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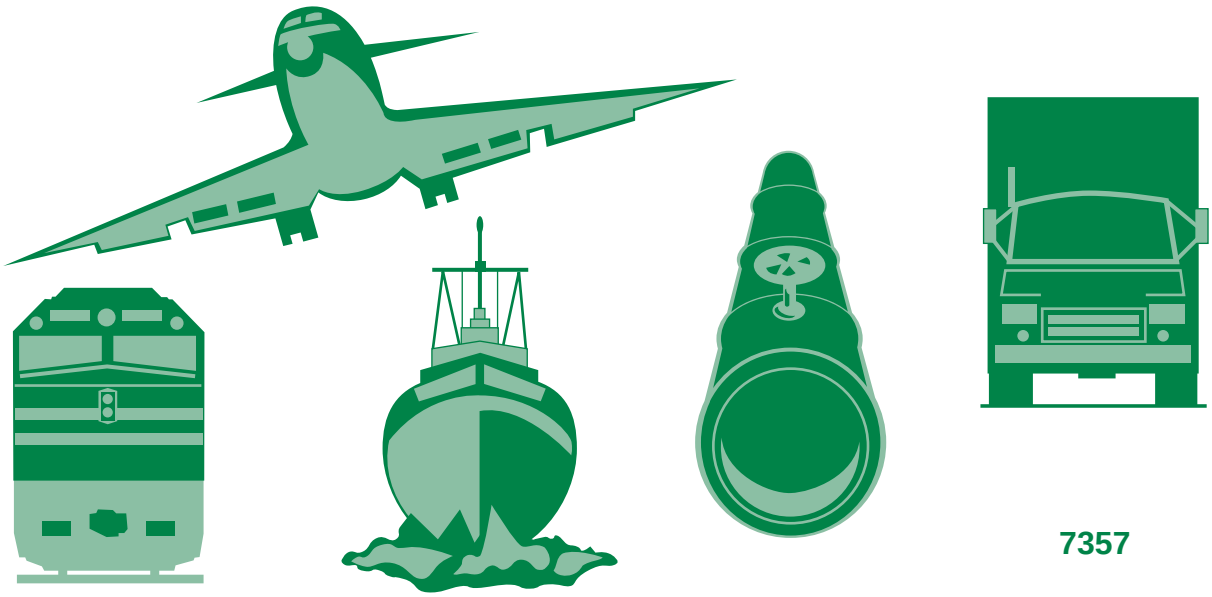
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

FIRE ON BOARD THE LIBERIAN PASSENGER SHIP *ECSTASY*
MIAMI, FLORIDA
JULY 20, 1998



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Notation 7357
Adopted May 1, 2001

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2001. Fire On Board the Liberian Passenger Ship *Ecstasy,* Miami, Florida, July 20, 1998. Marine Accident Report NTSB/MAR-01/01. Washington, DC.

Abstract: On the afternoon of July 20, 1998, the Liberian passenger ship *Ecstasy* had departed the Port of Miami, Florida, en route to Key West, Florida, with 2,565 passengers and 916 crewmembers on board when a fire started in the main laundry shortly after 1700. The fire migrated through the ventilation system to the aft mooring deck where mooring lines ignited, creating intense heat and large amounts of smoke. As the *Ecstasy* was attempting to reach an anchorage north of the Miami sea buoy, the vessel lost propulsion power and steering and began to drift. The master then radioed the U.S. Coast Guard for assistance. A total of six tugboats responded to help fight the fire and to tow the *Ecstasy.* The fire was brought under control by onboard firefighters and was officially declared extinguished about 2109. Fourteen crewmembers and eight passengers suffered minor injuries. One passenger who required medical treatment as a result of a pre-existing condition was categorized as a serious injury victim because of the length of her hospital stay. Carnival Corporation, Inc., the owner of the *Ecstasy,* estimated that losses from the fire and associated damages exceeded $17 million.

The National Transportation Safety Board determines that the probable cause of fire aboard the *Ecstasy* was the unauthorized welding by crewmembers in the main laundry that ignited a large accumulation of lint in the ventilation system and the failure of Carnival Cruise Lines to maintain the laundry exhaust ducts in a fire-safe condition. Contributing to the extensive fire damage on the ship was the lack of an automatic fire suppression system on the aft mooring deck and the lack of an automatic means of mitigating the spread of smoke and fire through the ventilation ducts.

The major safety issues discussed in this report are as follows: adequacy of management safety oversight, adequacy of the fire protection systems, adequacy of passenger and crew safety, and adequacy of engineering system design.

As result of its investigation of this accident, the Safety Board makes recommendations to the U.S. Coast Guard, American Classic Voyages, Carnival Corporation, Inc., Carnival Cruise Lines, Crystal Cruises, Disney Cruise Line, Norwegian Cruise Line, Orient Lines, P&O Princess Cruises International, Ltd., Radisson Seven Seas Cruises, Regal Cruises, Renaissance Cruises, Inc., Royal Olympic Cruises, Royal Caribbean Cruises, Ltd., and Silversea Cruises, Ltd., ABB, Inc., and the International Association of Classification Societies.

Contents

Acronyms and Abbreviations

ATF	Alcohol, Tobacco, and Firearms Bureau
Btu	British thermal unit
CFR	*Code of Federal Regulations*
CO	Carbon monoxide
COTP	Captain of the Port
CVE	Control Verification Examination
FMEA	Failure Mode and Effects Analysis
FSD	fire screen door
HSO	Health and Safety Officer
ICCL	International Council of Cruise Lines
IMO	International Maritime Organization
ISM Code	International Safety Management Code
LED	light emitting diode
LR	Lloyd's Register of Shipping
m^2	square meters
MSC	Maritime Safety Committee
MSO	Marine Safety Office
MVZ	Main Vertical Zone
RFSA	Retroactive Fire Safety Amendment
Ro-ro	roll on-roll off
SMS	Safety Management System
SOLAS	*International Convention for the Safety of Life at Sea*
STCW	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers

UHF	Ultra High Frequency (radio)
UTB	utility boat
WTD	watertight door

Executive Summary

On the afternoon of July 20, 1998, the Liberian passenger ship *Ecstasy* had departed the Port of Miami, Florida, en route to Key West, Florida, with 2,565 passengers and 916 crewmembers on board when a fire started in the main laundry shortly after 1700. The fire migrated through the ventilation system to the aft mooring deck where mooring lines ignited, creating intense heat and large amounts of smoke. As the *Ecstasy* was attempting to reach an anchorage north of the Miami sea buoy, the vessel lost propulsion power and steering and began to drift. The master then radioed the U.S. Coast Guard for assistance. A total of six tugboats responded to help fight the fire and to tow the *Ecstasy.* The fire was brought under control by onboard firefighters and was officially declared extinguished about 2109. Fourteen crewmembers and eight passengers suffered minor injuries. One passenger who required medical treatment as a result of a pre-existing condition was categorized as a serious injury victim because of the length of her hospital stay. Carnival Corporation, Inc., the owner of the *Ecstasy,* estimated that losses from the fire and associated damages exceeded $17 million.

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Factual Information

Accident Synopsis

On July 20, the Liberian passenger ship *Ecstasy* had departed Miami, Florida, and was en route to Key West, Florida, with 3,481 people aboard when the bridge began receiving a series of fire alarms. The first fire alarm, at 1710, indicated the ship's main laundry on deck No. 2. Within a matter of minutes, the fire alarm panel indicated heat and smoke detector activations in the stern thruster room, air conditioning plenums, an electrical room, and the two steering gear rooms. (See figure 1.) The bridge also began receiving telephone calls from crewmembers reporting smoke in various aft areas of the ship. Shortly thereafter, various sources, including a U.S. Coast Guard (Coast Guard) watchstander who was monitoring marine traffic in the channel, observed a large amount of smoke issuing from the stern of the *Ecstasy.* In compliance with Coast Guard instructions, the vessel's master ordered the ship to proceed to an anchorage area; however, before reaching the anchorage, the *Ecstasy* lost propulsion power and steering and began to drift. The master then radioed for assistance. A total of six tugboats responded to help fight the fire and to tow the *Ecstasy.* The fire was brought under control by onboard firefighters and was officially declared extinguished about 2109. Fourteen crewmembers and 8 passengers suffered minor injuries.

Accident Narrative

Preaccident Events

On July 20, 1998, the *Ecstasy* was moored alongside Pier 8, Port of Miami, preparing to depart on a round-trip 4-day cruise with stops at Key West and Cozumel, Mexico. Records indicate that, at 1500, the officer of the watch tested the navigation, communication, and vessel control equipment, and that all equipment operated properly.

About 1550, a member of the Biscayne Bay Pilots Association arrived on board and went to the pilothouse. The pilot stated that while waiting for passenger baggage to be loaded, he read a completed "pilot card," a checklist form indicating that all of the equipment had been tested and was in good order. He also observed a muster drill.[1] He said that he discussed the weather conditions with the master because he (the pilot) was concerned about reaching the sea buoy, where he would disembark, before approaching heavy rains moved into the area. In response to the master's question of whether the ship should delay sailing until after the rain passed, the pilot responded that if they left immediately, the ship could complete the transit to the pilot debarkation station before

[1] Regulations contained in the *International Convention for the Safety of Life at Sea* (SOLAS) require that a cruise ship conduct a passenger and crew muster drill within 24 hours of departure.

The photograph above shows the *Ecstasy* after the fire. The ship area indicated by the dotted line is illustrated in the cutaway below.

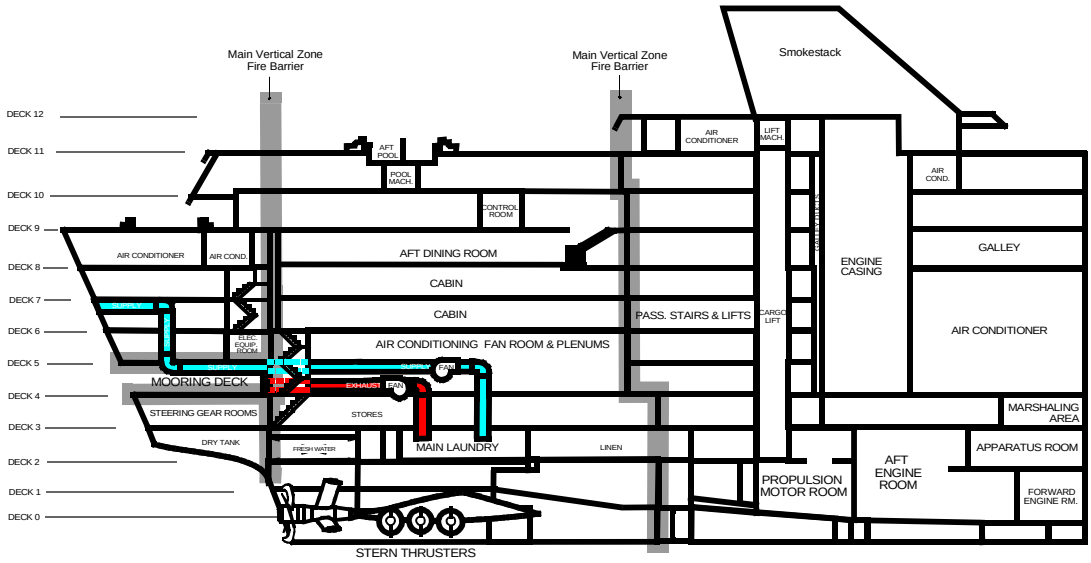

Figure 1. On the day of the accident, the fire alarm panel on the bridge indicated that the first alarm activated in the main laundry on deck No. 2. The ventilation system for the laundry penetrated a main vertical zone (MVZ) and exhausted onto the mooring deck. Other early fire alarms indicated that detectors activated in the stern thruster room, the air conditioning plenum between decks No. 4 and 6, an electrical room above the mooring deck, and both steering gear rooms below the mooring deck.

inclement weather arrived. After the muster drill was completed, the *Ecstasy* departed the Port of Miami with 2,565 passengers and 916 crewmembers on board.

After the *Ecstasy* departed its berth, crewmembers brought in and stowed the synthetic mooring lines on the aft mooring station, which was on deck No. 4. A bosun did a final inspection of the area and secured the two weather-tight doors leading from the mooring station to the passenger stateroom area on deck No. 4. He then exited the area using the center crew stairway. According to the bosun, the weather door to this crew stairway was always left open. The mooring station log indicates that the mooring deck was "all clear" and secured at 1650, meaning no machinery was in operation and no people were in the area. The bosun stated that he noted nothing unusual on the deck when he left.

Once the master directed the maneuver of the ship from the pier to mid-channel, the pilot began directing the passage out of the Port of Miami. The pilot stated that the onset of the voyage was routine. He further stated that no equipment malfunctions occurred, and the members of the bridge team performed their duties in a competent and professional manner.

The Accident[2]

About 1630, a mangle[3] in the *Ecstasy*'s main laundry (figure 2) malfunctioned. The laundry manager telephoned a repair request to the hotel engineer, who, in turn, paged the on-call galley fitter (first fitter). The first fitter said that he was in the fitters' workshop on deck No. 3, preparing to go off duty at 1730, when he was paged and told to go to the main laundry. He said that the laundry manager told him that the mangle was not working properly, and that its roller needed to be adjusted.

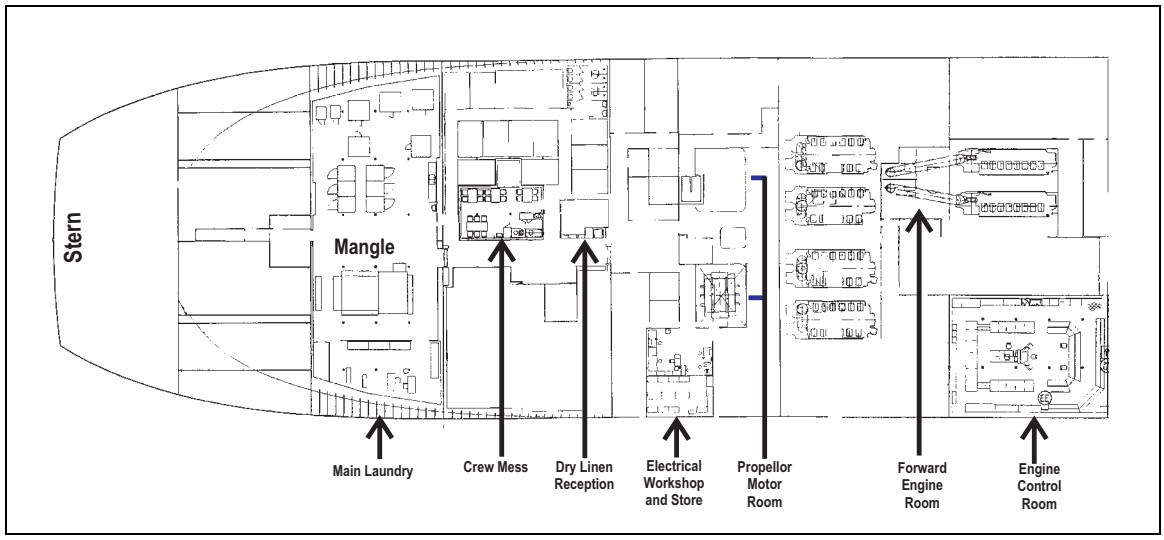

Figure 2. Layout of deck No. 2, aft of the smokestack. In the main laundry, the washers and dryers were on the port side of the ship, and the mangle was on the starboard side.

The first fitter said that when he arrived in the main laundry, the crew was still working and the dryers were running. He said that he tightened a bolt on the mangle's bridge, which directs the linen from the first roller to the second roller. He then started the mangle to determine whether the adjustment fixed the problem. When the mangle still would not work properly, he continued the process of tightening the bolt and starting the machine until the bolt broke at its weld to the mangle.

[2] The Safety Board interviewed the laundry manager and the two galley fitters to determine what occurred in the laundry room before the fire. This accident narrative is compiled using information obtained from those interviews. Because the fitters have the same job title, this report refers to the fitter who first arrived in the laundry as the "first fitter" and the fitter who joined him as the "second fitter."

[3] The mangle is a machine for ironing fabrics, such as table clothes and bed linen.

In the meantime, another galley fitter (second fitter) had finished checking a pump on one of the ship's Jacuzzis and was preparing to go off duty at 1730 when the galley engineer told him to help the first fitter in the main laundry. The second fitter said that when he arrived in the main laundry, the first fitter was adjusting a bolt on the mangle.

The second fitter said that the first fitter tightened a bolt on the mangle so much that the bolt broke off. Both fitters testified that the first fitter decided to weld the bolt back in place. They said that the first fitter went to the fitters' workshop to get the necessary equipment, which included a portable welding machine, welding rods, helmets, gloves, and tools. The second fitter said that he went to get an asbestos (fire) blanket from the machine shop area. Both fitters testified that, at this time, they did not obtain a "hot work permit," as required by Carnival Cruise Lines' Safety Management System (SMS) procedures,[4] because "it was standard procedure" to set up the equipment before calling the staff chief engineer to get a permit and to arrange for a fire watch.

The first fitter said that the location of the bolt, between the roller bed and the end plate on the mangle cabinet, was difficult to reach for welding. The second fitter stated that when he returned to the main laundry, the first fitter was lying on top of the mangle, aligning the broken bolt. The welding machine was on a table next to the mangle. (See figure 3.) The second fitter said, "I saw the welding unit on the table and the welding rod [cable] and ground cable were sitting on top of the panel to the mangle…." He stated that the ground cable was not connected to anything. The first fitter said that he had plugged the welding unit into an electrical outlet and had inserted a welding rod (electrode) into the rod holder.[5]

The second fitter climbed on top of the table next to the mangle. He said that, because the welding rod was hanging near the deck, he pulled the cable toward him. He then saw the welding rod come in contact with either the grounding clamp or the mangle, causing a spark. The second fitter testified that dryer lint was on the floor. The first fitter said that while he was looking down through the rollers of the mangle, he saw "a very small fire" on the floor and "yelled out" about a fire on the deck. Both fitters said that they jumped to the deck, went to the nearby sink, and got a glass of water, which they used to put out the fire underneath the mangle.

The second fitter testified that he saw fire "in the middle of the mangle" and retrieved a fire extinguisher, which he directed on the mangle. The first fitter testified that he saw "big flames" in the ventilation duct immediately above the mangle and that he took a CO_2 fire extinguisher and directed its spray into the overhead vent. He estimated that he battled the fire for about 5 minutes but had to abandon the firefighting effort because the laundry room was filled with smoke. Both fitters testified that when the fire alarms began to sound, they left the laundry and went to their emergency stations.

[4] For further information about Carnival Cruise Lines' SMS and the required procedures for company personnel, see "Operations," later in this report.

[5] The welding machine used by the fitters, a Unitor Miniweld model, did not have an *on-off* switch. The unit was energized when it was plugged in. The specifications for the Miniweld states that it "conforms to the Norwegian Maritime Directorate's rules for welding apparatus on board ships." Unitor has since discontinued manufacturing this model.

Figure 3. (Top) The mangle in the main laundry after Carnival made postaccident repairs to the area. The tables shown are in about the same location as the table on which the fitters placed the welding machine on the day of the fire. (Bottom left) The large uncovered opening in the overhead was one of three vents above the mangle that exhausted air and lint into the ventilation system. (Bottom right) Two fan units drew heat and lint from the pressing rollers into vertical ducts that were connected to the overhead ducts of the main laundry ventilation system.

A cabin steward who had gone to retrieve towels from a linen closet near the main laundry provided a different account of events. He said that he was at the linen closet door when he observed smoke in the main laundry. He said that when he went to investigate, he saw the two fitters working on the inboard side of the mangle. He then saw flames on the outboard side of the mangle, near the exhaust vents. He said that he retrieved a fire extinguisher to fight the fire; however, when one of the fitters dumped a jug of water on the side of the mangle where they were working, flames "appeared to jump up" to an overhead vent. The steward said that the smoke and flames became too great for him to fight with an extinguisher, so he activated the local fire alarm at the laundry room door.

About the same time, the laundry crew was preparing to eat when the laundry manager noticed smoke coming from the overhead vents in the crew galley.[6] He said that he and the assistant laundry manager went to investigate and saw smoke upon entering the laundry. The laundry manager stated that he did not see the fitters through the smoke. The manager and assistant manager left the laundry. The assistant laundry manager said that he pulled the manual fire alarm in the passageway forward of the laundry and closed the watertight door (WTD) at the laundry entrance. The manager closed the fire screen door (FSD) next to the WTD. The two men then reported to their emergency stations.

Activities on the Bridge

At the time that the *Ecstasy* departed Miami, the bridge team comprised the master, the pilot, the staff captain, a first officer, a second officer, a third officer (observer-trainee), and two quartermasters. As the *Ecstasy* entered the Bar Cut Channel, the pilot requested more speed so that the ship could arrive at the pilot debarkation station[7] before encountering the rainsquall, which was approaching from the northeast. At the pilot's request, the master increased the ship's throttle setting to full ahead maneuvering speed (110 rpm), or approximately 13 knots.

At 1710, an alarm sounded on the fire control panel on the bridge. The first officer said that he immediately went to the alarm panel to investigate the source of the alarm and observed that a light on the panel indicated that the alarm was in the main laundry on deck No. 2. He said that the first alarm was followed rapidly by alarms in the stern thruster room, the air conditioning room, and the steering gear room. The first officer said that when he informed the master about the alarms, the master ordered him to send the staff captain and the safety officer to investigate the source of the alarms and to report their findings. The first officer also sent the second officer and two roving fire patrolmen to investigate. A timeline of events beginning with the first fire alarm appears in Table 1.

[6] The laundry crew galley is located on the same deck and immediately forward of the ship's laundry.

[7] The master said that he normally disembarked pilots between buoys number 2 and 3 and the Miami sea buoy. On this night, he went past the sea buoy because he feared that if he stopped near it, the strong northerly current in the area of the sea buoy would cause the ship to drift into an anchorage north of the sea buoy where two ships were anchored. The pilot said he also wanted to put the *Ecstasy* in a clear area because he had traffic behind him, including an outbound passenger ship.

Table 1. Timeline of Events Onboard the Ecstasy

TIME	EVENT
1710	Fire alarm indicating the main laundry sounds on the fire control panel on the bridge. Master instructs first officer to send the staff captain and the safety officer to the scene to investigate the source of the alarm and to report their findings. The first officer also orders the second officer and two roving fire patrolmen to investigate.
+/- 2 min.	All alarms on the fire alarm panel and the sprinkler panel activate. First officer resets all alarms and activates low-level lighting throughout the vessel. During this time, the first officer begins to receive telephone calls from various crewmen reporting smoke.
+/- 5 min.	Alarm on the low-level lighting panel begins to sound.
1720	Master orders ventilation shut down in the two aftermost MVZs.
1724	Master assumes the conn from the pilot after the *Ecstasy* passes the sea buoy.
1725	Master orders first officer to make the “Alpha Team” code announcement alerting the ship’s Quick Response Team. Master orders the cruise director and the hotel manager to the bridge to handle emergency communications.*
1728	Master instructs hotel manager to report fire to the Coast Guard. Before call can be made, Coast Guard Group-Miami radios the ship asking if assistance is needed. Hotel manager asks Coast Guard to stand by while situation is assessed.
1730	Master orders the closure, in the three aftermost MVZs, of the WTDs on decks no. 1, 2, and 3 and the FSDs on all decks. Upon receiving reports of a large quantity of smoke in aft areas, the master orders all fire teams to marshal.
1740	Master orders security officer to clear passengers and crew from the aft part of the ship and chief steward to verify that cabins in smoke affected areas are empty. Fire teams are marshaled and prepared to attack the fire on the stern.
1754	Master is turning vessel to go the anchorage in compliance with the COTP order when the *Ecstasy* loses propulsion and steering and begins to drift. Chief engineer advises master that the computer controlling the propulsion systems is not working and his staff cannot determine the reason why because of the fire. Master radios the Coast Guard for assistance.
1800	Master orders general alarm sounded; passengers and crew begin to muster. Cruise director begins making status announcements to passengers about the fire.
1815	Coast Guard boarding team arrives onboard and is briefed by the master about the fire. Team advises master that he must obtain permission from the Port Authority to return to the Port of Miami. Team then proceeds aft to evaluate fire scene.

Table 1. Timeline of Events Onboard the Ecstasy

TIME	EVENT
1913	All responding tugs are at the scene. *Coastal Miami* is made fast to the *Ecstasy's* bow. Other tugs direct streams of water from their fire monitors at the stern of the *Ecstasy*.
1950	Shoreside firefighters board *Ecstasy* to assess fire scene.
1955	Crewmembers are released from their emergency stations
2109	Miami-Dade FD declares fire under control.
2130	Coast Guard COTP order grants permission for the *Ecstasy* to enter port.
0118	*Ecstasy* arrives at Pier 8, Port of Miami

*The cruise director provided status announcements to passengers, and the hotel manager maintained telephone communications with shoreside Carnival Cruise Lines officials.

The first officer stated that about 2 minutes later, all of the alarms on the fire panel seemed to light up at the same time. In response to this, he reset the panel display. The first officer also began to receive telephone calls from crewmembers reporting smoke in various aft areas. Shortly thereafter, a fault alarm began to sound on the bridge for the low-location lighting, that is, the lighting system that illuminates the emergency escape routes on the vessel. According to the master, the noise from this alarm, which could not be silenced on the bridge, interfered with bridge communications. The chief electrician was sent to check the main unit of the low-location lighting system. The electrician stated that when he could not immediately identify what triggered the fault alarm, rather than return to the bridge and disconnect the alarm mechanism, he shut down power to the system, which turned off all low-location lighting throughout the ship.

