1000 FREDERICK LANE, MORGANTOWN, WV 26508 · 304.285.5916

Two Career Land-Based Firefighters Die After Becoming Lost and Running Out of Air During a Marine Vessel Fire in Port – New Jersey

Executive Summary

On July 5, 2023, two career land-based firefighters died after becoming lost and running out of air while conducting a fire attack during a marine vessel fire in port. At 07:00 hours, a 692-foot roll-on/roll-off (ro/ro) vessel with a crew of 28 commenced vehicle loading operations while dockside in a port. At 21:00 hours, port workers and vessel crew members noticed a vehicle on deck 10 was on fire. Crew members immediately employed portable fire extinguishers and a shipboard water hoseline but were unsuccessful at controlling the fire. At 21:22, after evacuating the cargo decks and activating the emergency ventilation stop, the vessel's fixed carbon dioxide system was discharged for 10 minutes into cargo decks 6 to 11. The vessel's crew members then formed fire teams and deployed hoselines to fight vehicle fires and conduct boundary cooling. At 21:25 hours, fire department units were dispatched to a reported fire aboard the ro/ro vessel: Engines 5, 14, 16, 27; Ladders 4, 5, 8; Rescue 1l; Battalions 4, 5, and DC1. The incident commander staged at the top of the rear/stern ramp on deck 3 and was joined by the vessel's Chief Mate to provide an update on the situation. The incident commander canceled all mutual aid at 21:47 hours. Between 21:36 – 22:04 hours, firefighters from Engine 27 and Ladder 4 entered deck 11 and 10 to assess the fire situation and report findings. They encountered heavy smoke conditions on deck 11 and active fire on deck 10. Firefighters discovered their fire department hose did not connect to the vessel's hose stations. They used the vessel's hoses to extinguish vehicle fires on deck 10. At 22:14 hours, Ladder 4's captain noticed structural damage, including a twisted/warped steel I-beam, and left the deck to provide an update on the conditions. At 22:17 hours, Engine 16's captain and firefighter (deceased firefighter)

Photo 1: A view of the marine vessel fire in port. (*Courtesy of U.S. Coast Guard*)

entered deck 10 and assisted the remaining Ladder 4 firefighter (deceased firefighter). Conditions rapidly deteriorated and all three firefighters were ordered to withdraw. While evacuating, Engine 16's captain realized he was no longer in contact with the other firefighters. At 22:23 hours, a Mayday was called by a firefighter stating they were lost. Ladder 5 and Rescue 1 were deployed to deck 10 to search for the missing firefighters. Engine 16 firefighter was located by Ladder 5 and Rescue 1 at 22:40 hours. From 22:41 to 23:58 hours, firefighters from several companies rotated in and out on deck 10 to facilitate the rescue of the Engine 16 firefighter. Mutual aid resources were requested and began to arrive on-scene. Ladder 4 firefighter was located on deck 10 at 02:08 hours the next day, July 6, 2023. Both firefighters were removed from the vessel and pronounced deceased upon arrival to the hospital. At 06:40 hours, all onboard firefighting efforts ceased, and the vessel's crew abandoned the ship. The fire was finally extinguished by a private team of salvors/marine vessel firefighters on July 10, 2023.

Contributing Factors

- *Pre-planning for marine vessel fires*
- *Training on marine vessel firefighting*
- *Coordination with marine vessel fire response efforts*
- *Request and use of mutual aid resources*
- *Unified command with marine vessel representatives.*

Key Recommendations

Fire departments should:

- *Develop and maintain a comprehensive pre-fire plan for marine vessels per NFPA 1405, Guide for Land-Based Fire Departments that Respond to Marine Vessel Fires.*
- *Train fire officers and firefighters in marine vessel firefighting.*
- *Coordinate with marine vessel crew members and fire teams.*
- *Request and utilize mutual aid resources for all marine vessel incidents, such as fires, as early in the incident as possible.*
- *Establish and maintain unified command with marine vessel representatives throughout the incident.*

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Introduction

On July 5, 2023, two career land-based firefighters died after becoming lost and running out of air while conducting a fire attack during a marine vessel fire in port. On July 9, 2023, the U.S. Fire Administration (USFA) notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. From July 23 through August 5, 2023, a NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) investigator traveled to New Jersey to investigate this incident. NIOSH worked as a "partner agency" in a joint federal investigation with the Bureau of Alcohol Tobacco, Firearms and Explosives (ATF), National Transportation Safety Board (NTSB), and U.S. Coast Guard. The joint investigation team also worked with local and state agencies to include the Port Authority of New York & New Jersey and the New Jersey State Fire Marshal's Office. The joint investigation team met with representatives from numerous emergency response agencies involved in the incident, including local law enforcement and the responding fire departments. The investigation team also met with representatives of the Emergency Communications Center and Coroner's Office. The NIOSH investigator inspected and documented the personal protective equipment (PPE) including the self-contained breathing apparatus (SCBA) used by the deceased firefighters. The NIOSH investigator also reviewed the training records of specific personnel involved in the incident and the department's standard operating procedures and professional development program.

Fire Department

The career fire department in this incident has a 25 square mile jurisdiction, serves a population of 300,000 residents, and annually responds to an average of 16,700 calls. The fire department's jurisdiction consists of varying structures and occupancy types in a dense urban area. The response area also includes multiple waterways and one of the largest commercial shipping ports on the east coast.

The fire department's fire suppression division operates 16 engine companies, 8 ladder companies, and 2 rescue companies across 16 fire stations. Each company is typically staffed with four personnel with a minimum of three based on overall department staffing levels. The stations are organized into four battalions with each battalion supervised by a battalion chief and the overall shift under the leadership of a tour commander/deputy chief. Shifts operate on a 24-hour schedule followed by 72-hours off-duty.

The fire department has six divisions each with a unique purpose:

- Fire suppression division includes multiple special operations units such as hazardous materials response and urban search and rescue
- Training division provides professional development
- Arson squad responds to fires that appear to be suspicious in nature
- Fire prevention bureau enforces the Uniform Code of the State of New Jersey
- Community relations division educates the community on fire safety
- Special services division supplies firefighting equipment and gear

The fire department also operates two marine units/fire boats. This includes Fireboat 1, a 51-foot vessel with multiple deck mounted water monitors and Fireboat 2, a 27-foot vessel. These marine units are cross staffed by personnel from Engine 27 and Ladder 4. During the incident, neither of these marine units responded.

Training, Education, and Professional Development

The fire department involved in this incident did not have any formal, written guidance for marine vessel fires. It also did not have a mandatory marine vessel fire training program for its personnel. However, the fire department had conducted limited training in the past related to marine vessel fires including:

- June 2023, *Maritime Electric Vehicle Fire Seminar* (3-hours in length) provided by the Port Authority of New York & New Jersey, in conjunction with the New Jersey Office of Homeland Security and Preparedness.
    - The training provided awareness of marine vessel hazards through a brief video that provided a virtual walk through of a ro/ro vessel cargo deck. The seminar did not provide training on marine vessel firefighting tactics but did provide awareness on the dangers associated with lithium-ion batteries in maritime shipping environments.
- July – August 2014, *Marine Firefighting One, Marine Firefighting Two.*
    - Included a practical exercise.
- June 2016, *Boat Operator Simulator Training*, provided by the New York Police Department Counterterrorism Division for the fire department's marine units (Ladder 4 and Engine 27).
    - Focused on the operation of small watercrafts similar to the fire department's fireboats.

Engine 16 (deceased firefighter) held the rank of firefighter and had approximately 10 years of service with the fire department. He did not attend any of the offered trainings related to marine vessel fires. He completed the following New Jersey state training and certifications:

- Fire Fighter 1 & 2
- Hazardous Materials: Awareness & Operations
- Incident Management 1

Ladder 4 (deceased firefighter) held the rank of firefighter and had approximately 17 years of service with the fire department. He attended all the offered trainings related to marine vessel fires. He completed the following New Jersey training and certifications:

- Fire Fighter 1 & 2
- Hazardous Materials: Awareness & Operations
- Incident Management 1

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Apparatus, Staffing, and Communications

At 21:24 hours, the dispatch center (Dispatch) received a call from the Port Authority Police Department advising there was a fire aboard the ro/ro vessel.

At approximately 21:25 hours, the fire department dispatched the following units:

- Engines 5, 14, 16, 27
- Ladders 4, 5, 8
- Rescue 1
- Battalions 4, 5, and Deputy Chief 1 (DC1)

At the time of this incident, the county Public Safety Answering Point (PSAP) dispatched for 12 EMS agencies and 20 fire departments.

Marine Vessel Characteristics, Suppression System, and Cargo

The vessel involved in this incident was a 692-foot roll-on/roll-off (ro/ro) vessel that had a crew of 28, was built in 2011, and flagged in Italy (**see Photo 2**). Ro/ro vessels are specially designed ships that carry automobiles and other vehicles. Their construction can include low overheads, numerous decks, and straight and flat sides. Ro/ro ships often carry containers on deck in addition to vehicles [NFPA 1405 2020]. On the day of the incident, the vessel was in port to load approximately 920 used vehicles for export, an approximately 15-hour process. The vessel regularly transported used vehicles via transatlantic crossings from ports on the East Coast of the United States to ports on the African West Coast. The vessel's crew members were foreign nationals, and English was not their primary language. This language barrier posed a communication challenge throughout the incident. A short glossary of marine vessel terms can be found in **Appendix One**.

Characteristics

The vessel had 12 decks. In the front half of the vessel, vehicles were stored internally on decks 1-5 and cargo containers were stacked in the open on deck 6 for transport. In the rear half of the vessel, vehicles were stored internally on decks 3-11, and in the open on deck 12 for transport (**see Diagram 1 and 2**). Vehicles were loaded using a rear/stern ramp that led up to deck 3 (**see Photo 3**). During this incident, responding firefighters accessed the vessel to the incident fire decks via:

- The rear/stern ramp from the dock to deck 3
- Walking forward on deck 3 to the starboard ladderwell
- Climbing the starboard ladderwell from deck 3 to deck 11
- Exiting the starboard ladderwell at deck 11 and accessing an external set of stairs to deck 12 (necessary because the ladderwell did not extend to deck 12)
- Traversing from the starboard side across deck 12 to the port side
- Accessing the port ladderwell and descending to decks 11 or 10 (incident fire location)

Firefighters were guided along this route by the vessel's crew members. Vessel crew members directed use of the starboard ladderwell, instead of the port ladderwell, because this route was specified in the vessel's fire control and safety plan as the fire emergency route. This route was specified because the starboard ladderwell was "blind," absent of openings, onto decks 7-11. The lack of openings ensured

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that a door/hatchway could not be left open on those decks allowing smoke or fire to spread into the ladderwell. While this was a protected route, it required firefighters to travel a much longer distance to reach decks 10 and 11. The port ladderwell did provide direct access to decks 10 and 11 and was used during the fire department's firefighting actions. The vessel's steel structure impeded radio transmissions throughout the incident.

