

Report on the investigation of

the fire onboard

Star Princess

off Jamaica

23 March 2006



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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.”

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purpose is to attribute or apportion liability or blame.

The MAIB has conducted this investigation on behalf of the Flag State, the Bermuda Maritime Administration, with the MAIB taking the lead role pursuant to the IMO Code for the Investigation of Marine Casualties and Incidents (Resolution A.849(20)). MAIB wishes to acknowledge the pivotal contributions made to the investigation by the US Coast Guard and the National Transportation Safety Board of the United States, and to thank them for their exemplary cooperation and support.



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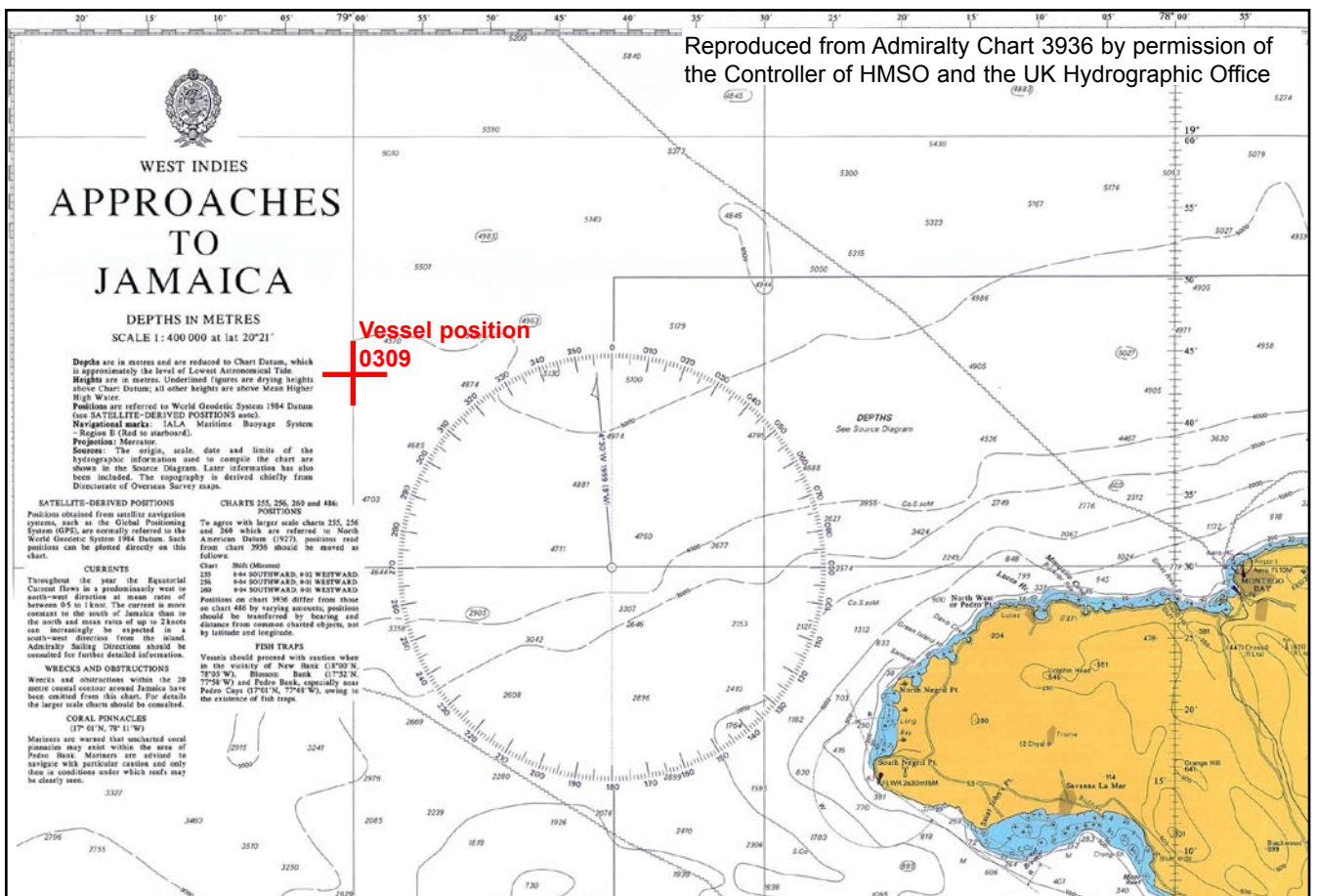
GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able Bodied seaman
BA	-	Breathing Apparatus
BRE	-	Building Research Establishment
BSI	-	British Standards Institute
CVE	-	Control Verification Examination
DNV	-	Det Norske Veritas
EEBD	-	Emergency Escape Breathing Device
ERO	-	Emergency Response Organisation
ESD	-	Emergency Shutdown System
ETO	-	Electro-Technical Officer
FBI	-	Federal Bureau of Investigation
FP	-	Fire protection
FSD	-	Fire screen door
FSS Code	-	International Code for Fire Safety Systems
GES	-	General Emergency Stations
GL	-	Germanischer Lloyd
GMDSS	-	Global Maritime Distress and Safety System
GRP	-	Glass Reinforced Plastic
ICCL	-	International Council of Cruise Lines
IMO	-	International Maritime Organization
ISM Code	-	International Management Code for the Safe Operation of Ships and for Pollution Prevention
LLL	-	Low location lighting
MAIB	-	Marine Accident Investigation Branch
MCA	-	Maritime and Coastguard Agency
MSC	-	Maritime Safety Committee

NTSB	-	National Transportation Safety Board
OOW	-	Officer of the Watch
PA	-	Public Address System
PAN PAN	-	International Urgency Call
PL	-	Photoluminescent
PM	-	Photoluminescent Material
PO	-	Petty Officer
PSSC	-	Passenger Ship Safety Certificate
RINA	-	Registro Italiano Navale
SMS	-	Safety Management System
SOLAS	-	International Convention for the Safety of Life at Sea
STCW	-	International Convention on Standards of Training, Certification and Watchkeeping incorporating the 1995 Amendments
TIC	-	Thermal imaging camera
UHF	-	Ultra High Frequency
UK	-	United Kingdom
US	-	United States
USCG	-	United States Coast Guard
UTC	-	Universal co-ordinated time
VDR	-	Voyage data recorder
VHF	-	Very High Frequency



Star Princess



Position of Star Princess

SYNOPSIS

At 0309 (UTC+5) on 23 March 2006, a fire was detected on board the cruise ship *Star Princess*. The ship was on passage from Grand Cayman to Montego Bay, Jamaica, with 2690 passengers and 1123 crew on board. The fire was investigated by the Marine Accident Investigation Branch (MAIB) on behalf of the Bermuda Maritime Administration, in co-operation with the United States Coast Guard (USCG), and the United States' National Transportation Safety Board (NTSB).

The fire started on an external stateroom balcony sited on deck 10 in the centre of main vertical zone 3, on the vessel's port side. It was probably caused by a discarded cigarette end heating combustible materials on a balcony, which smouldered for about 20 minutes before flames developed. Once established, the fire spread rapidly along adjacent balconies and, assisted by a strong wind over the deck, it spread up to decks 11 & 12 and onto stateroom balconies in fire zones 3 and 4 within 6 minutes. After a further 24 minutes, it had spread to zone 5. The fire also spread into the staterooms as the heat of the fire shattered the glass in stateroom balcony doors, but was contained by each stateroom's fixed fire-smothering system, the restricted combustibility of their contents, and their thermal boundaries. As the fire progressed, large amounts of dense black smoke were generated from the combustible materials on the balconies, and the balcony partitions. This smoke entered the adjacent staterooms and alleyways, and hampered the evacuation of the passengers, particularly on deck 12. One passenger died as a result of smoke inhalation, and 13 others were treated for the effects of the smoke.

A number of factors were identified which indicate that, although the balconies met the fire protection requirements of SOLAS II-2, the basic principles of this regulation did not apply to these, or other, external areas. These included:

- The balconies' polycarbonate partitions, polyurethane deck tiles, and the plastic furniture were highly combustible and produced large quantities of very thick black smoke when burned.
- The glass in the doors between the staterooms and balconies were neither fire rated to meet with the requirements of an 'A' class division, nor self-closing.
- The balconies crossed main zone fire boundaries, both horizontally and vertically without structural or thermal barriers at the zone or deck boundaries.
- No fire detection or fire suppression systems were fitted on the balconies.

The fire was extinguished within 1.5 hours after it had started. The crew fought the fire with water hoses from adjacent external areas, and from internal alleyways. Difficulty was experienced in reaching the fire due to the construction and partitioning of the balcony areas. A total of 79 staterooms were condemned after the fire, and a further 218 were damaged by fire, smoke, or water. The damaged area covered 3 vertical fire zones on 5 decks.

The initial findings of the investigation, together with guidance on the immediate actions to be taken, were brought to the attention of cruise ship operators through a Safety Bulletin published by MAIB and a safety notice issued by the International Council of Cruise Lines (ICCL). Included in the MAIB Safety Bulletin were recommendations to the UK Maritime Administration aimed at developing amendments to the 1974 SOLAS Convention to ensure that fire protection arrangements in external areas such as balconies were as robust as those currently applicable to internal areas of passenger ships. Following a submission to

IMO by the UK delegation at MSC 81 in May 2006, the committee approved both a circular (MSC.1/Circ 1187) for immediate distribution detailing operational measures recommended for immediate implementation on passenger ships with balconies, and proposed amendments to SOLAS and the FSS Code. The proposed amendments are aimed at ensuring that balcony partitions are non-combustible, restricting the use of combustible materials on stateroom balconies, and requiring ships with balcony furniture, which is not of restricted fire risk, be fitted with fixed fire detection and extinguishing systems. The proposed amendments to SOLAS will be considered for adoption at MSC 82 in December 2006.

In view of the responses to the recommendations issued in the MAIB's Safety Bulletin, no further recommendations have been made in this report.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *STAR PRINCESS* AND ACCIDENT

Vessel details

Registered owner	:	GP3 Ltd
Manager	:	Princess Cruise Lines Ltd
Port of Registry	:	Hamilton, Bermuda
Flag	:	Bermuda
Type	:	Passenger Cruise Ship
Built	:	2002 Fincantieri-Cantieri Navali Italiani S.p.A Monfalcone, Italy
Keel laid	:	1999
Classification Society	:	Registro Italiano Navale (RINA)
Construction	:	Steel
Length overall	:	289.623m
Gross Tonnage	:	108,977t
Propulsion motor power	:	42000kW
Service Speed	:	18 knots
Other relevant info	:	Two fixed pitch propellers. Fwd and aft thrusters

Accident details

Time and date	:	0309 (UTC +5) on 23 March 2006
Location of incident	:	18°43.5N 078° 59.8W
Persons on board	:	Crew: 1123 Passengers: 2690
Injuries/fatalities	:	One passenger died. 13 passengers and four crew were treated for the effects of smoke inhalation.
Damage	:	Severe fire damage on the port side to balconies and outboard staterooms in the central third of the ship's length in fire zones 3, 4 and 5 on decks 10, 11 and 12. Seventy-nine staterooms were condemned. There was also damage on the port side of decks 9 and 14.

1.2 NARRATIVE

1.2.1 General

The information in this section is based on recorded information from the vessel's VDR and fire detection system, witness interviews, and from responses to over 1000 questionnaires completed by passengers and crew following the accident. All times are UTC+5, and all courses are true.

1.2.2 Background

On 23 March 2006, *Star Princess* was on passage from Grand Cayman to Montego Bay, Jamaica with 1123 crew and 2690 passengers on board. The vessel was on a course of 102° at a speed of 17.7kts. The true wind was north east, force 4, and the relative wind was between 20° and 30° on the port bow at a speed of between 25 and 30kts. The sea was calm, the visibility was good, and it was dark. The air temperature was 25°C, and the relative humidity was 92%.

At 0250, a security patrol smelled burning amidships on the port side of deck 14. The smell was reported to the OOW by telephone, and the area was checked. Nothing was found, but the security patrol was instructed by the OOW to include the area during its overnight rounds.

1.2.3 Initial response

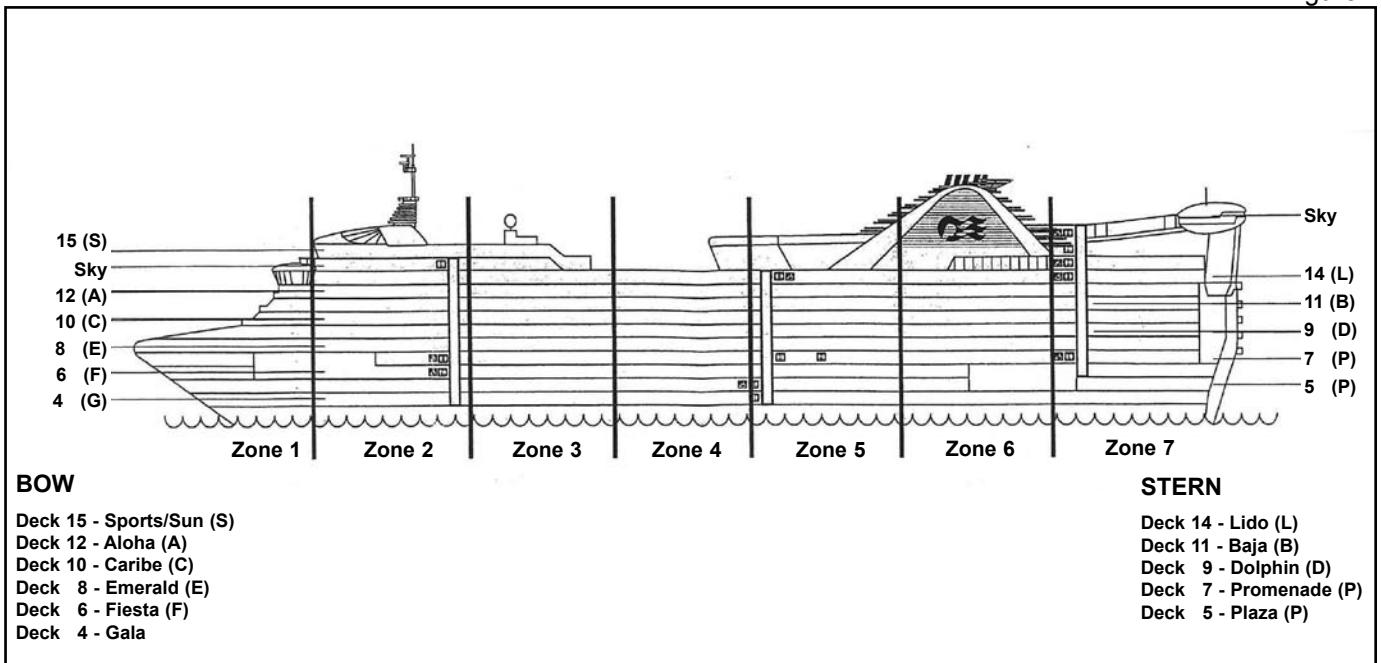
At 0309.20, the OOW was alerted by a manual call point alarm. The alarm had been activated in fire zone 2 on deck 11. Almost simultaneously, the bridge lookout reported he could see a fire on the port side of the ship's superstructure. The OOW immediately made a broadcast over the PA system for the assessment party to proceed to deck 11, fire zone 2, port side. The location was also passed to the assessment party via personal pagers.

