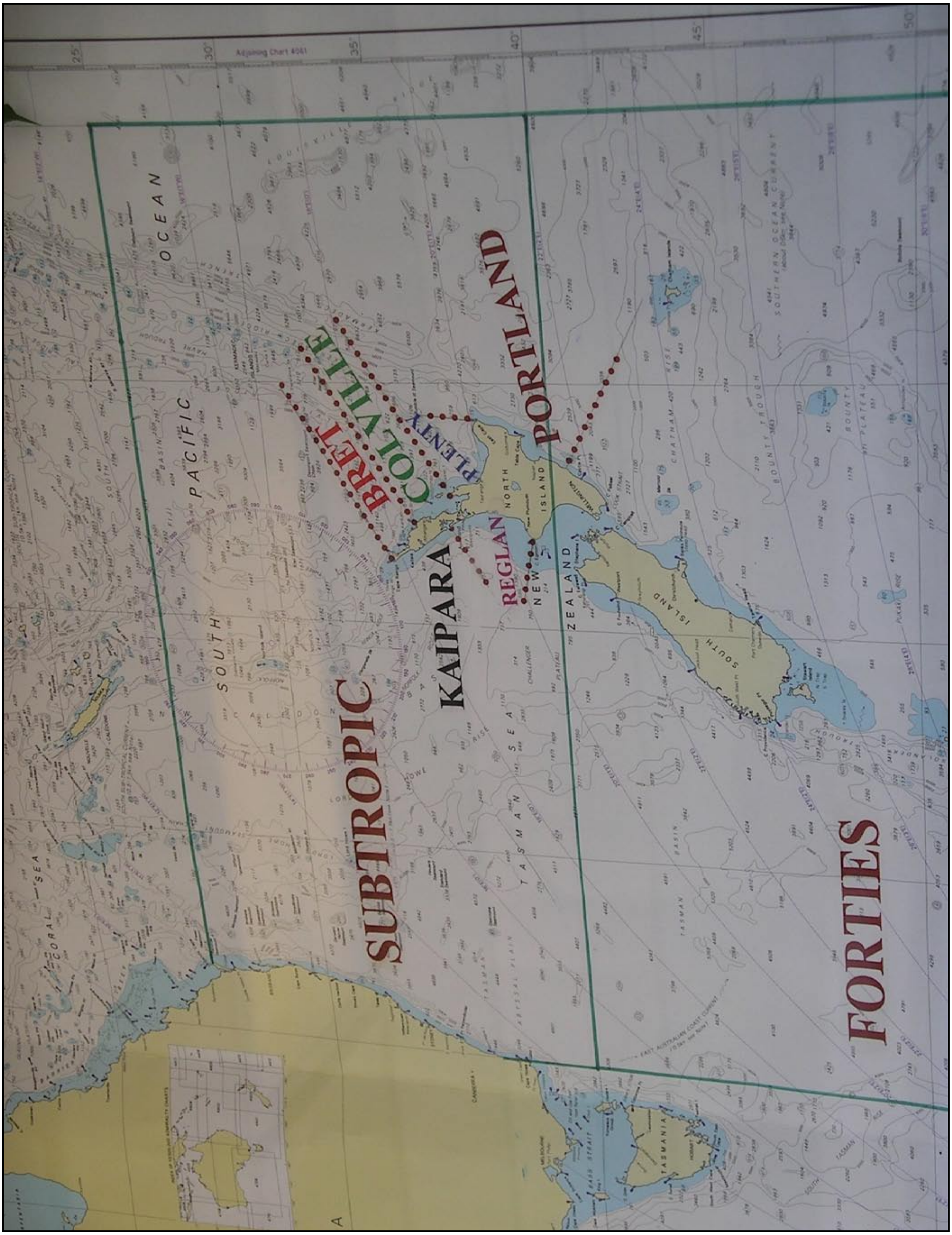
Further information was made available to the MAIB in the form of data from automated weather stations around Auckland Harbour, the Hauraki Gulf and some offshore islands; weather reports from ships at sea; and contour maps created from a wave analysis and prediction system.

A précis of the forecasts, warnings and observations is contained in **Annex 2**. Auckland Harbour is in sea area Colville, and *Pacific Star* also intended to pass through sea area Brett **(Figure 12)**. The data for these two areas only are included in the annex.

The gale warnings in force for area Colville were upgraded to storm warnings in the Marine Weather Bulletin issued at 1257 on 9 July 2007. This same forecast warned of 50 knot gusts in the afternoon of 10 July. The forecast issued at 1652, 9 July increased the expected wind speed for the afternoon of 10 July to 60 knots.

Pacific Star arrived in Auckland at 0700 on 10 July, in gale force wind conditions. A forecast issued at 0436 that morning indicated wind speeds of 40 to 50 knots and seas of 5m in height, with the low pressure system to the north of the island deepening during the day. The outlook estimated that the wind would start to moderate on the night of 11 July. Forecasts issued throughout the day, and received on board, showed little change to the forecast. However they did indicate the formation of a second low pressure area, combining with the initial low to form a complex depression. The forecast remained as 50 knots gusting to 60 knots for the afternoon, and the storm warning for area Colville remained in force. At 1527 an inshore weather forecast was issued, indicating gusts to 75 knots in Hauraki Gulf, but easing overnight. The 1628 coastal waters forecast maintained the storm warnings for both sea areas Colville and Brett. However, in area Colville, the wind was now predicted as 65 knots easing to 55 knots by morning. The Recreational Marine Forecast issued at 1647 for the sea area Bream Head to Cape Colville indicated the wind was expected to be easterly 65 knots gusting to 80 knots. This was amended at 2024 to indicate that, in the Hauraki Gulf north of Whangaparaoa Peninsula, the wind would be 65 knots gusting to 85 knots.

Figure 12



Photograph of chart on the bridge showing sea forecast areas

A long-wave monitoring system at Marsden Point had been providing data for 37 months. The report for the month of July 2007 centres on the storm of 10 July 2007. This report is included at **Annex 3**, and indicates that the wave heights were the largest that had been measured since the system was installed in 2004. The wave measuring buoy was washed away during the storm, and it is not clear if the wave height had peaked before this event occurred. However, analysis of data received from other monitoring buoys indicates that the storm peaked at around 2100, and this is supported by the observations of wind speed taken on board *Pacific Star.*

1.6 THE PORT OF AUCKLAND

The Auckland Regional Council Harbourmaster's Office (ARCHO) is responsible for the safety of navigation within the region's waters. Operational wind limits for vessels berthing at the commercial wharves of the Port of Auckland have been approved by ARCHO, and are based on the physical size and characteristics of a ship and the specific berth in use. Movement of a ship to or from a berth, when the wind conditions are outside these limits, is prohibited.

For the Princes Wharf, the operational limits are defined as follows:

> *Vessel greater than 150m and less than 240m long, wind peak greater than 45 knots, vessel may not sail unless authorised by Harbourmaster, Marine Services Manager and Senior Pilot. In addition to this, for all vessels, where the average wind speed is greater than 30 knots, the senior pilot is to review all movements, the tugs are to be manned and on standby, and a pilot posted to the pilot station. With the average wind speed greater than 35 knots, senior pilot is to review all movements, the tugs are to be manned and on standby, a pilot posted to the pilot station, and all departing vessels of greater than 80m to have two tugs assisting.*

1.7 CREW

Pacific Star was operating with a crew of 543. The majority of the staff were employed in the hotel department, and their jobs were to provide services for the passengers, such as cabin cleaning, restaurant service, bar and casino staff, entertainers and security. The bridge watches were a traditional 4-on, 8-off pattern, with the two second officers carrying out the 8-12 and 12-4 watches, and the two first officers sharing the 4-8 watch. This allowed the first officers to carry out their other duties elsewhere on the ship.