Photo 2. View of the vessel showing the open cargo container storage area in the front half of the vessel and the enclosed vehicle storage area in the rear half of the vessel.

(Courtesy of U.S. Coast Guard)

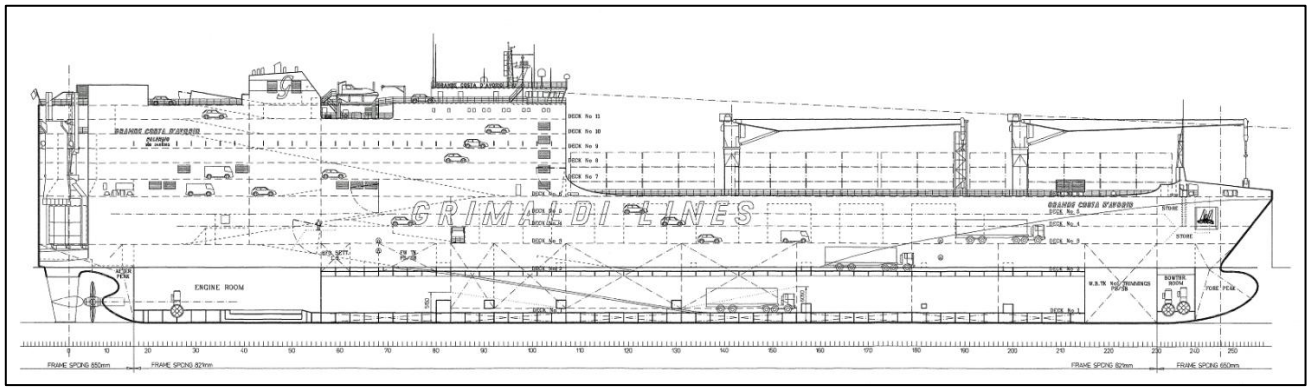

Diagram 1. View of the vessel showing the deck and cargo layouts.

(Courtesy of U.S. Coast Guard)

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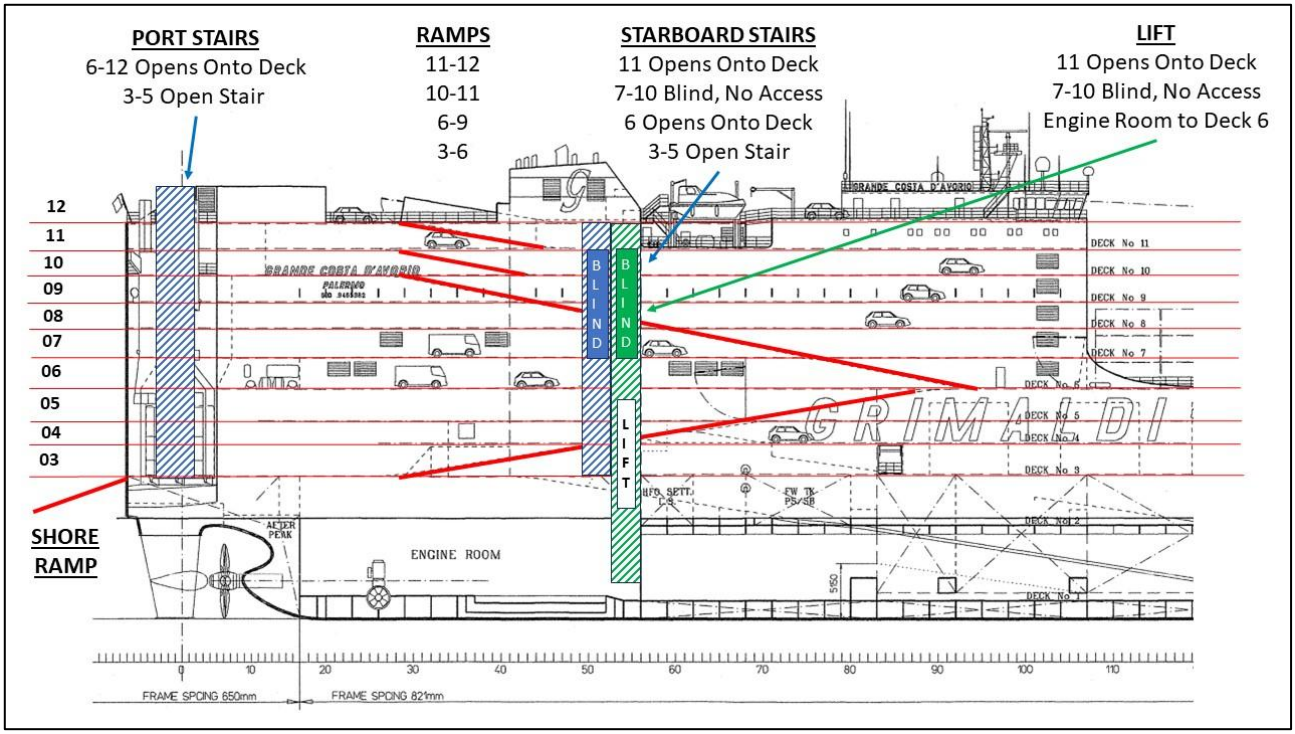

Diagram 2. View of the vessel showing the access between the various decks including ladderwells, the personnel lift (elevator), and vehicle ramps.

(Courtesy of U.S. Coast Guard)

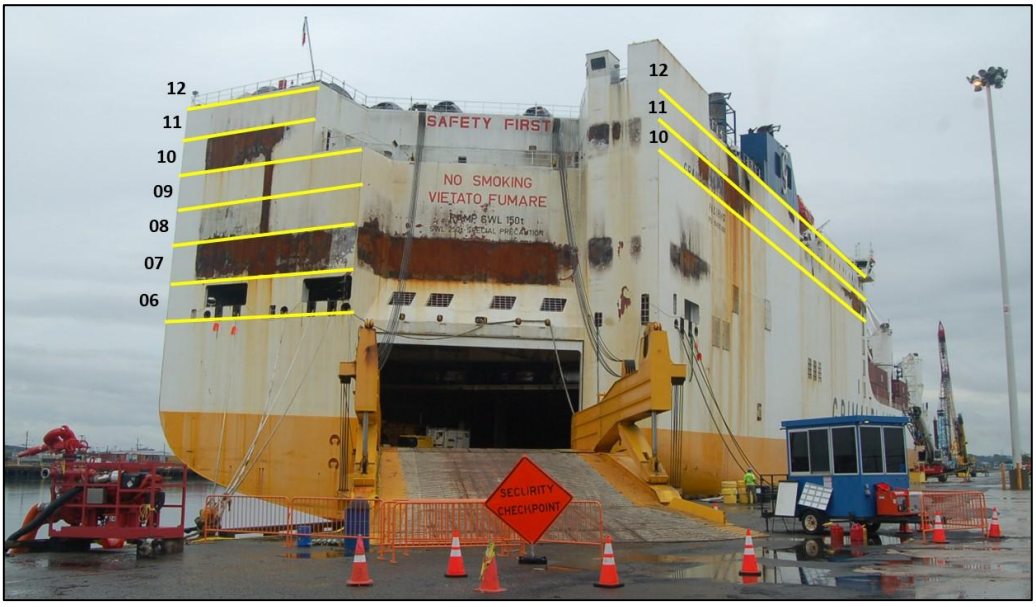

Photo 3. View of the vessel from the rear/stern with the deck levels noted. The rear/stern vehicle ramp is shown, which was used by all personnel during the incident to access deck 3.

(Courtesy of NIOSH)

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Fixed Suppression System

The vessel had a fixed, low-pressure, carbon dioxide fire suppression system. This type of system was used as an alternative to a water-based sprinkler system. Water-based systems release large amounts of water and may cause operational and stability issues if the water is not properly controlled by pumps. The carbon dioxide was stored in a liquid state in a refrigerated tank in a dedicated compartment in the mechanical space in the lower rear decks of the vessel. The carbon dioxide could be manually released when warranted via a network of piping and diffuser nozzles running throughout the vessel. The vessel was organized into six fire protection zones for the carbon dioxide suppression system (**see Diagram 3**). Zones A-C (cargo decks) were designed to have carbon dioxide discharged for 10 minutes to reach the intended concentrations for effective fire suppression.

The remaining zones for the steering gear, engine, and separator rooms were designed to have carbon dioxide discharged for two minutes to reach the intended concentrations. The primary controls for the system were in the carbon dioxide room on deck 3 and controlled the discharge of carbon dioxide into any of the six zones. Secondary controls for discharge into Zone A-C were located behind the navigation bridge on deck 12, and secondary controls for discharge into the steering gear, engine, and separator rooms were located at the Cargo Control Room on deck 3. The decks where the fire was located were in zone C, which included decks 6-11 in the rear half of the vessel.

When released into a space, carbon dioxide displaces the oxygen, lowering the levels to a point where combustion can no longer take place. To achieve the necessary concentration of carbon dioxide in a space it must be sealed to prevent carbon dioxide from escaping and fresh air from entering. Within this vessel, this was accomplished by shutting down the ventilation system and closing the weathertight doors (WTDs) that provided access to the vehicle ramps and decks in the rear half of the vessel.

The vessel maintained a fire alarm system, fire pumps, and dry chemical fire extinguishers. In accordance with marine regulations, the vessel was equipped with two sets of full firefighting PPE. Set #1 was in fire locker #1 located on the starboard side of deck 11. Set #2 was in fire locker #2 located on deck 12 just behind the bridge. The vessel's crew members were trained in firefighting on the vessel. This included the use of boundary cooling tactics which is the process of flowing water from hoselines on the vessel's hatchways, decks, and bulkheads to cool the steel to preserve structural integrity.

