1000 FREDERICK LANE, MORGANTOWN, WV 26508 · 304.285.5916

Career Battalion Chief Dies from Explosion while Fighting Tractor Trailer Fire – Georgia

Executive Summary

On September 4, 2024, a 35-year-old career battalion chief (Battalion 1) died while operating at a tractor trailer fire. He was the command officer at the incident and was killed while investigating the type of cargo that was held within the refrigerated trailer involved in the fire.

Photo 1: Fire conditions on arrival of Battalion 1.
(Photo courtesy of the fire department)

At approximately 0921 hours, the local public safety answering point (PSAP) received a call for a vehicle fire. While the incident was being dispatched to the responding units, the call type was updated to a tractor trailer fire with black smoke and multiple callers. Battalion 1 and Engine 11 were dispatched to the incident. Upon hearing the update from the dispatch center, Battalion 1 requested an additional engine company and that station 1 be re-paged for a tanker response. At approximately 0928 hours, Battalion 1 arrived on-scene and positioned past the involved tractor trailer, blocking traffic. Battalion 1 established command and sized the incident up as a tractor trailer fire with heavy fire involvement at the rear of the tractor, including tires and diesel fuel, with unknown cargo and occupant status. Battalion 1 provided a further update to all responding units that there was off-gassing at the rear of the tractor with an unknown source. He ordered Engine 11 to stop short, deploy an attack line from the front bumper, and utilize foam. Engine 11 stopped approximately 100’ short of the involved tractor trailer and deployed the 100’ 1 ¾-inch front bumper attack line. The Chief of the department (Chief 1101), who arrived just before Engine 11, assisted with deployment of the attack line. Engine 11’s officer extended the line with a 50’ section of attack line that was stored in the bumper well. At approximately 0931 hours, Battalion 1 updated dispatch that they had water on the fire and walked away from the engine crew. At approximately 0932 hours, while investigating at the rear of the trailer, Battalion 1 updated all units on-scene that the cargo was still unknown, but the rear of the trailer indicated it was refrigerated. At approximately 0933 hours, Battalion 1 attempted to open the rear trailer doors. The trailer

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exploded and Chief 1101 called to Battalion 1 on the radio stating they were okay. Battalion 1 did not acknowledge the message. At approximately 0934 hours, Chief 1101 updated dispatch that the trailer had exploded, was fully involved in fire, and he was going to check on Battalion 1. At approximately 0935 hours, Chief 1101 updated dispatch that Battalion 1 was down and requested air medical. At approximately 0937 hours, Chief 1101 assumed command of the incident and confirmed Battalion 1 was deceased on-scene.

Contributing Factors

- *Standard operating procedures/guidelines (SOPs/SOGs)*
- *Incident command*
- *Risk/benefit analysis*
- *Staffing*
- *Hazard recognition, including control zone establishment with unknown hazard.*

Key Recommendations

- *Fire service organizations should develop and maintain SOPs/SOGs with industry best practices*
- *Incident Commanders (ICs) should establish an Incident Management System (IMS) at all incidents*
- *ICs should integrate risk assessment as a risk management practice into their fireground strategy and tactic SOGs/SOPs*
- *Fire service organizations should follow the appropriate standards for organization and deployment of fire suppression operations, emergency medical operations, and special operations*
- *ICs should establish control zones on incidents where immediately dangerous to life and health (IDLH) environments exist*
- *Fire service training should provide insight and education towards commonly unrecognized pressure vessels in the form of intermodal freight trailers and mixed cargo trailers.*

For further information, visit the program website at www.cdc.gov/niosh/firefighters/fffipp/ or call toll free 1-800-CDC-INFO (1-800-232-4636). To access the report slides that summarize this incident and the recommendations, visit www.cdc.gov/niosh/firefighters/programs/pdfs/face202405RS.pdf.

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Introduction

On September 4, 2024, a 35-year-old battalion chief died while operating at a tractor trailer fire. On September 5, 2024, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. From September 25 through October 2, 2024, two NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) investigators conducted interviews virtually with fire officers and firefighters who responded to the incident. Photos taken at the scene, computer aided dispatch (CAD) notes, radio traffic audio, helmet camera, body camera, and drive camera footage obtained from the fire department were reviewed. NIOSH investigators also reviewed the training records of personnel involved in the incident and reviewed the department's SOPs and professional development model.

Due to the virtual investigation, on September 16, NIOSH's FFFIPP contacted the Fire Safety Research Institute (FSRI), part of the UL Research Institutes, to request assistance with fire analysis of this incident. Facts and the timeline surrounding the incident were discussed with the NIOSH team and gaps in the information were identified. Subsequently, on September 18, 2024, FSRI sent a team member to meet with the Chief of the Department to examine the remains of the trailer at a storage site in Georgia. The goal of the examination was to better understand the construction and fuel load of the refrigerated trailer itself. A sample of rigid foam insulation from the trailer was provided for testing to identify the foam type, and its potential as a fuel source for the smoke explosion.

Fire Department

Battalion 1 was a member of a combination fire department that has five stations with 31 full-time, 20 part-time, and 3 volunteer personnel that serve a population of approximately 25,000 within a 406 square mile area. The fire department is managed by a career fire chief employed by the county. The combination fire department is responsible for providing service to the entire county and has automatic aid agreements with the eight other volunteer departments located throughout the county.

The area served by the department contains a myriad of occupancies including resorts, an airport, single and multiple family dwellings, light commercial, warehouses, and heavy industrial complexes. The fire department is responsible for structural fire, aircraft rescue firefighting services, hazardous material response, technical rescue, and emergency medical services (EMS).

All department members, except for the fire chief, work a 24-hours on duty, 48-hours off duty rotating schedule. The minimum staffing for the department is 9 personnel including an on-duty battalion chief,

with full staffing of 11 personnel. The on-duty battalion chief oversees the staffing of five engine companies, one hazardous materials unit, and one brush unit operating out of five separate fire stations. Two personnel are assigned to each of the five stations. Fire and EMS are separate divisions within the department.

Training and Experience

Battalion 1 had 17 years of firefighting experience with a background in both the career and volunteer fire service. The minimum qualifications for the battalion chief position within the department include national certification in Firefighter I and II, Apparatus Operator-Pumper, Fire Officer 1, 2, and 3, Fire Instructor 1 and 2, Incident Safety Officer, and State Emergency Medical Technician Intermediate (EMT-I) or Advanced (AEMT), or Paramedic.

Battalion 1 had various professional certifications including Firefighter I and II, Hazardous Materials Awareness and Operations, Apparatus Operator - Pumper, Fire Officer 1, and Fire Instructor 1. He was promoted to the rank of battalion chief with an agreement that all necessary qualifications would be completed before the end of July 2026. This exemption was granted due to the department changing their professional development program for minimum standards within each rank. The department training records also indicated he had completed continuing education training in a variety of topics, such as pipeline emergencies, strategies and tactics of fire control, and building construction.

Apparatus, Staffing, and Communications

The minimum daily staffing of the combination fire department is comprised of four engine companies (minimum of two personnel each) and a battalion chief. The full, daily staffing of the combination fire department is comprised of five engine companies (minimum of two personnel each) and a battalion chief. The engine company personnel are responsible for staffing of and response with other apparatus housed in their station based upon call type.

