National Transportation Safety Board

Marine Accident Brief

Engine Room Fire Aboard Cruise Ship *Carnival Liberty*

Accident no.	DCA15FM035
Vessel name	*Carnival Liberty*
Accident type	Engine room fire
Location	West Indian Company Dock, Charlotte Amalie, St. Thomas, US Virgin Islands 18°20’N, 64°55.3’W
Date	September 7, 2015
Time	1133 Atlantic standard time (coordinated universal time – 4 hours)
Injuries	None
Property damage	$1.725 million est.
Environmental damage	None
Weather	Daylight, clear skies, temperature 86°F (30°C), southeast winds at 10 knots
Waterway information	Port of Charlotte Amalie, St. Thomas

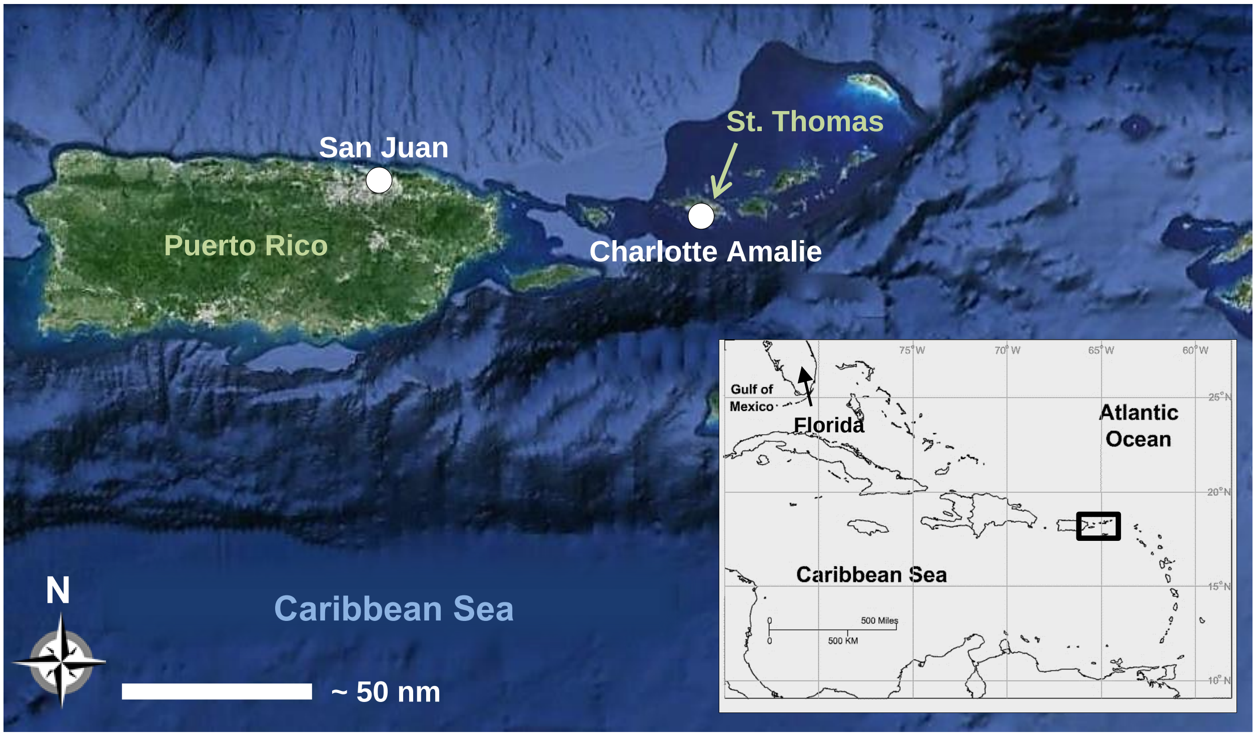
On September 7, 2015, about 1133 local time, a fire broke out in the engine room aboard cruise ship *Carnival Liberty*. At the time, the vessel was alongside the dock in the Port of Charlotte Amalie, St. Thomas, US Virgin Islands. The master ordered the passengers aboard the vessel to evacuate to the dock. The crew used the ship’s water mist- and carbon dioxide (CO_2) firefighting systems to extinguish the fire. No one was injured, nor was any environmental damage reported. Fire damage to the ship was estimated at $1.725 million.

The *Carnival Liberty* in San Juan, Puerto Rico, about 1 week after the accident.

Accident Events

Background

The *Carnival Liberty* arrived in Charlotte Amalie about 0700 on Monday, September 7, 2015, for its first port of call on a scheduled 7-day cruise. The cruise originated in San Juan, Puerto Rico, with 3,347 passengers and 1,151 crewmembers aboard. The slow vessel speed during the overnight transit required only two of the ship’s six diesel engine-driven generators (referred to as diesel generators, or DGs) that supply power both to electric-propulsion motors and ship's services to be online (DGs 1 and 3).[1]



Satellite image of the accident area in the Caribbean. (Background by Google Earth)