Meanwhile, the safety officer descended to the marshalling area on deck No. 3, where he observed smoke in the aft end of the passageway. He said that he immediately radioed the bridge asking that the master make the "Alpha Team"[8] code announcement. The staff captain stated that when he arrived at the marshalling area, he saw no flames but observed smoke spreading upward to deck No. 4. The staff captain radioed his observations to the master and asked that all five fire teams be alerted and that the entire aft MVZ be secured.

[8] An announcement of "Alpha Team" was the signal for the quick response team to assemble in the marshalling area. The quick response team, comprising the fire patrol chief and a 5-person environmental team, was the onboard unit required to respond first to a fire emergency and to take action to suppress a fire until the ship's fire teams could arrive.

About 1718, a pilot on an outbound vessel behind the *Ecstasy* observed smoke issuing from its stern as the *Ecstasy* approached buoys 2 and 3. (See figure 4.) The pilot called the *Ecstasy's* pilot informing him of the smoke. The *Ecstasy's* pilot replied that he and the master were aware of a fire on board the ship.

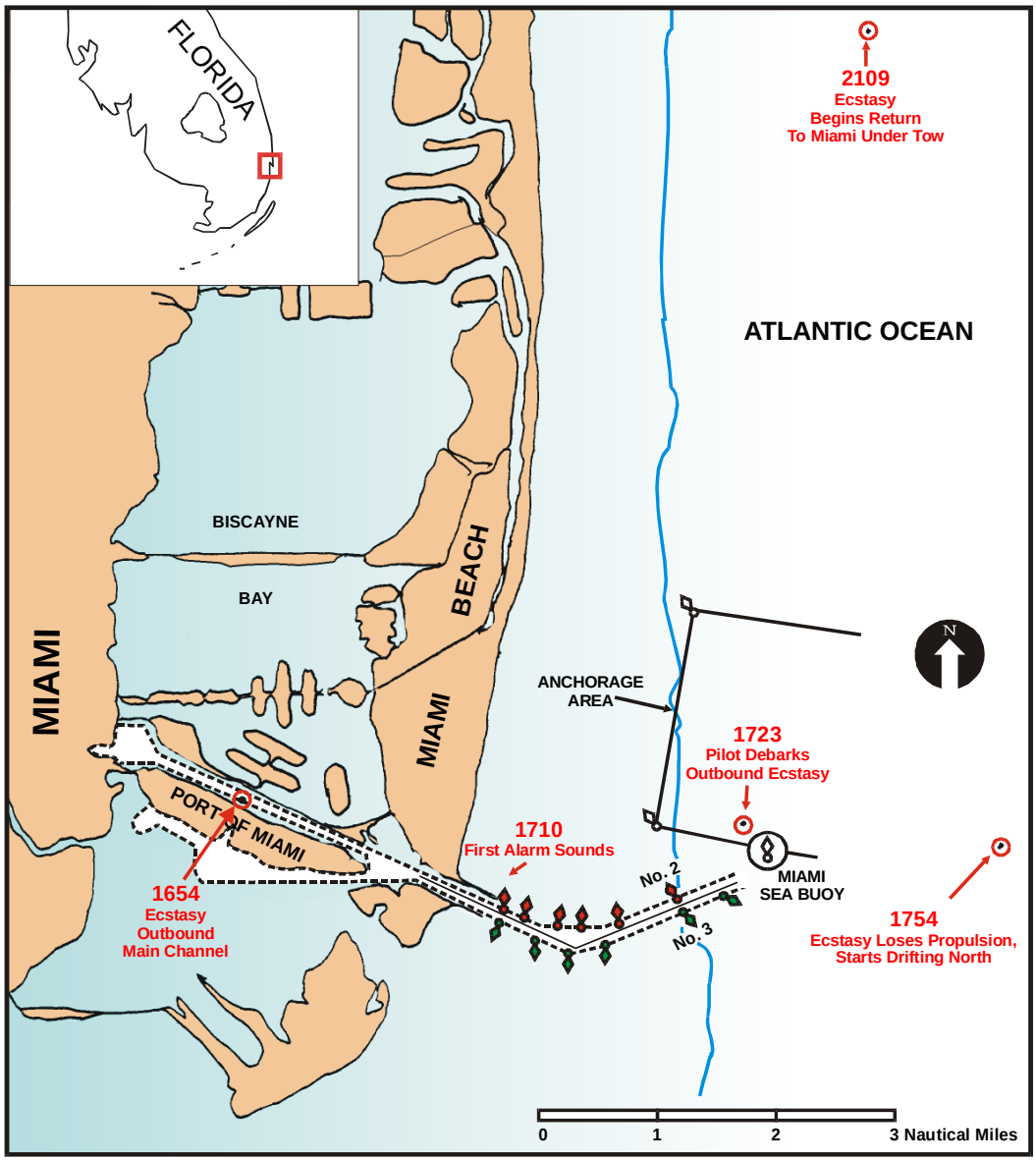

Figure 4. Route of the *Ecstasy* on the day of the accident. Buoys mark the channel to the Miami sea buoy, where State piloting requirements end and near the area where the pilot on the outbound vessel debarked.

At 1720, the master instructed the first officer to shut down all power to the ventilation systems on the aft part of the ship, specifically MVZs 1 and 2. The first officer also called the officer on watch in the engine control room to shut down the ventilation in all areas aft of the engine room. Shortly thereafter, in response to an alarm indicating that

the No. 2 stern thruster was overheating, the engine room watch requested that the bridge discontinue using the stern thrusters to prevent damaging them.

The *Ecstasy* was on a heading of 040° when it passed the sea buoy at 1723. The master said that he then relieved the pilot of his navigational duties, and the pilot left the bridge to disembark. At 1725, the master authorized the first officer to make the "Alpha Team" code announcement alerting the ship's fire teams to report to their emergency stations and to don equipment in preparation for firefighting.

At 1726, the pilot disembarked the *Ecstasy* onto a pilot boat. The *Ecstasy* master said that he then ordered the vessel on a southeast course at 6 knots while the staff captain and safety officer assessed the situation. The master said that he maintained the *Ecstasy* on a heading that carried smoke away from the ship and that avoided other marine traffic. The master called the cruise director and the hotel manager to the bridge to handle communications. The master directed the cruise director to provide status announcements to the passengers and the hotel manager to contact shoreside authorities, including Carnival officials, emergency responders, and the Coast Guard.

Before the hotel manager could report the fire to the Coast Guard, about 1728, a watchstander at Coast Guard Group–Miami who had been monitoring vessel traffic in the channel radioed to ask about the smoke streaming from the *Ecstasy's* stern and whether the ship needed assistance. The watchstander stated that the hotel manager responded that the ship had a fire in the laundry room but that they did not need help at that time. The hotel manager said that he asked the Coast Guard to stand by, as the situation was being assessed. The *Ecstasy's* hotel manager maintained telephone contact with Carnival Cruise Lines' director of operations throughout the emergency. The company implemented its crisis management plan, which included specific shore management assignments for responding to a shipboard fire.

At 1730, the master issued a series of orders to secure the aft area of the *Ecstasy.* He authorized the first officer to close all of the WTDs on deck Nos. 1, 2, and 3 in the aft portion of the ship and to close all FSDs on all decks in the three after-most MVZs. He ordered the ship's security officer to clear passengers and crewmembers from these MVZs and the casino manager to block the area so that no one could return to it after it had been cleared. The master then ordered the chief steward to verify that all cabins in the smoke-affected area were empty.

Shortly after 1750, the Coast Guard Group–Miami radio watchstander relayed a Captain of the Port (COTP)[9] order to the *Ecstasy* to proceed to the anchorage north of the sea buoy and anchor. At 1754, as the master turned the vessel to head for the anchorage area, the *Ecstasy* suddenly lost propulsion power and steering capability and began to drift. When the ship lost propulsion, the master requested that the Coast Guard send tugs to assist the vessel.

[9] The COTP is an officer within a district command designated by the Commandant to direct Coast Guard law enforcement activities within an assigned area.

The master said that when he contacted the chief engineer about the power loss, the chief engineer responded that his engineering staff could not determine the reason for the problem because of the fire.

At 1800, the master ordered the general alarm sounded alerting passengers and crewmembers to assemble at their muster stations. At the master's direction, the cruise director announced over the loudspeaker that there was a fire but that it was under control. He told Safety Board investigators that he provided status announcements to passengers about every 5-10 minutes. Upon receiving reports from crewmembers at an outside muster station that passengers were having problems hearing the loudspeaker announcements because news helicopters were flying close to the vessel, the cruise director radioed muster station personnel with status information to relay to passengers.

At the master's direction, the cruise director instructed mustered passengers not to return to their cabins for their lifejackets if they were berthed in the aft part of the ship. The cruise director announced that lifejackets would be provided to them at their muster stations. At the Safety Board's public hearing, the master testified that he did not order the crew to hand out lifejackets when passengers were mustered because efforts to contain the fire were successful and no one was in danger. He said that he wanted to maintain a calm environment by conveying the impression that the situation was under control and did not warrant the distribution of lifejackets. He therefore ordered the crew to stop distributing lifejackets to avoid panic among the passengers.

When smoke entered some muster areas, passengers were moved to other stations.

Fire and Rescue Response

Bridge logs indicate that the "Alpha Team" announcement, which alerted the quick response team to respond and other fire teams to prepare to marshal, was made at 1725. The quick response team narrowed the location of the main fire and smoke source to the aft mooring area on deck No. 4. At 1730, upon receiving reports of a large amount of smoke, the bridge ordered all fire teams to assemble. According to the safety officer, by 1740, the fire teams had assembled at the marshalling area on deck No. 3, had donned their gear, and had prepared for firefighting. He and the staff captain then led the teams aft toward the stern of the vessel.

The fire teams inspected several decks in the aft part of the ship for sources of heat and smoke but initially were unable to enter the mooring deck area because of the intense heat from the fire. Shipboard firefighters then attempted to cool the perimeters of the aft mooring deck by spraying water on the overhead of deck No. 3, the bulkhead forward of the aft mooring deck (deck No. 4), and the surface of deck No. 5. Some firefighters began boundary cooling by spraying water on the ship's exterior shell plating.

In the meantime, the tug *Coastal Key West* was tied up at Fisher Island (Miami Harbor) when its master overheard a radio call from the Biscayne Pilots Association to Coastal Tug and Barge, Inc., of Miami (Coastal Tug) advising of a fire on the *Ecstasy.* The Coastal Tug dispatcher radioed the *Coastal Key West* to assist. The tug got underway

about 1800 and arrived on scene at 1827. The *Coastal Key West* began directing a stream of water from a high-pressure fire monitor at the fire on the *Ecstasy's* stern.

The Coastal Tug dispatcher dispatched three other tugs, the *Coastal Florida,* the *Coastal Biscayne,* and the *Coastal Miami,* from the Port of Miami. They arrived within a half hour of the *Coastal Key West.* While the *Coastal Florida* and *Coastal Biscayne* joined the *Coastal Key West* in fighting the fire on the stern of the *Ecstasy* with their fire monitors, the *Coastal Miami* went to the *Ecstasy's* bow to prepare for towing the ship. The *Coastal Miami's* master also handled the radio communications between the *Ecstasy* and the tugs on scene. A short time later, the tug *Dorothy Moran* joined the other tugs in the firefighting efforts at the stern of the *Ecstasy.*

At 1835, a Coast Guard vessel carrying two representatives from the Marine Safety Office (MSO) Miami arrived alongside the *Ecstasy.* The *Ecstasy* master said that when the Coast Guard representatives came aboard, he gave them a status report on the fire and the conditions on the cruise ship. The Coast Guard representatives then proceeded aft to meet the *Ecstasy's s*afety officer. The safety officer said that he told the MSO officials that the fire was limited to the aft mooring deck on deck No. 4, but the fire teams had not been able to enter the area because of the intense heat and dense smoke.

At 1913, the tug *Coastal Miami* placed a towline on the *Ecstasy's* bow to keep the ship heading into the wind so that smoke moved away from the stern. The *Ecstasy* and *Coastal Miami* drifted north due to the effects of the Gulf Stream.[10] Some *Ecstasy* fire teams entered the aft mooring deck from the starboard side weather door and began cooling the area and extinguishing flames. Another fire team entered the mooring deck from the port weather door. Shortly thereafter, the fire teams notified the master that the fire had been extinguished. The *Ecstasy* fire teams continued to survey the aft decks in MVZs 1 and 2 for any residual signs of fire.

About 1950, four members of the Miami Beach Fire Department (Miami Beach FD), including a medical doctor, arrived aboard the *Ecstasy* and assisted onboard medical personnel in tending to the ship's firefighters and passengers. Shortly thereafter, Miami-Dade Fire Rescue Department (Miami-Dade FD) personnel and Carnival's director of firefighting training boarded the *Ecstasy.* After meeting with the master and Coast Guard personnel on the bridge, a command post was set up at the deck No. 3 marshalling area. At 1955, the crew was released from their emergency stations.

The crew firefighters led a team of Miami-Dade FD and Coast Guard personnel through the affected areas, including the aft mooring deck. After completing its assessment, at 2109, the team declared the fire under control. At 2130, the Coast Guard COTP, the Miami-Dade FD, and the Port of Miami granted permission to the *Ecstasy* to enter port. The cruise ship, under tow by six tugs, proceeded en route to the Port of Miami. At 0118, July 21, the *Ecstasy* arrived at Pier 8. Once the vessel was secured at its berth and the gangway was rigged, passengers began to disembark about 0220.

[10] The Gulf Stream current off the Straits of Florida flows northerly at a velocity between 2.5 to 3.5 knots.

Injuries

Table 2 is based on the International Civil Aviation Organization's injury criteria, which the Safety Board uses in accident reports for all transportation modes. Additional information about the injuries sustained by passengers and crewmembers appears under "Medical and Pathological."

Table 2. Injuries Sustained in the *Ecstasy* Accident

	Passengers	Crew	Total
Fatal	0	0	0
Serious	1*	0	1
Minor	8	14	22
None	2,556	902	3,458
Total	2,565	916	3,481

49 *Code of Federal Regulations* (CFR) 830.2 defines a *fatal injury* as: any injury that results in death within 30 days of the accident. A *serious injury* as: an injury that requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; results in a fracture of any bone (except simple fractures of fingers, toes, or nose); causes severe hemorrhages, nerve, muscle, or tendon damage; involves any internal organ; or involves second or third degree burns, or any burn affecting more than 5 percent of the body surface.

*As a result of this accident, one woman with chest pains and a pre-existing illness was admitted to the hospital for more than 48 hours, which met the definition of a serious injury.

Damages

Officials for Carnival Corporation, Inc., the *Ecstasy's* owner, estimated fire and associated damages to be $17 million. The *Ecstasy* was out of service for repairs until September 1998. Additional information about the damage to the ship appears under "Wreckage."

Personnel Information

General

According to company officials, Carnival hired only Italian deck and engineering officers. Its petty officers, including bosuns, carpenters, joiners, firemen, electricians, and plumbers, typically were either Filipino or Central American.

Master

The master, age 72, had been going to sea professionally for 52 years. He held unlimited master's licenses from Italy and from Liberia. He had sailed for Carnival Cruise Lines since 1985; he had been a master on company ships for all but the first 3 months of his time with the company. Four years before the July 20, 1998, fire, he had served as master on the *Ecstasy* for 8 months. He had been on the vessel for 1 month at the time of the fire.

Staff Captain

The staff captain, age 52, had been going to sea professionally since 1965. He held unlimited master's licenses from Italy and from Liberia. He had sailed for Carnival Cruise Lines since 1991 and had served in all officer positions from third officer to staff captain. The staff captain also served as the ship's Health and Safety Officer (HSO).

Safety Officer

The safety officer, age 35, had been going to sea professionally since he was 17 years old. He held unlimited master's licenses from Italy, from Liberia, from Panama, and from the United Kingdom. He acted as the on-scene commander of the ship's firefighting organization. He was also responsible for maintaining safety and firefighting equipment and for providing onboard emergency training for the crew.

First Officer

The on-duty first officer, age 42, was one of three first officers on board the *Ecstasy.* He held unlimited master's licenses from Italy, from Liberia, and from Panama. He had sailed on passenger ships for 6 years, exclusively with Carnival Cruise Lines.

Chief Engineer

The chief engineer, age 51, held unlimited chief engineer's licenses from Italy and from Liberia. He was responsible for the operation, maintenance, and repair of all shipboard engineering systems, including propulsion, electrical, plumbing, and air conditioning. He joined Carnival Cruise Lines in 1978 as a first engineer. He was promoted to staff chief engineer in 1981 and to chief engineer in 1986.

Galley Fitters

The "first" galley fitter, age 35, was on his second contract[11] with Carnival Cruise Lines. He had obtained welding certification in the Philippines and training from Unitor. He had been recently promoted to fitter from assistant fitter.

The "second" galley fitter, age 25, went to a 3-year trade school in Peru, where he received welding training and certification. He was hired by Carnival Cruise Lines in December 1996 as assistant fitter and later promoted to fitter.

[11] Each contract lasts 7 months.

Pilot

The pilot, age 38, held an unlimited master license with a Federal First Class Pilot's endorsement (for the Port of Miami to the sea buoy), issued by the Coast Guard, and a State Pilot Commission (pilot's license), issued by Florida. He was a member of the Biscayne Bay Pilots Association and had been a Miami ship pilot since August 1989.

Certification and Training Requirements

Preaccident requirements. In 1978, the International Maritime Organization[12] (IMO) and its member governments, or parties, established basic requirements for international seafarers. The *International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers* (STCW), 1978, which was adopted by the International Conference on Training and Certification of Seafarers on July 7, 1978, became effective on April 28, 1984. Since then, amendments to the STCW were adopted in 1991, 1994, and 1995.

In preparation for STCW 95 requirements that became effective January 1, 1999, representatives from the Coast Guard and five transportation organizations[13] cooperated in developing the curriculum offered at the RTM Simulation Training and Assessment Research (STAR) Center, which is a maritime training academy located in Dania, Florida. The coursework included training in the areas of crowd management, safety, and crisis management and human behavior.

Carnival's preaccident training and requirements. According to Carnival Cruise Lines' officials, the company sent its officers to the RTM STAR Center to meet the requirements of STCW 95. Company documents, including personnel files, indicate that, before the fire, the *Ecstasy's* deck officers had taken bridge team resource management training in the classroom and on a bridge simulator; the senior deck officers had taken command shiphandling. Although not required by STCW 95, Carnival Cruise Lines also sent its quartermasters (helmsmen) to bridge team resource management training.

In 1995, Carnival Cruise Lines established a policy requiring that all new hires speak English.

Firefighting training is the responsibility of Carnival Cruise Lines' Director of Firefighting Training. He stated that all firefighters, fire patrolmen, and officers receive basic and advanced firefighting training, which includes using simulators and hands-on firefighting techniques. The *Ecstasy's* "flag State,"[14] that is, the country in which the vessel was registered, had approved the company's basic and advanced courses as being in compliance with the STCW 95 Code.

[12] The IMO, a United Nations organization comprising 137 member states, establishes international maritime standards for the ships of the nations that are signatories to its conventions.

[13] Organizations that helped develop the STCW courses included Carnival Cruise Lines, Royal Caribbean Cruise Lines, American Airlines, Det Norske Veritas, and Lloyd's Register of Shipping.

[14] Another term for flag state is flag administration.

Carnival Cruise Lines had no written specific qualifications for fitters and no formal recurrent training program for ensuring that fitters were current in their welding skills. Each chief engineer or staff chief engineer was responsible for ensuring that the crewmembers in the engine department had the requisite skills and abilities to accomplish their jobs. All fitters, including the two welders involved in this accident, received on-board job-specific safety training, which included a review of proper practices when welding and procedures for obtaining a hot work permit.

Postaccident requirements. STCW 95 Section A-V/3, effective January 1, 1999, contains minimum requirements for the training and qualifications of masters, officers, and other crewmembers on passenger ships other than roll on-roll off (ro-ro) passenger ships. The STCW Code requires that seafarers receive currency training at intervals not to exceed 5 years.

The following excerpts from the STCW manual are selected training requirements in the areas of crowd management, safety, and crisis management and human behavior.

Crowd management training

1 The crowd management training required by regulation V/3, paragraph 4, for personnel designated on muster lists to assist passengers in emergency situations shall include, but not necessarily be limited to:

.1 awareness of life-saving appliance and control plans, including:

.1.1 knowledge of muster lists and emergency instructions,

.1.2 knowledge of the emergency exits; and

.2.1 the ability to give clear reassuring orders,

.2.2 the control of passengers in corridors, staircases and passageways,

.2.3 maintaining escape routes clear of obstructions,

.2.4 methods available for evacuation of disabled persons and persons needing special assistance, and

.2.5 search of accommodation spaces;

.3 mustering procedures, including:

.3.1 the importance of keeping order

.3.2 the ability to use procedures for reducing and avoiding panic,

.3.3 the ability to use, where appropriate, passenger lists for evacuation counts, and

.3.4 the ability to ensure that the passengers are suitably clothed and have donned their lifejackets correctly.

Safety training for personnel providing direct service to passengers in passenger spaces

3 The additional safety training required by regulation V/3, paragraph 6, shall at least ensure attainment of the abilities as follows:

Communication

.1 Ability to communicate with passengers during an emergency, taking into account:

.1.1 the language or languages appropriate to the principal nationalities of the passengers carried

.1.3 the possible need to communicate during an emergency by some other means such as by demonstration, or hand signals, or calling attention to the location of instructions, muster stations, life-saving devices or evacuation routes, when oral communication is impractical;

Crisis management and human behaviour training

5 Masters, chief mates, chief engineer officers, second engineer officers and any person having responsibility for the safety of passengers in emergency situations shall:

.1 have successfully completed the approved crisis management and human behaviour training required by regulation V/3, paragraph 8, in accordance with their capacity, duties and responsibilities as set out in table A-V/2;[15] and

.2 be required to provide evidence that the required standard of competence has been achieved in accordance with the methods and the criteria for evaluating competence tabulated in columns 3 and 4 of table A-V/2.

The RTM STAR Center manuals used to train seafarers on STCW requirements contain the information or instructions as noted below.

The crowd management manual, under "Maintaining Order at Muster Stations," states:

Accounting

Accurate accounting for passengers is extremely important. Searching for missing persons may be initiated based on roll call at Muster Stations. Passenger lists should be used for taking attendance; there should be a list of passengers assigned to each Muster Station.

The crisis management and human behavior manual, under "Shipboard Emergency Procedures," states:

[15] Excerpts from this table appear in appendix B of this report.

Emergency Scenarios

Formalized emergency procedures should be in place to meet the particular demands of a variety of situations. Depending on routes, passengers, ports of call, terminal security measures, and so forth, some such scenarios might include:

- Fire (in port/at sea)
- Grounding
- Collision (in port/at sea)
- Bomb threat
- Terrorist activities
- Extreme weather
- Epidemic
- Pollution
- Emergency assistance to other ships

The crisis management and human behavior manual advises that detailed requirements for emergency preparedness drills will be included in the company's SMS, and that drilling is an ideal means for determining whether in-place emergency procedures match up with available resources.

Carnival's postaccident requirements. According to Carnival Cruise Lines' officials, in fall 1998, the company began requiring its senior deck, engineering, and other officers to attend courses in crisis management and human behavior and crowd management. Crewmembers in safety-related positions were required to attend crowd management training.

Vessel Information

The *Ecstasy* was built in 1991 by Kvaerner Masa Shipyard (Kvaerner Masa) of Helsinki, Finland, for Carnival Corporation. The vessel was the second of Carnival Corporation's "Fantasy Class" ships, a series of eight cruise liners having the same basic design. The Fantasy class ships are typical of modern passenger cruise liners that are designed for unrestricted international voyages. At the time of its construction, the *Ecstasy* was required to comply with SOLAS 74 and its 1981 and 1983 amendments. The cruise ship was designed, built, and maintained under the rules of the Lloyd's Register of Shipping (LR) classification society. The *Ecstasy* held the highest vessel classification for construction. Additional information about vessel certification and inspections appears later in this section.

General Construction

The diesel-electric-propelled *Ecstasy* is 859.4 feet long, 103.4 feet wide, and admeasures 70,367 gross tons. The vessel has 13 decks and seven MVZs, which are separated by A-60 Class divisions.[16] (See figure 5.)

Main Laundry

The main laundry was on deck No. 2, within MVZ 2. The mangle (figure 3) was on the starboard side of the laundry space. When operating the mangle, laundry workers placed damp linens on the loading side of the machine. The mangle had strings coated with wax that directed the linen through the ironing machine's felt-covered rollers. The steam produced by the ironing action was removed by blowers and exhausted into two vertical ducts on the starboard side of the mangle. When workers turned off the mangle, its rollers automatically raised, preventing damage to the roller bed. The vertical ducts that interfaced with the mangle were attached to a main exhaust duct for the machine.

Two ventilation duct systems exhausted the air in the laundry space: one duct system exhausted the air over the mangle and the other duct system exhausted the air near the six dryers. The duct system dedicated to the mangle had three circular intake openings that were set flush with the stainless steel panels of the overhead and that were not covered by a grill or filter. The forwardmost intake opening was above the folding machine attached to the mangle, the second intake opening was directly above the mangle's rollers, and the third intake opening was at the end of the mangle where the linen was loaded.