Emergency calls are received into a county PSAP which utilizes a Motorola P25 800-Megahertz (MHz) encrypted tri-county simulcast trunking system and a CAD system. All dispatchers are state certified and required to complete a minimum of 10 hours of continuing education annually. The PSAP personnel in this incident averaged over 25 hours of continuing education and is currently in the process of obtaining Emergency Medical Dispatching certification. Each dispatcher handles the call and incident through completion, regardless of type of call. The various CAD event codes may prompt the call taker to ask additional and specific questions to provide to dispatched companies. This PSAP has a minimum staffing of two operators per shift with typical staffing of three or four operators per shift. The county system averages 40,000 calls yearly including emergency and non-emergency incidents for the sheriff, local, and state police departments, a combination fire department, eight volunteer fire departments, and three EMS departments. The PSAP also receives calls for public works, city workers, three animal control offices, city water, city gas, Department of Natural Resources (DNR), and railroads. This incident was dispatched using the event code for a vehicle fire and the CAD generated a specific, predetermined response plan to dispatch the appropriate units. See **Table 1** for the companies dispatched on the original call and **Table 2** for the fire unit status and staffing at the time of the explosion.

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Table 1: Initial Incident Dispatch

Resource Designation	Staffing Level
Engine 11	2 Personnel
Battalion 1	1 Personnel

Table 2: Fire Unit Status and Staffing at Time of Explosion

Resource Designation	Staffing Level	Status
Engine 11	2 Personnel	On Scene
Battalion 1	1 Personnel	On Scene
Chief 1101	1 Personnel	On Scene
Chief 8	1 Personnel	On Scene
Engine 12	2 Personnel	Enroute
Tanker 1	0 Personnel	Dispatched, not enroute

Personal Protective Equipment

Upon arrival at the scene, Battalion 1 exited his command vehicle in his daily work uniform (i.e., uniform boots, long pants, sweatshirt, and ball cap). He was wearing a radio strap and holder that held his portable radio and remote speaker microphone. As the incident progressed, Battalion 1 also donned a high visibility safety vest as well as his leather structural firefighting helmet. The helmet met current Occupation Safety and Health Administration (OSHA) standards.

Environmental Conditions

The weather on September 4, 2024, at 0853 hours was fair with no precipitation. The temperature was 69°F with winds out of the north northeast at 10 miles per hour. The humidity was 63% [Weather Underground 2024]. It should be noted that in Diagram 2 and other images contained within this report, the wind at the location of the fire was out of the east-southeast direction. This may be due to obstructions or topography that are different from the recording weather station.

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Involved Vehicle

The vehicle involved in this incident was a tractor trailer style commercial vehicle (**see Diagram 1 and Photo 2**). The trailer portion of the vehicle consisted of a container chassis with a refrigerated intermodal container secured to the chassis with twistlocks on all four corners of the container. The refrigerated intermodal container had a portable generator, or genset, affixed to the bulkhead of the container. The genset in this incident ran on diesel fuel and included a self-contained diesel fuel tank on the lower portion of the genset device. Based on the information provided by the UL Research Institutes team, a visual inspection of the diesel tank did not present any evidence of bulging or rupture. The container was loaded with frozen chicken.

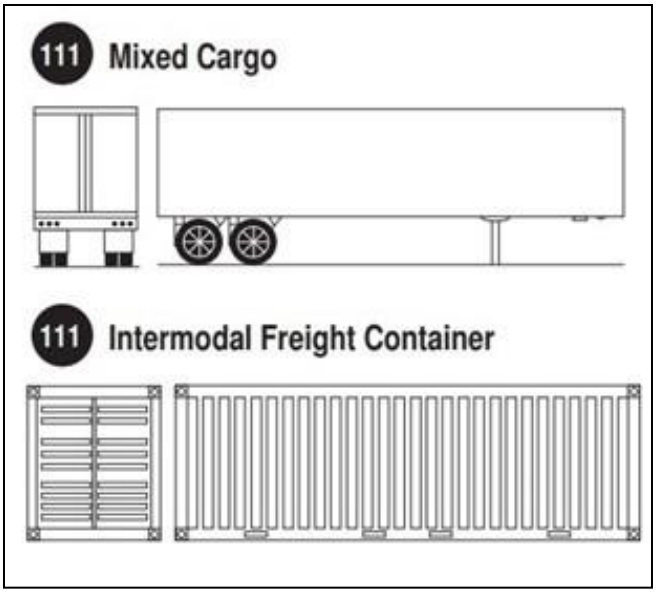

Diagram 1: Type 111 road trailers.
(Courtesy of 2024 Emergency Response Guidebook)

The 2024 Emergency Response Guidebook (ERG) identifies this type of trailer as a type 111 intermodal freight container. These containers are for general freight that carry bulk or non-bulk packages. They may transport hazardous materials/dangerous goods in small packages (e.g., bags, boxes, drums) or intermediate bulk containers (IBCs), sometimes referred to as "totes". These

Photo 2. Type 111 Intermodal Freight Container secured to trailer chassis with genset.
(Photo courtesy of UL FSRI)

containers typically have the doors for entering the compartment at the rear opposite the bulkhead [PHMSA 2024]. A summary of FSRI's trailer construction materials analysis findings can be found in **Appendix One**.

Timeline

The following timeline is a summary of events that occurred as the incident evolved. Not all incident events are included in this timeline. The times are approximate and were obtained by examining the dispatch records, audio recordings, witness statements, and other available information. All times are approximate and rounded to the closest minute. The timeline is not intended, nor should it be used, as a formal record of events.

Time (hours)	Fireground Operations, Response, and Details
0921	• PSAP case created and unit recommendations for vehicle fire response initiated.
0923	• Battalion 1 and Engine 11 dispatched. ○ PSAP updated responding units that they have received multiple calls of a tractor trailer box truck with black smoke coming from it.
0924	• Battalion 1 and Engine 11 enroute.
0927	• Battalion 1 requests additional engine company and Station 1 be re-paged for a Tanker.
0928	• Battalion 1 on-scene, established command. ○ "Heavy fire involvement at the rear of the tractor, unknown occupant status, unknown cargo"
0929	• Battalion 1 provides update to all responding units. ○ "Some type of off-gassing at the rear of the tractor, unknown source"
0930	• Battalion 1 orders Engine 11 to stop short and deploy the bumper line and begin using foam.
0931	• Engine 11 has water on the fire.
0932	• Battalion 1 updates all units on-scene stating, "unknown what the cargo is, it is a refrigerated trailer according to the rear."
0933	• Trailer explodes.

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Time (hours)	Fireground Operations, Response, and Details
	• Chief 1101 calls command, "everyone is 10-4 over here." • Chief 1101 calls Battalion 1, "Are you okay?"
0934	• Chief 1101 updates dispatch, "large explosion, trailer now fully involved, the entire trailer blew apart." • Chief 1101 going to check on Battalion 1.
0935	• Chief 1101 updates all units, "cannot find Battalion 1." • Chief 1101 updates, "Battalion 1 is down. Needs helicopter."