1.7.1 The master

The master of *Pacific Star* was 50 years old and had been at sea for 34 years. He had served on passenger ships since completing his cadetship with P&O in 1978. He had been master for 4 years on a number of ships within the fleet, and had been on *Pacific Star* for 6 weeks. This was the first time he had been on this ship. The first 3 weeks of his tour of duty had been spent working alongside the outgoing master to familiarise himself with the ship's operation before taking over command.

The master could cite two occasions during his time in command of passenger vessels when he had found it necessary to keep his vessel in port to avoid sailing into extreme weather conditions.

1.7.2 Crew experience

Table 2 lists the experience in rank and the time on *Pacific Star* for key officers.

Table 2 Experience of officers on board *Pacific Star*		
Position	**Experience in rank**	**Time on the ship**
Master	4 years	6 weeks
Staff Captain	2 weeks	2 weeks
Senior First Officer	1 week	3 weeks (2 week handover)
First Officer	8 months	16 months
Senior Second Officer	2 years	3 months
Second Officer	8 months in company	3 months
Chief Technical Officer	2 months	3 months (2 month handover)
Staff Engineer Officer	15 months	2 years

1.8 SAFETY MANAGEMENT SYSTEM

Pacific Star's management system had been developed by P&O/Princess, and was generic to ships operated by Princess Cruises and Carnival UK ships trading as P&O Cruises Australia, P&O Cruises UK, Cunard Lines and Ocean Village.

1.8.1 Planned maintenance and defect reporting

As required by sections 9 and 10 of the ISM Code, P&O/Princess had established a robust system of planned maintenance based around a computer software system. This was designed to ensure that ships within its fleet were maintained in conformity with national and international rules and regulations, and to ensure that the validity of certification was maintained.

The system enabled ship's staff to log and track the status of defects.

1.8.2 Passage planning

P&O/Princess's SMS procedure required that passage plans were prepared before any voyage commenced. These were 'berth to berth' passage plans and, while it was the master's overall responsibility to ensure these were prepared to an acceptable standard, they were normally produced by the 1st Officer. The SMS required that all deck officers were made aware of the contents of the passage plan before the vessel left her berth. Accordingly, a navigational briefing was conducted on 9 July before *Pacific Star*'s arrival in Auckland (Section 1.8.3 refers).

The SMS did not provide specifics on how to construct a plan, but listed the information that should be included in the plan and advanced the general principles to be followed. The instructions also referred to The Nautical Institute publication *Bridge Team Management - A Practical Guide,* which had been provided to all ships in the P&O/ Princess fleet. This publication includes detailed instructions for, and examples of, how to plan a passage. The guidance contained in this publication is in accordance with SOLAS Chapter V regulation 34 (Safe Navigation and Avoidance of Dangerous Situations), IMO resolution A893(21) Guidelines on Voyage Planning, and Annex 24 to the MCA publication “SOLAS, Guidance on Chapter V – Safety of Navigation”.

The original plan drawn up before the ship sailed had included all the required information, and had identified contingency plans for unforeseen eventualities during the pilotage when departing from Auckland. Once clear of the port, the plan incorporated a tried and tested planned track to the north.

Once clear of Auckland, when it was recognised by the master that the planned track to the north would expose *Pacific Star* to very strong winds on the beam, he ordered a change in the passage plan to keep the wind on the vessel’s starboard bow. The revised plan was carefully considered. Reviews were made of: the weather forecast to estimate the rate at which the wind was likely to veer; the chart to consider possible routes out of the Hauraki Gulf; and the charts and the sailing directions to consider any dangers in the alternative routes proposed.

1.8.3 Navigational briefing

The SMS required the first officer, in consultation with the master, to hold a briefing meeting for all deck officers covering the passage plan, port approaches and pilotage plans. Where the ship was engaged in a regular cruise circuit, this briefing was allowed to take the form of a general briefing at the commencement of the cruise, and thereafter take place when there was a change to personnel within the bridge team, a change to the ports visited, or a significant change to the plan. The SMS required that these briefings be attended by all bridge watchkeeping officers.

A checklist was to be completed for the briefing, and this was designed to act as an aide mémoire for the briefer to ensure that all salient points were discussed. On *Pacific Star*, a navigational briefing in accordance with the instructions was held on 9 July 2007, and included a review of the plans for arrival and departure from Auckland, the ports of the next cruise, and arrival back in Auckland. Significant discussions during this briefing included the weather forecast, and the securing of the ship for the forecast conditions.

1.8.4 Heavy weather routine

The ship’s heavy weather routine was incorporated into the SMS and contained two parts: general instructions and a checklist. The general orders directed the master to give instructions at the earliest opportunity to have the ship totally secured, and for all departments on board to secure loose gear. It also required entries to be made in the deck logbook, detailing when the precautions were complete, and when an announcement to passengers had been made to warn of heavy weather. The Heavy Weather Checklist is at **Annex 4**. This was completed on sailing from Auckland, with storm shutters fitted initially to the windows in 13 cabins on the starboard side forward on deck 5, and all the deadlights on decks 3 and 4 closed. The storm shutters were later moved to the port side forward once the ship had altered course on the morning of 11 July. The required announcements to passengers had been made, and entries to that effect were made in the bridge logbook. Signs, consisting of black writing on a yellow background, warning passengers of high winds, had also been placed on doors to the upper deck.

1.9 SHIP SURVEY

SOLAS requires a passenger ship engaged on international voyages to be subject to the following surveys:

a) An initial survey before the ship is put in service

b) A renewal survey once every 12 months

c) Additional surveys as occasion arises.

Additionally, regulations contained in SOLAS and MARPOL provide for an administration to entrust inspections and surveys to nominated surveyors or recognised organisations. IMO Resolution A739(18), *Guidelines for the Authorisation of Organisations Acting on Behalf of the Administration*, was adopted in November 1993, and was designed to ensure that common procedures were adopted by Administrations, to promote uniformity of inspections and maintain established standards. Appendix 1 of this Resolution describes the minimum standards for recognised organisations acting on behalf of the Administration. Appendix 2 lists the elements to be included in an agreement between the Administration and recognised organisation.

IMO Resolution A789(19), *Specifications on the Survey and Certification Functions of Recognised Organisations Acting on Behalf of the Administration*, lays down the minimum specification for organisations recognised as capable of performing statutory work on behalf of the Flag State Administration in terms of certification and survey functions connected with the issuance of international certificates. The specification is divided into four modules which cover the required functions of survey and certification: Management, Technical Appraisal, Surveys, and Qualifications and Training.

These two resolutions define the methodology to be employed should a Flag State Administration decide to delegate certain survey functions.

European Council Directive 94/57/EC of 22 November 1994, on common rules and standards for ship inspection and survey organisations and for the relevant activities of maritime administrations (as amended), introduced a free market ideal to ship survey, in that a suitably qualified and experienced organisation cannot be prevented from supplying its services within the European Community, provided that a Member State has decided to delegate such statutory duties. However, a Member State may restrict the number of organisations it recognises, based on its needs and on transparent and objective grounds. It refers to the IMO guidelines in Resolution A847(20) *Guidelines to assist flag States in the implementation of IMO instruments*, and lays out the procedure for authorisation and monitoring an organisation.

The requirements of Council Directive 94/57/EC were implemented in the UK by The Merchant Shipping (Ship Inspection and Survey Organisation) Regulations 1996 (SI 1996/2908), and entered into force on 31 December 1996. These regulations include a requirement for the organisation to have local representation in the UK, and lay down the duties of the recognised organisations. The regulations also make a distinction between recognised and authorised organisations. Recognised organisations are those recognised by a Member State of the European Community, while authorised organisations are those recognised organisations authorised by a written agreement with the MCA.