The two exhaust systems (figure 1) were separate from each other until the ducts exited into the aft mooring deck plenum. The blowers for each of the systems were in the double-deck air conditioning room that extended upward from deck No. 4. According to Carnival Cruise Lines' records, the mangle exhaust blower had a calculated linear flow velocity of 7.3 meters per second (m/s).[17]

Aft Mooring Deck

The mooring station on deck No. 4 is aft of the MVZ No. 1 forward bulkhead. The station is a covered space that is open to the weather on the port, starboard, and aft sides. (See figures 6a and 6b.) The station is used only when docking or undocking. The area has three electrically controlled winches that spool the large diameter polypropylene line (rope) that is used to moor the vessel. One winch is on the port side, one is on the starboard side, and one is in the center of the deck. Additional coils of mooring line are stored on wooden pallets on the mooring deck.

[16] SOLAS Regulation II-2/3.3 stipulates that A-60 class bulkheads and decks must be constructed of steel or other equivalent materials; suitably stiffened; capable of preventing the passage of smoke and flame for 1 hour; and insulated with approved, noncombustible materials that limit temperature increases.

[17] For a duct cross section measuring 1.03 meters, the fan capacity of the mangle blower was 7.5 cubic meters per second; the fan capacity of the dryer blower was 6.4 cubic meters per second.

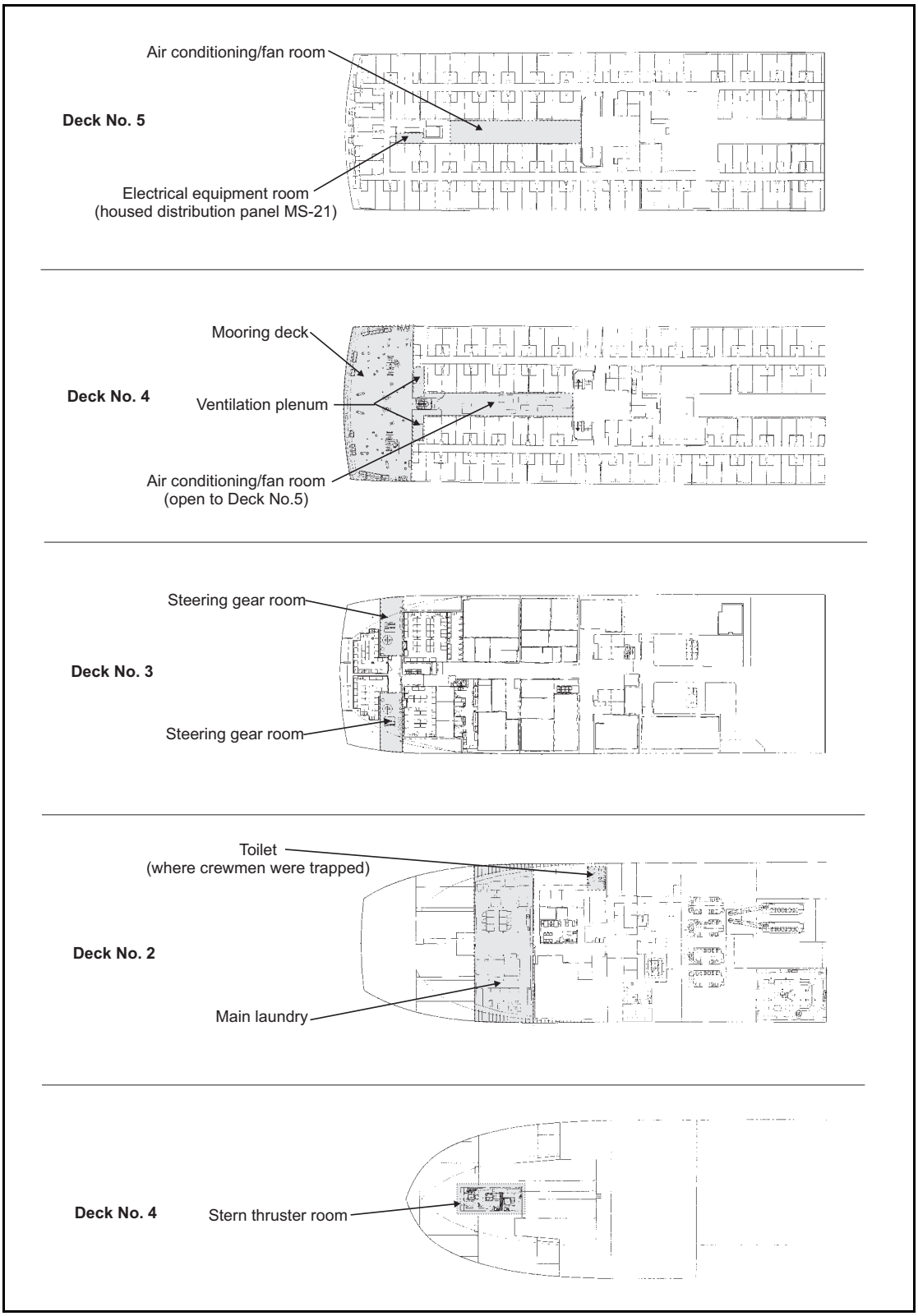

Figure 5. Plan views of decks 1-5.

Figure 6a. The ventilation system for the main laundry exhausted onto the mooring deck (shown above), where the synthetic mooring line was spooled on winches or stored on pallets.

Figure 6b. The *Ecstasy's* mooring station is a covered deck area that is open to the weather on the side and rear of the ship.

At the time of the fire, the mooring deck had 11 lengths of line, each measuring 220-meters and weighing about 900 pounds. The lines included three lengths of polypropylene line that were on the winch drums, seven pallets of polypropylene line, and one pallet of nylon line.

Several air handling systems vented to the mooring deck. A discussion and an illustration of the ventilation system appear later in this section.

Operating Systems

Steering. The steering system consisted of two rudder systems that were mechanically, electrically, and hydraulically independent of each other. The hydraulic equipment for each rudder system was housed in separate compartments on deck No. 3; one steering gear room was on the port side and the other steering gear room was on the starboard side. The steering gear rooms were directly below the mooring station on deck No. 4. The steering system was controlled from the bridge during normal operations, or, in an emergency, locally from the steering gear room.

Propulsion. SOLAS Chapter II-1, Part C, states, in part:

> Administrations shall give special consideration to the reliability of single essential propulsion components and may require a separate source of propulsion power sufficient to give the ship navigable speed, especially in the case of unconventional arrangements.
>
> Means shall be provided whereby normal operation of the propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative.

The *Ecstasy's* main power plant comprised six diesel generators that supplied all electric power for the vessel, including propulsion. The generators produced electricity at 6,600 volts and at a constant frequency of 60 hertz. Transformers and cycloconverters modified the voltage and frequency for use in driving the motors of the vessel's two propellers. (See figure 7.)

Output from the cycloconverters ran through electrical circuit breakers (called high-speed breakers) that were designed to prevent damage to the propulsion motors in the event of a power overload. The breakers generated a signal indicating their status, that is, whether they were open or closed, to the propulsion system computer. If the propulsion system computer did not receive a status indication from either of the breakers, the computer would shut down the system power at the cycloconverters.

The signals indicating the circuit breakers' positions passed through a distribution panel (MS-21) in an electric equipment room on deck No. 5, above the area where the fire occurred. Power cables from transformers supplying the distribution panel were in the ventilation intake plenum that was forward of the aft mooring station.

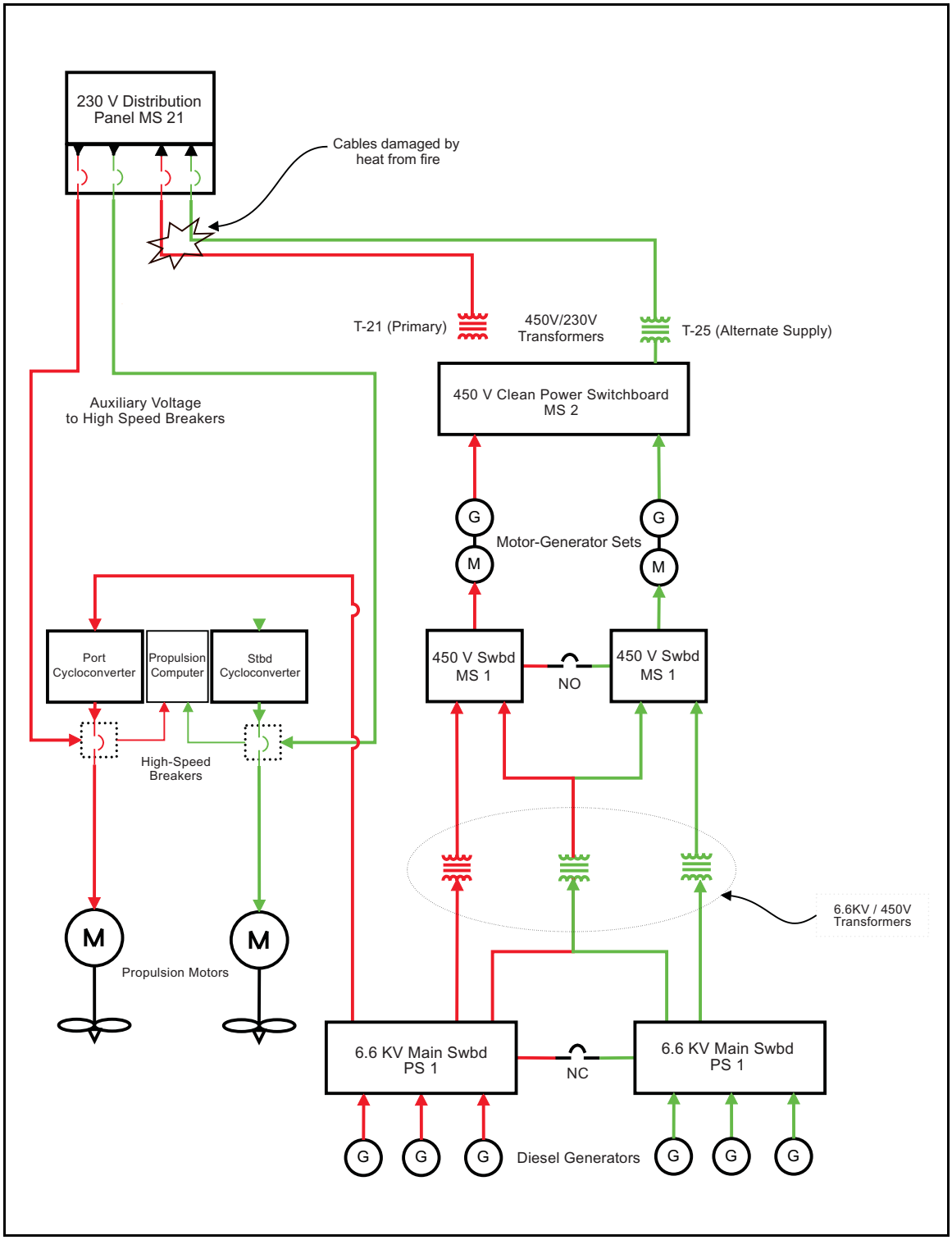

Figure 7. Schematic of the propulsion system's wiring.

The propulsion system had many redundant features and isolated components designed to provide reliability. Each propeller had an independent double-wound motor and each propulsion motor had two cycloconverters. In the event of power failure, the propulsion system computer had a battery backup, and each motor could use an emergency exciter. Each of the six independent diesel generators supplied isolated main distribution switchboards.

The propulsion system was designed and manufactured by ABB, a subcontractor to Kvaerner Masa, the shipbuilder. The integration of the propulsion system into the ship's other systems, notably the electrical distribution system, was the responsibility of Kvaerner Masa's designers. The specifications to the shipbuilder from ABB list the required voltage and current supplying the propulsion system. The specifications do not indicate that the voltage supply should be provided by independent sources. Kvaerner Masa routed the auxiliary voltage for both high-speed breakers through a single external interface (MS-21).

Officials for ABB, the propulsion system design company, stated that they did not do a qualitative failure analysis[18] of the propulsion system for the Fantasy class ships, including the *Ecstasy,* because SOLAS, LR, and Carnival did not require that a system performance analysis be conducted.

Low-location Lighting

SOLAS Chapter II-2, Regulation 41 requires that passenger ships constructed after January 1, 1994, have a low-location lighting system in all accommodation area interior passageways and stairways to assist passengers in identifying emergency escape routes when smoke impedes visibility.[19]

The low-location lighting system on board the *Ecstasy* consisted of a series of low-voltage, light-emitting diodes (LED) and photoluminescent signs marking exits, doors, and stairways. The electrical power supply for the system was in the emergency diesel generator room. In the event of a power loss from the emergency switchboard, a battery-powered DC/AC inverter provided a power backup for at least 60 minutes.

The lighting system was designed such that the loss of a single light, lighting strip, or power supply would not result in a system failure. The system was arranged in a series of independent zones. Each zone had two electrical loops that were powered by independent power transformers; the loss of a one transformer would not cause the failure of a loop. If a condition affecting the performance of the low-location lighting system did occur, a fault alarm would sound on the system's control panel, which was located on the navigation bridge. The system was designed such that the bridge watch could not silence the audible alarm at the control panel.

[18] Information about qualitative failure analysis appears in the "Other" section of this report.

[19] See IMO Resolution A.752 (18).

Fire Protection

Fire detection. SOLAS Chapter II-2, Regulations 12 and 13 specify the minimum design and installation requirements for a passenger vessel's fire detection system, including power elements, audible and visual alarms, control panels, and detectors.[20] Documents indicate that LR issued an approval certificate for the *Ecstasy's* fire detection system.

Consilium Marine AB of Sweden (Consilium) supplied most of the components in the *Ecstasy's* fire detection system. According to Consilium's technical data sheets, the Salwico C300 that was installed on the *Ecstasy* is a conventional fire detection system with a single central control unit. Group units, each containing loops of eight detectors, can be added to extend the system's capability. In the case of the *Ecstasy,* the vessel had 176 separate detector loops, each of which covered 20 to 30 cabins.

Two models of Consilium smoke detectors were installed on the *Ecstasy*; one type of detector was installed in cabins and staterooms, and a second type was installed in stairways and service spaces, including the main laundry. Manual pull alarms installed throughout the vessel supplemented the automatic smoke and heat detectors. An independent module, called the Detector Identification, controlled the zone or detector address function of the system.

The vessel's fire alarm panel, sprinkler fire suppression panel, and various emergency shutdown and closure controls, including the controls for the FSDs and WTDs, were mounted on a bulkhead immediately aft of the pilothouse. The fire detection panel had alarms that sounded and lights that illuminated to identify the loop in which an automatic detector activated or a person pulled a manual alarm station.

The control unit for the fire detection system was on the bridge, aft of the pilothouse. Once an operator identified the loop on the detection panel, he could activate the computerized video surveillance display at the control unit, which showed the area of the activated detectors. The control unit also had the capability of indicating individual smoke detector and circuit failure.

The fire detection system included a printer that generated a paper log of all activated detectors and manual pull alarms. On the day of the accident, the system logged 45 detector "events" within 2 minutes of the first alarm, between 1710 and 1712.[21]

The detection system printer registered alarm locations that did not exist, indicating the system panel had malfunctioned because of an electrical overload. Following this accident, Carnival upgraded the fire detection system on the *Ecstasy* to correct this problem.

[20] See SOLAS Chapter II-2, Regulation 13.

[21] The time resolution for the detector log printout was to the nearest minute.

Automatic sprinkler protection. SOLAS amendments adopted in 1992 require that all passenger cruise vessels constructed after October 1, 1994, and carrying more than 36 passengers be protected with an automatic sprinkler system or an approved equivalent fire suppression system for all accommodation and service spaces, stairway enclosures, and corridors. Ships built before 1994 must be retrofitted with automatic sprinklers within 15 years of construction or 2005, whichever is later. Because the *Ecstasy* was constructed in 1991, Carnival Corporation had until 2006 to comply with the SOLAS requirements for automatic sprinklers but voluntarily installed sprinkler protection in the *Ecstasy's* cabins and staterooms at the time the ship was built. According to LR, the sprinkler protection met SOLAS requirements.

Documents indicate that the flag administration interpreted the mooring deck design to be a category 5, "Open Deck Space," as defined in SOLAS regulations,[22] because the space was partially enclosed and directly open to the weather. SOLAS regulations do not require that fire detection or fire suppression equipment be installed in an open deck space, and no such equipment was installed on the *Ecstasy's* mooring deck before the 1998 fire.

SOLAS regulations specify the minimum sprinkler coverage and application rate for a ship's sprinkler system. The designs of the *Ecstasy's* pump and piling system indicate that, as stipulated in SOLAS Chapter II-2, Regulation 12, the vessel's sprinkler system provided coverage for a minimum area of 280 square meters (m^2) at a rate of 5 liters of water per m^2 per minute (5 $l/m^2/min$). The system was designed to supply water for about 30 sprinklers at a time, based on a coverage rate of slightly more than 10 m^2 for each sprinkler head.

Postaccident examination of the ship indicated that more than 60 sprinklers activated on the *Ecstasy.* (See table 3.)

The first officer who was monitoring the sprinkler alarm panel, stated that he remembered that fire zones 20 (deck No. 5, aft) and 32 (deck No. 7, aft) were the first zones that activated on the sprinkler panel and that several other flow alarms sounded shortly thereafter.[23]

Investigators observed that sprinkler zones 20 and 35 indicated a "Sprinkler Released" status, meaning the system had a pressure drop. Fire zones 6, 14, 15, 21, 22, 26, 32 and 33 indicated a "Master Valve Closed" status, meaning the water to these zones had been shut off. The remainder of the system was operational at about 5 bar pressure according to the gauge on the bridge.

[22] See SOLAS Chapter II-2 Regulation 26-2.2 (5).

[23] A flow alarm is an audible alarm that sounds on the bridge when a sprinkler head starts to flow water. The system does not record the flow alarm sequence.

Table 3. Location of activated sprinklers.

Deck	Location	Activated Sprinklers	Observations and Comments
1	Stern thruster room	None	Area was protected by a carbon dioxide system.
2	Main laundry	None	Because the laundry had higher operating temperatures, it was equipped with sprinklers having a glass-bulb actuating device.*
3	Port-side corridor	2	
	Refrigerated dry stores	2	
4	Mooring station	None	Area was not equipped with sprinklers.
	Port-side corridor	3	Sprinklers were immediately forward of the WTD leading to the mooring station.
	Aft-most outboard cabin	1	
	Aft-most inboard cabins	2	
	Central crew stairs	Several	
5	Cabins and adjacent corridors	40	Affected areas were above the mooring deck.
6	Port-side storage locker	2	Mattresses showed no evidence of dampness.
7	Aft-most cabin – port	2	Carpet was scorched.
	Closet in port cabin	1	
	Aft-most cabin - starboard	2	Carpet was scorched.
	Closet in starboard cabin	1	
	Starboard corridor	2	

*As the temperature near the sprinkler head increases, liquid in the glass bulb expands and overstresses the glass, ultimately causing the bulb to break at the sprinkler head's rated temperature, in this case, 93ºC. When the glass bulb breaks, the sprinkler head opens, allowing water to flow.

Ventilation Systems

SOLAS regulation II-2/16.3.1.3 requires that ducts ventilating category A machinery spaces, galleys, car deck spaces, ro-ro cargo spaces, or special category spaces be fitted with automatic fire dampers at the boundary penetrations of passages through accommodation spaces, service spaces, or control stations. Further, most ventilation ducts with cross-sectional areas exceeding 0.075 m^2 must be fitted with automatic fire dampers

that are capable of manual operation from both sides of the bulkhead or deck.[24] Only dampers that pass through spaces surrounded by A-class divisions without serving those spaces and that have the same fire integrity as the divisions that they pierce are excluded from this requirement.

SOLAS regulations do not include main laundries as a space in which the ventilation ducts must be equipped with automatic fire dampers. On the *Ecstasy,* the fire dampers in the main laundry ducts were manually operated under normal conditions. If the ventilation system suffered an electrical loss, the dampers would pneumatically shut.

All ventilation systems on the *Ecstasy* are equipped with fire dampers that close when ventilation is secured. During postaccident repairs, technicians verified that all fire dampers had functioned and closed when ventilation was secured from the bridge during the fire.

As mentioned earlier, air exhaust from the laundry ventilation system exited on the mooring deck. Intake vents on the port side of the mooring deck supplied fresh air to the stern thruster room, which was on deck No. 1, immediately below the main laundry.

A vertical vent duct inside the plenum penetrated decks No. 4 and 3 and then ran forward/outboard above the potable water tanks. Once on deck No. 2, the duct ran forward and inboard to supply the thruster room.

The supply intakes for the ship's air conditioning system are on the ship's transom (stern), two decks above the aft mooring deck. These ducts run forward between decks No. 6 and 7, and pass down through deck No. 5 and along the exposed overhead of the mooring deck before entering the air handling room on deck No. 4.

Vessel Certification and Inspections

General. The certification of a ship and its associated safety equipment and machinery is the responsibility of the "flag state," or the country in which the vessel is registered. Liberia, the *Ecstasy's* "flag state" at the time of the accident, is a signatory nation to SOLAS 74. Like most signatory nations, Liberia has incorporated SOLAS requirements into its national regulations. SOLAS requires that vessels meet the requirements of a recognized classification society or equivalent.[25] Liberia delegated certification inspection authority to LR to ensure that the *Ecstasy* met its national statutory requirements.

SOLAS regulations and classification society rules are intended to be complementary and nonduplicative. SOLAS provides detailed guidance on marine environment protection items, safety items such as structural fire protection, subdivision,

[24] SOLAS Regulation II-2/32.1 refers to the application of Regulation II-2/16; Regulation II-2/32 applies to ships carrying more than 36 passengers and Regulation 16 in its entirety does not.

[25] Regulation 3-1, Part A-1, Chapter II-1 of SOLAS 74, which entered into force in July 1998, states that, in addition to meeting applicable SOLAS requirements, ships shall be designed, constructed, and maintained in compliance with a classification society's structural, mechanical, and electrical requirements.

and damage stability, and general guidance on ship construction and essential shipboard engineering systems. A classification society provides detailed rules pertaining to ship structural design and essential shipboard engineering systems.

Classification. The *Ecstasy* was built and maintained under LR rules and held the highest vessel classification for construction (+100 A1). LR is a United Kingdom nongovernmental, nonprofit corporation founded in 1760 for the primary purpose of evaluating the structural and mechanical fitness of ships and other marine structures for their intended purpose. LR's classification of a vessel involves establishing and administering its standards, known as Rules and Regulations (rules), for the design, construction, and operational maintenance of marine vessels and structures. The *Ecstasy* was designed under 1987 LR rules.

Part 6, Chapter 2-1, "Electrical Installations–Equipment and Systems Design," of the 1987 LR rules states that the wiring for "essential services," that is, those services necessary for the propulsion and safety of the ship, should be duplicated. The following excerpts from the 1987 LR rules further define the electrical system design:

> Essential services that are duplicated are to be served by individual circuits separated throughout their length as widely as is practicable and without the use of common feeders, protective devices or control circuits.
>
> Where a duplicate supply is required, the two cables are to follow different routes which are to be as far apart as possible.
>
> Cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces, and other enclosed spaces of high fire risk except as necessary for the service being supplied.

The general design guidance section states, "The distribution system is to be such that essential services, which are duplicated, are supplied from separate sections of the switchboard."[26]

As part of this investigation, the Safety Board wrote LR asking the classification society to provide its interpretation of the rules cited above and the extent of their applicability to the electrical arrangement for the auxiliary voltage supply to the propulsion system's high-speed breakers. In its letter, the Safety Board states:

> Recognizing that there may be some differences between the approved as designed drawings and the as built drawings, please comment on the applicability of the rules to both sets of drawings, if the differences between them are significant. If the electrical arrangement for the auxiliary voltage to the high-speed breakers complied with these rules, please discuss how the rules are actually intended to be applied. And finally, please comment on any Lloyd's Register rule changes (if any) that have been made to the 1987 rules that may

[26] *Lloyd's Register of Shipping Rules and Regulations for the Classification of Ships*, Part 6, Control, Electrical, Refrigeration and Fire, January 1987, Chapter 2-1 Electrical Installations – Equipment and Systems Design, Section 2 System design – General, Subsection 2.1.6 Systems of supply and distribution.

address the reliability problems with the high-speed breaker auxiliary voltage supply arrangement that was installed aboard *Ecstasy.*

In its response, LR states:

> The high speed circuit breakers to which you refer are those on the motor side of the cycloconverters through which the motors receive their power. The voltage(s) supplied from MS 21 appear, from the manufacturer's data, to be primarily for the electrical closure of the circuit breakers.
>
> …after this fire, we were informed that the voltage supply from MS 21 is also used, internally within the cycloconverter, to provide a "circuit breaker closed" signal in order to "enable" the drives to start and to continue operating.
>
> The details of these internal connections were not provided to LR during LR's plan approval, and LR's surveys of the vessel's construction. Therefore, LR was not aware, prior to this casualty, that if these cables were burnt through propulsion would be lost.
>
> LR receives "design" plans for consideration at or before the time of construction of the vessel. It is these plans that our surveyors review and stamp "approved" against applicable classification requirements. Upon completion of construction "as built" plans are forwarded to LR for record purposes.
>
> We have checked the *Ecstasy* design plans approved by LR at the time of construction and the "as built" plans forwarded to us for record purposes. Neither show the detailed matters referred to in your letter.
>
> There have been no rule changes made since 1987 which address specifically high speed breaker auxiliary voltage supply arrangements similar to those installed aboard *Ecstasy.* However, based on the experience gained over the years of what was in 1987 an innovative design, the Rules have been changed to take into consideration commonality of electrical supplies.