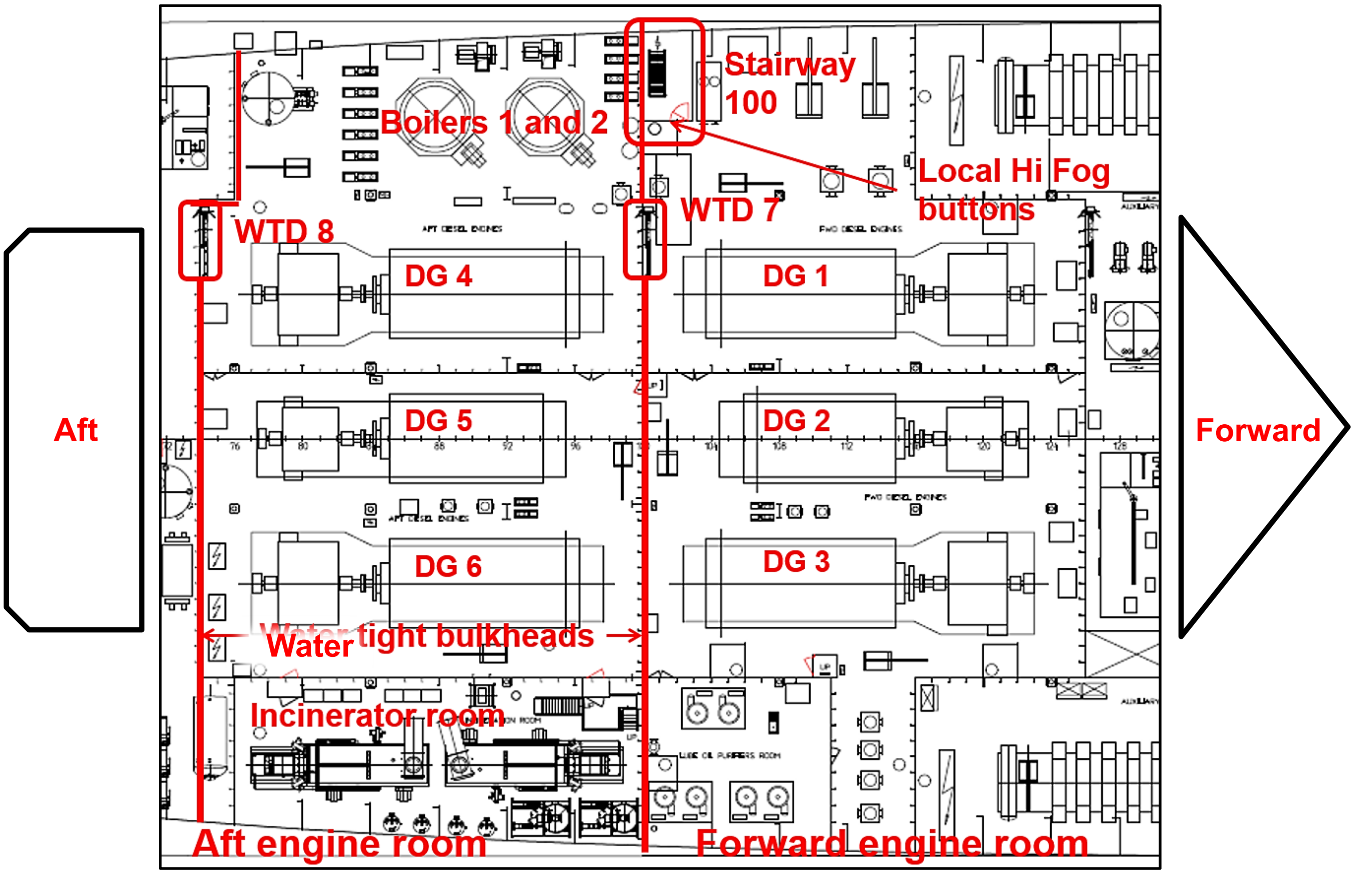
The arrival in port was uneventful. After the ship was berthed, the crew shut down DG 1 and started DG 4, putting it online (in service) with DG 3.[2] Also while in port, contractors began performing scheduled "hot work," welding brackets underneath the deck plates in the forward engine room near DG 1. Because of the work being conducted, the engine rooms' HI-FOG water-mist firefighting system, which was normally in automatic mode in the engine spaces, was set to manual mode so that the smoke and arc flash generated by the hot work would not to activate the heat, flame, or smoke detectors in the area.[3]

[1] The diesel-electric plant is configured to optimize space and efficiency with automatic load sharing and the capability to handle various configurations of the six DGs; only on rare occasions are all six DGs required to operate simultaneously. The number of DGs in use depends on the speed requirements (propulsion power) and the ship's internal power demands; such as air conditioning units, galleys, and lighting (often called "hotel load"). When a cruise ship is under way, typically at least two engines need to be operating to supply power for propulsion and ship services. As speed requirements increase, the number of DGs operating is also increased. Aboard a ship with six DGs, it is common to have an engine out of service for maintenance at any given time. While in port, given that the hotel load is the only power-demand on the ship, engineering staff can conduct inspections and maintenance projects.

[2] DG 4 is a four-stroke, intercooled, fuel-injected, and turbocharged Wartsila model 46 engine. The 12-cylinder, counterclockwise-rotating V-engine is capable of producing 12,600 kW of power. DG 4 was manufactured in 2004.

[3] In 2014, Carnival Cruise Line enhanced and upgraded fire protection on its ships as a result of the lessons learned from engine room fires aboard the *Carnival Triumph* and the *Carnival Splendor*. One such enhancement was the HI-FOG firefighting system; additional pumps, coverage areas, local push buttons, and power redundancy were all included. The HI-FOG upgrade was completed by the system manufacturer and tested with the approval of the ship's classification society, Lloyd's Register. The upgrade also included a new operation panel in the engine control room and a centralized section valve operation station in deck 0's main corridor. HI-FOG meets the requirements of the

The engine compartments were watertight and provided a fire-protection boundary between each space. Access between the forward and aft engine rooms was provided by a watertight door that could be closed either locally, remotely from the bridge, or via an emergency station on the deck above the engine room. The ship's main power was distributed via a main switchboard and bus ties located directly behind the aft engine room and separated by a fire-rated subdivision bulkhead. Electrical cables, covered with an intumescent coating, were routed in the overheads of the engine rooms to the main switchboard.[4]



Forward and aft engine rooms on deck C aboard the *Carnival Liberty*, with DGs 1–3 arranged side by side from port to starboard in the forward compartment, and DGs 4–6 side by side in the aft compartment. (Image provided by Carnival Cruise Line)[5]

International Convention for the Safety of Life at Sea (SOLAS) II-2/12 Res A.800, as well as International Maritime Organization (IMO) MSC/Circ. 1165 and IMO MSC/Circ. 913. HI-FOG is a "dry" system, which means water enters the piping only after specific valves for that section are opened. When activated in a specific area, either automatically or manually, a section valve opens and fine water mist emits from the mist heads on that line. The system on the *Carnival Liberty* was pressurized by pumps mounted on four separate skids that maintained a standby pressure of 25 bar (363 psi) and, when activated, a working pressure of 140 bar (2,030 psi). In the event of a loss of electrical power or if the system pressure fell below 30 bar (435 psi), a charged nitrogen bottle system would maintain pressure from a series of water cylinders for a duration dependent on how many sections were activated.