Merchant Shipping Notice M 1672 (as amended) sets out the criteria for implementation of Council Directive 94/57/EC, and lists the six classification societies authorised by the UK. Included in this list is RINa, which was the classification society for *Pacific Star*.

1.9.1 Classification societies

Classification societies are non-governmental organisations that promote the safety of shipping and protection of the environment. A classification society will set technical rules for the construction of vessels, and carry out periodic surveys to ensure that the rules continue to be met. Originally, the classification society was designed to give an independent review of the condition of a ship's hull and machinery such that a decision could be made by insurance underwriters on the risk involved in insuring that ship. The original intention has not changed, but the scope of work of the classification society has increased to include research into new ship design, and the development of technical safety standards for these new designs. Flag states may delegate certain survey requirements to the classification societies (see Section 1.9).

However, classification societies are not guarantors of the seaworthiness of a ship, because the classification society has no control over the ship's operation, or the maintenance between periodic surveys. The RINa class rules state:

> *Class assigned to a ship reflects the discretionary opinion of the Society that the ship, for declared conditions of use and within the relevant time frame, complies with the Rules applicable at the time the service is rendered.*

There is no international requirement for a ship to be registered with a classification society, since all the requirements for structural strength and compliance with legislation are enforced by the Flag State. SOLAS Chapter II-1, Part A-1, Reg 3-1 requires that ships must be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society which is recognised by the Administration in accordance with the provisions of regulation X1-1/1, or with applicable national standards of the Administration which provide an equivalent level of safety. However, there are advantages to having a ship in class, which include the fact that a class certificate provides documentary evidence that the ship is in compliance with society rules, and this evidences the status of ship's structure and machinery for insurers, bankers, crew, passengers, shippers, port authorities etc.

1.9.2 International Association of Classification Societies (IACS)

IACS consists of ten member classification societies and one associate member society, representing more than 90% of world cargo carrying tonnage. The purpose of IACS as stated in its charter is:

> *To work towards the improvement of standards of safety at sea and the prevention of pollution of the marine environment, to provide for communications and co-operation with relevant international and national maritime organisations and to co-operate closely with marine industries of the world. Each Member of Society is to promote the aims which the Association holds in common. Activities by Member Societies which are not associated with this purpose shall not fall within the jurisdiction of this charter.*

Membership of IACS is designed to provide an assurance of integrity and high standards, and these are maintained through a code of ethics and effective application of internal quality assurance. Membership of IACS requires compliance with the IACS Quality System Certification Scheme (QSCS), and this scheme requires the member society to be regularly audited by IACS. IACS procedures are defined under Unified Requirements (UR) or Procedural Requirements (PR), covering subjects such as training and qualification of surveyors (PR7), thickness measurement (PR19), strength of ships (UR S) and materials and welding (UR W). Uniform Interpretations (UI) are also issued to provide uniform interpretations of convention regulations and IMO resolutions where the wording is vague or allows interpretation to the satisfaction of an Administration. RINa is a member of IACS.

1.9.3 Delegation of responsibility for survey

A UK registered passenger ship is subject to an annual renewal survey of the Passenger Ship Safety Certificate, and annual inspection by her classification society. These surveys confirm the continued acceptable standards for, among other items, the condition of the hull. Since 2003, RINa has been permitted to conduct the hull survey on behalf of the MCA. However, the MCA reserves the right to carry out its own surveys if it considers it necessary, and retains certain parts of the survey for issue of the Passenger Ship Safety Certificate (PSC), such that a full survey of all required items is carried out each year. Ideally, the MCA and RINa surveyors attend a ship due for survey together so as to be able to discuss the results of their respective parts of the survey, and any concerns they may have with them. It also enables the MCA surveyor to maintain an overview of the actions of the RINa surveyor during the survey. This was difficult to arrange in the case of *Pacific Star*, with the individual surveys occurring on different occasions, so the MCA had no oversight of the RINa surveys while they were in progress.

The extent to which RINa was able to survey vessels on behalf of the MCA is described in a document entitled *Agreement governing the delegation of statutory functions and certification services for vessels registered in the United Kingdom between the United Kingdom's Maritime and Coastguard Agency and RINa.* This document defined the scope, terms, conditions and requirements of the delegation. For different classes of vessel, the document detailed the particular regulations against which RINa was authorised to survey on behalf of the MCA. When surveying passenger ships, RINa was granted a partial authorisation by the MCA, which covered the following regulations:

M.S. (Guarding of Machinery and Safety of Electrical Equipment) Regulations

M.S. (Hatches and Lifting Plant) Regulations

M.S. (Automatic pilot and Testing of Steering Gear) Regulations

M.S. (Survey and Certification) Regulations, as amended

M.S. (Fire Protection: Large Ships) Regulations, as amended

M.S. (Passenger Ship Construction: Ships of Classes I, II and II(A)) Regulations

M.S. (Passenger Ships on Domestic Voyages) Regulations, as amended.

The MCA retained responsibility for the survey of:

- All fire protection systems
- All lifesaving appliances and arrangements
- Crew accommodation (to ensure compliance with international conventions)
- Passenger accommodation (to ensure compliance with international conventions)
- Navigation lights, equipment and aids and compasses
- Functional testing of emergency controls: closing devices, remote stops, other distant controls (including oil fuel and lubricating oil tank outlet valves), location of controls for sea inlets, discharges and bilge injection
- Pilot, bulwark and accommodation ladders
- Point of access; pilot hoist
- Radio equipment and personnel
- Sprinkler, drencher and water spraying systems (normal and emergency power supplies)
- Functional tests of emergency power supplies
- Plans and particulars (re damage stability) for bilge pumping
- Certain aspects of hull and watertight subdivision i.e. spacing and location of watertight bulkheads etc., openings in bulkheads and decks including penetration by piping systems, means of closing openings in watertight and weathertight bulkheads, watertight spaces within watertight compartments, watertight doors, intact and damage stability and damage control plans.

Passenger Ship Safety Certificates continued to be issued by the MCA on the basis of a Declaration of Survey signed by RINa and the MCA.

A PSC for *Pacific Star* was issued by the MCA on 11 December 2006 following surveys by both the MCA and RINa. Having completed the survey of his areas of responsibility, the RINa surveyor signed a *Partial Declaration of Survey of a Classed Passenger Ship (Hull and Machinery)* on 11 October 2006, which included the following declaration:

> *I declare that on 11 October 2006 the items indicated below complied with the relevant UK legislation (subject to the exemptions granted by the MCA/DTLR); were in satisfactory condition; sufficient for the service intended and should remain so until 26 December 2007 (last range date of Annual inspection)*

The items indicated were hull construction and structure, main and auxiliary engines, main and auxiliary boilers (date of last examination 20 June 2006), bilge pumping arrangements, electrical equipment and installations, and steering gear. Included with the declaration was a printout of the survey status of the ship, including any class recommendations in force.

1.9.4 Previous problems with shell side ducts

In March 2003, a ship of similar construction to *Pacific Star*, and operating with the P&O/Princess fleet, suffered a failure of the ship's side plating in way of a downflooding duct. Although designed for a different purpose, the construction of the downflooding duct was identical to the ventilation ducts of *Pacific Star,* in that the forward and aft faces were formed by the transverse frames of the ship, the inboard side was a plate welded across the top of the frames, and the outboard side was the ship's shell plating. The ship was not classed by RINa at the time, but by another member of IACS. Recognising that the design of this type of duct meant that the internal surfaces could not be surveyed, the classification society concerned issued instructions to its surveyors to ensure that the ducts were opened up for inspection during survey. Further instructions were given for future ship design to include inspection plates in the duct at each deck to allow for thorough inspection and survey.