U.S. Coast Guard Examinations. The United States requires that ships that embark passengers from U.S. ports be examined by the Coast Guard for "substantial compliance" with the construction, equipment, and safety requirements of SOLAS. The Coast Guard examinations are referred to as Control Verification Examinations (CVEs). These examination procedures are contained in the Coast Guard's *Navigation and Vessel Inspection Circular (NVIC) No. 1-93,* which provides guidance regarding examinations for foreign cruise ship operators. The examination process involves three phases: an initial CVE, which is a plan review of new or existing vessels; an annual CVE, which is a review of the vessel's firefighting, lifesaving and emergency systems; and a quarterly CVE, which is a safety review of the vessel's operations. As of July 1,1998, the Coast Guard's examination for passenger vessels included International Safety Management (ISM) Code provisions, which are discussed later in this report, under "International Safety Requirements."

Before the July 1998 fire, the *Ecstasy* had undergone its last annual CVE on May 1, 1998. Coast Guard documents indicate no discrepancies were found during the CVE.

Waterway Information

The Port of Miami is the largest embarkation port for cruise ships in the United States, handling more than 3.1 million passengers annually. It is home port to 18 cruise ships. Carnival, Cunard, Norwegian Cruise Line, and Royal Caribbean International regularly operate cruise vessels from the Port of Miami.

From Pier 8, the *Ecstasy's* point of departure, to the harbor entrance, the channels and their respective dredged depths are as follows: Main Channel, 36 feet; Inner Bar Cut, 44 feet; Outer Bar Cut, 44 feet; and Government Cut, 42 feet. The widths of the channels vary from 400 to 600 feet. At Government Cut, two unmarked jetties protect the harbor entrance. Strong tidal currents run between the jetties. A northerly wind in the area causes a considerable southerly set[27] across the ends of the jetties. The mean range of the tide at the harbor entrance is 2.5 feet. Shoals extend about a mile offshore northward of the harbor entrance. Pilotage is compulsory for all foreign-registered vessels and is supplied by Biscayne Bay Pilots.

Meteorological Information

At the time of the accident, the weather was cloudy with rainsqualls. Winds were variable and out of the East/Northeast at 15-20 knots, producing waves of 1 to 2 feet. Visibility in the rainsqualls was limited to 1-2 miles; otherwise, visibility was unlimited. No thunderstorms were in the vicinity.

Operations

General

Carnival Cruise Lines' parent company, Carnival Corporation, owns or has interest in seven cruise brands that operate as separate companies. The corporation has full ownership in Carnival Cruise Lines, Holland-America Line, Windstar Cruises, Cunard Line, Seabourne Cruise Line, and Costa Crocierw S.p.A and minority ownership in Airtours' Sun Cruises. Combined, these lines operate 48 cruise ships. Carnival Corporation is scheduled to add 13 ships to its fleet by the end of 2005.

[27] Set is the direction in which the current flows.

Carnival Cruise Lines presently runs 16 passenger vessels on pleasure cruises that last 3 to 16 days and that include itineraries to the Bahamas, Caribbean, Panama, Mexico, Hawaii, and Alaska. At the time of the accident, the operating company regularly ran the *Ecstasy* on 3- and 4-day round-trip cruises from the Port of Miami. The 4-day cruises departed on Monday and had stopovers at Key West and Cozumel, Mexico. The 3-day cruises left on Friday and sailed to Nassau, Bahamas, where it docked for 1 day before returning.

International Safety Requirements

At the 1994 SOLAS Conference, the IMO General Assembly adopted a resolution entitled "The International Management Code for the Safe Operation of Ships and for Pollution Prevention," known, in brief, as the ISM Code, to encourage the continuous improvement of safety management skills in the maritime industry.

The ISM Code became effective on July 1, 1998, for all passenger ships and for the following vessel types of 500 gross tonnage and over: oil tankers, chemical tankers, gas carriers, bulk carriers, and high speed cargo ships.[28]

The ISM Code requires a company[29] to establish and maintain a documented SMS that, among other things, meets the following safety management objectives:

1. Provides for safe practices in ship operation and a safe working environment;
2. Establishes safeguards against all identifiable risks; and
3. Continuously improves safety management skills of personnel ashore and aboard vessels, including preparing for emergencies related both to safety and environmental protection.

The ISM Code establishes six functional requirements for an SMS:

- Policies for ensuring safety and protecting the environment;
- Instructions and procedures for ensuring safe vessel operation and environmental protection in compliance with international and domestic laws;
- Defined levels of authority and lines of communications between and among shipboard and shoreside personnel;[30]
- Procedures for reporting accidents and nonconformities;
- Procedures for preparing for and responding to emergency situations; and

[28] The rules for all other cargo ships and MODUs of 500 gross tonnage and over enter into effect on July 1, 2002.

[29] The ISM Code defines company, in part, as "the owner of the ship or any other organization or person…who has assumed responsibility for operation of the ship from the shipowner and who, on assuming such responsibility, has agreed to take over all the duties and responsibility imposed by the Code."

[30] The ISM code stipulates that a company's SMS clearly define and document the master's responsibilities and emphasize his authority in its SMS.

- Internal audits and management reviews.

The procedures required by the ISM Code must be documented and compiled in a Safety Management Manual (SMM), which must be maintained on board a company's ships.

The ISM Code requires that a company provide necessary resources and shore-based support to achieve SMS objectives that includes appointing a designated person or persons ashore having direct access to the highest level of management.

The flag state government is responsible for enforcing the ISM Code and for issuing documentation attesting that companies are in compliance with it. A company complying with the ISM Code is issued a Document of Compliance, a copy of which must be kept on board the ship. Ships in compliance with the ISM Code are issued a SMS document.

Carnival Cruise Lines' Safety Management System

LR certified that Carnival Cruise Lines' SMS and its vessels, including the *Ecstasy,* were compliant with the ISM Code in December 1997, or 6 months ahead of the IMO deadline.

Investigators reviewed the SMM maintained by Carnival Cruise Lines on board the *Ecstasy.* The SMM defines the organization of the company's SMS, states its policies, and lists the various operating manuals that cover key shipboard operations. Manual 00 of the company's SMM, entitled "Master Safety Management System," contains a policy statement, which says, in part:

> The main objectives of the SMS are to ensure the motivation of all CCL personnel through effective education and training, and to outline specific responsibilities for safety and environmental protection throughout all CCL operations.
>
> The SMS emphasizes a pro-active attitude toward the elimination of operational problems, such that require forward planning and prevention procedures, on the part of all Carnival Cruise Lines personnel, will eliminate the occurrence of problems detrimental to the standard of passenger service offered by Carnival Cruise Lines and ensure safety at sea, personnel safety, and avoidance of damage to the environment.

The individual manuals, in turn, identify operations that are considered special or critical, establish safe procedures for conducting those operations, and assign qualified individuals to perform the tasks necessary for the operations. For example, Manual 03, "Health and Safety," indicates that the goal of the company is to "eliminate work-related accidents, injuries, incidents and hazardous occurrences." Manual 03 states that management responsibilities include providing the information, instruction, training, and supervision necessary for compliance with health and safety requirements. The manual lists the staff captain as the designated HSO for the vessel and states that, as such, he is responsible for ensuring compliance with "all health and safety instructions, rules,

procedures, and guidance." The manual further states that crewmembers are responsible for taking all reasonable care for their own health and safety and for that of all others on board the ship and that they must cooperate with the company, master, chief engineer, and all others who are responsible for health and safety aboard ship.

SMS Manual 03, Section 5, "Safety Procedures," contains subsections on permit-to-work systems (5.7) and welding and flame cutting operations (5.13).

According to the SMS manual, a permit-to-work system covers "operations on board ship where the routine actions of one man may inadvertently endanger another." The system identifies foreseeable hazards posed by various tasks and operating environments and lists precautions and sequential actions to take when performing such tasks. The SMS manual states, "In all instances it is necessary, before the work is done, to identify the hazards[31] and then to ensure that they are eliminated or effectively controlled." The manual further advises that the first and most important step in eliminating or effectively controlling hazards is a situational assessment by the ship's officer who is experienced in the work and thoroughly familiar with relevant hazards. The subsection specific to hot or cold work stipulates that permits that grant permission for such work must be countersigned by the chief engineer, staff chief engineer, master, or staff captain.

The subsection on welding and flame cutting operations states, "No welding or flame cutting work should be undertaken unless the requirements of the 'Hot Work Permit' are fully satisfied." The manual stipulates that welding operations should be properly supervised and kept under regular observation and that a person with a suitable extinguisher should be stationed to keep watch on areas not visible to the welder.

Manual 07, "Safety of Operations—Engineering Department," states that the staff chief engineer or engineering officer team leader must ensure that all measures and precautions that are necessary for the safety of those concerned are taken before any repair or maintenance work begins. Investigators reviewed the *Ecstasy* records of hot work permits issued for various maintenance tasks outside the ship's machine shop and workshop. The log and copies of approved permits do not include an application or an approval for a welding project in the ship's main laundry on July 20, 1998. After the fire onboard the *Ecstasy*, Carnival Cruise Lines revised its SMS to include safeguards against unauthorized welding. See "Other Information," later in this report.

Manual 08, "Safety of Operations—Hotel Services," states that the laundry manager is responsible for, among other tasks, ensuring the safe operation of all laundry equipment and the proper cleanliness of the laundry room, laundry equipment, and the laundry crew galley. The manual lists 17 required safety procedures for the laundry area. The procedures specify the required operating temperatures for washers, dryers, and the mangle, proper handling of chemicals, and measures for handling linens, clothes, and uniforms. The laundry safety procedures also include prohibiting smoking in the laundry room and performing a fire risk assessment at regular intervals.

[31] At the time of the *Ecstasy* accident, Manual 03 did not include a section on job hazard analysis. Since the accident, Carnival Cruise Lines has developed and added a chapter "Safe Systems of Work - Job Hazard Analysis."

According to Carnival Cruise Lines' officials, at the time of the *Ecstasy* accident, all officers and crewmembers assigned to ships in the company's fleet had received a general overview training of the SMS. Employees had been given specific training in those areas of the SMS pertaining to their duties. The company had established a schedule of weekly reviews of the SMS, which included departmental meetings during which supervisors reviewed provisions of the SMS with crewmembers.

Additional Oversight Practices

According to Carnival Cruise Lines' officials, to complement its SMS, the company retained some management oversight practices that it had in place before it developed its SMS. Management representatives, typically a shoreside ship supervisor or a port engineer or port captain, visited each ship in the company's fleet at least once monthly to ensure that shipboard personnel were following and practicing corporate safety management policies. In addition, Carnival Cruise Lines had a quality control committee, headed by the company president, that visited each ship yearly to meet with the master, department heads, and the entire crew to answer any questions on corporate policy and vessel operations.

Medical and Pathological

Medical Findings

Medical responders examined at least 70 passengers and crewmembers to determine whether they were injured and required additional medical treatment. Six passengers were treated by medical personnel and local hospitals for pre-existing conditions; three passengers were treated for smoke inhalation. Fourteen crewmembers were treated for minor injuries, including smoke inhalation, chest pain, lower back pain, cervical strain, knee pain, and a knee contusion.

Toxicological Testing

Carnival's requirements. At the time of the *Ecstasy* accident, Carnival Cruise Lines' health and safety manual contained the following requirements pertaining to drug testing (italics added for emphasis):

1. All testing for drugs will be by the analysis of urine.
2. Prospective Company seafarers *may* be required to undergo drug testing prior to an offer of employment being made.
3. Company seafarers *may* be required to undergo periodic drug testing.
4. Unannounced testing *may* be carried out at intervals, initiated by Company. All unannounced drug testing, including urine sampling, will be carried out by shore personnel only.

5. Should circumstances permit, post casualty testing for drugs must also be carried out immediately after any safety or pollution accident or incident. The post casualty testing must be carried out on the Master and Chief Engineer and those other Officers and crewmembers who were performing any duty at the time of the incident or casualty.

About 0030, July 21, 1998, while the *Ecstasy* was under tow from the sea buoy to the Port of Miami, the Coast Guard notified Carnival Cruise Lines to conduct postaccident toxicological screening for drugs and alcohol. About 0430, or about 12 hours after the fire was detected aboard ship, technicians from Toxicology Testing Service, Inc., of Miami began taking blood specimens for alcohol testing and collecting urine specimens for drug screening. By 1100, the technicians had tested 79 crewmembers, including the officers and fitters discussed earlier in this report.

The first officer who was on bridge watch at the time of the fire and a junior electrician who was not on watch tested positive for cannabinoids. They were subsequently dismissed by Carnival. An oiler who was on watch in the engine room tested positive for alcohol. He stated, however, that he had consumed alcohol after the fire emergency had subsided.

According to Carnival Cruise Lines' officials, the company had not been conducting random drug tests of its shipboard crews before the *Ecstasy* fire. Following this accident, the company revised its hiring policies to require drug testing as a condition for employment. The company instituted a program of random drug testing and adopted a "zero tolerance" policy, meaning it will dismiss any employee who tests positive for illegal drugs.

Wreckage

Operating Systems

Propulsion system. Investigators noted that electrical cables in the ventilation exhaust plenum near the mooring deck were burned and melted. Some of these cables supplied voltage from an electrical distribution panel in an equipment room near the aft mooring station to the high-speed breakers for the port and starboard propulsion systems.

Following this accident, Carnival Corporation modified the voltage supply arrangement to the high-speed breakers aboard the *Ecstasy* by providing selectable redundant voltage supplies to each set of high-speed breakers from independent power sources. According to Carnival officials, the company also planned to modify the arrangement aboard other vessels in the *Fantasy* class.

Steering gear systems. During the accident, the port steering system completely failed, but the starboard hydraulic system continued to operate even though the monitoring system failed. The port and starboard steering gear rooms were on deck No. 3, directly

below the fire on the aft mooring deck. The electrical power and control cables for the steering systems were routed in cableways near the overheads of the steering gear rooms on deck No. 3. Investigators observed that the control cables and control system components in the steering gear control cabinet were burned and melted. The port steering gear room showed evidence of greater damage to a greater extent than the starboard steering gear room.

Stern thruster system. The temperature-sensitive equipment in the stern thruster room, including the power supply cables to the stern thruster electric motors, were burned and melted. Two of the three stern thruster electric drive motors were damaged by heat.

Low-location lighting. The wiring insulation on a portion of one low-location lighting loop was melted. The system was designed to sound an alarm on the bridge in the event of a power failure.

Air conditioning system. Investigators observed signs of heating-flame impingement on the transom next to the intake supply ventilators. This air conditioning duct ran beneath cabins and storage lockers on deck No. 7, where the carpet and furnishing sustained heat damage.

Other Damaged Areas

Table 4 summarizes the conditions and damage that investigators observed in various areas of the vessel during their postaccident examination of the *Ecstasy.*

Table 4. Damage by Deck Area

Deck	Location	Observed Conditions and Damage
2	Laundry room	Laundry space sustained no fire damage. Several areas within the space sustained heat and smoke damage. The mangle had smoke and soot on its underside. A light fixture near the mangle had melted. Mangle had melted and burned insulation in the electrical control cables of the control panel (under the loading end of mangle) and in the mangle's exhaust system. The housings of the two mangle exhaust blowers that removed steam from the rollers were caked inside with partially burned lint and wax.* Impeller blades on the aft exhaust blower fan were not attached to the fan motor shaft. All that was left of the fan impeller blades were rust colored metal flakes that were imbedded in the lint and wax. Impeller on the forward fan was caked with lint and wax but was otherwise intact. The ducts attached to the two mangle blowers sustained heat damage. The paint on the aft exhaust duct was blistered and charred; the forward exhaust duct had less heat damage. Both ducts contained burned debris. Felt on the loading end roller was burned on the edge nearest the aft blower. Ventilation duct above the mangle contained 2-3 inches of burned debris.

Table 4. Damage by Deck Area

Deck	Location	Observed Conditions and Damage
2	Laundry crew galley (pantry)	The galley and its contents were heavily covered with soot. Area showed no evidence of flame exposure.
3	Refrigerators and dry provision stores	Vent in the overhead above a sink contained soot. Port side: The overhead ventilation duct showed signs of intense heat. Near this vent, the steel deck was buckled and its paint was charred and cracked. The stainless steel sheathing of the cool storage space was warped, discolored blue, and had pulled away from joints. Starboard side: No visible damage. Vent covers had soot deposits.
4	Passenger cabins and corridors	Fire damage, which included scorched carpeting and furnishings, was limited to passenger cabins and corridor area nearest the WTDs.

* The strings that directed the linens through the mangle were coated with wax.

Survival Factors

This section contains the regulatory requirements, Carnival Cruise Lines' provisions and procedures related to shipboard emergency training and drills, passenger feedback obtained from interviews and a survey that the Safety Board mailed to a sample of passengers,[32] and a detailed description of the actions by the emergency responders to the incident.

Regulatory Requirements:

The following are excerpts from the SOLAS Regulations:

Regulation 18: 3.1, "Emergency Training and Drills":

> Each member of the crew shall participate in at least one abandon drill and one fire drill every month. The drills of the crew shall take place within 24 hours of the ship leaving port if more than 25 percent of the crew have not participated in abandon ship and fire drills on board that particular ship in the previous month. The Administration may accept other arrangements that are at least equivalent for those classes of ship for which this is impracticable.
>
> 3.2 On a ship engaged on an international voyage which is not a short international voyage, musters of passengers shall take place within 24 hours after their embarkation. Passengers shall be instructed in the use of the life-jacket and the actions to take in a emergency.

Regulation 25, "Drills":

> On passenger ships, an abandon ship drill and a fire drill shall take place weekly.

[32] See "Postaccident Survey," which appears later in this report.

Regulation 53, "Muster List and Emergency Instructions":

> The muster list shall show the duties assigned to members of the crew in relation to passengers in case of emergency. These duties shall include: warning the passengers; seeing that they are suitably clad and have donned their lifejackets correctly; assembling passengers at muster stations; keeping order in the passageways and on the stairways and generally controlling the movements of the passengers; ensuring that a supply of blankets is taken to the survival craft.

Emergency Procedures and Drills

Crew training. The *Ecstasy* safety officer stated that all crewmembers on board had participated in a "vessel familiarization program," as required by STCW. Investigators reviewed the program curriculum and a sampling of personnel training files. The courses provided by the safety officer included Safety Communication, Signs and Alarms; Crew Muster Stations, How to Locate and Don Lifejackets; Man Overboard Initial Action; Fire Emergency Initial Action; Medical Emergency Initial Action; Close and Open Weathertight, Watertight, and Fire Screen Doors; and Vessel Familiarization Assessment.

A station bill on board the *Ecstasy* specified the responsibilities and emergency stations for each crewmember in the event of an emergency. According to the safety officer, fire drills were held weekly and were conducted as if an actual emergency existed. Crewmembers were required to report to fire stations with firefighting equipment and simulate a response to a fire.

At the time of the accident, Carnival Cruise Lines had not developed a crowd management plan, including crowd control training for crewmembers. According to the *Ecstasy's* safety officer, he and the staff captain provided instruction on proper crowd control procedures to crewmembers who were assigned to direct passenger evacuation, muster station leaders, lifeboat commanders, and other supervisory personnel during the weekly emergency drills and other routine training. The safety officer stated that the Coast Guard tested the crewmembers' knowledge of crowd management procedures during annual and quarterly CVEs. He indicated that, during emergencies when routine procedures did not apply, the master or other officers provided instructions specific to the situation.

Passenger drill. Before the *Ecstasy* departed Miami, passengers were required to participate in an abandon ship, or muster, drill. According to the cruise director, he followed a script during the drill, which contained the following instructions:

- Crewmembers will guide passengers to their muster stations and instruct them how to wear the lifejackets.
- If passengers must abandon ship, lifeboats would be lowered to the embarkation deck to allow them to board the boats.
- If passengers do not have enough lifejackets in their cabin for the number of occupants including children, a cabin steward will provide extra lifejackets.

- A placard in each passenger cabin provides emergency instructions. (See appendix C.)

According to passengers and shipboard personnel, passengers were not told during the drill how to determine which crewmembers would assist them. They said that, during the drill and the actual emergency, the crewmembers having primary responsibility for assisting passengers and distributing lifejackets did not wear any type of identification.

Passenger accountability. According to Carnival Cruise Lines' officials, shoreside personnel prepared a manifest, which was provided to shipboard personnel, of all passengers who booked a cruise on the *Ecstasy.* As passengers boarded the vessel, they were asked to sign for a computerized "sign and sail" card that was used to make purchases. Shipboard personnel used the computer data to confirm which booked passengers actually boarded the *Ecstasy.* Throughout the cruise, the crew used the computerized cards to determine which passengers debarked and boarded the vessel at travel stops.

The lifejackets provided in each stateroom were imprinted with the letter of the muster station to which the occupants of that stateroom were to report during a drill or an emergency. Crewmembers in charge of the muster stations determined whether or not passengers had reported to the correct station by the lettered lifejackets that they wore. A list of the passengers who were supposed to report to a given muster station was not maintained at the muster station or provided to the muster station leader.

During an emergency, crewmembers were assigned to search each stateroom to make sure that it was vacant and were required to place a towel around the exterior doorknob indicating that the stateroom had been searched.

Lifesaving equipment. An LR "Record of Equipment for the Passenger Ship Safety Certificate," issued May 2, 1997, indicates the *Ecstasy's* lifesaving equipment met the requirements of SOLAS 74, as amended in 1998.

The SOLAS 98 amendments stipulate the following requirements for personal lifesaving appliances under regulation 7.2, "Lifejackets":

> 2.1 A lifejacket complying with the requirements of paragraph 2.2.1 or 2.2.2 of the Code shall be provided for every person on board the ship and, in addition:
>
> .1 a number of lifejackets suitable for children equal to at least 10 percent of the number of passengers on board shall be provided or such greater number as may be required to provide a lifejacket for each child; and
>
> .2 a sufficient number of lifejackets shall be carried for persons on watch and for use at remotely located survival craft stations. The lifejackets carried for persons on watch should be stowed on the bridge, in the engine control room and at any other manned watch station.

> 2.2 Lifejackets shall be so placed as to be readily accessible and their position shall be plainly indicated. Where, due to the particular arrangements of the ship, the lifejackets provided in compliance with the requirements of paragraph 2.1 may become inaccessible, alternative provisions shall be made to the satisfaction of the Administration which may include an increase in the number of lifejackets to be carried.

The SOLAS 98 amendments contain additional requirements for personal life-saving appliances at regulation 22, which states, in part:

> 2.1 In addition to the lifejackets required by regulation 7.2, every passenger ship shall carry lifejackets for not less than 5 percent of the total number of persons on board. These lifejackets shall be stowed in conspicuous places on deck or at muster stations.
>
> 2.2 Where lifejackets for passengers are stowed in staterooms which are located remotely from direct routes between public spaces and muster stations, the additional lifejackets for these passengers required under 7.2.2 shall be stowed either in the public spaces, the muster stations, or on direct routes between them….

The LR certification attachment indicates that the *Ecstasy* carried the following life-saving appliances: 10 immersion suits; 270 thermal protection aids; 18 lifeboats; 2 rescue boats, and 36 life rafts. The LR form indicates that the *Ecstasy* had 3,738 adult lifejackets and 356 child lifejackets, or a total of 4,094 lifejackets, to accommodate a maximum load of 3,560 people.

Carnival Cruise Lines' records indicate that, on the day of the accident, the *Ecstasy* carried 4,368 adult-size lifejackets and 578 child-size lifejackets, or a total of 4,946 lifejackets. (Appendix D shows the location of the lifejackets.) As indicated earlier in this report, the ship did not sail with a maximum load. The passenger manifest listed 2,342 adults and 223 children, and the crew manifest showed 916 crewmembers.

Postaccident survey. The Safety Board mailed questionnaires to 300 passengers who had been on the *Ecstasy* asking about the muster drill and whether they encountered any problems during the actual emergency. The Board received 126 responses, which are summarized below.

All 126 responders indicated that they participated in the drill. Most passengers stated that the drill proved valuable during the actual emergency in that they were able to identify the general emergency alarm, don their lifejackets, and find their muster and lifeboat stations. They indicated that they appreciated being told that the ship had a fire squad and extra lifejackets on board. Seventy-nine passengers indicated that, during the actual emergency, the ship's crewmembers seemed well trained and organized and did a good job. All responders said that they heard the cruise director announce "a minor fire situation," which was under control, and that they were to report to their muster stations. Passengers described the crewmembers as calm and helpful in directing passengers and addressing their questions. Responders stated that the cruise director made frequent announcements, both in English and in Spanish, throughout the emergency. Some

responders who initially reported to an outside muster station said that, because of helicopters flying nearby, they occasionally had problems hearing announcements broadcast over the loudspeaker system. They said that when they advised the crewmembers of the problem, they notified "officials" [the cruise director], who then relayed status accounts to muster personnel, who, in turn, provided the information to the passengers.

Fifty-three survey responses identified various problems or situations that were not addressed during the drill. Several people indicated that the drill did not include specific information about fire emergencies, including what to do if they encountered smoke or fire. A number of respondents said that they could not report to their station because of smoke, and the drill did not provide information about what to do if a muster station was not available. Some passengers indicated that they had problems recognizing crewmembers to direct or assist them during the emergency.