[4] An *intumescent coating* is a sealant or coating that swells and chars when heated, thus protecting the material underneath or sealing a gap in the event of a fire.

[5] Carnival Corporation & PLC has a portfolio of global cruise line brands that includes Carnival Cruise Line, Fathom, Holland America Line, Princess Cruises, Seabourn, P&O Cruises (UK), P&O Cruises (Australia), Cunard,

In addition to the HI-FOG system, the *Carnival Liberty* was fitted with a Daspos spray and gas leakage alarm system, which also was recently added to the ship as a result of the major fleet-wide safety enhancement program. By way of multiple sensors in the engine rooms, the Daspos system was capable of detecting even small quantities of vapor, mist, or spray from heavy fuel, diesel oil, hydraulic oil, or lubricating oil. Alarms from the Daspos system were announced on an audible/visual panel in the engine control room (ECR), on a local display in the engine room, and through the ship's integrated automation system (IAS). In addition, Daspos was connected to the ship's computer network so that it could send alarm information to various shipboard staff and shoreside company personnel by email.

The *Carnival Liberty* was also equipped with a CO_2 firefighting system that provided protection to all engine spaces. The system consisted of a bank of 86 bottles, located on deck 11 aft, below the ship's exhaust stack near the emergency diesel generator room. Release of CO_2 was manually activated either from a station near the ECR or from the CO_2 station on deck 11.[6]

After the ship was docked in the Port of Charlotte Amalie, the engineering crew changed the fuel supply for the engines from heavy fuel oil with a working temperature of 266 degrees F (130 degrees C) to lower sulfur-content marine gas oil with a working temperature of 104 degrees F (40 degrees C), as required by regulations.[7] At 0740, the crew logged the fuel changeover as complete; no problems with the fuel system were noted during the changeover.

About 0800, the engineering crew changed watch as scheduled. The off-going engineer reported no problems or discrepancies to the second engineer who was taking over. A third engineer, an oiler, and a fire patrolman also started watch at the same time. While the second engineer manned the ECR, the other watch personnel conducted rounds that involved monitoring, checking, and maintaining machinery in the engine spaces. None of the on-duty personnel that investigators interviewed noted any problems or unusual observations in the time leading up to the fire.

Onset of Fire

About 1130, the third engineer went to the ECR where he spoke briefly with the second engineer on duty. Seconds later, alarms sounded on the ship's IAS. The first alarm activated at 1133 and indicated low pressure for feed oil boost pump B, which provided fuel pressure to the engines. Less than 1 second later, numerous alarms activated for DG 4, including oil leak detection and low pressure for the fuel oil inlet. After checking the alarms on the screen, the second engineer told the third engineer that he received a "strange alarm" for the fuel system on DG 4, and he instructed the

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AIDA Cruises, and Costa Cruises. Carnival Corporation sets safety, health, and environmental policy for the operating brands.

[6] The CO_2 system underwent its last annual inspection and test on June 30, 2015, with all tests completed satisfactorily. All cylinders were weighed and found to be within limits. There was only one remark on the technical report that stated there was no evidence of when the flexible hoses were last replaced. The technician recommended replacement of these hoses, which was not done prior to the accident. The directional valves in the CO_2 system were inspected in 2011 with the next inspection required in 2016.

[7] The International Convention for Prevention of Pollution from Ships (MARPOL 73/78/97) Annex VI is the main international treaty addressing air pollution prevention requirements from ships. Annex VI requirements include both engine-based and fuel-based standards and apply to US-flag ships wherever located and to non-US-flag ships operating in US waters (www.epa.gov/enforcement/marpol-annex-VI). The *Carnival Liberty* was exempt from MARPOL Annex VI regulation 14 by the Environmental Protection Agency (EPA) and the US Coast Guard as a result of the company's trial program to install exhaust gas cleaning capacity on its ships.

third engineer to go immediately to the area to check on it. Seconds later, several additional alarms sounded from the automation system.

About the same time, numerous fire alarms for the forward and aft engine rooms activated on the bridge. The officer of the watch called the second engineer in the ECR to advise him about the alarms he had received. According to the ship's fire detection system, the first alarm received on the bridge was from a flame detector above DG 4 at 1133, with an additional flame detector for the HI-FOG system activating about 9 seconds later. Subsequently, numerous smoke, heat, and flame detectors activated in the area.

15:33:07.618	!	F02	PT06035B	FO BOOST.PMP B PRESS	MEAS. < LL
15:33:14.621	!	F02	PT06029B	FO FEED PMP B PRESS.	MEAS. < LL
15:33:15.419	!	F05	XS06090B	FO BOOSTER SYSTEM B	ALARM
15:33:15.619	!	F02	LS06043ADG4	DG4 FO LEAK. IP A-B.	ALARM
15:33:22.338	--	F02	PT06029B	FO FEED PMP B PRESS.	MEAS. < LL
15:33:23.623	!	F02	PT06040DG4	DG4 FO INLET PRESS.	MEAS. < LL
15:33:23.858	!	F02	PT06040DG5	DG5 FO INLET PRESS.	MEAS. < LL
15:33:32.339	!	F07	HIFOG.205	AUTO RELEASE REQ. ON	ALARM
15:33:32.930	!	F07	XS54006	FIRE ALRM AFT DDGG R	ALARM
15:33:35.621	!	F08	XS09036DG4	DG4 COMMON FAIL	ALARM
15:33:44.628	—	F07	999XA002	DASPOS SYS COMM ALM	ALARM
15:33:47.975	!	F07	XS54013	FIRE ALRM TURB/CASIN	ALARM
15:33:59.640	!	F08	MS17044B	E.R.1 EXHAUST FAN B	COMMON ALARM
15:34:00.740	!	F08	XS43029A	UPS 24VDC EART.FAULT	ALARM
15:34:02.625	!	F02	PT06029B	FO FEED PMP B PRESS.	MEAS. < LL