The manual call point alarm was activated by a passenger in stateroom B254¹, who saw an orange glow from his balcony. The glow was on a balcony below and to his left. By the time he had alerted friends in the next stateroom (B250), the glow had turned into a fully blown fire. The occupants of adjacent staterooms on deck 11 were then alerted by the banging on doors and shouting. One passenger was also able to inform the customer service desk by dialling 911, the ship's medical emergency number.

When the first of the assessment party arrived on deck 11, passengers were leaving their staterooms sited on the port side of zone 3. The party entered one of the outboard staterooms in the vicinity of B302, and from its balcony, saw the fire on balconies further aft. The OOW was contacted by VHF radio at 0312, and informed that the fire was in the vicinity of staterooms B306 and B308. A still of a video, taken from the balcony of B302 at the time of the report to the OOW, is at **Figure 2**. When the senior first officer, who was in charge of the assessment party, arrived at the scene and saw the scale of the fire, he immediately requested the bridge to broadcast the crew alert.

¹ Each deck on board *Star Princess* was given a name as well as a number, and all staterooms were prefixed by the first letter of the name of the deck on which they were located. The names of each deck are shown at **Figure 1**. The first digit of each stateroom number corresponds with the numerical zone within the ship in which the stateroom is located. Staterooms with even numbers were located on the port side of the ship.

Figure 1



Drawing showing deck and zone layout

Figure 2



Still from video taken at 0311

On hearing the OOW's announcement for the assessment party, the captain and staff captain went to the bridge. From the port bridge wing, they saw that the fire appeared to be located mainly on the outside of the ship, and its flames were moving from forward to aft. The staff captain then proceeded to the safety centre², from where the crew alert signal was activated at 0313, and the fire screen doors in fire zones 1, 2 and 3 were closed at 0314. The ventilation was also stopped by using master switches for each of the affected zones. This was in addition to a pre-programmed smoke strategy, which automatically activated in the local deck and zone areas where the initial smoke detectors were triggered.

At 0317, the captain reduced speed, and then altered course towards the north in order to reduce the wind over the deck. During this manoeuvre, which was requested by the senior first officer via the staff captain, the relative wind shifted to the starboard bow at 0320, and the flames became more vertical. The senior first officer also requested that General Emergency Stations (GES) be initiated. The signal for GES was sounded at 0320, after which the passengers were instructed to go to their muster stations. The lifeboats and liferafts were then prepared. Because the fire was on the outside of the ship's port side, the port boats were not put out until adequate protection from fire hoses had been provided, and only the starboard liferafts were inflated.

1.2.4 Fire-fighting

Immediately following crew alert, six hoses were rigged on deck 14 to cool the deck, which was getting very hot. Boundary cooling was also quickly established on deck 7 in way of the port lifeboats. By 0326, the deck fire party had entered zone 3 from forward. Two, three-man teams of firefighters with BA were used in rotation, which searched only the outboard staterooms as they advanced. Priority was given to controlling the fire, by fighting it from intact balconies, and through broken balcony doors. A hose party wearing smoke respirators, which were found to be very useful in the smoky conditions, was deployed on the forward balconies to play water onto the balconies on deck 10 immediately aft, and below, the advancing BA team. Hoses were also deployed on balconies forward and aft of the fire by the boundary cooling and the engine fire party to fight the fire from as close as possible on decks 9 to 12. Access between the balconies was impeded where the keys to the doors in the balcony partitions were not readily available. Difficulty was also encountered in handling fire hoses around the partitions.

The fire continued to move quickly aft, and by 0340 at least seven hoses had been rigged in zones 3, 4, and 5 on deck 15, to direct water onto the fire below. A port list had been applied in order to allow the large amount of water being put on to the fire to run over the ship's side. From 0400, the fire appeared to start to reduce in size, and at 0436, the captain informed the passengers, by a public announcement, that the fire was out.

1.2.5 Rescue of passengers

Between 0344 and 0402, the engine fire party recovered two male passengers from the alleyway in zone 3 on deck 12; the first was semi-conscious, and the second, unconscious. Shortly after, a further two passengers, who were able to walk, were rescued from stateroom A340 in the same area. At 0425, the unconscious casualty was pronounced dead by a ship's medical officer.

² The safety centre (spelled 'safety center' in the ship's on board documentation) was located immediately aft of, and accessible from, the bridge. Details of the safety centre and its facilities are at **Annex A**.

1.2.6 Post-fire actions

The search of the fire-affected internal areas was completed at 0641. By this time, the captain had decided that it was safe to resume passage to Montego Bay, and had adjusted course and increased speed accordingly. As the fire-damaged areas were cooled and dampened, fires re-ignited in staterooms C402 and C510, which were quickly detected and extinguished. The ship arrived in Montego Bay at 0945, and at 0954, the identity of the deceased passenger was confirmed. As all passengers and crew were now accounted for, the passengers were then allowed to leave their muster stations.

Figures 3 to 6 show the activation of smoke and heat alarms recorded on the vessel's fire detection system, and a chronology of significant events is at **Table 1** below:

0250	Smell of burning detected amidships on the port side of deck 14. The relative wind was 27° on the port bow at 30 knots.
0309	Fire seen by passenger and manual call point activated on deck 11 zone 2, port side. Fire seen from port bridge wing immediately after alarm.
0310	Broadcast for assessment party to proceed to deck 11 zone 2, port side. First Smoke detectors triggered deck 15, zones 5 and 6
0311	First smoke and heat detectors triggered in deck 10, zone 3 (C316 and C318) First smoke detector triggered in deck 11, zone 3 (alleyway by B324) Hi-fog flow alarm triggered deck 10, zone 3
0312	Captain and Staff Captain arrive on the bridge/safety centre First heat detector in deck 11, zone 3 (B322)
0313	Crew alert broadcast
0314	Fire screen doors closed Hi-fog flow alarm triggered in deck 11, zone 3 First smoke detector triggered in deck 12, zone 4 (A402)
0315	First heat detector in deck 12, zone 4 (A402)
0316	First smoke detector triggered in deck 11, zone 4 (B402) First smoke detector triggered in deck 10, zone 4 (C402) First manual call point activated in deck 12, zone 4 (by A342)
0317	All ventilation stopped Order given to reduce ship's speed First heat detector triggered in deck 11, zone 4 (B406) First smoke detector triggered in deck 12, zone 3 (alleyway by A340) First heat detector triggered in deck 10, zone 4 (C402) Hi-fog flow alarm triggered in deck 11, zone 4 First heat detector triggered in deck 12, zone 3 (A338)
0318	First smoke detector triggered in deck 14, zone 3 (pizza bar) Hi-fog flow alarm triggered in deck 10, zone 4 Hi-fog flow alarm triggered in deck 12, zone 3 Commenced course alteration to port
0320	General Emergency Stations broadcast Relative wind now on starboard bow
0322	First smoke detector triggered in deck 14, zone 4
0323	First smoke detector triggered in deck 14, zone 5
0325	Order given to prepare the ships' lifeboats Progressively established boundary cooling on decks 14, 15, 7,8, and 9
0326	Deck fire party enters into fire affected area on deck 11 with firefighters with CABA
0328	Captain orders an urgency message to be sent. The message is prepared but not transmitted
0331	First smoke detector triggered in deck 11, zone 5
0332	First smoke detector triggered in deck 12, zone 5
0334	First heat detector triggered in deck 11, zone 5
0338	Engine fire party enter deck 12, zone 3 with firefighters equipped with breathing apparatus First smoke detector triggered in deck 10, zone 5 First heat detector triggered in deck 10, zone 5 First heat detector triggered in deck 12, zone 5
0344	Casualty reported on deck 12, zone 3
0402	Further casualty reported on deck 12, zone 3
0425	Second casualty on deck 12, zone 3 pronounced dead
0518	Speed increased and course altered toward Montego Bay
0520	Smoke extraction commenced in fire affected areas
0548	Deck 11, zones 3,4, and 5 search complete
0641	Search of fire affected areas complete
0945	Ship arrives Montego Bay
0954	All passengers and crew accounted for. Fatality identified