Several of the responders expressed dissatisfaction about the lack of consistency in the crew's provision of lifejackets to the mustered passengers. During the drill, the passengers were advised that, in the event of an emergency, if they could not retrieve the lifejackets from their staterooms, they would be provided lifejackets after reporting to their muster stations. Seventy-nine survey responders said that they either obtained lifejackets from their cabin or were provided lifejackets by crewmembers. Forty-seven passengers said that they never received lifejackets. Two passengers stated that when they asked for lifejackets, a crewmember started to pass them out and then reportedly was ordered to stop doing so by his superiors because they were concerned that distributing lifejackets might cause panic. One passenger stated that one crewmember told her not to retrieve her lifejacket from her stateroom and later another crewmember told her to get her lifejacket from her cabin; however, when she attempted to do so, she could not reach her stateroom because of the smoke.

Seventy-two responders, primarily those who had been in the aft section of the *Ecstasy*, indicated that the emergency alarm and the announcements to muster did not occur until after they saw or smelled smoke in their cabins and the passageways. Several passengers estimated that the time between the first evidence of smoke and the emergency alarm was 30 minutes or more. Other responders indicated that they first learned about the ship's fire from television news reports.

Trapped Crewmen

A cabin steward whose cabin was on deck No. 2, close to the main laundry, described to Safety Board investigators how he and another crewmember became trapped by heavy smoke during the fire. About 1805-1810, he was in the passageway when he heard some of the laundry crewmembers talking in Chinese. He returned to his cabin where he smelled smoke. When he went back out into the passageway, the laundry workers were talking, "maybe arguing." One of the laundry workers told him to close his door, whereupon he returned to his cabin. He then saw a small amount of smoke coming from his vent. He returned to the passageway and saw that the laundry crew had left. He went back into his cabin to grab a lifejacket and saw heavy gray smoke coming from the

vent. He then realized that a fire might have broken out so he left his cabin and started knocking on cabin doors to alert others.

The steward found one other crewmember. The steward said that the two of them attempted to escape from deck No. 2; however, heavy smoke filled the passageways, severely limiting their visibility. The steward said that, based on survival techniques that he learned from the safety officer and the safety information booklet, he started to take refuge in a common area toilet facility. He then realized that the other crewmember had not followed him but had continued down the passageway. Holding a towel to his face, the steward felt his way along the bulkhead in the direction of the crewman, who was coughing and calling for help. The steward told the crewmember to calm down and follow him. They went into the toilet facility, where the steward turned on the water in the shower, and they soaked their hair and clothes.

The steward told the crewmember to stay low. Smoke started to enter the shower area, whereupon the crewmember panicked and tried to open the door. The steward put his nose toward the shower drain to get air and directed the other crewman do the same. The steward said that, when he next opened the door to the corridor, the passageway was totally black. He began to pound on the bulkhead to attract attention. The crewmember went into the passageway. The steward put a towel over his nose and followed the crewmember into the passageway, where they heard the sounds of the firefighting teams checking the area and called out to them. The shipboard firefighters then led the two crewmembers above deck.

Emergency Response

The local agencies responding to the *Ecstasy* fire included the Coast Guard, Miami Beach FD, Miami-Dade FD, Coastal Tug, and Moran Towing, Inc.

The response agencies were notified or learned of the *Ecstasy* fire from various sources within about a half hour of each other. The MSO-Miami watchstander, after seeing the *Ecstasy* with smoke streaming from its stern, telephoned and verified the presence of a fire with the ship's master about 1728. About the same time, vessel pilots reported the fire to the Biscayne Pilots Association, which notified Coastal Tug. Shortly thereafter, about 1745, Miami area residents reported a fire on board a ship in the channel to Miami Beach FD, which contacted Miami-Dade FD.[33]

The COTP implemented a unified command system employing two operating bases. Initially, the Coast Guard and Miami Beach FD operated from the MSO-Miami Operations Center, and Miami-Dade FD, Carnival, port officials, and area police operated from a post established at the Port of Miami. Miami-Dade FD subsequently sent an additional representative to the MSO-Miami location. The parties remained in telephone communications with each other and officers on board the *Ecstasy* to coordinate activities throughout the incident. The specific actions of the various response agencies are summarized below.

[33] Miami-Dade FD had jurisdiction when the ship was at the Port of Miami and Miami Beach FD had jurisdiction while the ship was in Government Cut Channel and offshore.

Coast Guard. Upon learning of the fire on board the *Ecstasy,* MSO-Miami paged the COTP, who was off duty, and radioed Coast Guard vessels to respond. The COPT said that he immediately returned to the operations center, arriving about 1800. When the COTP arrived at the operations center, the executive officer briefed him and advised him that a safety zone had been established around the *Ecstasy.*[34] The COTP said that he radioed the *Ecstasy's* master, who told him that the fire was contained to the aft mooring deck by the ship's MVZ boundaries and that the crew and waterside tugs were actively fighting the fire.

The COPT said that when Miami Beach FD and Miami-Dade FD representatives arrived, he implemented a unified command system at the operations center. Based on information that the *Ecstasy's* fire was contained and that no one on board had sustained a serious injury, the COTP stated that the unified command members agreed that the first objective was to get the fire under control and then return the ship to port to disembark the passengers. The COTP stated that transferring the passengers to another vessel would have "presented unwarranted danger" to them.

In the meantime, a Coast Guard 41-foot utility boat (UTB) had arrived on scene at the *Ecstasy* and was assisting a Coastal tug in spraying water on the fire. A Coast Guard vessel carrying two MSO personnel arrived shortly thereafter. The MSO personnel boarded the *Ecstasy* about 1835 and went to the bridge where the master gave them a status report on the fire and shipboard activities. One of the MSO personnel, a chief warrant officer, radioed the information to the MSO duty officer and then went to meet with the ship's safety officer in the aft section of the *Ecstasy.* The warrant officer said that as he proceeded aft, he checked conditions on the ship. He said that the passengers were at the muster stations and that they had either donned their lifejackets or had them nearby. He noted that the low-level lighting was not illuminated. While the warrant officer was examining conditions below deck, the other MSO employee remained on the bridge, relaying information to the unified command center.

At 2100, upon receiving a report from Coast Guard personnel on the *Ecstasy* that the fire was under control, the COTP and the Miami-Dade FD made a unified decision to bring the ship back to the Port of Miami. Pilots who had been sent to the *Ecstasy* to assess the piloting requirements for the cruise ship directed the positioning of tugs at the bow, stern, and both sides of the vessel. The ship was then turned and maneuvered back toward the entrance channel to Miami. By 2400, the *Ecstasy* had been towed back to the sea buoy area. Upon being advised by the pilot that the ship was handling well, the COPT granted permission for the *Ecstasy* to berth, which was accomplished about 0130 July 21, 1998, at Pier 8, Port of Miami. After discussions with Carnival Cruise Lines officials and Miami Dade FD, the COTP ordered that all passengers be disembarked as soon as possible.

Local fire departments. Upon receiving several 911 calls from area residents reporting a possible ship fire, the Miami Beach FD contacted the fire dispatch office and

[34] 33 CFR 165.20: A Safety Zone is a water area, shore area, or water and shore area to which, for safety or environmental purposes, access is limited to authorized persons, vehicles, or vessels. It may be stationary and described by fixed limits or it may be described as a zone around a vessel in motion.

was told that the Coast Guard was in radio communication with the *Ecstasy* and that the fire was reportedly under control. Based on area television coverage of the fire, an FD division chief later telephoned the Coast Guard to report that the fire did not appear to be controlled and then went to the Coast Guard operations center to participate in the unified command operations. Once there, he contacted the Miami-Dade FD to join the unified command structure and to request shipboard firefighting resources.

By 1930, the two fire departments had assembled and dispatched two strike teams on Coast Guard cutters to the *Ecstasy.* Strike team No. 1 consisted of Miami-Dade FD firefighters[35] who were to assess the fire conditions and advise the unified command whether the *Ecstasy* should be allowed into port. Strike team No. 2 consisted of Miami Beach FD firefighters and medical personnel who were to triage and treat the injured.

Once on the Ecstasy, the strike team No. 1 leader conferred with the Coast Guard representatives, the master, and Carnival Cruise Lines' firefighting safety training director about the heat and smoke conditions, and all agreed that the ship could not return to port until the fire was confirmed out. They established a fire operations center in the marshaling area near the stern on deck No. 3 and developed an action plan to systematically assess the fire area by searching all 10 decks in the aft section of the ship. While the strike team No. 1 leader remained at the marshaling area, the strike team members attempted to enact the plan to confirm the status of the fire but could not do so because of the heat and smoke conditions. The fire team members were then stationed at the fire doors to monitor the affected areas and check for developing fires while the passageways were ventilated, thereby dissipating some of the heat and smoke.

After strike team No. 1 completed its assessment, the strike team leader briefed the COTP, Carnival Cruise Lines representatives, and other personnel about the status of the fire. At his recommendation, the firefighters continued to ventilate the affected areas and selected teams continued to monitor conditions on decks No. 5, 6, and 8. The Miami-Dade hazardous materials team monitored the entire ship for transfer of carbon monoxide from the fire area. About 2109, the fire was declared extinguished.

While the fire was being assessed, strike team No. 2 examined and treated at least 70 patients and arranged transport for those requiring further medical treatment at area hospitals. Strike team No. 2 also established a rehabilitation area to examine the *Ecstasy* crew firefighters as they completed their firefighting operations.[36]

Emergency Preparedness Drills and Exercises

On October 3, 1997, representatives from Carnival Cruise Lines, the Port of Miami, the Biscayne Pilots, area emergency response agencies, and the Coast Guard participated in a marine firefighting table-top exercise that simulated a fire on board the *Ecstasy.*

[35] Strike team No. 1 was a firefighting suppression team.

[36] The strike teams did not participate in any active firefighting. All shipboard firefighting efforts were undertaken by *Ecstasy* crewmembers.

On December 16, 1997, Carnival Cruise Lines held a Crisis Management Team exercise to practice the company's Crisis Management Plan for responding to emergencies on its cruise ships. The exercise was a simulation of a crisis aboard a Carnival Cruise Lines' vessel that focused on the assembly of the Crisis Management Team. Carnival Cruise Lines conducted notifications according to the Crisis Management Plan. The exercise scenario involved a fire in the ship's laundry spaces. Carnival Cruise Lines representatives attended a High Capacity Passenger Vessel Incident Response, Planning and Risk Management Workshop on September 20-21, 1995, sponsored by the Coast Guard and Massachusetts Maritime Academy.

Tests and Research

Metallurgical Testing

After the accident, Safety Board investigators examined the welding unit because of the second fitter's statement about witnessing an arc. Three beads of weld-like material were found on the ground clamp. The Safety Board performed metallurgical tests on the beads found on the ground clamp, on welding rods from the vessel's shop, and on the rod found in the welding machine after the fire. The material in the beads was found to be consistent with the material found in the welding rod in the electrode.

Debris Testing

Safety Board investigators collected mooring line remnants and debris samples from the surface of the mooring deck to send for testing at the Bureau of Alcohol, Tobacco, and Firearms (ATF) laboratory in Atlanta, Georgia. No accelerant material was found in any of the samples.

Mooring Line Testing

The Safety Board contracted testing to determine the combustibility of the polypropylene line used on the mooring deck. The line material had heat applied to it at a constant rate (three different heat fluxes/amounts were tested). The amount of heat given off was measured. The testing determined that the average heat of combustion[37] for the line was 18,217 Btu (British thermal units) per pound (Btu/lb). The average heat of combustion for gasoline is about 19,000 Btu/lb. The minimum amount of applied heat required to ignite the line in 14 seconds was 80 kW/m^2. A table in appendix E lists the heat release rate information in more detail.

Lint Testing

Because fire consumed the lint on the *Ecstasy,* Safety Board investigators collected lint samples for combustibility testing from the laundry exhaust system of a sister ship, the *Fantasy.* (The examination of sister ships is discussed in the next section.) Tests conducted

[37] The heat of combustion is the amount of heat that the material gives off when it burns.

by ATF fire specialists showed that the lint was ignited easily by a spark and burned for several seconds, leaving little residual material behind. The minimum heat flux for an ignition was equal to 11.5 kW/m^2.

Other Information

Examination of the Imagination *and the* Fantasy

After the *Ecstasy* fire, Safety Board investigators examined the *Imagination* and the *Fantasy,* two Fantasy line ships having the same basic arrangement as the *Ecstasy.*

The mangles on the *Imagination* and the *Fantasy* differed from the mangle on the *Ecstasy.* The *Imagination's* mangle was built by the same company; however, the machine was a later model, and its exhaust system was configured differently. The mangle in the *Fantasy's* main laundry was manufactured by a different company

The main laundry ventilation system on the *Imagination* varies slightly from that on the *Ecstasy* and the *Fantasy.* The plenum is divided into two sections: lower section for accommodation exhaust and upper section for laundry exhaust. In addition, the dryers on the *Imagination* had been fitted with a "centrifugal" filter. The air from the dryers is vented into this filter and then sent out the exhaust vent. According to the laundry manager, the filter removes a large amount of lint and is cleaned about every 3 hours, or about four times a day, during laundry operation. He stated that the filter does not completely remove lint from the air exhausted out on to the mooring deck.

On the mooring deck, investigators removed the louvers on the exhaust plenum and observed lint accumulated in the plenum as well as the intake filters for the thruster room. They also noted that lint had collected on stored rope on the deck and on the spindled rope on the winches. Further examination revealed that the lint was forced down into the fibers of the rope. According to shipboard officials, the mooring crew washed down the deck about once a week.

During inspections of the *Fantasy,* investigators noted that the centrifugal filter used on the *Imagination* was not yet in place on the *Fantasy* or on the *Ecstasy.* The mangle and the dryer had separate duct systems similar to the *Ecstasy.* The *Fantasy* had a large amount of accumulated lint. According to the *Fantasy's* chief engineer, the accessible areas of the exhaust ducts and plenum are cleaned about every 20 days, and the ducts and plenum had been cleaned about 4 or 5 days before this inspection. Investigators observed several inches of accumulated lint in the dryer ducts and plenum. The mangle duct contained about ½ of an inch of lint that was coated with a waxy or oily substance.

On the mooring deck, the stored rope had accumulated large piles of lint. Investigators noted that the lint had become embedded into the rope fibers.

Carnival Cruise Lines' Postaccident Actions

On August 10, 1998, Carnival Cruise Lines, as part of its SMS program, issued to its fleet *Operations Safety Bulletin (OSB) No 04-98,* which states, in part:

> DESCRIPTION: Lint and other fibrous material might collect in the ship's exhaust system and can pose a serious fire hazard. Even with our filtering system, a certain amount can get past the present filters. This OSB is being provided to alert the vessels to this potential fire risk.
>
> ACTION REQUIRED: Immediately conduct an extensive examination of all ducts that are part of the exhaust system which originates from or near the laundry. You are to remove all panels that are necessary to enable personnel to determine the amount of lint in the duct system. Any lint found is to be removed by all available means including but not limited to, vacuuming, sweeping, hand cleaning, washing, etc. You are to take photos prior to cleaning as well as after the cleaning to establish the status before and after.
>
> As the SMS requires, all dryer filters are to be inspected, cleaned and logged. The filter cleaning schedule is to be posted with records for signatures as per previous instructions. A thorough fire risk and cleanliness inspection of all areas of the laundry and adjacent spaces are to be completed on a regular basis and logged. Ensure that any outstanding work order for laundry equipment repairs be completed, especially any dryer thermostats.
>
> ATTENTION ENGINEERING: Effective immediately, locate a suitable space to lock up all portable welding machines to prevent unauthorized use. Continue to use the Hot Work Permit as required by the SMS.
>
> COMPLETION REPORT REQUIRED: When finished with your examination, forward a report of your findings, including photos to the attention of Director of Fleet Safety. The time for completion is 15 September 1998.

Carnival Cruise Lines made procedural changes to facilitate the ready identification of crewmembers whose primary emergency duties involved crowd management. According to the ship's safety officer, before the *Ecstasy* accident, he had procured bright green hats, imprinted with the word "crew," to issue to employees who were in charge at muster stations. He had not had the opportunity, however, to distribute the hats before the *Ecstasy* sailed on July 20. At the suggestion of Safety Board investigators, Carnival Cruise Lines revised the information presented at its emergency drills to include an announcement advising passengers that crewmembers wearing the green hats were proficient in English and were specifically assigned to assist passengers during an emergency.

Carnival Cruise Lines installed equipment and made system modifications to reduce the amount of lint buildup in the ventilation ducts. The company added lint screens to all exhaust louvers in the main laundry and installed turbo-filters on the laundry dryers to reduce the amount of lint entering the exhaust ducts. The company also modified the exhaust plenums and fire dampers on the *Ecstasy* as well as other Fantasy Class ships in its fleet.

After the *Ecstasy* fire, Carnival Cruise Lines modified to the design of the *MV Paradise,* a ship that was under construction, to include the addition of sprinklers on the vessel's covered mooring decks. The company also began a program of retrofitting the mooring decks of its existing cruise ships with deluge sprinkler systems. According to Carnival Cruise Lines' senior officials, the aim of the company is to install sprinkler protection on the mooring decks of all its ships by the end of 2001.

Related Safety Board Actions

Locally sounding smoke alarms. As a result of fires on board the cruise ships *Universe Explorer* in 1996 and *Vistafjord* in 1997,[38] the Safety Board, in April 1997, issued the following safety recommendations to the International Council of Cruise Lines (ICCL[39]):

> M-97-37
>
> Without delay advise members to install automatic smoke alarms that sound locally in crew accommodation areas so that crews will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.
>
> M-97-38
>
> Without delay advise members to install automatic smoke alarms that sound locally in passenger accommodation areas so that passengers will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.

Concurrently, the Safety Board issued the following safety recommendations to the Coast Guard:

> M-97-39
>
> Propose that the IMO require all passenger vessels to have automatic smoke alarms that sound locally in the crew berthing areas so that crews will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.
>
> M-97-40
>
> Propose that the IMO require all passenger vessels to have automatic smoke alarms that sound locally in the passenger accommodation areas so that passengers will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.

[38] (a) National Transportation Safety Board, *Fire on Board the Panamanian Passenger Ship* Universe Explorer *in the Lynn Canal Near Juneau, Alaska, July 27, 1996,* Marine Accident Report NTSB/MAR-98/02 (Washington, DC:NTSB, 1998). (b) National Transportation Safety Board, *Fire Aboard the Passenger Ship* Vistafjord, *near Grand Bahama Island, Bahamas, April 6, 1997,* Marine Accident Report NTSB-MAB-98/01 (Washington, DC:NTSB, 1998).

[39] ICCL is an industry association comprising the 16 largest cruise lines that call on major ports in the United States and abroad. Each year ICCL's cruise vessel operators carry more than 5 million U.S. passengers on 93 ships.

On May 5, 1997, the ICCL responded that it had distributed Safety Recommendations M-97-37 and -38 to its members for review and consideration and that the recommendations would be an agenda item at the next meeting of its technical committee. Based on these actions, the Safety Board classified Safety Recommendations M-97-37 and -38 "Open—Acceptable Response," pending further action by the ICCL on the issue.

On July 25, 1997, the Coast Guard responded that it concurred with Safety Recommendations M-97-39 and -40. The agency subsequently made a proposal in May 1998 to the IMO asking that the fire safety amendments to SOLAS 74 be revised to require automatic locally sounding smoke alarms on passenger ships. The IMO, in May 2000, referred the action for consideration to a subcommittee of its Maritime Safety Committee (MSC). Based on the Coast Guard's actions, the Safety Board classified Safety Recommendations M-97-39 and -40 "Open—Acceptable Response."

In October 1999, the ICCL wrote the Safety Board asking that Safety Recommendations M-97-37 and -38 remain in an open status pending final action by the IMO's MSC on the Coast Guard proposal. The ICCL subsequently presented to the MSC on December 17, 1999, an issue paper opposing the Coast Guard's proposal that focused on two propositions: false alarms and crowd management. The ICCL stated that on a daily basis as many as 20 or more false alarms occur as a result of normal sensitivity of smoke detectors. With regard to the issue of crowd management, the ICCL maintained that automatic local-sounding smoke alarms would increase the risk of mass panic by passengers and impair effective crowd control by ship crews.

In April 2001, a Coast Guard official advised the Safety Board that, as a result of concerns from some Administrations and the technical questions raised by the ICCL, the proposal for locally sounding alarms was removed from the MSC agenda and not considered. The Coast Guard is presently evaluating whether to again introduce the proposal as an agenda item at the next meeting of the MSC, which is spring 2002.

In the 25 months following the Safety Board's issuance of Safety Recommendations M-97-37 and -38, the Board investigated three cruise ship fires, including the 1998 accident on the *Ecstasy.* The other accidents are summarized below.

On September 19, 1999, a fire broke out in the engineroom of the Liberian cruise ship *Tropicale* in the Gulf of Mexico. The fire was restricted to the engineroom and smoke did not enter the accommodation spaces; therefore, no one sustained smoke inhalation injuries. However, 1,096 passengers and 605 crewmembers were put at risk.

On May 20, 2000, a fire broke out in a crew cabin on the Netherlands cruise ship *Nieuw Amsterdam* in Glacier Bay, Alaska. While the fire was restricted to one deck, smoke from the fire progressed upwards through nine decks. A passenger was forced to crawl on his hands and knees along the passageway outside his cabin due to the heavy smoke. The cruise ship was carrying 1,201 passengers and 566 crewmembers.

Following the *Nieuw Amsterdam* accident investigation, the Safety Board elected to classify Safety Recommendations M-97-37 and -38 "Closed—Reconsidered" and issued the following safety recommendations to 18 individual cruise ship owners and their operating companies on July 11, 2000:

> M-00-6
>
> Without delay, install automatic local-sounding smoke alarms in crew accommodation areas on company passenger ships so that crews will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.
>
> M-00-7
>
> Without delay, install automatic local-sounding smoke alarms in passenger accommodation areas on company passenger ships so that passengers will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.

As of March 2001, 12 companies, representing about 86 percent of the North American trade,[40] had responded to the Safety Board regarding the installation of locally sounding alarms in both crew and passenger accommodation areas.

One company, Celebrity Cruises, indicated that it had installed locally sounding alarms in accommodation areas as requested. The Safety Board, therefore, classified M-00-6 and -7 "Closed—Acceptable Action" for Celebrity Cruises.

Eleven companies, including Carnival Cruise Lines, responded that they supported the recommendations and intended to install locally sounding smoke alarms on their cruise ships. As a result, the Safety Board classified M-00-6 and -7 "Open—Acceptable Response" for the following companies: American Classic Voyages, Carnival Cruise Lines, Crystal Cruises, Disney Cruise Line, Holland-America Line, Westour, Inc., Norwegian Cruise Line, Princess Cruises, Radisson Seven Seas Cruises, Renaissance Cruises, Royal Caribbean International, and Seabourne Cruise Line (Cunard Cruise Lines). The Safety Board classified M-00-6 and -7 "Closed—No Longer Applicable" for Premier Cruises because the company is no longer in operation.

In July 2000, at the same time that the Safety Board made recommendations for locally sounding alarms directly to the cruise ship companies, the Board issued the following recommendations to the ICCL:

> M-00-8
>
> Withdraw your opposition to the amendment of the Safety of Life at Sea Convention chapter II-2 to require automatic local-sounding smoke alarms in crew accommodation spaces on board passenger ships and support a full discussion of the technical issues and any further U.S. Coast Guard actions on this matter before the IMO.

[40] At the time of the accident, about 99 cruise ships operated out of North America. The 12 responding companies owned 85 of the 99 vessels.

M-00-9

> Withdraw your opposition to the amendment of the Safety of Life at Sea Convention chapter II-2 to require automatic local-sounding smoke alarms in passenger accommodation spaces on board passenger ships and support a full discussion of the technical issues involved and any further U.S. Coast Guard actions on this matter before the IMO.

On October 13, 2000, the ICCL responded that it did not oppose the technical discussion of audible smoke alarms in its paper to the IMO and was concerned by the interpretation of the paper. The ICCL letter further stated that member operators had agreed to install in new and existing ships audibly sounding smoke detectors that would "immediately alert persons to the presence of smoke in their cabin or stateroom or in the corridor outside."

In a follow-up letter on November 7, 2000, the ICCL President enclosed a standard for locally sounding smoke detectors that had been adopted by the ICCL Board of Directors, which represented all 16 member operators. The ICCL President indicated that the adopted policy was ICCL's response to safety recommendations M-00-8 and -9.

In a February 7, 2001, press release announcing the adoption of the mandatory industry standards, the ICCL stated that member lines would integrate the industry standards into their SMS to ensure compliance through internal and external audits.

On April 19, 2001, the Safety Board responded to the ICCL:

> The Safety Board is pleased that on November 1, 2000, the ICCL adopted a policy to member cruise line companies to install audibly sounding smoke alarms in both crew and passenger spaces. The Board is further pleased that the ICCL will continue to support full and open discussion of technical and operational issues associated with any proposal directed toward the enhancement of safety on board passenger ships….
>
> The Safety Board's November 1, 2000, advisory acknowledged four of your member organizations (Disney, Radisson, Crystal, and Holland-America) for taking the initiative to install smoke alarms on their vessels, and the ICCL for developing its policy for smoke alarms on member cruise vessels.
>
> However, the ICCL has not complied with the recommended action because the ICCL is on record at the IMO objecting to locally sounding alarms per its issue paper dated December 17, 1999. Until this paper is superceded, ICCL has not formally withdrawn its opposition at IMO, which is the subject of the M-00-8 and M-00-9. The Safety Board suggests that ICCL submit to IMO its new policy in support of locally sounding alarms. Accordingly, until the ICCL has superceded its December 17, 1999, issue paper, Safety Recommendations M-00-8 and -9 are classified 'Open—Acceptable Response.'