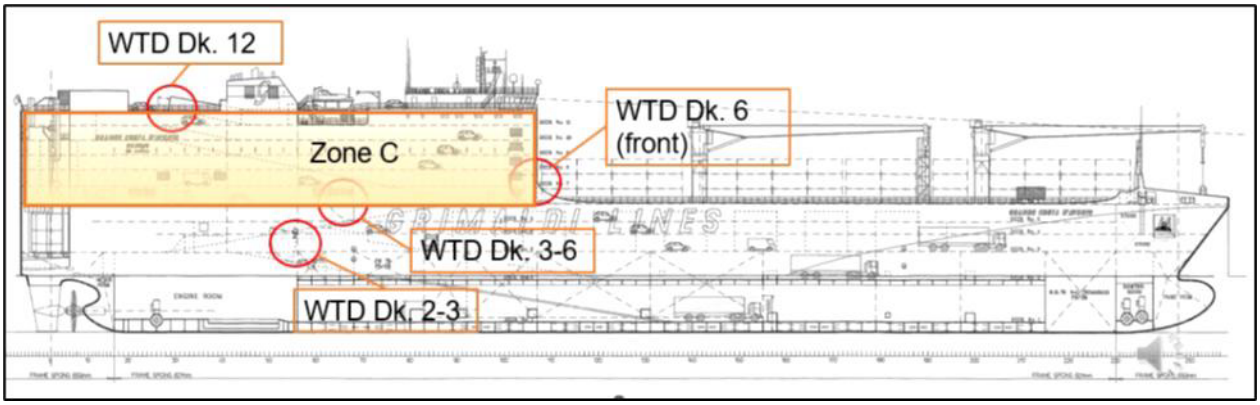

Diagram 3. Vessel fire protection zones and weather tight doors (WTDs).

(Courtesy of U.S. Coast Guard)

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Cargo

The cargo was comprised of used vehicles such as sedans, trucks, and vans. The vehicles were loaded using three methods based on their operational condition. Fully operational vehicles were driven directly onto the vessel by a port-based worker. Vehicles that were not fully operational, but with functional steering and braking, were pushed on the vessel using a "pusher vehicle." These pusher vehicles were regular vehicles that were modified to add a push bar on the front. Vehicles that were not fully operational or lacked steering or breaking were loaded with heavy equipment. The vehicles were loaded via the rear/stern ramp which led to deck 3. From there, they were driven up a series of ramps that connected the decks to the location where they were stored and secured for transport.

Incident Timeline

The following timeline is a summary of events that occurred as the incident evolved shortly after 21:00 hours on July 5, 2023. Not all incident events are included in this timeline. The times are to the minute and were taken from the fire departments' *National Fire Incident Reporting System* (NFIRS) fire reports, dispatch log, on-scene accountability documentation, and interview notes.

Time	Fireground Operations, Response, and Details
July 5, 2023	
07:00 Hours	• Ro/ro cargo loading operations begin.
20:58 Hours	• Pusher vehicle loads an inoperable sedan onto the vessel with operator noticing the pusher vehicle starting to operate erratically and make an unusual noise.
21:00 Hours	• Pusher vehicle and sedan arrive on deck 10. • Port workers and vessel crew members notice pusher vehicle is on fire. • Vessel fire alarm activated.
21:01 – 21:14 Hours	• Portable fire extinguishers and a hoseline are used unsuccessfully to extinguish vehicle fire. • Emergency ventilation stop are activated, closing the louvered vents that supplied fresh air and stopped the ventilation fans that exhausted air from the decks. • Hoselines deployed on decks 9 and 10 by vessel crew members.
21:15 – 21:21 Hours	• Evacuation of decks with active fire and preparation for a release of the carbon dioxide system. • Crew members secure the WTDs, except WTD deck 12. Crew members were unable to access the WTD deck 12 controls due to the heat and smoke exhausting from the door. As a result, this WTD did not seal properly. • Fire breaks out on deck 12 in the vehicles.

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Time	Fireground Operations, Response, and Details
21:22 Hours	• Accountability of all vessel crew members and the evacuation of port-based workers confirmed. • Carbon dioxide system discharged in Zone C. • Fire teams deploy multiple hoselines on deck 12 to fight vehicle fires and conduct boundary cooling.
21:24 Hours	• Dispatch receives a call from the Port Authority Police Department advising there was a fire aboard the vessel.
21:25 Hours	• Fire department units dispatched: Engines 5, 14, 16, 27; Ladders 4, 5, 8; Rescue l; Battalions 4, 5, and DC1.
21:32 Hours	• Engine 27 arrives on-scene.
21:35 Hours	• Battalion Chief 5 (BC5) arrives on-scene and assumes command and staged at the top of the rear/stern ramp on deck 3. • Chief Mate meets with BC5 to provide update on situation.
21:36 – 21:40 Hours	• Engine 27 enters deck 11 to assess conditions and report findings to BC5 noting heavy smoke but no active fire.
21:41 Hours	• DC1 arrives on-scene and assumes command from BC5. • BC5 stages on deck 12 and serves as command of operations.
21:43 Hours	• Battalion Chief 4 (BC4) and Ladder 4 arrive on-scene and check in at the rear/stern of deck 3.
21:47 Hours	• Dispatch advises DC1 that mutual aid resources, including a fireboat unit, were responding. DC1 responds to Dispatch requesting cancelation of all mutual aid resources.
21:50 Hours	• Engine 27 and Ladder 4 requested to check conditions on deck 10.
22:00 Hours	• Vessel's Chief Mate and Bosun report to the WTD on deck 12 and try to manually close it with no success. This malfunction contributed to the limited impact of the carbon dioxide suppression system.
22:04 Hours	• Engine 27 advises BC5 that they had an active fire on deck 10 and they needed to get a hoseline in place for fire attack.

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Time	Fireground Operations, Response, and Details
22:06 – 22:12 Hours	• Firefighters attempt to connect the fire department hose to the vessel's hose station and realize that hose fittings were not compatible and suitable adapters were not present.
22:14 Hours	• Ladder 4 enters deck 10 and begins to extinguish vehicle fires. • Ladder 4's captain uses a thermal imaging camera and notes that the steel I-beam directly above the fire's location is twisted/warped and there was a significant amount of heat in the ceiling. • Ladder 4's captain leaves deck 10 for a face-to-face due to radio issues to alert BC4 of the conditions. Ladder 4 firefighter (deceased firefighter) remains on deck 10. • Ladder 4's captain is ordered to deck 12 to rehab due to the soles of his boots separating.
22:17 Hours	• Engine 16's captain and firefighter (deceased firefighter) enter deck 10 and assist the remaining Ladder 4 firefighter.
22:19 Hours	• Conditions deteriorate on deck 10 and BC4 makes multiple radio transmissions requesting Engine 16 withdraw.
22:22 Hours	• Engine 16's captain orders the Ladder 4 firefighter, who was experiencing a low air alarm on his SCBA, to lead the group out followed by the Engine 16 firefighter. The group began following the hoseline back out of deck 10 in zero visibility conditions. • An event occurs within the decks that forces heavy black smoke and heat out of the deck 10 hatchway and into the ladderwell, forcing the staged firefighters to evacuate.
22:23 Hours	• Engine 16's captain realizes he is no longer in contact with the Engine 16 firefighter and Ladder 4 firefighter. He becomes disoriented and makes a Mayday transmission that is not heard due to the steel structure of the vessel. • A firefighter makes a Mayday call stating, *"We cannot find our way out. We are lost."*
22:24 – 22:29 Hours	• Dispatch calls BC4 and DC1 requesting confirmation that they heard the Mayday. • Dispatch sounds the radio emergency alert tones to alert on-scene personnel of the Mayday. For the next several minutes, there are numerous radio transmissions made by multiple firefighters and

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Time	Fireground Operations, Response, and Details
	Dispatch to determine the details of the Mayday and which firefighters needed assistance.
22:30 Hours	• DC1 requests a Personnel Accountability Report (PAR). • PAR confirmed for all units but Engine 16 and Ladder 4.
22:32 Hours	• Ladder 5 and Rescue 1 deployed to deck 10 to search for the missing firefighters.
22:34 – 22:40 Hours	• Ladder 5 locates the missing Engine 16 firefighter who is wedged between two vehicles and is unconscious. • Ladder 5 advised BC5 via radio that they have located a firefighter and need help.
22:41 Hours	• Multiple firefighters from several companies rotate in and out on deck 10 to facilitate the rescue of the Engine 16 firefighter.
22:49 Hours	• Chief of Department (C1) self-dispatches and arrives on-scene. He does not assume Command.
23:06 Hours	• Vessel's crew members discover that the fire is rapidly developing on deck 11 and causing vehicle fires on deck 12 to reignite.
23:13 Hours	• C1 contacts Dispatch and requests the response of mutual aid resources and a third alarm.
23:45 Hours	• BC4 and BC5 request that the vessel's ventilation system be turned back on to remove smoke and heat from deck 10 to aid the search and rescue operations. • Ventilation system improves smoke and heat conditions on deck 10 but feeds fresh air into deck 11, which rapidly intensifies and spreads the fire.
23:57 Hours	• DC1 requests a PAR. • PAR confirmed for all units but Engine 16 and Ladder 4.
23:58 Hours	• Engine 16 firefighter is freed from between the vehicles and begins to be removed from deck 10.
July 6, 2023	

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Time	Fireground Operations, Response, and Details
00:16 Hours	• A Mayday was called by Engine 10 for firefighters with the mutual aid rescue in the port ladderwell at deck 9. These firefighters ran out of air and were suffering from smoke inhalation. This Mayday caused some confusion for DC1 when it was cleared as some on-scene personnel believed this was the lost firefighter. • Members from another mutual aid rescue responded to the Mayday and began evacuating the firefighters down the port stairwell.
00:45 Hours	• The vessel's crew members use the vessel's provision crane to lower the Engine 16 firefighter to the pier where he was transported by EMS to the hospital and pronounced deceased.
00:49 Hours	• Search continues for the missing Ladder 4 firefighter.
01:14 – 02:07 Hours	• Multiple mutual aid rescue companies search various decks for the missing Ladder 4 firefighter.
02:08 Hours	• Missing Ladder 4 firefighter located on deck 10, he is unconscious with his facepiece removed. • Removal process from deck 10 begins.
03:06 Hours	• Ladder 4 firefighter is on the dock and turned over to EMS. He is transported to the hospital where he is pronounced deceased.
06:40 Hours	• All onboard firefighting efforts cease, and the vessel's crew abandons the ship.
July 10, 2023	
	• Fire is extinguished by a private team of salvors/marine vessel firefighters.