Table 1 - Chronology of significant events

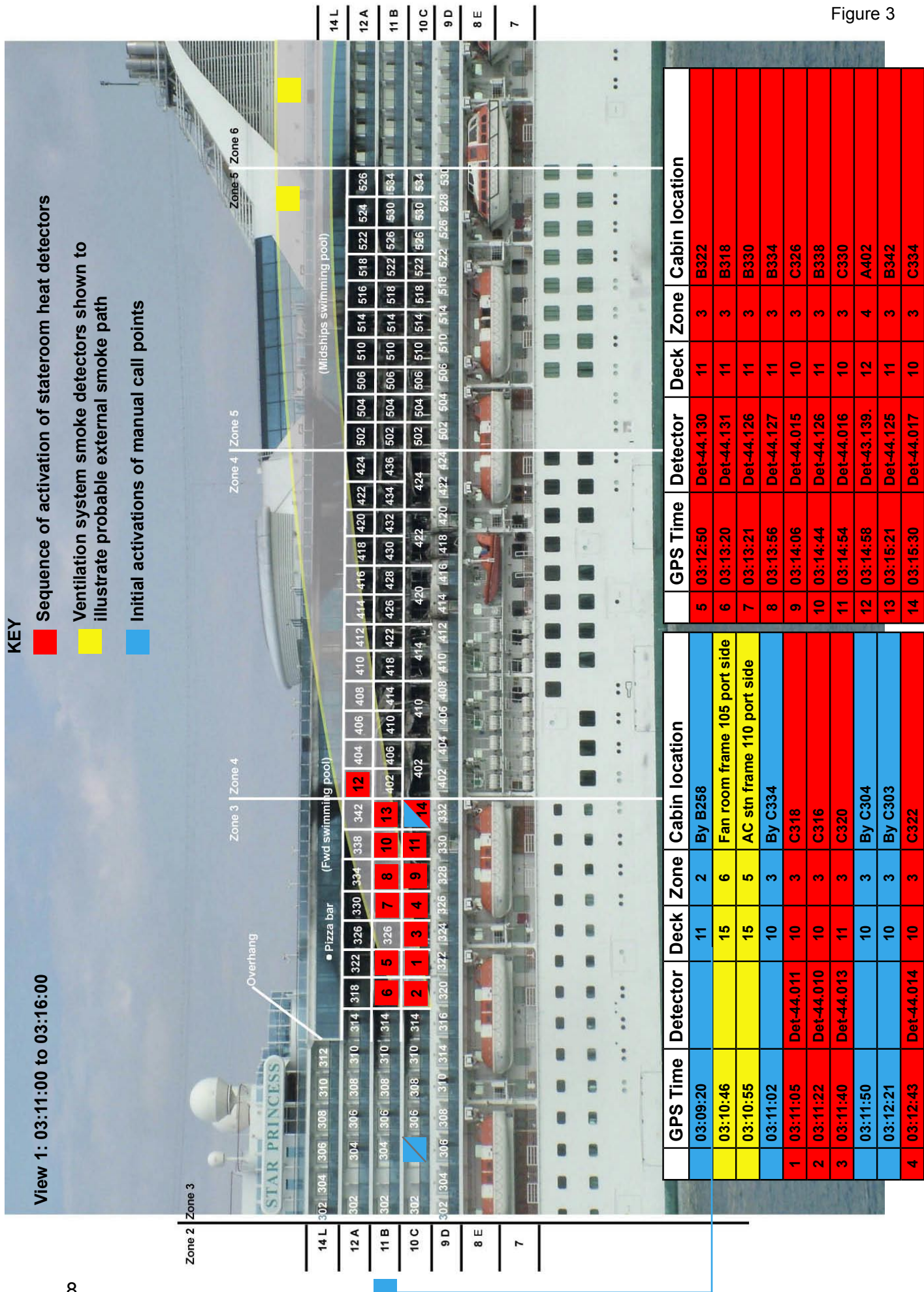


Figure 3

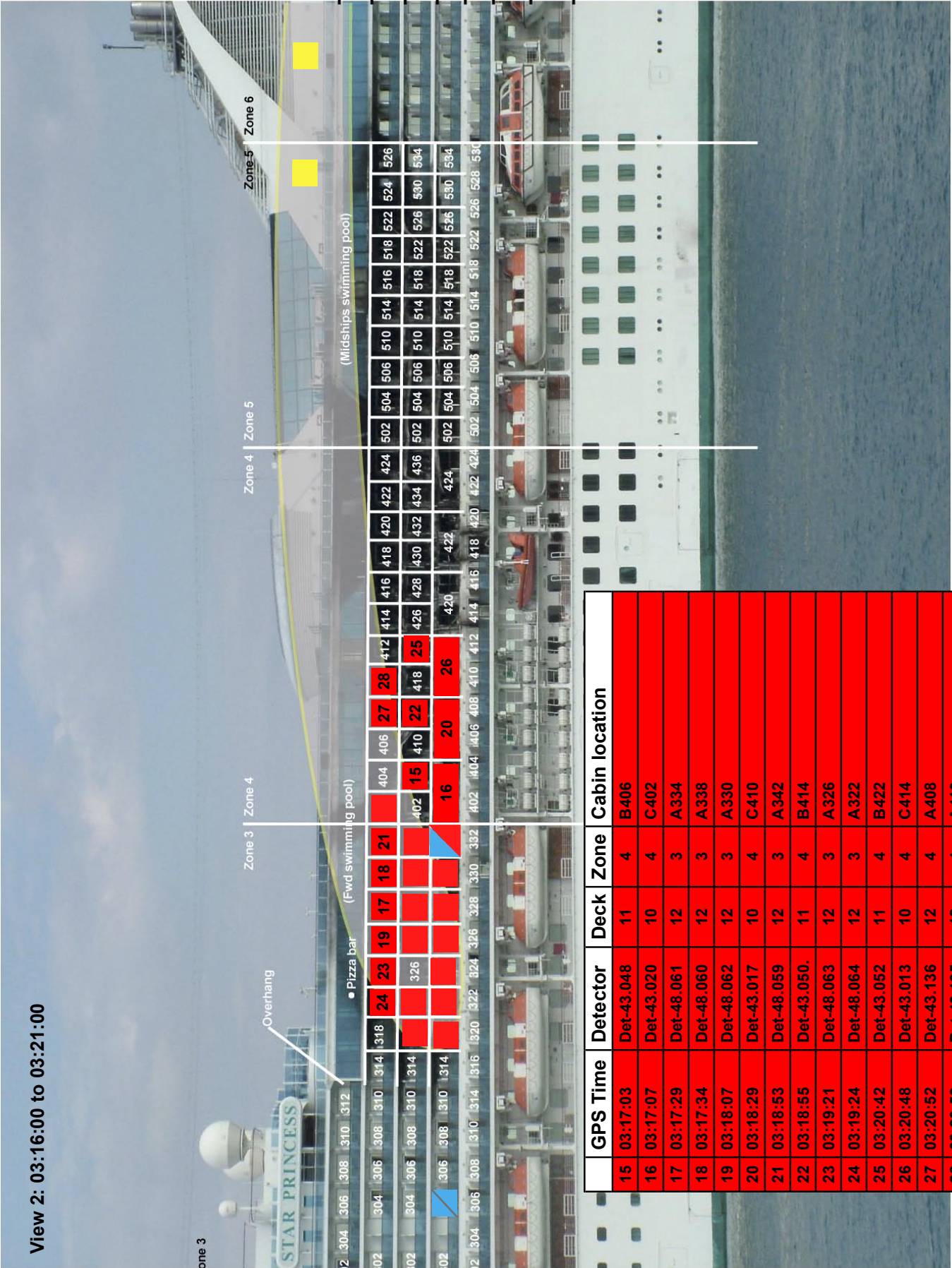
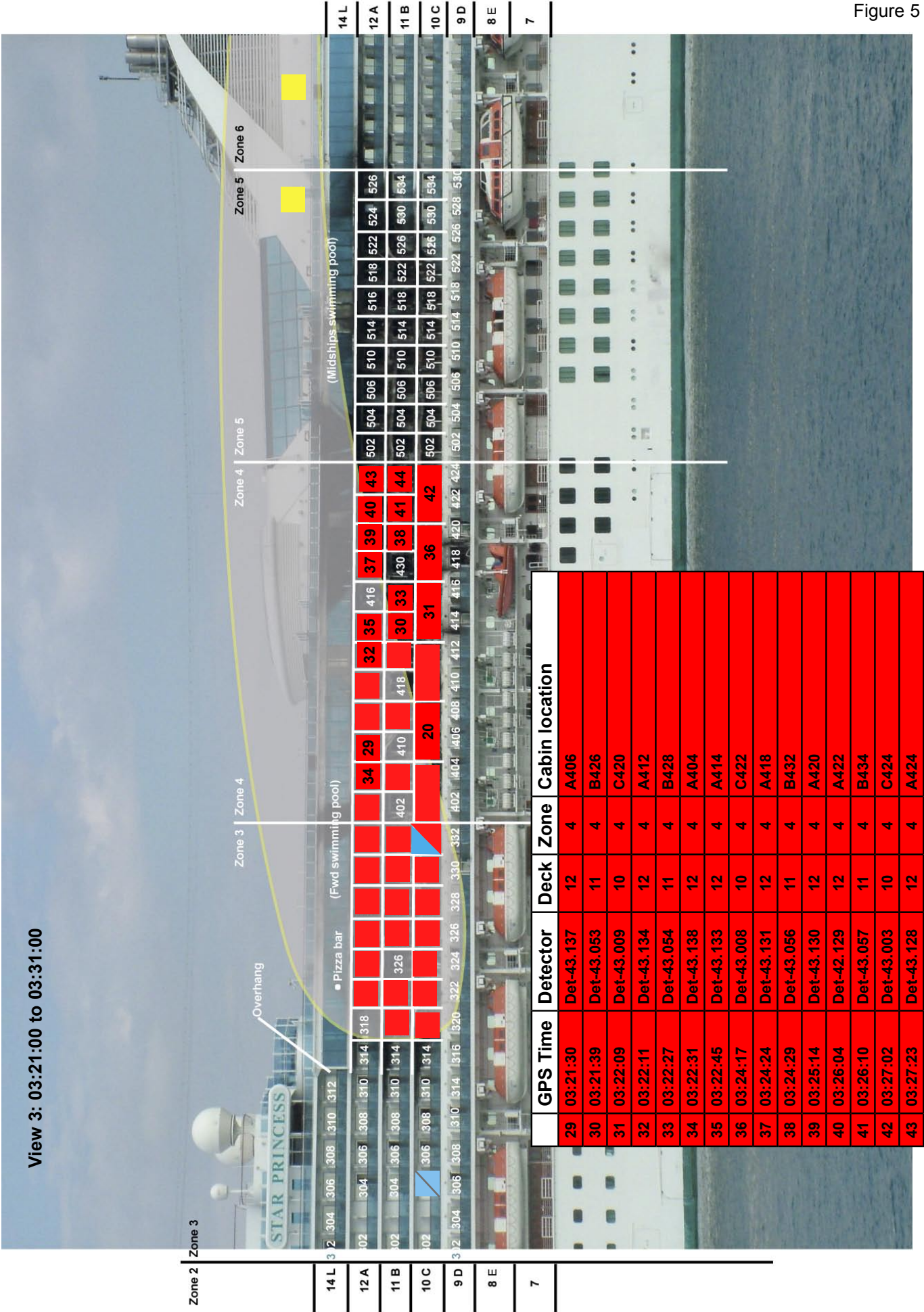
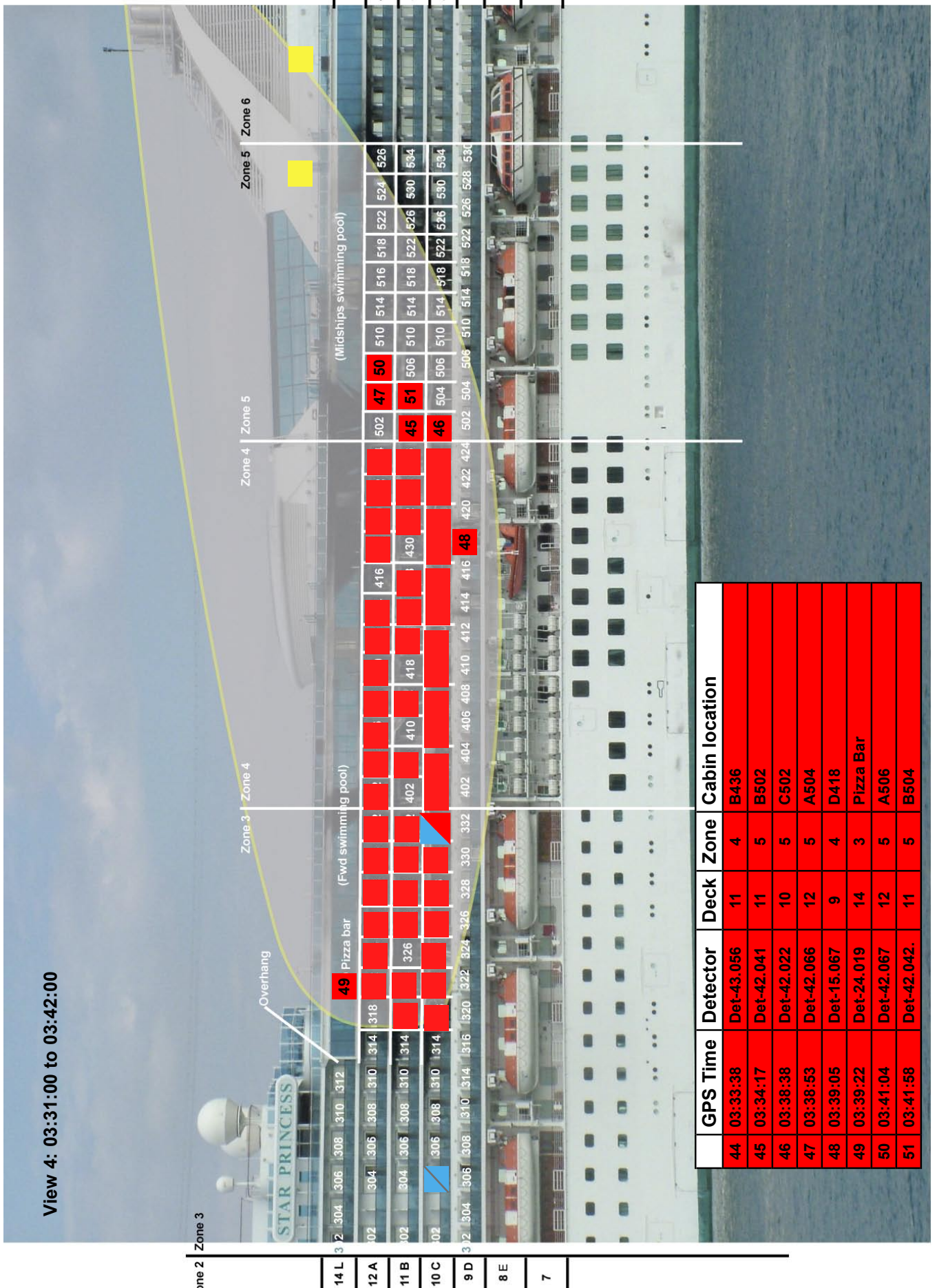


Figure 4

Figure 5



11



The passengers on board *Star Princess* were disembarked in Montego Bay, and the ship sailed for the Bahamas on the evening of 25 March. Following temporary repairs to the fire damaged areas, in the Bahamas, the ship proceeded to Bremerhaven, Germany, for permanent repair. A summary of the repairs undertaken is at **Annex B**. The ship re-entered service on 15 May 2006.

1.3 EVACUATION OF STATEROOMS ON THE PORT SIDE

1.3.1 Deck 10

Many passengers in the outside staterooms in zone 3 of deck 10 were woken by noises on their balconies. On investigation, the flames on the balcony of C316 were about 1m high and covered the length of the balcony. At about the same time, the curtains in C318 caught fire when its balcony doors were opened to investigate a glowing object outside. The alarm was raised by passengers banging on the doors of adjacent staterooms, and a manual call point was activated at 0311.02. Several passengers also attempted to raise the alarm by dialling 911 from their stateroom telephones, but there was no response. Some passengers on deck 10, including those in staterooms C316 and C322, were still in their staterooms when the glass in their respective balcony doors collapsed. Large clouds of thick black smoke, which smelled of burning plastic, then entered these staterooms, and the visibility was immediately reduced. At the time, the alleyway door of C316 was wedged open with a wooden wedge³, but its occupants managed to close it behind them as they left. Smoke filled the alleyway in zone 3, as the passengers evacuated from the smoke-affected staterooms.

1.3.2 Decks 11 and 12

Following the arrival of the assessment party on deck 11, all of the staterooms were cleared of passengers in zones 3, 4, and 5. On deck 12, passengers who were not woken by noises on their balconies were woken by noise in the alleyway, banging on doors, the PA announcements from the bridge, and the signal for the crew to proceed to crew alert. None appear to have been alerted by the audible alarms fitted to the smoke and heat detectors fitted in each stateroom and in the alleyway. After hearing the crew alert signal, an elderly male passenger in A402 opened his balcony door and was overcome by thick black smoke. The door could not be closed, and the water mist head in the stateroom was activated. The smoke detector fitted in the stateroom activated at 0314.40. The passenger and his wife left the stateroom, but the male passenger collapsed when making his way to his muster station; he had suffered a respiratory arrest. The first manual call point to be activated on deck 12 was at 0316.08, which was located outside stateroom A342. An extract of the ship's fire plan, showing the port side of zone 3 on deck 12, and the recorded times of the smoke and heat detector alarms fitted, is at **Figure 7**.

As the last of the passengers were leaving, or preparing to leave, their staterooms in zone 3 on deck 12, the alleyway became engulfed in thick, black smoke. The smoke, which appeared to have entered the alleyway towards its aft end, contained large orange flames and glowing embers, and forced members of the assessment party who had proceeded to the area and rigged a hose, to retreat from the alleyway to the

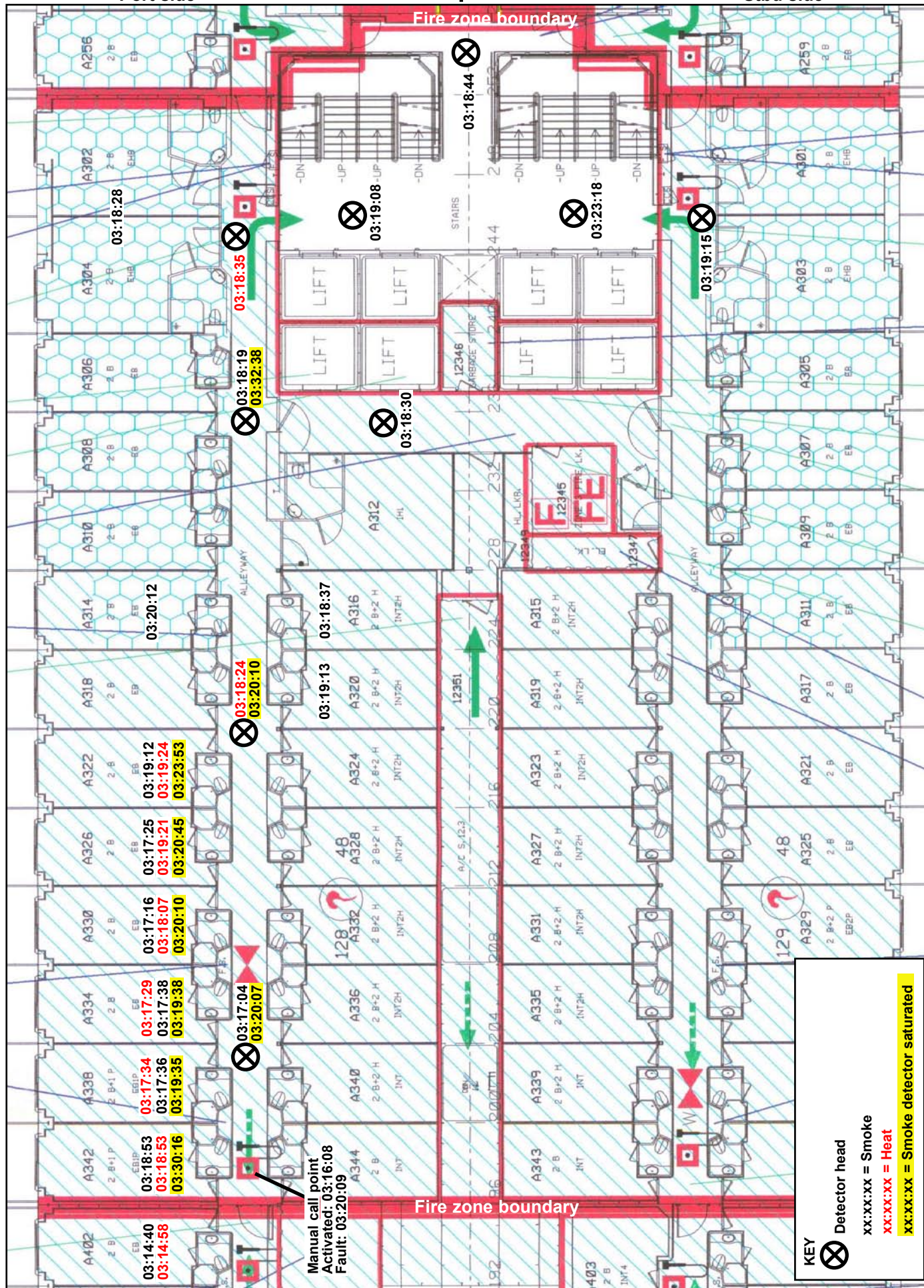
³ Wedges were provided in each stateroom to assist the stateroom stewards when cleaning.