This information, although available to one society's inspectors, was not promulgated among the classification societies, so surveyors from other societies were not aware of the problem.As a result of this incident, P&O/Princess introduced an inspection procedure for downflooding ducts, which was included in its computerised planned maintenance system. However, the scope of the procedure was not expanded to include other ducts of similar construction, e.g. ventilation ducts.

1.10 PORT STATE CONTROL INSPECTION

The responsibility for compliance with the provisions of national and international legislation rests with the shipowner /operator. The Flag State is responsible for enforcing compliance and, where authorised, recognised organisations carry out surveys and issue certificates on their behalf. However, it is an unfortunate fact that not all shipowners/operators carry out their responsibilities, and not all flag states ensure compliance. The result is that there are some ships at sea in an unsafe condition, threatening the lives of those on board as well as the marine environment.

In order to reduce the number of sub-standard ships at sea, a group of initially 14 European Countries signed the Paris Memorandum of Understanding (MoU) on Port State Control. The MoU is a system of harmonised inspection procedures designed to target and subsequently eradicate sub-standard ships. Ships are targeted for inspection according to a points system. More points are awarded for older ships, from less reputable flags with a poor inspection history, and for those ships which have not been inspected for more than 12 months. The higher the number of points, the more likely it is that a ship will be inspected. The inspection is intended to confirm compliance with the following internationally accepted instruments:

- International Convention on Load Lines 1966, as amended, and its 1988 Protocol, (LOADLINES 66/88);
- International Convention for the Safety of Life at Sea (SOLAS), 1974, its Protocol of 1978, as amended, and the Protocol of 1988, (SOLAS 74/78/88);
- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978, as amended (MARPOL 73/78);
- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended (STCW 78);

- Convention on the International Regulations for Preventing Collisions at Sea 1972, as amended (COLREG 72);
- International Convention on Tonnage Measurement of Ships 1969 (TONNAGE 1969);
- Merchant Shipping (Minimum Standards) Convention, 1976 (ILO Convention No. 147).

Should a Port State Control inspection reveal serious deficiencies, then the ship will be detained in port until the deficiencies are rectified.

Since the establishment of the Paris MoU, other groups of countries have agreed regional MoUs with a similar purpose and scope (Table 3). Some countries are signatories to more than one MoU, where they are located within the area covered by different MoUs.

Table 3 – Memoranda of understanding for port state control

	Number of Authorities	Area	Year of introduction
Paris	27	Europe and Atlantic basin	1982
Tokyo	18	Asia/Pacific	1993
Caribbean	25	Caribbean	1996
Acuerdo de Vina del Mar	13	Latin America	1992
Indian Ocean	13	Indian Ocean	1999
Mediterranean	10	Mediterranean	1997
Black Sea	6	Black Sea	2000
Abuja	19	West and Central Africa	1999
Riyadh	6	The Gulf region	2004
(USCG)		No MoU but carries out inspections of ships	

1.10.1 Port state control inspection of *Pacific Star*

Pacific Star had been inspected by Tokyo MoU PSC surveyors seven times since registration under the UK flag in December 2005. The first five inspections occurred at variable intervals between 27 December 2005 and 23 January 2007, and the last two in April 2007. At none of these inspections was the ship detained, however deficiencies were identified and re-inspected at follow-up inspections, as required by the MoU. None of the deficiencies raised any questions over the structural condition of the vessel.

Under the Tokyo MoU, the authorities concerned generally avoided inspecting a vessel which had been inspected in the previous 6 months. The targeting factor was weighted against those ships which had not been inspected in the last 12 months. However, the inspection interval was adjusted for vessels that registered a High Risk. *Pacific Star* was defined as High Risk, mainly due to the numerical weighting given to the ship's age (29 of a total of 42 points overall). This meant that the interval between inspections for this ship was generally less than 6 months.

1.11 NON-DESTRUCTIVE TESTING

Non-destructive testing (NDT) could be described as *testing that does not destroy the test object*. In the marine environment, NDT is regularly used to provide thickness measurements of component parts of the ship's structure **(Figure 13)**. A ship is designed to have certain minimum dimensions (or scantlings) for the material used in its construction, to provide sufficient strength. Classification societies recognise that a ship made of steel will corrode over time, so rules have been established to allow a certain reduction in the scantlings before a part of the ship's structure must be replaced. To assess the thinning of the metal, NDT is used, the most common of which is ultrasound testing.

Figure 13

Non-destructive testing in dry dock, Brisbane

Ultrasound testing uses short pulses of high frequency sound waves. A transducer is held against the surface of the material and pulses of sound enter the test material. The pulse of sound is reflected by the back wall of the test piece, and received back at the transducer. The time interval between transmission and reception is directly related to the thickness. This method is particularly useful in the marine environment, since it only requires access to one face of the test piece, and the equipment can be highly portable and can give accurate results. However, operation requires careful attention by trained technicians, who must have the technical knowledge to carry out the test; importantly, without careful assessment of the item being tested, the thickness measured may include the thickness of paint and scale.

A number of organisations, such as the British Institute of Non-Destructive Testing (BINDT), and The American Society for Non-Destructive Testing (ASNT) provide examination and certification systems for NDT technicians, including refresher courses, which will lead to, and maintain, qualification. Under the BINDT system the candidate works towards Personal Certification in Non-destructive Testing (PCN) at two levels, with examination approved at centres worldwide. The ASNT system is similar and, again, available worldwide, but has three levels of certification.

IACS members approve thickness measuring companies, based on the qualifications of their employees and the quality systems in place. IACS maintains a list of these approved companies. Approval indicates that the company will have suitably qualified personnel (examples being the BINDT PCN and the ASNT certificate), and that the working practices and schemes are of a suitable standard. Many companies are approved by more than one classification society, and the individual approval by a society is dated with a maximum lifespan of 5 years.

IACS provides a Procedural Requirement for Thickness Measurement (PR19). This procedure covers a requirement for initial meeting and briefing of the tester, what must be reported to the surveyor immediately (e.g. weld corrosion, buckling or deformation of the structure etc.), and the routine to be adopted for additional gauging.

1.12 PASSENGER QUESTIONNAIRES

Following the accident, the MAIB sent a total of 106 passenger questionnaires to passengers, picked at random from the passenger list provided by Princess Cruises. This represented 336 passengers. Of the questionnaires sent out, 40 were completed and returned, and 2 were returned “not known at address”.

The reports from passengers showed that in general they felt that the master and ship’s staff kept them informed of the situation. Specifically, the replies mention the master’s pre-sailing announcement, and the instructions to be careful while moving about the ship. The master’s announcement following the storm on the morning after sailing from Auckland was also notable since he stated that it was the worst storm he had ever experienced. Many of the returns mention that one or more of their party were sea-sick, and that anti-sea-sickness remedies were available from the medical staff.

Overall, the passenger questionnaire returns indicate that the passengers were kept informed of the situation, and were content with the actions taken by crew and shore staff.

SECTION 2 - ANALYSIS

2.1 AIM

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

2.2 DAMAGE TO THE SHIP

Apart from the breaking of a number of fixtures and fittings, the most significant damage to the ship was the exacerbation of pre-existing corrosion damage in way of the forepeak tank and a ventilation duct. Pre-existing corrosion damage in a number of other ventilation ducts was subsequently identified. This is discussed further in Section 2.5.

The satellite communications dome was designed to withstand a wind speed of 100 knots, which is rarely encountered. The maximum relative wind speed observed during the incident was 95 knots, but it is not known at what stage the dome failed. The satellite dish was then exposed to the elements until it, too, failed. If it is accepted that the dome failed at or near the peak of the wind speed, not accounting for any shock loading on the mounting due to ship movement, then the dome failed within 5% of its designed maximum wind speed parameter.