Personal Protective Equipment

At the time of the incident, both firefighters were wearing full structural firefighting turnout gear. Both firefighters were wearing NIOSH Approved® SCBAs. The NIOSH investigator examined and documented the PPE at the local law enforcement agency. Both the NIOSH investigator and a representative of the SCBA manufacturer examined the SCBAs. It was determined that the function of the deceased firefighters' PPE and SCBAs were not contributing factors in this incident. No further evaluation or testing of the turnout gear and SCBA was conducted by NIOSH.

Weather Conditions

On July 5, 2023, at 21:24 hours, the weather conditions were as follows: temperature of 84° F, humidity of 65%, with variable winds at 8mph, no precipitation, and fair conditions [Weather Underground 2023].

Investigation: Pre-Fire Department Response

On the morning of July 5, 2023, the ro/ro vessel arrived at the port of New Jersey. The vessel was scheduled to load approximately 920 used vehicles at this port location, in a process that would take approximately 15 hours. At approximately 07:00 hours, the vehicle loading operation began with port-based workers loading the vehicles onto the vessel under the oversight of the vessel's crew members.

At 20:58 hours, a pusher vehicle, operated by a port-based employee, pushed an inoperable sedan steered by another port-based employee up the rear/stern ramp of the vessel. The worker operating the pusher noted that it started to operate erratically and created an unusual noise. At approximately 21:00 hours, the pusher and the sedan arrived on deck 10. Upon arrival, several port workers and some of the vessel crew members began to yell that the pusher was on fire. The pusher operator witnessed flames coming from under the front half of the vehicle and the engine compartment. The operator exited the pusher and noticed that fire was "dripping down" onto the deck from the underside of the vehicle. The pusher operator retrieved a portable dry chemical fire extinguisher from the bulkhead of the vessel and attempted to extinguish the fire. The vessel's fire alarm was then activated. The vessel's Chief Mate and another crew member who observed the fire also started using portable dry chemical fire extinguishers to fight the fire. These efforts were ineffective, and the fire continued to grow.

The Chief Mate radioed the Third Mate via his portable UHF radio advising him of the fire on deck 10. He requested that the Third Mate shut down the ventilation system, notify the vessel's Captain (VC), and then respond to deck 10 to assist with the firefighting operations. The Third Mate notified the VC, who was off duty in his stateroom, of the situation. After being notified by the Third Mate, the VC reported to the bridge.

At approximately 21:06 hours, the VC reached the bridge and activated the emergency ventilation stop, which closed the louvered vents that supplied fresh air and stopped the ventilation fans that exhausted air from the decks. He also started the vessel's fire pump which supplied water pressure to the fire hose stations. The VC called the Chief Engineer and advised him to report to the vessel's engine room and stand by for further orders. With the ventilation shut down, deck 10 rapidly filled with heavy black smoke. This impacted both visibility and the ability to breathe clean air. Realizing that the conditions were deteriorating, the Chief Mate radioed the Bosun and advised him to don full firefighting PPE (full structural firefighting gear and SCBA) and report to deck 10.

The Bosun proceeded to fire locker 1 and donned the full firefighting PPE. While they waited for the Bosun to arrive on deck 10, the Chief Mate and another crew member deployed one hoseline on deck 9 and one on deck 10. Once the fire hoses were charged, they began applying water toward the fire. Approximately 2-3 minutes later, the Bosun arrived with full firefighting PPE and took over the firefighting efforts for the vehicle fire on deck 10. The VC ordered additional vessel crew members to check decks 11 and 12 for signs of fire. The First Assistant Engineer advised that there was heavy smoke coming out of the WTD on the ramp leading up from deck 11 to deck 12. The second officer also advised that there was smoke visible on deck 11. The heat and smoke conditions on deck 10 continued to

deteriorate. The chief mate radioed the VC and advised that the conditions on deck 10 were rapidly deteriorating and that he could hear explosions from vehicle tires and windows failing.

At 21:15 hours, the VC ordered the Chief Mate and crew members to evacuate the involved decks and prepare for a release of the carbon dioxide fire suppression system. The VC ordered the crew members to secure the vessel's four large hydraulically operated WTDs. The Chief Mate, Bosun, and other crew members from Fire Team 1 that had operated on decks 9 and 10 to fight the fire, withdrew downward from those decks using the vehicle ramps. Along the pathway down those ramps, the Chief Mate closed the WTDs needed to close off the lower half of Zone C which included the two doors on deck 6, one at the top of the ramp coming up from deck 5, and one that led out onto the open cargo deck in the front half of the vessel. As a precaution, if fire spread outside of Zone C, he also closed the WTD on deck 3 at the top of the ramp coming up from deck 2.

This left the final WTD that needed to be closed to secure Zone C on deck 12 at the top of the ramp coming up from deck 11. The VC ordered the crew members with Fire Team 2 to secure this door. The vessel's Fitter, who was the hose operator for Fire Team 2, also donned full firefighting PPE, and was standing by with other crew members outside of fire locker 2 on deck 12. The only controls to close the hydraulic WTD were located approximately 5-6 feet from the entrance down inside of the ramp. Once an operator closed the door from this location, they had to use another point to exit the ramp. The closest exit route required them to travel down the ramp to deck 11. Once on deck 11, they traveled approximately 120-130 feet along the port side toward the rear/stern of the vessel where they reached the rear/stern port ladder well. The First Engineer, who was the leader of Fire Team 2, advised the VC that there was heavy black smoke and heat coming out of the WTD. He also advised that the Fitter, who had made the entry, did not believe that it was safe to carry out the operation with him being forced to exit via a walk through the adverse conditions across deck 11. The VC agreed with the high risk of that operation and instructed Fire Team 2 to use a fog pattern from a fire hose to cover the opening, creating a blockage to prevent air movement in or out of the ramp. This was not an accepted or effective technique to seal off a carbon dioxide suppression system space.

At approximately 21:17 hours, crew members observed and reported to the VC that fire had broken out in the vehicles on deck 12. The VC then called the Chief Engineer, who was responsible for operating the carbon dioxide system, and ordered him to report to the carbon dioxide room and prepare for a release of the system in Zone C. At 21:19 hours, in preparation for a release of the carbon dioxide system, the VC ordered a full muster of all crew members over the radio, repeated that order over the vessel's announcement system, and sounded the vessel's general alarm. Following this order, all vessel crew members were accounted for. After closing the lower WTDs, the Chief Mate, who was standing by on deck 3 by the rear/stern ramp, advised the VC that he observed the port-based workers exit the vessel and that he believed they were all off the vessel. He checked the decks as he evacuated down from deck 10 and did not observe any port-based workers remaining on the vessel.

At 21:22 hours, the VC had full accountability of all crew members and believed that all port-based workers evacuated the vessel. He ordered the Chief Engineer to discharge the carbon dioxide system into Zone C. Over the next 10 minutes, the system discharged roughly 20 tons of carbon dioxide into Zone C. Shortly after the system was released, the Chief Mate who moved up to deck 12, indicated that the volume and velocity of the smoke coming out of the WTD on deck 12 decreased, and that the smoke color changed from dark black to light grey. This change in conditions indicated that the carbon dioxide

had a positive impact on the fire conditions. At this time, the two Fire Teams deployed multiple hoselines on deck 12 to fight the vehicle fires that had broken out and began to conduct boundary cooling on deck 12.

Investigation: Fire Department Response

At 21:24 hours, Dispatch received a call from the Port Authority Police Department advising there was a fire aboard the ro/ro vessel (**see Photo 4**).

At approximately 21:25 hours the fire department dispatched:

- Engines 5, 14, 16, 27
- Ladders 4, 5, 8
- Rescue 1
- Battalions 4, 5, and DC1

While the fire department units were responding to the scene, several conversations took place between the DC1, Dispatch, and the Port Authority. The Port Authority advised that there were 5-6 vehicles on fire. Dispatch requested the vessel's cargo manifest from the Port Authority. DC1 requested to have Engine 27 respond to the scene via Fireboat 2. However, Engine-27 (staffed with 3) arrived on the scene at 21:32 hours and did not respond with the Fireboat. Engine 27's captain and a firefighter proceeded up the rear/stern ramp to deck 3. Engine 27's driver/operator stayed with the apparatus.

Photo 4: A view of the vessel and the conditions at the time of the fire department arrival. (*Courtesy of U.S. Coast Guard*)

Around this time, the majority of the vessel's crew members were on deck 11 providing boundary cooling and on deck 12 fighting the vehicle fires. At the top of the ramp from the dock to deck 3, the Engine 27 firefighters were met by crew members and a Port Captain (a port-based worker who assisted with the loading operations) to discuss the operational details. The Port Captain escorted the Engine 27 firefighters to the starboard ladderwell and guided them up to deck 11. They were met by the vessel's Third Mate at deck 11 for a status update.

At approximately 21:35 hours, BC5 arrived on-scene and assumed command of the incident. He staged at the top of the rear/stern ramp on deck 3. He made a request through Dispatch to have the vessel crew members bring the vessel's manifest and blueprints to him. BC5 then met with the Chief Mate who provided an update. The Chief Mate advised that the fire had started in vehicles on deck 10 and that the carbon dioxide suppression system had been discharged into the deck spaces. Language barriers between the crew members and BC5 resulted in an inadequate exchange of information.

At 21:36 hours, Engine 27's captain advised the Third Mate that they wanted to enter deck 11 to assess the situation. The Third Mate repeatedly advised that the carbon dioxide system had been discharged

into the space and that an SCBA would be required to enter it safely. The Engine 27 firefighters donned their SCBAs and entered deck 11 on the starboard side just outside of the starboard ladderwell. They searched across deck 11 from the starboard to port side, walked up the vehicle ramp from deck 11 to deck 12, and then returned to deck 11 and the original point of entry. Engine 27's captain noted that deck 11 was full of heavy smoke, but they did not identify any active fire. He reported this information via radio to BC5. The Engine 27 firefighters moved up to deck 12 where the vessel's crew had just finished extinguishing the vehicle fires on the deck.