Port side



Stbd side

Figure 7



Extract of fire control plan showing detection times on deck 12, zone 3

elevator lobby at its forward end. It also prevented the section leader, responsible for clearing the staterooms in zones 2 and 3 when the GES was sounded, from entering the area. The section leader checked that the staterooms on the starboard side were clear of passengers. He held a master key for staterooms A201 to A237, and was able to physically check these were empty. As each stateroom was checked, a towel was placed on the door handle, and the door was left ajar on the latch to enable quick access for the fire-fighters. The section leader did not hold a master key for staterooms A239 to A321, and was only able to check these staterooms by banging on the doors. It was normal practice for the section leader to request additional master keys to staterooms from his zone commander, but on this occasion he was unable to do so because all of the telephone lines were busy. This also prevented the section leader from informing his zone commander that he had been unable to check the staterooms on the port side of zone 3.

Of the passengers who were still in zone 3, married couples in A344 and A320 covered their mouths with wet towels before leaving their staterooms. They headed forward on entering the alleyway, which was in accordance with the instructions posted on the inside of their stateroom doors. The fire screen door at the aft end of the alleyway was closed. The passengers from A344 crawled on their hands and knees for a few metres before becoming separated, but the female passenger assumed her husband had made it to safety when she heard a door ahead of her slam shut. The passengers from A320 were forced to the deck by the intense smoke soon after entering the alleyway, and were also separated. The two female passengers escaped through one of the forward fire screen doors, where they were met by several of the crew. They did not see the low-location lighting⁴ fitted on the inboard side of deck in the alleyway (**Figure 8**), and the passenger from A344 was wet by the water mist system, which activated just before the door was opened.

When the passengers in A340 opened their stateroom door to leave, they were engulfed in a large ball of black smoke, which they could not avoid inhaling. The passengers immediately assessed that the smoke made the alleyway impassable and closed the door. The telephone was then used to call for assistance using its speed dial functions, and by dialling 911, but there was no response. The couple wetted towels, put a mattress against the door, and lay on the floor. They were able to hear the captain's announcements over the PA system.

1.4 THE SEARCH ON DECK 12

On hearing the crew alert signal, the engine fire party mustered at its fire locker on deck 4. Five of the party dressed in fire-fighting suits and collected their BA. A sixth member of the BA party had difficulty dressing because his fire suit was too small, and did not collect his BA or the remaining helmet, which contained a thermal imaging camera (TIC). None of the party wanted to wear this helmet because it was considered to be too heavy and cumbersome.

⁴ To meet the requirements of SOLAS Chapter II -2 Regulation 13, the means of escape on board *Star Princess* were marked with either electric lighting or photoluminescent (PL) low location lighting systems (LLL). A PL system is a lighting system which uses PL material containing a chemical such as zinc sulphide that has the quality of storing energy when illuminated by visible light. The PL material emits light which becomes visible when the ambient light source is less effective. Without the light source to re-energize it, the PL material gives off the stored energy for a period of time with diminishing luminance.

Figure 8



Alleyway in deck 12, zone 3

After leaving the fire locker shortly after 0324, the fire party made its way to deck 11 via the forward staircase, where it was met by its officer in charge, the staff engineer. The staff engineer agreed with the senior first officer that, as the deck fire party was already working on deck 11, the engine fire party would cover deck 12. However, following calls from the staff captain to assist the boundary cooling team, the engine fire party first went to deck 14. Two firefighters with BA then stayed on deck 14, and the remainder of the party moved to deck 12.

On arrival at the forward staircase between zone 2 and zone 3, the staff engineer donned a smoke respirator and opened a fire screen door at the forward end of zone 3. Although the alleyway was full of thick black smoke, and was very hot, he managed to locate two female passengers in one of the first staterooms and escort them to safety. The two firefighters who had been boundary cooling on deck 14 then re-joined the fire party and entered the alleyway in zone 3, wearing BA. Although the firefighters carried flashlights, the visibility in the

thick black smoke, combined with the water mist, made it very difficult to see more than 0.5m ahead. Movement was achieved mainly by touch; the PL lighting fitted to the deck was not seen. The firefighters opened the doors on both sides of the alleyway using master keys, and checked that they were empty. When the firefighters were about 15m along the alleyway, a semi-conscious male was found lying face up. The man was pulled to safety, and a stretcher party was called for. He was later identified as the male occupant of A320.

Soon after firefighters re-entered the alleyway, a second male casualty was found about 10m further aft from where the first casualty was found. He was unconscious, and the assistance of the party's three other firefighters in BA was required to remove him from the alleyway. A medical party quickly attended to the casualty, who had stopped breathing and did not have a pulse. The casualty was ventilated and given chest compressions but could not be revived. He was later identified as the male occupant of A344. During the next re-entry, the passengers in A340 were located and escorted to safety. A further re-entry was made, during which the search progressed to about half way within zone 5. All of the searches were conducted by the same firefighters, who changed the compressed air cylinders of their BA after the first casualty was recovered.

1.5 PASSENGER MUSTERS

There were four muster stations used on *Star Princess*, designated 'A' 'B' 'C', and 'D'. The muster stations utilised public areas such as the ship's theatres, bars, and restaurants on deck 7. The allocation of muster stations was based on stateroom location. The maximum number of passengers at each station varied between 535 in muster station 'B' to 1064 in muster station 'C'. Passenger lists were provided in alphabetical order at each of the muster stations.

Passengers in zone 3 on decks 10, 11, and 12 were all allocated to muster station 'B' located in Tequila's Bar, the Hearts and Minds chapel, and the internet café on deck 7. Many of these passengers were the first to arrive at the muster station, and a number arrived before the GES signal was sounded. After leaving the smoke-filled alleyway on deck 12, the female passenger from A344 was escorted from the scene to muster station 'A' in the Princess Theatre, rather than to muster station 'B', her designated station. She was wearing her night clothing, and was covered in soot. She was also wet. After being seated, the passenger asked the crew in the station about the well-being of her husband. Enquiries to muster station 'B' indicated that her husband had been accounted for. Friends of the passengers from A344 were also told that the couple had been accounted for after they informed the crew at muster station 'B' that their companions were not in the muster station as expected. Records from muster control show that the passengers in A344 were reported missing by muster stations 'A' and 'B' at some point during the muster process. However, the name associated with A344 reported by muster station 'B' was incorrect. After being in the muster station for about 5 hours, concerned passengers highlighted the poor medical condition of the female passenger to the crew, and she was taken to the medical centre in a wheelchair.

Results of the initial head counts were not received by muster control until about 1.5 hours after the GES was sounded. The roll calls which followed, using both passenger name and stateroom number, had to be repeated several times, and took between 2 and 3 hours to complete. No loudhailer was provided in muster station 'C' as required by company instructions. This made passenger control and the completion of a roll call difficult.

1.6 COMMUNICATIONS

At 0328, the captain discussed the need to broadcast a distress or an urgency message with the ETO and the GMDSS operator. The captain decided to transmit a PAN PAN message, which had already been prepared on the ship's GMDSS. The GMDSS operator updated the information contained in the message, including passenger numbers, but he did not send the message because he was not aware an instruction had been given to do so.

Communications between the staff captain and the persons in charge of the fire and boundary cooling parties was via UHF radio. Although the staff captain had difficulty in contacting the staff engineer in the early stages of the fire-fighting effort, and was forced on one occasion to prompt communication via the ship's PA system, UHF communications were generally reliable. VHF radios were used for communication between the senior first officer and the staff engineer and their respective fire parties. The primary language used on most of the radio transmissions was English, although Italian was occasionally used between the staff captain and the staff engineer, and the staff engineer and some of his team.

The captain kept the passengers informed of the situation through PA announcements. The first of these was made at 0323, followed by a further eight up to 0517, by which time the fire was extinguished and the ship had resumed passage to Montego Bay. Feedback from passengers indicates that the majority of passengers consider they were kept fully informed during the time spent in their muster stations. The PA system was audible in all public areas and alleyways, but a small number of passengers, including those in A344, had difficulty in hearing public announcements in their staterooms.

1.7 CASUALTIES

The deceased passenger was a 72 year old American, weighing about 110kg. Following an autopsy in Montego Bay on 24 March 2006, the immediate cause of death was attributed to:

Asphyxia secondary to inhalation of smoke and irrespirable gases as products of incomplete combustion, in an elderly individual with evidence of Atherosclerotic Cardiovascular Disease in conjunction with Chronic Glomerular Nephritis, pending histology and toxicology.[sic]

A further 13 passengers, suffering from effects of smoke inhalation, were treated in the ship's medical centre. Eleven of these passengers had been located on the port side of deck 12, of which eight occupied staterooms in zone 3, including the passengers rescued from A340. Following the ship's arrival in Montego Bay, the injured male passengers from A320 and A402 were taken by air ambulance to a clinic in Florida. Another four passengers were landed to a local hospital.

1.8 POST-FIRE SURVEY AND DAMAGE

Following the fire, representatives from the MAIB, and the US Coast Guard, NTSB and FBI attended the vessel to investigate the fire.

Fire damage extended over the balconies and outboard staterooms in the central third of the ship's length, in Fire Zones 3, 4 and 5 on the port side (**Figure 9**). The most severe damage was on decks 10, 11 and 12 (**Figure 10**) in which 79 outside staterooms were seriously damaged by fire. A further 218 were damaged by fire, smoke, or water. One balcony on deck 9 was seriously damaged by fire, and numerous others sustained minor damage caused by falling debris. Semi enclosed public areas on the port side of deck 14 were damaged by heat and smoke (**Figure 11**). Minor smoke damage and debris of the products of combustion was evident on deck 15.

The fire generated sufficient heat to melt the aluminium structure of decks 11 and 12 (**Figure 12**). The heat also caused glass in the balcony balustrades and doors to shatter, which allowed the fire to penetrate into the outside staterooms (**Figure 13**).

At the outer boundaries of the damaged areas, the balcony partitions were charred and melted, and sagged under their own weight (**Figure 14**). Where this occurred, it was possible to see that the partitions had burned before their aluminium frames distorted. In all other places, the partitions were reduced to ash and their frames partially or totally melted. The plastic furniture and deck tiles were mostly reduced to ash within the fire affected area, and were melted and scorched at its outer boundaries (**Figure 15**). The only electrical fitting provided on each of the balconies was an exterior light sited over the balcony doors. There was no evidence of any electrical failure or arcing on these fittings.

Fire damage in the staterooms was worst immediately inside their balcony doors, and reduced towards their interior. A rapid reduction in temperature was shown by undamaged chocolates found on many bedside tables, and bedding and furnishings, which looked charred (**Figures 16 and 17**), but were in many cases only stained with heavy soot washed from the smoke by the water mist.

The most severe damage to a stateroom was in C510 (**Figure 18**), where the water mist head was found on the deck, having failed to activate. The heat generated had buckled the stateroom's deckhead panels, and its door to the alleyway was also badly buckled and very nearly breached.

Soot deposits indicated that smoke entered the ship and reached internal alleyways in accommodation spaces through staterooms via open balcony doors. **Figures 19 and 20** show the soot deposits outside the entrance to staterooms of A330 and A338. The stateroom door of the latter was held open due to the insertion of a wedge in its self-closing mechanism. Although soot stains were evident in zone 3 on deck 12, they were less evident in zone 4 (**Figure 21**).

Figure 9



Extent of damage on ship's port side

Figure 10



Damage to balconies

Figure 11



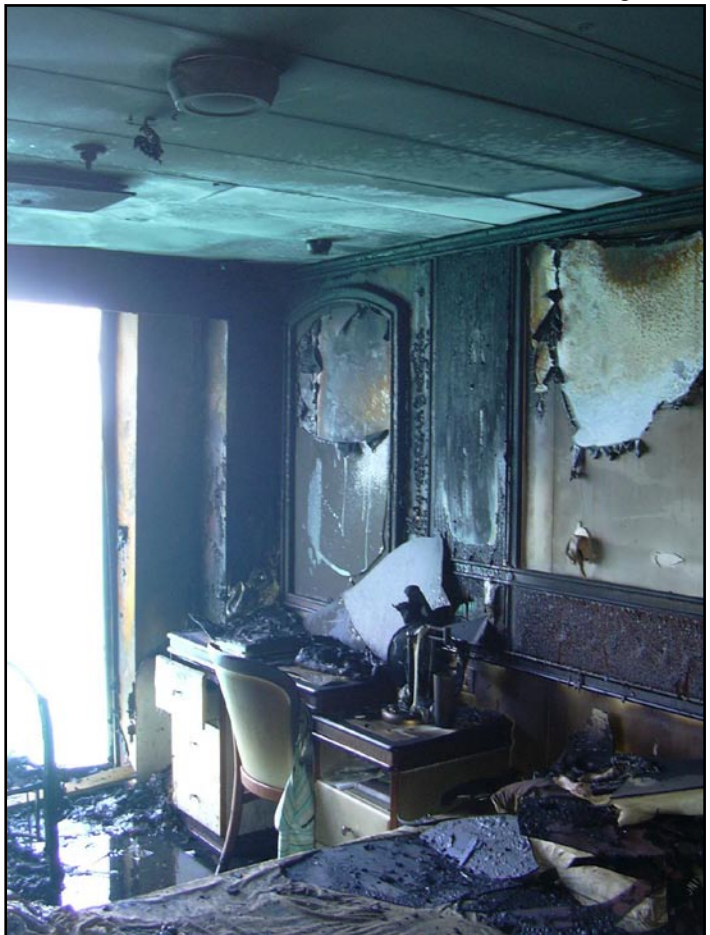
Damage to deck 14

Figure 12



Melted aluminium structure

Figure 13



Damage to stateroom

Figure 14



Melted polycarbonate partition

Figure 15



Partially melted balcony furniture



Figure 16 and 17
Soot in stateroom interior



Figure 18



Stateroom C510

Figure 19



Door to A330

Figure 20



Door to A338

'A' class fire door between Zone 3 and Zone 4

Alleyway in Zone 4

Figure 21



'A' class fire door between zones 3 and 4 on deck 12, port side

1.9 STRUCTURAL FIRE PROTECTION

1.9.1 General

Star Princess was designed and built by Fincantieri Shipyard in Italy for Princess Cruises. She was the third in a series of passenger cruise ships, following *Grand Princess* and *Golden Princess*. Although the vessel was not identical to the previous vessels, there were no significant differences. During construction, *Star Princess* was registered with the Liberian administration, and was required to comply with SOLAS 74 as amended. The vessel was designed and built under the rules of both Lloyds Register of Shipping, and Registro Italiano Navale (RINA). Lloyds Register was responsible for the certification of all statutory requirements on behalf of the Liberian register. As the ship was to be used to embark passengers from US ports, she was also subjected to Control Verification Examinations (CVEs) by the US Coast Guard before entering service, and periodically thereafter. This was to demonstrate 'substantial compliance' with the construction, equipment, and safety requirements of SOLAS. Before entering service in 2002, the vessel was transferred to the Bermuda Register of Shipping and maintained under the rules of RINA alone.