0937	• Chief 1101 assumes command.
	  ○ Chief 1101 confirmed that Battalion 1 is deceased on scene.
	  ○ Chief 1101 updates still working on fire attack, contents of trailer still unknown.

0938	• Chief 1101 confirmed contents of the trailer as frozen chicken.
0958	• Chief 1101 transfers command to Engine 13 ○ Still fighting fire, Personnel accountability report (PAR) okay, 6 personnel working.
1028	• Fire is knocked down. Hitting hot spots.
1528	• Command terminated. • Scene turned over to Sheriff's Office. • Roadway still closed.

Investigation

On September 4, 2024, at approximately 0921 hours, the local PSAP received a call for a vehicle fire. The case was generated in the CAD system and the call taker gathered information. While the incident was being dispatched, the call type was updated to a tractor trailer fire with black smoke reported by multiple callers.

The companies dispatched on the original call included Battalion 1 and Engine 11, see **Table 1**. Upon hearing the update from the dispatch center, Chief 1101 called Battalion 1 by mobile phone to suggest the upgrade of the assignment as well as to let Battalion 1 know he was enroute. Battalion 1 said he would be able to see what they were dealing with momentarily and they hung up. Battalion 1 could see a significant smoke column and requested an additional engine company and that Station 1 be re-paged for a tanker response, see **Table 2**. Chief 8 self-dispatched to the scene to assist.

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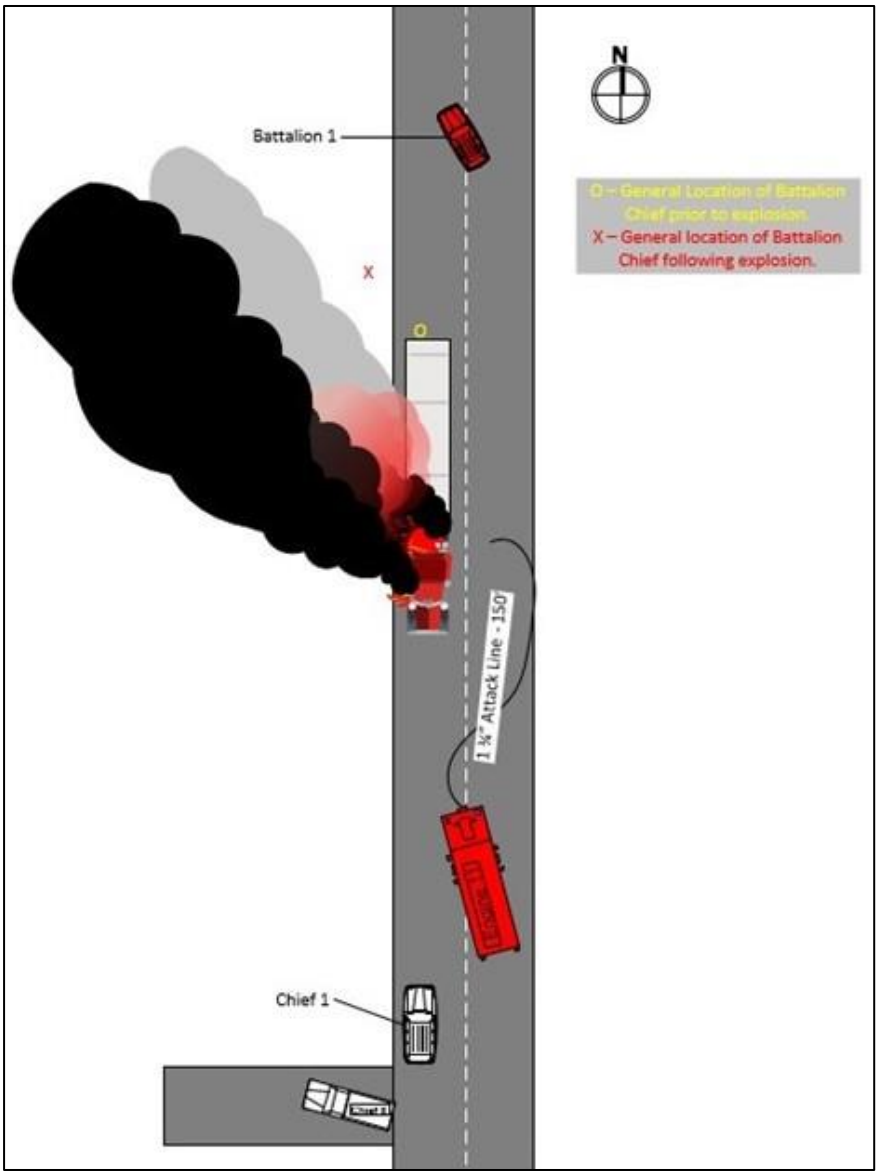

Diagram 2: Approximate locations of all on scene apparatus and attack line at the time of explosion.
(Diagram prepared by NIOSH)

At approximately 0928 hours, Battalion 1 arrived on-scene and positioned his vehicle past the involved tractor trailer on the North side, blocking the south bound lanes to close the road in that direction. Battalion 1 established command of the incident and sized the incident up as a tractor trailer fire with heavy fire involvement at the rear of the tractor including the tires and diesel fuel tanks. The fire from the rear of the tractor provided direct flame exposure to the underside of the front portion of the trailer. The fire extended up between the rear of the tractor's cab and the front of the trailer. The cargo and occupant status were unknown upon his arrival and relayed to the dispatch center. Battalion 1 provided an additional update to all responding units that there was off-gassing and fire involvement at the rear of the tractor from an unknown source. He ordered Engine 11 to stop short, South of the incident, deploy an attack line from the front bumper, and utilize foam. Engine 11 stopped approximately 100' short of the involved tractor trailer and deployed the 100' 1¾-inch front bumper attack line. Chief 1101, who arrived just before Engine 11, assisted with deployment of the attack line. Engine 11's officer extended the line with a 50' section of attack line that was stored in the bumper well. At approximately 0931 hours, Battalion 1 updated dispatch that they had water on the fire and walked away from the engine crew.

At approximately 0932 hours, while investigating at the rear of the trailer, Battalion 1 updated all units on-scene that the cargo was still unknown but the rear of the trailer indicated it was refrigerated. At approximately 0933 hours, as Battalion 1 attempted to open the rear trailer doors, the trailer exploded

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and Chief 1101 called to Battalion 1 on the radio, stating they were okay. Battalion 1 did not acknowledge the message.

At approximately 0934 hours, Chief 1101 updated dispatch that the trailer had exploded, was fully involved in fire, and he was going to check on Battalion 1. At approximately 0935 hours, Chief 1101 updated dispatch that Battalion 1 was down and requested a medical helicopter. At approximately 0937 hours, Chief 1101 assumed command of the incident and confirmed Battalion 1 was deceased on-scene. Chief 1101 updated that crews were still working on fire attack, and contents of the trailer were still unknown. At approximately 0938 hours Chief 1101 confirmed with the driver that the cargo was frozen chicken.