Inspection and maintenance of ventilation ducts. As a result of the *Ecstasy* fire, on October 20, 1998, the Safety Board issued the following safety recommendations to cruise vessel owners and operators embarking passengers from United States ports:

M-98-125

Immediately inspect, within your fleet of ships, the laundry ventilation systems, including ducts, plenums, and exhaust terminuses, for any combustible material, such as lint, and clean the systems, as necessary, to reduce the risk of fire. (Urgent)

M-98-126

Institute a program to verify on a continuing basis that the laundry ventilation systems, including ducts and plenums, remain clean and clear of any combustible material that poses a fire hazard on your vessels.

Of the 22 recipients, all but one responded that they had taken measures and had initiated on-going inspection programs to comply with the recommended actions.[41] As a result, the Safety Board classified Safety Recommendations M-98-125 and -126 "Closed—Acceptable Action."

Related Coast Guard Actions

Regulatory changes. Based on findings in the *Ecstasy* accident investigation, the Coast Guard, on May 21, 2000, amended its *Marine Safety Manual, Volume II*, adding the following information on laundry room exhaust ducts and requiring inspectors to examine those ducts for potential safety problems (amendments italicized).

> **Galley *and Laundry Room* Exhaust Ducts:** A number of shipboard fires have originated in the exhaust ducts of galley ranges and fryers, *and recently in laundry room ventilation systems.* These fires have resulted in serious damage, injury, and loss of life aboard the vessels involved. Unmaintained exhaust duct work will become saturated with cooking grease and pose a fire hazard. Unfortunately, such areas have been overlooked during vessel inspections. The following procedures shall be followed during biennial and mid-period inspections of U.S. vessels and during SOLAS verification examinations of foreign vessels:
>
> All vessels: a. (6) Examine laundry room vents, ask if the company has a cleaning and maintenance program (check records–part of ISM/SMS responsibility).[42]

Postaccident findings. According to Coast Guard officials, MSO-Miami began inspecting laundry room ventilation systems as part of regular CVEs in November 1998. Since that time, Coast Guard inspectors reportedly have found that, in every case, the ventilation ducts on the inspected cruise ships have had no unsafe lint buildup and that the

[41] The cruise lines that responded favorably include the following: American Hawaii Cruises and Delta Queen Steamboat Company, Carnival Cruise Lines, Commodore Cruise Lines, Crystal Cruises, Celebrity Cruises, Inc., Costa Cruise Lines, Cunard Lines, Ltd., Disney Cruise Line, Holland-America Line, Norwegian Cruise Line, Premier Cruises, Radisson Seven Seas Cruises, First European Cruises, Mediterranean Shipping Company, Orient Lines, Inc., Princess Cruises, Regal Cruises, Inc., Renaissance Cruises, Inc., Royal Olympic Cruises, Royal Caribbean International, and Silver Sea Cruises, Ltd. The cruise line that has yet to respond is Bergen Line Services.

[42] *USCG Marine Safety Manual, Vol. II: Material Inspection*, Section B: Domestic Inspection Program, Chapter 1: Inspection of Vessels for Certification (21 May 2000): B1-79.

companies have revised their SMS to include procedures for maintaining the ventilation ducts in a fire-safe condition.

Qualitative Failure Analysis

Regulatory requirements. In 1988, the Coast Guard issued regulations (46 CFR 62, "Vital System Automation"[43]) requiring the use of a qualitative failure analysis of certain automated systems, including propulsion control systems. In proposing the regulatory requirement that designers, manufacturers, and/or shipyards perform and submit system failure analysis, the Coast Guard stated that the use of advanced automation technologies such as electronics and microprocessors made it increasingly difficult, "at times impossible, for the Coast Guard, ship owners/operators, and classification societies to evaluate safety." The Coast Guard further stated:

> The Coast Guard has chosen to propose safety performance standards that, to the greatest extent practicable, state the desired operation or function without addressing detailed design criteria…As an alternative to detail evaluation, the Coast Guard proposes (to require) a failure analysis of the design and a self-certification of design compliance to certain…standards. [This process] emphasizes the responsibility of the parties most familiar with any automation system, i.e., the designer and manufacturer, to evaluate and certify the safety of the system. It also provides an evaluation means that is suited to technological changes. In most cases, the failure analysis will identify a preferred fail-safe state. Systems that would be required to be independent, that is, have arrangements that provide a level of safety and reliability equivalent to complete duplication, include:
>
> - Controls systems
> - Alarms and instrumentation (monitoring systems)

The IMO subsequently adopted regulations requiring that a failure modes and effects analysis (FMEA)[44] be performed for the machinery and control systems of high-speed vessels.[45] The IMO and classification societies presently do not require the use of FMEA for passenger vessel propulsion system designs.[46]

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[43] Subpart 62.10 defines *system* as an arrangement of elements that interact to perform a specific function and *vital system* as that which is essential to the safety of the vessel, its passengers, and its crew.

[44] An FMEA is an inductive approach to identifying engineering design deficiencies by examining each individual component or process in a system to determine how its failure or deviation from intended performance might affect the entire system. By conducting a FMEA, engineers can modify the design of a system before it is built to avoid catastrophic or significant system failures.

[45] The *International Code of Safety for High Speed Craft*, adopted in 1994, mandated the use of FMEA because these craft employed new technologies.

[46] LR's *Propulsion and Steering Machinery Redundancy* contains provisional rules that are in addition to the classification society's *Rules and Regulations for the Classification of Ships*. LR's provisional rules, which are optional for vessel owners, stipulate the use of FMEA in designing propulsion systems, electrical power supplies, essential services, control systems, and steering arrangements. According to LR's provisional rules, the FMEA report must show that a single failure in the propulsion and related auxiliary systems will not cause loss of all propulsion or steering capability.

Analysis

General

This analysis first identifies factors that can be readily eliminated as causal or contributory to the fire and determines where and how the fire started and how it spread. The report then discusses the following major safety issues, which were identified during the investigation:

- Adequacy of management safety oversight;
- Adequacy of fire protection systems;
- Adequacy of passenger and crew safety; and
- Adequacy of engineering systems design.

This report also discusses the effectiveness of the emergency response effort.

Exclusions

The weather was not a factor in this accident. The vessel's navigation, propulsion, and steering systems had no bearing on the cause of the fire. No engineering difficulties occurred before the outbreak of the fire. From documents and statements, the Safety Board determined that all officers were properly licensed and certified by the Liberian government and were qualified to serve in their positions. Postaccident drug and alcohol screenings of 79 crewmembers were negative for 76 individuals. The first officer tested positive for marijuana, indicating that he had used the drug sometime in the weeks before the fire occurred. However, based on witnesses' descriptions of the first officer's actions on the bridge during the emergency, no behavioral evidence indicated that he was impaired by drugs at the time of the fire. Because the personnel who tested positive for drugs have been dismissed from service and because of the improvements that Carnival Cruise Lines has made to its drug-testing program since this accident, the use of drugs and postaccident testing will not be discussed further in this report.

Accident Analysis

The *Ecstasy* experienced a major fire at the aft end of the ship that affected two MVZs. A combination of fire, heat, and smoke damaged the main laundry room, the stern thruster room, an air conditioning room, an electrical equipment room, the aft mooring deck, and the steering gear room. In addition, some passenger staterooms and crew cabins on deck Nos. 2, 4, 5, and 6 sustained heat and smoke damage. The cruise ship

subsequently lost propulsive power and most steering and had to be towed back to Miami. During the onboard emergency, all passengers evacuated safely from the affected areas; however, two crewmembers became trapped on deck No. 2, and firefighting teams had to rescue them. Nine passengers were treated for injuries resulting from pre-existing conditions or smoke inhalation, and 14 crewmembers sustained minor injuries from firefighting activities and/or smoke inhalation.

Fire Ignition and Propagation

Although Safety Board investigators found evidence of fire damage, smoke damage, or both in several aft areas of the *Ecstasy,* they readily narrowed the potential origin of the fire to either the aft mooring deck or the main laundry.

The Safety Board examined the mooring deck because of the extensive fire damage to the area. Investigators considered various sources of ignition, including electrical malfunctions, discarded smoking materials, and accelerants. Electrical malfunctions could have occurred in the three control boxes for the winches**.** The wiring in the control boxes had been exposed to intense heat and the insulation on the wires in the boxes burned away. Investigators found no evidence of arcing or failure, however, in any of the wiring. Examination of the motor controller panels for the winches, located in the steering gear room on deck No. 3, also revealed no failures.

Investigators found no evidence that smoking materials had been discarded or any inflammable liquids had been stored on the deck. Moreover, ATF testing of the debris samples collected after the fire showed no evidence of any accelerant used to intentionally set the fire (arson). The prolonged fire on the mooring deck might have destroyed any evidence of ignition caused by smoking material or accelerants. Other evidence, however, indicates that the fire did not originate on the mooring deck. Support for this contention is based on the dynamics of air flow in the ventilation systems connecting the mooring deck to the laundry room, the condition of the ventilation systems, and the events that took place in the main laundry room before the sounding of the first fire alarm.

A pathway was necessary for fire to have spread from the mooring deck to the main laundry. Conditions existed, however, that would have prevented the fire from spreading in this manner. Before the master ordered the shut down of the power ventilation system in MVZs 1 and 2, two ventilation duct systems from the main laundry, separately servicing the dryers and the mangle, exhausted air into the mooring deck at a rate of roughly 7 meters per second. If the fire had originated in the mooring deck and spread to the main laundry, the flames would have had to travel through one or both of the duct systems in the opposite direction of the exhaust airflow. Based on Safety Board calculations and in accord with current research on flame movement, the flames could not have traveled against an airflow of such velocity**.**[47]

[47] A.C. Fernandez-Pello and T. Hirano, "Controlling Mechanisms of Flame Spread," *Combustion Science and Technology,* Vol. 32, (1983): 1-31.

The condition of the ventilation duct systems also supports the contention that the fire did not spread from the mooring deck to the main laundry. Had such spreading occurred, fire damage would have been evident in both the dryer and the mangle ventilation duct systems, since at their terminus on the mooring deck they come together; therefore, both vent systems would have been equally subject to any source of fire on the mooring deck and equally susceptible to fire damage. This was not the case. Although the mangle's ventilation system exhibited extensive fire damage, the dryer's ventilation system was virtually unscathed. Using fiber optic scope technology, the investigators detected unburned lint inside of the dryer ventilation system and no evidence of fire or fire-related damage. The Safety Board concludes that although the *Ecstasy's* mooring deck sustained the heaviest fire damage, it was not the point of origin for the fire.

Events occurring in the main laundry room further support the finding that the fire did not originate on the mooring deck but, instead, began in the laundry room. The second fitter testified that he and the first fitter were setting up welding equipment to repair the mangle in the laundry room when a welding rod that was dangling near the deck came in contact with either the grounding clamp or the mangle, causing a spark. The second fitter also stated that, at the time the spark occurred, dryer lint covered the deck. Both fitters testified that a "small" fire started on the deck and that a fire on the mangle and a fire in the overhead duct subsequently occurred.

A cabin steward who was retrieving towels from a nearby linen closet observed smoke in the main laundry. He said that when he went to investigate, he saw the two fitters working on the inboard side of the mangle and observed flames on the outboard side of the mangle, near the exhaust vents. He said that he retrieved a fire extinguisher to fight the fire; however, when one of the fitters dumped a jug of water on the side of the mangle where they were working, flames "appeared to jump up" to the overhead vent. The smoke and flames became too great for him to fight with an extinguisher, so he activated the local fire alarm at the laundry room door. The first officer confirmed that the first fire alarm, which sounded on the fire control panel at 1710, indicated the main laundry. Alarm printouts show, however, that the first fire alarm was automatically activated.

The Safety Board found that the fire and smoke damage supported all or portions of the witnesses' testimonies. The evidence of fire in the main laundry was limited to the area of the mangle. Metallurgical analysis showed that the welding deposits on the grounding clamp were similar to the material in the electrode's welding rod, which confirmed that the welding rod had struck the ground clamp. Examination of other electrical appliances in the laundry revealed no evidence of arcing. Moreover, investigators found no evidence of discarded smoking materials or accelerants that might have served as an ignition source in the laundry. The Safety Board concludes that the fire on board the *Ecstasy* started in the main laundry and was ignited by an arc from a welding machine.

Fire damage to the mangle power cables and soot deposits on the loading end of the mangle showed that the fire spread across the floor up onto the mangle. Damage to the aft roller and melted wax from the mangle strings showed that the fire spread onto the roller. The fitters had turned off the mangle to work on it. As a result, the rollers were in a

raised position, which left a gap between the rollers and the entry housing to the adjacent exhaust ducts. This gap allowed the fire to spread into the roller exhaust ducts, which was evidenced by heat damage to the paint on the exhaust ducts. In addition, the roller exhaust ducts contained several inches of burned debris.

Postaccident examination of the mangle blowers revealed that they were caked with partially burned lint and wax. The impeller on the aft fan had disintegrated, leaving rust-colored metal flakes imbedded in the lint and wax. The absence of an operational fan in this duct allowed more lint to accumulate in it than in the forward duct, which resulted in the aft duct sustaining far greater heat damage.

In addition to the damage in the mangle's vertical exhaust ducts, investigators found 2-3 inches of burned debris in the main ventilation duct above the machine. Fire damage was present throughout the mangle exhaust duct system of the *Ecstasy,* indicating the fire probably proceeded through this system into the air conditioning room where it spread through the plenum exhaust ducts onto the mooring deck. The fire then ignited lint that had been exhausted to the mooring deck and that had become imbedded in the mooring line. The burning lint, in turn, ignited the mooring lines, which fueled a large, intense fire that raged for more than 2 hours, damaging deck areas above, forward, and below the mooring deck. Hot gases and smoke transferred from the mooring deck to other areas of the vessel through the air conditioning ventilation system before bridge personnel secured the system. The ventilation supply intakes for the stern thruster room, which are next to the laundry room's exhaust plenum on the mooring deck, transferred smoke and heat from the fully developed fire through the vent ducts into the stern thruster room, causing extensive damage there. Hot gases and smoke traveling through the ventilation ducts also caused extensive heat damage and sooting in the steering gear rooms, several passenger cabins on decks Nos. 4, 5, 6 and 7, and the laundry crew galley. The injection of smoke and fire gases from the mooring deck fire into the intake systems caused the almost simultaneous activation of smoke detectors on four different decks.

Based on the amount of burned lint debris on the *Ecstasy,* investigators examined the main laundries of other Fantasy vessels and found large lint accumulations in their laundry exhaust systems, particularly the mangle exhaust ducts next to and above the machine. On one such ship, the *Fantasy,* the chief engineer stated that he had initiated a program of cleaning the exhaust ducts and plenum about every 20 days after he had experienced a problem closing a damper and had found the ducts clogged with lint. Although crew personnel had cleaned the ducts 4-5 days before the Safety Board's inspection, investigators found several inches of lint buildup in the dryer ducts and the plenum. They also found that the mangle duct contained about ½ of an inch of lint and was coated with a waxy/oily substance. On the mooring deck, investigators found that lint exhausted through the ventilation system had settled on and become imbedded in the mooring lines.

Flammability tests of lint collected from the sister ships showed that the material was ignited easily by a spark and burned for several seconds, leaving little residual material behind. Therefore, the large lint buildup in the exhaust vents and the ventilation system represented such a hazard that a fire might have occurred even if the fitters had

followed the required welding permit procedures and had arranged to have a vessel safety officer present. Upon observing the laundry area, a safety officer probably would have required the fitters to eliminate the obvious lint that was on the deck and, possibly, the lint on the mangle. At the time of the accident, Carnival Cruise Lines' SMS did not contain procedures for inspecting or maintaining the laundry exhaust vents. The safety officer probably would not have examined the vents in the overhead and identified the greatest fire risk. Thus, when the fitters began to work, the sparks shooting upward from their welding might still have ignited a blaze that crewmembers could not put out with the available fire extinguishers. The Safety Board concludes that the lint that accumulated in the ventilation duct of the main laundry created a serious fire hazard on the *Ecstasy.*

As a result of the *Ecstasy* fire, on October 20, 1998, the Safety Board issued the following safety recommendations to cruise vessel owners and operators embarking passengers from United States ports:

> M-98-125
>
> Immediately inspect, within your fleet of ships, the laundry ventilation systems, including ducts, plenums, and exhaust terminuses, for any combustible material, such as lint, and clean the systems, as necessary, to reduce the risk of fire. (Urgent)
>
> M-98-126
>
> Institute a program to verify on a continuing basis that the laundry ventilation systems, including ducts and plenums, remain clean and clear of any combustible material that poses a fire hazard on your vessels.

Of the 22 recipients, all but Bergen Line Services responded that they had taken measures and had initiated on-going inspection programs to comply with the recommended actions. As a result, the Safety Board classified Safety Recommendations M-98-125 and -126 "Closed—Acceptable Action."

The Safety Board's investigation of the *Ecstasy* fire, specifically its focus on lint buildup problems, and its Safety Recommendations M-98-125 and -126 also prompted a beneficial change to the Coast Guard's vessel inspection guidelines. On May 21, 2000, the Coast Guard amended *Marine Safety Manual, Volume II* to require that, as part of a regular CVE, its inspectors examine a vessel's laundry exhaust ducts for potential safety problems. In addition, the Coast Guard inspectors must review the cruise ship company's SMS to ensure that it contains procedures for routine cleaning and maintenance of the laundry room vents. The Coast Guard began inspecting laundry room ventilation systems in November 1998.

According to Coast Guard officials, since the cruise ship companies have established procedures for inspecting and maintaining the laundry room ventilation systems on their vessels, Coast Guard CVE inspectors reportedly have found that, in every case, the ventilation ducts on cruise ships have had no unsafe buildup of lint.

The Safety Board concludes that the procedures and standards for inspecting and maintaining laundry ventilation systems adopted by the marine industry and government agencies following the *Ecstasy* fire will improve safety on cruise ships.

Adequacy Of Management Safety Oversight

The presence of lint in the main laundry and the mooring deck, specifically the buildup in the mangle exhaust ducts and the particles imbedded in the mooring line, represented a fire hazard that could have been ignited by any number of sources. However, the decision of the fitters to weld before arranging for a shipboard safety official to assess the area for risks raised questions about the adequacy of Carnival Cruise Lines' SMS.

When the first galley fitter broke the mangle bolt, he decided to weld it back in place. He returned to the fitter workshop to obtain a portable welding machine and related equipment while the second fitter obtained a fire blanket. After setting up the welding equipment, the fitters energized the welding machine and inserted an electrode into the electrode holder. For safe operations, a welding machine should not be energized until immediately before welding.

Carnival Cruise Lines' SMS manual contains numerous safety procedures for workers performing welding operations, including a prohibition against undertaking welding "unless the requirements of the 'Hot Work Permit' are satisfied." The permit requirements for welding include applying in writing to the duty engineering officer, who, before approving the application, must assess the intended work area for hazards and either eliminate them or take precautions to control the risk, such as posting a fire guard. Neither fitter followed the hot work permit procedures. They both testified that they were aware of the requirement to obtain a hot work permit and that they intended to apply for one after setting up the welding equipment. They also admitted that, when they energized the welding machine, they were not following proper welding procedures that they learned in welding school or during their service on Carnival's vessels. The Safety Board concludes that the fitters' (welders') lack of full compliance with the hot work permit procedures in Carnival Cruise Lines' SMS manual increased the risks of fire in the main laundry.

Following this accident, Carnival Cruise Lines revised its SMS to require that engineering supervisors secure all portable welding machines to prevent employees from circumventing required safety procedures. Now, the welding machines are not released to fitters until a hot work permit is issued.

Although Carnival Cruise Lines' SMS manual contained extensive procedural safeguards for welding, it did not prevent unauthorized welding. Carnival Cruise Lines is one of several subsidiaries of Carnival Corporation. The Safety Board is concerned that the SMS procedures and manuals for the other vessels in Carnival Corporation's fleet may not contain processes to prevent employees from performing unauthorized hot work. The Safety Board believes, therefore, that, for the ships in its fleet, Carnival Corporation

should revise the SMS to include processes for preventing unauthorized flame cutting, grinding, or other activities that might ignite a fire.

Adequacy Of Fire Protection Systems

Sprinkler System

Sprinkler systems are designed to provide an appropriate level of protection for the space that they occupy and the amount of combustibles that are present. On the *Ecstasy,* a passenger cruise ship, sprinklers were installed mainly in accommodation areas, including staterooms and cabins. The sprinkler system, therefore, was designed for spaces that contained furniture, carpeting, paneling, and so forth.

In the *Ecstasy* accident, however, conditions occurred that put unusual demands on the sprinkler system. In the main laundry on deck No. 2, the fire's area of origin, the ignition of the comparatively small amount of lint across the floor released insufficient heat to trigger the heat-activated sprinklers in the overhead. The small flames spread first to the mangle's vertical exhaust ducts and then its overhead exhaust ducts where the high lint buildup fueled a larger fire. The mangle's overhead exhaust duct, constructed of noncombustible metal, contained the fire, and the air flow within the duct carried the fire from the laundry to the exhaust plenum on the mooring deck. The fire exited onto the mooring deck, which lacked fire protection, and ignited the lint debris that, in turn, led to the development of the major conflagration.

Before the ventilation system in MVZs 1 and 2 was shut down, ventilation fans drew intense heat from the large fire on the mooring deck to various ship areas that were protected by sprinklers, which caused them to activate. In addition, the heat from the mooring deck fire was so great that it triggered sprinklers in deck areas immediately above and forward of the mooring deck. Although the sprinkler discharge in areas that were remote from the mooring station had no effect on the fire and heat source, the discharges prevented the spread of fire further into the vessel.

The discharge area, that is, the number of sprinklers discharging water, was twice as great as the design capabilities of the ship's water delivery system. Even though the number of sprinklers that opened created a demand for water that taxed the water supply, the sprinkler system provided proper protection in this accident. The Safety Board concludes that the vessel's automatic sprinkler system limited the spread of fire from the mooring station to adjoining decks, thereby preventing a significantly worse fire that would have caused greater damage and perhaps additional injuries.

When the *Ecstasy* was built in 1991, Carnival Cruise Lines had until 2006 to comply with SOLAS requirements for automatic sprinklers. Nevertheless, the company elected to install sprinkler protection in the *Ecstasy's* cabins and staterooms at the time of construction. After the fire on board the *Ecstasy,* Carnival Cruise Lines modified the fire suppression system of the *MV Paradise,* one of its ships under construction, to include

sprinkler coverage of the vessel's mooring decks. The company also began a program of retrofitting the mooring decks of its existing cruise ships with deluge sprinkler systems. According to Carnival Cruise Lines' senior officials, the aim of the company is to install sprinkler protection on the mooring decks of all its ships by the end of 2001. The Safety Board applauds Carnival Cruise Line's past and continuing efforts to improve fire safety on the ships in its fleet.

The flag administration for the *Ecstasy* before the accident had categorized the vessel's mooring station as an open deck, which meant that the area was not required to have smoke detectors or sprinklers. If the mooring station had been equipped with detectors, the bridge would have received earlier notification of a fire site. In addition, if sprinklers had been installed and had activated on the mooring deck, the water may have extinguished the ignited lint before the mooring line caught fire. At the least, water from activated sprinklers would have knocked down the flames of the mooring deck fire, which probably would have enabled shipboard firefighters to enter the mooring station and combat the fire. The Safety Board concludes that if an automatic fire suppression system had been installed on the mooring deck, the fire on the *Ecstasy* would have been located and extinguished much sooner, thereby minimizing the extent of fire damage on the vessel and aft mooring deck.

As it was, the high fuel load on the mooring deck caused extensive damage. The mooring station had 11 mooring lines, each measuring 220-meters and weighing about 900 pounds. The line itself is not easy to ignite. Inspection of a sister vessel showed that large amounts of easily ignitable lint had accumulated on the mooring deck and had become imbedded in the stored mooring lines. Assuming that the *Ecstasy* had a similar accumulation of lint, the fire venting from the mangle exhaust plenum probably ignited the lint, which, in turn, ignited the polypropylene mooring line. The Safety Board contracted independent tests by Omega Point Laboratories, which determined that the polypropylene line had an average heat of combustion of about 18,217 Btu per pound. Thus, the consumption of the polypropylene line on this deck could have yielded as much as 150 million Btu of heat. Once ignited, the amount of heat released from polypropylene rope per pound is equivalent to that of a comparable amount of gasoline.

The investigation showed that the fire consumed most of the fuel (polypropylene line) on the mooring deck before firefighters were able to reach the deck and extinguish it. A pallet of nylon line survived the fire but was melted. Two lengths of polypropylene rope were partially consumed and the others were completely destroyed.