1.9.2 Regulation

The regulations covering '*Construction – Fire protection, fire detection and fire extinction*' are in SOLAS⁵ Chapter II-2, in which Regulation 9 (Containment of fire) states:

The purpose of this regulation is to contain a fire in the space of origin. For this purpose, the following functional requirements shall be met:

- .1 the ship shall be subdivided by thermal and structural boundaries;*
- .2 thermal insulation of boundaries shall have due regard to the fire risk of the space and adjacent spaces; and*
- .3 the fire integrity of the divisions shall be maintained at openings and penetrations.*

In general terms, the regulation requires that in ships carrying more than 36 passengers, the hull, superstructure and deckhouses are to be sub-divided into main vertical and horizontal zones by A-60 class divisions. It also requires that bulkheads not requiring to be A-60 class divisions shall be at least 'B' class or 'C' class divisions as prescribed in SOLAS II-2 Regulation 9 Table 9.1. The class of division required between decks is prescribed in Table 9.2.⁶

Proposals to amend Regulation 9 of SOLAS II-2 to extend the fire protection requirements to semi-enclosed external areas used as restaurants, swimming pools, mooring decks, and galleys, were discussed at FP 50⁷. The proposals were not finalised due to time constraints, and the matter remains pending further discussion.

⁵ The SOLAS Consolidated Edition 2004 is used throughout this report. Differences in the text of previous editions are noted where applicable.

⁶ Tables 9.1 and 9.2, and the definitions of 'A', 'B' and 'C' class divisions are at **Annex C**

⁷ FP 50 was the IMO fire protection sub-committee, which met in February 2006.

1.9.3 Categorisation of balconies

Star Princess has 15 decks and seven main vertical zones⁸ (**Figure 1**). A structural fire plan was provided by Fincantieri, which was approved by Lloyds Register of Shipping and RINA. An extract of the structural fire plan for deck 11 (**Figure 22**) shows that the external balconies were categorised as open deck spaces (category 5) which Paragraph 2.2.3.2 of Regulation 9 of SOLAS defines as:

*Open deck spaces and enclosed promenades clear of lifeboat and liferaft embarkation and lowering stations. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces shall be ventilated by permanent openings.*⁹

Staterooms were categorised as accommodation spaces of moderate fire risk (category 7)¹⁰. During the course of the investigation, discussions with industry bodies, including ship builders, classification societies, and national maritime administrations, indicated that this practice has been consistently used since the first ships with external balconies were built in the mid 1980's. They also indicated that the doors between the balconies and the accommodation spaces did not have to be fire-rated, or self closing, due to an exemption provided in SOLAS II-2 Regulation 9, Paragraph 4.1.1.6, which states:

The requirements for 'A' class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles, provided there is no requirement for such boundaries to have 'A' class integrity in paragraph 4.1.3.3.¹¹ The requirements for 'A' class integrity of the outer boundaries of the ship shall not apply to exterior doors, except for those in superstructures and deckhouses facing lifesaving appliances, embarkation and external assembly station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.

The first ship the MAIB is aware of to have been constructed with external balconies is *Royal Princess* (since renamed *Artemis*), which entered service in 1984 (**Figure 23**). The ship was built in Helsinki, Finland, and was UK registered. Review of the vessel's structural fire protection plan, which was approved by the MCA, indicates that the balconies were treated as open deck spaces, although this was not specifically annotated. The exemptions for doors and glass partitions and windows in 'A' class boundaries were noted on the plan. The balcony partitions on *Royal Princess* were made of GRP on a substantial steel frame, and the decks and furniture were both made of hardwood.

⁸ Main vertical zones are those sections into which the hull, superstructure and deckhouses are divided by 'A' class divisions, the mean length and width of which on any deck does not exceed 40m

⁹ The second sentence was added in the Convention's 1983 amendment.

¹⁰ The fire loading for the outside staterooms on *Star Princess* was: Volume – 0.078m³, calorific value 961.4mj per m², which was based on facings, mouldings, decorations and veneers, but not furnishings. The maximum acceptable fire volume was 0.135m³ and the maximum acceptable calorific value was 2433.2mj per m²

¹¹ Paragraph 4.1.3.3 refers to windows facing lifesaving appliances, embarkation and assembly stations, external stairs and open decks used for escape routes.

Balcony categorisation

Figure 22



Extract of fire protection plan for deck 11 on *Artemis* (ex *Royal Princess*)

Figure 23



Balconies on board *Artemis* (ex *Royal Princess*)

1.9.4 Design and construction

Star Princess is typical of modern cruise ship design in having a large number of balconies outside passenger staterooms. The majority of her balconies run along most of the ship's length on decks 9 to 12. The balconies on decks 9 and 10 were constructed on a steel deck, and those on decks 11 and 12 were made from lightweight extruded aluminium, attached to the steel superstructure with transition pieces and supported by aluminium brackets in a cantilever. Stainless steel tie bars linked the outboard edges of decks 11 and 12 to the steel deck of deck 14 above. A profile of decks 9 to 14 is at **Figure 24**.

The balconies on deck 10, which contributed to the strength of the vessel's structure, and those on deck 9, which were directly above the lifeboats and liferafts, were considered to meet the applicable regulations and were approved by Lloyds Register and RINA. The structural aspects of the technical specification for the balconies on decks 11 and 12, which neither contributed to the strength of the vessel's structure, nor had to meet prescribed fire protection requirements, were also examined and found acceptable by the classification societies.

Access to the balconies from the staterooms was via sliding glass doors of similar appearance to those used in many domestic homes (**Figure 25**). The glass used in the balcony doors was double glazed and mounted in an aluminium frame with an overall dimension of 1870mm x 716mm, and a thickness of 25mm. The glass used was 5mm toughened 'float clear' glass, which had been impact tested in accordance with BSI 6202, but was not fire rated.

Balconies were separated by vertical partitions (**Figure 26**), which had small gaps at the deck and deckhead. The partitions provided privacy and shelter, and were fitted with a door, which could be locked by a universal square-ended 'T' bar shaped key. The partitions were constructed from 8mm polycarbonate sheet, secured in an aluminium framework. This was one of several types of material used by Fincantieri for balcony partitions, and *Star Princess* was one of 19 ships on which it had used the material. The materials the shipbuilder used on the balconies of other vessels included: acrylic, acrylic –polycarbonate mixtures, and aluminium composite. Materials known to be used for balcony partitions by other ship builders includes glass, steel, high pressure laminated boards, galvanised sheet, and plywood.

The decks of the balconies on board *Star Princess* were covered with a polypropylene tile (**Figure 26**). On decks 9 and 10, the tile was laid on top of a flexible screed coated with polyurethane self-levelling paint, but on decks 11 and 12 it was laid on top of a painted metal deck. Polypropylene tiles were laid on top of the deck coatings to provide a non slip finish and allow surface water to drain. This was one of three types of deck covering used by Fincantieri for this purpose, the others were teak, and a teak effect resin. A balustrade was fitted at the outboard edge, consisting of glass panels topped with a hardwood rail.

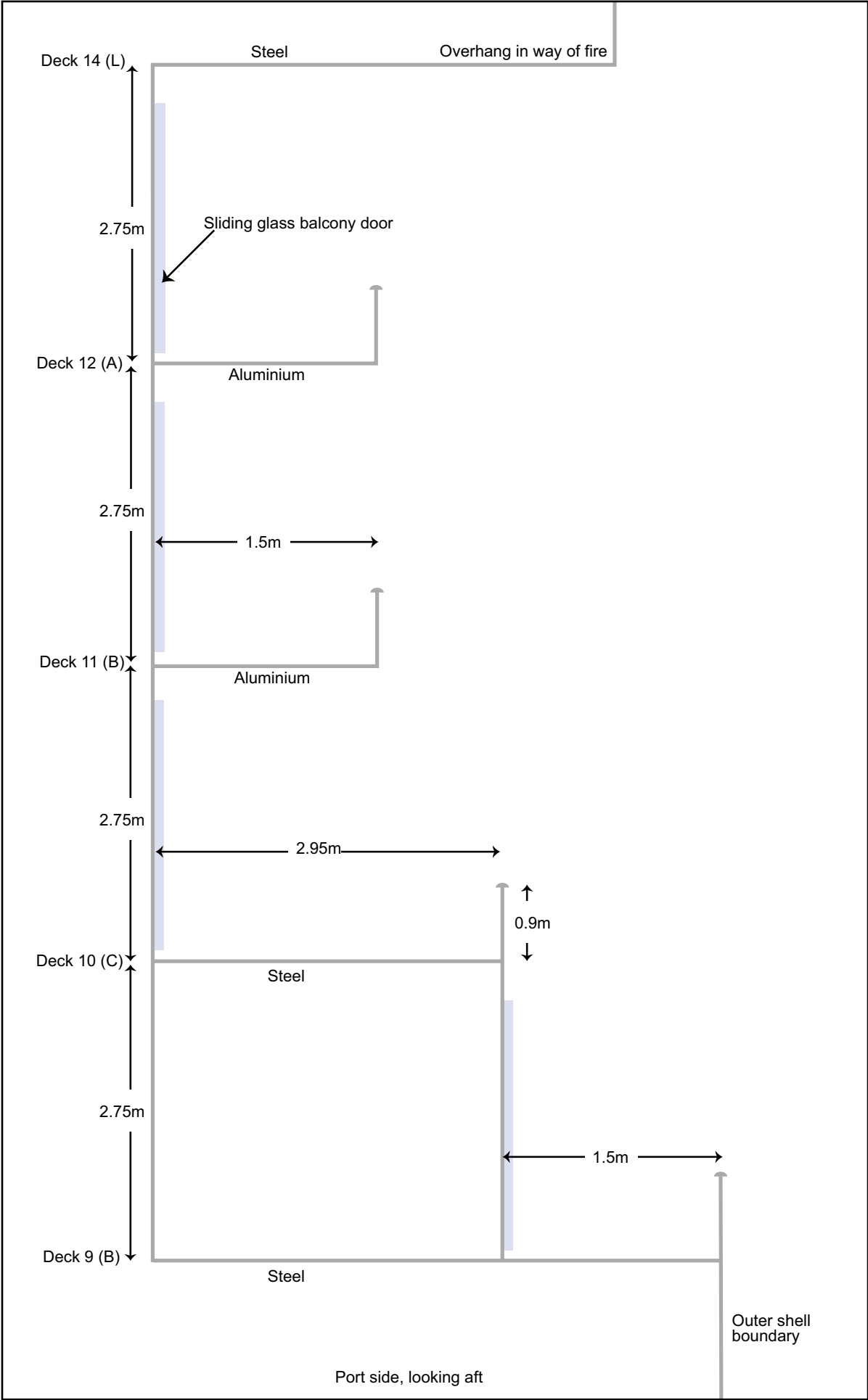


Figure 25



Balcony doors

Figure 26



Balcony partitions, furniture and deck tiles

The selection of the material used for the partitions and deck covering was determined by a number of factors, including: durability in a marine environment, weight, aesthetics, cost, and availability. The characteristics of the materials used, regarding combustibility and toxicity when burning, were not a consideration. Regulations 3 and 6 of SOLAS Chapter II-2 detail the requirements for the use of non-combustible and combustible materials¹², and smoke generation potential and toxicity, respectively. The purpose of the latter is to *reduce the hazard to life from smoke and toxic products generated during a fire in spaces where persons normally work or live*, but the requirements are applicable only to internal spaces.

1.9.5 Items on balconies

Lightweight plastic chairs, table and footstools (**Figure 26**) of the type commonly available for outdoor recreational use were provided for each balcony. The first heat detectors to activate were in staterooms C316 and C318, and items on the balcony of stateroom C316 at the time included two large cotton towels provided by the ship and draped over the plastic chairs, a bathing suit, and a pair of water shoes, all of which had been on the balcony for several hours. The passengers in C318 were smokers, and the last occasion a cigarette was smoked on the balcony was shortly after midnight. The cigarette end was then extinguished in an ashtray. The passengers in C316 were non-smokers, and were travelling companions of the passenger in C318. The door in the partition between the stateroom balconies was unlocked, but it is not certain whether it was open or closed.

1.10 FIRE DETECTION AND SUPPRESSION SYSTEMS

1.10.1 Detection

Star Princess was fitted with a *Consilium Salwico CS3000 Fire Detection System, Hi-Fog control and Fire Patrol System*, which was type approved by a number of Classification Societies including Lloyds Register and RINA. Sensors fitted throughout the ship had unique identities, which enabled the system to interpret the location and type of each alarm that was triggered. Sensor faults were also detected. The system was interfaced with the:

- General alarm system
- Ventilation and damper system
- Safety Management System (SMS)
- Machinery control system

The fire detection system monitored the presence of smoke and heat separately, via individual and combined smoke and heat detectors. Combined heat and smoke alarms were fitted in passenger accommodation areas, and emitted an audible alarm when activated. This was a single tone, which stopped when an alarm was acknowledged by an operator. Audible alarms were fitted in response to a NTSB recommendation to the cruise industry following its investigation into the fires on board the cruise ship *Ecstasy* in 1998, and *Nieuw Amsterdam* in 2000.

¹² A *non-combustible material* is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, this being determined in accordance with the Fire Test Procedures Code. A *combustible material* is any material other than a non-combustible material.

Heat detectors were triggered at 57°C, or where the rate of temperature rise exceeded 3°C per minute. Operation of an alarm initiated the automatic operation of fire doors, dampers, and the shutdown of ventilation systems in its deck and zone. The manual call points in public areas only provided an alarm; they did not trigger an automated response or provide an audible alarm at the point of activation. During the first 10 minutes after the operation of the manual call point at 0309.20, 215 alarms were recorded. The times of detection used in this report are based on the system's recorded information.

1.10.2 Suppression

The ship's firemain was supplied by three 230m³/hr pumps operating in automatic or manual modes to maintain a system pressure of 10.5 Bar. An additional 25-40m³/hr pump maintained system pressure under standby conditions. Water pressure was maintained at between 8 and 8.5 Bar during the fire-fighting operation, using the small and one large fire pump.