Photo 3 and Photo 4. View of fire behavior on passenger side of vehicle (top photo) and view from the fire attack team as Battalion 1 declared water on the fire (bottom photo).
(Photos courtesy of fire department)

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Photo 5. View of driver side of involved vehicle following extinguishment.
(Photo courtesy of fire department)

Photo 6. View of passenger side of involved vehicle following extinguishment. ***(Photo courtesy of fire department)***

At approximately 0958 hours, Chief 1101 transferred command to Engine 13, crews were still fighting fire, PAR was okay, and they had six personnel working. At approximately 1028 hours, command reported the fire was knocked down with crews still extinguishing hot spots. At approximately 1528 hours, command was terminated, the scene was turned over to the Sheriff's Office, and the roadway would remain closed.

Cause of Death

According to the State Bureau of Investigation, Department of Forensic Sciences report, an autopsy was performed by the Office of the Medical Examiner. The manner of death was classified as an

accident. It was noted Battalion 1 was in close proximity to a vehicular fire and explosion. The cause of death was listed as blunt force, blast, and thermal injuries of the head and torso.

Contributing Factors

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

- SOPs/SOGs
- Incident Command
- Risk/benefit analysis
- Staffing
- Hazard recognition, including control zone establishment with unknown hazard.

Recommendations

Recommendation #1: Fire Service Organizations should develop and maintain SOPs/SOGs with industry best practices.

Discussion: SOPs/SOGs establish the basic framework for conducting emergency operations safely and effectively. Some procedures are specifically directed toward safety; others support safe operations by establishing a system of predictable and consistent operations. Coordination, consistency, and standard approaches are all important and valuable components of safe emergency operations [USFA 2018].

In this incident, the IC was the first to arrive on the scene. The IC provided a scene size up report and established command. He positioned his apparatus to provide a safe working area for incoming crews and to establish a Traffic Incident Management Area (TIMA) [NFPA 1091 2024]. The IC then made the effort to perform his 360-degree size up as dictated by the department SOGs. But, due to the smoke drift, only about 270-degrees of the incident was viewed immediately upon his arrival. Once Battalion 1 exited his vehicle he completed his 360-degree size-up, provided his incoming units with updates including something off-gassing at the rear of the tractor, the level of fire involvement, and their initial set of orders on arrival. Following the initiation of fire attack by the first arriving engine and additional personnel who arrived in non-suppression apparatus, the IC continued to operate within the hot zone of the incident in an investigation mode. The purpose of the IC operating within the hot zone performing investigation was to determine the cargo being transported by the motor carrier.

NFPA 1550 section 6.2.2, *Standard for Emergency Responder Health and Safety*, states that fire departments should prepare and maintain written policies and SOPs that document the organization structure, membership, roles and responsibilities, expected functions, emergency operations, and training requirements. This includes:

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- the types of standard evolutions that are expected to be performed
- the evolutions that must be performed simultaneously or in sequence for different types of situations
- the minimum number of members required to perform each function
- the number and types of apparatus and personnel that will be dispatched to different types of incidents in accordance with NFPA 1710 or NFPA 1720.

The standard also states these SOPs should specify the procedures that will be employed to initiate and manage operations at the scene of an emergency incident and post-incident control and mitigation of emergency scene contaminants [NFPA 1550 2024].

The department in this incident provided copies of their SOGs for the NIOSH investigators to review. The SOGs contain the requirements for personnel operating on vehicle fires, specifically commercial vehicle fires. The SOG covering incidents where fire is showing requires personnel to be in full protective clothing, including self-contained breathing apparatus. If the vehicle involved is a tractor trailer, the SOG states that command should be in the investigation mode to determine if any hazardous materials are involved. If there are hazardous materials, the type and amount of material should be determined, and command should refer to the appropriate hazardous material SOG. If there are no hazardous materials or if the vehicle involved is a bus, then a search for any victims should be made.

Fire service organizations with similar SOGs could benefit from adding language about conducting this type of investigation from outside of the hot zone, preferably uphill and upwind whenever possible. Additionally, ensuring the incident response meets the requirements set forth by the applicable NFPA 1710 or NFPA 1720 standard allows for additional personnel to respond and perform necessary tasks, reducing task oversaturation by individual personnel.

The frequency at which SOGs should be reviewed and revised is also specified within NFPA 1550 section 6.2.4. The standards articulate that fire departments should evaluate current trends and research to determine if policies and procedures are appropriate at least annually or following a near miss or catastrophic event [NFPA 1550 2024]. The guidelines under which the department was operating on this incident were effective as of August 2022 and were due for review in August 2023 based upon the recognized best practice set forth in the standard. The department confirmed that they perform SOG reviews and training on a rolling calendar basis and intend to continue doing so.

Fire service organizations could benefit from revisiting SOPs/SOGs in their system at least annually as well as evaluating SOPs/SOGs for appropriate risk management strategies. As written, SOPs/SOGs support safe operations and avoid unnecessary risk while allowing for deviation when necessary.

Recommendation #2: ICs should establish an IMS on all incidents.

Discussion: ICs are responsible for everything that occurs on the fireground. This includes being able to decipher all the information that is presented to them upon their arrival at the incident, make sound decisions, develop an Incident Action Plan (IAP), and employ an IMS on all incidents. Personnel

cannot control the specific emergency they will face when they arrive to an incident. However, a well-developed command system and training program provides a solid base for personnel to refer to while operating [Pieper 2020].

NFPA 1550 Chapter 21 Command Safety states that the first arriving responder from an emergency services organization has responsibility for the incident, should assume the role of IC for the incident, and maintain the following responsibilities [NFPA 1550 2024]:

- Conduct an initial and ongoing situational assessment of the incident
- Establish an effective communications plan
- Develop incident objectives from the situational assessment and form applicable strategy and tactics
- Develop an IAP for the management of the incident
- Review, evaluate, and revise the strategy and tactics based on the needs of the incident and deploy resources as needed
- Provide for the continuity, transfer, or termination of command
- Maintain an effective supervisory span of control.

Industry best practices recommend that the IC establish an incident command post (ICP) and remain in the immediate area for the duration of the incident. It is up to the department and IC to determine the most appropriate command post for their incident. Some command post examples include the front lawn or Alpha/address side of a structure, inside the cab of the apparatus with the best vantage point, or the IC's vehicle. NFPA 1550 standard 21.11 states how the IC should choose and set up their ICP in the initial stages of an incident. Specifically, the standard states how to provide safety for the command staff of an incident based on whether it is a single commander or a team. It would benefit the IC to select an ICP that includes the following considerations [OSFC 2003, NFPA 1550 2024]:

- Sound – If the ICP is quiet, there is less of a chance for the IC to miss radio transmissions.
- Location – Although ICs want to be able to see as much as they can, it is important to provide a buffer from staging crews and distractions. The ICP should be located in the cold zone of an incident.
- Stationary – Moving ICs may find it more difficult to maintain focus as there are more opportunities for them to be distracted.
- Better radio – Most apparatus and command vehicles have a more powerful radio than the portable radio issued to personnel.
- Protection from the elements – A warm or cool and dry ICP will allow for the IC to concentrate on the incident.