At 21:41 hours, DC1 arrived on-scene and assumed command from BC5. This transfer of command was communicated via radio traffic as BC5 left the area and transitioned to deck 12 when DC1. A crew member escorted BC5 to deck 12, via the starboard ladderwell, and assumed command of operations. Once on deck 12, BC5 met with and spoke to the VC who advised that he had accounted for all the vessel's crew members. The VC also advised BC5 that the fire had originally started on deck 10 and that the carbon dioxide suppression had been released on decks 6-11.

At 21:42 hours, Engine 27's captain reported to BC5 that there was no fire on deck 11 and that the vehicle fires on deck 12 had been extinguished. This message was also relayed via radio to DC1. At approximately 21:43 hours, BC4 and Ladder 4 arrived on-scene and checked in at the rear/stern of deck 3. They were advised by DC1 to report to deck 12. While traveling up the starboard ladderwell, BC4 opened the hatchway on deck 6 to check the conditions. He was immediately overcome by the carbon dioxide coming out of the deck. He was able to shut the hatchway back and regain his breath before losing consciousness. He regained consciousness and was assisted away from this location.

Between 21:44 and 21:46 hours, Engine 27 firefighters used the port ladderwell located at the rear/stern of deck 12 to access deck 11 and noted that the conditions were unchanged since their last check. After this, they experienced low air in their SCBAs and returned to deck 12 to change out their SCBA cylinders. At 21:47 hours, Dispatch advised DC1 that mutual aid resources, including a fireboat unit, was responding. DC1 responded to Dispatch that they would not be needed and could be canceled. Dispatch confirmed the request and canceled all mutual aid resources.

At 21:49 hours, BC5 provided an update to DC1 via radio. He noted that he was with VC on deck 12, the crew members had hoselines in place, and the fire was knocked down. Additionally, he noted that the fire started on deck 10 and that the compartments were sealed, and the carbon dioxide system was deployed. They were sending Engine 27 firefighters check decks 11 and 10. DC1 acknowledged and noted that he sent Ladder 4 to deck 10.

At 21:50 hours, Engine 27 advised BC5 that the vessel crew members had multiple hoselines in operation on the top deck, but there was no active fire on that deck. Although the vessel crew members were conducting boundary cooling on decks 12 and 11 per their training, the Engine 27 firefighters did not understand this process, which caused confusion as to why they were flowing water without any active fire. BC5 responded to Engine 27 and requested they check the conditions on deck 10. Engine 27 responded they could not because were out-of-air and were going to change their cylinders out. BC5 then radioed Ladder 4 and asked them to check deck 10.

Around this time, BC4 reached deck 12 and conducted a face-to-face briefing with BC5. They decided that BC4 would station himself at the port ladderwell to lead operations on decks 10 and 11. BC5 would

remain at the staging area on deck 12 closer to where crews were coming out of the starboard ladderwell on deck 11 and then making the transition up to deck 12.

At 21:52 hours, BC5 provided DC1 with an update that the vessel held 5,000 vehicles, he had two confirmed fires, with the one on deck 10 not being verified. DC1 acknowledged the update. At approximately 21:53 hours, Engine 27 traveled back down the port stairwell and opened the hatchway to access deck 10. At 21:54 hours, Engine 27 radioed to BC5 that there was heavy smoke on deck 10. They entered deck 10 and started checking it for fire.

At approximately 22:00 hours, the vessel's Chief Mate and Bosun reported to the WTD on deck 12. They determined that given the improvement in conditions and reports of no fire on deck 11, they could attempt to close the WTD (**see Photos 5 and 6**). An attempt was made to close the door, but a fault/malfunction light appeared on the control panel indicating that the door would not operate. They decided to cease and consider other options.

Photo 5. WTD on deck 12 that failed to close.

(Courtesy of NIOSH)

Photo 6. Inside the WTD, showing the door controls on the left.

(Courtesy of NIOSH)

At 22:04 hours, Engine 27 advised BC5 that they had an active fire condition on deck 10 and they needed to get a hoseline in place for fire attack. During this timeframe, the hatchway from the port stairwell leading into deck 10 was left open allowing fresh air to flow into deck 10. BC5 acknowledged the request and advised Engine 27 to secure a hoseline from one of the vessel's teams operating on deck 12. BC5 and BC4 confirmed there was fire on deck 10 with BC4 advising DC1 that they had confirmed that there was fire on deck 10.

Between 22:06 and 22:12 hours, there were requests for firefighters to bring additional lengths of hoseline to deck 12. The original plan was to connect the fire department hose to the vessel's hose station so that a hoseline could be extended from deck 12 to deck 10 for fire attack. Once the firefighters attempted to connect the fire department hose to the vessel's hose station, they realized that the hose fittings were not compatible. The vessel's hose was a 1½ metric diameter with an international coupling (**see Photos 7 and 8**).

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Photos 7 and 8. Vessel's 1½ inch fire hose and coupling.

(Courtesy of NIOSH)

Due to the incompatibility, additional lengths of hose were then brought by vessel crew members and connected to a hoseline already in use from a hose station towards the rear/stern of deck 12. Working together, the firefighters and crew members deployed the operational hoseline to deck 10. Once there, Engine 27 firefighters deployed it into deck 10 and initiated fire attack on the original vehicles which had reignited. Once the fire was knocked down, they left the hoseline in place and exited deck 10 via the port ladderwell.

At approximately 22:14 hours, BC4 ordered Ladder 4 to enter deck 10, follow the hoseline that Engine 27 left in place, and provide a status report on conditions. At this time, BC4 was stationed in the port ladderwell at the entrance to deck 10. Ladder 4 followed the hoseline into deck 10 with the smoke conditions getting heavier as they advanced further into the deck. When they reached the nozzle, there were small pockets of fire left in the vehicles, which they extinguished. Ladder 4's captain assessed the situation using a thermal imaging camera and noted that the steel I-beam directly above the fire's location was twisted/warped and there was a significant amount of heat in the ceiling.

Ladder 4's captain tried to relay this information to BC4 via radio, but the radio transmission failed due to interference from the vessel's steel structure. Ladder 4's captain noticed firefighters from Engine 16 in the vicinity, and he decided to follow the hoseline back to the deck 10 hatchway to alert BC4 of the situation face-to-face. A Ladder 4 firefighter (deceased firefighter) remained to ensure the fire was extinguished. At approximately 22:17 hours, BC4 ordered Engine 16's captain and firefighter (deceased firefighter) to enter deck 10 and assist the Ladder 4 firefighter as needed. They entered deck 10, followed the hoseline to the nozzle where they found the Ladder 4 firefighter working to overhaul the burning vehicles.

At approximately 22:18 hours, Ladder 4's captain reached the deck 10 hatchway and reported on the warped I-beam and high ceiling heat level conditions. BC4 relayed to DC1 that there were multiple vehicles on fire, the fire had been knocked down, and they were mopping up. DC1 acknowledged the report. Standing in the port ladderwell, Ladder 4's captain realized that the soles of his fire boots had separated and that his feet were possibly injured. He advised BC4 of the situation, who told him to evacuate back up to deck 12.

The other two members of Ladder 4 entered deck 10. They followed the hoseline, stopping several times along the way to straighten the hoseline, which was tangled up. They reached the area where Engine 16 and the other Ladder 4 firefighters were operating. They then worked to overhaul the burning vehicles. They observed no additional fire but recognized that the smoke and heat levels were rising. Concerned about their air supply, two of the Ladder 4 firefighters returned to the hatchway and provided BC4 with an update.

At 22:19 hours, Engine 16's captain advised via radio that they were on the hoseline with Ladder 4 and were going to push on as there was no additional fire at that time. At the same time a Ladder 4 firefighter reached the hatchway and advised BC4 of the deteriorating conditions. Hearing that the vessel's structure had possibly been impacted by the fire and that smoke and heat conditions were deteriorating, BC4 requested Engine 16 to withdraw from deck 10. BC4 made multiple radio transmissions from 22:20 to 22:22 hours ordering Engine 16 to bring the hoseline back out. Engine 16 did not respond to any of these radio calls.

At 22:22 hours, Dispatch also attempted to reach Engine 16 with no response. While BC4's order to withdraw was not acknowledged on the radio, Engine 16's captain heard one of the transmissions and advised Engine 16 firefighter and Ladder 4's firefighter (deceased firefighters) to withdraw. Engine 16's captain ordered the Ladder 4 firefighter, who was experiencing a low air alarm on his SCBA, to lead the group out followed by the Engine 16 firefighter. The group began following the hoseline back out of deck 10 in zero visibility conditions.

While waiting in the port ladderwell for the Engine 16 and Ladder 4 firefighters, an event occurred within the decks that forced heavy black smoke and heat out of the deck 10 hatchway and into the ladderwell. This caused the conditions in the ladderwell to rapidly deteriorate, forcing the firefighters there to evacuate. Some of the firefighters evacuated upward to deck 12 and others evacuated down the ladderwell. BC4 left the port ladderwell and went to meet BC5 on deck 12 to tell him what happened.

Mayday Transmissions

At 22:23 hours, Engine 16's captain, who was verbally and physically guiding the firefighters out, realized that he was no longer in contact. At that time, he came to a loop/pile of hose and was struggling to maintain his orientation on the hose. He made a Mayday call alerting that he was separated from his firefighters and disoriented. Due to the steel structure of the vessel, this Mayday call was not captured by the radio communication system. A firefighter then made a Mayday call stating, *"We cannot find our way out. We are lost."*

At 22:24 hours, Dispatch called BC4 and DC1 requesting confirmation that they heard the Mayday. DC1 replied *"Negative,"* and Dispatch advised that a firefighter reported that he could not find his way back out. An additional radio transmission was made by Engine 16's firefighter with the first part being inaudible and the final part being, *"We are lost."*

Engine 16's captain, while disoriented on the hoseline, traveled in a constant direction, which he believed was the direction of the port ladderwell. He reached the port bulkhead and followed it back to the hatchway at the port ladderwell. He took the ladderwell back to deck 12 and alerted the BC4 and BC5 of the situation.

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Dispatch then sounded the radio emergency alert tones to alert on-scene personnel of the Mayday. For the next several minutes, there were numerous radio transmissions made by firefighters and Dispatch to determine the details of the Mayday, and which firefighters needed assistance.