In the past, cruise ships typically were designed with mooring decks having either no overhead or an overhead and large permanent openings in the vessel's side shell. Because the mooring deck area was open to the weather elements, the risk of fire was low; therefore, SOLAS did not require mooring decks to have fire protection. Modern cruise ship design, such as that of the Fantasy Class vessels, typically incorporates the mooring station into the superstructure, often below accommodation and service spaces. Many mooring stations have openings that can be closed with hatches or covers. Despite this loss of openness, SOLAS still categorizes these mooring stations as open decks that are not required to have fire protection systems. Some newer ship designs also place ventilation

inlets and outlets on the mooring decks. The Coast Guard, recognizing the safety issues inherent in the design arrangement, has proposed that the IMO clarify the category for mooring decks such as the type on the *Ecstasy.* The Coast Guard recommended that, for all new construction, a partially covered mooring deck be categorized as an auxiliary machinery space. This categorization would not only require fire protection systems (detection and suppression) but also prohibit using the space as a ventilation terminus.

The status of the Coast Guard's proposal at IMO is pending. Regardless of whether the IMO does or does not agree to categorize mooring decks as recommended by the Coast Guard, any action taken by the IMO will not take effect immediately and may affect only certain cruise ships. The Safety Board is convinced that all efforts should be made without delay to minimize the potential for fire on mooring decks that are incorporated into the vessel structure, such as the mooring decks on the Fantasy Class cruise ships. The Board recognizes that some mooring decks are used to store only anchors or small combustibles or both and, thus, might not warrant fire protection. To optimize safety, cruise ship companies need to examine their mooring stations for fire risk and determine the need for detection and suppression systems. The Safety Board believes, therefore, that the cruise ship companies should, for existing vessels having mooring deck arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install automatic fire suppression systems on mooring decks that contain high fire loads and presently have no automatic fire protection.

Ventilation System

SOLAS II-2 Regulation 16 requires that the ventilation systems for high-risk areas such as category A machinery spaces and galleys have an automatic fire damper where a duct crosses an A-class boundary to mitigate the spread of smoke and fire. SOLAS does not include laundries in the category of high-risk areas, despite the fact that laundry ventilation systems can accumulate appreciable amounts of ignitable lint.

Fires in laundry facilities, including associated storerooms, can generate significant amounts of heat and smoke, frequently with lethal consequences, as the Safety Board discovered during its investigation of fires on board the *Universe Explorer* and the *Vistafjord*. Based on its findings in these two accidents, which killed 6 people and injured 72 others, the Safety Board determined that timely isolation of a fire is crucial to mitigating the effects of heat and smoke.

The ventilation ducts in the *Ecstasy's* main laundry had fail-safe fire dampers; however, if the ventilation system did not lose power, the dampers had to be shut by someone present in the area or by someone on the bridge. In this accident, if the fire in the overhead had triggered the closure of the laundry fire dampers, the shutdown would have occurred several minutes before the bridge personnel secured the ventilation system, which would have resulted in appreciably less heat, smoke, and flame escaping from the main laundry and spreading to the mooring deck.

A passive means for actuating the closure of fire dampers in certain areas is required by various interpretations of SOLAS, including Coast Guard regulations.[48] The most commonly required passive closure mechanism is a weight- or spring-activated fusible link that melts at a given temperature, allowing the fire damper to close. A fusible link can be designed to actuate at various temperatures, depending on the metal used in the mechanism. It potentially offers a more fail-proof method of closure and, consequently, a greater margin of fire safety because an external power source is not needed to drive the damper.

The Safety Board concludes that if the main laundry's fire dampers had been equipped with a passive means of closure, such as a fusible link, the heat from the fire would have caused the dampers to shut sooner, which, in turn, might have prevented the spread of fire beyond the laundry area.

While automatic fire dampers with passive actuating mechanisms are one way to effectively stem the spread of smoke and fire through ventilation systems in high-risk areas, such dampers are not the only method of mitigating the danger. The Board considers the individual cruise ship companies best qualified to analyze their vessels' design and engineering arrangements and to devise measures for dealing with the problem. The Safety Board, therefore, believes that Carnival Cruise Lines should, for the vessels in its fleet, engineer, design, and implement system modifications to mitigate the spread of smoke and fire from the laundry rooms through the ventilation ducts to other areas of the vessel. Further, cruise ship companies should, for existing vessels with ventilation system arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install an automatic method or system to mitigate the spread of smoke and fire from laundry spaces through the ventilation ducts to other vessel areas.

Fire Detection System

During the *Ecstasy* fire, many smoke detectors activated within a few minutes. The time and sequence of the first five recorded smoke detector alarms are consistent with reports of where the fire started and how the fire and smoke spread through the ventilation system. The first smoke alarm indicated the main laundry room. The next alarms indicated the stern thruster room, the air conditioner room, and the portside steering gear room. According to the first officer, about 2 minutes after the first alarm, all the detector alarms on the fire panel appeared to activate at the same time, and, as a result, he reset the system. The activation of all alarms on the fire panel resulted from an electrical overload of the system. Despite the overload, the fire detection system provided an early warning of a fire, correctly identifying not only the fire zone but also the time and location of the first detectors. The Safety Board concludes that the fire detection system performed properly by providing an early indicator of a fire.

[48] NVIC No. 09-97.

Adequacy of Passenger and Crew Safety

Although no one was seriously hurt in the *Ecstasy* accident, the Safety Board identified several areas in which improvements could be made to the safety practices on the ship.

Passenger Drill

SOLAS requirements stipulate "musters of passengers shall take place within 24 hours after their embarkation." Carnival Cruise Lines conducted an emergency drill for the *Ecstasy's* passengers before the vessel sailed, which, in this case, was beneficial, given that the fire broke out within a half hour of the ship's departure from port. Passengers received instructions in English and Spanish to prepare them for an evacuation, including information on how to don their lifejackets and on where to assemble in the event of an emergency. During the drill, the bridge sounded the general alarm signal, and passengers had to practice the route to their assigned muster stations as if they were participating in a real emergency.

Of the 300 passengers surveyed by the Safety Board about the emergency, 126 responded. More than half of the respondents, or 79 passengers, indicated that the drill was valuable in preparing them for the actual emergency. The remaining survey respondents identified various problems or situations that were not addressed during the drill. Several people indicated that the drill did not include specific information about fire emergencies, including what to do if they encountered smoke or fire. A number of respondents who had to move to a different muster station because of smoke said that the drill did not provide information about what to do if a muster station was not available. One person stated that she did not hear any instructions from the crewmembers at her muster station but followed the crowd when everyone started leaving the station. Several passengers commented that they could not readily distinguish those crewmembers who were trained to assist them because vessel personnel all wore the same uniforms.

For an emergency drill involving several thousand people to be effective, the information disseminated must be concise and essential for survival. The Safety Board notes that, in addition to the practice drill, Carnival Cruise Lines provides passengers with emergency information in a variety of ways. The company broadcasts general cruise information, including emergency procedures, on television monitors at the embarkation point where passengers line up to board the ship. In the staterooms, Carnival Cruise Lines posts evacuation procedures on placards and broadcasts emergency procedures on a television channel devoted to cruise information. The company has television monitors at the bars in passenger lounges to disseminate announcements and other information.

Safety Board investigators reviewed the drill script used by the *Ecstasy's* cruise director as a reference for necessary subjects to cover in the drill. The script makes no mention of actions that passengers should take if they see smoke or if their muster station is not available.

The Safety Board concludes that although most survey respondents indicated that the *Ecstasy* practice drill adequately prepared them for the actual fire emergency, the drill content lacked information about actions to take if you see smoke or fire or if your muster station is unavailable that might have better prepared some passengers who encountered such conditions.

Before the *Ecstasy* fire, the vessel safety officer had purchased bright green hats for crewmembers in safety sensitive positions to wear to distinguish them from other crewmembers. He had not had the opportunity to distribute the hats before the ship sailed. At the suggestion of Safety Board investigators, Carnival Cruise Lines revised its vessel emergency drill procedures to advise passengers that crewmembers wearing the green hats are specifically assigned to assist them during an emergency. Based on the survey responses from *Ecstasy* passengers, the company needs to provide passengers with additional safety information. The Safety Board, therefore, believes that Carnival Cruise Lines should revise the safety information disseminated to passengers to include actions to take if they encounter smoke or fire and/or if their muster station is not available.

Immediately following the accident, a party to the investigation questioned whether the noise generated by local news helicopters created communications problems between the crew and passengers during the emergency. All survey respondents indicated that they heard frequent announcements. Some respondents who were assigned to the outside muster station stated that when they advised crewmembers that the helicopter noise made it difficult to hear the loudspeakers announcements, the crewmembers quickly notified the bridge, and the cruise director then relayed necessary information and status accounts by having his assistants go to the muster station. The smoke from the fire subsequently necessitated moving the passengers at the outside muster station, which eliminated the problem. The Safety Board concludes that although the noise from the news helicopters may have interfered somewhat with the communications with passengers on the outside deck, crewmembers were able to effectively communicate with the mustered people and manage the emergency.

Accountability Procedures

Shipboard personnel used two methods to account for passengers during the fire emergency. At the muster stations, the crewmembers noted the letters imprinted on the lifejackets worn by passengers to ensure that they had reported to the correct station. The muster station crews did not have a list, by name, of passengers assigned to the respective stations. In the passenger accommodation areas, crewmembers checked each stateroom to determine whether it was empty. They then wrapped a towel around the doorknob to show other searchers that the stateroom had been checked. Neither of these procedures provides assurance that the vessel has accounted for all passengers. Depending upon the time and location of a fire or emergency condition, passengers might not be able to report to their muster station. In this accident, three MVZs were closed as a result of the fire and passengers had to go to other MVZs to find a muster station.

Identifying which people are missing by searching the staterooms and cabins assumes that an occupant will remain in his or her quarters and not go to another location.

Further, this method of accounting for individuals can be dangerous, depending on the emergency conditions. In this accident, two crewmen who were unable to exit their deck because of heavy smoke initially sought refuge in a crew cabin. They were following survival techniques in a shower when one of the men panicked because of worsening smoke conditions. He left the toilet facility and began feeling his way along the bulkhead of the smoke-filled passageway. The other crewman followed the first man to try and convince him to return to the safety of the shower. The severity of the smoke-inhalation injuries that they sustained was limited only because fire team members searching the area happened upon the crewmembers. (Additional analysis of the trapped crewmen's situation appears later in this report.) The Safety Board concludes that the procedures used by the *Ecstasy's* shipboard personnel did not adequately account for passengers and crewmembers during the emergency.

SOLAS leaves the method of devising procedures to account for passengers and crew during an emergency up to the companies. The ISM Code presently stipulates the need for cruise ship companies to account for passengers and crewmembers. Courses developed by the Coast Guard and the marine industry to meet the emergency preparedness requirements contained in amendments to the STCW stipulate that the preferred method of accounting for people at muster stations is by name so that rescue crews can employ more systematic methods of searching for missing persons.

The Safety Board is aware that the *Ecstasy* maintained an electronic manifest of all passengers on the ship. When passengers boarded the ship, their names were entered into a computer and they were issued magnetic cards that tracked their purchases and their debarkations and embarkations at travel stops. Given the advancements in computer technology, magnetic cards or other computer-based devices and equipment could be used to quickly determine who has not mustered during an emergency.

Because even short delays in identifying missing people can have fatal consequences, it is essential for companies to have systematic procedures to account for people by name. Further, the *Ecstasy* accident demonstrates that accounting procedures must address different emergency scenarios. As mentioned previously, the location and movement of the fire forced the closure of three MVZs, and, as a result, some *Ecstasy* passengers had to be moved to other muster stations. Depending on the time of the alarm and the location of passengers and crewmembers, several hundred people might be forced to report to an alternate muster station.

The Safety Board is aware that Holland-America, another subsidiary of Carnival Corporation, accounts for its passengers by taking roll at muster stations. Despite its experiences in the *Ecstasy* accident, however, Carnival Cruise Lines has not indicated that it intends to change its accountability procedures. The Safety Board is convinced that, during a fire emergency, an accurate accounting by name is essential for passenger and crew safety. The accounting methods used on a ship should be incorporated into the SMS procedures presently required by SOLAS. The Safety Board believes, therefore, that, for the ships in its fleet, Carnival Corporation should develop plans to account for all passengers in common emergency scenarios, in particular, a situation involving the inaccessibility of one or more MVZs and/or muster stations.

Lifejacket Distribution

In 1997, LR certified that the number, type, and arrangement of lifesaving equipment on board the *Ecstasy* met the requirements of SOLAS 74, as amended in 1998. At that time, the ship carried 4,094 lifejackets to outfit a full crew and passenger complement of 3,560 people. The Board is pleased to note that Carnival Cruise Lines subsequently elected to exceed the minimum SOLAS requirement for extra lifejackets, increasing the number by more than 20 percent, to a total of 4,946. On the day of the fire, the ship was carrying 3,481 people, meaning that the ship had 1,465 extra lifejackets.

Despite having more than enough lifejackets on board the vessel, some passengers perceived a lack of available lifejackets when the actions of the crewmembers were not consistent with information provided at the practice drill and posted on stateroom placards. Before the emergency, passengers were told to obtain lifejackets from their staterooms when the general alarm sounded and to proceed immediately to their muster stations. They were also told that if they were unable to obtain their lifejackets from their staterooms at the time of the alarm, they should proceed immediately to their muster station and lifejackets would be issued to them. During the emergency, the cruise director reinforced these instructions when he announced that passengers who could not obtain their lifejackets from their staterooms should proceed immediately to muster stations.

The responses from the passengers who answered the Safety Board survey showed that 79 of 126 people either obtained lifejackets from their cabin or were provided lifejackets by crewmembers. Forty-seven passengers said that they never received lifejackets. Two passengers stated that they became concerned when they asked for lifejackets and a crewmember started to pass them out and then reportedly was ordered to stop doing so. One passenger stated that one crewmember told her not to retrieve her lifejacket from her stateroom and later another crewmember told her to get her lifejacket from her cabin; however, when she attempted to do so, she could not reach her stateroom because of the smoke.

At the public hearing on the *Ecstasy* accident, the master testified that he wanted to maintain a calm environment and avoid panic among the passengers by conveying the impression that the situation was under control and did not warrant the distribution of lifejackets. While the lack of uniformity in distributing the lifejackets did not cause a mass panic, it did cause several passengers to become uneasy. Moreover, when a concerned passenger attempted to return to her stateroom to retrieve her lifejacket, she was put at risk of potential injury. The Safety Board concludes that the lack of consistency between the information about lifejacket distribution provided at the practice drill and the actual provision of lifejackets at the muster stations created unnecessary confusion among some passengers on the *Ecstasy.*

After the *Ecstasy* fire, in fall 1998, Carnival Cruise Lines began requiring its senior deck, engineering, and other officers to attend courses in crisis management and human behavior and crowd management so that they met the STCW training standards that became effective in January 1999. The company also required crewmembers in safety-related positions to attend crowd management training.

As part of its mandate, the Coast Guard conducts quarterly CVEs of a vessel's operations to determine if they comply with SOLAS safety requirements. In this capacity, the Coast Guard could assist cruise ship companies in determining the effectiveness of muster drills addressing various contingencies. The Safety Board, therefore, believes that, as part of its quarterly CVEs, the Coast Guard should review a drill scenario in which one or more MVZs are inaccessible and evaluate the procedural effectiveness of the crew in crowd control, crisis management, lifejacket distribution, and passenger accountability.

Locally Sounding Smoke Alarms

When the first fire alarm sounded on the bridge, the master ordered two bridge officers to investigate the source of the alarm and report their findings. About 20 minutes elapsed before he ordered the aft three MVZs secured and the cruise director to announce that passengers who were quartered in the aft areas should either leave or not return to the areas, depending upon their present location. The master did not order the general alarm until 50 minutes after the first fire alarm sounded on the bridge.

Of 126 passengers who answered the Safety Board survey, 72 responders, or more than half, said that they smelled or saw smoke in the staterooms and passageways before hearing the general alarm. A few passengers indicated that they saw a television report on the fire before receiving any emergency notification. One passenger said that, upon seeing smoke, she returned to her stateroom to awaken a sleeping relative. A crewman became aware of emergency conditions when smoke entered his room through a vent.

Sounding the general alarm after a fire team verifies the location of the fire does not necessarily provide enough time to escape from a smoke-filled environment. The *Vistafjord* and *Universe Explorer* accidents demonstrated how quickly smoke could spread during a fire and that passengers and crewmembers needed to be warned immediately if smoke was in the area. As a result of its investigation of these two accidents, the Safety Board issued Safety Recommendations M-97-39 and -40 asking the Coast Guard to propose that the IMO require locally sounding alarms in passenger and crew accommodation areas. The Coast Guard subsequently made the proposal to the IMO, which referred the action for consideration to an MSC subcommittee. In Spring 2000, because of the concerns of some Administrations and the technical concerns of the ICCL, the MSC did not consider the locally sounding alarm proposal. It was removed from the agenda and no further action was taken on it. The next available time that the proposal can be introduced as an agenda item is Spring 2002. The Coast Guard is evaluating what actions it might take on the proposal.

The Safety Board also issued Safety Recommendations M-97-37 and -38 asking that the ICCL advise its members to install locally sounding smoke alarms in passenger and crew accommodation areas. The ICCL at first advised the Safety Board that the recommendations would be an agenda item at the next meeting of its technical committee and then later asked that the recommendations remain in an open status pending action by the IMO.

The Safety Board subsequently investigated the May 20, 2000, fire on board the Netherlands cruise ship *Nieuw Amsterdam* in which a passenger was forced to crawl on his hands and knees along the passageway outside his cabin due to the heavy smoke. As a result of this and previous accident investigations, on July 11, 2000, the Safety Board elected to classify Safety Recommendations M-97-37 and -38 "Closed—Reconsidered" and issue safety recommendations directly to the individual cruise ship companies serving North America. Safety Recommendations M-00-6 and -7 asked that cruise companies, without delay, install locally sounding alarms in accommodations areas to afford people the maximum available escape time during a fire.

The Safety Board has been very pleased by the response of the cruise ship industry. As of April 2001, 12 companies, representing about 85 percent of the North American trade,[49] had responded to the Safety Board regarding the installation of locally sounding alarms in both crew and passenger accommodation areas. One company, Celebrity Cruises, indicated that it had installed locally sounding alarms in accommodation areas as requested. The Safety Board, therefore, classified M-00-6 and -7 "Closed—Acceptable Action" for Celebrity Cruises.

Eleven companies responded that they supported the recommendations and intended to install locally sounding smoke alarms on their cruise ships. The eleven companies included American Classic Voyages, Carnival Cruise Lines, Crystal Cruises, Disney Cruise Line, Holland-America Line/Westour, Inc., Norwegian Cruise Line, Princess Cruises, Radisson Seven Seas Cruises, Renaissance Cruises, Royal Caribbean International, and Seabourne Cruise Line (Cunard Cruise Lines). One respondent, Disney Cruise Line, indicated that, pending identification of the technology needed to modify its existing smoke detector systems, it had equipped its vessels with a system that triggers a special ring on the telephone in guest and crew cabins when smoke is detected. As a result, the Safety Board classified M-00-6 and -7 "Open—Acceptable Response" for these companies. The Safety Board classified M-00-6 and -7 "Closed—No Longer Applicable" for Premier Cruises because it is no longer in operation.

On January 22, 2001, the Safety Board requested information about the status of M-00-6 and -7 to the following companies: Costa Cruise Lines, Orient Lines, Regal Cruises, Royal Olympic Cruises, and Silver Sea Cruises. To date, the Board has yet to receive a response. The Safety Board has, therefore, classifies M-00-6 and -7 "Open—Unacceptable Response" for these five companies.

On February 7, 2001, the ICCL issued a press release indicating that its member lines had unanimously agreed to establish mandatory industry standards stipulating, among other requirements, that the vessels of each ICCL member have "smoke alarms that sound in all passenger and crew staterooms and adjacent corridors as well as on the bridge." The ICCL release further stated that, for most guidelines, member lines would integrate the industry standards into their SMS to ensure compliance through internal and external audits.

[49] At the time of the accident, about 99 cruise ships operated out of North America. The 11 responding companies owned 83 of the 99 vessels.

Means of Communication in Cabins

A cabin steward was in his cabin when he smelled smoke and saw smoke coming from a vent. He left his quarters and was knocking on other cabin doors to alert other crewmembers when he heard the general alarm. Another crewmember joined the cabin steward and the two men attempted to leave the deck only to be blocked by dense smoke.

The crewmembers made their way into a cabin shower where they stayed until one of the men became alarmed by the smoke buildup. He tried to escape by leaving the cabin and feeling his way along the passageway bulkhead. The cabin steward went after the first man and tried to convince him to return to the safety of the shower. About this time, a firefighting team responding to the fire in the main laundry happened upon the men and directed them to safety. The cabin steward later stated they were only able to avoid serious injuries because they followed emergency survivability procedures, such as soaking themselves in a shower and breathing air from the shower drain. The crewmembers' accommodation areas had no call system by which the men could signal for help. The Safety Board concludes that the lack of a means to call for help from the crew cabins delayed the rescue of two crewmembers and contributed to the severity of their smoke inhalation injuries.

The Safety Board had addressed the need for passenger and crew cabins to be equipped with a means of signaling for emergency assistance for more than 8 years. (A summary of the safety recommendations issued and actions taken appears in appendix F.) Following its investigation of the fire on the *Universe Explorer,* the Safety Board asked that both the Coast Guard and the ICCL take actions regarding emergency call systems on cruise ships. The Safety Board issued Safety Recommendation M-98-32. On October 16, 1998, the Coast Guard responded that it would discuss the available options for any necessary improvements with the SOLAS working group on fire protection and would propose changes to the IMO, if appropriate. Based on this action, the Safety Board classified Safety Recommendation M-98-32 "Open—Acceptable Response." The Safety Board issued Safety Recommendation M-98-59 to the ICCL asking that it recommend that member passenger ship companies install emergency call systems. The Safety Board subsequently advised the ICCL that the Board was disappointed that the association had not taken the recommended action and, on February 18, 1999, classified Safety Recommendation M-98-59 "Closed—Unacceptable Action."

The crewmembers' inability to signal for help in the *Ecstasy* fire demonstrates again that existing SOLAS requirements for emergency communication are not adequate. Even though the *Ecstasy's* passageways had telephones, their accessibility depended upon a person being able to reach a telephone. In this accident, the cabin steward who first smelled and saw smoke tried to alert crewmembers in nearby cabins of the fire. Conditions worsened considerably during the brief time that he knocked on cabins doors, and dense, suffocating smoke prevented his and another crewmember's escape. The men did not have the option to walk to or spend time on a corridor telephone.

A similar situation occurred in the *Universe Explorer* accident, but with fatal consequences. Rescuers found three dead crewmembers in the passageway and two dead

crewmembers in their cabins. If they did not have the time and opportunity to reach an emergency exit, it is unlikely that they had time and opportunity to locate a corridor telephone to let someone know they needed immediate help. In its report on the *Universe Explorer* accident, the Safety Board discussed the simple call button system used to summon flight attendants on commercial airlines. Hospitals and nursing facilities employ a similar system to enable patients to signal for nursing assistance. The Safety Board believes that cruise ship companies should 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.

Emergency Response

Despite some setbacks, including an overload of the smoke alarm system and an unusually large and intense blaze, the *Ecstasy* personnel conducted the onboard response to the fire efficiently and in accordance with Carnival Cruise Lines' procedures. The master effectively managed and monitored the incident by having the safety officer oversee the fire teams, by having the hotel manager maintain communications with shoreside management and the COTP, and by having the cruise director annotate times and events on a emergency action checklist. The ship's firefighters demonstrated the effectiveness of their previous drills and firefighting training by quickly mustering equipped teams and containing the fire to the mooring station. With help of the tugs cooling the exterior of the *Ecstasy's* stern, shipboard firefighters extinguished the fire as the fuel load was consumed. The safety officer had fire teams search the quarters in the area affected by the fire; the teams rescued two crewmembers who were trapped in a cabin near the laundry.

The shoreside response was effective because the unified command system employing two operating bases allowed several agencies to jointly manage the emergency response. The Coast Guard and Miami Beach FD initially operated from the MSO-Miami Operations Center, and Miami-Dade FD, Carnival, port officials, and area police operated from a post established at the Port of Miami. Miami-Dade FD subsequently sent an additional representative to the MSO-Miami location. The parties remained in telephone communications with each other and officers on board the *Ecstasy* to coordinate activities throughout the incident.

Shoreside officials indicated that the participation of Carnival, the Coast Guard, and local agencies in joint planning sessions and practice drills simulating accident scenarios attributed to the good response coordination. In addition, Carnival's crisis management plan, which included specific personnel assignments for managing a fire condition on the *Ecstasy* and for handling the safety and comfort of passengers and crewmembers, was adequately implemented. The Safety Board concludes that the emergency response by shipboard and shoreside firefighters to the fire was timely and appropriate, resulting in the fire being properly contained and extinguished.

Adequacy Of Engineering Systems Design

The fire on the *Ecstasy* caused the partial or complete failure of three systems: low-location lighting, steering, and propulsion. Although the loss of engineering and emergency systems did not ultimately endanger the ship and its passengers in this accident, the potential threat to vessel safety from the failure of vital systems, especially propulsive power, is significant.

The low-location lighting system was designed to sound an alarm on the bridge in the event of a power failure to the system. In this accident, the heat from the fire melted the wiring insulation on a portion of one lighting loop, triggering an alarm that the ship's officers considered intrusive during the emergency operations. When the nature and location of the failure was not readily detectable at the lighting system's main unit, the chief electrician elected to shut down power to the system. After this accident, Carnival Cruise Lines redesigned the low-location lighting system to permit the audible alarm to be silenced without the need to shutdown the entire system.