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- Place to write and record – It is imperative that an IC can write or record information related to operations, whether it be crew assignments, which units are in staging, mayday information, or even something as simple as a phone number.
- Better intel equipment – An IC wants to know anything and everything about the incident, whether it is hazardous materials, occupancy data, target hazard information, etc.

There are times when conditions outside the ICs control prevent the first arriving officer from taking a command role and they must engage in operations on the fireground. This could be an instance of less-than-ideal staffing, an imminent rescue, or a situation that requires the IC to take an investigation style stance. Investigation mode means the IC must determine what conditions are for the incoming crews. This could include determining involvement of hazardous materials, fire conditions, occupancy status, etc. Referring to the previous recommendation, fire department policies should acknowledge this reality while also setting the expectation that ICs should be performing command functions and not operational functions. Exceptions to this are infrequent and not the rule of day-to-day operations. If the IC must perform in an investigative role, it is imperative that they transfer command to the next arriving qualified officer or remove themselves from the command role as soon as possible [Pieper 2020].

The SOGs provided by the fire department in this incident for vehicle fires specifically direct the IC to be in an investigation mode and not in a command position. This forces the IC to be engaged in some level of operations inside the hot zone versus being in a controlled and safer environment with a good vantage point of ongoing operations. The Incident Command SOG for the involved department also does not specify the methodology the command officers should follow on arrival other than establishing command, giving the size-up report, mode of operation, and delegating assignments. Specifying the need for a relatively stationary command setup and the necessity of employing an accountability system and IAP for the incident is important.

The Incident Command Structure (ICS) is a standardized approach to the command, control, and coordination of on-scene incident management that provides a common hierarchy within which personnel from multiple organizations can be effective. ICS specifies an organizational structure for incident management that integrates and coordinates a combination of procedures, personnel, equipment, facilities, and communications. Deploying the ICS on every incident can help hone and maintain skills needed to coordinate efforts effectively, is applicable across disciplines, and enables incident managers from different organizations to work together [FEMA 2017].

Recommendation #3: ICs should integrate risk assessment as a risk management practice into their fireground strategy and tactic SOGs/SOPs.

Discussion: In this incident, the IC followed the department SOGs that were specifically developed for a tractor trailer fire. He established command, provided a size-up, gave the initial company orders, and requested additional resources. Then, based on the direction of the SOGs, the IC entered the hot zone multiple times to investigate what the tractor trailer was hauling. He stated over the radio that the trailer contained unknown content on more than one occasion. He stated the trailer was refrigerated.

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Applying different risk management techniques in coordination with following the SOGs may have limited the number of personnel operating in the hot zone of the incident.

The concepts of operational risk management have always been important considerations for emergency response organizations [USFA 2018]. Some risks are unavoidable and are accepted as part of the duty of a firefighter or line officer. The nature of the activities of emergency responders exposes them to a high level of inherent risk. Conditions or circumstances can exist in which the proper response is to not take actions that could place the lives of responders in danger [USFA 2018]. Fire service personnel can reduce the risk of injury or death while operating on the fireground if they are able to identify the nature of the threat, determine the risk potential, and incorporate risk management practices into the operational plan.

A high level of risk management is involved in directing emergency operations and in regulating the responders' exposure to emerging incident hazards. Emergency incident risk management expands the standard approach to directing and conducting emergency operations by incorporating risk evaluation and the assessment of optional approaches to the problems at hand. NFPA 1550 standard 18.3.2.1 states that the IC should integrate risk management practices in the regular functions of incident command and at emergency operations the IC should evaluate the risk to members operating at the scene [NFPA 1550 2024]. This means the IC should determine the life safety profile of the incident and apply the most appropriate level of risk to first responders consistent with the following principles shown in Chapter 10.4 of NFPA 1550 [2024]:

- Activities that present a significant risk to the safety of members should be limited to situations where there is a potential to save endangered lives.
- Activities that are routinely employed to protect property should be recognized as inherent risks to the safety of members, and actions should be taken to reduce or avoid these risks.
- No risk to the safety of members should be acceptable when there is no possibility to save lives or property.
- In situations where the risk to fire department members is excessive, activities should be limited to defensive operations.

There are times in which a tactical command style can be beneficial. Chief Curt Isakson explains that the command style known as "tactical command" is out of a command vehicle, equipped with all personal protective equipment, and involved in a more up close and personal size-up which assists in not only managing the incident but also in getting personally involved in the mitigation of the incident. He also expresses his perspective of the importance of choosing the command style or mode to fit the incident and that there is not always a one size fits all approach. The command location and style must fit the incident to provide the best outcome for life-safety of both civilians and firefighters, while still placing property as a second priority [Isakson 2021].

In this incident, the contents of the trailer were unknown other than it was refrigerated. The bulk of the fire was located between the rear of the tractor and the trailer bulkhead. Bystanders told the IC that the

driver was out of the vehicle and had fled the scene. The department SOG for tactical priorities listed the hierarchy of the incident as follows:

1. Life safety
2. Incident stabilization
3. Property conservation.

Knowing the driver of the tractor trailer departed the vehicle partially eliminates the life safety concern. Without knowing if it was a driver team or a single driver, the priority cannot totally be ignored without contacting the driver who fled the scene. Battalion 1 gave orders to the first arriving engine company to stop short of the incident and to stretch an attack line for fire attack. This began the process of addressing the priority of incident stabilization. Risk assessment, as part of an overall risk management process, is ongoing throughout the entirety of an incident starting at the arrival of the first emergency responder until the incident is deemed over and command is terminated. All actions and tactics should have any new or changed information applied to them to ensure personnel safety and operational effectiveness.

The role of the IC can be very overwhelming and difficult when the incident is complex and multifaceted. The IC has overall authority for the management of the incident and for some it can be a daunting task. The ICS provides a framework that allows it to be adapted and scaled based upon the incident [NFPA 1550 2024].

Recommendation #4: Fire service organizations should follow the appropriate standards for organization and deployment of fire suppression operations, emergency medical operations, and special operations.

Discussion: The department involved in this incident became a combination fire department in 2019. NFPA 1720 section 3.3.16.1 defines a combination fire department as one having emergency service personnel comprising less than 85 percent majority of either volunteer or career membership. NFPA 1720 section 3.3.16.2 defines a volunteer fire department as a fire department having volunteer emergency service personnel comprising 85 percent or greater of its department membership [NFPA 1720 2020]. Although it is not clear which standard they were following, the department in this incident should have been utilizing the information in NFPA 1710 due to the percentage of volunteer membership being approximately 5.6 percent of the total membership.

Chapter 5 of NFPA 1710 provides minimum standards for staffing of various fire suppression companies. The department involved in this incident is responsible for primarily staffing engine companies. Engine companies are fire companies whose primary functions are to pump and deliver water as well as perform basic firefighting and search and rescue. Further, these companies should be staffed with a minimum of four on-duty members. However, the standard recommends that these companies be staffed with a minimum of five on-duty members in first-due response zones that experience a high number of incidents, geographical restrictions, geographical isolation, or urban areas, as identified by the authority having jurisdiction [NFPA 1710 2020].