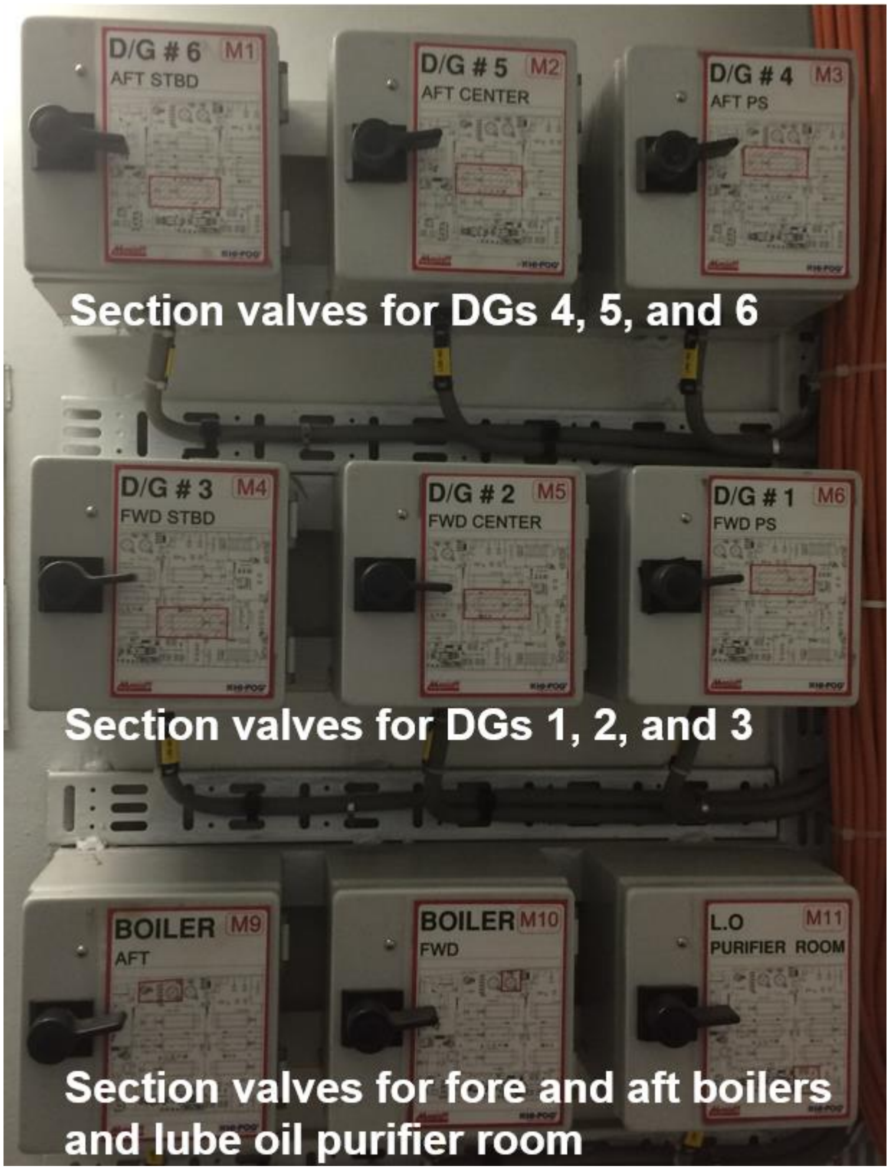
Initial alarm printout from the *Carnival Liberty*'s IAS; the times are reported in Greenwich mean time, 4 hours ahead of Atlantic standard time.

In the forward engine room, the fire patrolman assigned to the hot work near DG 1 heard an explosion. He turned in the direction of the sound and saw black smoke coming from the opening of watertight door 7 that was just a few steps away from him, forward of DG 4. He went to the door opening and saw a fire on DG 4 in the aft engine compartment. Recognizing the fire was too big to fight, he closed the watertight door, which was allowed to be open in port, and radioed the bridge via his handheld radio to alert the crew there to call "alpha code," which is the emergency code for fire. Knowing that the HI-FOG system was in manual mode because of the ongoing hot work, the fire patrolman called his supervisor (the chief fire patrolman) and requested that he ask the ECR crew to set the HI-FOG system back to automatic mode. He then went to stairway 100, nearby in the forward engine compartment, where he knew that the local HI-FOG activation buttons were located.

Images from the ship's closed-circuit television of DG 4 from forward looking aft. The red box on the left image highlights the first visual sign of open flame. The right image shows the same area less than 1 second later.

At the stairway, the fire patrolman met the third engineer and the motorman who had already started opening the manual-release boxes to activate the HI-FOG system locally. According to the third engineer, he activated all the buttons that were available at that location because he was not able to see the exact location of the fire in the aft engine room once the watertight door was closed. The ship's IAS recorded the first HI-FOG release at a section valve for DG 4 at 1134. Immediately thereafter, IAS documented the release of HI-FOG section valves also for the aft engine room port cable trays, the aft boiler, the forward boiler, DG 5, the aft engine room starboard cable tray, and DG 6. After a few more seconds, at 1135 according to IAS, the section valves released for DGs 1–3, the forward port and starboard cable trays, the forward engine room bilge, and the forward engine room (port and starboard).