At 22:30 hours, DC1 requested a PAR, with the responses being:

- PAR: Engine 5, Engine 14, Engine 27, Ladder 5, Ladder 8, Rescue 1, BC4, BC5, DC1
- Engine 16's firefighter was missing
- Ladder 4 was missing two firefighters

Dispatch advised DC1 that there were four firefighters, two from Engine 16 and two from Ladder 4, who were still missing. The two firefighters from Ladder 4, who were being reported as missing, had traversed down the port ladderwell when the smoke and heat rushed out into the ladderwell at 22:22 hours. They ultimately made their way down and out of the ladderwell onto deck 3. Those firefighters attempted to respond to the PAR via radio, and eventually one of them advised that they were evacuating and that Engine 16's firefighter and Ladder 4's firefighter were in distress on deck 10.

At 22:32 hours, DC1 advised via the radio that Ladder 5 and Rescue 1 had been deployed as a Firefighter Assist and Search Team (FAST). DC1 also requested a progress report on the fire from BC5 and requested additional units from Dispatch. At 22:34 hours, DC1 requested an update from BC4 who advised that Ladder 5 was entering deck 10 following the hoseline in place and that he had a backup crew ready to go behind them. DC1 acknowledged and advised that all personnel entering should use a rope. At 22:35 hours, Engine 10 and Engine 29 were dispatched. DC1 advised Dispatch that he had the two missing Ladder 4 firefighters at the staging area. At 22:36 hours, BC5 confirmed accountability with DC1 that all personnel were accounted for except the Engine 16 firefighter and Ladder 4 firefighter.

At approximately 22:34 hours, two members of Ladder 5 entered deck 10 and began searching for the two missing firefighters. The other two members of Ladder 5 stood by in the port ladderwell. Conditions were heavy smoke with zero visibility, but there was no active fire on deck 10. They followed the hoseline to the nozzle. Once they reached the nozzle, they attached a search rope to one of the burned-out vehicles and continued their search efforts. At that time, they heard a personal alert safety system (PASS) alarm sounding nearby. Using a thermal imaging camera to help navigate through the maze of vehicles, Ladder 5 moved towards the sound of the PASS. After traveling approximately 35-40 feet from where the search rope was secured, they located the Engine 16 firefighter who was in an upright standing position, wedged between an SUV and truck. He was unconscious and did not respond to voice commands. His helmet was off and his facepiece was partially off of his face. Ladder 5 worked to remove the Engine 16 firefighter from between the vehicles. A member of Ladder 5 utilized a rapid intervention kit to place a facepiece on the Engine 16 firefighter to provide an active air supply. Engine 16 firefighter remained unconscious and unresponsive throughout the process.

From approximately 22:37 to 22:40 hours, BC4 requested via radio for Ladder 5 to withdraw from deck 10. Several inaudible transmissions were heard on the radio at that time. At 22:40 hours, Ladder 5 advised via radio that they located a firefighter and needed help.

Rescue Operations for Engine 16 Firefighter

Between 22:41 to 23:58 hours, multiple firefighters from several companies rotated in and out on deck 10 to facilitate the rescue of Engine 16 firefighter. The rescue teams were forced to cut the lashing straps holding the vehicles in place and utilize battery powered hydraulic extrication tools to move the vehicles enough to free Engine 16 firefighter. Throughout this rescue period, Engine 16 firefighter was supplied breathing air via the rapid intervention kit. This was an extremely resource and labor-intensive operation due to the challenges of moving the needed equipment onto the vessel, to the staging area on deck 12, and to the rescue operations of deck 10. This was also a challenging rescue operation in terms of air management as the fire department utilized 30-minute SCBA cylinders. Multiple replacement SCBA cylinders were moved to the staging area on deck 12. The fire department's mobile cascade was out-of-service during this incident.

During this period, the fire department focused all of its personnel and resources towards the rescue of the Engine 16 firefighter and did not carry out any firefighting operations anywhere on the vessel. While there was no active fire on deck 10, the fire continued to grow on deck 11.

At 22:49 hours, there was an attempt to place a fire department aerial ladder to deck 12 to facilitate the removal of the missing firefighters once they were recovered. At 22:54 hours, based on the Mayday calls, C1 self-dispatched and arrived on-scene. C1 reported to deck 3 and spoke with DC1. C1 does not assume Command.

At 23:06 hours, the vessel's crew members discovered that the fire was rapidly developing on deck 11, leading to vehicle fires reigniting on deck 12. The crew members continued boundary cool and fire suppression activities. Boundary cooling resulted in water pooling on the surface of deck 12 which began to boil and produce steam to the point where personnel were sustaining burns. This forced the firefighters on deck 12 to seek refuge at locations out of the water, including taking shelter in or on top of the vehicles stored there.

At 23:17 hours, the VC discussed the option of discharging the carbon dioxide fire suppression system again in Zone C with DC1 and C1. DC1 decided not to allow the discharge out of fears that it would negatively impact the search and rescue operations. Based on the inability to use an aerial ladder to reach deck 12 and the coming challenge of removing the missing firefighters from deck 10, they decided that a technical rope rescue operation was warranted.

At 23:13 hours, C1 contacted Dispatch and requested the response of mutual aid resources, the Urban Area Security Initiative (UASI) Rescue from a neighboring fire department. C1 also requested a second rescue for rapid intervention. Based on this call, the rescue companies that made up the UASI Rescue, along with their Incident Management Team, began responding to the incident. A third alarm was dispatched at 23:18 hours for additional personnel and resources to support the search & rescue operations which included Engine 18, Ladder 6, Ladder 7, and BC3. At 23:35 hours, C1 requested an update on the responding UASI rescues and Dispatch advised that mutual aid resources from two fire departments were responding. C1 requested the response of a rescue from an additional mutual aid fire department. Following this request, the first mutual aid resources arrived on-scene and reported to staging.

At 23:36 hours, BC4 advised DC1 that he had spoken to the vessel's crew members, and he had confirmed that a crane on the forward/bow end of deck 12 on the starboard side could be used to lower

the missing firefighters to the dock (**see Photo 9**). At 23:41 hours, the first arriving mutual aid rescue company was sent to deck 10 to assist with the rescue operations. At 23:45 hours, BC4 and BC5 requested that the vessel's ventilation system be turned back on. The intent was to remove smoke and heat from deck 10 to aid the search and rescue operations. The VC contacted the Chief Engineer and advised him to reopen the dampers and restart the exhaust fans. BC5 also had a hatchway in the front/bow part of deck 11 on the starboard side opened. While these efforts did initially improve the smoke and heat conditions on deck 10, they ultimately fed fresh air to deck 11 which rapidly intensified and spread the fire.

At 23:47 hours, DC1 confirmed the plan to use the crane to transport the firefighters and at 23:49 hours confirmed that there was fire on deck 11. Between 23:50 and 23:55 hours, a PAR was conducted with the following results:

- PAR: Engine 5, Engine 6, Engine 10, Engine 14, Engine 18, Engine 19, Engine 27, Engine 29, Ladder 5, Ladder 6, Ladder 7, Ladder 8, Ladder 11, Rescue1, BC1, BC4, BC5

At 23:57 hours, BC4 advised DC1 that the crane was ready for operations, and the Engine 16 firefighter was freed from between the vehicles at 23:58 hours. He was immediately carried up the ladderwell to deck 12. This labor-intensive process took approximately 10-minutes. When the Engine 16 firefighter reached deck 12, he was placed in the bed of the truck to avoid the scalding water pooling on the deck. EMS crews, who had been forward staged on deck 12, attempted lifesaving procedures.

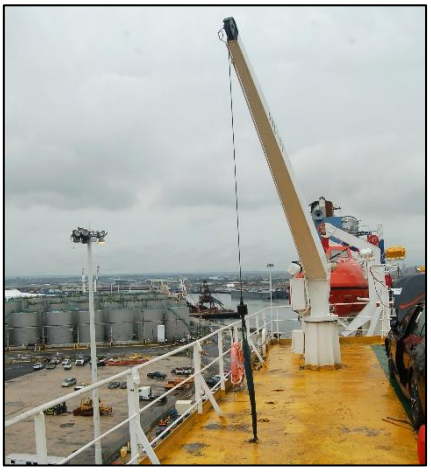

Photo 9. The vessel's crane used to lower the missing firefighters.

(Courtesy of NIOSH)

At 00:16 hours, a Mayday was called by Engine 10 for firefighters with the mutual aid rescue in the port ladderwell at deck 9. These firefighters ran out of air and were suffering from smoke inhalation. Members from another mutual aid rescue responded to the Mayday and began evacuating the firefighters down the port stairwell. This Mayday caused some confusion for DC1, when it was cleared as some on-scene personnel believed this was the lost firefighter. At 00:20 hours, calls were made by BC5 to shut down the exhaust system. The exhaust fans were discharging smoke directly out onto deck 12, impacting all firefighters staged and operating there. The vessel's crew members responded to those calls and shut the exhaust system down. At 00:30 hours, the UASI Rescue group requested assistance from an additional mutual aid fire department that had specialized personnel and equipment for technical rescue and marine vessel fires.

At 00:45 hours, firefighters carried the Engine 16 firefighter across deck 12 to the starboard side of the vessel and placed him into a stokes basket. The vessel's crew members used the vessel's provision crane to lower the Engine 16 firefighter to the pier where he was transported by EMS to the hospital and pronounced deceased.

Search for Ladder 4 Firefighter

At 00:49 hours, the search continued for the missing Ladder 4 firefighter. DC1 sent companies to the port and starboard ladder wells to search for possible areas of refuge. At 00:52 hours, DC1 ordered all companies off the vessel to regroup. At 01:01 hours, BC1 advised DC1 that all personnel were off of decks 10, 11, and 12. From approximately 01:08 to 01:20 hours, a PAR was conducted with all units confirming PAR with the exception of Ladder 4. At 01:14 hours, it was decided that the UASI rescue companies would serve as a rescue branch under the overall incident command. A UASI rescue branch command post was established on the dock. They began organizing the arriving UASI Rescues, ensuring that they were all issued UASI portable radios for common communications. They ensured that the companies, when possible, were utilizing 60-minute SCBA cylinders. They also ensured that personnel entered the vessel with search ropes. At approximately 01:15 hours, a mutual aid fireboat arrived on-scene and stood by next to the vessel.

At 01:27 hours, the first of the UASI Rescue companies entered the vessel with a Rescue Operations Chief and proceeded via the port ladderwell to deck 8 where a new staging area was established. From 01:30 to 01:45 hours, the vessel crew unsuccessfully attempted to use several different mechanical/physical techniques to close the WTD on deck 12. The crew members also continued to perform boundary cooling on deck 12 as the fire on deck 11 gained intensity.