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If the department were operating under the NFPA 1720 standard as a combination department, the following information should be utilized with the implementation of more volunteer membership. Based on the metrics provided by the department, the county could be considered a rural and remote area. Specifically, there is less than 50 people per square mile and a travel distance from the second due engine is greater than eight miles [USCB 2020]. The data preceding this shows that the staffing should be six personnel within 14 minutes of dispatch at least 80% of the time. **Table 3** displays the staffing and time standards for volunteer and combination fire departments as specified in NFPA 1720.

Table 3: Staffing and Response Time (Adapted from NFPA 1720)

Demand Zone	Demographics	Minimum Staff to Respond	Response Time (Minutes)	Meets Objective (%)
Urban area	>1,000 people/mi^2 (2.6 km^2)	15	9	90
Suburban area	500 – 1,000 people/mi^2 (2.6 km^2)	10	10	80
Rural area	<500 people/mi^2 (2.6 km^2)	6	14	80
Remote area	Travel distance ≥ 8 mi (12.87 km)	4	Directly dependent on travel distance	90
Special risks	Determined by AHJ	Determined by AHJ based on risk	Determined by AHJ	90

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Recommendation #5: ICs should establish control zones on incidents where IDLH environments exist.

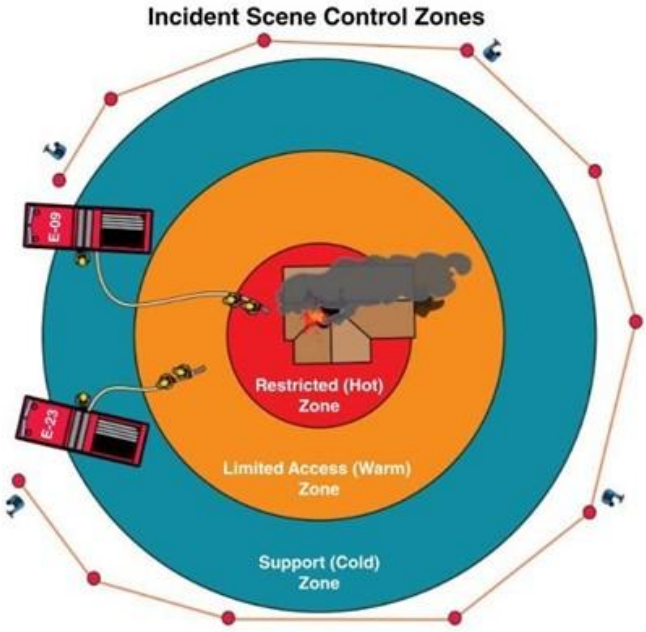

Diagram 3: Incident Scene Control Zones 1. ***(Courtesy of International Fire Service Training Association)***

Discussion: NFPA 1550, chapter 18.3.1.4, states the IC should have the responsibilities and duties of all unassigned incident command system positions. In organizations where personnel are not plentiful and arriving early at incidents, this creates a situation in which task oversaturation for the IC can happen quickly. NFPA 1550 chapter 5 states the Incident Safety Officer (ISO) role is a position within the ICS at an incident or planned event that is charged with ensuring action is taken to mitigate any immediate life safety threats. Within the scope of the ISO position is the necessity to determine hazardous incident conditions and advise the IC to establish or modify control zones at any given incident. These control zones must be communicated to on-scene personnel and entry into the hazardous area must be controlled by the ISO as specified in chapter 5 of NFPA 1550. These actions require the ISO to possess comprehensive knowledge of hazardous conditions, operations, departmental SOPs/SOGs, control zones protocols, and the IMS. An ISO also needs to be able to evaluate the effect of proximity for incident hazards so that risk to members will be limited to emergency responders assigned tasks to mitigate the incident (i.e., in the hot zone) [NFPA 1550 2024].

In this incident, the IC applied various techniques that fell under responsibilities of an ISO. He ordered Engine 11 to stop short of the affected vehicle, placing it outside of the hazard zone. He applied the process outlined in the department SOGs and attempted to locate the driver as well as determine if the cargo was considered a hazardous material. The IC also communicated all other hazards noticed during his ongoing investigation of the incident including that there was something off-gassing at the rear of the tractor and that the trailer was refrigerated.

The International Fire Service Training Association (IFSTA), *Essentials of Fire Fighting 8th Edition: Firefighter 1*, states that control zones can have a variety of labels depending on operations being conducted within those zones. The most common terms used to describe these areas are hot, warm, and cold zones.

The hot zone is the area closest to the hazard such as a fire or hazardous material. This is where trained personnel work to mitigate the problem. Only personnel directly tasked in mitigating the problem are allowed to enter this zone, which limits crowds and confusion at the most critical area of the scene.

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Photo 7 and Photo 8. Driver side of trailer just prior to explosion (left photo) and change of smoke behavior and expansion of container as explosion is occurring (right photo).
(Photos courtesy of fire department)

These personnel wear protective clothing and equipment appropriate for the incident's hazards [IFSTA 2024].

The warm zone is immediately outside the hot zone and serves as the transition area. Personnel in the warm zone directly support personnel working in the hot zone by providing emergency lighting, fire protection, or other support functions. These personnel wear full protective clothing and equipment and are ready to enter the hot zone if needed [IFSTA 2024].

The cold zone surrounds the warm and hot zones. The cold zone may include the ICP and locations for the rapid intervention crews, public information officer, rehabilitation area, and staging areas for personnel and portable equipment. The outer boundary of the cold zone serves as the control line for the general public (i.e., crowd-control line). Personnel working in the cold zone should wear protective clothing and equipment appropriate for the tasks they must perform and the hazards they may encounter [IFSTA 2024].

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Recommendation #6: Fire Service training should provide insight and education around commonly unrecognized pressure vessels in the form of intermodal freight trailers and mixed cargo trailers.

Discussion: The 2024 edition of the ERG indicates there are several types of road trailers in use in the United States and includes a road trailer identification chart for emergency responders. Several of these trailers call out either design pressures or maximum allowable working pressures (MAWP). The road trailer involved in this incident was a 111 intermodal freight container. The ERG lists distinctive characteristics and uses for this type of trailer [PHMSA 2024] Including:

- For general freight that carry bulk or non-bulk packages
- May transport hazardous materials/dangerous goods in small packages (e.g., bags, boxes, drums) or IBCs, sometimes referred to as "totes"
- Cargo door(s) in the rear.

What is not provided through the ERG is the MAWP for several types of trailers including the 111 intermodal freight container. The other trailer types identified with no noted MAWP include the 117 compressed gas/tube trailer, 134 dry bulk cargo trailer, and 137 vacuum tanker. The fire service is not taught to recognize type 111 trailers as a pressure vessel. When impinged by fire, these trailers can become pressurized. The same fire dynamics principles that apply to structure fires, apply here as well. As the temperatures inside of a closed compartment increase, the pressure inside the compartment also increases. Without a sufficient pressure relief vent(s), the pressure continues to build. The Type 111 trailers, when configured for refrigerated applications, have void spaces between the inner and outer floor, walls, and roof that are filled with combustible foam plastic insulation. This means that even an empty trailer has a significant fuel load.