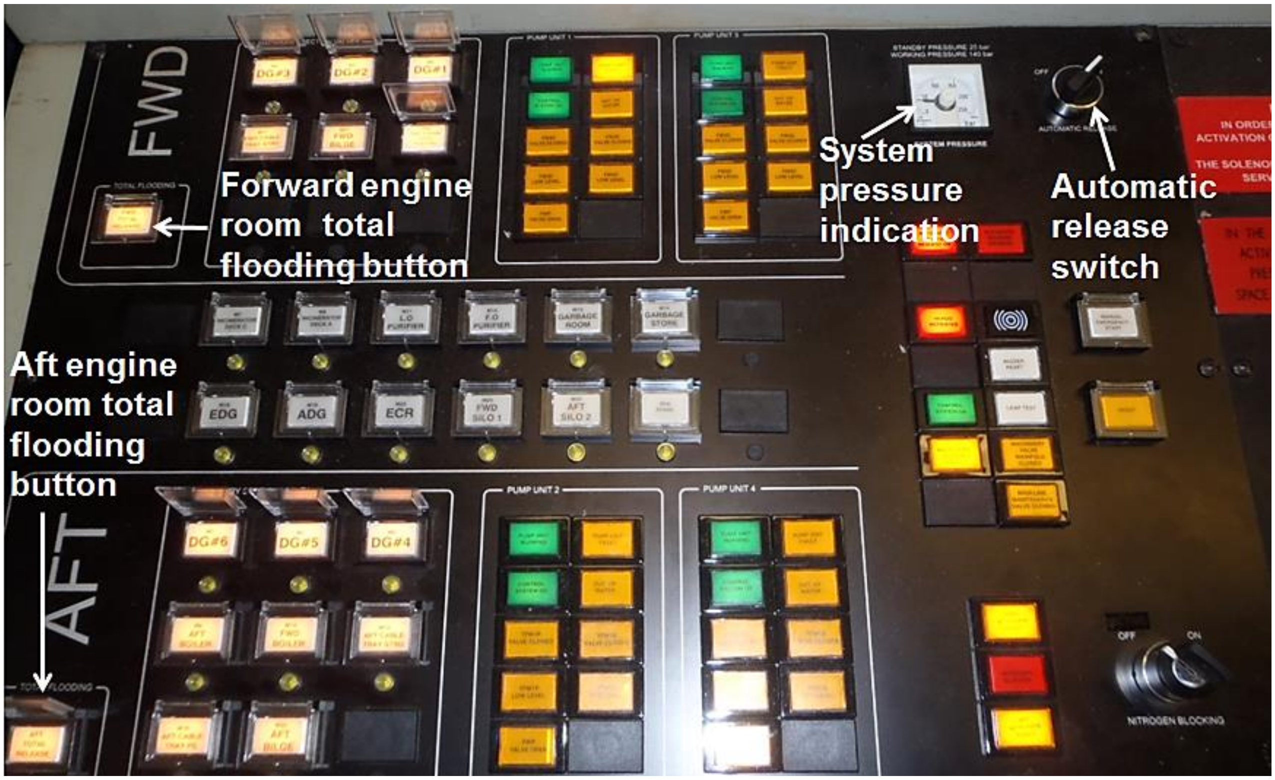
Once the buttons were pushed, the third engineer exited the forward engine room by stairway 100 and returned to the ECR; the fire patrolman remained behind. He told investigators that he once again pushed the HI-FOG buttons for DGs 4–6 because he was unsure if they had activated (he could not see into the aft engine room behind the closed watertight door, but he saw the HI-FOG system operating in the forward engine room). He exited the area shortly after hearing the alpha code announcement and went to his emergency station, where he joined the quick-response team. Before leaving, the fire patrolman instructed the welding contractors to evacuate the area, which they did.



HI-FOG activation boxes inside stairway 100 on deck C in the forward engine room.

Meanwhile, the second engineer was alone in the ECR managing numerous alarms and communications. Using the automation system, he started DG 1 in the forward engine room and shut down DG 4. The staff chief engineer, who was in his office next door, arrived in the ECR after receiving an email alarm on his computer activated by the Daspos oil leak-detection system. Both he and the second engineer observed the fire near DG 4 on the closed-circuit television (CCTV) screen view from a camera located near DG 4. The staff chief engineer went to the main HI-FOG panel in the ECR where they saw that the "total flooding" buttons were activated for the forward and aft engine rooms.[8] However, according to the HI-FOG manual, which was specific to the *Carnival Liberty*, the system was designed for total flooding in one engine space at a time, not both. Total flooding could be activated only from the ECR and not locally or from the bridge. No crewmember that investigators interviewed could recall who pushed the buttons for total flooding.

[8] The "total flooding" button activates eight section valves in the aft engine room and six in the forward engine room.



The HI-FOG control panel in the ECR at 1207, about 35 minutes after the fire started. The panel indicates that all section valves in both the forward and aft engine rooms are open. The system pressure in this picture is 26 bar. (Photo by Carnival Cruise Line)

The chief engineer, who was in the ship's luggage/marshalling area on deck 0 before the fire started, told investigators that he made his way to the ECR after hearing the HI-FOG pumps activate (he knew that no maintenance or testing was scheduled for them). When the chief engineer arrived in the ECR, the second engineer updated him as to what had happened and actions taken. The staff chief engineer and another engineer went to the fuel and lube oil quick-closing valve station just outside the ECR where they activated the inlet and outlet quick-closing valves for DGs 4–6. Shortly thereafter, the staff chief engineer, with permission from the chief engineer, also activated the quick-closing valves for the fuel oil feeder modules for the boilers and DGs 4–6.

At 1136, the alpha code announcement was made from the bridge to alert all quick-response and fire teams of a fire on deck C and to go to their stations. The ship's master, who was with the staff captain on the way to the officers' mess hall on deck 0 for lunch, turned around and ran up the stairs to the bridge on deck 8. The master arrived on the bridge about 1138 and received a situation report from the bridge officer on duty. He was informed of the fire in the aft engine room and that all the watertight doors were closed. The master told investigators that he looked at the HI-FOG indication panel and saw that the system was running but at only 40 bar of pressure, which he knew was well below the normal operating pressure of 140.

Following the alpha code announcement, the rest of the engineering staff began to arrive at the ECR to muster and to carry out their emergency duties. The staff chief engineer exited the ECR and went to his emergency station. Personnel in the ECR began to complete their safety management system (SMS) checklists for an engine space fire, including shutting down the fans and dampers in the aft engine room, which were recorded as being stopped and closed at 1137.

At 1141, the master received an update from the chief engineer stating that the ventilation to the aft engine room had been shut off, DG 4 was shut down, the quick-closing valves were closed, and the emergency diesel generator and an additional diesel generator on deck 12 were ready to be placed online if needed.[9] The master then requested that the chief engineer let him know when a roll call of engineering personnel was complete and told him to prepare for CO_2 discharge.

The master looked at the bridge's fire detection system display and saw numerous smoke detectors activating in the engine casing (comprising the exhaust piping) all the way up to deck 14. Concerned with the low pressure of the HI-FOG system, the master asked the chief engineer if the pumps were running, which he confirmed they were. Given the low pressure and the potential for spread of smoke throughout the ship, the master made a "crew alert" announcement at 1140 for all crew to go to their emergency stations.