A Marioff Hi-Fog water mist system was fitted throughout the ship's internal spaces. The system complied with SOLAS requirements and was type approved by a number of classification societies. It was also designed and maintained in accordance with the US National Fire Protection Association standard NFPA750. The water mist system appears similar to a typical sprinkler, but operates at a significantly higher pressure, which forces water through specially designed nozzles to produce a fine mist.

The system pipe work fitted in the accommodation areas was filled with fresh water at a standby pressure of 25 Bar, and connected to an automatic water mist head in each stateroom. Each head is activated by a heat frangible bulb, filled with an alcohol based liquid, which shatters at 57°C and allows water to flow from the head at a pressure of between 60 and 135 Bar. They provide effective coverage of an area up to 16m². Flow detectors in the distribution system detect the initial flow, which automatically starts high pressure pump units to provide a system pressure of up to 140 Bar. The manufacturer's operations manual states:

The 140 bar pump pressure can be maintained with the high pressure pumps (28) for an area of about 100m². In case additional sprinklers are activated, the system pressure will drop until the system pressure reaches about 80 bar. At this stage the 80 bar pumps (26) will start to supply the system with water. The system is dimensioned so that the required minimum water flux density can be maintained continuously for the full 280m² design area. [sic]¹³

During the fire on 23 March 2006, an estimated 168 water mist heads were activated, and were kept running for over 4 hours in order to cool the fire-affected areas. The water mist maintained a barrier against the fire at a system pressure of about 48 Bar, with 2 pump units running in automatic mode and the third manually controlled to boost pressure. The water mist system used about 300 tonnes of fresh water over 3 decks and 3 fire zones during the 4 hour operating period. Examples of staterooms in which the system activated are shown at **Figures 16 and 17**. A small number of water mist heads in fire-affected staterooms failed to activate, including in C510 (**Figure 18**).

¹³ Paragraph 2.3.3.2 of the FSS Code requires *the pump and piping system shall be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of 280² at the application rate specified in paragraph 2.5.2.3.*

1.11 TESTS

1.11.1 Reconstruction

On 3 April 2006, Princess Cruises and Carnival Corporation arranged a reconstruction of the accident using undamaged materials removed from *Star Princess*. Balcony partitions were erected at the fire training ground of the Warsash Maritime Centre¹⁴ to match the dimensions of a typical balcony. The reconstructed balcony was fitted with deck tiles, and white plastic furniture. Ventilation was provided by fans, and by the wind, which increased during the test.

The fire demonstration was started using a cigarette lighter flame applied to one of the ship's cotton towels. The towel was draped over the back of a chair, which was placed close to a partition.

1.11.2 Testing of materials

A programme of fire testing was commissioned with Building Research Establishment (BRE)¹⁵, to examine the reaction to fire of the materials found on the balconies. Experiments were conducted to test ignition and propagation mechanisms, and establish the performance of materials relative to standard IMO tests for similar materials used in internal areas. Samples of both fire damaged and undamaged materials were removed from *Star Princess* for testing. In addition to the tests, BRE were also commissioned to provide an expert interpretation of the reconstruction at Warsash. Observations of a video of the reconstruction at Warsash, along with photographs, are at **Annex D**. A summary of the BRE test report is at **Annex E**.

1.11.3 Water mist heads

Following the fire, a number of water mist heads were removed from the ship and tested by their manufacturers, Marioff, in Finland. The test report concluded that, of the eight heads identified as not having activated, seven had not done so because the frangible glass bulbs were empty. The remaining head did not activate because, although the frangible bulb had broken, the screw threads of the water mist head were damaged. This possibly prevented the head from being fully screwed into its housing assembly, and resulted in a stop valve not opening as designed.

The test report drew attention to Service Bulletin 002/2005 distributed to shipowners in May 2005, in which the manufacturer encouraged shipowners to undertake regular examination of sprinklers '*to ensure their functionality*' [sic]. The report also stated that the most likely reasons why the alcohol had been released from the bulbs, was rough handling during transportation and installation, and small cracks caused by impact.

1.11.4 Tests for accelerants

A number of items, along with debris, were removed from the initial seat of the fire by a forensic chemist from the FBI Explosives Unit. Subsequent tests on the materials indicated that no accelerants were present.

¹⁴ The Warsash Maritime Centre is owned by Southampton Solent University, and provides certification programmes from cadetships to Class 1 for both deck and engineer officers, short courses to develop skills such as fire-fighting and sea survival, and continuing professional development modules for more experienced officers.

¹⁵ BRE is accredited by the IMO, UK Government Departments and UKAS (United Kingdom Accreditation Service)

1.12 EMERGENCY ORGANISATION

1.12.1 References

Extracts from the ship's Emergency Response Organisation (ERO) documentation, which specifies the ship's: procedures at the various stages of an emergency; emergency parties; zone organisation; and passenger muster organisation, are at **Annex F**.

1.12.2 Response to emergencies

The following is an extract from Princess Cruises' fleet regulations:

If it is necessary to sound Crew Alert, this must be the sole priority of the ship. Passenger activities must be suspended. If an area is affected by smoke, or part of an area has hot spots or heat transfer, passengers must be evacuated from the area. Careful consideration must be given to calling passengers to their Muster Station at an early stage in any emergency.

The control and direction of passengers in an emergency is of the utmost importance. The Crew Alert signal should normally be sounded first to ensure crew members are in position to assist passengers. The General Emergency Stations signal will then be sounded several minutes later to allow crew members to achieve this.

To avoid the risk of confusion or panic, careful consideration must be given before sounding the General Emergency Stations signal without preceding it with the Crew Alert Signal. This should only be carried out in cases of extreme emergency when the danger to passengers is so immediate that there is no time to wait for the crew to take up their emergency positions.

1.12.3 Assessment party

The assessment party comprised six officers, including the senior first officer and the staff engineer. The task of the party was to quickly evaluate a situation and report its findings to the bridge. No members of the party were equipped with breathing apparatus.

1.12.4 Fire parties

The deck fire party comprised 20 personnel with the senior first officer in charge, and was generally used as the lead fire party in accommodation areas. The senior first officer was nominated as the on-scene commander for all incidents outside machinery spaces. The engine fire party comprised 27 personnel with the staff engineer in charge, and was used as the lead fire party in machinery space fires. The staff engineer was nominated as the on-scene commander for all machinery space incidents. Both parties were multinational, and included British and Italians.

The muster points for the deck and engine fire parties were at their respective fire lockers situated on deck 4. Each party had six crew nominated to dress in fire-fighting suits, gloves, helmets, and boots, and to carry breathing apparatus (**Figure 27**). The helmets were fitted with VHF radios, and one helmet in each team was fitted with a thermal-imaging camera (TIC). A hand-held thermal imaging device, primarily for the



Firefighters' suits and BA

use of the boundary cooling party, and a number of emergency escape breathing devices (EEBD)¹⁶ and respirators were also available in the main fire lockers. EEBDs were also kept in other fire lockers sited on various decks in each main vertical zone, including in Zone 3 on deck 12 by the forward baggage lifts.

Both the deck and engine fire parties, along with the boundary cooling party, were required to muster as soon as a broadcast for the assessment party was made.

1.12.5 Emergency telephone numbers

The ship's medical emergency number was 911. The number was monitored at the customer services desk, which was manned 24 hours per day. When the number was dialled, all telephones at the desk were programmed to ring. The customer services desk was not manned after the crew alert signal was sounded.

1.13 PASSENGER SAFETY INFORMATION

Before leaving Port Everglades, Florida on 19 March 2006, passengers were required to attend a muster drill, and to listen to a recorded announcement in English, which detailed important safety information. This was in accordance with SOLAS Chapter III Part B Regulation 19 2.2 and 2.3. A transcript of the recording, which is included in Princess Cruises Fleet Regulations, is at **Annex G**.

¹⁶ An EEBD is a 10 minute duration air or oxygen device, which is only to be used for escape from a hazardous atmosphere. Regulation 13 of SOLAS Chapter II-2 requires passenger ships carrying more than 36 passengers to carry at least four EEBDs in each main vertical zone.

A safety video was also shown continuously over the stateroom TVs on the same day. The video included: description of signal for GES; how to locate muster stations and what to take; how to don lifejackets; the action to take on detecting a fire; the operation of manual call points, including notification that no sound will be heard; to smoke in designated areas only and not to throw lighted cigarettes over the side; and the abandon ship procedure. Safety information, including the ship's smoking policy, was also included in an information docket provided in each stateroom. The location and directions to allocated muster stations were affixed on the inside of each stateroom door.

1.14 THE CREW

1.14.1 Language

Star Princess had a crew of 1123 comprising a wide variety of nationalities and professions. The ship's officers were mainly British or Italian. The working language on board was English, and all officers whose native tongue was not English, were required to pass a Berlitz standard English test. Princess Cruise fleet regulations state:

Communications with an emergency party, such as a Fire Party, may be carried out in a language appropriate to the party members, eg Italian. [sic]

All communications to and from the Bridge, and all Bridge internal communications are to be carried out in English. [sic]

Ratings were also required to be able to speak English, although the standard required varies with the nature of their duties. English language training was provided on board.

1.14.2 Alcohol and rest

On the ship's arrival in Montego Bay the captain, staff captain, OOW, and senior first officer, were screened for alcohol. The results were negative. Scrutiny of the records of hours of work indicate that the captain, staff captain, senior first officer, and the staff engineer met the rest requirements of STCW 95 for the days in March until the time of the fire.

1.15 TRAINING AND CERTIFICATION

1.15.1 Fire-fighting

In its fleet regulations, Princess Cruises states:

- 1. Senior First Officers and Staff Engineer Officers are to attend a company fire course every three years.*
- 2. All other Deck and Technical Officers, Deck PO's and Deck AB's are to have attended a Company Fire Course every 5 years.*
- 3. 2 Security PO's/Patrolmen are to have attended a Company Fire Course in the previous 5 years.*
- 4. Any person appointed to a rank referred to in paragraphs 1,2,or 3 above, who is new to the company or who is undertaking their first appointment in one of those ranks, is to be in possession of an STCW 95 Advanced Fire Fighting Certificate issued within the previous 3 years. He is to attend a Company Fire Course at the earliest opportunity, but in any case within 2 years of joining the company.*

The company's fire course is held at the Warsash Maritime Centre and the East Midlands Airport fire training facilities in the UK. The courses have been operating since 1988, and about 25 courses are run per year, each with about 14 ships' crew. The course is 5 days in duration and its syllabus is similar to the STCW advanced fire-fighting course, except that it is a day longer and contains more practical training. The course, which includes basic search and rescue techniques, is designed specifically for the crews of Princess cruise ships and utilises all of the equipment normally found on board. This includes the helmet mounted TIC, which is provided in excess of regulatory requirements. No problems were reported regarding the use of this helmet during the courses conducted. The senior first officer and staff engineer on board *Star Princess* last completed the company fire course in March and August 2004, respectively. The Staff Captain completed the course in April 2000. All members of the fire parties had completed an advanced fire-fighting course to meet the requirements of STCW 95. This course only has to be completed once.

Emergency drills were conducted weekly on board *Star Princess*. No fire drills were planned or conducted on balconies. The last fire drill to be completed before 23 March was on 9 March; a damage control drill was conducted on 17 March. A fire drill in the accommodation area was planned for 23 March while the ship was in Montego Bay. The staff engineer recalls a member of his fire party struggling to put on a fire-fighting suit during a recent drill, but he had not been made aware that the problem prevented the man from undertaking his nominated role. Emergency drills were witnessed by the Bermudan administration during the vessel's annual renewal of her PSSC, and by the USCG during periodic control verification inspections. The last drill to be witnessed by the Bermudan administration was on 25 January 2006, which was a fire in the laundry.

Ten instructors were employed by Princess Cruises to provide on board training to its ships' crews in a variety of subjects, including sea survival. The instructors visit ships in groups of between three and four, and also set, and oversee, crew drills.

1.15.2 Muster personnel

All crew members nominated to carry out emergency duties as stairway guides or muster personnel received continuous on board training to meet the requirements of Section A-V/3 of STCW 95. Fleet regulations instructed the use of volunteer passengers and other ships' crew during drills to assist with stairway guides and muster personnel exercising their duties, but did not require any accounting procedures to be conducted. The person in charge of muster station 'A' had no experience in conducting a roll call during the 6 years she had been engaged in passenger muster duties.

1.16 SHIP MANAGEMENT

1.16.1 General

Princess Cruises, based in Santa Clarita in California, USA, is a wholly owned subsidiary of the Carnival Corporation. The company operates 15 passenger cruise ships, which carry over one million passengers each year. Other cruise operators owned by the Carnival Corporation include Holland America Line, Seabourn Cruise Line, Windstar Cruises, P&O Cruises, Cunard, Ocean Village, Costa Cruises, Swan Hellenic, AIDA, and P&O Australia.

1.16.2 Audit

Princess Cruises audits its ships annually. About five of its ships are also audited by the Carnival Corporation each year. The last internal audit on board *Star Princess* was completed by the company's manager of maritime compliance in June 2005. The manager of maritime compliance is also the designated person, as required by the ISM Code, for all of the company's cruise ships. All deficiencies highlighted were of a localised nature and, with the exception of some missing detail on the ship's fire control plan, were rectified by November 2005. The information missing from the fire control plan concerned its issue and revision date, and the identification of a store and a fire screen door.

1.16.3 Response

The marine vice president of Princess Cruises was informed by telephone of the fire on board at 0323 on 23 March. An emergency response plan was immediately put into effect, and the company emergency response team assembled at its emergency response centre in Santa Clarita, California. A direct telephone link was maintained between the centre and the ship until after the ship arrived in Montego Bay.

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 SIMILAR ACCIDENTS

During the course of this investigation, the MAIB was made aware of six fires on the balconies of cruise ships during which either plastic chairs or beach towels had caught alight. A cigarette end started one fire; the cause of the remaining five was not known. Following the fire on board *Star Princess*, one passenger reported that during the voyage, a discarded cigarette end had landed on one of the plastic chairs on his balcony, and had left a burn mark. Several other passengers reported that discarded cigarette ends had also landed on their balconies.

In 2003, a fire was started on a cruise ship after sparks from the funnel made contact with the padding to a roller skating track and ignited it. With winds in excess of 30 knots over the deck, the fire quickly spread further aft over a children's slide and the remaining roller skating area. The padding and decking was not required to be fire resistant or non-combustible. The padding material was later found to be highly flammable.