Glass for windows and side scuttles on ships is required by the MCA to conform to British Standards BS MA 24 or BS MA 25, or the equivalent International Standards ISO 1751 and ISO 3903. The glass inspected by the MAIB was marked as compliant with the standards. It is clear from reports received by the MAIB that the windows that broke did not do so as a result of impact, but rather as a result of the strain imposed on them by the movement of the ship during the storm. This is evidenced by the fact that the majority of the broken windows, although crazed, did not fall apart.

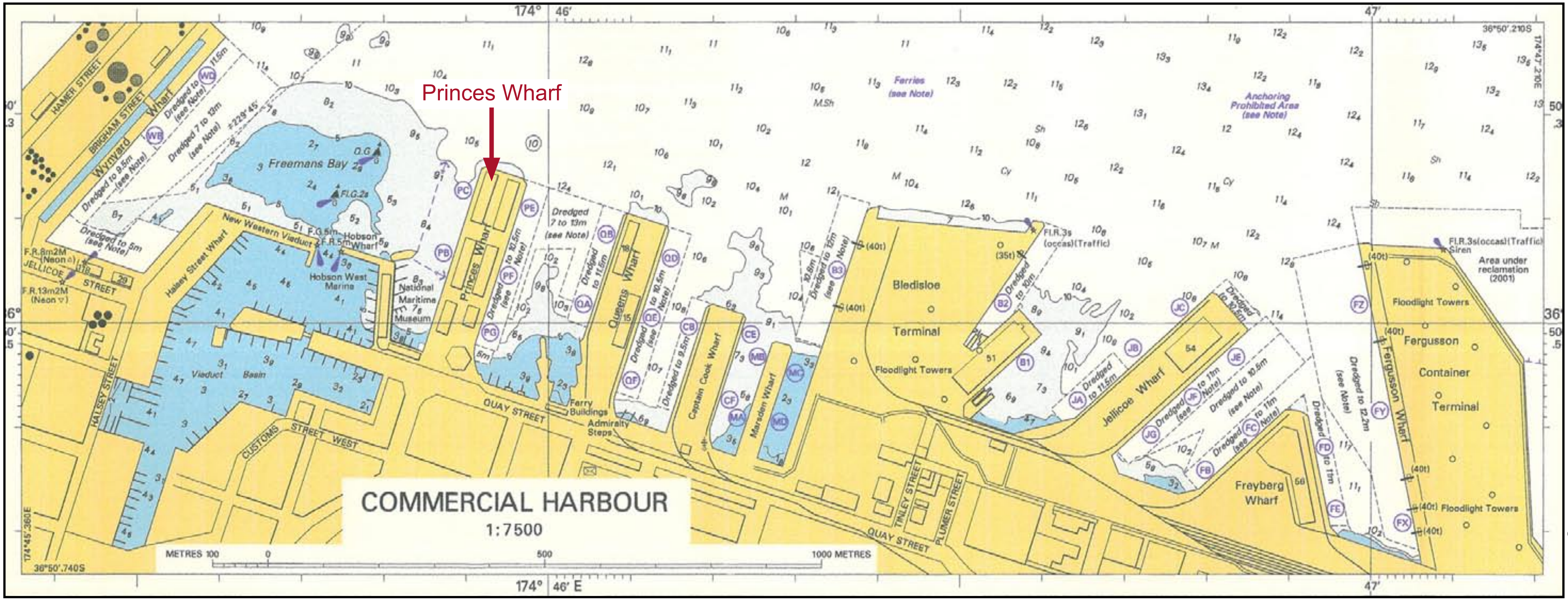
2.3 THE MASTER'S DECISION TO SAIL

Had the ship remained in port, then the rough weather conditions would not have been encountered, and the subsequent damage to the vessel avoided. The appropriateness of the master's decision to sail therefore requires analysis.

2.3.1 Weather conditions

Pacific Star was lying quietly alongside Princes Wharf **(Figure 14)**, and to have remained alongside while the storm passed through the area would probably not have caused her to sustain damage, since the wind was blowing directly onto the berth, and the berth was adequately fendered. However, the ship was scheduled to sail in accordance with her itinerary, precautions for heavy weather had been taken on board, and passengers and crew had been warned to expect rough weather following departure. Although the wind speed was nearing the Port of Auckland's declared upper limit for safe operations at the berth, there was no reason for the ship not to have left the berth as planned.

Figure 14



Ports of Auckland

The company policy was such that even though there was a schedule for the cruise, should the master decide to remain alongside there was no pressure on him to sail if he believed it unsafe to do so. In fact this master had remained in port on two previous occasions on different company ships when he had considered that to sail would not have been appropriate. In this case, the master considered it safe for the ship to sail as planned.

However, once at sea and clear of the port, the wind speed recorded on board was substantially in excess of the forecast wind speed, which could not have been anticipated before sailing (see Section 2.4). The master's actions thereafter in amending the passage plan, heaving-to, and riding out the storm overnight were correct for the situation in which he found himself.

2.3.2 Condition of the ship

In deciding whether or not to sail, a master needs to take a number of factors into account, including the overall condition of the ship. In addition to the valid certification, he should be guided by his own knowledge and experience as well as those of the company and ship's staff.

Pacific Star was 25 years old. She remained in class and held valid safety certification, but her age should have raised a question in the mind of the master when he was considering whether he could prudently leave Auckland and expose his vessel to the expected severe weather conditions in the Hauraki Gulf. Her engines were also ageing, and their continued reliability, particularly in heavy weather, should have been carefully considered in evaluating whether or not to sail and in developing contingency plans.

The ship's shell doors were known to be leaking in rough weather. This was an ongoing maintenance item, and with the new seals on board a programme of renewal was in progress. The ship's hotel staff were aware of the problem, and maintained an occasional watch on the doors, mainly to clear up any water that may have entered the ship. Although in isolation not a significant risk to the safety of the ship, this was nevertheless indicative of the ship's age and the possibility of further unidentified maintenance issues.

As the ship proceeded across the Hauraki Gulf, there was a danger that, had the engines failed, *Pacific Star* would have been blown onto a lee shore on the west side of the Gulf. As happened, the turbo-blower vibration alarm activation reduced the maximum power available to half, but this was enough to maintain steerage and heading in the prevailing conditions.

2.3.3 Officer experience

The experience of key officers in rank and on board *Pacific Star* was generally limited (Table 2). This is not to suggest that the officers lacked experience, qualification or ability, only that they had not served in the rank or on board *Pacific Star* for very long.

The lack of experience of the key officers might have limited any advice they could have provided to the master, particularly with respect to the ability of the ship to withstand the forecast weather, or the potential technical problems that might be caused in the expected sea conditions.

2.3.4 Master's decision

The wind speed was within the limit for safe operations. Although *Pacific Star* was old, the master had no reason to doubt her seaworthiness. The wind that was eventually experienced could not have been anticipated. It is therefore considered that the master was justified in his decision to sail; appropriate preparations were taken for bad weather; and the master's actions once at sea were correct.