The steering system components were designed to be redundant. The system had two rudder systems that were mechanically, electrically, and hydraulically independent of each other. The systems were housed in separate rooms on opposite sides of deck No. 3. The power and control cables for both rudder systems were routed along the overheads of their respective steering gear rooms. Thus, when the conflagration on the mooring deck went unchecked and raged for more than an hour, the intense heat that was conducted through the overheads of the steering gear rooms melted the cables, causing the steering system to fail. Despite the failure of the steering system, the crippled *Ecstasy* could have maneuvered at low speeds by using the bow thrusters if the ship had not lost propulsion.

The most critical system failure in this accident was, therefore, the loss of the propulsion system. The port and starboard propulsion systems were supposed to be redundant and isolated. The *Ecstasy* had been built to LR regulations, which clearly stipulate the need to provide independent and isolated power supplies to essential components of the vessels engineering systems, such as propulsion. The auxiliary voltage to the high-speed breakers for both propulsion systems, however, was routed through the same distribution panel. When this panel sustained heat damage, both propulsion systems failed. The Safety Board, therefore, concludes that the failure to separate the power circuitry in the design arrangement of the auxiliary voltage supply to the high-speed breakers of the propulsion systems resulted in inadequate isolation of essential system components, which, in turn, resulted in the shutdown of both propulsion systems when a single distribution panel was damaged.

Hazardous situations that may result from a ship losing propulsive power include vessel grounding, inability to avoid severe weather conditions, and passenger evacuation at sea. Thus, it is essential that all propulsion system components be redundant and isolated. Following the *Ecstasy* accident, Carnival Cruise Lines advised the Safety Board that it had modified the vessel's electrical system by adding a backup circuit breaker and wiring to provide an alternate source of electrical power for the high-speed breakers.

Carnival Cruise Lines owns seven other Fantasy Class ships that may have similar propulsion system arrangements as the *Ecstasy.* In correspondence to Safety Board investigators, the cruise ship company did not indicate whether it had examined or intended to examine its other vessels to identify design problems in their propulsion systems. The Safety Board, therefore, believes that Carnival should examine the propulsion systems on the ships in its fleet and, if necessary to provide redundancy, modify the arrangement of the auxiliary voltage circuitry to the high-speed breakers where a single source supplies both port and starboard propulsion systems.

The company that designed the *Ecstasy's* propulsion system, ABB, is a major supplier of cycloconverter propulsion systems to marine customers. Consequently, other vessels might be operating with an ABB propulsion system similar in design to that on the *Ecstasy.* The Safety Board, therefore, believes that ABB should advise its customers with ships having the same propulsion system design arrangements as the *Ecstasy* of the potential for system failure from the loss of auxiliary voltage to the high-speed breakers and recommend design changes to the propulsion system that would minimize these effects.

Even though the *Ecstasy's* propulsion system had a number of design features that were intended to reduce the likelihood that both port and starboard systems would fail as a result of single fault, the importance of isolating the auxiliary voltage source to the high-speed breakers was not identified before or during the vessel construction. ABB officials stated that they did not do a formal failure analysis, such as an FMEA, of the propulsion system design because SOLAS, LR, and Carnival did not require them to perform one.

A qualitative failure analysis, such as the FMEA method, can identify potential failures and rank them according to the probability of occurrence, the severity of effects, and the probability of detection. System failure analyses are widely used in many other industries as part of the overall movement toward quality improvement in processes and products. In addition, IMO now requires that a failure analysis be performed during the design of navigation equipment and bridge systems. The Coast Guard has required the use qualitative failure analysis techniques in evaluating the reliability and safety of vital system automation on U.S. flag vessels since 1988. In proposing the regulatory requirement that designers, manufacturers, and/or shipyards perform and submit system failure analysis, the Coast Guard stated that the use of advanced automation technologies such as electronics and microprocessors made it increasingly difficult, "at times impossible, for the Coast Guard, ship owners/operators, and classification societies to evaluate safety."

Classification societies, however, have not seen the need to require failure analyses on vital automation systems in spite of the fact that these systems are becoming even more complex and difficult to evaluate. The LR stated that during its plan approval and surveys of the *Ecstasy's* construction, it was not provided details of the propulsion system's internal connections. Therefore, LR was not aware, prior to the casualty, that the propulsion would be lost if the cables to the high-speed breakers were burned through.

If a qualitative failure analysis of the *Ecstasy's* propulsion system had been performed during its design phase, the failure probability of the single power source may have been rated low. However, the high severity of the failure effect, that is, the total loss of the propulsion system, should have led the designers to implement design modifications.

The Safety Board is aware that qualitative failure analysis typically is not applied to existing systems because analyzing and changing system arrangements after construction is often difficult and costly. However, a qualitative failure analysis can be an important technique to maximize the reliability and safety of a system before it is built, when changes can be easily made. The Safety Board concludes that, to ensure the highest levels of safety and reliability, ship owners should use qualitative failure analysis techniques in the design and construction of their vessels. The Safety Board, therefore, believes that, in the construction of new passenger ships, owners should use qualitative failure analysis techniques to identify system components whose failure might cause a complete loss of propulsive power and take action to mitigate identified problems. The Safety Board also believes that the International Association of Classification Societies (IACS) should recommend that its members require systems designers, manufacturers, and/or shipyards to perform and submit qualitative failure analyses to ensure the fail-safe operation of propulsion systems on new passenger ships.

Conclusions

Findings

1. Although the *Ecstasy's* mooring deck sustained the heaviest fire damage, it was not the point of origin for the fire.

2. The fire on board the *Ecstasy* started in the main laundry and was ignited by an arc from a welding machine.

3. The fitters' (welders') lack of full compliance with the "hot work" permit procedures in Carnival Cruise Lines' safety management system manual increased the risks of fire in the main laundry.

4. The lint that accumulated in the ventilation duct of the main laundry created a serious fire hazard on the *Ecstasy.*

5. The procedures and standards for inspecting and maintaining laundry ventilation systems adopted by the marine industry and government agencies following the *Ecstasy* fire will improve safety on cruise ships.

6. If an automatic fire suppression system had been installed on the mooring deck, the fire on the *Ecstasy* would have been located and extinguished much sooner, thereby minimizing the extent of fire damage on the vessel and aft mooring deck.

7. The vessel's automatic fire sprinkler system effectively limited the spread of fire from the mooring station to adjoining decks, thereby preventing a significantly worse fire that would have caused greater damage and perhaps additional injuries.

8. If the main laundry's fire dampers had been equipped with a passive means of closure, such as a fusible link, the heat from the fire would have caused the dampers to shut sooner, which, in turn, might have prevented the spread of fire beyond the laundry area.

9. The fire detection system performed properly by providing an early indicator of a fire.

10. Although most survey respondents indicated that the *Ecstasy* practice drill adequately prepared them for the actual fire emergency, the drill lacked information about actions to take if you see smoke or if your muster station is unavailable that might have assisted passengers who encountered conditions or situations contrary to those during the drill.

11. Although the noise from the news helicopters may have interfered somewhat with the communications with passengers on the outside deck, crewmembers were able to effectively communicate with the mustered people and manage the emergency.

12. The procedures used by the *Ecstasy's* shipboard personnel did not adequately account for passengers and crewmembers during the emergency.

13. The lack of consistency between the information provided at the practice drill about the provision of lifejackets and the procedures that crewmembers followed in distributing lifejackets during the actual emergency created unnecessary confusion among some passengers on the *Ecstasy.*

14. The lack of a means to call for help from the crew cabins delayed the rescue of two crewmembers and contributed to the severity of their smoke inhalation injuries.

15. The emergency response by shipboard and shoreside firefighters to the fire was timely and appropriate, resulting in the fire being properly contained and extinguished.

16. The failure to separate the power circuitry in the design arrangement of the auxiliary voltage supply to the high-speed breakers of the propulsion systems resulted in inadequate isolation of essential system components, which, in turn, resulted in the shutdown of both propulsion systems when a single distribution panel was damaged.

17. To ensure the highest levels of safety and reliability, ship owners should require the use of qualitative failure analysis techniques in the design and construction of their vessels.

Probable Cause

The National Transportation Safety Board determines that the probable cause of fire aboard the *Ecstasy* was the unauthorized welding by crewmembers in the main laundry that ignited a large accumulation of lint in the ventilation system and the failure of Carnival Cruise Lines to maintain the laundry exhaust ducts in a fire-safe condition. Contributing to the extensive fire damage on the ship was the lack of an automatic fire suppression system on the aft mooring deck and the lack of an automatic means of mitigating the spread of smoke and fire through the ventilation ducts.

Recommendations

As a result of its investigation of this accident, the National Transportation Safety Board makes the following recommendations:

New Recommendations

To the U.S. Coast Guard:

During control verification examinations, review a drill scenario in which one or more main vertical zones are inaccessible and evaluate the procedural effectiveness of the crew in crowd control, crisis management, lifejacket distribution, and passenger accountability. (M-01-1)

To Carnival Corporation:

For the ships in your fleets, revise the safety management system to include processes for preventing unauthorized flame cutting, grinding, or other activities that might ignite a fire. (M-01-2)

For the ships in your fleets, develop plans to account for passengers and crewmembers in common emergency scenarios, in particular, a situation involving the inaccessibility of one or more main vertical zones and/or muster stations. (M-01-3)

To Carnival Cruise Lines:

For the ships in your fleet, engineer, design, and implement system modifications to mitigate the spread of fire and smoke from the laundry rooms through ventilation ducts to other areas of the vessel. (M-01-4)

Examine the propulsion systems on the ships in your fleet and, if necessary to ensure redundancy, modify the arrangement of the auxiliary voltage circuitry to the high-speed breakers where a single source supplies both port and starboard propulsion systems. (M-01-5)

Revise the safety information disseminated to passengers to include actions to take if they encounter smoke or fire and/or if their muster station is not available. (M-01-6)

To American Classic Voyages, Carnival Corporation, Inc., Crystal Cruises, Disney Cruise Line, Norwegian Cruise Line, Orient Lines, P&O Princess Cruises International, Ltd., Radisson Seven Seas Cruises, Regal Cruises, Renaissance Cruises, Inc., Royal Olympic Cruises, Royal Caribbean Cruise Lines, and Silversea Cruises, Ltd.:

For existing vessels with ventilation system arrangements similar to Carnival Cruise Lines' Fantasy Class ships, install an automatic method or system to mitigate the spread of smoke and fire from laundry spaces through the ventilation ducts to other vessel areas. (M-01-7)

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)

In the construction of new passenger ships, use qualitative failure analysis techniques to identify system components whose failure might cause a complete loss of propulsive power and take action to mitigate identified problems. (M-01-9)

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)

To ABB, Inc.:

Advise your customers owning ships with the same propulsion system design arrangements as the *Ecstasy* of the potential for system failure from the loss of auxiliary voltage to the high-speed breakers and recommend design changes to the propulsion system that would minimize these effects. (M-01-11)

To the International Association of Classification Societies:

Recommend that your members require systems designers, manufacturers, and/or shipyards to perform and submit qualitative failure analyses to ensure the fail-safe operation of propulsion systems on new passenger ships. (M-01-12)

Previously Issued Recommendations Resulting from this Accident Investigation

M-98-125

Immediately inspect, within your fleet of ships, the laundry ventilation systems, including ducts, plenums, and exhaust terminuses, for any combustible material, such as lint, and clean the systems, as necessary, to reduce the risk of fire. (Urgent)

M-98-126

Institute a program to verify on a continuing basis that the laundry ventilation systems, including ducts and plenums, remain clean and clear of any combustible material that poses a fire hazard on your vessels.

Previously Issued Recommendations Classified in this Report

The following Safety Recommendations were issued to 18 cruise line companies on July 11, 1990:

M-00-6

Without delay, install automatic local-sounding smoke alarms in crew accommodation areas on company passenger ships so that crews will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.

M-00-7

Without delay, install automatic local-sounding smoke alarms in passenger accommodation areas on company passenger ships so that passengers will receive immediate warning of the presence of smoke and will have the maximum available escape time during a fire.

Based on no response from five cruise line companies, the Safety Board, therefore, classifies, in this report, the safety recommendations as indicated:

M-00-6 (previously classified "Open—Acceptable Response") is classified "Open—Unacceptable Response" for Costa Cruise Lines, Orient Lines, Regal Cruises, Royal Olympic Cruises, and Silver Sea Cruises in the section of this report entitled "Locally Sounding Alarms."

M-00-7 (previously classified "Open—Acceptable Response") is classified "Open—Unacceptable Response" for Costa Cruise Lines, Orient Lines, Regal Cruises, Royal Olympic Cruises, and Silver Sea Cruises in the section of this report entitled "Locally Sounding Alarms."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CAROL J. CARMODY
Acting Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

GEORGE W. BLACK, JR.
Member

Adopted: May 1, 2001

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Appendixes

Appendix A

Investigation

The Safety Board first became aware of the accident through national media coverage on the evening of July 20, 1998. Later that evening, the Safety Board dispatched a 12-person team from Washington, D.C. The team arrived in Miami shortly after midnight and boarded the *Ecstasy* when it docked. Safety Board investigators met with Carnival representatives, the Coast Guard, and local emergency response agencies. Later in the morning of July 21, investigators began examining the fire scene and interviewing witnesses. The initial on-scene investigation lasted from July 21-26; investigators returned to the *Ecstasy* on three occasions while it underwent repairs. The on-scene investigation ended on August 24, 1998.

The following organizations were parties in the investigation: Carnival Cruise Lines, the Republic of Liberia, the U.S. Coast Guard, the Miami-Dade Fire Rescue Department, and the Florida Division of State Fire Marshall.

The Safety Board held a public hearing in regard to the accident in Miami on February 17-18, 1999.

Appendix B

STCW Code

Specification of minimum standard of competence in crisis management and human behavior

Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Organize shipboard emergency procedures	Knowledge of: .1 the general design and layout of the ship .2 safety regulations .3 emergency plans and procedures The importance of the principles for the development of ship-specific emergency procedures, including: .1 the need for pre-planning and drills of shipboard emergency procedures .2 the need for all personnel to be aware of and adhere to pre-planned emergency procedures as carefully as possible in the event of an emergency situation.	Assessment of evidence obtained from approved training, exercises with one or more prepared emergency plans and practical demonstration	The shipboard emergency procedures ensure a state of readiness to respond to emergency situations
Optimize the use of resources	Ability to optimize the use of resources, taking in account: .1 the possibility that resources available in an emergency may be limited .2 the need to make full use of personnel and equipment immediately available and, if necessary, to improvise Ability to organize realistic drills to maintain a state of readiness, taking into account lessons learnt from previous accidents involving passenger ships; debriefing after drills.	Assessment of evidence obtained from approved training, practical demonstration and shipboard training and drills of emergency procedures	Contingency plans optimize the use of available resources Allocation of tasks and responsibilities reflects the known competence of individuals Roles and responsibilities of teams and individuals are clearly defined

Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Control response to emergencies	Ability to make an initial assessment and provide an effective response to emergency situations in accordance with established emergency procedures **Leadership skills** Ability to lead and direct others in emergency situations, including the need: .1 to set an example during emergency situations .2 to focus decision making, given the need to act quickly in an emergency .3 to motivate, encourage and reassure passengers and other personnel **Stress handling** Ability to identify the development of symptoms of excessive personal stress and those of other members of the ship's emergency team Understanding that stress generated by emergency situations can affect the performance of individuals and their ability to act on instructions and follow procedures	Assessment of evidence obtained from approved training, practical demonstration and shipboard training and drills of emergency procedures	Procedures and actions are in accordance with established principles and plans for crises management on board Objectives and strategy are appropriate to the nature of the emergency, take account of contingencies and make optimum use of available resources Actions of crewmembers contribute to maintaining order and control

Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Control passengers and other personnel during emergency situations	Human behaviour and responses Ability to control passengers and other personnel in emergency situations, including: .1 awareness of the general reaction patterns of passengers and other personnel in emergency situations, including the possibility that: .1.1 generally it takes some time before people accept the fact that there is an emergency situation .1.2 some people may panic and not behave with a normal level of rationality, that their ability to comprehend may be impaired and they may not be as responsive to instructions as in non-emergency situations .2 awareness that passengers and other personnel may, *inter alia*: .2.1 start looking for relatives, friends, and/or their belongings as a first reaction when something goes wrong .2.2 seek safety in their cabins or in other places on board where they think that they can escape danger .2.3 tend to move to the upper side when the ship is listing .3 appreciation of the possible problem of panic resulting from separating families	Assessment of evidence obtained from approved training, practical demonstration and shipboard training and drills of emergency procedures	Actions of crewmembers contribute to maintaining order and control
Establish and maintain effective communications	Ability to establish and maintain effective communications, including: .1 The importance of clear and concise instructions and reports .2 The need to encourage an exchange of information with, and feedback from, passengers and other personnel	Assessment of evidence obtained from approved training, exercises and practical demonstration	Information from all available sources is obtained, evaluated and confirmed as quickly as possible and reviewed throughout the emergency

Appendix C

Ecstasy Emergency Procedures Placard

Emergency Procedures

Emergency Drills are held on board according to international maritime laws and are compulsory: All passengers must participate. The purpose of the drills is to acquaint all passengers with the correct procedure to be followed in the unlikely event of an emergency during the voyage.

There are six muster stations which are identified and located as follows:

Muster Station [A] Blue Sapphire Lounge (Atlantic Deck Forward)

Muster Station [B] City Lights Blvd. (Promenade Deck Forward)

Muster Station [C] City Lights Blvd. (Promenade Deck Midship)

Muster Station [D] Stripes Discotheque (Promenade Deck Midship)

Muster Station [E] Starlight Lounge (Promenade Deck Midship)

Muster Station [F] Patio Pool Area (Lido Deck Midship)

The purpose of assembling all passengers at the muster station is to clear the decks of all people enabling the crew to prepare the boats and at the same time, passengers are comfortably standing by near the embarkation stations to which they will be led according to the orders given by the master and his officers in charge. No suitcases, bags, parcels or articles of any kind, except blankets, can be taken to muster stations and into the lifeboats.

DO NOT PANIC!

Don’t use the elevators

Avoid Useless Confusion and/or Noise.

Emergency Signals

Fire on board

Two long blasts of the ship’s whistle supplemented by a continuous two-tone alarm signal over the loudspeakers.

Abandon ship

Seven or more short blasts followed by one long blast of the ship’s whistle supplemented by the same signal over the loudspeakers.

Whenever either of the above alarms is given, passengers shall go to their cabins, put on their lifejackets and then proceed calmly to their muster station, using whenever possible, the most direct route following the coloured muster station arrows via the main exits. Otherwise a secondary escape route via emergency exits may be used. The room steward will provide lifejackets for children at the start of each voyage.

How to put on your lifejacket:

1. Place lifejacket overhead
2. Bring strap around body and fasten closure
3. Adjust to a snug fit by pulling free end of strap
4. Cross arms across chest and enter water feet first

In darkness, pull orange plastic ring to start light.

Your muster station is [example] Muster F Station

Appendix D

Number And Arrangement Of Lifejackets On the *Ecstasy*

Checklist for Lifejackets				Section C 8
#	Location	Total	Type	Remarks
1	Lido Deck-Locker Near L/Boat # 4	89	Adult	To Be Used for Distribution During Pax Boat Drill
2	Lido Deck-Locker Near L/Boat # 4	92	Child	To Be Used for Distribution During Pax Boat Drill
3	Lido Deck-Locker Near L/Boat # 4	7	Infants	To Be Used for Distribution During Pax Boat Drill
4	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
5	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
6	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
7	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
8	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
9	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
10	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
11	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
12	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
13	Lido Deck-Bench By L/Boat # 4	18	Adult	Spare Requested by SOLAS
14	Lido Deck-Bench By L/Boat # 4	14	Child	Spare Requested by SOLAS
15	Lido Deck-Bench By L/Boat # 4	14	Child	Spare Requested by SOLAS
16	Lido Deck-Bench By L/Boat # 4	14	Child	Spare Requested by SOLAS
17	Lido Deck-Bench By L/Boat # 4	14	Child	Spare Requested by SOLAS
18	In Front of Cab. R-53	37	Child	Spare Requested by SOLAS
19	In Front of Cab. R-187	38	Child	Spare Requested by SOLAS
20	In Front of Cab. M-83	37	Child	Spare Requested by SOLAS
21	In Front of Cab. M-205	38	Child	Spare Requested by SOLAS
22	In Front of Cab. U-45	37	Child	Spare Requested by SOLAS

Checklist for Lifejackets				**Section C 8**
#	**Location**	**Total**	**Type**	**Remarks**
23	In Front of Cab. U-179	38	Child	Spare Requested by SOLAS
24	In Front of Cab. E-64	37	Child	Spare Requested by SOLAS
25	In Front of Cab. C-153	38	Adult	Spare Requested by SOLAS
26	Verandah Deck	68	Adult	Pax Cabins
27	Lido Deck	67	Adult	Crew Cabins
28	Lido Deck (Bridge)	4	Adult	For Personnel on Watch
29	Empress Deck	618	Adult	Pax Cabins
30	Upper Deck	532	Adult	Pax Cabins
31	Main Deck	686	Adult	Pax Cabins
32	Riviera Deck	640	Adult	Pax Cabins
33	Deck #3	175	Adult	Crew Cabins
34	Deck #2	484	Adult	Crew Cabins
35	Deck # 1	301	Adult	Crew Cabins
36	Tender # 7 – 8 - 14 - 15 - 16 - 17	480	Adult	For Tender Service
37	Tender # 7 – 8 - 14 - 15 - 16 - 17	48	Child	For Tender Service
38	Deck #2 – Bosun Store	48	Adult	Spare
39	Deck #2 – Bosun Store	50	Child	Spare
40	Atlantic Deck – By Children Playroom	11	Child	Spare
	Total Lifejackets On Board =	4,946*		

*Column adds up to 4,936.

Total Adult Spares Requested by SOLAS = 5% of 3,560 = 178 (See Lines # 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 12)
Total Children Spares Requested by SOLAS = 10% of 2,634 = 264 (See Lines # 13 - 14 - 15 - 16 - 17 - 18 - 19 - 20 - 21 - 22 - 23 - 24)

Appendix E

Metallurgical Tests - Heat Release Table

Average HRR* (kW/m^2) in the Following Times	Heat Flux Applied		
	25 kW/m^2	**50 kW/m^2**	**75 kW/m^2**
60 seconds	104.4	142.2	234.3
180 seconds	177.8	241.8	403.7
300 seconds	266.6	319.3	598.7

*HRR: Heat release rate

Appendix F

Safety Recommendations on Call Systems

In a 1993 special investigation report concerning passenger ship accidents,[50] the Board made the following safety recommendation to the Coast Guard:

> M-93-39
>
> Analyze the desirability and feasibility of equipping passenger staterooms with an emergency call system by which trapped passengers can signal their plight.

The Coast Guard ultimately advised the Safety Board that it had discussed the desirability and feasibility of installing emergency call systems in passenger staterooms with the SOLAS Working Group on Fire Protection and, based upon that discussion, determined that "an additional emergency call system would not improve passenger-to-crew communications and would require additional maintenance."

The Safety Board disagreed with the Coast Guard's actions and, on May 21, 1997, classified Safety Recommendation M-93-39 "Closed—Unacceptable Action," based, in part, on the Coast Guard's failure to perform the analysis requested.

Following its investigation of the fire on the *Universe Explorer*, the Safety Board asked that both the Coast Guard and the ICCL take actions regarding emergency call systems on cruise ships. The Safety Board issued the following recommendation to the Coast Guard:

> M-98-32
>
> Recommend to the IMO that passenger and crew cabins on cruise ships be required to be equipped with an emergency call system so that people trapped during a fire emergency have a means of signaling their location.

On October 16, 1998, the Coast Guard responded that it would discuss the available options for any necessary improvements with the SOLAS working group on fire protection and will propose changes to the IMO, if appropriate. The Safety Board followed up by advising the Coast Guard that the current regulations were not sufficient in the event of a fire with heavy smoke. Based on the Coast Guard's indicating that it would work with the SOLAS working group, the Safety Board classified M-98-32 "Open—Acceptable Response."

The Safety Board issued the following recommendation to the ICCL:

[50] For additional information, read Special Investigation Report—*Accidents Involving Foreign Passenger Ships Operating from U.S. Ports 1990-1991* (NTSB/SIR-93/01).

M-98-59

> Recommend that member passenger ship companies 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.

The ICCL responded that it had distributed the recommendation to its members for review and consideration. The Safety Board followed up by urging specific action to encourage the installation of emergency call systems as requested in the recommendation. The ICCL subsequently advised that SOLAS requirements and recent amendments stipulated a number of fire safety improvements addressing, among other measures, means of escape, low-location lighting, and smoke alarms. Moreover, SOLAS required cruise ship companies to train and designate crewmembers to search the ship for people who might be in their cabins or in non safety-designated locations.

On February 18, 1999, the Safety Board responded that it was disappointed that the ICCL had not recommended that member companies install emergency call systems. The Board stated:

> A telephone system might not be able to handle the number of calls that might be made in an emergency. An emergency call system could identify the stateroom in which a passenger or crewman is trapped. Because the ICCL has only discussed this recommendation with its technical committee and has not recommended that member companies install emergency call systems, M-98-59 has been classified 'Closed—Unacceptable Action.'