On 20 July 1998, a fire occurred on board the Liberian registered passenger ship *Ecstasy*. The fire was investigated by the US NTSB, which determined that the fire had started in a laundry space, and spread to the aft mooring deck via lint in the ventilation system. The NTSB investigation report concluded that the lack of an automatic fire suppression system on the aft mooring deck, which was categorised as an open deck space, contributed to the extensive fire damage caused. Recommendations in the investigation report to a number of cruise ship owners and operators, including Princess Cruises and the Carnival Corporation, included:

For existing vessels with mooring deck design arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install fire detection and suppression systems on mooring decks that carry high fire loads and presently have no automatic fire protection (M-01-8)

Install emergency call systems in passenger staterooms and crew cabins so that people trapped during a fire emergency will have a means of signaling their location (M-01-10) [sic]

2.3 FIRE IGNITION AND PROPAGATION

2.3.1 Seat of the fire

The time, location, and sequence of the activation of the smoke and heat detectors fitted, along with video evidence, the accounts of passengers, and the survey of the damage, indicate that the fire started in the vicinity of the stateroom balconies of C316 and C318, on deck 10. The alarms in these staterooms were the first to activate in the accommodation area, and the sequence of alarm activation (**Table 1**) shows that the fire spread upwards and aft. **Figure 3** illustrates that C316 was the lowest and most forward stateroom of the fire-affected area. Video evidence taken at 0311 from B302

on deck 11 (**Figure 2**) confirms that the base of the fire was in the vicinity of these staterooms. It also confirms that the fire was sufficiently developed to collapse the glass in the balcony door of C316, and ignite the curtains in C318 when its balcony door was opened. Given that the passengers in C318 saw only a glowing strand of material across their balcony door, rather than flames, it is probable that the fire was more developed nearer the aft boundary of the balcony of C316. The glowing strand was possibly molten material from either a balcony partition, or a light cover over the balcony doors.

2.3.2 Cause of ignition

There was no evidence that accelerants were used to intentionally set the fire, and the only electrical fittings on the balconies were the enclosed light fittings above the balcony doors. The damage to the light fittings on the balconies of C316 and C318 was consistent with exposure to an external heat source; there was no evidence of arcing or failure. In the absence of any evidence to the contrary, it is considered that the most likely source of ignition was a discarded cigarette end.

The time lapsed from the smell of burning first being reported to the OOW at 0250, and the manual call point being activated at 0309.20, indicates that the fire probably smouldered for about 20 minutes before flames developed. This was consistent with the fire being started by a discarded lighted cigarette end landing on combustible materials. Although the ignition of towelling material from *Star Princess* by a lighted cigarette end was not reproduced during the BRE tests (**Annex E**), possibly due to the small scale of the samples used and the difficulty in simulating the ambient conditions experienced on 23 March, other towelling samples did ignite in this manner. Furthermore, it is highly likely some of the synthetic garments on the balcony of C316 would have done likewise, or at least assisted in the transition from smouldering to flame.

The dangers of the casual discarding of cigarette ends, which have not been properly extinguished, are well acknowledged by many shipping companies. The potential for discarded cigarette ends falling onto combustible material is demonstrated by at least one of the previous balcony fires detailed in **Paragraph 2.2**. Although passengers on board *Star Princess* were instructed to properly extinguish cigarette ends in the ash trays provided during the safety video shown throughout the day of embarkation, and in the safety literature provided in the staterooms, the cigarette ends found on balconies after the fire, and the scorching of a plastic chair by a discarded cigarette end, indicates that this instruction was not always adhered to. As the last cigarette to be smoked on the balcony of C318 was nearly 3 hours before the smell of burning was reported, and an ash tray was used on the balcony, it is highly probable that the cigarette end igniting the fire was discarded elsewhere.

2.3.3 Propagation

The smoke and heat detector alarms included in **Table 1** indicate the fire spread from a balcony in the middle of zone 3 on deck 10, to balconies and staterooms on decks 10, 11 in zones 3 and 4 within 6 minutes, and to zone 5 in almost exactly 30 minutes. Analysis of the reconstruction of the fire at Warsash, the tests conducted by BRE, the sequence of fire detection alarm activation, and the environmental conditions, indicate that the fire spread rapidly due to two major factors. First, the materials in the balcony furniture, deck tiles, and partitions were readily ignitable by flame, and generated large

amounts of heat. The screed beneath the deck tiles was also likely to have contributed to the fire load and localised combustion. Second, once fire was established, the strong wind over the deck provided ample oxygen, spread molten and burning debris, and generated local 'blow-torch' effects in the gaps above and below the partitions which increased the temperature of the fire in these areas.

Although manoeuvring of the ship was initiated within 5 minutes of the captain arriving on the bridge, this was 8 minutes after the alarm had been raised, and it took until 0320 for the relative wind to shift to the starboard bow, thus sheltering the fire. During this period, the fire had already covered about half of the final damaged area (**Figure 5**). The frequency of alarms reduced significantly after 0320, which highlights the importance of the relative wind in the development and growth of external fires, and the need to consider manoeuvring as soon as possible.

2.4 FIRE PROTECTION

2.4.1 Categorisation

The installation of balconies has become increasingly common on modern passenger vessels since the mid 1980's. Since then, external balconies have been consistently categorised as 'open deck spaces' (Category 5) with regard to the fire protection requirements of SOLAS Chapter II-2, by ship designers, national administrations, and classification societies worldwide. Therefore, the categorisation of the balconies on board *Star Princess* as open deck spaces was accepted practice, and the main influences on the materials used were based on weight, commercial and maintenance considerations. This is evidenced by the wide-range of materials used within the industry.

The fire protection regulations do not prescribe the combustibility, smoke generation potential, and toxicity of materials used on open deck spaces, but they do specify that bulkheads between open deck spaces and accommodation spaces (categories 6 to 8) shall be 'A' class divisions (**Table 9.1 at Annex C**). However, the regulations exempt the doors in these divisions from the 'A' class requirements for fire integrity at the outer boundaries of the ship, apart from those adjacent to survival craft stowage, embarkation, and descent. Furthermore, the regulations do not prescribe the integration of the boundaries of open deck spaces with a vessel's fire zones, or require either fixed fire detection or suppression systems to be fitted. Therefore, although the balconies on board *Star Princess* met the requirements of the fire protection regulations:

- The polycarbonate partitions, the deck tiles, and the plastic furniture were highly combustible and produced large quantities of very thick black smoke when burned.
- The glass in the doors between the staterooms and balconies were neither fire rated to meet with the requirements of an 'A' class division, nor self-closing.
- The balconies crossed main fire boundaries, both horizontally and vertically, without structural or thermal barriers at the zone or deck boundaries, and
- No fire detection or fire suppression systems were fitted.

As a result, the fire was able to develop undetected for about 20 minutes. Thereafter, it was then able to penetrate into the staterooms via the balcony doors, and to cross zone and deck boundaries unchecked. This clearly demonstrates that the regulation's purpose to contain a fire in its space of origin was not achieved.

2.4.2 Preventative action

To prevent the re-occurrence of this type of accident on board existing and future passenger cruise ships, it is imperative that immediate action be taken to address the risk of fire in external areas such as balconies, and to stop the risk of spread of any such fire. This is recognised by ICCL which, after a meeting with the MAIB, promptly issued a safety notice to its members dated 13 April 2006 recommending the immediate implementation of precautionary measures. These measures focussed on increased vigilance, the removal of passengers' personal items from balconies, the re-emphasis of fire safety to passengers and crew, and crew training. However, while such measures might be effective in the short term, it would be impossible to maintain their effectiveness over an indefinite period. Consequently, ICCL also recommended that fire risk assessments be carried out on all external areas, particularly balcony areas, and that:

In accordance with the results of the fire risk assessment, and in consultation with regulatory authorities replace all inappropriate materials on balcony areas with materials that are determined to be acceptable. Replace all combustible balcony dividers on a priority basis and as soon as possible with dividers that are of non combustible material.

A plan to make any replacements of materials should be developed as a final step of the fire risk assessment, with the aim of completing this action within six months from the issue of this safety notice. [sic]

The MAIB strongly endorses that, as a minimum, balcony partitions should be constructed from non-combustible materials. Notwithstanding the possible use of active measures such as fire detection and suppression systems, this is considered to be the only way of ensuring that a fire is unable to spread in these areas.

Amendment to the regulations is required to ensure the basic principles of SOLAS II-2, particularly the application of passive measures such as the use of non-combustible materials are applied, not only to balconies, but also to other external deck spaces. Had the balcony partitions on board *Star Princess* been non-combustible, and her balcony furniture and deck tiles been of restricted combustibility, the risks of the fire spreading, and thick black smoke entering the passenger accommodation, would have been substantially reduced. The introduction of active measures, such as fire detection and fire suppression systems in external areas would also reduce the risk of fire spread. In this case, fire detectors would have alerted the bridge sooner, and a sprinkler system might have extinguished the fire before it spread to adjacent balconies, or knocked its flames down sufficiently to reduce its rate of growth. However, notwithstanding the obvious benefits of these active measures, the lack of activation of some of the water mist heads in staterooms indicates their potential to fail, and where these measures are required internally, they are fitted in addition to, not instead of, structural and thermal boundaries. Furthermore, restrictions on the fire-loading of accommodation spaces in which they are fitted still apply. There is no reason why balconies or other external deck spaces should be treated differently.

2.5 SMOKE INGRESS INTO PASSENGER ACCOMMODATION

The sequence of smoke alarms (**Table 1** and **Figure 7**) indicates that smoke entered the internal alleyways in the passenger accommodation via the outboard staterooms. Once smoke entered the staterooms through open balcony doors, or doors of which the glass had collapsed, it was then able to move to the alleyways through the ventilation louvres in the stateroom to alleyway doors (**Figure 19**), or through doors opened as passengers evacuated. This movement of the smoke would have been enhanced by the natural flow of air generated by the ship's forward motion. It is also likely that the smoke from the fire was entrapped and funnelled, to some degree, by the overhang of deck 14, which would account for the ingress of smoke being more severe on deck 12 than on the decks below.

Figure 7 shows that smoke ingress into zone 3 on deck 12 engulfed the entire alleyway in 1.5 minutes, and was particularly dense towards its aft end where the detectors outside stateroom A334 and A318 were saturated within 3 minutes of their activation¹⁷. For such a quantity of smoke to enter the alleyway in such a short space of time, it must have entered through one or more open stateroom doors towards the aft end, above the fire's origin. This was evident from the soot staining outside staterooms A330 (**Figure 19**) and A338 (**Figure 20**). Although the first smoke detector to activate on deck 12 was in zone 4 (A402), the smoke damage in zone 4 was significantly less than the damage in the alleyway of zone 3 (**Figure 21**). Therefore, the smoke in zone 3 is highly unlikely to have originated from zone 4. The flames and embers seen in the smoke in the alleyway were possibly caused by volatile gases within the smoke, which ignited on meeting with a fresh supply of oxygen.

The tests conducted by BRE confirmed that the polycarbonate partitions, the plastic furniture, and the polypropylene deck tiles produced thick black smoke when burned. Exposure to this smoke, the levels of which would have prevented the use of these partitions and deck tiles in internal areas, had serious consequences. In particular, the passenger who died from asphyxia was in the aft section of the alleyway in zone 3 on deck 12, where the smoke was most concentrated, for about 40 minutes. The semi-conscious passenger recovered from the same area probably survived because he was towards the forward end of the alleyway, and was exposed to the smoke for about 25 minutes. Given the low visibility within the dense smoke, it was not surprising that the PL lighting was not seen.

The permanent provision of door wedges, which were used during the evacuation of the staterooms, have the potential to turn self-closing doors into openings in fire class divisions, and facilitate both smoke and fire spread. The practice of leaving stateroom doors ajar once passengers have been cleared, has similar potential.

2.6 RESCUE OF PASSENGERS

In addition to the incapacitation of the passengers in the alleyway, the smoke in zone 3 on deck 12 also trapped the passengers of A340 in their stateroom. Although the wives of the collapsed passengers had expressed concern regarding the wellbeing of their husbands, and the passengers in A340 had tried to call for help via their

¹⁷ It is acknowledged that the performance of detector heads is unlikely to be identical due to changes over time as dirt accumulates on the sensor surfaces. This is one possible explanation for the activation of the smoke alarms outside staterooms B324 and A340 moments before the first alarms activated in the adjacent staterooms.

stateroom telephone, the crew was not immediately aware of the predicament of these passengers. The probability that passengers were still in this area only became fully apparent when the staff engineer recovered two other passengers from a stateroom at the forward end of the alleyway, shortly after arriving at the scene. As the engine fire party did not leave its fire locker on deck 4 until about 0324, and proceeded to deck 12 via deck 11 then deck 14, they would not have arrived on deck 12, zone 3 until about 0335. By this time the casualties had been in the alleyway for at least 15 minutes.

The manual call points proved effective in raising the alarm, but the availability of emergency call systems in staterooms, as previously recommended by the NTSB following the fire on board *Ecstasy* in 1998, would also have allowed the passengers in A340 to quickly notify the crew of their entrapment. However, the staterooms were equipped with a telephone, which should have been equally as effective. A permanently manned telephone contact point, particularly if 911, 999, 000, and other emergency numbers are used, has the advantage over other alarm systems in passenger ships in that: passengers are able to raise an alarm in a familiar manner; the crew are provided with more information than just location; passengers are aware their report has been received, and; little or no re-enforcement is required during passenger safety briefings. On this occasion, although a number of passengers called the ship's medical emergency number, 911, which was an instinctive action, particularly for American passengers, only one of these calls appears to have been answered before the crew alert was sounded. The calls made after the crew alert was sounded, including the call from the passengers in A340, were not answered because the customer service desk was no longer manned.

During the search of deck 12, the action of the two firefighters in BA, who successfully recovered the passengers from the alleyway and A340 in very difficult conditions, was praiseworthy. Nevertheless, the search for further trapped passengers was interrupted while these firefighters changed air cylinders following the recovery of the first casualty. Had the firefighters been rotated in a similar fashion to the deck fire party on deck 11, and another two firefighters been inserted into the alleyway at this point, a near continuous search might have been possible. However, time would have been required to brief the relieving firefighters, who would probably have also needed additional time to orientate themselves in the smoky conditions. In making his decision on how the fire party was deployed, the staff engineer had to balance these factors, with others such as the personal strengths and experience of the individuals concerned, plus the demands on the party to extinguish the fire from the adjacent balconies.

TICs are frequently used to assist in searches, and in locating the seat of a fire. In this case, although a helmet mounted TIC was intended for use by the fire party, it was not used. Similarly, EEBDs were available in the ship's fire lockers, one of which was sited adjacent to the lift lobby from where the engine fire party was operating. While it is acknowledged that it is often beneficial to employ the 'drag and lift' technique to remove unconscious or semi-conscious casualties as quickly as possible from a smoke filled environment, the use of EEBDs could have been of benefit to the passengers from A340. These passengers could have donned the devices under the supervision of the firefighters, in the relative security of their inboard stateroom. They would then have been able to transit the near 40m of alleyway to safety, without inhaling further smoke.