From approximately 01:43 to 01:48 hours, the first UASI search operation occurred on deck 10 for the missing Ladder 4 firefighter. Throughout this search, rescue companies were staged as the rapid intervention company on deck 8. Rescue companies were able to search approximately 100 feet into deck 10.

From approximately 01:48 to 01:58 hours, the second UASI search operation deployed two rope search lines, one closer to the port side and one closer to the starboard side. The search ropes were deployed approximately 150-200 feet, making it to about the mid-point of the deck. At the end of their search, an "explosion" occurred above them on deck 11, blowing debris down onto deck 10. After hearing the explosion, they evacuated deck 10.

Throughout the first two search operations there were no signs of Ladder 4 firefighter's location. At this point, the UASI search operations had covered approximately the rear/stern half of deck 10. Throughout these search operations, the fire was burning on deck 11 pushing heat and smoke down onto deck 10. At no time during the search operations was there any fire on deck 10. At 01:59 a PAR was conducted for the UASI companies for which all personnel were accounted.

From approximately 02:00 to 02:09 hours, the third UASI search operation took place. They searched deck 10. UASI Rescue 5 (R5) split into two teams following the two search lines previously deployed. The team operating on the rope closest to the starboard side found a discarded firefighter flashlight. They took this as a possible sign that the missing firefighter could be in the area. When that team reached the end of the original search rope, they heard a PASS device sounding. They deployed an additional rope search line approximately 75 feet in the direction of where the PASS was sounding. At 02:08 hours, R5 located the missing Ladder 4 firefighter (**see Photo 10**). He had his SCBA on, but his facepiece was not in place.

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Photo 10. Location (deck 10) where Ladder 4 firefighter was found.

(Courtesy of ATF)

The R5 officer attempted to notify command via radio and activated the emergency alert button on his radio. However, he received no response. The R5 officer then followed the search ropes back to port ladderwell where he provided the rescue operations chief with an update. Along with another rescue company, R5 started the process of removing the down firefighter. The Ladder 4 firefighter was initially placed in a stokes basket for removal, but the basket continued to get caught on objects as they tried to move. So, the Ladder 4 firefighter was carried by firefighters until they reached the area closer to the rear/stern of the vessel, and then he was placed back in the stokes basket. The removal process from deck 10 took approximately 15 minutes.

At 02:24 hours, additional mutual aid resources were taken out of staging at deck 8 and assigned to assist with the removal of the Ladder 4 firefighter. A rope rescue mechanical advantage system had been rigged in the ladderwell to assist with the movement of the downed firefighter up from deck 10 to deck 12. At 02:35 hours, the Rescue Branch Operations Chief provided a progress report that the downed firefighter was being moved from deck 10 to 12 via a stokes basket using a manpower intensive operation. From 02:38 to 02:46 hours, the UASI Rescue Branch conducted PAR with all units being accounted for. At 03:01 hours, the Rescue Branch Operations Chief provided a progress report that the downed firefighter was being rigged for lowering by the vessels crane. At 03:06 hours, Ladder 4 firefighter was on the dock and turned over to EMS. He was transported to the hospital where he was pronounced deceased.

Termination of Incident

Once the Mayday operations were cleared, all firefighting operations ceased on the vessel. The fire continued to grow on deck 11 and spread to decks 12 and 10 for the next several hours. At approximately 05:40 hours, the VC requested that the fireboat, which had responded via mutual aid, direct their master streams onto the vessel's exterior and deck 12 for boundary cooling and fire extinguishment. All onboard firefighting efforts were ceased at 06:40 when the vessel's crew abandoned the ship. The fire continued to burn out of control for the next five days, ultimately involving decks 7-12

in the rear half of the vessel. The fire was finally extinguished by a private team of salvors/marine vessel firefighters on July 10.

Fire Origin and Growth

The origin of the fire was determined by the ATF National Response Team to have been from the deck 10 pusher vehicle (**see Photo 11**). The vehicle had been used throughout the day to push disabled vehicles onto the vessel. The ATF investigation determined that the transmission in the vehicle overheated, which resulted in the release of flammable transmission fluid. Several witnesses described fire "dripping down from under the vehicle" consistent with this finding. The fire was ruled as accidental.

Photo 11. The pusher vehicle experienced a transmission failure, serving as the origin and cause of the fire on deck 10.

(Courtesy of ATF)

At approximately 21:00 hours, the fire initially developed in the pusher vehicle and then transitioned to the vehicle that was being pushed. The fire then spread primarily upward via:

- Direct flame contact that traveled through the lashing holes in the deck ceiling/floor.
- Convection traveled through the lashing holes in the deck ceiling/floor and up the vehicle loading ramps from deck to deck.
- Conduction as the steel structure was heated and the heat was transferred to the combustible/flammable components of the vehicles.

Throughout the Mayday search and rescue efforts from approximately 22:23 to 03:00 hours, the fire grew and spread through the vehicles on the deck 11. There were no efforts made by the responding fire

departments to extinguish the fire on deck 11, which raised the temperature of the floor on deck 12 to a point where personnel could no longer stand on the deck for any period of time without the risk of sustaining burns.

Contributing Factors

Occupational injuries and fatalities are often the result of one or more contributing factors or key events in a larger sequence of events. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatalities:

- Pre-planning for marine vessel fires
- Training on marine vessel firefighting
- Coordination with marine vessel fire response efforts
- Request and use of mutual aid resources
- Unified command with marine vessel representatives.

Cause of Death

According to the Coroners' report, the cause of death for the deceased firefighters was industrial fire injuries which included smoke inhalation with high levels of carboxyhemoglobin, heat exposure, and severe pulmonary edema, pulmonary congestion, and edema.

Recommendations

Fire departments should:

Recommendation #1: Develop and maintain a comprehensive pre-fire plan for marine vessels per NFPA 1405, Guide for Land-Based Fire Departments that Respond to Marine Vessel Fires.

Discussion: The responding fire department did not have a pre-fire plan for marine vessel fires. These types of fires are among the most difficult to extinguish and represent a high-hazard/low-frequency type of event. A comprehensive pre-fire plan is critical to prepare for handling these emergencies.

NFPA 1405 recommends fire departments develop pre-fire plans for marine vessel fires. These plans are intended to be reviewed and available for use of each fire alarm responding unit. Much like a pre-incident plan, they are a document developed by gathering general and detailed data that is used by responding personnel to effectively manage emergencies. They identify deviations from normal operations and can be complex and formal, or simply a notation about an approach to a particular problem [NFPA 1405 2020; NFPA 1660 2024]. General pre-fire plans focus on areas and environments such as a port where marine vessels are in the jurisdiction. Specific pre-fire plans focus on target hazards and provide specific information on a vessel's characteristics, hazards, and systems. A pre-fire plan includes operational procedures such as the early need to locate and obtain a marine vessel's stability plans, cargo manifest, dangerous cargo manifest, blueprints, safety plan, and fire control plan as part of the incident response. These documents are critical for the incident commander and their staff for developing strategy and tactics for life hazards, locating the fire or emergency, access, vessel systems/equipment that can be utilized, and ventilation [NFPA 1405 2020].

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When developing pre-fire plans, fire departments could consider using a tool such as the *Sample Vessel Fire Checklist* provided in Annex C of NFPA 1405. This checklist provides an operations worksheet to document and manage the following information during a response to a marine vessel fire [NFPA 1405 2020]:

- Incident notification
- Additional incident indicators
- Initial report on conditions
- Vessel construction
- Cargo information
- Fire situation
- Exposures
- Water supply
- Vessel systems
- Incident strategies, objectives, tactics, and tasks
- Fire confinement and control

Special Resource Considerations

The unique nature of a marine vessel fire requires methods and resources beyond those normally used at a residential structure fire. There are special resource considerations for responding to a marine vessel marine that a pre-fire plan entails, discussed below.

Adequate Staffing:

NFPA 1710 and NFPA 1720 recommend that marine firefighting units be staffed with a minimum number of members as required based on the tactical and occupancy hazards of the response. This includes the number of personnel necessary for safe and effective firefighting performance relative to the type of marine vessel [NFPA 1710 2020; NFPA 1720 2020]. NFPA 1405 notes that marine vessels often are compared to high-rise buildings in terms of being a unique environment requiring special considerations for the number of personnel and resources. NFPA 1710 recommends a minimum of 42 responding firefighters for an initial high-rise alarm assignment. This includes those needed for search-and-rescue teams, officers dedicated to overseeing entry points of fire floors, evacuation management teams, vertical ventilation operations, and firefighters to transport equipment to a staging location [NFPA 1710 2020]. This incident had similar needs that called for a large number of firefighters. Much like a high-rise building fire, additional unassigned firefighters should be on-scene, staged, and ready to assist with fireground operations in the event of an emergency or to facilitate the rehabilitation of firefighters performing various tasks [NIOSH 2016].

Appropriate Equipment:

In this incident, neither the fire department nor the vessel had the appropriate adapters to connect the fire department hoses to the fire stations on the vessel. Additionally, the fire department in this incident

utilized 30-minute SCBA cylinders. Due to the size and complexity of the fire on the vessel, firefighters had to change cylinders repeatedly due to a quick depletion of their air. To avoid running out of air in the hazardous environment onboard, firefighters were limited to a short duration of working on response and rescue tasks. The need for additional SCBA cylinders was further compounded by the process of transporting cylinders from the fire apparatus onto the pier, to the vessel, and then to the equipment staging location onboard. For marine vessel fires, fire departments should use a mobile cascade system to supply and fill SCBA cylinders at emergency incidents. However, the fire department's mobile cascade unit was out-of-service the day of the incident. To allow a specified number of SCBA users to be deployed without interruption, as many as three times that number of SCBA units should be available on the scene. This allows backup personnel to have their equipment ready to immediately relieve personnel who have exhausted their air supply and provide extra units in the event of failures or equipment problems [NFPA 1900 2024].

Communications:

The structure of most large vessels creates communication challenges for firefighters as experienced during this incident. Large amounts of steel often hamper the ability for portable radios to transmit messages to the communications radio system including when on deck or holds below the waterline. Consequently, a marine vessel fire response may require alternative means of communications. NFPA 1405 suggests runners, sound-powered phones, wired systems, and the ship's fixed communication systems as alternatives [NFPA 1405 2020].