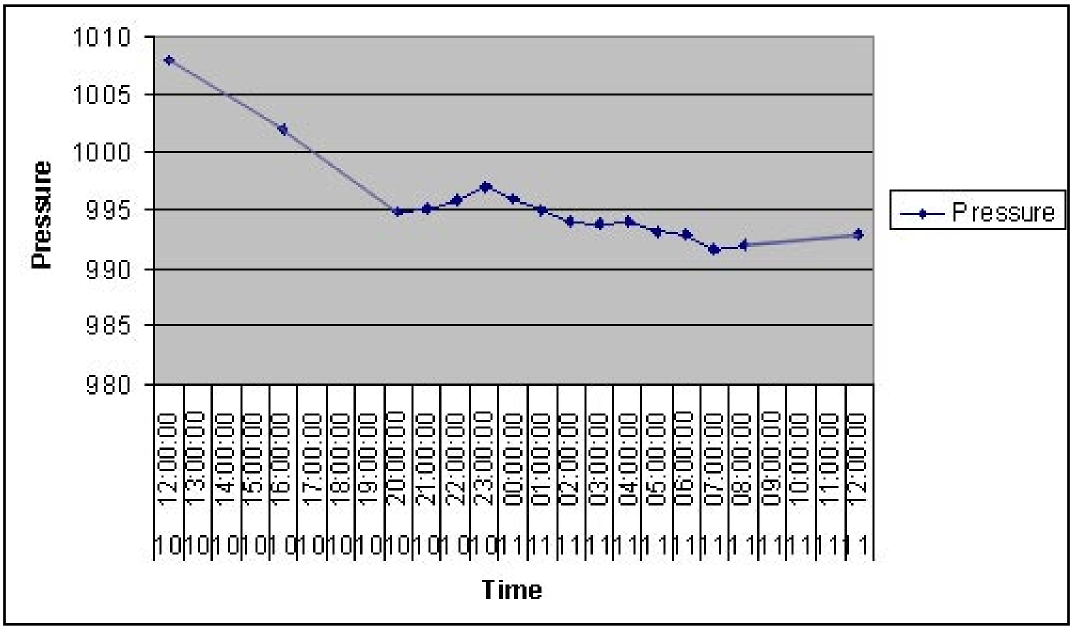
2.4 THE WEATHER

Forecast weather received on board *Pacific Star* was as detailed in Section 1.5 and at **Annex 2**. At no point before the vessel sailed from Auckland was the wind forecast to exceed 70 knots in gusts. Once at sea, the bridge watchkeeping officers of *Pacific Star* noted sustained winds of 80 knots, with gusts to 95 knots. However, for reasons unknown, the wind speeds recorded in the deck logbook reached force 10 as maximum (48 – 55 knots). The observed wind speed should have been recorded as force 12 (65 knots and above).

Wind strength is not just a function of pressure difference between one place and another. The actual pressure difference plays a part but, more importantly, the rate at which the pressure changes i.e the pressure gradient, will determine the overall wind speed. The clearest indication of a steep pressure gradient, and therefore strong winds, is depicted on weather charts as a number of isobars bunched close together. As these closely packed isobars pass over an observer, the barograph records a steep drop or rise in pressure.

Diagram 1 shows the pressure trend from 1200 on 10 July, to 1200 on 11 July 2007. This agrees with the barograph trace recorded on *Pacific Star*. Neither indicates the rapid drop in pressure that would indicate the onset of strong winds. Why was this and why were the forecast and actual wind strengths different?

Diagram 1



Atmospheric pressure 10 – 11 July 2007

From the synoptic weather charts for the days before and after the incident, two major factors can be seen to be influencing the weather **(Figures 15a and 15b)**. The developing second centre of the low pressure system to the north-west of New Zealand's North Island, and a ridge of high pressure lying across the country in a north-east/south-west line. As the low pressure approached in a south-easterly direction, it was forecast that the high pressure ridge would also move south east, but that it would not move as fast as the low pressure system, and therefore the pressure gradient would increase, represented on the synoptic charts by the bunching of isobars. The wind was therefore forecast to increase. However, the ridge of high pressure remained almost stationary. This had two effects: firstly, little change in pressure occurred at the ship; secondly the pressure gradient increased beyond that expected, resulting in much stronger winds being experienced than those forecast. From observations on board *Pacific Star* it would not have been possible to predict this.

2.5 SHIP CONDITION

The damage to the forepeak, the ventilation duct at frame 30-31 and subsequently to other ventilation ducts, occurred because of long term corrosion in these areas, thinning the plate to a thickness where there was no longer sufficient strength in the material to contend with the additional stress caused by the heavy weather.

2.5.1 Design

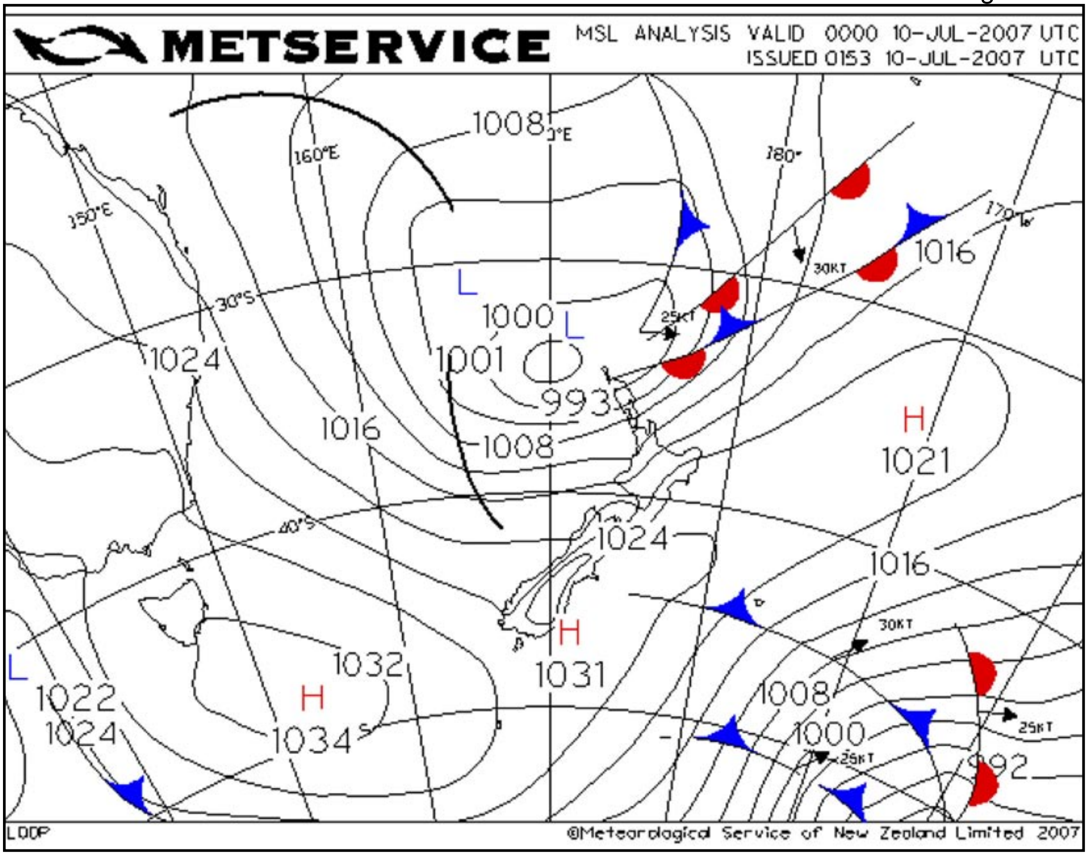
It is uncommon for a ship of this size to have been designed with transverse framing. However, the design met the classification society strength requirements, and using the gap between the frames as a ventilation duct was an efficient use of space. The ducts, however, were designed and built in such a way that it was impossible to inspect the steel work inside. Even if the inside of the duct had been coated before being closed up, condensation would have regularly formed in the duct, which over time would have broken down the coating, leading to corrosion. The design of the ducts did not allow for either periodic re-coating of the inside of the duct or for routine inspection of it. This could have been achieved by fitting removable inspection plates at each deck to allow a surveyor or inspector to internally examine the ship's side, and for preventative maintenance to be carried out.