Although the engine fire party had only five, rather than six, firefighters with BA, as only two of these were used during the search and rescue on deck 12, it is impossible to determine to what extent, if any, this deficiency impacted on the speed and manner of the recovery of the trapped passengers. The use of Italian on the party's VHF radio was not in accordance with the company's regulations, and potentially resulted in the non-Italian members of the party not being fully aware of what was happening. It is possible that a greater proficiency in English would have assisted key personnel to continue to communicate in English in the stressful and demanding conditions experienced.

2.7 EMERGENCY RESPONSE

2.7.1 Command, control and communication

The initial actions taken after the alarm was raised at 0309, including the calling of the assessment party, and the signalling of the crew alert and GES, were prompt and in accordance with the ship's written procedures. The actions to close the fire screen doors, stop the ventilation, and to prepare the lifeboats and liferafts were also timely. Assisted by accurate reports and advice from the senior first officer at the scene of the fire, along with the ship's safety management system, the captain and staff captain quickly determined the nature of the fire and prioritised the fire-fighting effort.

It was fortunate that the fire was contained and extinguished by the crew. Had external assistance been required, the time lost by not sending the PAN PAN message could have been significant. The failure to send the message on this occasion, despite its preparation, underlines: the need for clear instructions in emergency situations; the need to encourage all personnel to approach their seniors if they consider an important safety action has been inadvertently omitted, and; the usefulness of checklists in emergency situations.

The captain kept the passengers fully informed during the time they were in the muster stations via frequent and comprehensive announcements. The management of Princess Cruises were also kept fully informed through the open telephone link between the ship and its emergency response centre.

2.7.2 Alerting of passengers

The passengers in the fire affected staterooms and alleyways on decks 10 and 11 appear to have been alerted and able to evacuate to safety in good time, whereas the activation of the manual call point outside A342 on deck 12 at 0316 indicates that the passengers in this deck were not fully aware of the situation until between 5 and 7 minutes after those on the decks below. **Table 1** and **Figure 7** show that smoke was first detected in the aft section of the alleyway at 0317 and had become saturated by smoke at 0320, the same time as the GES was signalled. Had the GES been sounded earlier, it is possible that a greater degree of urgency might have been instilled in the passengers in zone 3 on deck 12, and a more rapid evacuation might have followed. However, as the assessment party was already clearing the staterooms on the affected decks; as there was no indication of significant smoke entering the alleyway of zone 3 on deck 12 until 4 minutes after the crew alert signal was sounded, and; as the fire-fighting effort would probably have been hampered in the panic and confusion that is likely to have followed the signalling of GES before the crew had time to take up their positions, the interval between the sounding of the crew alert and the GES was understandable.

2.7.3 Fire-fighting

The possibility of a fire on one of the ship's balconies did not form part of the shipboard emergency drill scenarios. Balcony fires were not drilled by the ship's crew. Consequently, the situation faced by the firefighters was unexpected and even more challenging than otherwise might be the case. The fire-fighting strategy was unrehearsed, and the fire already covered decks 10, 11, and 12 in zones 3 and 4, and was spreading further aft, by the time the fire-fighting effort was started. Furthermore, the fire was on the outside of the ship and difficult to access. Therefore, it was not surprising that unforeseen difficulties were encountered, including the availability of keys for balcony divides, the handling of hoses, and the quantity of smoke in the open deck areas. In the circumstances, the ship's crew merits commendation for its application and energy in bringing the fire under control within about 1 hour.

2.8 EFFECTIVENESS OF THE WATER MIST SYSTEM

The combined effect of the water mist system and restricted use of combustible materials in staterooms prevented the fire from spreading further into the ship despite temperatures on the balconies reaching in excess of the 550°C (the temperature required to melt the aluminium structure). The effective performance of the water mist system both in extinguishing the fire, and cooling the affected areas, is clearly shown by the comparison of the damage to C510 (**Figure 18**), where the water mist head did not operate, and the fire re-ignited after being extinguished, to staterooms in which the system successfully operated (**Figures 16 and 17**). The effectiveness was also shown by the cooler temperatures towards the interior of the staterooms, as illustrated by the undamaged chocolates.

Notwithstanding the failure of nine water mist heads, it is probable that the water mist system operated beyond the regulatory requirements to cover a minimum of 280m². The 168 heads which activated in the fire affected areas covered an equivalent area in excess of 2000m², and although the system pressure reduced below normal levels as more heads activated, sufficient pressure was maintained to effectively contain the fire. Given the amount of damage caused where the system failed to activate, this was extremely fortunate.

2.9 ACCOUNTING OF PASSENGERS

During an emergency, the purpose of muster stations is to provide passengers with a place of safety, ensure that no passengers are missing, and to ensure that embarkation into survival craft is undertaken in a controlled manner. The method by which passengers are accounted for in the muster station is left to the discretion of shipowners and operators. Whatever method is used, the mustering of several thousand passengers, particularly by name and stateroom number, will inevitably take a long time. Notwithstanding difficulties such as names which are difficult to pronounce, language, identical surnames, and passengers not hearing, the calling of 500 names alone will probably take well over 1 hour. A head count of so many people is also unlikely to be accurate and will need to be repeated several times. Regardless of the procedure used, any roll call procedure will also require good communications between, and co-ordination of, the muster stations in order to resolve the discrepancies caused by passengers attending the wrong location.

The problematic nature of passenger muster was recognised by Princess Cruises, which preferred to ensure that passengers were clear of affected areas, in preference to conducting a roll call (**Annex G-paragraph 1.7**). This policy is a positive measure, which is likely to be effective during many emergencies, and overcomes problems such as passengers not hearing the PA announcements. Unfortunately, on this occasion, dense smoke prevented all of the staterooms in the fire affected areas from being systematically checked, and a full roll call was initiated. As all of the passengers from the staterooms on the port side of zone 3 on decks 10, 11, and 12 were allocated to muster station 'B', had the passenger lists provided also been arranged by zone and deck, as well as alphabetically, a roll call limited to these passengers would have been possible. In conjunction with telephone calls to the staterooms in the affected areas, this would probably have facilitated a quicker and more effective resolution of any missing passengers.

The communication and co-ordination difficulties encountered during the roll call conducted on board *Star Princess* were highlighted by the inaccurate information passed to the widow of the deceased passenger and her friends. They also contributed to the inability to identify the deceased passenger until over 6 hours after GES was signalled. It is acknowledged that, although the crew in the muster stations were trained in accordance with the regulations, the situation they faced was very difficult, and one which was virtually impossible to have rehearsed on a realistic scale. Until advances in technology are forthcoming, the completion of a full roll call on board large passenger cruise ships will be difficult to achieve within a reasonable timescale.

SECTION 3 - CONCLUSIONS

3.1 FINDINGS

The following safety issues have been identified as a result of this investigation. They are not listed in any order of priority.

1. During the course of this investigation, the MAIB was made aware of six fires on the balconies of cruise ships during which either plastic chairs or beach towels had caught alight. [2.2]
2. The fire started on the balconies in the vicinity of staterooms C316 and C318, on deck 10, and was probably ignited by a cigarette end discarded elsewhere. [2.3.1, 2.3.2]
3. The fire spread rapidly across zones and decks because of the combustible materials on the balconies, and the strength and direction of the wind over the deck. [2.3.3]
4. The balconies on board *Star Princess* were categorised as 'open deck spaces' to which the prevailing fire protection regulations did not prescribe the combustibility, smoke generation potential, and toxicity of materials used. [2.4.1]
5. Amendment to the regulations is required to ensure the basic principles of SOLAS II-2, particularly the use of passive measures such as the use of non-combustible materials, are applied not only to balconies, but also to other external deck spaces. [2.4.2]
6. Smoke entered the alleyway in zone 3 on deck 12 through outside staterooms, preventing a number of passengers from evacuating safely, and resulting in the death to one passenger, and serious injury to others. [2.5]
7. The materials used in balcony partitions and deck tiles, would not have been allowed to be used within the ship due to the dense smoke generated by them when burned. [2.5]
8. The use of door wedges in self-closing doors, and leaving such doors ajar, has the potential to breach openings in fire class divisions. [2.5]
9. The probability that passengers were trapped only became fully apparent when the staff engineer recovered two passengers from a stateroom at the forward end of the alleyway on deck 12, zone 3, shortly after arriving at the scene at 0335. [2.6]
10. Passengers trapped in A340 were not able to alert the crew to their situation by calling 911 from their stateroom telephone, because the customer service desk was not manned after the crew alert was signalled. [2.6]
11. Following the recovery of the first casualty from deck 12, the search for further trapped passengers was interrupted while firefighters changed air cylinders. [2.6]
12. The engine fire party did not utilise all of the equipment available during its search and rescue operation, and the composition of the party and use of Italian during radio communications, were not in accordance with on board procedures. [2.6]

13. The initial actions taken after the alarm was raised at 0309, including the calling of the assessment party, and the signalling of the crew alert and GES, were prompt and in accordance with the ship's written procedures. [2.7.1]
14. Had the fire not been contained, the time lost by not sending an urgency (PAN PAN) message could have been significant. [2.7.1]
15. Although some passengers in zone 3 on deck 12 were not alerted to the situation until between 5 and 7 minutes after those on the decks below, the interval between the sounding of the crew alert and the GES was understandable. [2.7.2]
16. As the fire was difficult to access, had not been drilled, and was already well established by the time the fire-fighting effort was started, the application and energy of the ship's crew to bring it under control in about 1 hour, merits commendation. [2.7.3]
17. The combined effect of the water mist system and the restricted use of combustible materials in staterooms prevented the fire from spreading further into the ship, despite temperatures on the balconies reaching in excess of the 550°C. [2.8]
18. Given the amount of damage caused where the water mist system failed to activate, it was extremely fortunate the system operated beyond the minimum regulatory requirement. [2.8]
19. The difficulties and inaccuracies of the roll call were highlighted by the inaccurate information passed to the widow of the deceased passenger and her friends, and contributed to the inability to identify the deceased passenger. [2.9]
20. Had a roll call initially been started with the passengers from the staterooms in the fire-affected areas, a more rapid and accurate determination of those missing might have been possible. [2.9]

SECTION 4 - ACTION TAKEN

The International Council of Cruise Lines:

Issued a safety notice dated 13 April 2006 to notify its members of the preliminary indications from the fire on board *Star Princess*, and to urge immediate action. This action included the aim of replacing combustible balcony partitions with non-combustible partitions within 6 months. A copy of the safety notice is contained within **Annex H**.

The Council has also stated its intent to review the important lessons learned from this accident, with the aim of developing and promulgating further safety guidance to its member companies.

The Marine Accident Investigation Branch:

Issued a Safety Bulletin 1/2006 (**Annex H**), which included the following recommendations:

To the Maritime Administration of the United Kingdom:

- 2006/162 Submit a formal request to the forthcoming eighty-first session of the International Maritime Organization (IMO) to:
- consider the issue comprehensively, with a view to urgently developing appropriate amendments to the 1974 SOLAS Convention, to address hazardous external areas of passenger ships, such as balconies, and ensure that they meet appropriate standards of fire protection, such as those currently applicable to internal areas of passenger ships;
 - in the interim, issue appropriate urgent guidance on fire protection of external areas of passenger ships, such as balconies.

To cruise lines and operators/managers of passenger vessels:

- 2006/163 Take urgent action to comply with the measures identified in the ICCL Safety Notice attached at Annex A.

To Flag States:

- 2006/164 Urgently review the fire safety integrity of external areas of passenger ships on their Register, to ensure that the immediate and medium-term actions taken in the light of this Safety Bulletin are effective.

On 20 June 2006 the MAIB posted on its web site the companies and operators from which positive assurance had been received that they were adopting measures to comply with the recommendations in Safety Bulletin 1/2006 and the ICCL Safety Notice, within the timescale prescribed.

The International Maritime Organization:

Following a submission by the UK delegation (MSC 81/4/6) in response to the recommendation in the MAIB Safety Bulletin 1/2006, MSC 81 approved, in May 2006, a circular for immediate distribution detailing operational measures recommended for immediate implementation on passenger ships with balconies (**Annex I**).

The committee also approved proposed amendments to SOLAS Chapter II, and the FSS Code submitted by its passenger ship safety working group with the aim of ensuring that balcony partitions are non-combustible, restricting the use of combustible materials on stateroom balconies, and requiring ships with stateroom balcony furniture which is not of restricted fire risk be fitted with fixed fire extinguishing and fire detection systems. The proposed amendments (**Annex J**) will be considered for adoption by MSC 82 in December 2006.

The committee also instructed its Sub-Committee on Fire Protection (FP) to:

- As a high priority, review the fire safety of external areas on passenger ships and make recommendations, as appropriate, with a target completion date of 2007; and
- As a high priority, develop performance standards for fixed water-spraying, fire detection and fire alarm systems for cabin balconies, with a target completion date of 2008.

Cruise lines:

On 1 October 2006, ICCL confirmed in writing that 14 of its member companies (including Princess Cruise Lines) had implemented the immediate actions and conducted the fire risk assessments of balcony areas as recommended in its Safety Notice. ICCL also confirmed that its members had all developed plans of action for the replacement of identified combustible balcony partitions with suitable non-combustible materials. In this respect, the Carnival Corporation expects to complete this work on all 26,400 balconies on its 81 ships by the end of December 2006.

The MAIB will continue to update its website (www.maib.gov.uk) with the names of cruise line companies which have completed the replacement of combustible balcony partitions, as soon as it has been informed by the companies concerned.

Princess Cruise Lines:

In addition to the actions taken in response to the ICCL safety notice, the MAIB Safety Bulletin, and the MSC circular, additional action taken by Princess Cruise Lines includes:

- Issued guidance regarding fighting a balcony fire, and initiated drills on its ships overseen by its fleet instructors.
- Initiated measures to form a BA party on all its ships, dedicated to the role of the search and rescue of passengers.
- Arranged fire-fighting refresher training for the fire parties on board *Star Princess*.
- Checked the availability of fire suits of various sizes on all its ships.
- Revised its emergency response organisation to ensure that the medical emergency number of 911 continues to be answered after the crew alert signal has been sounded.

- Arranged for door wedges provided in staterooms to be removed, and for crew to be instructed to ensure stateroom doors are closed after checking that they are clear of passengers.
- Arranged for inclusion of confirmation that an urgency or distress message has been sent on the appropriate bridge checklists.
- Provided additional respirators on board its ships
- Increased the number of, and improved the accessibility to, stateroom master keys during stateroom searches.
- Modified its passenger mustering system, including the provision of additional telephone lines in muster control, the designation of telephone operators within each muster station, and the dialling of staterooms within affected areas.
- Introduced an enhanced English language assessment for all deck, technical, and fire-fighting personnel, supported by an on board English language improvement programme.

SECTION 5 - RECOMMENDATIONS

In view of the action already taken, and in progress, no further recommendations are made as a result of this investigation.

**Marine Accident Investigation Branch
October 2006**