Accountability:

The construction, layout, and access limitations of large marine vessels can complicate efforts to collect and maintain the status and location of the resources working in, or potentially working in, an immediately dangerous to life and health environment at an incident. A personnel accountability system should be utilized to readily identify both the location and function of all members operating at an incident scene [NFPA 1550 2024].

Expanding Incident Command Functions:

Major incidents can involve great complexity and extend into additional operational periods, requiring a variety of tactics and resources to bring a situation under control. An incident commander should ensure adequate staffing, rest and rehabilitation including food and water, medical care for firefighters, specialized equipment, and employ the assistance of an incident management team. This includes components of the incident command system involved with information management that support the incident commander such as planning, operations, and logistics [NIOSH 2024; NFPA 1550 2024].

Recommendation #2: Train fire officers and firefighters in marine vessel firefighting.

Discussion: The fire department in this incident did not have any training or policies for marine vessel firefighting or the operation of marine vessel fire suppression systems. None of the firefighters from the

department received any professional development related to marine firefighting in the five years before the incident.

NFPA 1405 recommends marine firefighting training and professional development for land-based firefighters which includes [NFPA 1405 2020; NFPA 1010 2024]:

- Unique aspects of combating vessel fires
- Vessel types and potential products transported by vessels
- Vessel construction and structural hazards
- Stability and dewatering
- Safe access to the vessel and egress from
- Suppression and ventilation
- Scene safety considerations at marine incidents
- Available resources for assistance

Recommendation #3: Coordinate with marine vessel crew members and fire teams.

Discussion: Throughout the incident, firefighters on-scene reported being confused by the response efforts of the marine vessel crew members and fire teams (e.g., when they performed boundary cooling). This lack of specific training inhibited integrated response operations.

NFPA 1010 also recommends preparing land-based firefighters to coordinate response efforts with the marine vessel's crew members and fire teams. This includes having a working knowledge of marine vessel terminology, how to use vessel communications equipment, and the operation of onboard fire extinguishing systems [NFPA 1010 2024]. Training on coordination is critical to ensuring cooperative and complementary efforts by both response entities, especially as the vessel's crew members will have a greater working knowledge of the vessel, its layout and cargo, and the fire control plan details.

Many of these training topics can be requisitioned or developed by fire departments using resources provided by firefighter associations, port authorities, the U.S. Coast Guard, or maritime academies. In addition to trainings, NFPA 1405 recommends fire departments conduct tabletop exercises and full-scale drills where land-based firefighters can practice marine firefighting tactics or run-through the procedures outlined in a pre-fire plan on a marine vessel as a simulated situation. These exercises and drills also provide an opportunity to practice working with crew members and other partners in a potential marine vessel fire response [NFPA 1405 2020; USCG 2022].

Recommendation #4: Request and utilize mutual aid resources for all marine vessel incidents, such as fires, as early in the incident as possible.

Discussion: Several automatic mutual aid resources were dispatched early in the incident, including a fireboat. These resources were cancelled by the incident commander about 20 minutes into the incident response, prior to the on-scene resources understanding the extent of the fire and resources needed. Additional fire departments, including units specializing in rescue and marine firefighting, were later requested by the incident commander.

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Adequate resources and staffing levels are necessary at an incident scene to accomplish stabilization tasks and be available for unexpected emergencies. The first arriving fire department unit should perform a size-up of the marine vessel fire and use this to determine if more assistance in the form of additional alarms or specialized resources may be needed [NIOSH 2016; NFPA 1405 2020]. Mutual aid agreements between different fire departments provide a means of assistance, including resources and staffing levels when personal resources are insufficient. These mutual aid resources are often dispatched for immediate joint response on first alarms as part of a communication center's dispatch protocol [NFPA 1710 2020; NFPA 1720 2020]. Requesting mutual aid resources early allows for adequate resources and staffing levels before a critical need arises. Mutual aid resources can also provide specialized resources based on the unique variables of the incident. For example, the mobile cascade unit for the fire department was out-of-service the day of the incident. Recognizing the special consideration for air supply, a mutual aid mobile cascade could have been requested by the incident commander to support this logistics need.

Recommendation #5: Establish and maintain unified command with marine vessel representatives throughout the incident.

Discussion: During this incident, the Chief Mate of the vessel met with the incident commander to provide an overview of the situation. The language barrier between the Chief Mate and the incident commander prevented effective communication and development of an incident action plan. The incident commander eventually abandoned efforts to unify command of the incident. This inhibited information sharing and tactics coordination on things like the general arrangement of each deck, fire suppression system function, and potential effects of changing tactics on existing hazards.

Unified command is an application of the incident command system where designated members of different agencies, jurisdictions, or disciplines collectively participate in managing an incident as an integrated team. The members establish a common set of objectives and strategies which address multiagency or multijurisdictional priorities. This type of command structure allows agencies with different functional authorities and responsibilities to perform integrated incident operations without losing individual agency responsibility, authority, or accountability [NFPA 1550 2024]. Unified command is often utilized for complex incidents that involve multiple jurisdictions, agencies, or functional responsibilities. The use of this system [NRT 2007]:

- Allows for information sharing
- Ensures logistical support and coordination of resources
- Reduces duplicative efforts and chances for conflict
- Establishes awareness of individual plans, actions, capabilities, and limitations
- Encourages a cooperative response environment

<u>Addressing Language Barriers</u>

One of the most common challenges associated with marine firefighting are language barriers. As identified in this incident, crews of the marine vessels may not speak the preferred language of the port of call. If this situation exists, it can significantly complicate information sharing and coordination. The

use of automated direct translation between languages does not always guarantee understanding. NFPA 1405 recommends that pre-plans for marine areas include lists of interpreters who are always available to assist with communications [NFPA 1405 2020]. Additionally, the U.S. Coast Guard recommends that emergency response services include translation mobile applications in their planning process to decrease language barriers [USCG 2023].

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Investigator Information

This incident was investigated by Mike Richardson, Investigator (former), with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, WV. This investigation report was authored by Mike Richardson, Investigator (former), and Dr. Wesley R. Attwood, Investigator and Program Advisor, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Pittsburgh, PA.

CDR Chris Barger, Lead Investigating Officer, U.S. Coast Guard, and Bart Barnum, Marine Casualty Investigator, National Transportation Safety Board, provided an expert review of the investigation report. A subject matter expert review was provided by William A. Burket, Senior Director MIRT, Virginia Port Authority. The NFPA Emergency Response & Responder Safety Division and Dr. Laura Syron, Director, NIOSH Center for Maritime Safety and Health Studies, also provided a technical review.

Additional Information

U.S. Coast Guard Marine Casualty Investigation Program

The Coast Guard investigates a myriad of casualties or accidents that involve vessels subject to U.S. jurisdiction, including deaths, injuries, equipment failures, property loss, and environmental damage. These investigations determine the associated human performance, equipment, and environmental causal factors, in order to make safety recommendations or take enforcement actions aimed at preventing recurrences. Marine Casualty reports, including resulting Safety Alerts and Findings of Concern, can be accessed at https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Inspections-Compliance-CG-5PC-/Office-of-Investigations-Casualty-Analysis/Marine-Casualty-Reports/.

National Transportation Safety Board Office of Marine Safety (OMS)

The OMS investigates marine casualties to determine the probable cause of each casualty and identify safety recommendations that will prevent similar events in the future. Investigated casualties include those classified by the US Coast Guard as major marine casualties in US territorial waters or involving US flagged vessels worldwide, and casualties involving both US public (government) and nonpublic vessels. In addition, the office investigates select catastrophic marine casualties, as well as those of a recurring nature. Access to Marine Investigation reports can be found at https://www.ntsb.gov/investigations/AccidentReports/Pages/Reports.aspx?mode=Marine.

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Disclaimer

The information in this report is based upon dispatch records, audio recordings, witness statements, and other information that was made available to the National Institute for Occupational Safety and Health (NIOSH). Information gathered from witnesses may be affected by recall bias. The facts, contributing factors, and recommendations contained in this report are based on the totality of the information gathered during the investigation process. This report was prepared after the event occurred, includes information from appropriate subject matter experts, and is not intended to place blame on those involved in the incident. Mention of any company or product does not constitute endorsement by NIOSH, Centers for Disease Control and Prevention (CDC). In addition, citations to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date. *NIOSH Approved is a certification mark of the U.S. Department of Health and Human Services (HHS) registered in the United States and several international jurisdictions.*

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Appendix One

Marine Vessel Glossary
(*Courtesy of the U.S. Coast Guard*)

Aft – moving towards the rear of the vessel

Bow – the front of the vessel

Forward – moving towards the front of the vessel

Starboard – standing at the rear/stern of a vessel facing forward, the starboard side is on the right.

Stern – rear of the vessel

Port – standing at the rear/stern of a vessel facing forward, the side is on the left.

Ladderwell – a vertical angled ladder used for access from deck to deck. Similar to stairs, however it is a steeper angle.

Hatchway – a doorway through a wall/bulkhead.

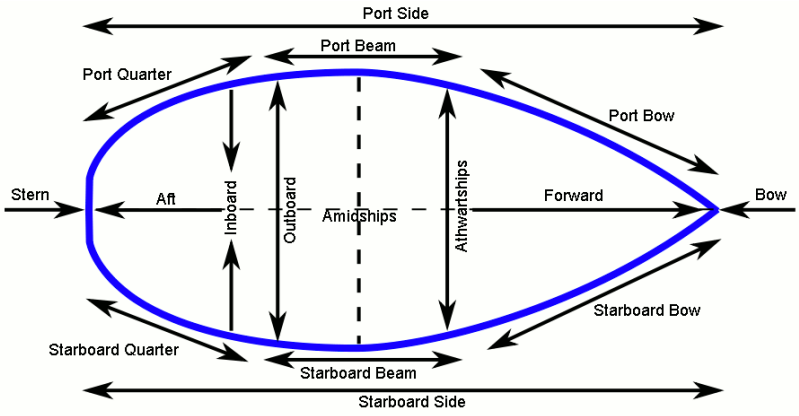
Bulkhead – a vertical wall.

Deck – a horizontal floor surface.

Boundary Cooling – applying water to decks, bulkheads, and hatchways to cool the structure to maintain structural integrity

Weather Tight Door – door/hatchway when closed/sealed prevents weather elements such as water from reaching the other side.

Escape Truck – a vertical ladder that provides movement from deck to deck.



General Shipboard Directions