In November 2005, the International Association of Classification Societies (IACS) published a *Ship Structure Access Manual*. The preamble to this document states:

> *Ships should be designed and built with due consideration as to how they will be surveyed by flag state inspectors and classification society surveyors during their in-service life and how the crew will be able to monitor the condition of the ship. Without adequate access, the structural condition of the ship can deteriorate undetected and major structural failure can arise. A comprehensive approach to design and maintenance is required to cover the whole projected life of the ship.*

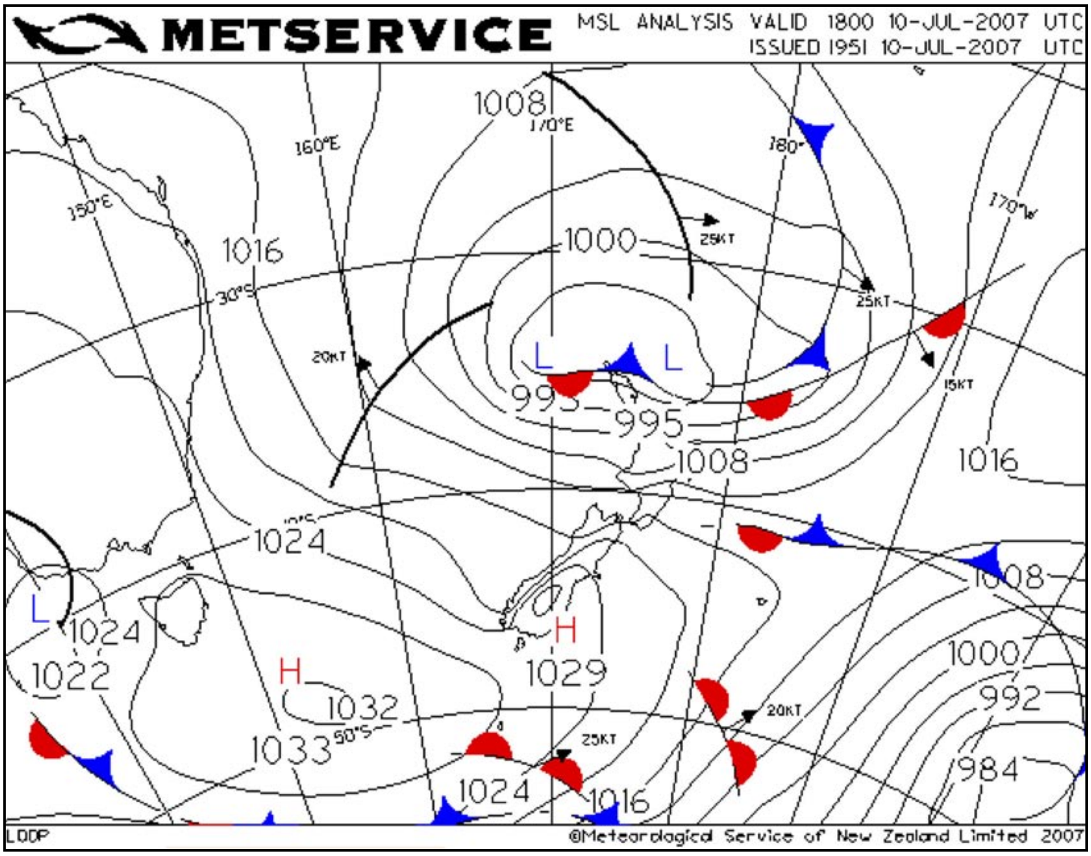
This, however, was issued 23 years after the ship was constructed. That the issue of accessibility to the ship's structure for survey has been recognised, acknowledges that there may be a problem with the survey of older ships where consideration of access for survey had not been made at the design stage. No common rules or guidance are provided for class surveyors to focus on access to ventilation ducts of this design and similar constructions for inspection and NDT survey.

Figure 15a



MSL analysis, valid at 0000 10 July 2007

Figure 15b



MSL analysis, valid 1800 10 July 2007

The forepeak tank of *Pacific Star* had originally been coated with epoxy paint, and reportedly re-coated in 2001, but this had degraded. As the ship's loading did not vary very much throughout her life, and in an effort to keep the ship on an even keel, a constant level of sea water was kept in the forepeak tank. In addition to general corrosion due to the continually damp atmosphere above the water level within the tank, and the poor state of the tank coating, the structure would have suffered increased localised corrosion in the area of the constant water line as a consequence of its regular wetting due to surface movement. When the storm damage highlighted the problem on the starboard side of the tank, a similar patch of localised corrosion was discovered in the corresponding position on the port side of the tank although this corrosion was found to be within the limits of acceptable diminution. Both patches were approximately $30cm^2$. These areas were not identified during previous surveys of the tank, possibly because they did not stand out against the poor visual condition of the tank. No rules or guidance are provided for class surveyors to focus on the internal water line area of a tank for inspection and NDT survey.

2.5.2 Survey and inspection

A passenger ship under the UK flag is subject to a number of surveys and inspections, designed to ensure that a ship remains safe. As previously explained, *Pacific Star* was subject to annual surveys by the MCA and RINa for the re-issue of the Passenger Ship Safety Certificate.

A secondary and independent source of regulatory monitoring is Port State Control inspection. Its purpose is to confirm compliance with international standards, and also to confirm the status of the ship's certification. However, given time and accessibility constraints during routine ship operations, a Port State Control inspection is unlikely to identify deficiencies that would normally be identified only at a Passenger Ship Safety Certificate renewal. Since coming under the UK flag, the ship has been subjected to a number of Port State Control inspections, none of which highlighted problems with the ship's structure.

A third source of monitoring is a requirement of the International Safety Management (ISM) Code, Section 10. This requires a company to *establish procedures to ensure that the ship is maintained in conformity with the provisions of the relevant rules and regulations.* The ISM Code is not prescriptive concerning the exact procedure to be followed and which relevant rules and regulations are included, with the onus placed on the company to identify the requirements, and to integrate the procedures into the ship's operational maintenance routine. *Pacific Star* was provided with a computerised planned maintenance system, the role of which was to identify routine maintenance requirements, record actions taken and to highlight items approaching due date for survey.

Ultrasound surveys of *Pacific Star* had taken place on 7-19 November 2005 and 3-12 February 2007. The first survey included the forepeak and measured thicknesses of the internal structure of the tank, and also certain plates of the side shell. The results of the survey of the tank showed areas where the plate thickness had been reduced, but had not reached the limit of allowable diminution. The side shell plates tested showed evidence of diminution up to a maximum reduction of 12.2% of the plate's original thickness. This was below the maximum allowable diminution of 30% for localised areas of corrosion under class rules.

The second ultrasound survey was carried out at sea and in port, and was targeted at areas where specific problems had been identified. This included tank boundaries, certain tank internals, engine room pipework, and ventilation ducts. Both the forepeak tank and the ventilation duct at frame 30-31 starboard were included in the survey. However, only the forepeak tank top and after bulkhead were surveyed, and the ventilation duct was only surveyed from inside the ship, with the fourth boundary of the duct, the shell plating, not being surveyed since it was inaccessible from inside the ship. The survey of the forepeak tank targeted areas of corrosion previously identified by visual inspection, and was partly used to determine the full extent of the corroded area, and the size of an insert plate required to effect repairs. This level of corrosion, requiring the renewal of a section of the after bulkhead and a further section of the tank top, should have prompted a further check on the condition of other parts of the tank's structure, including the shell plating. However, the ultrasound survey was restricted to areas where diminution had been previously identified and to the tank's internal members.