Additionally on this unit, there was an integrated refrigeration unit that consisted of pressurized cooling lines and a compressor system much like in a typical refrigerated trailer. The various containers integrated into the refrigeration system could suffer a catastrophic failure as the refrigerant becomes heated when exposed to fire. This could eventually lead to a boiling liquid expanding vapor explosion (BLEVE). In this incident, the refrigeration overpressure appeared to ventilate and maintain safer pressures. This incident is not believed to be the result of a BLEVE.

In the *Principles of Heavy Vehicle Extrication* by IFSTA [2023], personnel are taught the five-step process for heavy vehicle extrication which includes the following steps:

1. Identify vehicle and cargo weight hazards (identify the load)
2. Stop the crush
3. Lower the smaller vehicle
4. Lift the load
5. Separate and extricate.

In this incident, the vehicle was upright on its wheels. The first applicable step of the process upon arrival is identifying the load. Part of identifying the load is contacting the driver of the vehicle who

should know what they are hauling. In this incident, Battalion 1 was unable to locate the driver of the vehicle because they left the immediate area. The driver was located later into the incident by Chief 1101 and the cargo information was relayed after the explosion occurred. The trailer was not placarded to indicate any hazardous materials and Battalion 1 approached the rear of the trailer to further investigate. He eventually tried to open the rear cargo doors of the trailer at the same time the trailer suffered a catastrophic failure. The IFSTA *Principles of Heavy Vehicle Extrication* states that if a cargo area of a tractor trailer or box truck is involved in fire, consider calling for additional suppression resources as these fires require extensive overhaul operations [IFSTA 2023].

The fire service at large is aware of the potential surrounding a catastrophic failure of tank trailers or fuel tanks such as a BLEVE or a burn through that contributes to significant fire growth and potential. However, the same care is not taught for type 111 trailer responses, which may support more complacent responses. A smoke explosion, like this case, can happen in any fire in a compartment. This could be a structure fire, or something different such as the trailer in this instance. The key indicators as the compartment is filled with products of combustion and oxygen is consumed or limited all it takes is the introduction of oxygen to the mixture to support a violent reaction. The IFSTA Principles of Heavy Vehicle Extrication teaches the explosion hazards of undeployed air bags, energy-absorbing bumper struts, support struts (such as in hoods, trunks, and hatchbacks), suspension struts, shock absorbers, fuel containers, seatbelt pretensioners, and vehicle tires. The fire service should be taught that even though explosion hazards are less prevalent than fire hazards, there is a risk associated with explosion hazards at heavy vehicle incidents [IFSTA 2023].

The dangers of the unrecognized pressure vessel can be deadly, as seen in this incident. One pressure vessel that is present on every vehicle fire are the tires of the vehicle. Fire service personnel are educated of the potential dangers when these rupture but is not emphasized to the level it could be. Commercial vehicle tires contain significantly more pressure than passenger car tires before they are on fire. Tires rupturing without being impinged in fire have incredible force potential and fires amplify the force potential. Another commonly overlooked or unrecognized pressure vessel are the various air bags in commercial vehicles. These are in the suspension, the cab supports, and even the seats inside the passenger compartments. Fire service personnel must be educated to identify these other less known pressure vessels including the cargo compartments of the vehicle, especially when they are the refrigerated style. Pressure can build in these containers unbeknownst to fire service personnel operating in their vicinity with potentially deadly outcomes. A summary of FSRI's fire analysis findings can be found in **Appendix Two**.

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Investigator Information

This incident was investigated by Louis (Rick) Lago (former), Investigator, and Stephen J. Ringer, Investigator, both with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, WV. The report was written by Stephen J. Ringer. Dan Madrzykowski and Keith Stakes from the Fire Safety Research Institute, part of the UL Research Institutes, provided an expert review of the

expert review of the investigation report. The NFPA Emergency Response & Responder Safety Division also provided a technical review. An expert technical review was provided by Thomas Cook, CPSE credentialed Chief Fire Officer and Chief Training Officer.

Disclaimer

The information in this report is based upon dispatch records, audio recordings, video 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 reference in this document were accessible as of the publication date.

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Appendix One

Trailer Construction Materials Findings
(*Courtesy of UL FSRI*)

At the time of the examination, the heavily damaged tractor trailer had been moved to a storage area and was basically in 5 pieces (areas). The remains of refrigerated trailer (intermodal shipping container), the trailer frame that the intermodal container sat on, remains of the tractor, the diesel generator that powered the refrigeration system, and cargo that is in 3 roll off dumpsters.

The intermodal portion of the refrigerated trailer had been reduced to the floor, front wall, and some sections of the sides, Figure 1. The floor, walls and roof of the refrigerated trailer had void spaces between the exterior metal of the trailer and the interior metal lining of the trailer. By design, the void spaces were filled with a blown in foam that sets up as a rigid foam plastic. This provides the insulation for the refrigerated trailer. This foam could be a significant source of fuel. It was noted that foam insulation had been consumed completely or showed significant mass loss in areas of the trailer that had been exposed to the exterior fire sources.

Photo 9 and Photo 10. Photographs of the remains of the refrigerated trailer. Rear view on the left and front view on the right. Most of the foam insulation had been burned out of the front portion of the trailer.
(Photos courtesy of UL FSRI)

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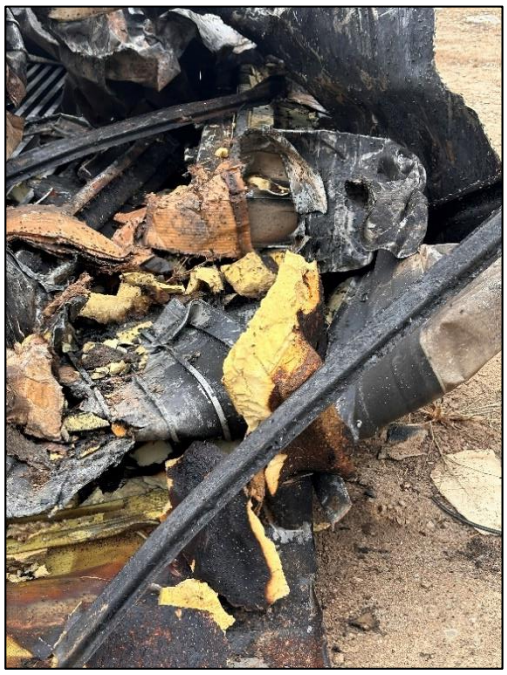

Photo 11 and Photo 12. Some of the remaining foam insulation. Partially charred foam from a wall panel (left photo) and partially charred foam in the floor section of the trailer (right photo).
(Photos courtesy of UL FSRI)

Photo 13 and Photo 14. The foam sample from the trailer flooring section that was provided for testing. Bottom of the sample (left photo) and top of the sample (right photo).
(Photos courtesy of UL FSRI)

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Foam Analysis

The foam samples used for testing were cut out of the foam from the truck, so that no char or residue were part of the test samples.

A pyrolysis gas chromatography with mass spectrometry (Py/GC-MS) analysis of the foam was conducted. This type of analysis is used to evaluate the chemical composition of pyrolyzates from a wide range of organic materials, providing information to identify the test material. Organic materials such as foam plastics that can be pyrolyzed can be analyzed by GC-MS. The mass spectrum is used to identify the compounds in the sample and compare them against a library of known materials, to identify the best match for the pyrolyzed sample.