About the same time, the master noticed that the main integrated safety management control system (SMCS) had frozen electronically. The SMCS is a computer system that integrates all fire alarms, emergency shutdowns, fire door controls and status indications, ventilation controls, and CCTV video into a large display located behind the bridge with the ship's general arrangement, fire, and damage control plans. Because this display was stuck electronically, bridge personnel had to access different systems on the bridge—fire detection, CCTV, and various mimic panels for control of emergency shutdowns, fire, and watertight doors—to determine the state of the situation.

In the ECR, the chief engineer looked at the CCTV for the engine spaces. He saw smoke and spray from the HI-FOG system and flames in the vicinity of DG 4. Footage from a camera monitoring the ship's exhaust stack showed black smoke exiting, which the chief engineer believed to be from DG 1. Thinking there was also a problem with that DG, he shut it down from the indication panel by opening the circuit breaker. With only DG 3 online, he directed the chief refrigeration engineer in the ECR to stop the air conditioning compressors, which were high electricity consumers. DG 3 remained running the entire time, and at no point did the ship transition to emergency or auxiliary power. After the accident, the quick-closing valve for DG 1 was found in the closed position. When DG 1 was later restarted, no anomalies with the engine were reported.

The engineering staff conducted the roll call to ensure that all personnel were out of the engine spaces. At 1145, the chief engineer informed the master that the engine room was evacuated and all personnel were accounted for. On receiving this information, and seeing that the HI-FOG panel indicated a low operating pressure, the master ordered the chief engineer to activate the CO_2 system in the aft engine room. At 1147, the chief engineer confirmed to the master that the system was activated. Bridge and engine personnel were able to verify the discharge of CO_2 on the CCTV.

However, a valve that directed the CO_2 toward the aft engine room did not operate properly and triggered a gas leakage alarm in the CO_2 room on deck 11. An engineer whose emergency duty was to stand by at the CO_2 room heard the alarm, donned a self-contained breathing apparatus (SCBA), and entered the space to investigate. Inside, he noticed that directional valve A was partially open, so he kicked the hydraulic arm to ensure that the valve was completely open. Investigators were later provided with a postaccident maintenance test report.[10] It identified a

[9] The additional diesel generator is a company enhancement based on the *Carnival Splendor* and *Carnival Triumph* accidents. This generator is not a replacement for the emergency diesel generator but rather an additional source of power to provide basic hospitality services aboard in the event the ship's main power is not available.

[10] Mozzanica and Mozzanica S.r.l. fire protection and engineering maintenance test report RT15-LI-001A, September 12, 2015.

missing gasket for one of the pilot cylinders as the reason for the partial opening of the directional valve. The report stated that the missing gasket and, in turn, the partially open directional valve "generated a loss of pressure inside the directional valve control line."

CO_2 directional valve A that had to be kicked to a fully-open position.

Following the release of CO_2 in the aft engine room, at 1148, the master sounded the ship's general emergency signal of seven short blasts and one long blast to alert all passengers and crew that there was an emergency. Because the *Carnival Liberty* was in port, and in accordance with the company emergency response manual, the master requested the cruise director to direct all passengers to evacuate the ship via the two gangways located on deck 0. The master told investigators he had good confidence the fire was under control, but he was concerned about smoke and the risk it posed to passengers. The crew made announcements to passengers in both English and Spanish.

At 1150, the master ordered a bridge officer to radio the US Coast Guard and request assistance. Once it was made clear that the ship was alongside the dock in St. Thomas, the Coast Guard began asking for information necessary to appropriately plan for the response. The master informed the Coast Guard about the fire on DG 4, the discharge of CO_2, and the passenger evacuation. The Coast Guard asked if anyone was injured, to which the master said no; he also said that the engine room had been evacuated. The Coast Guard then requested to know the ship's next port of call. The master replied that he and the crew were busy dealing with an emergency and then handed the radio to another bridge officer so that he could return to his emergency duties. The Coast Guard responded that its personnel were working on getting assistance.

The HI-FOG system continued to operate with low-pressure readings and, at 1203, the master asked the chief engineer why the system did not have adequate pressure. The chief engineer informed the master that all pump skids were running and that the "total flooding" section valves were open in both the forward and aft engine rooms. To address the low pressure, the chief engineer requested that the HI-FOG system be reset, which would stop the water-mist in both engine rooms, and they could then reactivate the system in the aft engine room where the fire originated. About 1211, the ECR crew shut down the HI-FOG system to reset it. Doing so restored all locally activated section valves to the closed position, and the operating pressure began returning to normal. About 2 minutes later, the ECR crew informed the bridge crew that the HI-FOG system was back online with "total flooding" mode in the aft engine room. The bridge crew requested the safety officer to have the fire squads take temperature readings on bulkheads adjacent to the aft engine room to verify that the fire was extinguished.

It is significant that the crewmembers were unaware that the HI-FOG system was incapable of delivering total flooding to both engine rooms simultaneously, and that they then had to use the CO_2 system to try to extinguish the fire. Furthermore, they did not consider, nor did any checklist specify, returning the HI-FOG system to automatic from manual mode immediately after confirmation of a fire. According to the system manufacturer, returning the HI-FOG system to automatic mode would have activated the HI-FOG section valves only in affected areas (based on smoke- and flame-detector activations). The NTSB concludes that comprehensive crew training and familiarity regarding the use and limitations of fixed water-based local application systems in machinery spaces are crucial to safe operations. The NTSB therefore recommends that Carnival Corporation & PLC implement ship-specific familiarization training regarding the use and limitations of fixed water-based local application systems in machinery spaces.

The quick-response and fire teams that assembled in the handling area on deck 0 had been standing by to respond to the fire. The on-scene commander, the safety officer, and the staff chief engineer communicated directly with the bridge command and control teams. Throughout the emergency, they ensured that the area was evacuated, monitored smoke conditions in various compartments, performed boundary cooling in adjacent spaces, and measured bulkhead temperatures in areas adjacent to the aft engine room. At 1236, the command and control team on the bridge was informed that the temperature at watertight door 7 was 102 degrees F (39 degrees C) and, at door 8, the temperature was 89 degrees F (32 degrees C). Both temperatures indicated to the master that the fire was extinguished.