By not extending the scope of the second ultrasound survey, P&O/Princess missed an opportunity to identify areas on the side shell within the forepeak where excessive corrosion had developed. Similarly, P&O/Princess missed an opportunity to identify areas of ventilation duct side shell corrosion by not expanding its planned maintenance system to include other ducts of similar construction when, in March 2003, failure of a ship's side plating in way of downflooding ducts occurred. Although the latter incident was reported to IACS through the vessel's classification society, the lessons learned were not promulgated to other classification societies, including RINa.

Although the forepeak was regularly inspected it was impossible to internally inspect the ventilation ducts. Reliance was therefore placed on external examination. The forepeak plating was visually inspected, and a hydrostatic test carried out in November 2005, and again in November 2006 as a part of the hull annual survey. On both occasions the condition of the tank coating was described as poor. However, there was no requirement for the tank to be coated, no deficiencies were identified in respect of the tank's shell plating and no remedial action was undertaken.

2.5.3 Non-destructive testing using ultrasound

RINa rules detail the areas of a ship that require thickness measurement during class renewal survey. For any age of ship, suspect areas are required to be measured, and as the ship ages, the scope of the measurement increases. At age 10 years or more, the internals of the fore and after peak tanks are included in the thickness measurement requirements. By the time the ship is 15 years old this requirement is extended to include, among other areas, thickness measurements of all wind/water strakes, all keel plates, and exposed structure of the ship.

To measure the thickness of a sample of metal, an ultrasound transducer is held touching the sample. The sound pulse is reflected by the boundary between the back wall of the sample and the air. Where scale or paint is securely attached to the sample, this may be included in the thickness measured. Since the speed of sound in paint is slower than that in steel, by approximately three times, an inflated value for the thickness of the sample will be gained where the paint layer is included in the test (1mm of paint will increase the thickness reading by approximately 3mm). "Single echo only gauges" register only the first back wall echo signal from the material, and will include the surface coating and give an erroneous Thickness Measurement (TM). All TM firms approved by any classification society must have equipment that utilises the multi-echo technique. The delay between the echoes at the probe face is exactly equal to the time taken to pass through the metal twice, therefore coatings such as paint are ignored and the measurement displayed is of the metal thickness.

The thickness measured by ultrasound testing is the thickness below the transducer, and is limited by the width of the transducer. A number of measurements are taken, an IACS standard for which is five in a star pattern per square metre. The ultrasound thickness measurements will give an overall impression of the thickness of the plate, and if the transducer happens to be put in an area of higher corrosion should lead the operator to investigate further. Five measurements covering approximately 5 square centimetres, is a small sample of a plate of 10,000 square centimetres. However, the operator's experience, and a visual inspection of the appearance of the plate in question, will normally dictate the optimum positions for the measurements to be taken, and/or the need for more extensive investigation. This experience is underscored by the operator's required qualification to undertake non-destructive testing.

Although the class rules require the shell plating thickness to be measured, it is possible that the measuring transducer may be placed inadvertently only on thicker parts of the structure giving a false impression of the overall state of the plate. Smaller areas of extensive corrosion may not be picked up, unless a survey by sight is carried out, and the surveyor is able to identify suspect areas for further investigation. In this case, the structure of the ship did not allow for the ship side plating at the ventilation ducts to be visually inspected internally, and should a survey not measure thickness at a corroded place in the ventilation duct, there would be no indication of corrosion problems in the duct.

Survey and inspection relies on the skill and experience of the individual surveyor, who normally works autonomously, and on the current practice of using ultrasound equipment for measuring shell plating thickness. This can result in non-representative ultrasound readings being relied upon and areas of localised corrosion not being detected.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN ACTIONS BEING TAKEN AND/OR A RECOMMENDATION BEING MADE

1. No rules or guidance are provided for class surveyors to focus on the internal water line area of a tank for inspection and NDT survey, thereby relying on general observation to detect excessive localised corrosion. [2.5.1]

2. Ships may be designed with no means of access, for the purpose of internal inspection, to ventilation ducts of the design used on *Pacific Star* thereby relying on general external observation for detecting excessive localised corrosion. [2.5.1]

3. No common rules or guidance are provided for class surveyors to focus on access to ventilation ducts of the design used in *Pacific Star* and similar constructions for inspection and NDT survey, thereby relying on general external observation for detecting excessive localised corrosion. [2.5.1]

4. Lessons learned from previous problems with ducts of similar design were not promulgated and applied by other member classification societies. [2.5.2]

5. Forepeak tank top and after bulkhead steel replacement did not result in action being taken by P&O/Princess to identify further potential forepeak corrosion problems. [2.5.2]

6. Although an inspection procedure was included in its planned maintenance system when it was established that there were problems with downflooding ducts, P&O/Princess did not expand the procedure to include other ducts of similar construction. [2.5.2]

3.2 OTHER SAFETY ISSUES

1. The weather conditions were in excess of those forecast, from the information available to the master on board *Pacific Star*; it would have been impossible to predict this. [2.4]

2. The current practice of using ultrasound equipment for measuring shell plating thickness can result in non-representative readings being relied upon and areas of localised corrosion not being detected during survey. [2.5.3]

SECTION 4 - ACTIONS TAKEN

4.1 RINa has:

- Amended its Instructions to Surveyors **(Annex 5)**. Additionally, specifically for *Pacific Star,* a memorandum has been recorded in the ship status to draw the attention of the shipowner and surveyors to the structural ventilation ducts of the ship. This memorandum requires that the surveyor carries out an internal inspection of all the ducts at any annual survey.

- Required manholes to be fitted to all ducts on *Pacific Star.*

4.2 THE MARITIME AND COASTGUARD AGENCY has:

- Written to IACS on two issues based on this accident and its experience of surveying younger vessels with similar design features. Firstly, it has recommended that ventilation and downflooding ducts should have adequate access to enable them to be coated internally and that they should be regularly inspected and the coatings maintained. Secondly, it has strongly recommended that external and internal inspections should start respectively from the second and third class renewal surveys.

4.3 P&O/PRINCESS CRUISES has:

- Carried out an assessment of other ships in its fleet to identify those with ducts of similar design. One ship was identified, and localised wastage discovered in one duct. Corrective maintenance was carried out to the satisfaction of the Flag Administration and classification society.

SECTION 5 - RECOMMENDATIONS

Cruise Lines International Association is recommended to:

2008/112 Work with IACS to produce guidance for ship owners and operators, and ship's staff, concerning the preparation required for structural surveys, particularly with reference to the following:

- Cleaning, staging, scaling and lighting within tanks and other enclosed spaces
- Accessibility to all parts of the ship's structure
- Provision of information to the surveyor concerning the normal working level of the liquid contained within a tank, and any previous problems associated with the space to be surveyed.

Such guidance should be passed to their members for dissemination to ship owners and operators and to ship's staff.

The International Association of Classification Societies is recommended to:

2008/113

1. Work with the passenger ship industry through CLIA to develop guidance for shipowners and operators, and ship's staff, concerning the preparation required for structural surveys, particularly with reference to the following:

- Cleaning, staging, scaling and lighting within tanks and other enclosed spaces
- Accessibility to all parts of the ship's structure
- Provision of information to the surveyor concerning the normal working level of the liquid contained in a tank, and any previous problems associated with the space to be surveyed.

2. Distribute such guidance to its member classification societies, to allow them to issue instructions to their society surveyors, as deemed appropriate.

2008/114 Continue its best efforts to improve and make more effective the process by which lessons learned by one of its member classification societies are promulgated to the other members.

Princess Cruises is recommended to:

2008/115 Review the scope and application of its defect reporting systems to ensure that the full potential consequences of safety critical defects, when identified, are carefully extrapolated with respect to the vessel concerned and other vessels that may be affected throughout its fleet.

Marine Accident Investigation Branch
February 2008

Safety recommendations shall in no case create a presumption of blame or liability