Samples of the foam were prepared as a powder to ensure the sample was homogeneous for Py/GC-MS and microscale combustion calorimetry experiments. The temperature range for the pyrolysis of the sample was 300-900 °C with a temperature ramp of 5 °C/s. Pyrolyzates were directed into the GC-MS column and identified by the MS. Peaks consistent with polyisocyanurate foam were observed in the chromatogram.

The polyisocyanurate foam was also subjected to a series of tests to determine its potential heat release rate capability. Powdered foam samples were tested with the microscale combustion calorimeter (MCC) in general accordance with ASTM D 7309-21. The samples were heated from room temperature to 700°C at a heating rate of 1°C/s. The peak specific heat release rate in the MCC was observed at 371 °C and was measured as 293 W/g and the specific heat of combustion was 25.4 MJ/kg.

Foam samples, approximately 100 mm square and 25 mm thick, were tested in the cone calorimeter in general accordance with ASTM E 1354-23. Cone samples were tested at radiant exposures of 25 kW/m2, 50 kW/m2, and 75 kW/m2. Two of the cone calorimeter results for the 75 kW/m2 are presented here, the averaged peak heat release rate of 697 kW/m2 and the averaged heat of combustion of 20.2 MJ/kg. The higher heat flux was chosen to represent the heat flux closest to flame impingent from the outside of the truck. The measure protocols and the full dataset created can be viewed at https://materials.fsri.org/materialdetail/polyisocyanurate-spray-foam

Compared to materials like wood, https://materials.fsri.org/materialdetail/wood-stud, under similar test conditions, the foam insulation has an average peak heat release rate twice as high as wood, and an average heat of combustion, 30% higher than wood.

The fire service take away, even if the refrigerated trailer were empty, it still has a large fuel load, with the potential for significant fire or explosion hazard.

The material analysis of the foam shows that its pyrolyzates and combustion products could have been a source of fuel for the smoke explosion that occurred within the trailer.

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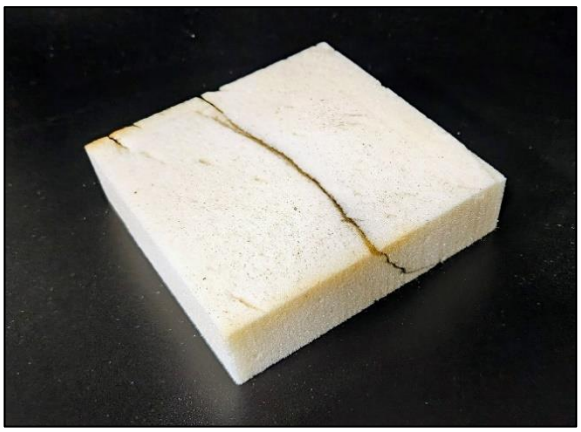

Photo 15 and Photo 16. One of the foam samples prepared for testing in the cone calorimeter (left photo) and amount of flame generated by the foam sample during a cone calorimeter test (right photo).
(Photos courtesy of UL FSRI)

Summary

In addition to fuel sources such as tires and diesel fuel, the fire service needs to recognize other fuels that are used in the construction of the tractors and trailers, including fiberglass and foam insulation. Furthermore, based on the fire analysis of the incident there are several considerations for the fire service regarding refrigerated trailer fires due to the insulating foam, the trailer contains a significant amount of fuel (hazard), even if it is empty.

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Appendix Two

Fire Analysis Findings
(*Courtesy of UL FSRI*)

Still images taken from a video of the incident show notable changes to smoke and fire coming from the trailer. The smoke and flames prior to suppression seem to cycle, build, stop, and start again, see Photos 17 through 19. After initial knockdown, the smoke from the trailer again seems to cycle or pulse until the explosion, Figure 8. After the explosion the ventilation limited/fuel rich environment is the truck resulted in a vent point ignition, followed by an increased amount of fire, Figures 9 and 10. The images captured throughout the incident captured pulsating fire behavior indicative of the onset of a smoke explosion.

Photo 17 and Photo 18. The photograph on the left shows the fire at approximately 0928, the fire has been burning for almost eight minutes. The images are approximately two seconds apart. The photograph on the right shows a noticeable amount of dense black smoke from the underside of the trailer. It seems to have enough pressure to flow against the direction of the wind, then it stops.
(Photos courtesy of UL FSRI)

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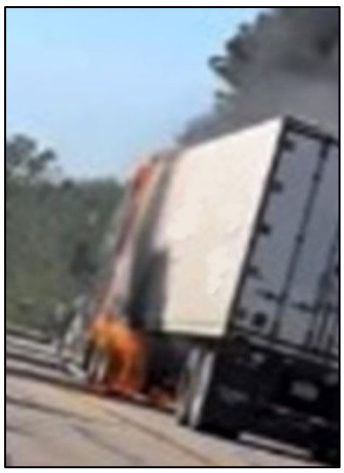

Photo 19 and Photo 20. This set of images was recorded between 0929 and 0930. The interval between the image on the left and the image on the right is about five seconds. These images show flames jetting upwind from a localized point under the trailer. This may be an indication of pressurized fire gases exiting an opening in the trailer.
(Photos courtesy of UL FSRI)

Photo 21 and Photo 22. Between 0930 and 0931, just prior to water on the fire, the image on the left shows that the flame jetting had stopped and then started again 35 seconds later. Seven seconds later the flame jet stopped again.
(Photos courtesy of UL FSRI)

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Photo 23, Photo 24, and Photo 25. These images are one second apart between 0932 and 0933. Dense black smoke flow from under the trailer once again is pushing out. This was seconds before the explosion.
(Photos courtesy of UL FSRI)

Photo 26 and Photo 27. These images provide a sense of the amount of energy released by the explosion in terms of a blast, projectiles, and thermal radiation. The image on the right shows the latched door that was blown off the trailer.
(Photos courtesy of UL FSRI)

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Photo 28 and Photo 29. After the explosion, the inside of the trailer was still a fuel rich environment providing the conditions for a "vent point" ignition, as shown on the left. As additional air was entrained into the smoke the area of flaming combustion increased. The source of the fuel for the fire is mainly the trailer and not the cargo.
(Photos courtesy of UL FSRI)

Summary

The fire analysis showed it is important to recognize that ventilation limited fire conditions can occur in compartments on wheels, such as this refrigerated trailer, just as they occur in compartments in fixed structures. Fires burning inefficiently in a ventilation limited compartment can generate significant amounts of gaseous fuel. When a portion of the compartment contains an explosive mixture of oxygen and gaseous fuel, all that is needed to generate a smoke explosion is a source of heat.

Based on the fire analysis of the incident there are several considerations for the fire service regarding potential fire behavior of refrigerated trailers:

1) Compartment fire dynamics apply to compartments that are part of a tractor trailer such as: the closed refrigerator trailer, tanks, and tires.
2) Watch for pulsating fire behavior indicative of the potential for a smoke explosion and maintain a safe distance.