According to the ship's log book, at 1614, a fire squad wearing self-contained breathing apparatuses entered the aft engine room near DG 4 and noted that the temperature inside was 111 degrees F (44 degrees C) with no heat sources present. At that time, the master declared the fire extinguished. The engineering crew then began work to restore ventilation and air conditioning in preparation for the passengers' later return to the ship.

General Emergency and Evacuation of Passengers

On the evening of September 6, the day before the ship departed San Juan for St. Thomas, a general emergency and evacuation drill had been held for all passengers, as required by the International Convention for the Safety of Life at Sea (SOLAS). During the drill, the passengers were familiarized with the ship's emergency procedures and signals and where to go in the event of an emergency. They were instructed that, on hearing the general emergency signal of seven short blasts and one long blast via the ship's whistle and internal alarm, they should proceed to an assembly station (also known as a muster station) pre-assigned based on the passengers' stateroom numbers.

At the time the evacuation was ordered, many of the passengers had already gone ashore to visit Charlotte Amalie. About 541 passengers still remained aboard the ship, according to the ship's A-Pass system. A-Pass is a computerized access control system that allows the ship's security personnel to accurately identify passengers and crew and keep track of who is on and off the ship. When a person leaves the ship at the gangway, their company-issued identification card is scanned to log their exit from the ship. Normally, if passengers did not have their card with them when trying to exit, they were asked to retrieve it before being allowed to leave the ship. An alternative method did exist whereby security personnel would manually enter into the computer system persons exiting or boarding the ship; however, that process was time-consuming.

According to Carnival's emergency response plan, A-Pass was to be used to account for guests and crew during a ship evacuation to the dock until an electronic mustering system was in place.[11] As remaining passengers and crew were exiting the ship, the master received a report that many of the passengers evacuating by the gangways did not scan out via the A-Pass system. Some of them did not have their identification cards, and efforts to manually log persons off the ship created a bottleneck for those trying to exit the vessel during the evacuation. Although A-Pass was effective in determining how many guests were on the ship at the time of the evacuation order, it was not an efficient means to account for guests and crew during the emergency.

On learning that people were exiting the vessel without being accounted for via A-Pass, the master contacted the company in charge of port security and informed their personnel of the problem and that he needed their assistance in lining up the passengers on the dock. The port security company informed him that the lineup was under way and that the passengers were being directed to a parking area to be ready for the ship's crew to do a headcount.

There were also young children aboard the ship who, while their parents were ashore, were in the care of the ship's youth center staff. When the evacuation was ordered, the youth center staff safely evacuated the children to the dock and remained with them until the parents returned.

The ship's crew responsible for the evacuation were trained in directing passengers to their shipboard muster stations and had to adapt to the order to evacuate to the dock. The muster control crew, made up of key shipboard hotel staff, kept the command and control team on the bridge informed of the evacuation progress. Company SMS checklists were used to track and monitor each of the ship's seven main vertical fire zones, each having a zone leader and crew to assist in directing the passengers off the ship. But because not all of the passengers were aboard the ship, the muster control crew had to print out a separate list to account for the ones who were aboard when the evacuation order was given. In addition, passengers with special needs had to be gathered and assisted off the vessel. All passenger staterooms and public spaces aboard were checked to ensure no one remained. From the time the general emergency alarm sounded, 48 minutes passed before the crew could confirm that the ship was fully evacuated; however, a full account of the passengers had not been completed.

On the dock, passengers and crew assembled to await a roll call in the 86-degree F (30-degree C) air temperature. In addition, about this time, some passengers who had exited the ship before the evacuation were starting to return to the ship and eventually became mixed with the evacuated and waiting passengers on the dock. Muster station leaders and ship's officers, who were on the dock to keep everyone organized, found themselves in a challenging situation for which they

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[11] *Electronic mustering* (e-muster) is an electronic system that can be used to accurately account for passengers and crew during an emergency or other incident.

had not been prepared. About 1300, bridge personnel were informed that some passengers were overheating and in need of water, and that other passengers were leaving the area without being accounted for. The ship's staff provided passengers on the dock with water and shelter by way of awnings and canopy covers from both the ship and port services.

Because most of the passengers that evacuated the ship did not scan out through the A-Pass system when leaving, the muster control crew had to cross-reference the printed list of people who were aboard before the general alarm sounded to the actual passengers and crew on the dock. This process was only marginally successful and a full headcount was not completed. While updating the company headquarters crisis management center, the master and the ship's hotel director stated that the passenger-count from the dock would not be accurate. About 1400, the A-Pass system indicated that 451 passengers were still aboard. Although the crew were confident that this high number resulted from passengers' not scanning out through A-Pass as they evacuated, the process of verification was still uncertain and tedious.

Coast Guard personnel boarded the *Carnival Liberty* about 1330 and the crew briefed them about the situation. Passengers on the dock were still not able to board the ship; accordingly, the crew and shoreside crisis management teams arranged for all passengers to be accommodated at local hotels until further notice. Later that same evening, about 2030, passengers were allowed to return to the ship and began doing so. Just before midnight, the crew were able to determine that all passengers on the manifest were accounted for. However, because of the fire damage to the ship, Carnival Cruise Line canceled the remainder of the scheduled voyage and arranged for the passengers' return home.

In evacuating a partial passenger-count onto a dock in port, the ship's command and crew had to adapt to an unfamiliar situation. They had not trained for such an event; further, no specific applicable company policy or procedures were in place about it at the time. Cruise ship crew training and drills commonly focus on a known number of passengers aboard because the assumption is that the ship is at sea. In addition, lack of space on the dock, environmental conditions, crowd control, and wait time further hampered the evacuation process. Thus, during the emergency, the crew were unable to accurately account for all persons during the emergency. The NTSB concludes that preplanned procedures to account for all persons aboard are essential in the event of a mass evacuation of a ship while in port. The NTSB therefore recommends that Carnival Corporation & PLC develop and/or improve procedures to manage and account for all persons aboard in the event of a mass evacuation of a ship while in port. The NTSB further recommends that the Cruise Lines International Association inform its members about the circumstances of this accident, including the need to plan for accounting for all persons aboard in the event of a mass evacuation of a ship while in port.

Personnel

Bridge and engine officers were appropriately credentialed and certificated as per the vessel's flag requirements. Following the accident, the master, chief engineer, staff captain, staff chief engineer, and bridge and engine watchkeeping personnel on duty were tested for alcohol and other drug use in accordance with Coast Guard requirements. All results were negative.

Maintenance and Inspections

According to the ship's maintenance records for DG 4, the most recent maintenance on cylinder A2's fuel-injection pump took place on June 3, 2015, during a 45,000-hour overhaul of the engine. "Team D," composed of the ship's crew, conducted the maintenance, supervised by the ship's senior first engineer who was responsible for engine maintenance. DG 4 had 42,680 hours at the time of the overhaul and, at the time of the fire, about 480 additional hours. According to the comments in the maintenance history, the pump had all parts and O-rings replaced in accordance with the Wartsila 46 manual section 16.1.4 and section 07.

On September 3, 2015, less than 1 week before the accident, the crew had inspected DG 4 to record and analyze its performance during a 75-percent load test; no deficiencies were noted.

Postaccident Examination

The fire on DG 4 originated from the fuel supply inlet flange for cylinder A2's high-pressure fuel-injection pump. Investigators found that one of the four flange bolts was missing and another was loose but attached.[12] The missing bolt was found in the gallery for the cylinder bank and was collected for laboratory examination along with the loose bolt still attached to the flange.

Left, location of the fire in the A bank of DG 4. Right, fuel-injection pump for cylinder A2 with suspect flange circled in yellow after the fire.

The laboratory examination of the two bolts, conducted at NTSB headquarters in Washington, DC, confirmed that neither bolt was deformed or showed signs of being stretched. Further, the detached bolt had no wear on its threads; the attached but loose bolt had rotational wear in three of its threads (11–13).

Subsequent testing by a commercial laboratory of the two bolts, along with the two remaining bolts from cylinder A2 (not examined by the NTSB), found no signs of excessive or insufficient bolt preload such as thread-root cracking or plastic deformation of the threaded bolt shank.

[12] The flange bolts were carbon steel, size M12, and 65 mm long.

Left, the bolt found attached to the housing of the fuel-injection pump for cylinder A2. Discoloration and residue can be seen in some of the threads. Right, the bolt that was found detached.

The Wartsila 46 diesel engine instruction manual that was provided to investigators specified tightening torques for multiple bolt connections for the fuel-injection pump.[13] Specific torque values for the bolts that connected to the fuel supply inlet flange were not included; however, the torque value for their dimensions and strength class was outlined in a general table called "Tightening Torques for Other Screws and Nuts." It recommended that torque-measuring tools be used when tightening screws and nuts. None of the crewmembers that investigators interviewed were present at the time of the last maintenance and did not know if torque-measuring tools, which were available aboard the ship, were used when reconnecting the fuel-injection pump.

The NTSB concludes that the source of the fuel spray was loosened bolts on the fuel supply inlet flange to DG 4**,** likely resulting from improper tightening during prior maintenance and vibration of the piping over time.

Findings

1. Comprehensive crew training and familiarity regarding the use and limitations of fixed water-based local application systems in machinery spaces are crucial to safe operations.

2. Preplanned procedures to account for all persons aboard are essential in the event of a mass evacuation of a ship while in port.

3. The source of the fuel spray was loosened bolts on the fuel supply inlet flange to diesel generator 4, likely resulting from improper tightening during prior maintenance and vibration of the piping over time.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the engine room fire aboard the *Carnival Liberty* was loosened bolts, likely resulting from improper tightening during prior maintenance and vibration of the piping over time, on a fuel supply inlet flange on diesel generator 4, which triggered an uncontrolled fuel spray from the inlet flange onto a hot surface on the diesel generator.

[13] Wartsila instruction manual W12V46 document ID DBAA563627b.

Recommendations

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

To Carnival Corporation & PLC:

> Implement ship-specific familiarization training regarding the use and limitations of fixed water-based local application systems in machinery spaces. (M-17-18)
>
> Develop and/or improve procedures to manage and account for all persons aboard in the event of a mass evacuation of a ship while in port. (M-17-19)

To the Cruise Lines International Association:

> Inform your members about the circumstances of this accident, including the need to plan for accounting for all persons aboard in the event of a mass evacuation of a ship while in port. (M-17-20)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ROBERT L. SUMWALT III
Acting Chairman

CHRISTOPHER A. HART
Member

EARL F. WEENER
Member

T. BELLA DINH-ZAHR
Member

Adopted June 21, 2017

Vessel Particulars

Vessel	***Carnival Liberty***
Owner/operator	Carnival Cruise Line
Port of registry	Panama City
Flag	Panama
Type	Cruise ship
Year built	2005
Official number (US)	N/A
IMO number	9278181
Construction	Steel
Length	951.8 ft (290.2 m)
Draft	27.3 ft (8.3 m)
Beam/width	143 ft (43.6 m)
Gross and/or ITC tonnage	110,320 gross tons
Engine power; manufacturer	16,896 hp (12,600 kW) Wartsila diesel generator 4
Persons aboard for the voyage (not at the time of the emergency)	4,498 (3,347 passengers and 1,151 crew)

NTSB investigators worked closely with our counterparts from Coast Guard Marine Safety Unit St. Thomas throughout this investigation.

For more details about this accident, visit www.ntsb.gov and search for NTSB accident ID DCA15FM035.

The NTSB has authority to investigate and establish the probable cause of any major marine casualty or any marine casualty involving both public and nonpublic vessels under Title 49 *United States Code*, 1131. This report is based on factual information either gathered by NTSB investigators or provided by the Coast Guard from its informal investigation of the accident.

The NTSB does not assign fault or blame for a marine casualty; rather, as specified by NTSB regulation, “[NTSB] investigations are fact-finding proceedings with no formal issues and no adverse parties . . . and are not conducted for the purpose of determining the rights or liabilities of any person.” Title 49 *Code of Federal Regulations*, 831.4.

Assignment of fault or legal liability is not relevant to the NTSB’s statutory mission to improve transportation safety by conducting investigations and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report. Title 49 *United States Code*, 1154(b).